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PHYSICAL OPTICS DIVISION – ENGINEERING DEVELOPMENT SECTION

4 May 1946

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A SURVEY OF THERMAL RADIATION FROM SURFACE VESSELS

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Part I (December 1945 – March 1946)

By H. L. Clark

Report H-2764

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Tables 5
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A SURVEY OF THERMAL RADIATION FROM SURFACE VESSELS

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ABSTRACT

Measurements of the operating ranges of a standarized thermal detector and their dependence upon weather conditions were initiated in December 1945 at the Bureau of Ships Test Station, Lewes, Delaware. These measurements are made during the first week in each month and will continue through December 1946. The targets employed are surface traffic passing through Delaware Bay and the U.S.S. Callao, a converted German weather ship. The maximum ranges at which these targets can be detected are recorded together with other pertinent data, such as air temperature, absolute humidity, and visibility. The total power radiated by the Callao together with the effective radiation density provided by the sky and sea background are also measured. It is hoped to show how and why these factors influence the operating range of a given detector throughout the various seasons of the year.

This report, which is one of a series of three, describes the equipment being employed in these measurements. It also presents the data accumulated to date. Due to the incompleteness of this work, no conclusion can yet be drawn. However, it does appear as though both the absolute humidity and the temperature of the air influence the operating ranges independently. Together they help determine the value of the effective background radiation against which any target has to be differentiated.

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CHAPTER 1

INTRODUCTION

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The general problem of thermal ship detection resolves itself around the limitations offered by atmospheric conditions. The amount of thermal radiation received from a surface vessel by a given detector is determined by three variables: (1) the radiation temperature of the target; (2) the radiation temperature of that patch of sky and water against which the target signal is compared; and (3) the transmission of the atmosphere. A large percentage of the thermal radiation radiated by an "average" vessel is contributed by exposed hot spots on that vessel such as the smokestack and boiler room plates. The magnitude of such radiation is determined by the degree of exposure of the hot spots to wind and spray. The remainder of the radiation from an average vessel is due to the ambient temperature of the hull and superstructure which in turn is determined by the temperature of the air and water. Thus the total power radiated by such a vessel is influenced very much by weather conditions. This is particularly true, of course, for vessels without hot spots[1]. This energy is reduced in magnitude by the absorption of the atmosphere[2,3] before it reaches a given detector. The detector responds to the difference between this power and the power received from the sky and water background. In most cases, this difference is only a small fraction of either radiation value and is, of course, very dependent upon atmospheric conditions.

During the war a number of thermal detecting devices were developed, constructed and tested. Unfortunately, however, because of their experimental nature, their behavior was often erratic and in many cases, they were affected by weather conditions more than the radiation which they were supposed to receive. As a result the overall picture of exactly how and why the radiation received from a target varies with weather conditions has become somewhat confused.

It is therefore the purpose of this report and other reports to follow to clarify this situation and attempt to show how the various complex factors influence the operating range of a given detector.

To do this a series of sample measurements have been initiated. These measurements are made over a period of one week at the beginning of each month and are to continue for one year. The procedure is as follows:

A standardized thermal detector has been set up at the entrance to Delaware Bay and is scanned over passing traffic. Threshold ranges (obtained by radar) at which the detector can just detect these vessels are recorded together with atmospheric data such as wet and dry bulb readings, visibility and so on. This procedure will yield the nominal operating range for a given detector of known sensitivity on all classes of vessels for all seasons of the year. It is hoped to correlate these ranges with wet and dry bulb readings or absolute humidity values. Simultaneously with these readings, threshold ranges

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are also recorded for a test vessel, the U.S.S. Callao. In addition to these, the Callao's radiated output is measured (with a portable radiation meter) at short distances each time. Also the radiation from that patch of sky and water against which the Callao is observed by the land based detector is also measured each time. (This is done with the detector.) Atmospheric conditions are also recorded. From this second set of readings will come the nominal operating range on the same target for all seasons of the year. It is hoped, in this case, to correlate these ranges with the radiation given off by the target, the radiation from the sky and water, and the absolute humidity readings.

Measurements were initiated in December 1945 but did not really get underway until February 1946. They will continue until sufficient data have been accumulated to show the trends over a whole year's period.

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CHAPTER 2

THE DETECTOR

The detector, as shown in Plates 1 and 2, is installed in the Bureau of Ships Test Station, Lewes, Delaware at the entrance to Delaware Bay. It is arranged to scan along the horizon over an arc extending from 60° T to 120° T. Any surface vessels appearing in this arc are viewed against a sky, rather than a land background.

The detector consists of an optical system in which is mounted the sensitive receiving element. The electrical output of the element is fed to a 5 cps. preamplifier attached to the optical system. As shown in Plate 3 the optical system is mounted on a servo driven scanner which is controlled remotely by a master sluing unit which also drives the stylus of a chemical recorder. Thus recorder stylus and scanner move in synchronism. A scale mounted in the recorder is calibrated to read the true bearing of the scanner. Any signal from the sensitive element in the optical system, after being amplified to a suitably large value, is fed to a final power amplifier whose output goes to the recorder stylus and hence marks the recorder paper. Thus if thermal radiation should be received by the optical system from a given bearing, the end result would be a mark on the recorder chart at a point corresponding to that bearing. The darkness of the mark is roughly proportional to the intensity of the radiation received. Since the paper in the recorder advances a small amount at the end of each scan, a thermal target at constant bearing would produce a vertical line of pips on the paper, whereas a target which was changing bearing would produce a curved line of pips showing the target's bearing at all times. The maximum operating range of this detector is determined by the minimum thermal signal it can detect which in turn is determined (in this case) by the inherent noise level in the amplifier system. By keeping the noise level as constantly low as possible, it is possible to keep the effective sensitivity of the detector constant. A built-in calibrator which consists of a shuttered lamp synchronized with the recorder stylus can be switched in to make sensitivity checks.

The optical system consists of a 24-inch, f/2.5 parabolic mirror of astronomical quality. Tests on this mirror by the Naval Observatory showed the solid angle subtended by the circle of confusion to be considerably less than the solid angle subtended by the sensitive thermal element employed in this case. Hence there is no possibility of the image of any target within the optical field of view of this system spilling over the edges of the thermal element. Plate 4 shows the optical system. In the focal plane of the system and symmetric with the optic axis is the receiving element. It is a compensated Bismuth - Antimony thermopile manufactured by the Epply Laboratories of Newport, R. I. This type of element was chosen because it is readily available and because the sensitivity from element to element does not vary more than ten per cent. It has a time constant (time to build up to 63 per cent of maximum value) of 1/20th of a second. Its sensitivity to radiation square-chopped at 5 cycles per second is roughly 5 millivolts per watt per square centimeter. Its resistance is 7 ohms. The approximate physical dimensions of the element are shown in Plate 5 together with the angular dimensions of the optical field of view which it subtends. As can be seen from this drawing,

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the approximate optical field of view for one receiving area is 1/16th of a degree wide by 1/8th of a degree high. The element as supplied by Epply is in a steel case with a rock salt window. This has been mounted in an air-tight housing with a silver chloride window. The housing contains a small desiccator filled with CaCl to insure dryness and prevent the rock salt window from deteriorating. The silver chloride window in the housing has been treated with hardened Ag_2S to prevent solarization and consequent loss of transmission.[4] It does not transmit visible light. Because of this, the detector can be employed during the daylight hours of overcast days with the same result as obtained during darkness. The optical system is aligned with the horizon so that the image which falls on the receiver is two-thirds sky and one-third water.

The preamplifier is shown in Plate 6. The wiring diagram is shown in Plate 7. The fundamental frequency contained in the positive and negative lobed voltage pulse generated by the compensated thermopile when the optical system scans across a point source of radiation is approximately 5 cycles per second. Since the duration of the pulse is approximately 1/5th of a second, the bandwidth of the amplifier is also 5 cycles. The frequency response of the preamplifier is shown in Plate 8. This tuning is obtained by employing three pentode stages wherein plate load shunting and interstage undercoupling is employed. The input transformer is a special unit designed for use at 5 cycles per second. It has a turns ratio of 300 and an effective gain of 170 when operating with a 5-ohm primary load and a 15-megohm secondary load. The input tube into which the transformer must work employes no bias whatsoever other than that provided by the grid current in the absence of a grid leak resistor. This arrangement not only provides for maximum grid input impedance but also minimum tube noise.[5] Unfortunately, however, the low frequency flicker noise (not shot noise) in this input tube is roughly 4 times greater than the Johnson noise from the thermopile. Hence the limiting noise level in this amplifier is not the Johnson noise in the input load as it should be. The vacuum tubes in this country are such as to prevent successful transformer coupled operation except at frequencies of 20 cycles per second or higher. (Flicker noise falls off as $1/f^2$ for constant bandwidth where f is the resonant frequency of tuning.) Special precautions have been taken to employ paper condensers rather than electrolytic condensers at all decoupling points. (The leakage drift in electrolytics is rich in low frequency harmonics.) Wire wound resistors are employed in the low signal stages to prevent current noise from contributing to the total noise level in the amplifier. Despite all these precautions, the noise level is unduly high being equivalent to 2.5×10^{-9} volts at the thermopile. An output meter is built into the preamplifier and can be switched in to check the noise level. Since this amplifier is employed for absolute measurements also, it has to be linear. Its linearity curve is shown in Plate 9.

The scanner upon which the optical system and preamplifier are mounted is a modified standard 36-inch searchlight base (Navy type 36-16H). The yokes have been cut off flush with the top of the servo unit housing and a steel platform has been bolted on. The slip ring assembly has been removed. Internally the servo system which provided elevation control for the searchlight drum has been removed. An A.C. operated D.C. voltage power supply has been added to the servo train unit. Plate 10a shows the servo amplifier and

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D.C. power supply. Plate 10b shows the servo drive motor and control transformers. The synchro system which controls the scanner base is a standard two speed unit employing a one speed channel and a thirty-six speed channel. The static error involved in this system is less than ± 1/10th of a degree. The dynamic error is the same order of magnitude except at the ends of a given scanning sector where reversals are necessary. At these points the error is considerable. However, the system locks in again after about one degree of travel.

The final amplifier, which is shown in Plate 11, situated in the same cabinet as the recorder, is of the chopper type. Any incoming signal is chopped at 120 times per second at the input. From there on through, the signal is amplified as a five cycle envelope on a 120-cycle carrier. The amplifier is capable of delivering 25 volts across a 3,000-ohm load. The wiring diagram of this amplifier is shown in Plate 12. The output of this amplifier is first full-wave rectified before being applied to the recorder paper. The impedance of the paper is not linear. It varies from 3,000-ohms for a very faint line to 30 ohms for a dark line. Ten volts at 12 milliampers will produce a very dark line at the stylus speed used (about 1/4-inch per second). The power amplifier also supplies a small negative bias voltage which keeps the paper broken down and produces a faint grey line at all times. Signals are variations (light or dark) in this gray line.

The recorder is an early model of an S.S.D. (Stabilized Ship Detector) unit produced by the Leeds and Northrup Co., Philadelphia, Pa. under a Bureau of Ships contract. It is a combination recorder and master sluing unit. The sluing unit has been modified to provide a scanning speed of about one degree per second. The paper width is 10 inches and corresponds to an arc of 40 degrees. This 40 degree sector may be moved anywhere over the sector scanned by this detector (between 60° T and 120° T). Limit switches are provided which enable one to cut down the scanning arc. At the end of each scan, the paper advances 1/16th of an inch. A bearing scale which is calibrated in true bearing of the scanner is situated across the top of the paper. A backlash adjustment is provided in the recorder to compensate for the signal time delay in the amplifiers and lag in the servo system. The writing mechanism consists of a platinum iridium stylus and a monel writing roller bed. The stylus must be kept negative with respect to the roller. The paper employed is manufactured by Inventions Incorporated, New York, N.Y. It is a paper of the chemical type and yields a black mark on a white background. It does not discolor, fade or shrink. However, its storage life is not very long being the order of three months before it starts to discolor and turn brown. If used before this period, however, discoloration does not take place.

The entire detector system is calibrated in two ways. Before and after each series of measurements the thermopile and the preamplifier are calibrated in the laboratory against a blackbody source at 60° C. Calculations then yields the sensitivity of the system. In the field the calibrator built into the optical system is employed. This provides a check on the entire system exclusive of the silver chloride window in thermopile housing and parabolic collecting mirror. To calibrate the system, the thermopile housing is removed and one half of the compensated thermopile is covered. The calibrator provides synchronized pulsed radiation of proper duration at

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the surface of the thermopile. The intensity of this radiation is 10^{-6} watts per square centimeter and provides a trace similar to that shown in Plate 13. This trace is considered as being 100 per cent above threshold. Calculations then yield the sensitivity of the entire system. Both calibrations yield a value of 7 or 8 x 10^{-11} watts per square centimeter incident upon the surface of the mirror as the absolute minimums detectable energy density for this system.

To avoid confusion, it should be stated here that this detector is a standardized measuring device. It was never intended to be a prototype of any land based or shipborne detector for use in Naval warfare. Detectors have been built with more sensitivity and with only 1/10th the size and weight.

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The value of the density of effective power incident upon the mirror is equal to the above value of power density multiplied by the factor due to mirror. This factor is arrived at by considering the effective collecting area of the mirror, its reflectivity, the effective collecting area of the thermopile, and the transmission of its windows. The calculations will not be presented here. The value of this factor is 2×10^{-5}. Hence the effective radiation density is

$$F_{\substack{\text{eff} \\ \text{(background)}}} = \left[2 \times 10^{-5}\right] \left[\frac{D_1}{D_2} \left(a\, T^4_{\text{black body}} - a\, T_o^4 \right) + \left(a\, T_o^4\right)\right] \text{ watts/cm}^2 .$$

The first term in the above equation yields the relative effective power density due to the background. That is to say it is the increment above or below ambient radiation contributed by the background. This term is usually negative in the winter time and positive during the summer months which means that the background radiation temperature is usually less than air temperature in the winter time and greater in the summer time. The sign of this term is determined by D_1. With a radiation meter whose output is a D.C. voltage, the sign of D_1 is determined by the polarity of this voltage. In this case, however, where the output voltage is A.C., a 180-degree phase reversal takes place when D_1 is negative with respect to D_2. That is why an oscilloscope is employed for these measurements rather than a vacuum tube voltmeter. The voltage phase of D_1 with respect to D_2 must also be observed as well as its magnitude.

The entire expression above yields the absolute value of effective power density incident upon the surface of the collecting mirror. The power emitted from the background per unit area of background can be calculated from this value.

The value of the absolute effective radiation from the background, F_{eff}, is one of the factors which determine the operational characteristics of any detector. It is the difference between a portion of this quantity and power density received from a target which produces the signal in a detector. Thus for a target at a range, d, the power density difference at a detector is

$$\Delta F = \left[\frac{W_T}{\pi d^2} \cdot e^{-\lambda d} + K\right] - \left[F_{\substack{\text{eff} \\ \text{background}}} \cdot \frac{\frown T}{\frown D}\right]$$

where ΔF = difference in power densities in watts/cm2
W_T = total effective power emitted by target in watts
d = range in centimeters
π = 3.1416
e = 2.718
λ = atmospheric transmission in per cent per cm
k = contribution by atmosphere in path between target and detector in watts/cm^2
F_{eff} = effective background power density at detector as defined above
$\frown T$ = solid angle subtended at detector by target
$\frown D$ = solid angle of optical field of view of detector.

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The minimum detectable value of ΔF, of course, determines the maximum range at which a given target can be detected. As stated previously, the value for the subject detector is 7 or 8 x 10^{-11} watts/cm^2.

At the present time the above expression is not useable because K, the contribution by the atmosphere in the path between the target and detector, is not known and λ, the transmission of the atmosphere which is a function of several variables, has not been measured for all conditions.

Certain simplifying assumptions can be made[1] which result in a useable expression. Such an expression is

$$\Delta F = \frac{W_T - \phi_B A_T}{\pi d^2} \cdot e^{-\lambda d}$$

where ϕ_B = power radiated from background per unit area of background in watts per cm^2

A_T = area of target in cm^2

F, W_T, π, e, d, λ = same as above.

This expression assumes that the absorption of radiation by the atmosphere is the same for the target as for the background which obviously is not the case because of the difference in spectral distribution of the respective outputs[2]. It is usually assumed that the atmospheric absorption (and hence λ) is zero however. As has been pointed out[1], the background radiation value, ϕ_B, should be measured with the detector to which the above expression is being applied rather than with the portable radiation meter used for shipboard measurements. This avoids the necessity of assuming that the background is of uniform brightness[6,7,8] and can be measured with devices of any optical field of view

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CHAPTER 4

THE PORTABLE RADIATION METER

The equipment employed in making radiation measurements aboard the U.S.S. Callao is shown in Plate 15. It consists of a radiation telescope, amplifier plus power supply and battery, and an indicating meter. A black body can to be filled with water is provided for calibration purposes. The telescope is made up of a 45 mm diameter 30 mm focal length mirror in the focal plane of which is mounted a single junction, 2.5-ohm, copper-cupron thermocouple which subtends a 4 x 4 degree field of view. The amplifier is an early model D.C. breaker-type amplifier produced by the General Motors Corp. of Detroit, Mich. It has a noise level corresponding to an input signal of 10^{-8} volts. The indicating meter is a 0-10 ma. milliammeter of about 40-ohms resistance.

The instrument is calibrated by first adjusting the gain so that a 10-microvolt input signal produces an output of 10 ma. The instrument is then zeroed against the black body can of water at air temperature. At a second temperature of the black body can, the meter deflection is observed. Then

$$D_4 \backsim (\varphi_{can} - \varphi'_o)$$

where D_4 = meter deflection in milliamperes

φ_{can} = power emitted per unit area of can at second temperature in watts/cm^2

φ'_o = power emitted per unit area of can at air temperature in watts/cm^2.

The instrument is continually zeroed against the black body can at air temperature. When pointed at a portion of the ship, a new meter deflection results. Then

$$D_3 \backsim (\varphi_{ship} - \varphi''_o)$$

where D_3 = deflection in milliamperes due to ship

φ_{ship} = power emitted per unit area of ship in watts/cm^2

φ''_o = power emitted per unit area of can at air temperature in watts/cm^2 (This may be different from φ'_o).

Combining the two expressions yields

$$F_{ship} = \frac{D_3}{D_4} (\varphi_{can} - \varphi'_o) + (\varphi''_o)$$

or

$$F_{ship} = \frac{D_3}{D_4} (\alpha T_{can}^4 - \alpha T_o'^4) + \alpha T_o''^4$$

watts/cm^2

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where α = Stefan-Boltzman constant
= 5.72×10^{-12} watts per cm^2 per degree^{-4}
T_{can} = elevated temperature of can in ^oK
T'_o = air temperature of can at time of calibration in ^oK
T''_o = air temperature of can at time of ship measurement in ^oK .

This value multiplied by the area in cm^2 yields the total radiated output for the surface under consideration. A summation of all such values yields the total power radiated by the Callao for a given aspect.

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CHAPTER 5

TEST PROCEDURE

Before starting a series of measurements, the detector is calibrated as previously described and a calibration record similar to that of Plate 13 is obtained.

Threshold ranges on surface traffic trhough Delaware Bay are obtained with the aid of a Navy type SG radar set. The radar operator picks out a particular vessel, either outbound or inbound, and telephones the bearing to the detector operator. The detector is then made to scan five degrees either side of this bearing and ranges which are relayed from the radar operator are recorded on the recorder tape every thousand yards. Once a threshold has been established, the time and wet and dry bulb readings are also recorded. The name of the vessel is then obtained from the Navy operated Harbor Entrance Control Post which challenges all vessels. This is also recorded. A recording of the type shown in Plate 15 is obtained. This Plate is misleading in that it does not have the clarity of the original, hence the apparent threshold range is less.

Every hour or so, the detector is made to scan over a lightship which is stationed 6,500 yards out at a bearing of 078 degrees T. This vessel is a relatively weak target having no hot spots of any appreciable magnitude. The strength of the signal from this vessel is a good indication of atmospheric conditions. It was found at the beginning of this series of tests that a black body receiver such as the thermopile employed in this detector responds to the slowly flashing light on the lightship and produces a trace as shown in Plate 17. Installation of a blackened silver chloride window in the thermopile housing eliminated this.

