

DECLASSIFIED

NRL-54

REPORT NO. R-1351

DATE 15 March 1945

SUBJECT

FR-2351

Investigation of Window Types

For S-Band Use

DECLASSIFIED by NRL Contract
Declassification Team
Date: 19 Aug 2014
Reviewer's names: A. THOMPSON,
P. HANNA
Declassification authority: NAVY DECLASS
MANUAL, 11 DEC 2012, DR PERIES

NAVAL RESEARCH LABORATORY

BELLEVUE, D. C.

DISTRIBUTION STATEMENT A APPLIES
Further distribution authorized by UNLIMITED only.

DECLASSIFIED

15 March 1945

COPY NO. 73

DECLASSIFIED

Report No. R-2351
NRL Problem S15R-S.

NAVAL RESEARCH LABORATORY
Washington 20, D. C.

Radio Division - Search Radar Section

INVESTIGATION OF WINDOW TYPES
FOR S-BAND USE

by

T.D. Hanscome

Approved by

R.C. Guthrie
Head, Search Radar Section

Dr. A. Hoyt Taylor
Superintendent, Radio Division

A.H. Van Keuren, Rear Admiral, USN
Director, Naval Research Laboratory

Title Page - 1 page (a)
Abstract - 1 page (b)
Table of Contents - 2 pages (c,d)
Text - 13 pages
Table - 2 pages
Plates - 31 pages

DECLASSIFIED

DECLASSIFIED

Abstract

Present U.S. Navy Window for the S-band has its maximum effect when used against S-band radars having horizontally polarized antennas. When used at low altitude (small angles of elevation from the radar), the present S-band Window has little or no effect against radars having vertically polarized antennas. A random-falling type of S-band Window is required for use in rockets and shells to be used to screen surface targets. In this use, elevation angles will always be small.

Thirteen Window types were tested. Two new package types which give the desired results are recommended. These are now specified in NavAer Specifications #622. They are type 10270F(017) which contains 34,400 dipoles and type 10397 which contains 60,000 dipoles. The material used in 10270F(017) is particularly adaptable to shell and rocket loading under compression. The 10397 package is light and is recommended for use when weight is the limiting factor.

-b-

DECLASSIFIED

DECLASSIFIED

Table of Contents (Cont'd)

	<u>Plate</u>
Photograph of CAFJ 10270A(017)A	30
Echo Response Versus Number of Dipoles	31

DECLASSIFIED

DECLASSIFIED

INTRODUCTION.

1. This report is an account of tests made at the Naval Research Laboratory to find a satisfactory type of "Window" for use in the "S" band of radar frequencies for either horizontal or vertical polarization of the radar waves.

1-1. References pertinent to this report are contained in a list at the end of the text. The work on which this report is made was conducted under the authorization of NRL Problem S15R-S in accordance with the letter of reference 1.

1-2. A previous Window report from this laboratory, reference 2, discussed the general properties of U.S. Navy Window. It was noted that the standard S-band Window, CAFJ 10270A(017), falls so that its length is always horizontal. This would be unimportant were it not for the fact that radar using vertically polarized emission would be almost invulnerable to this type of Window at low elevation. In particular, vertically polarized S-band fire-control radar, when used for surface gun-laying, would not be disturbed by the use of CAFJ 10270A(017) since its return for vertically polarized radiation is very small. (This Window material is still effective, however, if the angle of elevation from the radar is large. As the angle of elevation is increased the component of the radiation in the horizontal plane increases. For Window directly overhead the radar-antenna polarization is immaterial, since in this case both the electric and magnetic vectors of the radar signal lie in a horizontal plane.)

1-3. During the search for a satisfactory type of Window for vertically polarized emission many types were tested, including one having the same dimensions as the "Shims" (so-called because of their obvious former use) used by the German Air Force against U.S. Army radar equipment on the Anzio beach-head. (See letter of reference 5.)

DESCRIPTION OF MATERIALS TESTED.

2. The widths of the various materials tested for S-band use ranged from .045 inch to .188 (3/16) inch, and lengths ranged from 1-13/16 to 1-7/8 inches. Detailed information on the types tested is given in the following paragraphs, and a tabulation of this information is contained in Table 1.

2-1. CAFJ 10270A(017) is the U.S. Navy standard S-band Window (see Spec. RE 13A 836B). This material contains 16,000 dipoles in a single sleeve package. Ordinarily two sleeves serve as a unit; i.e., 32,000 dipoles simulate a heavy bomber. The material of which CAFJ 10270A(017) is made is called "Navy A" material. Soft aluminum foil of .00035-inch thickness is laminated between two sheets of tissue weighing 12 lbs. per ream. Each dipole is 3/16 inches wide by 1-7/8 inches long. (See photograph of Plate 19.)

2-2. CHA-5(3) is composed of 30,000 to 40,000 dipoles half of which are .0008-inch-thick hard aluminum foil .045 inch wide backed with 15-lb. tissue. The other half are .0008-inch-thick bare foil nominally .045 inch wide. The material is cut in a rotary chaff cutter (reference 6) in conveniently large lengths, then a bundle of chaff containing the desired number is cut to the proper length in a guillotine cutter. The Window so cut is then placed in a rectangular sleeve folder having end flaps to

DECLASSIFIED

prevent the material from falling out at the ends. The numeral 3 in parentheses is used to designate the size of the package; i.e., CHA-5(3) is a triple unit and contains three times the number required to simulate a heavy bomber. The numeral 5 indicates the S-band, i.e., nominally 2700 to 3400 Mc. A triple unit for the S-band should contain 80 to 90 thousand dipoles. It will be noted in Table 1 that there were 30 to 40 thousand dipoles in the CHA-5(3) packages used in these tests. The photograph of Plate 20 shows CHA-5(3)A. The CHA-5(3) is similar except for dimensions.

2-3. CHA-5(3)A. (Navy designation CAFJ 10397). The letter A in this case indicates modification effected for these tests. The CHA-5(3)A is produced by the same methods as used for the CHA-5(3) except that the material used is .0008-inch-thick hard foil .045 inch wide backed with 15-lb. tissue glued only half way. The unglued portion of the tissue serves as a spinner (similar to that on the maple leaf seed) to favor a fall with a component of the length vertical. Furthermore, the glue on the other half of the dipole weighs it down and thus increases the vertical component. The term "split chaff" will be applied to this material. This technique of cutting chaff to length in a guillotine cutter was developed by Standard Rolling Mills, Inc., at the specific request of the Bureau of Ships, in order to adapt Chaff materials to use in theatres of the war where the length required cannot be predetermined. The application of this technique to S-band Window greatly reduces the weight and bulk of the package. (See photograph of Plate 20).

2-4. Shims. See paragraph 1-3. Shims are made of .00035-inch-thick foil laminated between 12-lb. tissue. Their dimensions are 4.7 inches long and 1.7 inches wide. One of the holes is of 3/8-inch diameter and the other two are of 3/4-inch diameter. The 3/4-inch-diameter holes are centered with respect to the width of the strip and are 3/4-inch from each end. The 3/8-inch-diameter hole is centered 1-7/8-inch from one end. (See the photographs of Plates 21 and 22.)

2-5. CAFJ 10325(017)X. This material is made from Navy A stock except that the foil is not continuous on the strip. Six S-band dipoles are affixed to each strip. The spacing between dipoles is roughly 0.8 wavelength. All dipoles are aluminum. This material was originally made to try to get an S-band material that would fall in a random manner and thus provide echoing material for vertically polarized radars. For further discussion of CAFJ 10325(017)X see paragraph 4-6-1 through 4-6-3 of the report of reference 2. This package is similar to that shown in the photograph of Plate 23.

2-6. CAFJ 10325(017). This is the material specified in RE 13A 836B. Thirty-pound paper is used instead of 12-lb. tissue, and the aluminum dipole at one end of the strip is replaced by a lead-foil dipole. These modifications were made to reduce "birdsnesting" and to increase the vertical component. (See photograph of Plate 23.)

2-7. "Long pigtails". For this material an S-band dipole 3/16-inch wide is glued to one end of a 3/16-inch by 4-inch piece of 15-lb. tissue. The extra tissue extending 2-3/16 inches beyond the end of the dipole serves as a tail to favor fall with the length of the strip vertical. (See the photographs of Plates 24 and 25.)

DECLASSIFIED

- 2-8. "Short pigtailed". This material is similar to "split Chaff" except that it is cut entirely by guillotine machines. Each dipole is 1-13/16 inches long and 3/16 inches wide. The 15-lb. tissue is glued only half the length of the dipole. (See the photographs of Plates 26 and 27.)
- 2-9. Horizontal Coherent Streamers. These are long strings of 300 dipoles spaced one-half wavelength and glued to a paper streamer so that the length of the dipole runs across the width of the streamers. (See the photograph of Plate 28.)
- 2-10. Vertical Coherent Streamers. These are strings of dipoles similar to the foregoing except that the spacing is about 0.8 wavelength and the length of the dipole is parallel to the length of the streamer. (See the photograph of Plate 29.)
- 2-11. CAFJ 10270A(017)A. This is a combination package containing 4800 dipoles of "Navy A" material and 11,200 "short pigtailed". Two sleeves of CAFJ 10270A(017)A constitute a unit. All material is guillotine-cut. (See the photograph of Plate 30.)
- 2-12. CAFJ 10270A(017) Mod. 1 is similar to CAFJ 10270A(017)A except that the package is made large enough to simulate a heavy bomber by use of a single sleeve - i.e., 27,200 "short pigtailed" and 7200 ordinary flat dipoles. For this package the "Navy A" stock is modified by interleaving it with .0008-inch-thick hard aluminum bare foil. This permits an increase in the number of dipoles per stack from 200 to 300, without increase in size or weight.

EQUIPMENT AND METHODS USED IN TESTS.

3. The tests were conducted at the NRL Chesapeake Bay Annex. At this location are installed various U.S. Navy shipboard-type radar equipments. The site overlooks the Bay from a cliff of about 100-foot height, so that radar propagation factors encountered in actual naval service are effectively simulated.

Radar Equipment.

3-1. The S-band radars used for tests of Window were the SG and SF surface-search equipments. The SG antenna is horizontally polarized. The SF antenna is normally horizontal also, but was rotated 90° to provide vertically polarized radiation for these tests.

Measurement Technique.

3-2. The relative strengths of the echo signals from the various types of Window were determined by use of an "artificial echo" from a pulsed r-f signal generator. The output of the generator was fed into the radar receiver r-f input through a decoupling "T" joint in the transmission line. The amplitude of the generator output was controllable by an attenuator which allowed setting and reading output level to better than 1/2 db accuracy. The generator pulse was synchronized with the radar pulse rate, and "phased" to appear at the desired point (i.e., "range") on the radar indicator. The procedure used for measuring the strength of an actual echo was to adjust the signal generator "delay"

DECLASSIFIED

until the artificial echo and actual echo are close to the same "range" (on the radar A-scope); the attenuator was then adjusted until the actual and artificial "pips" were of the same height. The reading of the signal generator was noted, and the radar antenna was then pointed at a standard target (a corner reflector of sheet aluminum mounted on pilings in Chesapeake Bay at a range of approximately 3800 yards from the radar installations). A similar reading of the signal-generator attenuator was obtained for the standard-target echo. The difference between the two attenuator readings is equal to the actual (db) difference in received-echo power from the standard target and from the "Window" or other experimental target. For the sake of comparison, the db reading for the standard target is subtracted from the db readings for the Window. Thus the decibel values plotted are these difference values; i.e., a value of zero db represents a signal level equal to that of the standard-target echo. The use in this way of the standard target for comparison eliminates errors due to variation, over a period of time, of various characteristics of the radar system or signal generator.

Determination of Aircraft-Target Polarization Characteristics.

3-3. Signal-generator readings of the signal return from the corner-reflector standard target known as the "South Dolphin" were taken on the SF radar for both polarizations in order to determine the difference (if any) in propagation characteristics between horizontally and vertically polarized radiation, for a low-angle target. The variation in signal level of the echo from the South Dolphin with change in polarization was found to be small (order of 1 db). The echo with horizontal polarization is slightly greater than with vertical polarization on the same equipment. To determine the most desirable ratio of vertical to horizontal response, db readings of an aircraft (SNB-1) were made in both polarizations simultaneously. The difference between the horizontal and vertical responses was small. Hence the desired Window characteristic is approximately equal response to the two polarizations.

Test Procedure.

3-4. The Window material to be tested was released from an SNB-1, with a chute installed in the camera hatch, flying on a radial course from the radar at ranges of 6000 yards or greater, at 1500-foot altitude for all tests. The elevation of the Window was never greater than 5 degrees. Two to four drops were made on each flight at intervals great enough to be resolved on both radars. The db levels and ranges of the echoes were read as frequently as possible (usually about two readings per minute). Readings of standard-target echo level were taken at frequent intervals during the tests.

3-4-1. The height of the signal-generator pulse on the radar indicator was adjusted until it was equal to the short-interval maximum height of the Window echo. Occasionally, abnormally large short-duration maxima of the Window-echo height were observed, but measurements of this type of maximum were not made, partly because of the short duration and partly because these long-period variations did not contribute much to the

DECLASSIFIED

"apparent" height of the echo. As a result, the db readings represent the signal level as it appears to the operator.

3-4-2. During most of the tests the wind was off-shore so that the Window moved away from the radar. The information obtained from the tests is plotted on a log-log scale; i.e., the Window-echo signal level in decibels is plotted against the logarithm of the range on semi-log paper. The same data could be plotted against time if information on signal duration and rate of fall were desired. The time at which each reading was made was entered in the operator's data sheets. The "rate-of-fall" information tabulated in paragraph 4 was derived from the operator's data sheets by use of the time interval between first and last reading for each Window cloud in conjunction with the known altitude of the SNB-1. The graphs shown are preferred as a method of presenting the data. A line having a slope equal to "minus 4" represents the signal return versus range for an ideal target in free space (i.e., radar echo power inversely proportional to fourth power of range). Such a line showing a "fourth-power" variation can be drawn through the graphed data and used to estimate mean return. This method helps because of the rather large dispersion of readings usually obtained with equivalent radar-cross-section measurements. The fourth-power line serves as a base line or axis from which to measure the echoes since it effectively reduces all readings to the same range. The theory fundamental to this interpretation of data is given in the reports of references 8 and 9.

Factors Affecting Interpretation of Data.

3-5. The height of a Window "pip" can be expected to fluctuate for several reasons. Some of this fluctuation is at rates which necessitate their consideration in interpretation of pip-height measurements.

3-5-1. First, there is the normal fluctuation characteristic of Window echoes. For S-band Window these fluctuations occur at an average rate of about 25 per second (see reference 10).

3-5-2. Second, there is the fluctuation that is due to the Window clouds falling through the interference pattern within the free-space antenna pattern. This second type of fluctuation will not be great in amplitude and the average recurrence frequency will depend on the range from the radar and on window rate-of-fall. It will not be great in amplitude because the cloud of Window will disperse vertically to the extent that it will not lie entirely within a single interference lobe and hence deep nulls will not appear. At range R the vertical distance between minima is given by $d = H_2 - H_1 = \frac{R\lambda}{2h}$ where H_1 and H_2 are adjacent alti-

tudes for minimum return, h is the antenna height, λ the wavelength and R the range. This is an approximate formula valid for $R \gg h$, and $R \gg H_{1,2}$. For R = 10,000 yards or 30,000 feet, h = 140 feet, $\lambda = 1/3$ feet, d = 36 feet approximately. The vertical dimension of the cloud of Window remains less than 36 feet for only a very short time after ejection from the aircraft, and hence the lobe structure will not produce large fluctuations.

DECLASSIFIED

3-5-3. Third, there exists a rapid fluctuation in the echo within the period of the 25-per-second type. This is probably due to the addition of vector returns from the many reflectors of the Window cloud, taking account of random amplitudes and phases. This fluctuation is similar to noise and affects the fine structure of each pulse. The amplitudes are generally small and do not affect the amplitude of the apparent return (i.e., the average of a number of pulses) except possibly in the rare case of the occasional abnormally large pulse mentioned in paragraph 3-4.

3-5-4. A fourth type of fluctuation which is ascribed to fluctuating propagation conditions was observed over periods long compared with the duration of a given set of measurements. To minimize this effect, db readings of Window signals were referred to the echo returned from a standard target, the "South Dolphin" mentioned in paragraph 3-3. The use of the standard target does not entirely cancel propagation effects because of the fact that the standard is necessarily near the surface of the water and the Window clouds were necessarily 1000 feet or so high and at a different bearing and range from the radar set. However, the Window was kept as low as possible, and readings were taken on the echo from the SNE-1 whenever time was available for the measurement.

DATA OBTAINED.

4. The graphs on Plates 1 through 18 inclusive present the data taken during the tests, plotted as described in paragraph 3-4-2. This form of graph is frequently used in plotting data on radar-cross-section measurements. It permits direct comparison between different types of Window measured at different times since all measurements are referred to a permanent standard target. The curve "A" which appears on all graphs is drawn to represent the ideal radar echo returned from a target whose cross section is approximately that of a heavy bomber - e.g. B-17. The correct position of this curve is known only approximately. Complete data for aircraft are not available for the SG and SF used. Measurements on an actual target of cross section represented by the curves "A" would give points with considerable scatter about the curves (amounting to as much as 15 db either way). If a curve is drawn through the "center of gravity" of the measurements for the Window, the db difference between the Window response and required response as represented by the curves "A" can be read off the graphs by noting the difference between a point on the "A" and a point on the Window curves at the same abscissa. For example, in Plates 1 and 2 the SNE-1 echo is seen to be about 8 db below the "A" response for both vertical and horizontal polarization. The following table includes rate-of-fall information as well as db level referred to curve "A".

(See table on next page)

DECLASSIFIED

Window Type	Radar Polar.	DB Level Referred to "A"	Rate of Fall
CAFJ 10270A(017)	H	0	120-150 ft/min
CAFJ 10270A(017)	V	-13	
CHA-5(3)	H	-7	110-140 ft/min
CHA-5(3)	V	-18	
CHA-5(3)A	H	-5	110 ft/min
CHA-5(3)A	V	-5	
Shims	H	-5	200 ft/min
Shims	V	-5	
CAFJ 10325(017)X	H	-10	250 ft/min
CAFJ 10325(017)X	V	-13	
CAFJ 10325(017)	H	-10	250 ft/min
CAFJ 10325(017)	V	-20	
Long Pigtailes	H	-10	250 ft/min
Long Pigtailes	V	-12	
Short Pigtailes	H	-12	175 ft/min
Short Pigtailes	V	-10	
CAFJ 10270A(017)A	H	-8	H Component 150 ft/min
CAFJ 10270A(017)A	V	-5	V Component 175 ft/min
CAFJ 10270A(017) Mod 1	H	-4	H Component 150 ft/min
CAFJ 10270A(017) Mod 1	V	-5	V Component 175 ft/min

The db levels given in the table are graphical estimates and are not accurate on an absolute scale. Their accuracy relative to each other is good to plus or minus 1 db for most of the graphs and is not worse than plus or minus 3 db. Three db corresponds to a factor of 2 in the number of dipoles required; i.e., twice the number of dipoles will increase the echo return by 3 db. The last item, CAFJ-10270A(017) Mod 1, is now designated as CAFJ 10270F(017) in NavShips specifications 16F2(RE). The CHA-5(3)A is designated as CAFJ 10397. See report of reference (7).

