RADIATION LABORATORY, CONFERENCE ON P7 CATHODE RAY TUBE
5-6 APRIL 1943, RADIATION LABORATORY, MIT

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Radiation Laboratory
Conference on P7 Cathode Ray Tubes
Held April 5 and 6, 1943,
Radiation Laboratory, M.I.T.

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Abstract

A conference was held at the Radiation Laboratory on April 5th and 6th 1943 to discuss problems associated with the production and operation of tubes using the long persistent cascade screen designated by the letters"P7". The main subjects of discussion and the conclusions arrived at are presented in two sections with headings "Reports and Discussion" and "Decisions". Two Appendices are included the first of which presents graphical and tabular information concerning the performance characteristics from the standpoint of screen properties of hundreds of tubes which have been examined in the past few months. The second Appendix presents certain experimental information concerning the operation of the electron gun used in the magnetically focussed and magnetically deflected cathode ray tubes employing P7 screens.

Wayne B. Nottingham

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CONFERENCE ON P7 CATHODE RAY TUBES HELD APRIL 5 AND 6, 1943,
RADIATION LABORATORY, M.I.T.

I. INTRODUCTION

The specifications for P7 screens were first formulated in August, 1942. Since that time, hundreds of representative samples of tubes manufactured by the General Electric Company, the RCA Manufacturing Company, and others have been examined to determine whether or not the production as represented by these samples was meeting the requirements put forth in the August specifications. A close check was maintained on the production from the General Electric Company, and as the manufacturing processes became better controlled, a distinct trend was observed in the properties of the screens produced. In particular, there was a very notable increase in the "buildup" at a small sacrifice in tube brightness. Although most of the measurements on tubes were made with the M.I.T.-P7 screen measuring equipment, occasional tubes were examined in actual operating radar systems. Generally speaking, the higher buildup tubes were found to be slightly superior to the lower buildup tubes in terms of the minimum detectable signal. The General Electric Company representatives were encouraged to continue this trend towards higher buildup tubes, and modifications were made in the August specifications so that these tubes would not be classified as being outside of the specifications limits. In view of these changes, it became necessary to reconsider the specifications and attempt to formulate some new limits. The reformulation was accomplished at this conference and will be discussed in detail below.

Other problems important to the Manufacturers and also to the Armed Services needed discussion and clarification. Some of these were:

(a) Tube and screen blemishes.

(b) Electron gun characteristics.

(c) Operational tests and their relations to the P7 screen measurements.

These and other items formed the subject matter for the conference reported herewith.

II. REPORTS AND DISCUSSION

The first part of the conference, conducted under non-service auspices, was devoted to reports and discussions on tube characteristics, tube defects, and manufacturing methods. A brief resumé of these is given below.

A. Measurements on Light Output of P7 Screens, by W. B. Nottingham (Radiation Laboratory). Data are from Radiation Laboratory and Camp Evans Signal Laboratory measurements.

A graphical and tabular presentation of the results of certain tests on P7 screens was prepared for use in this conference. This entire presentation is incorporated within this report as Appendix I. In the present discussion of these results therefore, references will be made to the figures of Appendix I attached hereto.

The curves shown in Figures 1 and 2 show very distinctly the trend in the G.E. tubes toward lower values of cb_1. This quantity is a measure of the light output 1 second after a single raster excitation of a totally de-excited cathode ray tube screen. Figures 5 and 6 also show a trend toward lower values of light output as indicated by cb_5. However, the decrease in cb_5 is notably less than that in cb_1, and therefore the buildup $G_{5:1}$, which is measured directly by the $\log^{-1}(cb_5 - cb_1)/100$ is increased. This increase shows clearly on Figures 9 and 10. In particular, the 5-inch tubes produced late in 1942 have a most probable buildup value, $G_{5:1}$, of 7.5, while those produced since January 1943 have a most probable buildup ratio, $G_{5:1}$, of 11.3, with the lowest value observed being higher than the most probable value of earlier production. Figure 10 shows that similar results were obtained on the 7-inch tubes.

Light intensity measurements made under operating conditions have shown that in normal operation (a) the background noise, which represents random bombardment of the screen, excites the screen to a level comparable with cb_2 or cb_3 and in some cases as high as cb_5, and (b) signal intensities are often much higher than cb_5. Therefore higher light outputs such as those corresponding to cb_{10} are of interest. For this reason additional figures have been prepared and have been inserted along with the others in Appendix I as figures No. 17-24 inclusive. Figures 17 and 18 should be compared with Figures 1 and 2 and Figures 5 and 6. It is easy to see that the changes which have been brought about in the G.E. tubes have reduced cb_{10} notably less than they have reduced cb_5 and cb_1. We note also that the buildup factor $G_{10:1}$ as indicated on Figures 21 and 22 has increased for its most probable value from 14 to 24. It is interesting to compare this number with the results recorded in Radiation Laboratory Report 62-3 of October 7, 1942. In Table II of that report it was pointed out that a representative value for $G_{10:1}$ of tubes made in the U.S.A. was 10 while the extreme value at that date was 22.4. We now note that the most probable value for our late G.E. production is even in excess of 22.4.

The results presented in Figures 3, 4, 7, 8, and others applying to the RCA tubes were obtained very largely from measurements made by the Camp Evans Signal Laboratory. A very large number of tubes has been measured both in the Radiation Laboratory and at Camp Evans. It has, therefore, been possible to maintain a close check on the absolute values obtained in both Laboratories for the quantities of interest, so that results obtained at the two laboratories are accurately comparable. It is obvious upon inspection of these curves that the RCA production as represented by the sampling shown has not undergone the same systematic modifications as were so clearly demonstrated in connection with the General Electric tubes. This does not indicate that the RCA tubes cannot be made to conform more closely with the recent production of the General Electric tubes, but simply indicates that under the influence of the August 1942 specifications there was no stimulus to encourage changing the properties of the P7 screens as they are being manufactured by the RCA.

Since changes can be made in the properties of these screens by systematic variations in the manufacturing procedure, it is important, in making any comparisons between the data presented in this report on RCA versus G.E. tubes, that the reader recognizes that these curves represent the facts as regards past measurements, and that they should not be used as a basis for comparisons which might be made in the future. Although there will always be a considerable range in the properties of tubes all classified as "P7", it will not be possible to predict on the basis of these data alone what properties are likely to be found associated with tubes produced by a given manufacturer.

It has been extremely difficult to determine, by objective means, a suitable limiting value on the flash which is not objectionable in the operation of P7 screen tubes. It is, however, the general conceneus of opinion that extremely high flash is undesirable, and therefore flash should not go entirely unspecified as regards its maximum permissible value.

The results of observations of "integrated flash" are shown in Figures 13-16 and also in Figures 25 and 26, the last two of which have been added to the original set.

It is shown in Figures 13 and 14 that the relative flash as indicated by $cb_i - cb_1$ has increased as a result of the systematic modifications which have been made in the G.E. tubes of types 5FP7 and 7BP7. This increase in the value of $cb_i - cb_1$ must be associated with the fact that cb_1 has been decreasing more rapidly than cb_i, as the buildup in these tubes has been increased by very nearly 50%. It is quite clear from an inspection of Figures 13-16 that the requirement that $cb_i - cb_1$ should not exceed 235 would reject quite an appreciable percentage of tubes.

Since, as previously mentioned, background intensities equivalent to cb_3 or greater are always present in actual operation, there was a strong current of opinion at the conference that it would be better to formulate a specification for $cb_i - cb_5$ instead of $cb_i - cb_1$. It is to be expected that higher buildup tubes will be made in the future and that this will be done by decreasing cb_1 more than by increasing cb_5. Since such a change will reduce cb_i less than cb_1, tubes will at once seem to have higher flash under the older definition of flash ratio. If cb_i is related to cb_5 instead of cb_1, the difference (cb_i - cb_5) will probably remain constant or else decrease as higher buildup tubes are produced. In order to present information on this quantity, Figures 25 and 26 have been prepared showing the percentage of tubes which would have been rejected from the G.E. and RCA production since the beginning of 1943 if the limits were set at any of the various values indicated on the abscissae of these curves.

B. Report by R. E. Johnson (RCA).

Mr. Johnson showed the results of comparative measurements on a small group of tubes at Camp Evans, at the RCA's Lancaster plant and at the RCA's Harrison plant. The results indicated that, although there was a good correlation between measurements on a relative basis, the absolute scales at the three locations are quite different.

C. Report by Lieutenant E. A. Anderson (Camp Evans).

Lieut. Anderson displayed briefly charts giving a summary of all measurements on P7 screens made at Camp Evans. These results, which give summarizing totals for all types of tubes, indicate that the screen characteristics of 9-inch and 12-inch tubes are not quite as good as those of the 5-inch and 7-inch tubes.

D. Operational Measurements on P7 Tubes by L. J. Haworth (Radiation Laboratory).

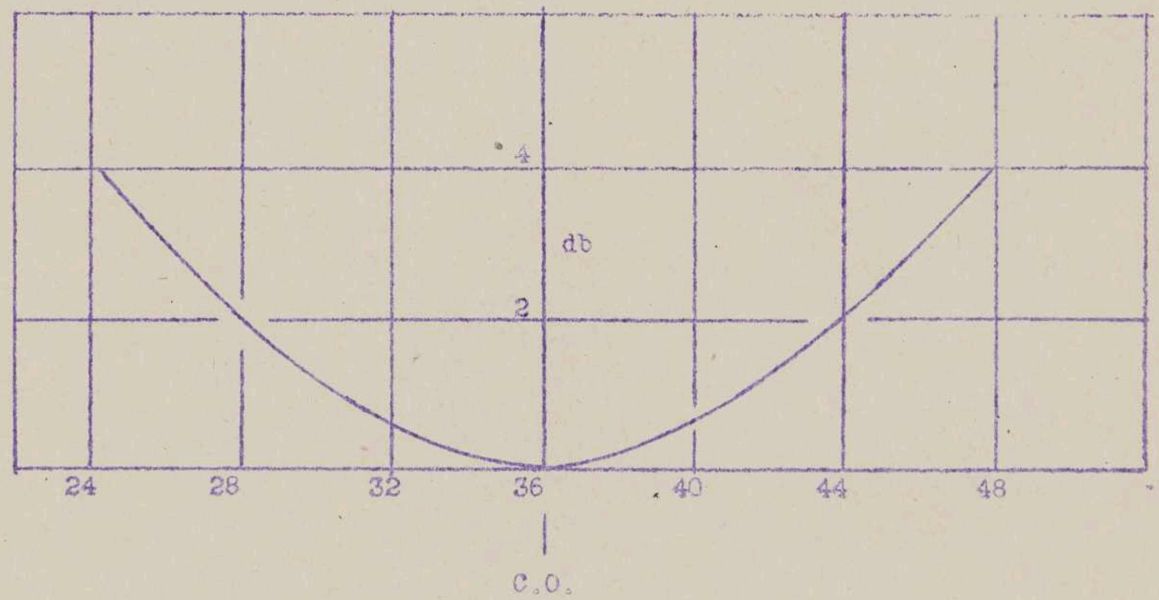
On numerous occasions since the early development of the P7 screen, operational tests have been carried out in order to investigate the relative merits of tubes having different properties as regards gun characteristics and screen characteristics (including buildup, flash, and brightness). At the suggestion of Mr. Baller of the Camp Evans Signal Laboratory, a section of the Radiation Laboratory Indicator Group undertook a systematic set of experiments of an operational nature to determine quantitatively, if possible, the value of having high buildup tubes, for example, and the value of having tubes of increased brightness.

Electrical circuits were arranged so that two cathode ray tubes could be operated simultaneously from the same power supply and the grids driven from the same receiver. The receiver system had all of the components of an actual radar system except the antenna. Artificial signals were introduced in the "RF" part of the system. An attenuator which formed the coupling from the signal generator to the receiving system was calibrated in db units. The presentation used was of the type known as PPI, and involved the use of a high speed sweep applied to a pair of deflecting coils in such a way that the electron beam swept out from the center of the tube 500 times per second. The time required for the beam to move from the center of the tube to the periphery was approximately 430 μs. By suitable adjustment, the sweep could be caused to rotate around the tube with angular velocity between 4 r.p.m. and 20 r.p.m. Most of the measurements were made with a rotational speed of approximately 8 r.p.m.

Under normal operation, the cathode ray tube is biased to cut-off with the receiver gain reduced to zero. As the receiver gain is increased, the output noise from the receiver drives the grid positive with respect to its cut-off. The observer, therefore, sees a bright line traced out in the form of a radius from the center of the tube to its periphery. This line has been popularly called the "spoke" of the PPI. By suitably adjusting the apparatus, it was possible to superimpose on this noise the artificial signal. This signal could be located at any point on the face of the tube and generally gave the appearance of a short circular arc at a radius equal to about two-thirds of the radius of the tube and an arc length of approximately 8°. Measurements were made by having an observer look for the signal on the face of the tube when the operator was free to move the signal from place to place without the observer knowing where to expect to find it. It was decided arbitrarily that if the observer did not discover the location of the signal upon the third application of it to a given spot on the tube, he was said to have failed to make the observation. The signal strength was increased in a new location and a new trial begun. This was repeated until an observable intensity was obtained.

One of the first problems was to find the bias voltage measured with respect to the tube's cut-off bias for which signals were most easily detected. In order to give a specific example of the results obtained here, Figure 1 is shown.

RELATIVE SIGNAL STRENGTH needed for MINIMUM DETECTION as a function of GRID BIAS



Grid bias voltage

Figure 1

The tube used had a cut-off voltage of 36 volts with a first anode voltage of 205 volts. The results shown in the figure indicate that if the operating bias voltage is set exactly equal to the cut-off voltage the tube exhibits its maximum sensitivity , when observations are made in total darkness. Deviations from the cut-off voltage either to higher or lower bias values result in a measurable increase in the input signal needed to detect the presence of the signal on the tube. Note that deviations from the cut-off bias of approximately 6 volts from either side of cut-off necessitate a one db increase in the signal strength in order to be detected on the tube illustrated.

After having determined the most favorable method of biasing the cathode ray tube, comparisons were made between tubes. In order to equalize the electrical characteristics, tubes to be compared were adjusted to the same grid bias, and the cut-off point attained by varying the first anode potential. Under these conditions (see section on electrical characteristics) the screen current versus grid swing characteristics are identical to a high degree of approximation.

A number of tubes were selected covering a range of cb_1 from 270 to 360, and of cb_5 from 360 to 450. The range in buildup factor, $G_{5:1}$, extended from 3 to 12.

Over this wide range in brightness and buildup there was no appreciable difference in the minimum detectable signal when the observations were made in total darkness and on the particular system described, in which the only distracting influence was the receiver noise. Experiments were also made in the presence of ambient light with intensities at the tube face up to as high as 12 foot-candles. Under practically all conditions of ambient light, tubes with a given buildup, but with varying degrees of brightness, were always better the brighter the tubes. Obviously, the higher the ambient light, the more clearly the advantage of bright tubes was apparent. Tubes with a given value of cb_1 but with increased buildup, and therefore higher cb_5 values, showed a distinct improvement when the brighter tubes were compared with less bright ones in the presence of ambient light. A comparison between tubes having the same values of cb_5, but having different values of cb_1 and therefore different buildup values, showed slight differences in favor of the higher buildup tubes. Thus one may conclude that a sacrifice of cb_1 to gain buildup is never a disadvantage as long as cb_5 remains practically unaltered.

Many of the tests were carried out by allowing the observer to make his observation by watching the tube continuously. Other experiments were made in which the time of observation was delayed either two or four seconds after the application of the signal to the tube. The results of these observations were in complete accord with those taken previously and again indicated that for a given buildup the brighter the tube the better; but for a given brightness of cb_5 or cb_{10}, the higher the buildup, the better.

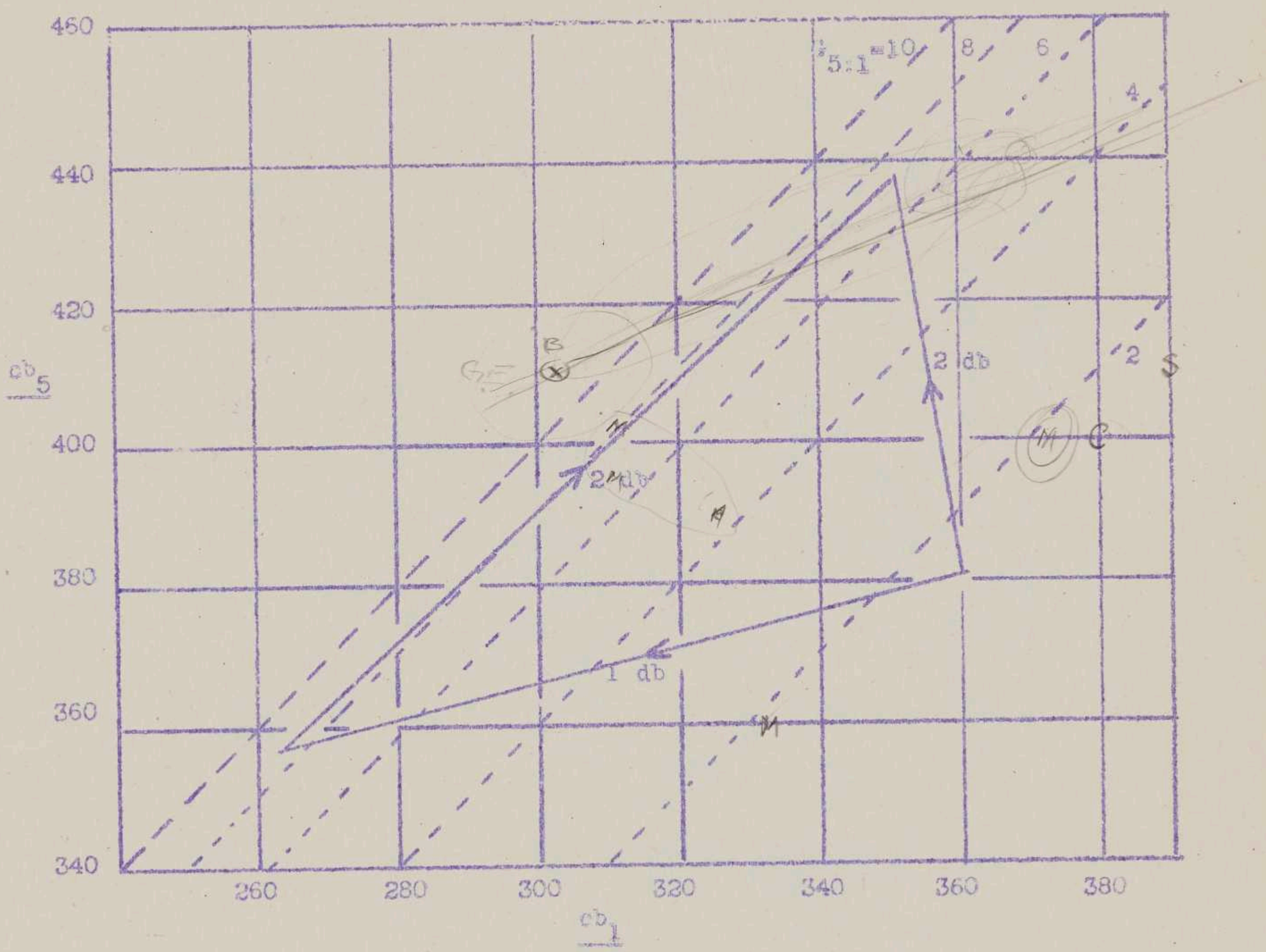


Figure 2

Figure 2 may serve as a rough summarization of these results. For a given tube, the brightness cb_1 is plotted as the abscissa and cb_5 as the ordinate. The 45° lines are lines of constant buildup. The heavy lines with arrows indicate the directions of improved operation and the approximate gain in terms of the reduction in signal input for the minimum detectable signal.

Related experiments are being continued and a more complete report will be presented in the near future.

E. Tube and Screen Blemishes (General Discussion)

The following types of tube blemishes most likely to be encountered with cathode ray tubes having P7 screens were discussed.

(1) Bright spots
(2) Holes
(3) Black specks
(4) Screen graininess
(5) Shaded and mottled areas and green spots
(6) Getter Shadows
(7) Water marks
(8) Siphon marks
(9) Bulb blemishes
(10) Surface scratches

Each of the items thus summarized in this table will be discussed individually below in the same order in which it is recorded in the table. The tube manufacturers have experienced considerable difficulty on account of the non-uniformity of the standards of quality required for cathode ray tubes with P7 screens. The requirements as covered by the minutes of the "Sub-Committee on Cathode Ray Tube Blemishes of RMA" covering their meeting held at Corning, New York, on September 15, 1942, are not entirely suitable for use in connection with P7 screens. On this account, manufacturers have been passing tubes which are definitely acceptable under the requirements laid down by the RMA Sub-committee, and yet, when these tubes are inspected by the customer producing completed Radar systems, they are too frequently rejected and returned to the tube manufacturer. Quite a number of these rejected tubes were examined during the conference, and it was generally agreed that a large fraction of the rejected tubes should be reconsidered for acceptance since experiments at the Radiation Laboratory showed that in most cases the tube blemishes forming the basis for the rejection were insufficient to interfere seriously with the use of the tubes in actual operating systems. In order to eliminate the confusion now existing, it will be necessary to formulate some method of inspection and standardization as soon as possible.

(1) Bright Spots. Experiance with the inspection of cathode ray tubes having P7 screens indicates that there are roughly speaking two forms of bright-spot blemishes. The first form shows up as a brilliant point-like source of light which has an intensity far in excess of the average intensity of the surrounding area when both are being bombarded by electrons. These extremely bright spots are very objectionable and if there are more than two or three of them over the entire face of the tube, its usefulness is seriously impaired.

When the tube is operated with a uniform bombardment of electrons over the entire screen, it is often possible to note relatively large numbers of bright spots of the second form, having apparently only two or three times the brightness of their surrounding area. If these spots are small and not too closely located with respect to each other, then a relatively large number of them may be visible over the screen without in any way impairing the usefulness of the tube. There is a very serious difficulty in connection with these two classes of bright spots, owing to the great difficulty of distinguishing one class from the other. The fact that the very bright spots are so objectionable makesit imperative that some method be worked out so that tubes with more than two or three of these in the face may be rejected. The exact maximum number of these bright spots to be allowable probably depends on the tube type.

(2) Holes. In the screens of cathode ray tubes there are certain types of holes that are effectively just as objectionable as the bright spots discussed in the section above this. The main reason for this is that holes usually appear as pin point

centers of darkness surrounded by a ring of very intense illumination. It is the intense illumination surrounding the hole that causes it to be so seriously objectionable. Therefore, the total number of extremely bright areas including the bright spots and the rings should remain equal to or less than, say, three for acceptable tubes. Holes which may exist, but which are not surrounded by bright rings, are not nearly so objectionable, and, therefore, a relatively large number of these may be permitted on acceptable tubes if they are small in diameter. Obviously, the larger the diameter of the hole, the smaller the number which should be permitted on the tube which is classified as acceptable.

