R-2429

REPORT NO. R-2429

DATE 1 January 1945

SUBJECT

XBF SEARCH RADAR EQUIPMENT

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FR-2429

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Report R 2429
Problem No. S 43R-S

NAVAL RESEARCH LABORATORY

Washington 20, D. C.

Radio Division - Special Development Section

XBF Search Radar Equipment

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ABSTRACT

This report covers the development at the Naval Research Laboratory of a standardized 200 Mc/s high power search radar for shipboard use. This equipment was designated at the Laboratory and is the XBF and the first of the SR series.

The Radar XBF was constructed in two sections; one a Transmitter Console containing the high power oscillator, keyer units, power supply, the R.F. and first I.F. circuits of the receiver. The second section, the Indicator Console, contains the remaining I.F. and video circuits of the receiver, I.F.F. coordinator, P.P.I., Range Scope, Antenna Bearing Indicator and Transmitter control unit. This equipment is standard in that the Indicator Console is universal and may be used with a Transmitter Console of any frequency.

This equipment is tunable from 175 to 225 Mc/s and gives an output of nearly one half megawatt. The available pulse lengths are 1, 5 and 20 microseconds at repetition rates of 180, 180 and 60 c.p.s. Provision is made within the receiver to automatically maintain optimum adjustment of the bandwidth and pulse length. Anti-Jam circuits are provided so that maximum advantage may be gained over a jamming signal.

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XBF SEARCH RADAR EQUIPMENT

1.0 INTRODUCTION

The multiplicity of Radar designs in the fleet brought out the need for one standardized system. Hence, NRL was authorized by Bureau of Ships Problem Request No. S43R-S to undertake the development of a high power standardized 200 Mc. search radar for shipboard use. This experimental equipment is now designated at the Model XBF.

1.1 The system is composed of two main units: (1) a transceiver consisting of the Transmitter Oscillator, Keyer, Monitor Receiver, Monitor Scope, Power Supply and Control Circuits; (2) an Indicator Console consisting of the Console Receiver, Plan Position Indicator, Range Scope, Antenna Bearing Indicator, IFF Coordinator and General Control Panel. The Indicator Console is the standardized part of the equipment and is designed for both long wave and centimeter wave installations. All of the units contained within the console are interchangeable with others so that in case of a failure during operation, they may be quickly removed and replaced with other similar units. These units have separate power supplies so that they may be operated independently of the remainder of the equipment and serviced on the bench. The controls on the indicator console panel are simplified, i.e., only the controls absolutely essential to operation are placed on the panel. This arrangement reduces the number of highly trained personnel necessary to operate the equipment. (Four remote PPI lines are fed from the console. These remote units are similar to the PPI unit in the console.)

1.2 The scheme of standardization thus accomplishes the following:

- (a) Reduces the number of controls
- (b) Reduces the number of units
- (c) Makes maintenance and repair a simpler job since the units are independent
- (d) Reduces to a minimum the number of types of consoles necessary in the fleet.
- (e) Makes conversion from long wave to centimeter wave or vice versa a simple matter requiring only the change of the transceiver unit
- (f) Simplifies the training of operating personnel.

1.3 One of the main problems in the installation of an equipment is getting the gear through the hatches on the ship. The XBF equipment design was based on a consideration of the maximum allowable unit size which would permit easy installation on destroyers or larger vessels.

1.4 While complete performance data are not available, calculations and preliminary experimental results indicate that the reliable range

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for aircraft should be at least 100 miles.

2.0 GENERAL DISCUSSION OF THE EQUIPMENT

2.1 The Model XBF was designed to provide the first 200 Mc model of standardized shipborne radar equipment for the Navy. This equipment is constructed in two main units, namely a Transceiver and an Indicator Console. The Indicator Console is the standardized part of the equipment. It was intended that the Indicator Console be used either with a long wave or a centimeter wave Transceiver, so that the necessity for a large number of different units might be eliminated and the installation of a new equipment might consist only of replacing the Transceiver. All of the units in the Console are standard; that is, they are suitable for both VHF/UHF and centimeter wave equipment.

2.2 Simplicity and ease of operation were the primary design considerations. This, of course, reduces the number of highly trained operators necessary to operate the equipment. The system of control was simplified so that all controls not used continuously such as anti-jam, were placed behind a sub-panel where they would be protected until operational conditions called for their use. This arrangement eliminates the possibility of an operator moving the wrong control during battle conditions.

2.3 The main controls are located at the Transceiver. These consist of a main power switch, automatic "raise and lower plate voltage relay", and a pulse length control. The pulse length control is interconnected with the bandwidth control on the Console Receiver so that optimum conditions (receiver bandwidth approximately equal to the reciprocal of the pulse length) is always maintained, regardless of the intentions of the operator. This removes the possibility of an inexperienced operator preventing the equipment from performing at optimum, by not setting the bandwidth control so that the above-mentioned optimum conditions exist. A duplicate set of controls is located on the General Control Panel in the Console. This permits complete control of the entire equipment to be taken over at the console which may be at some position remote from the transceiver. Control is transferred from one unit to the other by means of a "Remote-Local" switch on the Transceiver.

2.4 Provision is made on the console to supply a limited video signal to twelve remote Plane Position Indicators; a syncro signal is also supplied to operate the bearing indicators on the remote units. The video signal for these remote units is supplied through four coaxial lines from the Indicator console. A "termination box" at the console allows the termination at the end of these four lines to be adjusted to the correct value with a minimum of labor.

2.5 General specifications require the following:

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(a) 115 volt, 60 cycle, single phase operation
(b) Frequency coverage is accomplished in four bands; 175 to 185 Mc/sec, 185 to 195 Mc/sec, 195 to 205 Mc/sec, 215 to 225 Mc/sec. The 210 Mc band is reserved for other use.
(c) Peak power output of 500 Kw
(d) Variable repetition rates and pulse length with provision to maintain in the receiver the condition for minimum visible signal, i.e., the receiver bandwidth is approximately equal to the reciprocal of the pulse length, as follows:

    (1) 60 c.p.s. ± 10% @ 20 u.sec.; Receiver Band Width equals 50 Kc/s.
    (2) 200 c.p.s. ± 10% @ 4 u.sec.; Receiver Band Width equals 250 Kc/s.
    (3) 200 c.p.s ± 10% @ 1 u.sec.; Receiver Band Width equals 2 Mc/s.

(e) Anti-jam circuits in the console receiver
(f) Echo box tuning
(g) Plan Position and "A" type range presentation
(h) "A" type range presentation monitoring of the signal at the transceiver - with provision for use of the unit as a portable service oscilloscope.
(i) The equipment to be constructed in two main units.

    (1) Transceiver - containing the oscillator, Power supply, Duplexer, tuning stubs, Monitor Receiver, and Monitor Oscilloscope.
    (2) Indicator Console - containing the Console Receiver, Plan Position Indicator, Range Scope, I.F.F. Coordinator and General Control Panel.

2.6 .6 General views of the Transceiver and Indicator Console are shown in plates 1 to 13.

3.0 DISCUSSION OF THE GENERAL UNITS

3.1 Transceiver

The transceiver contains the following units:

(1) Oscillator, tuning stubs and duplexer
(2) Power supply Keyer Unit and Transmitter Controls.
(3) Monitor Receiver and Echo Box.
(4) Monitor Oscilloscope.

3.2 The overall dimensions of the transceiver are 72 inches x 28 inches x 22 inches; the total weight is 1260 pounds. Plates 1 and 2 show various views

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of the completed unit from which a relative idea of the dimensions may be obtained.

3.3 Plate 1 shows the disposition of the individual units within the transceiver. Across the top of the panelfront are the various meters: plate voltage; plate current; grid current; oscillator filament voltage; and hours of operation. On the right hand side of the transceiver in order are the Monitor Scope, Monitor Receiver, and Keyer units. To the left of these three units is the oscillator. Behind the oscillator to the rear of the frame, are the duplexer and tuning stubs. Below the keyer and oscillator is a row of tuning knobs which control the oscillator frequency and adjust the stubs and duplexer. Below the tuning controls is the power supply compartment with the main power switch in the center of the panel.

3.4 There are several unusual features that add greatly to the operational value of the equipment. The Keyer unit, Monitor receiver and Monitor Scope are all removable from the transceiver frame. Both Monitor Receiver and Monitor Scope have separate power supplies that allow them to be operated independently of the remainder of the equipment and is thus an aid to servicing. Provision has also been made for the monitor scope to be used as a "service-scope", which facilitates servicing the equipment in the field.

3.5 Overall dimensions of the transceiver frame were dictated by consideration of the available space in the confined space of the passageways and radar room of a vessel, hence these dimensions are as small as is consistent with the size of the required components. Due to the restricted space, the arrangement of oscillator and power supply components were of prime importance to maintain accessibility.

4.0 <u>INDICATOR CONSOLE</u>:

4.1 The Indicator Console contains the following units:

(1) Console Receiver
(2) General Control Panel
(3) I.F.F. Coordinator
(4) Plan Position Indicator
(5) Range Scope
(6) Bearing Indicator
(7) Junction Box

4.2 The disposition of these units within the console is shown in Plate 3. The Range Scope and antenna control are on the extreme right of the console while the Plan Position Indicator is in the center. The main receiver is in the upper left hand corner of the console and immediately below it are the General Control Panel and I.F.F. Coordinator. The junction box occupies the

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entire top portion of the console. Various views of the individual units are shown in Plates 1 thru 13.

4.3 There are several unique features in the console that add considerably to its usefulness. All of the units within the console are removable and have separate power supplies. This arrangement permits the individual units to be serviced independently of the remainder of the equipment. Four remote P.P.I. video lines are fed from the console. These P.P. I.'s are identical to the one in the console except that they are in individual weather-proof cases. This further standardization decreases the number of different units necessary. Only controls required for normal operation are placed on the console panel. All other controls not normally used, such as anti-jam, "A" scope gain, and I.F.F. delay are placed behind a sub panel on the individual units.

4.4 Various mechanical features of the console are as follows:

(1) The console frame work and chassis is constructed entirely of aluminum. The weight of the completed console and associated equipment is 550 pounds. Four recessed lift hooks are provided at the corners of the unit.

(2) Provision is made on the General Control Panel to dim all the pilot lights except that of the P.P.I. which has its own dimmer. Since there are twelve remote P.P.I.'s throughout a vessel it is a simplification to allow each unit to have its own panel light control.

(3) There is no forced ventilation, but free circulation of air is provided by means of louvers in the back and side panels of the console frame.

(4) Sliding tracks are provided in the Console so that all of the units may be removed easily. A catch locks the chassis framer securely on the runners when they are pulled about two thirds of the distance out. This lock prevents the unit from moving either in or out while a service run is being made on it and acts as a precaution against the operator injuring himself or the unit as the ship rolls during a storm. The unit may be removed by releasing the catch and disconnecting the terminal boards.

(5) Terminal boards are provided on each unit so that interconnection between units can be made through the "junction box" in the top of the console.

(6) The entire Console is shock mounted.

(7) Cable Distribution. This is a unique feature of the Indicator Console and performs several important functions. Cables from various units in other parts of the ship are brought in to a junction box in the top of the console unit for distribution. The main cables are then distributed to separate terminal strips within the junction box.

5.0 MONITOR SCOPE:

5.1 The Monitor Scope is included in the transmitter to fulfill two purposes. It provides at the transmitter a Range scope for observing received signals for the purpose of checking the operation of the system for optimum performance, and is also usable as a service scope for checking these or other circuits. It supplies for this purpose a synchronizing pulse and a sweep at 60 pps. To facilitate its use as a service scope, it is placed in a portable case with a handle attached, and is thus completely self-contained and portable.

5.2 The scope provides two sweep ranges of 20 and 80 miles, and a third range of several thousand microseconds which is locked with the 60 cycle power line for test operation. A video amplifier with a gain control is included to adjust the signals to the desired level.

5.3 The Monitor Scope is an independently portable unit removable from the transceiver frame by loosening of four thumb screws on the panel and sliding it out the front. The outside case is removable by taking out seven masking screws and sliding the chassis with the panel out the front of the case.

5.4 The power supplies are self-contained. Power is supplied through plugs at the rear of the unit. These plugs are so arranged to plug into the proper receptacle as the unit is placed in the transceiver frame. The fixe plugs on the back are 115 volts 60 cycle power input, video input, test signal input, sync pluse input, and sync pulse output.

5.5 Shock mounts are included for all tubes of which there are seven in number.

5.6 The basic circuit is a single kick or "slave" multivibrator which generates rectangular pulses of 255 and 1020 microseconds duration for the two ranges of 20 and 80 microseconds respectively. A positive pulse from this is used to unblank the cathode ray tube for the sweep duration. A negative pulse is used to shut off a triode drawing current through a large inductance. The sudden stoppage of current through the choke gives rise to high voltage. The inductance is tuned with capacity to a low frequency such that the portion of the used voltage, for 255 and 1020 microseconds deviates from a linear slope by only a small percentage. This voltage is generated in one half of a center tapped choke. A similar voltage of opposite phases is induced in the other half of the choke by transformer action. This gives a balanced sweep voltage and is applied to the horizontal plates of the cathode ray tube. This multivibrator is synchronized by means of a pulse from the keyer unit.

5.7 When the scope is in test position, a pulse is formed by a 6SN7 tube keying the multivibrator and putting out a sync pulse for external test circuits. The sweep when in this position is several thousand microseconds long. A complete diagram is given in Plate 14.

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6.0 POWER SUPPLY, KEYER, CONTROL CIRCUIT:

6.1 Specifications for this equipment call for the following.

(1) Power supply rating 0 to 15000 volts DC at 150 Ma with a primary rating of 115 volts 60 cycles.

(2) Oscillator filaments require 15 volts at 15 amperes with provision for adjustment to compensate for line voltage variations.

(3) Pulse Width Repetition Rate

1 usec ± 10% @ 195 cps. ± 10 cycles
4 usec ± 10% @ 195 cps. ± 10 cycles
20 usec ± 10% @ 60 cps. ± 5 cycles

(4) Unit controllable from either the local or remote console position.

(5) Emergency switch for entire system is in the Transceiver.

6.2 When the plate voltage is turned off by any one of several means the plate variac returns to zero before plate voltage is again applied. Also when the unit is manually keyer (by blocking the grid) the plate voltage is held to a value not greater than the operating voltage of the oscillator.

6.3 A time delay in the plate voltage control circuit is provided so that the plate voltage will not be applied to the oscillator before the filaments have reached their operating temperature.

6.4 When the unit is standing by and the plate voltage is off, the filament voltage is automatically reduced to 80 per cent of operating value which increases the effective life of the oscillator tubes. Provision is made for turning filaments off and leaving the blower on in order to cool the tubes for quick servicing.

6.5 The repetition rate is variable from 55 to 65 cycles per second in 5 steps and 185 to 205 cycles per second in 5 steps. The keyer has three pulse shaping circuits - one for each pulse length. There is an artificial transmission line in the plate circuit to improve the pulse shape.

6.6 When the main power at the local transceiver is turned on the remote controls may operate the unit if control has been transferred to the Console. An emergency off switch is provided at the Console. The oscillator plate voltage may be turned off from the local position even though control is at the remote position. The plate voltage may be read at both positions at all times.

6.7 The venier control of the repetition rate is available only at the local transceiver, while manual keying can be performed only at the Console.

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6.8 The keyer which can be removed from the transceiver as a complete unit is located just above the power supply on the right side. It is shown removed from the rack in Plates 9 and 10. On the front panel of the keyer is located the local controls for the plate voltage, the pulse width switch, repetition rate vernier, and switch for transferring control from local to remote and vice versa. There is also a pilot light for the plate voltage and a pilot light which indicates when the control is at the local.

6.9 The remote transmitter control is located in the lower left corner of the console is shown in Plates 1, 3 and 6. On this control panel is located a plate voltmeter, plate voltage controls and pilot light, dial light dimmer, console on-off switch, and pilot light that indicates when control is at this panel. At the bottom of this panel behind a small drop door is the phantom target switch and manual keying switch. When this door is closed, the keying switch is forced to the "on" position.

6.10 The remote pulse width change switch is located on the receiver of the console and automatically maintains the optimum condition that the bandwidth is equal to the reciprocal of the pulse length. The high voltage rectifier circuit uses two 8020's as voltage doublers and has a positive output. The voltage output is controlled by 2 ganged motor driven variacs. The artificial transmission line for maintaining the oscillator voltage constant while the oscillator is pulsed, the grid blocking circuit for manual keying, plate current meter, overload relay coils, and synchronizing pulse transformer are located in the negative to ground side of the rectifier circuit. This location simplifies insulation problems.

6.11 When the manual key is in the "off" position, the grid is blocked by a high negative bias, and at the same time an impedance is inserted in series with the primary of the plate transformer to prevent the no load voltage rising above the full load value. If the plate voltage is off an impedance is inserted in series with the primary of the oscillator filament transformer to reduce the filament voltage to about 80 per cent of normal voltage when the tubes have reached thermal equilibrium. A variac is used to adjust the filament voltage to the proper setting.

6.12 When the plate voltage is first turned on, a winding on the grid synchronizing choke is connected to the 60 cycle power circuit. This insures that the oscillator will start keying and not draw a heavy plate current which will trip the overload relay. When the variac reaches about 30 per cent of its travel the choke winding is disconnected from the power circuit and the oscillator is self-keyed at some predetermined frequency set by the synchronizing trap circuit.

6.13 The basic keyer circuit is shown in Plate 15. It differs from most grid keyers in that it contains no vacuum tubes and yet provides variable frequency synchronization. It may be self-synchronized or externally synchronized. Basically the operation of the circuit is as follows: The oscillator is a self-pulsing self-quenching type in which a delay line controls the duration of the pulse and a resonant trap circuit controls the repetition period.

6.14 The quenching network operates as follows in controlling the duration of the pulse: the delay line presents to the grid current an impedance $Z_o = \sqrt{L/C}$, the surge impedance of the line. The grid voltage therefore remains constant and equal to $I_g Z_o$ until the impulse propagated down the line is reflected (this reflection occurs because the line termination is much greater than Z_o) and returned. The potential at the input then abruptly becomes $2 I_g Z_o$. The surge impedance of the line must be high enough to provide a bias which when doubled quenches the oscillation. This action of the delay line controls the duration of the pulse, so that it does not vary appreciably with variations in grid current or with changes in the operating potentials of the tubes. Another advantage of the use of a delay line rather than a single condenser for the quenching circuit is that the bias is maintained nearly constant during the pulse.

6.15 Referring to Plate 15, the delay line used had a characteristic impedance of 67 ohms and consisted of three lines which could be connected in tandem to increase the delay time. By using a 67 ohm line a compromise between high power, good efficiency and long life was attained. The coils $L1 - L10$ are determined by the desired time delay per section as well as the characteristic impedance.

6.16 The discharge circuit $L_{12} - R_1$ consists of a large imductance and sufficient resistance to give critical damping during the discharge period so that a very nearly straight line discharge is obtained. This helps give a steeper voltage curve near the starting bias.