4-1. CAFJ 10270A(017) is the present form of S-band Window supplied to the Fleet. Data taken with this material is assembled in graphs of Plates 3, 4 and 5. The graph of Plate 3 shows the echo power versus range with the number of dipoles as a parameter. Each curve for the SG shows a maximum return which occurs when the Window has dispersed to the extent that it approaches the ideal density of one dipole per square wavelength of projected area of the cloud (projected on a surface perpendicular to the radar beam), but has not begun to lose its identity as a compact body of echoing material. It has been noted in other Window reports that the life of the Window is limited by its dispersion. The graph of Plate 4 presents data taken for a number of Window clouds of the same size (i.e., same number of dipoles) at different ranges. In order to compare echoes at different ranges, it was desirable to learn how closely the fourth-power law was followed by Window clouds at different ranges. The deviations indicated in the graph of Plate 4 are not greater than those usually observed for a non-fixed target, hence the assumption of fourth-power-law validity was used freely in interpreting the results. The initial readings for each cloud were taken soon after the Window was ejected from the aircraft. These readings are all low because the cloud had not developed fully. Such points on the graph are marked by a vertical line on the graph

DECLASSIFIED

of Plate 5 presents data taken on SG and SF for comparison of vertical and horizontal echoes. Few points appear for vertical polarization because the echo disappeared shortly after the Window was ejected from the aircraft. CAFJ 10270A(017) was expected to have no vertical component at all, but for a short time after ejection, turbulence and the high density of the dipoles apparently results in a vertical component.

4-2. CHA-5(3). It should be noted that the samples of CHA-5(3) that were used for these tests contained about 36,000 dipoles. The graphs of Plates 6 and 7 show the points taken on the SG and SF for horizontal and vertical polarizations respectively. The echo for vertical polarization is about 11 db below that for horizontal. Comparing the results on the graphs of Plates 6 and 7 with the graphs of Plates 1 and 2 shows that the echo for horizontal polarization is about 1 db above the SNB-1 echo and that the echo for vertical polarization is about 10 db below the SNB-1 echo. CHA-5(3) is not in general suitable for use at low angles of elevation against vertically polarized equipments.

4-3. CHA-5(3)A now carries the Navy designation CAFJ 10397. The graphs of Plates 8 and 9 show the echo signal level for this type of Window in the two polarizations; horizontal on the SG, and vertical on the SF. The effectiveness falls off rather rapidly, i.e., the echo decreases with time more rapidly than it should for the amount by which the Window increases in range. As noted before, this property appears to be characteristic of Window responses, particularly for high-resolution radars.

4-4. Shims were made to the dimensions of the ones dropped by the Luftwaffe over Anzio. Material of the same dimensions but without the holes was also tested. The graph of Plate 10 presents the data for both types with holes and without holes. From the point of view of the weight required Shims are very inefficient. The weight of the bundles used was $5\frac{1}{4}$ lbs. To produce an echo equal to that produced by 1 lb. of CAFJ 10397, approximately 10 lbs. of Shims are required. The Shims used by the Luftwaffe were made of .01-inch shim stock, and a "package" must have weighed 25 to 50 lbs. in order to produce a strong enough echo to disturb auto-following equipment. The amplitude of this echo would still be considerably below that of the aircraft. No measurements were made for vertically polarized radiation.

4-5. CAFJ 10325(017)X material did not perform as desired. Bird-nesting was great. Theoretically, the advantages of a coherent strip of dipoles whose length is parallel to the strip can be realized only for vertically polarized radiation, because the sharpness of the reflection pattern increases faster than the magnitude of the maximum of the main lobe. Also, when the radar polarization is vertical, unless the dipoles fall with their length vertical there is a net loss in efficiency. The CAFJ 10325(017)X fell in a random manner and as a consequence the echo amplitude was low. See the graph of Plate 11.

4-6. CAFJ 10325(017) is a modified form of CAFJ 10325(017)X in which heavier backing is used and each strip is weighted. This type was a small improvement for horizontal polarization, but no better for vertical

DECLASSIFIED

polarization. Since the weight was increased by the modifications, this type is actually less efficient than the CAFJ 10325(017)X. See the graph of Plate 12.

4-7. "Long Pigtaileds" were subjected to only one test because of the fact that they occupy more packing space per dipole than the short types. The "long pigtaileds" were the first dipoles to give good results for vertically polarized radiation. If the number of dipoles were the only quantity to be minimized, the "long pigtaileds" would be recommended. However, the short pigtaileds were found to have a net advantage over the "long pigtaileds". Results of the "long pigtail" test are presented in the graph of Plate 13.

4-8. "Short pigtaileds" were more promising because of their compactness and because of greater facility in manufacture. It will be noted in the table of paragraph 4 that 5000 "long pigtaileds" give the same response as 11,200 "short pigtaileds"; i.e., twice as many "short pigtaileds" are required to give the same effect as a given number of "long pigtaileds". The "short pigtaileds" are used in the recommended package (paragraph 4-11) in preference to the "long pigtaileds" because they are more easily manufactured, they have a lower rate of fall, and they can be packed more compactly with ordinary S-band dipoles. Results are presented in the graph of Plate 14.

4-9. Tuned Rope. The horizontal-coherent and vertical-coherent streamers (otherwise known as "tuned Rope") were tested with the hope that a tuned streamer might be used to bring up the S-band response for the balloon-borne decoys of the LOAEV type. In this test the streamers were dropped from the aircraft and were supported by parachutes. The response was roughly the correct order of magnitude, but the fluctuations were very great. The results shown in graph of Plate 15 do not indicate the extent of this fluctuation and consequently do not give a correct basis for evaluation. The echo signal disappeared for seconds at a time. This occasional disappearance of the echo, considered with the violent fluctuations, makes identification and recognition of echoes produced by this means a simple matter.

4-10. CAFJ 10270A(017)A combines "short pigtaileds" and standard Window in a single package. During the tests, the operators in the aircraft noted the difficulty in handling two sleeves. As a result, single sleeves were dropped during a second series of tests, resulting in wider than usual vertical scattering of points on the graph (a factor of 2 in the number of dipoles results in a difference of 3 db in the response). Results are presented in graphs of Plates 16 and 17.

4-11. CAFJ 10270A(017) Mod. 1 is the material designed from the results of the foregoing tests. In NavShips Specifications 16F2(RE) and NavAer Specifications M-622 it is designated as 10270F(017). Results for this material are shown in graph of Plate 18.

CONCLUSIONS AND RECOMMENDATIONS.

5. Of the several types of Window tested, two types have sufficient

DECLASSIFIED

general efficiency to be considered for use in the Fleet. The term "general efficiency" includes, in addition to radar-reflecting characteristics, considerations of compactness, lightness, and ease or difficulty of manufacture. These two types are CHA-5(3)A (specified as type 10397 in BuShips Spec. 16F2(RE)) and CAFJ 10270A(017) Mod. 1 (specified as 10270F(017)). The first of these is desirable because of lightness, the second for its compactness and because the same material is suitable for use in rockets and shells. The 10397 material suffers considerably from birdsnesting, but gives the required response with less weight of material than does the 10270F(017) material. Both types are more difficult to produce than Window for lower frequencies. Of the two types the 10270F(017) uses more raw material, it is heavier, but is more easily manufactured than the 10397. Both the 10270F(017) and the 10397 can be used in automatic dispensers. If weight is the limiting factor, 10397 is to be recommended. If the Window is to be loaded under pressure (e.g., in rocket or shell or tightly in a dispenser) the 10270F(017) is to be recommended.

ACKNOWLEDGMENTS.

6. Acknowledgments are due to Standard Rolling Mills, Inc., Brooklyn, New York, for supplying both ideas and test materials at short notice. This company's estimates of production facility of the several types aided the design and test program. Test facilities other than those provided by the Naval Research Laboratory were made available by the Bureau of Aeronautics at Radio Test, Patuxent River Naval Air Station. The Bureau of Ships guided the design trends and expedited the procurement of samples and test facilities.

DECLASSIFIED

DECLASSIFIED

References

1. BuShips letter to NRL S-567-5(924) Serial S-920-5123 dated 6 July 1943 assigning problem S15R-S.
2. "Features of Design, Preparation and Use of Naval Window" - NRL secret report R-2289 of 22 May 1944.
3. "Return Cross Sections from Randomly Oriented Resonant Half Wave Chaff", NDRC Div. 15 Technical Memorandum 411-TM-127 of 19 June 1944.
4. "The Dependence of the Response of Microwave Chaff on Polarization and Angle of Elevation", NDRC Div. 15 Technical Memorandum 411-TM-126 of 22 June 1944.
5. MGRA's Liaison letter #7, JEIA serial 3655, dated 15 May 1944 (German Use of Window at Anzio).
6. "Preliminary Description and Operating Instructions for G-502 and G-503 Cutters", NDRC Div. 15 Technical Memorandum 411-TM-28 dated 23 July 1943.
7. "Window Types for Naval Use in the Frequency Range 80-3000 Mc", NRL confidential report R-2443 (Estimated date, March 1945).
8. NRL Secret Report RA 3A 213A, dated 24 January 1944: "Radar Cross Section of Ship Targets".
9. NRL Secret Report R-2232, dated 18 February 1944: "Radar Cross Section of Ship Targets, II".
10. "Review of Window" RRL (OEMsr-411) Secret Report 411-91 dated 30 May 1944.

Appendix 1Determination of Ratio of Numbers of Standard Navy "A"Dipoles to "Split Pigtail" Dipoles

On theoretical grounds (as borne out by the results shown in graph of Plate 3), the echo power increases linearly with the number of dipoles in a Window cloud. Since both types of dipoles have responses in both polarizations, a graphical method is the most direct method for obtaining the ratio of numbers of "Navy A" dipoles to split pigtails required to give equal response in the two polarizations. The graph of Plate 31 gives the response versus numbers, i.e., the db response versus the logarithm of the number of dipoles. The horizontal response of the Navy "A" material is given by the curve A_h , the vertical response by A_v . The horizontal response of the split pigtails is given by the curve B_h , the vertical response by B_v . These curves are drawn to have the slope predicted by theory and to pass thru the experimental points (indicated by circles on the graph). The graphical method is used to determine the desired ratio as follows. A point on the B_v curve is chosen. This point represents the echo power from N_0 dipoles, say 40,000. N_0 pigtails has a horizontal response x db less than the vertical response (2 db by these measurements). The number of "Navy A" dipoles required to give the same response can be read from the graph by drawing a horizontal line from the 40,000 point on the B_h curve through the A_h curve. The intersection with the A_h curve gives the number N_1 of "Navy A" dipoles to give the same horizontal response as N_0 pigtails, in this case 7100. To bring the horizontal response of the split pigtails up " x " db, the horizontal response should correspond to a number N_2 "Navy A" dipoles determined by the formula:

$$\log \frac{N_2}{N_1} = \frac{x}{10}$$

The number of "Navy A" dipoles to be added is then $N_2 - N_1$. For the example cited, $N_0 = 40,000$; $N_1 = 7100$; $x = 2$ db.

$$\log \frac{N_2}{N_1} = 0.2 \quad \text{hence} \quad \frac{N_2}{N_1} = 1.58.$$

$$N_2 - N_1 = (1.58 - 1) N_1 = .58 N_1 = 4120.$$

Hence 4120 "Navy A" dipoles must be added in order to produce equal responses in the two polarizations. This gives a ratio of ten to one for split pigtails to "Navy A" dipoles. This ratio gives the minimum number of "Navy A" dipoles required. Manufacturing considerations dictated the use of the ratio of approximately four to one. Calculated by this means, the ratio obtained is an approximation. The accuracy can be increased

by successive approximations. The ten to one ratio gives a vertical response 0.13 db above the horizontal response. The ratio four to one (used in 10270F(017)) gives a horizontal response 0.37 db above the vertical response. The accuracy obtained is due to the fact that the vertical response of the Navy "A" material is very low compared to the horizontal response.

TABLE 1

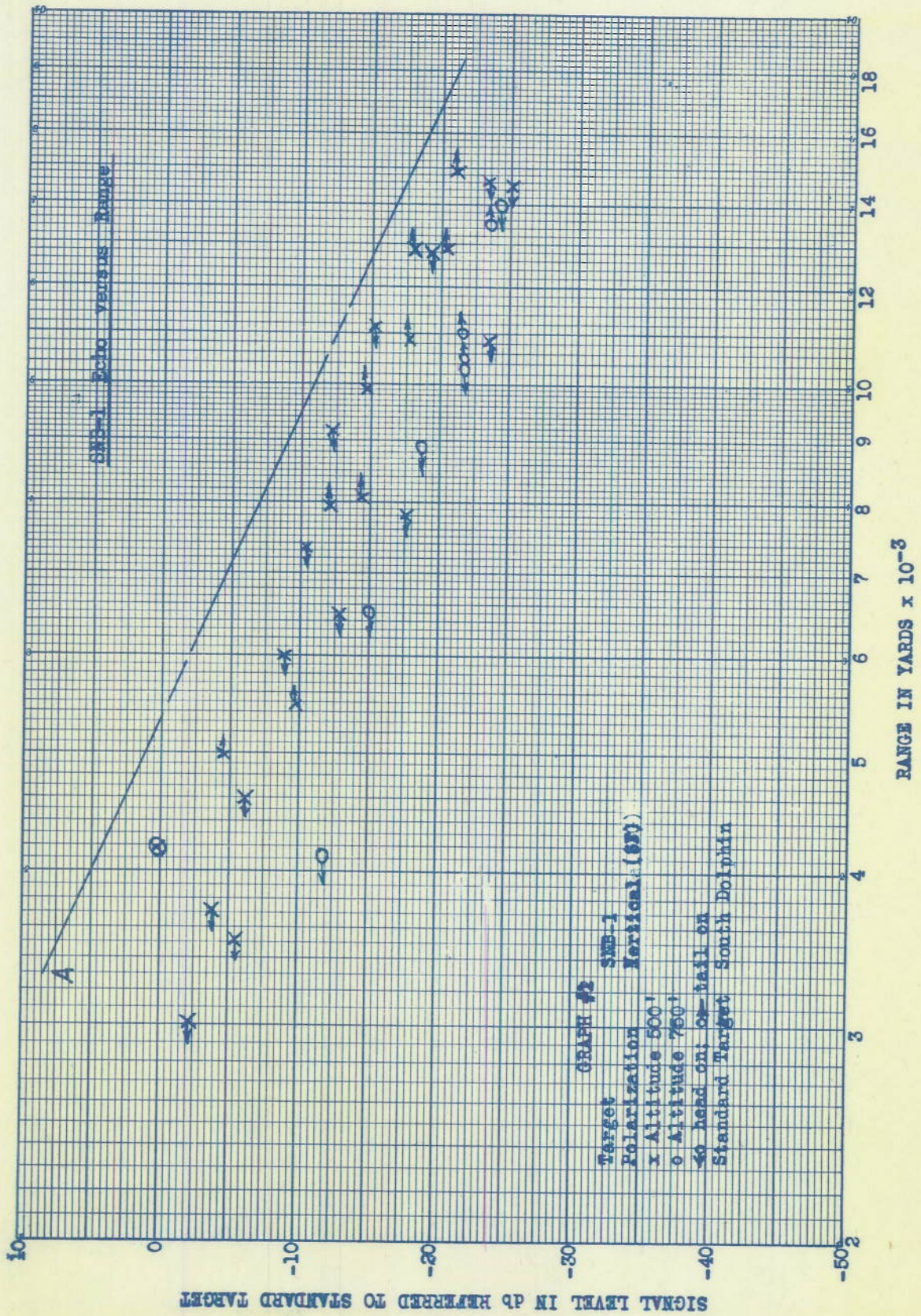
Designation	Dimensions	Weight Per Pks.	Dipoles Per Pkge.	Material	Preparation
CAFJ 10270A(017)	3/4" x 1-3/4" x 20"	428 gms.	16,000	Navy A	Guillotine cut
CHA-5(3)	1-3/16" x 2" x 12"	195 gms.	36,000	Chaff 1/2" x 1/2"	Rotary cut in sleeve.
CHA-5(3)A	1-3/16" x 2" x 16"	347 gms.	56,000	Split Chaff	Rotary cut in sleeve.
Shims	2 1/4" x 4-3/4" x 18 1/2"	2370 gms.	6,400	Navy A	Die cut
Shims - no holes	2 1/4" x 4-3/4" x 18 1/2"	2400 gms.	6,400	"	"
CAFJ 10325(017)X	3/4" x 2 1/4" x 20"	429 gms.	6 dipoles/strip 1600 strips	"	Guillotine-cut in sleeve.
CAFJ 10325(017)	1-3/4" x 1-3/4" x 20"	277 gms.	6 dipole/strip 600 strips	Navy B	Guillotine-cut in sleeve.
Long Pigtails	3/4" x 1 1/4" x 20"	243 gms.	5,000	Special	Guillotine-cut in sleeve
Short Pigtails	3/4" x 1-3/4" x 13"	11,200		"	"
Horizontal Streamers	O.D. 2 1/2" rolls	84 gms.	300	"	By Mfr.;
	O.D. 3 1/2" rolls	90 gms.	300	"	Requires
	O.D. 4" rolls	95 gms.	300	"	Splitting
Vertical Streamers	O.D. 4-3/4" x 1 1/2"	126 gms.	300	"	
CAFJ 10270A(017)1	3/4" x 1-3/4" x 20"	425 gms.	11,200 short pigtails 4,800 std.	Special A	Guillotine-cut

DECLASSIFIED

TABLE 1 (Cont'd)

<u>Designation</u>	<u>Dimensions</u>	<u>Weight Per Pls.</u>	<u>Dipoles Per Pkge.</u>	<u>Material</u>	<u>Preparation</u>
CAFJ 10270A(017) Mod 1	1 1/2" x 2" x 18"	800 gms.	27,200 short pigtaills	Special A	Guillot ine-cut
			7,200 A inter- leave		

