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FR-2559

NAVAL RESEARCH LABORATORY REPORT

1 June 1945

DEVELOPMENT OF XBF-1 L-BAND RADAR EQUIPMENT

BY
A. A. VARELA
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H. W. LANCE

Radio Division - Search Radar Section
Report No. R-2559; Problem No. S43R-S

[redacted] FR-2559

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Reviewer's name(s): A. THOMPSON, P. HANNA
Declassification authority: NAVY DECLASS MANUAL, 11 DEC 2012, 08 SERIES

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Abstract (b)
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ABSTRACT

The XBF-1 is an experimental high power L Band radar equipment designed to serve as an electrical prototype for the SR-1. The equipment covered by this report consists of a paraboloid antenna and a transceiver that operates in conjunction with the new standard SR console. Consideration of the primary design parameters as well as the development and operation of the major components is discussed in detail in the text.

The system is tunable by means of five knobs within the band 400 to 425 Mc. Pulse lengths are 1 or 6 microseconds with repetition rates of 500 or 165 respectively, and pulse power of 600 kw is obtained from a single 7C22 triode oscillator tube. The antenna consists of a 7' x 17' paraboloid illuminated by a pair of dipoles with parasitic reflectors. The beam widths are; horizontal 10°, vertical 23°, and the antenna gain is 21 db relative to an isotrope.

The modulator is of the artificial line type with discharge by means of three mercury cathode gap tubes. A tapped transformer and stepper relay provides voltage control.

The receiver has a two stage 446 tube pre-amplifier with ganged tuning. The noise factor is about 7.5 db. High cathode resistors in the i-f stages provide automatic anti-blocking characteristics. A j/s ratio of 60 db or better is obtained with strong jamming and variation in output noise level is within 2.5 db. Protection against M.C.W. jamming is provided by inductive fast time constant (F.T.C.) coupling from the detector and suppression of nearby clutter (S.T.C.) is accomplished without introduction of extra tubes by deriving bias on two i-f stages from the synchronized pulse.

Performance to be expected from the system is discussed and by detailed comparisons with other systems it is shown that maximum ranges superior to the SK-2 could be expected. Actual tests with aircraft targets at known altitudes showed results far inferior to those anticipated however and a maximum reliable range of about 100 miles. Further investigation of the system was precluded by the decision of the Bureau of Ships not to utilize the 400 Mc band for air search radar.

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1. INTRODUCTION.

1-1. Authorization and References. The equipment described in this report was developed under the authorization of NRL Problem S43R-S in accordance with the letter of reference 1. This and other references pertinent to this report are contained in the list of References which follows the text.

1-2. Problem Scope. NRL Problem S43R-S calls for development and construction of models of high power ship-borne radar equipment for aircraft early warning and fighter director service operating in the frequency bands 400-425 Mc and 550-650 Mc and to operate in conjunction with the SR standard indicator and control console. Progress on the problem was held up by the lack of suitable transmitter tubes and two false starts on the transmitter were made with tubes that proved unsuitable. Construction of the XBF-1 transmitter around the 7C22 tube was begun in February 1944 while that tube was still in the development stage.

1-3. Nature of the XBF-1. The XBF-1 operates on the 400-425 Mc band and is believed to meet the requirements of the problem. To expedite its completion it was constructed with the intent that it serve as a reliable operational model rather than as a mechanical prototype. However, considerable thought was given to arrangement of components from the viewpoint of accessibility and ease of operation, and mechanically important parts such as the oscillator tube mounting, high voltage connectors, and the r-f plumbing were carefully designed and constructed with the intent that they serve as prototypes.

2. GENERAL DESIGN CONSIDERATIONS.

2-1. Desired Detection Range. Maximum reliable ranges of aircraft detection required of the subject equipment were not specified in the problem request and the performance desired has been gleaned from numerous operational sources. The British Admiralty has concluded (Ref. 6) that a reliable early warning range on high flying aircraft of 120 n. miles is required by aircraft carriers. In our Fleet the SK appears to have adequate sensitivity for general search service. Tests at Chesapeake Bay Annex show that when operating properly the SK should have a reliable range of at least 130 n. miles for planes above 15,000 ft., but the average reliable range from fleet reports during 1943 (Ref. 7) was only 85 n. miles. This undoubtedly includes numerous instances of planes at less than 15,000 ft., but even so the reports indicate that the general level of performance must be far below optimum. It was concluded then that the XBF-1 should have a reliable detection range on high altitude planes of at least 100 n. miles and preferably 120 n. miles coupled with a higher degree of performance reliability than is shown by existing systems. This performance standard obviously required design of the system to give maximum practical power and sensitivity.

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2-2. Gain Limitations. Antenna gain is limited by practical considerations of permissible size and allowance for ship roll. With a 17 ft. x 7 ft. antenna the XBF-1 was expected to have a disadvantage of about 5 db in effective antenna gain compared to the SK and 3-4 db must be allowed for solid dielectric cable loss. Other than improvement in alignment stability and reliability there was no hope for appreciable gain in the receiver sensitivity. It was therefore thought necessary to use the maximum pulse energy practicably obtainable.

2-3. Pulse Lengths. It has been shown (Ref. 8) that the effect on minimum detectable signal of a radar receiver by bandwidth, pulse length and repetition rate may be described by the following empirical relationship:

$$e_{min} = K \left(B^{\frac{1}{2}} + \frac{1}{TB^{\frac{1}{2}}}\right) \left(\frac{1640}{F}\right)^{1/5 \text{ to } 1/8}$$

where B = receiver band width

T = pulse length

F = repetition rate

and the exponent of the final factor decreases as the oscilloscope screen persistence increases. In the interest of sensitivity therefore it is desirable to use as long a pulse as possible. However lengthening the pulse brings objections:

(a) Target definition and discrimination are reduced.

(b) To avoid exceeding average power limitations the repetition rate must be reduced and it is undoubtedly true that operator fatigue rate becomes greater with lowered repetition rate, particularly below 150 cycles.

(c) Optimum receiver band width is inversely proportional to pulse length and hence allowable frequency drift or allowable tuning misalignment decreases proportionately.

(d) Effective emission from an oxide cathode decreases.

(e) Frequency modulation increases while the tolerable limits decrease.

Six microseconds at 180 per second was chosen as the most likely compromise, the 7022 oscillator and the modulator switch gaps being the primary limiting factors. A one microsecond pulse at 500 cycles was also provided to give improved target discrimination. The duty cycle was made smaller with the short pulse to allow about 20% increase in the pulse power which is feasible because of the reduction in emission requirements and point discharge tendencies in the oscillator tube.

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2-4. Transmitter Power Requirement. In order to eliminate installation and leakage difficulties of pressurized transmission line the Bureau of Ships asked that polyethylene cable be used in this system. Allowing for 100 ft. of RG-20/U this introduces a loss of between three and four db. With consideration of this loss and the limiting factors outlined above it appeared that a pulse power of at least 500 kw was needed to obtain the desired detection ranges. Several tube types were tried and numerous oscillators were constructed before reliable operation at this level was obtained. The 7C22 oscillator developed by Bell Telephone Laboratories was finally adopted and is easily capable of 600 kw pulse power.

2-5. Reliability Improvements. Failure reports indicate that the primary sources of failure or poor performance in existing service equipments are, roughly in order of importance:

(1) Transmitter tubes.

(2) Preselector tubes (446).

(3) Pressurized coax transmission lines.

(4) Receiver tubes.

(5) Relays, high voltage condensers, variacs, etc.

(6) Mistuning and misalignment of circuits resulting from complicated tuning procedure.

In the XBF-1 attention was paid to these items and it is believed very great improvement has been achieved.

(1) The 7C22 can be expected to give greatly superior life compared with tubes now in service because of:

(a) Large cathode area (40 sq. cm.) giving a very high ratio of max. emission current to operating pulse current.

(b) Large safety factor on grid temperature.

(c) Sealed in oscillator circuit eliminating contact and flashover troubles.

(2) 446 Lighthouse tubes are used but it has been found that by reducing the plate voltage to 150 (250 has generally been used) the life is greatly increased without appreciable loss in receiver performance.

(3) RG-20/U solid dielectric cable with a wide safety factor on voltage applied is used for r-f transmission. The

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antenna employs a simple feed which is filled with polyethylene and the only air insulated lines are short lengths in the transmitter. These are three inch and do not require pressurization since the ambient is warm.

(4) The number of tubes has been kept at the minimum consistent with the required performance.

(5) Relays were selected with regard to shock and vibration characteristics and general ruggedness and are accessibly located. No variacs are used. Voltage control is accomplished by tapped transformers. Remote control of the modulator voltage is by means of a latching step relay.

(6) Tuning has been simplified by efficient tracking and ganging of controls. At present there are five tuning controls but it is expected that by use of fixed transformers the two matching stubs can be eliminated or at least be required only when tubes are changed. An experimental four step motor driven mechanical tuning unit for remote selection or automatic frequency change has been designed and is being constructed. One of these would be attached to each control.

3. SYSTEM SPECIFICATIONS.

3-1. Mechanical Specifications.

Transceiver Dimensions:

68" high x 28" wide x 25" deep.

Transceiver Principal Components:

Receiver Preselector and I-F Amplifier (removable chassis)
Receiver Power Supply (removable chassis)
Monitor Oscilloscope (removable chassis)
Modulator Trigger (removable chassis)
Transmitting Oscillator (removable)
R-F Plumbing (built-in)
Modulator (built-in)
Power Supply (built-in)
Echo Box (built-in)

Antenna Size - 17' x 7'.
Antenna Weight - 375 lbs., excluding pedestal. Exp. model with heavy steel framework.

R-F Transmission Line RG-20/U or RG-18/U Cable.

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3-2. Photographs. Various views of the transceiver are shown in Plates 21-31. The antenna is shown in Plates 17-19.

3-3. Operation Data and Electrical Specifications.

Frequency - Tunable over band 400 to 425 Mc.
Pulse Power - 600 kw.
Pulse Length - 1 or 6 microseconds. May be switched during operation.
Repetition Rate - 500 ± 15/sec. with 1 microsecond pulse, or 165 ± 5/sec with 6 microsecond pulse.
Receiver Band Widths - 1100 or 350 kc.
Receiver Noise Factor - 7.8 db above ideal.
Receiver Output - .75 volts peak on 70 ohm line.
Antenna Gain - 21.5 db above isotropic radiator.
Antenna Beam Widths - 10° horizontal
22° vertical.
Transmission Line Loss - 100 ft. RG-20/U Two-Way - 4 db.

3-4. Circuit Diagrams and Parts List. A schematic diagram of the transceiver is given in Plate 32 and a general parts list is given in Table 1. The modulator trigger unit schematic is given in Plate 33. This latter unit differs from that used in the SR-2 equipment which employs a multivibrator stabilized by a small filamentary lamp. This circuit is reported to have considerably better stability than that of the XBF-1 and although it is more complex it is probably preferable.

4. THE ANTENNA.

4-1. Type Considerations. A multi-element array was first proposed and designed but was rejected because of the great number (48) of radiators and the resulting complexity of the feed. Work was therefore directed toward development of a paraboloid reflector with a simple feed system giving less than 2:1 mismatch over the band.

4-2. Reflector Size. The maximum horizontal dimension of the reflector was limited by the allowable turning radius of shipboard installations. Since the SK antenna has a turning radius of 9' 6" it was concluded that a 17' diameter dish, when mounted, would be acceptable. The vertical dimension was limited by ship roll. The SK vertical beam, which has been considered too narrow, is about 17° at half power points and gives about 6 db loss in signal strength with 10° deck tilt. A 7' high paraboloid gives a 22° beam at 425 Mc or about 3.6 db loss in signal strength with 10° deck tilt which seemed satisfactory. Distortion of the dish to obtain a blunt vertical beam was not attempted but might be desirable.

4-3. Reflector Shape. Following reference 9 the focal length of the paraboloid should be an integral number of half waves and the ratio of f/D should approximate 0.3. From these two factors a focal length of 150 cm was determined.

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4-4. Illumination. Reference 10 explains that a uniform irradiation of the entire dish results in excessive side lobes but by tapering down the field strength toward the edges of the dish good results can be obtained. A standing wave ratio of 2:1 keeps maximum voltage comfortably within the specification limit for RG-17/U cable and was taken as the limit for variation of impedance of the antenna feed over the 25 Mc band.

4-5. Feed System.

4-5-1. Primary Vertical Beam Requirements. Plate 1a shows theoretical vertical half-patterns for a feed consisting of a pair of dipoles and parasites and for a single dipole and parasite. These are theoretical patterns and correspond quite closely to those obtained in practice, and they are plotted to the same relative voltage scale. Thus the field intensity looking into the paraboloid along its axis, for a single dipole and parasite, is only 67% of the field intensity for a pair of dipoles and parasites. The dashed vertical line at 35° shows where the top of the paraboloid intercepts the beam. The horizontal patterns of the two feeds should be approximately the same, giving similar illuminations of the paraboloid and equal beam widths in the horizontal patterns. However the vertical illumination of the paraboloid is more nearly uniform for the single dipole and parasite, which should cause a slightly narrower vertical beam from the paraboloid. The energy which is not intercepted by the paraboloid will be distributed more or less uniformly in space. The relative gains of the paraboloid for the two feeds may be estimated by noting that the average illuminations are approximately 90 and 65 in relative voltage. This corresponds to a 2.8 db gain when using the pair of dipoles and parasites. Even though factors neglected in this estimate should reduce the advantage to only 2 db, the additional complication of the pair feed is clearly justified since the advantage to the system is then 4 db or 26% increase in maximum range.

4-5-2. Slot Dipole. The first feed system tested was the slot dipole, similar to that in the AMES II (Reference 11). Primary patterns showed that the radiation was too uniform in the horizontal plane, and the vertical beam was too broad. Excessive back radiation, coupled with the fact that a complicated system of feeding through a line balance converter and transformer was necessary, made another type feed more desirable.

4-6. Radiator Shape.

4-6-1. Folded Dipoles (Ref. 12). Folded dipoles, when tried, seemed to have good impedance qualities until the parasites were added. Besides the fact that the parasites narrowed the band width, the process of going from an unbalanced line to the balanced radiators required a line balance converter, which was of itself frequency selective.

4-6-2. Ellipsoids. A feed was constructed, adapted from the broad band RCA television antenna (Ref. 13) which is fed directly from an unbalanced line. This adaptation was fed at only one end. The dummy end was formed of a half ellipsoid. Due to the time required to get antennas of this type made in the shop, only one model was tested. It was felt that, with a slight change in some of the dimensions, better results could be obtained. To save time, therefore, an antenna with variable dimensions, which could be constructed at the workbench, was sought.

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4-6-3. Cylinders. From telescoping brass tubing, an array similar to the ellipsoids was constructed. Instead of the ellipsoid which terminated the inner conductor, a cone was turned from brass and fitted onto the brass tubing. The other end of the radiator, the dummy end, as well as the parasite was made from tubing of the same size. Many tests were taken while the length of radiators, the length of parasites, spacing between the radiator and parasite, spacing at the throat section, where the transmission line merged into the radiator, were varied one at a time. The "inductive shunt" of reference 13 was used to good advantage for support and the inductance introduced was cancelled by varying the spacing at the throat. The dipoles were fed approximately at the 100-ohm impedance points. Hundred-ohm line from these points joined at a "T" to form a 50-ohm line which was fed by the transmitter. With this system, excellent results were obtained over a very large frequency range. In order to avoid any air-filled sections the entire transmission line up to and through the throat section was filled with polyethylene, the size of the inner conductor being changed to maintain the 50-ohm and 100-ohm impedances. Tests taken on the impedance of this array showed that the broad band of frequency was still obtained. Primary patterns of this feed showed that the beam was 10° off from the axis of symmetry. With this array in the dish, it was found that such a beam gave asymmetrical side lobes. When the array was placed in the dish at an angle so that the beam was directed to the center of the screen, balanced side lobes were obtained. Reason showed that this beam was off because both radiators were fed at the same end. Accordingly, a new array was built with the radiators fed at opposite ends and with the 50-ohm feeder off center enough so that it was a half wave length extra of 100-ohm line to one dipole. This took care of the phase difference introduced in feeding the radiators at opposite ends. Primary patterns (Plates 4-9) showed that the beam was then symmetrical and impedance measurements showed that the matching qualities were not adversely affected. The completed feed system demounted from the reflector is shown in Plate 20.

4-7. Radiator Location. The illumination of the dish varies as the position of the feed is varied and therefore the field strength pattern varies. It had been determined that the impedance of the array depended on its spacing from the screen (Ref. 14). Tests were run to determine where the feed should be placed. Starting at the focal point, and moving directly away from the screen, measurements were taken every few centimeters. The results showed that the best pattern was obtained at 157.5 cm and the best impedance match at 163 cm. Because the patterns between these two points showed only a slight difference, the spacing for best impedance was decided upon. Patterns at this frequency were: (Plates 1-3).

Frequency	Beam Width	Side Lobe	Back Lobe
400	10°	9%	5%
412	10°	13%	2%
425	10.5°	11%	3%

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Impedance measurements at this spacing (Plate 10) gave a standing wave ratio of better than 1.57 to 1.

4-8. Radiator Mounting. Rigid support of the radiator without interference with the pattern presented a problem of some difficulty. However, it was found that a large cone with its base on the reflector did not appreciably degenerate the patterns. The cone shown in the photographs (Plates 17 and 19) was the experimental one made of copper foil. This was later replaced by a suitable aluminum sheet cone which appears to be satisfactorily rigid. Shock and vibration tests have not been made.

4-9. Gain Measurements. In order to obtain the gain of the antenna, it was compared to a standard antenna of which the gain was known. The standard was a ten foot dish of focal length three feet. This was fed by a dipole and parasite placed at the focus. By a method of graphical analysis (Ref. 15), the gain of this 10 foot dish was found at various frequencies. This result checked favorably with gain calculated from two different formulae. In comparing the two, the 10 foot dish was mounted at the same level as the SR-1. Careful steps were taken to be sure that the same amount of power was fed into the two dishes. A slotted line and stubs were placed in the feed line. By means of the stubs the line was flattened. A voltage indicator placed on the line, read the same for each antenna. The field strength of each was measured 150 yards away. Since the power input to each was the same, the squares of the field strength readings were proportional to the power gains.

Calculated and measured gain of 10 foot dish:

By graphical integration	By $G = 8.25 (D/\ )^{1.8}$	By $G = .66 (D/\ )^2$
100.5 or 20.0 db	104 or 20.2 db	108 or 20.3 db over point source.

Measured gain of XBF-1 Antenna:

Frequency	Relative Power	Decibels
400	129	21.11
412	149	21.74
425	127	21.04

over a point source.

4-10. IFF Antennas.

4-10-1. Mark 3. The antenna used was the best of three experimental models. The radiators in each model were alike. They were similar to the SR-1 feed in that they could be fed with coaxial cable, (RG-18/U) with no necessity for line balance converters.

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4-10-2. The first attempt was a dipole and parasite placed at about the focus of the paraboloid. Although the resulting beam width was good, excessive side lobes were present. Various spacings were tried in an effort to taper the primary radiation, but the lobes remained.

4-10-3. The second model consisted of four radiators mounted on the screen a half wave length apart. The current distribution was 1:2:2:1. A theoretical pattern calculated with this distribution at the mid-frequency showed a beam width of 32° and negligible side lobes. This is exactly what was measured at the mid-frequency.

4-10-4. In an attempt to narrow the beam, one more radiator was added on each side. A calculated pattern of these six radiators spaced a half wave apart with current distribution 2:3:4:4:3:2 showed a beam of 22°. But because of the curvature of the screen, the last two radiators were almost a half wave in front of the others. In feeding these with different length cables, to take care of this fact, it was found that reactance of the radiators reflected back into the feed lines to give different phasing at different frequencies. Various attempts to feed these radiators in phase over the entire frequency band failed, and the second model of four radiators was adopted.

4-10-5. The final results for the IFF antenna are: (Plates 11-13)

Frequency	Beam Width	Side Lobe	Back Lobe
187	29	0%	7%
172	32	8%	7.5%
157	39.5	0%	10%

The standing wave ratio for this antenna (Plate 14) is better than 2 to 1 over the whole band.

4-10-6. Mark 4. This is an antenna adapted from the SK Mark IV. It was built up for the SC, but the problem was cancelled before it went into production. This consists of eight pairs of voltage fed vertical dipoles of current distribution 2:4:8:10:10:8:4:2. These radiators are mounted on a flat screen three by eight feet which can be mounted on top of the SR-1 screen. The pattern of this array followed closely the calculated pattern (Plate 15).

Frequency	Beam Width	Side Lobe	Back Lobe
473 & 490	17	3%	2%

4-10-7. The standing wave ratio (Plate 16) is better than 1.3 to 1 at the operating frequencies.

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4-10-8. Antenna patterns of the SR-1, taken with the Mark 3 mounted on the screen and a screen simulating the Mark 4 mounted above the dish, showed no noticeable change.

4-10-9. Mark 5. The construction of a Mark 5 antenna is a separate problem, but provision has been made for mounting this interchangeably with the Mark 4.

5. THE TRANSMITTING OSCILLATOR.

5-1. Description. The 7C22 tube developed by Bell Telephone Laboratories comprises twin triode elements mounted at the ends of a concentric line system with capacitive coupling provided between cathode-grid and grid-plate cavities so that push-pull oscillation takes place. The copper shell forms the anode and the evacuated container. Tuning over the range 390 to 430 Mc is accomplished by bellows condensers at the ends between grid and plate, and output is derived from a loop at the center. The cathodes are oxide coated cans each with an effective area of about 40 sq. cm. The grids are gold plated to suppress emission but partial cathode bias is desirable to alleviate instability resulting from grid emission.

5-2. Tentative 7C22 Specifications.

Frequency range - 390 to 430 Mc.
Rotation of tuning gears for 400-425 Mc
Frequency Range - 1¾ to 2½.
Heater voltage - 9 volts (Increased with age as necessary).
Heater current - 30 amperes.
Plate to cathode voltage - 17.5 kv.
Load resistance presented to modulator (with 20 ohm cathode resistor) - 275 ohms.
Pulse power - 600 kw.
Maximum duty cycle - .0011
Efficiency (including bias loss) - 45%.
R-F Load Impedance, Stable Range - 80 - j15 to 62 + j50 ohms.
Cathode resistor - 20 ohms.
Grid resistor - 200 ohms.
Weight - 12.5 lbs.

A Rieke diagram of the loading characteristics is given in Plate 33. Recent life tests show that more than 600 hours can be consistently obtained.

5-3. Tracking. The two tuning gears mesh with gears fixed in the mount and ganged to the tuning control on the panel so as to give a drive ratio of one to one from the control to the tube gears. No appreciable loss in performance results from ganging of the tuning gears, but it is of course essential to align the tube gears with marks on the shell and to turn the control down before the tube is inserted. The tuning characteristics varies widely from tube to tube and hence recalibration of the dial is necessary when a tube is changed.

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5-4. Frequency Drift. Early models of the 7C22 showed very severe frequency shift with change of ambient temperature and with warm-up. This fault was corrected by some changes in design and the tube is now satisfactory in this regard. Change with ambient is negligible. The stand-by conditions as a function of time is shown by Plate 34. Life tests have shown no advantage in operation of the heater at reduced voltage during stand-by and stand-by with full heater voltage is therefore recommended as it permits immediate operation of the system and eliminates a time delay relay.

6. R-F TRANSMISSION SYSTEM.

6-1. Transmitter Load Matching. A schematic diagram of the r-f plumbing showing the load matching stubs and duplexing system is given in Plate 35. The matching stubs, duplexing tanks, and interconnecting lines are made of three inch air filled transmission line with connections to the solid dielectric cable by means of polyethylene insulated reducing fittings. The stub junctures are one eighth wavelength apart and the juncture of stub A (toward the transmitter) is separated from the 7C22 output terminal by about $3\frac{1}{2}$ wave lengths of transmission line. The matching conditions are shown by a Reike diagram on Plate 33 in which the arcs (a), (b), and (c) are experimentally determined load impedance lines for the 7C22 for 100%, 87%, and 72% full output respectively. The lines (d), (e), (f), and (g) show frequency pulling by the load, (d) and (f) being the approximate limits for stable operation. The circles (h) and (i) give the loci of impedance presented by tuning stub A for the band limits of 400 and 425 Mc with stub B correctly set. The diameter of the circles is determined by the setting of stub B and the position of the centers of the circles is determined by the wave lengths of line from the 7C22 terminal to stub A, the value taken in the diagram being 3.4 at 400 Mc or 3.6 at 425 Mc (approximately that in the XBF-1). From the standpoint of standing wave ratio in this line as well as stability of the oscillator it is apparent that this line length is fairly critical and to keep within the 11 kv maximum voltage rating of the RG-17/U (2:1 SWR) on the one hand and the stability limit on the other the length should be between 3.38 and 3.45 wave lengths at 400 Mc. It is recognized that if the antenna impedance could be held closely to 50 ohms a fixed transformer would suffice for the tube and the stub tuning might be dispensed with. Work is being carried on with this in view.

6-2. Tuning Procedure. Stub A is tuned for minimum grid current the value of which is determined by Stub B and should not exceed 8 ma. It has been found with some tubes that more stable operation is obtained by operating somewhat off the minimum grid current setting.

6-3. Duplexing System. A schematic diagram of the duplexing system appears in the right hand side of Plate 35. The transmitter decoupling tank consists of a "half-wave series gap" concentric line 3/8 wave long at mid-band with a 1/4 wave connection to the main line displaced 1/4 wave length from the receiver tank connection. For a given

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open circuit impedance this type of tank has a lower gap current and hence greater gap life than any other known type (Ref. 16). The receiver decoupling tank is of the same type, i.e., series tuned, but is provided with a shunt spark gap because this placement of the gap affords adequate receiver protection, whereas a series gap does not, at the high pulse power level of the XBF-1. In order to eliminate coupling to the receiver by mutual reactance of the rod supporting the gap electrode from the outer conductor the inner gap electrode is mounted on a ring which is insulated from the inner conductor, the capacity between the two being such as to provide series resonance with the inductance of the gap rod. Neglecting the spike at the start of the pulse the voltage impressed on the receiver line is about ten volts. The spike occurs prior to firing of the gap and has a peak magnitude of about 200 volts but is of a small fraction of a microsecond duration and gives no trouble. Gang tuning of the two tanks is accomplished without loss. The insertion loss of the system is about 0.6 db and does not vary appreciably over the band.

6-4. Antenna Rotary Joint. A double coaxial rotary joint using liquid silicone (Dow-Corning Ignition Compound) has been developed at NRL and is used with the XBF-1. A complete report on this joint will be issued in the near future.

7. MODULATOR.

7-1. Description. The modulator is of the artificial line type with a triggered series gap switch. D-C semi-linear charging is used with the same choke for both pulse lengths. Type E five section pulse forming networks with a surge impedance of 37.5 ohms are used; this value of impedance having been taken as a desirable compromise between the more common 50 and 25 ohm values in consideration of excessive voltage for air insulation on the one hand and excessive coulombs per pulse for the switch gaps on the other.

7-2. Requirements. Since the 7C22 is rated at the desired output with 17.5 kv applied and with 50% plate efficiency, the impedance of the oscillator may be taken as 255 ohms. However a 20 ohm cathode biasing resistor is necessary so that the total load resistance is about 275 ohms. A potential of 19.1 kv is then required and the pulse power into the load is 1,335 kw. Maximum duty cycle is

$$6.3\ (6 \pm 5\%)\ \times 10^{-6} \times 175\ (170 \pm 5) = .0011$$

and maximum average power is 1.47 kw.

7-3. Pulse Transformer. The spark gaps can be expected to introduce about 2 ohms in the discharge circuit so the pulse transformer primary should present 35.5 ohms. The ideal ratio of the transformer is then 2.78. Actually an excellent impedance match was obtained with this ratio which indicates that with allowance for transformer losses the oscillator efficiency and impedance were somewhat higher than stated above or the network impedance was lower than nominal.

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7-4. Input Power. Allowing losses of 90 watts for the spark gaps and 10 watts for the pulse network the average power required by the network is 1.57 kw. The primary pulse power is 1.43 megawatts and the charged voltage of the network is 14.64 kv. About a 50 volt drop in the charging choke can be expected and the requirements of the main high voltage supply are accordingly about 7.4 kv and 1.58 kw. Because of the lack of equipment for accurate measurement of impulse voltages these figures have not been closely checked, however 600 kw in r-f power was obtained with a supply voltage of 7.5 kv.

7-5. Mercury Cathode Spark Gaps. The 1B32 gap tube consists of a glass bulb mounted on a Kovar cup which contains a metallic sponge saturated with mercury. The mercury serves as the cathode and is desirable because it does not sputter onto the glass. The anode is a rod held by the glass bulb and the filling is hydrogen and argon at about atmospheric pressure. Maximum ratings proposed (Dec. 1, 1944) for the 1B32 gaps are as follows:

Peak Current (i_p) - 300 amperes

Pulse Length (T_p) - 6.1 microseconds

Repetition Rate (F) - 2000 per second.

Duty Cycle (FT_p) - .0012

Rep. Rate x Peak Current (Fi_p) - 40×10^4

Coulombs per Pulse - 1.28×10^{-3}

Average Current - .25 amperes

Nominal Operating Voltage - 5.7 kv per gap

Steady operating range for three gaps is 12.5 to 18.7 kv with reduction to 13.5 to 17.1 kv at end of life. Maximum allowable temperature of the cathode is 150° C. In the XBF-1 peak current is 208 amperes, average current is .23 amperes, and the coulombs per pulse is 1.31×10^{-3} for a 6.3 microsecond pulse or 1.27×10^{-3} for a 6.1 microsecond pulse. To stay within the limits on pulse length and coulombs per pulse, the SR-1 pulse network nominal double delay time and maximum tolerance should not exceed 6.1 microseconds. There is no direct forced draft on the gaps in the XBF-1 but there is good air circulation produced by the oscillator blower and it is expected that the temperature limit will not be exceeded. Lack of final design gaps has prevented a check.

7-5-1. Reverse Current. Life of the 1B32 gaps is terminated by sputtering of the anode material onto the glass walls resulting in clinging of the mercury. Sputtering of the anode is produced by reverse current in the modulator circuit and the rate is in general proportional to the average value of this current. In the normal

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case the impedance presented to the modulator for reverse current is simply the open circuit impedance of the pulse transformer (about 400 ohms) since the oscillator will not conduct and if the reverse e.m.f. is not too great the current will be insufficient to sustain ionization and the gaps will extinguish. Hence some degree of mismatch with the load lower than the network can be tolerated. In the XBF-1 taps were provided on the transformer and a good match with no sign of reverse current was obtained with a 1:2.78 turn ratio. Reverse current is also produced however by arcing of the oscillator tube and for this there is no practical circuit cure. At full power and 180 p.p.s. a 7C22 was found to arc at an average rate of once a second giving an average reverse current of about a milliampere. With the short pulse and higher rate this figure should be slightly lower.

7-6. Primary Trigger. Primary trigger for the 4C35 is supplied from a blocking oscillator driving a cathode follower. The permissible shift in pulse rate produced by tube change or voltage change in this unit is established by arbitrarily setting a limit on loss of sensitivity of the system resulting from lowering of the nominal or center repetition rate to allow for shift, maximum duty cycle having been set by other factors. Thus, with a maximum allowable duty cycle of .0012 and a maximum pulse length of 6.1 microseconds, the limit on repetition rate is 167 per second and allowing adjustment of $\pm$ 5 cycles a center frequency of 162 is obtained. If allowance of $\pm$ 5 cycles for frequency shift of the pulser is made the center frequency must then be dropped to 157. With a P.P.I. the increase in minimum detectable signal (voltage) with decrease in repetition rate is according to the relationship

$$\frac{e_2}{e_1} = \frac{F_2}{F_1}^{.22}$$

Hence a decrease in F from 162 to 157 gives a loss in sensitivity of less than one tenth db and $\pm$ 5 cycles appears to be a reasonable tolerance. Difference in characteristics between individual tubes was found to be the strongest factor in frequency shift and with a simple blocking oscillator change of tubes produced up to $\pm$ 6 cycles shift. The introduction of a parallel L-C circuit in the grid return as shown in the circuit schematic, Plate 36, improved stability somewhat and from twenty different tubes the maximum difference in frequency obtained was 8 cycles. The Q of the stabilizing circuit is about 15 and the resonant frequency is made about 3% higher than the desired frequency to allow for the transient phase shift produced by the grid impulse current. A line voltage change of $\pm$ 10% produced a frequency shift of + 1.5 and - 1 cycles.

7-7. High Voltage Wiring. RG-27/U pulse cable was used in the high voltage circuits. It was found that simple terminations such as corona shields at the ends of the conducting rubber sheath or aquadag coatings were unsatisfactory and because the Type B Radiation Laboratory terminals were excessively large a simplified small connector with a

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filling of Dow-Corning #4 Sealing Compound was developed. This connector has proved satisfactory and Naval approval has been requested.

8. RECEIVER.

8-1. General Description.

8-1-1. The XBF-1 receiver is a superheterodyne using two r-f stages; oscillator; converter; eight i-f stages with non-amplified back-bias applied to all but the first stage, and with variable bandwidth and sensitivity time control incorporated; a detector with inductive F.T.C. coupling to the video, and video amplifier. Plates 48, 49 and 50 show front, top and bottom views of this receiver. Plate 37 is a schematic diagram of the receiver circuit.

8-1-2. The preamplifier unit contains the two r-f stages, the oscillator and the converter, all tuned by means of a single tuning dial from the front panel. Trimmers are provided on the side of the unit for alignment. The two r-f stages are identical and consist of capacity tuned concentric tank circuits using lighthouse tubes. The converter consists of a similar circuit for its grid cathode tank and feeds into the first i-f stage from its plate circuit. The oscillator, also using a lighthouse tube, consists of a capacity tuned reentrant tank using a leaky grid pedestal for field penetration to secure the necessary feedback. It is so proportioned that it will track the r-f and converter stages directly. Plates 51 and 52 show photographs of the preamplifier unit partially disassembled. The general arrangement of the parts can be seen in these photographs.

8-1-3. The i-f amplifier consists of 8 stages using 6AC7 amplifier tubes with non-amplified back-bias applied to all stages except the first. Gain is controlled by controlling the grid bias on the second and third stages. Sensitivity time control is also applied to these grids. The circuit used merits some discussion because of its extreme simplicity.

8-1-4. Because of the use of air gaps in the duplexer its recovery is extremely fast and the sensitivity time control need only follow a fourth power law curve without requiring a flat portion or slow rise at the start of the sweep. Plate 53 shows the circuit used to obtain this characteristic. It will be noted that no tubes are used and that only one resistor, one potentiometer, one condenser and one pulse transformer comprise the circuit. Operation is as follows: When the synchronizing signal pulse from the synchronizing line is applied to the pulse transformer, a strong positive pulse is generated at point (1). Condenser C_1 charges on this pulse through the diodes (formed by the grids and cathodes of the two i-f tubes) and the series grid decoupling resistors and coils. When the trailing edge of the synchronizing signal pulse returns point (1) to ground potential, point (2) will be negative because of the charge on condenser C_1 and will put high bias on the two i-f stages thus reducing their gain. Resistor R_1 will then discharge

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condenser C_1 slowly and return the grids to normal operating potential (and hence to normal gain).

8-1-5. Condenser C_1 is made small enough to charge completely during the shortest pulse used. Resistor R_1 is adjusted to give the desired recovery time and a potentiometer (screw driver controlled) in the primary of the pulse transformer allows the extent of the reduction in gain to be controlled. This circuit has been found to very closely approximate a fourth power law when these components are correctly set.

8-1-6. All i-f transformers are double-tuned, using slug tuning, with the exception of the third. It is a single tuned variable bandwidth transformer. Its bandwidth is controlled by controlling the resistance load across it and gain is simultaneously equalized by changing the cathode resistor of the second stage.

8-1-7. The detector is a 6H6 diode supplying negative output and coupled directly to a 6AC7 video amplifier. A relay, operated by either a local or a remote switch, connects a small choke across the detector output for inductive fast time constant (F.T.C.). D.C. reinsertion is accomplished by operating the first video amplifier at zero bias.

8-1-8. All power for the receiver is supplied from external power supplied in another unit in the main frame.

8-2. Sensitivity.

8-2-1. The sensitivity was measured at numerous points throughout the tuning range. These measurements were made using the minimum detectable signal technique.