6.17 The high Q resonant trap circuit operates in such a manner that the grid voltage is caused to have a steep rise in the vicinity of the oscillator starting potential, thus obtaining a definite syncronization with the resonant frequency of the trap circuit. If there were no means of syncronization provided, the oscillator would start oscillating again when the charge on the line had been reduced by the action of the discharge circuit until the starting bias had been reached, and in this case the repetition rate would be subject to considerable variation with changes in oscillator loading and in tube potentials. However, the resonant syncronizing circuit makes a great reduction in the variation of repetition rate with changes in tube operating conditions. An additional advantage of the syncronizing circuit is that the steeper rise of grid voltage improves the oscillator plate efficiency by reducing the amount of power wasted during the interval immediately preceeding the pulse. In order to get maximum stability and maximum rate of change of grid voltage at the keying point the peak of the sinusoidal voltage on the "trap" circuit should be approximately one half the peak voltage on the delay line which is $2\hat{I}_g Z_o$. Hence the Q of the LC circuit should be such that the charge dissipated per cycle for this amplitude is equal to the charge restored by the grid current pulse. It was found that with a Q of approximately ten sufficient syncronizing voltage was obtained with a trap circuit capacitance between five and ten times the total capacitance of the delay line. The value of the inductance was thus determined from the desired repetition rate and the capacitance.

7.0 TRANSMITTER OSCILLATOR

(a) Type oscillator: 6 tube ring oscillator using the "grounded plate" circuit.

(b) Tube type: RCA 8014A

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(c) Frequency Range: 175-225 Mc. This frequency range was divided into four bands, namely:

(1) 180 mc band - 175 to 185 mc
(2) 190 mc band - 185 to 195 mc
(3) 200 mc band - 195 to 205 mc
(4) 220 mc band - 215 to 225 mc

The "210 mc band" is reserved for other use.

(d) Power Output: The plate voltage rating on the 8014A was originally 15 KV but later this rating was revised downward to 13.5 Kv. This new plate voltage rating cuts the output power of the XBF oscillator to a value near 400 KW.

(e) Power required to operate:

(1) Plate power 15 KV at 150 ma
(2) Filament power for 6 tubes is 1350 watts

(f) The balanced output coupling was used in the final model, but it was found that the oscillator was too lightly loaded working into an impedance of 365 ohms and consequently the loading was increased. The final value of the load impedance was 311 ohms.

(g) Characteristic impedance of the transmission line is 50 ohms. A 3" coaxial line is used.

(h) Tuning Controls: The filament frame length is tuned for optimum power output over each band and then remains fixed for that band. Frequency tuning over each band is accomplished by tuning the grid frames.

7.2 The plate voltage rating of the 8014A tube is 13.5 KV. The filament power required per tube is 225 watts (15 volts at 15 amperes.) Grid cut off bias, (measured at EP = 4000 V and Ip = 5 ma) is in the vicinity of 145 to 150 volts. A cut off bias of over 160 volts is too remote for satisfactory operation and tubes in this category should not be used.

7.3 Data taken from life tests indicate that the 8014A has longer life when mounted with the grid connection in a downward position.

7.4 A photograph of the oscillator is shown in Plate 2. The anode assembly is in the center, the grid frames at the bottom and the filament frames at the top. The output transmission line comes in at the top and extends down inside the filament frames. The circuit diagram is shown in Plate 16.

7.5 The filament frame assembly is supported entirely by the top plate of the oscillator box. This was done so that the entire filament assembly could be removed for inspection, repair or replacement merely by lifting it out the top of the oscillator unit.

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7.6 The filament frames themselves are low impedance coaxial lines. These coaxial frames eliminate the usual filament R.F. bypass mica condensers.

7.7 The inner conductor of the output transmission line is connected to three alternate filament frames and the outer conductor is connected to the three remaining frames.

7.8 It has already been stated that the oscillator works into a load impedance of 311 ohms. This is accomplished by means of a quarter wave matching transformer section of 125 ohms, impedance. This transformer matches the 311 ohm load to the 50 ohm characteristic impedance of the transmission line. It begins at the inner conductor coupling "spider" and thus nearly the whole transformer section is inside the oscillator box. The filament frame shorting bar is adjusted manually.

7.9 The anode assembly is supported on four two inch Moldarta insulators which stand on a 1/2 inch thick plate of cloth inserted bakelite. Each tube rests in a counter bored recess in the bottom plate and is clamped by a retaining ring from above. The space between the upper and lower anode mounting plates is the anode air chamber. Cooling air from the blower enters this chamber through an opening in the bottom plate and disperses through the anode fins on the tubes. The temperature at the anode with the filaments on only is approximately 100° C.

7.10 The grid assembly is supported from the bottom end plate of the oscillator box on four 1.5 inch Isolantite insulators. At the base of the grid frames is an air manifold which takes part of the cooling air and conducts it up through the grid frames to cool the tubes at the grid seals. The grid connection to a tube is made through a collet and a bellows is provided just below this collet to prevent breakage of the tube due to mechanical strain. The grid frames are tuned by means of a shorting bar which is driven by two stainless steel screws connected through a gear mechanism and brought out to a front panel control.

8.0 <u>TUNING STUBS AND DUPLEXERS</u>:

8.1. The transmission line to the antenna includes two tuning stubs for impedance matching, and two duplexer tanks for decoupling and receiver protection. The tuning stubs are adjustable from the front panel as are the tuning condensers in the duplexers. The duplexers are similar to those in the Model SC Radar equipments. The only difference in the XBF duplexers is in physical appearance. The tanks are straightened out; that is, they are in line with the quarter wave section which connects the duplexer tank to the transmission line.

8.2 The stubs and duplexers were mounted rigidly to the transmitter frame and since the oscillator was shock mounted, it was necessary to install a flexible section of transmission line between the oscillator and the tuning stubs. A test was run to determine whether too much frequency shift would result from deflection of this flexible section.

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There was no observable frequency shift due to deflection and only very slight shift due to tension or compression.

8.3 Performance Data:

Warm up frequency drift data have been taken on the XBF oscillator. Each test was made from a cold start. These curves are shown in Plate 24. A heterodyne frequency meter was used to measure the frequency.

8.4 Power Output data were recorded during the month of July 1943. Unfortunately, the 8014A tubes which were being received at that time were inferior to tubes which had been received earlier. Due to the fact that only a very few tubes were available for power test in the XBF, it was often difficult to keep the transmitter running at 15 KV which was then the rated voltage for the 8014A. A set of power readings were obtained over the band using the 1 microsecond pulse length and a plate voltage of 15 KV. These data were all in excess of 500 KW. The output power curves are shown in Plate 25. Efficiency curves over the band are shown in Plate 26.

9.0 <u>RECEIVER</u>

9.1 The receiver is constructed in two units, one of which the Monitor Receiver, is located in the transceiver frame while the Main Receiver is in the indicator console. Both of these units are independent as each has its own power supply.

9.2 The Monitor Receiver is a complete receiver in itself and furnishes video to the Monitor scope in the transceiver frame; also, it provides an I.F. signal of 15 Mc to the console receiver. All anti-jam circuits and the video distribution system are located in the main receiver in accordance with the standardization scheme of the XBF-SR equipment.

9.3 Specifications for the receiver call for the following:

(a) Continuously variable frequency from 175 to 225 Mc/s.

(b) Split I.F. amplifier; one section to be broad band and the other narrow band for monitoring purposes.

(c) Variable band width of 2 Mc, 250 Kc, 50 Kc. steps.

(d) Anti-jam devices.

(e) "A" scope output in the console

(f) P.P.I. output to four video lines, which furnishes a 2 volt limited signal with 0.75 rms. volts of noise.

(g) Echo-box tuning with provision for use as a wave meter.

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9.4 The monitor receiver contains the high frequency Preselector which consists of a GL-446 used as a grounded grid amplifier, a GL-446 converter and a 955 oscillator which is tuned on the high frequency side of the converter. The oscillator and converter are tracked together while the cathode tank of the i.f. stage has a separate control. This arrangement gives nearly a single dial control receiver since the cathode tank circuit is broad and is consequently used only to obtain better signal to noise ratios. This section tunes from 170 to 230 Mc/S with a very small tracking error.

9.5 Following the converter are four stages of 15 Mc amplification using 6AC7's and a 6H6 diode detector which furnishes a video signal to the monitor scope. The bandwidth of this channel from the antenna to the detector is approximately 300 Kc and the gain is 10^5 times.

9.6 A 70 ohm coaxial transmission line is tapped on the cathode of the third I.F. stage. This furnishes a 15 Mc/S signal for the Console Receiver. The bandwidth of these first three stages is adjusted so that the overall bandwidth of the Main Receiver from Antenna to detector is approximately 2 Mc.

9.7 Gain is controlled by varying the negative grid bias on the control grids of the first two I.F. tubes. This control may be used both locally and in the Indicator console.

9.8 The "Echo Box" is in the Monitor Receiver frame. This is simply a very high Q resonant tank made of a capacity tuned concentric line. A 955 is used as a diode and a meter is also provided so that the echo box may be used as wave meter.

10.0 <u>CONSOLE RECEIVER</u>:

10.1 This unit is located in the console and is furnished a 15 Mc/S I.F. signal through the coaxial line from the Monitor Receiver. It consists of five 6AC7 I.F. amplifiers, a 6H6 diode detector, a 6SN7 balanced video, a 6AC& video, 6SN7 limiter, a _SN7 buffer to feed I.F.F. and marker signals into the video system and two 6AG7's as cathode followers to furnish a video signal to the four P.P.I. lines.

10.2 The first I.F. stage is the bandwidth control circuit and consists of a variable Q single tuned circuit in the plate of the first I.F. tube; this circuit is so adjusted that the gain varies inversely as the square root of the bandwidth. Therefore, as the bandwidth is changed the density of noise on the Range scope screen will not change. Also the center frequency is adjustable over a range of ± 1 Mc. The bandwidth switch is "tied in" with the pulse length control on the transmitter, so that optimum conditions are always maintained, i.e., bandwidth equal to 1/pulse length.

10.3 All of the anti-jam devices are in the Main Receiver and consist of the following:

(a) Two tunable 15 Mc bridged T rejection filters in cascade are placed in the coaxial line just before the first I.F. stage. Re-

[redacted]

jection ratios of 65-70 DB can be obtained quite easily. These filters can be tuned anywhere within the 2 Mc pass band and thus any undesired signal appearing within this pass band can be attenuated.

(b) The last three I.F. stages have the conventional fast time constant back bias which allows an echo to be visible through almost any strength of CW signal. By varying the back-bias time constant, a considerable advantage may be obtained over railings up to 200 Kc repetition rate.

(c) The third anti-jam control in the balanced video; this system tends to balance out undesired signals but allows the desired signals to remain visible.

(d) The variable bandwidth has been found to be of considerable advantage when attempting to work through a jamming signal.

10.4 Performance Data:

(a) The noise factor of the entire receiver measures consistently less than 6 db.

(b) Selectivity curves are given in Plates 27 and 28.

(c) Noise output on the P.P.I. line equals 0.7 volt R.M.S.

(d) Peak P.P.I. signal: 2.5 ± 5 volts

(e) Noise output to "A" scope is 0.2 volts R.M.S.

(f) Tuning Range: 170 to 230 m.c./s

(g) An overall video response curve is given in plates 29 and 30.

11.0 IFF COORDINATOR

11.1 There are three controls on the front panel, one consists of a lock on, key position lever switch, and the other two are potentiometers in a recessed compartment in the lower half of the panel. The potentiometers control the I.F.F. delay in microseconds, and the receiver gain. The sub-panel has a hinged cover plate which can be locked close with a turn latch. These controls are not necessary for normal operation and are therefore placed in a sub-panel. The switch is used to apply the I.F.F. signals on the indicator when placed in the challenge positions. When in the off position the transmitter trigger is by-passed around the I.F.F. control and goes directly to the "A" scope. Various views of the I.F.F. control unit are shown in Plates 3 and 9.

11.2 The fundamental circuit of the I.F.F. control unit is the conventional "Eccles Jorden" multivibrator. This circuit is synchronized by the

[redacted]

transmitter and supplies a positive and negative square wave which is used as a blocking bias in the "A" scope I.F.F. video and radar video. This blocking bias is applied to the cathode of the I.F.F. and radar videos and alternately "cuts off" tubes depending on the polarity of the square waves at any given instant.

11.3 For further discussion, let the transmitter pulse be called A and B where A denotes the first and all odd numbered pulses to follow, while B denotes the second pulse and all even numbered pulses to follow. The first snyc pulse A from the transmitter performs several functions simultaneously. First it trips the multivibrator and starts the sweep across the indicator tube. This is accomplished by taking a positive signal from the plate of V902 in the Eccles Jorden placing it through a cathode follower and then supplying to the Range Scope. At the same time, positive and negative square waves are taken from the cathodes of V901 and V902 and supplied to the I.F.F. and radar video circuits in the Range Scope. This results in the I.F.F. video being blocked while the radar video is opened. This of course, allows only radar signals on the indicator.

11.4 The second sync pulse which was designated B reverses the Eccles Jorden circuit and as a result, the polarity of the square waves are reversed in the video circuit now causing the I.F.F. video to open and block the radar video by the same method it performed the reverse functions before. As before, there were two more functions performed simultaneously with those already described on the B pulses. One is supplying the trigger for the BL transmitter. This is accomplished by taking a square wave from V901, amplifying it and passing it through a cathode follower which is used as an impedance transformer and then transmitting it to the "BL".

11.5 From the plate circuit of V901 a square wave is taken and used to trip a delay multivibrator. The output of which is passed through a cathode follower and then used to give a variable delay trigger to the Range Scope, to start the I.F.F. sweep. The artifical delay is provided to permit operation with some I.F.F. systems. This delay is variable from 0 to 80 microseconds. The switching of traces on the cathode ray tube gives the effect of two traces simultaneously appearing on the screen, radar signals appear on the upper trace and I.F.F. signals on the lower trace.

12.0 RANGE SCOPE

12.1 (a) Input power: 115 volt, 60 cycles.

(b) Video input: 2.5 volt positive

(c) Video bandwidth: 1.5 Mc at 3 db down

(d) ± 100 yard accuracy of absolute range.

[redacted]

(e) Movable step calibrated in yards on both 4 and 20 miles.

(f) Video circuit is required to pass from one microsecond pulse to 4000 microseconds with an attenuation of less than 20 per cent from the start to end of the pulse.

(g) Horizontal and vertical centering controls to be able to shift spot one inch in either vertical or horizontal direction.

(h) Four range scales 4, 20, 80, and 400 miles.

(i) 60 to 2500 cycle repetition rate

(j) 1/4 to 20 useconds pulse width.

12.2 The range scope is constructed around a five inch cathode ray tube, which can be removed from the front with very little effort by loosening the four thumb screws, removing the front bezel and unclamping the tube clamp.

12.3 An engraved lucite scale, is provided in the bezel, to assist in estimating the range. This scale is kept simple so that approximate range can be determined rapidly without confusion.

12.4 The counters on the 8000 yard and 40,000 yard ranges are illuminated by pilot lights that are automatically turned on by the range switch. These pilot lights are also readily accessible when the front bezel is removed. The engraved mechanical range scale is lighted indirectly through the lucite scale and when no lighting is needed it can be dimmed or turned off at will from the control panel by a selector switch. Veeder-Root counters are used on the 8000 and 40,000 yard ranges. Twenty turns of the range crank is required to go from a minimum to a maximum range. The range potentiometer is covered so that dust would not upset its linear characteristics. A mechanical detent switch is provided so that an electrical range step can be switched when the range crank is pulled out.

12.5 The range scope requires a 7.5 volts positive trigger pulse from 1/4 to 20 microseconds in length which is amplified and differentiated through tube V601A. This in turn trips the multivibrator which generates a positive and negative square wave of 48 to 4800 usec. duration. The tube V601B generates a negative gate which holds the grid of tube V606A negative while the condenser C is being charged. When the grid becomes positive, thus making the tube conducting, the condenser is discharged and the developed sawtooth is coupled to a push-pull amplifier whose outputs are directly coupled to the horizontal plates of the cathode ray tube. By this method two objectives are accomplished: a constant current sweep is produced thus eliminating the usual DC restoration circuits, and a very economically balanced sweep with one per cent or better linearity is also obtained. "Jitter" due to power line transients are reduced to a minimum.

12.6 The positive gate from the plate of tube V602 is applied to the grid of the cathode ray tube which intensifies the beam as it starts its path

[redacted]

across the tube. The return trace is "blanked" out on the return sweep.

12.7 The marker circuit consists of a shocked oscillator tube V608A and the oscillations are amplified by a multivibrator whose output is amplified and biased so that the pips are generated from the base line. Switch S turns the markers on and off at will.

12.8 Two video inputs are provided, so that the gates generated by the Eccles-Jordan in the I.F.F. coordinator can block these inputs. Through the resistance network a certain DC shift is obtained giving a split trace. The top trace is used for the radar echo and the bottom trace is used for the I.F.F. identification echo. The split trace can be separated from 1/8 inches to 1 inch by potentiometer, R.684.

12.9 The video bandwidth is 1.5 Mc wide at about 2 DB down and has an overall gain of 200 with a positive output.

13.0 <u>PLAN POSITION INDICATOR</u>

13.1 The remote and local Plan Position Indicators are similar in design and construction. This is a part of the system of standardization and as a result greatly reduces the number of different units required in the system. It is required that the Plan Position Indicator conform to the following specifications:

(a) Power Input: 115 volt 60 cycles.

(b) Monitor PPI furnishes a properly terminated positive synchronizing pulse having a peak amplitude of from 7.0 to 40.0 volts.

(c) Operates from a positive synchronizing pulse of from 5.0 to 37.5 volts with a repetition rate of 60 to 1100 pulses per second with a pulse length of 1/2 to 20 usec.

(d) Requires a 2.0 ± 0.5 volt limited video signal for operation.

(e) Bearing information repeated with 3/4 of a degree accuracy.

(f) Range markers required for calibration with provision to permit a 10% extension of the radius of sweep.

13.2 The Plan Position Indicator was designed around a yoke housing a seven inch cathode ray tube. A design was used that permits the tube to be removed with a minimum of effort. Alignment is secured automatically when the tube is replaced. A novel method of centering the beam is used. This is accomplished by mechanically rotating the focus coil both transversely and longitudinally by means of a handle.

13.3 The chassis is divided into three individual sections; namely, the rotating yoke, power supply, and video circuits. This design allows the tube and components to be removed with a minimum of effort.

13.4 The PPI is provided with a bezel having an edge lighted lucite window with its outer edge engraved from zero to 360 degrees in one half degree steps. Another lucite window is placed in the bezel that has a curser engraved upon its face which is used as a mechanical marker and can be turned by hand.

13.5 The synchronizing pulse from the transceiver unit is differentiated by C501 and R509 and then amplified in tube V50A. This pulse output is used to drive a multivibrator consisting of tubes V502 and V501B. Correct timing of the multivibrator is determined by selection of the proper time constants with switch S502A.