(3) Black specks. Black specks are sometimes due to impurities within the screen and sometimes due to imbedded impurities in the glass. As long as the number of these remains within the limit as set down in the RMA specifications, the existence of black spots and specks should not be sufficient reason to reject tubes which are otherwise satisfactory. Such black specks are obviously objectionable and every precaution should be taken to eliminate them, and yet, in comparison with the interference caused by the bright spots, they are decidedly less objectionable.

(4) Screen Graininess. With the reasonably fine-grained phosphors which are now being used in connection with the "liquid settling" and "paste" methods of application, the screens are generally sufficiently free from graininess to be entirely satisfactory. In contrast, experience shows that the average tubes produced in the U.S.A. using the method of air settling have a degree of graininess which is often objectionable. In the operation of any tube as it is connected to a radar receiver, the electron beam bombards the face of the tube in the course of time with an intermittent random bombardment which excites the screen and leaves the impression of a grainy structure. When a signal appears on the tube, the bombardment is no longer random and, therefore, the excitation is smoother and can be distinguished from "noise" excitation provided the phosphor itself is free from inherent

graininess. It is, therefore, important that manufacturing methods should be adopted which produce cathode ray tubes with P7 screens which are as free from graininess as possible when being bombarded or excited by a uniform distribution of electron density over the area of the screen.

(5) Shaded and mottled areas and green spots.. Some P7 screens show areas of non-uniform emission of light due to some non-uniformity in the application or the drying of the screen when it was being manufactured. Variations in the light intensities over separate square-inch areas are not permitted to exceed a factor of two according to the RMA standards. Although such variations are objectionable for many applications of P7 tubes, it seems as though the RMA upper limit could reasonably be applied to this tube type. In some screens there is a form of "mottling" due to a non-uniformity in the apparent color of the screen without much change in the absolute brightness. This may be objectionable in a limited number of applications of these tubes, and should be avoided as much as possible. Mottling, however, is not likely to interfere with the detection of weak signals, and as long as the visual evaluation does not exceed the impression of a two to one non-uniformity, such mottling should not be made the basis for tube rejection.

The "green spot" blemish is very commonly found in cathode ray tubes in general and often makes its appearance in P7 screens. Some inspectors do not seem to distinguish between the "green spot" blemish and the "bright spot" blemish. There is a big difference between these spots as far as actual operating systems are concerned, and the "green spot" is decidedly less objectionable. The RMA specifications on "dark specks" are written in such a way as to apply also to "bright spots". If these were re-worded so as to apply to the "green spot", it seems as though the limits as imposed by RMA standards would be satisfactory.

(6) Getter shadows. Shadows are sometimes created by the improper mounting of the "getter". This shadow is differentiated from the areas discussed in paragraph (5) in that it is due to the

actual interception of the electrons by the improperly placed getter clip. As long as this shadow does not extend more than a few millimeters inside of the minimum useful screen diameter, then it should not be made ground for rejection.

(7) Water marks. Disturbances in the uniformity of the P7 screen are often noted around the outside edge of the screen. Such blemishes which lie outside of nine-tenths of the radius of the tube can be permitted to be very noticeable without seriously impairing the usefulness of the tube.

(8) Siphon marks. At the point of siphoning on a liquid-settled screen, this blemish is often observable. It is felt, however, that in case this blemish does not extend appreciably inside of the quality circle that it should not be taken as reason for rejecting the tube. Again, it is obviously desirable to try to eliminate such blemishes in the manufacturing process.

(9) Bulb blemishes. The RMA report of September 15, 1942 covers most of the points of importance in connection with the blemishes of the actual glass blank. Since these have been agreed upon for cathode ray tubes in general, it seems as though there is no reason why a different set of standards should be used in connection with tubes having P7 screens. It was recommended that specifications following closely the details of the RMA report should be used by the P7 manufacturers and also by the inspectors representing the consumers.

(10) Sürface scratches. On account of carelessness of handling either by the tube manufacturer or the customer, cathode ray tube faces often become scratched. Tubes of the 5FP7 and the 7BP7 type which have very obvious scratches on the face have been tested under pressure conditions with the conclusion that these scratches do not seriously interfere with the strength of the bulb. A number of bulbs have also been examined in an operating system and although the scratches on the face of the bulbs were very evident

in ordinary light, they did not seem to interfere appreciably with the usefulness of the tube; in fact, they were hardly apparent at all unless the light which illuminated the scratches came from outside of the tube instead of from the fluorescence or phosphorescence of the cathode ray tube screen.

In view of the above remarks, it is evident that it would be very desirable to form a special committee to formulate specifications to be applied to cathode ray tubes having P7 screens, since there are some points upon which a departure from the RMA specifications is undoubtedly necessary. It seems likely that the best way to maintain tube quality as regards blemishes is to describe the most common ones and set limits on the number and size of the blemishes and also furnish at each inspection point "limit tubes" which have been inspected by the Radiation Laboratory or else by the Services on operating radar systems. After specifications have been formulated and agreed upon, they should be put into force by the inspectors at the cathode ray tube manufacturing plant and also by the inspectors for the customer. It is important that decisions in this regard should be made as soon as it is at all possible to do so.

F. _Electron Gun Characteristics_ by T. Soller, Radiation Laboratory.

Dr. Soller discussed at some length the difficulties encountered with cathode ray tubes that have electron gun characteristics differing as widely as they now can differ under present specification for beam cut-off by the control grid. The present specification allows a range in cut-off voltage between -25 volts and -75 volts with 250 volts on the first anode with respect to the cathode.

In Appendix 2 of this report, data are presented which illustrate the fact that, in the magnetically focussed tubes now in use with electron guns of the "single crossover" type, the observed beam current increases in proportion to the third power of the grid drive voltage as measured from the beam cut-off potential of the tube. In equation form, this may be expressed as follows:

$$i_p = A(E_{co} - E_{cl})^3 \qquad (1)$$

where $(E_{co} - E_{cl})$ is the grid drive. (a)

It is also shown in Appendix II that with guns of the present general design there is a relationship between the grid drive factor A and the cut-off value of the grid potential E_{co}. This relationship illustrated by Figure 27 of Appendix II. Since the plate current depends on the grid potential in this non-linear way, it is impossible to define the trans-conductance of a cathode ray tube according to the conventional method. The constant A of the above equation, however, serves as the most direct measure of the response of the tube to a given grid drive.

For the range in cut-off voltage now permitted there is an expected range in A of 6:1. Stated in another way, for a small grid drive, of 10 volts for example, the beam current in a tube with a cut-off voltage of -25 volts may be expected to be six times as large as the beam current in a tube with a cut-off voltage of -75 volts. In order to obtain the same beam current on the 75 volt tube, the grid drive must be increased to 18 volts. If the maximum acceptable cut-off voltage is reduced to 60 volts then the expected variation in the tube response will be reduced from 6 to 4. Such a change would therefore achieve two objectives: (1) decrease the range in response to be expected, and (2) make it possible to use all tubes in sets now in existence which do not have a sufficient receiver gain to drive the present highest cut-off tubes.

From the manufacturing point of view, it is desirable to have the range of acceptable cut-off values of voltage as wide as possible, and the user must design driving equipment so that the least responsive tube can be driven satisfactorily. With the high gain thus demanded, signals as strong as 30 volts or more might possibly be delivered and the requirement would be that the tube should not defocus seriously under this high grid drive. It is obvious that a tube with a cut-off voltage of only 25 volts must have a higher response than a tube with a cut-off value at 60 volts so that a smaller grid drive will permit the maximum beam current that service may demand; and yet under these operating conditions serious defocussing must not take place. These facts have a direct bearing on the "gun characteristic" specification and demand that some practical method of inspection should be agreed upon which will allow for a determination of the cut-off voltage and at the same time a determination of the "grid drive factor" A, or a directly related quantity which could serve as a "go - no go" indication of the value of A.

G. Radiation Laboratory Proposal for Beam Current Specification

It was pointed out in the conference that the present method of specifying the emission properties of the electron gun, which calls for a certain minimum current to be delivered at zero bias, is not satisfactory. A request was made at the conference that the problem should be taken under immediate consideration and some new method for specifying the minimum beam current should be proposed. The discussion which follows is a response to this request and is, therefore, not part of the conference proceedings. It has been discussed with the RCA representatives subsequent to the conference.

As stated in the conference report above, the beam current in magnetic tubes with single cross-over guns may be expressed by equation (1). The fact that there seems to be a definite relationship between the grid drive factor A and the beam cut-off voltage E_{co} was also mentioned and is illustrated by Figure 27 of Appendix II. The heavy line drawn in this figure, identified by the letters a-a, represents as well as it can be determined the minimum value of A, as a function of the cut-off voltage E_{co}, which can be taken as acceptable for new tubes. The margin between this line and the least possible value of A is small and must be included as a safety factor against tube aging.

The line referred to may be represented by the equation which follows :

$$A = \frac{150}{(0.3\,E_{co} + 13.5)^3} \quad \mu a/volt^3 \qquad (2)$$

The value of A given by this equation is, therefore, considered the minimum acceptable value as a function of the cut-off voltage E_{co}; E_{co} represents the negative bias in volts with respect to the cathode when the first anode is 250 volts positive with reference to the cathode.

The justification for making use of a relationship between A and E_{co} as expressed by Equation (2) is that it permits a very easy test procedure. Two possible test methods are outlined below. A number of considerations indicate that in either case to make the test at 150 μa for the electron current in the beam would be about the best compromise when all factors are considered. For a given gun characteristic as represented by Equation (1), the bias voltage for testing the gun may be identified by E_{cT}, and the test current demanded (i.e., 150 μa) may be identified by i_{pT}. If these symbols are substituted in Equation (1), and that equation is combined with Equation (2), then Equation (3) is obtained.

$$E_{cT} = E_{co} - \sqrt[3]{\left(\frac{i_{pT}}{150}\right)} \cdot (0.3\ E_{co} + 13.5) \qquad (3)$$

The specified value of test current i_{pT}, may be inserted on the right hand side of Equation (3), and the numerical coefficient $(i_{pT}/150)^{1/3}$ may be computed. Obviously, if i_{pT} is 150 μa, then this coefficient is unity, and Equation (3) reduces to Equations (4).

$$E_{cT} = 0.7\ E_{co} - 13.5 \qquad (4a)$$

$$E_{cT} = 0.7\ (E_{co} - 19.3) \qquad (4b)$$

From Equations (4), a table of values has been constructed relating E_{co} to E_{cT}, and including the minimum values of A as computed by Equation (2). The table given below, could be used in the following manner. Determine for a given electron gun the value of E_{co}. Read from the table the bias voltage at which the beam current should be 150 μa or more. Set the bias to this value and observe the beam current. If it exceeds 150 μa, then the grid drive factor A exceeds that required by Equation (2). An alternative method would be to set the grid bias so that the beam current is exactly 150 μa and note whether or not the bias exceeds that required by Equations (4). In case it does, then the grid drive factor is above the proposed specification limit.

The determination of E_{co} may be made by noting the bias voltage at which the raster becomes invisible if the observation is made with quite dark surroundings. If the ambient light on the tube is not sufficiently low, then the beam in the form of a line may serve as a better observational method for determining the cut-off voltage of a given tube.

BIAS VOLTAGES AT WHICH TEST CURRENT SHOULD BE 150 μa OR MORE, AS A FUNCTION OF CUT-OFF BIAS E_{co} (FIRST ANODE + 250 VOLTS)

E_{co}	E_{cT}	Min A	E_{co}	E_{cT}	Min A
25	4.0	16.21×10^{-3}	45	18.0	7.65×10^{-3}
26	4.7	15.54	46	18.7	7.39
27	5.4	14.92	47	19.4	7.15
28	6.1	14.28	48	20.1	6.93
29	6.8	13.75	49	20.8	6.70
30	7.5	13.20	50	21.5	6.49
31	8.2	12.70	51	22.2	6.30
32	8.9	12.18	52	22.9	6.10
33	9.6	11.72	53	23.6	5.91
34	10.3	11.31	54	24.3	5.75
35	11.0	10.87	55	25.0	5.55
36	11.7	10.47	56	25.7	5.40
37	12.4	10.10	57	26.4	5.24
38	13.1	9.74	58	27.1	5.10
39	13.8	9.40	59	27.8	4.95
40	14.5	9.07	60	28.5	4.81
41	15.2	8.75	61	29.2	4.68
42	15.9	8.45	62	29.9	4.55
43	16.6	8.15	63	30.6	4.42
44	17.3	7.90	64	31.3	4.30

A consideration of Equation (4b) shows that this test procedure may be simplified to the extent of making it very nearly automatic in requiring no reference to tables and meter readings beyond the necessary determination of the cut-off voltage. The circuits shown in Figures 3 and 4 are practically self-explanatory and show how the conditions required by Equations (4) can be satisfied without any more work on the part of the operator than to snap a switch from the "cut-off" test position to the "150 μa test" position. In the latter position, satisfactory tubes should always deliver more than 150 μa. Any tubes falling below that value would have grid drive factors below the required limit.

Since the current obtained from a tube using any specified drive condition is directly proportional to the grid drive factor A, then under the test conditions specified above, the amount by which the observed current exceeds 150 μa is a direct measure of the amount by which the observed grid drive factor exceeds the minimum necessary for satisfactory tube operation. Experience shows that a reasonable bogey value for the beam current under the conditions of operation described would be 200 μa. This value is probably not far from the mean value found in tubes now being produced.

H. Focussing properties of cathode ray tubes.

Although practically all the tubes which have been examined for sharpness of focus by using the 200 line raster or the 40 or 50 line raster method of excitation show perfectly satisfactory focus, a considerable fraction of these tubes turn out to be rather unsatisfactory for many applications. Practically all of the tubes which have shown poor PPI presentation, for example, have been found

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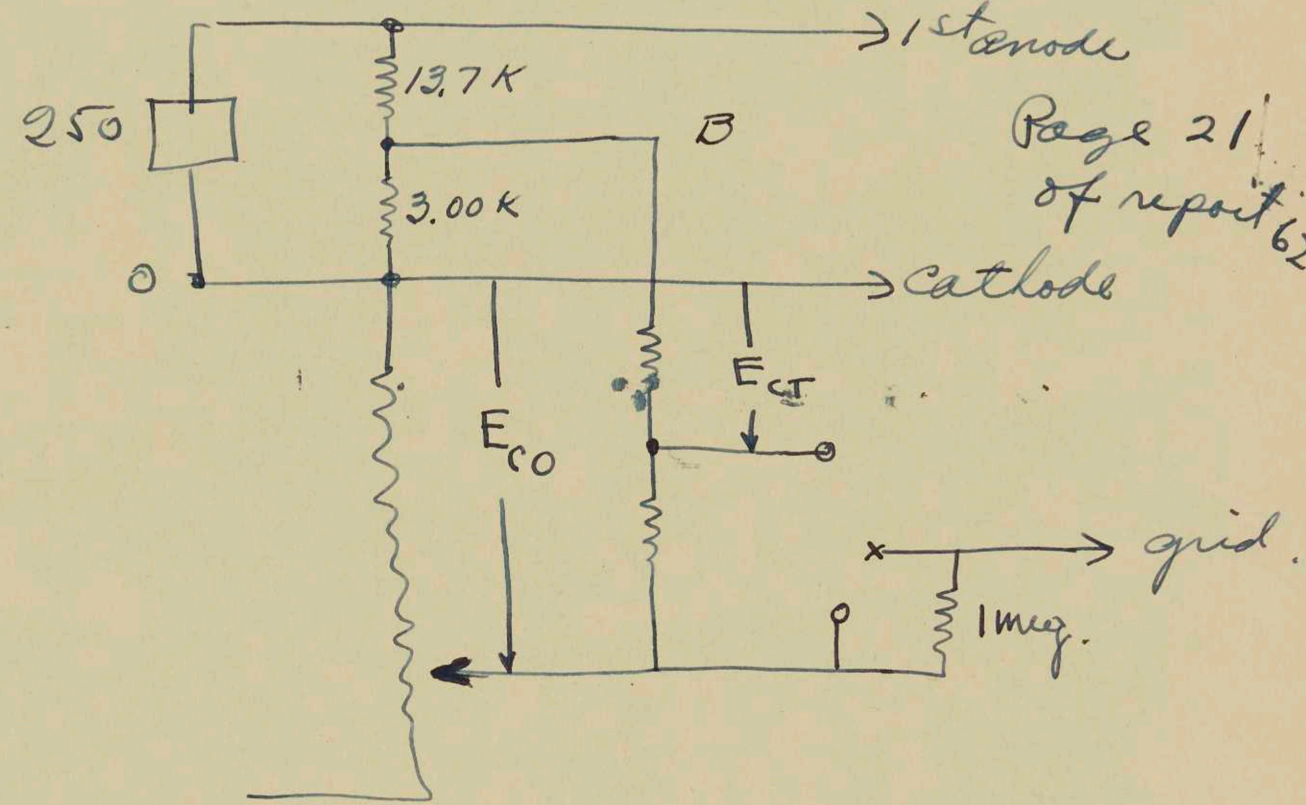


Equation (4a) give abs. value of test bias and reads

$$E_{CT} = 0.7 E_{co} - 13.5 \qquad (4a)$$

To have this read correctly as to sign it should read

$$E_{cT} = 13.5 + 0.7 E_{co} \qquad (4c)$$

Insert $E_{co} = -25$ in (4c) to get

$$E_{cT} = 13.5 - 17.5 = -4 \text{ volts}$$

Put $|25|$ in (4a) to get

$$E_{cT} = 17.5 - 13.5 = 4 \text{ volt} = \text{absolute value OK.}$$

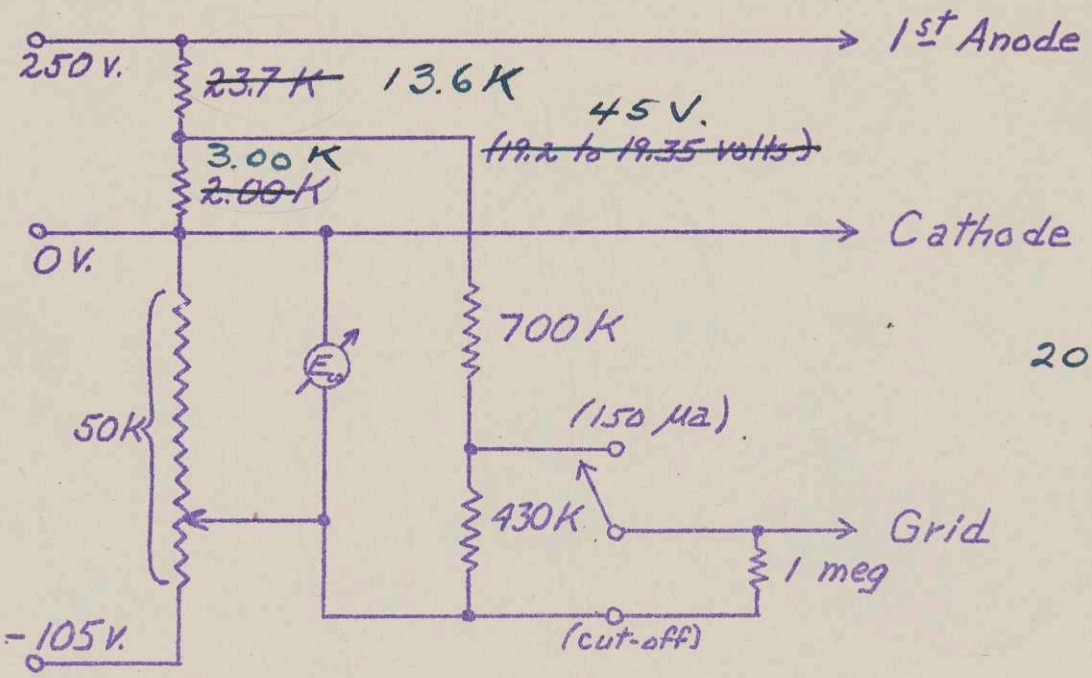
From above diagram

$$E_{cT} = B - 0.7(B - E_{co})$$

$$= 0.3 B + 0.7 E_{co}$$

compare with 4c to get

$13.5 = 0.3 B \quad \therefore \quad B = 45$ Volts.



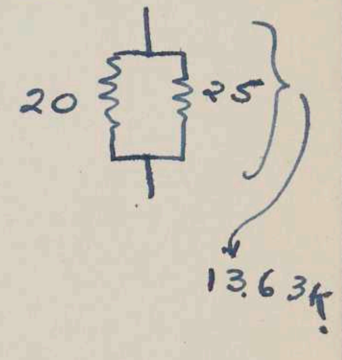


Fig. 3
A circuit for the 150 µamp. beam current test

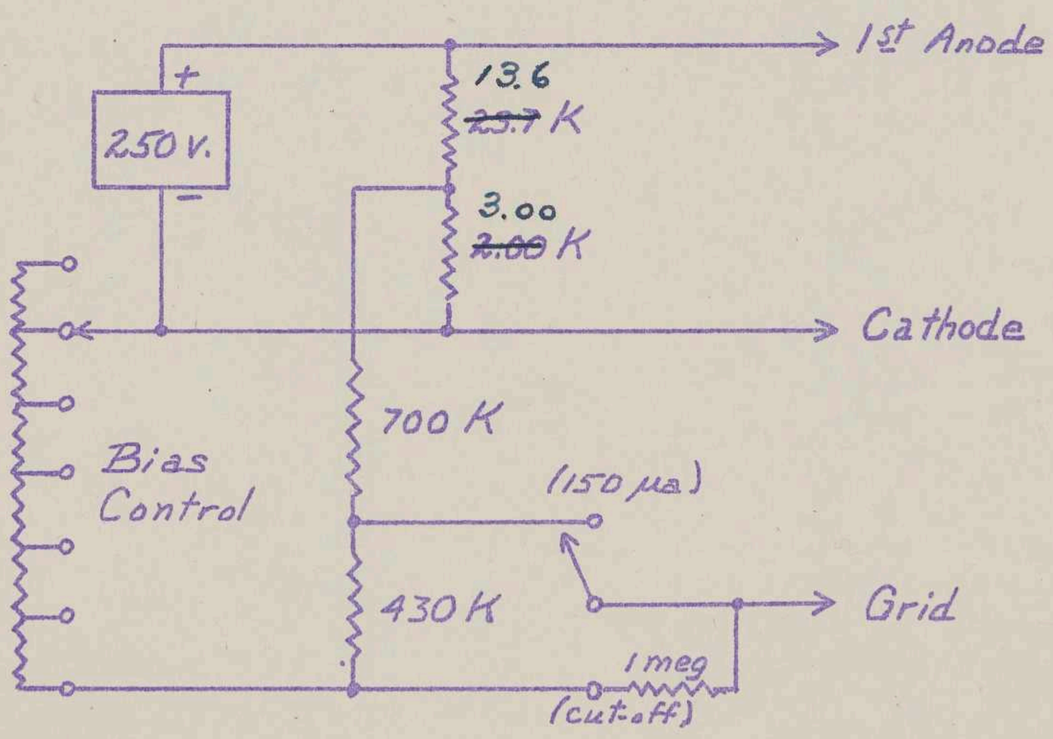


Fig. 4
Circuit for the 150 µamp. beam current test
using the MIT screen test unit

to have an electron emission from the cathode which is non-uniform. This non-uniformity is associated mainly with poor emission in the very center of the cathode. In spite of the importance of this problem, no practical method has yet been devised for setting up a suitable method of test and means of specification which will insure that tubes which pass inspection will be satisfactory for service use. It is important that steps should be taken to discover a practical solution to this problem of cathode inspection.