8-2-2. The receiver was set up with a Dumont type 241 oscilloscope as indicator and put into operation. An r-f pulse synchronized to the indicator was applied to the receiver from a signal generator. This pulse was delayed from the start of the sweep so that it would appear at a convenient point on the range scale. The signal was then increased from zero until just distinguishable and its level read. Several readings were taken in this manner. Between readings the pulse delay was changed to eliminate the observational error which would have resulted had the pulse appeared at the same place each time. The average of these readings was taken as the minimum detectable signal.

8-2-3. The noise factor was then computed from the minimum detectable signal by means of the formula from reference 8.

$$e_n = \frac{2\,V_{min}}{\left[B^{\frac{1}{2}} + \frac{1}{TB^{\frac{1}{2}}}\right]\left(\frac{1640}{F}\right)^{1/6}} \qquad (1)$$

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e_n = equivalent noise level in uv/mc.

V_{min} = minimum detectable signal in uv.

B = overall receiver bandwidth in Mc.

T = pulse width in usec.

F = system repetition rate in c.p.s.

8-2-4. This formula was developed empirically and is based on extensive and reliable data taken at the Naval Research Laboratory.

8-2-5. Formula (1) gives the equivalent noise level (e_n) in uv/Mc. The noise factor (NF) in db is then computed from the relationship:

$$NF = 20 \log \frac{e_n}{.55} + 2 \qquad (2)$$

8-2-6. The correction + 2 appears in formula (2) since formula (1) is based on driving the attenuator at relatively high speed by means of a motor drive. The present tests used low speed hand drive, hence the 2 db correction. This correction also was determined at this laboratory.

8-2-7. The absolute sensitivity of the receiver when tracked properly was found to be 7.8 db at 415 Mc and about 10.8 db at 395 Mc and 425 Mc. The loss of 3 db could be eliminated by slight readjustment of the trimming condensers. Gain was also measured and was found to be down 6 db at the ends of the band.

8-3. Frequency Drift.

8-3-1. Frequency drift was measured both during the warm-up period and as supply voltage varied. This measurement was made by applying a signal from a standard signal generator and tracking the drift of the receiver as it warmed up. After it was thoroughly warmed up, voltages were varied ± 10% and the shift in receiver tuning noted. The results of these tests are shown in Table 3. It should be noted that oscillator plate voltage is regulated in the radar so the variations due to plate voltage changes and to combined change in plate and heater voltages will not occur in actual operation.

8-4. Overall Bandwidth.

8-4-1. The overall bandwidth was measured by applying an r-f signal modulated at low frequency to the input of the receiver and reading the level of the demodulated video output on a scope. The level of this signal was set to give a convenient output level from the video for use as a reference level and this reference level was maintained constant, as the signal was tuned through the pass band, by readjusting the r-f input level. A plot of the reciprocal of the r-f level then gave

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the overall pass characteristics of the receiver. This curve is included as Plate 38. It will be noted that the bandwidth is 920 kc for the broad band position and 500 kc for the narrow band position. The latter is broader than intended and will be reduced to 350 kc.

8-5. Video Pass Characteristics.

8-5-1. The video pass was measured by feeding a sine wave signal of variable frequency into the detector output circuit through a resistance approximating that of the detector. An oscilloscope was used to measure the output level resulting from a constant input level as the frequency of the input signal was varied through the pass band. This output level was then plotted against frequency to give the response curve. Plate 39 shows the response curve of the video both with normal detector output coupling and with short time constant (F.T.C.) coupling.

8-6. Sensitivity Time Control.

8-6-1. The sensitivity time control (S.T.C.) characteristics were measured for both the long and the short pulse positions. This was done by applying a delayed simulated echo pulse to the receiver from a signal generator. This simulated echo pulse was synchronized to the synchronizing signal from the transmitter by connecting to the synchronizing line to the indicator and was variable in range from one-half mile to twenty miles. The transmitter was operated normally except that it was fed into a water cooled load instead of to the antenna.

8-6-2. The simulated echo was set at the 20 mile maximum range and its level set to give a convenient deflection on the indicator. It was then moved into a shorter range and the level readjusted to give the same indicator deflection. The difference in db between this level and the level at 20 miles gives the loss in gain at that particular range.

8-6-3. The loss in gain was measured at a number of points between 1/2 to 10 miles and was plotted as a function of range. Plate 54 shows the results of this test. It also shows a fourth power law curve for comparison (Curve a).

8-6-4. It will be noted that the curve for the long pulse (Curve d) shows too great a reduction in gain whereas the curve for the short pulse (Curve c) shows insufficient reduction in gain. In both cases the gain is returned to normal too fast.

8-6-5. It is apparent that the capacities in the S.T.C. network do not charge rapidly enough for the short pulse, the discharge time is too short, and the voltage from the pulse transformer is too high. Simple calculations show that these objections can be corrected by changing C, (Plate 53) from .0015 mfd to .003 mfd and R_1 from 50,000 ohms to 180,000 ohms. Curve b, Plate 54, shows the expected characteristic after making these changes. Beyond one mile the maximum

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deviation from the fourth power law is only 2 db and at one-half mile it is only 4 db.

8-7. Anti-Jam Measurements - General Procedure.

8-7-1. The receiver was set up and a pulsed r-f signal applied to it from a signal generator. This signal generator was a self-pulsed generator with variable pulse rate, variable pulse delay time and variable pulse width. It was set to a pulse repetition rate of 1000 cycles and a pulse width of 5 microseconds. A Dumont type 241 oscilloscope synchronized to the synchronizing signal output of the signal generator was used as indicator. The pulse delay time was set to place the pulse at a convenient point on the trace of the indicator. Jamming was supplied by a similar r-f signal generator set to deliver cw or amcw as required. The outputs of the two r-f signal generators were connected together and to the receiver by means of a Tee fitting.

8-7-2. Minimum detectable signal measurements were made by slowly increasing the signal from zero until it was just distinguishable. Several readings were taken in this manner with the pulse delay time being changed between readings to eliminate the observational error which would have resulted from anticipation of the pulse location on the sweep. The average of these readings gave the minimum detectable signal. The same procedure was used whether jamming was or was not present.

8-7-3. The minimum detectable signal was first measured by the method of paragraph 13-2 with no jamming applied. This measurement gave the unjammed sensitivity of the receiver in db referred to an arbitrary level depending on losses in the r-f cables and connectors used to connect the generators and receiver. This unjammed sensitivity was taken as the zero level from which the loss in sensitivity was computed in the case of each type of jamming.

8-7-4. The jamming signal under study was then applied and adjusted to the desired level. The minimum detectable signal was again determined by the method of paragraph 8-7-2 and the difference between this sensitivity and the unjammed sensitivity gave the loss due to jamming. Since the attenuator on the signal generator reads directly in db, the loss was given in db.

8-7-5. The loss is measured at a number of points as the jammer is tuned through the receiver pass band. Results are then plotted to show the loss in sensitivity as a function of jammer frequency.

8-8. Anti-Jam Performance - "A" Scope.

8-8-1. The receiver was tested using the types and levels of jamming shown in Table 2. The results of this test are included as Plates 40 to 43.

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8-8-2. It will be noted that the loss in sensitivity shown for cw is a maximum of 24 db. This loss is partly due to the fact that the use of direct detector to video coupling necessitated the use of the short time constant (F.T.C.) to prevent overload of the video on the d-c output from the detector. The pulse from the generator used to generate the simulated echo had a very long build-up time and therefore suffered a considerable loss when the fast time constant was used. The loss using an echo returning from the transmitter pulse was five to ten db less than that shown on the curve.

8-8-3. It will also be noted that the curves are distinctly asymmetric. This results from the asymmetry of the overall pass band as shown in Plate 38.

8-8-4. The peaks of loss which appear displaced about 2¼ Mc on either side of zero beat are the result of the video pass being somewhat narrow for the particular i-f pass characteristics. In the presence of off frequency cw jamming the pulse comes through as a beat between the echo and the jamming. If the jamming is strong and several Mc off frequency it will still get through the i.f. and cause this beat which, unless video pass is sufficient, will not pass through the video amplifier. Plate 47 shows two photos in which this beat is visible. The one-sided character of this beat is due to the d.c. reinsertion in the video. In this receiver there is a noticeable loss due to insufficient video bandwidth but it is not sufficiently great to warrant an increase in the video pass band.

8-9. Anti-Jam Performance - PPI.

8-9-1. No direct tests of a-j performance on a PPI were made. However, experience has indicated that a receiver which has good a-j performance on an "A" scope will perform equally well on PPI if it has a low change in gain as jamming is applied (Reference 19). The gain of the XBF-1 was measured as jamming was applied. This curve is included as Plate 44.

8-10. Recovery Time.

8-10-1. To obtain good performance against clutter and window or against railings jamming it is absolutely essential that a receiver have fast recovery and that it not overload on strong blocks of signals. Plates 45 and 46 show photos of the recovery of the XBF-1 from a strong pulse (50 mv). These photos show no indication whatsoever of delay in recovery, there being noise showing on the trailing edge of the pulse. Plate 45, lower, shows the recovery from a 5 usec pulse when the short time constant is in the circuit. In this case the receiver is essentially back to normal 4 usec after the start of the pulse.

8-11. Amplified vs. Non-Amplified Back-Bias.

8-11-1. Constancy of Gain. Plate 44 shows the variation in gain of the XBF-1 to be ± 25% as the jamming level is increased

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from zero to 50 mv. This variation is considerably less than has as yet been obtained in any other receiver tested at this laboratory, including numerous systems using amplified back-bias, and not only indicates that performance will be very good on a PPI but also that such a system using non-amplified bias could be adapted for use in fire control. It is true that a large number of stages is required to obtain this constancy of gain but this does not mean an increase in the total number of tubes since back-bias amplifier tubes are eliminated. A receiver similar to the one described in this report but using amplified back-bias had only 6 i-f stages but had a total of 8 tubes in the i-f amplifier.

8-11-2. Recovery Time. Plates 45 and 46 clearly show that recovery time in a non-amplified back-bias system can be made extremely short. However, to obtain this fast recovery it is necessary to use very small condensers across the high cathode resistors of the back-biased stages. These small condensers reduce build-up time correspondingly, and, in the presence of zero-beat jamming, cause degeneration of the pulse modulation components and an attendant increase in loss. However, the very short cathode time constants are very valuable in that much higher jamming modulation frequencies can be tolerated without paralysis of the receiver. Furthermore, if the jamming is slightly off frequency the pulse energy will appear as a beat between jamming and pulse carriers and will not suffer the above mentioned loss. In actual practice even laboratory signal generators have sufficient unintentional frequency modulation to prevent zero-beat conditions being maintained and the loss in sensitivity is therefore very slight. Since jamming transmitters are difficult to set on frequency and have considerable frequency modulation inherent to modulated oscillators, this objection to non-amplified back-bias is inconsequential.

8-11-3. Simplicity. The non-amplified back-bias system has an advantage over the amplified type as is used in the SR-2 and SG-3 in that all stages are identical, except for the variable bandwidth stage, and except for the high cathode resistors and biased grids are perfectly orthodox. Instruction of technicians in its operation and servicing is therefore simplified. Operation is also automatic and no IAVC switch is required.

8-11-4. Reliability. Both types of back-bias amplifiers have a very favorable characteristic in that overall gain is not appreciably affected by variation of tube transconductance so that low gain or regeneration troubles are very unlikely to occur. The non-amplified back-bias system is superior in this regard in that each tube establishes its own level and back-bias amplifiers do not enter the picture.

8-11-5. Stability of the XBF-1 receiver is excellent, there being no tendency to oscillate with maximum gain and a 50 mv signal applied to the r-f input.

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8-11-6. Operation of the receiver is very simple. The F.T.C. switch is the only anti-jam control and this does not adversely affect the unjammed performance. The gain control is not critical and since there is no receiver overload and but slight change in gain at the highest practical jamming levels this control would ordinarily not be touched.

8-12. Summary of Receiver Characteristics.

(a) The noise factor is 7.8 db at the center of the band and varies less than 3 db throughout the band without trimming.

(b) Frequency drift is 60 kc in the first 5 minutes of warm-up. Voltage causes a 6.0 kc change in tuning.

(c) Overall bandwidth is 920 kc in the broad position and 500 kc (to be reduced) in the narrow position.

(d) Video pass is 1.26 Mc with normal coupling and from 120 kc to 1.1[illegible] Mc with F.T.C. coupling.

(e) The S.T.C. characteristic is at present unsatisfactory but can be expected to deviate from the fourth power law by not more than 4 db after changes in constants are made.

(f) The overall anti-jam characteristics compare favorably with other receivers tested at this laboratory and are satisfactory.

(g) The change in gain is less than ± 2.5 db for jamming levels up to 50 mv.

9. MAXIMUM RANGE COVERAGE.

9-1. Calculated Maximum Range. Taking a medium bomber in the maximum of one of the interference pattern lobes as the standard condition and assuming that the effective reflecting area remains constant, the maximum detectable range may be calculated from the following relationship:

$$R_{max} = 544 \times 10^{-6} \left[\frac{G^2 \lambda^2 P_t K_1 K_2}{124 P} \right]^{1/4}$$ (Ref. 20)

where G = 128 - power gain of antenna over an isotropic radiator.

= 50 sq. meters - "effective reflecting area" of a medium bomber.

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$= .73$ meter - wavelength

$P_t = 600 \times 10^3$ watts - transmitter pulse power.

P_r = minimum detectable power at receiver input

K_1 = transmission line loss

K_2 = duplex system loss

Since with this system the PPI would ordinarily be used for search, P_r should refer to PPI presentation. Now investigation at this Laboratory has shown that, except for arcs approaching spot size, the minimum detectable signal is a logarithmic function of the arc length such that doubling the arc produces about 1.34 db increase in sensitivity. Since this is clearly a manifestation of integration phenomena and the only concern is with the number of traces on which the signal is presented, it appears legitimate to combine the effects of repetition rate, antenna beam width, and antenna rotation speed. Assuming an antenna speed of 4 r.p.m. a rough statement of this factor may be given as:

$$8.2 \left(\frac{1}{F\theta}\right)^{.22}$$

and the expression for minimum detectable signal on a PPI becomes:

$$e_{min} = 0.238 \overline{NF} \cdot B^{\frac{1}{2}} \left(1 + \frac{1}{TB}\right)\left(\frac{1}{F\theta}\right)^{.22}$$

or, with a 50 ohm input:

$$P_r = 1.13 \times 10^{-15} \overline{NF} \cdot B^{\frac{1}{2}} \left(1 + \frac{1}{TB}\right)\left(\frac{1}{F\theta}\right)^{.22}{}^2$$

For the XBF-1

$$\overline{NF} = 2.45 \quad (7.8 \text{ db})$$

$$\theta = 10^\circ$$

when $T = 6 \times 10^{-6}$ sec.,

$B = 0.3$ Mc.

$F = 180$/sec

$P_r = 1.78 \times 10^{-14}$ watts

For the shorter pulse:

$T = 10^{-6}$

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$B = 1$

$F = 500$

$P_r = 3.53 \times 10^{-14}$ watts

The attenuation of 412 Mc on RG-20/U cable is 1.8 db per 100 ft. Since a 2:1 mismatch may occur a reasonable figure for the two-way loss is 4 db. Hence

$K_1 = 0.4$

By measurement the duplexer loss was about 0.8 db

$K_2 = 0.83$

Substitution of the numerical values gives the following results:

With the 6 microsecond pulse

$R_{max} = 242$ nautical miles

With the 1 microsecond pulse

$R_{max} = 204$ nautical miles.

9-2. Comparison with SK-2 System. A check on the foregoing calculation is afforded by comparison with an SK-2 system on which the various factors have been measured and actual maximum range data has been obtained. In this system the pertinent factors are:

$G = 16.5$ db

$= 1.4$ m

$P_r = 170 \times 10^3$ w.

$K_1 = 2.6$ db 120 ft. RG-18/U

$K_2 = .8$ db

$P_r = 1.17 \times 10^{-14}$ watts

The maximum range calculated from these values is 174 nautical miles. This checks very closely with actual flight tests in which a B-24 at 30,000 feet was detected in the first lobe from 168 n. miles in to 155 n. miles. Compared with the SK-2 the XBF-1 stacks up about as follows:

		Db
Antenna Gain x Wave Length Factor	$(G)^2$	+ 3.5
Transmitter Peak Power	P_t	+ 5.5
Transmission Line Loss	K_1	- 1.7
R.F. Plumbing Loss Factor	K_2	0.0
Receiver Pulse Sensitivity	P_r	- 1.8
Net advantage of XBF-1		+ 5.5

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Thus the XBF-1 can be expected to substantially outperform the SK-2 and extrapolation from results with the latter equipment puts the XBF-1 lobe tips at about 240 miles.

9-3. Comparison with the AN/TPS-1B System. The pertinent factors of this system are as follows:

= .25 m.	P_t = 600 kw
F = 200/sec.	T = 4 usec
B = .35 Mc	$\overline{NF}$ = 11 db

The antenna is a 4 x 15 ft. paraboloid giving a possible gain of 30 db and a probable gain of perhaps 27 db. With a PPI the minimum detectable power should be about 9.0×10^{-14} watts and the calculated lobe tip range with = 50 sq. m. is about 235 n. miles. At the Chesapeake Bay Annex a B-24 was detected from 185 to 172 n. miles showing the actual lobe tip to be about 200 n. miles. Compared to this equipment the XBF-1 has a 12 db disadvantage on antenna gain, a 9.3 advantage from wavelength, a 3.2 disadvantage on r-f transmission line losses, and a 7 db advantage on minimum detectable power, giving a net advantage of about 1 db. By comparison with the AN/TPS-1B observed ranges then the XBF-1 lobe tips can be expected to reach to about 212 n. miles.

9-4. Anticipated Coverage Pattern of XBF-1. The foregoing calculations and comparisons indicate that with top performance the lobe envelope of an SR-1 should be between 210 and 240 nautical miles. Taking 220 as a compromise figure and assuming an antenna height of 110 ft. the vertical coverage pattern is shown by the dashed lobes in Plate 55. Experience with service equipment and performance reports from the Fleet indicate that average performance of naval search radar is some seven db below par. Application of this factor reduces the lobe maxima to 147 miles and coverage on this basis is indicated on Plate 55 by the solid lines.

9-5. Overhead Coverage. A plane directly overhead will have at least 6 db greater echo area than in head-on aspect and the reduction in gain of the system that is permissible before a plane overhead at 30,000 feet becomes undetectable is

$$= 40 \log \left(\frac{30{,}000}{6000\ R_{max}} \right) - 6$$

Taking R_{max} as 150 miles

$$= -65 \text{ db}$$

Then if the S.T.C. is not effective beyond 5 miles such a plane will be detectable and will appear without regard to antenna position if the field strength in the perpendicular is not more than 32 db down from the main beam. Plates 7, 8, and 9 show that the field intensity at the top

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and bottom edges of the dish is 60 to 70% of the intensity at the center. With this condition perpendicular lobes with field intensity at least 10% that of the main beam can be expected and accordingly there should be no difficulty in detection of overhead planes.

9-6. Experimental Coverage Results. The XBF-1 was set up at the Chesapeake Bay Annex and on 2 and 4 December tests with a B-24 target at various altitudes were carried out. A record of the signals obtained with the plane on 7,500 ft., 15,000 ft. and 22,500 ft. runs is given in Plate 56. The - 7 db lobes from Plate 55 are superimposed and clearly fit the data since the plane was not picked up in the first lobe on the 22,500 ft. run. Performance was therefore 7 db below that anticipated. Investigation of the discrepancy has not been possible because of the decision by the Navy not to obtain air search equipment on the 400 Mc band.

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REFERENCES

1. BuShips conf. ltr C-NXs-17055(916A) Serial 0-916-6521 dated 17 Feb. 1943 to the Director, NRL, assigning problem to develop transmitter, receiver and antenna units on new frequency bands for replacement in the XBF/SR System.

2. NRL secret ltr S-F125(375) Serial 1381 to BuShips reporting conference between NRL and BuShips representatives on XBF-1 and XBF-2 program.

3. BuShips conf ltr Section 938 Serial 103(938) dated March 22, 1944 to the Director, NRL requesting assignment of problem S43.1R-C to develop XBF-1 prototype receiver using 30 Mc i-f strip.

4. Conference at Radiation Laboratory, MIT, on April 8, 1944 between RL, NRL, BuShips, Raytheon, and RCA representatives concluding that SR standard console receiver unit should contain video distribution amplifier only.

5. Conference at BuShips on June 7, 1944 between BuShips, Raytheon, RCA and NRL representatives regarding console video unit specifications.

6. O.S.R.D. London Mission Report 4/15/43 requirements of a fighter interception control radar for aircraft carriers as stated by the British Admiralty.

7. BuShips Radar Performance Reports for period 1 January 1943 to 1 January 1944.

8. Minimum Detectable Radar Signal and its Dependance upon Parameters of Radar Systems, by A.V. Haeff, NRL Report RA-3A-208A.

9. Effect of Paraboloid on Size and Shape of Beam Patterns, Radiation Laboratory Report 54-9.

10. Theory of Radiation with Paraboloidal Reflectors, Radiation Laboratory Report 5-1S.

11. AMES Type II Mark II Aerial Equipment, T.R.E. Memorandum 7/Mo 110/CHW.

12. Vertical Elevation Beam Antenna Using Variable Frequency, National Research Council Report 260-6-3.

13. Television Transmitting Antenna for Empire State Building, RCA Review April 1939.

14. Contribution of Dish to Impedance of Antenna, Radiation Laboratory Report 442.

15. Graphical Analysis of Beam Patterns from Paraboloidal Reflectors, Radiation Laboratory Report 54-11.

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16. Antenna Duplexing, by R.A. Herring, Jr., NRL Report R-2213.

17. BuShips conf ltr S-S67/36(485-J) Serial 2184 to NRL dated 18 March 1942 assigning problem S45R-S(X4-28S) to develop anti-jam receiver circuits.

18. NRL ltr S-S67-5/RCM(374:THC) Serial 374 to BuShips reporting the general requirements for satisfactory a-j performance for PPI.

19. Investigation of Anti-Jam Receivers for Search Radar, by T.H. Chambers, NRL Report R-2392.

20. Factors Determining Radar Range, by R.C. Longfellow, General Electric Co. Report EMT-522.

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TABLE I

PARTS LIST FOR:

XBF-1 Remote Transceiver Control Panel and XBF-1 Transceiver Unit,
Excluding Receiver, Monitor, and Keyer for Gap Tubes

Part No.	Name and Purpose	Size	Rating	Manufacturer
C101	Power supply filter condenser	1 mfd	10 kv.	G.E.
C102	Surge by-Pass condenser	2 mfd	1000 v.	Cornell-Dubilier
C103	Meter by-pass condenser	.01 mfd	2500v. d.c.t.	C-D type 4E-21010 Cat. 260-T
C104	Osc. grid-cathode by-pass	1 mfd	1000v.	Cornell-Dubilier
C105	H.V. Sw. Motor phasing cond.	3.75 mfd	330v. a.c.	G.E. Cat. 21F218
C106	Meter by-pass condenser	.01 mfd	2500v. d.c.t.	C-D type 4E-21010 Cat. 260-T
C401	" " "	"	"	"
C107	Grid meter filter condenser	1.0 mfd	1000v.	
C108	" " by-pass "	.01 mfd	2500v. d.c.t.	
C109	Surge by-pass condenser (H.v. D.C. meter circuit)	1.0 mfd	1000v.	
C110	Trigger coupling condenser	50 mmfd	20 kv	NRL
C111	" " "	"	"	Glass plate
C112	Pulsing condenser for T105	.005 mfd	7.5 K.V. working 12 K.V. test	Sprague Mica removed from case. (C110, 111 and C112 are mounted in oil in can with trigger transformer)

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Part No.	Name and Purpose	Size	Rating	Manufacturer
F101	Transmitter plate fuse	30 amp.	250 v.	Bussman Mfg. Co. Renewable fuse #1015
F102	" " "	"	"	"
F103	Receiver-indicator fuse	15 amp.	"	"
F104	" " "	"	"	"
F105	Transmitter filament fuse	10 amp.	"	"
F106	" " "	"	"	"
F107	Synchro fuse	30 amp.	"	"
F108	" "	"	"	"
F109	Heater fuse	5 amp.	250 v.	"
F110	" "	"	"	"
I101 I401	Main power pilot assembly (blue)	(See note #1)		Dialco 77-58
I102 I402	Filament pilot assembly (green)	"		"
I103 I403	Radiation pilot assembly (red)	"		"
	Radio panel lights miniature bayonet	T3-1/4 bulb #44 base	6.3 v. 250 ma.	G.E.

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Part No.	Name and Purpose	Size	Rating	Manufacturer
K101	Plate contactor and shorting bar relay	2 pole normally open	25 amp. contacts	Allen-Bradley A-209 (See note #2)
K102	Plate overload relay	.1-.4 amp. D.C.		Westinghouse type MN over-current relay. Navy type CAY 29139 Style 1161105.
K103	Time delay relay #1 (3 min.)	Single pole normally open	10 amp. 115 v.	R.W. Cramer Co., Inc.
K104	Radiation relay	4 pole normally open	3-10 amp.poles 1-25 amp.poles	(See note #3)
K105	Receiver-indicator relay	5 pole normally open	10 amp. 115 v.	(See note #4)
K106	Time delay relay #2 (1 min.)	single pole normally open	10 amp. 115 v.	R.W. Cramer,Co., Inc.
K107	H.V. control stepper relay	single pole 6 pos. plus one. single pos. pole which closes with the lowest voltage position of the 6 position pole.	25 amp. for 6 pos. arm. 5 amp. for single position arm.	Struthers-Dunn
K108	H.V. relay to switch 4C35 thyratron	2 pole. One normally open One normally closed.	15 K.v. ins.	NRL

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Part No.	Name and purpose	Size	Rating	Manufacturer
L101	Charging choke	100 H. at 250 ma. av. D.C. This value of inductance is sufficient to produce nearly constant current charging.		NRL
L102	Filament dropping choke	35 MH	2.5 amp. 60 cycle	NRL
L103	Grid meter decoupling choke	10 MH	20 K.v. ins. (See note #5)	NRL
M101	Transmitter power supply voltmeter	0-10KV DC scale	1 ma movement	Westinghouse type NX-35 Style WG-45949-S.
M102	Transmitter plate milliammeter	500 ma.		
M103	" filament voltmeter	150V. AC	25-133 cycles	G.E. type #AO-22 model 8AO22 USN type #CG22 084
M104	Tube hour meter	Max. hrs. 9,999.9	115 v. 60 cycle	R.W. Cramer Type RT-2H
M105	Transmitter grid milliammeter	10 ma		
M106	Echo box meter	100 u amp.		
R101	Transmitter cathode resistor	20 ohms	120 watt	
R102	" grid "	200 ohms	10 watt	
R103	Charging resistor for C112	.40 meg	80 watt	(4) Sprage 20F

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Part No.	Name and Purpose	Size	Rating	Manufacturer
R104	Plate dropping resistor	45 ohms	20 watt	
R105	I.V. sw. motor phasing resistor	330 ohms	35 watt	Sprague type 35F
R106	Voltmeter shunt	18000 ohms	1 watt	
R107	" "	"	"	
R108	Grid meter resistor			
R109	Trigger cube equalizing res.	1 meg.	12 watt	Sprague
R110	" " " "			
R111	" " " "			
R112	IC Voltmeter multiplier	5 meg.	5 k.v.	Sprague MFA
R113	" " "	"	"	"
S101	Pulse length change switch	SPDT	3 amp. 125 v.	Arrow. H. and H. Toggle
S102	Radiation switch	(See note 6)	10 amp. 125 v.	Donald P. Mossman, Inc. lever action Series 4101
S402	" "	"	"	" "
S103	High voltage "OFF" push-button	One N.C. pole One N.O. pole	Heavy duty button unit red	Allen-Bradley type X-49580
S403	" " " "	"	"	" " " "
S104	High voltage "ON" push-button	"	Heavy duty unit black	Allen-Bradley Type X-49579

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Part No.	Name and Purpose	Size	Rating	Manufacturer
S404	High voltage "ON" push-button	One N.C. pole One N.O. pole	Heavy duty button unit black	Allen-Bradley Type X-49579
S105	High voltage "RAISE" push-button	"	"	" " " "
S405	" " " " "	"	"	" " " "
S106	High voltage "LOWER" push-button	"	"	" " " "
S406	" " " " "	"	"	" " " "
S107	Main power on emergency off switch	DPST	115 v. AC	(See note #7)
S407	Indicator power on - emergency off switch	"	10 amp. 125 v.	Cutler-Hammer
S108	Delay line change over high voltage switch	(See note #8)		Communications Prod. type 88
S109	Delay line change over control switch	(See note #9)		Oak Switch
S110	Remote-local control switch	(See note #10)	10 amp. 125 v.	Donald P. Hoseman Lever action series 4101
S111	Filament voltage adjusting switch	Single pole 25 amp. 10 position 300 v. ac. (See note #11)		Ohmite model 312
S112	Plate overload relay reset button	Single pole 3 amp. normally open	125 v. ac.	Arrow, H. & H.
S412	" " " " "	"	"	"

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Part No.	Name and Purpose	Size	Rating	Manufacturer
S113	Interlock switch			G.E. 7760014
S114	" "			
S115	Echo box switch	SPST	3 amp. 125 v.	Arrow, H & H Toggle
S116	Transmitter filament sw.	SPST	10 amp. 125 v.	Cutler-Hammer
S117	Heater switch	DPST	10 amp. 125 v.	" "
T101	Rectifier fil. transformer	130 v.a. Prd:115 v 60 cycle	Sec: 5v 26 amp. 12 kv ins.	NRL 416 Varnish impreg. Electrostatic shielding P-S
T102	Transmitter filament transformer	(See note #12)		NRL 1056
T103	Transmitter plate transformer	Supply should have a DC output of 250 ma at 7500 volts. Primary should be tapped to give 50%, 75%, 81%, 87.5%, 94% and 100% of the rated output voltage.		
T104	Main pulse transformer	37.5 ohms pri.265 ohms sec.		NRL
T105	Pulse transformer to fire trigger tubes	5:1 step up turns ratio		NRL
T106	Pilot light transformer Indicator dial-light	Prd:115 v. 60 cycle	Sec. 6.3V. 2 amp.	NRL
T401	Transformer	Pri:115 v. 60 cycle	Sec. 6.3V. 4V. and 2V. at 2 amp.	NRL

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Part No.	Name and Purpose	Size	Rating	Manufacturer
V101	Rectifier tube 371-A			Western Electric
V102	" " "			" "
V103	Gap tube 1B42			" "
V104	" " "			" "
V105	" " "			" "
V106	7J22 oscillator tube			" "
	Line filter	.01 mfd	75 amp.	NRL
	1 microsecond delay line	5 section 37.5 ohm	15 kv. 540c.p.s. max. rep. rate	Sprague 15-E5-1-600-37.5p
	6 microsecond delay line	6 section 37.5 ohm	15 kv 200c.p.s. max. rep. rate	Sprague 15-E6-6-200-37.5p
	Blower	Size #1	Laby conoidal	Buffalo Forge Co.
	Blower motor	1/12 HP	115 V. 60 cycle 3450 RPM	

Unless otherwise specified, all ratings expressed in this table consist of working values.

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NOTES

1. Pilot Light Assemblies - Diaco "Vari-Dim" assembly, mechanical shutter type D.V. 628, brass, black nickle finish, smooth sand-blasted overall lenses, for miniature bayonet bast lamps.

2. A shorting bar has been affixed to the Allen-Bradley A209 relay armature. This bar discharges the main filter condenser through the charging choke.

3. The XBF-1 at present has an Allen-Bradley B620 relay for the radiation relay. This relay has no 20 Ampere contacts. To overcome this, two 10 Ampere contacts are used in parallel for the heavy current lead. Other relays are under consideration.

4. This relay should be quite resistant to shock, as it employs a latch-in contact to keep it energized. In the present model, we are using a counter-balanced Signal co-relay having two 10 ampere poles and two 35 ampere poles. This relay was developed especially for this purpose. However, an additional 10 amp. contact is now needed to operate the filament pilot light.

5. The grid meter decoupling choke consists of 17 universal wound sections, 1" diameter form, 1/8" cam, 70 turns per section, wound with #30 s.s.e. wire. There is 1200 V. across each section, and 20 Kv between the high end of the choke and ground. Total length of the coil is six inches.

6. Radiation Switch - Donald P. Mossmas lever action series 4101, position 1 - non-locking, 1 form B contact. Position 2 - Locking, 1 form B contact. Contact rating standard, 10 amps AC. May be either in left or right position.

7. The present model uses a Westinghouse Type [illegible] "multi-breaker" Style #16955. However, no power for synchro excitation is furnished by this model. If this power were actually furnished by the transmitter main power switch, as shown on the schematic diagram, then a 75 amp. switch would be necessary.

8. Delay Line Change Over High Voltage Switch - Motor driven switch. Motor: General Electric Synchronous Induction motor. Model 5SMY50H36 volts 115, Amps. 3. 60 cycle. Torque 40 in/oz. 75 RPM. 40°C rise. High voltage section: Revised Communications Products Transmitting switch.

9. Low Voltage Control Section: 4 section oak switch. Special design. For revisions see blueprint.

10. Remote Local Control Switch - Donald P. Mossman, Inc., lever action, series 4101. Postion 1 - Locking; Position 2 - no throw.
Contacts - 14 form C, distributed as follows: position 1 - 8 form C; position 2 - 6 inverted form C. Contact rating standard 10 amp. AC.

11. The use of this switch is tentative. A snal action non-shorting type switch in which the arm cannot stop between contacts is desired.

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12. Filament Transformer - Primary: 115V, 60 cycle. tapped at 100, 105, 110, 115, 120, 125, 130 volts. Secondary 11V 28A. Secondary insulation for 20 KV pulse. Uncased. Secondary wound on 3 1/2 inch bakelite tubing to lower interwinding capacity.
Construction details: Primary - Mandrel 1 1/2 inch x 2 1/4 inch.
Core insulation, .022 inch armoweld. 299 turns. #15 enamel wire.
Lug leads. Turns/inch - 16.
Interlayer insulation - .015 armoweld. Width 2 1/4 inch. Tapped at 230, 241, 253, 264, 276 and 287 turns respectively.
Secondary - Fit over 3 1/2 inch bakelite tube. 34 turns. 9 layers.
4 turns/inch. Wire .1 x .2 inch. Width 1 inch. Wrap with 2 layers linen tape.
Impregnate. 3 layers black varnish cambric tape. Core - window 2 1/2" x 4 1/2". Cross section 1 1/4 inch wide x 1 7/8 inch stack.
Lamination obtained by cutting in half a 6 1/4 inch VE1250 Allegheny Ludlum lamination.

