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BRL R 51

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REPORT NO. 51

THE DISPERSION OF AND DISPERSION LIMITS FOR THE A. A. FUZE MK III WITH RECOMMENDED DISPERSION LIMITS

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February 1937

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BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

Report No. 51

HHZ/RHK/swa
Aberdeen Proving Ground, Md.
February 9, 1937

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with

RECOMMENDED DISPERSION LIMITS

ABSTRACT

Causes of the dispersion in the time of flight of powder train fuzes are mentioned. It is shown that the dispersion of the A. A. Fuze Mk III can be considered to depend only upon the mean pressure along the trajectory. By the aid of this result, the dispersions are calculated as a function of elevation and fuze setting.

Dispersion limits for specifications are recommended. No recommendations are made concerning calibration requirements for the fuze, since insufficiently complete data concerning the temperature of the fuze, the pressure of the atmosphere and the mean time of flight have been obtained from past firings.

A knowledge of the magnitude of the time dispersions obtained with powder train time fuzes under the various conditions of use is needed for many purposes. This information is almost indispensable in the preparation of specifications for the procurement of such fuzes and in the preparation of firing tables for ammunition with which they are used. This report is written chiefly for the purpose of analyzing the existing data and applying them to the preparation of specifications.

Information concerning the time dispersion obtained with powder train fuzes, of a high degree of accuracy and in extensive form, can be obtained only from the statistical analysis of the results of a large number of firings with the fuzes in question under conditions of firing representing the whole range of firing conditions under which the fire is to be used. Results of such firings are seldom, if ever, available in sufficient quantity to permit reliable conclusions to be drawn from the statistical analysis of these data alone. The reliability of the conclusions drawn from such data can be considerably improved if in their analysis and in the interpretation of the results due consideration is given to the effects of those factors which are known from previous experience to influence the time dispersion and to the manner in which these factors exert their influence. It seems appropriate, therefore, in this study first to consider briefly these factors.

Fuzes when fired at zero time settings give a certain amount of time dispersion. This dispersion is probably caused by variations in

<u>a</u> the time required for the concussion mechanism to function.
<u>b</u> the time required for the concussion primer to function.
<u>c</u> the time required to ignite the powder in the time train.
<u>d</u> the time required to communicate the flame from the first ring to the second train.
<u>e</u> the time required for the base charge to be ignited and to function.

This dispersion is inherent in the fuze and will depend upon its design. It will be present regardless of the other conditions which affect dispersion, such as lack of uniformity in the composition and loading of the material of the time train, the speed of rotation during the flight of the projectile, atmospheric pressure, etc. It may be considered to be a characteristic of the fuze and practically independent of the conditions of use. This dispersion will be called the "ignition component" of the total dispersion.

It is evident that the remaining portion of the total dispersion will have a magnitude of zero when the fuze is set for zero burning time. It will later become evident that the magnitude of this portion will increase as the time setting of the fuze is increased. In other words its magnitude will be some function of the time setting. It will therefore be designated as the "time setting component" of the total dispersion. There are several causes which are known to contribute to this component.

It is known that the "time setting component" of the total dispersion is a function of the following quantities:

Quantities Affecting Time Setting Component	Symbol
Time of flight	t
Heterogeneity of materials and loading conditions	h
Spin of the projectile	ω
Pressures in various parts of the trajectory*	$p_1, p_2, p_3 \ldots\ldots p_n$
Times during which the projectile lies within the various parts of the trajectory*	$t_1, t_2, t_3 \ldots\ldots t_n$

Of course there may be other unknown factors which contribute their share to the "time setting component" of the time dispersion.

Using the notation given above, the 'time setting component', T, may therefore be expressed as follows:

$$T = f(t,h,\omega,p_1,p_2 \,..\, p_n, t_1 t_2 \ldots t_n)$$

It is evident that this must be an extremely complicated function. The available data are too meager to permit an attempt to define the function even approximately. Although it is impractical to give it a definite functional form, we do know something about the functional relationships involved when all of the independent variables except various ones are kept constant.

* For convenience the trajectory is considered to be divided up into n parts.

Regarding the effect of spin, we know in a general way, for instance, that as the spin is increased up to about 10,000 r.p.m. its effect is to reduce the time dispersion to some extent. As the spin is increased above about 22,000 r.p.m. its effect is in the opposite direction producing marked increases in the time dispersions. The lowest time dispersions are obtained when the spin is between about 10,000 r.p.m. and about 22,000 r.p.m.

When the atmospheric pressure under which a powder train time fuze burns is decreased below a certain limit the burning time and the time dispersion for any given time setting are increased. Past experience indicates in a general way that this effect is negligibly small so long as the atmospheric pressure along the trajectory is greater than about 0.70 to 0.80 atmosphere. As the pressure decreases below this value, its effect on the time dispersion increases gradually and becomes much more marked when it falls below 0.5 to 0.6 atm.

The "time setting component" of the total time dispersion which is obtained under the most favorable firing conditions, namely, when the spin is between about 10,000 r.p.m. and about 22,000 r.p.m. and the pressure along the trajectory to the point of burst is always greater than about 0.8 atm., can then be considered to be due to the heterogeneity of materials and loading conditions.

We shall shortly proceed to consider the dispersion results obtained in recent (1935 and 1936) firings of the A. A. Time Fuze Mk III. Before doing so, however, we mention the reasons why we are interested in the results obtained in these particular firings.

When the war-time stocks of meal powder for loading into the time trains of time fuzes had been used up, great difficulty was experienced in procuring meal powder suitable for this purpose. After a considerable amount of experimentation it was believed that the powder represented by the American Powder Mills' lots 880, 881, and 882 was the most suitable for the purpose that could be had. It was then decided to adopt as standard, powder having the characteristics of these powders; the suitability of the powders subsequently submitted to be determined by performance tests which would insure as precisely as practicable that the powders accepted would have burning characteristics in every way equivalent to those of the lots mentioned above. Such powders are to be loaded into time rings according to the practice that has been developed at Picatinny Arsenal.

A considerable number of fuzes were loaded with powder that is a blend of lots 880, 881, 882 referred to above and sent to the Proving Ground for firing tests. The fuzes were inserted into the 3" A. A. Shell Mk IX and fired at a velocity of 2800 ft/sec. from 3" guns having a twist of rifling of 1 in 40*. Because the fuzes were loaded with the standard powder composition, we are especially interested in the results obtained. For convenience, we call the fuzes so loaded the Standard Mk III Fuze.

The firings made with these standard fuzes consist of the acceptance tests of lots 1355-11 to 1355-25 inclusive, lot 4264-1, lots 5286-1 to 6 inclusive, and the experimental firings directed by OO 471.812/3616 (APG 471.821/178-8).

The results of the firings of the Standard A. A. Time Fuze Mk III are given in table I on p. 16. This table gives for the various firings the mean time of flight, the standard deviation, the mean deviation, and the maximum dispersion or bracket. While these different measurements of dispersion are given in Table I, for the remainder of the report we shall concern ourselves chiefly with the standard deviation since, as is pointed out in APG Ballistic Laboratory Report No. 63, the sample standard deviation affords the most reliable estimate of the dispersion characteristics of the 'population' from which the samples are taken.

Analysis of Experimental Results.

The averages of the standard deviations are given in Table II which is Table IV of Report No. 63 entitled "A Study of the Statistics and Methods of Rating the Performance of Time Fuzes".

As was stated on page 1, the object of the analysis of these firings of the standard A. A. Mk III fuze is to provide a basis for setting dispersion limits in the specifications. To permit firings under as wide a variation of cloud conditions as possible, the dispersion limits should be set not merely for a few combinations of fuze settings and times of flight but rather as a continuous function of the elevation for a number of fuze settings. With this end in view, we seek to obtain the dispersion of the standard fuze as a function of the elevation at various constant fuze settings. If the dispersion, D, is a function of the fuze setting, s, and the elevation, θ, so that $D = f(s,\theta)$ we shall attempt to obtain $D = f(\theta)$, at various constant s's. The values of s for which we obtain these functions will be 10, 15 and 20 sec. Thus, more exactly we wish to obtain the following functions:

* A few rounds were also fired from a gun with a 1/25 twist.

$$D = f_{10}(\theta)$$
$$D = f_{15}(\theta)$$
$$D = f_{20}(\theta)$$

As indicated by the subscripts, the functions f_{10}, f_{15} and f_{20} are in general different from each other.