I. High Speed Production Testing. Reported by W. B. Nottingham

For the past few months there has been some interest on the part of certain manufacturers in the possibility of devising a test which could be applied to all tubes being produced. Figures 12 a,b,c, and d of M.I.T. Radiation Laboratory Report Section 6-4s (January 22, 1942) show that the nature of the build-up property of a P7 screen can be determined by observing the build-up in light intensity with only 500 microseconds between pulses. The patterns shown in the figure referred to are photographs taken when a pulse of electron current was delivered to the tube for a period of 6 microseconds and repeated every 500 microseconds. The pattern was formed by having a horizontal sweep lasting 0.01 seconds and a vertical deflection showing the instantaneous light intensity as a function of the time.

By means of a very simple circuit, it has been possible to modify the raster applied to the cathode ray tube under test in such a way that every tenth line of the 200-line raster makes its appearance. The intervening 9 lines are suppressed by grid modulation. The normal circuits of the M.I.T. test equipment allow twenty of these lines to be applied to the same region of a cathode ray tube within one-sixtieth of a second. The normal coupling circuit for the 931 photomultiplyer tube may be used to drive a suitable amplifier and that in turn to drive the plates of the recording cathode ray tube. With a synchronized 60-cycle linear sweep the recording tube shows the pattern of the light increase as a function of the time when the 20 pulses are applied to a given area of the cathode ray tube under investigation. Some correlation data have been obtained and were presented during the conference. A demonstration of the equipment was given.

On the basis of the evidence now at hand, it seems as though this equipment or some modification of it could be adapted quite easily for the use of factory testing in order to insure that all tubes produced have the requisite build-up properties and the requisite brightness.

III. DECISIONS ETC.

The second day of the conference, conducted under service auspices, was devoted to recommendations and discussions leading toward the establishment of specifications.

A. Screen Specifications. At the request of Lieutenant Anderson and Mr. Greer, the Radiation Laboratory representatives recommended specifications for the light output of P7 screens.

It was recommended, with the results of the operational tests as supporting evidence, that cb_1 be dropped as a means of specification, and that flash be specified in terms of cb_i and cb_5 rather than by cb_i and cb_1 for reasons described above.

A request was also made to supply a "bogey" value for each of these properties. By this term we mean a value which should represent the mean of production if it is possible to attain it.

It was decided that new specifications, embodying the recommended values, should be placed in effect on June 5, 1943 unless evidence is presented by the manufacturers or others that there should be further alterations.

The specifications as adopted are tabulated below.

	Property	Limits	"Bogey"
1a	cb_5	380 cb	410 cb or more
1b	B_5	12.5 m.f.l.	25 m.f.l. or more
2	$G_{5:1}$	5	12 or more
3a	cb_i-cb_5	180	*130 or less
3b	Ratio equivalent to cb_i-cb_5	63	*20 or less

*These values have been chosen subsequent to the conference.

The standard conditions for measurements are as follows:

Anode voltage (relative to cathode) = 4000 volts

Grid voltage (G_2, for magnetically focussed tubes) = 250 volts

Raster size (focussed beam)= 7.1 x 7.1 cm giving a total area of 50 cm^2. (Beam is defocussed for measurement.)

Duration of raster = 1/60 sec. The raster is formed by means of linear sweeps with the horizontal sweep frequency 12 kc and the vertical sweep frequency 60 cycles. Except in the case of the measurement of fluorescence, the raster is repeated at one-second intervals.

Distance of raster from axis of calibrated 931 multiplier tube = 30 cm.

Beam current = 60 μa defocussed to a spot approximately 0.25 cm in diameter.

Red light: sufficient to de-excite the phosphor before buildup and integrated flash measurements so that the results are within 3 cb of those that would have been obtained after total de-excitation.

Filter: Wratten No. 15 or its equivalent.

Although the use of the "centibel" scale has been found convenient and adopted by nearly all the laboratories measuring P7 screens, the formula, given below, may be used to convert cb values into brightness values expressed in foot-Lamberts.

$$\text{Ft. lamb.} = 2x10^{-6} \times 10^{\frac{cb}{100}}$$

The application of the formula to cb_5 of the above table gives for B_5 the value 12.5; and the ratio equivalent 130 of

$cb_i - cb_5$ has been calculated by taking the anti-log of 1.8.

If it is necessary to take a measurement with a beam current which is different from 60 μa, then the area covered by the raster must be increased or decreased in exact proportion to the current used. Since the standard area is 50 cm^2, a reduction in beam current to 20 μa would necessitate a reduction in raster area to 16.7 cm^2. In order to make comparisons with the cb values tabulated above, the cb area correction may be added to the observed results. This correction is obtained by computing $100 \times \log_{10} \left[\frac{50}{\text{Area}}\right]$.

The first step in obtaining the integrated flash is to integrate the light obtained during one second after a raster is applied to a de-excited screen. Simple computations then yield an equivalent light intensity, the integrated flash or cb_i, which, if maintained constant for 0.1 seconds, would give the same integral. Previously cb_i has been considered relative to cb_1, and the criterion for setting the "flash" specification has been $cb_i - cb_1$. Now, however, the integrated flash is to be related to cb_5, and the new "flash" specification is to be based on $cb_i - cb_5$. The new flash ratio, FR_5, is $\log^{-1}\left(\frac{cb_i - cb_5}{100}\right)$ or the ratio between the brightness corresponding to cb_i and the brightness, B_5, corresponding to cb_5.

The bogey values suggested in the table above are largely determined by an inspection of the distribution function found in the G.E. production since January 1943. These tubes represent a very satisfactory state of production, and it seems very desirable to attempt to make tubes in the future which are as good as these or better.

B. Screen Blemishes. After further discussion and demonstration of blemishes it was agreed that the question should be fully investigated as quickly as possible.

In particular, at the request of the service representatives, the Radiation Laboratory agreed to examine a number of borderline cases of blemishes of all sorts and furnish a report as to their detrimental effects. Samples of such tubes will be distributed, if possible, to the points where tubes are being examined by service inspectors.

C. Electrical Properties. The following future steps were agreed upon.

A study will be made, by the manufacturers, of the feasibility of confining the range of cut-off voltages for cathode ray tubes having magnetically focussed guns of the single cross-over type to the range -25 volts to -60 volts when the first anode is maintained 250 volts positive with respect to the cathode. Should this limitation prove possible these values will ultimately be adopted as specification limits.

The Radiation Laboratory will attempt to formulate a new type of specification with regard to the beam current delivered when the grid voltage is reduced by the application of signals such as those found in operating radar sets. Such a specification would be much more significant than the present requirement of a minimum beam current at zero grid bias.

D. Request for tube specification on all tubes: Mr. Greer explained that the problem of formulating uniform specifications which could be applied by all manufacturers of cathode ray tubes of a given approved type would be more capable of solution if all manufacturers would submit to him all of the detailed specifications applied by the manufacturer in his production of the tubes. This request applies to all tests including electrical and physical measurements as well as the instructions for inspections that must be done by the inspectors without the help of measuring equipment. This request applies also to all cathode ray tube types and is not to be interpreted to apply only to the cathode ray tubes containing P7 screens.

E. Summary of action:

(1) Unless well substantiated objections are presented prior to June 5, 1943, the new limits as recommended in this report on Page 24 shall go into effect.

(2) Samples of tubes which mark border-line cases as regards blemishes of all types will be examined and distributed if possible to the points where tubes are being inspected.

(3) An attempt will be made to confine the range of cut-off voltages for cathode ray tubes having magnetically focussed guns of the single cross-over type to the range -25 volts to -60 volts when the first anode is maintained at 250 volts positive with respect to the cathode.

(4) A new test is to be considered which will measure the cut-off voltage and the beam current when the grid bias is reduced to a suitable voltage. This criterion is to be substituted for the present requirement for a minimum beam current at zero voltage.

(5) Some operational tests will be continued and a complete report presented.

(6) Specifications on all cathode ray tubes are to be sent to Mr. Greer of the Bureau of Ships in Washington.

Appendix I

GRAPHICAL AND TABULAR PRESENTATION OF RESULTS OF RECENT TESTS ON P7 SCREENS

The figures which are contained in this Appendix from 1 to 16 and all of the tabular information were presented at the P7 Screen Conference. The figures from 17 to 26 have been produced as the result of the interest shown at the Conference in the presentation of these data. In making use of these data, particular attention should be directed to the discussion found on Page 3 through 4.

GRAPHICAL AND TABULAR PRESENTATION
OF RESULTS OF RECENT TESTS ON P7 SCREENS

INDEX TO FIGURES

Mfr.	Type	cb_1	cb_5	$G_{5:1}$	$cb_i - cb_1$
GE	5FP7	Fig. 1	Fig. 5	Fig. 9	Fig. 13
	7BP7	2	6	10	14
RCA	5FP7	Fig. 3	Fig. 7	Fig. 11	Fig. 15
	7BP7	4	8	12	16

INDEX TO TABLE --(results of tests on miscellaneous lots of tubes)

Mfr.	Type	No. of tubes
DuMont	5CP7	6
National Union	5FP7	16
Philco	5FP7	9
Rauland	12DP7	4
Res. Ent. Ltd.	9HP7	2
	9MP7	2
Sylvania	5FP7	41

EXPLANATION OF SYMBOLS AND TESTS

A summary of results of measurements of P7 long-persistence cascade screens was prepared and made available as a Radiation Laboratory report, No. 62-2 of August 12, 1942. Since that time several hundred tubes have been examined using the Radiation Laboratory measuring equipment here at the Laboratory and also the measuring equipment at the Camp Evans Signal Laboratory. The results of these recent tests have been analyzed in detail and the information put in such a form that it should be relatively easy to digest and interpret. The resulting collection of Figures has been prepared for use in connection with the conference of April 5 and 6, 1943. The graphical presentation is for tubes produced by the General Electric Company and the RCA Manufacturing Company. In addition the Table shows the results obtained for smaller lots produced by other companies. The above chart will serve as a quick reference in order to locate any particular results.

In connection with the graphs, the results presented apply to cb_1 , cb_5 , $G_{5:1}$ and $cb_i - cb_1$. These quantities are all described in considerable detail in the Radiation Laboratory report 62-2, and will therefore be defined very briefly below.

The light intensities observed are all expressed on the logarithmic scale found very convenient for calculation and comparison and known as the "centibel" scale or "cb" scale. It is the practice throughout the Radiation Laboratory to describe the performance of all other parts of an operating system - amplifiers, etc. - in terms of the "decibel" scale. On that scale a change in power of a factor ten is a change, expressed on the conventional logarithmic scale, of one "bel". A change of power by a factor 100 is on that scale 2 bels. As the name implies, 10 db = 1 bel and in like manner 100 cb = 1 bel. Obviously 10 cb = 1 db.

The "zero level" of the centibel scale is based on certain considerations of the power radiated from a source with a wavelength distribution of energy, that expected from the yellow component of the cascade screen known as P7. A consideration of this and also the necessary geometrical factors allows for a conversion of the light intensities measured on the centibel scale to surface brightness expressed in foot-lamberts. This conversion formula as it applies to the particular geometrical arrangement used in the tests of 5-inch and larger tubes under standard operating conditions is as follows:

$$\text{Ft.-lamb.} = 2 \times 10^{-6} \times 10^{\frac{cb}{100}} .$$

cb_1 is the phosphorent light intensity observed one second after the application of a "standard raster" to the tube. cb_5 is the same except that it is observed one second after the fifth raster. cb_{10} is the same but observed one second after the tenth raster. cb_i is observed by means of an integrating circuit, and is a measure of the integral of the light obtained during the application of the first raster and integrated out to one second. Suitable calculation allows the observed integral to be transformed into an equivalent light intensity which applied for one tenth of a second would have given the same integral. $cb_i - cb_1$ gives the difference in the cb values of the flash relative to the one-second persistence intensity.

$$\text{Flash ratio} = \log^{-1} \frac{cb_i - cb_1}{100} .$$

Operating experience has shown that the "buildup factor" for a P7 screen is an important characteristic. One of these buildup factors is described as $G_{5:1}$ and may be defined as the ratio of the light intensity obtained one second after the fifth raster to the light intensity obtained one second after the first raster when these are expressed on a linear light scale instead of the centibel scale. In practice it turns out to be rather easier to calculate if the antilogarithm of the difference between cb_5 and cb_1 is used to calculate the factor $G_{5:1}$. Similarly the factor $G_{10:1}$ may be calculated.

In the tabular information the fluorescent light intensity is also recorded. This is obtained by applying the raster continuously. That is, one complete raster is repeated every sixtieth of a second and the intensity on the entire screen is measured.

The standard conditions for excitation measurement are:

Anode voltage (relative to cathode) = 4000 volts.

Grid voltage (G_2, for magnetically focussed tubes) = 250 volts.

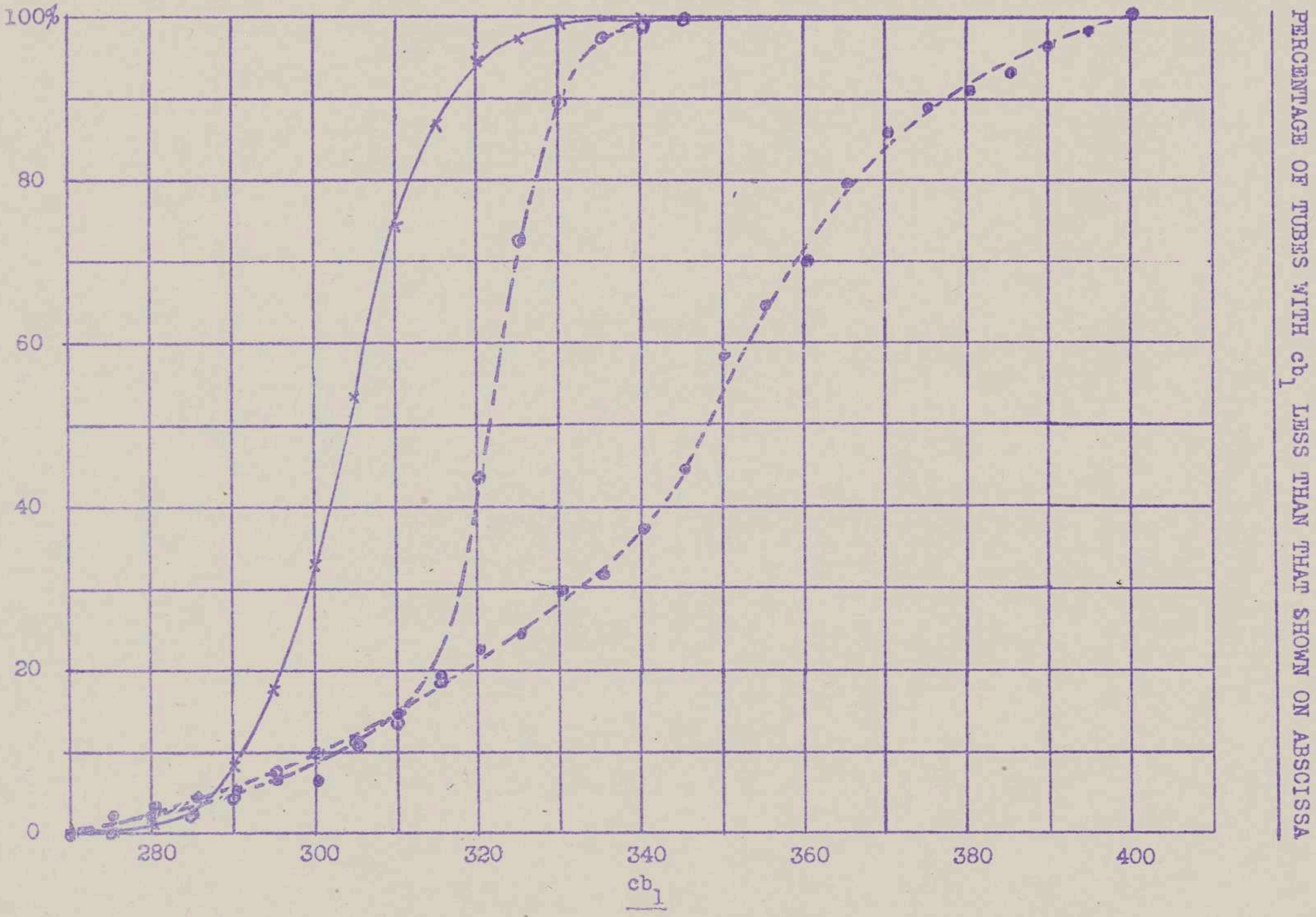
Raster size (focussed beam) = 7.1 x 7.1 cm giving a total area of 50 sq cm.

Duration of raster = 1/60 sec. The raster is formed by means of linear sweeps with the horizontal sweep frequency 12 kc and the vertical sweep frequency 60 cycles. Except in the case of the measurement of fluorescence, the raster is repeated at one-second intervals.

Distance of raster from cathode of calibrated 931 multiplier tube = 30 cm.

Beam current = 60 μa, defocussed to a spot approximately .25 mm in diameter.

Red light: sufficient to de-excite the phosphor before buildup and integrated flash measurements so that the results are within 2 cb of those that would have been obtained after total de-excitation.



GE TUBES — TYPE 5FP7

Group I: 8/1/42 – 11/1/42
No. of tubes: 95

Group II: 11/1/42 – 1/1/43
No. of tubes: 89

Group III: 1/1/43 – 4/1/43
No. of tubes: 106

Fig. 1

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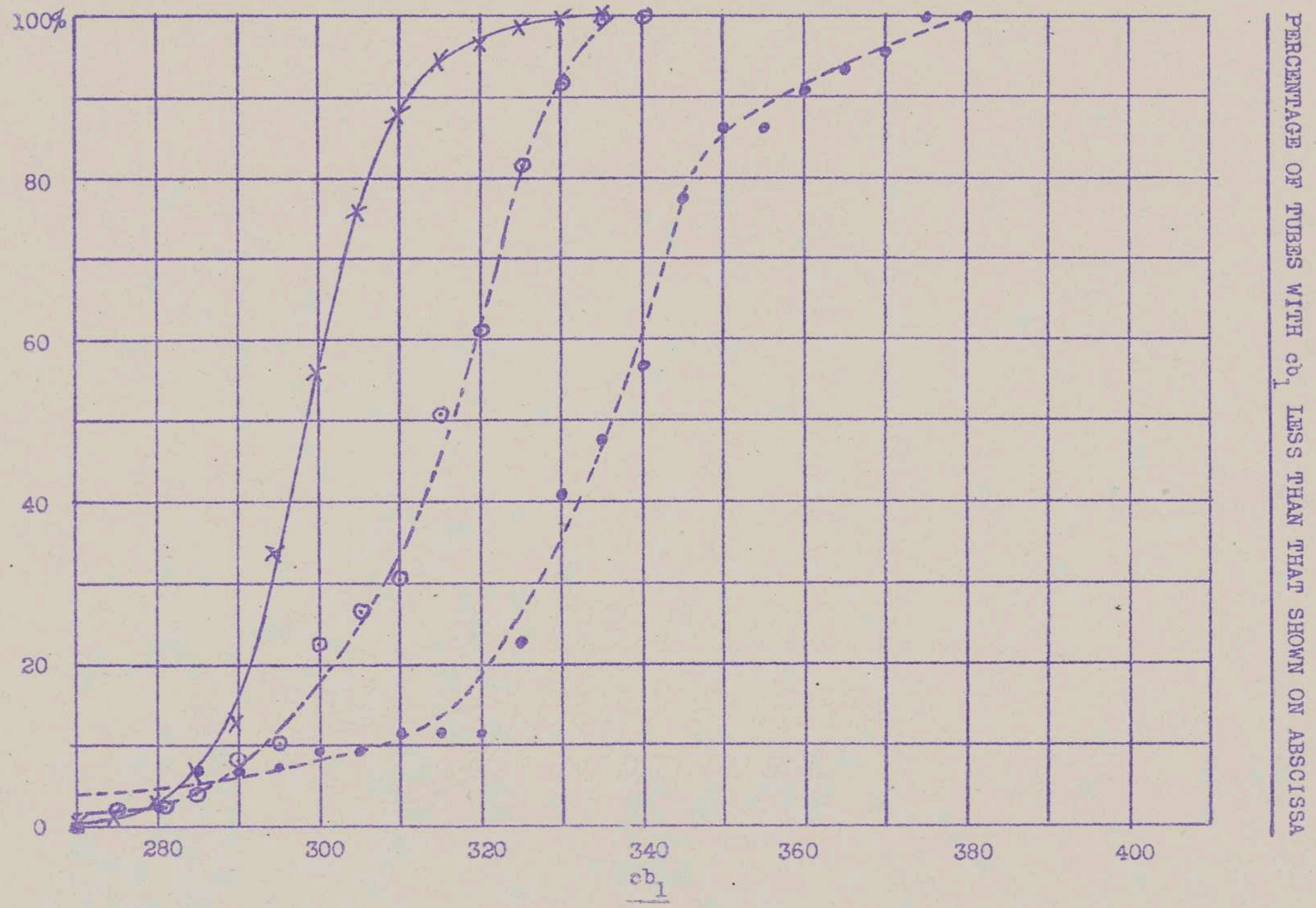