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Table 2

Types of Jamming Used in Test of XBF-1 Receiver

Modulation

Type of Signal	Type	Percent	Level
CW			10 uv
			100 uv
			1 mv
			10 mv
			50 mv
MCW	1000 cy Sine	25	10 uv
			100 uv
			1 mv
			10 mv
			50 mv
MCW	50 kc Sine	25	10 uv
			100 uv
			1 mv
			10 mv
			50 mv
MCW	1000 cy Sine + 50 kc Sine		10 uv
			100 uv
			1 mv
			10 mv
			50 mv

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Table 3

Frequency Drift of XBF-1 Receiver

During Warm-up

Time	Frequency	Drift
00 min.	400.00 Mc	900 kc
05	400.90	40
10	400.94	20
15	400.96	0
30	400.96	0
45	400.96	0
1 hr. 00 min	400.96	0
1 15	400.96	0
1 30	400.96	0
1 45	400.96	0
2 00	400.96	0

With Voltage Variation

E_p	E_h	Frequency	Drift
Normal	Normal	400.00	--
-10%	Normal	400.06	+ 60 kc
+10%	Normal	399.98	- 20 kc
Normal	Normal	400.00	--
Normal	- 10%	400.00	0 kc
Normal	+ 10%	399.94	-60 kc
Normal	Normal	400.00	--
- 10%	- 10%	400.02	+ 200 kc
+ 10%	+ 10%	399.90	- 100 kc

[redacted]

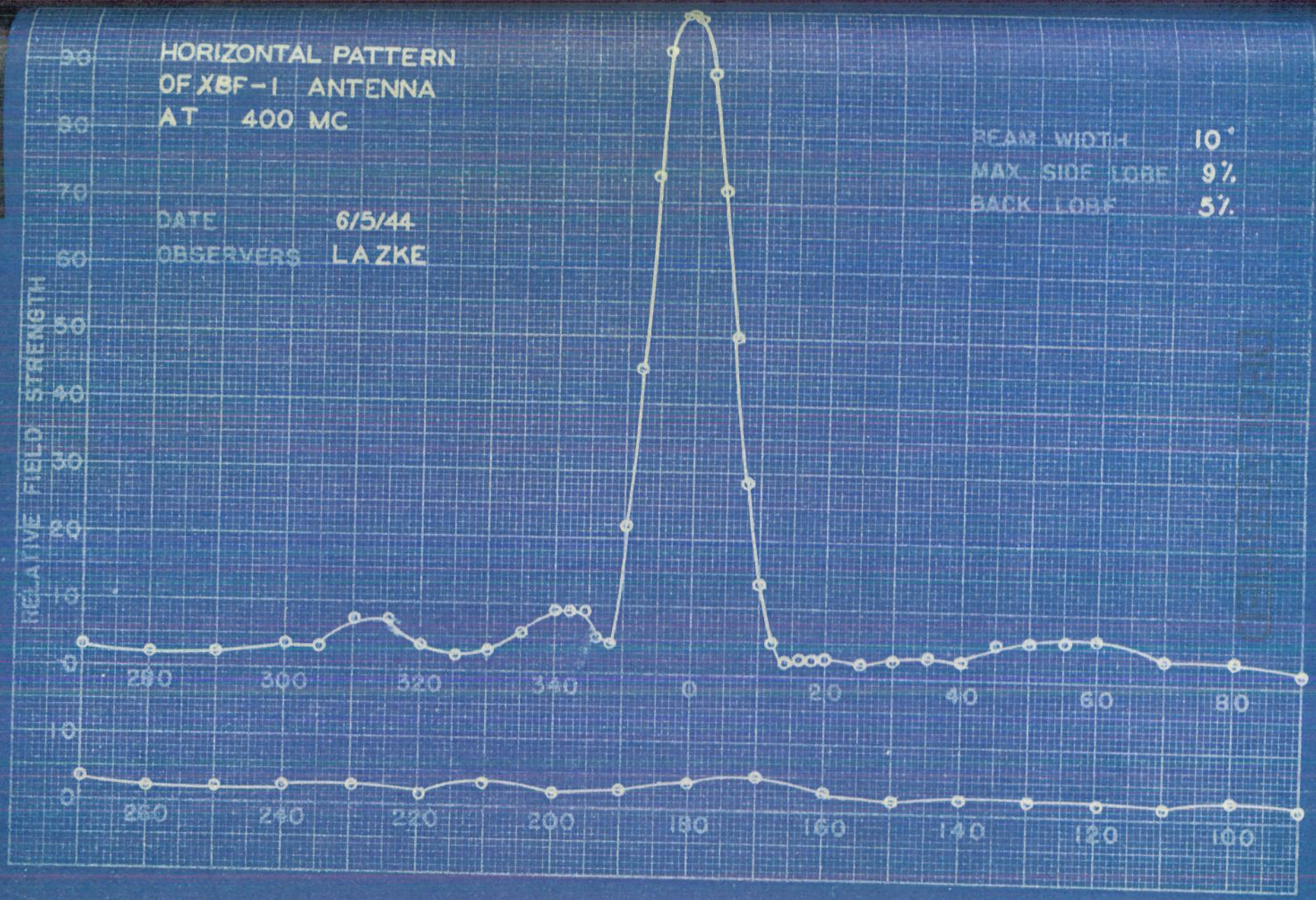
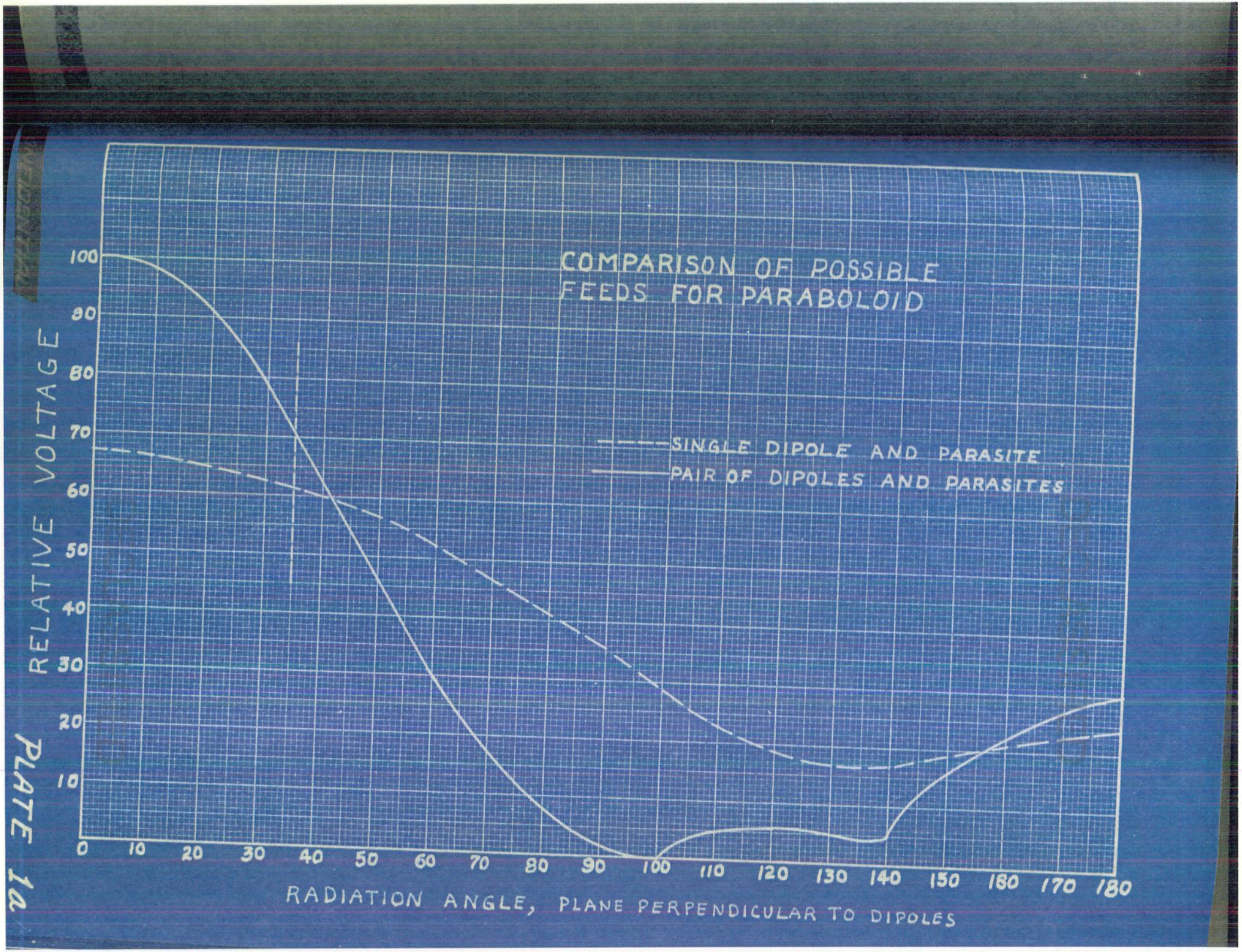
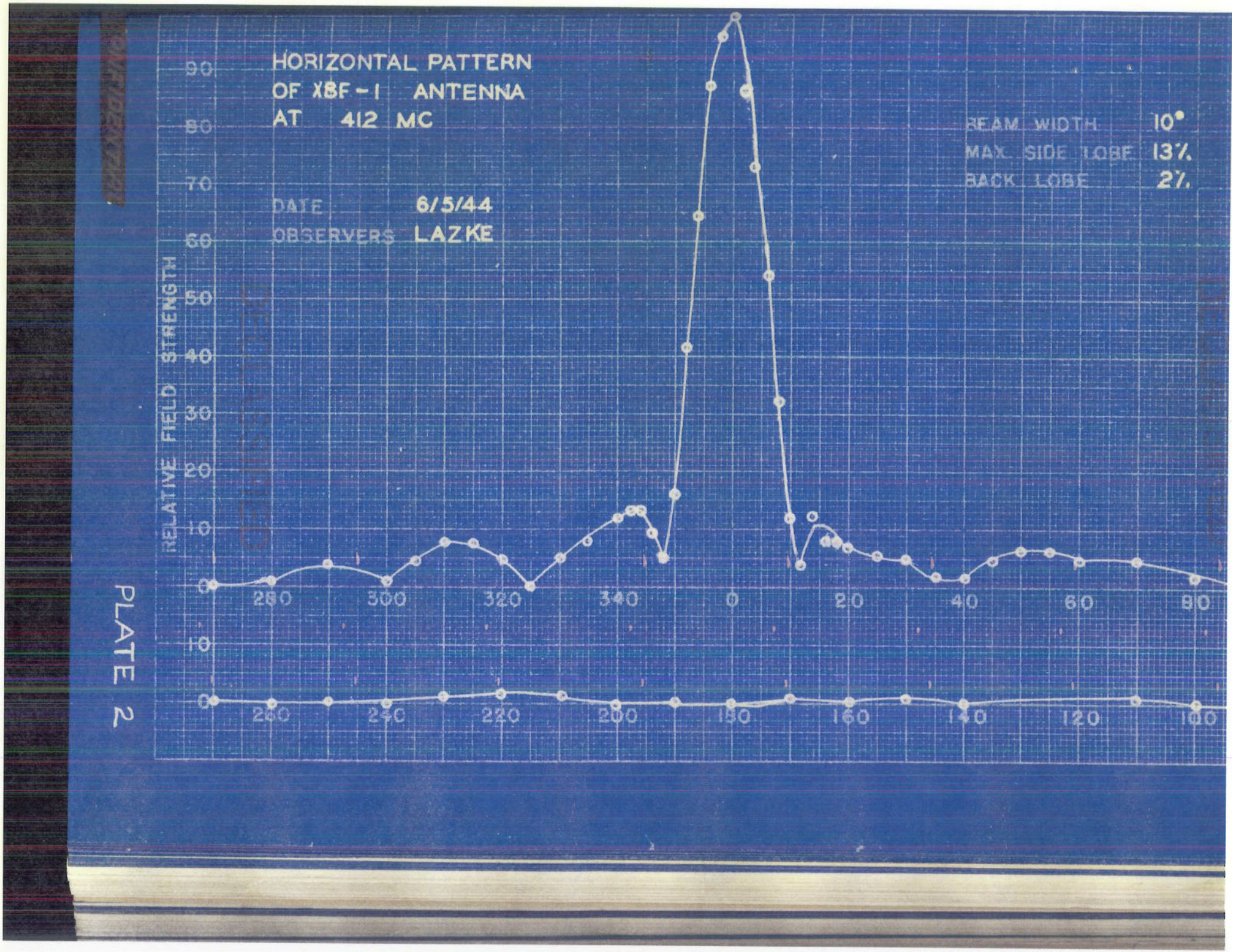

HORIZONTAL PATTERN
OF X8F-1 ANTENNA
AT 400 MC
DATE 6/5/44
OBSERVERS LAZKE
BEAM WIDTH 10°
MAX. SIDE LOBE 9%
BACK LOBE 5%
RELATIVE FIELD STRENGTH
90
80
70
60
50
40
30
20
10
0
280
300
320
340
0
20
40
60
80
260
240
220
200
180
160
140
120
100

PLATE 1


COMPARISON OF POSSIBLE
FEEDS FOR PARABOLOID
SINGLE DIPOLE AND PARASITE
PAIR OF DIPOLES AND PARASITES
PLATE 10
RELATIVE VOLTAGE
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
RADIATION ANGLE, PLANE PERPENDICULAR TO DIPOLES


HORIZONTAL PATTERN
OF XBF-1 ANTENNA
AT 412 MC
DATE 6/5/44
OBSERVERS LAZKE
BEAM WIDTH 10°
MAX. SIDE LOBE 13%
BACK LOBE 2%
RELATIVE FIELD STRENGTH
90
80
70
60
50
40
30
20
10
0
280
300
320
340
0
20
40
60
80
10
0
260
240
220
200
180
160
140
120
100
PLATE 2

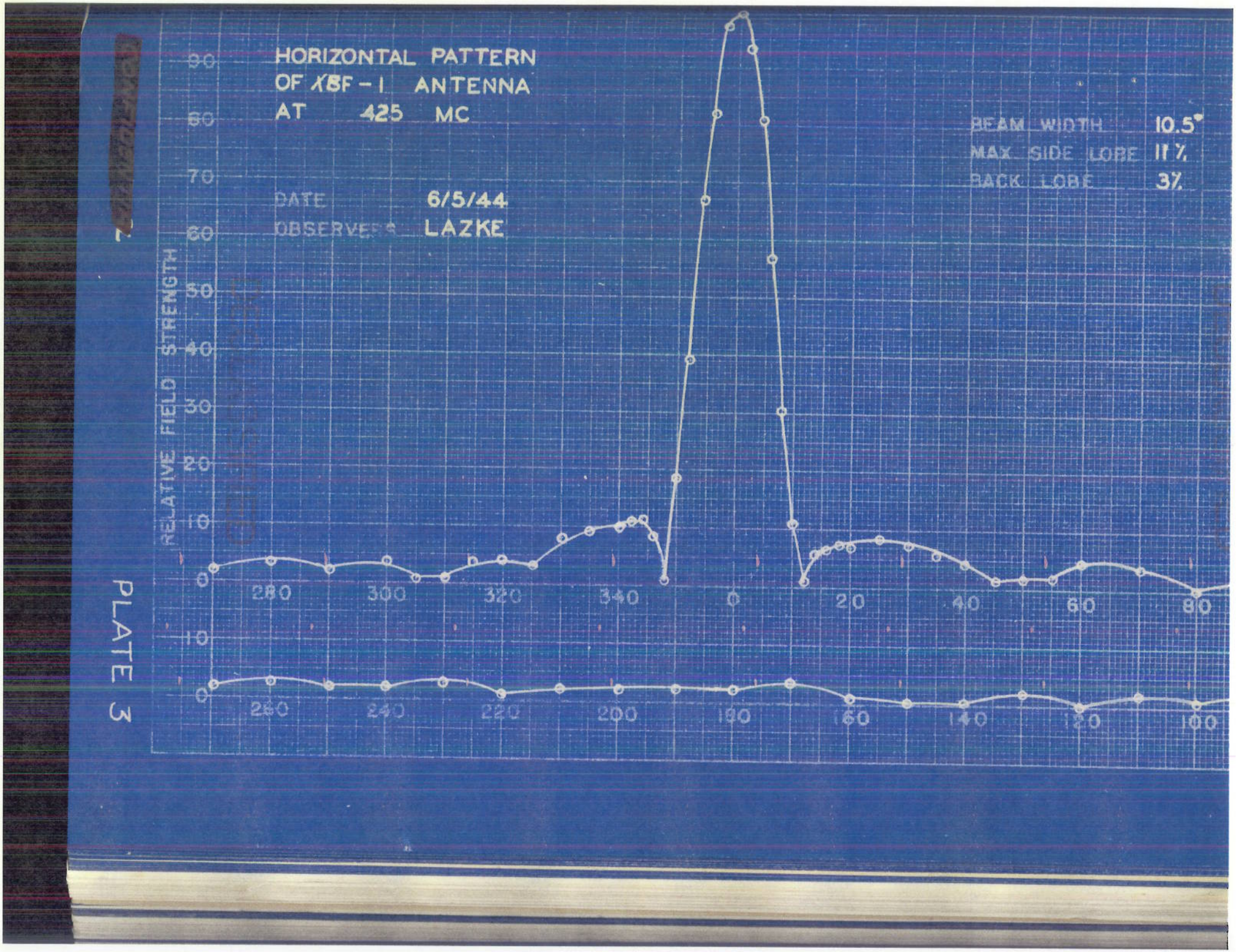
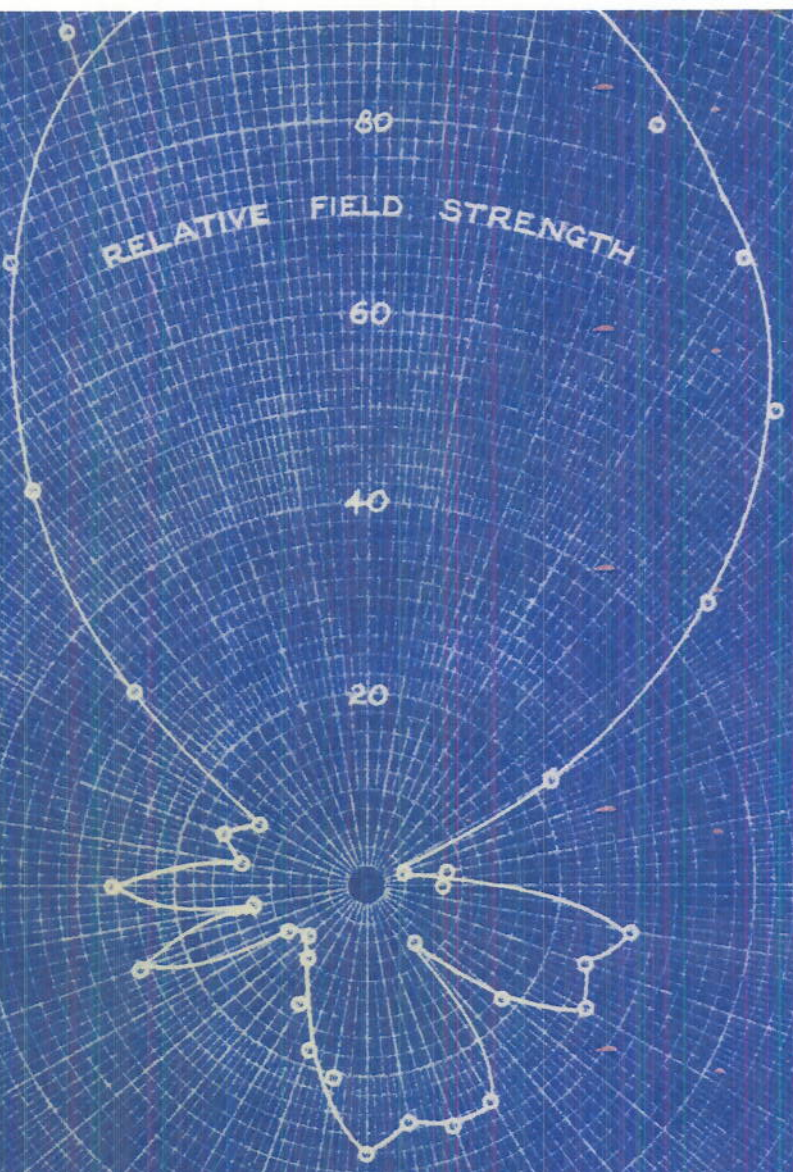

HORIZONTAL PATTERN
OF XBF-1 ANTENNA
AT 425 MC
DATE 6/5/44
OBSERVER LAZKE
BEAM WIDTH 10.5°
MAX SIDE LOBE 11%
BACK LOBE 3%
RELATIVE FIELD STRENGTH
90
80
70
60
50
40
30
20
10
0
280
300
320
340
0
20
40
60
80
10
0
260
240
220
200
180
160
140
120
100

PLATE 3



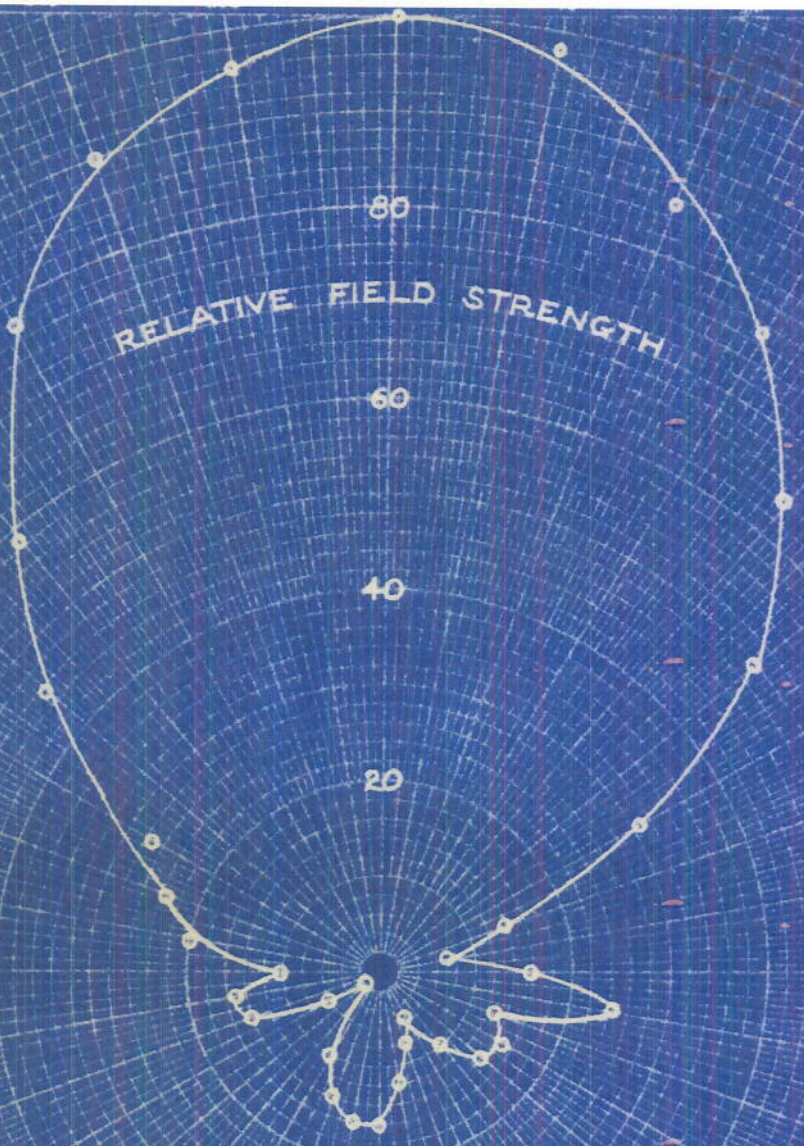
PRIMARY HORIZONTAL PATTERN

X8F-1 ANTENNA FEED SYSTEM

400 MC

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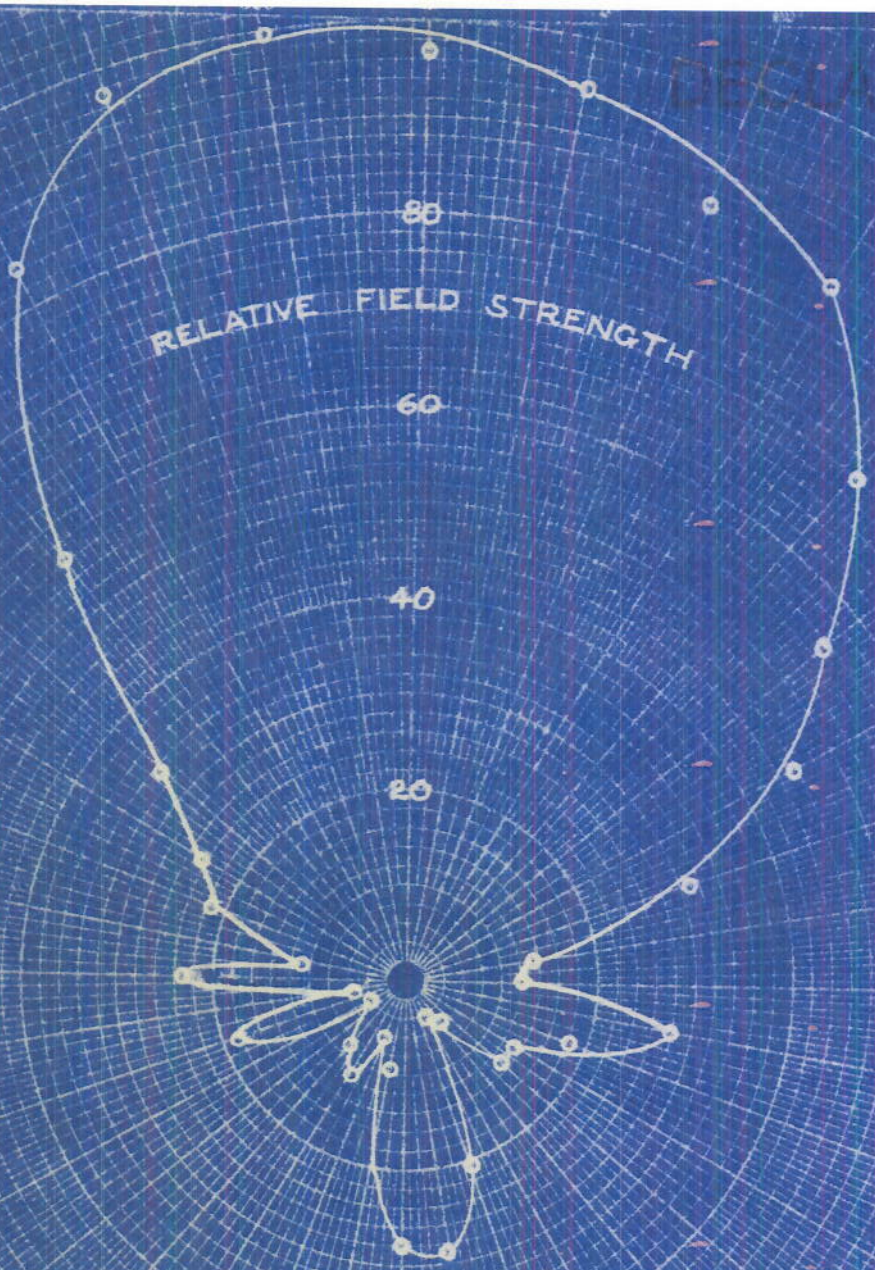
PLATE 4



PRIMARY HORIZONTAL PATTERN
X8F-1 ANTENNA FEED SYSTEM
412 MC

PLATE 5

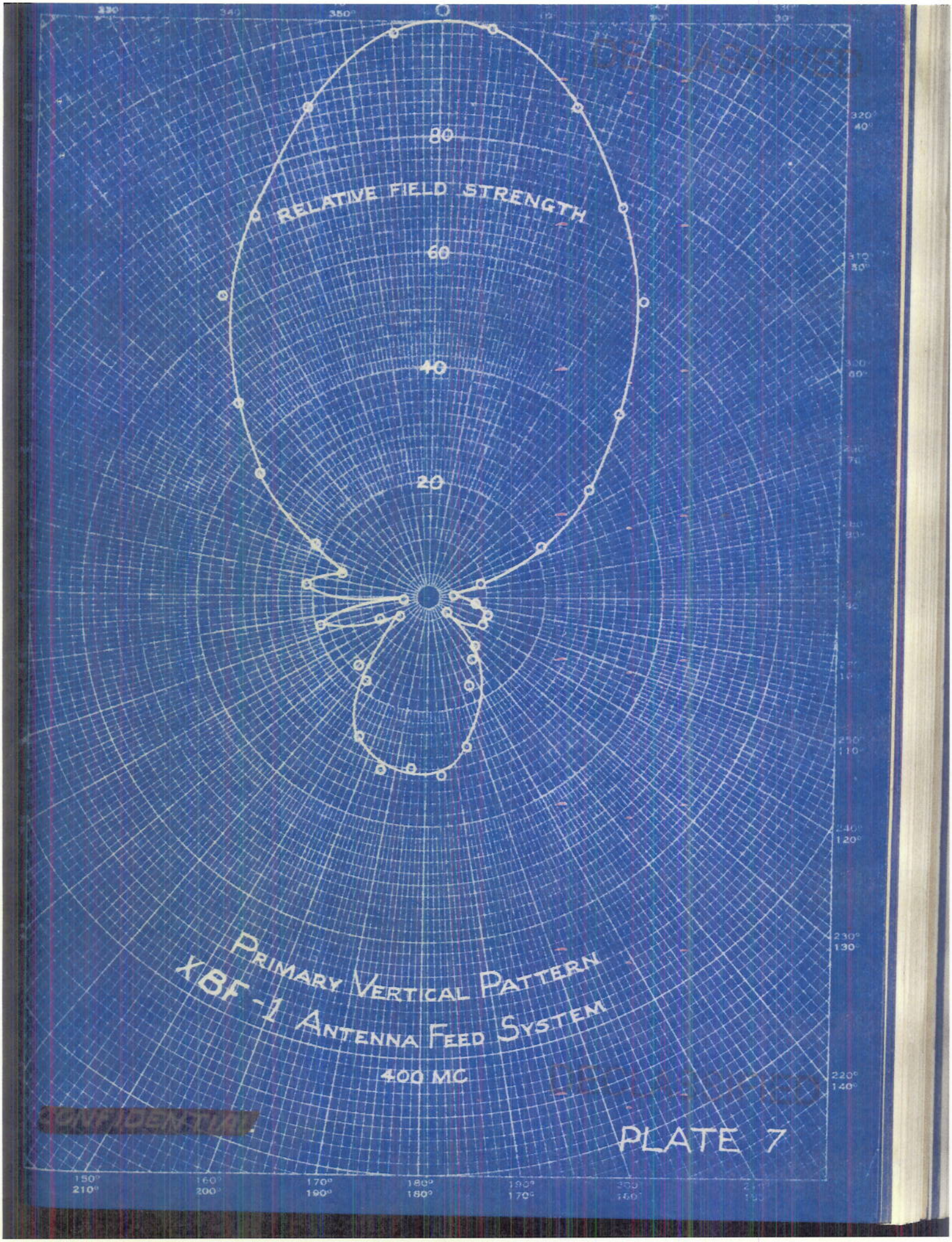
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PRIMARY HORIZONTAL PATTERN
X8F-1 ANTENNA FEED SYSTEM
425 MC

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PLATE 6



PRIMARY VERTICAL PATTERN

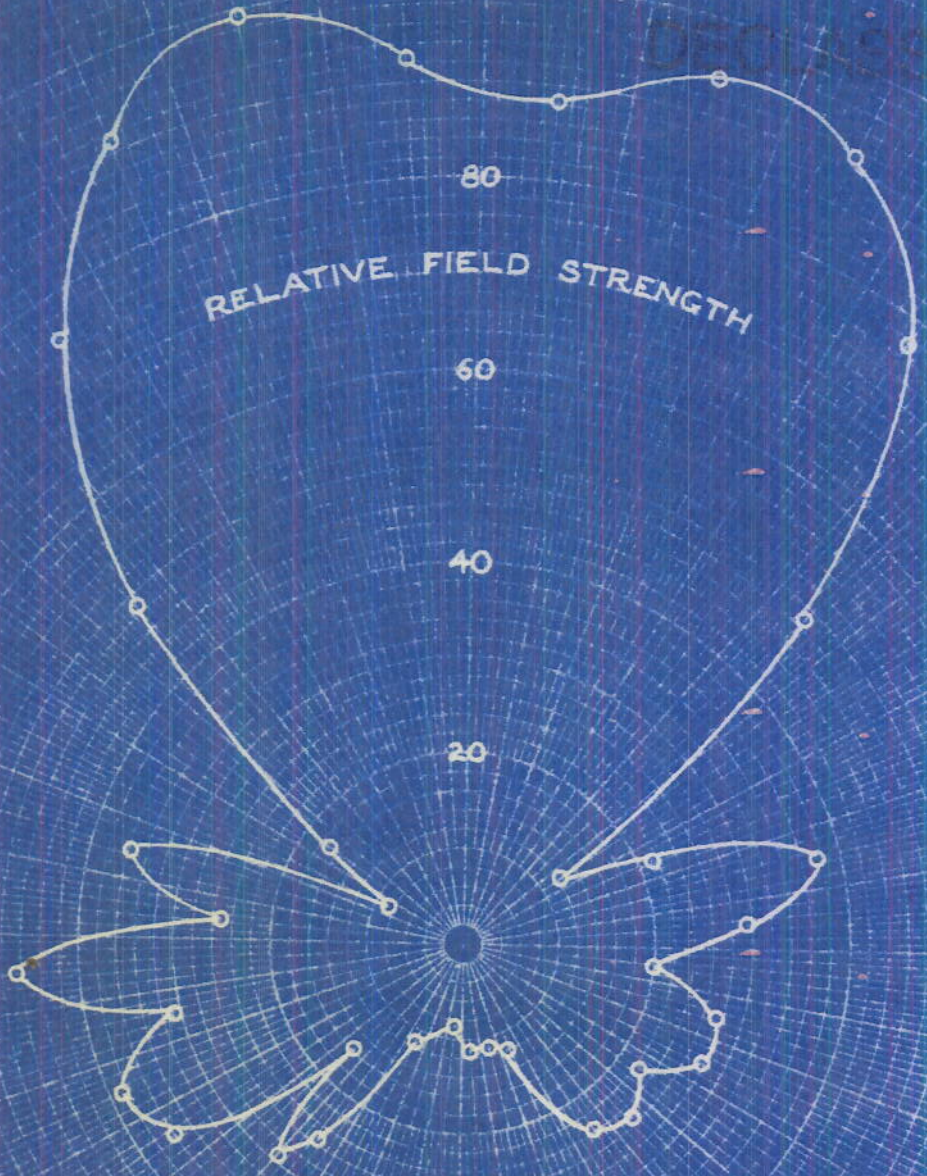
XBF-1 ANTENNA FEED SYSTEM

400 MC

PLATE 7

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DECLASSIFIED

DECLASSIFIED



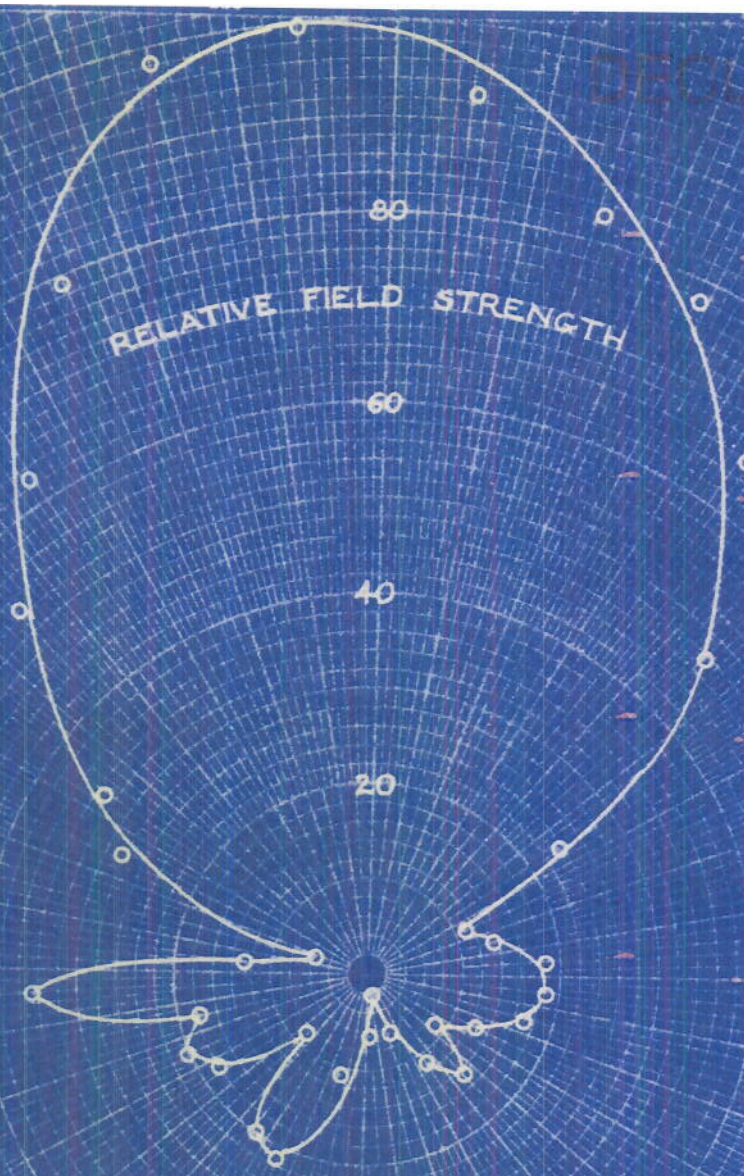
PRIMARY VERTICAL PATTERN
X8F -1 ANTENNA FEED SYSTEM
412 MC