13.6 From the anode of V501B a pulse is obtained that drives the grid of V503A, negative. While the negative pulse exists at the grid of V503A, the tube is cut off thus allowing one of the condensers C511 to C514 to charge up through the corresponding resistance. The proper resistance is selected by switch S502B. When the pulse is removed the condenser that has been selected, discharges through V503A. A saw tooth wave is thus produced that is used for the sweep. This sweep voltage is amplified in V503B, and V504A. Tube V504A then drives a 807 V505 which has a D.C. restorer in its grid circuit to prevent its average bias from changing. The pulse amplifier V505 has an unbypassed cathode resistor, that feeds back the voltage developed across it to the cathode of V503B. This method of degeneration greatly minimizes the distortion and the saw tooth wave appearing at the output of V505 is practically identical to that applied to the grid of V503B. The resistors R531 and condenser C516 compensate the circuit so that the entire amplifier (including the deflection yoke) is flat up to nearly two megacycles. The sawtooth output voltage from V505 is applied to the deflection yoke L501, which produces the cathode ray tube sweep. The switch S301 produces a slight unbalance of current in the yoke that allows the trace to be displaced from the eenter.

13.7 The unblanking voltage is obtained from the anode of V502. The positive going square wave appearing there is applied directly to the plate of the cathode ray tube V506. When the anode of V502 is positive the trace is intensified and thus can be observed. During the flyback time the anode of V502 is negative and the trace is less intense and cannot be seen.

13.8 A high potential of 4800 volts DC is applied to the anode of the cathode ray tube V506 which is a 7BP7 having a 7 inch long persistant screen. The tube is focused by varying the current in the coil L503 by means of resistor R558.

13.9 Markers are produced by a shocked oscillator V507 which has a high Q resonant circuit in its cathode. The negative square wave from V501 B drives V507 to cut-off and shocks the particular LC circuit chosen by switch S502C into oscillation. The damped oscillation from the oscillator operates a multivibrator consisting of tubes V507 and V508A, which produce the marker pips. Amplitude of the marker pips are controlled by R550. The pips are amplified in V508B and V509A and are coupled into the cathode of the cathode ray tube V506 through C582 and R553.

[redacted]

13.10 The video signal from the receiver output is amplified in tube V512 and is mixed with the marker signal in the cathode of V506. A DC restorer V509B is provided to maintain a constant DC level.

13.11 Antenna sense is repeated by means of a synchro control transformer. The error voltage developed on the rotor of this transformer is coupled to the grid of V510A. This synchro shaft is coupled mechanically through a 1:1 gear to the PPI yoke. An anti-hunt circuit consisting of a series resonant circuit is placed in the grid circuit of V510A. The error voltage is amplified in V511 and applied to a two phase motor B502 which drives the yoke through a 100:1 gear.

13.12 The power supplies fro the PPI unit are entirely conventional and should require no discussion.

13.13 An Alleghany MuMetal shield is used which has been properly heat treated in an atmosphere of dry hydrogen. With the use of these shields transformers and highly strong magnetic fields can be brought in the vicinity of the unit. This also protects the presentation from the extreme high fields found aboard Naval vessels.

14.0 BEARING INDICATOR

14.1 The Bearing Indicator unit provides antenna control and bearing indication. The antenna control circuits provide for the rotation of the antenna in either direction at speeds up to five revolutions per minute, as well as "Sector Sweep" over any 90 degree sector. Relative antenna bearing, true antenna bearing, and the ship's bearing may be obtained from this equipment directly with an accuracy of one-half degree. Arrangements are included for switching the Plan Position Indicators, connected to the system, to relative or true bearing.

14.2 The antenna is rotated by a direct durrent motor mounted in the pedestal. This motor is of the permanent magnet type; the speed of which is controlled by an Amplidyne Generator which is not an integral part of the equipment. The Amplidyne Generator output is regulated by the Control amplifier incorporated in the Bearing Indicator unit.

14.3 Sector Sweep is accomplished by electrically reversing the slewing motor by switch S-805 which is driven by the slewing motor at the same speed as the antenna. A mechanical differential is arranged in the Sector Sweep system to eliminate the troublesome slip rings and brushes usually needed to provide continuously variable sectors.

14.4 Sector Sweep, Automatic Rotation, or Manual Rotation may be selected by the switch S-901. For Manual Slewing the hand crank is pulled out to engage a positive action clutch.

15.0 CONCLUSION:

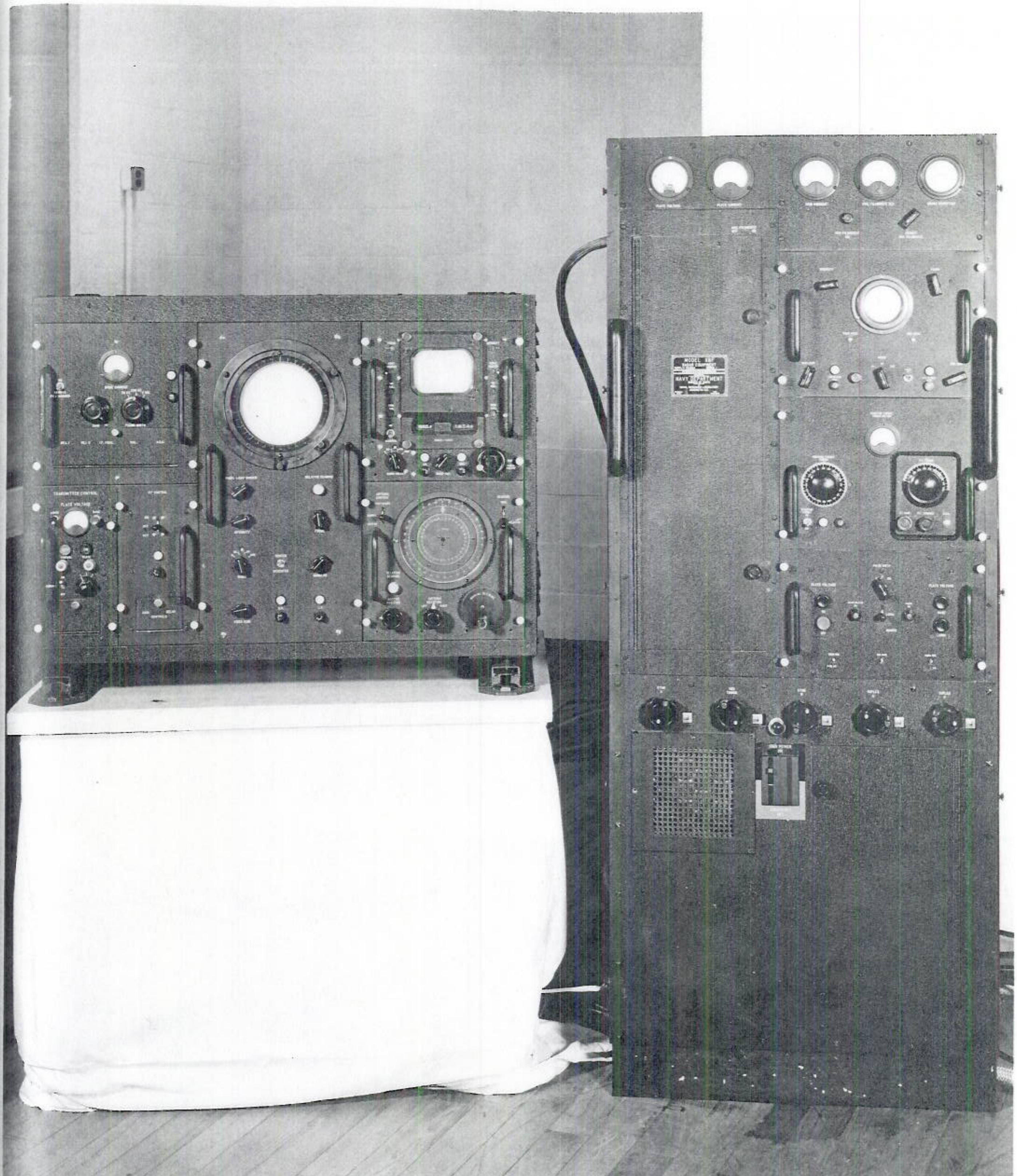
15.1 In general the XBF equipment has served as a start for the standardization of Search Radar equipment for the United States Navy.

15.2 The XBF Radar system has been in operation at the Naval Research Laboratory for several months. It was then moved to the Chesapeake Bay Annex of NRL and has been working satisfactorily for sometime at that location. Since this model has been completed the Westinghouse Electric and Manufacturing Company of Baltimore have built several models of the SR equipment with the XBF serving as a prototype. A higher frequency version of this same equipment (400 M.C.) has been built and consists of a new transceiver unit which is known as the XBF/SR-1. The SR-2 equipment is being built by the Radio Corporation of America at Camden and is a 600 M.C. equipment. The standardized console is also used on the SG-3 equipment by Raytheon Manufacturing Company.

16.0 ENCLOSURES

16.1 Photographs and blueprints listed in table of contents.

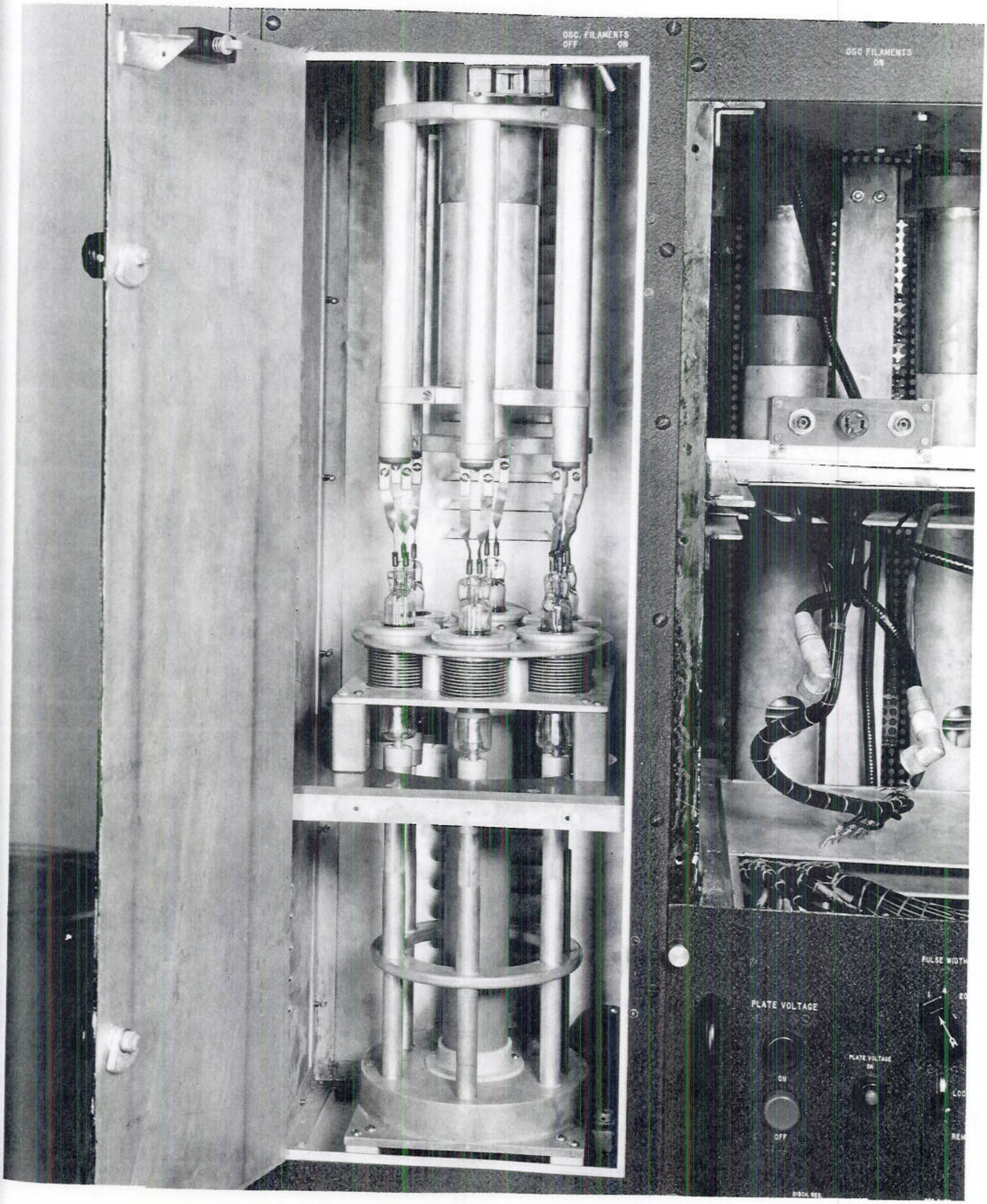
[redacted]



FRONT VIEW TRANSCEIVER AND INDICATOR CONSOLE

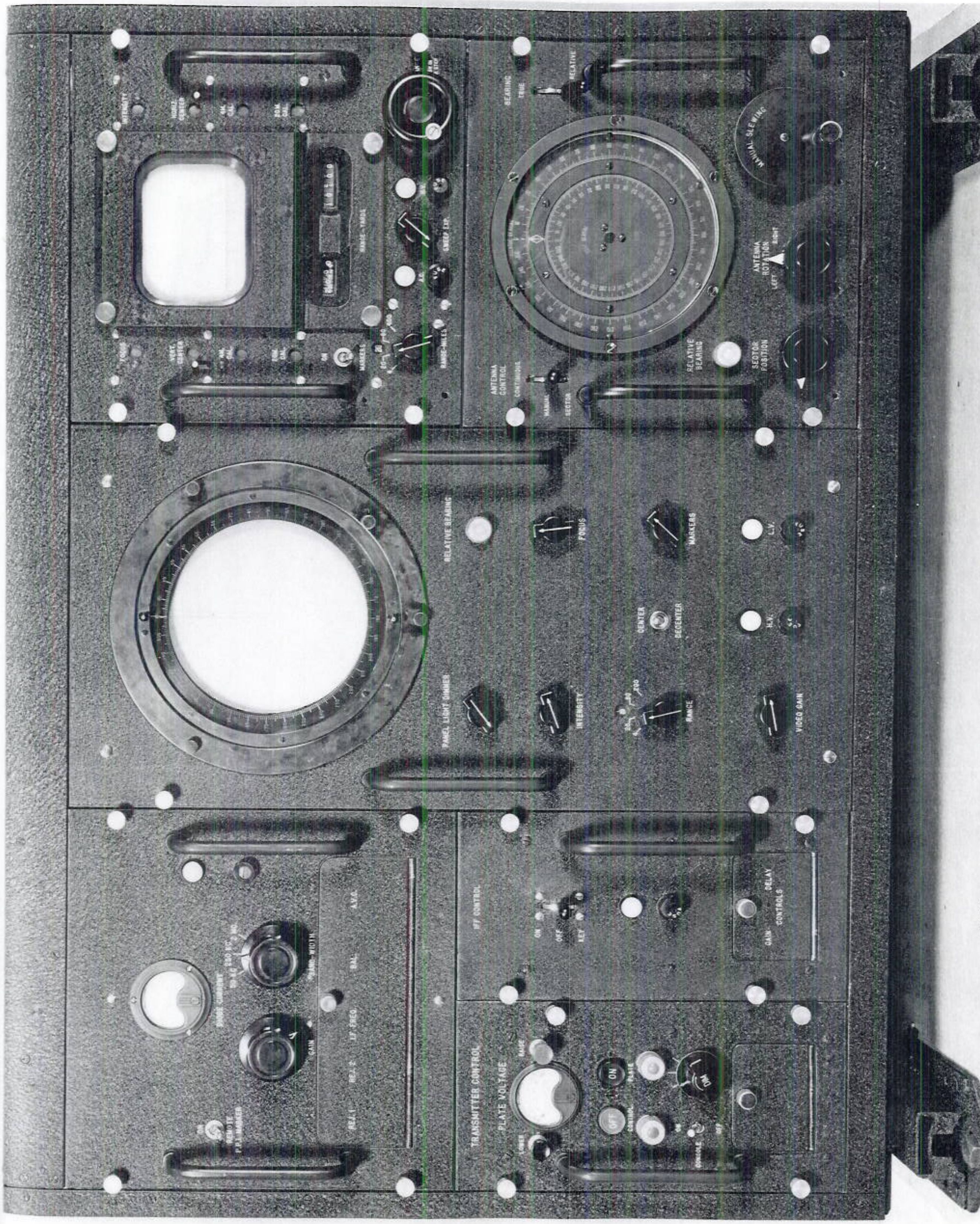
[redacted] DECLASSIFIED

PLATE I



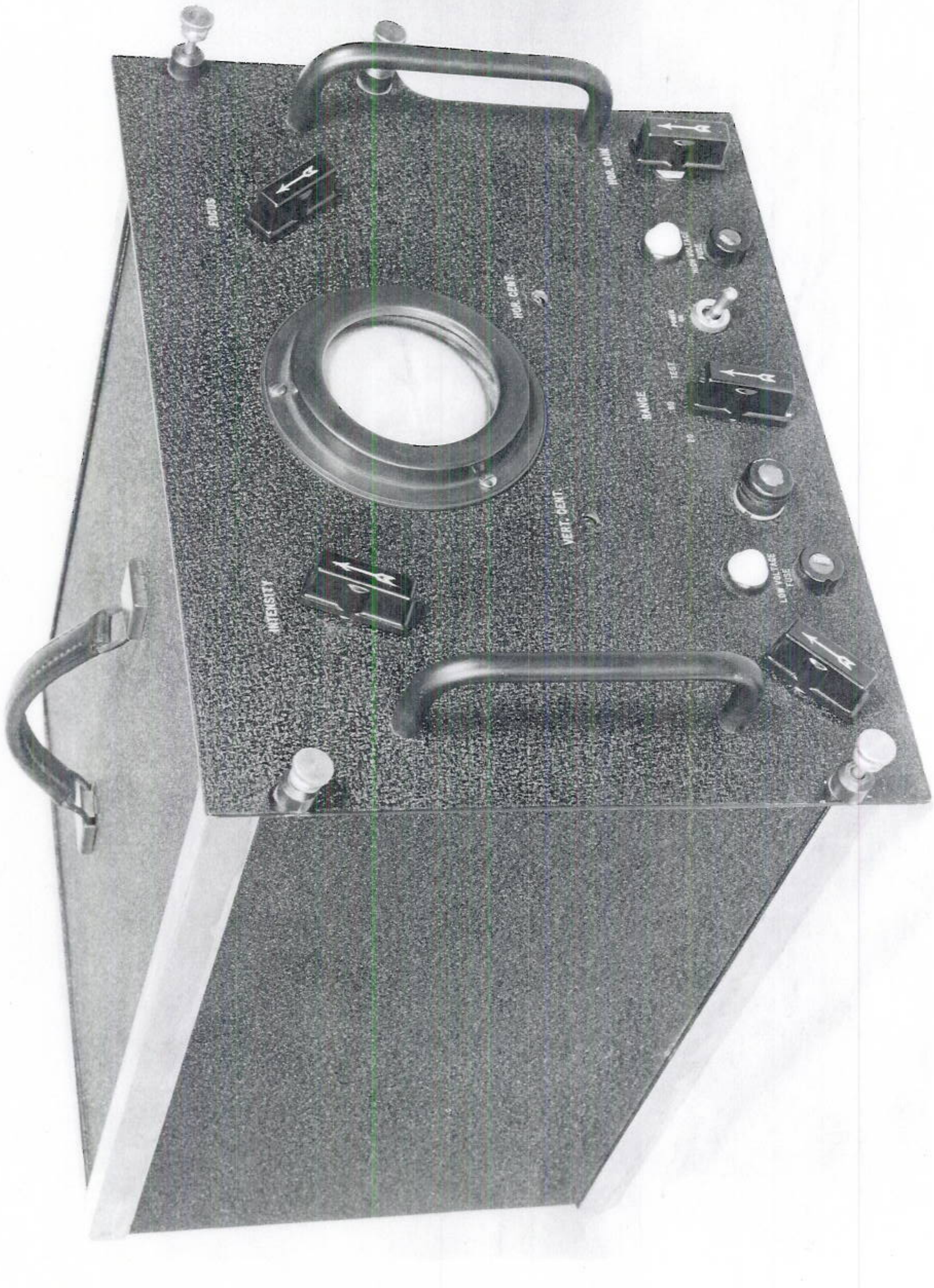
FRONT VIEW OF OSCILLATOR COMPARTMENT

[redacted]