The threshold ranges on passing traffic together with other pertinent data including signal intensities from the lightship (Overfalls or its sistership Relief) are tabulated for the first few months of operation in Tables 1 through 4, inclusive.

Measurements are also made on the U.S.S. Callao, shown in Plates 18 and 19, each month. Threshold ranges are obtained for both bow and stern aspects. As can be seen from the photographs, the stern aspect presents more smokestack than the bow aspect and as a result the stern threshold ranges are greater, usually by a factor of two. The Callao's threshold ranges together with other pertinent data are included in Tables 1 through 4. Attempts are made to obtain three bow and three threshold ranges for each of the three nights that the Callao is available. However, weather or other conditions sometimes prevent this.

While threshold measurements are being obtained by the detector on shore, absolute radiation measurements are being made aboard the Callao with the portable radiation meter. The results are shown in Plates 20 through 31. The Callao's bow silhouette is fairly symmetrical except for a projection on the starboard side which is due to the ship's launch. This lack of symmetry shows up in the radiation diagrams. When making bow radiation measurements, the hull, supersturcture, launch, and stack are measured. The stern radiation

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plots show less symmetry because of a relatively hot port vent and a relatively cool stbd. vent. When making these measurements, the hull, superstructure, launch, port vent, stbd. vent, and stack are measured. Both bow and stern measurements show the supersturcture to be at or near air temperature. The hull is usually a slight bit cooler. The stack is the hotest portion with the port vent next. The stbd. vent is usually at or below air temperature. The launch and superstructure are the same.

Immediately after the Callao's last run, the detector on shore is converted into a radiation meter for background radiation measurements. These are made at the same bearing (120° T) as the Callao's bearing during the test runs. The results to date are listed in Table 5. Since these measurements are made after the shipboard measurements, the correlation may not be too good in some cases. However, practical difficulties prevent it from being otherwise.

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CHAPTER 6

RESULTS

The threshold ranges obtained thus far on surface traffic passing through Delaware Bay have been plotted in Plate 32. Also plotted, there, are air temperature in degrees F. and absolute humidity in centimeters of precipitable water vapor per sea mile. The latter was obtained from wet and dry bulb readings by use of available tables[3,6]. It will be noted that for every increase in absolute humidity there was a decrease in the threshold ranges for that period and vice-versa. However, this is not the case for the air temperatures. In March, for example, there was an increase in air temperature which resulted in no decrease in threshold ranges followed by a decrease in temperature which produced a decrease in the ranges. During this period the absolute humidity remained fairly constant. Hence the changes in ranges cannot be attributed to changes in absolute humidity. There are many other influencing variables including the power output of the vessels observed during this period. Nothing is known about them. All that the present data shows is that most of the vessels encountered are "hot targets" - even hotter than the U.S.S. Callao - and that the ranges at which they can be detected are influenced both by the temperature of the air and the absolute humidity.

The data obtained from the U.S.S. Callao are plotted in Plate 33. Here are presented: the threshold ranges for both bow and stern aspects; the air temperatures at the time bow and stern thresholds were obtained; the absolute radiation from the vessel from both bow and stern; and the effective background radiation incident upon the detector. Here too, the effects of absolute humidity upon threshold range are evident. Even more evident is the effect of background radiation. In March, the value of background radiation rose slightly and then leveled off. The bow radiation from the Callao continued to rise. The result was a slight decrease then an increase in the bow threshold ranges as the target and background differential increased. The absolute humidity was increasing during this period. In other words, threshold ranges are also determined by how well the target contrasts with the background. The degree of contrast is determined partially by the amount of background radiation which in turn is determined both by the air temperature and absolute humidity acting independently.

From the foregoing, it appears highly adviseable to investigate the magnitude of target and background radiation differentials as a function of wave length. At the present time detectors compare that portion of target radiation transmitted by the water vapor window against the total radiation from the background, a procedure which leaves much to be desired.

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REFERENCES

1. J. A. Sanderson, Infra Red Radiation from Targets LCT and LCI Empolyed in Treals of Ship Detectors at Cape Henlopen, NRL Report H-2249, 22 February 1944.

2. J. Strong, Heat Radiation Investigations at the California Institute of Technology, NDRC Report, 20 August 1942.

3. E. O. Hulburt, Atmospheric Attenuation of Infra Red Radiation, NRL Report H-2348, 22 July 1944.

4. J. A. Sanderson, The Chemical Treatment of Silver Chloride Sheets to Produce Filters Transmitting Far Infra Red Radiation, NRL Report H-2339, 3 June 1944.

5. Markus and Zeluff - "Electronics for Engineers," page 358, McGraw-Hill, 1945.

6. J. Strong and C. P. Butler, Thermal Radiation from Targets and Background, Div. 16, NDRC, OSRD 5372, 30 March 1945.

7. J. A. Sanderson, Radiation Temperature of the Sky and the Sea Horizon, NRL Report H-2505, 18 April 1945.

8. H. L. Clark, Thermal Gradients at the Horizon, BuShips Electrical Section (660) Report No. 7, 15 Sept. 1944.

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[redacted]

TABLE 1

Threshold Ranges For December 1945
(Thermopile #1285)

Vessel	Aspect	Range Yards	Time	Date	Wet/Dry of	Remarks
Calao	Stern	13,000	2215	12/4/45	38/41	Light Rain.
Calao	Stern	14,000	1940	12/7/45	42/46	Hazy - Cannot see Cape May.
Calao	Bow	7,500	2020	12/7/45	42/45	Hazy - Cannot see Cape May.
Calao	Stern	14,000	2100	12/7/45	42/45	Hazy - Cannot see Cape May.
Calao	Bow	7,500	2140	12/7/45	42/45	Hazy - Cannot see Cape May.
Unidentified (Liberty Ship)	Bow	15,000	2030	12/7/45	42/45	Hazy - Cannot see Cape May.

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TABLE 2

Threshold Ranges For January 1946
(Thermopile #1289)

Vessel	Aspect	Range Yards	Time	Date	Wet/Dry of	Remarks
Relief	Stern	6500 (weak)	2100	1/7/46	53/54	Very foggy - Cannot see light on Relief.
Unidentified	Port	4500	2230	1/7/46	54/54	Very Foggy - No trace from Relie
Chester's Son	Stern	18,000	1050	1/8/46	44/44	Overcast - Raining lightly.
Tug & Tow (Wooden Barge)	Stbd-stern	Tug - 13,000 (strong) Tow - 10,000	1350	1/8/46	46/48	Overcast - Tug moved out of scanning sector.
Fall River (Cruiser)	Stern	20,000	1500	1/8/46	44/45	Overcast - High on horizon.
Portsmouth (Cruiser)	Stern	20,000	1530	1/8/46	43/44	Overcast - High on horizon.
George Walton	Stern	14,000	1555	1/8/46	42/44	Overcast
C. Tarpon	Stern	15,500	1625	1/8/46	42/44	Overcast
Princeton (Carrier)	Stbd-stern	13,000	1835	1/8/46	42/44	Darkness
Relief	Port	6,500 (intermittent)	1925	1/8/46	41/42	
Cornwallis	Stbd-stern	17,000	2025	1/8/46	41/42	
Relief	Port	6,500 (medium)	2115	1/8/46	41/43	
John Evans (Destroyer)	Stern	6,500	2125	1/8/46	41/43	Trace disappear when DD swung stern to.
Sapacreek	Stbd-stern	17,000 (approx.)	2155	1/8/46	41/43	Ship went out o scanning sector

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TABLE 2 (cont'd)

Threshold Ranges For January 1946
(Thermopile #1289)

Vessel	Aspect	Range Yards	Time	Date	Wet/Dry of	Remarks
Relief	Stern	6,500 (medium)	2220	1/8/46	41/43	
Macon (Cruiser	Stern	10,000	1300	1/9/46	46/46	Hazy - Raining lightly.
Bangust (Destroyer)	Stbd-stern	11,500	1450	1/9/46	47/49	Hazy - Cannot see Relief.
Relief	?	6,500 (inter-mittent)	1500	1/9/46	47/49	Relief is not visible.
Port Royal Oak	Stern	8,800	1950	1/10/46	43/47	Clear - See Cape May.
Duncan U. Fletcher	Stbd-stern	14,500	2055	1/10/46	42/45	
Relief	?	6,500 (weak)	2200	1/10/46	41/44	
Bellinger	Stbd-stern	14,000	2300	1/10/46	40/43	Intermittent trace near threshold.
Atoneana (Swedish Cargo)	Stbd-stern	9,000	2330	1/10/46	39/42	
Gold Creek	Stern	19,500	1530	1/11/46	36/41	Overcast - See Cape May.
Wm. S. Baer	Stern	17,000	1610	1/11/46	35/40	Overcast - Very Clear.
Tug & Tow	Port-stern	Tug - 14,500	1610	1/11/46	35/40	Overcast - Very Clear.
Relief	Port	6,500 (Very Strong)	1610	1/11/46	35/40	Overcast - Very Clear.
August Belmont	Bow	20,000	1625	1/11/46	36/40	Overcast - See Cape May.

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Threshold Ranges For January 1946
(Thermopile #1289)

Vessel	Aspect	Range Yards	Time	Date	Wet/Dry of	Remarks
Lynn Boyd	Bow	14,500	1915	1/11/46	37/40	Raining lightly - See Cape May.
Hope Victory	Port-bow	16,000	1940	1/11/46	37/40	Raining lightly - See Cape May.
Sidney Wright	Stbd-stern	14,500	2100	1/11/46	37/39	Raining lightly - See Cape May.
Stancourt	Stern	20,500	2110	1/11/46	37/39	Raining lightly - See Cape May.
Relief	?	6,500 (weak)	2120	1/11/46	37/39	Raining lightly - See Cape May.

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TABLE 3

Threshold Ranges For February 1946
(Thermopile #1289)

Vessel	Aspect	Range Yards	Time	Date	Wet/Dry of	Remarks
Unidentified	Bow	17,000	2320	2/4/46	27/31	Cannot see Cape May - Stars out.
Overfalls	Bow	6,500 (Very Strong)	2330	2/4/46	27/31	Overcast - Hazy
Sun	Stern	21,000	0136	2/5/46	32/35	Overcast - Hazy
Pine Bluff Victory	Bow	18,000	1209	2/5/46	32/35	Overcast
Central Victory	Stern	20,500	1324	2/5/46	32/35	Overcast - Snow flurries.
Overfalls	Port	6,500 (Very Strong)	1324	2/5/46	32/35	Overcast - See Cape May.
Ormar (Calmar Line)	Bow	22,000	1240	2/5/46	32/35	Overcast
Leerdam	Stern	18,000	1414	2/5/46	34/35	Snow flurries.
Overfalls	Port	6,500 (weak)	1414	2/5/46	34/35	Cannot see Cape.
Unidentified (Foreign)	Stern	14,500	1710	2/5/46	33/36	Overcast
Chas. J. Folger	Bow	17,000	1744	2/5/46	33/36	Overcast - Cannot see Cape May.
Calao	Stern	14,000	1945	2/5/46	35/36	Overcast - Can now see Cape May.
City of Canberra	Stern	22,000	1958	2/5/46	35/37	See Cape May.
Calao	Bow	9,200	2015	2/5/46	35/37	See Cape May.
Calao	Stern	11,000	2053	2/5/46	36/37	Raining lightly - Cannot see Cape May.

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TABLE 3 (cont'd)

Threshold Ranges For February 1946
(Thermopile #1289)

Vessel	Aspect	Range Yards	Time	Date	Wet/Dry of	Remarks
Calao	Bow	5,500	2126	2/5/46	36/37	Raining lightly.
Overfalls	?	6,500 (medium)	2126	2/5/46	36/37	Raining lightly.
Calao	Stern	7,000	2021	2/6/46	54/55	Cannot see Cape May. Heavy fog just lifting.
Calao	Bow	2,000. (approx.)	2035	2/6/46	54/55	Light fog - Cannot see Cape May.
Calao	Stern	5,000	2050	2/6/46	54/55	Light fog - Cannot see Cape May.
Calao	Bow	3,000	2218	2/6/46	47/50	Getting colder very fast.
Calao	Stern	5,500	2230	2/6/46	44/44	Raining very hard.
Overfalls	Port	6,500 (medium)	1807	2/7/46	34/37	Hazy - Cannot see Cape May.
John H. Moorehead	Stern	16,500	1830	2/7/46	33/37	Hazy - Cannot see Cape May.
Henry H. Richardson	Bow	18,700	1816	2/7/46	34/37	Hazy - Cannot see Cape May.
Calao	Stern	17,500	1955	2/7/46	32/36	Hazy - Cannot see Cape May.
Calao	Bow	11,500	2020	2/7/46	32/35	Northern lights are extremely bright.
Calao	Stern	17,800	2116	2/7/46	31/35	Northern lights - Cannot see Cape May.
Calao	Bow	12,000	2151	2/7/46	31/34	Northern lights - Cannot see Cape May.

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TABLE 3 (cont'd)

Threshold Ranges For February 1946
(Thermopile #1289)

Vessel	Aspect	Range Yards	Time	Date	Wet/Dry of	Remarks
Overfalls	Port	6,500 (medium)	2200	2/7/46	31/34	Clear - Cannot see Cape May.
Wm. C. Yeager	Stern	19,000	1828	2/8/46	31/33	Very clear- Can see Cape May.
Overfalls	?	6,500 (Very Strong)	1828	2/8/46	31/33	Very clear- Can see Cape May.
Alcoa Pilgrim	Stern	20,000	2054	2/8/46	32/34	Very clear- Can see Cape May.
Sun (Tanker)	Bow	27,500	2130	2/8/46	32/34	Very clear- Can see Cape May.
South Mountain	Bow	13,500	2137	2/8/46	32/34	Very clear- Can see Cape May.
Overfalls	?	6,500 (Very Strong)	2137	2/8/46	32/34	Very clear- Can see Cape May.
Unidentified	Stbd.	20,500	2230	2/8/46	32/35	Cloudy - Cannot see Cape May.
Overfalls	?	6,500 (Very Strong)	2230	2/8/46	32/35	Cloudy - Cannot see Cape May.

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TABLE 4

Threshold Ranges For March 1946
(Thermopile #1289)

Vessel	Aspect	Range Yards	Time	Date	Wet/Dry of	Remarks
Overfalls	?	6,500 (strong)	2302	3/4/46	50/60	Hazy - Cannot see Cape May.
Unidentified (Weather ship)	Bow	12,000	0030	3/5/46	50/60	Hazy - Cannot see Cape May.
Griffco (British)	Stern	17,000	0113	3/5/46	50/61	Hazy - Cannot see Cape May.
John Holland	Stern	18,000	0126	3/5/46	50/61	Hazy - Cannot see Cape May.
Overfalls	?	6,500 (weak)	0126	3/5/46	50/61	Hazy - Cannot see Cape May.
Atlantic Mariner	Stbd-stern	14,000 (approx.)	1851	3/5/46	48/51	Foggy - Cannot see Cape May.
Overfalls	?	6,500 (strong)	1852	3/5/46	48/51	Light on Overfalls barely visible.
Horse Shoe	Stbd-stern	18,000 (approx.)	2049	3/5/46	44/45	Hazy - Cannot see Cape May.
Cape Fear	Stern	19,000	2100	3/5/46	46/48	Hazy - Cannot see Cape May.
Sweetwater	Bow	9,500	2131	3/5/46	48/52	Hazy - Cannot see Cape May.
Overfalls	?	6,500 (strong)	2310	3/5/46	44/45	Misty
Calao	Stern	10,500	2331	3/5/46	44/45	Misty
Calao	Stern	11,500	0129	3/6/46	48/52	Cannot see Cape May.
Calao	Stern	10,000	2031	3/6/46	46/47	Cape May is now visible.
Monte Rciar (Spanish)	Stern	17,500	2110	3/6/46	48/49	Cape May is now visible.

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TABLE 4 (cont'd)

Threshold Ranges For March 1946
(Thermopile #1289)

Vessel	Aspect	Range Yards	Time	Date	Wet/Dry of	Remarks
Calao	Bow	6,600 (no signal)	2107	3/6/46	48/49	Cape May is now visible.
		Replaced thermopile #1289 with #1288 here.				
Calao	Stern	10,900	2150	3/6/46	50/52	Cape May is visible.
Calao	Stern	12,000	2319	3/6/46	49/52	Cape May is visible.
Overfalls	?	6,600 (weak)	2325	3/6/46	47/48	Cannot see Cape May now.
Unidentified	Stern	8,500	2320	3/6/46	47/48	Cannot see Cape May now.
Calao	Bow	6,000	2358	3/6/46	46/47	Cannot see Cape May now.
Overfalls	?	6,700 (medium)	2358	3/6/46	46/47	Cannot see Cape May now.
Albert E. Watts (Sinclair Tanker)	Stbd-stern	10,000	1520	3/7/46	61/70	Overcast - Cloudy cannot see Cape May.
Betty Zane	Bow	8,000	1605	3/7/46	61/69	Overcast - Cloudy cannot see Cape May.
Overfalls	Port	6,600 (faint)	1605	3/7/46	61/69	Overcast - Cloudy, cannot see Cape May.
Unidentified	Stern	12,000	1951	3/7/46	61/66	Very Clear - See Cape May.
Unidentified	Stbd-stern	11,000	2020	3/7/46	56/60	Local squall of driving rain eventually cut of signal

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TABLE 4 (cont'd)

Threshold Ranges For March 1946
(Thermopile #1288)

Vessel	Aspect	Range Yards	Time	Date	Wet/Dry of	Remarks
Overfalls	Stbd.	6,500 (no trace)	2110	3/7/46	54/56	Raining lightly - Cannot see Cape May.
Florida	Stern	6,500	2112	3/7/46	54/56	No rain-Light fog.
Unidentified	Stbd-stern	12,000	2216	3/7/46	55/56	Clearing - Cannot see Cape May.
Strickland	Stern	12,200	2250	3/7/46	53/54	Still Foggy.
Calao	Stern	9,000	2251	3/7/46	53/54	Still Foggy.
Overfalls	Stbd.	6,500 (weak)	2250	3/7/46	53/54	Still Foggy.
Calao	Bow	5,900	2335	3/7/46	54/54	Still Foggy.
Overfalls	Stbd.	6,500 (no trace)	2335	3/7/46	54/55	Foggy - Cannot see Cape May.
Calao	Stern	13,000	0030	3/8/46	54/55	Foggy - Cannot see Cape May.
Calao	Bow	6,500	0102	3/8/46	54/55	Foggy - Cannot see Cape May.
Fernold	Stern	14,000	0102	3/8/46	54/55	Clearing - Cannot see Cape May.

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Table 5

Effective Background Radiation Density at Detector
(February 1946 to March 1946)

Date	Time	Air Temp. °C	PPT H_2O Cm/SeaMi	Rel. Density Watts/cm^2	Abs. Density Watts/cm^2	Remarks
2/6/46	2340	6.0°	1.1	-1.8×10^{-8}	76×10^{-8}	Raining Hard.
2/8/46	0030	4.5°	0.7	-3.5×10^{-8}	72×10^{-8}	Very Clear.
3/6/46	0140	12.5°	1.3	$+0.15 \times 10^{-8}$	76×10^{-8}	Light Haze.
3/7/46	0015	14.0°	1.5	$+1.8 \times 10^{-8}$	80×10^{-8}	Light Haze.
3/8/46	0120	13.0°	1.9	$+3.5 \times 10^{-8}$	80×10^{-8}	Thin Fog.