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PLATE 8

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PRIMARY VERTICAL PATTERN
*8F-1 ANTENNA FEED SYSTEM
425 MC

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PLATE 9

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IMPEDANCE OF XBF-1 ANTENNA

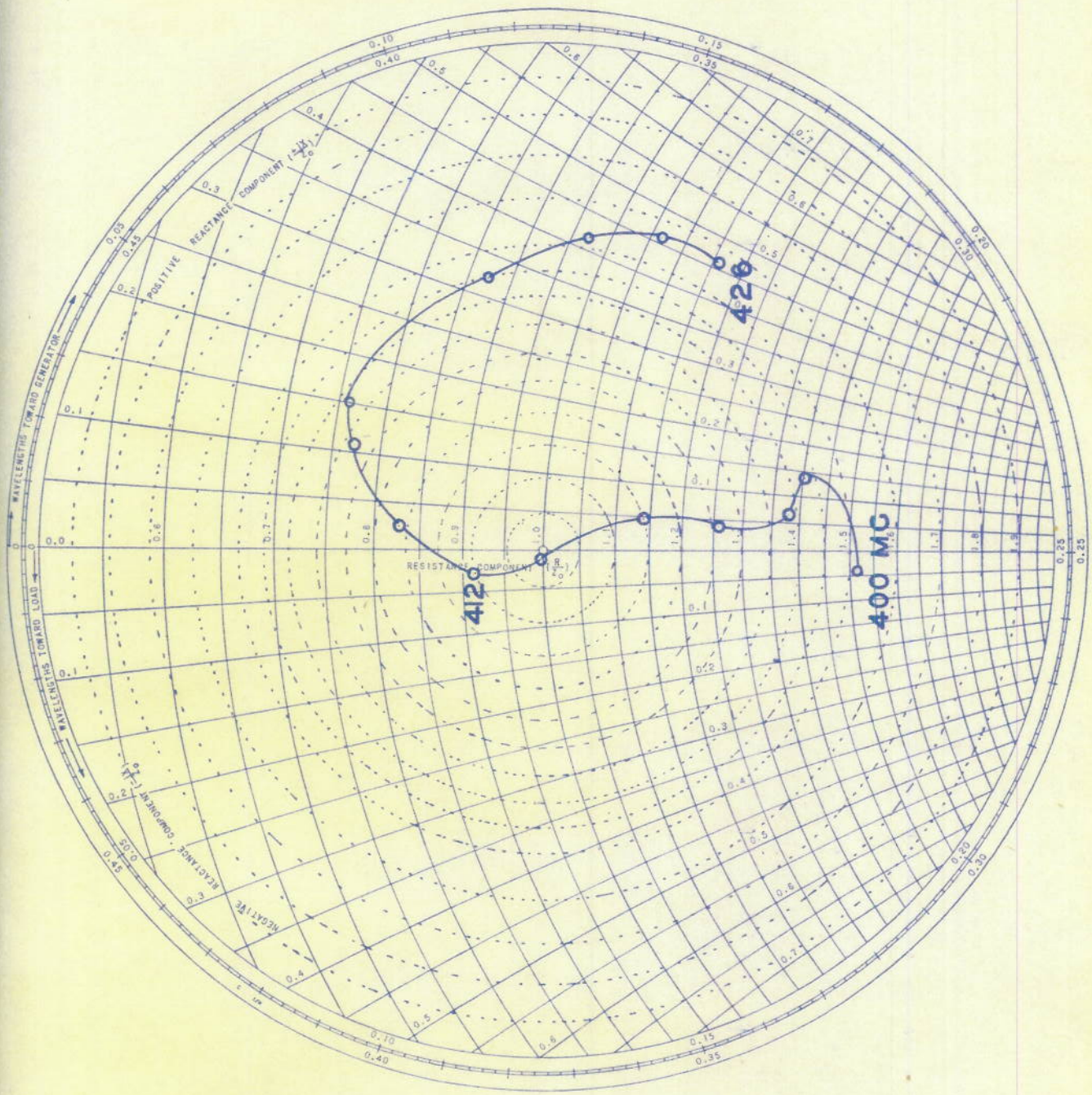
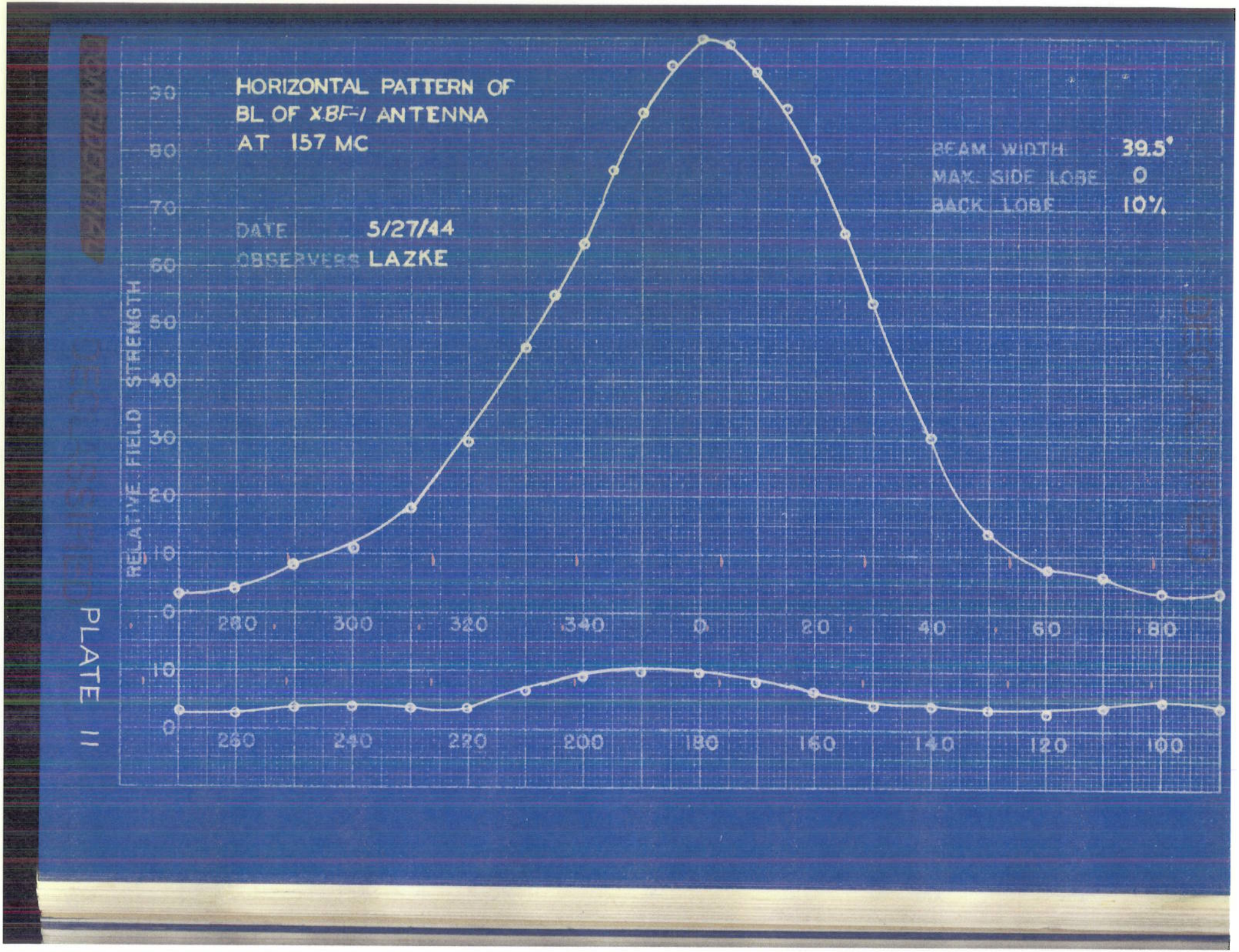
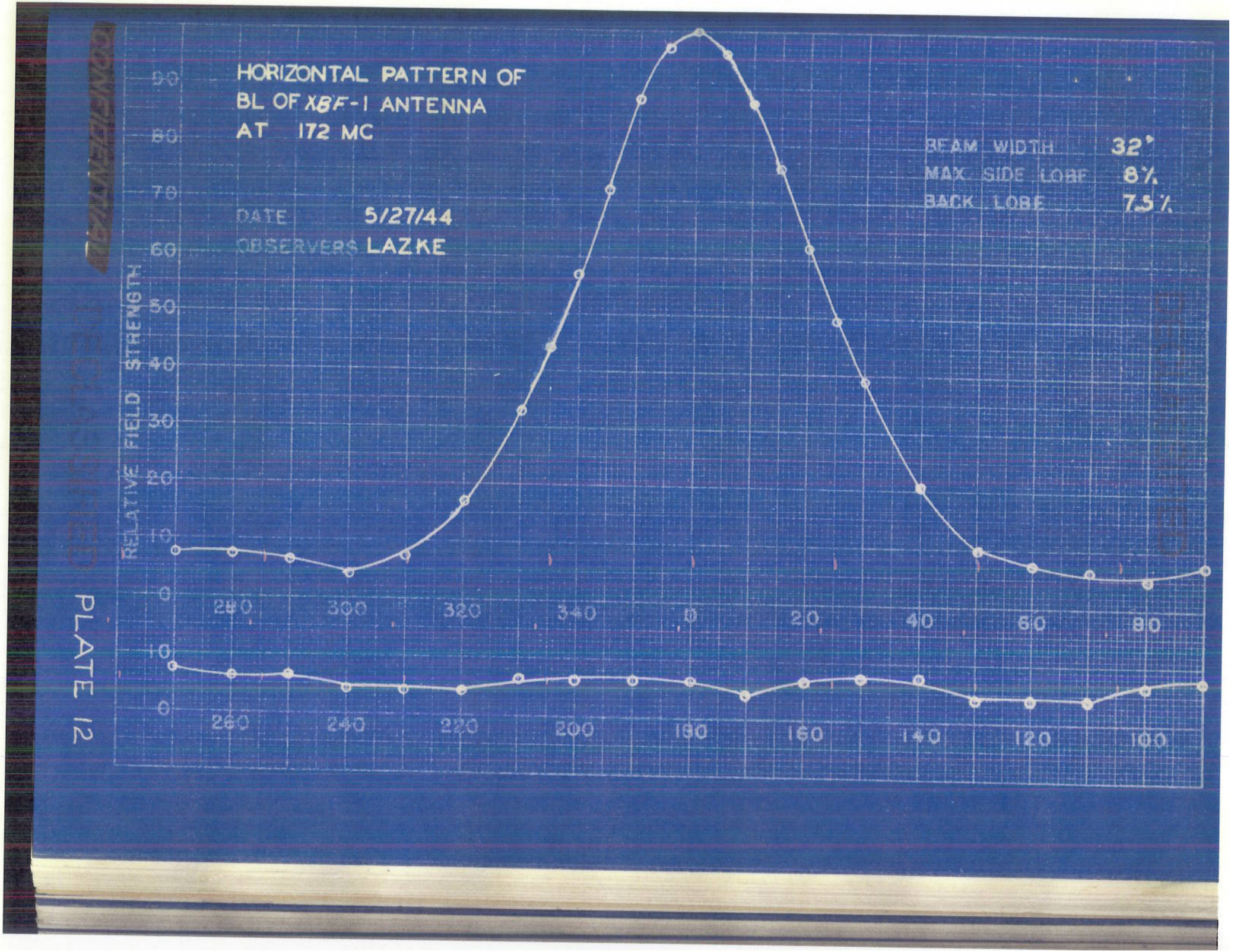


PLATE 10

DECLASSIFIED


HORIZONTAL PATTERN OF
BL OF XBF-1 ANTENNA
AT 157 MC
DATE 5/27/44
OBSERVERS LAZKE
BEAM WIDTH 39.5°
MAX. SIDE LOBE 0
BACK LOBE 10%
RELATIVE FIELD STRENGTH
90
80
70
60
50
40
30
20
10
0
280
300
320
340
0
20
40
60
80
10
0
260
240
220
200
180
160
140
120
100
PLATE 11


HORIZONTAL PATTERN OF
BL OF XBF-1 ANTENNA
AT 172 MC
DATE 5/27/44
OBSERVERS LAZKE
BEAM WIDTH 32°
MAX SIDE LOBE 8%
BACK LOBE 7.5%
RELATIVE FIELD STRENGTH
90
80
70
60
50
40
30
20
10
0
280
300
320
340
0
20
40
60
80
260
240
220
200
180
160
140
120
100
CONFIDENTIAL
PLATE 12

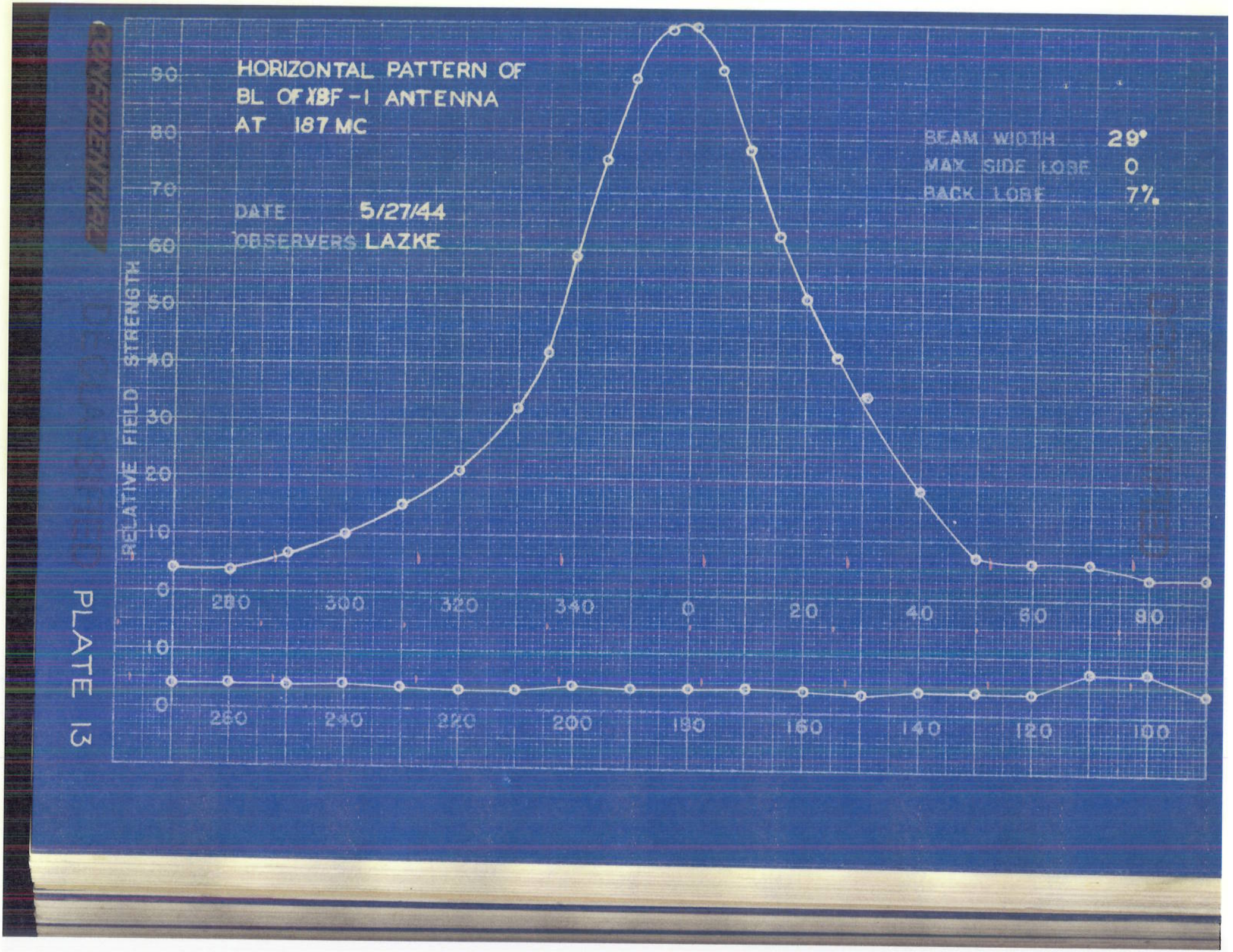
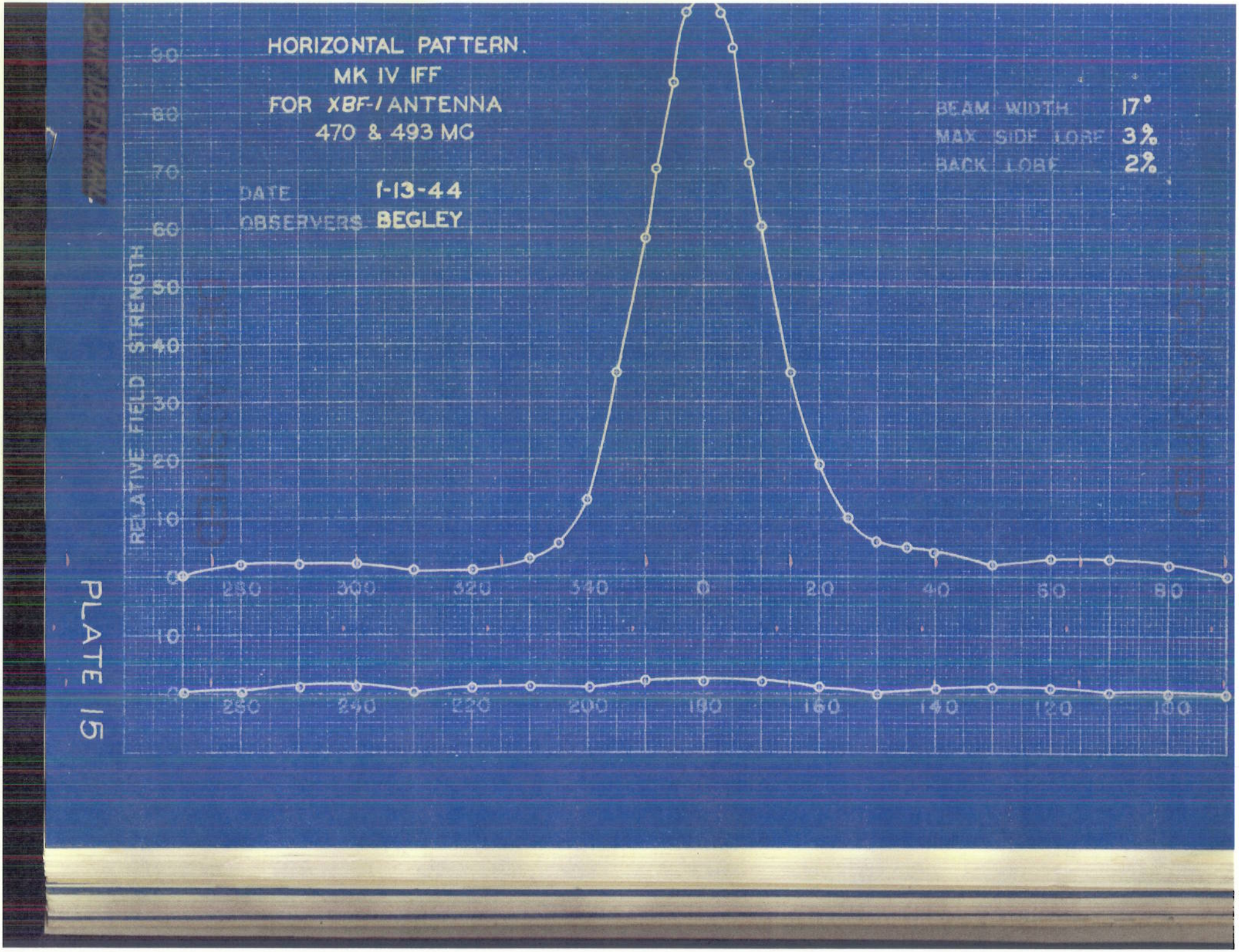

CONFIDENTIAL
HORIZONTAL PATTERN OF
BL OF XBF-1 ANTENNA
AT 187 MC
DATE 5/27/44
OBSERVERS LAZKE
BEAM WIDTH 29°
MAX SIDE LOBE 0
BACK LOBE 7%
RELATIVE FIELD STRENGTH
90
80
70
60
50
40
30
20
10
0
280
300
320
340
0
20
40
60
80
260
240
220
200
180
160
140
120
100
PLATE 13

PLATE 14

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NO. 3110. 20 DIVISIONS PER INCH BOTH WAYS. 120 BY 180 DIVISIONS.
CODEX BOOK COMPANY, INC., NORWOOD, MASSACHUSETTS.
PRINTED IN U.S.A.


HORIZONTAL PATTERN.
MK IV IFF
FOR XBF-1 ANTENNA
470 & 493 MC
DATE 1-13-44
OBSERVERS BEGLEY
BEAM WIDTH 17°
MAX SIDE LOBE 3%
BACK LOBE 2%
RELATIVE FIELD STRENGTH
90
80
70
60
50
40
30
20
10
0
280
300
320
340
0
20
40
60
80
10
0
260
240
220
200
180
160
140
120
100
PLATE 15

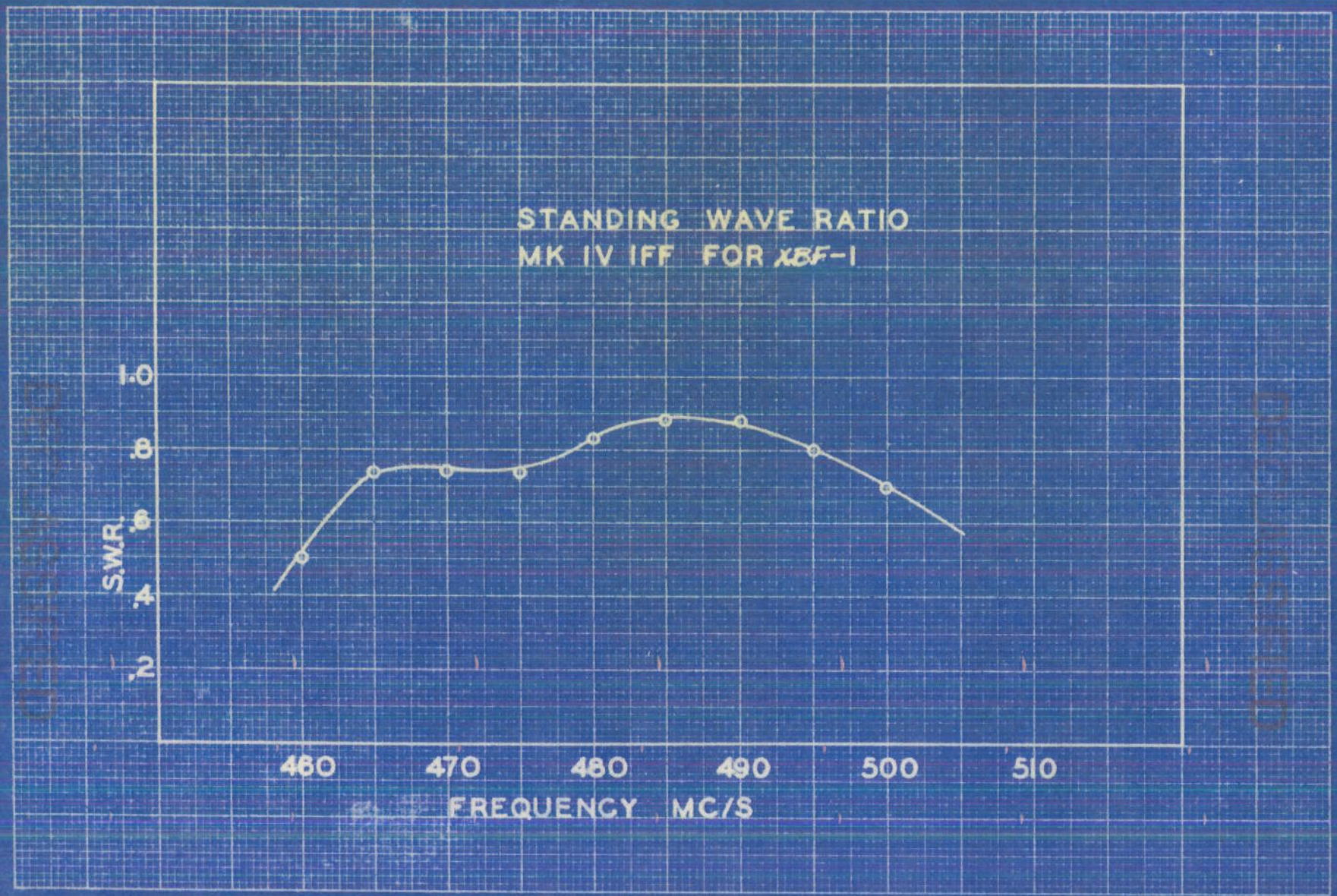
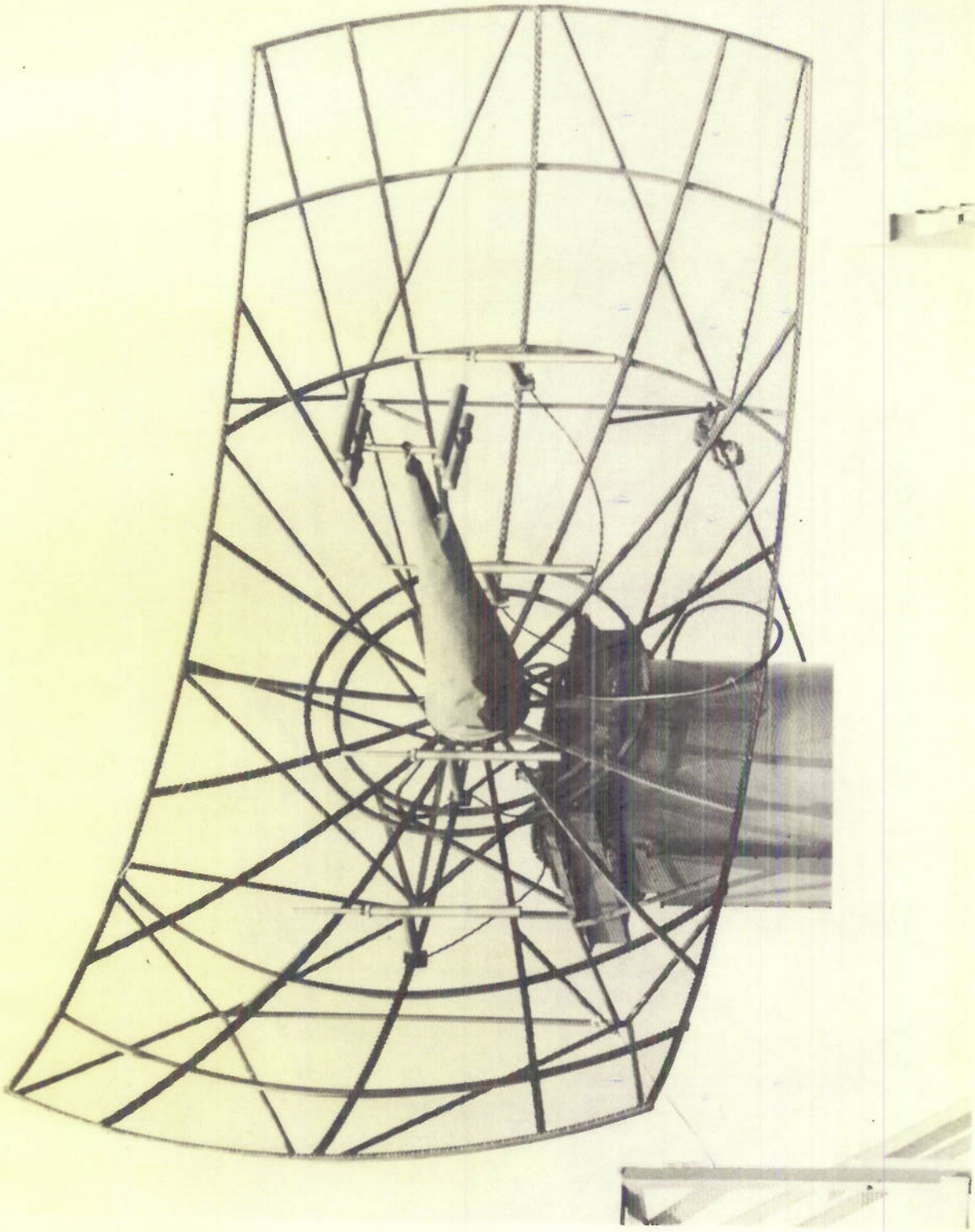