FRONT VIEW OF INDICATOR CONSOLE

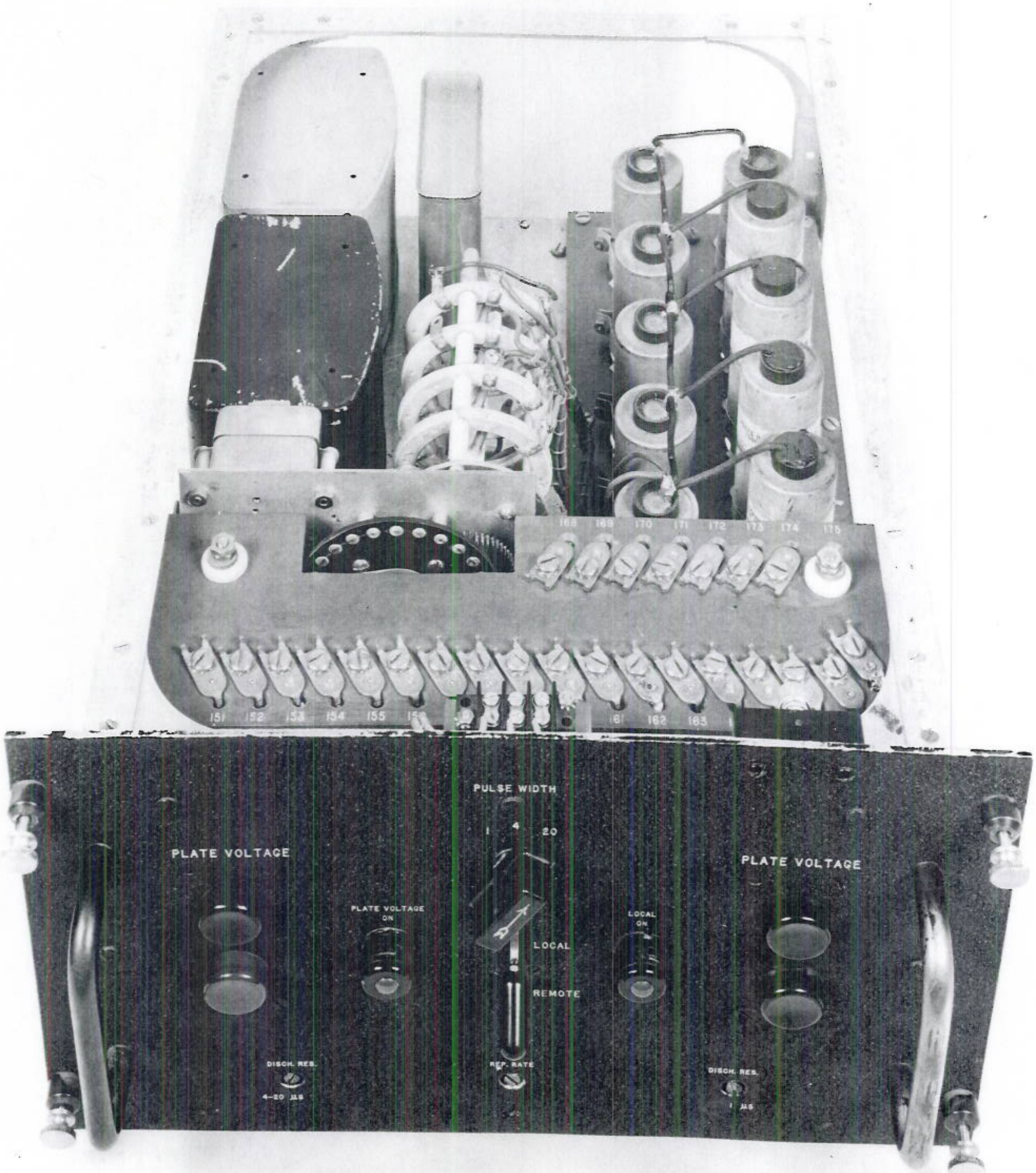
[redacted]



3/4 VIEW OF MONITOR SCOPE

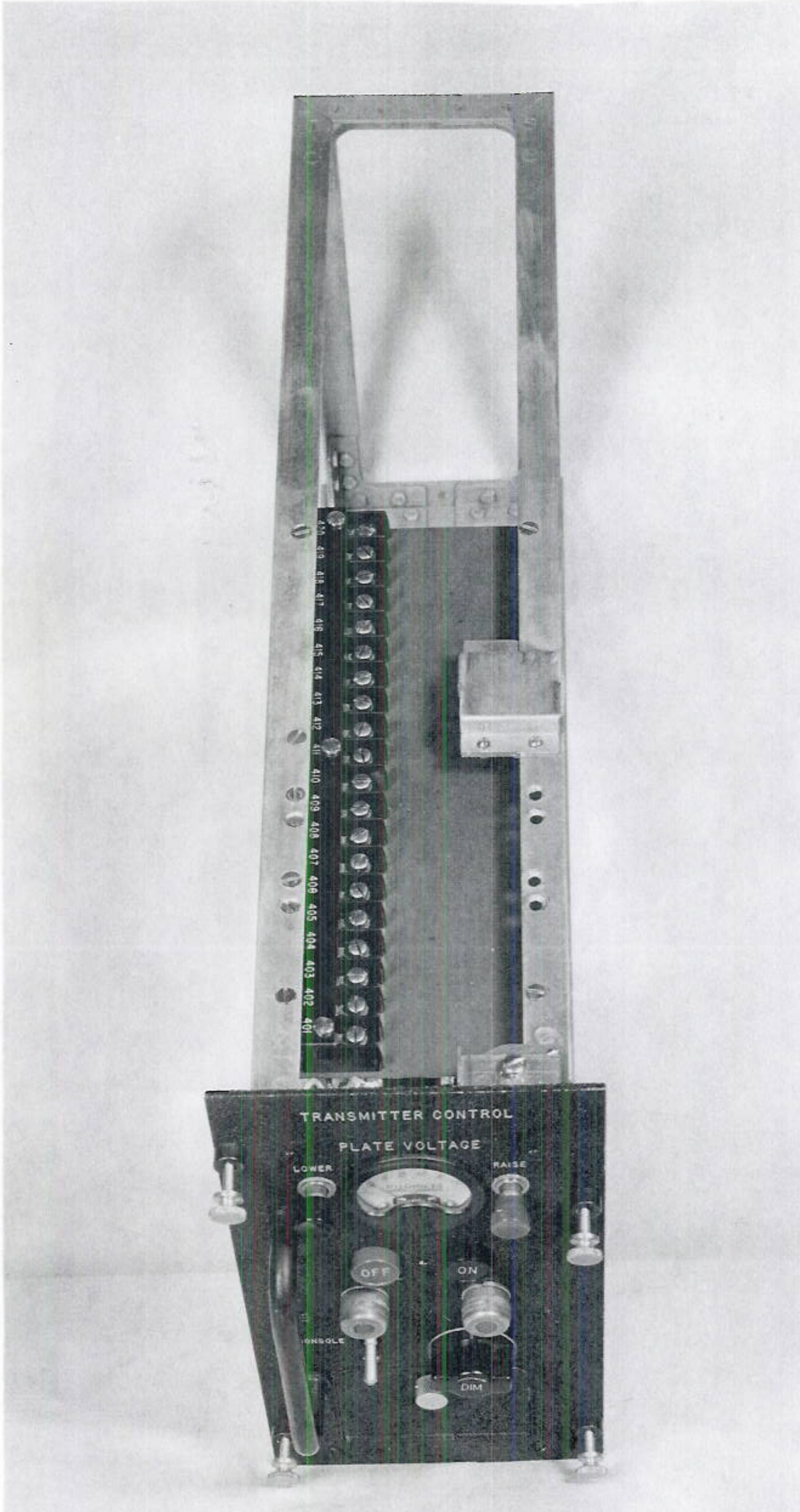
[redacted]

[redacted]



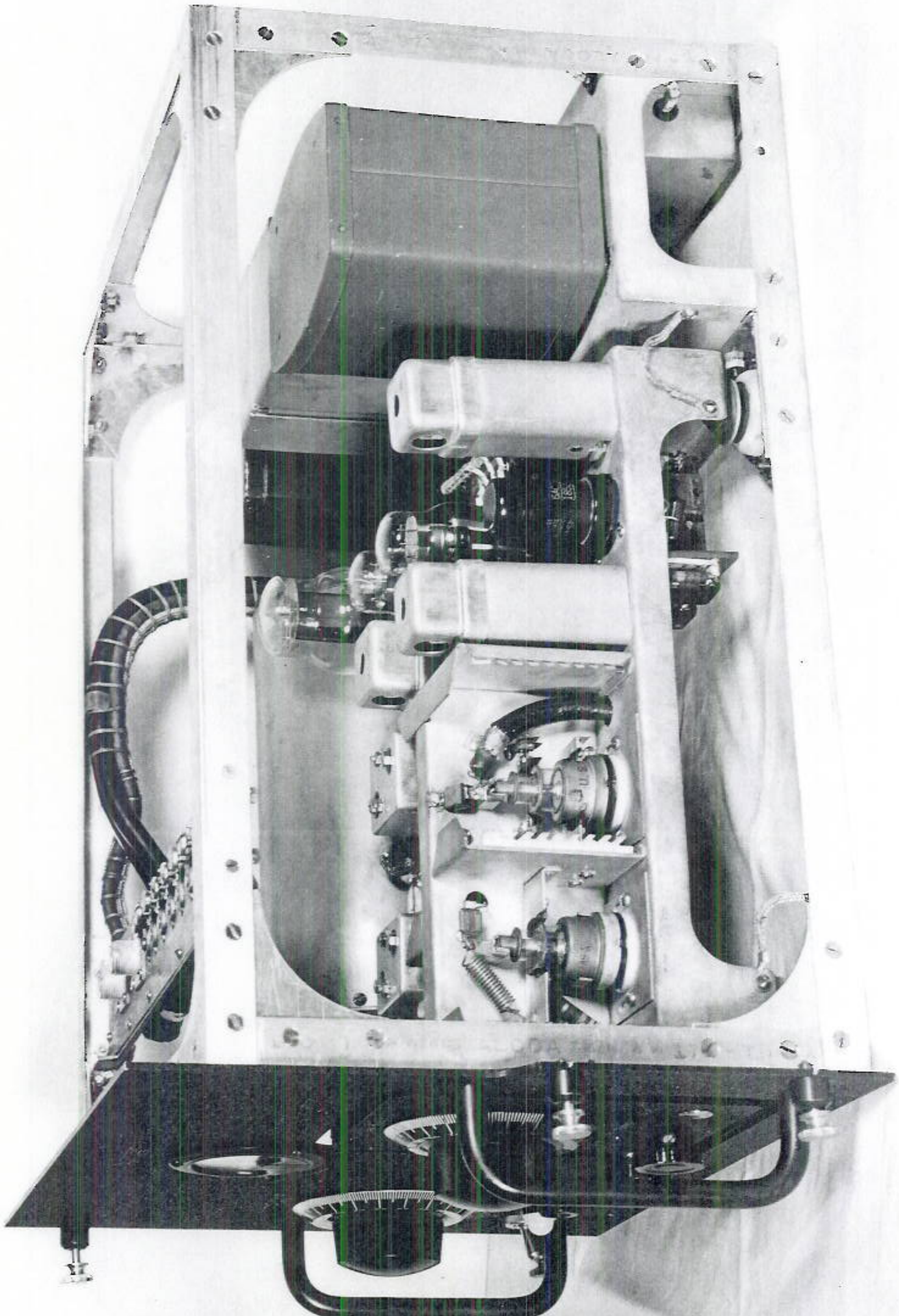
TOP 3/4 VIEW OF KEYER UNIT

[redacted]

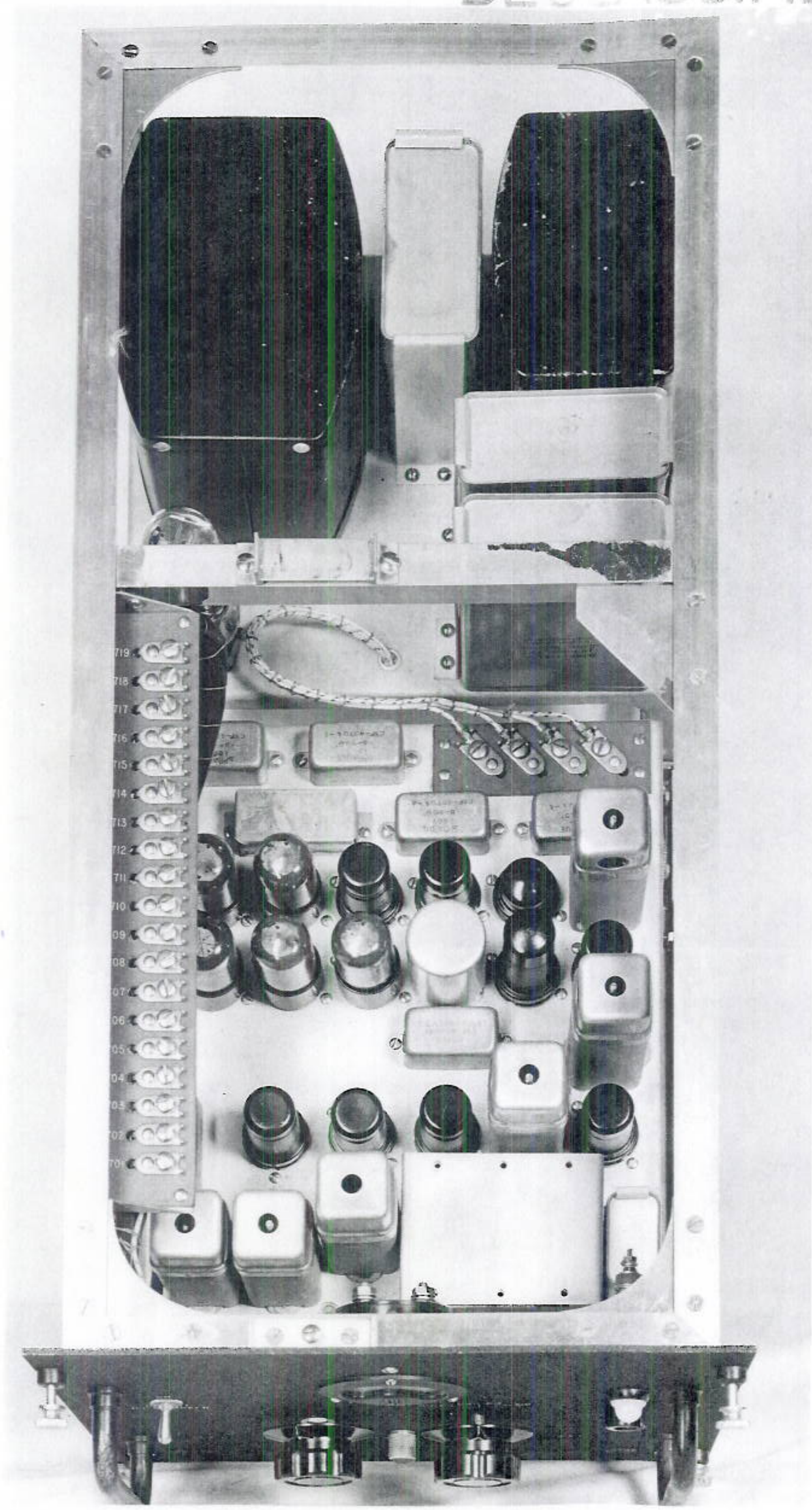


TOP 3/4 VIEW OF TRANSMITTER CONTROL UNIT
IN THE INDICATOR CONSOLE

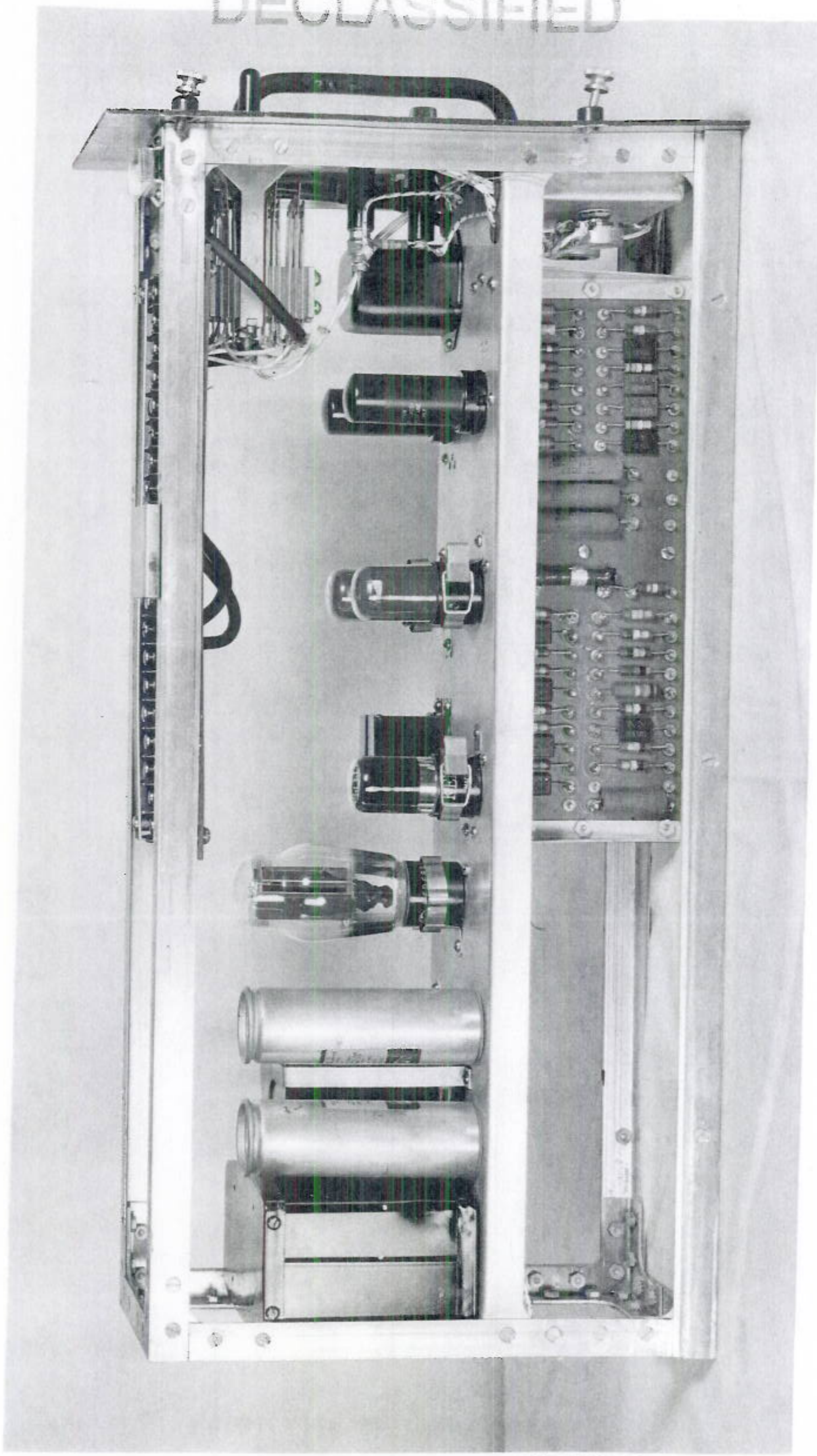
[redacted]