DECLASSIFIED



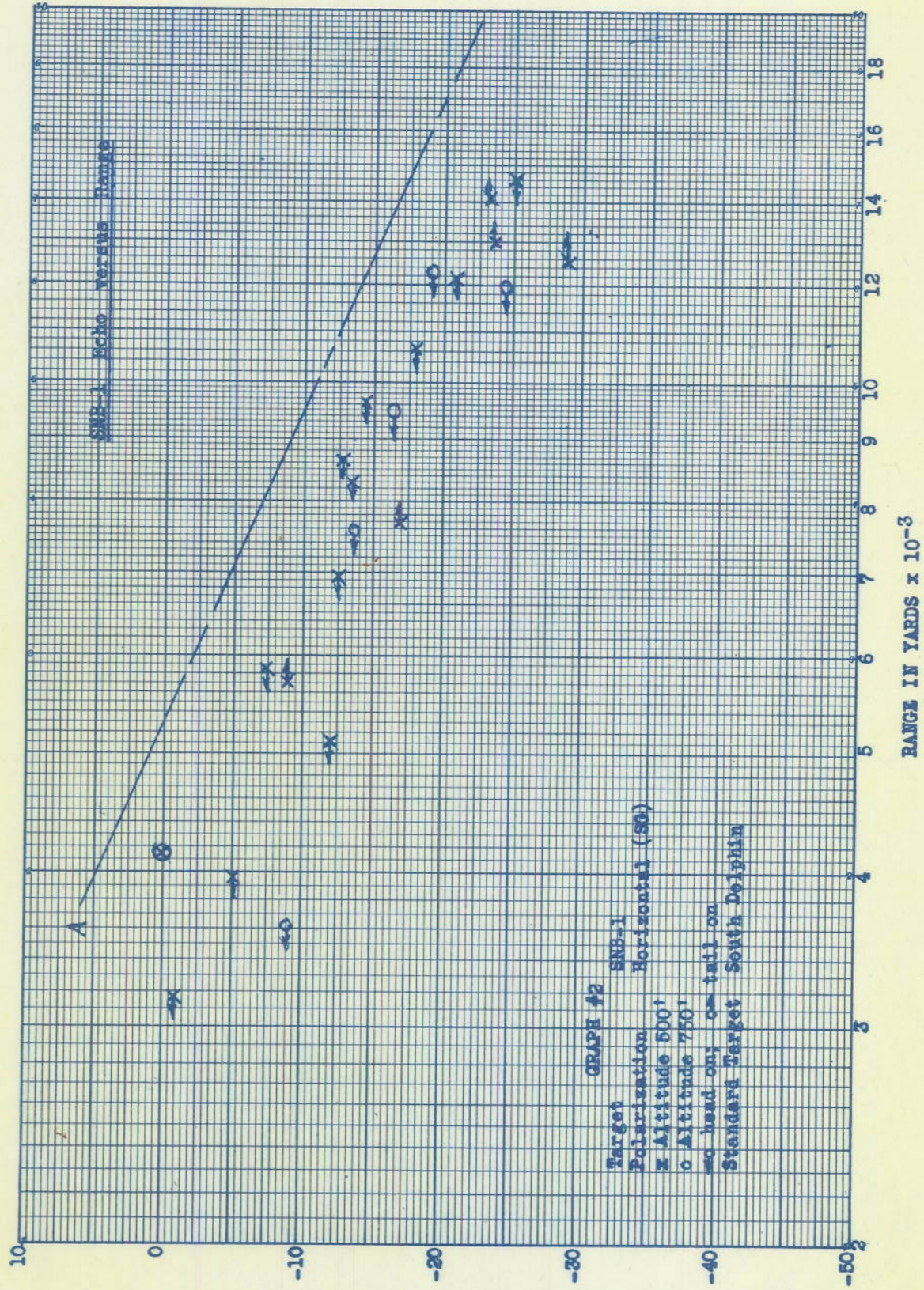
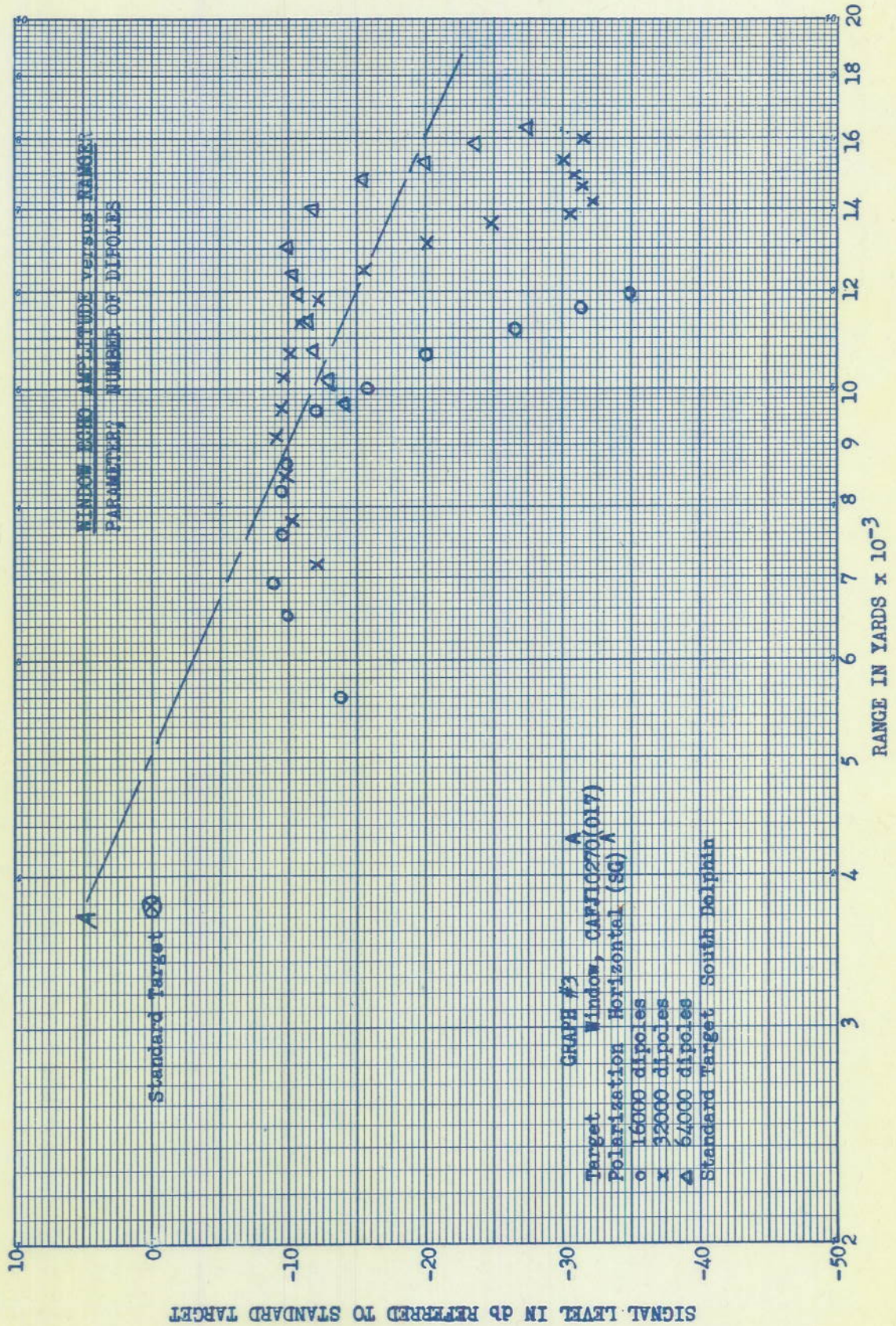


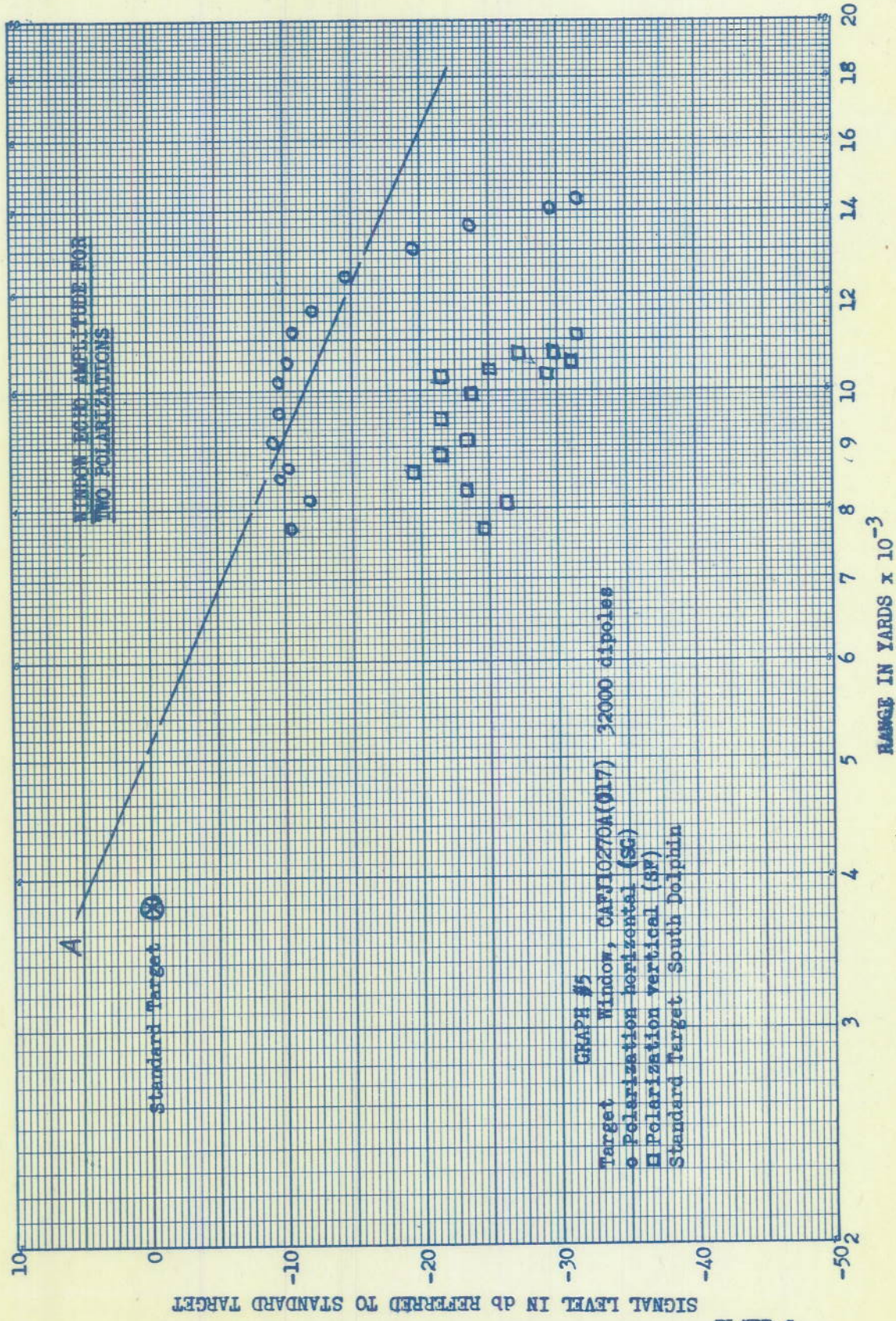
PLATE #2

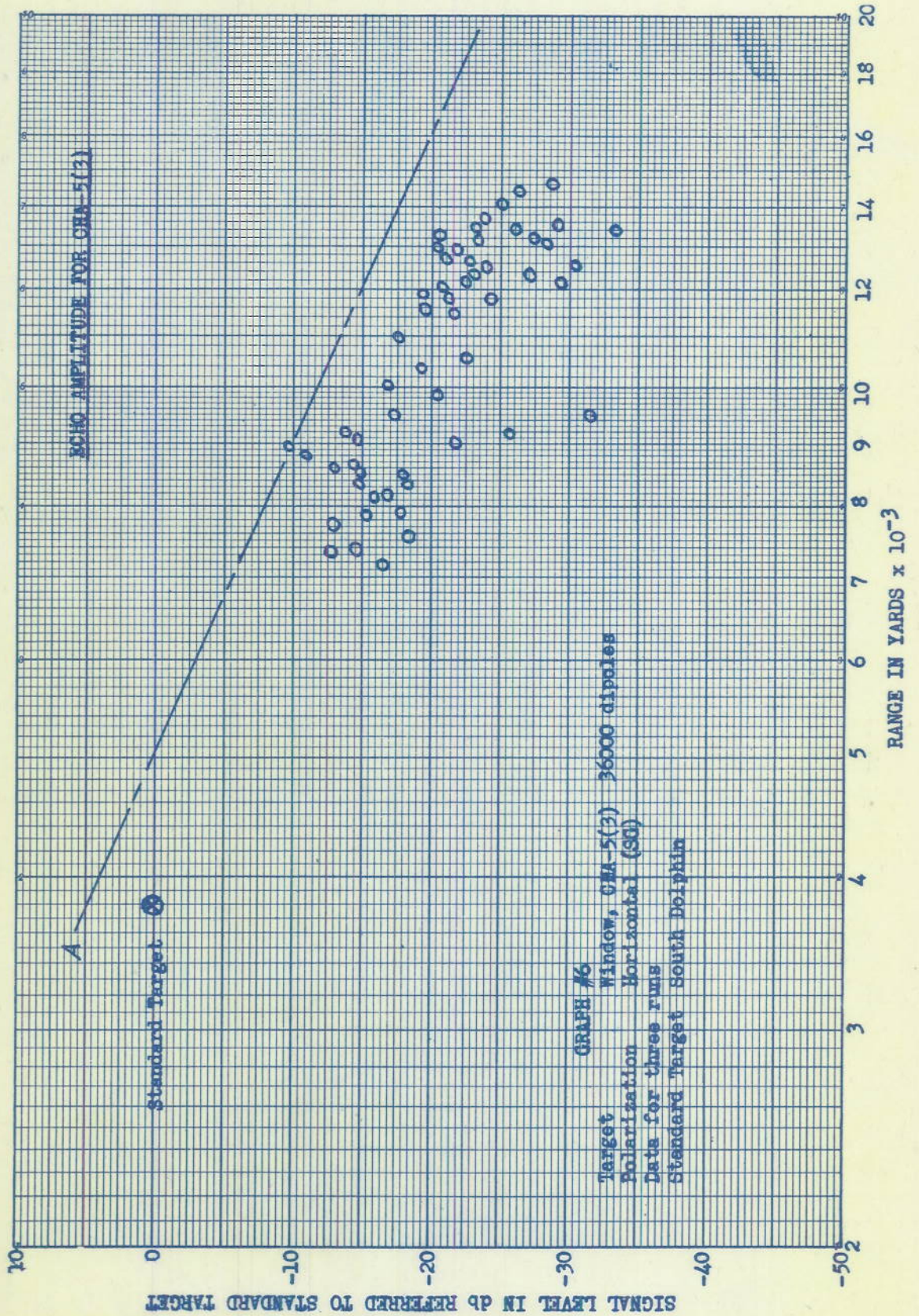
SIGNAL LEVEL IN DB REFERRED TO STANDARD TARGET