STANDING WAVE RATIO
MK IV IFF FOR XBF-1
1.0
.8
.6
.4
.2
S.W.R.
460
470
480
490
500
510
FREQUENCY MC/S

PLATE 16

DECLASSIFIED

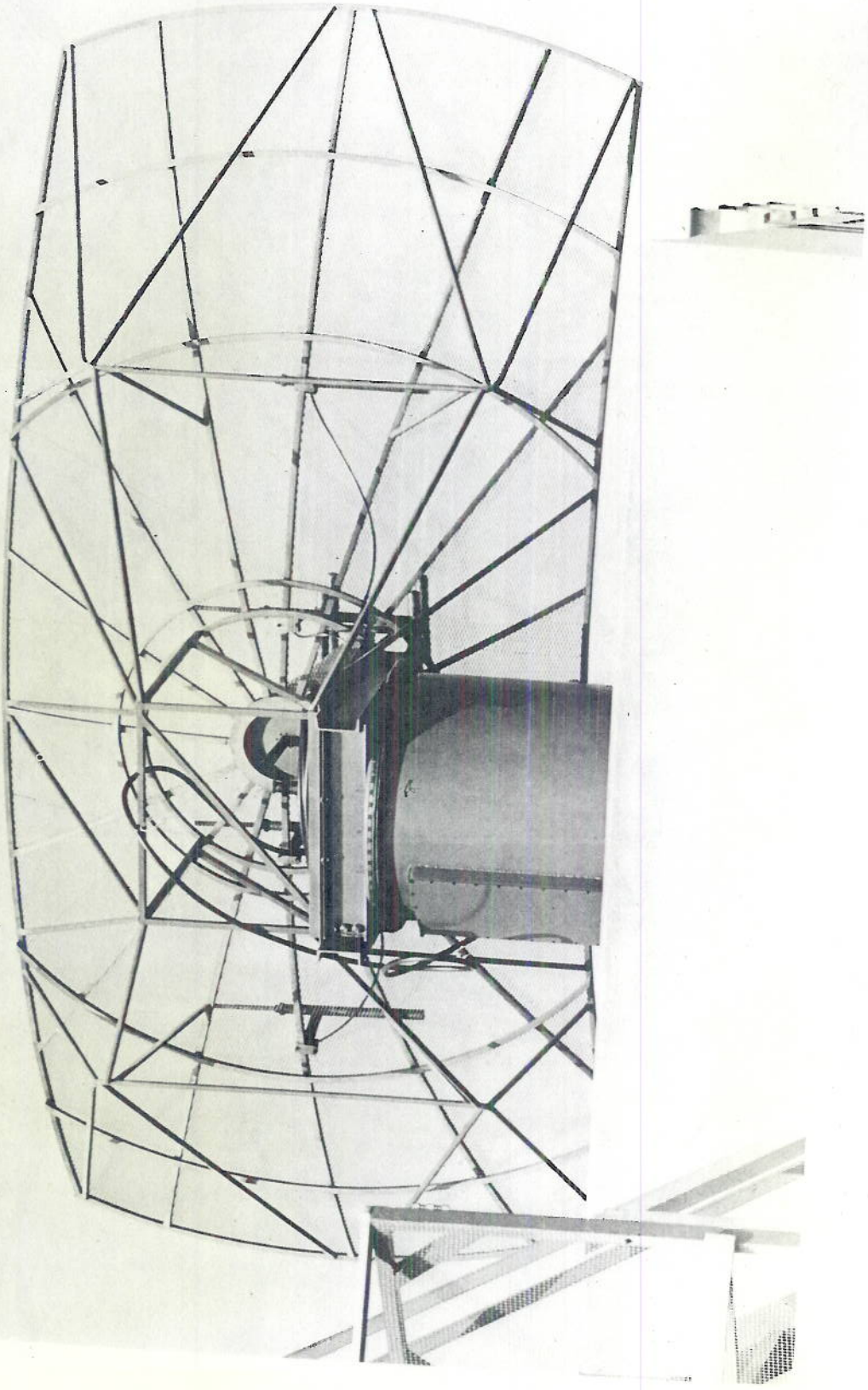


DECLASSIFIED

CONFIDENTIAL

PLATE 17

DECLASSIFIED



DECLASSIFIED

PLATE 18

DECLASSIFIED

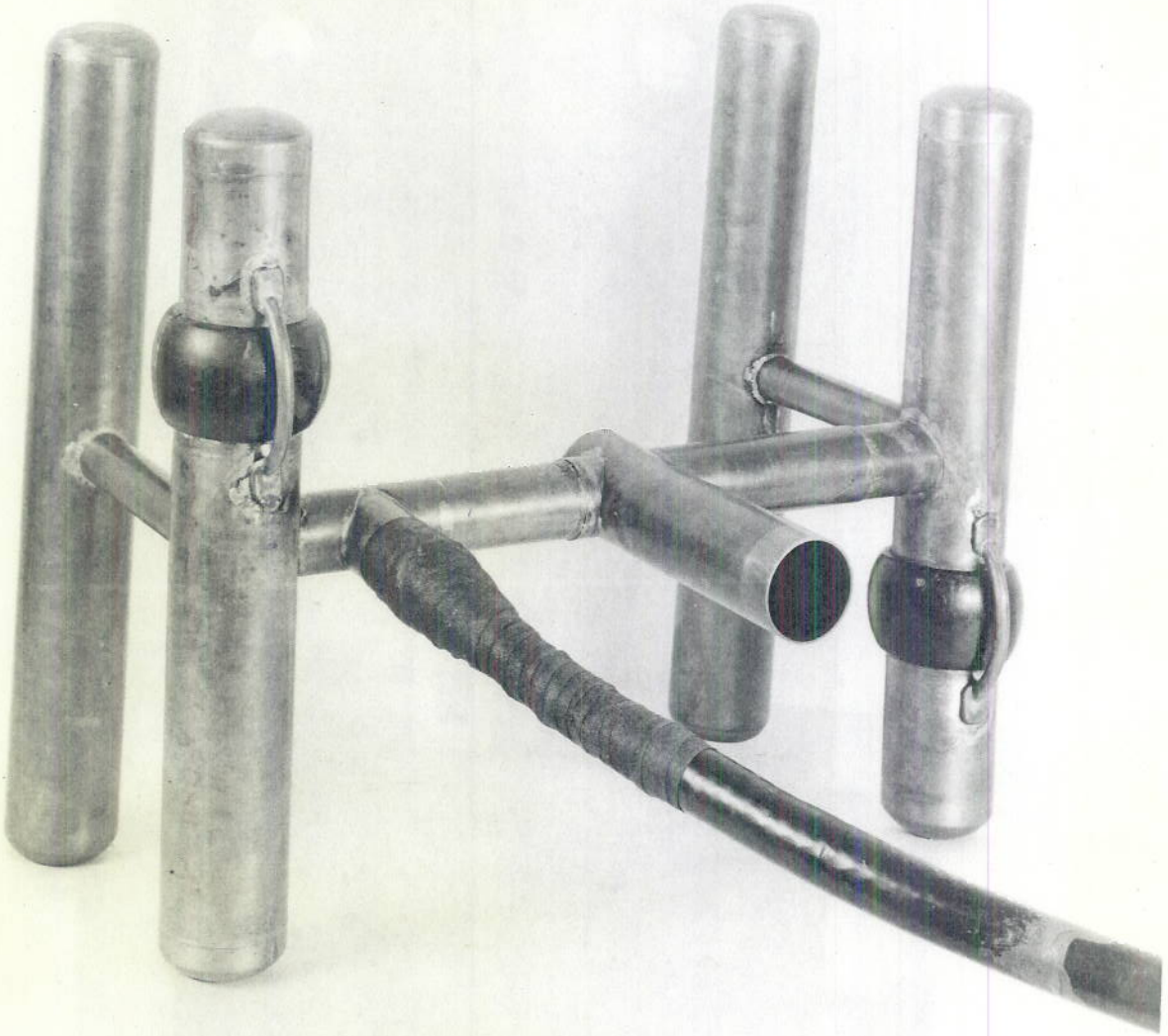


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PLATE 19

DECLASSIFIED

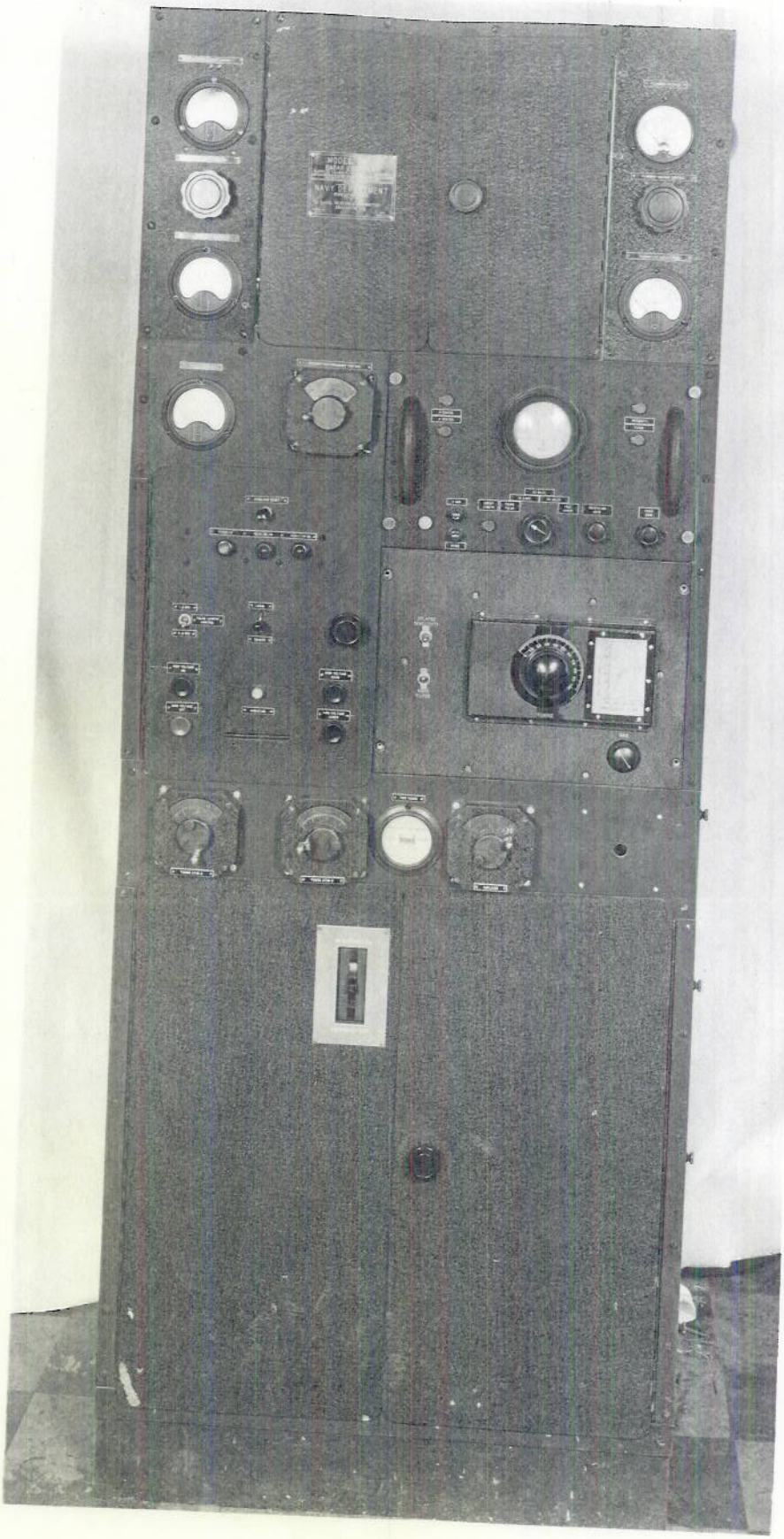


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PLATE 20

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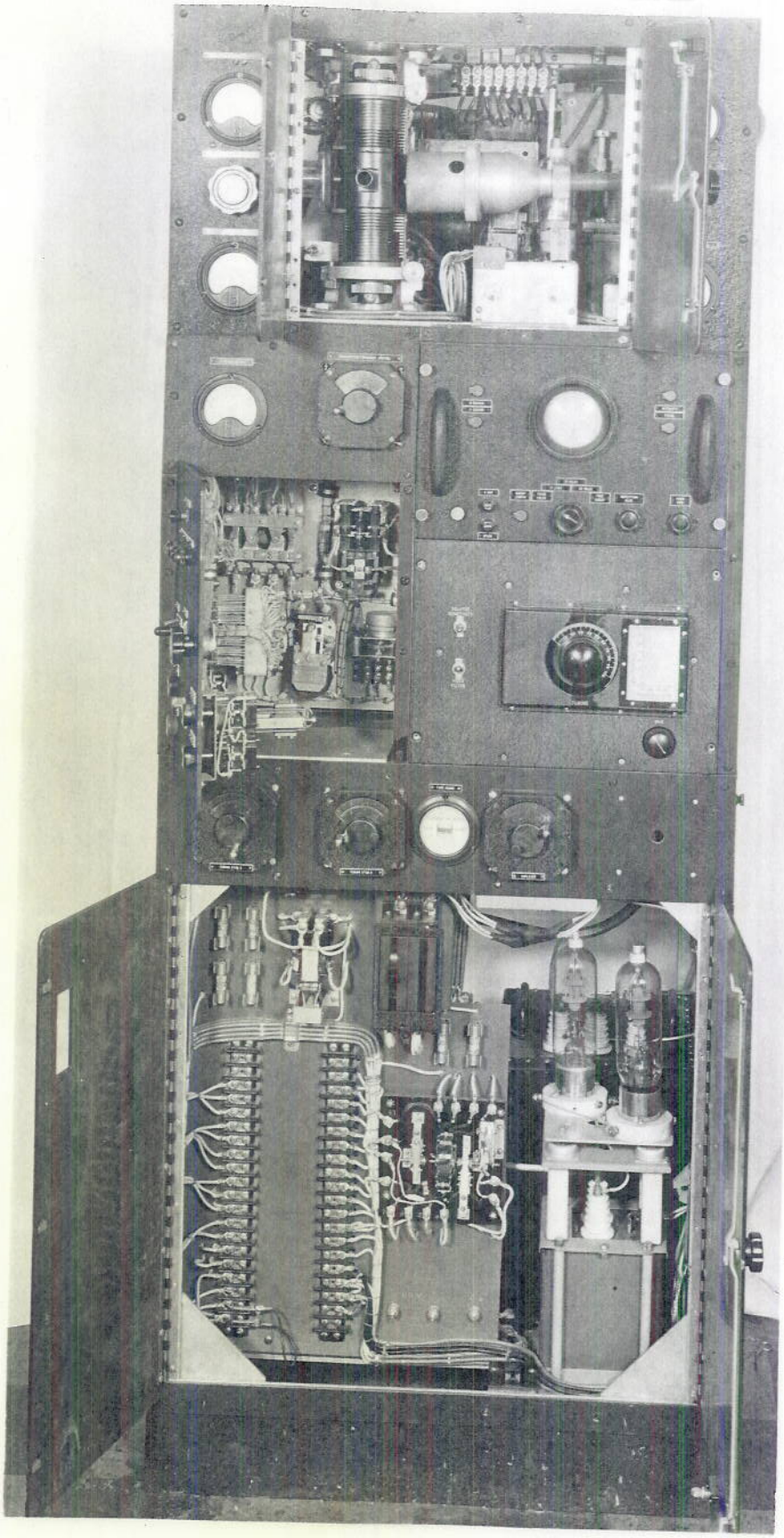


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PLATE 21

DECLASSIFIED

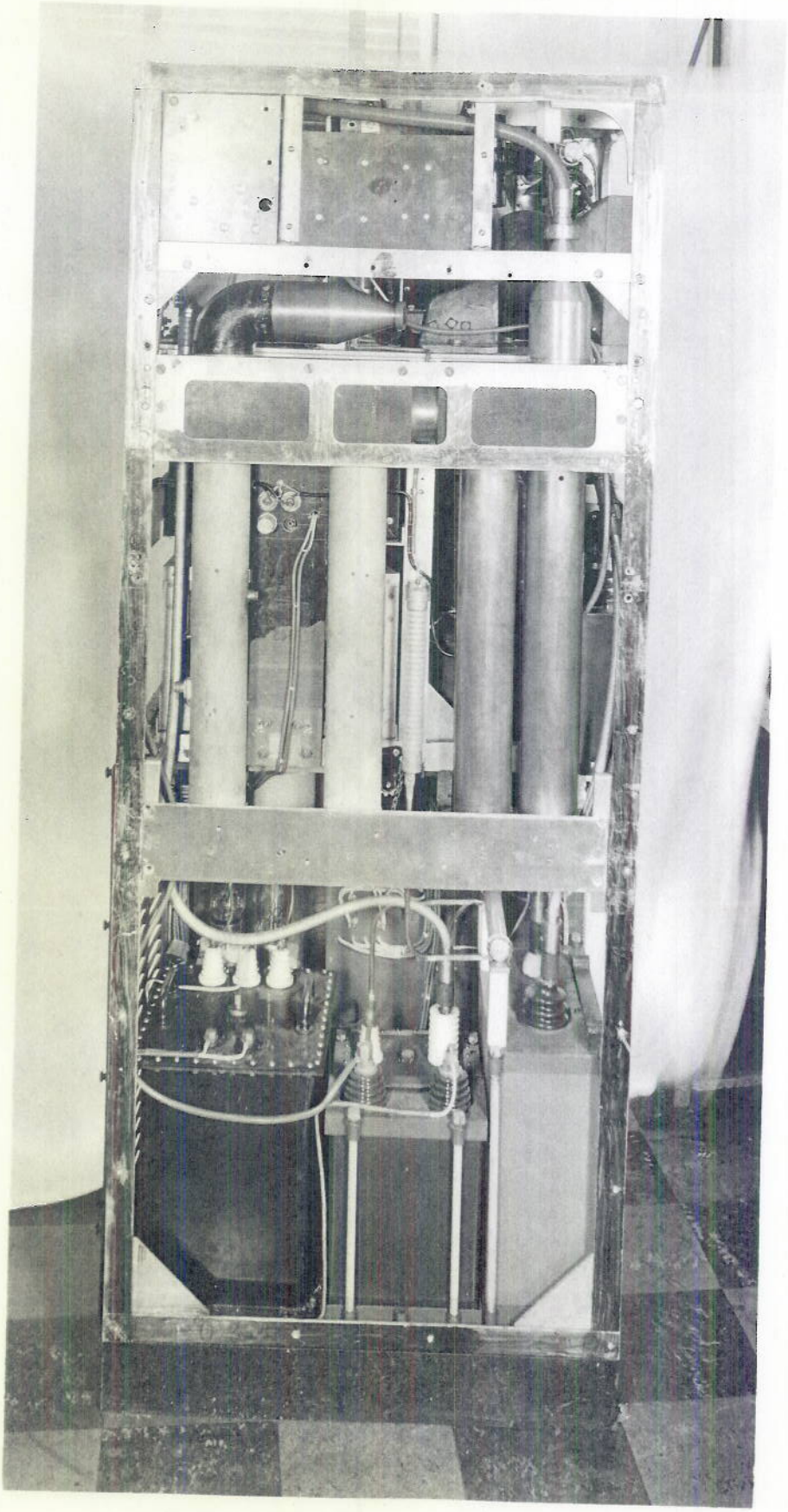


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PLATE 22

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PLATE 23

DECLASSIFIED

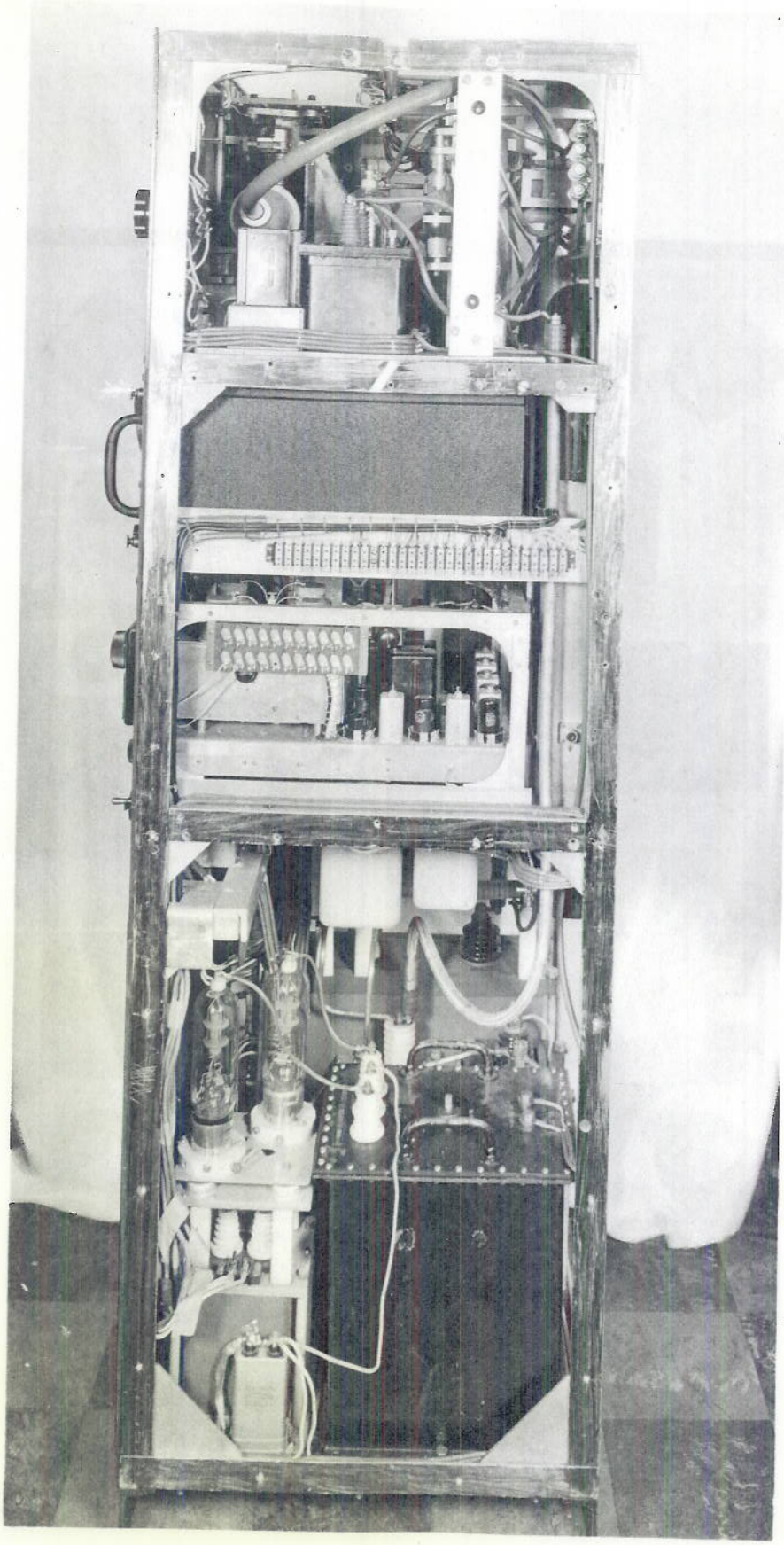


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PLATE 24

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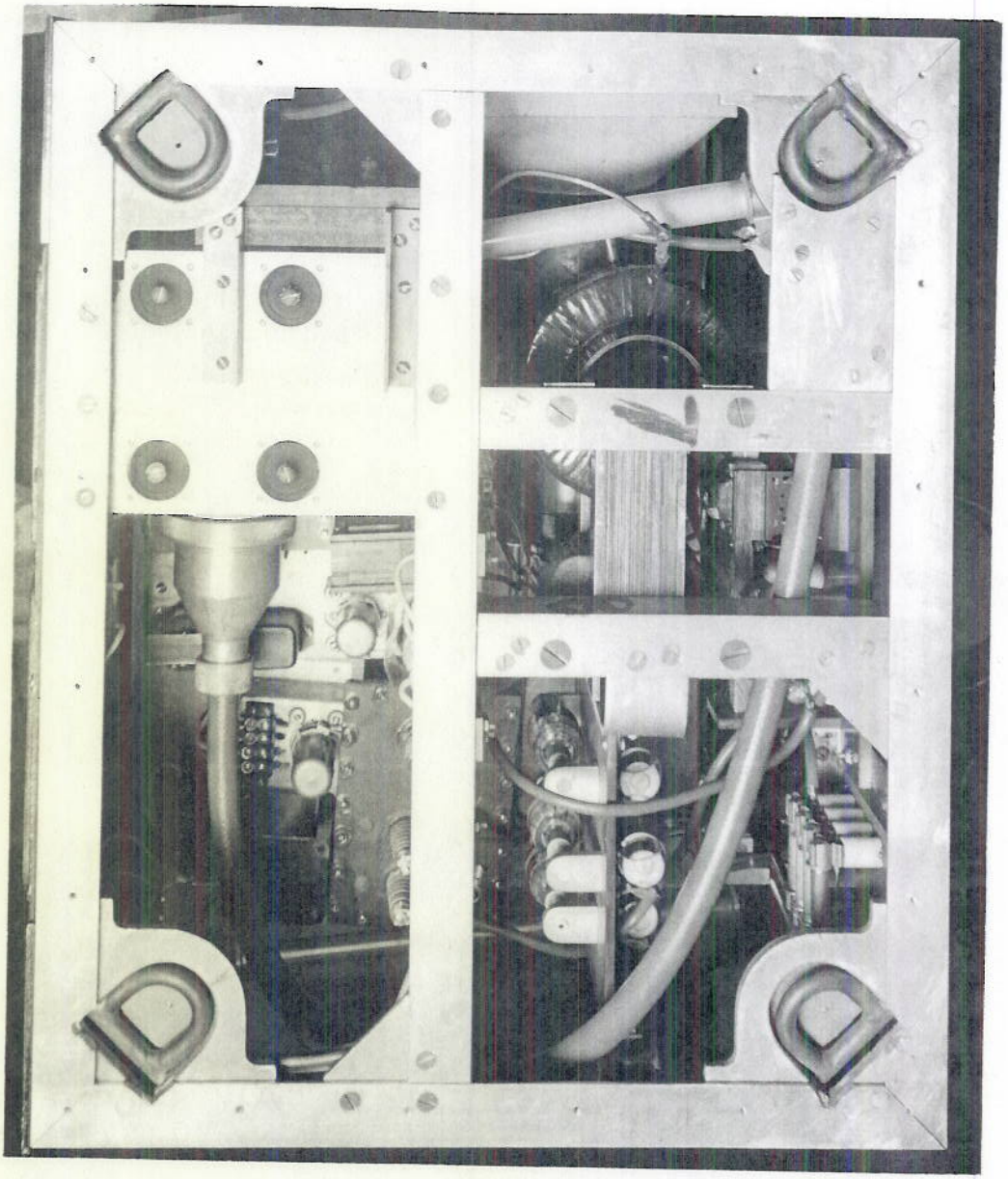


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PLATE 25

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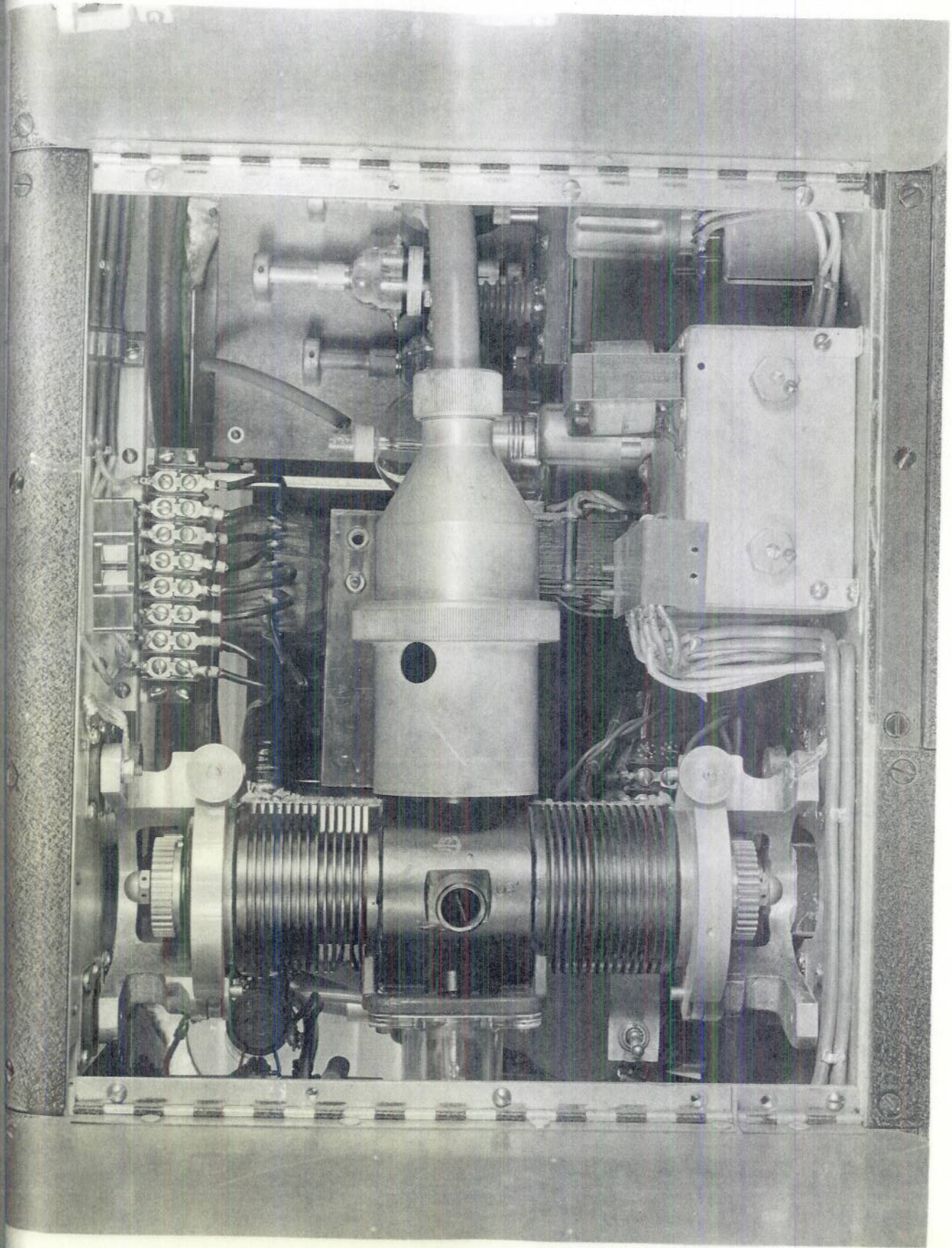