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PLATE I

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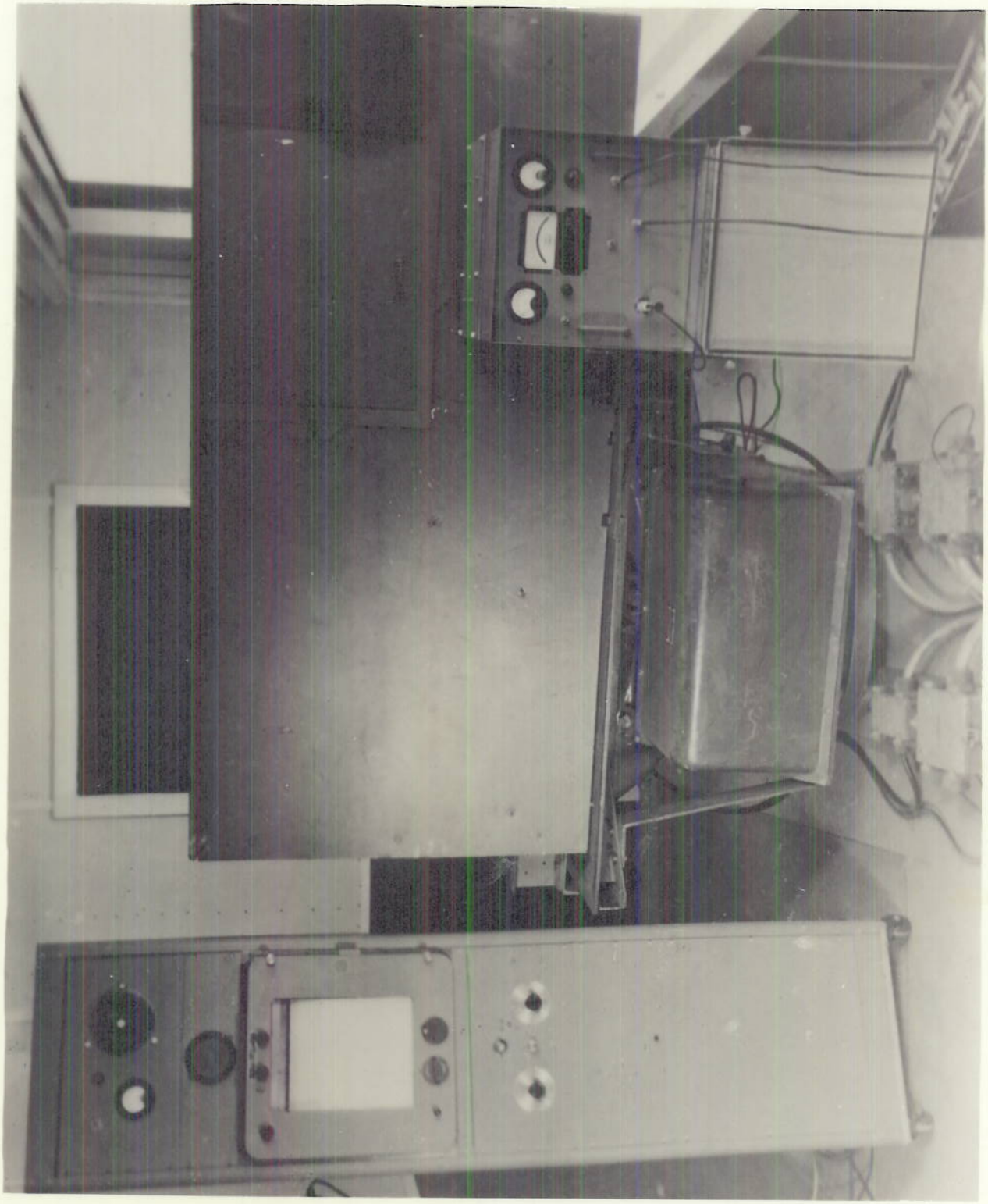

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PLATE 2

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DETECTION SYSTEM DIAGRAM

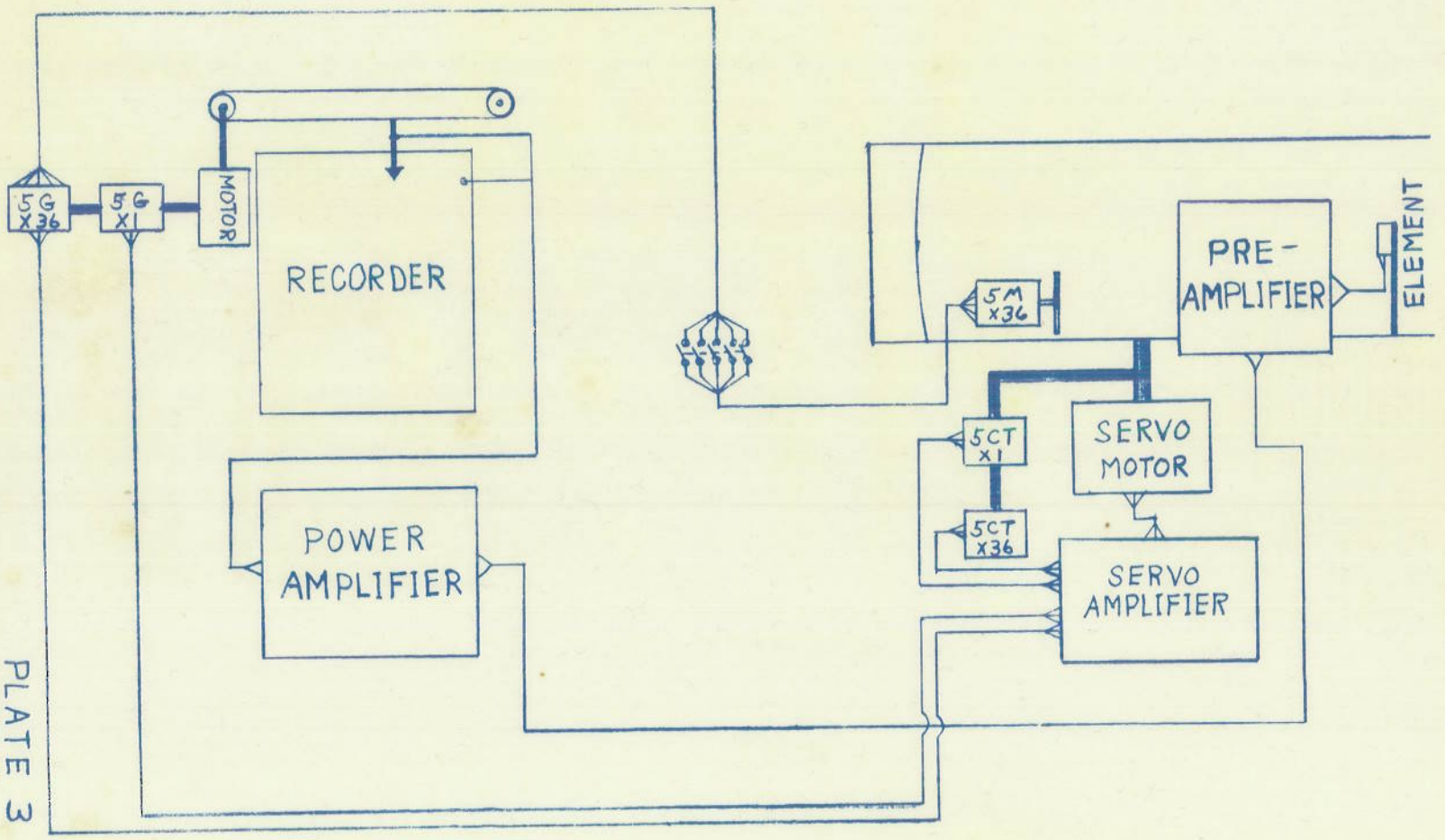

PLATE 3
H-2764

5G - Navy Synchro Generator, Size 5
5CT - Navy Control Transformer, Size 5
X1 - Base Speed
X36 - 36 Times Base Speed
5M - Navy Synchro Motor, Size 5

PLATE 3

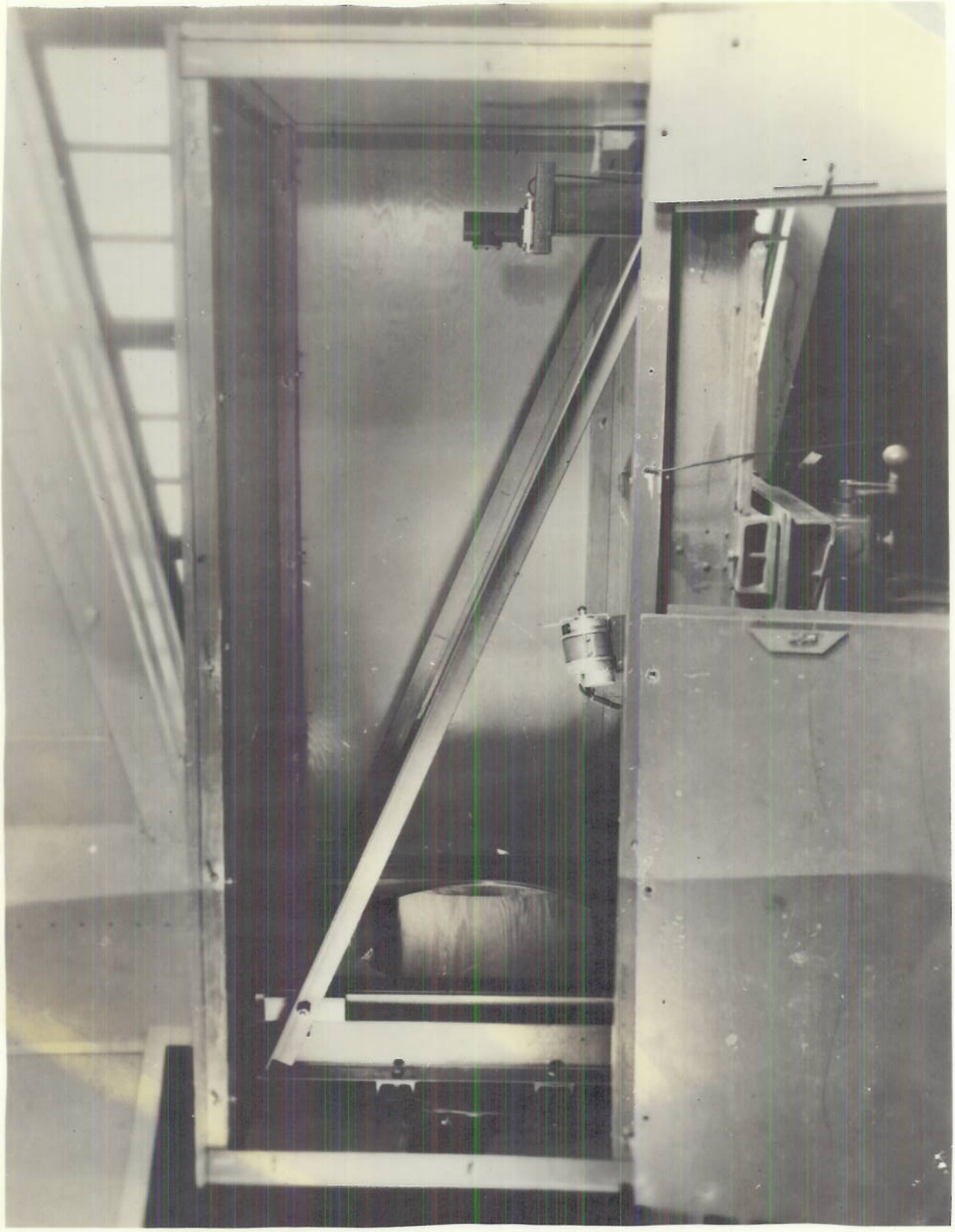

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PLATE 4

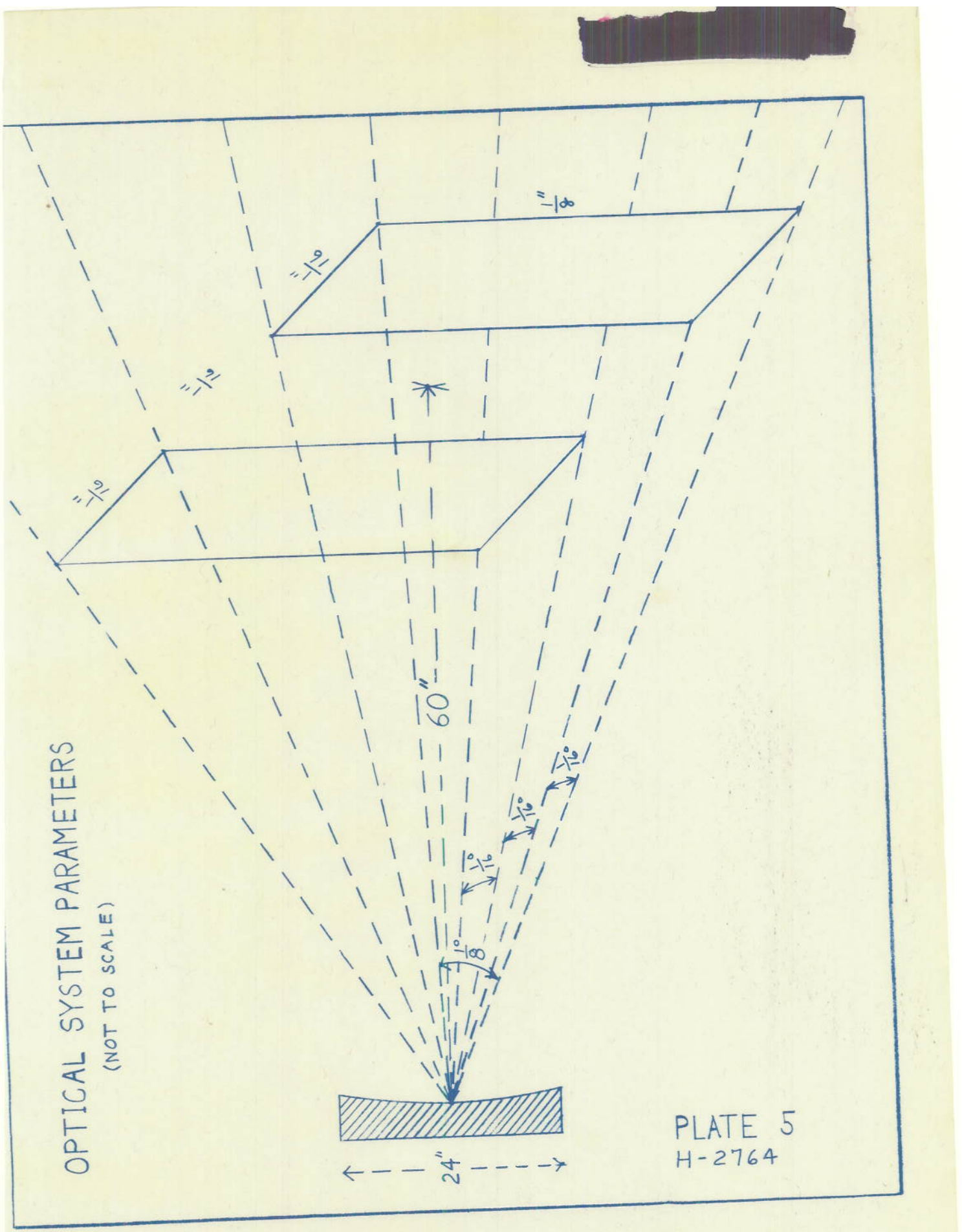

PLATE 5
H-2764

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PLATE 6

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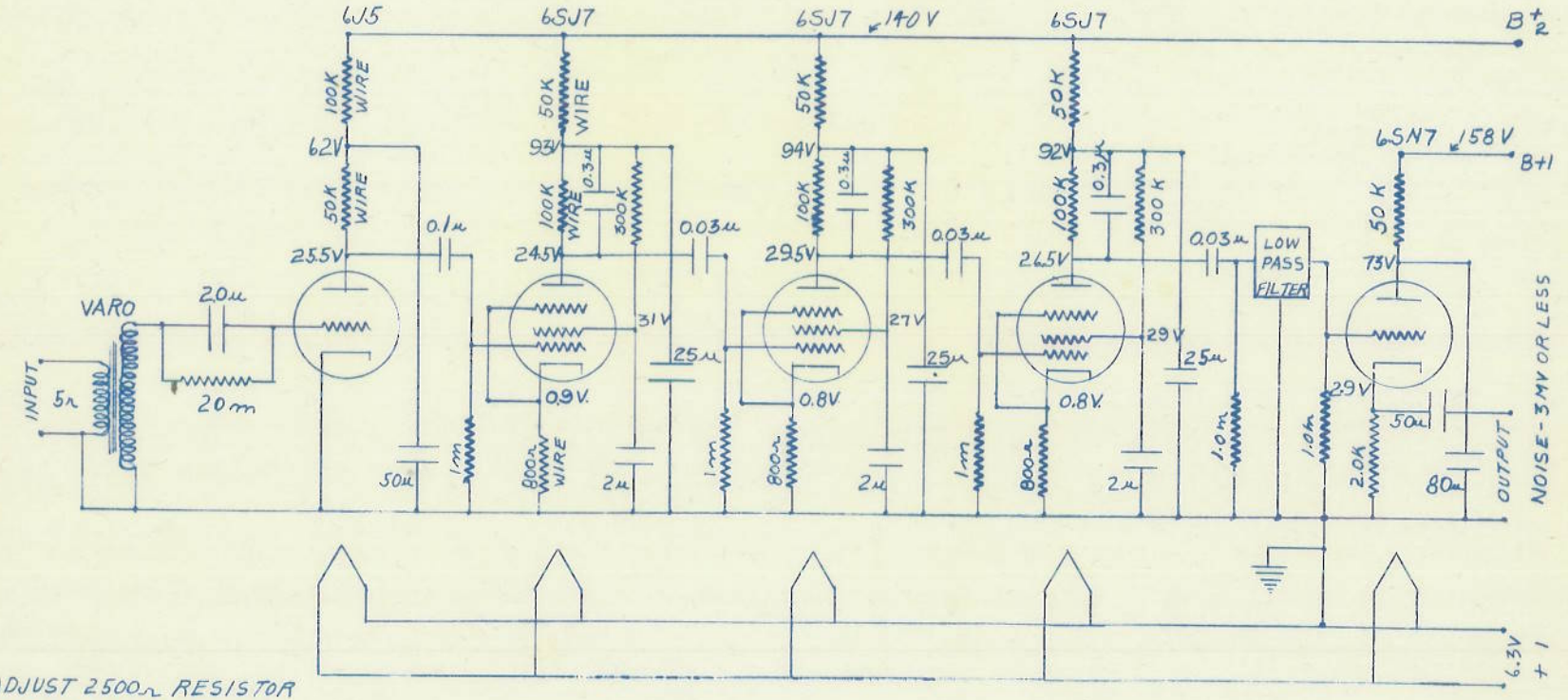
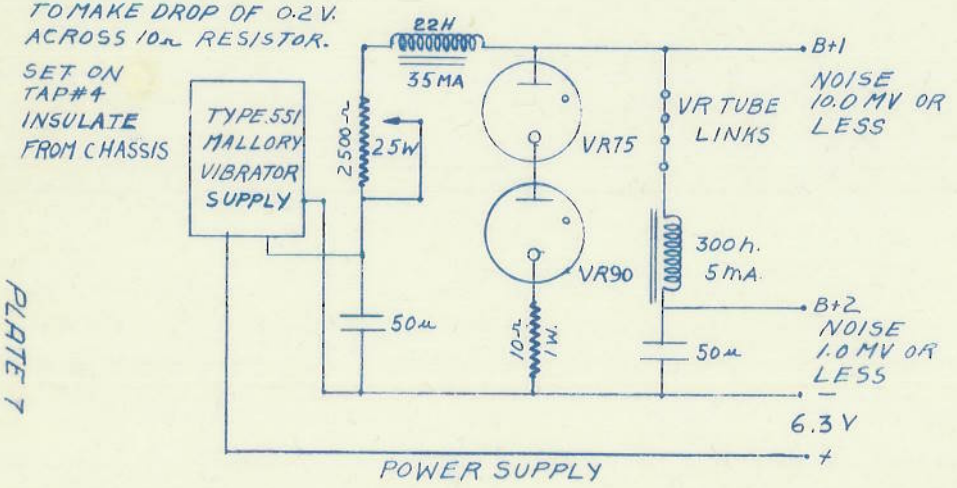
H-2764

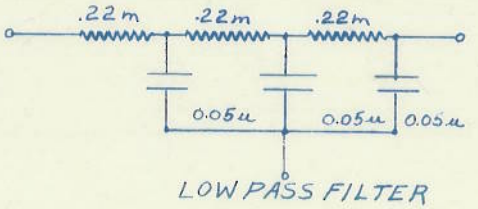


ADJUST 2500Ω RESISTOR TO MAKE DROP OF 0.2 V. ACROSS 10Ω RESISTOR.