In obtaining the functions, f, we attempt to satisfy two conditions: (1) the functions, f, must be consistent with the general theoretical results which are given in the preceding pages and (2) the functions must be consistent with the empirical results which are given in Table II.

Since, in the present instance, it may be plausibly assumed that the spin is constant and also that the effect of the heterogeneity of the materials and loading conditions should be practically the same for all elevations, the only influence which should affect the form of the functions, f, is the varying pressure on the fuze.

Since it appears to be impractical to attempt to consider the various pressures in the different parts of the trajectory, as a first step in the analysis, we proceed to obtain the dispersion as a function of the mean atmospheric pressure on the fuze*. The mean pressure, $\bar{p}$, is defined by the following equation:

$$\bar{p} = \frac{\int p\,dt}{t},$$

where p is the pressure at any time, t, along the trajectory.

As a first step, we determine $\bar{p}$ as a function of the elevation for the 10, 15, and 20 sec. fuze settings. By the aid of the trajectories of the 3" Mk IX shell for the velocity of 2800 f/s, $\bar{p}$, has been computed. The results are shown in Chart 1, on which $\bar{p}$ is plotted as a function of the elevation for 10, 15, and 20 sec. fuze settings.

By the aid of results given in Chart 1 and the mean standard deviations given in Table II, the mean standard deviation is plotted as a function of $\bar{p}$. The results are given in Chart 2. The circles represent all the dispersion results given in Table II.

* For this analysis to be complete, we should of course include the dynamic as well as the static pressure but in view of the extra labor which this would entail, we neglect the dynamic contribution to the pressure on the fuze.

The centers of the circles represent the average standard deviations for the given fuze settings and elevations and the radii of the circles are the estimated probable errors of the average standard deviations.

The radii were computed as follows:

The mean population standard deviations as estimated from 10 round groups for various fuze settings and elevations are given in Table II. The ratio of the standard deviation of the estimated population standard deviation to the population standard deviation for a single 10 round group as obtained from Table II of report 63 is .239. This enables us to compute the standard deviation of the estimated population standard deviation based on a single 10 round group. Let this be called $\sigma_{\sigma_{10}}$. Then if the standard deviation of the estimated population standard deviation based on the mean of k 10 round groups is designated by $\sigma_{\bar{\sigma}_{10}}$ it can be shown that

$$\sigma_{\bar{\sigma}_{10}} = \frac{\sigma_{\sigma_{10}}}{\sqrt{K}}$$

For a normal distribution*, the probable error, ε, i.e. an error which is as likely as not to be exceeded, is given by

$$\varepsilon = .675 \times \text{pop. stand. deviation.}$$

This enables us to compute the probable error, ε, of the estimated population standard deviation based on k 10 round groups by the relation:

$$\epsilon = \frac{.674\,\sigma_{\sigma_{10}}}{\sqrt{K}}$$

From chart 2, it appears that on the whole, the correlation between the mean standard deviation and the mean pressure is excellent. In fact, the representative curve drawn through the plotted points comes, with one exception, as close to the centers of these points, on the average, as one would expect in view of the probable errors of the points. The exception is the point for 45° elevation and 15 second fuze setting. The center of the circle for the 45° elevation and 15 sec. fuze setting is

* The distribution of the standard deviations obtained from 10 round groups is not exactly normal, but is nearly enough so that the factor .675 is not greatly in error, especially when we deal with the average of several groups.

distant from the curve by about 4 probable errors. Such a discrepancy would be expected to occur for one point in about 100, and the total number of points is only 9. This discrepancy seems a serious one. An attempt will be made later to explain it.

While the curve on chart 2 represents all but one of the observed dispersions as closely as might be expected, to test further the adequacy of the assumption that for the firings of the 3" gun with a twist of rifling of 1 in 40 and velocity of 2800 f/s the mean standard deviation is a function of the mean pressure only, the observed mean standard deviations were plotted against the mean time of flight in chart 3. On this chart were also placed curves of constant elevation as deduced from charts 1 and 2. It will be noticed that the curves which are based on chart 2 represent the observed points in a very satisfactory manner with the exception of the 45°, 15 sec. point which has been previously referred to. It will also be noticed that the forms of the curves on plot 3 are consistent with the considerations given in the discussion of the factors affecting the dispersion of time fuzes on pp 2,3. In the case of the 30° firings, there is a very appreciable ignition component of the standard deviation, about .053. Furthermore for the 30° firings, where the mean pressure $\bar{p}$ is high, there is very little increase in the dispersion as the time of flight increases. On the other hand as the elevation is increased, the rate of increase of dispersion with time of flight increases more and more rapidly. This increase in the rate of increase in dispersion as the time of flight increases is doubtless due to the reduction in air pressure and the elevation is increased, with a given time of flight.

Anomalous Results Obtained at 45° Elevation and 15 sec. Fuze Setting.

As was pointed out on page 7 the mean standard deviation obtained from the firings at 45° and 15 sec. fuze setting differs so considerably from the standard deviation given by the curve as drawn on chart 2 that it is rather unlikely that the discrepancy is due to chance. An examination of chart 3 makes it even clearer that the results obtained at 45° elevation and 15 sec. fuze setting are inconsistent with the other dispersion results. While there is of course a possibility that this anomalous result may be due to chance, the likelihood is so small that it seems expedient to seek some other explanation of the discrepancy. There appear to be two possible ones:

Either the fuzes which were fired at this elevation and fuze setting differ distinctly in quality from the rest of the fuzes or else the measurement of the times of flight of these fuzes was inaccurate. Of these two explanations, the latter seems to be the more plausible one. In the measurement of these times of flight, the fuze chronograph was not used. While the precision obtained with human operators of stop watches and electric clocks has, on the whole, been satisfactory there is always a possibility that due to unfavorable weather conditions considerable inaccuracies may creep in to the time of flight measurements.

The individual results obtained by the timers for all firings at 45° elevation and 15 sec. fuze setting are given in the attached Table III.

It is clear from the considerable dispersions between timers and from the number of rounds which are marked lost that, during some of these firings, conditions must have been unfavorable for accurate timing. The hypothesis is therefore tentatively adopted that the anomalous results at 45° elevation and 15 sec. fuze setting are due to inaccurate timing. The results obtained at this elevation and fuze setting will therefore be disregarded.

Recommended Dispersion Limits

As was stated on page 1, the chief object of this report is to draw up dispersion limits to be used in the specifications of the A. A. Fuze Mk III. Inasmuch as the A. A. Fuze Mk III, loaded with powder lots 880, 881, 882 is taken to be the standard fuze, it follows that the limits should be set in such a way as to insure with as great a precision as is practicable, that the fuzes accepted under the specifications shall not be inferior in quality to the standard fuze. Inasmuch as the most important quality of the fuze, the dispersion, cannot be accurately measured by a small number of rounds, it follows, in setting dispersion limits, that we cannot hope with certainty to cause the rejection of fuzes inferior to the standard fuze because if this were done, there would be a very considerable probability of causing the rejection of fuzes which are as good as or superior to the standard fuze. Thus the adopted dispersion limits have to be a compromise. They should discriminate as effectively as possible between good and inferior fuzes without involving the expenditure of too large a number of rounds. Before making concrete recommendations for the dispersion limits of the Mk III fuze, we consider the limits which have been used in the past for the combination fuze Mod. 1907 and the A. A. Fuze Mk III.