CONFIDENTIAL

DECLASSIFIED

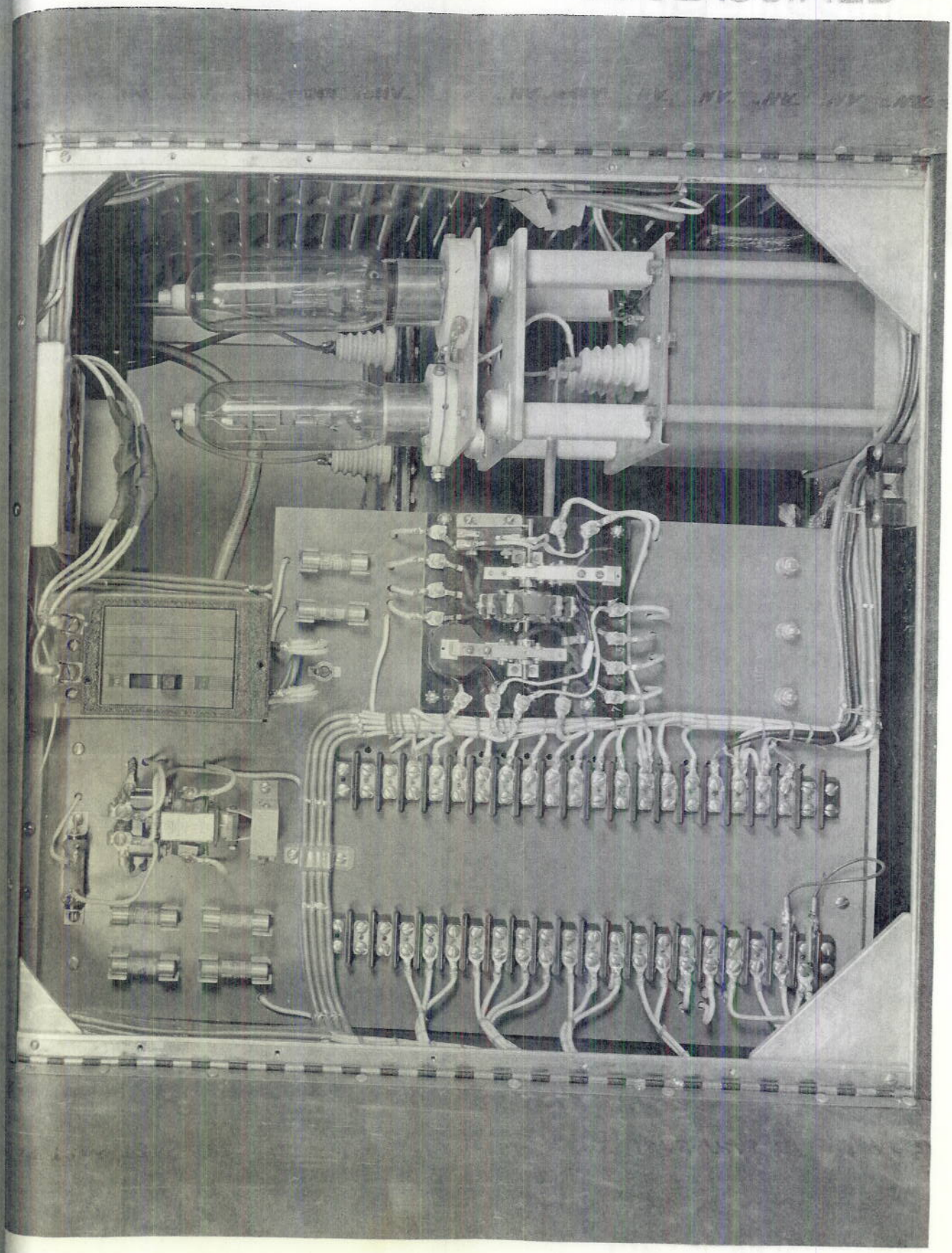
PLATE 26

DECLASSIFIED



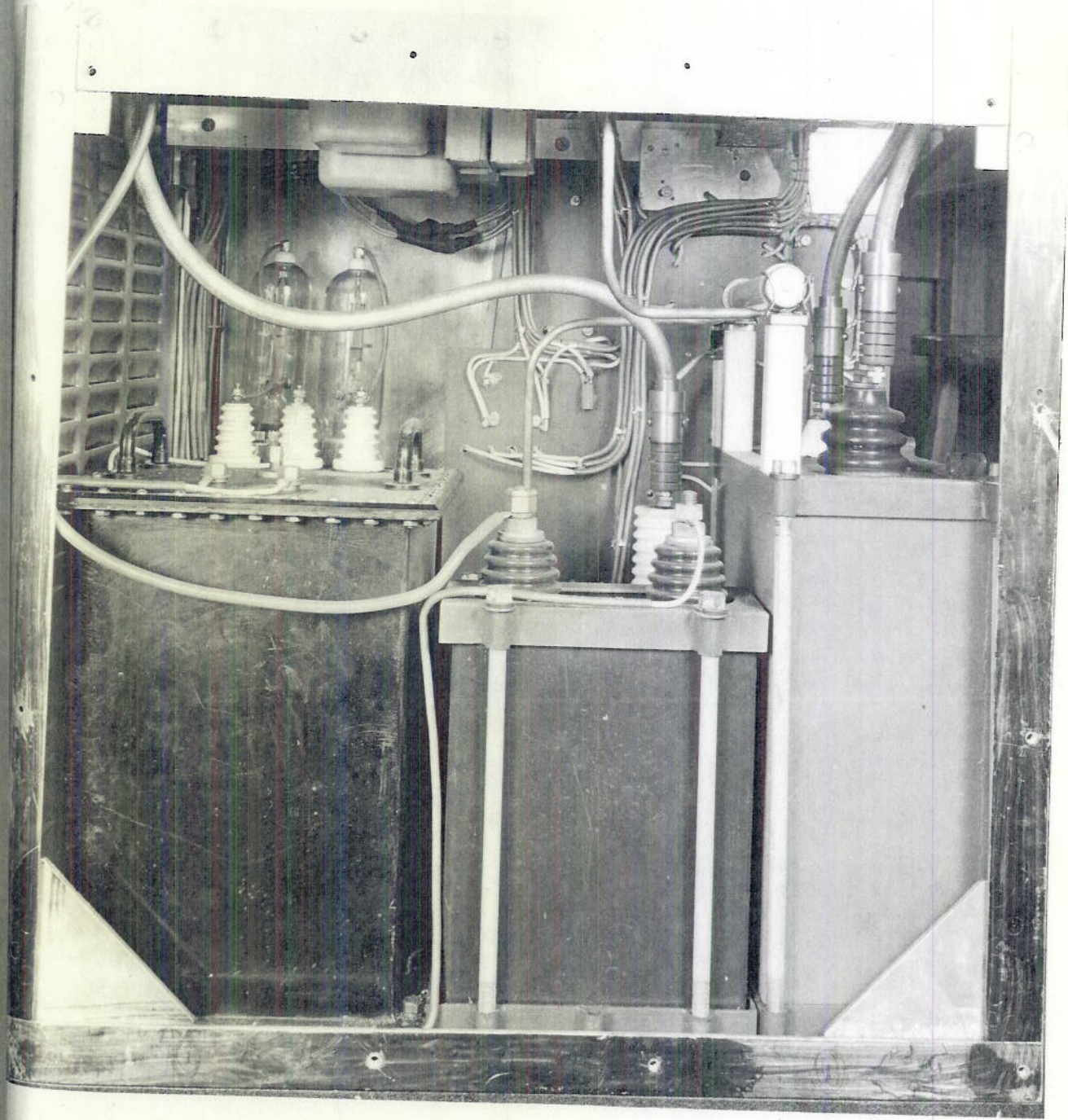
DECLASSIFIED

DECLASSIFIED



DECLASSIFIED

DECLASSIFIED

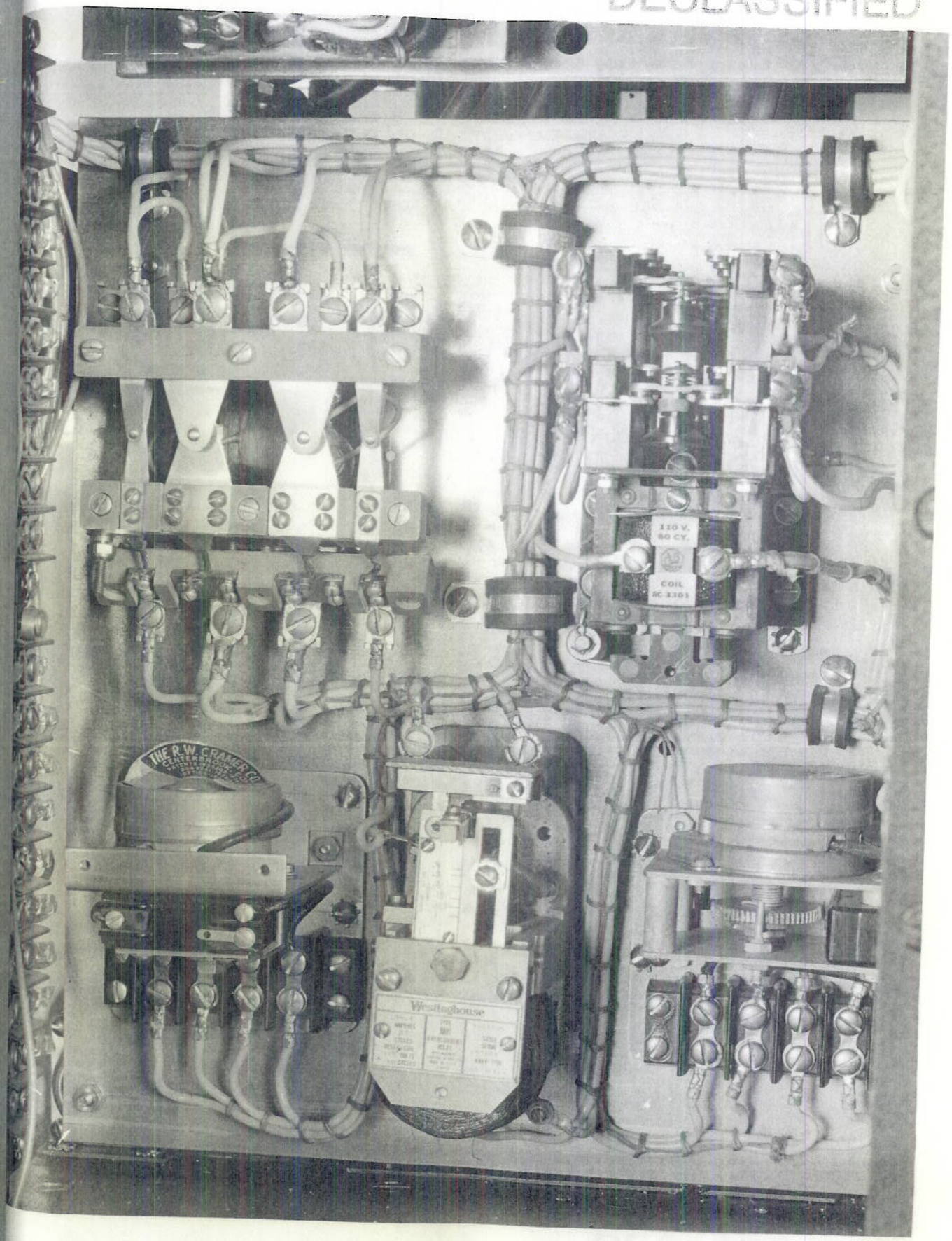


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PLATE 29

DECLASSIFIED

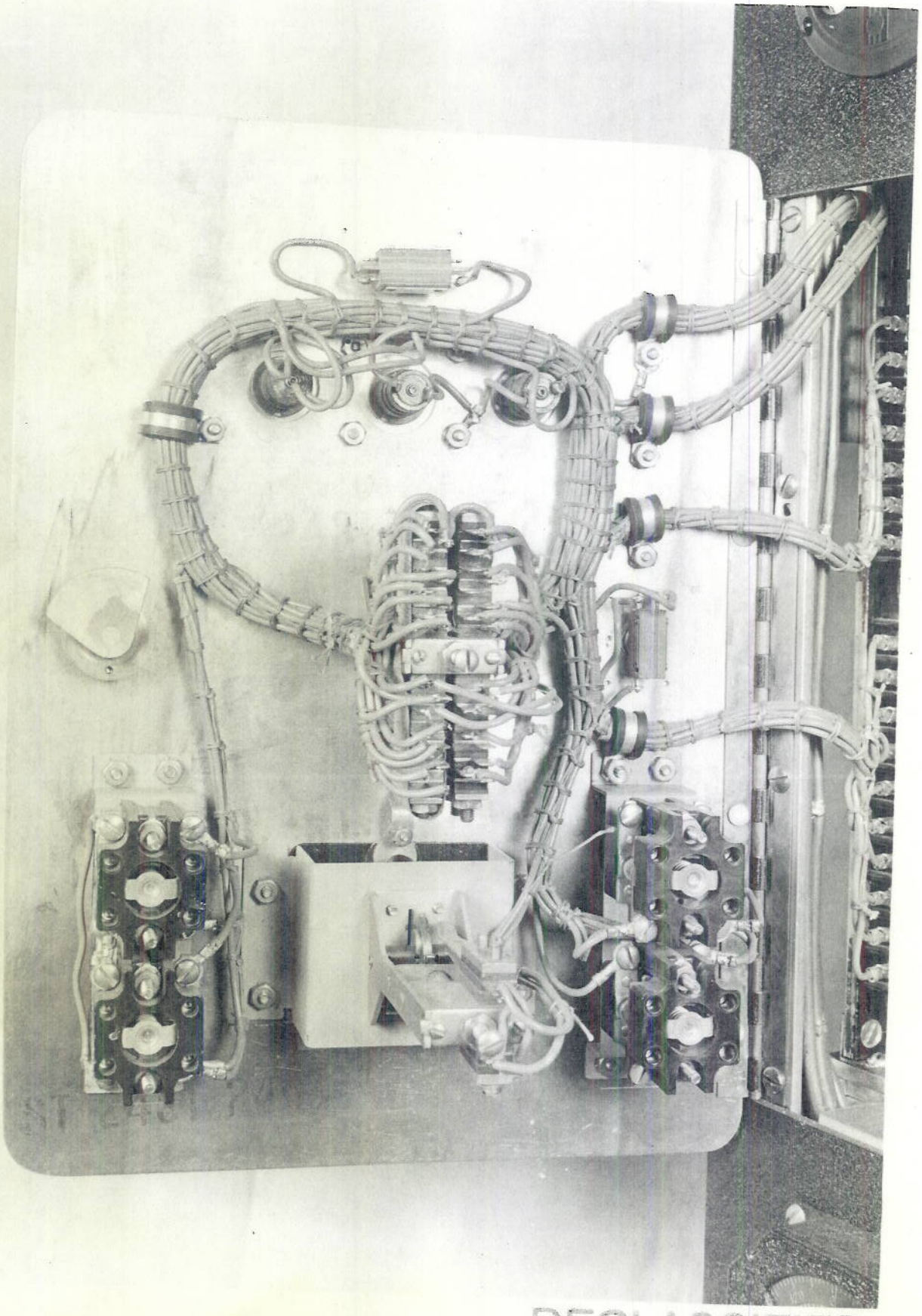


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PLATE 30

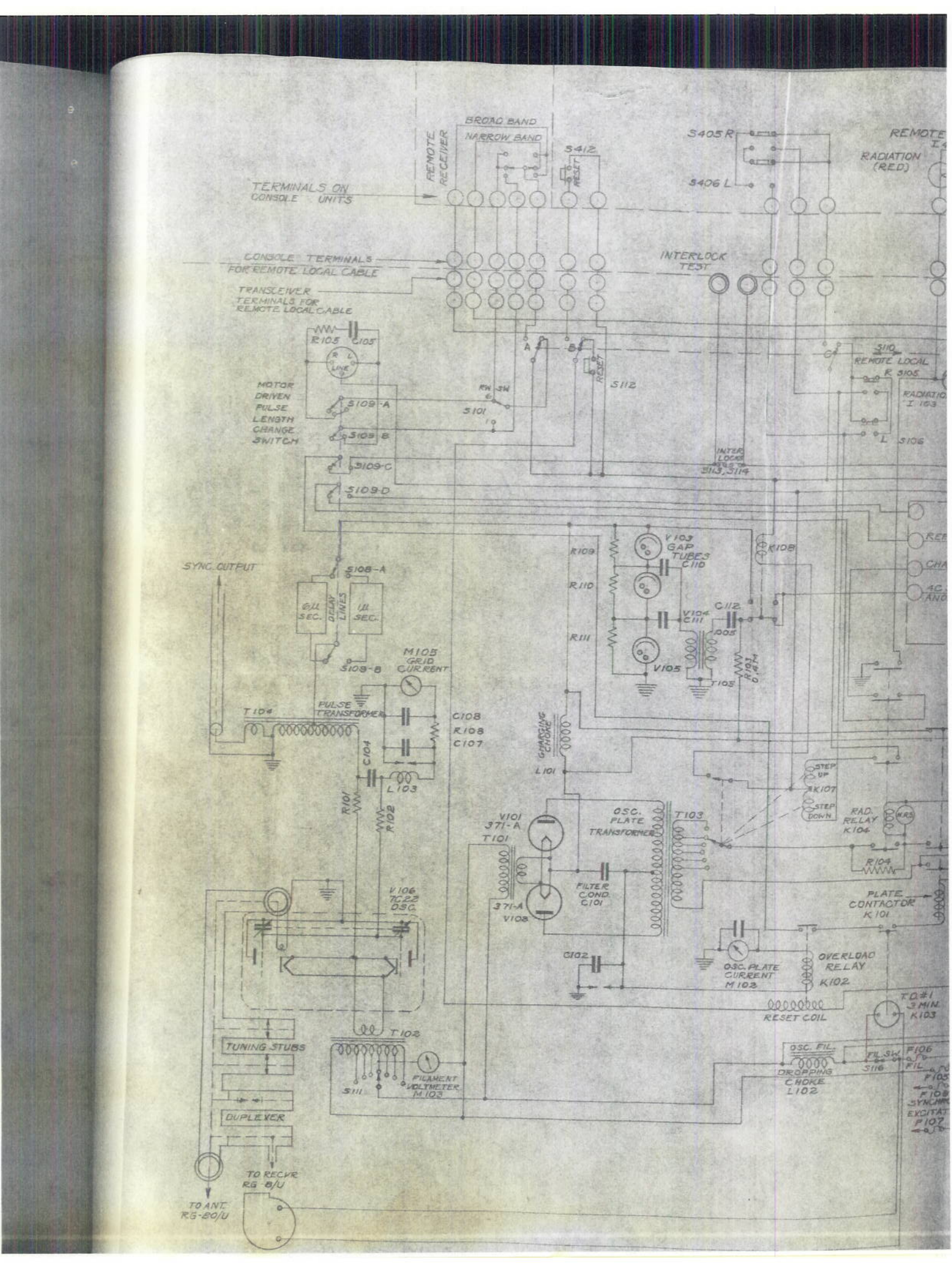
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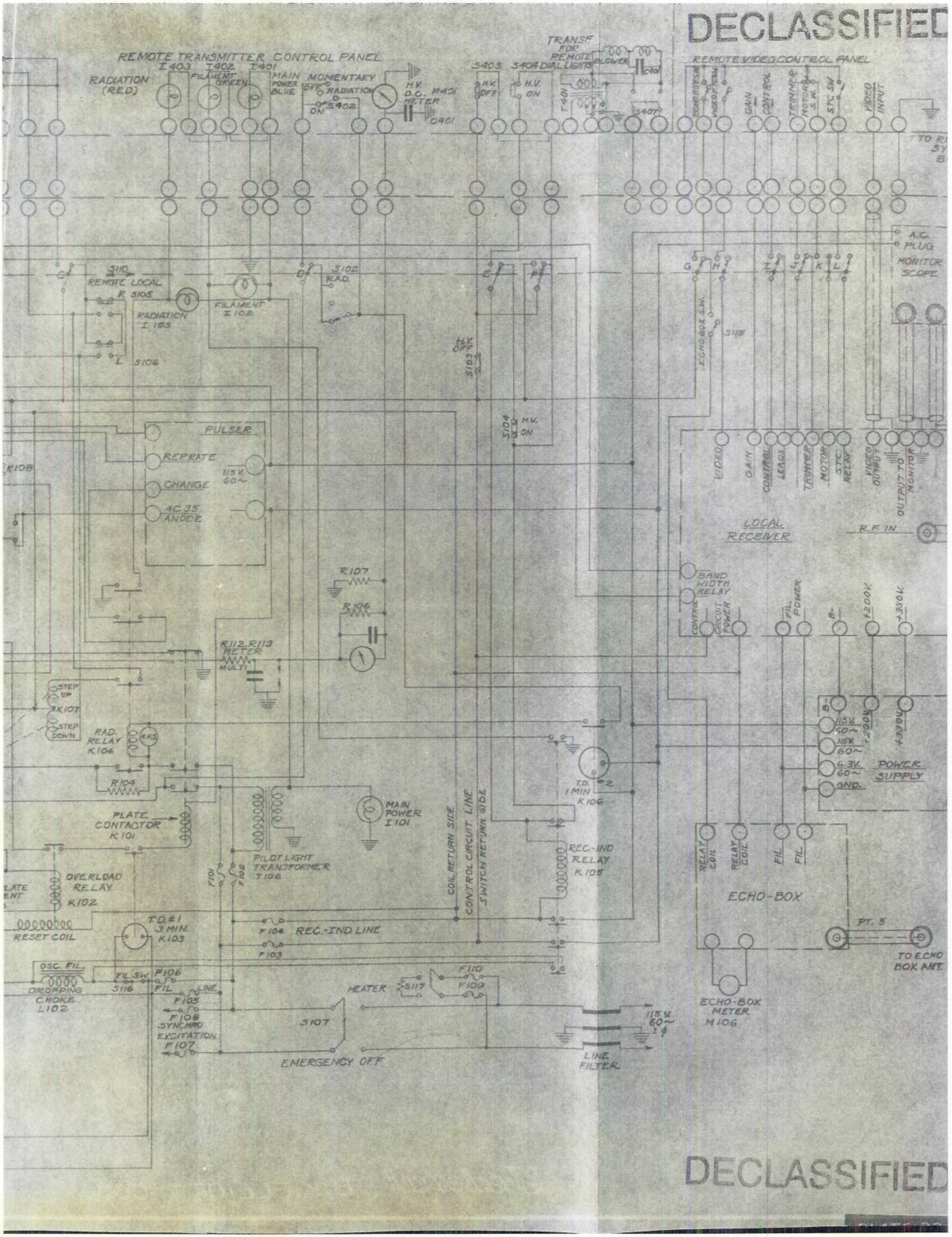
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PLATE 31


BROAD BAND
NARROW BAND
REMOTE RECEIVER
S412
RESET
S405 R
S406 L
REMOTE
RADIATION (RED)
TERMINALS ON CONSOLE UNITS
CONSOLE TERMINALS FOR REMOTE LOCAL CABLE
TRANSCEIVER TERMINALS FOR REMOTE LOCAL CABLE
INTERLOCK TEST
R105
C105
LINE
MOTOR DRIVEN PULSE LENGTH CHANGE SWITCH
S109-A
S109-B
S109-C
S109-D
RW SW
S101
S112
S110
REMOTE LOCAL
R 3105
RADIATIO
I 163
L
S106
INTER LOCKS TO S113, S114
SYNC. OUTPUT
S108-A
6 μ SEC.
DELAY LINES
1 μ SEC.
S108-B
M105 GRID CURRENT
T104
PULSE TRANSFORMER
C108
R108
C107
C104
L103
R101
R102
R109
R110
R111
V103 GAP TUBES
C110
R108
V104
C111
C112
V105
T105
R107
R106
GRADING CHOKE
L101
STEP UP
K107
STEP DOWN
RAD. RELAY K104
M.R.S.
R104
V101 371-A
T101
OSC. PLATE TRANSFORMER
T103
FILTER COND. C101
371-A V108
V106 7C22 OSC.
PLATE CONTACTOR K101
C102
OSC. PLATE CURRENT M103
OVERLOAD RELAY K102
RESET COIL
T.D. #1 3 MIN. K103
TUNING STUBS
T102
S111
FILAMENT VOLTMETER M103
OSC. FIL.
DROPPING CHOKE L102
FIL. SW. S116
F106
FIL.
F105
F108
SYNCHR
EXCITAT
F107
DUPLEXER
TO RECVR RG-8/U
TO ANT. RG-80/U

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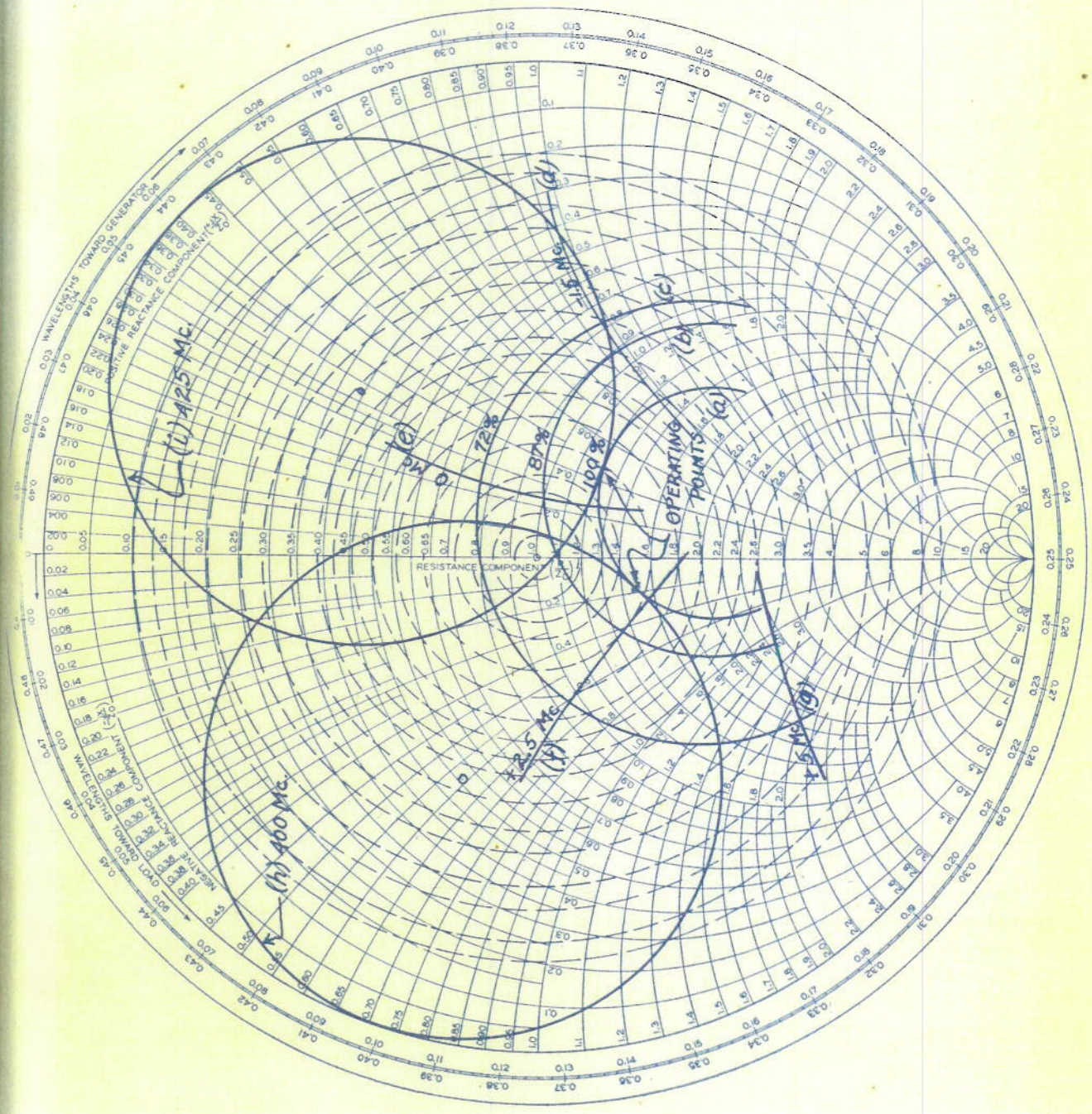
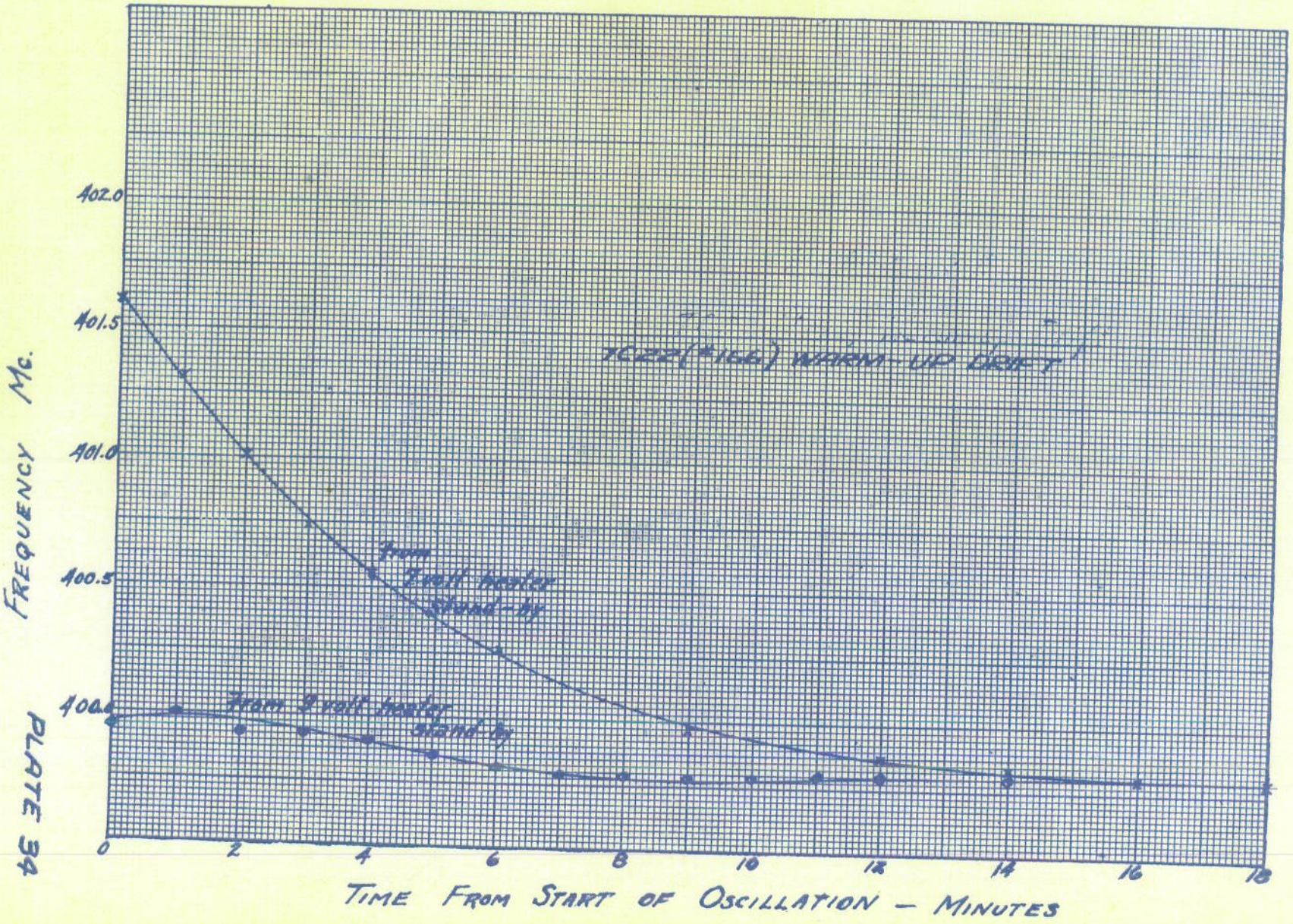


PLATE 33

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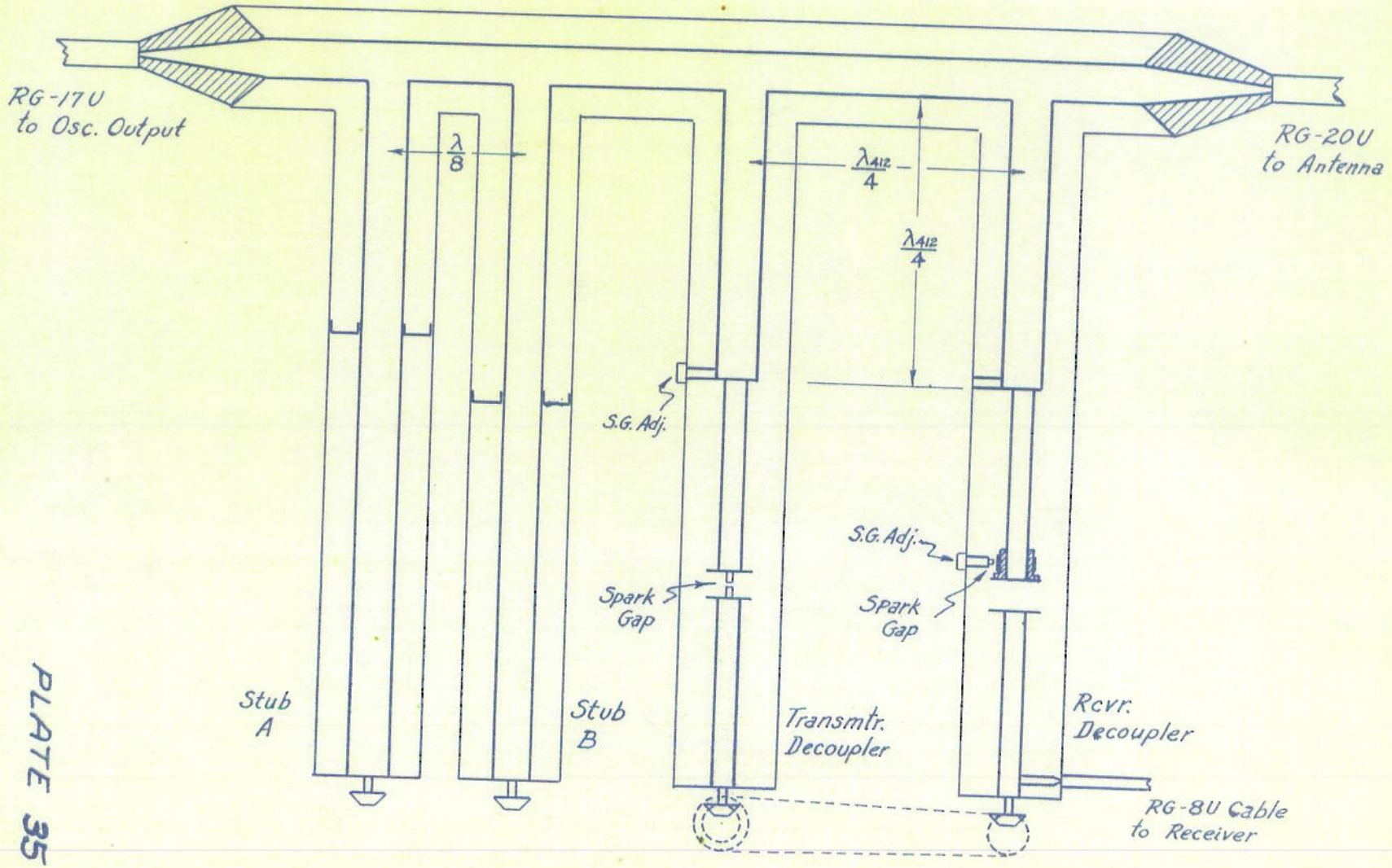
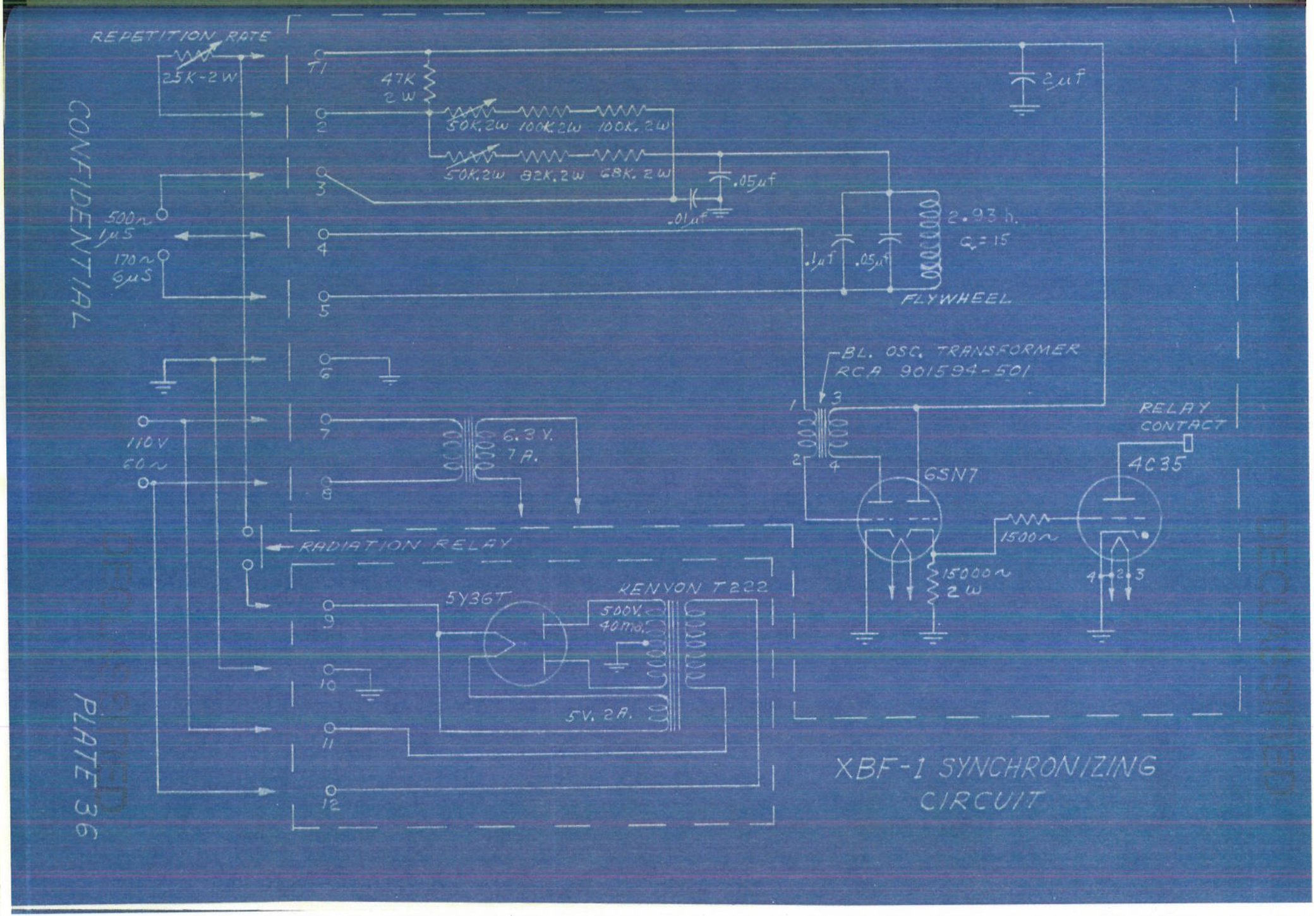
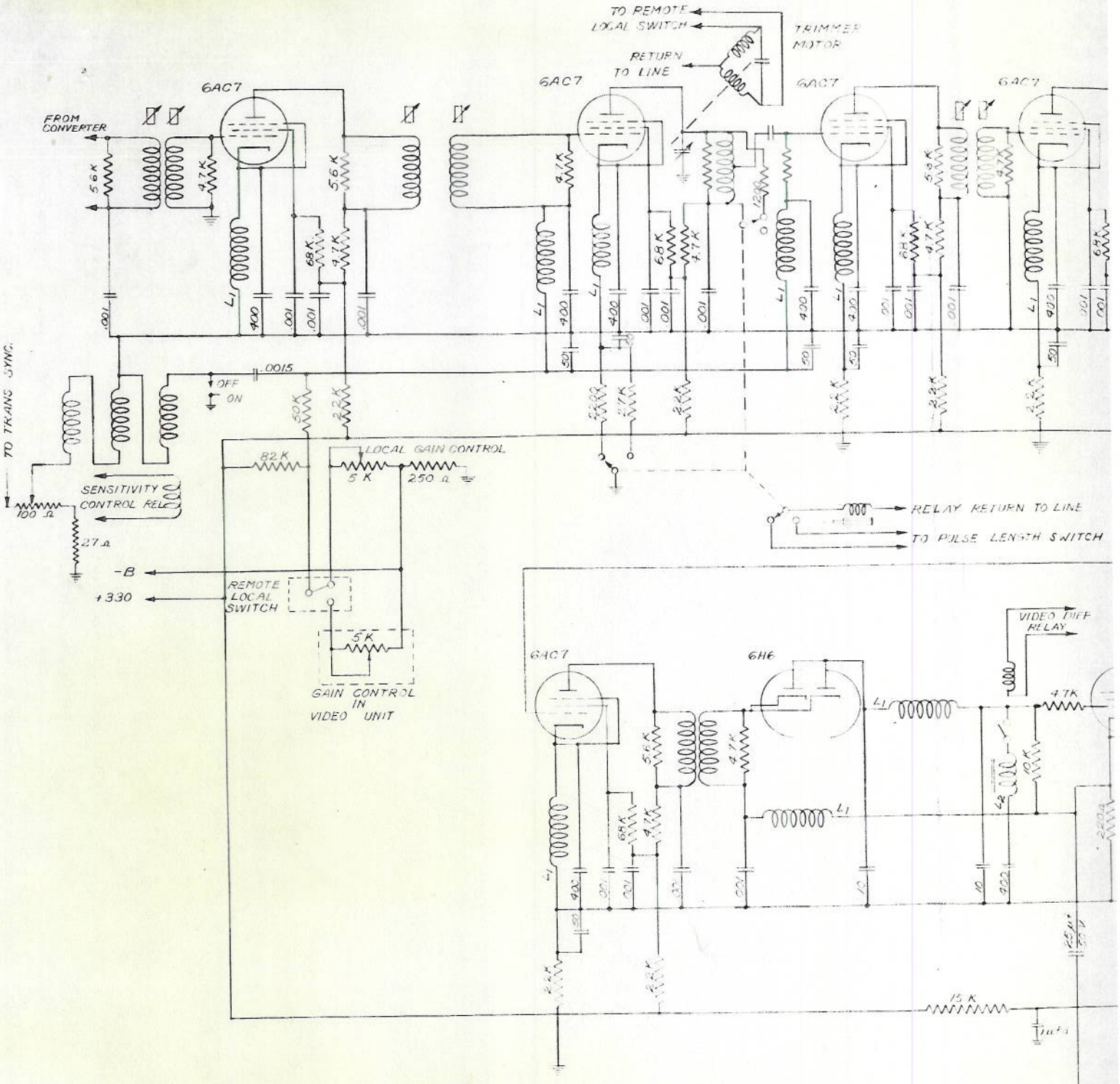


PLATE 35

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REPETITION RATE
25K-2W
T1
47K 2W
50K. 2W
100K. 2W
100K. 2W
50K. 2W
82K. 2W
68K. 2W
.05μf
.01μf
2μf
2.93 h.
Q = 15
.1μf
.05μf
FLYWHEEL
500n 1μS
170n 6μS
BL. OSC. TRANSFORMER
RCA 901594-501
110V 60n
6.3V. 7A.
RELAY CONTACT
6SN7
4C35
RADIATION RELAY
1500n
15000n 2W
5Y3GT
KENYON T222
500V. 40ma.
5V. 2A.
XBF-1 SYNCHRONIZING CIRCUIT
CONFIDENTIAL
PLATE 36

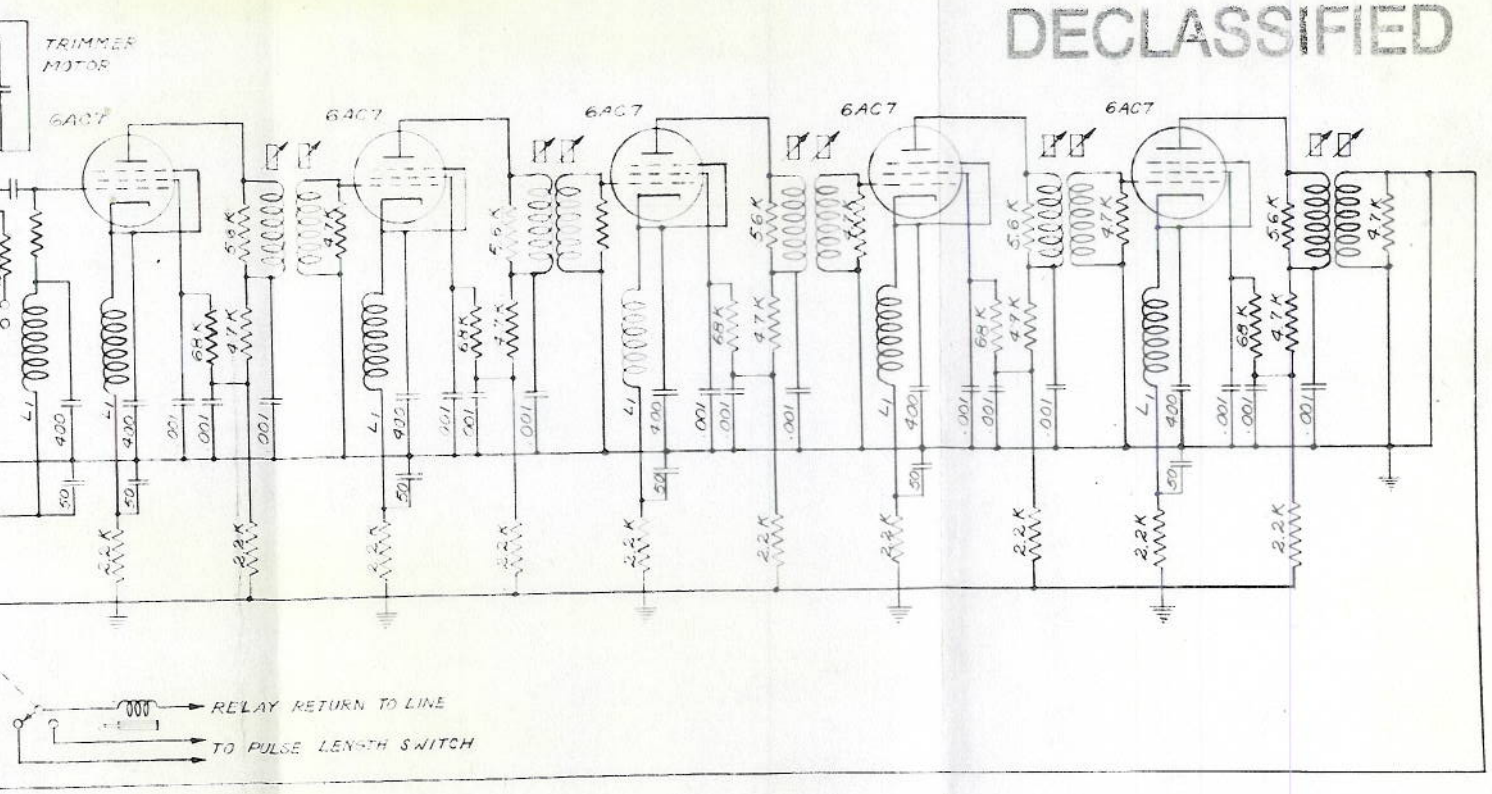


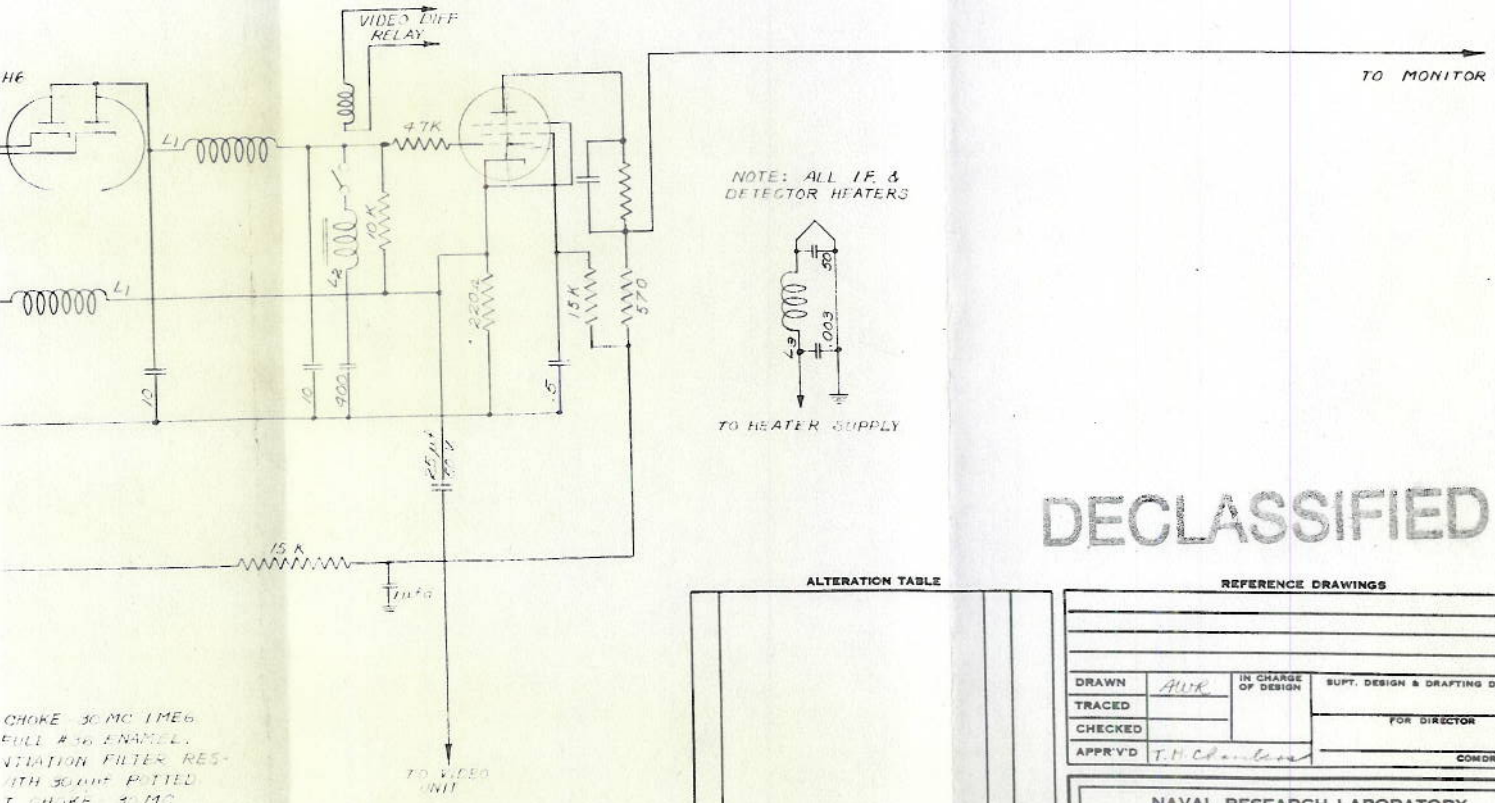
L_1 - SELF RESONANT CHOKE 30 MC 1 MEG ½W RESISTOR FULL #36 ENAMEL.