SET ON TAP #4

INSULATE FROM CHASSIS





5cps PREAMPLIFIER

RESISTERS ARE CARBON 1W. UNLESS OTHERWISE SPECIFIED.
GROUND TO CHASSIS AT ONE POINT ONLY

PLATE 7

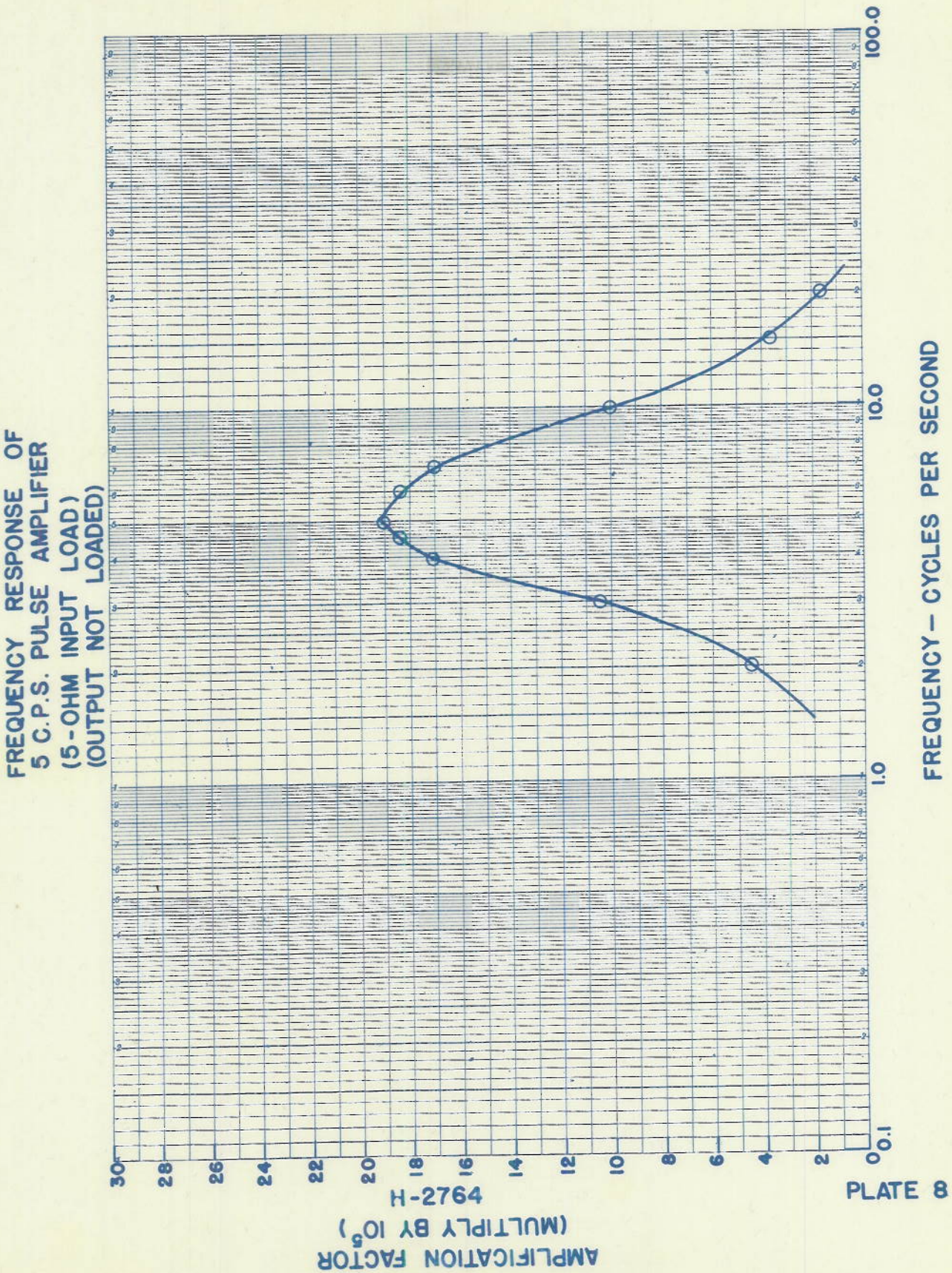


PLATE 8

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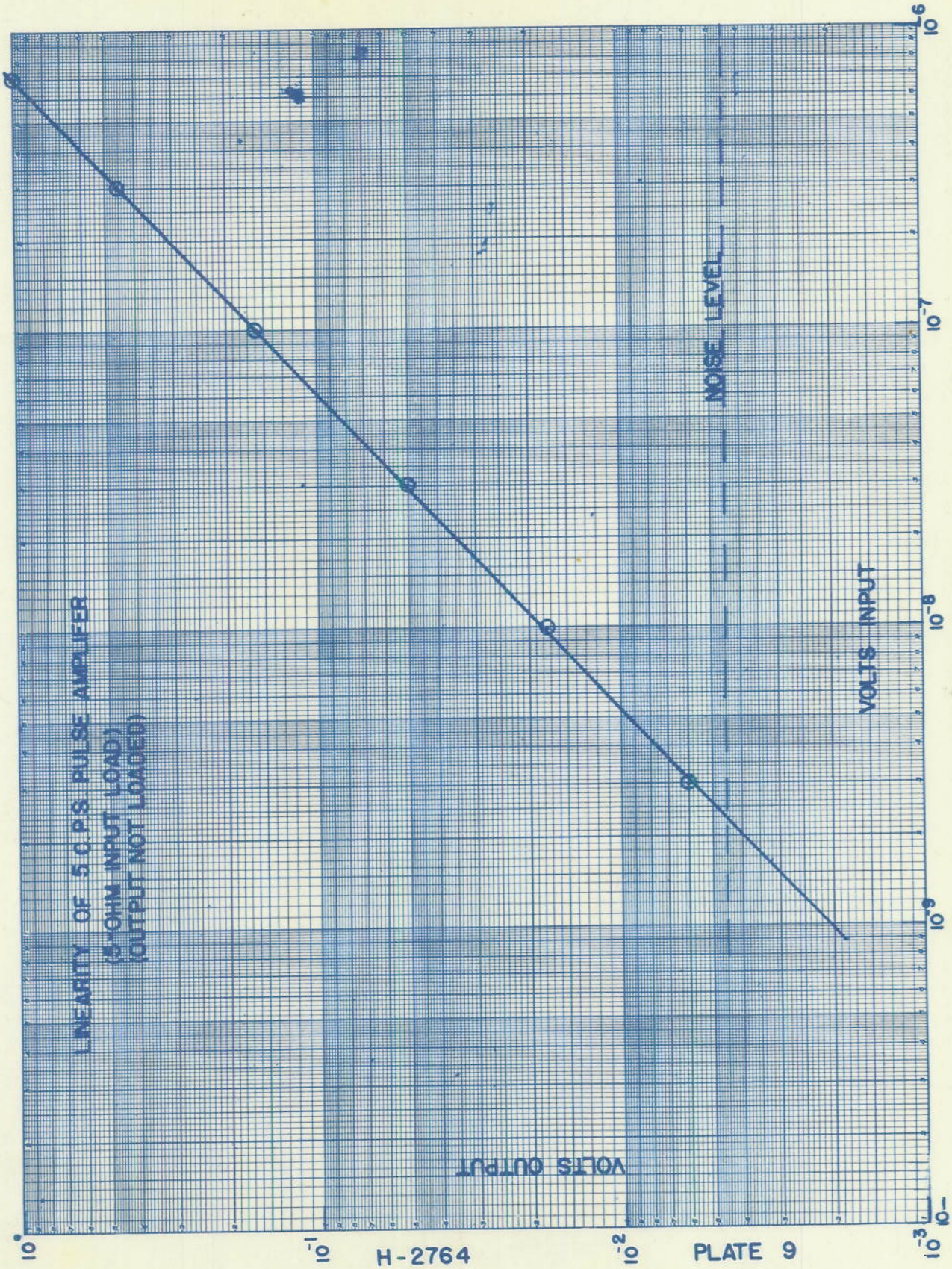

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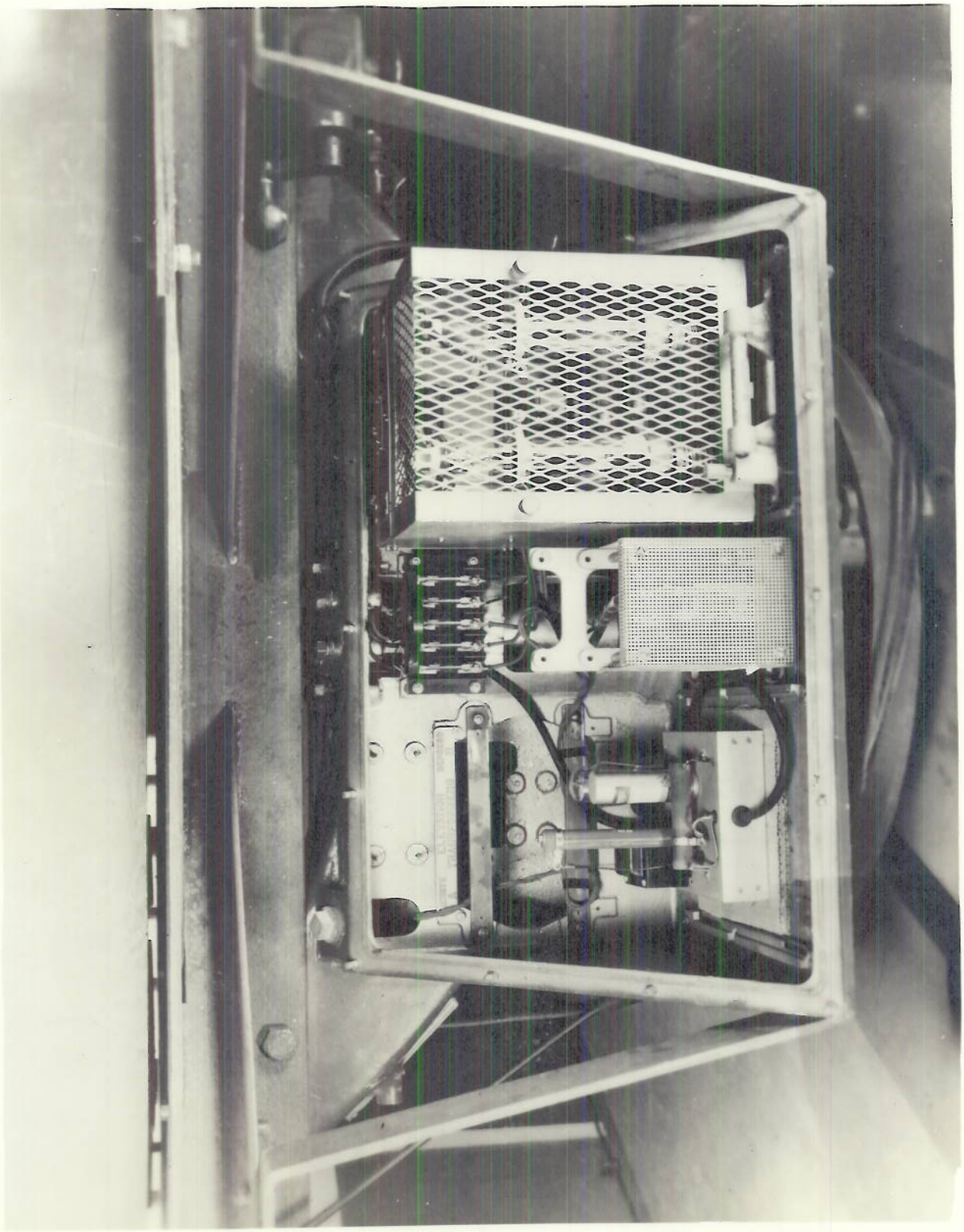

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PLATE 10A

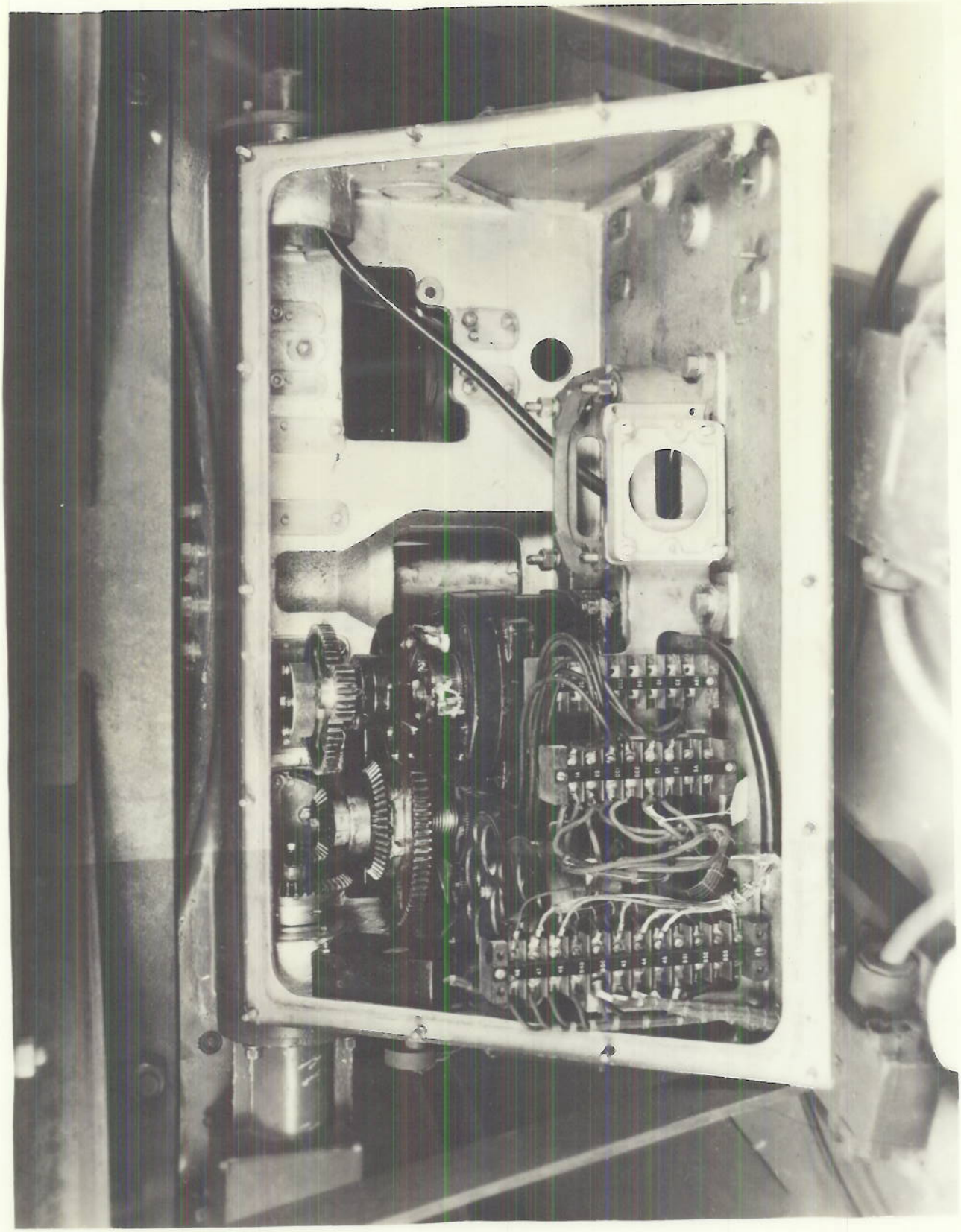

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PLATE 10B

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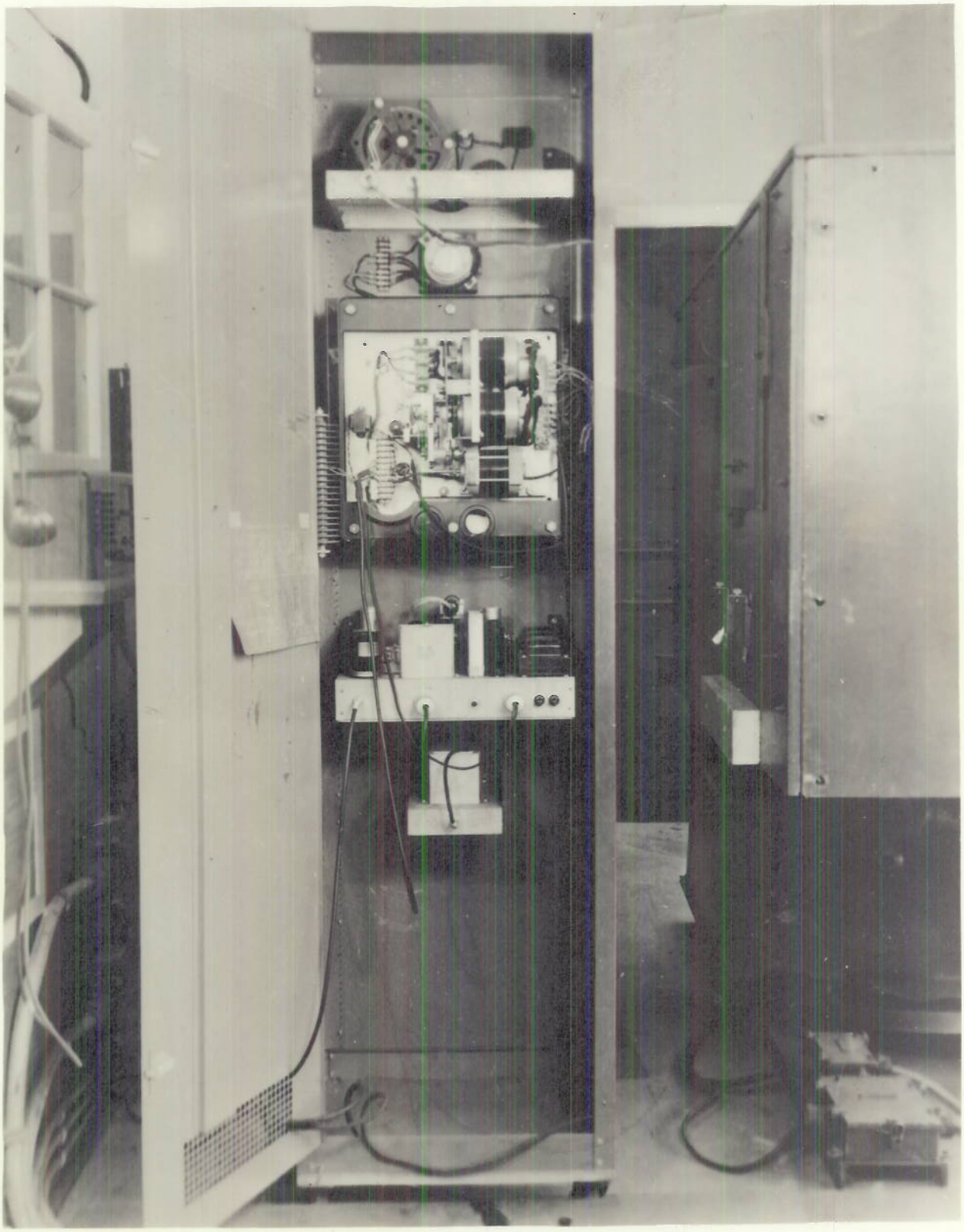