The upper limits for the total dispersion of the powder train fuzes as given in past specifications are as follows:

21 Sec. Combination Fuze Model 1907

Specifications of Apr. 6, 1917..0.2 sec. + 3.5% of time setting
" " Apr.12, 1918..0.4 sec. + 1.0% of time setting

A. A. Time Fuze Mk III

Specifications up to Apr. 26, 1930 .. 0.3 sec. + 5 1/4% of mean time of flight.

It may be seen that the specifications allowed for an ignition component of the dispersion. It will be noted, however, that in the specification requirements just quoted the firing conditions (spin and atmospheric pressure) are not specified, nor are allowances made for the effects of variations in these conditions.

When these requirements were established the 21 Sec. Combination Fuze Model 1907 was used almost exclusively on shrapnel fired from the 75 mm Gun Model 1897 against targets on the ground. Under these conditions the spin is about 17,800 r.p.m. and the mean effective atmospheric pressure along the trajectory is always well above 0.9 atmospheres. The firing conditions therefore were such that the possible variations in them had little or no effect on the time dispersions and the manner in which the limits on the "time setting component" was expressed seems to be logical.

The A. A. Time Fuze Mk III on the other hand was, at the time the above limits were established, being fired from the 75 mm Gun Model 1897 on A. A. Truck Mount and from the 3" A. A. Guns. When fired from the former gun it was given a spin of about 17,400 r.p.m. and when fired from the latter it received a spin of about 24,900 r.p.m. Furthermore these guns were fired at such elevations that the mean effective atmospheric pressure along the trajectory varied from more than 0.9 atm. to less than 0.75 atm. It seems, therefore, that the manner in which limits for the "time setting component" of the total time dispersion of this fuze was expressed was not logical. We believe that in setting the limits for the time dispersions of powder train time fuzes which are to be fired from guns which give them different spins and at high angles of elevation the effect of spin and the variation of the atmospheric pressure along the trajectory should be duly recognized.

From the results shown on plots 2 and 3, it appears that we have succeeded in obtaining a satisfactory means of calculating the dispersion of the standard Mk III fuze when fired at 2800 f/s from a 3" gun with a twist of rifling of 1/40, for fuze settings varying from 10 to 20 sec. and for the elevations from 30° up to 75°. Since these fuzes which are loaded with powder from lots 880, 881, 882, are considered the standard fuze on the basis of which the specifications for the fuzes which are to be manufactured, are to be written, it follows that the limiting standard deviations which are allowed in the specifications should be a certain ratio of the dispersions given in plots 2 and 3.

In Report No. 63, it was recommended that there be two sizes of samples, a 20 round sample used for both test and retest of the first lot of a contract and in retests of lots subsequent to the first lot, and a 10 round sample to be used for the first test of lots subsequent to the first lot. It is recommended in Report No. 63 that the dispersion limits be set in such a way that if a lot of fuzes has a quality equivalent to that of the standard Mk III fuze, then the chance that a 20 round sample of the lot will fail to pass the test will be 1 in 50 and the limits should be so set that the chance of rejection for a 10 round sample will be 1 in 20. If this recommendation is followed, the ratio of the limiting standard deviation to the mean standard deviation of the standard fuze should be set at 1.41 both for the 10 round sample and the 20 round sample. (See Report No. 63 p. 10).

Chart 4 has been drawn showing the mean standard deviation of the standard fuze as a function of elevation for 10, 15 and 20 second fuze settings and the recommended maximum permitted standard deviations for the 10 and 20 round samples.

To put the recommended maximum permitted standard deviations in a form more convenient for use in the specifications, Table IV has been constructed by the aid of the curve in Chart 4. Table IV on page 23 shows the recommended maximum permitted standard deviations as a function of the elevation for the 10, 15 and 20 second fuze settings.

No maximum permitted standard deviations much greater than .2 of a sec. are given in the table for two reasons (1) because it is believed that when the standard deviation is greater than .2 of a sec. the effectiveness of the fuze is very much reduced and (2) because our knowledge of the standard deviations of the fuzes for standard deviations greater than .2 of a second is relatively inaccurate.

It will be noted that the limiting standard deviations are given in Table IV to thousandths of a second. This may be considered surprising in view of the fact that in case the fuzes are timed by stop watches of the ordinary type the time of flight cannot be measured more closely than to the nearest hundredth of a second. The thousandths of a second are retained because, although the individual times of flight for the fuze may be expressed only to a hundredth of a second, to eliminate the thousandths place in computing the mean time of flight and the standard deviation would involve an appreciable change in the chance of a fuze's being rejected. Suppose for example that in the maximum permitted standard deviation for 35° elevation and 10 sec. fuze setting we round off .115+ to .12; then it can be shown that the chance of failure in a 10 round group will be reduced from 1 in 20 to 1 in 33 and in a 20 round group from 1 in 50 to 1 in 125 while the chance that a fuze having twice the dispersion of the standard fuze will pass the test of a 10 round sample will increase from 1 in 10 to 1 in 7.5 and the chance that it will pass the test of a 20 round sample will increase from 1 in 70 to 1 in 40.

These are the considerations by which the retention of the thousandths place in the maximum permitted standard deviation is justified.

Dispersion Results Estimated using Maximum Dispersion or Bracket instead of Standard Deviation.

In view of the fact that in the past the limiting dispersions have been stated in terms of maximum dispersion, total dispersion, or bracket, it was thought worthwhile to plot the results obtained with the standard fuze when the dispersion estimates are made by means of the bracket. This plot constitutes chart 5. Chart 5 shows the bracket vs. the elevation for various fuze settings as obtained from the tests of the standard fuzes. There are also some other curves which are so drawn that the chance that the bracket will be exceeded in a 10 round group of the standard fuze is one in 20*. Thus in a certain sense these curves may be said to correspond to the limiting standard deviation curves which are drawn on plot 4. However, as was pointed out in Report No. 63, the use of the standard deviation will enable us to compute the dispersion of the fuzes more accurately and therefore the use of the standard deviation is much to be preferred to that of the bracket when the groups have as many rounds as 10 or more.

+ When the report was first written the figure was .115. During revision it was changed to .116. The alteration does not affect the force of the argument.

* The points for these curves should have been obtained by multiplying the corresponding points of the mean standard deviation curves by $\frac{4.48}{.923} = 4.85$.

By mistake, the factor 4.80 was used instead of 4.85. The difference is hardly appreciable.

Precision of time of flight measurements.

It is of course obvious that one can not expect the fuzes tested for acceptance to meet the rather strict proposed specifications unless the times of flight are accurately measured.

At the Proving Ground during the last few years, a great deal of attention and care has been centered upon obtaining accurate measurements when using electric clocks and stop watches. In spite of this care, however, it appears, as mentioned on page 9, that some of the measurements which have been made of the times of flights of the standard fuze have not been reliable. As long as great care is taken to obtain accurate measurements of the time of flight, as is normally done at the Proving Ground, it is probable that sufficient precision for measuring the dispersion of time fuzes will be obtained even if the measurements are made in the day-time with electric clocks or stop watches. Of course greater precision would be obtained if the timing were done on clear nights or if it were done either in the day-time or night time by the photo-electric fuze chronograph. If the timing were to be done during war time by stop watches at some newly established proving ground, it appears doubtful whether the day time measurements would be of sufficient precision to prevent the accidental rejection of good fuzes. It therefore seems expedient that at such establishments the timing should be done either at night by stop watches and electric clocks or preferably by the photo-electric fuze chronograph.

Although as has been said, under favorable circumstances, the precision obtained with the stop watches is sufficiently good for the purpose of measuring the dispersion in the time of flight of fuzes, it appears to be insufficient for accurate calibration measurements. If accurate calibration measurements are to be made, it appears that the photo-electric fuze chronograph (or some other automatic apparatus) will have to be used for that purpose.