RECEIVER UNIT IN TRANSCEIVER

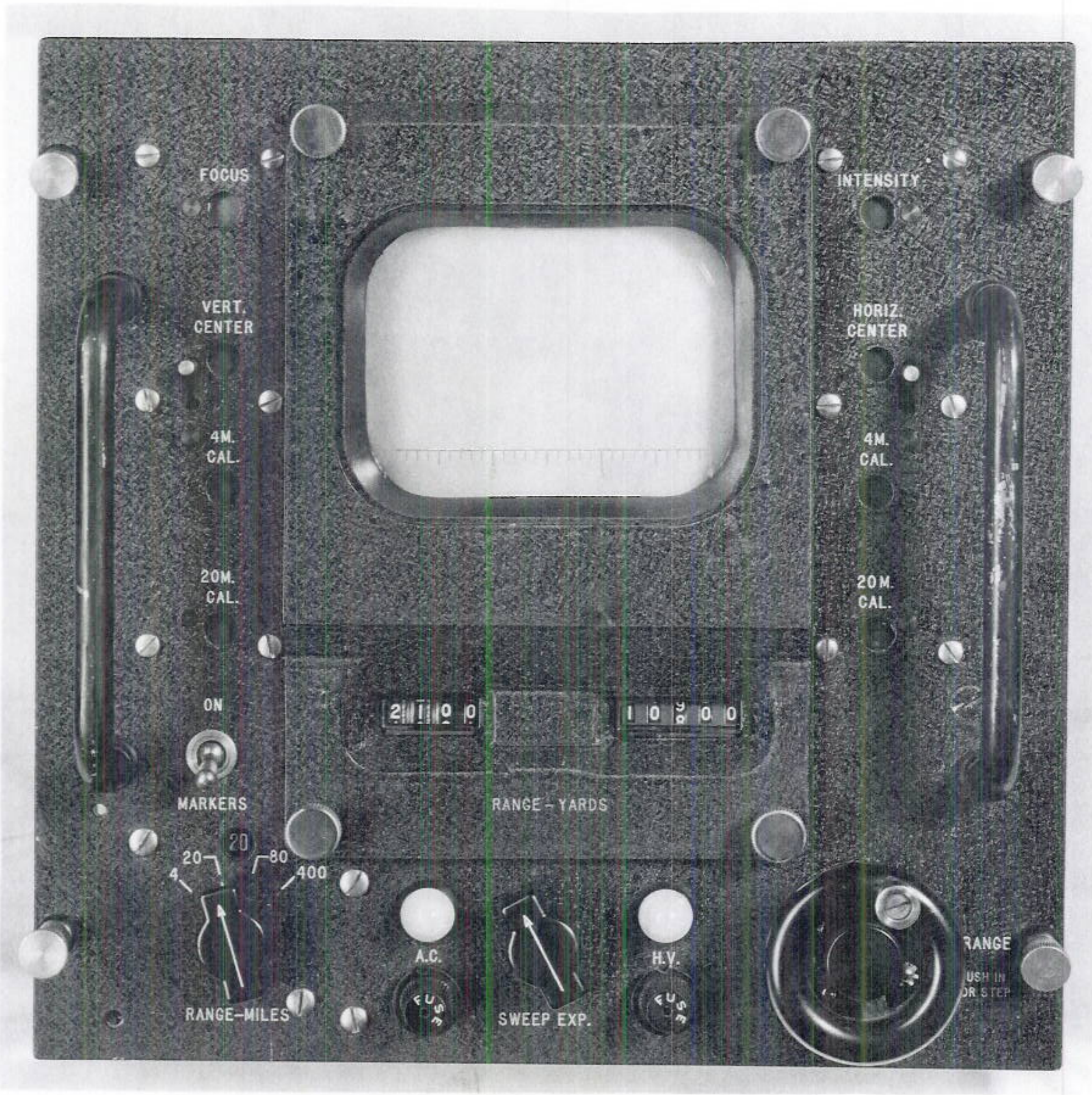


RECEIVER UNIT IN THE INDICATOR CONSOLE

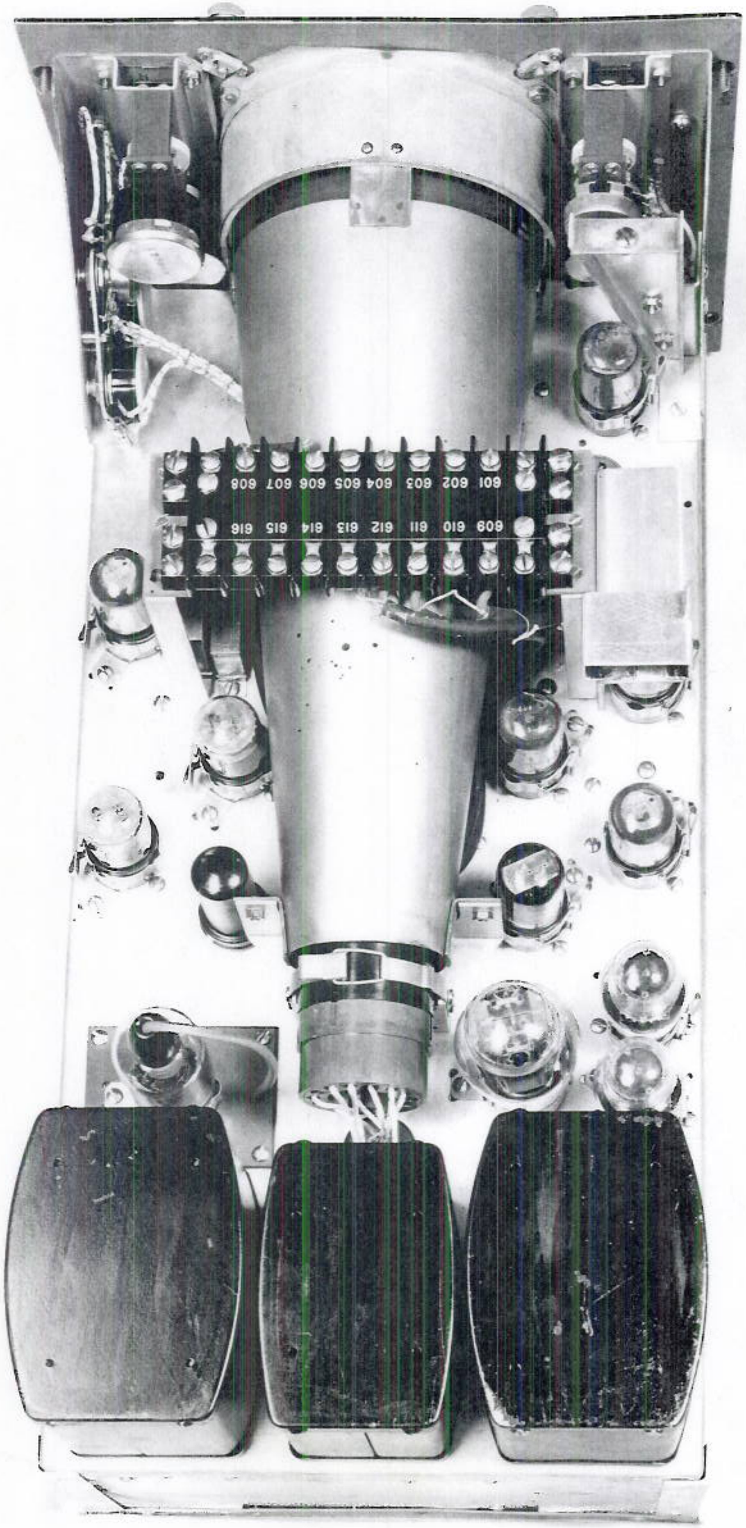


DECLASSIFIED

IFF COORDINATOR UNIT IN THE INDICATOR CONSOLE

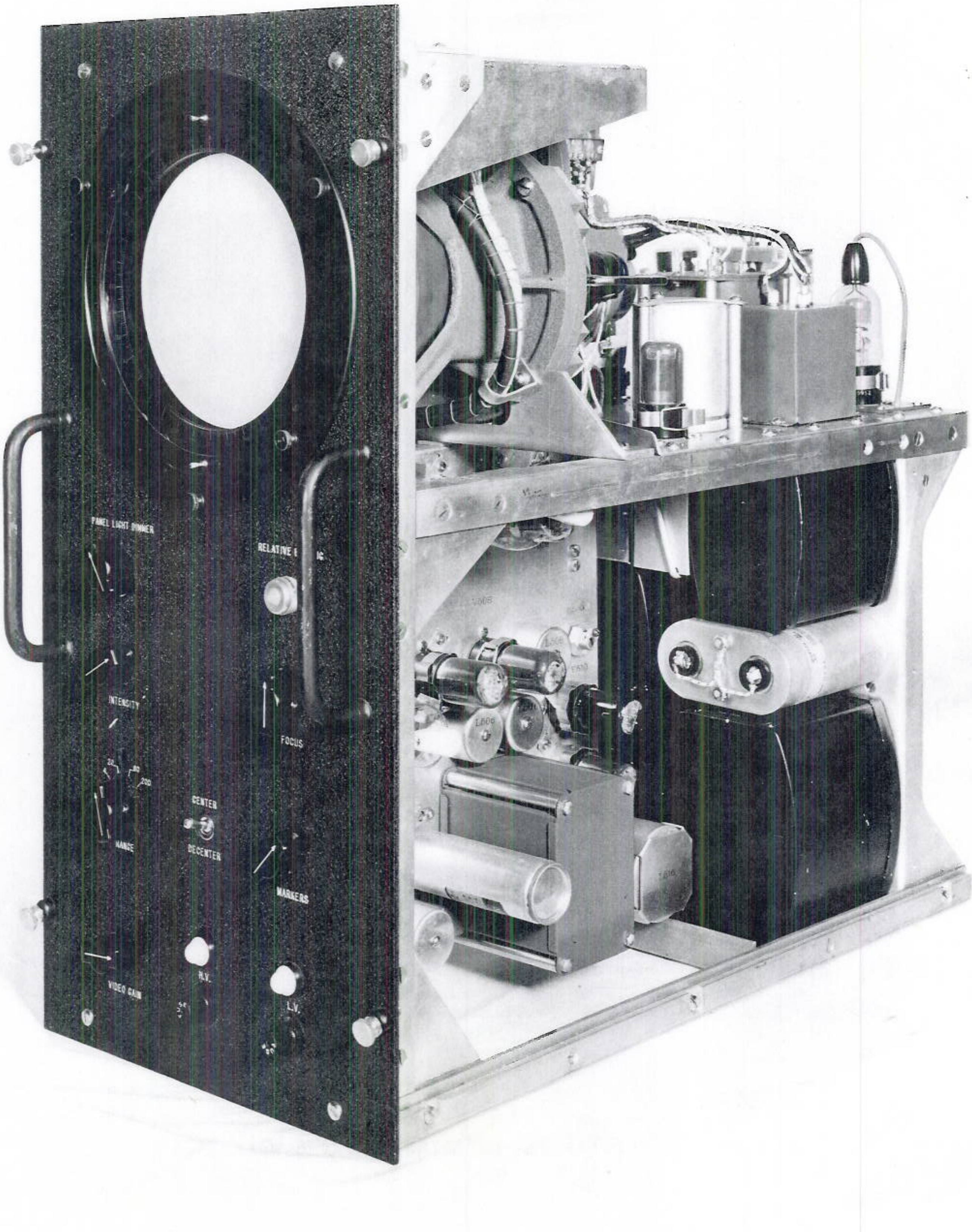


FRONT VIEW OF RANGE SCOPE



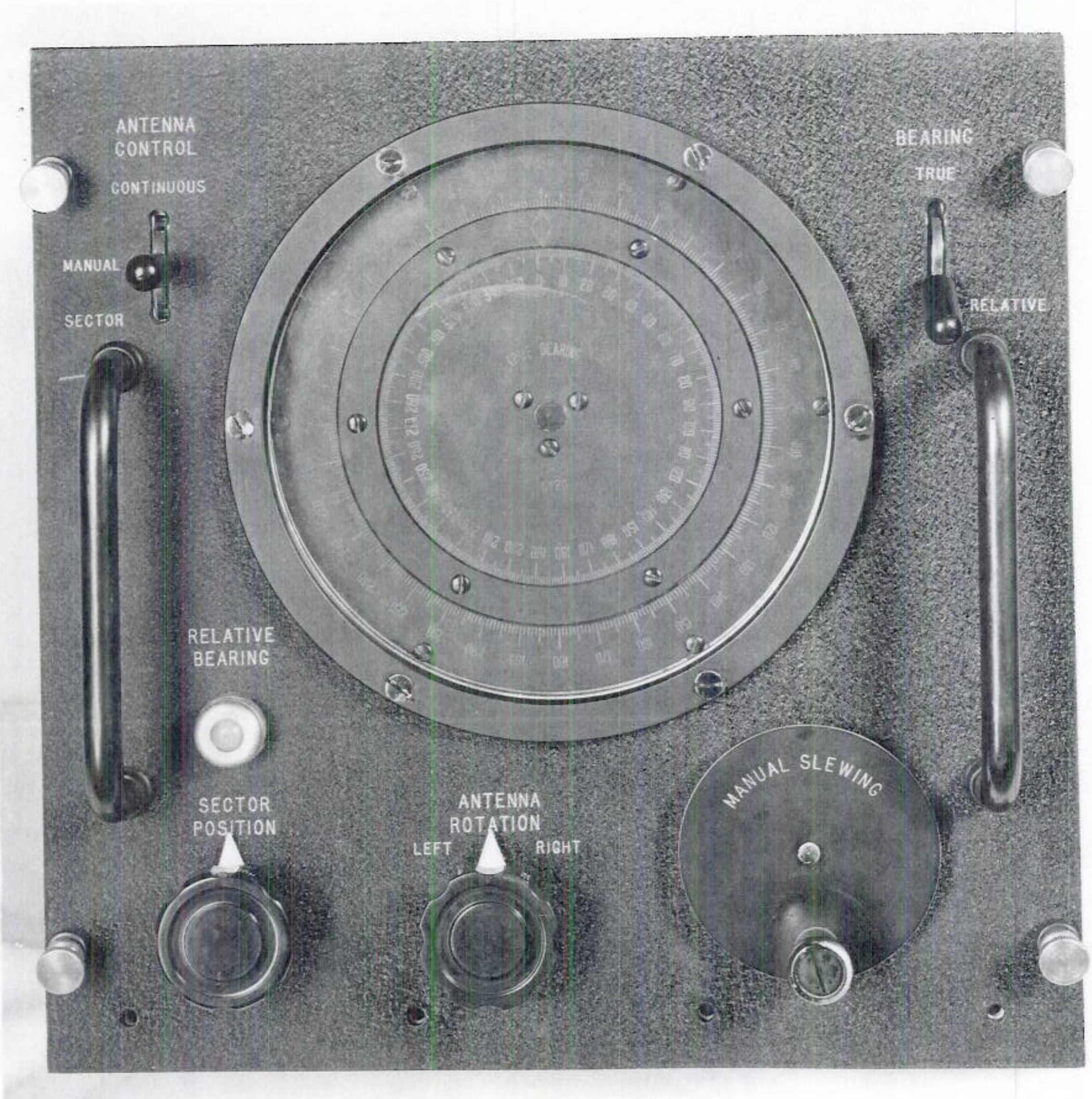
TOP VIEW OF RANGE SCOPE

DECLASSIFIED



FRONT 3/4 VIEW OF PPI INDICATOR

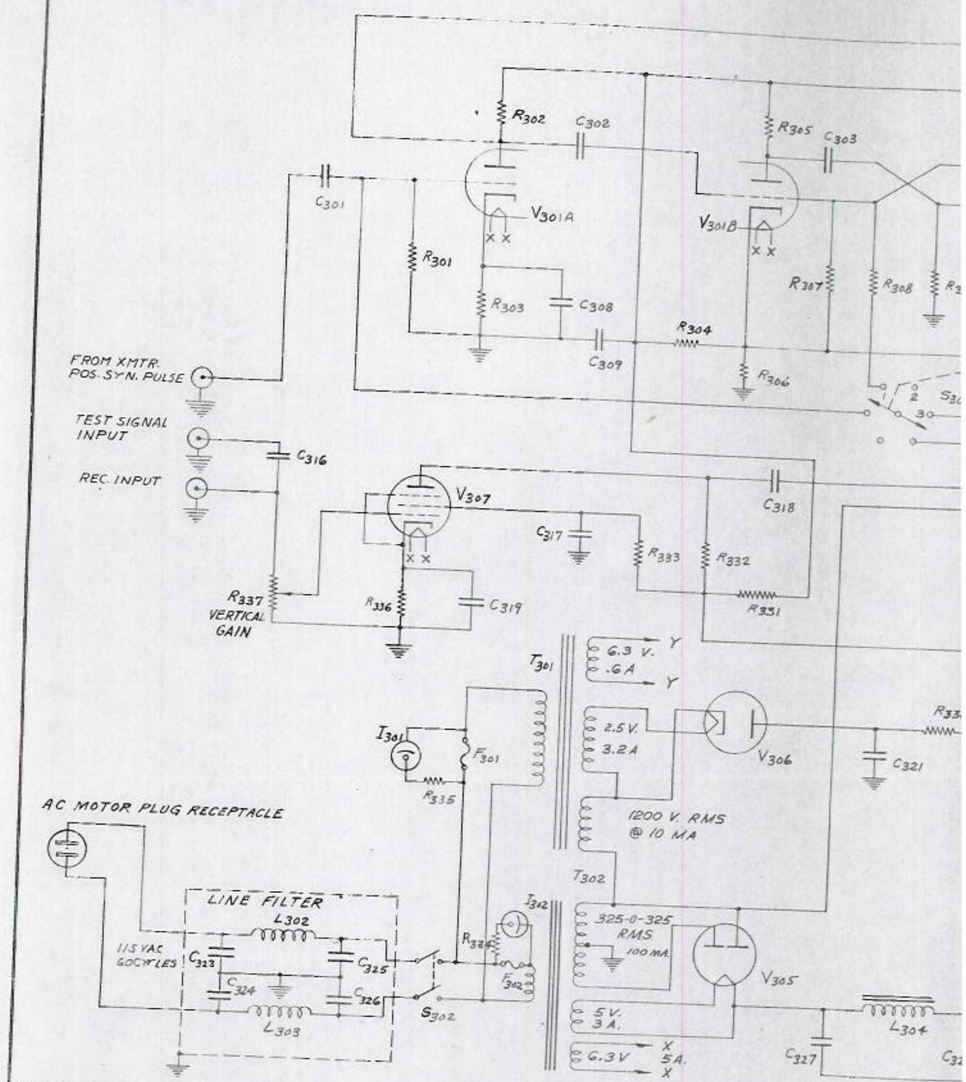
[redacted]