L_2 - VIDEO DIFFERENTIATION FILTER RESONANT AT 1 MC WITH 30 mmf POTTED

L_3 - SELF RESONANT CHOKE 3 MC 1 MEG ½W RESISTOR #36 ENAMEL

DECLASSIFIED





NOTE: ALL I.F. & DETECTOR HEATERS

CHOKE 30 MC 1ME6
FILE #36 ENAMEL
NTIATION FILTER RES-
ITH 30 MF POTTED
T CHOKE 30 MC
STOR #2W ENAMEL

DECLASSIFIED

ALTERATION TABLE

REFERENCE DRAWINGS

DRAWN	AWR	IN CHARGE OF DESIGN	SUPT. DESIGN & DRAFTING DIVISION
TRACED			FOR DIRECTOR
CHECKED			
APPR'V'D	T.H. Chamberlain		COMDR. U.S.N.

SYMBOLS AND THEIR EQUIVALENT TOLERANCES (UNLESS OTHERWISE NOTED)

SYMBOL 2	± .0010	SYMBOL 3½	± .0100
SYMBOL 2½	± .0030	SYMBOL 4	± .0250
		SYMBOL 5	

NAVAL RESEARCH LABORATORY
WASHINGTON 20. D. C.

RECEIVER MODEL #1
FOR
XBF-1 EQUIPMENT
SCHEMATIC DIAGRAM

SCALE

DATE

RA 46F 349A

PLATE 37 SHEET

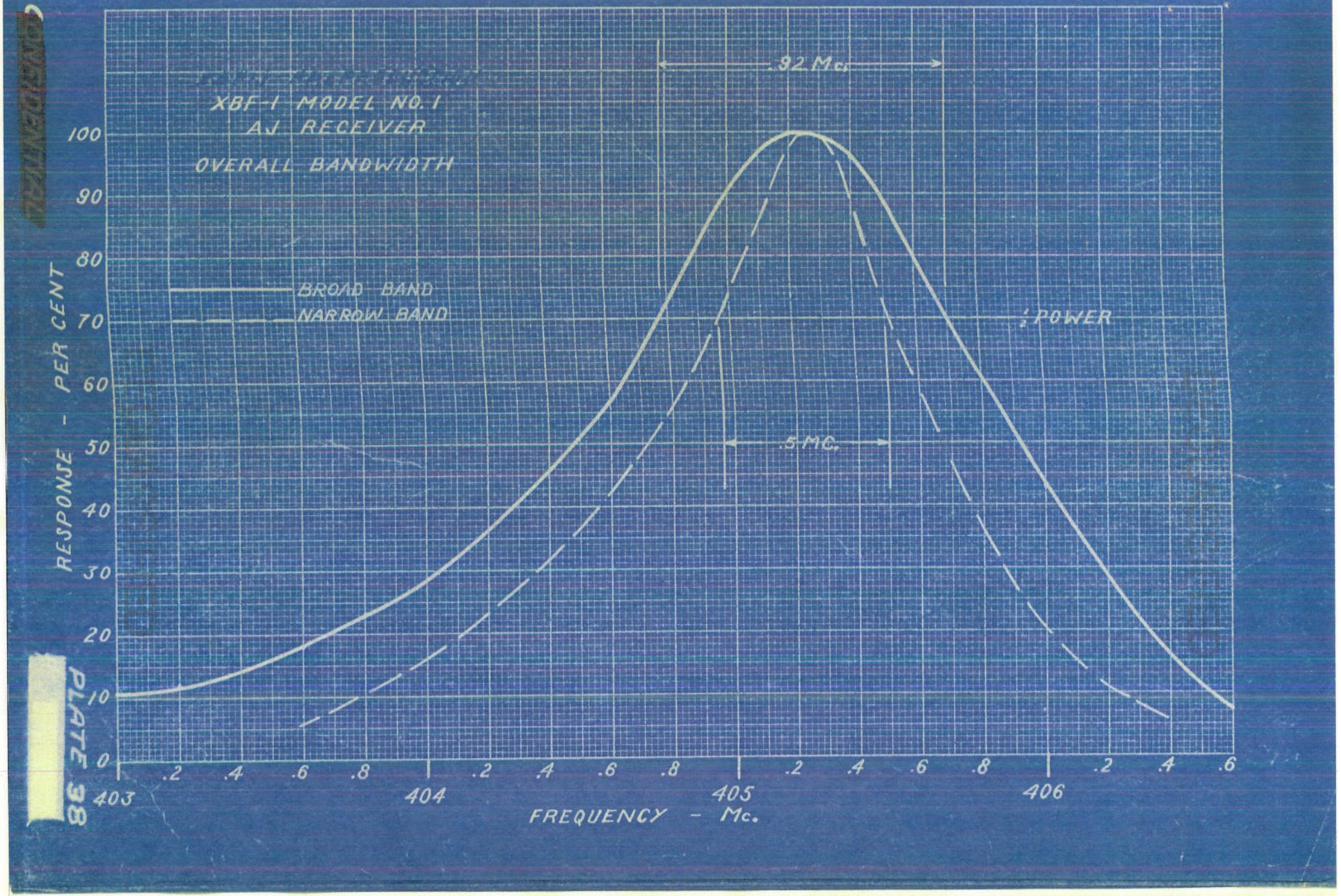
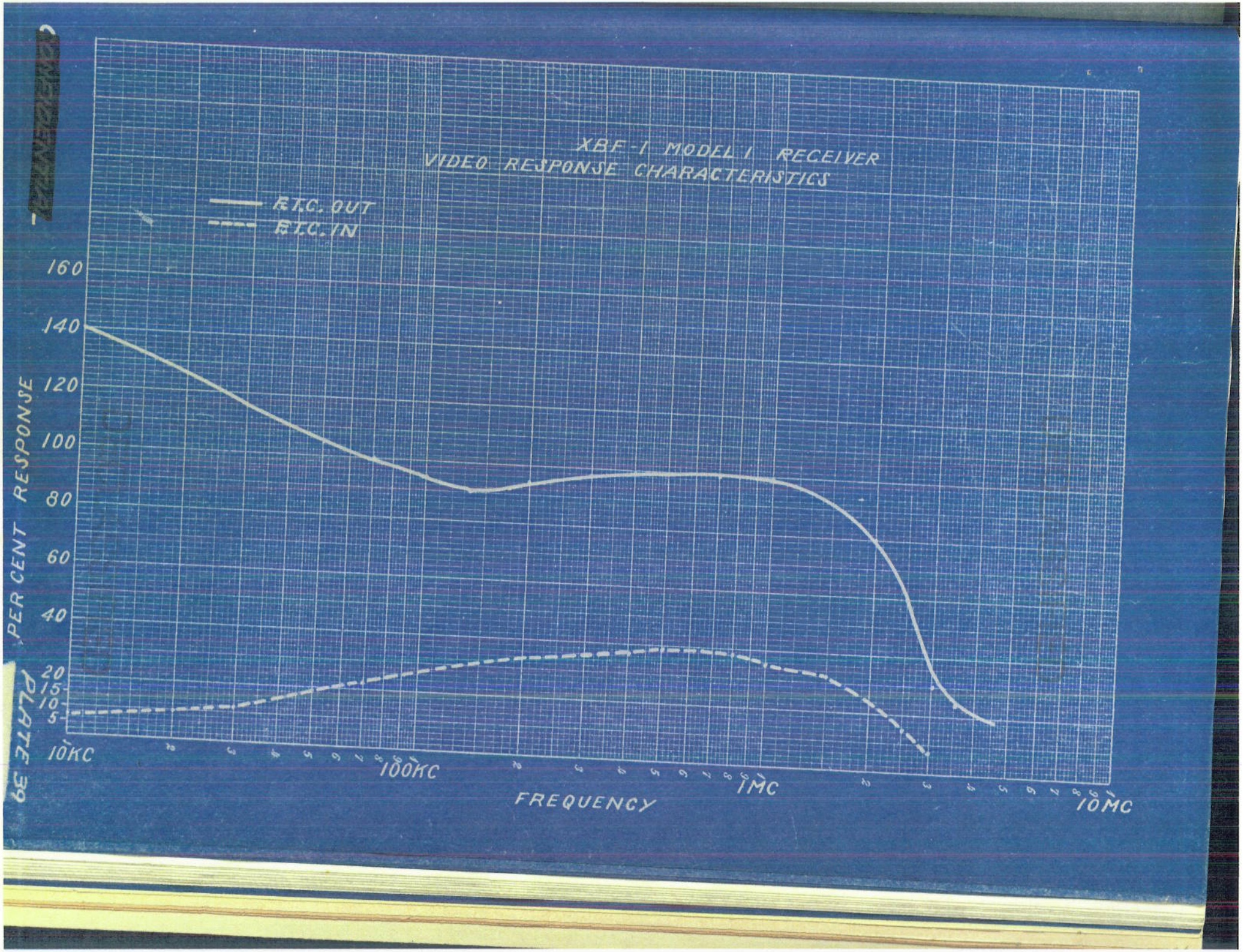

XBF-1 MODEL NO. 1
A.I. RECEIVER
OVERALL BANDWIDTH
BROAD BAND
NARROW BAND
.92 Mc.
½ POWER
.5 MC.
RESPONSE - PER CENT
100
90
80
70
60
50
40
30
20
10
0
.2
.4
.6
.8
403
404
405
406
FREQUENCY - Mc.

PLATE 38


XBF-1 MODEL 1 RECEIVER
VIDEO RESPONSE CHARACTERISTICS
R.F.C. OUT
R.F.C. IN
160
140
120
100
80
60
40
20
15
10
5
PER CENT RESPONSE
10KC
100KC
1MC
10MC
FREQUENCY
PLATE 39

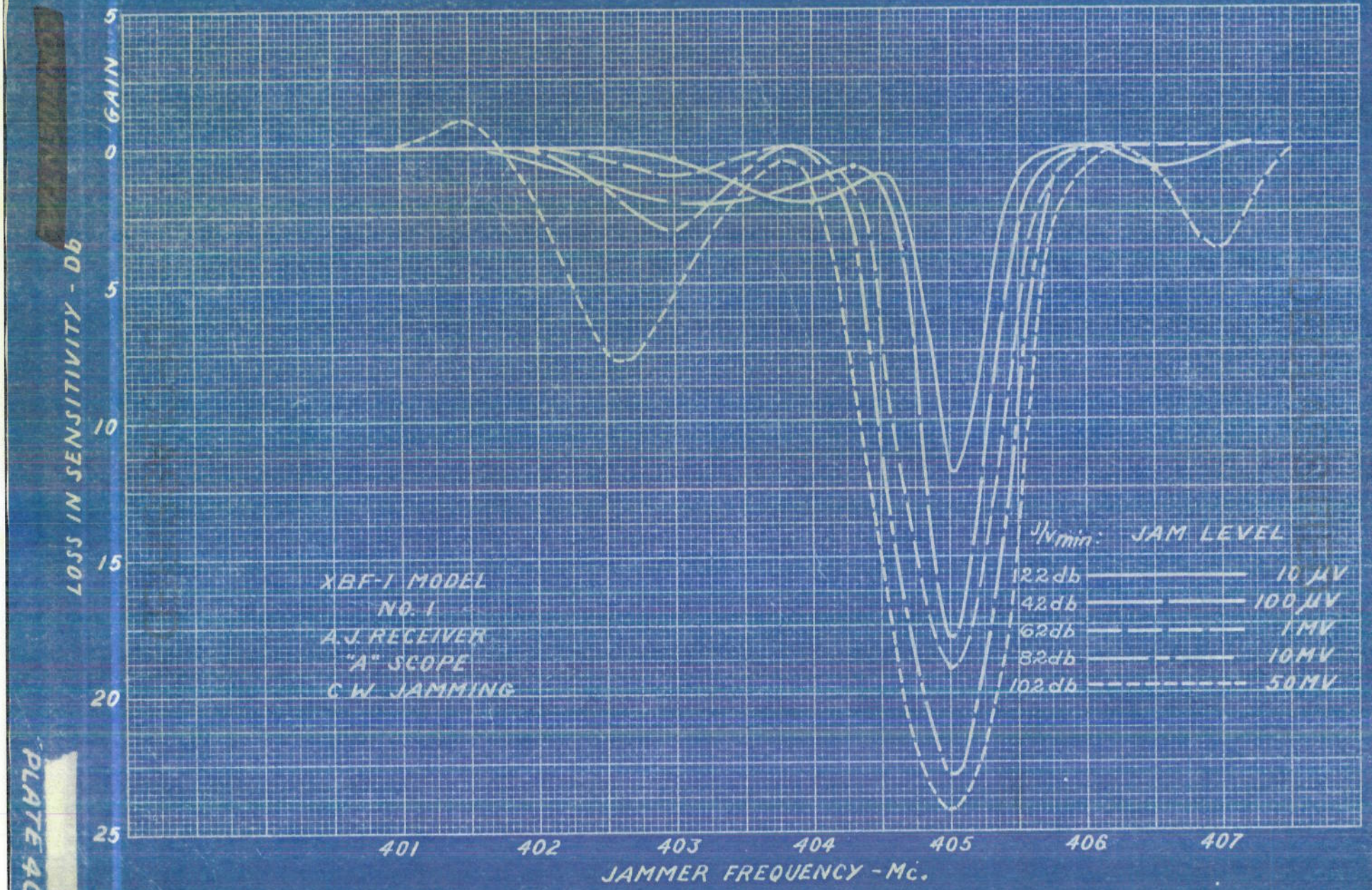
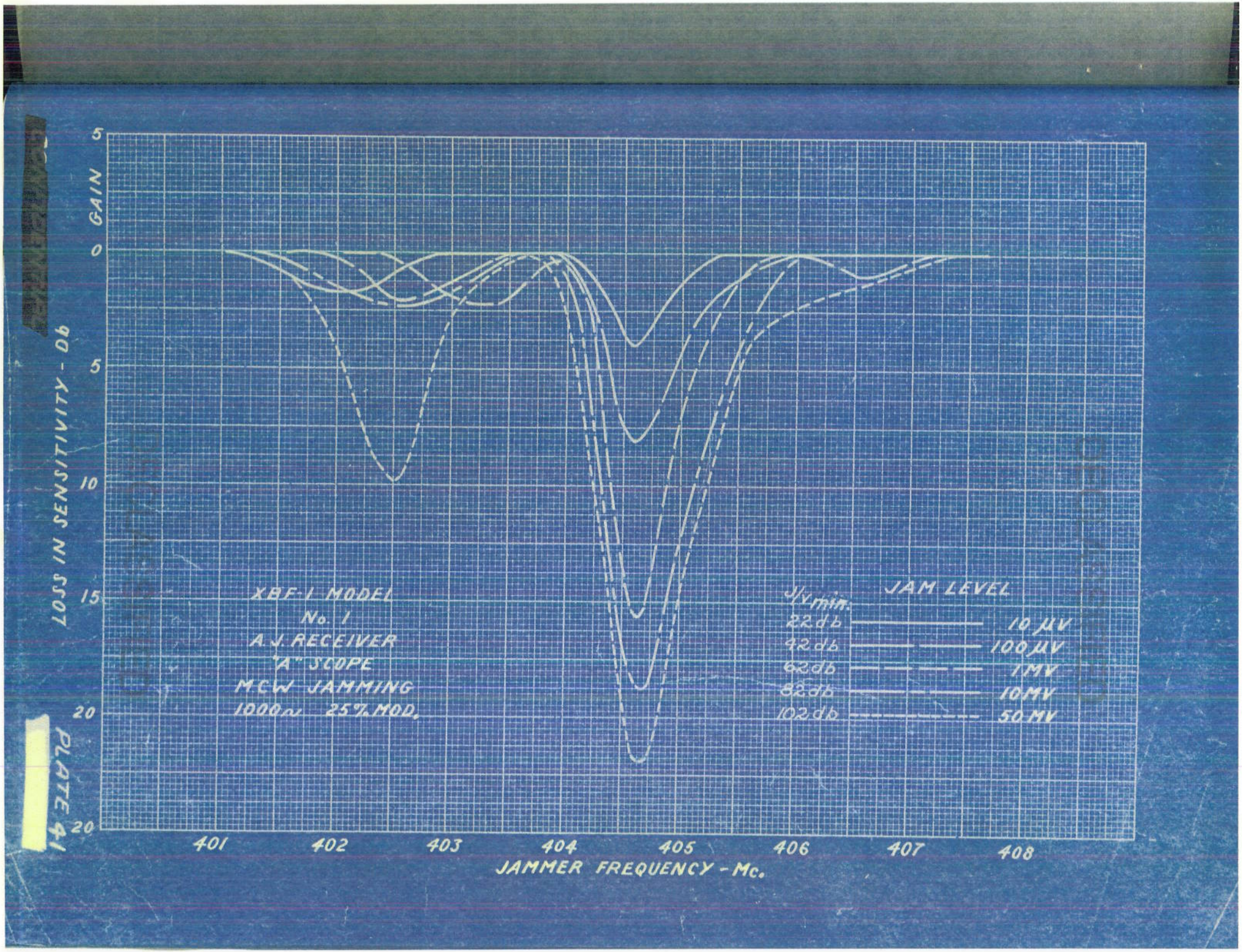

LOSS IN SENSITIVITY - DB
GAIN
5
0
5
10
15
20
25
401
402
403
404
405
406
407
JAMMER FREQUENCY - Mc.
XBF-1 MODEL
NO. 1
A.J. RECEIVER
"A" SCOPE
C.W. JAMMING
J/N min: JAM LEVEL
122 db — 10 μV
42 db — 100 μV
62 db — 1 MV
82 db — 10 MV
102 db — 50 MV

PLATE 40


LOSS IN SENSITIVITY - Db
5
0 GAIN
5
10
15
20
20
401
402
403
404
405
406
407
408
JAMMER FREQUENCY - Mc.
XBF-1 MODEL
No. 1
A.J. RECEIVER
"A" SCOPE
MCW JAMMING
1000∼ 25% MOD.
J/S min.
JAM LEVEL
22 db
10 μV
42 db
100 μV
62 db
1 MV
82 db
10 MV
102 db
50 MV
PLATE 41

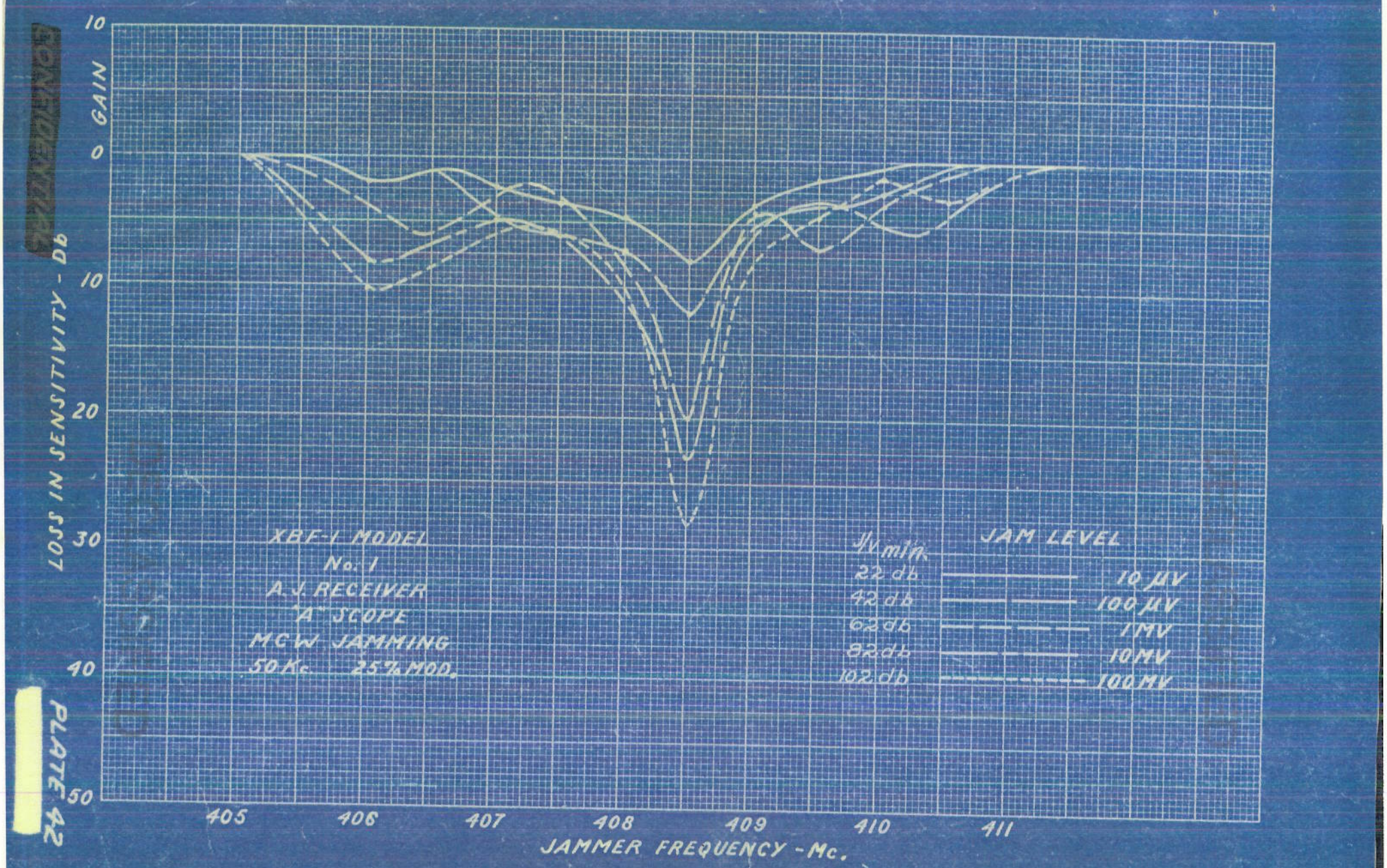

10
0 GAIN
0
10
20
30
40
50
LOSS IN SENSITIVITY - DB
405
406
407
408
409
410
411
JAMMER FREQUENCY - Mc.
XBF-1 MODEL
No. 1
A.J. RECEIVER
"A" SCOPE
MCW JAMMING
50 Kc. 25% MOD.
JAM LEVEL
μv min.
22 db
42 db
62 db
82 db
102 db
10 μV
100 μV
1MV
10MV
100MV

PLATE 42

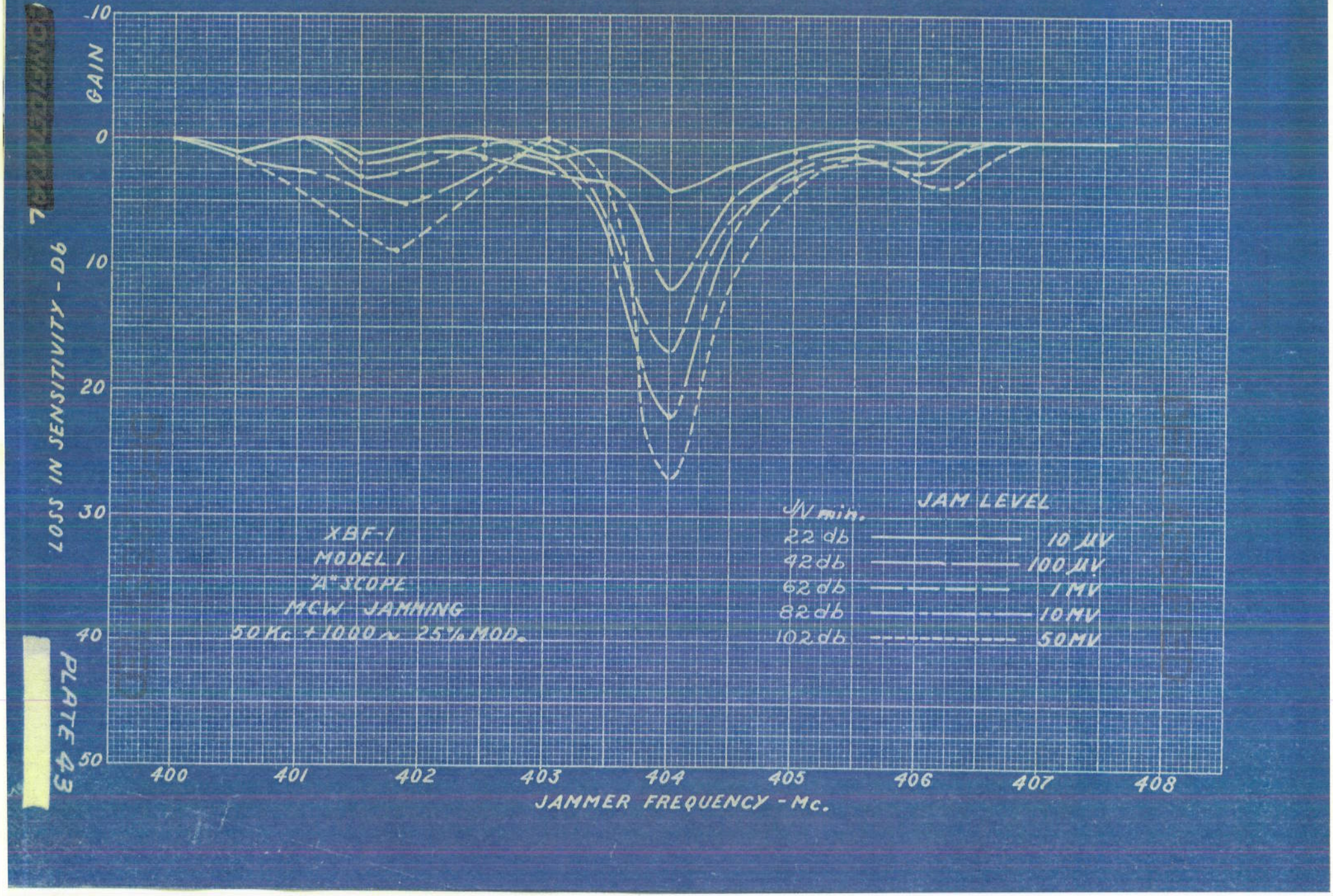

GAIN
10
0
10
20
30
40
50
LOSS IN SENSITIVITY - DB
XBF-1
MODEL 1
"A" SCOPE
MCW JAMMING
50 Kc ± 1000 ~ 25% MOD.
JAM LEVEL
dN min.
22 db
42 db
62 db
82 db
102 db
10 μV
100 μV
1 MV
10 MV
50 MV
400
401
402
403
404
405
406
407
408
JAMMER FREQUENCY - Mc.

PLATE 43

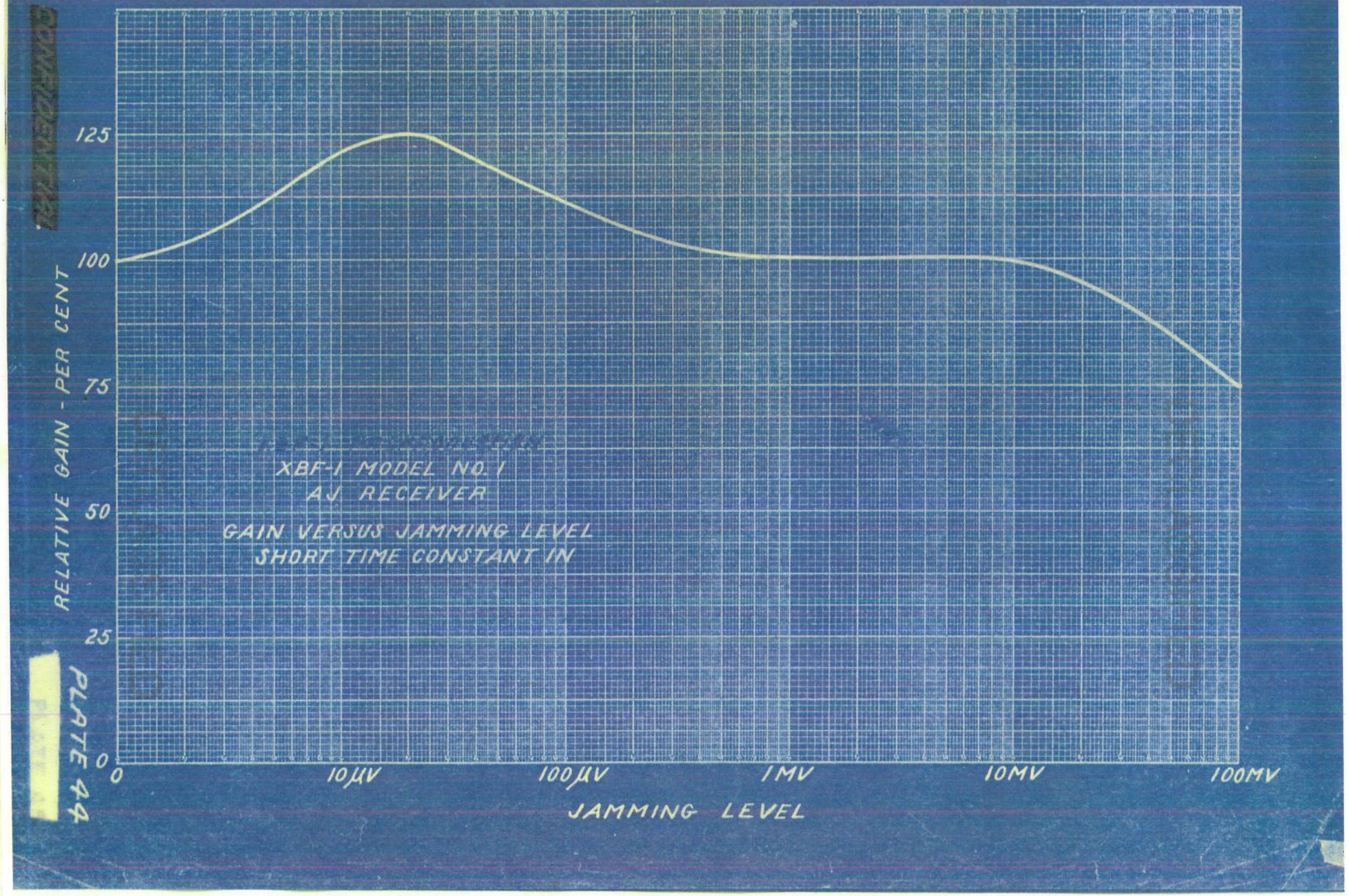
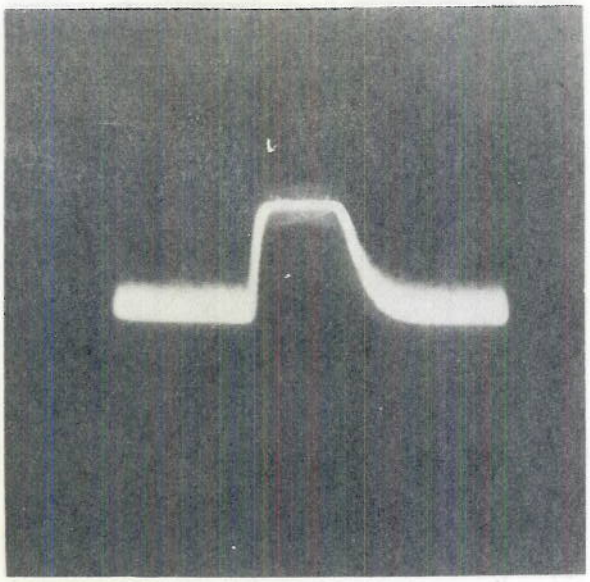
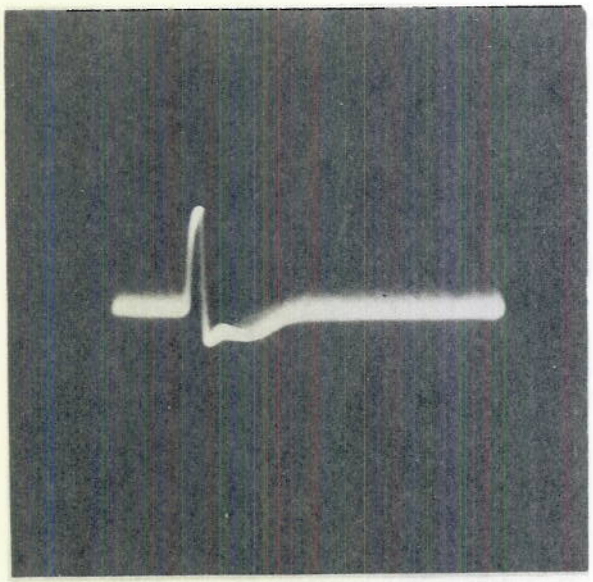

125
100
75
50
25
0
RELATIVE GAIN - PER CENT
XBF-1 MODEL NO. 1
AJ RECEIVER
GAIN VERSUS JAMMING LEVEL
SHORT TIME CONSTANT IN
0
10μV
100μV
1MV
10MV
100MV
JAMMING LEVEL

PLATE 44

DECLASSIFIED



5 SEC PULSE 25 SEC SWEEP FTC OUT

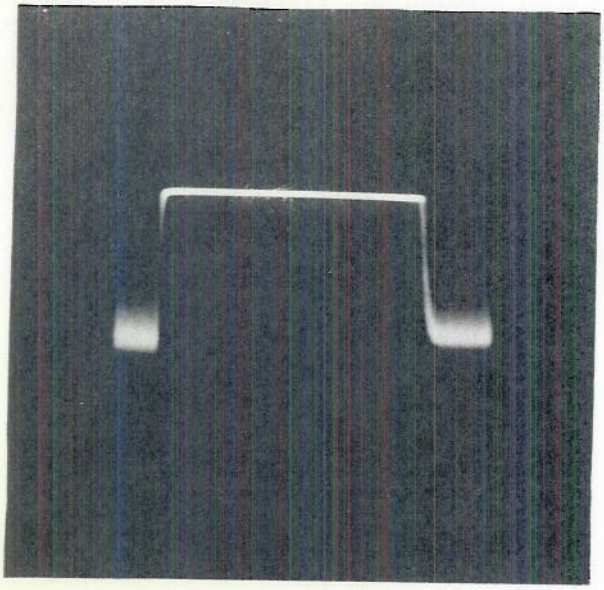


5 SEC PULSE 25 SEC SWEEP FTC IN

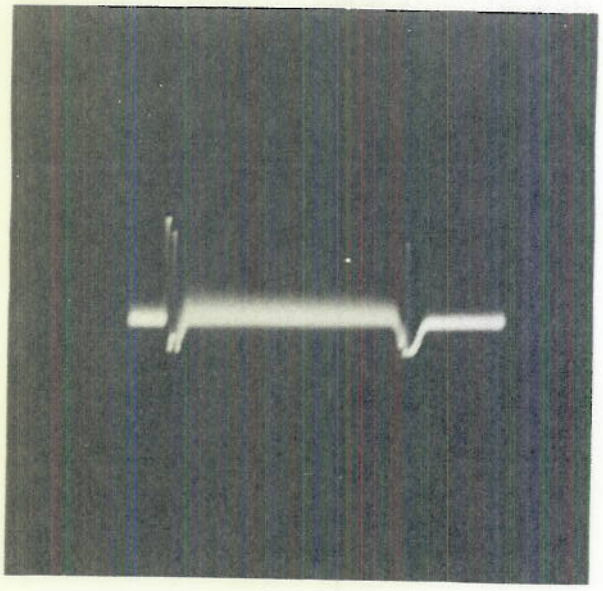
RECOVERY OF XBF-1
RECEIVER TO 50 MV PULSE

DECLASSIFIED

DECLASSIFIED



30 μSEC PULSE 50 μSEC SWEEP FTC OUT



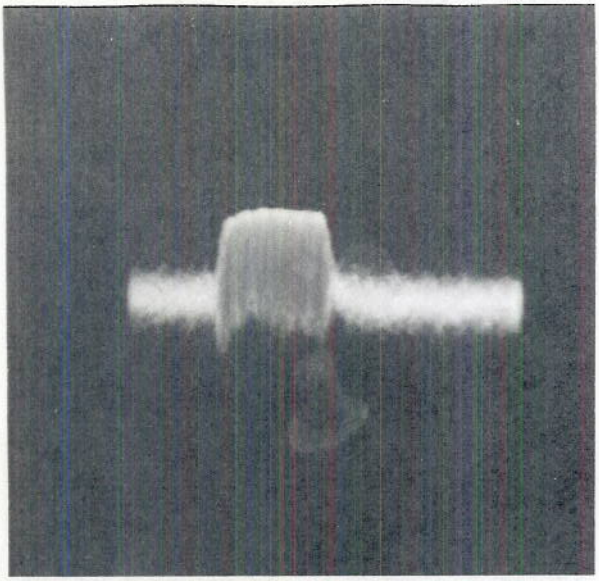
30 μSEC PULSE 50 μSEC SWEEP FTC IN

RECOVERY OF XBF-1
RECEIVER TO 50 MV PULSE.