We may regard the error, E, made by a given operator of a stop watch as composed of two terms; the first E_d, the determinate error, is approximately constant at least for given conditions of firing and the weather, and is mainly due to the reaction and response time of the operator. Added to this there is an accidental error, E_a, which may be positive or negative, which is due to the unavoidable and unpredictable variations in the reaction and the response time of the observer.

As has been pointed out in the preceding pages, the accidental part of the error, E_a, is small enough, at least under favorable conditions, when the greatest care is used, to permit fairly accurate measurements of dispersion in the time of flight of powder train fuzes. On the other hand the determinate error E_d is so large and so variable from day to day and from observer to observer that it renders the accurate determination of the mean time of flight impossible from stop watch measurements.

As the result of comparative tests with the fuze chronograph, it appears that E_d may vary from -.04 to +.18 producing a total time of flight variation of .2 of a sec. It thus appears that if the times of flight are measured by human operators, the mean time of flight may have an error as great as $\pm$.1 sec. To provide accurate calibration measurements of the fuzes a more accurate instrument than the stop watch, such as the photo-electric chronograph or motion picture camera is required.

A report, No. 69, is being written discussing the precision of the time of flight measurements by stop watches and electric clocks.

<u>Calibration of the Fuzes</u>

In this report there have been proposed no calibration requirements for the specifications. While it is highly desirable that the specifications contain such requirements, it appears to be impracticable to draw them up at the present time because during the past tests of the standard fuze no account has been taken of the variations in air pressure from normal nor of the temperature of the fuze before firing and while moving along the trajectory.

Furthermore the mean time of flight measurements obtained with electric clocks and stop watches seem to be insufficiently precise. In the future, consideration of these previously omitted factors should be taken into account. If this is done then data will accumulate on the basis of which calibration requirements may be written for the specifications.

<u>Resumé</u>

1. The factors influencing the dispersion of powder train fuzes are discussed. It is pointed out that, among other factors, dispersion is influenced by the heterogeneity of the powder and loading conditions, by spin, and by the air pressure on the fuzes.

2. The empirical results obtained with the standard A. A. Fuze Mk III are analyzed. It is shown that the assumption that the dispersion depends only on the mean pressure appears to account

satisfactorily for most of the observed results and allows calculation of the dispersion at any desired elevation and fuze setting within the elevation - fuze setting domain of the firings of the standard fuze.

3. On the basis of the observed dispersion of the standard fuze maximum permitted standard deviations for the specifications are set down.

4. It is pointed out that unless great care is taken, or the photo-electric chronograph is used, the time of flight measurements will be unsatisfactory as far as dispersion measurements are concerned. For accurate calibration measurements, the photo-electric fuze chronograph or some other automatic apparatus is required.

5. It is pointed out that there are insufficient data for setting up calibration requirements. Further firings under carefully measured conditions are required.

The authors of this report are indebted to Mr. Ruckman and Miss Mark for assistance in the computations.

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Table I - DATA

Tabulated Results of Tests of 3 Inch A. A. Time Fuzes Mark III A2 made with Blends of Powder Lots 880, 881, and 882. Fuzes Armed the 12.7 Pound Mark IX Shell Fired at 2800 f/s.

Lot No.	No. Rounds in Group	Average Burning Time	Bracket	Mean Deviation	Standard Deviation	Method of Timing
10 Second Setting, 30° Elevation, 1/40 Twist Gun:						
5286-5	13	8.67	0.22	0.05	0.06	Fuze
-6	10	8.72	0.31	0.08	0.08	Chronograph
-6	9	8.76	0.21	0.03	0.08	"
10 Second Setting, 60° Elevation, 1/40 Twist Gun:						
1355-11	10	9.51	0.67	0.18	0.20	Stop Watch
-12	10	9.73	0.48	0.11	0.13	"
-13	10	9.54	0.48	0.10	0.13	"
-14	10	9.09	0.30	0.07	0.09	"
-15	10	9.97	0.53	0.11	0.14	"
-16	9	9.56	0.38	0.09	0.11	"
-17	10	9.66	0.40	0.10	0.12	"
-18	10	9.70	0.51	0.13	0.15	"
-19	10	9.66	0.64	0.11	0.16	"
Retest("	10	9.63	0.41	0.12	0.14	"
"	10	9.56	0.44	0.10	0.13	"
-20	10	9.67	0.36	0.11	0.12	"
-21	10	9.67	0.32	0.09	0.10	"
-22	10	9.54	0.33	0.08	0.10	"
-23	10	9.56	0.34	0.10	0.11	"
-24	10	9.49	0.40	0.09	0.11	"
-25	10	9.66	0.12	0.04	0.05	"
4264-1	10	9.97	0.37	0.12	0.13	"
5286-1	10	9.74	0.66	0.16	0.19	"
-2	10	9.61	0.36	0.09	0.11	"
-3	10	9.81	0.33	0.10	0.12	"
-4	9	9.73	0.30	0.07	0.08	Fuze Chron.
-5	9	9.64	0.49	0.14	0.16	"
-6	6	9.78	0.11	0.03	0.04	"

Table I (cont'd)

Lot No.	No. Rounds in Group	Average Burning Time	Bracket	Mean Deviation	Standard Deviation	Method of Timing
10 Second Setting, 75° Elevation, 1/40 Twist Gun						
1355-11	10	9.69	0.61	0.13	0.17	Stop Watch
-14	9	10.33	0.33	0.09	0.11	"
-17	10	9.68	0.45	0.11	0.13	"
-20	10	9.98	0.64	0.13	0.18	"
-23	10	9.70	0.33	0.08	0.09	"
4264-1	10	10.18	0.26	0.07	0.08	"
5286-1	10	9.94	0.30	0.05	0.06	"
-4	8	9.96	0.51	0.14	0.16	Fuze Chron.
15 Second Setting, 30° Elevation, 1/40 Twist Gun						
5286-5	10	13.72	0.33	0.08	0.10	Fuze
-5	11	13.82	0.41	0.11	0.12	Chronograph
-6	10	13.78	0.27	0.06	0.07	"
15 Second Setting, 45° Elevation, 1/40 Twist Gun						
1355-12	10	15.14	0.73	0.18	0.21	Stop Watch
-15	8	15.43	0.62	0.19	0.21	"
-18	10	15.11	0.58	0.15	0.18	"
-22	10	14.82	0.49	0.16	0.15	"
-24	10	14.67	0.72	0.14	0.20	"
5286-2	10	15.18	0.57	0.17	0.18	"
-5	10	14.97	0.31	0.06	0.08	Fuze Chron.
15 Second Setting, 70° Elevation, 1/40 Twist Gun						
5286-5	12	16.57	0.79	0.16	0.21	Fuze
-6	10	16.42	0.62	0.17	0.21	Chronograph
-6	9	16.40	0.34	0.07	0.10	"

Table I (Cont'd)

Lot No.	No. Rounds in Group	Average Burning Time	Bracket	Mean Deviation	Standard Deviation	Method of Timing
20 Second Setting, 30° Elevation, 1/40 Twist Gun						
5286-5	10	18.98	0.21	0.06	0.07	Fuze Chron.
-5	11	18.99	0.32	0.08	0.10	" "
-6	10	18.92	0.24	0.04	0.07	" "
-6	10	19.06	0.41	0.10	0.12	" "
20 Second Setting, 45° Elevation, 1/40 Twist Gun						
1355-13	10	21.14	0.87	0.14	0.21	Stop watch
-16	10	21.34	0.48	0.10	0.13	"
-19	10	21.63	1.67	0.38	0.45	"
Retest(-19	10	20.94	0.45	0.09	0.12	"
(-19	9	20.96	0.51	0.14	0.17	"
-21	10	21.18	0.51	0.20	0.17	"
-25	10	20.92	0.85	0.17	0.22	"
5286-3	10	21.50	0.53	0.11	0.15	"
-6	10	21.25	0.83	0.16	0.22	Fuze Chron.
20 Second Setting, 70° Elevation, 1/40 Twist Gun						
5286-5	9	25.09	0.53	0.12	0.16	Fuze Chron
-6	4	24.67	0.93	0.32	0.38	" "
-6	10	25.31	0.64	0.19	0.22	" "
-6	10	25.36	0.77	0.19	0.26	" "