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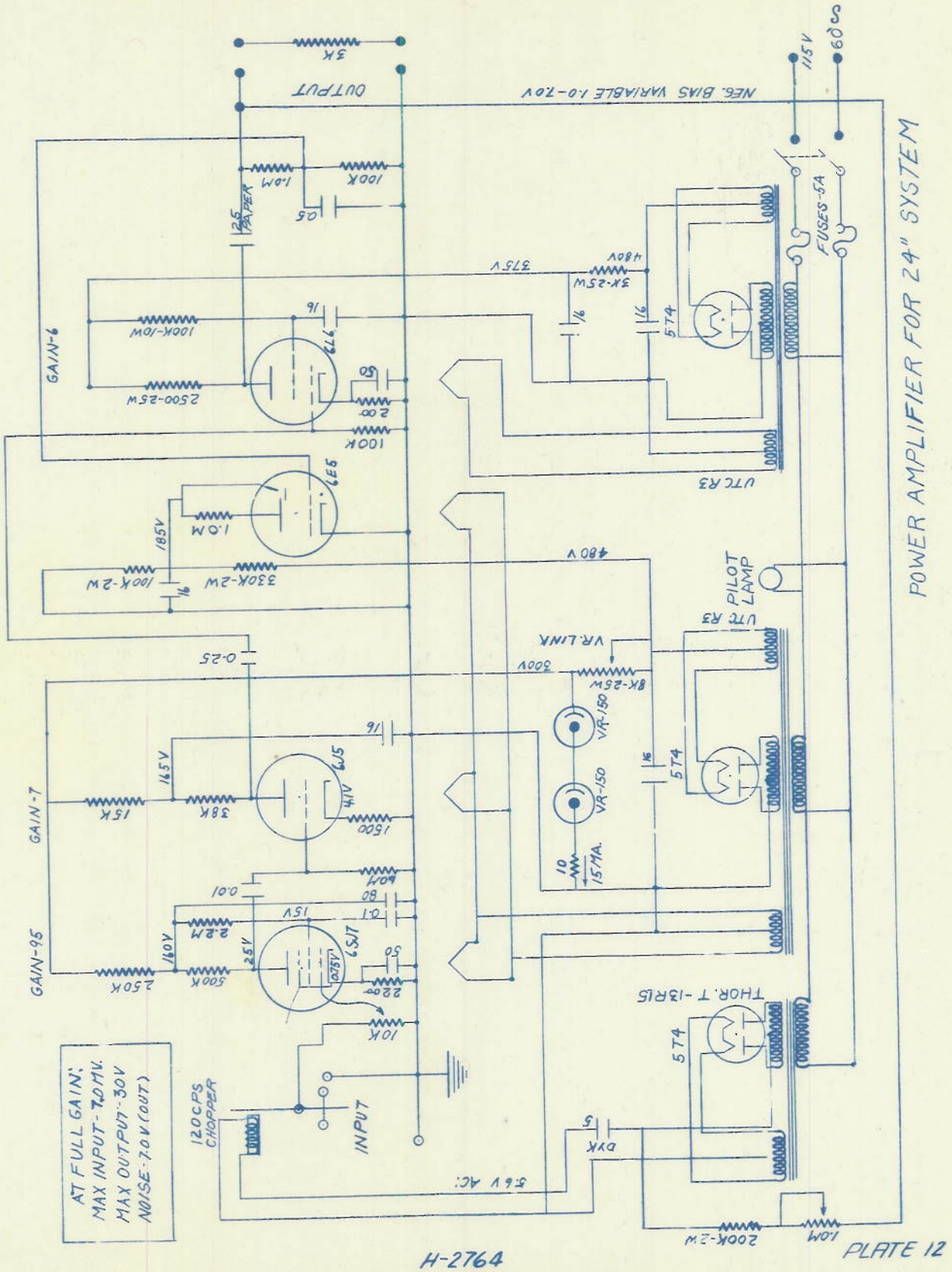
PLATE 11



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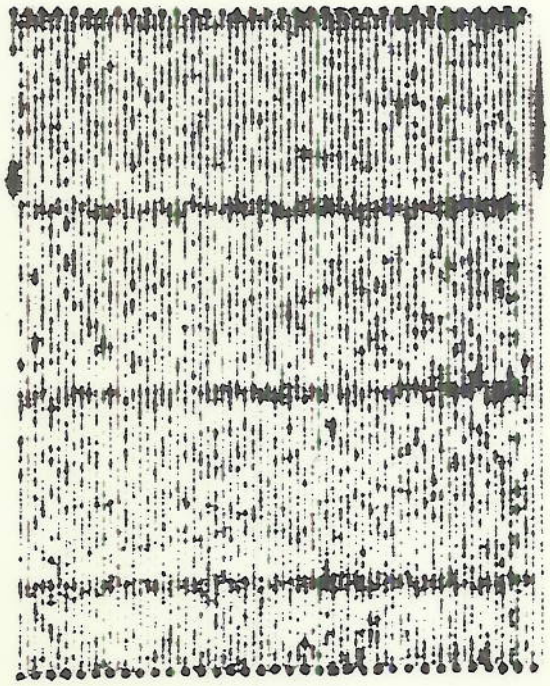
CALIBRATION



FILM

DECLASSIFIED

PLATE 13

DECLASSIFIED

PLATE 14

[redacted]

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PLATE 15

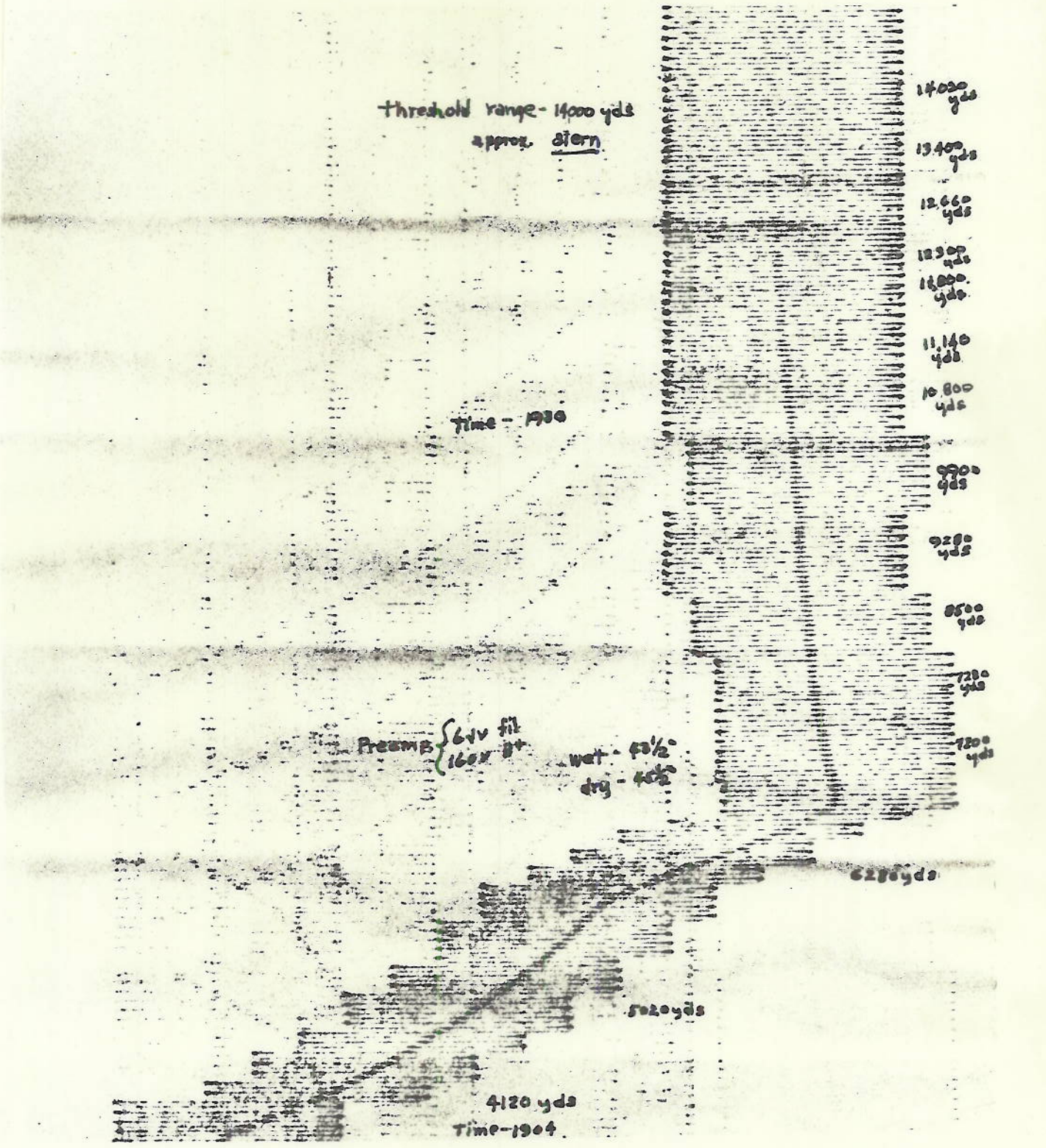

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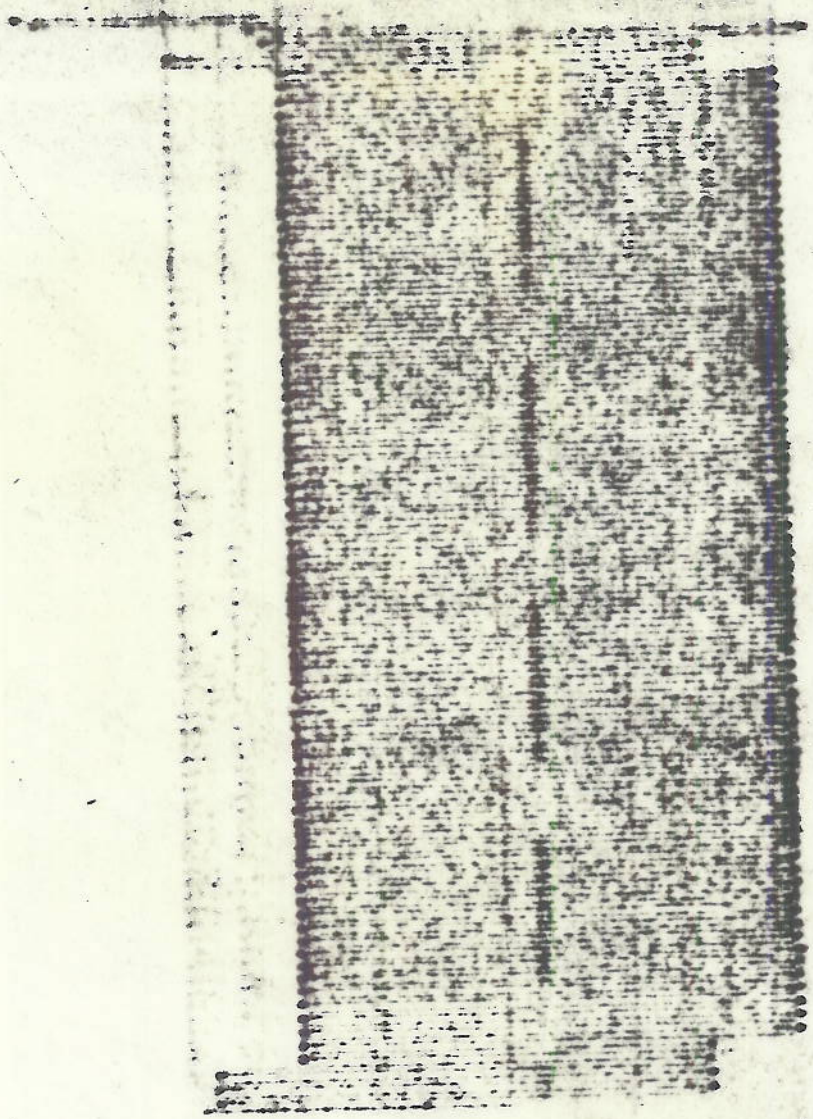
PLATE 16

Scanning Across
Overfalls Lightship
Dec 4, 1945

End



Start

Time 2200

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PLATE 17

[redacted]

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PLATE 18

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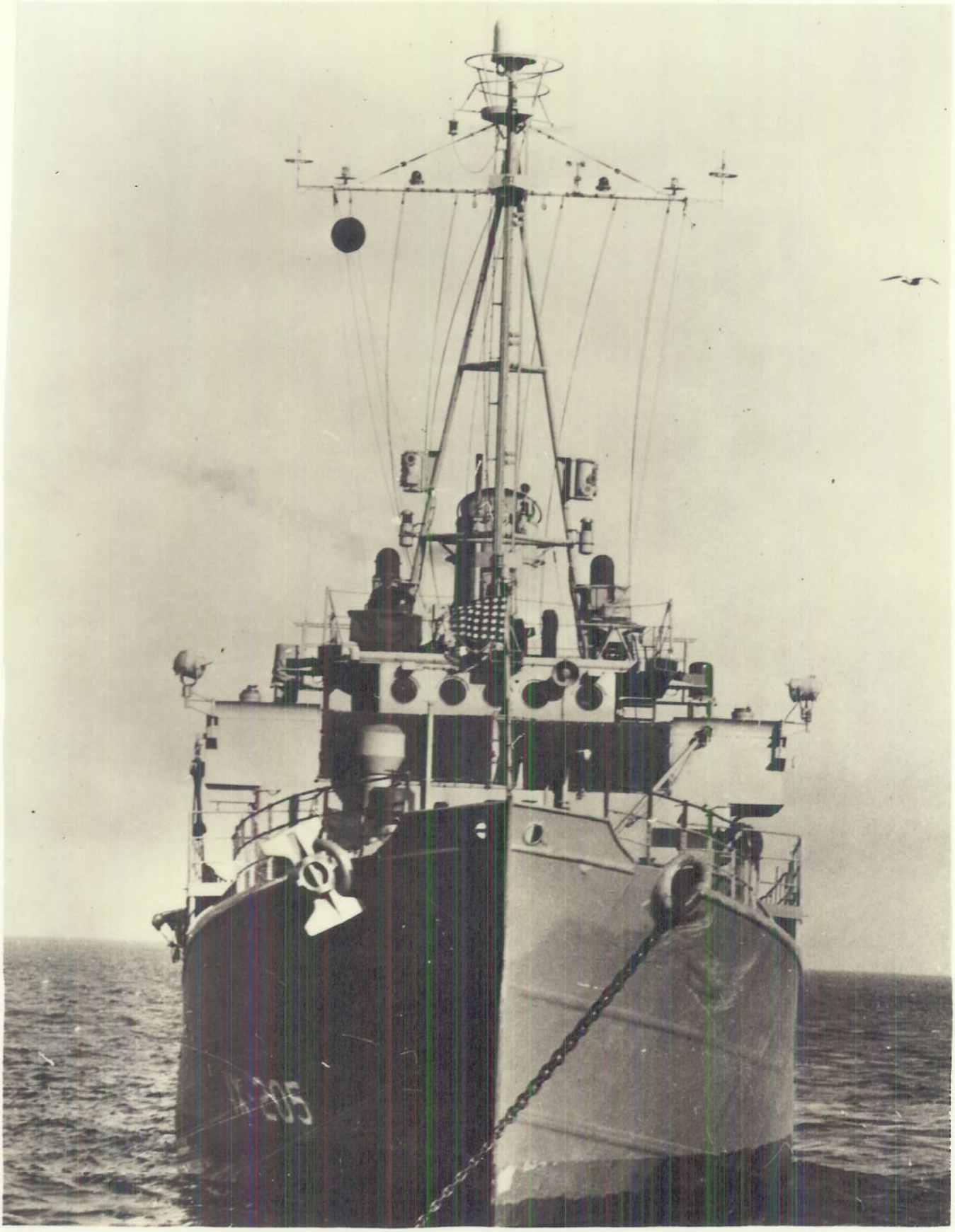

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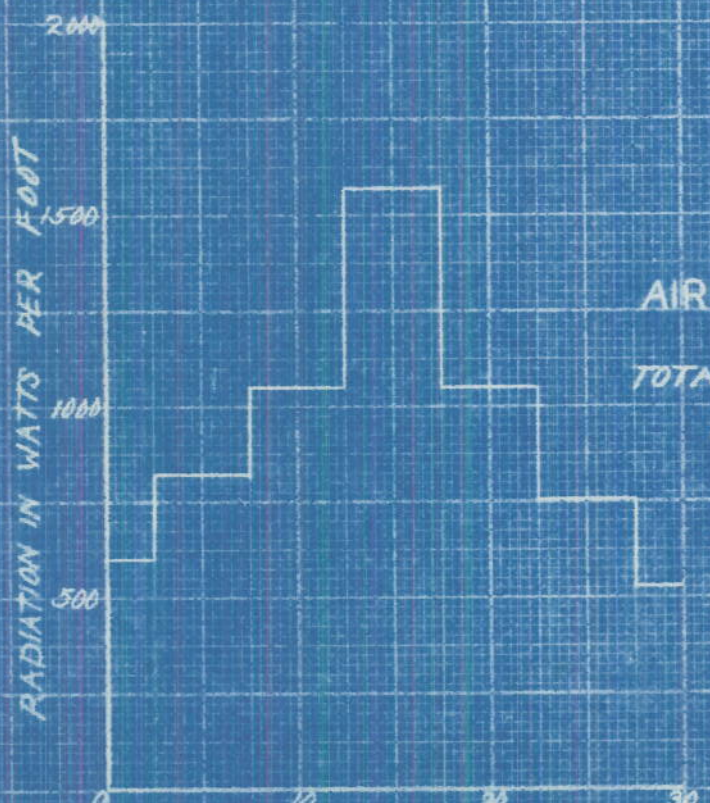
PLATE 19

[redacted]

BOW
DEC 7, 1945

Scale: 1" = 10'



AIR TEMP. 7.0°C

TOTAL RADIATION
29100 WATTS

PLATE 20

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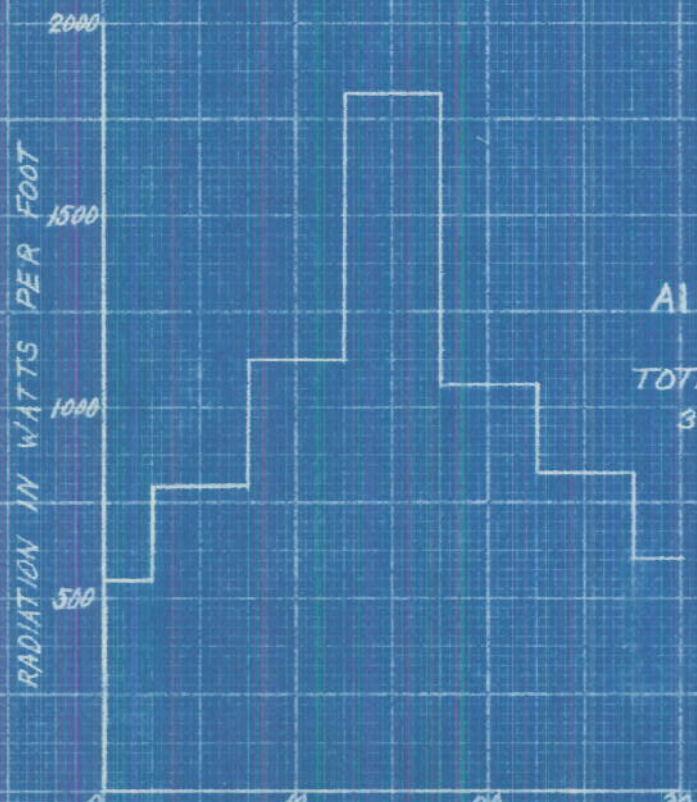
STERN
DEC 7, 1945

Scale: 1"=10'



AIR TEMP. 7.0°C

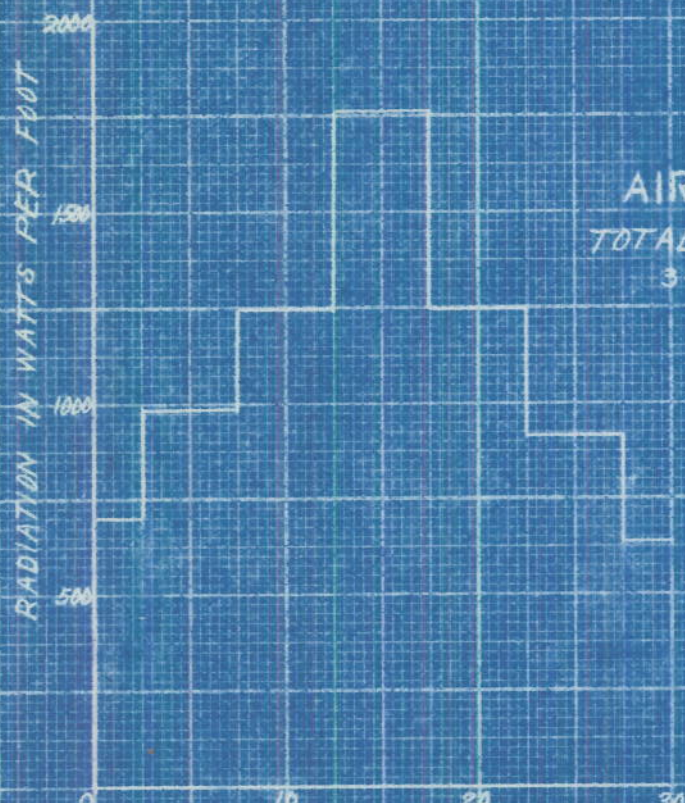
TOTAL RADIATION
31000 WATTS

PLATE 21

DECLASSIFIED

BOW
FEB 6, 1946

Scale: 1" = 10'