PLATE 2



CONFIDENTIAL





CONFIDENTIAL

CONFIDENTIAL

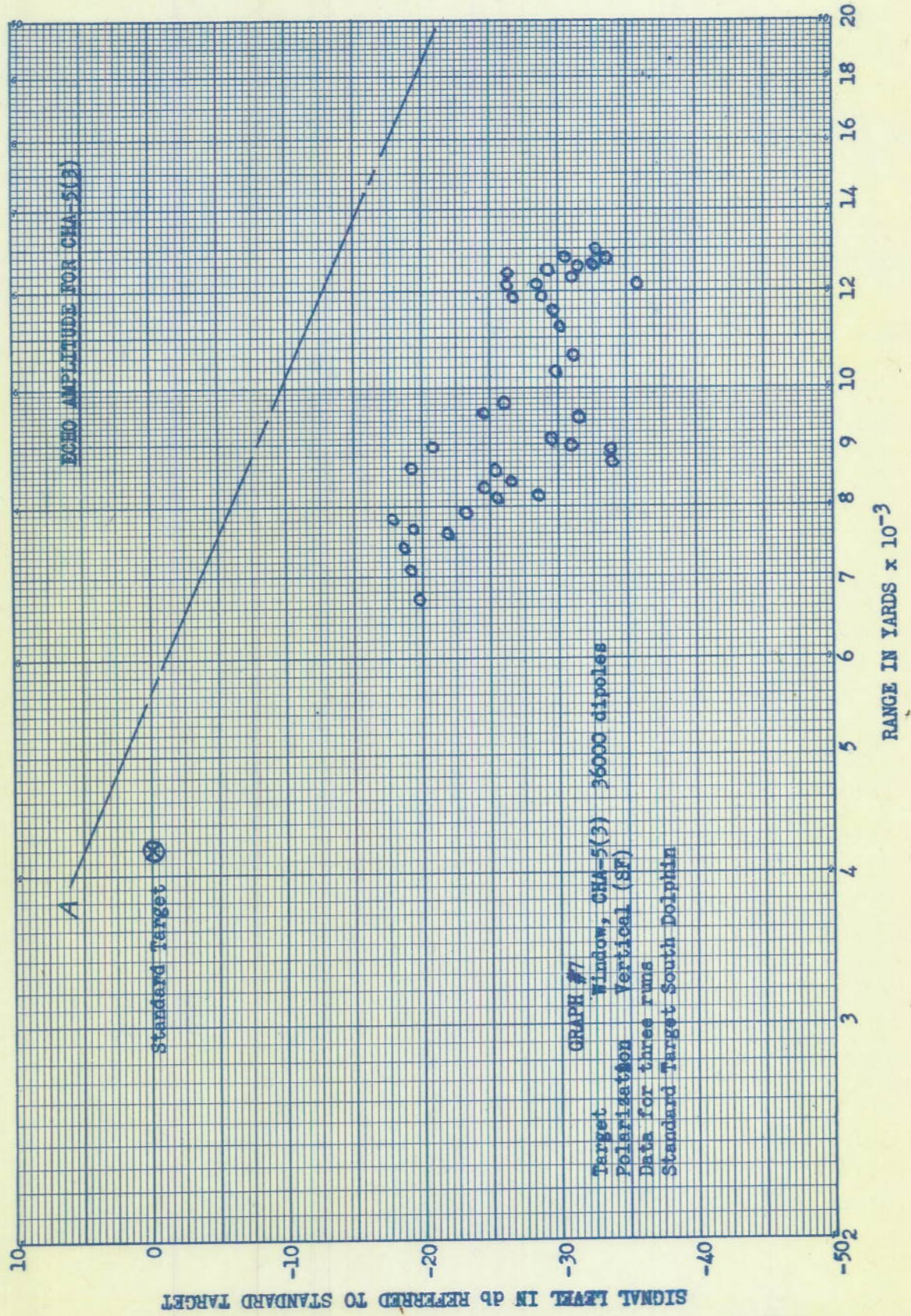
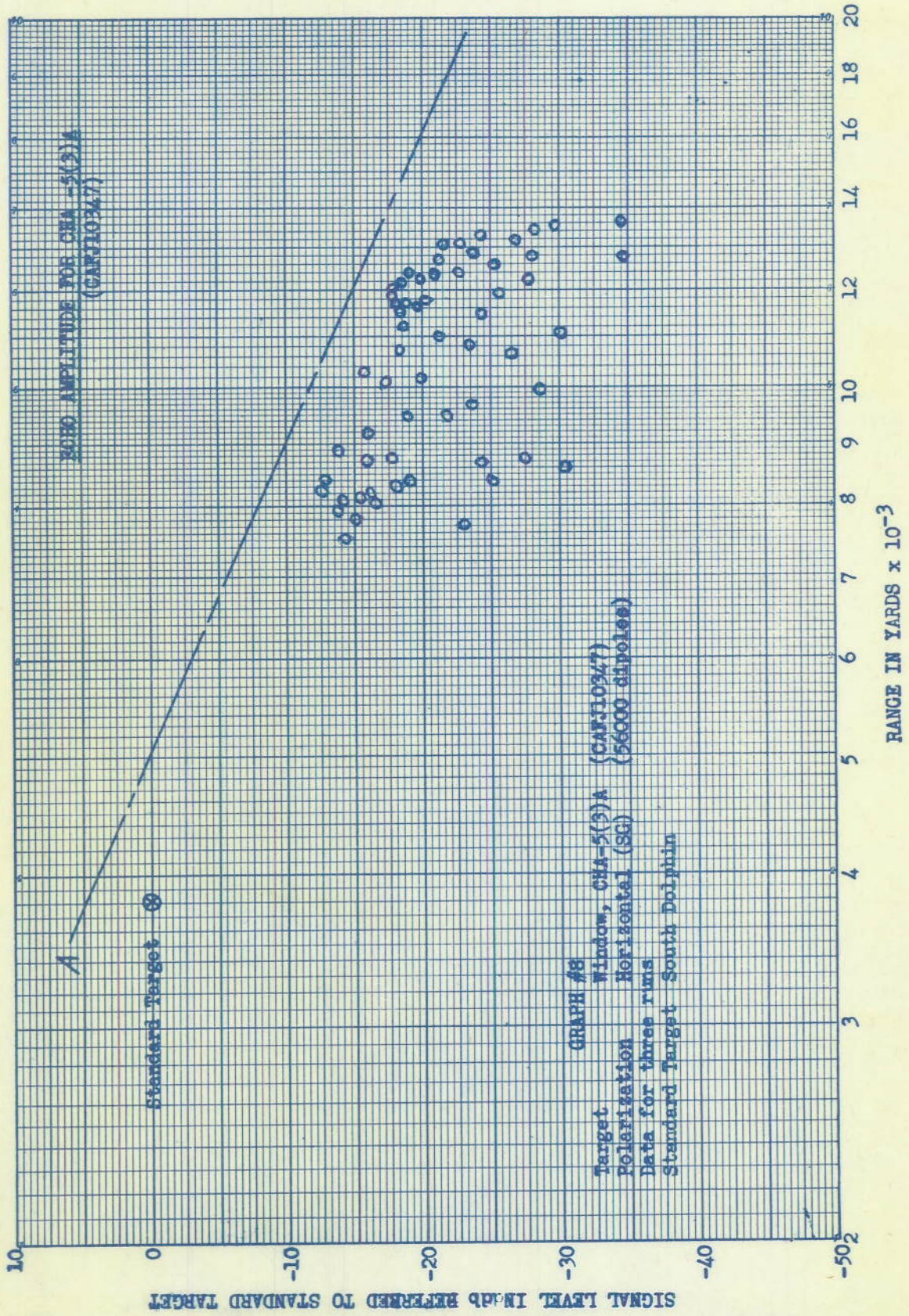
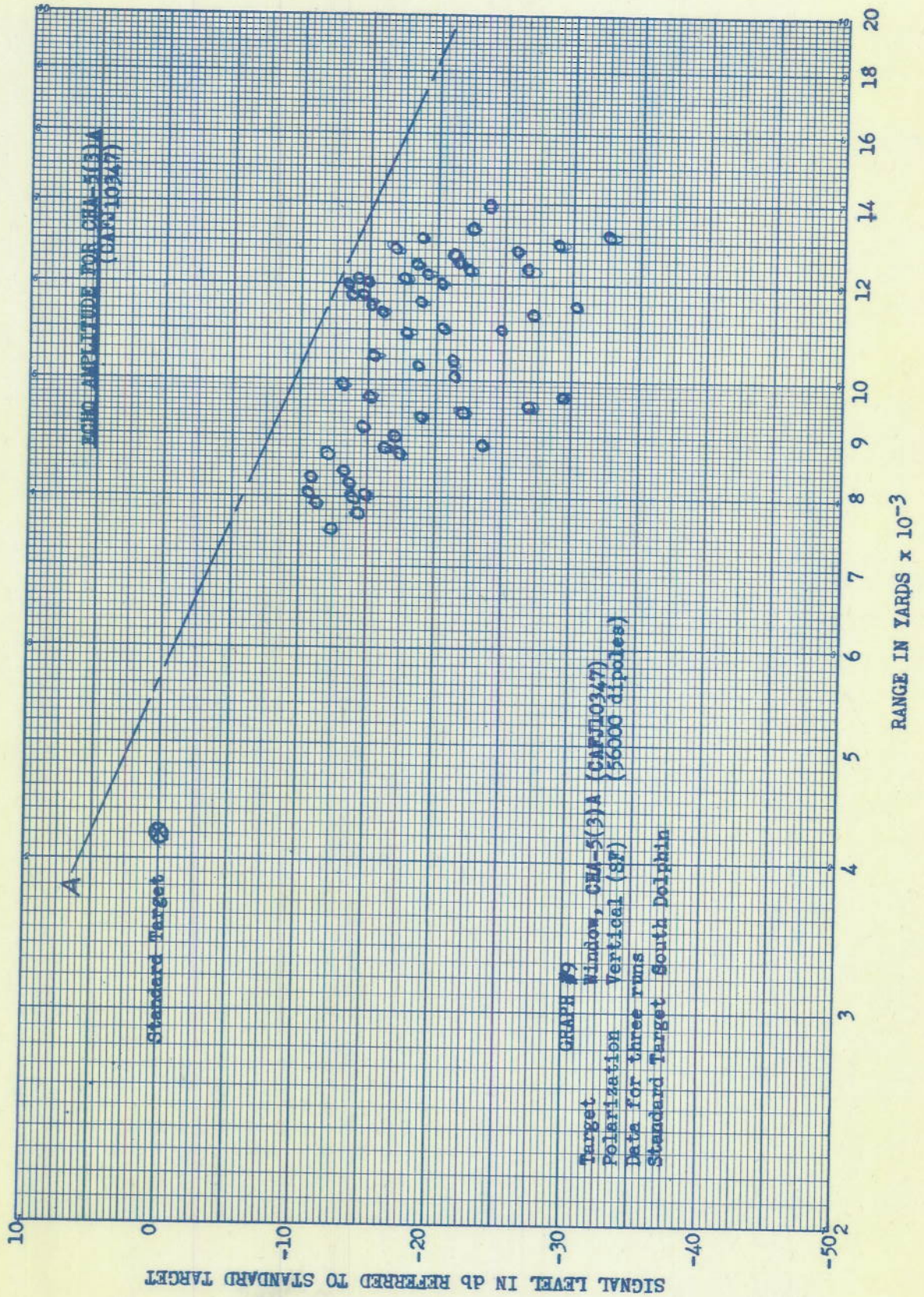


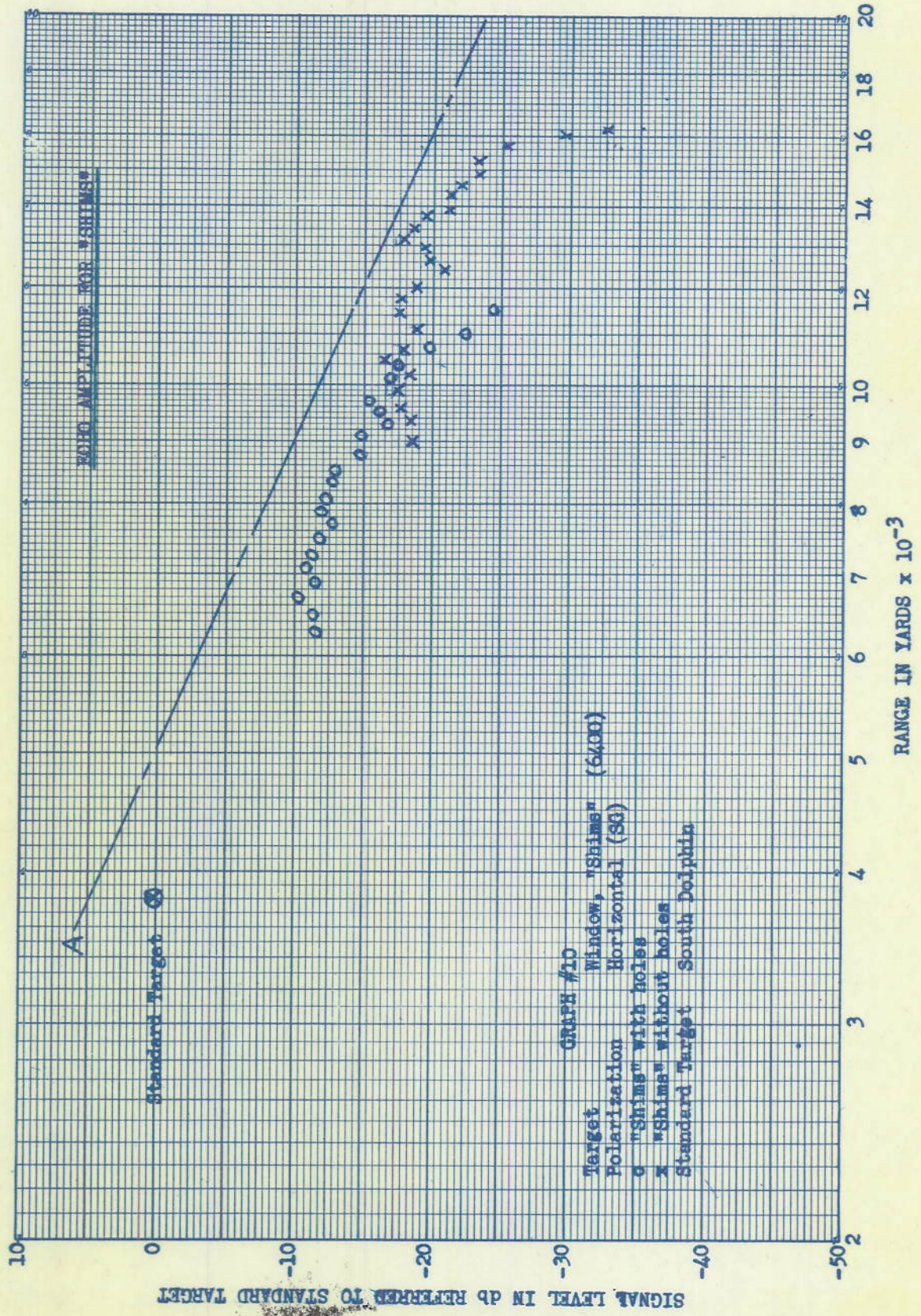
PLATE 7

CONFIDENTIAL





CONFIDENTIAL



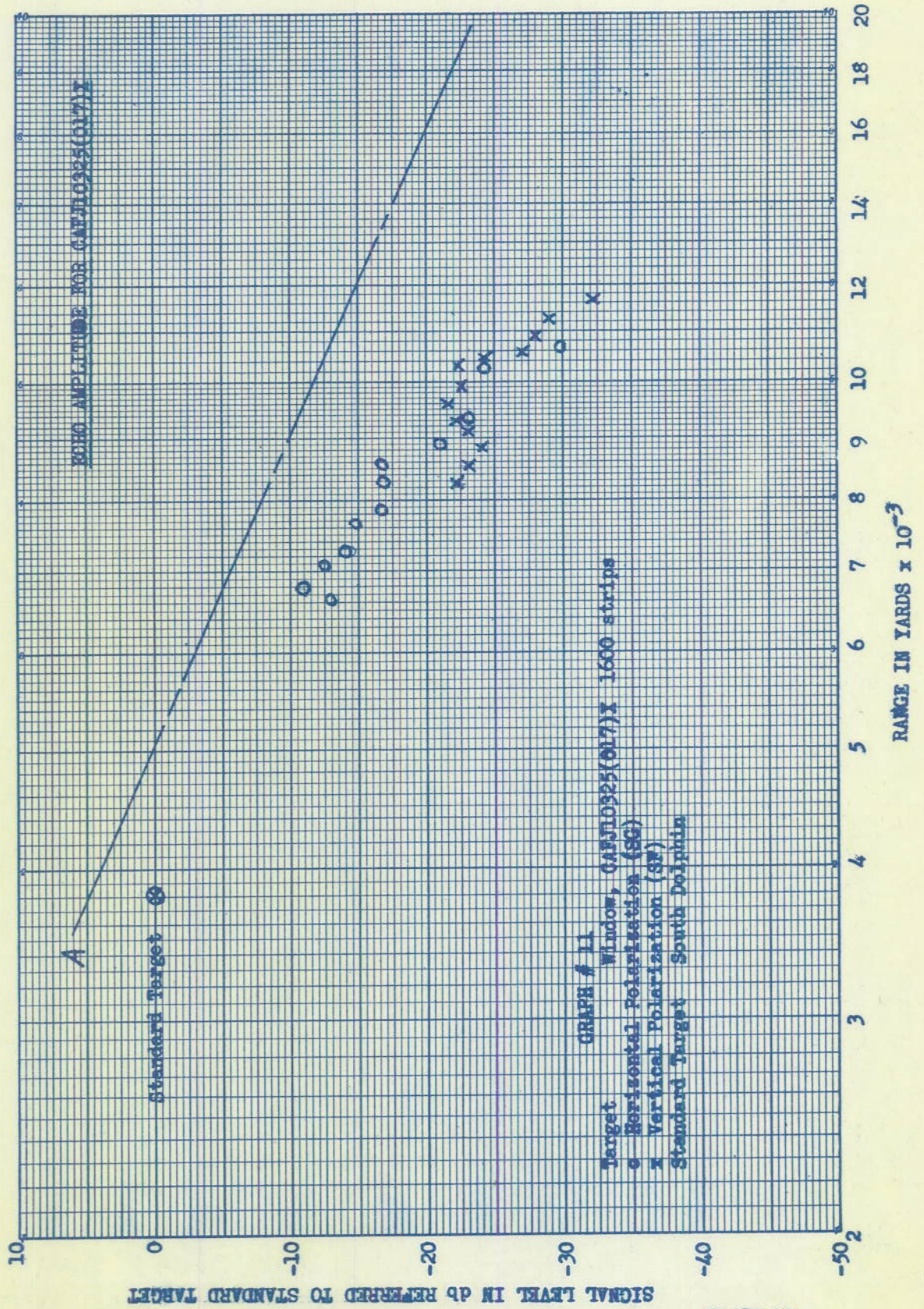
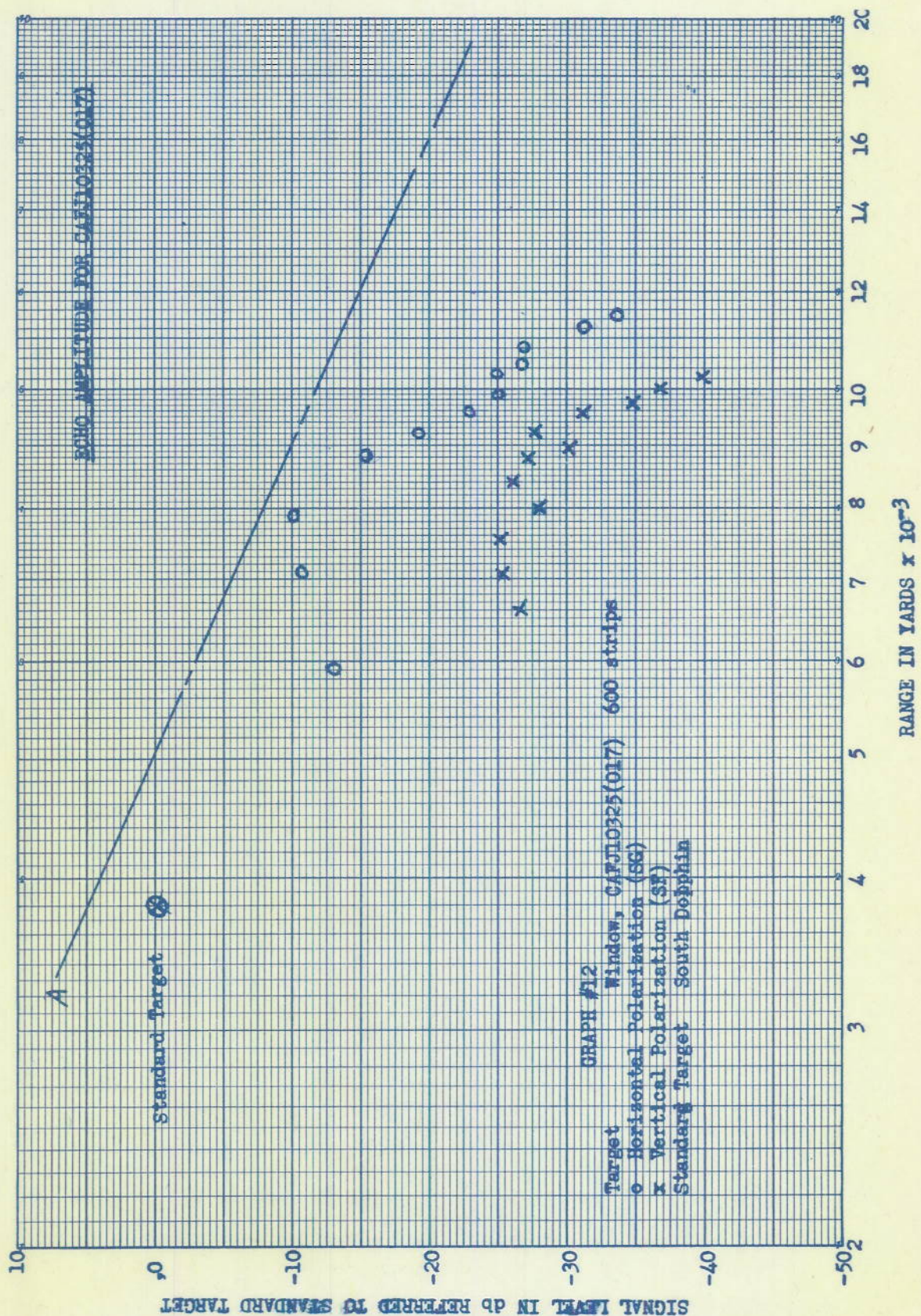