TABLE II

Summary of 21 second A.A. Mark III A2 Fuze Firings from Jan. 1, 1935 to Oct. 1, 1936

Gun Twist	Elev. deg.	Fuze Setting sec.	No. of 10 Rd. Groups	Mean Time of Flight sec.	Average Standard Dev. sec.	Est. Population Standard Dev. sec.	Method of Timing
1/40	30	10	3	8.712	0.074	0.080	Fuze chronograph
"	30	15	3	13.777	0.097	0.105	" "
"	30	20	4	18.983	0.090	0.097	" "
"	45	15	7	15.06	0.173	0.187	Stop watch
"	45	20	9	21.20	0.174*	0.189	" "
"	60	10	23-1/2	9.68	0.122	0.132	" "
"	70	15	3	16.470	0.171	0.186	Fuze chronograph
"	70	20	3-1/2	25.189	0.253	0.274	" "
"	75	10	8	9.93	0.122	0.132	Stop watch
1/25	60	10	19	10.45	0.475	0.515	" "

* Average of eight groups. First test of lot 1355-19 was eliminated because of poor timing of timers.

TABLE III

Time of Flight Measurements at 45° Elevation and 15 Sec. Fuze Setting

Results of Individual Timers (Stop Watch)

Lot No.	Rd. No.	Thompson	Barr	Peck	Stahl	Average
1355-12	2198	15.54	15.47	15.70*	15.47	15.49
	2199	15.14	15.42	15.41	15.52	15.37
	2200	15.06	15.61	15.48	15.42	15.39
	2201	15.16	15.06	15.32	15.26	15.20
	2202	15.01	14.95	15.10	15.09	15.04
	2203	14.96	14.93	15.02	15.07	15.00
	2204	15.00	14.96	15.03	15.12	15.03
	2205	14.98	15.06	15.25	15.17	15.12
	2206	14.73	14.73	14.80	14.79	14.76
	2207	15.00	14.97	15.03	15.00	15.00

Lot No.	Rd. No.	Barr	Atkinson	Burns	Stahl	Average
1355-15	2276	16.26[L]	17.12[L]	15.61	16.04	15.83
	2277	15.72	15.59	15.50	15.54	15.59
	2278	15.44	16.01[L]	15.44	15.21	15.36
	2279	15.11	15.14	15.23	15.37	15.21
	2280	15.15	15.33	15.56*	15.29	15.26
	2281	15.13	15.37	15.25	15.29	15.26
	2282	15.20	15.24	15.52	15.31	15.32
	2283	15.24*	15.68	15.61	15.61	15.63

Lot No.	Rd. No.	Sentman	Atkinson	Stahl	Burns	Average	
1355-18	2340	14.87	14.98	14.98	14.80	14.91	(hang fire)
	2341	15.17	15.05	15.07	14.99	15.07	
	2342	15.32	15.28	15.24	15.17	15.25	
	2343	15.19	15.16	15.14	15.04	15.13	
	2344	15.40	15.35	15.40	15.35	15.38	
	2345	15.10	14.99	15.07	15.01	15.04	
	2346	15.36	15.40	15.50	15.24	15.38	
	2347	14.85	14.75	14.83	14.75	14.80	
	2348	15.02	14.96	15.00	14.92	14.98	
	2349	15.17	15.16	15.17	15.12	15.16	

* not used in figuring average.
L marked late by observer and not used in figuring average.

TABLE III (CONT'D.)

Time of Flight Measurements at 45° Elevation and 15 Sec. Fuze Setting

Results of Individual Timers (Stop Watch)

Lot No.	Rd. No.	Sentman	Atkinson	Stahl	Burns	Average
1355-22	2570	14.79	14.76	14.61	14.61	14.69
	2571	15.05	15.18	15.17	15.03	15.11
	2572	14.62	14.72	14.72	14.60	14.67
	2573	14.75	14.72	14.72	14.55	14.69
	2574	14.95	14.86	14.90	14.81	14.88
	2575	15.00	15.01	15.09	14.86	14.99
	2576	14.92	14.96	14.97	14.86	14.93
	2577	14.72	14.76	14.77	14.70	14.74
	2578	14.87	14.82	14.87	14.58*	14.85
	2579	14.63	14.58	14.64	14.35*	14.62

Lot No.	Rd. No.	Barr	Stahl	Thompson	Sentman	Average
1355-24	2702	14.57	14.55	14.54	14.78*	14.55
	2703	14.59	14.60	14.57	14.67	14.61
	2704	14.26	14.27	14.26	14.36	14.29
	2705	14.82	14.91	14.79	14.92	14.86
	2706	14.54	14.64	14.64	14.69	14.63
	2707	14.84	14.90	14.85	14.93	14.88
	2708	14.55	14.56	14.55	14.65	14.58
	2709	15.01	15.00	15.01	15.03	15.01
	2710	14.47	14.54	14.53	14.70	14.56
	2711	14.70	14.73	14.71	14.87	14.75

Lot No.	Rd. No.	Barr	Thompson	Burns	Stahl	Average
5286-2	318	15.52	15.20	15.80L	Lost	15.36
	319	15.26	Lost	15.36	15.36	15.33
	320	14.98	14.92	15.00	15.07	14.99
	321	14.99	15.01	14.96	15.11	15.02
	322	15.32	15.28	15.18	15.32	15.28
	323	15.33	15.15	15.21	15.21	15.23
	324	15.50	15.48	Lost	15.60	15.53
	325	14.93	15.00	14.98	14.93	14.96
	326	14.96	15.02	14.91	15.09	15.00
	327	15.06	15.05	15.16	15.11	15.10

* not used in figuring average.
L marked late by observer and not used in figuring average.

TABLE III (CONT'D.)

Time of Flight Measurements at 45° Elevation and
15 Sec. Fuze Setting

Lot No.	Rd. No.	Stahl	Durham	Twombly	Peck	Average	Barr
		Results of Individual Timers (Electric Clock)					Stop Watch
5286-5	125	15.09	14.84	15.03	15.11 L	14.99	14.82
	126	14.79	14.69	15.14 L	15.20 L	14.74	14.85
	127	14.91	15.03	15.80 L	14.89	14.94	14.93
	128	15.12 L	14.95	15.69 L	15.00	14.98	15.03
	129	Lost	14.90	15.08 L	14.96	14.93	15.09
	130	15.00	15.14 L	15.53 L	15.05	15.03	14.98
	131	14.99	14.99	15.31 L	15.05	15.01	15.00
	132	14.99	14.95	15.13 L	15.01	14.98	14.95
	133	15.01	15.05	15.13 L	15.12 L	15.05	15.01
	134	15.02	14.97	15.03 L	15.05	15.01	14.91

* not used in figuring average.

L marked late by observer and not used in figuring average.