FRONT VIEW BEARING INDICATOR AND ANTENNA CONTROL UNIT

[redacted]

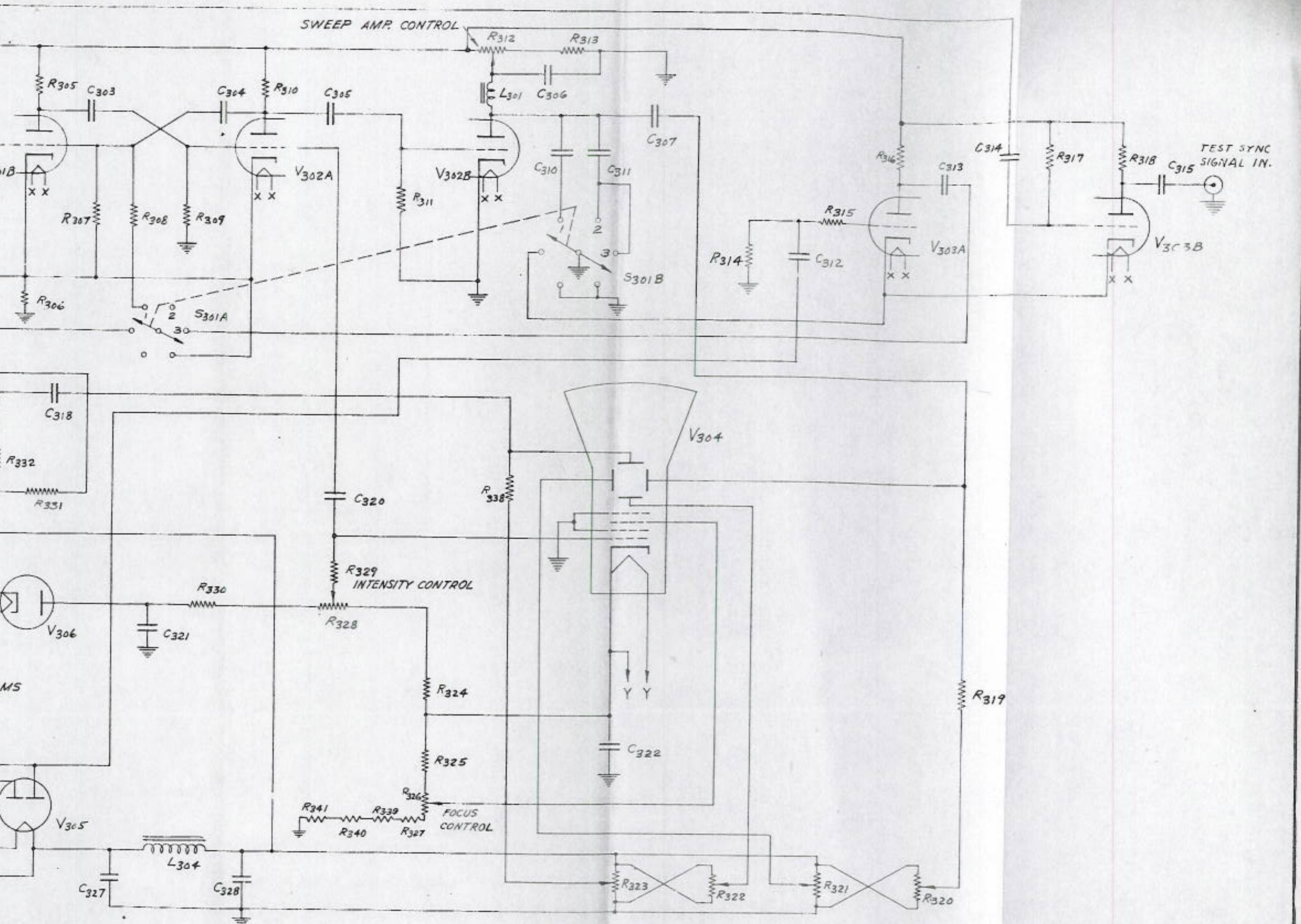
N. R. L. 66



LEGEND OF CIRCUIT COMPONENTS

NO.	DESCRIPTION	NO.	DESCRIPTION	NO.	DESCRIPTION	NO.	
	CAPACITOR						
C301	.05 µf - PAPER 400 W				RESISTORS		
302	500 µµf MICA			R301	100K ½ W		RESIS
303	.1 µf PAPER 600 V			302	100K 1 W	R329	270K
304	.005 µf - MICA			303	1800 ½ W	330	270K
305	.1 µf PAPER 600 V			304	39K 2 W	331	1K
306	.1 µf " 600 V			305	10K 10W	332	10K
307	.05 µf OIL FILLED PAPER 2000 V			306	1K 1W	333	25K
308	.1 µf PAPER 600 V			307	100K ½ W	334	27K
309	.1 µf " 600 V	F301	1 AMP. AUTO FUSE & HOLDER	308	33K ½ W	335	27K
310	.014 µf MICA OR PAPER	F302	1 " " " " "	309	1 MEG ½ W	336	680K
311	.05 µf PAPER			310	10K 10W	337	100K
312	500 µµf MICA			311	10K ½ W	338	270K
313	.05 µf PAPER	I301	NEON INDICATOR FOR FUSE	312	25K POT. WIRE WOUND 3W	339	330K
314	100 µµf MICA	I302	" " " "	313	82K 2W	340	330K
315	.1 µf PAPER 600 V			314	1 MEG ½ W	341	270K
316	.1 µf " 600 V	L301	200 HENRY CHO. 10MA. UTC-HC116	315	270K ½ W		
317	1 µf " 600 V	L302	20 µh. LINE FILTER 1.5 AMP.	316	100K 1W		
318	.05 µf " 600 V	L303	20 µh " " 1.5 AMP.	317	1MEG 1W		
319	25 µf ELECTROLYTIC 50 V	L304	10 h FILTER CHOKE 105 MA.	318	100K 1W		
320	.05 µf OIL FILLED PAPER 2500 V	L301	NRL - 286	319	270K 1W		
321	.5 µf " " " 2500 V			320	DUAL 500K CARBON POT.		
322	.5 µf " " " 2500 V			321	" " " "		
323	.1 µf PAPER 600 V			322	" " "		
324	.1 µf " 600 V			323	" " " "		
325	500 µµf MICA			324	120K - 2W		
326	500 µµf " "			325	470K - 2W		
327	10 µf PAPER 600 V			326	75K WIRE WOUND POT.		
328	10 µf " 600 V			327	330K - 2W		
				328	75K WIRE WOUND POT.		

FIED



OF CIRCUIT COMPONENTS

DESCRIPTION	NO.	DESCRIPTION	NO.	DESCRIPTION
ORS		RESISTORS	S301	3 POSITION TAP SWITCH 2 SECTION
W	R329	270K 1W	S302	DPST TOGGLE SWITCH
W	330	270K 2W		
W	331	1K 2W		
W	332	10K 10W		
OW	333	25K 5W	T301	H.V. POWER TRANSF. NRL 287
W	334	27K ½W	T302	L.V. " "
W	335	27K ½W		
W	336	680K 1W		
W	337	100K POT. (COMPOSITION)		
W	338	270K 1W		
V	339	330K - 2W		
E WIRE WOUND 3W	340	330K - 2W		
W	341	270K - 2W		
½W				
-W				
W			V301	6SN7GT TUBE
W			302	" "
W			303	" "
W			304	3BP1 TUBE
OOK CARBON POT.			305	5Y3GT "
" "			306	RKR72 "
"			307	6AG7 "
" "				
2W				
2W				
RE WOUND POT.				
2W				
RE WOUND POT.				

ALTERATION TABLE

b	MADE CCT. CHANGES 6-16-43	JEM
c	MADE CCT. CHANGES 8-2-43	MHH

SYMBOLS AND THEIR EQUIV. TOLERANCES (UNLESS OTHERWISE NOTED)

SYMBOL 1	±.0005
SYMBOL 2	±.0010
SYMBOL 2½	±.0030
SYMBOL 3	±.0050
SYMBOL 3½	±.0100
SYMBOL 4	±.0250
SYMBOL 5	

DELINEATOR	JJA	IN CHARGE OF RADIO DRAFTING	CHIEF DRAFTSMAN
TRACER		CRS.	[signature]
CHECKER	R. L. Ramp.		

APPROVAL

RADIO ENGINEER	SUPT. OF RADIO DIVISION
H. O. Lorenzen	A. Hoyt Taylor

FOR DIRECTOR — R. C. Pole — COMDR. U. S. N.

BUREAU OF SHIPS | REFERENCE

U. S. NAVAL RESEARCH LABORATORY
"BELLEVUE," ANACOSTIA, D. C.

MONITOR INDICATOR

MODEL XBF EQUIPMENT

SCHEMATIC DIAGRAM

SCALE DATE MAR. 20, 1943

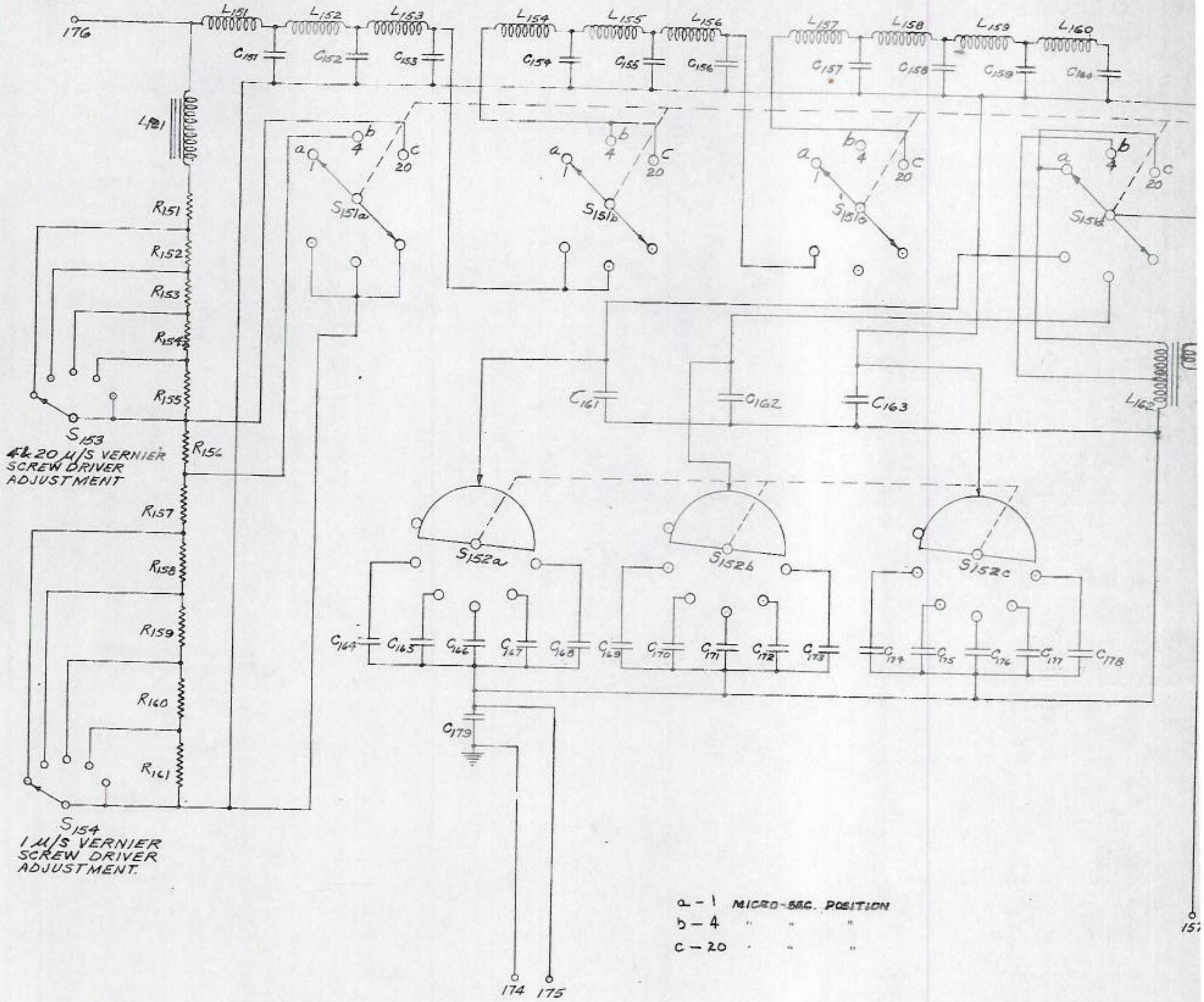
RA 60F 2630

PLATE 14

FIED

DECLASSIFIED

N. R. L. 66

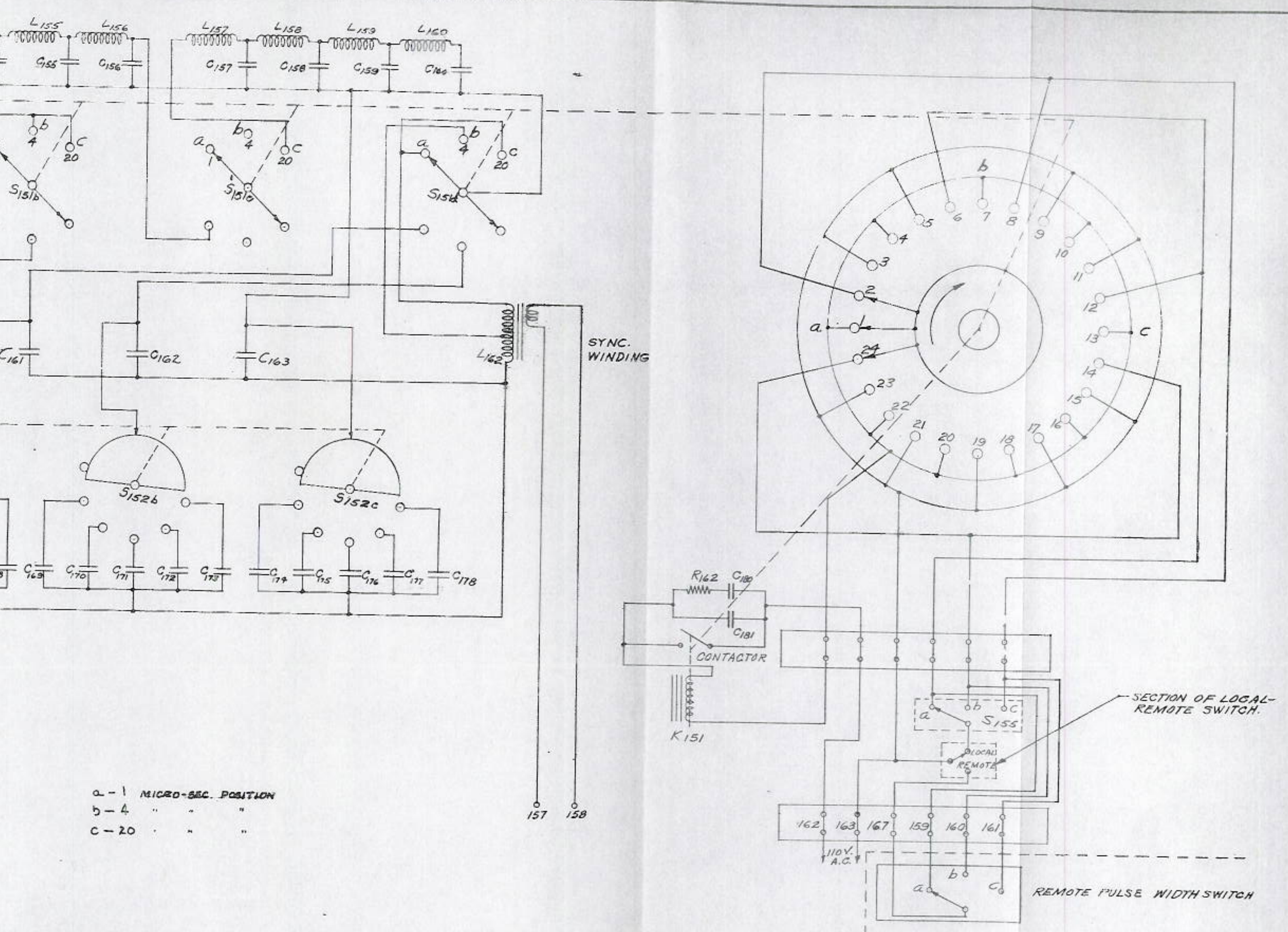


R151	60K. 75W.
152	10 K. 25W.
153	" " " "
154	" " " "
155	" " " "
156	15 K. 25 W.
157	250K. " "
158	25K. 10W.
159	" " " "
160	" " " "
161	" " " "
162	15Ω " "
S151a	LINE DISCHARGE RESISTANCE SWITCH
151b	4 μ/S LINE SWITCH
151c	20 μ/S " "
151d	SYNC. TRAP SWITCH
S152a	ROTARY SWITCH-SHORTING TYPE (SCREW DRIVER ADJ.)
152b	" " " " " " "
152c	" " " " " " "
S153	4 & 20 μ/S VERNIER " " "
S154	1 & 20 μ/S VERNIER " " "
S155	LOCAL PULSE WIDTH SW.

C151	0.0025 MFD. 7500V. PYRANOL
152	" " " "
153	" " " "
154	" " " "
155	0.01 " " "
156	" " " "
157	0.03 " " "
158	" " " "
159	" " " "
160	" " " "
161	0.70 " 1000V OIL FILLED OR MICA
162	0.15 " " " " " "
163	0.08 " " " " " "
164	0.05 " " " " " "
165	0.10 " " " " " "
166	0.05 " " " " " "
167	" " " " " " "
168	" " " " " " "
169	0.01 " " " " " "
170	" " " " " " "
171	" " " " " " "
172	" " " " " " "
173	" " " " " " "
174	0.005 " " " " " "
175	" " " " " " "
176	0.0025 " " " " " "

C181	0.1 MFD. 1500V.
L151	11 μh
152	"
153	"
154	"
155	45 μh.
156	" "
157	133 "
158	" "
159	" "
160	" "
161	300 HY. 30 MA.
162	7 HY. TAPPED AT 3 HYS. - SYNCHRONIZI
K151	GUARDIAN STEPPER RELAY (SPEC.

ASSIFIED



MFD. 7500V. PYRANOL	C181 0.1 MFD. 1500V.
" "	L151 11 μh
" "	152 "
" "	153 "
" "	154 "
" "	155 45 μh.
" "	156 " "
" "	157 133 "
" "	158 " "
" "	159 " "
1000V OIL FILLED OR MICA	160 " "
" "	161 300 HY. 30 MA.
" "	162 7 HY. TAPPED AT 3 HYS.-SYNCHRONIZING CHOKE
" "	
" "	K151 GUARDIAN STEPPER RELAY (SPECIAL)
1500V.	