GE TUBES - TYPE 7BP7

Group I: 8/1/42 - 11/1/42
No. of tubes: 44

Group II: 11/1/42 - 1/1/43
No. of tubes: 49

Group III: 1/1/43 - 4/1/43
No. of tubes: 90

Fig. 2

vi

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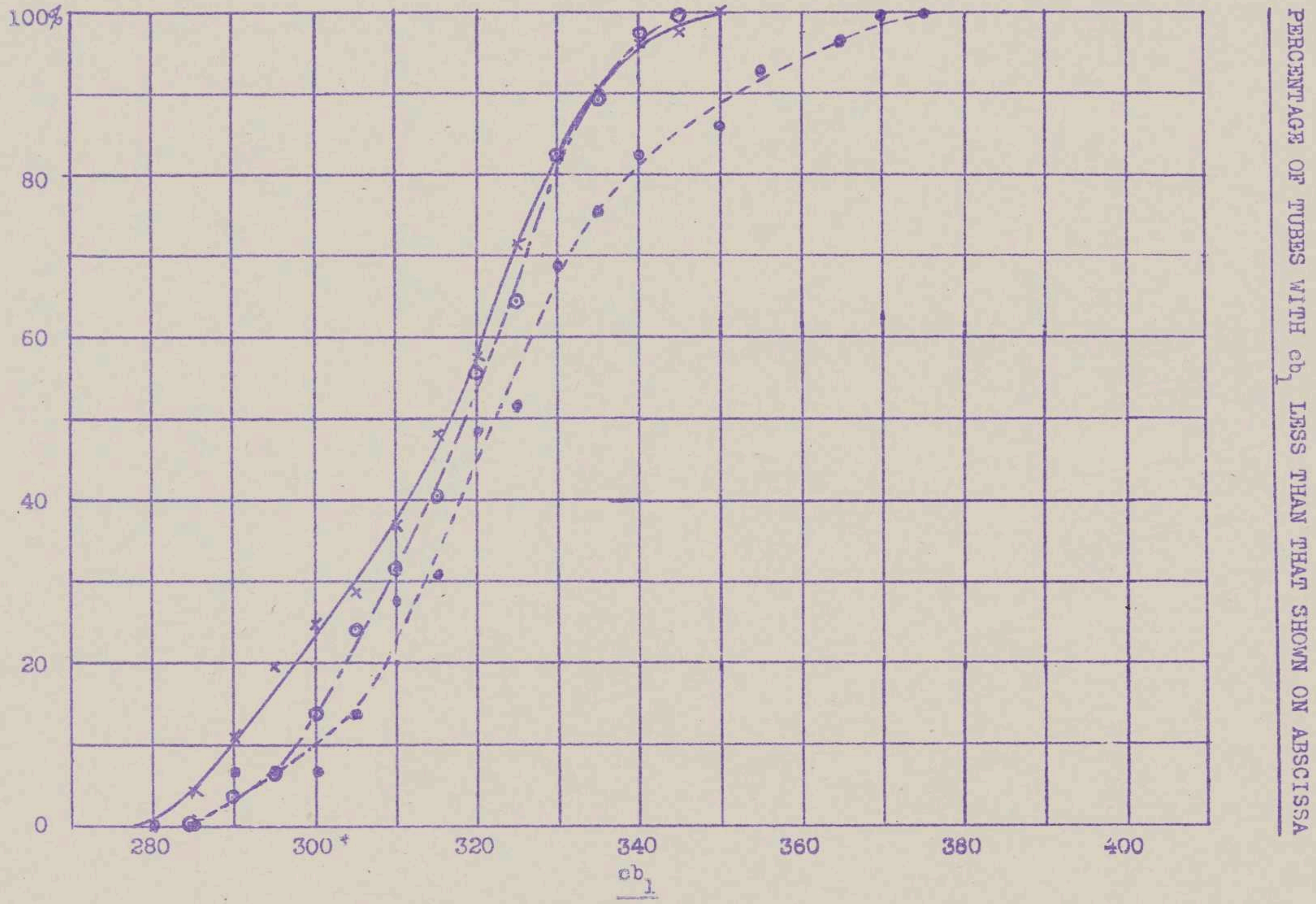

RCA TUBES - TYPE 5FP7

GROUP I: 8/1/42 - 11/1/42
No. of tubes: 29

GROUP II: 11/1/42 - 1/1/43
No. of tubes: 79

GROUP III: 1/1/43 - 4/1/43
No. of tubes: 73

Fig. 3

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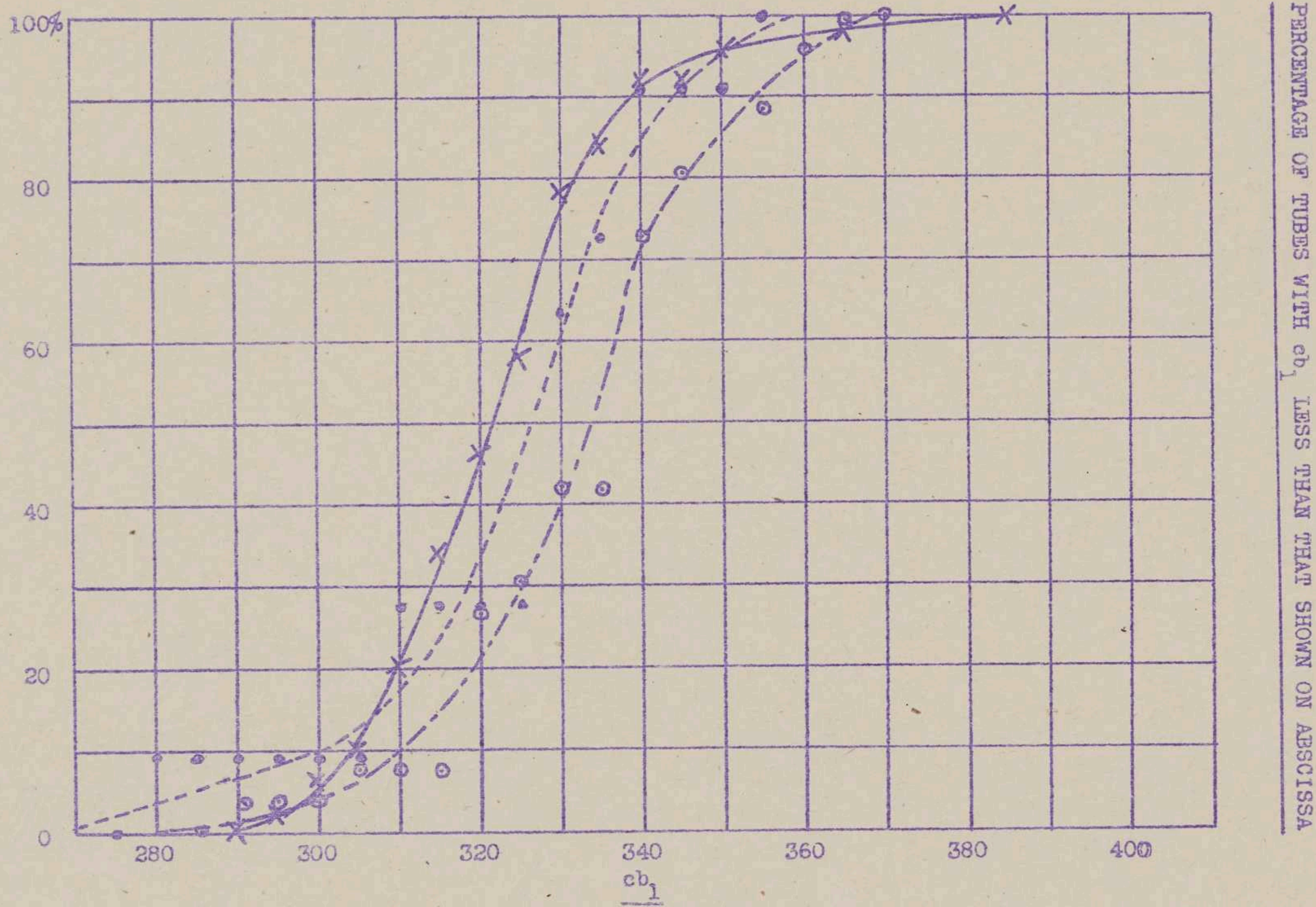

RCA TUBES - TYPE 7BP7

Group I: 8/1/42 - 11/1/42
No. of tubes: 11

Group II: 11/1/42 - 1/1/43
No. of tubes: 26

Group III: 1/1/43 - 4/1/43
No. of tubes: 50

Fig. 4

viii

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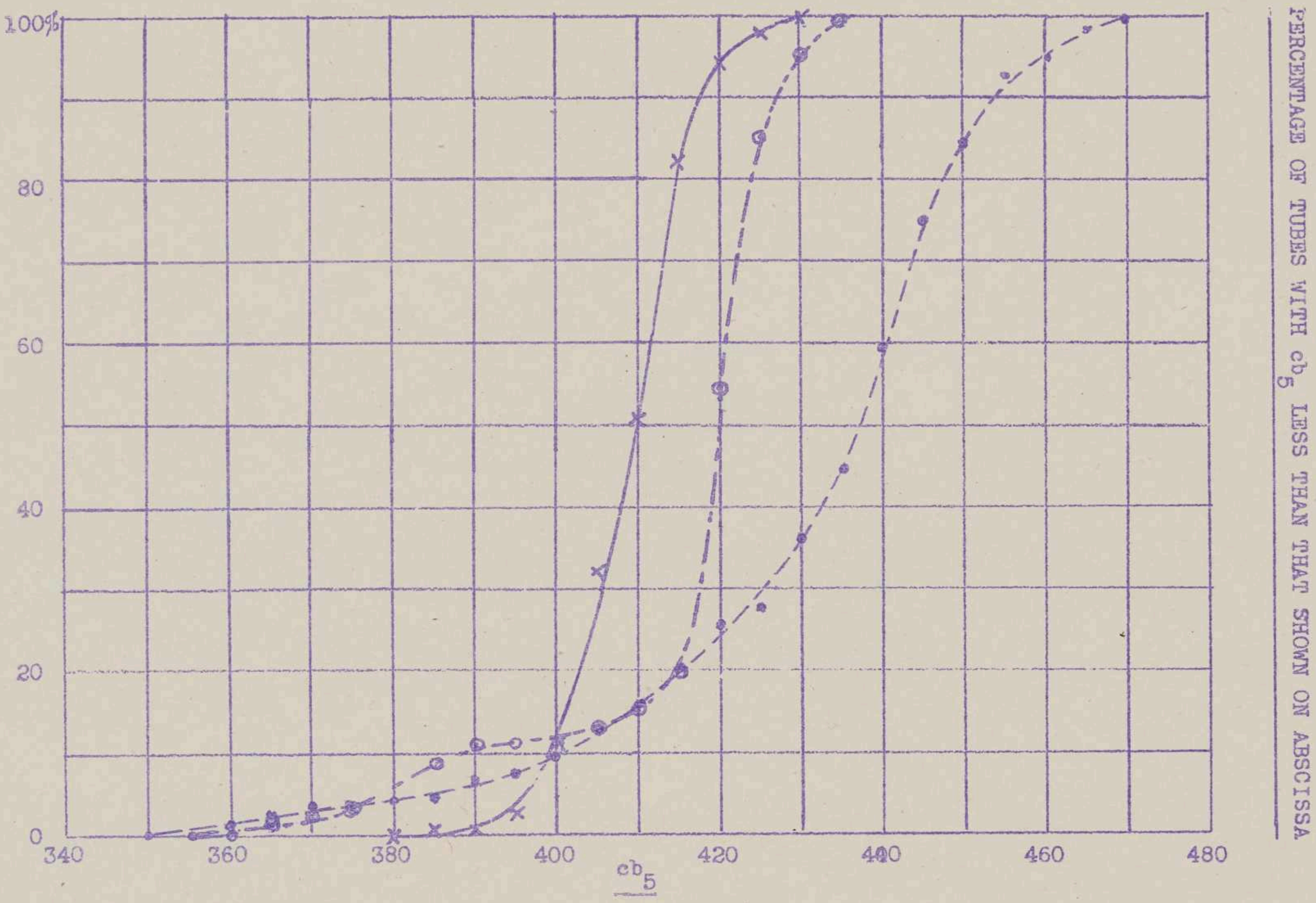

GE TUBES - TYPE 5FP7

Group I: 8/1/42 - 11/1/42
No. of tubes: 95

Group II: 11/1/42 - 1/1/43
No. of tubes: 89

Group III: 1/1/43 - 4/1/43
No. of tubes: 106

Fig. 5

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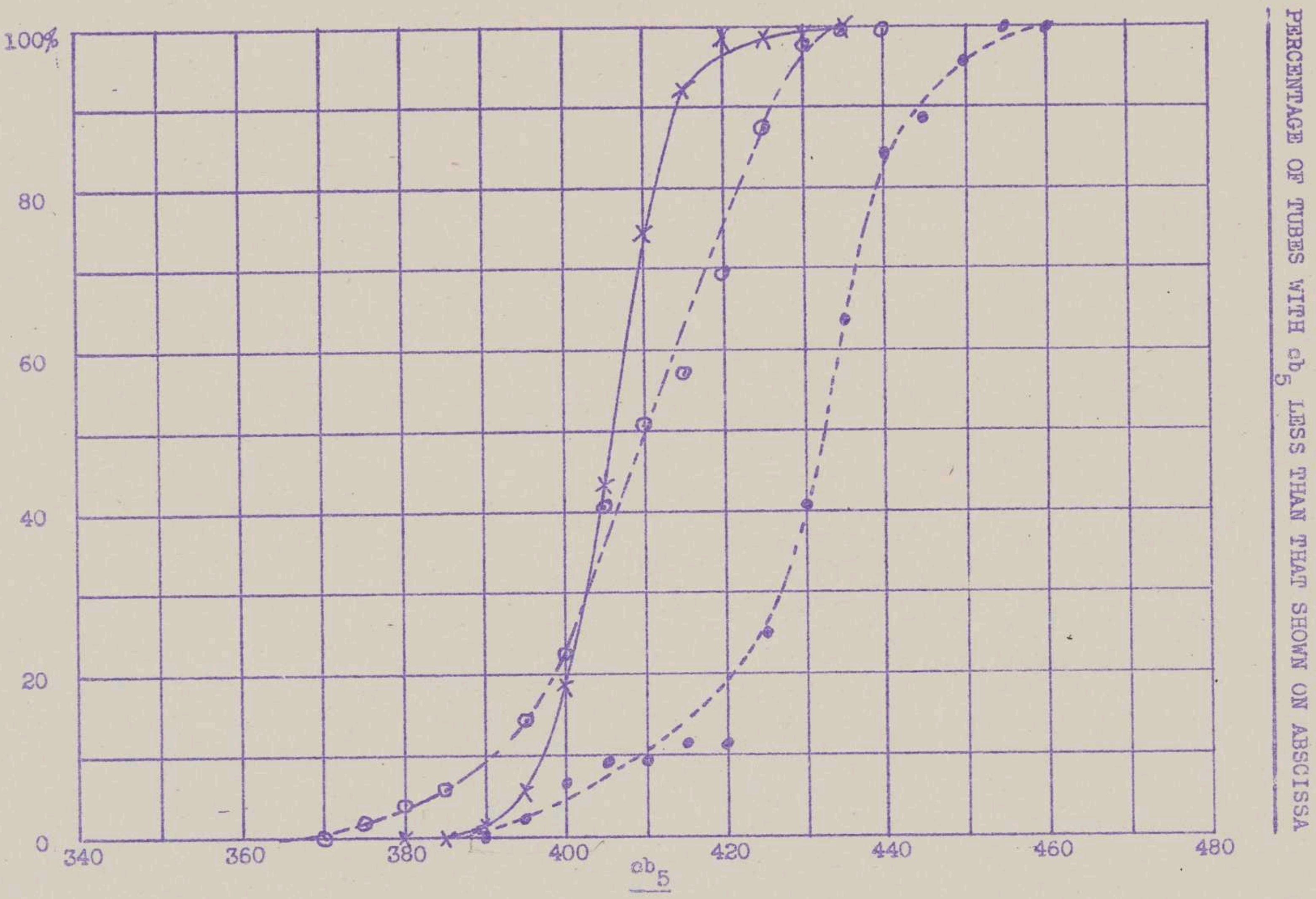

GE TUBES - TYPE 7BP7

●- - - - -● Group I: 8/1/42 - 11/1/42
No. of tubes: 44

○—- - -—○ Group II: 11/1/42 - 1/1/43
No. of tubes: 49

×———× Group III: 1/1/43 - 4/1/43
No. of tubes: 90

Fig. 6

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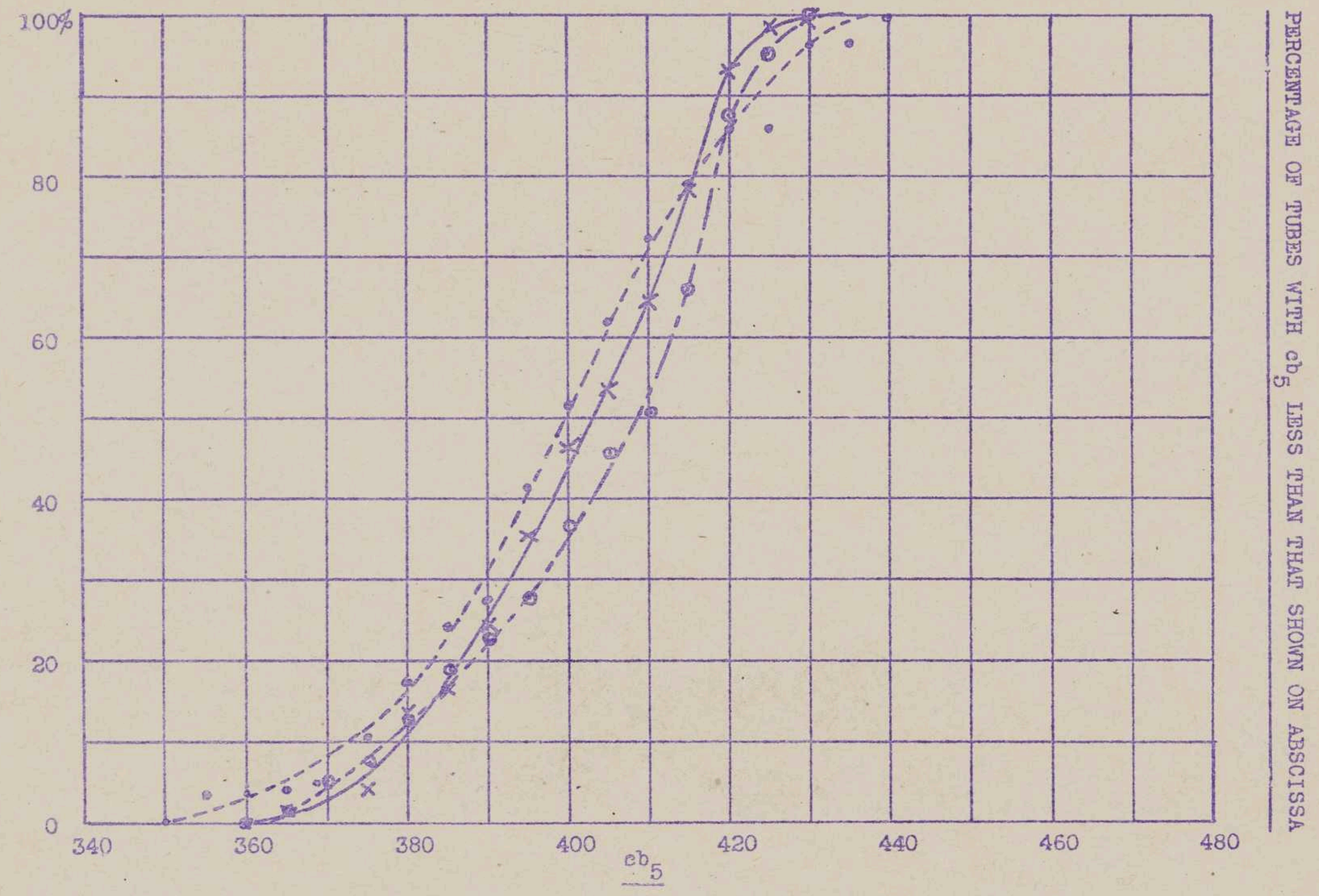

RCA TUBES - TYPE 5FP7

Group I: 8/1/42 - 11/1/42
No. of tubes: 29

Group II: 11/1/42 - 1/1/43
No. of tubes: 79

Group III: 1/1/43 - 4/1/43
No. of tubes: 73

Fig. 7

x1

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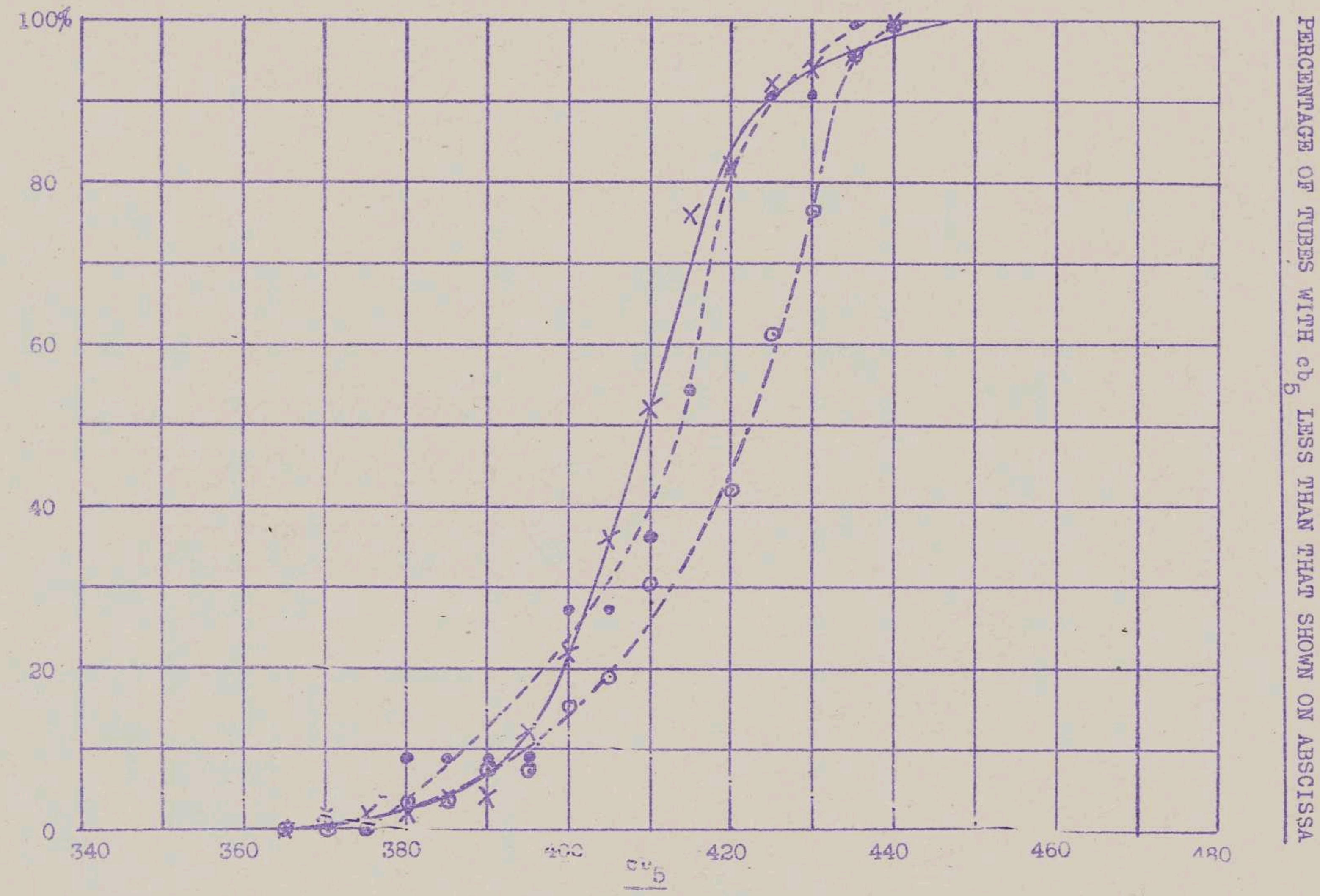