PLATE 11

CONFIDENTIAL



SIGNAL LEVEL IN db REFERRED TO STANDARD TARGET

CONFIDENTIAL

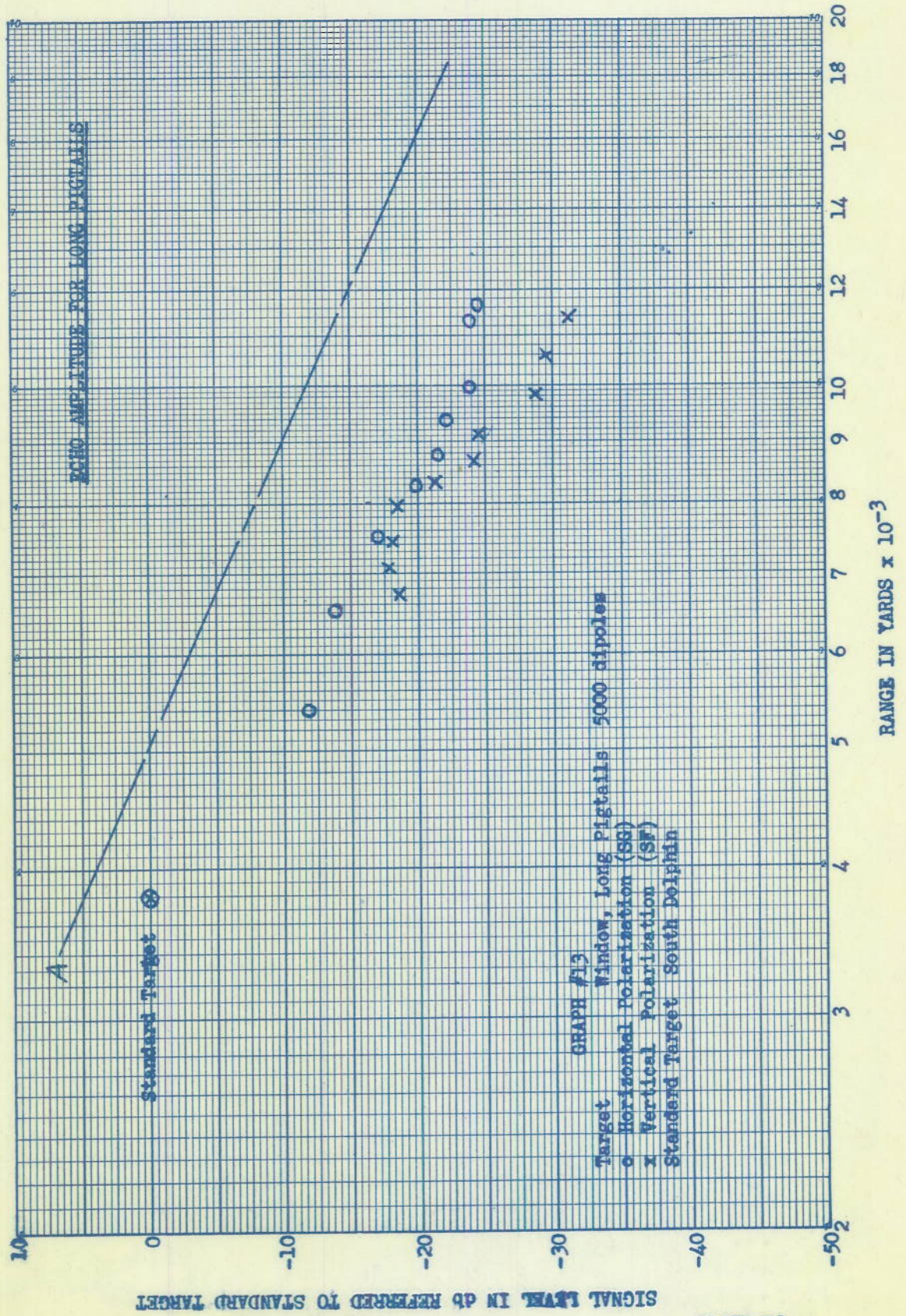
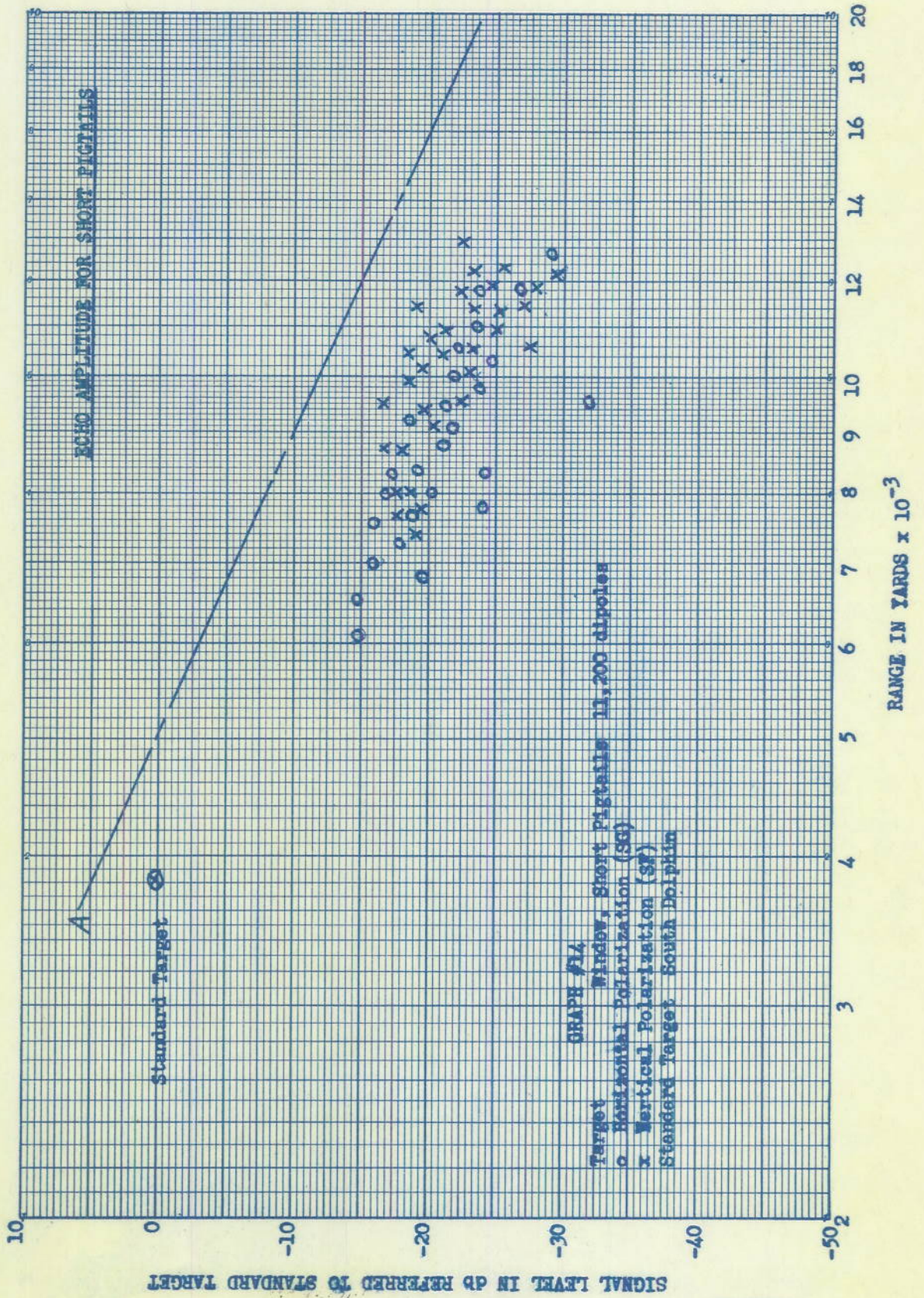


PLATE 13

CONFIDENTIAL



CONFIDENTIAL

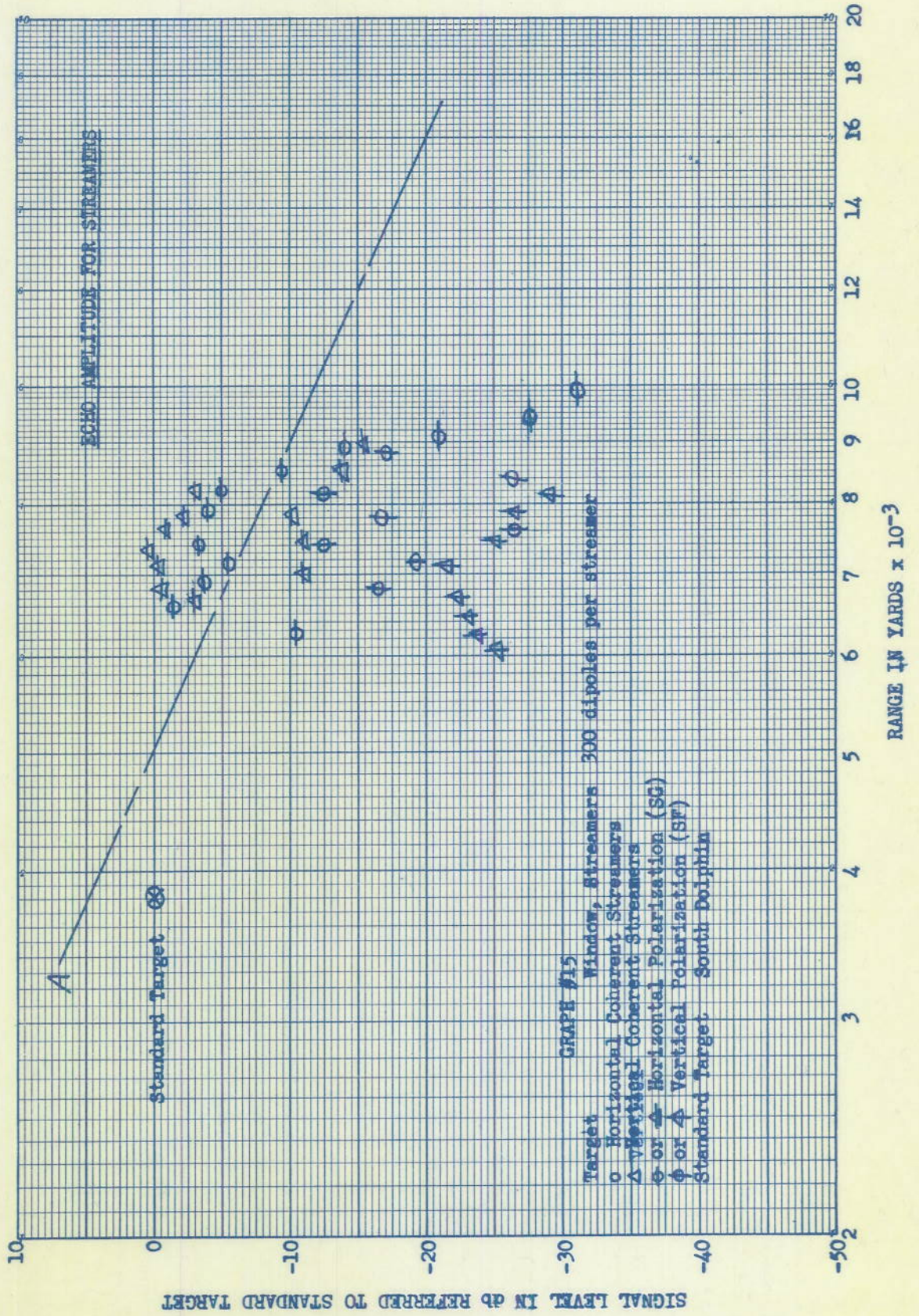
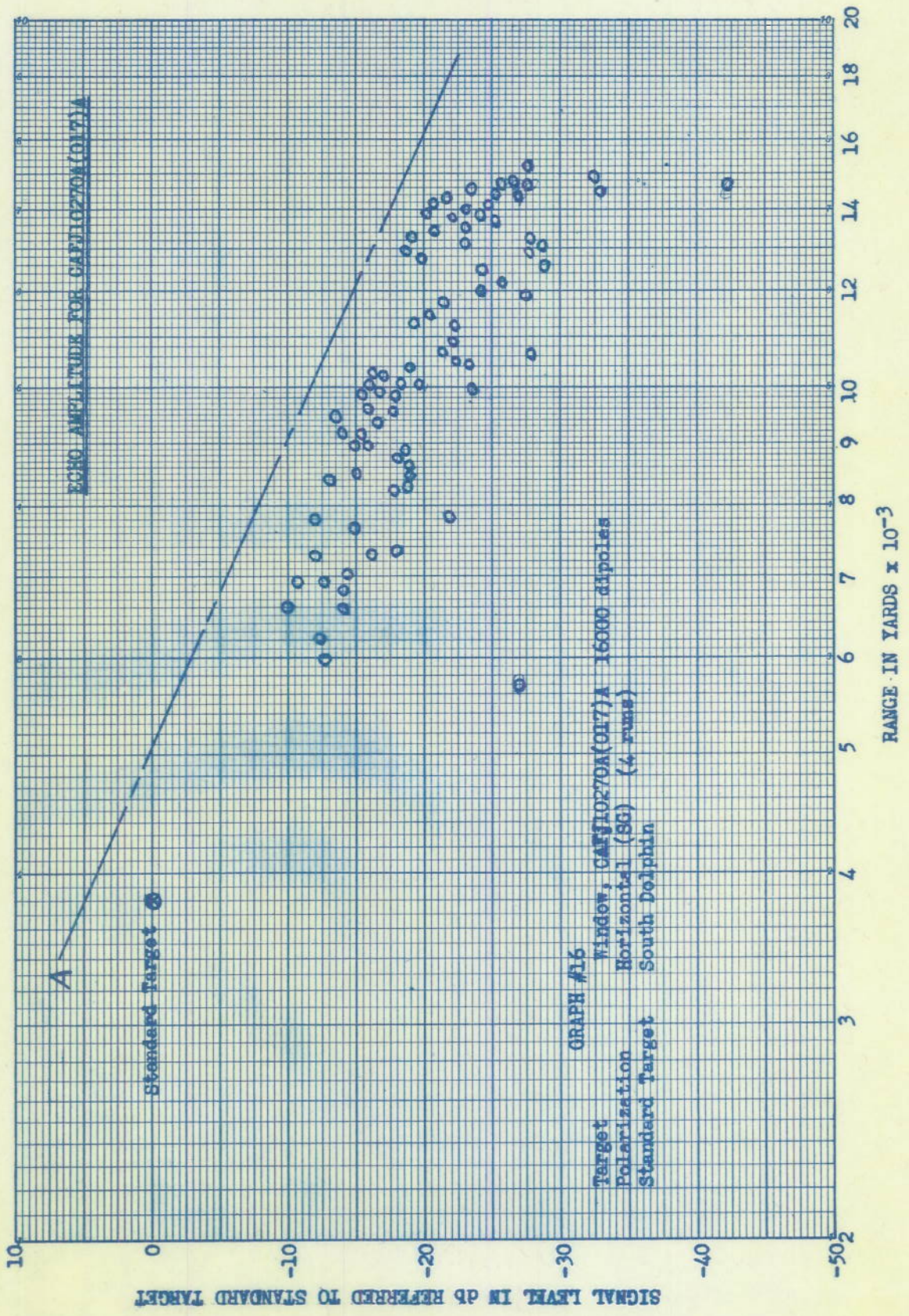