ALTERATION TABLE

SYMBOLS AND THEIR EQUIV. TOLERANCES (UNLESS OTHERWISE NOTED)

SYMBOL 1	±.0005
SYMBOL 2	±.0010
SYMBOL 2½	±.0030
SYMBOL 3	±.0050
SYMBOL 3½	±.0100
SYMBOL 4	±.0250
SYMBOL 5	

DELINEATOR	RRB	IN CHARGE OF RADIO DRAFTING	CHIEF DRAFTSMAN
TRACER			
CHECKER	R. L. Ramp	CRS.	JM

APPROVAL

RADIO ENGINEER	SUPT. OF RADIO DIVISION
H. O. Lorenzen	A. Hoyt Taylor

FOR DIRECTOR — R. Nicole, COMDR. U. S. N.

BUREAU OF SHIPS — REFERENCE

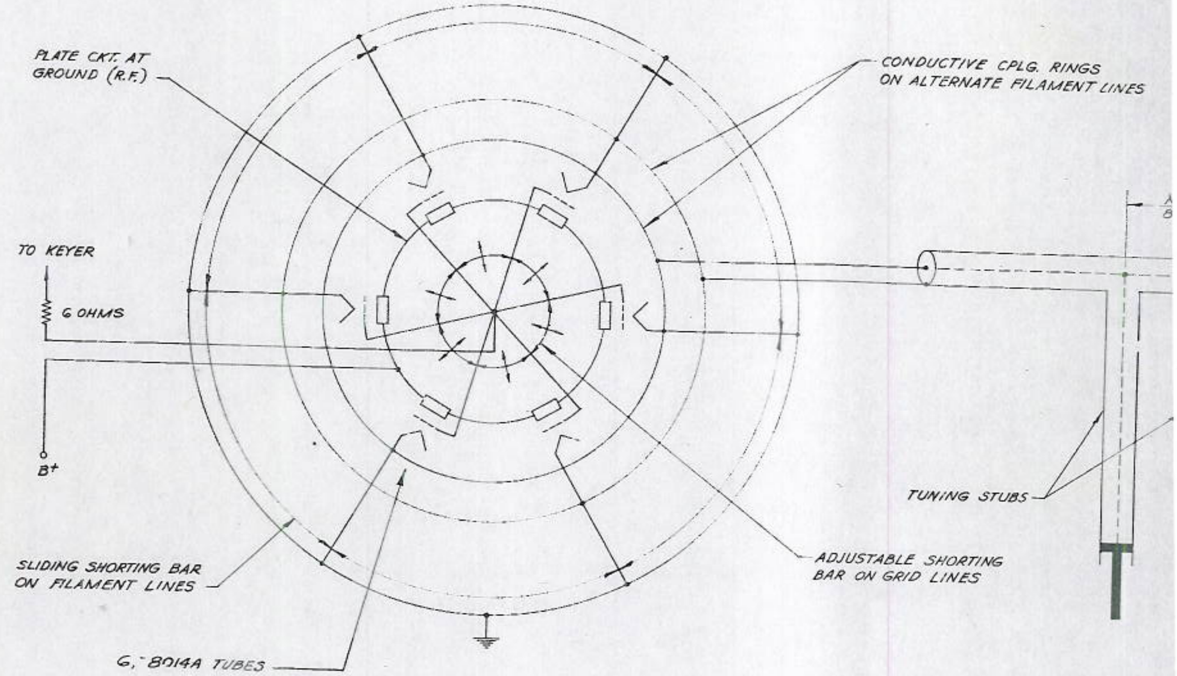
U. S. NAVAL RESEARCH LABORATORY
"BELLEVUE," ANACOSTIA, D. C.

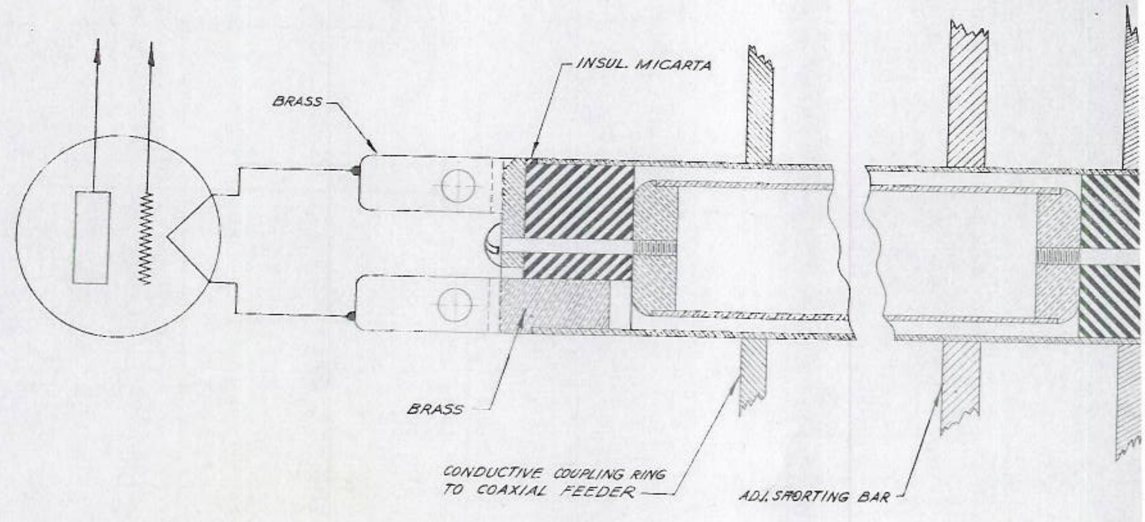
KEYER UNIT
MODEL XBF EQUIPMENT
SCHEMATIC DIAGRAM

SCALE — DATE 4-7-43

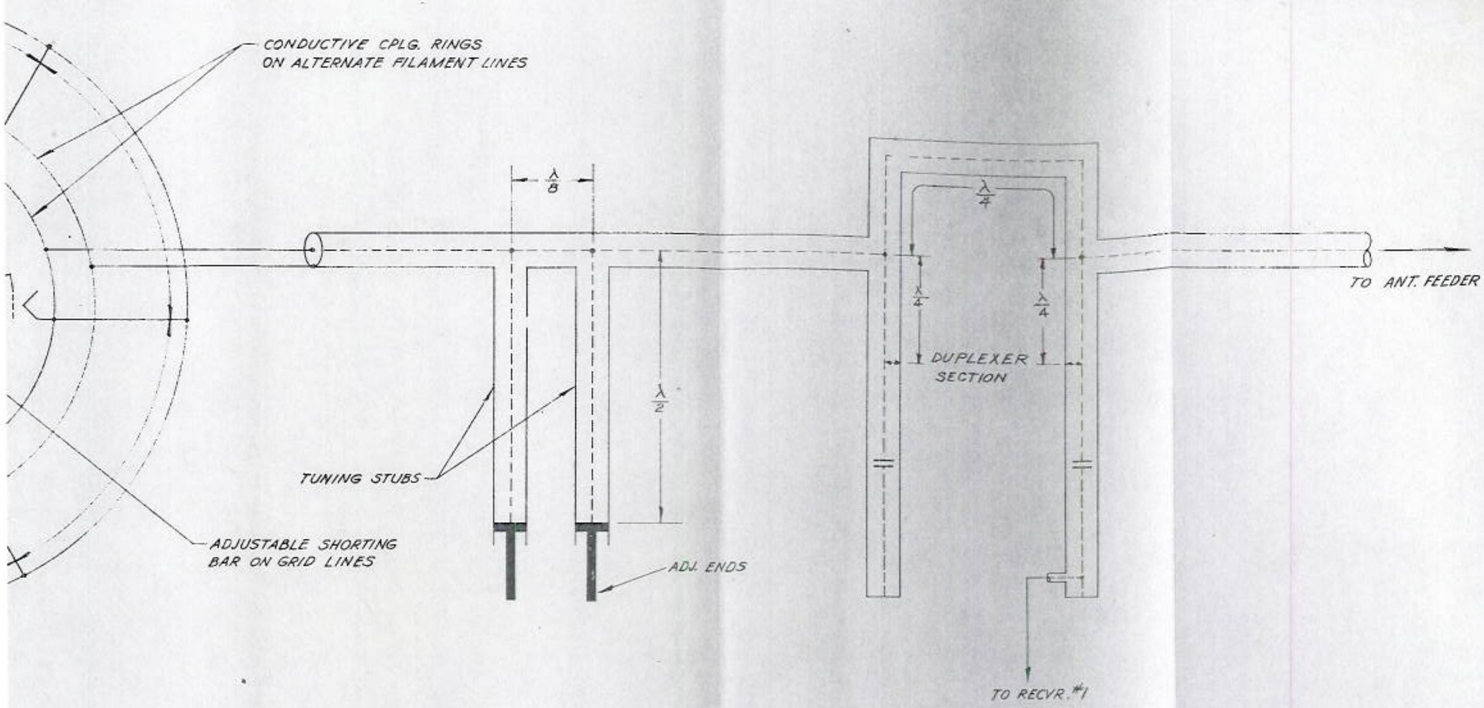
RA 67F 221A

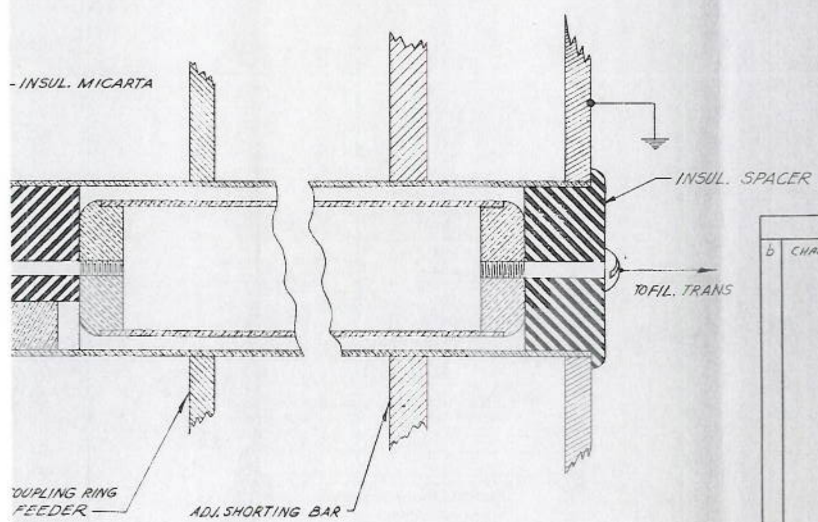
N. R. L. 66





DETAIL OF FILAMENT LINE





DETAIL OF FILAMENT LINE

ALTERATION TABLE	
b	CHANGED DUPLEXER SECTION 6-16-43 JEM

SYMBOLS AND THEIR EQUIV. TOLERANCES (UNLESS OTHERWISE NOTED)

SYMBOL 1	±.0005
SYMBOL 2	±.0010
SYMBOL 2½	±.0030
SYMBOL 3	±.0050
SYMBOL 3½	±.0100
SYMBOL 4	±.0250
SYMBOL 5	

DELINEATOR	JJA	IN CHARGE OF RADIO DRAFTING	CHIEF DRAFTSMAN
TRACER		CRS	
CHECKER	R. L. Ramp		

APPROVAL

RADIO ENGINEER	SUPT. OF RADIO DIVISION
H O Lorenzen	A Hoyt Taylor
FOR DIRECTOR	
	COMDR. U. S. N.
BUREAU OF SHIPS	REFERENCE

U. S. NAVAL RESEARCH LABORATORY
"BELLEVUE," ANACOSTIA, D. C.

OSCILLATOR & DUPLEXER

MODEL XBF EQUIPMENT

SCHEMATIC DIAGRAM

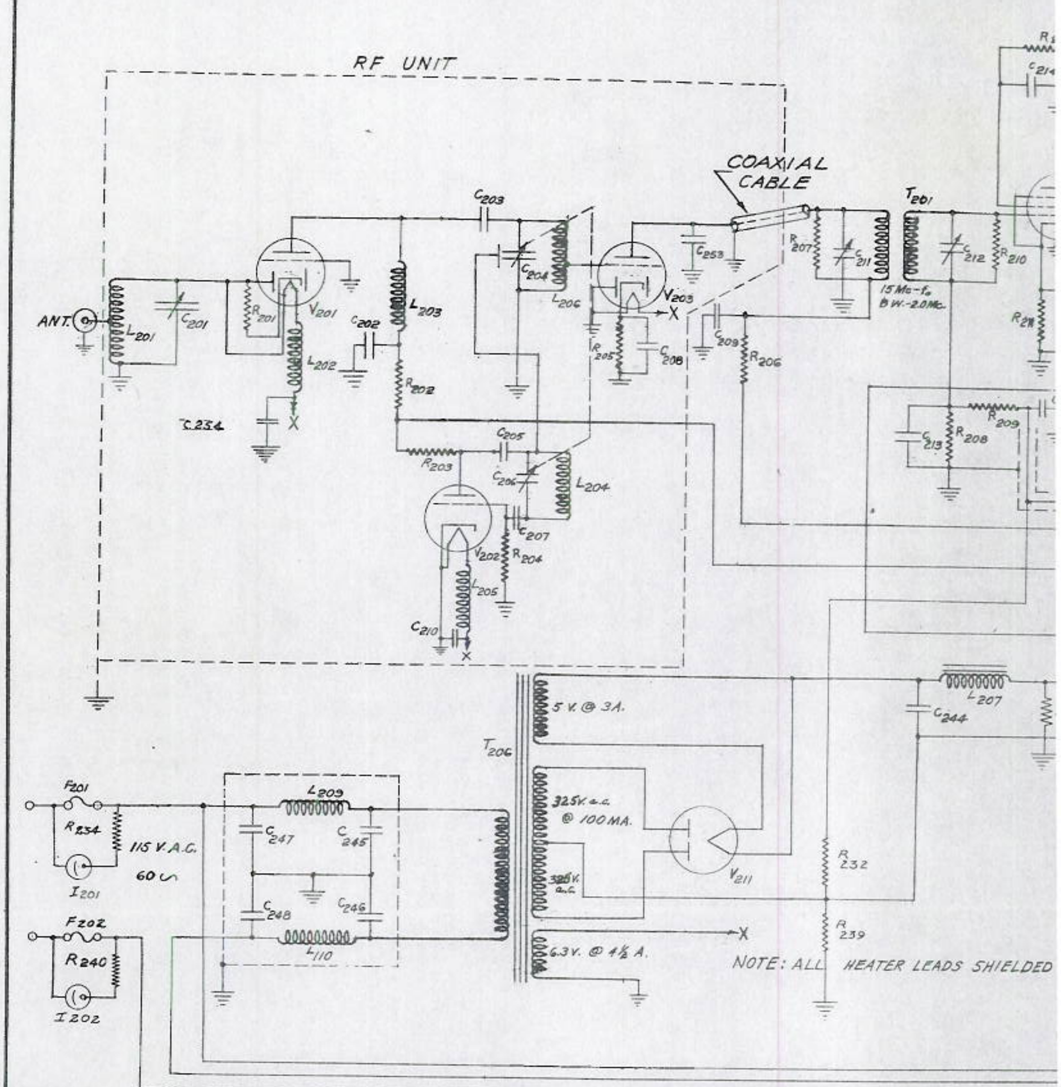
SCALE

DATE MARCH 20, 1943

RA 35F 240B

PLATE 16

N. R. L. 66



LEGEND OF CIRCUIT COMPONENTS

NOTE	-ALL MICA CONDENSERS-600V.D.C. RATING	C231	25 μμf-MICA	L201	ANTENNA COIL		R215	2200Ω-½W
C201	2-16 μμf VARIABLE (ROTARY)	232	.001 μf-MICA	202	HEATER CHOKE		216	4700Ω-½W
202	50 μμf-MICA-	233	.001 μf-MICA	203	PLATE CHOKE		217	180Ω-½W
203	50 μμf-(RCA TOOTHPICK TYPE)	234	.001 μf-MICA	204	OSC. COIL		218	2200Ω-½W
204	2-16 μμf VARIABLE (ROTARY)	235	.001 μf-MICA	205	OSC. HEATER CHOKE		219	2700Ω-½W
205	50 μμf (RCA TOOTHPICK TYPE	236	50 μμf-MICA	206	CONVERTER GRID COIL		220	1200Ω-½W
206	2-16 μμf VARIABLE (ROTARY)	237	25 μμf-MICA	207	12 HENRY FILTER CHOKE T-17C00B		221	180Ω-½W
207	30 μμf-(RCA TOOTHPICK TYPE)	238	50 μμf-MICA				222	1200Ω-½W
208	500 μμf-MICA	239	.01 μf-MICA	209	LINE FILTER CHOKE (20 μh-1 AMP)		223	4700Ω-½W
209	500 μμf-MICA	240	.001 μf-MICA	210	LINE FILTER CHOKE (20 μh-1 AMP)		224	1200Ω-½W
210	.005 μμf.-MICA	241	.001 μf-MICA	211	R.F. CHOKE		225	180Ω-½W
211	25 μμf VARIABLE (ROTARY)	242	.001 μf MICA	212	SOLENOID RELAY COIL		226	1200Ω-½W
212	25 μμf VARIABLE (ROTARY)	243	10 μf-TUBULAR PAPER-600V.D.C				227	10KΩ-½W
213	.001 μf-MICA	244	10 μf-TUBULAR PAPER-600V.D.C				228	1200Ω-½W
214	.001 μf-MICA	245	500 μμf-MICA	M201	0-100 μ AMPS.			
215	.001 μf-MICA	246	500 μμf-MICA				230	4700Ω-½W
216	.001 μf-MICA	247	.1 μf-PAPER-600V. D.C.			±%		
217	.001 μf-MICA	248	.1 μf-PAPER-600 V. D.C. *	R201	220Ω-½W	10	232	5.6KΩ-½W
218	25 μμf-VARIABLE ROTARY	249	SPECIAL-SEE DETAIL DRAWING	202	4700Ω-1W	20	233	25K. POT.-W.W.
219	25 μμf- " "	250	.001 μf-MICA	203	12000Ω-2W.	10	234	120K-½W
220	.01 μf-MICA	251	.01-MICA	204	22KΩ-½W	10	235	180K-2W
221	.001 μf-MICA	252	.01 μf-MICA. *	205	1200Ω-½W	10	236	680Ω-1W
222	.001 μf-MICA	253	5 μμf-RCA TOOTHPICK TYPE	206	82KΩ-1W	20	237	22KΩ-½W.
223	.001 μf-MICA	254	100 μμf-MICA	207	1800Ω-½W	10	238	47Ω-1W
224	10 μμf-MICA	255	10 μμf-MICA	208	1000Ω-½W	20	239	330Ω-5W
225	25 μμf-MICA	256	.01 μf	209	10KΩ-½W	20	240	120K-½W
226	.001 μf-MICA	257	.01 μf-MICA	210	1800Ω-½W	10	241	22K.-1W
227	.001 μf-MICA	258	.01 μf- "	211	180Ω-½W	10	S201	S.P.S.T. TOGGLE SWIT
228	.001 μf-MICA	259	.01 μf- "	212	1200Ω-½W	20		
229	.001 μf-MICA	260	.01 μf- "	213	2200Ω-½W	10		
230	50 μμf-MICA	261	.01 μf- "	214	1200Ω-½W	20		