Fig. 8

RCA TUBES - TYPE 7BP7

Group I: 8/1/42 - 11/1/42
No. of tubes: 11

Group II: 11/1/42 - 1/1/43
No. of tubes: 26

Group III: 1/1/43 - 4/1/43
No. of tubes: 50

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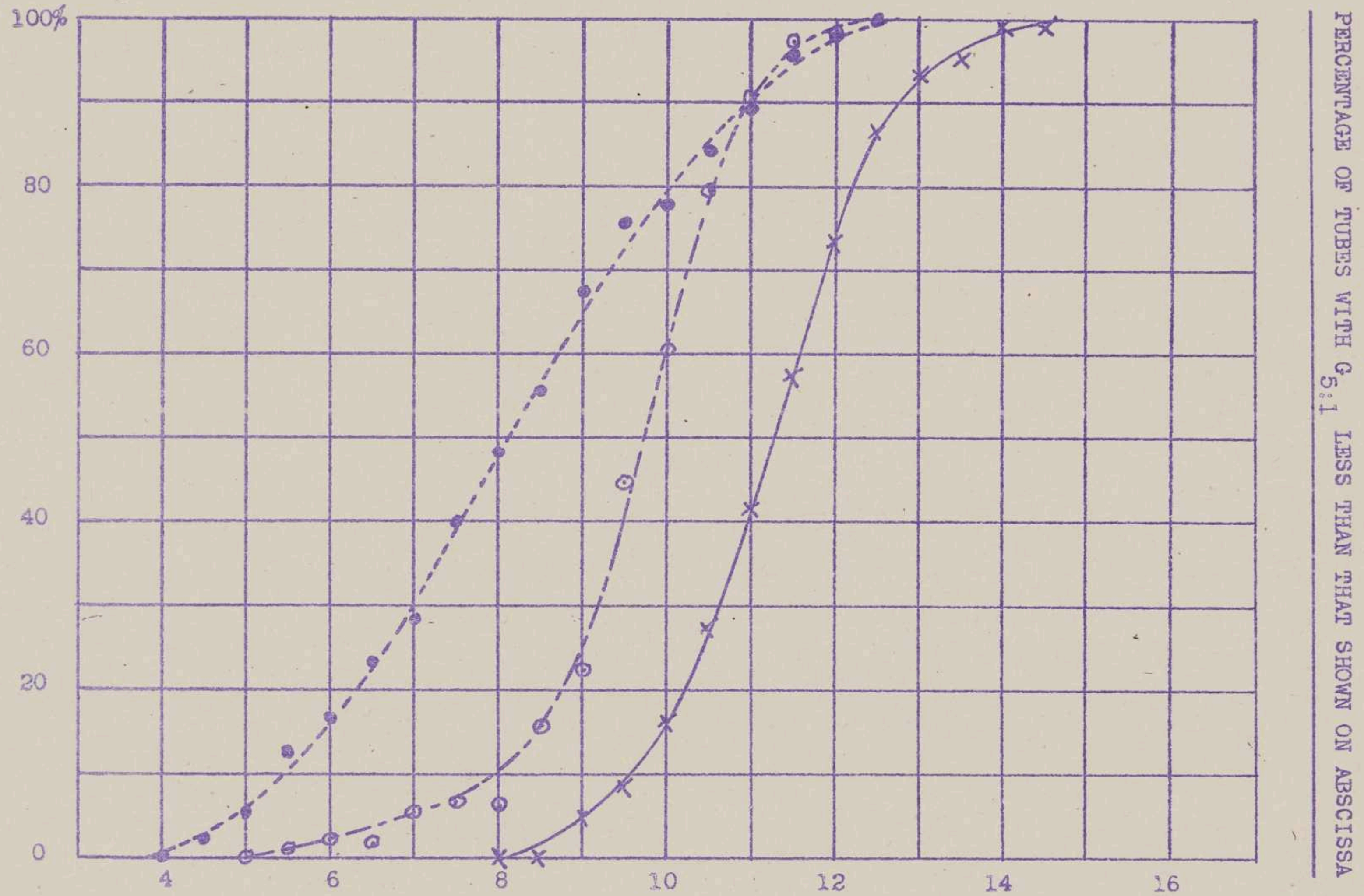


$G_{5:1}$

GE TUBES - TYPE 5FP7

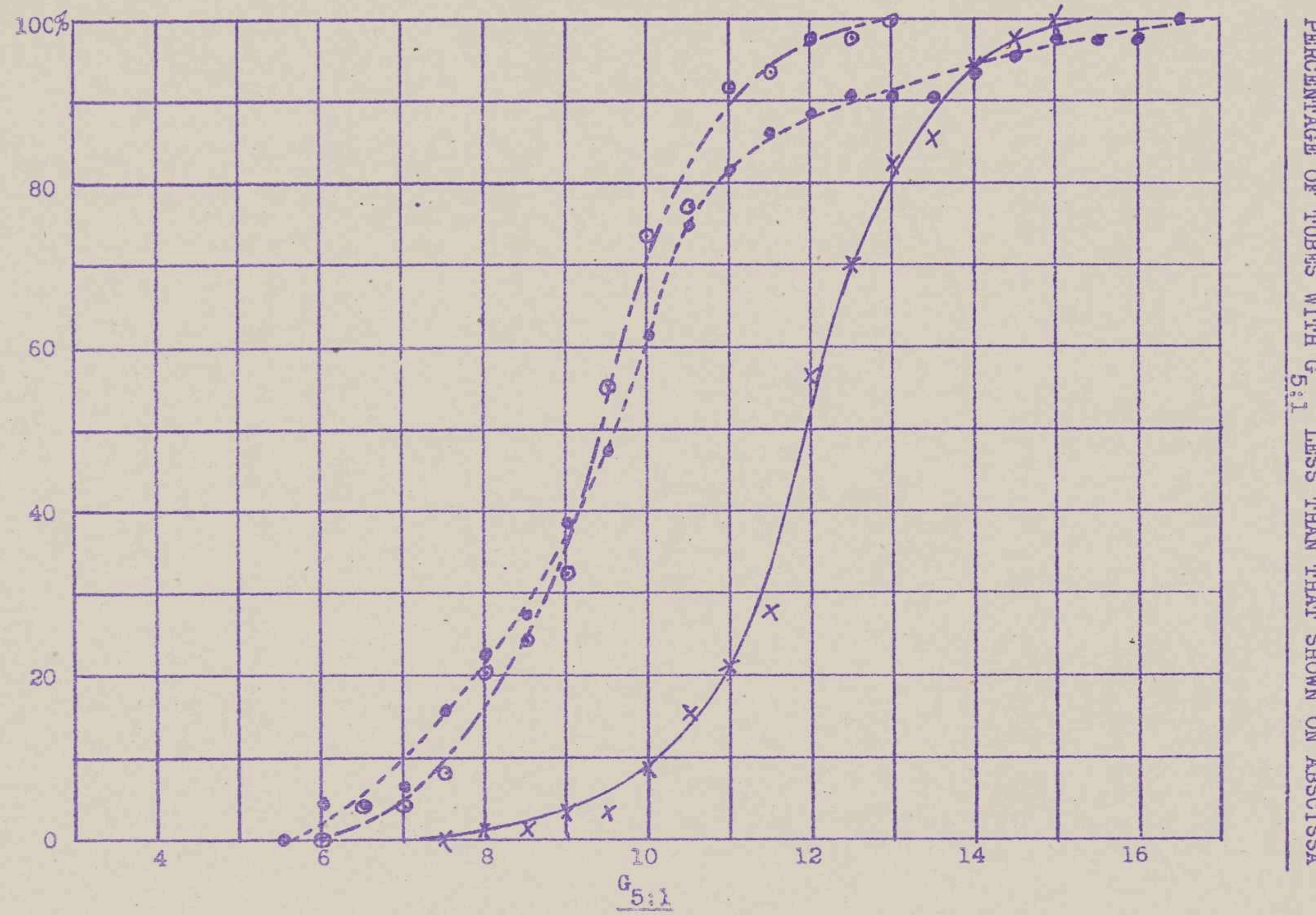
●- - - - ● Group I: 8/1/42 - 11/1/42 No. of tubes: 95

o-- - --o Group II: 11/1/42 - 1/1/43 No. of tubes: 89

x———x Group III: 1/1/43 - 4/1/43 No. of tubes: 106

Fig. 9

CONFIDENTIAL



GE TUBES - TYPE 7BP7

Group I: 8/1/42 - 11/1/42
No. of tubes: 44

Group II: 11/1/42 - 1/1/43
No. of tubes: 49

Group III: 1/1/43 - 4/1/43
No. of tubes: 90

Fig. 10

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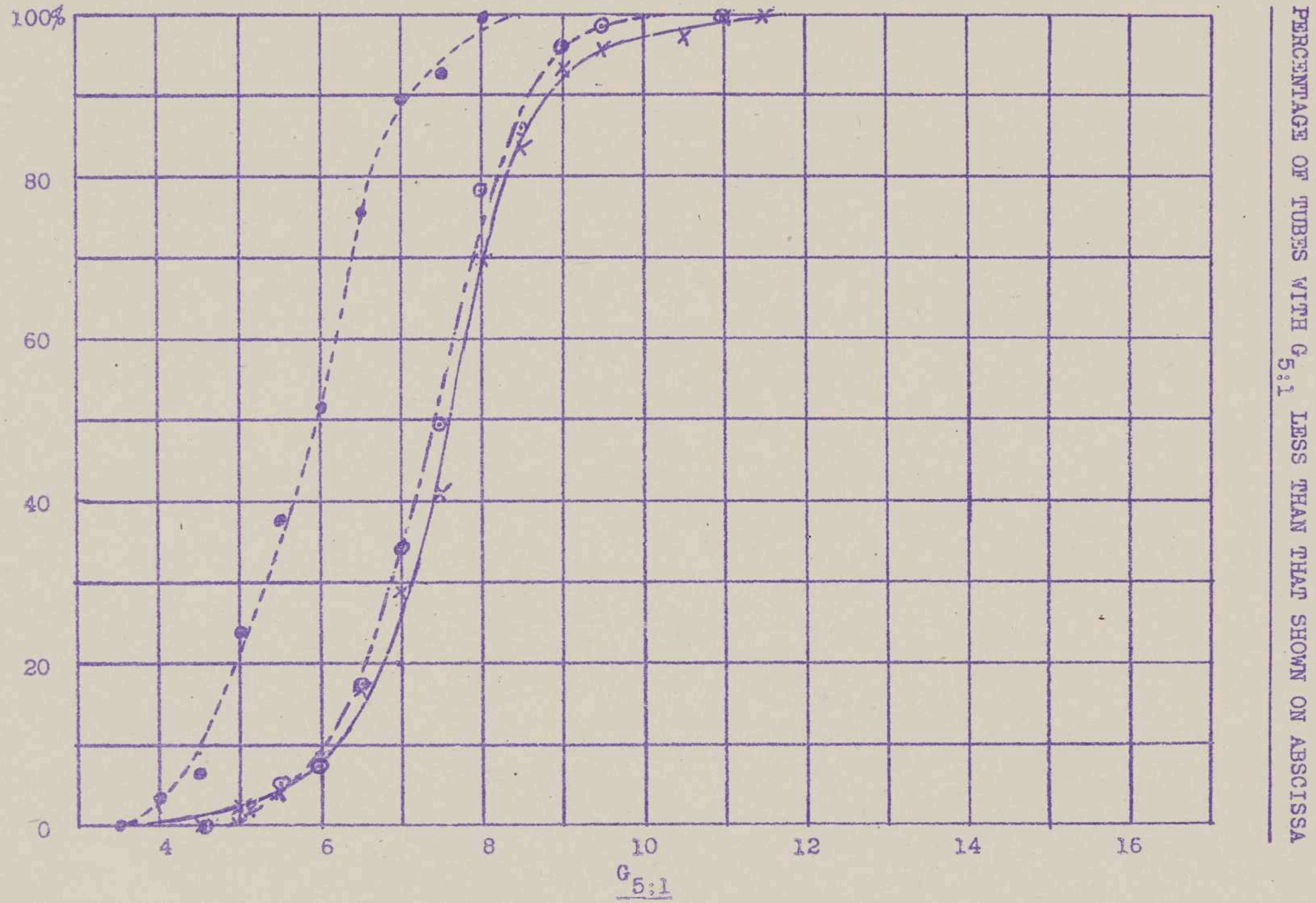

RCA TUBES - TYPE 5FP7

●- - - - ●	o—-—-—o	x———x
Group I: 8/1/42 - 11/1/42	Group II: 11/1/42 - 1/1/43	Group III: 1/1/43 - 4/1/43
No. of tubes: 29	No. of tubes: 79	No. of tubes: 73

Fig. 11

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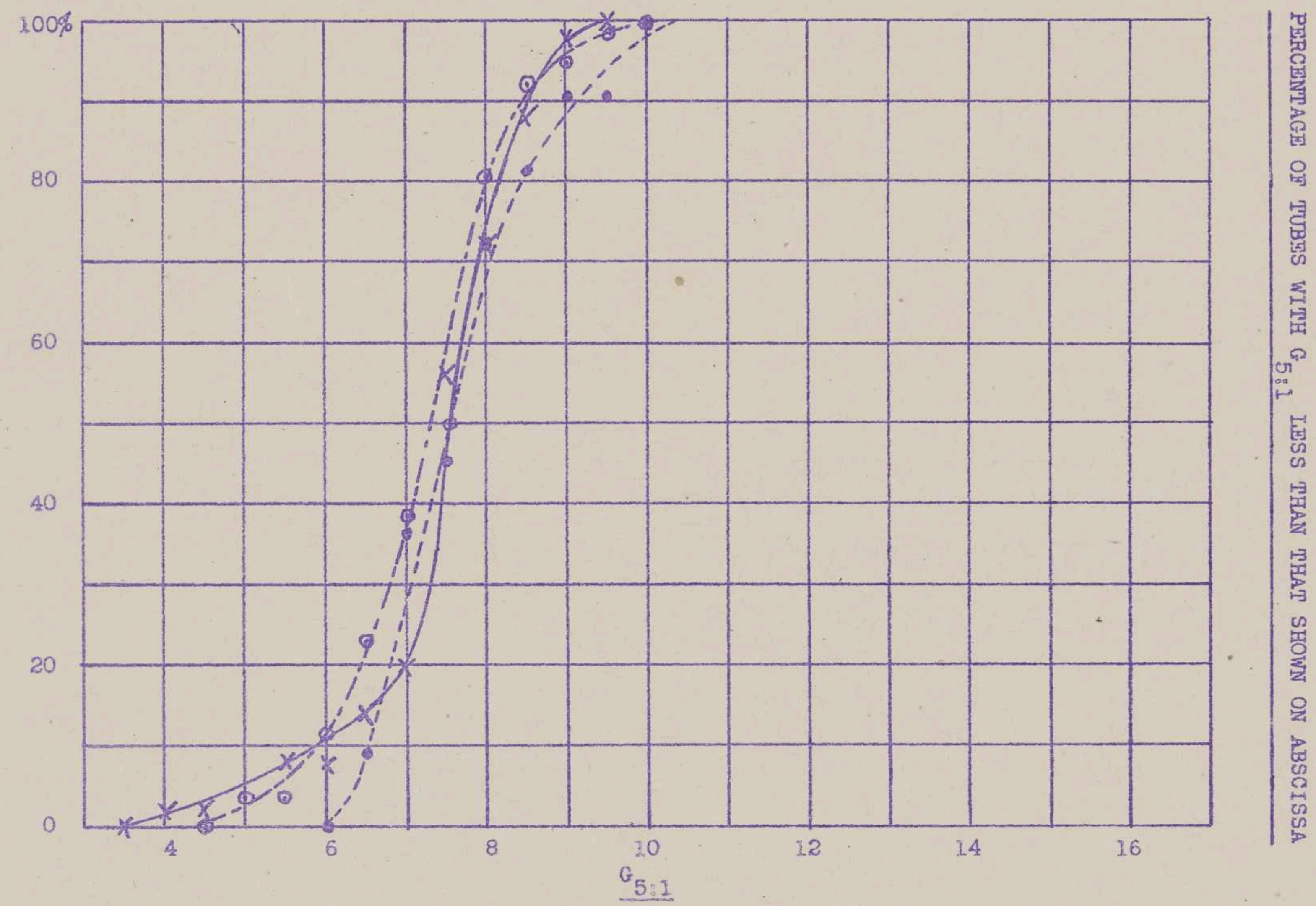


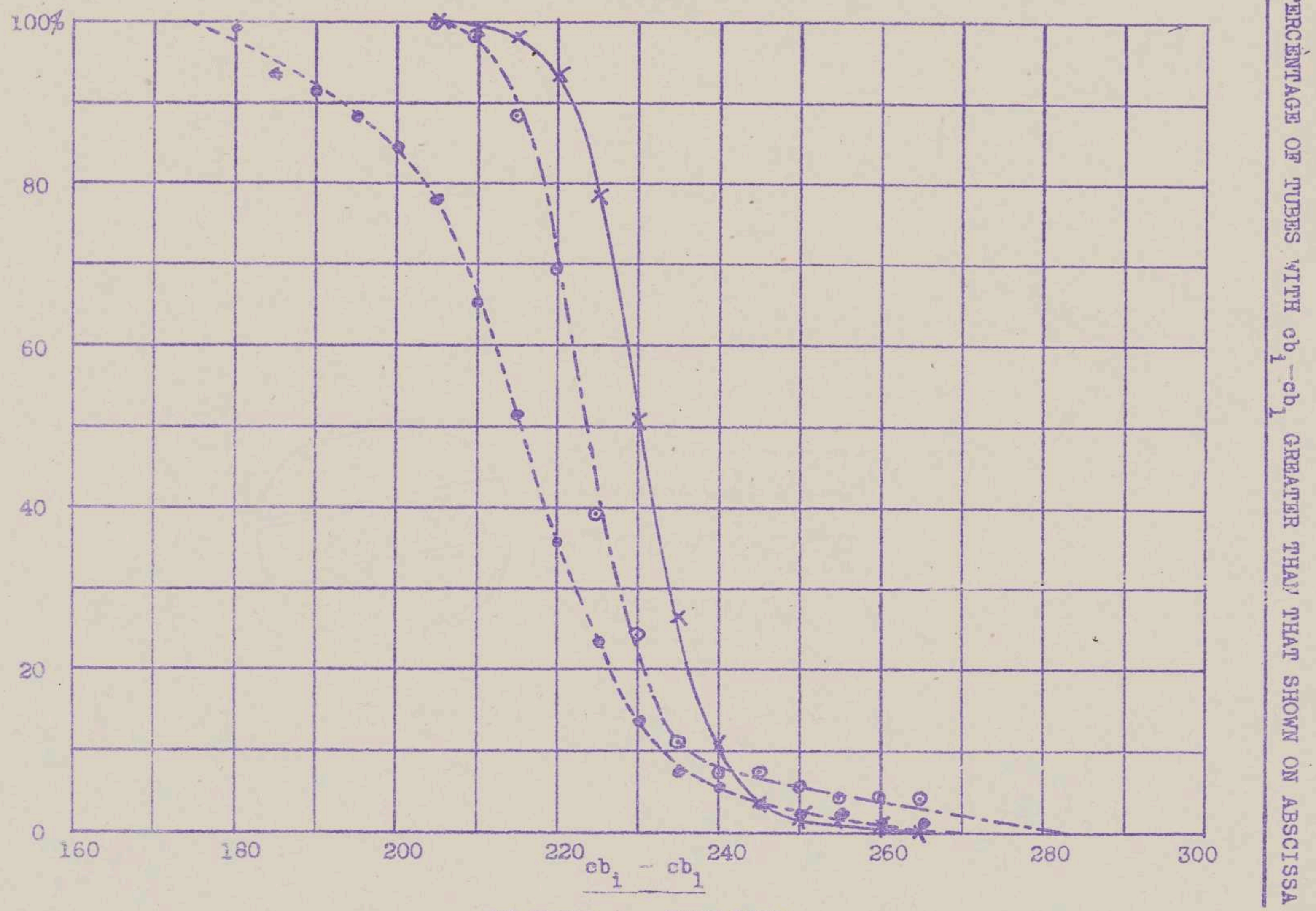
RCA TUBES - TYPE 7BP7

●– – – – ● Group I: 8/1/42 - 11/1/42
No. of tubes: 11

○– · – · – ○ Group II: 11/1/42 - 1/1/43
No. of tubes: 26

×———× Group III: 1/1/43 - 4/1/43
No. of tubes: 50

Fig. 12



GE TUBES - TYPE 5FP7

Group I: 8/1/42 - 11/1/42
No. of tubes: 95

Group II: 11/1/42 - 1/1/43
No. of tubes: 89

Group III: 1/1/43 - 4/1/43
No. of tubes: 106

Fig. 13

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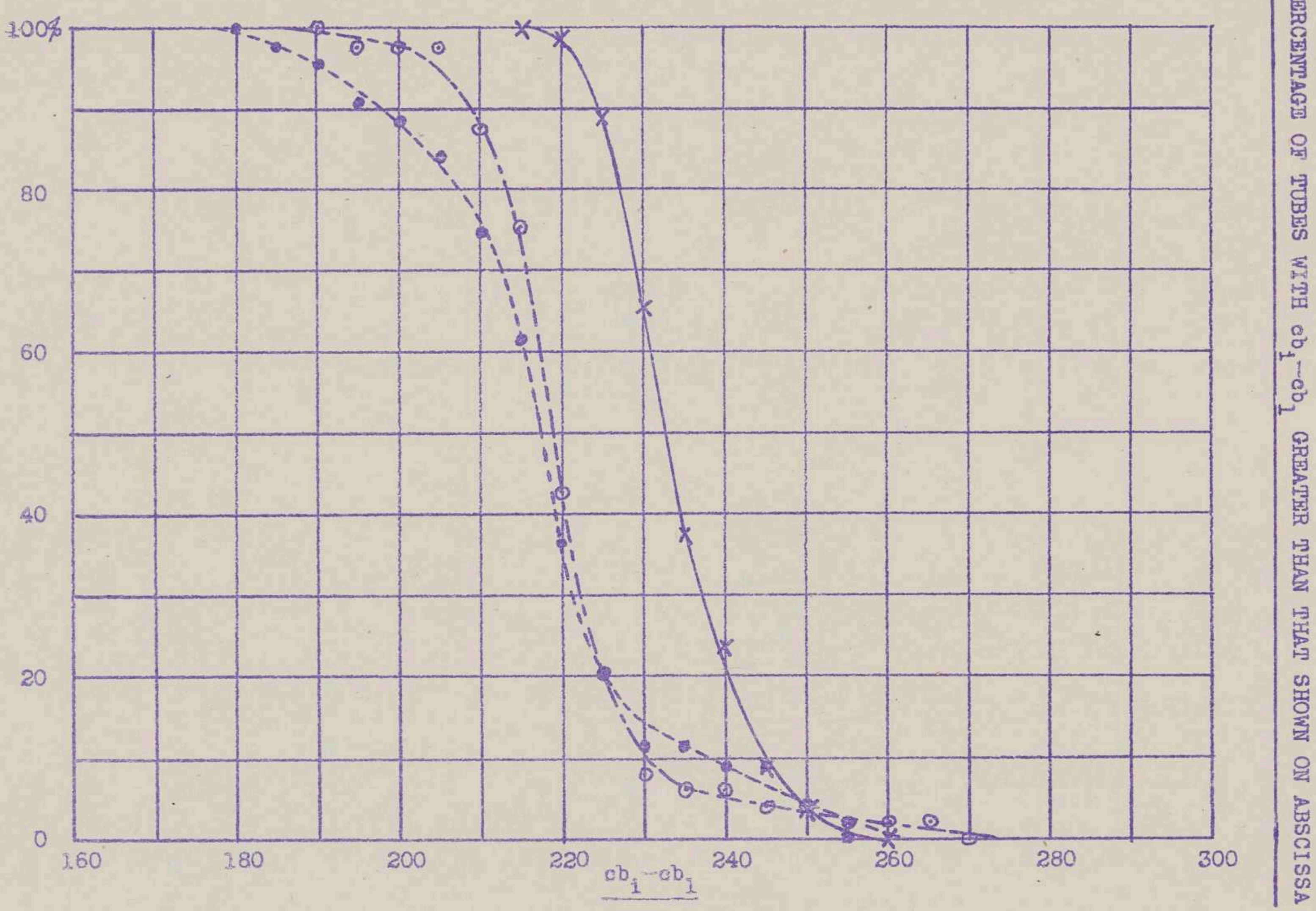