PLATE 15

CONFIDENTIAL



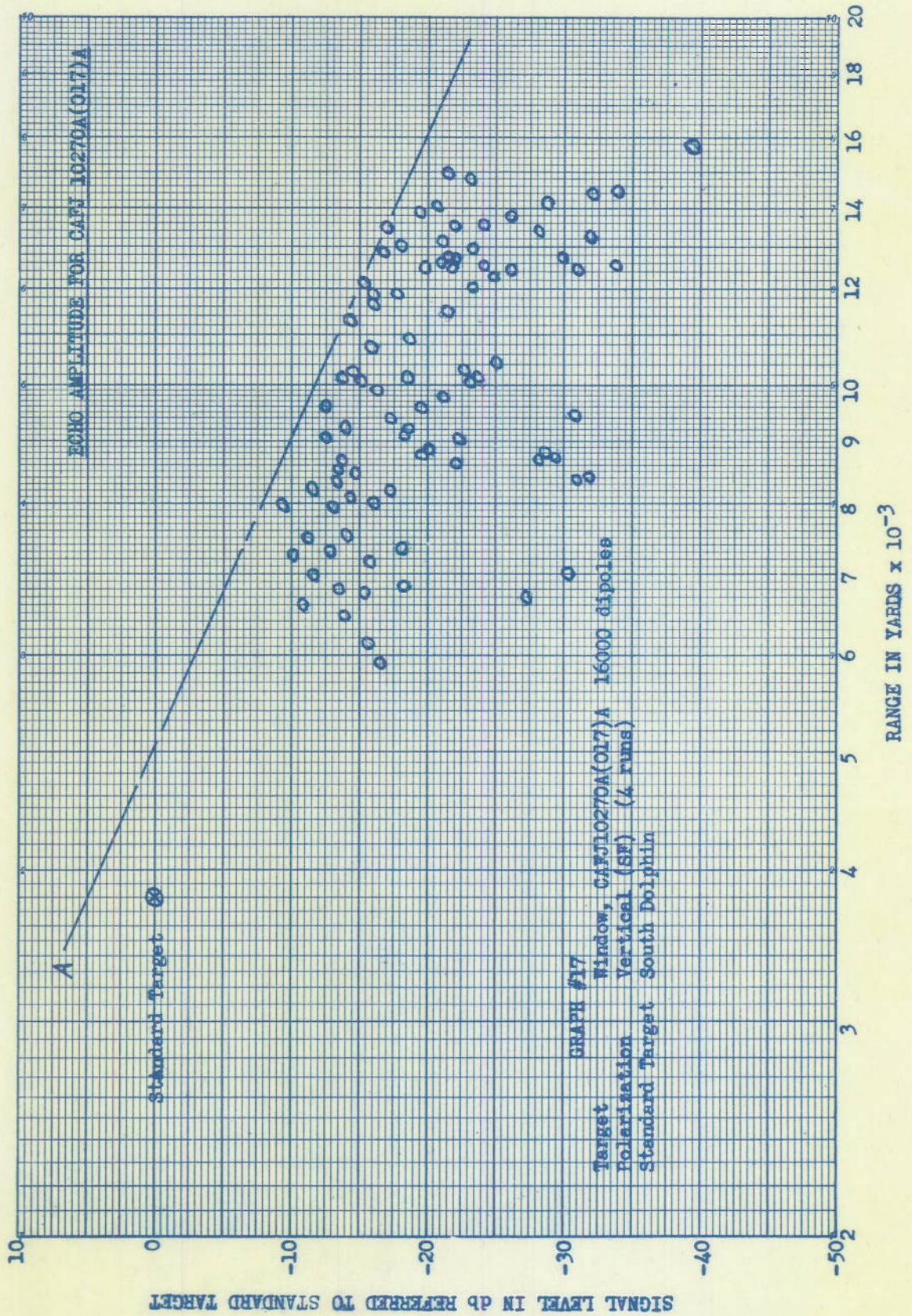
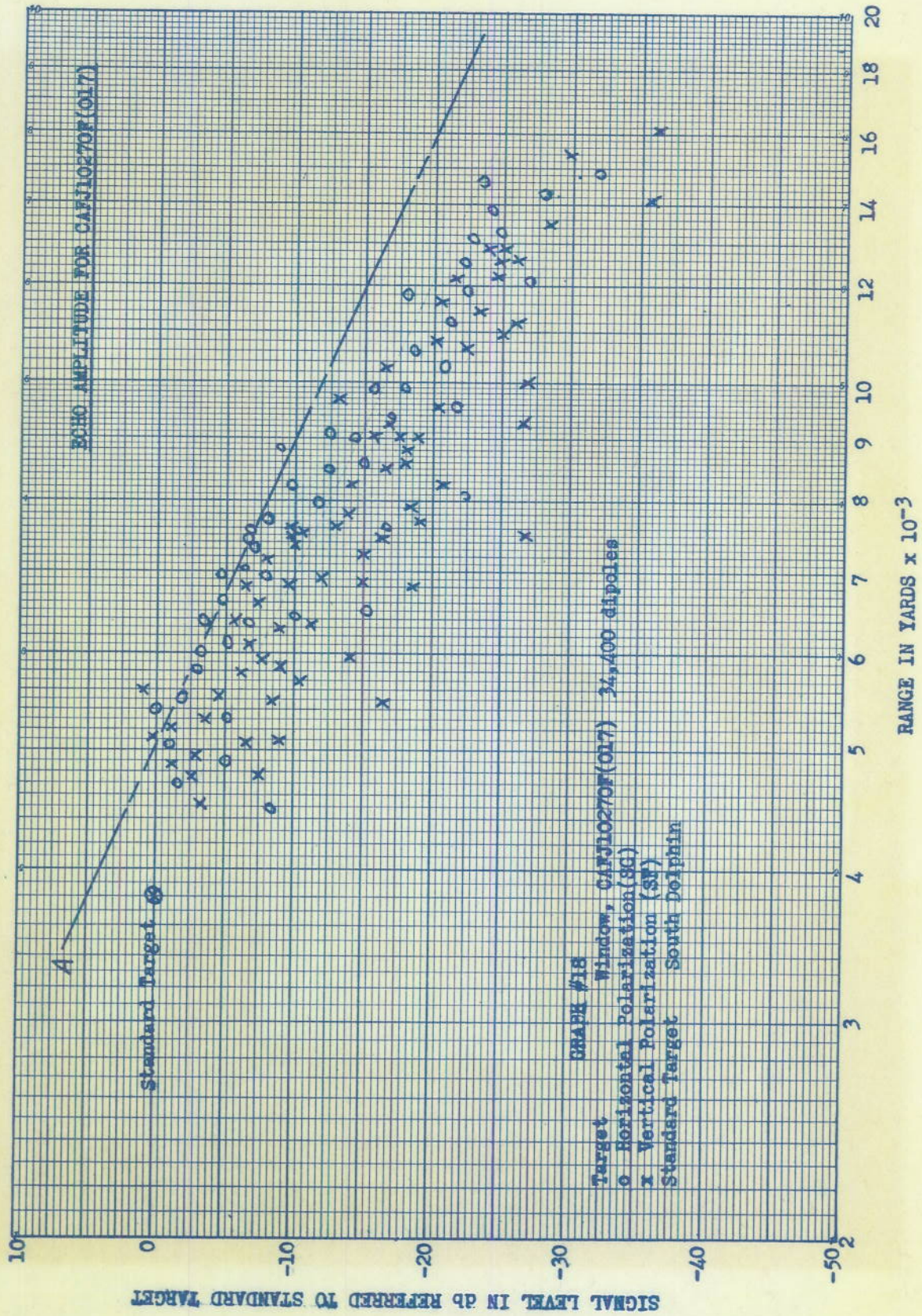
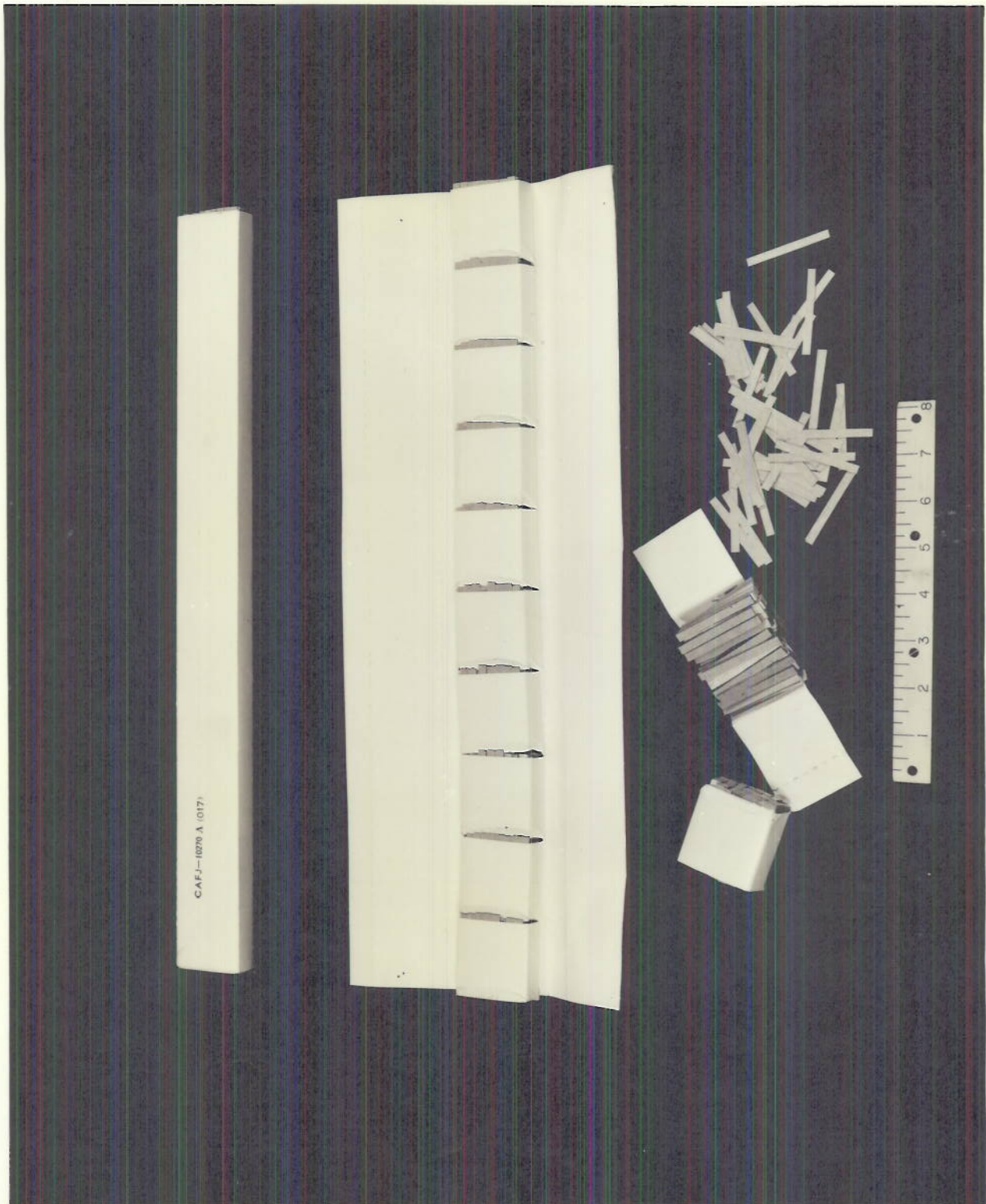