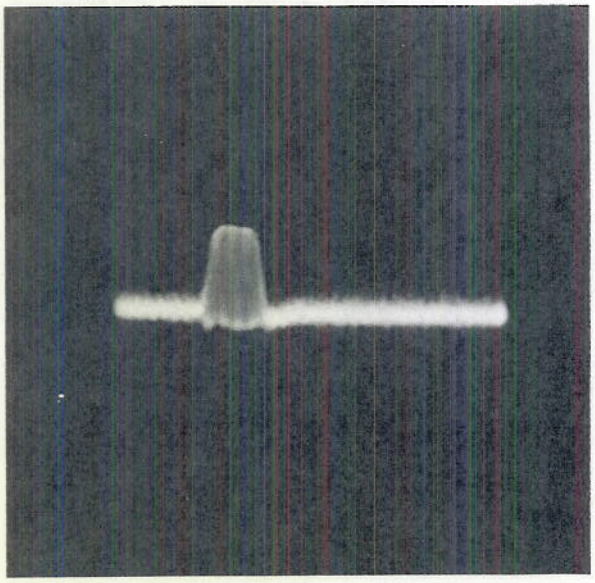
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CONFIDENTIAL

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5μ SEC PULSE 15μ SEC SWEEP FTC IN 1 MC BEAT NOTE



2μSEC PULSE 15μ SEC SWEEP FTC IN 1.5 MC BEAT NOTE

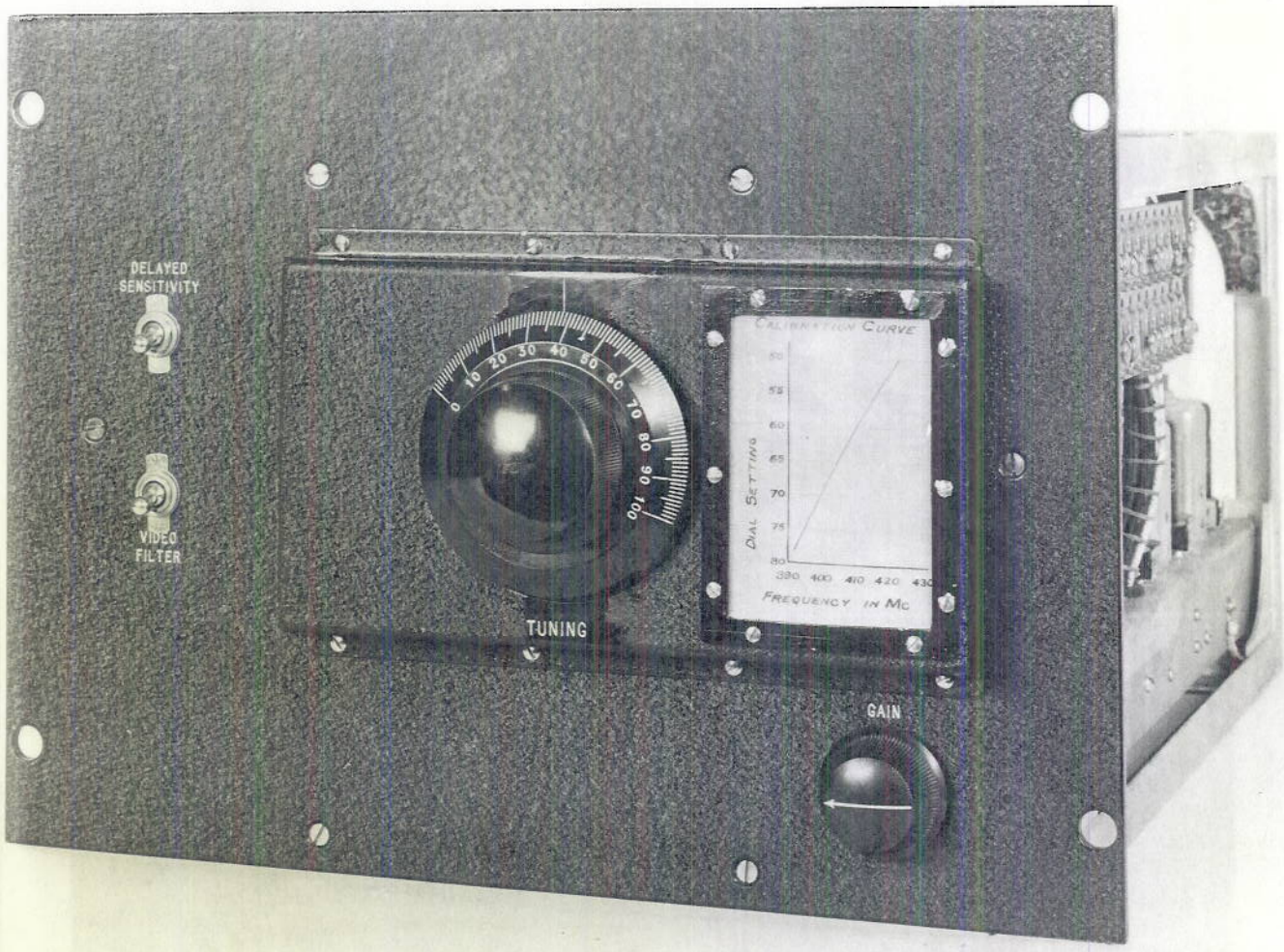
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DETECTOR OUTPUT IN THE PRESENCE OF
OFF FREQUENCY JAMMING.

XBF-1 RECEIVER 10μV PULSE
10 MV CW JAMMING

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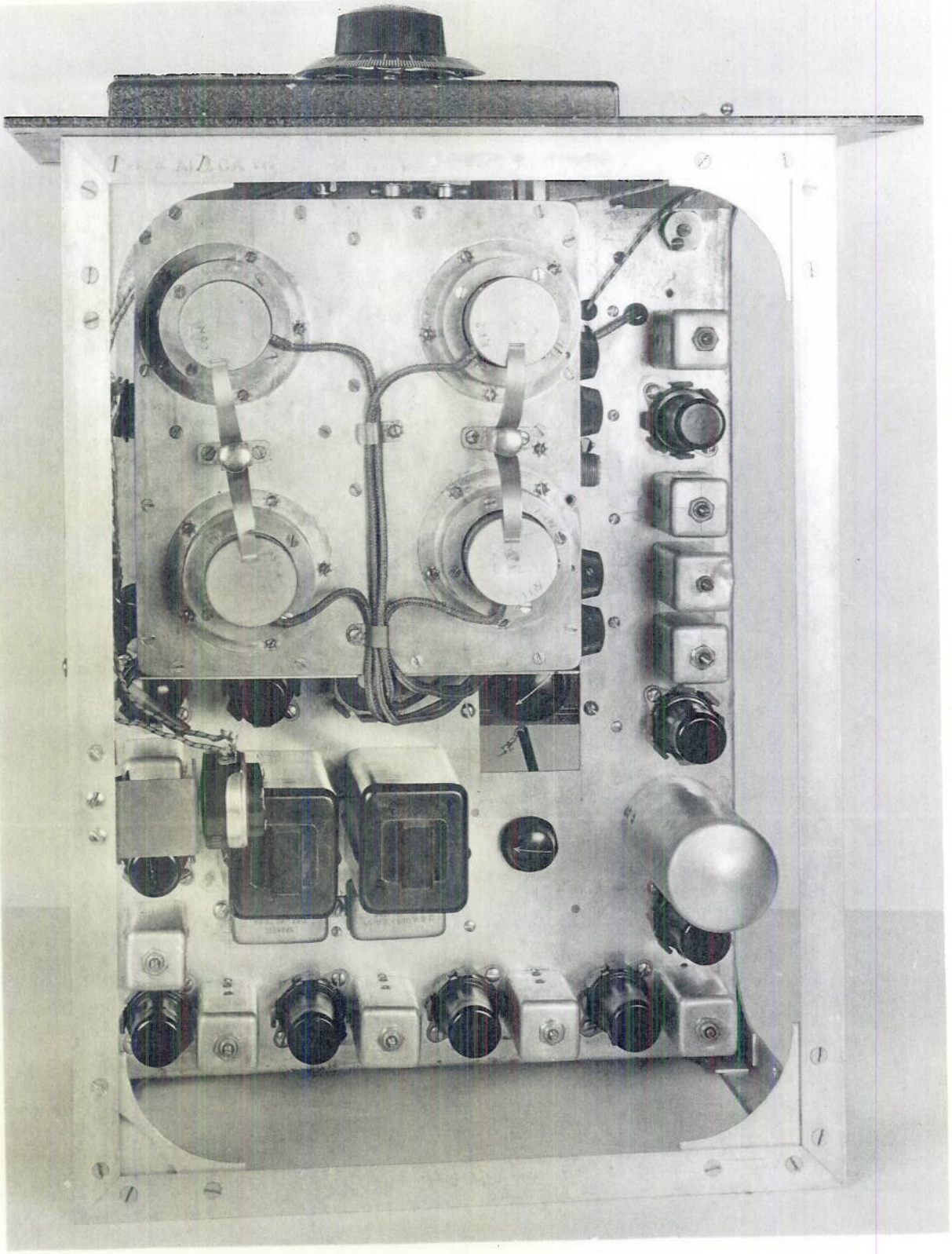
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XBF-1 MODEL NO.1 RECEIVER FRONT VIEW

DECLASSIFIED

DECLASSIFIED

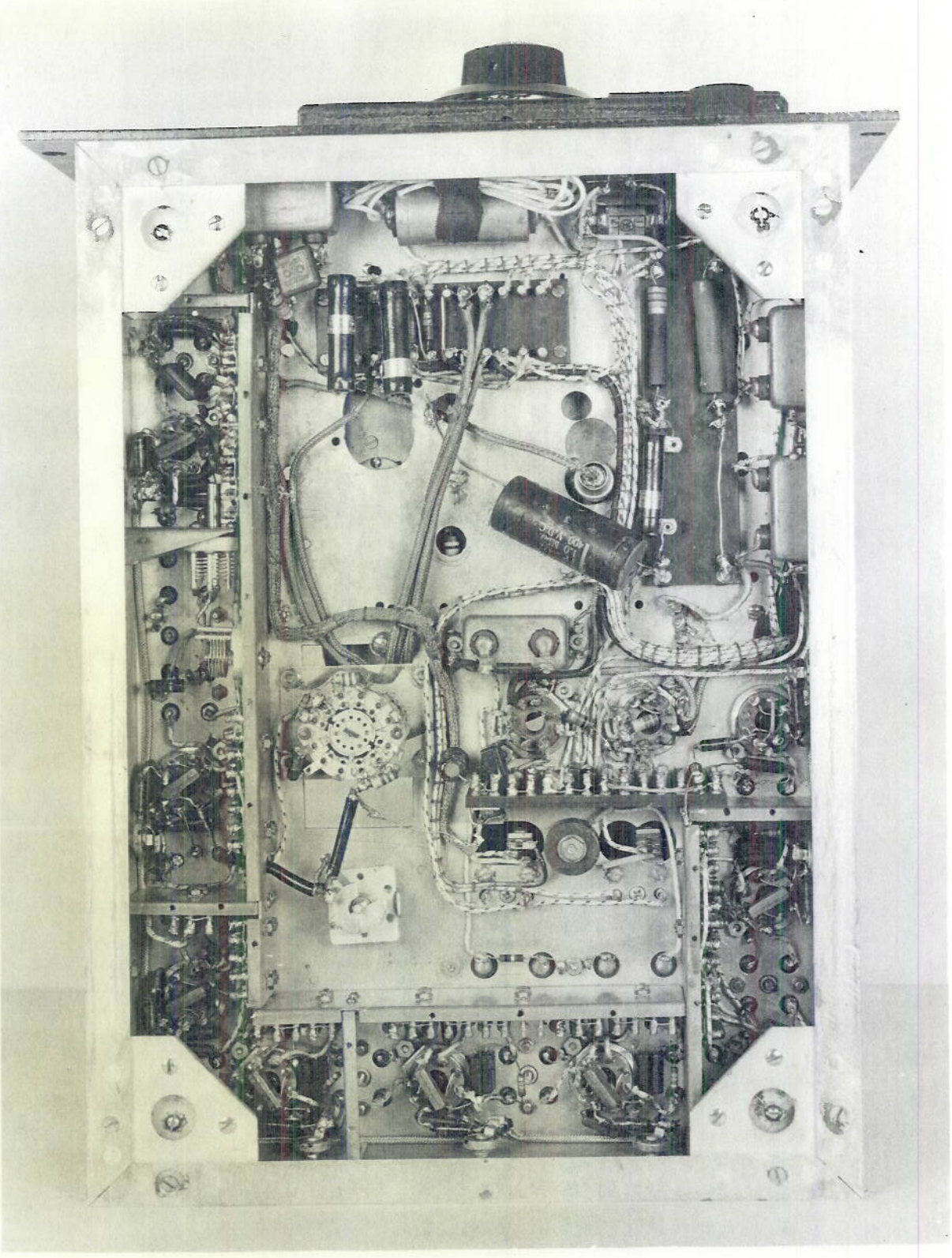


XBF-1 MODEL NO.1 RECEIVER TOP VIEW

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DECLASSIFIED

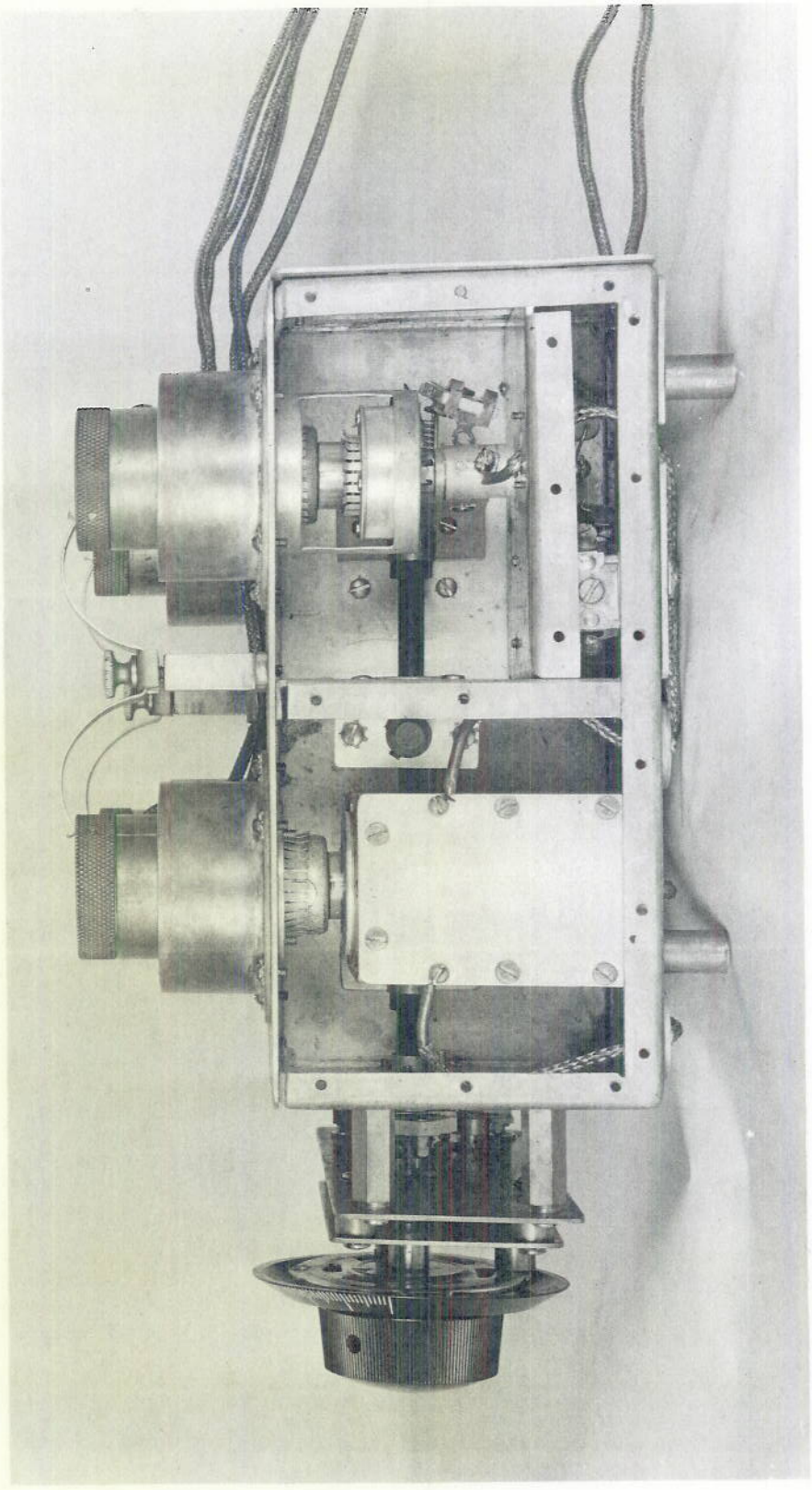


XBF-1 MODEL NO.1 RECEIVER BOTTOM VIEW

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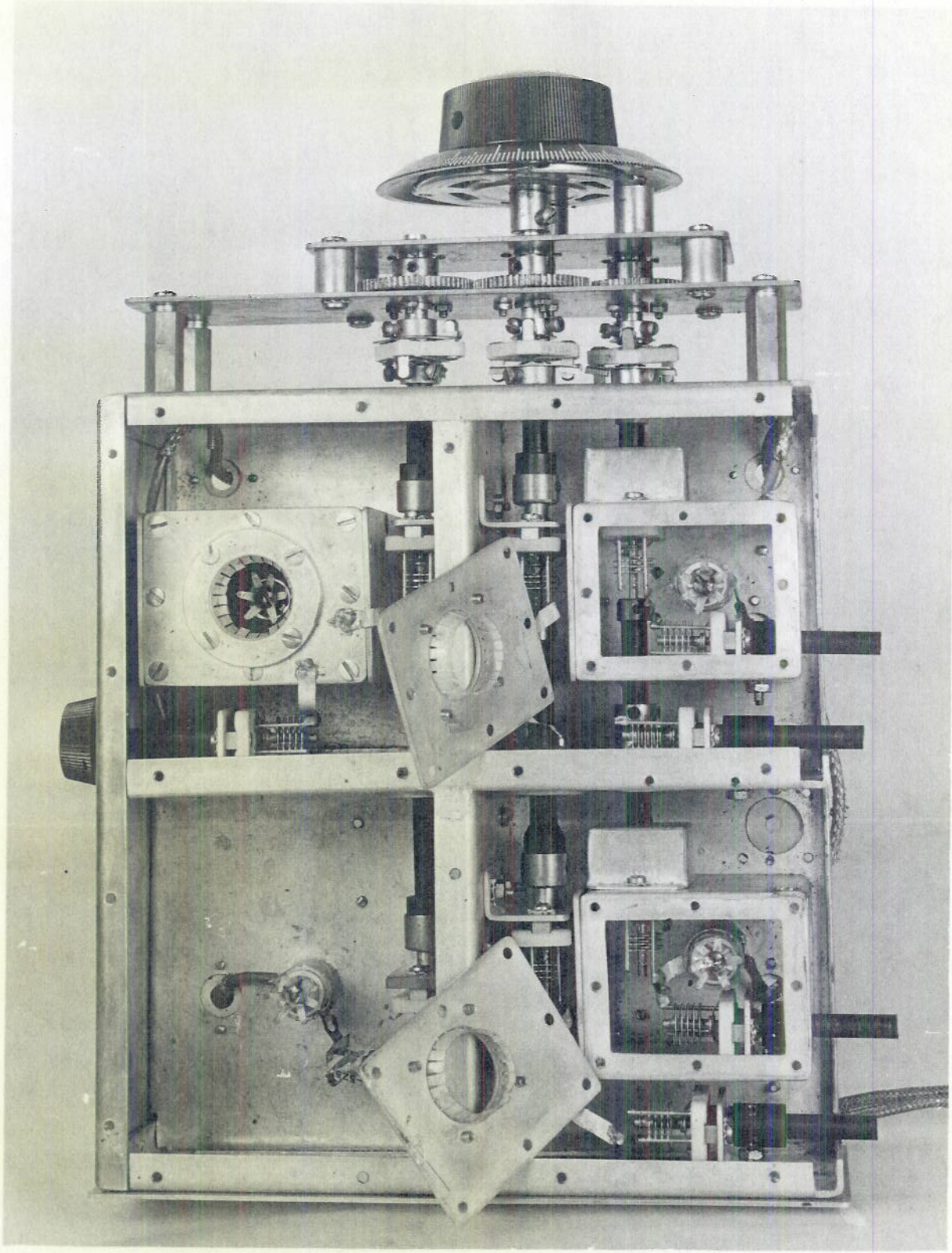


XBF-1 PREAMPLIFIER UNIT LEFT SIDE VIEW - DISASSEMBLED

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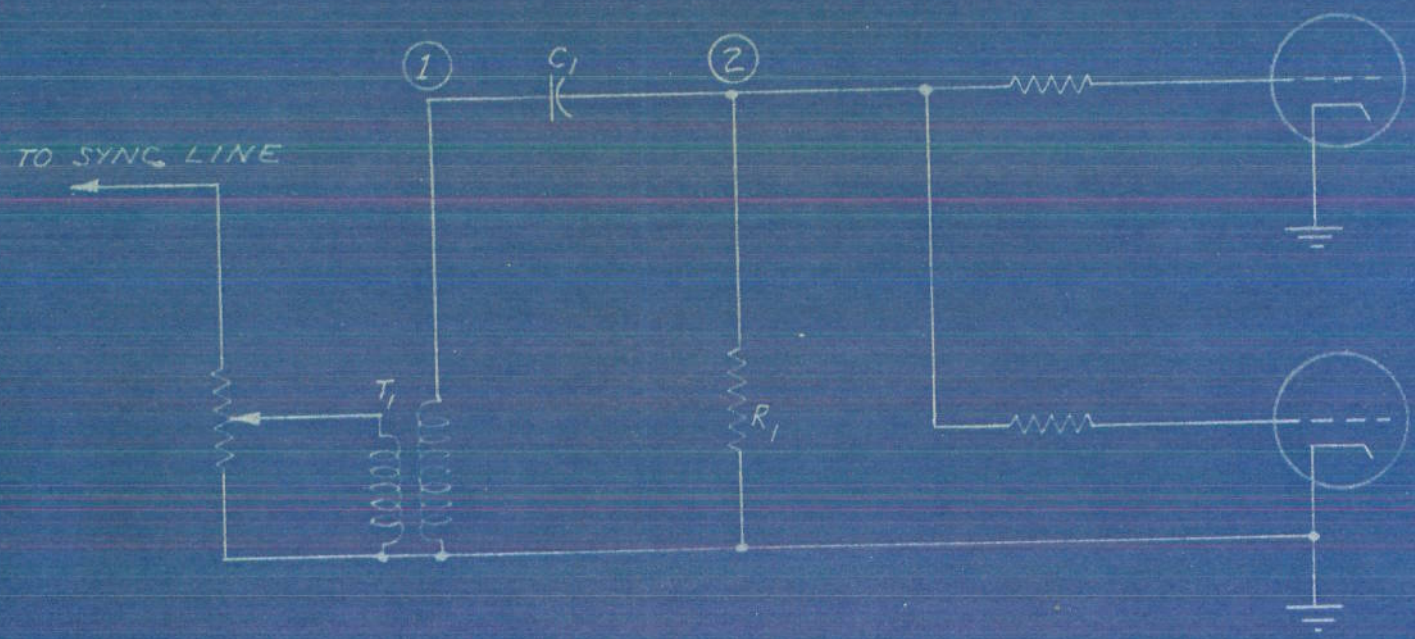
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XBF-1 PREAMPLIFIER UNIT TOP VIEW - DISASSEMBLED

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BASIC CIRCUIT OF
SENSITIVITY TIME CONTROL

PLATE 53

DECLASSIFIED

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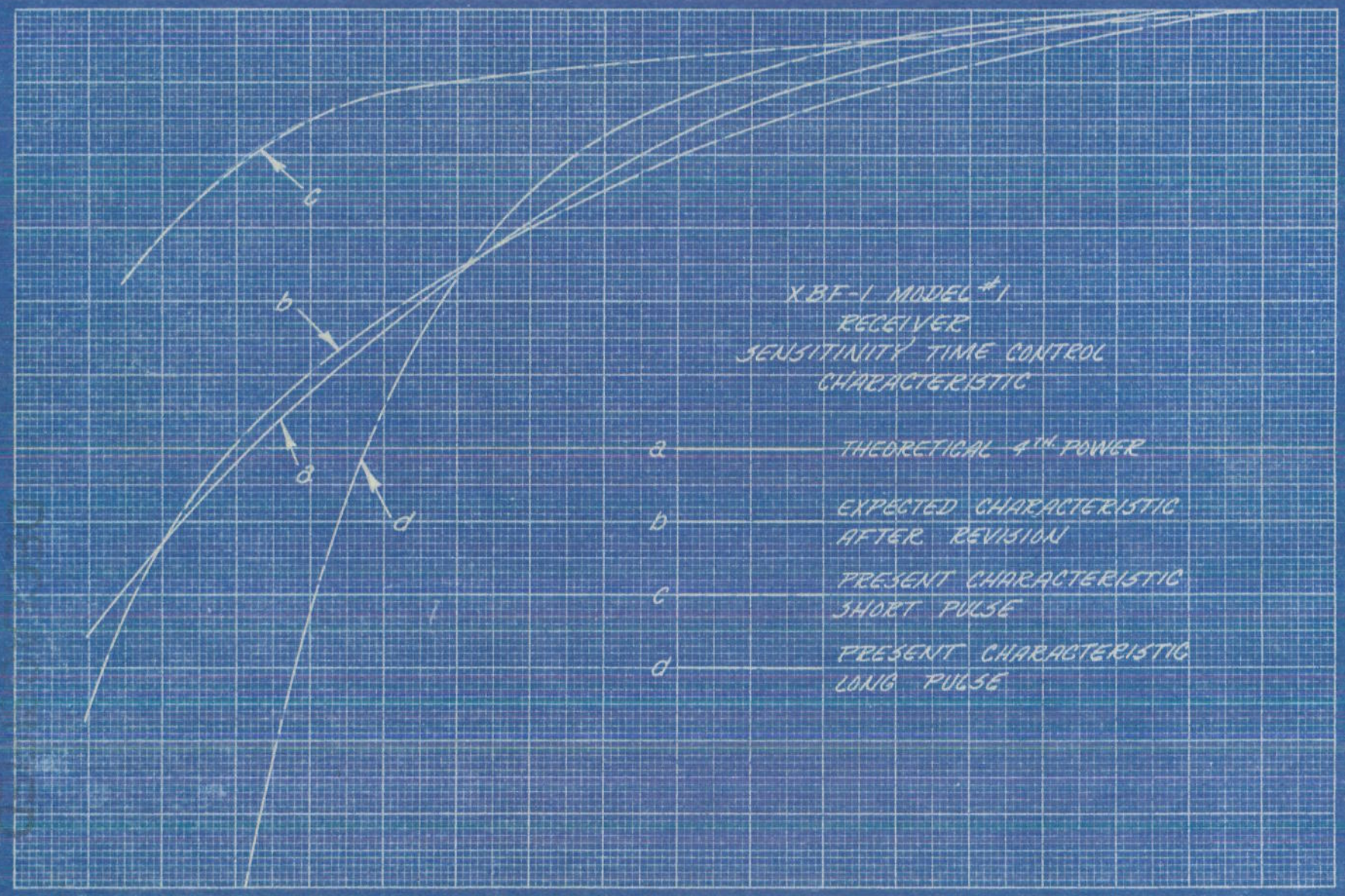
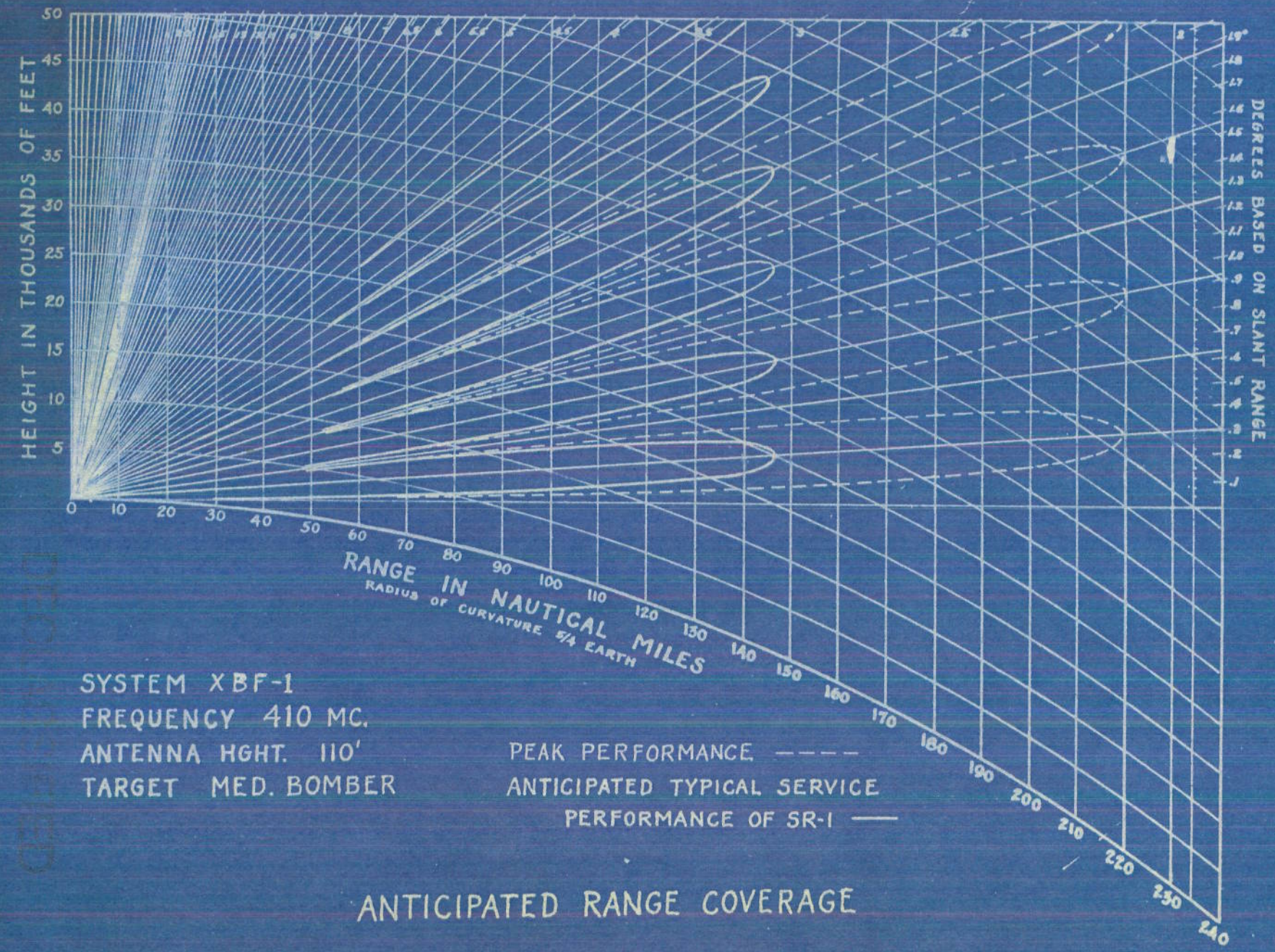


PLATE 54

CONFIDENTIAL



SYSTEM XBF-1
FREQUENCY 410 MC.
ANTENNA HGHT. 110'
TARGET MED. BOMBER

PEAK PERFORMANCE – – – –
ANTICIPATED TYPICAL SERVICE PERFORMANCE OF SR-1 ——

PLATE 55

ANTICIPATED RANGE COVERAGE

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CONFIDENTIAL

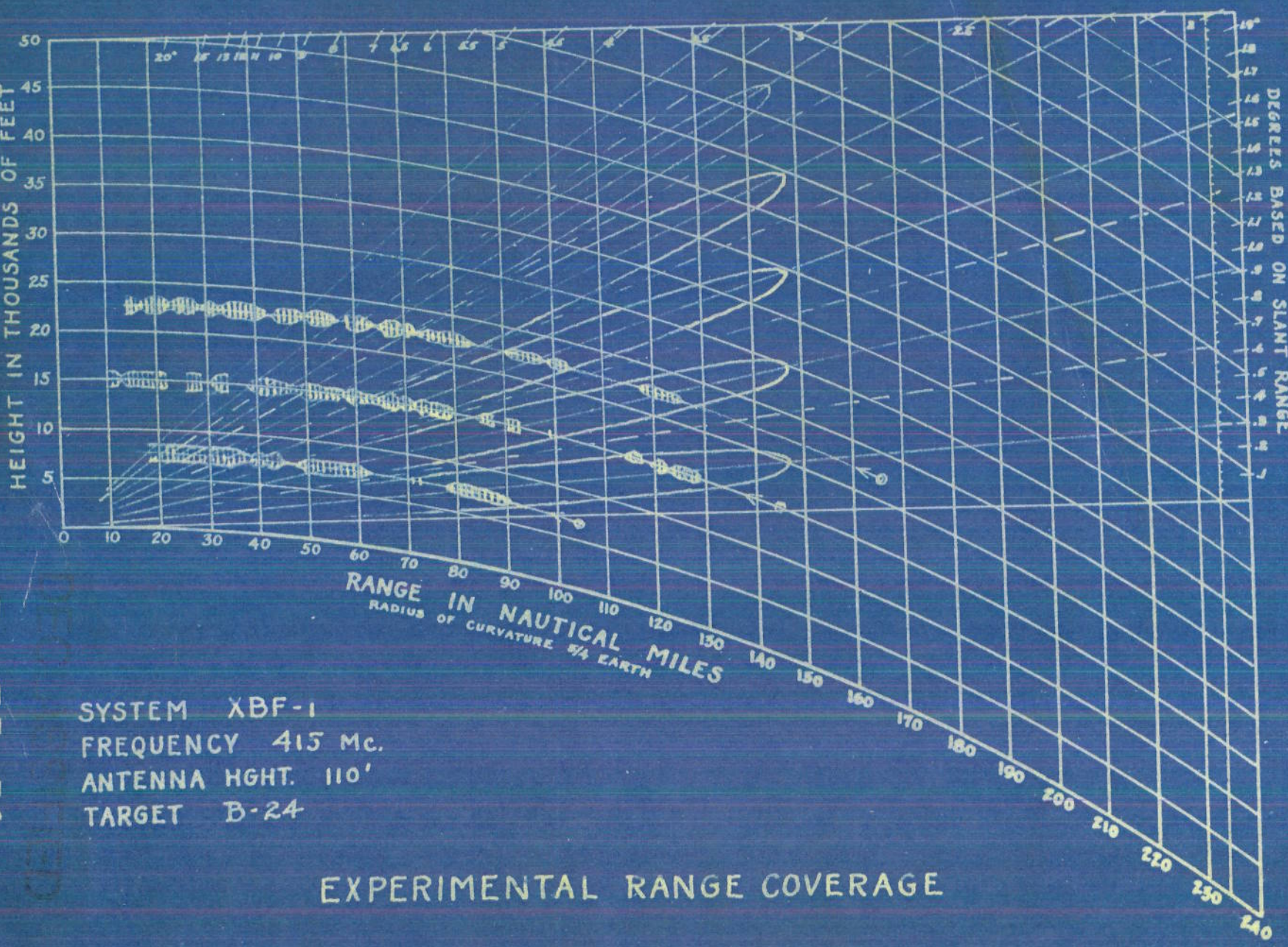


PLATE 56

SYSTEM XBF-1
FREQUENCY 415 Mc.
ANTENNA HGHT. 110'
TARGET B-24

EXPERIMENTAL RANGE COVERAGE