GE TUBES — TYPE 7BP7

Group I: 8/1/42 - 11/1/42
No. of tubes: 44

Group II: 11/1/42 - 1/1/43
No. of tubes: 49

Group III: 1/1/43 - 4/1/43
No. of tubes: 90

Fig. 14

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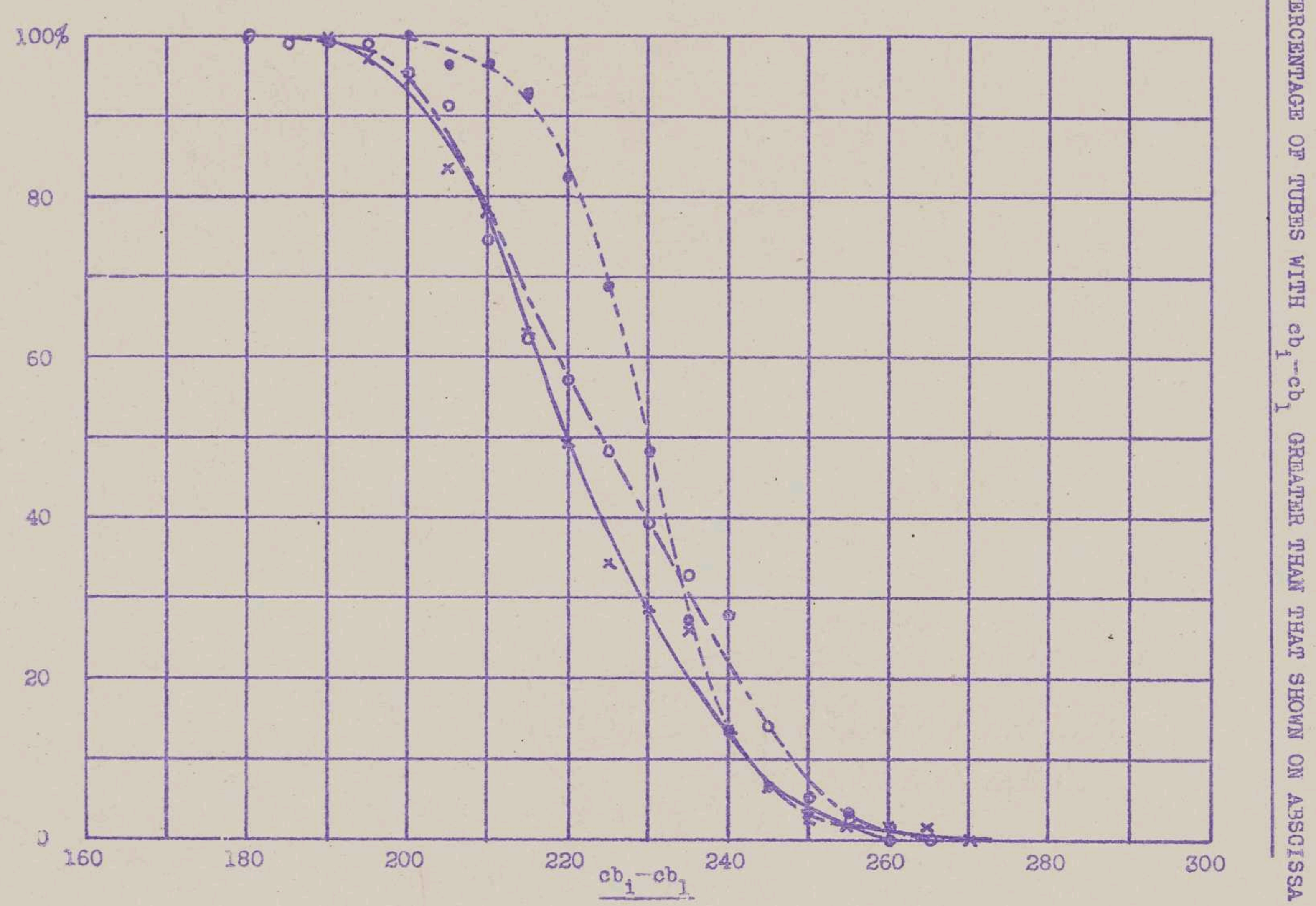

RCA TUBES - TYPE 5FP7

Group I: 8/1/42 - 11/1/42
No. of tubes: 29

Group II: 11/1/42 - 1/1/43
No. of tubes: 79

Group III: 1/1/43 - 4/1/43
No. of tubes: 73

Fig. 15

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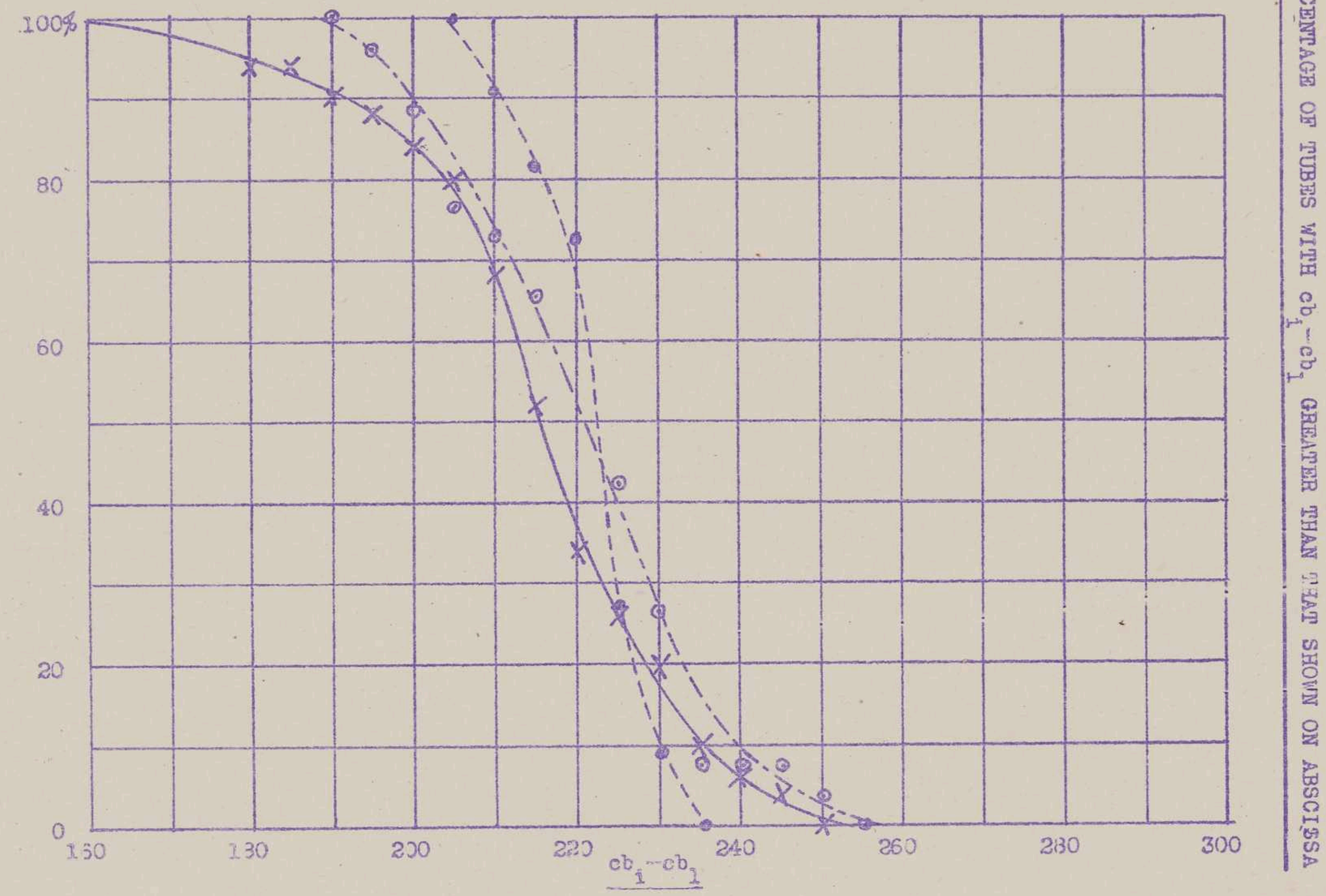

RCA TUBES - TYPE 7BP7

Group I: 8/1/42 - 11/1/42
No. of tubes: 11

Group II: 11/1/42 - 1/1/43
No. of tubes: 26

Group III: 1/1/43 - 4/1/43
No. of tubes: 50

Fig. 16

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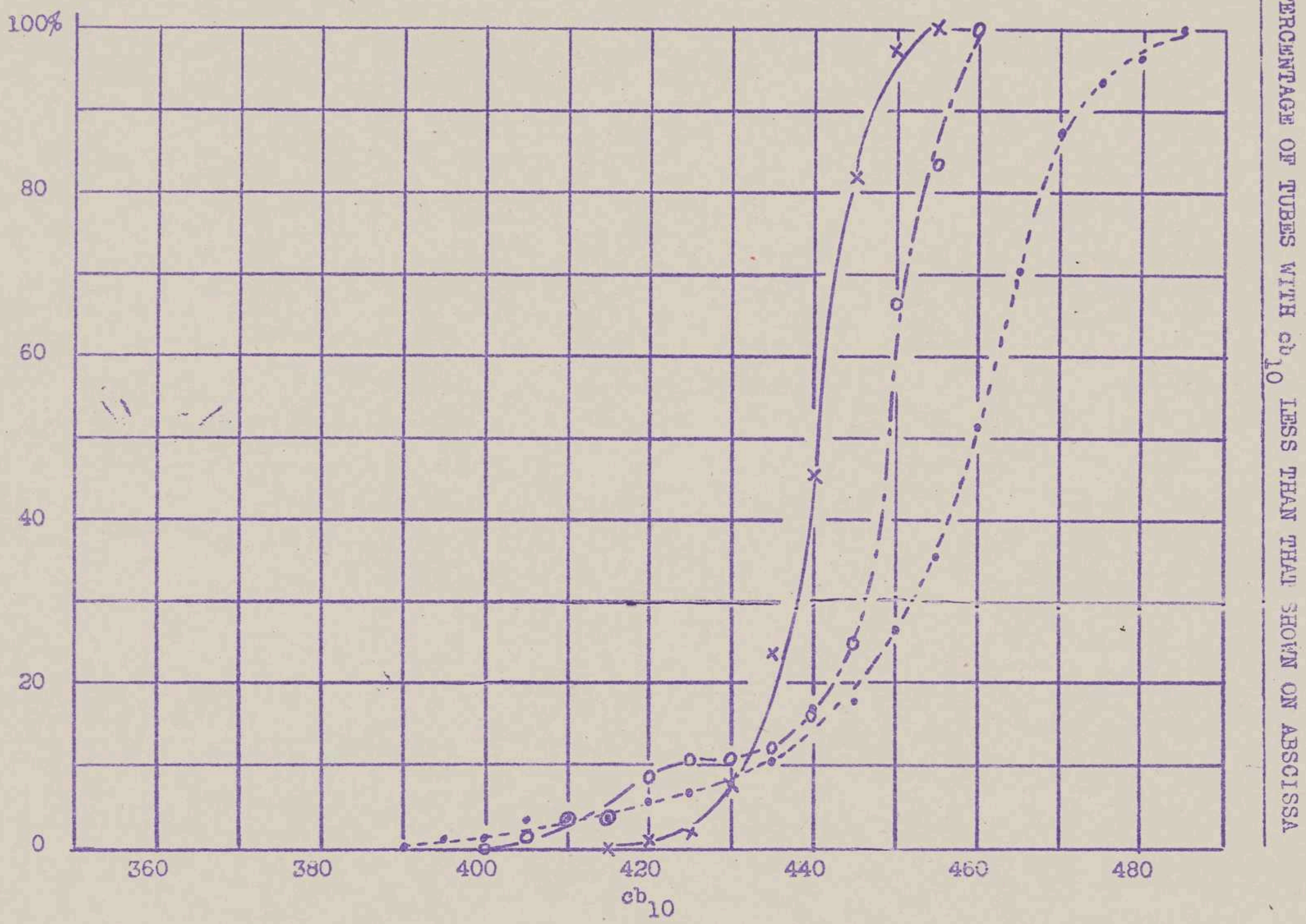

G.E. TUBES - TYPE 5FP7

Group I: 8/1/42 - 11/1/42
No. of tubes: 95

Group II: 11/1/42 - 1/1/43
No. of tubes: 89

Group III: 1/1/43 - 4/1/43
No. of tubes: 106

Fig. 17

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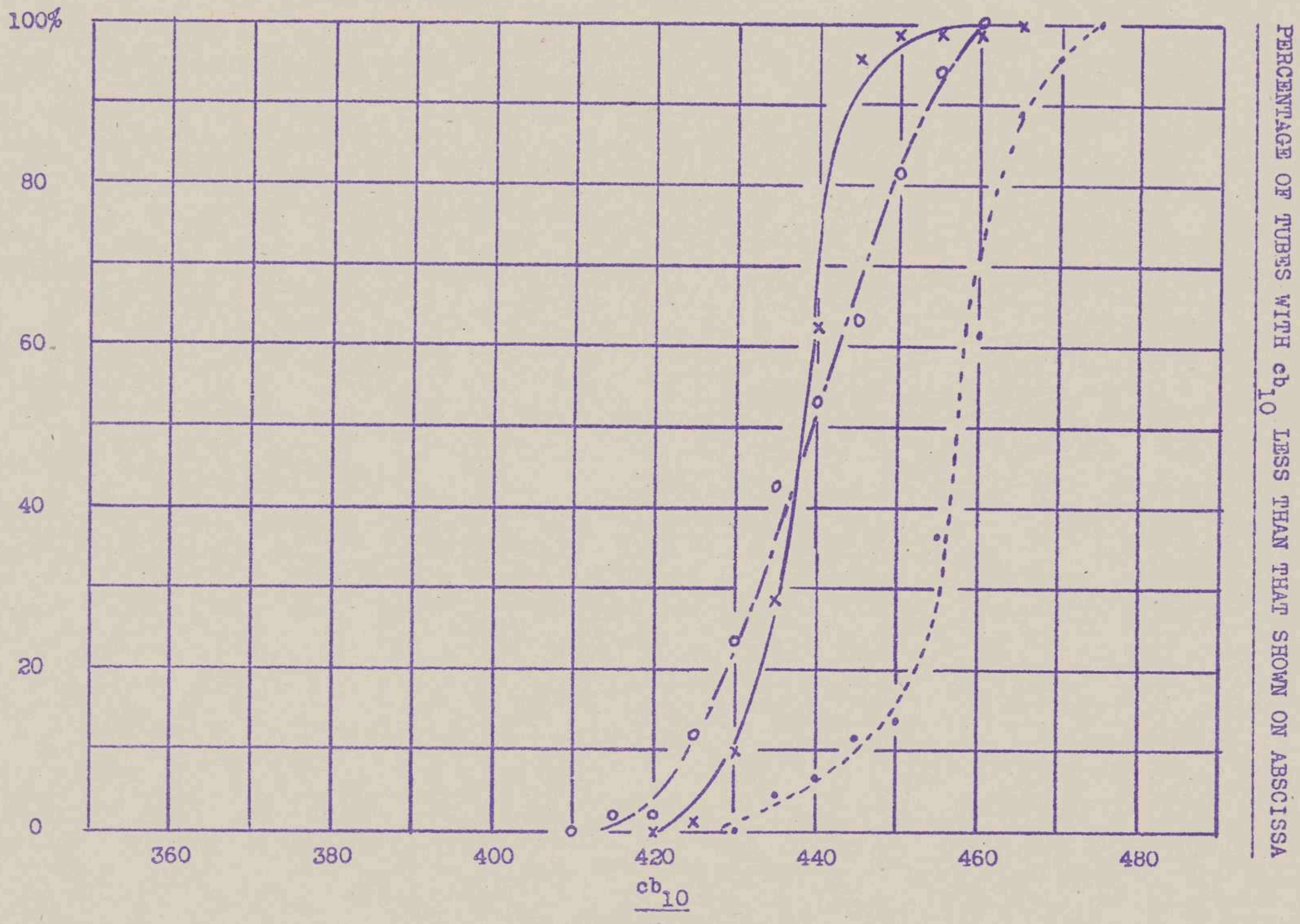

G.E. TUBES - TYPE 7BP7

Group I: 8/1/42 - 11/1/42
No. of tubes: 44

Group II: 11/1/42 - 1/1/43
No. of tubes: 49

Group III: 1/1/43-4/1/43
No. of tubes: 90

Fig. 18

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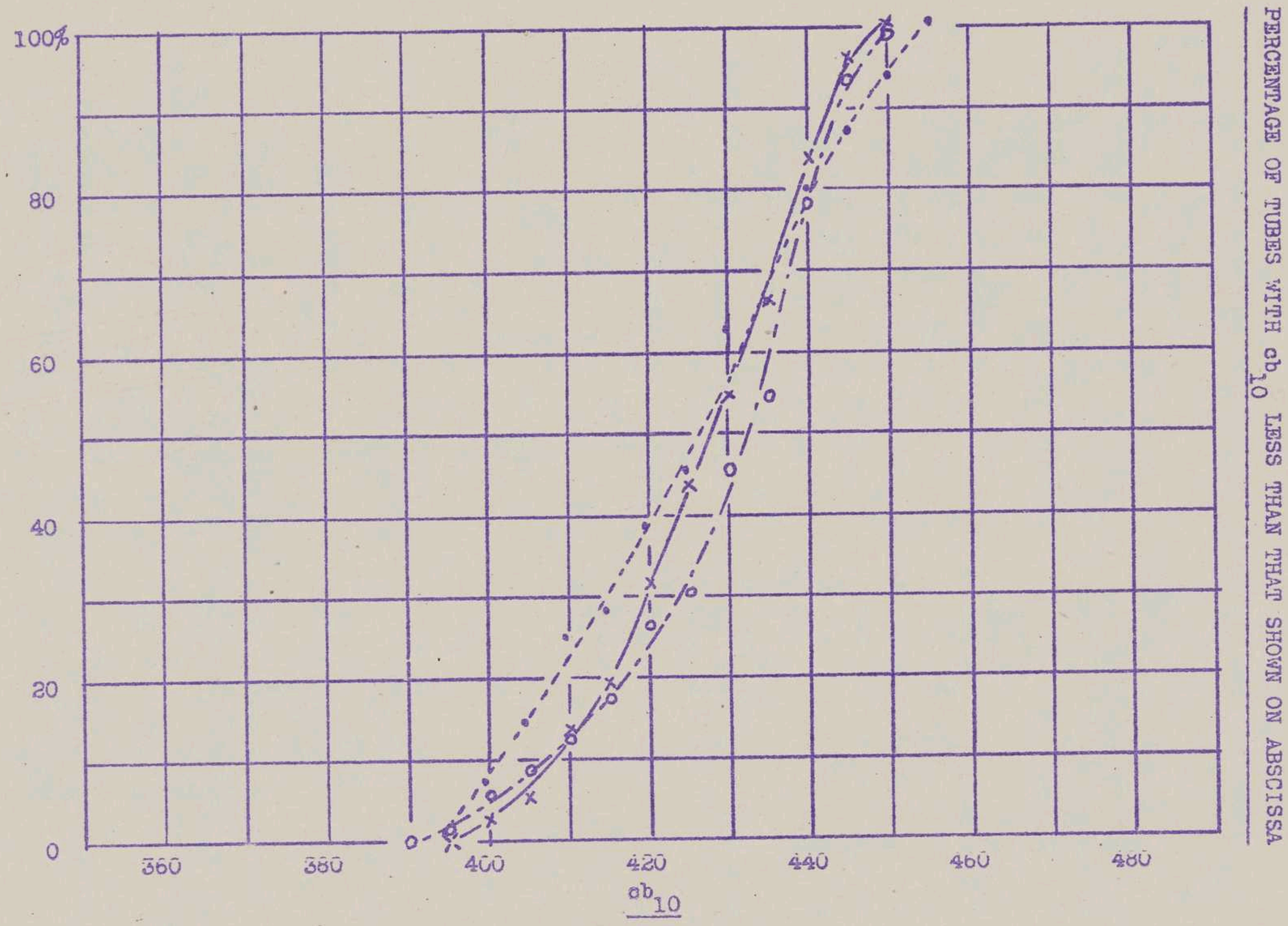