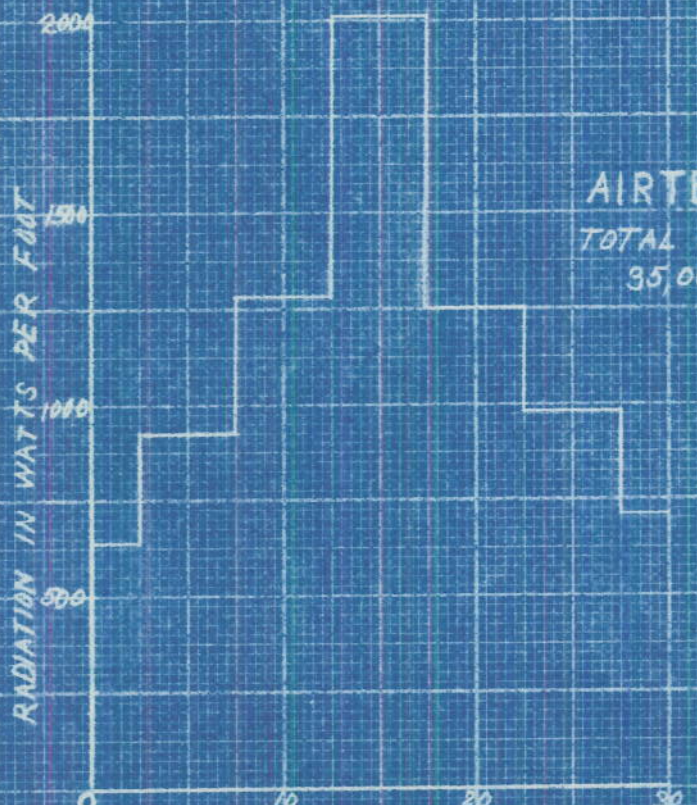
AIR TEMP. 3.4°C
TOTAL RADIATION
34,000 WATTS

PLATE 22

DECLASSIFIED

STERN
FEB 6 1946

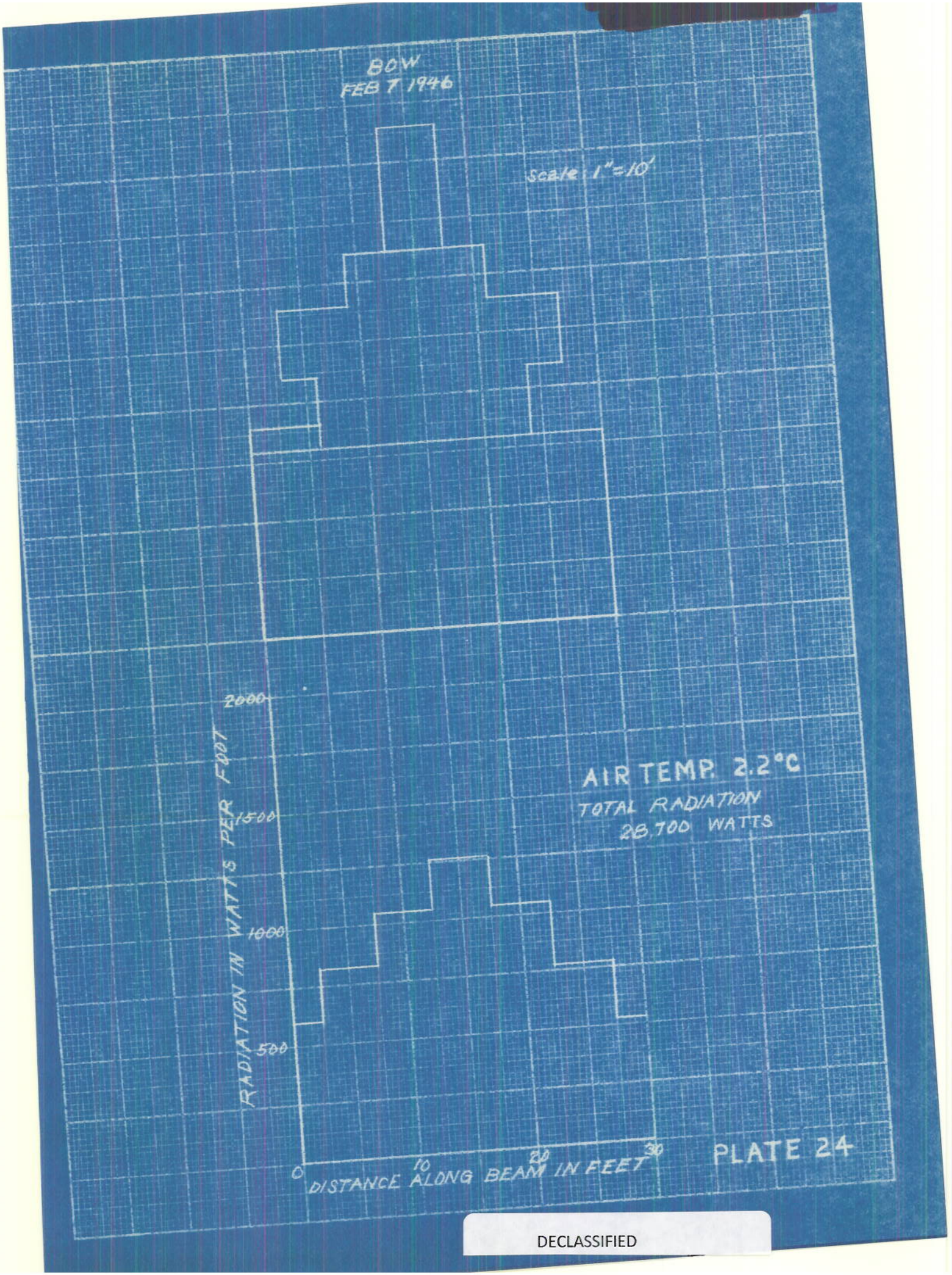
Scale: 1"=10'



AIRTEMP. 3.4°C
TOTAL RADIATION
35,000 WATTS

PLATE 23

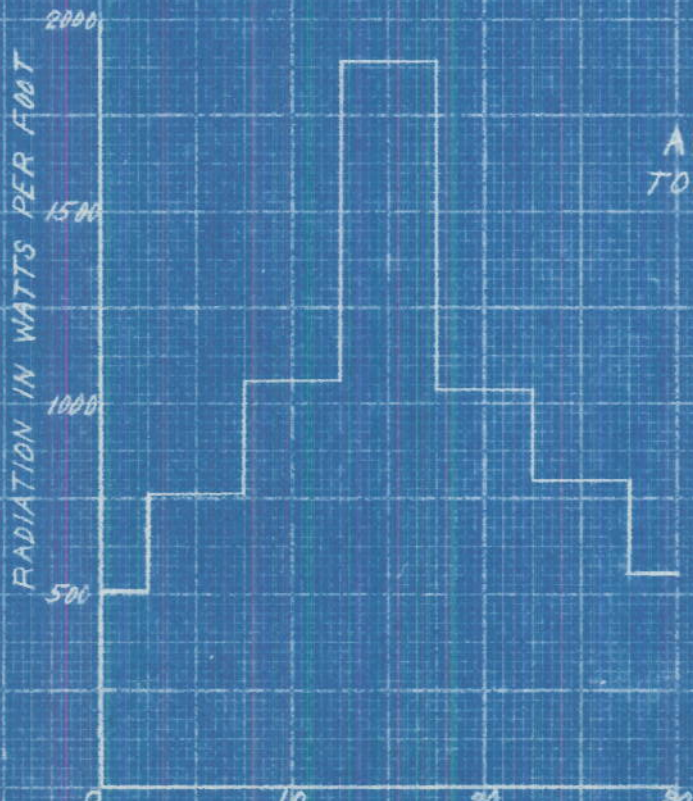
DECLASSIFIED



DECLASSIFIED

STERN
FEB 7 1949

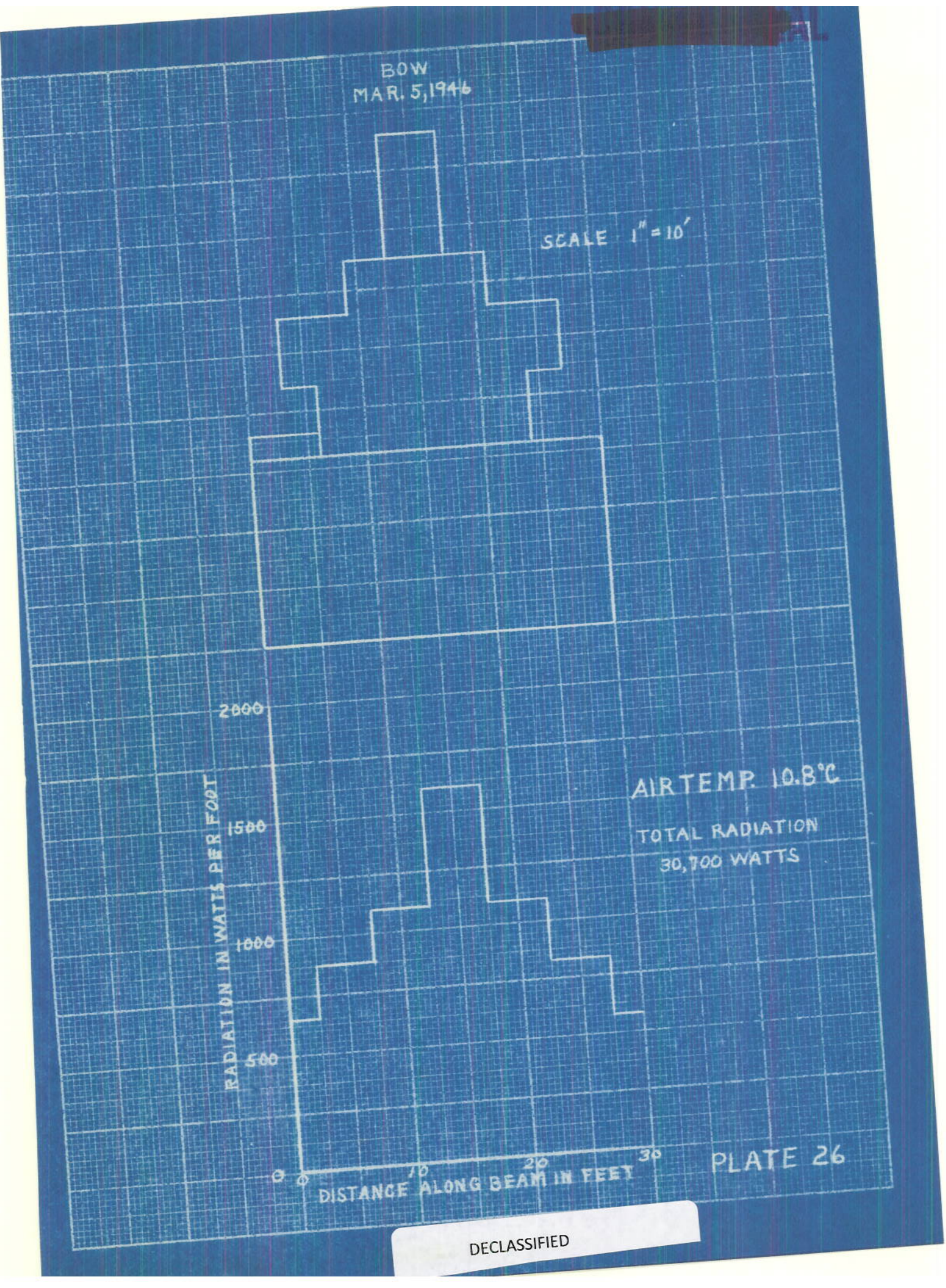
Scale: 1" = 10'



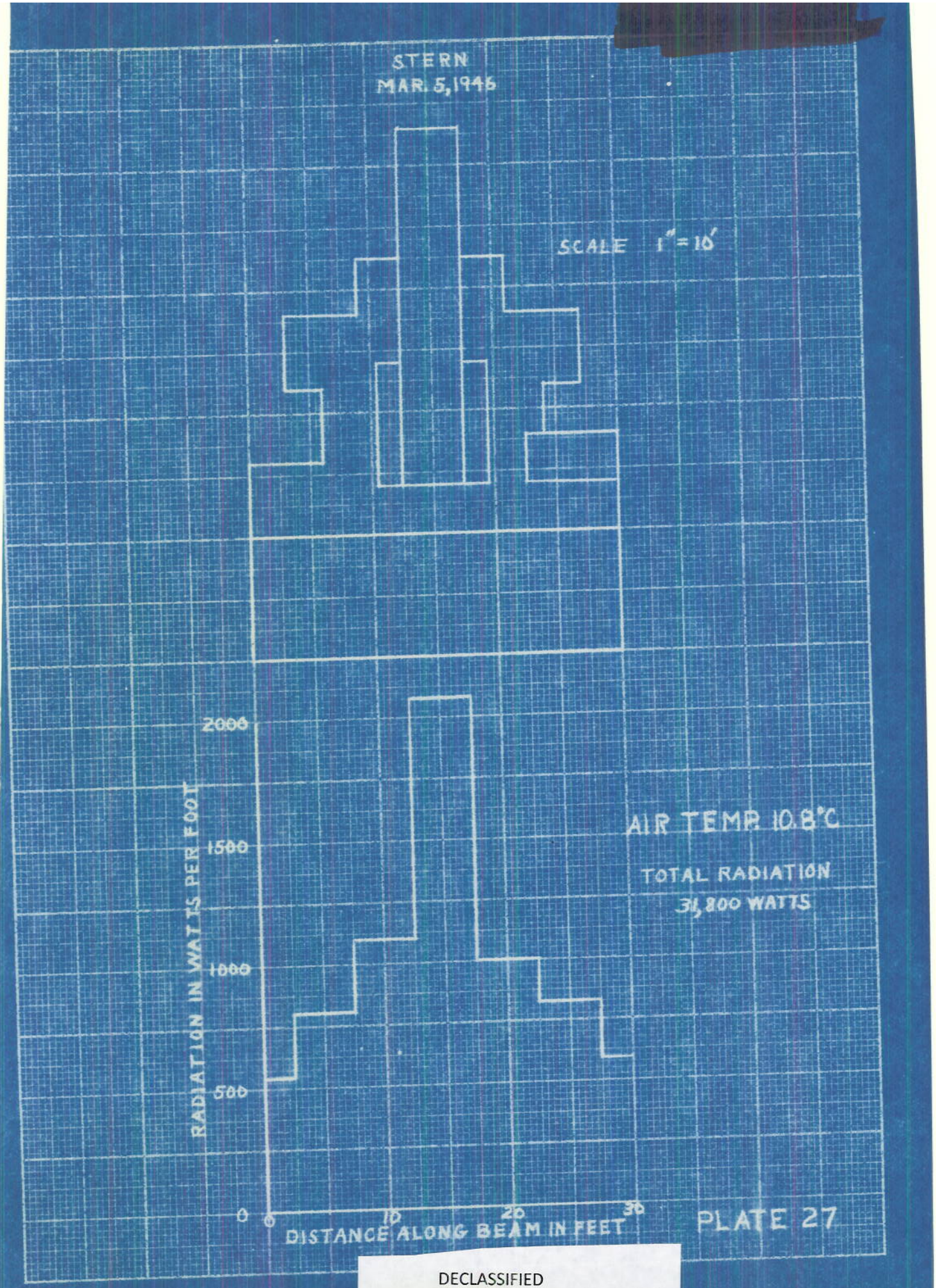
AIR TEMP. 2.2°C
TOTAL RADIATION
31,500 WATTS

PLATE 25

DECLASSIFIED



DECLASSIFIED



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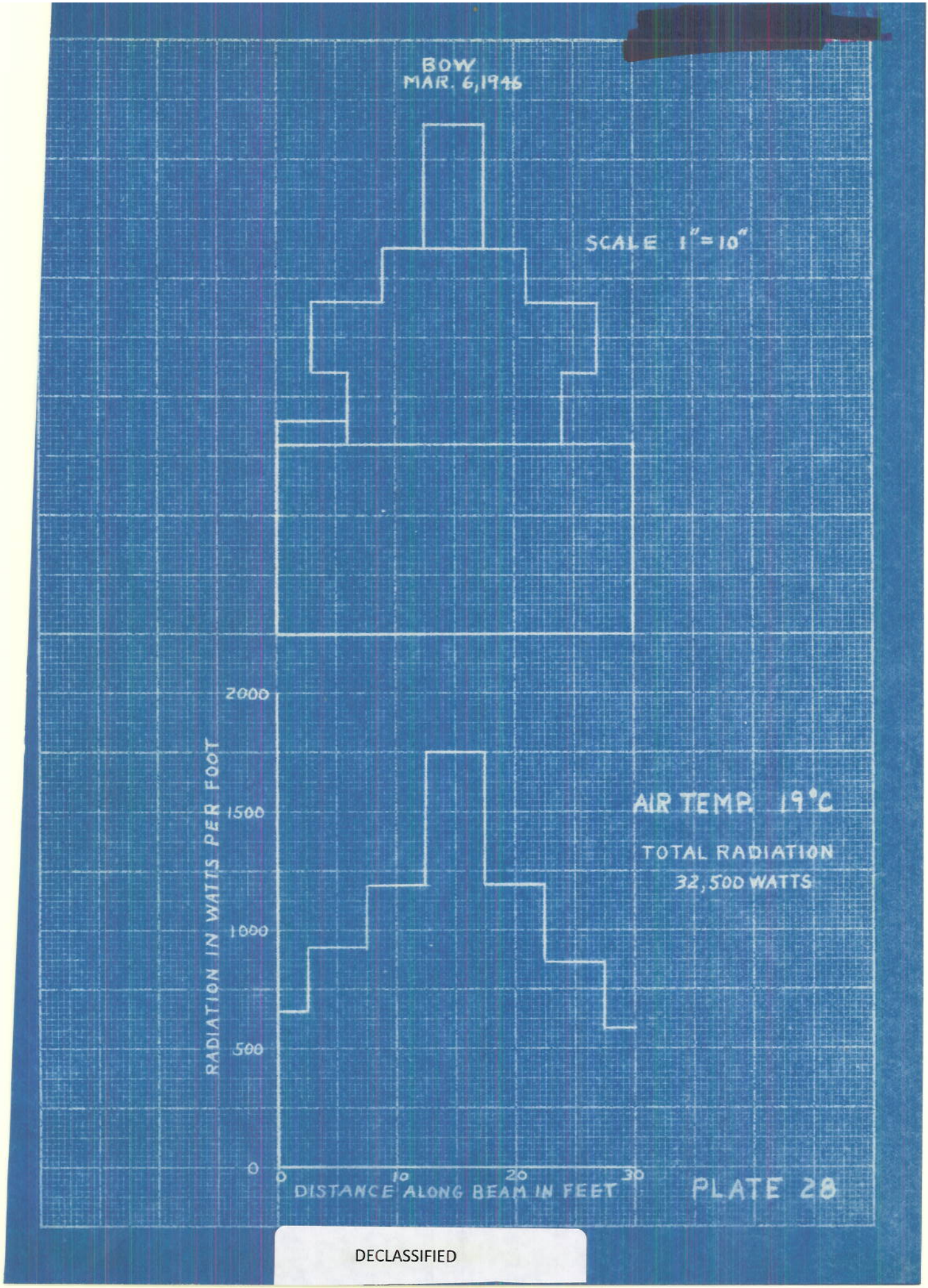