PLATE 17



DECLASSIFIED



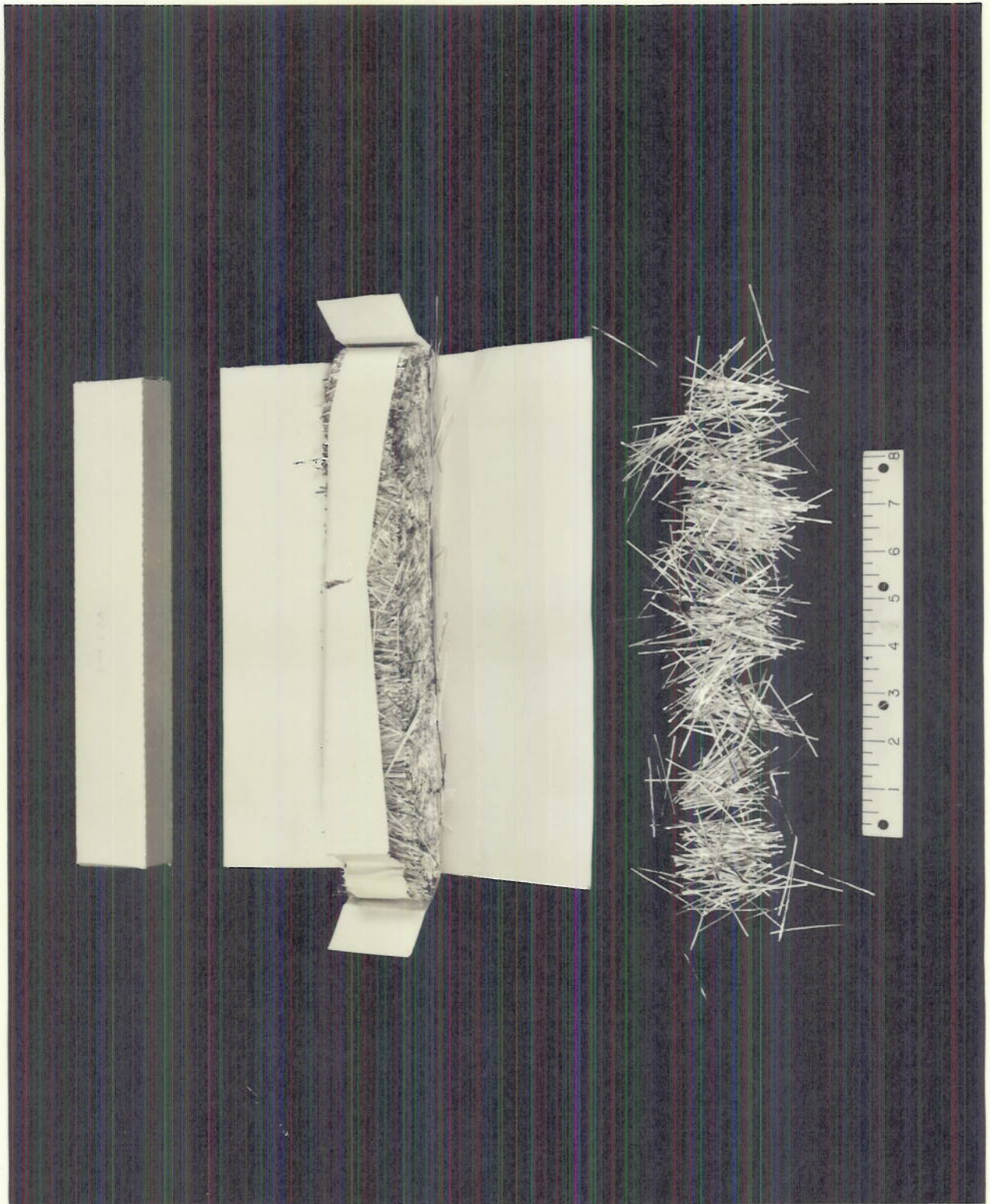
CAFJ-10270A (017)A

~~CONFIDENTIAL~~

DECLAS. IEL

PLATE 19

DECLASSIFIED



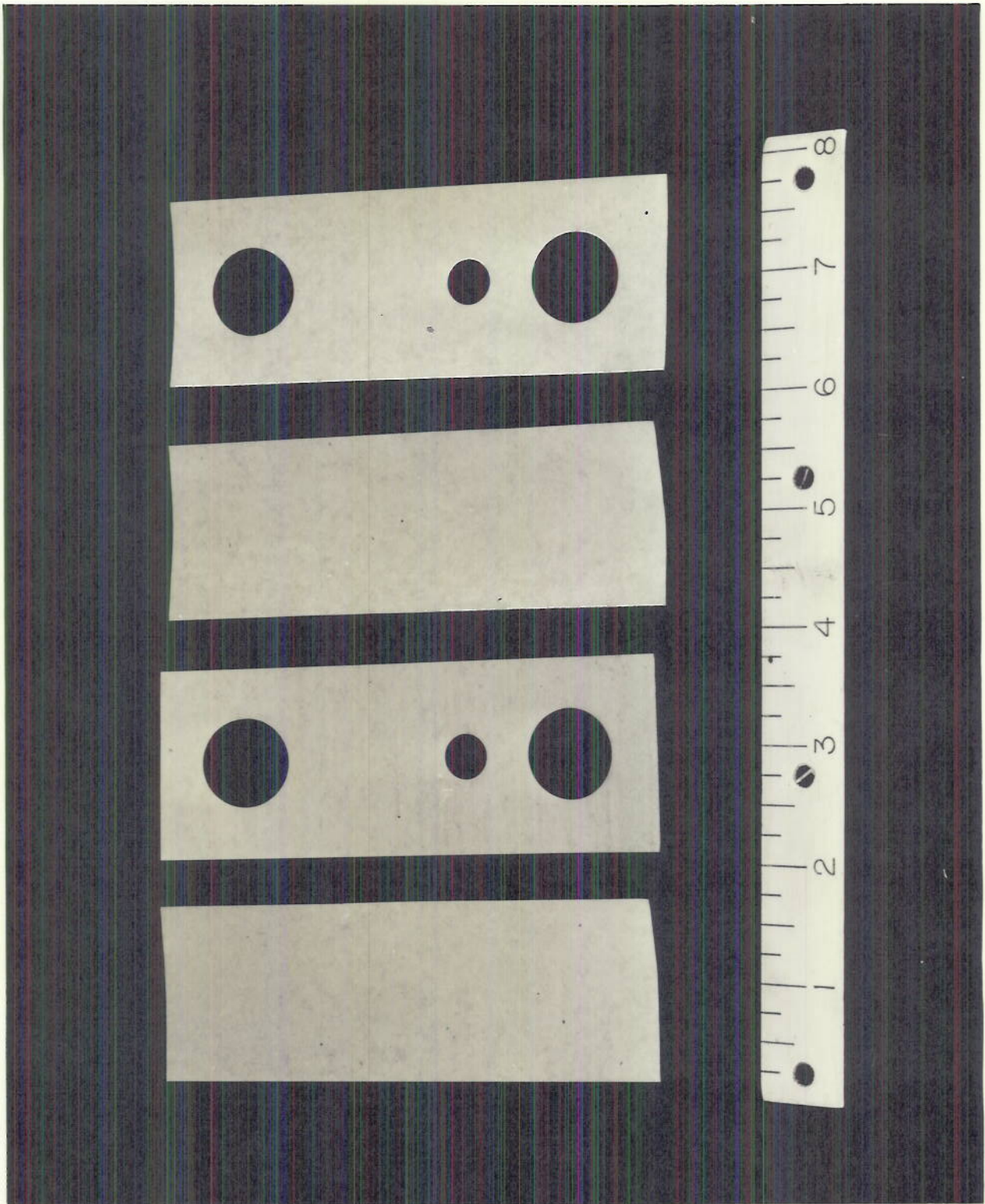
CHA-5-(3)A

~~CONFIDENTIAL~~

DECLASSIFIED

PLATE 20

DECLASSIFIED



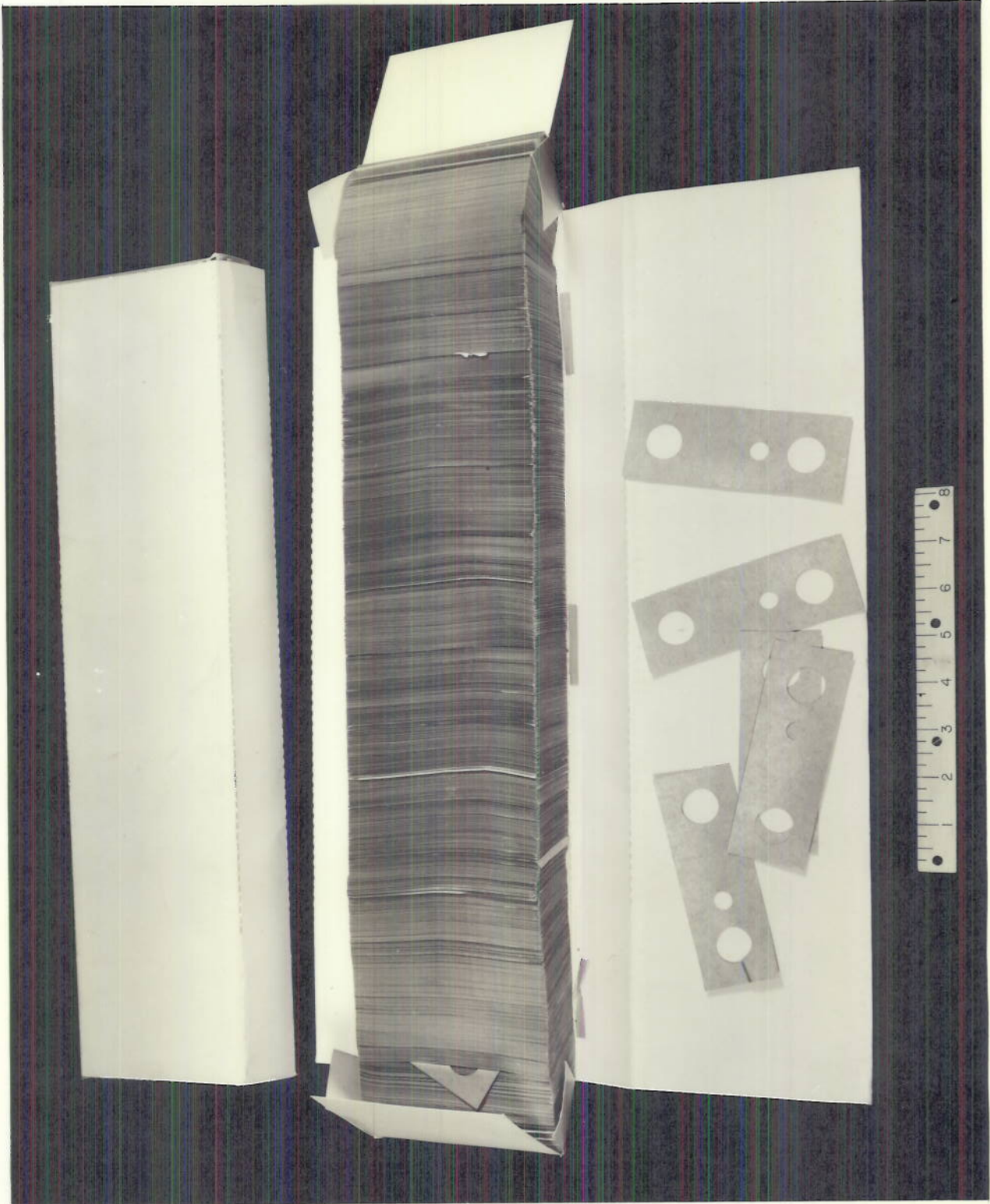
SHIMS

CONFIDENTIAL

DECLASSIFIED

PLATE 21

DECLASSIFIED



SHIMS

~~CONFIDENTIAL~~

DECLASSIFIED

DECLASSIFIED



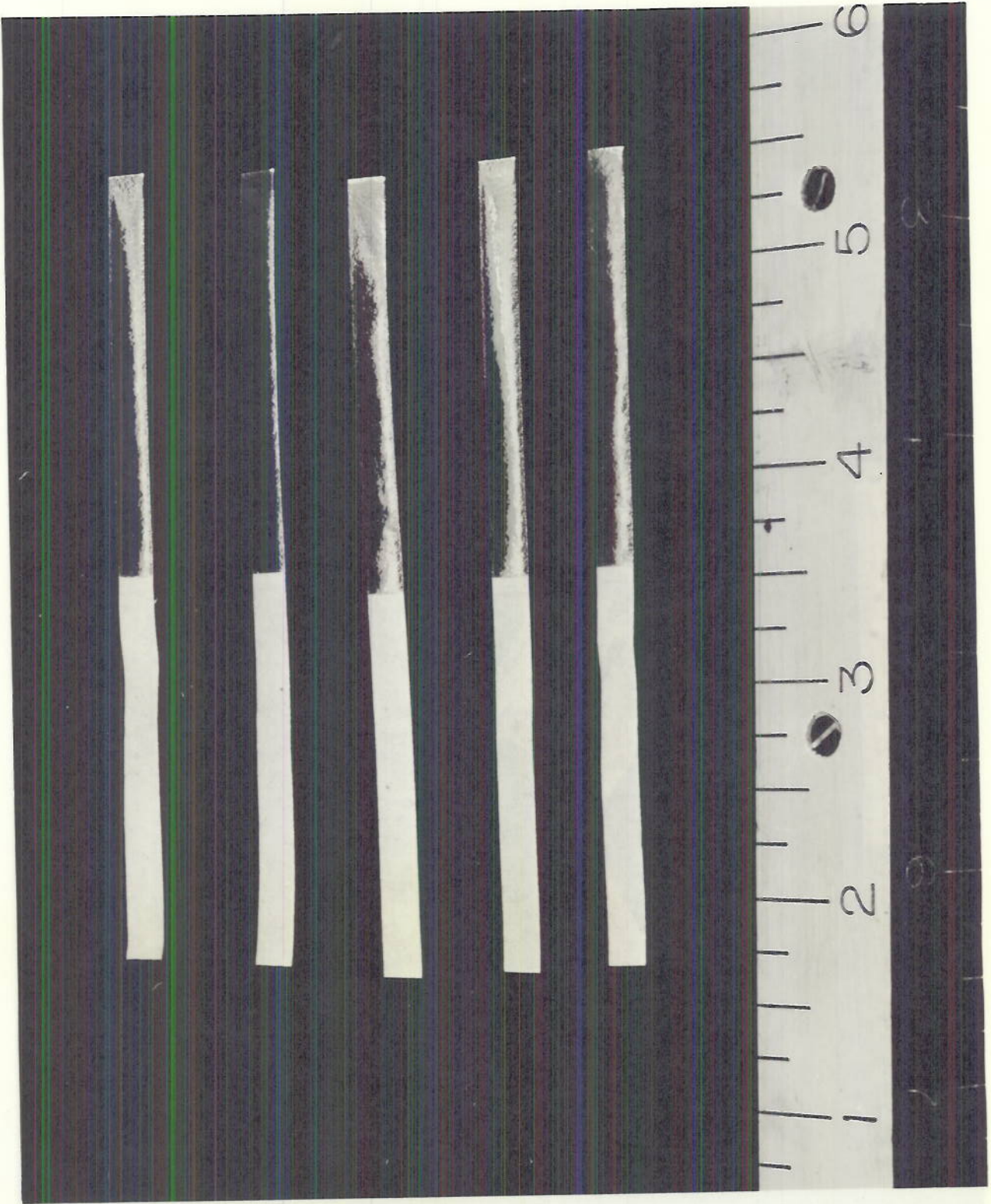
CAFJ-10325 (017)