RCA TUBES - TYPE 5FP7

Group I: 8/1/42 - 11/1/42
No. of tubes: 29

Group II: 11/1/42 - 1/1/43
No. of tubes: 79

Group III: 1/1/43 - 4/1/43
No. of tubes: 73

Fig. 19

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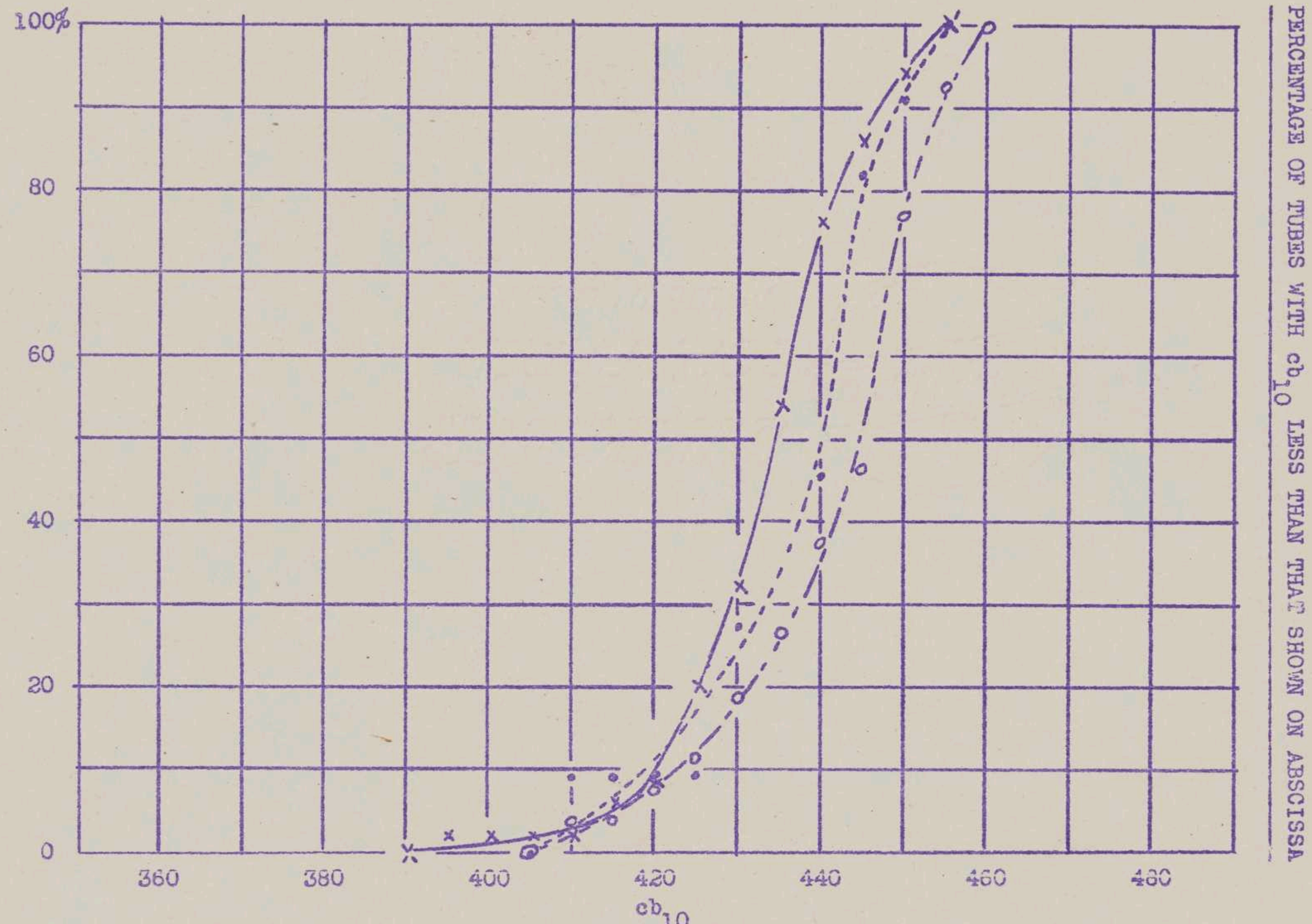

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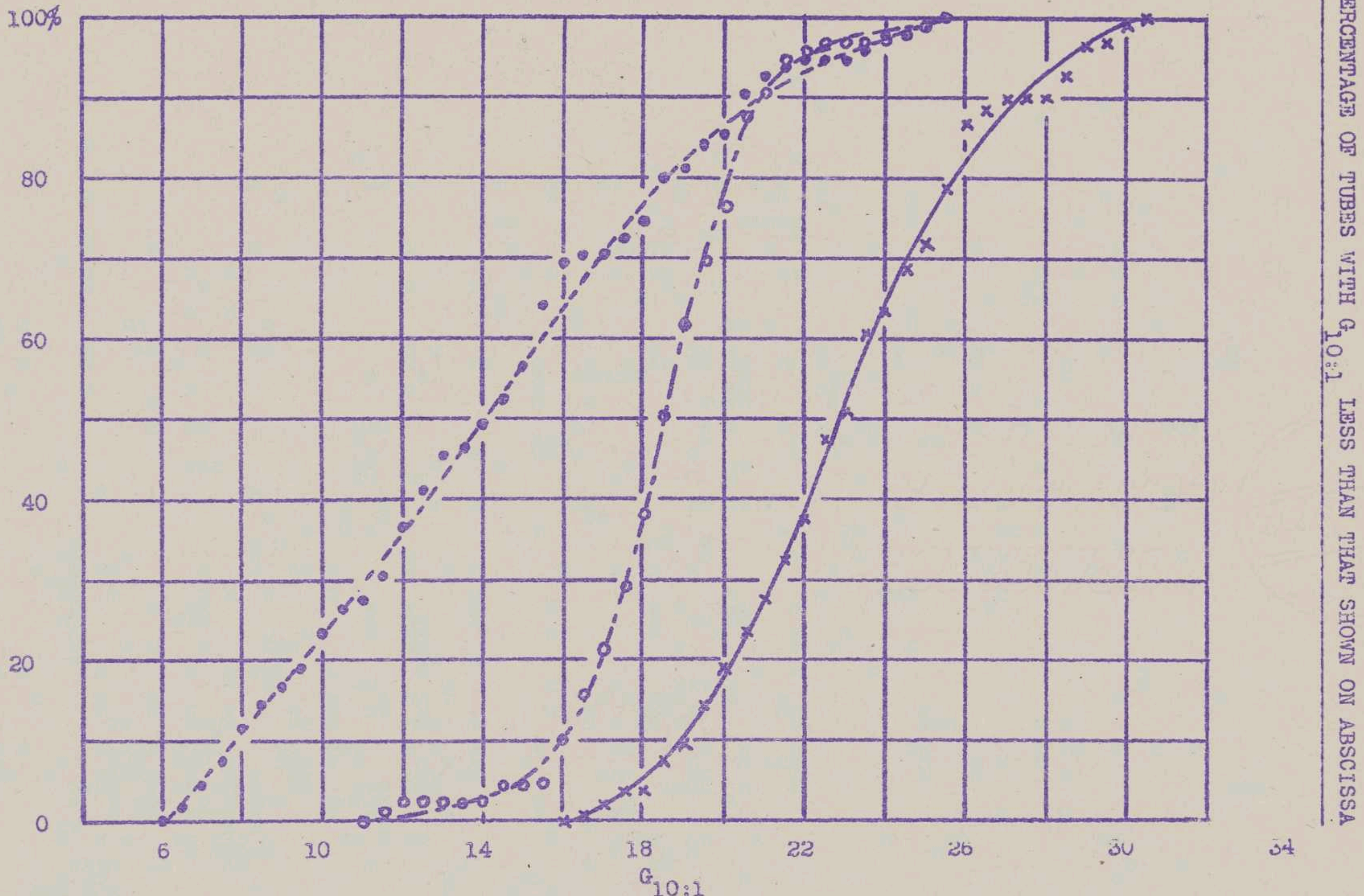
Fig. 20

RCA TUBES - TYPE 7BP7

- - - - - -	— — — — —	————————
Group I: 8/1/42 - 11/1/42 No. of tubes: 11	Group II: 11/1/42 - 1/1/43 No. of tubes: 26	Group III: 1/1/43 - 4/1/43 No. of tubes: 50



G.E. TUBES - TYPE 5FP7

Group I: 8/1/42 - 11/1/42
No. of tubes: 95

Group II: 11/1/42 - 1/1/43
No. of tubes: 89

Group III: 1/1/43 - 4/1/43
No. of tubes: 106

Fig. 21

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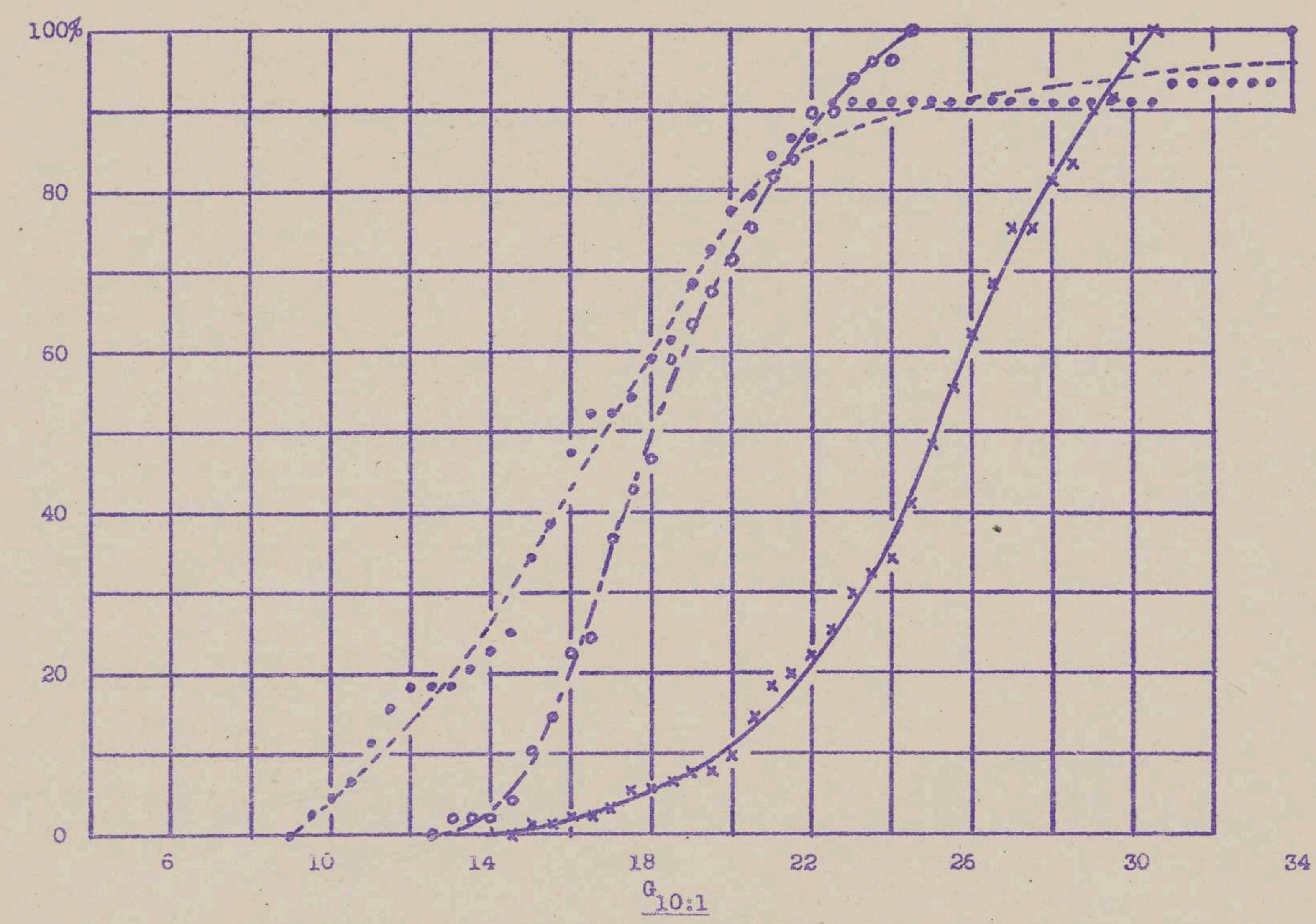

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G.E. TUBES - TYPE 7BP7

Group I: 8/1/42 - 11/1/42

No. of thbes: 44

Group II: 11/1/42 - 1/1/43

No. of tubes: 49

Group III: 1/1/43 - 4/1/43

No. of tubes: 90

Fig. 22

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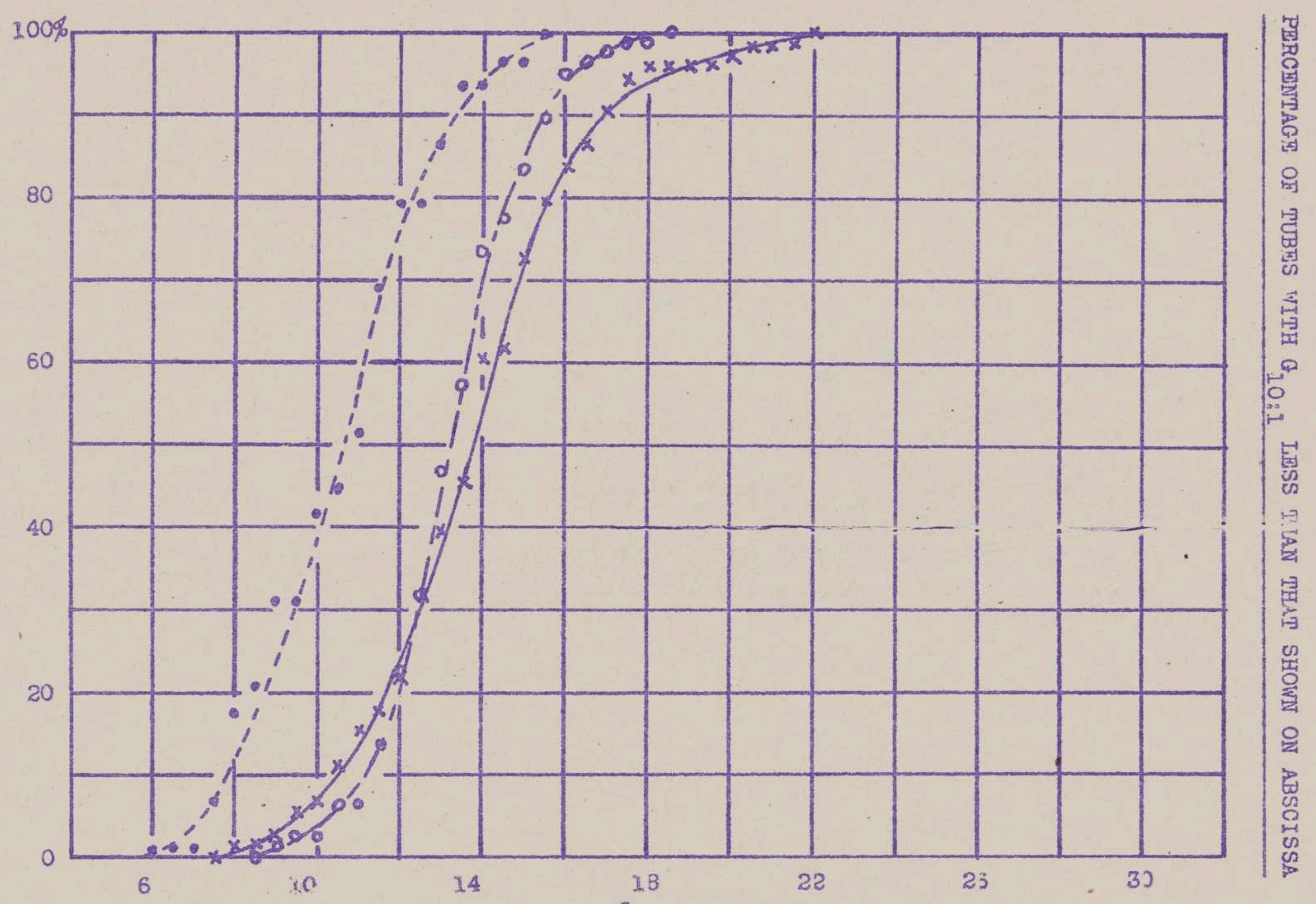

$G_{10:1}$

RCA TUBES - TYPE 5FP7

- - - - - - Group II 8/1/42 - 11/1/42, No. of tubes: 29

— - — - — Group II: 11/1/42 - 1/1/43, No. of tubes: 79

———— Group III: 1/1/43 - 4/1/43, No. of tubes: 73

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Fig. 23

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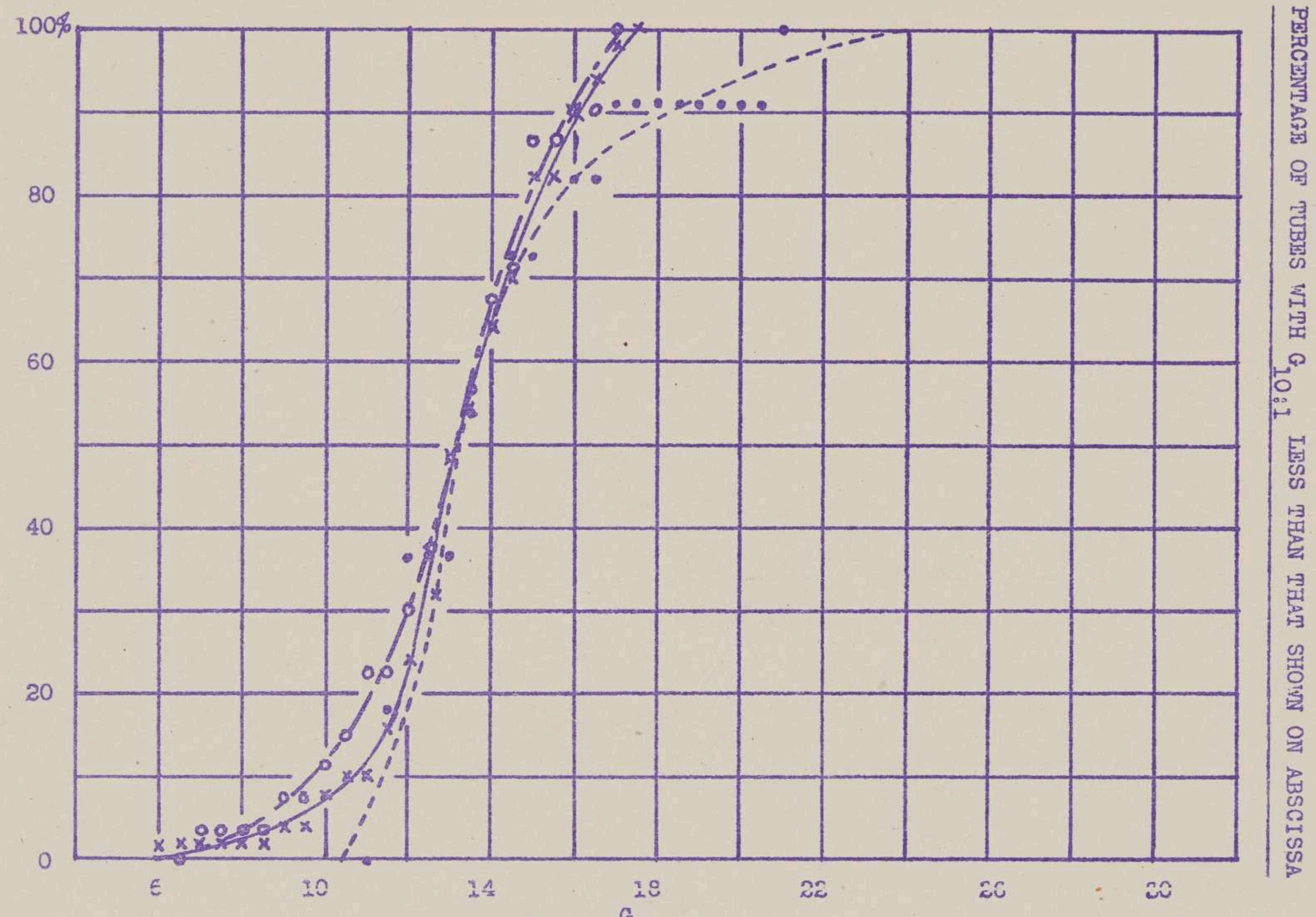

$G_{10:1}$

RCA TUBES - TYPE 7BP7

- - - - - - Group I: 8/1/42 - 11/1/42, No. of tubes: 11

— - — - — Group II: 11/1/42 - 1/1/43, No. of tubes: 26

———— Group III: 1/1/43 - 4/1/43, No. of tubes: 50

Fig. 24

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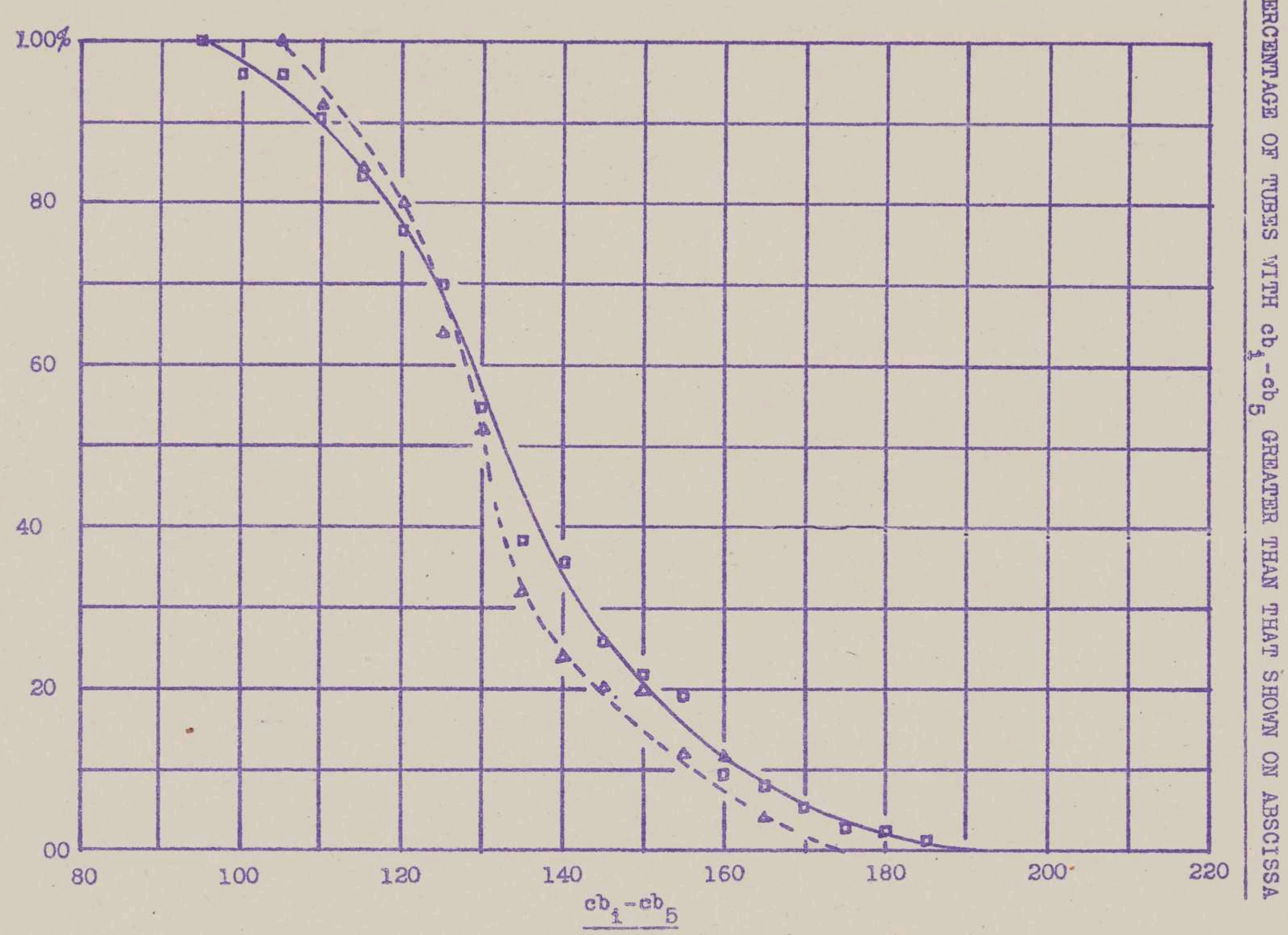