TABLE IV

Recommended Maximum Permitted Standard Deviation

Angle of Elevation degrees	Maximum permitted standard deviation Fuze Setting 10 sec.	Fuze Setting 15 sec.	Fuze Setting 20 sec.
30	.104	.125	.140
35	.116	.144	.165
40	.128	.164	.193
45	.141	.185	.223
50	.154	.206	-
55	.168	.227	-
60	.180	-	-
65	.192	-	-
70	.202	-	-
75	.209	-	-

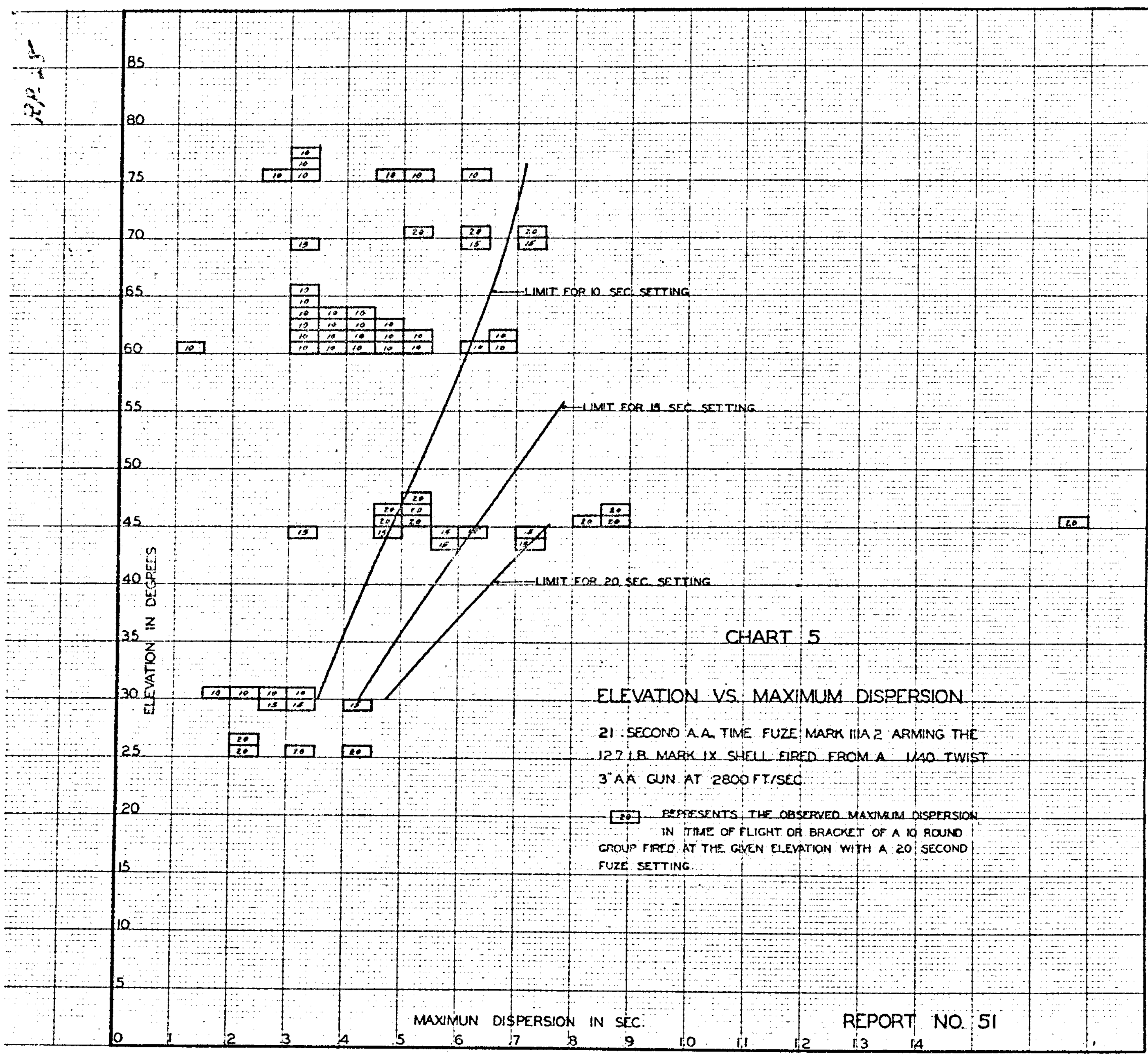
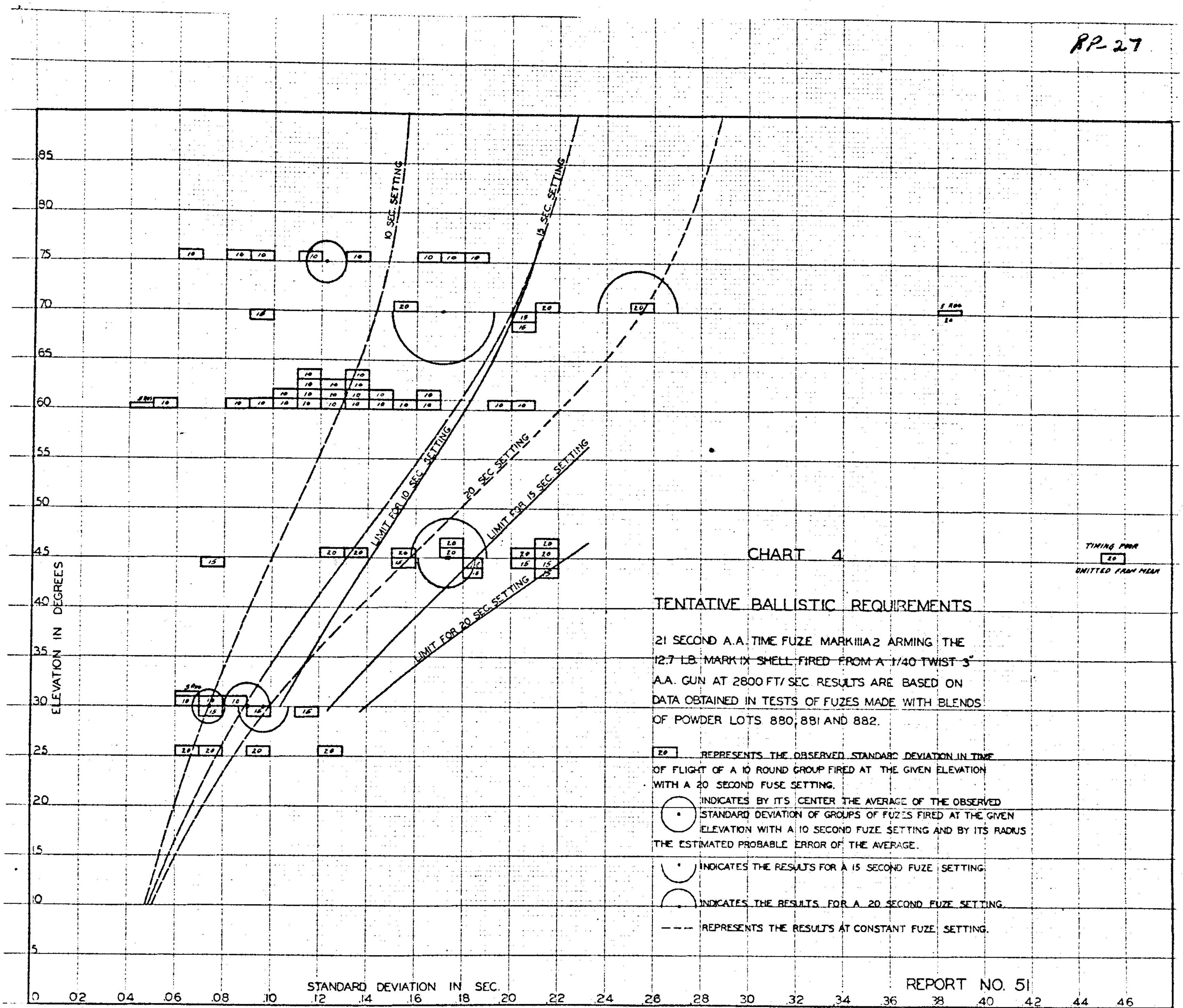


CHART 5
ELEVATION VS. MAXIMUM DISPERSION
21 SECOND A.A. TIME FUZE MARK IIIA 2 ARMING THE 12.7 LB. MARK IX SHELL FIRED FROM A 1/40 TWIST 3" AA GUN AT 2800 FT/SEC.
20 REPRESENTS THE OBSERVED MAXIMUM DISPERSION IN TIME OF FLIGHT OR BRACKET OF A 10 ROUND GROUP FIRED AT THE GIVEN ELEVATION WITH A 20 SECOND FUZE SETTING.
LIMIT FOR 10 SEC. SETTING
LIMIT FOR 15 SEC. SETTING
LIMIT FOR 20 SEC. SETTING
ELEVATION IN DEGREES
MAXIMUN DISPERSION IN SEC.
REPORT NO. 51