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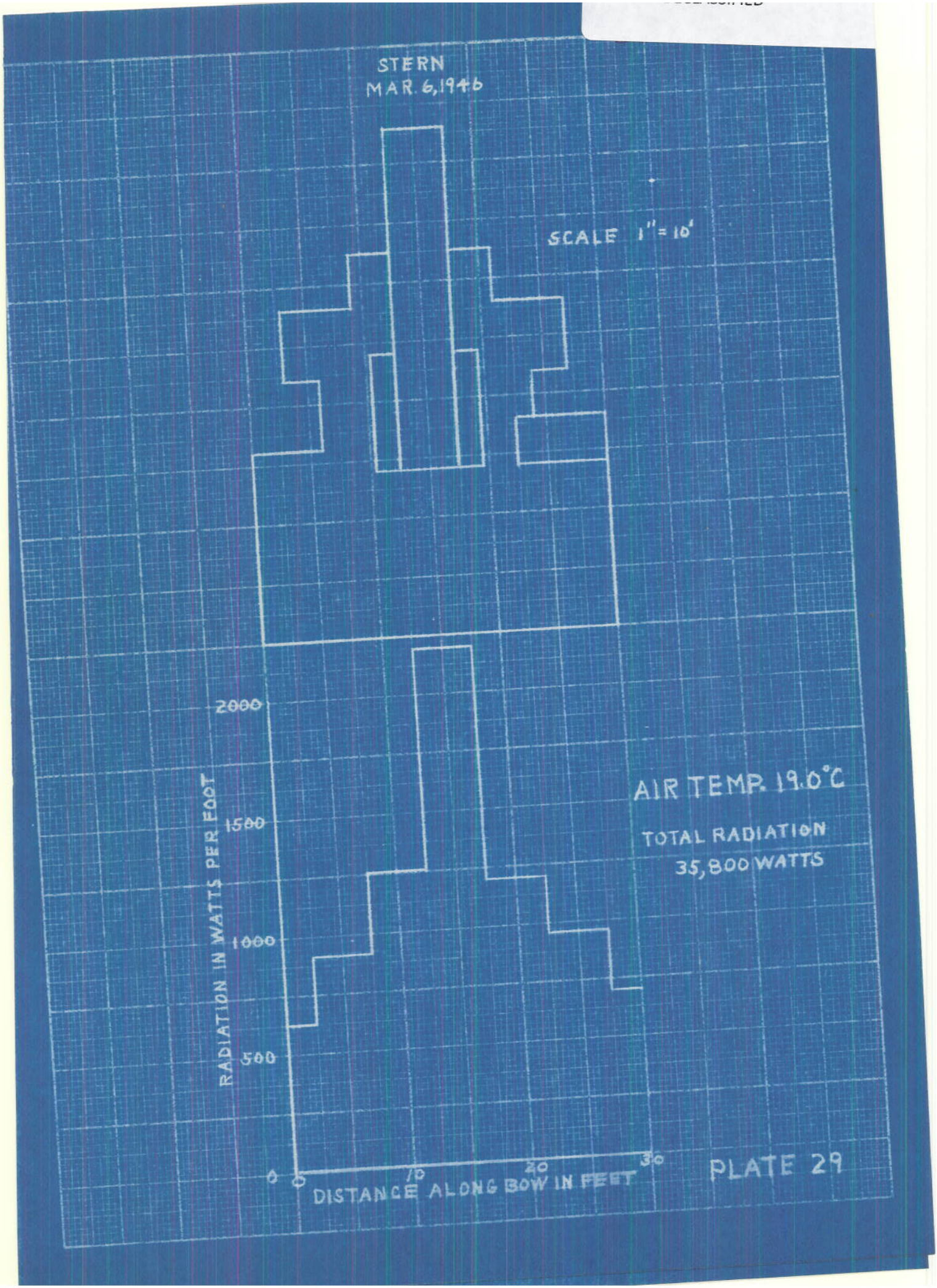
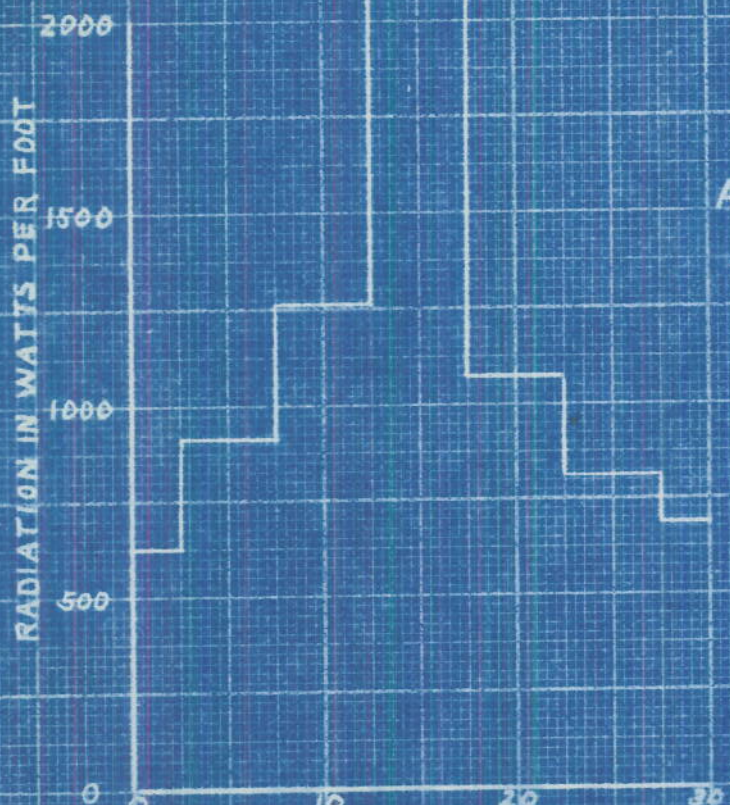

STERN
MAR. 6, 1946
SCALE 1" = 10'
AIR TEMP. 19.0°C
TOTAL RADIATION
35,800 WATTS
RADIATION IN WATTS PER FOOT
2000
1500
1000
500
0
10
20
30
DISTANCE ALONG BOW IN FEET
PLATE 29

STERN
MAR. 7, 1946

SCALE 1" = 10'



AIR TEMP. 16.7°C

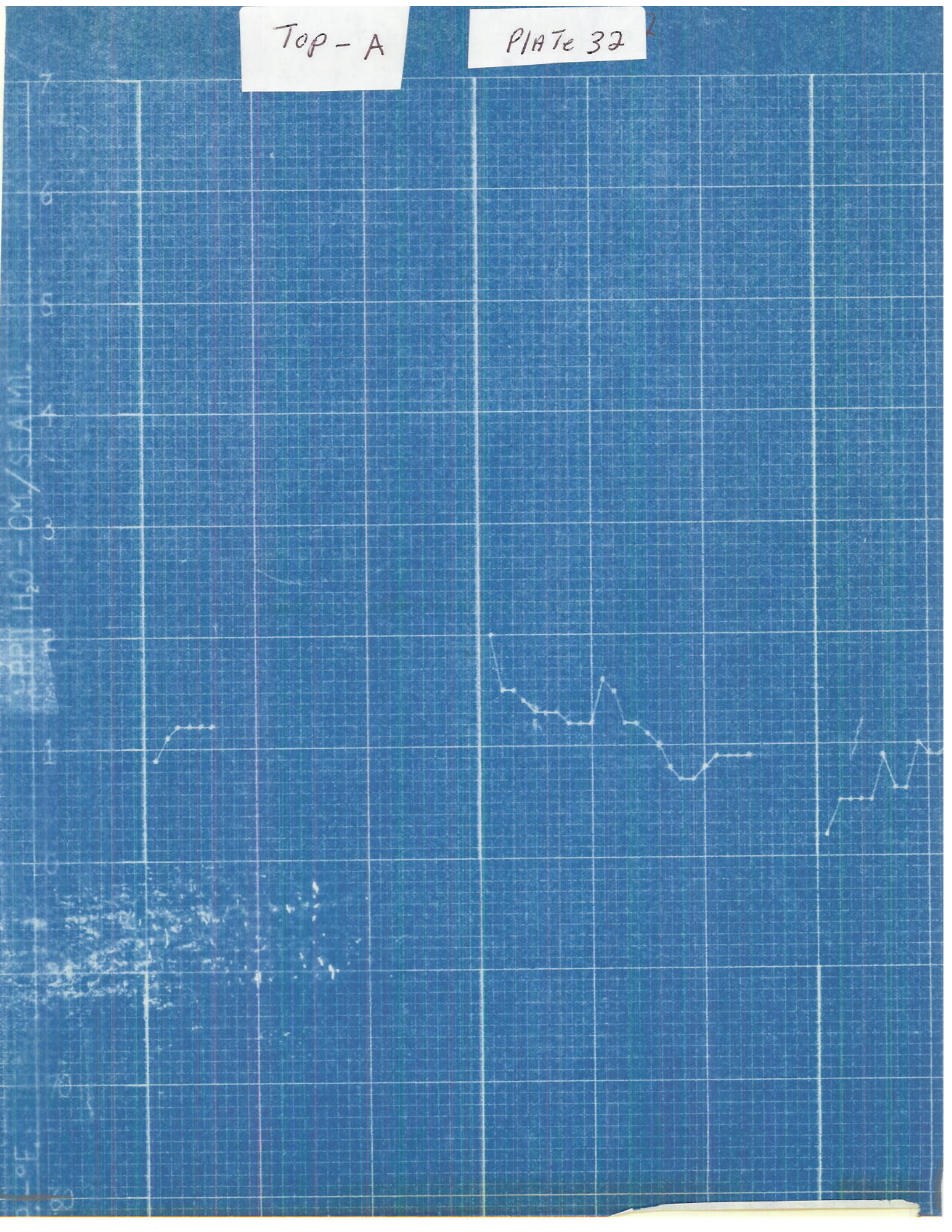
TOTAL RADIATION
35,700 WATTS

PLATE 31

DECLASSIFIED

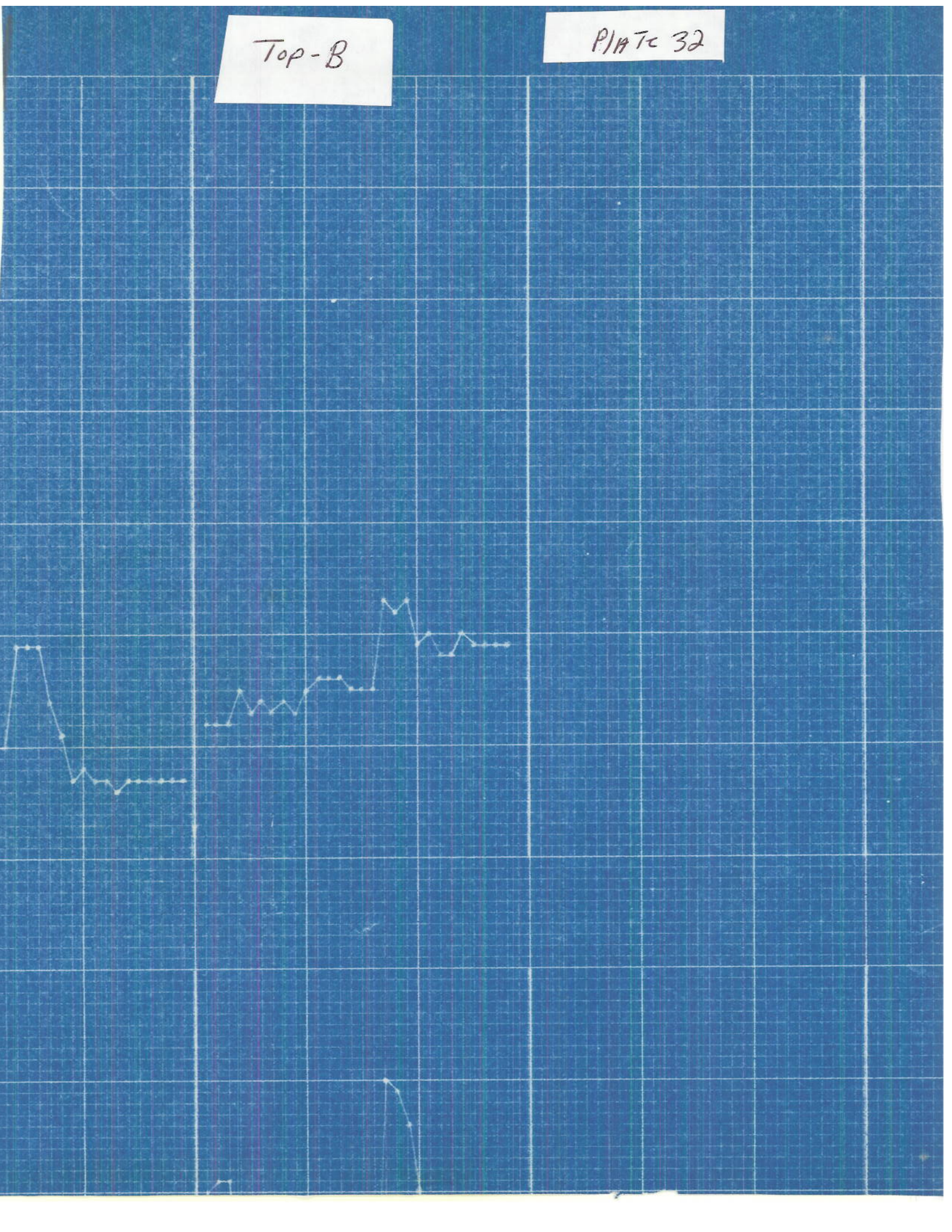
TOP - A

PLATE 32



Top-B

PlATe 32



Top-e

1945-1946

Plate 32

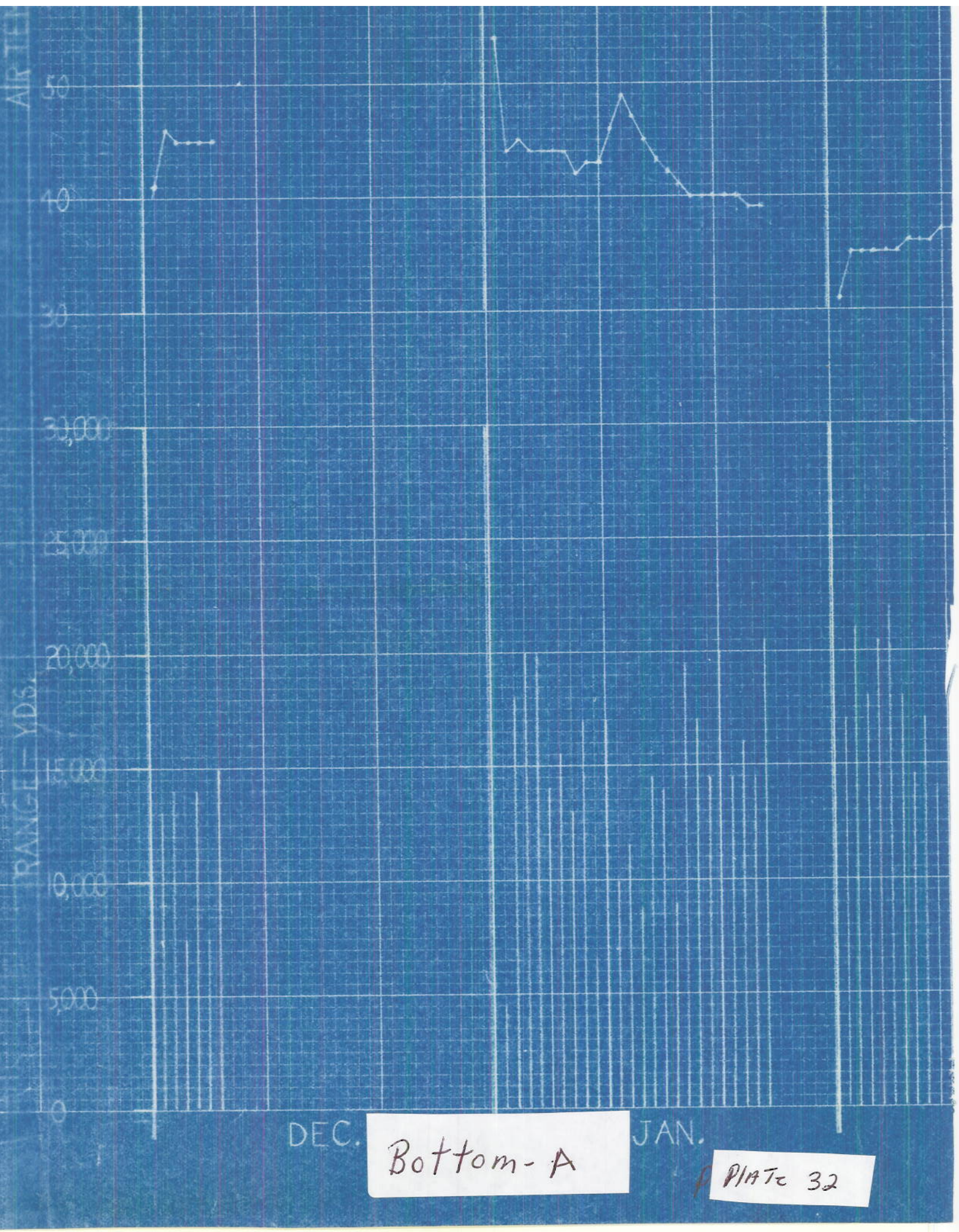
Top - D

PLATE 32

PLATE 32

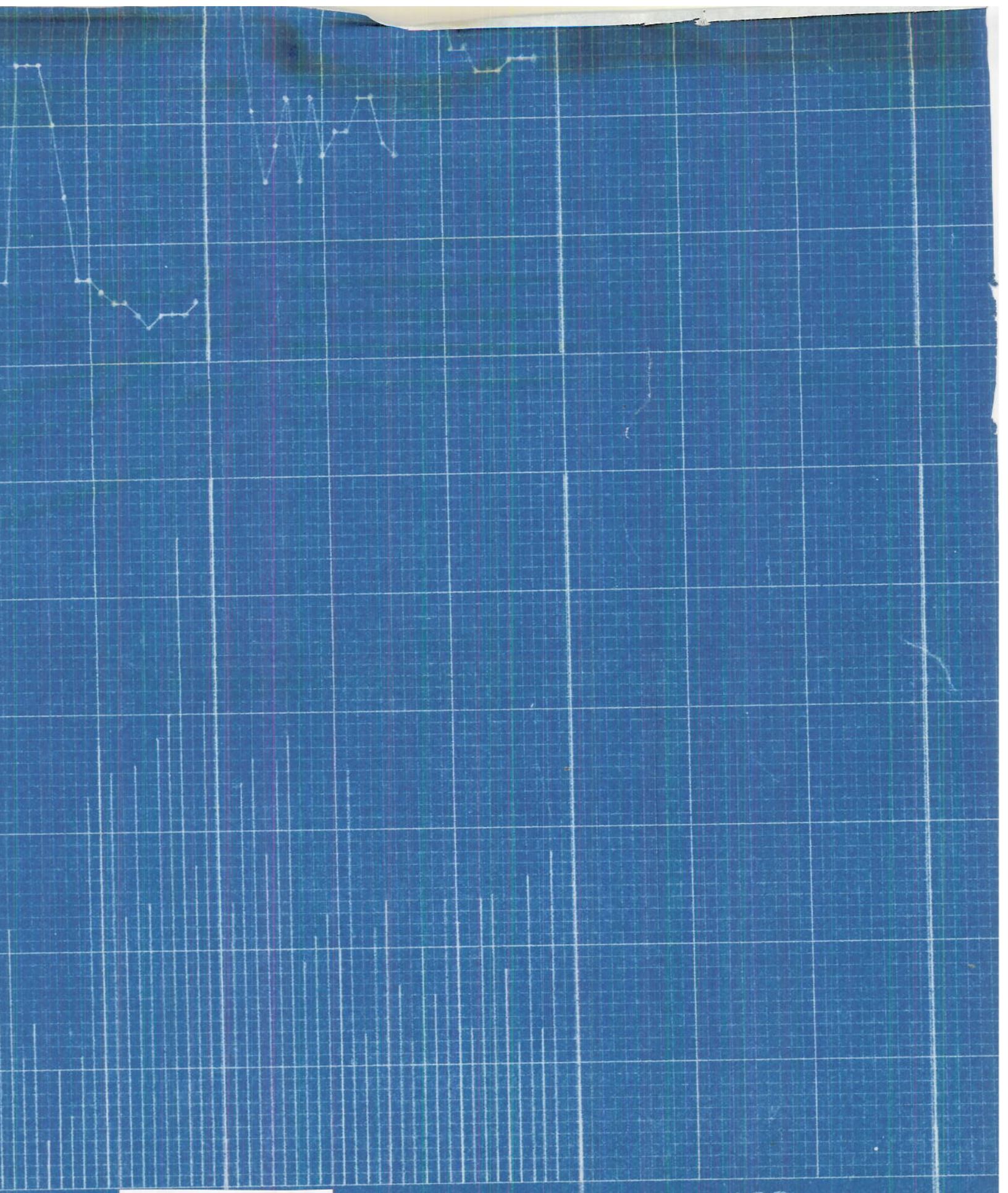
Top - E

[redacted]