RCA TUBES - TYPES 5FP7 AND 7BP7

Tubes measured by Signal Corps 1/15/43 - 4/1/43

□ ———— □ 5FP7   △ - - - - △ 7BP7

Fig. 25

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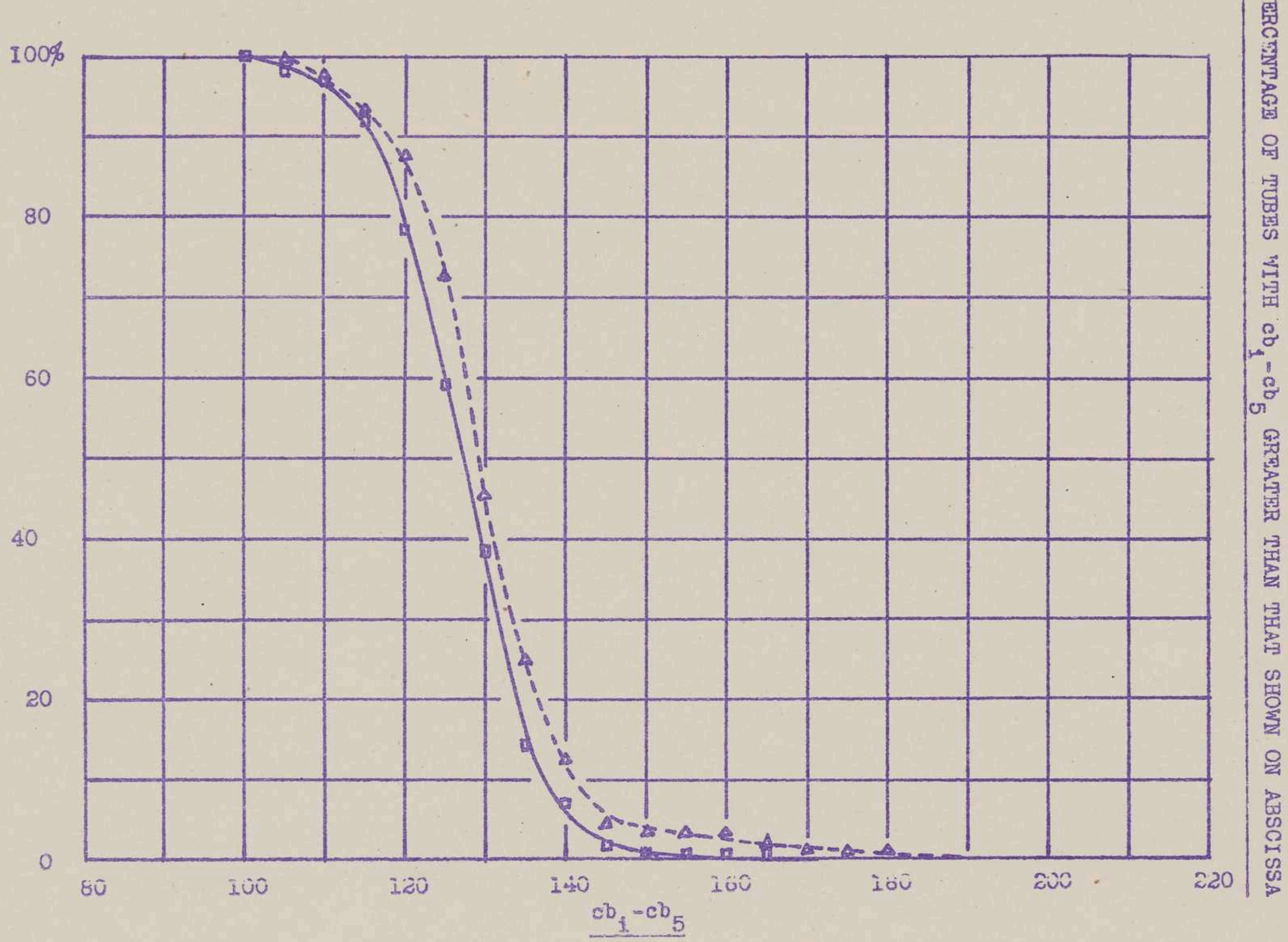

G.E. TUBES - TYPES 5FP7 AND 7BP7

Tubes measured by Signal Corps 1/15/43 - 4/1/43

□ ———— □ 5FP7

△ - - - - △ 7BP7

Fig. 26

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RESULTS OF TESTS ON MISCELLANEOUS LOTS OF TUBES WITH P7 SCREENS

Tube	cb_f	cb_1	cb_5	cb_{10}	$G_{5:1}$	$G_{10:1}$	$cb_i - cb_1$	Date of test	Remarks
						DuMont - Type 5CP7			
3225E	672	340	423	443	6.8	10.7	217	Jan. 1943	This lot measured at 20 μa. values listed are reduced to 60 μa.
3245E	681	346	421	441	5.6	8.9	195		
3247E	674	338	419	440	6.2	10.0	220		
3250E	674	342	423	444	7.1	11.5	218		
3253E	677	337	414	437	5.9	10.0	232		RCA coated screen.
3256E	676	337	414	437	5.9	10.0	227		" " "
						National Union - Type 5FP7			
2	703	383	434	450	3.2	4.7	225	Jan. 1943	
3	691	363	418	433	3.6	5.0	231		
5	684	365	426	443	4.1	6.0	216		
8	691	365	431	451	4.6	7.2	220		
10	699	372	436	453	4.4	6.5	225		
11	688	357	428	447	5.1	7.9	225		
1	688	380	455	472	5.6	8.3	169	Feb. 1943	
2	687	372	451	468	6.2	9.1	166		
3	693	385	459	475	5.5	7.9	169		
4	688	372	453	471	6.5	9.8	173		
12-6	687	379	453	470	5.5	8.1	172	Mar. 1943	Tested by Signal Laboratory.
45-1	680	356	436	455	6.3	9.8	193		
52-1	680	359	438	458	6.2	9.8	184		
53-H	688	384	454	471	5.0	7.4	183		
61-1	681	374	450	466	5.8	8.3	163		
81-B	681	372	448	466	5.8	8.7	172		
						Philco - Type 5FP7			
1	670	360	431	448	5.1	7.6	200	Oct. 1942	
3	667	357	427	443	5.0	7.2	203		
1H	675	350	427	446	5.9	9.1	217		
1	674	351	409	430	3.7	6.1	233		Special bulb.
2	680	357	411	432	3.4	5.6	236		" ".
3SP	697	374	445	462	5.1	7.5	206		
5SP	697	373	445	461	5.3	7.6	211		

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TESTS ON MISCELLANEOUS LOTS (cont.)

Tube	cb_f	cb_1	cb_5	cb_{10}	$G_{5:1}$	$G_{10:1}$	$cb_i - cb_1$	Date of test	Remarks
				Philco - Type 5FP7 (cont.)					
10	668	358	430	447	5.3	7.8	183	Dec. 1942	
11	679	374	444	459	5.0	7.1	184		
				Rauland - Type 12DP7					
65	671	319	412	437	8.5	15.1	226	Jan. 1943	
75	671	330	424	445	8.7	14.2	227	Mar. 1943	
123	676	320	421	445	10.2	17.8	225		
145	680	351	433	451	6.6	10.0	218		Special screen
				Research Enterprises, Ltd. - Types 9HP7 and 9MP7					
R575	676	337	420	441	6.8	11.0	223	Dec. 1942	Sent to Radiation Lab. for standard-
R736	682	350	427	448	5.9	9.6	217		ization. Type 9HP7.
W2659	682	332	422	449	7.9	14.8	225	Feb. 1943	Sent to Radiation Lab. for standard-
W2866	676	328	423	450	8.9	16.6	223		ization. Type 9MP7.
				Sylvania - Type 5FP7					
1	650	239	313	353	5.4	13.5	271	Oct. 1942	
2	625	245	308	349	4.2	10.8	267		
3	650	240	313	355	5.4	14.5	269		
4	646	245	304	346	3.9	10.1	265		
1	677	371	445	461	5.5	8.0	175	Dec. 1942	
2	672	313	417	444	11.0	20.4	213		
3	676	325	418	445	8.5	15.9	223		
4	676	321	416	441	8.9	15.9	227		
5	677	318	442	458	5.5	8.0	180		
6	671	376	462	479	7.2	10.7	202		
2	669	311	413	442	10.5	20.4	213	Mar. 1943	
65K	664	292	401	432	12.3	25.1	226	Mar. 1943	This group was selected as being
98K	665	285	395	428	12.6	26.9	245		acceptable probably by proposed
4L	663	283	395	429	13.2	28.8	226		modified specifications but not by
6L	666	294	392	425	9.5	20.4	234		those adopted in Aug. 1942.

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TESTS ON MISCELLANEOUS LOTS OF TUBES (concl.)

Tube	cb_f	cb_1	cb_5	cb_{10}	$G_{5:1}$	$G_{10:1}$	$cb_i - cb_1$	Date of test	Remarks
						Sylvania - Type 5FP7 (cont.)			
8L	665	287	397	431	12.6	27.6	223	Mar. 1943	Continuation of group on preceding page
20L	669	285	298	431	13.5	28.8	232		
82L	673	304	403	434	9.8	20.0	230		
4M	672	300	400	432	10.0	20.9	235		
64M	675	292	394	431	10.5	24.6	242		
11J	665	286	402	434	14.5	30.2	234	Mar. 1943	Tested by Signal Laboratory. Tubes selected as being close to cb_5 limit.
18J	666	294	408	440	13.8	28.9	222		
26J	654	324	408	429	6.9	11.2	212		
47J	659	298	399	426	10.2	19.1	220		
81J	657	306	397	426	8.1	15.8	223		
93J	663	305	399	428	8.7	17.0	225		
97J	667	291	389	424	9.5	21.5	226		
1K	660	305	402	431	9.3	18.2	217		
7K	659	299	401	430	10.5	20.5	219		
37K	669	291	403	435	13.2	27.6	233		
53K	669	284	401	433	14.8	30.9	245		
61K	659	290	392	422	10.5	21.0	226		
64K	653	279	384	416	11.2	23.5	237		
87K	683	370	445	462	5.6	8.3	191		
3L	661	327	404	427	5.9	10.0	209		
14L	667	295	393	427	9.5	21.0	234		
15L	670	300	397	428	9.3	19.1	236		
46L	658	304	396	423	8.3	15.5	224		
88L	665	298	373	407	5.6	12.3	247		
5M	672	302	399	433	9.3	20.5	235		
30M	670	302	400	432	9.5	20.0	232		

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ADDITIONAL DATA - DUMONT 5CP7

4/5/43

Tube #	cb_1	$G_{5:1}$	$G_{10:1}$	Flash Ratio	$cb_i - cb_1$	Date of test
C1257A	344	7.1	12.0	164	222	Two week period
C1008	343	7.8	13.4	155	219	preceding
C12A	347	7.3	12.3	130	211	3/20/43
C361A	355	6.5	9.5	180	226	
28103R	349	7.5	13.2	160	220	
C1256A	340	7.7	14.0	168	223	
719R	346	7.5	12.9	175	224	
C11A	357	5.9	10.5	160	220	
4615Q	350	6.8	10.3	128	211	
7596Q	350	6.4	10.3	185	227	
C185A	344	7.6	13.0	132	212	
C363A	347	5.7	9.2	199	230	
C359A	347	6.5	9.5	181	226	
C1841A	350	6.5	11.7	183	226	

The data above was taken from a report on P-7 production dated 3/20/43.

All tests are with reduced pattern size (4.1 × 4.1 cm) and 20 μamp. beam current thus keeping standard Q. Since the light output was reduced one-third 47 cb was added to all cb readings to reduce them to the equivalent of 60 μa.

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Appendix II

GRID DRIVE FACTOR AND CUT-OFF DETERMINED FOR SINGLE CROSS-OVER ELECTRON GUNS

The earliest cathode ray tubes tested at the M.I.T. Radiation Laboratory were designed using a "double cross-over" electron gun. In order to obtain higher current densities and a more uniform distribution of electrons over the beam, the "single cross-over" gun was later adopted. At that time an examination was made of the beam current as a function of the grid voltage, and it was found that a plot using the cube root of the beam current for the ordinate and the grid potential as the abscissa showed a straight line relationship between these variables. The intercept of the straight line on the grid voltage axis was found to correspond to the grid voltage of "cut-off" for the electron beam. The cut-off voltage for a given tube cannot be defined in an absolutely unambiguous way because of the fact that, when normal voltages are applied to a tube, there is no grid potential for which the beam current is exactly zero independent of the sensitivity of the measuring instrument. The beam current which corresponds to the "effective" cut-off is probably somewhat less than 0.1 μa. It is this beam current or this cut-off which is found at the grid voltage at which the intercept of the above straight line occurs. The cut-off voltage thus defined is represented by E_{co}, and experiment shows that this is very nearly the ideal voltage for grid bias for operation of a radar system.

The equation which represents the beam current as a function of the grid voltage is given as follows:

$$i_p = A (E_{co} - E_{cl})^3 \qquad (1)$$

where i_p is the beam current to the screen, A is the grid drive factor, and $(E_{co} - E_{cl})$ is the grid drive. For any tube with this type of gun, the proportionality constant A or the "grid drive factor" is a direct measure of the response of the gun to a given grid drive, and in that sense serves as the nearest equivalent to the transconductance which plays so important a part in ordinary tube operation. Figure 28 of Appendix II shows three straight lines which represent the plot described above for three different guns having widely different cut-off values of $E_{co} = 24$ to $E_{co} = 69$ volts. It is clear upon inspection that the slope of the straight line for the tube with the cut-off value of 24 is decidedly higher than that for the tube with a cut-off of 69. This seems to be a universal rule for guns of this type which have active cathodes. Figure 27 of this Appendix shows the results obtained on a large number of different tubes all operated at 250 volts on the first anode. Here the A value is plotted as the ordinate, and the corresponding E_{co} is plotted along the abscissa. All of the points lie above the solid line designated by a-a, and the line drawn roughly through the center of the group of points represents the "bogey" value mentioned on page 20 of this report.

The limit line a - a was arrived at under the influence of two considerations. The first of these was an estimate, on the part of the members of the Radiation Laboratory most aquainted with the needs of radar systems, of the minimum value of the grid drive factor A which would give satisfactory operation in tubes with various values of grid cut-off E_{co}. After having determined roughly the locations of this minimum value, a line was drawn which fits the empirical equation given as Equation (2) and discussed at some length on pages 17 to 18.

The second consideration is that of ease of testing. The circuits of Figure 3 and 4 of the report show that a test for the limit line a - a is very easy to accomplish.

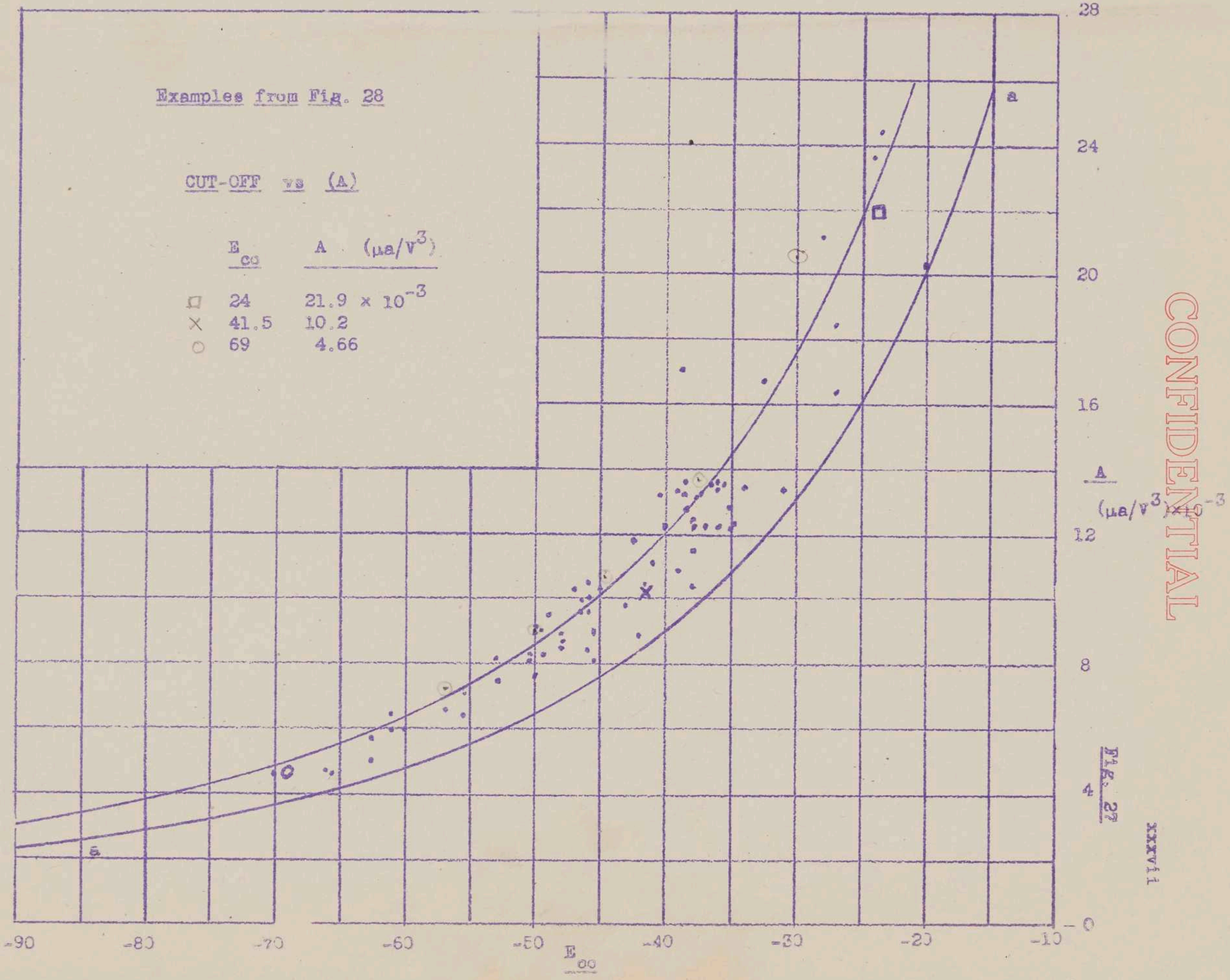
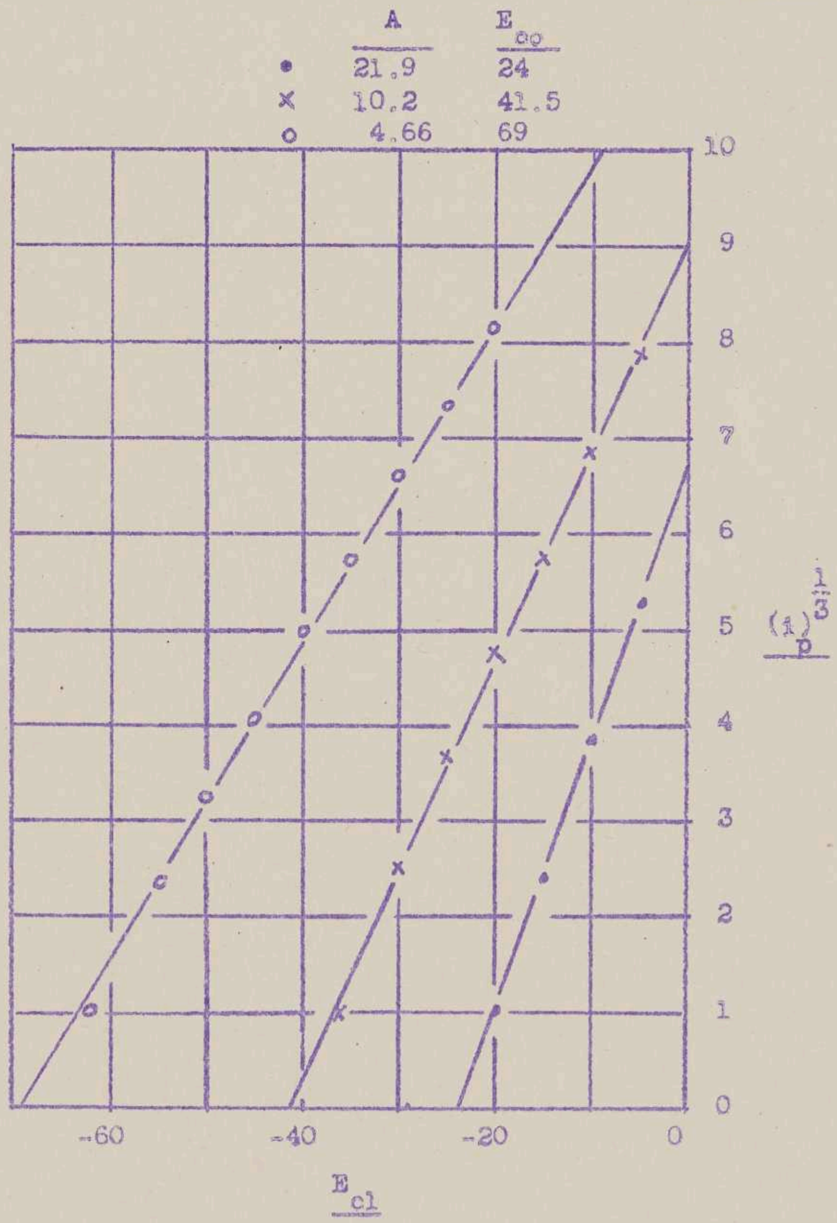

Examples from Fig. 28
CUT-OFF vs (A)
E_{co} A (μa/V³)
□ 24 21.9 × 10⁻³
× 41.5 10.2
○ 69 4.66
a
a
28
24
20
16
12
8
4
0
A
(μa/V³)×10⁻³
-90
-80
-70
-60
-50
-40
-30
-20
-10
E_{co}

Fig. 27

Fig. 28

STATIC CHARACTERISTICS OF THREE 5FP7 CATHODE RAY TUBES



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