ARS-9


RP-27
CHART 4
TENTATIVE BALLISTIC REQUIREMENTS
21 SECOND A.A. TIME FUZE MARKIIIA2 ARMING THE 12.7 LB. MARK IX SHELL FIRED FROM A 1/40 TWIST 3" A.A. GUN AT 2800 FT/SEC RESULTS ARE BASED ON DATA OBTAINED IN TESTS OF FUZES MADE WITH BLENDS OF POWDER LOTS 880, 881 AND 882.
20 REPRESENTS THE OBSERVED STANDARD DEVIATION IN TIME OF FLIGHT OF A 10 ROUND GROUP FIRED AT THE GIVEN ELEVATION WITH A 20 SECOND FUSE SETTING.
INDICATES BY ITS CENTER THE AVERAGE OF THE OBSERVED STANDARD DEVIATION OF GROUPS OF FUZES FIRED AT THE GIVEN ELEVATION WITH A 10 SECOND FUZE SETTING AND BY ITS RADIUS THE ESTIMATED PROBABLE ERROR OF THE AVERAGE.
INDICATES THE RESULTS FOR A 15 SECOND FUZE SETTING.
INDICATES THE RESULTS FOR A 20 SECOND FUZE SETTING.
REPRESENTS THE RESULTS AT CONSTANT FUZE SETTING.
TIMING POOR
20
OMITTED FROM MEAN
10 SEC. SETTING
15 SEC. SETTING
20 SEC SETTING
LIMIT FOR 10 SEC. SETTING
LIMIT FOR 15 SEC. SETTING
LIMIT FOR 20 SEC. SETTING
ELEVATION IN DEGREES
STANDARD DEVIATION IN SEC.
REPORT NO. 51

RS-10

RP-26

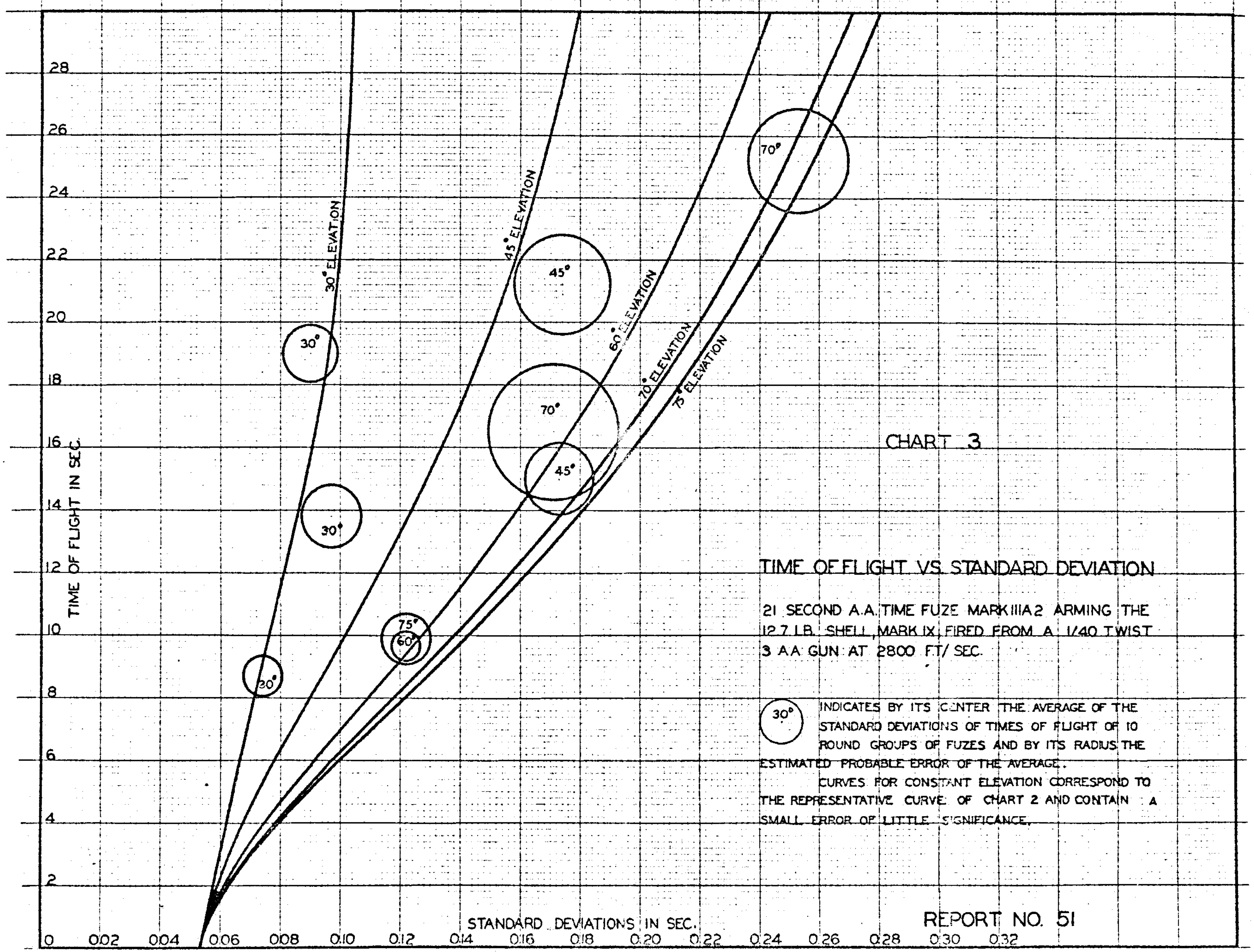


CHART 3

TIME OF FLIGHT VS. STANDARD DEVIATION

21 SECOND A.A. TIME FUZE MARK IIIA2 ARMING THE 12.7 LB. SHELL, MARK IX, FIRED FROM A 1/40 TWIST 3 AA GUN AT 2800 FT/SEC.

30° INDICATES BY ITS CENTER THE AVERAGE OF THE STANDARD DEVIATIONS OF TIMES OF FLIGHT OF 10 ROUND GROUPS OF FUZES AND BY ITS RADIUS THE ESTIMATED PROBABLE ERROR OF THE AVERAGE.

CURVES FOR CONSTANT ELEVATION CORRESPOND TO THE REPRESENTATIVE CURVE OF CHART 2 AND CONTAIN A SMALL ERROR OF LITTLE SIGNIFICANCE.