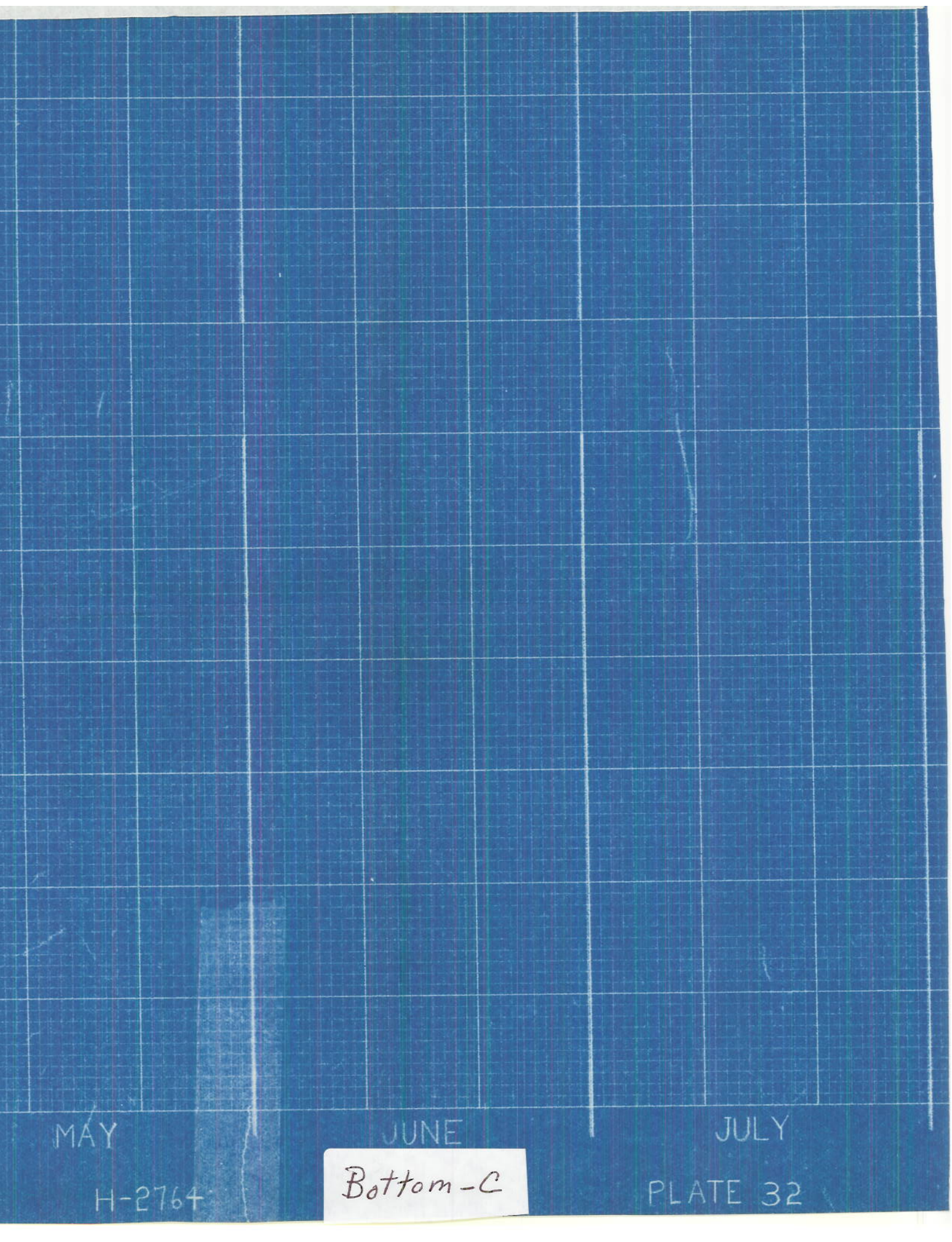
Bottom-A

PLATE 32



Bottom - B

PLATE 32


MAY
JUNE
JULY
Bottom-C
H-2764
PLATE 32

Bottom - D

AUG. SEPT. OCT.

CROSS SECTION 10 X 10.
TRADE ☆ MARK

PLATE 32

32

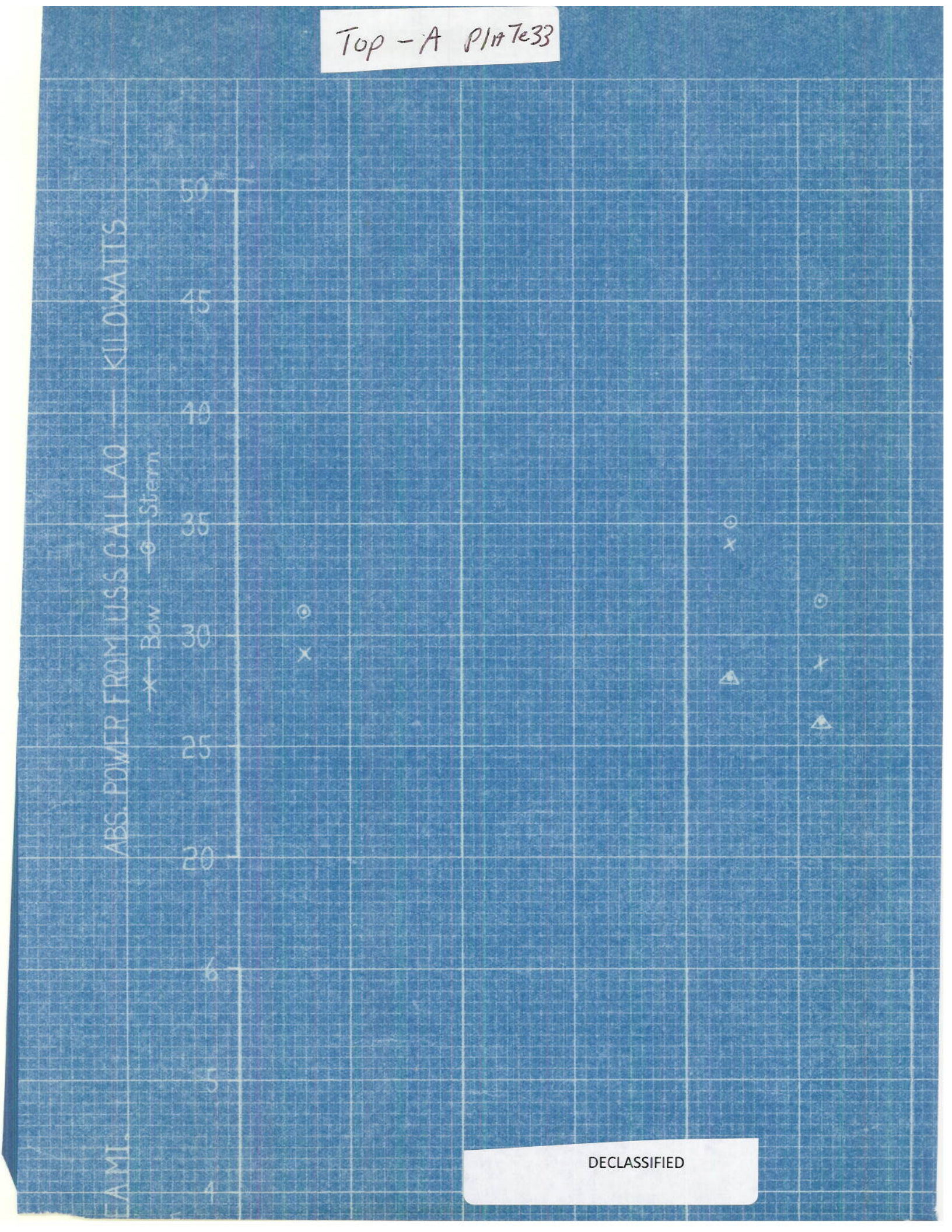
Bottom - E

NOV. DEC.

PLATE 32

DECLASSIFIED

Top - A Plate 33



DECLASSIFIED

Top - B PLATE 33

1945 - 1946

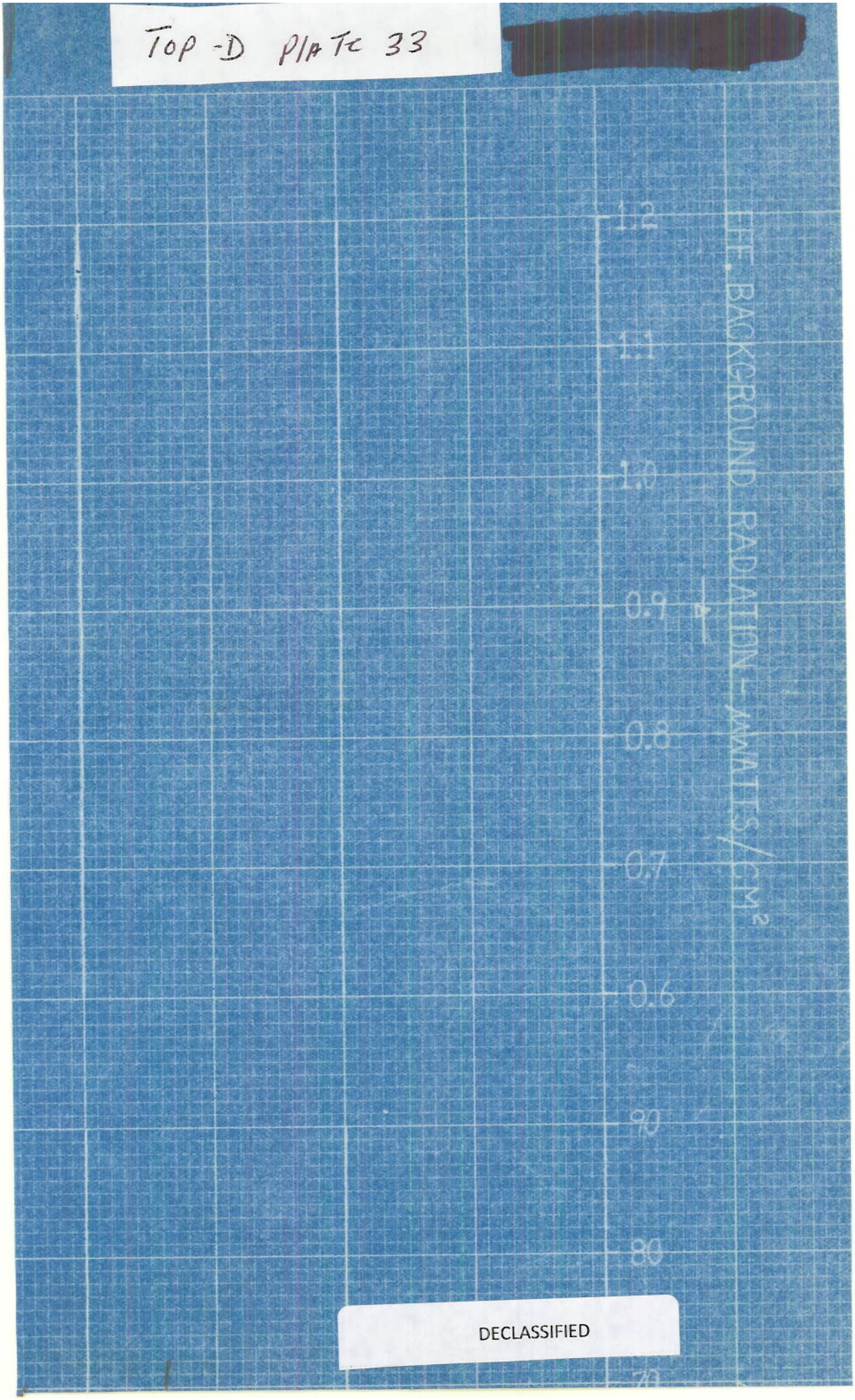
DECLASSIFIED

TOP-C PLATE 33

DECLASSIFIED

Top -D Plate 33

[redacted]



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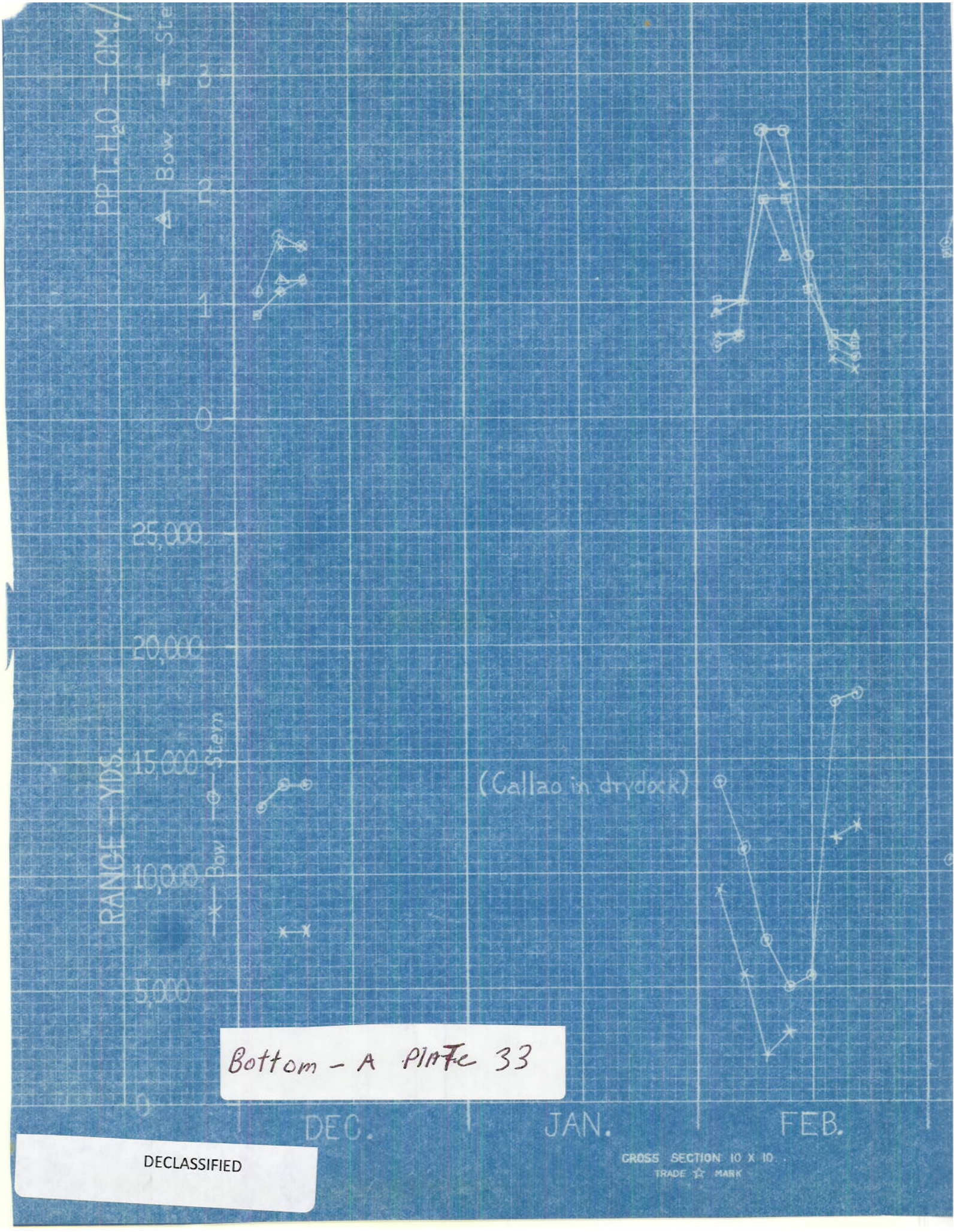
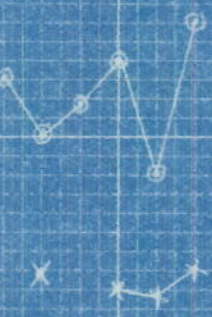


Bottom - A Plate 33

DECLASSIFIED



MAR. APR. MAY JUNE J

DECLASSIFIED

Bottom

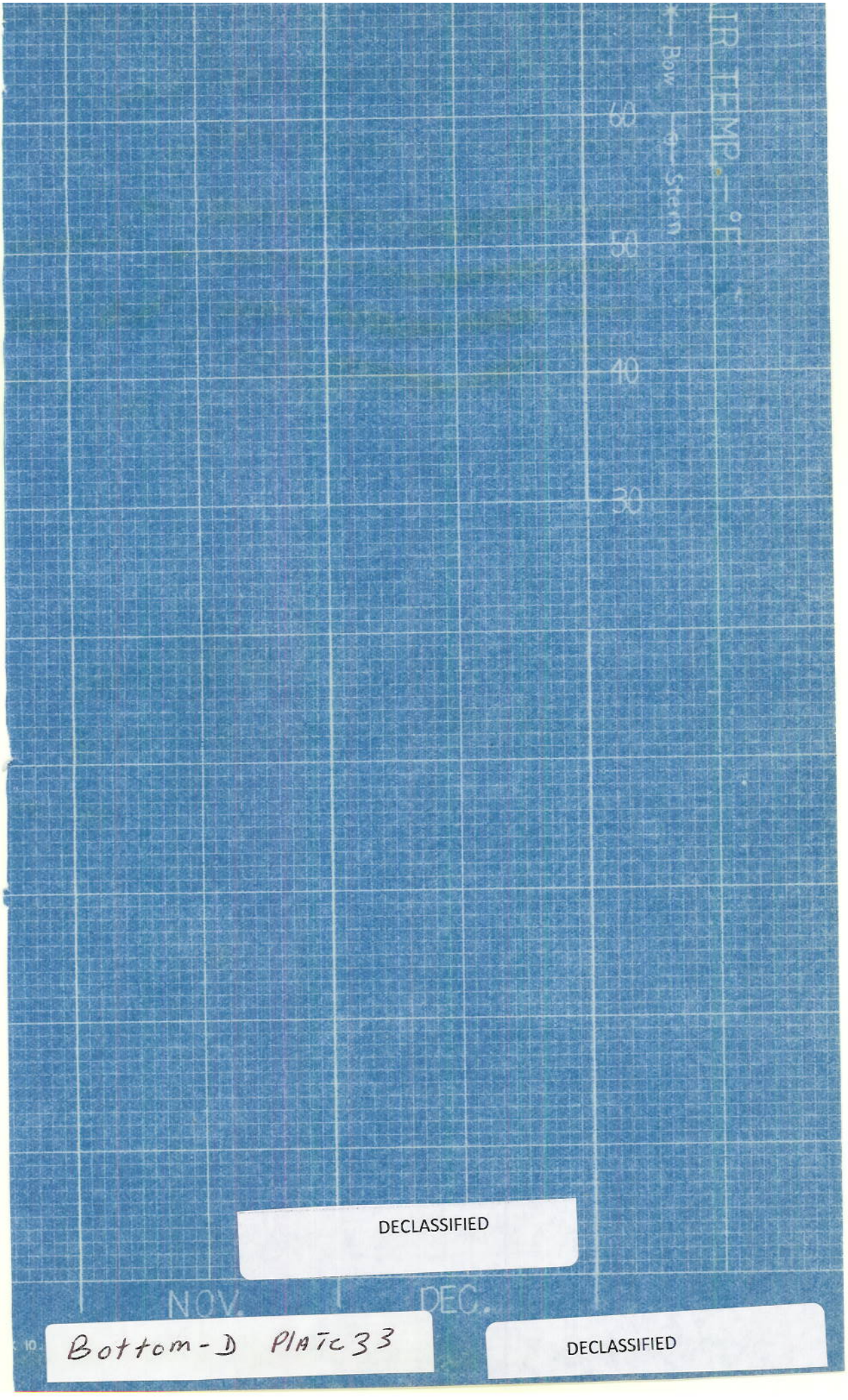
PLATE 33 H-2764

DECLASSIFIED

ULY AUG. SEPT. OCT.

Bottom - c PLATE 33

CROSS SECTION 10
TRADE ☆ MARK



DECLASSIFIED

Bottom-D PLATE 33

DECLASSIFIED

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