~~CONFIDENTIAL~~

DECLASSIFIED

PLATE 23

DECLASSIFIED



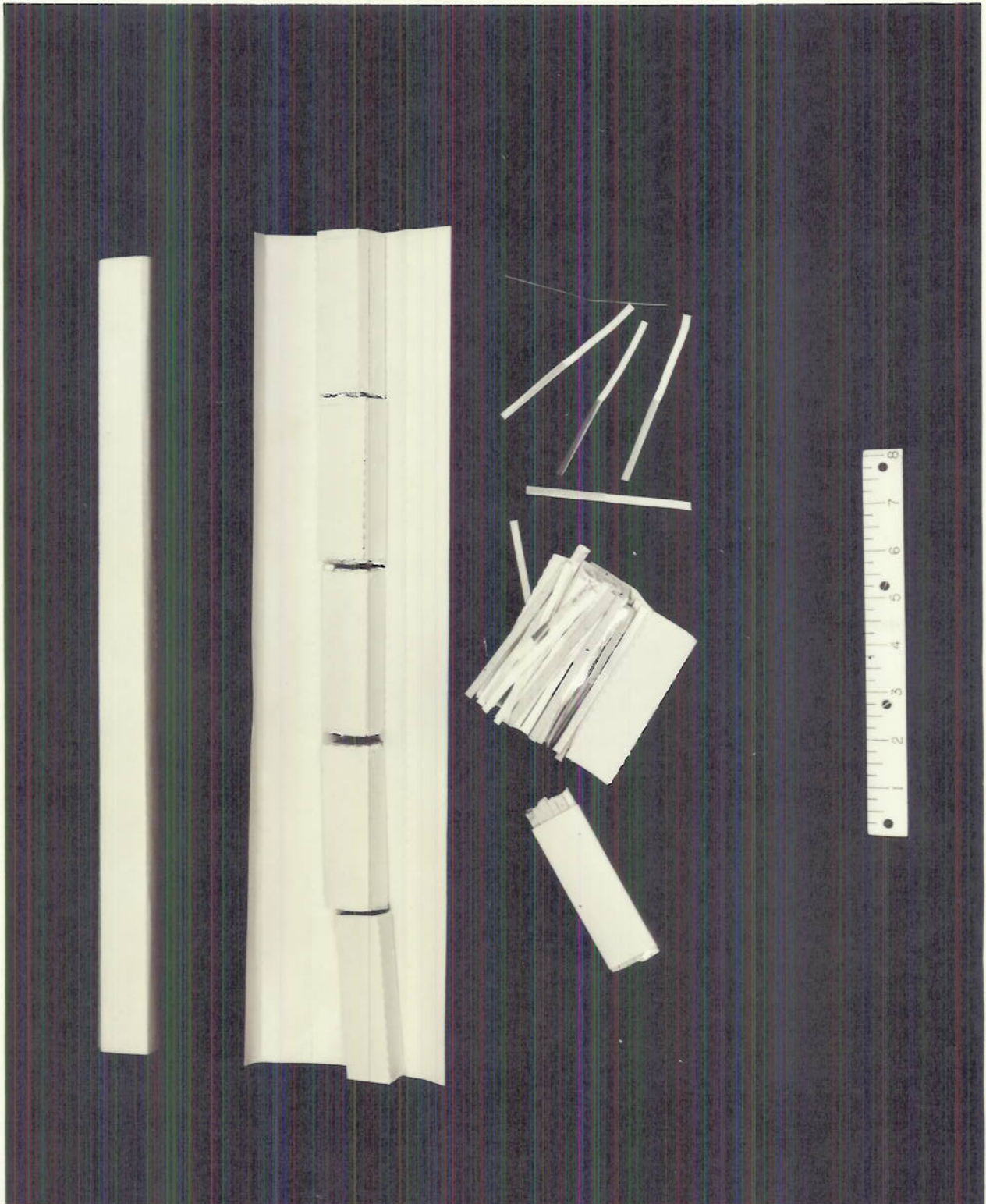
LONG PIGTAILS

~~CONFIDENTIAL~~

DECLASSIFIED

PLATE 24

DECLASSIFIED



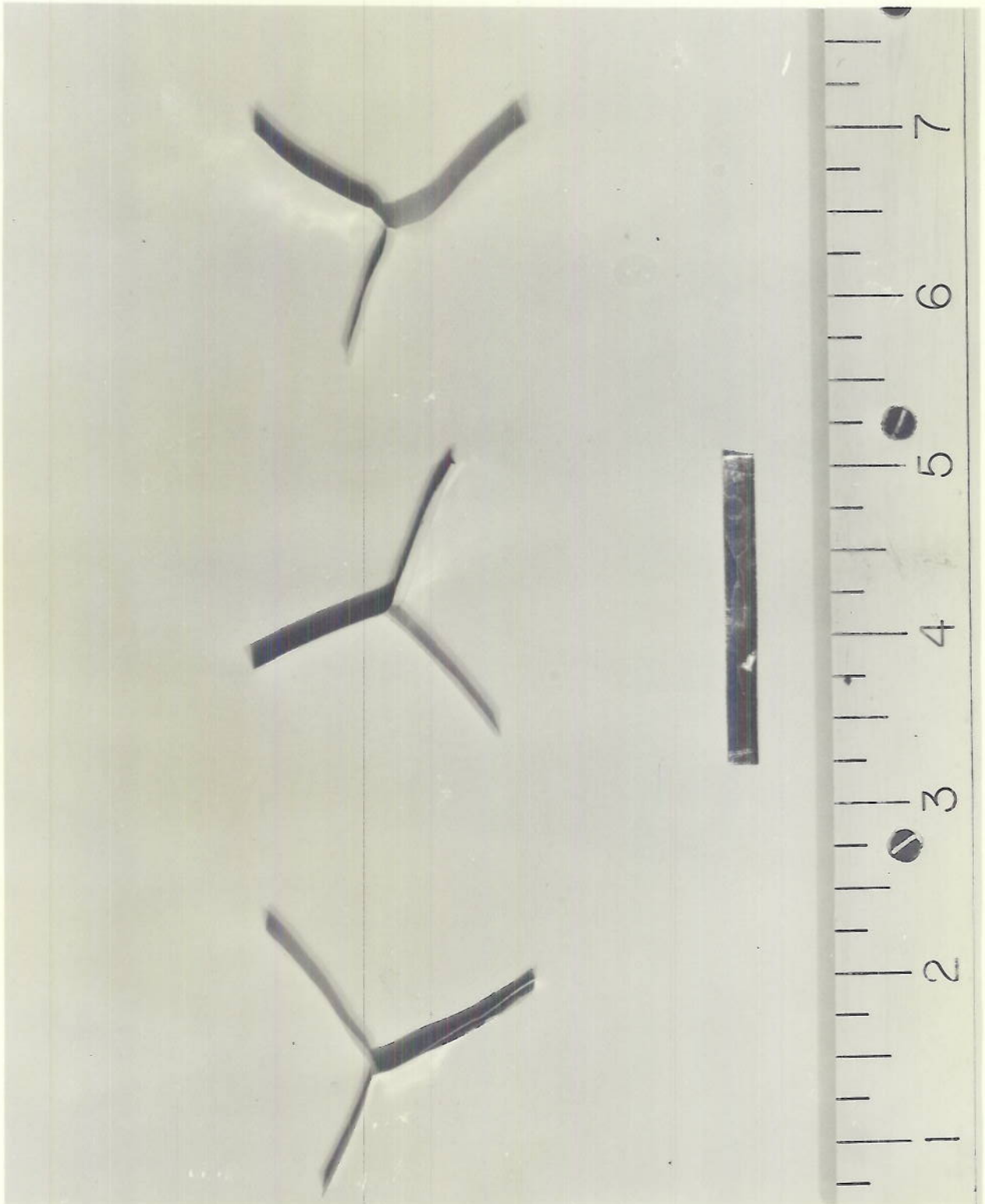
LONG PIGTAILS

~~CONFIDENTIAL~~

DECLASSIFIED

PLATE 25

DECLASSIFIED



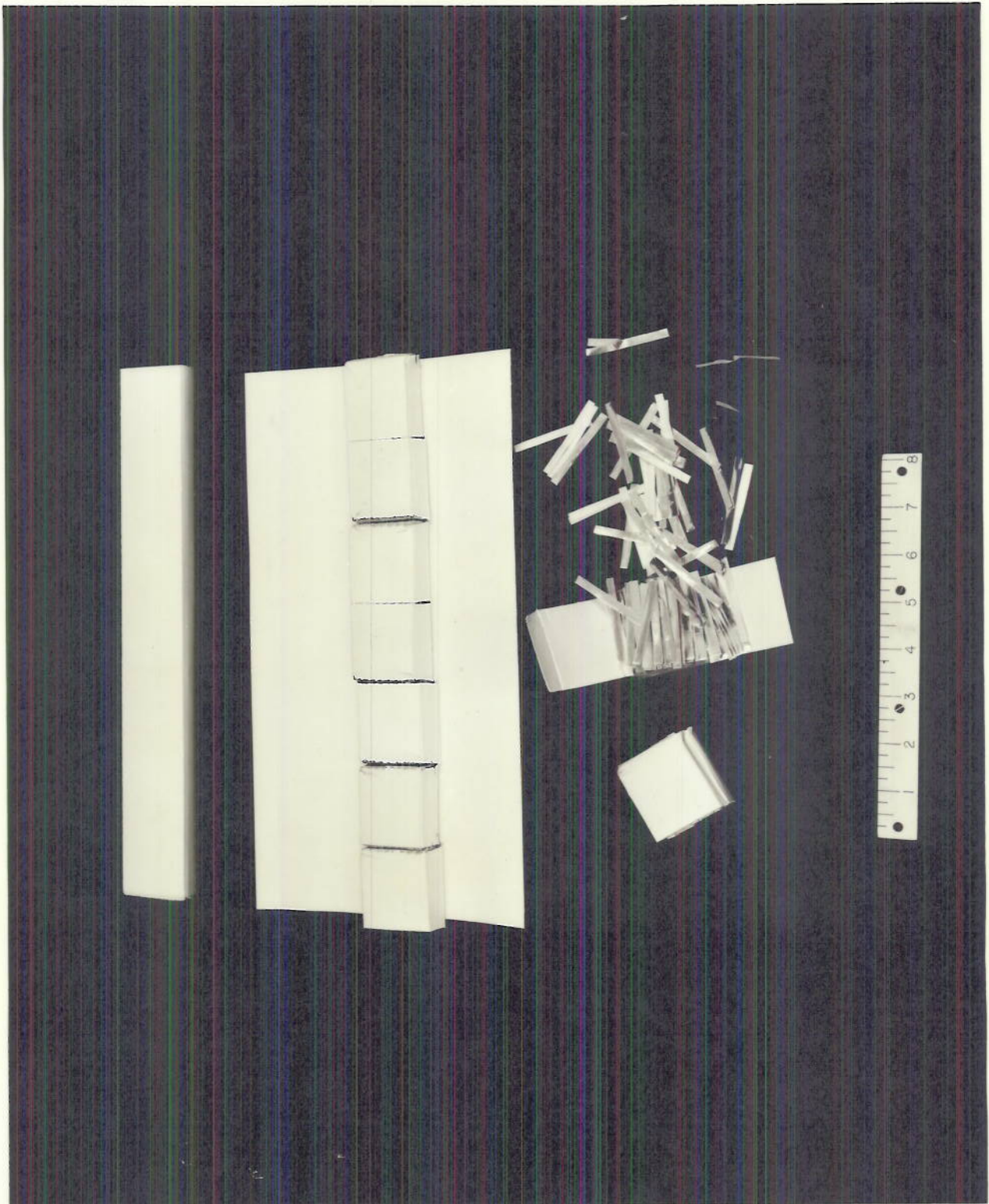
SHORT PIGTAILS

~~CONFIDENTIAL~~

DECLASSIFIED

PLATE 26

DECLASSIFIED

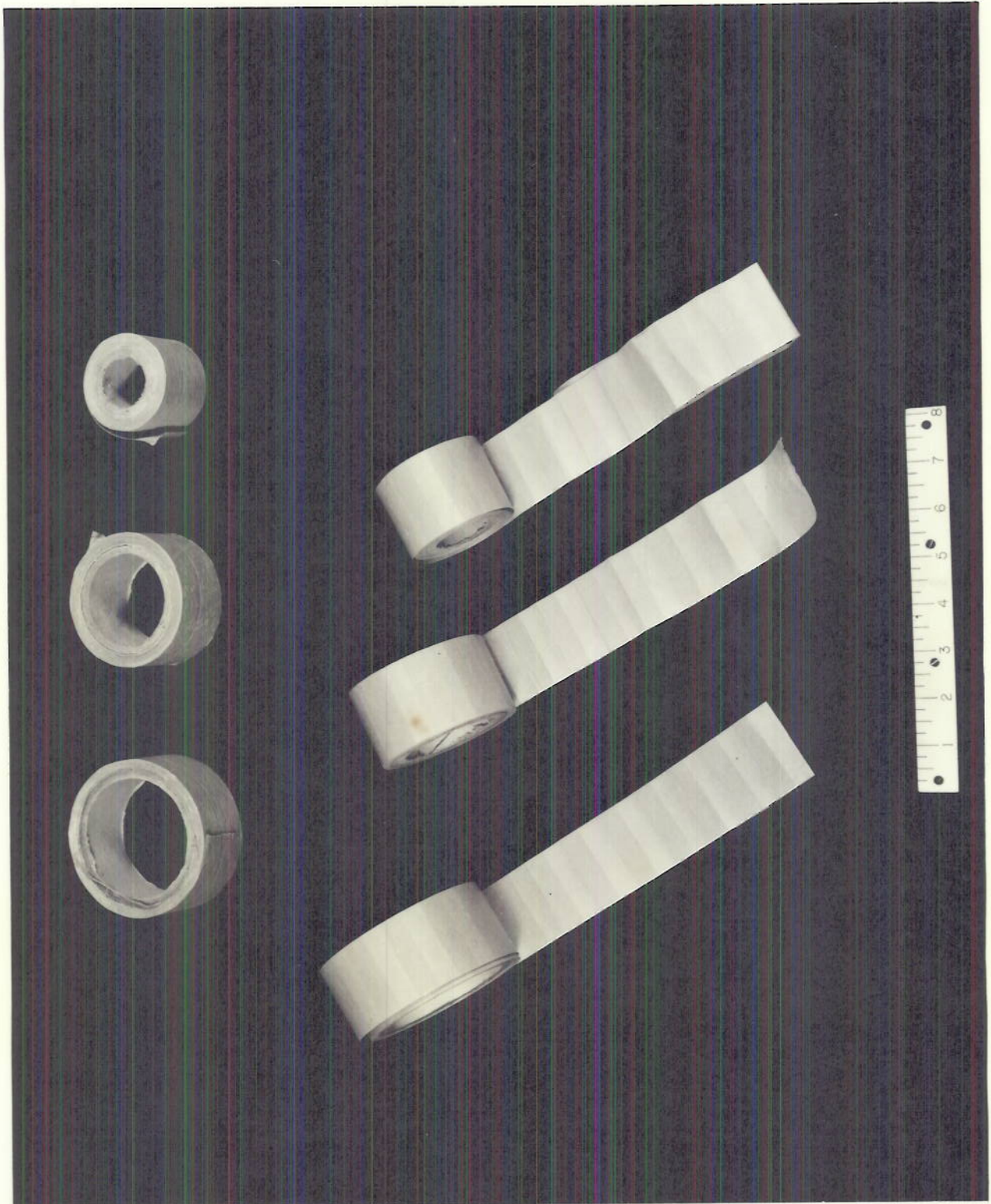


SHORT PIGTAILS

~~CONFIDENTIAL~~

DECLASSIFIED

DECLASSIFIED



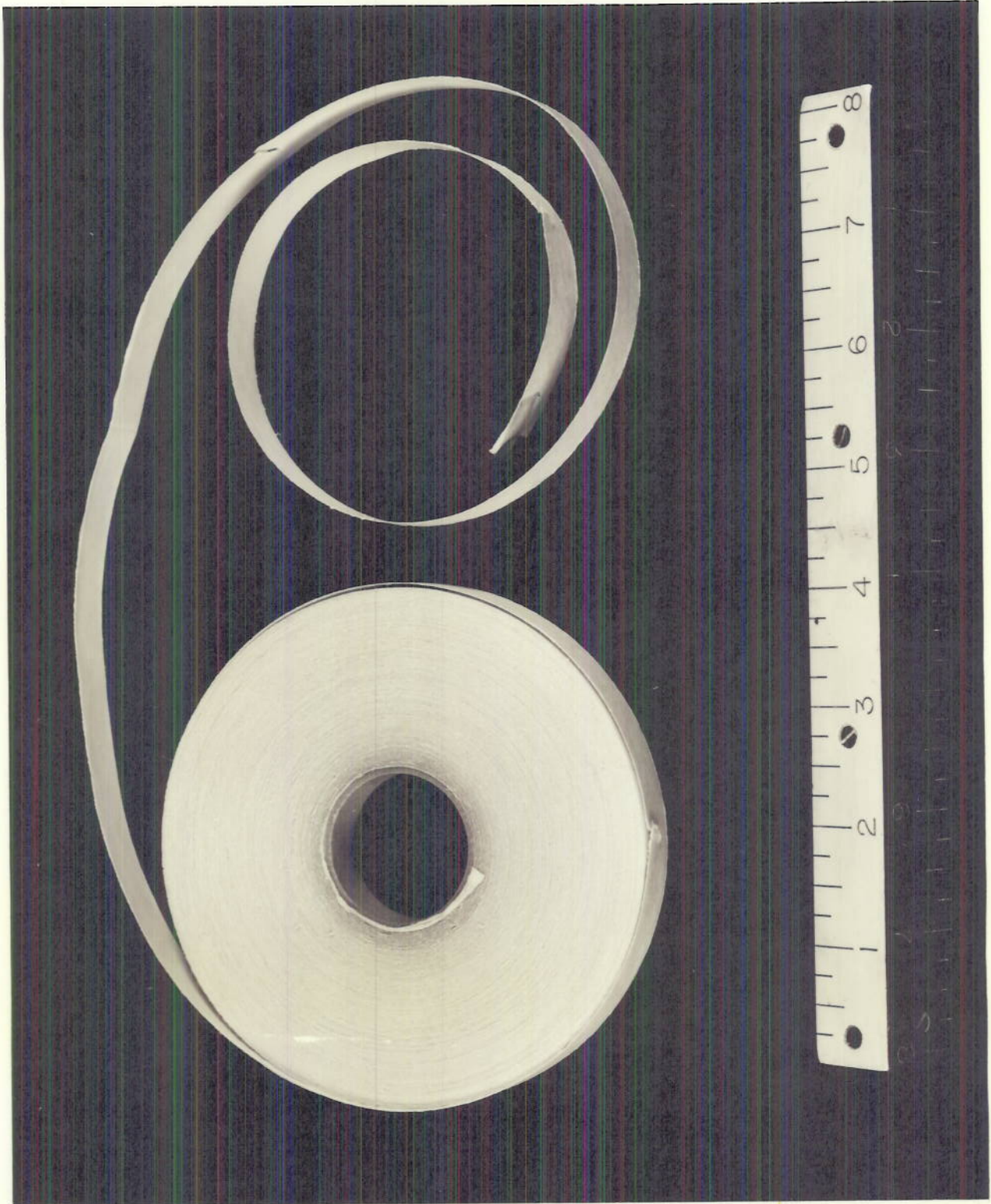
HORIZONTAL COHERENT STREAMERS

~~CONFIDENTIAL~~

DECLASSIFIED

PLATE 28

DECLASSIFIED



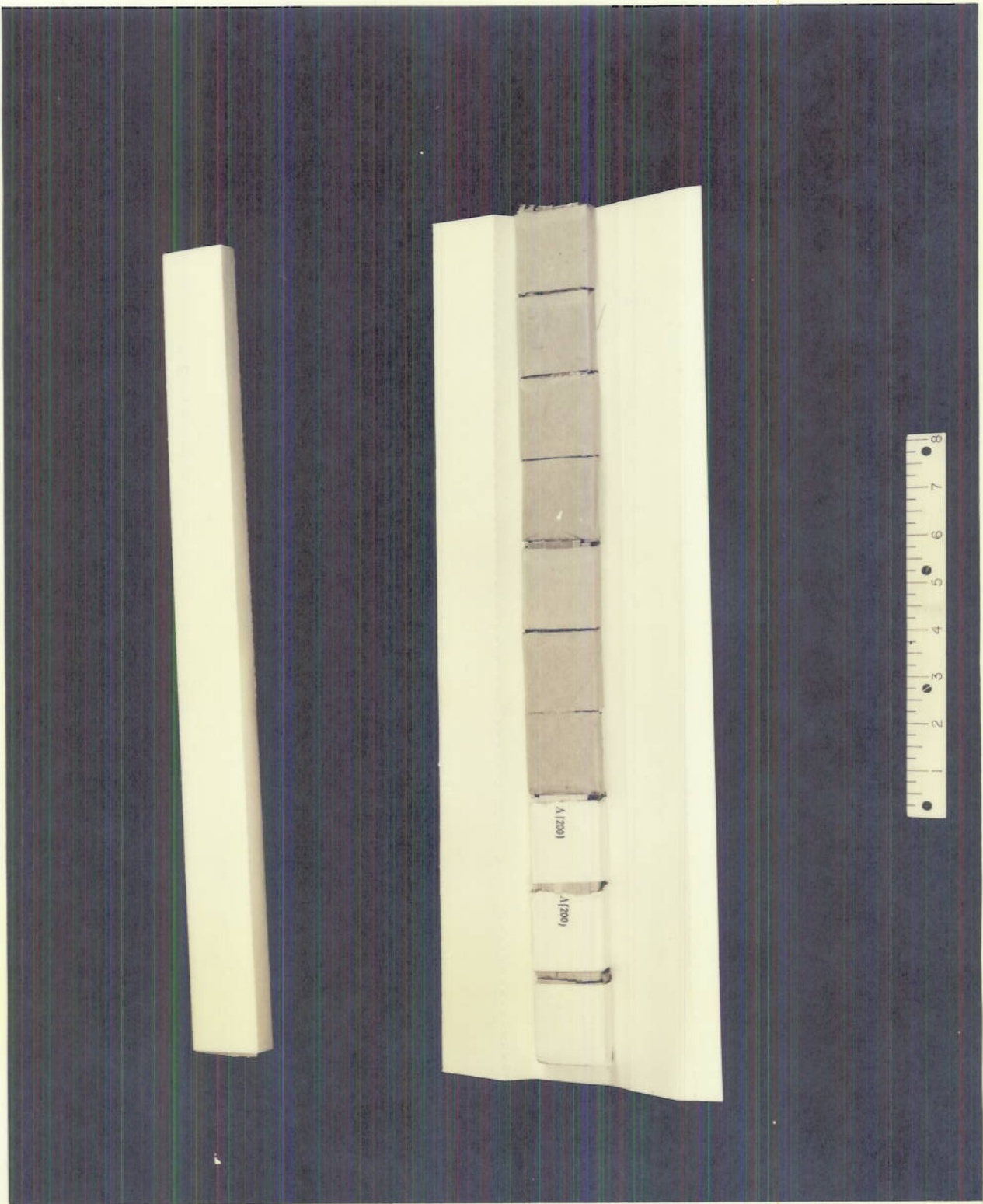
VERTICAL COHERENT STREAMERS

CONFIDENTIAL

DECLASSIFIED

PLATE 29

DECLASSIFIED

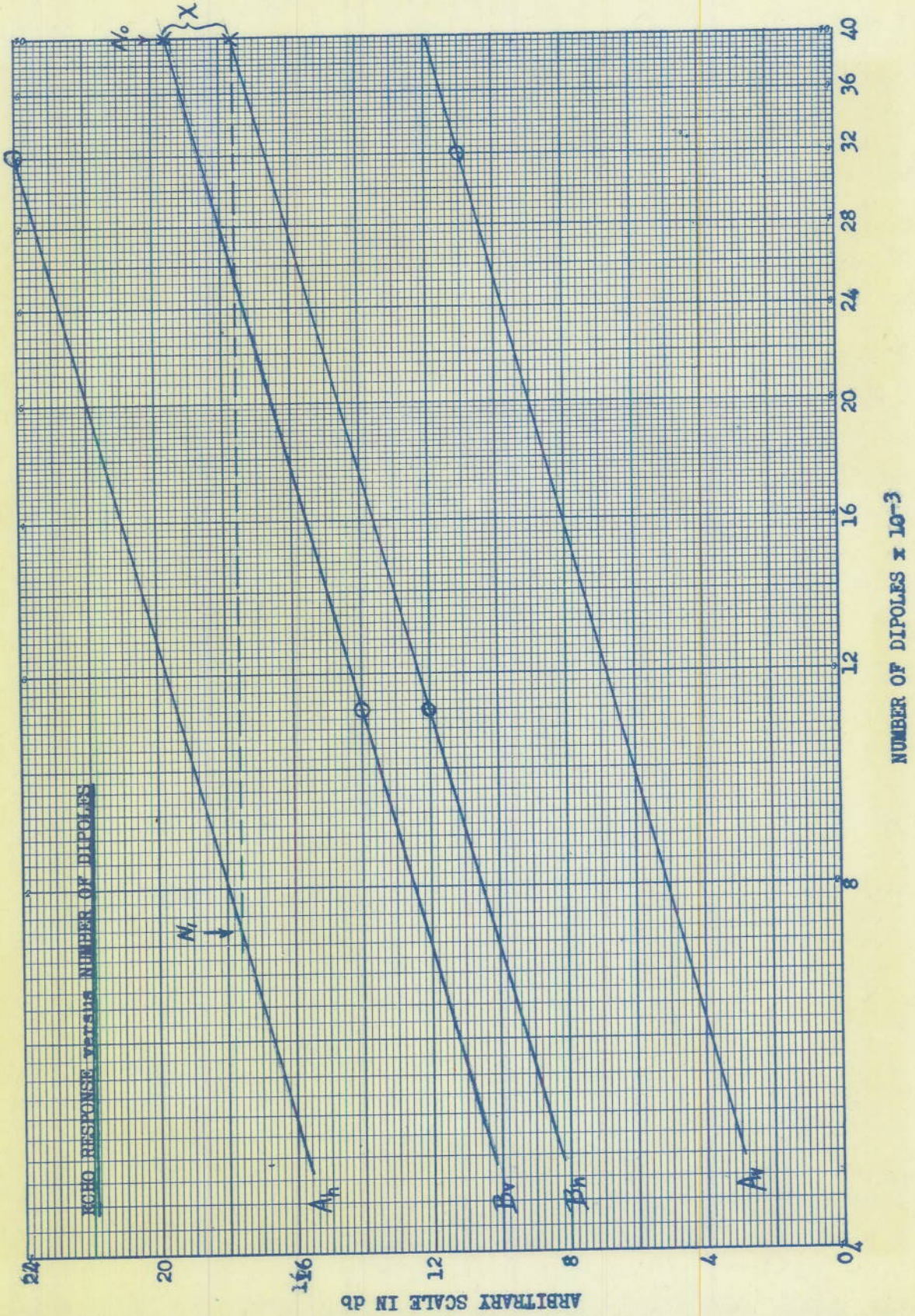


CAFJ-10270A (017)

~~CONFIDENTIAL~~

DECLASSIFIED

PLATE 30



DECLASSIFIED

Distribution List

- 5 Chief of the Bureau of Ships, Navy Department, Washington 25, D.C.,
Attention: Code 938, Copies 2-6.
- 1 Commander-in-Chief, U.S. Fleet, Navy Department, Washington 25, D.C.
Attention: Code F45, Copy 7.
- 1 Chief of Naval Operations, Navy Department, Washington 25, D.C.,
Attention: Code Op-20-S, Copy 8.
- 1 Chief of Naval Operations, Navy Department, Washington 25, D.C.,
Attention: Code Op-25-A2, Copy 9.
- 1 Coordinator of Research & Development, Navy Department, Washington 25,
D.C., Copy 10.
- 1 Commandant, U.S. Marine Corps Headquarters, Plans and Policies Division,
Navy Department, Washington 25, D.C., Copy 11.
- 1 Chief of the Bureau of Aeronautics, Navy Department, Washington 25,
D.C., Attention: Code Aer-E-3143, Copy 12.
- 1 Chief of the Bureau of Ordnance, Navy Department, Washington 25, D.C.,
Attention: Code Re4f, Copy 13.
- 1 Chief of Naval Operations, Navy Department, Washington 25, D.C.,
Attention: Code Op-16-1-V, Copy 14.
- 2 Chief of Naval Operations, Navy Department, Washington 25, D.C.,
Attention: Code Op-16-FA-1, Copies 15, 16.
- 1 Navy Representative, JEIA, c/o Joint Communications Board, Room 2103
Munitions Building, Washington, D.C., Copy 17.
- 1 Commander-in-Chief, U.S. Pacific Fleet, Fleet Post Office, San Francisco,
California, Copy 18.
- 2 Commander-in-Chief, U.S. Atlantic Fleet, Fleet Post Office, New York,
New York, Copies 19, 20.
- 1 Commander, Seventh Fleet, Fleet Post Office, San Francisco, California,
Copy 21.
- 1 Commander, Twelfth Fleet, Fleet Post Office, New York, New York,
Copy 22.
- 1 Commanding Officer, Radio Materiel School, Anacostia Station, Washington,
D.C., Attention: Code 493A, Copy 23.
- 1 Superintendent, U.S. Naval Academy, Annapolis, Maryland, Attention:
Head of the Postgraduate School, Copy 24.
- 1 Officer in Charge, Naval Auxiliary Air Station, San Clemente Island,
San Diego 46, California. Attention: Special Projects School for
Air, Copy 25.
- 1 Officer in Charge, Naval Training School (Radar), Massachusetts Insti-
tute of Technology, 470 Atlantic Avenue, Boston 10, Massachusetts,
Copy 26.
- 3 Message Center Branch, G-2 Division, Military Intelligence, Room 1C774
Pentagon Bldg., Washington 25, D.C., Copies 27, 28, 29.
- 6 Chief Signal Officer, Room 4D235, Pentagon Bldg., Washington 25, D.C.
Attention: Intelligence Branch, SPSOI-4, Copies 30-35.
- 1 Air Communications Officer, Headquarters, Army Air Forces, Washington,
25, D.C., Copy 36.
- 2 Director, AAF - Air Technical Service Command, Wright Field, Dayton,
Ohio, Attention: Radio and Radar Section (TSERR), Copies 37, 38.
- 5 British Admiralty Delegation, Room 3030, Navy Department, Washington
25, D.C., Attention: Lt. Comdr. J.H. Buscombe, RNVR, Copies 39-43

DECLASSIFIED

DECLASSIFIED

Distribution List (Cont'd)

- 4 Royal Air Force Delegation, Room 717, 1424 - 16th Street, N.W.,
Washington, D.C., Attention: Director of Signals, Copies 44-47.
- 1 British Army Staff, Grafton Hotel, Room 528, 1139 Connecticut Avenue,
N.W., Washington, D.C., Attention: Col. A.J. Fisher, Copy 48.
- 1 Joint Intelligence Committee, Canadian Joint Staff, 2222 S Street, N.W.,
Washington, D.C., Copy 49.
- 2 New Zealand Air Mission, Room 2503 Munitions Building, Washington,
D.C., Attention: Squadron Leader A.W. Stockwell, Copies 50, 51.
- 1 Director, USN Radio and Sound Laboratory, San Diego, California,
Copy 52.
- 1 Commanding Officer, U.S. Naval Air Station, Patuxent River, Md.,
Attention: Director of Test, Copy 53.
- 2 OSRD, Liaison Office, Group A, Room 724, Dupont Circle Building,
Washington 25, D.C., Copies 54, 55.
- 1 Chief of Division 15, NDRC, 1 River Road, Schenectady, New York,
Copy 56.
- 1 Navy Liaison Officer, Radio Research Laboratory, Harvard University,
18 Divinity Avenue, Cambridge, Massachusetts, Copy 57.
- 1 General Headquarters, SWPA, Office of the Chief Signal Officer,
Section 22, A.P.O. 500, San Francisco, California, Copy 58.
- 1 Chief of the Bureau of Personnel, Navy Department, Washington, D.C.
Attention: Code 42E10, Copy 59.
- 1 Commander Air Force, Pacific Fleet, Fleet Post Office, San Francisco,
California, Attention: RCM Officer, Copy 60.

DECLASSIFIED