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11-59

RP-25

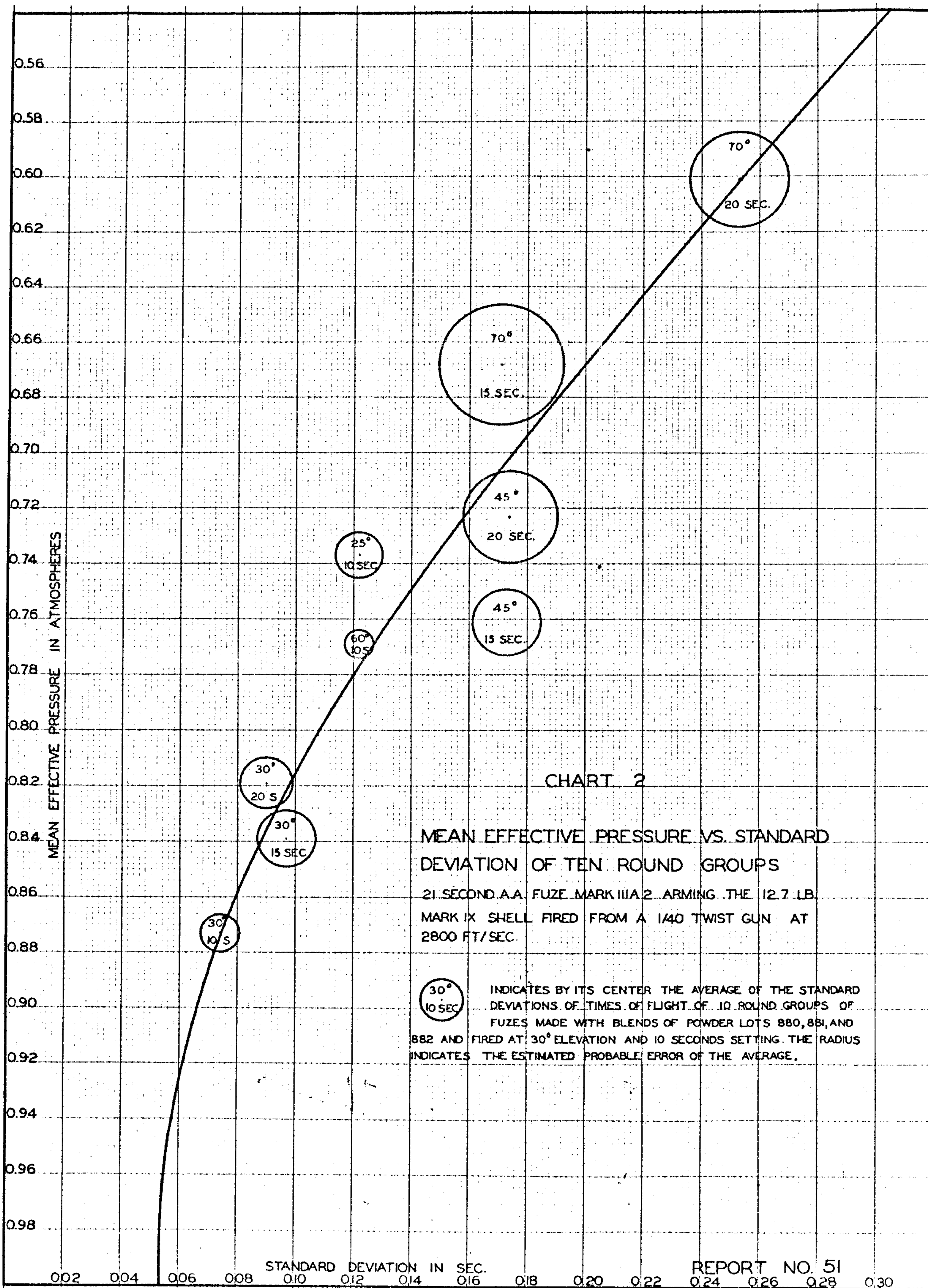
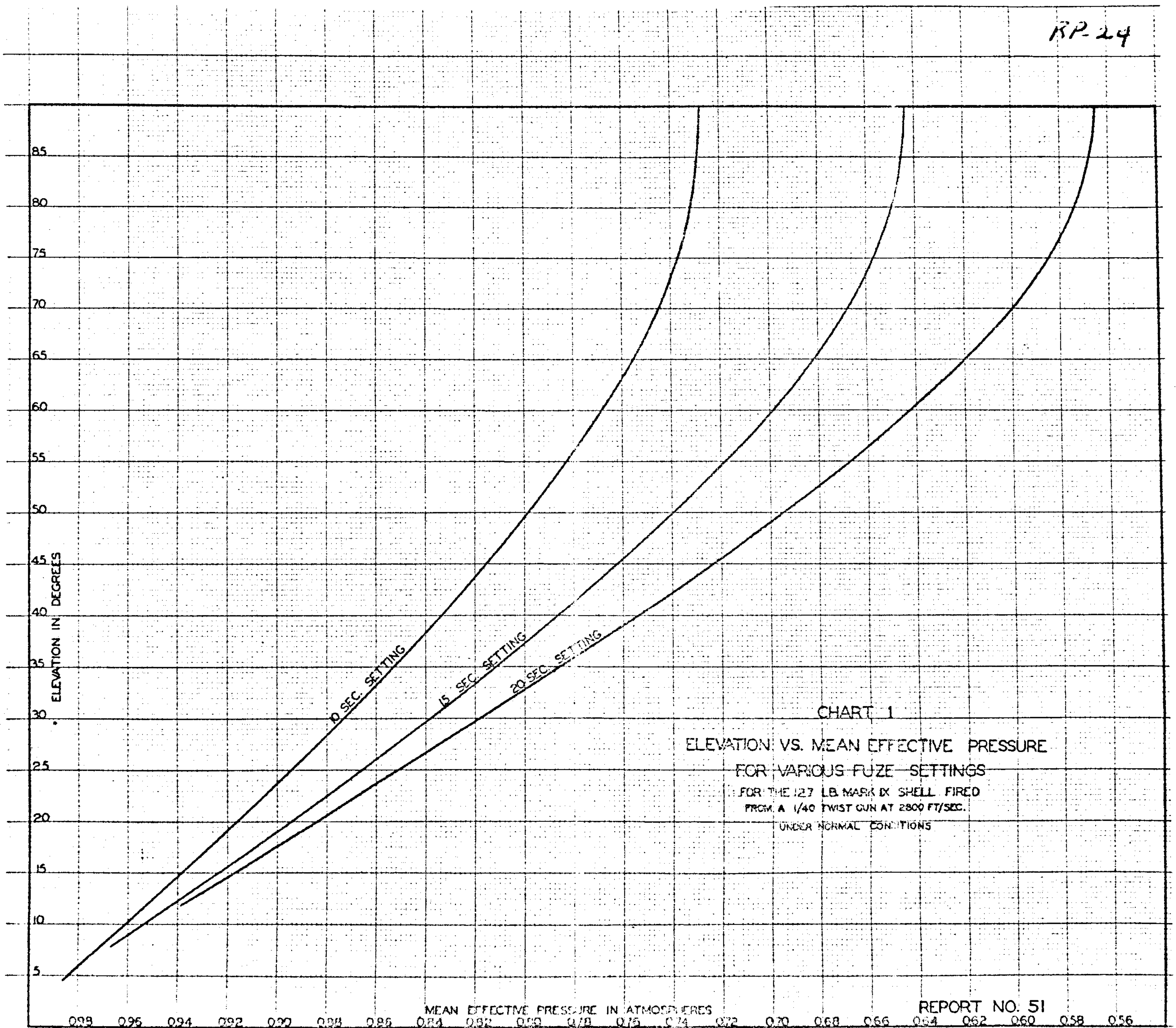


CHART 2
MEAN EFFECTIVE PRESSURE VS. STANDARD DEVIATION OF TEN ROUND GROUPS
21 SECOND A.A. FUZE MARK IIIA 2 ARMING THE 12.7 LB. MARK IX SHELL FIRED FROM A 1/40 TWIST GUN AT 2800 FT/SEC.
30° 10 SEC. INDICATES BY ITS CENTER THE AVERAGE OF THE STANDARD DEVIATIONS OF TIMES OF FLIGHT OF 10 ROUND GROUPS OF FUZES MADE WITH BLENDS OF POWDER LOTS 880, 881, AND 882 AND FIRED AT 30° ELEVATION AND 10 SECONDS SETTING. THE RADIUS INDICATES THE ESTIMATED PROBABLE ERROR OF THE AVERAGE.
MEAN EFFECTIVE PRESSURE IN ATMOSPHERES
STANDARD DEVIATION IN SEC.
REPORT NO. 51
0.56
0.58
0.60
0.62
0.64
0.66
0.68
0.70
0.72
0.74
0.76
0.78
0.80
0.82
0.84
0.86
0.88
0.90
0.92
0.94
0.96
0.98
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
0.22
0.24
0.26
0.28
0.30
70° 20 SEC.
70° 15 SEC.
45° 20 SEC.
25° 10 SEC.
45° 15 SEC.
60° 10 S
30° 20 S
30° 15 SEC.
30° 10 S

R.S. 12

RP-24



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