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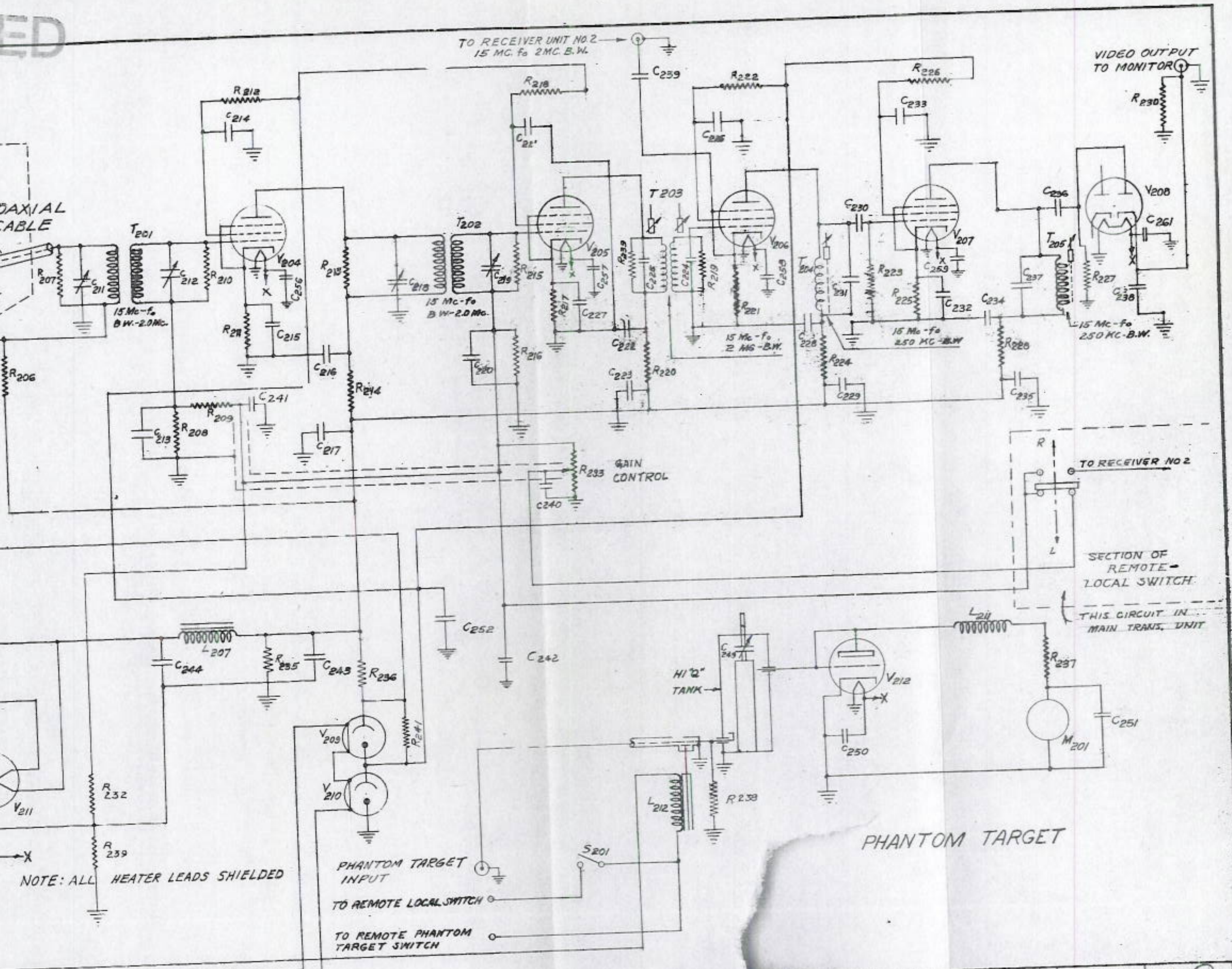


OMPONENTS	±%			±%		
COIL		R215	2200 Ω - ½ W	10		
CHOKE		216	4700 Ω - ½ W	10	T201	I.F. TRANSFORMER
HOKE		217	180 Ω - ½ W	10	202	I.F. TRANSFORMER
		218	2200 Ω - ½ W	20	203	I.F. TRANSFORMER
ER CHOKE		219	2700 Ω - ½ W	10	204	I.F. TRANSFORMER-SINGLE TUNED
ER GRID COIL		220	1200 Ω - ½ W	20	205	I.F. TRANSFORMER-SINGLE TUNED
FILTER CHOKE T-17C00B		221	180 Ω - ½ W	10	206	POWER TRANSFORMER —
		222	1200 Ω - ½ W	20		
ER CHOKE (20μh-1 AMP)		223	4700 Ω - ½ W	10		
ER CHOKE (20μh-1 AMP)		224	1200 Ω - ½ W	20		
KE		225	180 Ω - ½ W	10		
RELAY COIL		226	1200 Ω - ½ W	20	V201	GL446 PRESELECTOR
		227	10K Ω - ½ W	10	202	955 OSCILLATOR
		228	1200 Ω - ½ W	20	203	GL446 CONVERTER
AMPS.				10	204	6AC7 I.F. AMP.
		R30	4700 Ω - ½ W	10	205	6AC7 I.F. AMP.
	±%			10	206	6AC7 I.F. AMP
½ W	10	232	5.6K Ω - ½ W	10	207	6AC7 I.F. AMP.
1 W	20	233	25K POT. - W.W.	10	208	6H6-DETECTOR
- 2W.	10	234	120K - ½ W	20	209	VR150-30 VOLTAGE REGULATOR
½ W	10	235	180K - 2 W	20	210	VR150- " " "
½ W	10	236	680 Ω - 1 W	20	211	5U4G RECTIFIER
1 W	20	237	22K Ω - ½ W.	5	212	955 ACORN TRIODE
½ W	10	238	47 Ω - 1 W	10		
½ W	20	239	330 Ω - 5 W	10	F201	2 AMP. AUTO FUSE & HOLDER
½ W	20	240	120K - ½ W		202	" " " "
½ W	10	241	22 K. - 1 W	20		
½ W	10	S201	S.P.S.T. TOGGLE SWITCH		T201	NEON LIGHT INDICATOR FOR FUSE
½ W	20				202	" " " "
½ W	10					
½ W	20				*	VARIES WITH DIFF. TUBES

ALTERATION TABLE

b	CHG'D. CCT.	6-21-43	J.J.R.
c	CHG'D. CCT.	7-16-43	W.O.B.
d	MADE CCT. CHANGES	8/2/43	M.H.K. EWR 9-10-43
e	CHGD CCT.		

SYMBOLS AND THEIR EQUIV. TOLERANCES (UNLESS OTHERWISE NOTED)

SYMBOL 1	±.0005
SYMBOL 2	±.0010
SYMBOL 2½	±.0030
SYMBOL 3	±.0050
SYMBOL 3½	±.0100
SYMBOL 4	±.0250
SYMBOL 5	

DELINEATOR	DIENER	IN CHARGE OF RADIO DRAFTING	CHIEF DRAFTSMAN
TRACER		CRS.	[signature]
CHECKER	R. L. Ramp.		

APPROVAL

RADIO ENGINEER	SUPT. OF RADIO DIVISION
[signature]	A. Hoyt Taylor
FOR DIRECTOR	[signature] COMDR. U. S. N.
BUREAU OF SHIPS	REFERENCE

U. S. NAVAL RESEARCH LABORATORY
"BELLEVUE," ANACOSTIA, D. C.

RECEIVER UNIT NO. 1

MODEL XBF EQUIPMENT
SCHEMATIC DIAGRAM

SCALE

DATE MARCH 17, 1943

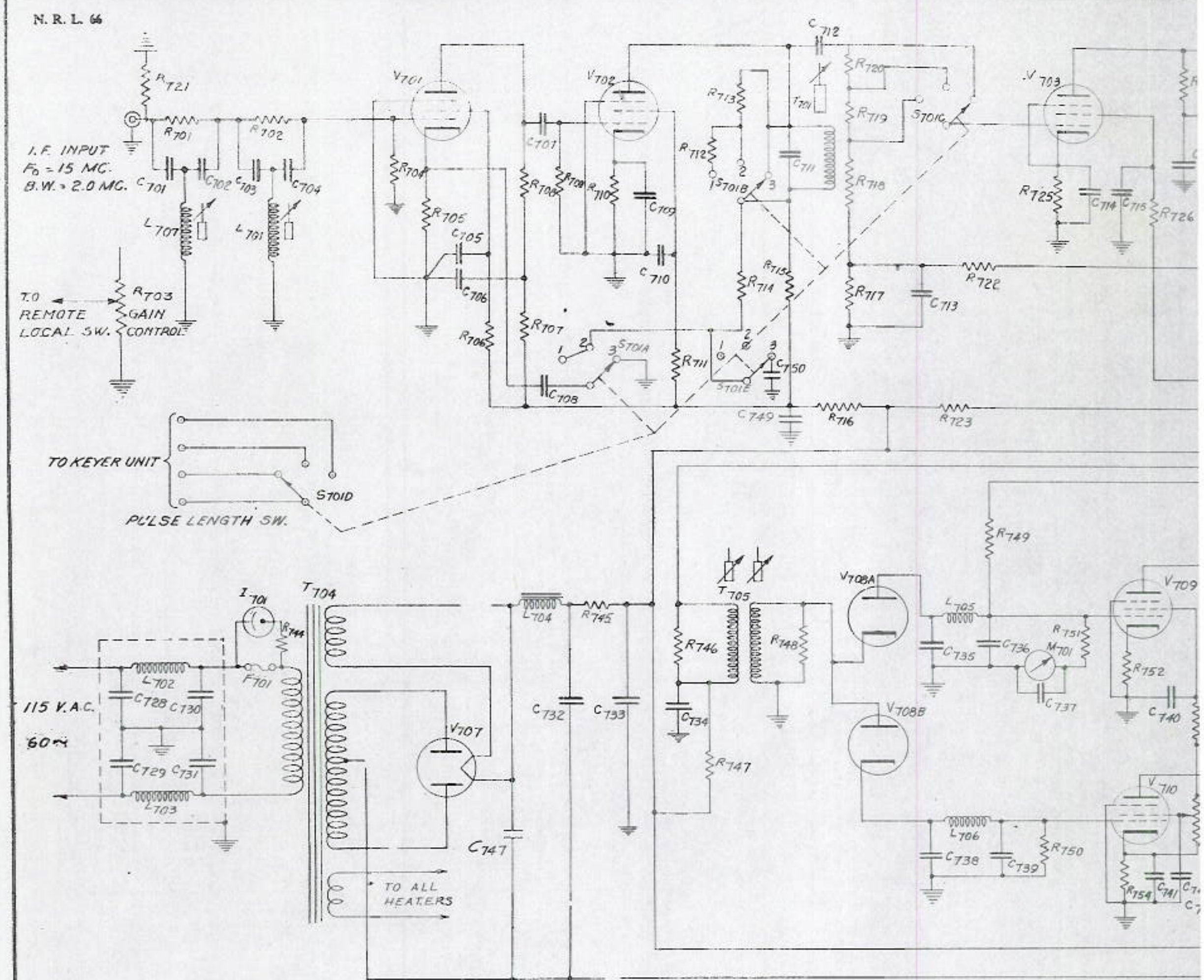
RA 46F 319E

PLATE 17

SIFIED

CLASSIFIED

N. R. L. 66



S 701 SWITCH POSITION
1 - 50 KC BW. - 20 µs PW
2 - 250 KC " - 4 " "
3 - 2 MC " - 1 " "

R701	4 X RESISTANCE OF L1 - ½ W.
702	4 X " " L2 - ½ W.
703	25 K. POT. - W.W.
704	100 - ½ W.
705	68 - ½ W.
706	27K - 1W.
707	1000 - ½ W.
708	1000 - ½ W.
709	1000 - ½ W.
710	150 - ½ W.
711	27K - 1 W.
712	10 K - ½ W.
713	3300 - ½ W.
714	300 ± 5 % - ½ W.
715	10K - 2W.
716	2700 - 10 W.
717	18K - 2 W.
718	390 - ½ W.
719	100 - ½ W.
720	8200 - ½ W.
721	100 Ω - ½ W
722	5600 - 1 W.
723	5600 - 10 W.
725	18K - 5 W.
726	27K - 1 W.
727	4700 - ½ W.
728	1200 ½ W.
729	5600 - 1 W.
730	18K - 2 W.
731	6800 - ½ W.
732	68 - ½ W.
733	470 - ½ W.

R734	27 K - 1 W.
735	4700 - ½ W.
736	1000 - ½ W.
737	18K - 2 W.
738	5600 - 1 W.
739	22 K - 2 W.
740	6800 - ½ W.
741	68 - ½ W.
742	470 - ½ W.
743	27K - 1 W.
744	120K - ½ W.
745	600 Ω - 25 W.
746	4700 - ½ W.
747	1200 - ½ W.
748	4700 ½ W.
749	100 K - ½ W.
750	10K - ½ W.
751	10K - ½ W.
752	100 - ½ W.
753	27K - 1W
754	1K - 1W.
755	25K POT - 2 W.
756	2700 - 2 W.
757	100 K - ½ W.
758	1800 - ½ W.
759	390 - ½ W
760	2700 - ½ W.
761	100 - ½ W.
762	390 ½ W
763	100 K - ½ W.
764	560 - ½ W.
765	33 - 5 W
766	68 - 5 W.

R767	27 - 5 W.
768	100 - ½ W.
769	100 ½ W.
770	100K - ½ W.
771	390 - ½ W.
773	390 - ½ W.
775	390 - ½ W.
777	390 - ½ W.

NOTE - ALL MICA COND. - 600V. D.C. RATING

C701	15 µµf. - MICA
702	" " "
703	" " "
704	" " "
705	.002 µf. "
706	" " "
707	50 µµf. "
708	.002 µf. "
709	" " "
710	" " "
711	10 µµf. "
712	50 µµf "
713	.002 µf. "
714	" " "
715	" " "
716	" " "
717	" " "
718	" " "
719	" " "
720	" " "

C721	.002 µf. - MICA
722	" " "
723	" " "
724	1 µf PAPER - 400 V.
725	.05 " " "
726	10 µµf
727	.5 µf - PAPER - 600V.
728	.1 " " "
729	.1 " " "
730	500 µµf - MICA
731	" " "
732	10 µf - PAPER - 600V
733	" " " "
734	.002 µf - MICA
735	10 µµf - "
736	" " "
737	.002 µf "
738	10 µµf "
739	" " "
740	.5 µf - PAPER - 600 V.
741	" " " "
742	" " " "
743	" " " "
744	.1 " " "
745	" " " "
746	.5 " " "
747	10 " " "
748	0.5 µf " "
749	.001 µf MICA
750	.0025 µf MICA
L701	FILTER COIL
702	LINE FILTER CHOKE
703	" " "

L704	
L705	
L706	
L707	
I701	N
V701	6
702	
703	
704	
705	
706	6
707	5
708	6
709	6
710	
711	6
712	
713	
714	
715	
T701	S
702	I
703	
704	P
705	I
F701	2
S701	W
702	
703	S
M701	O

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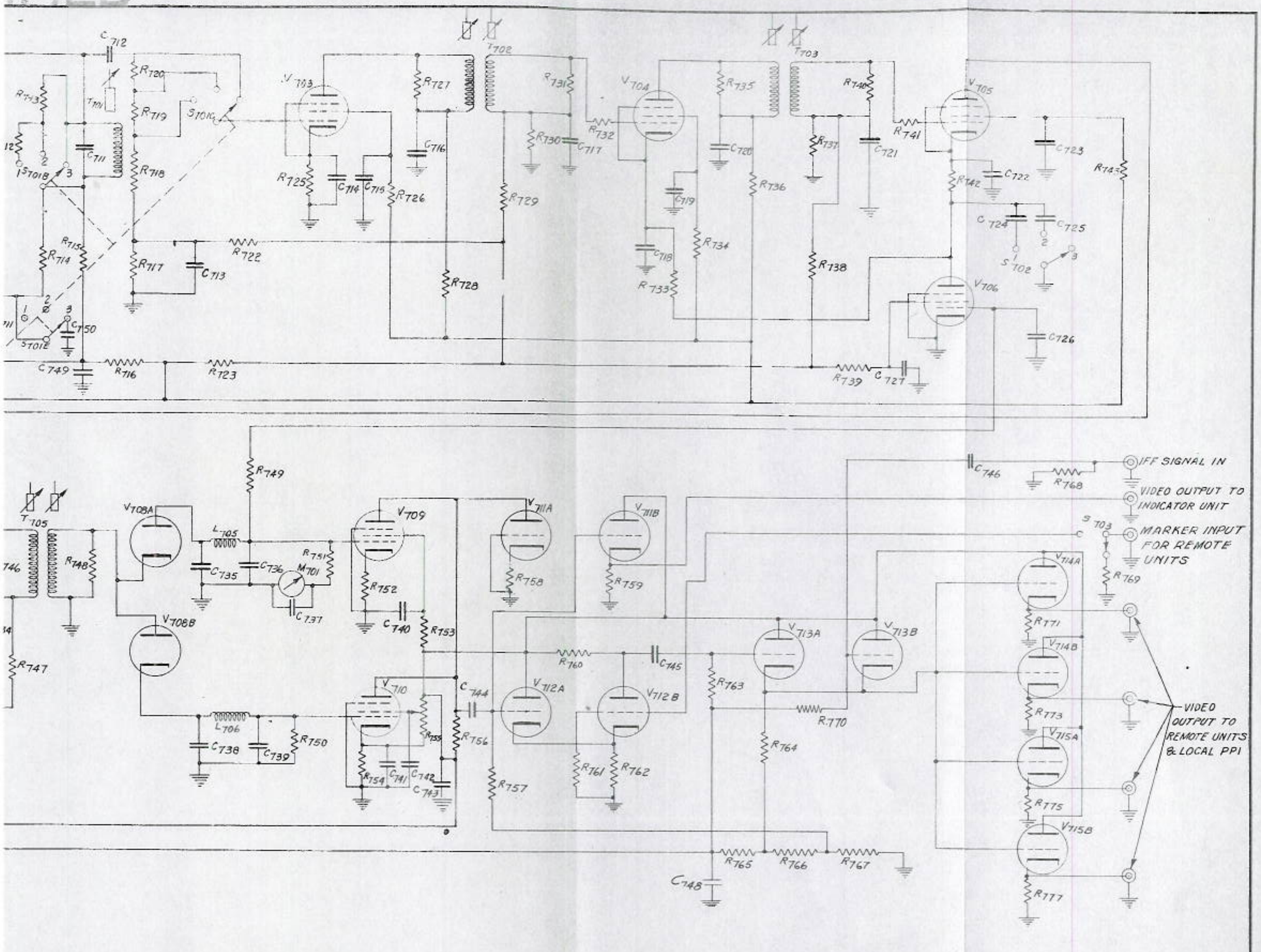


COND.-600V. D.C. RATING
MICA

C721	.002 μf.-MICA
722	" " "
723	" " "
724	1 μf PAPER-400 V.
725	.05 " " "
726	10 μμf
727	.5 μf-PAPER-600V.
728	.1 " " "
729	.1 " " "
730	500 μμf-MICA
731	" " "
732	10 μf PAPER-600V
733	" " " "
734	.002 μf-MICA
735	10 μμf- "
736	" " "
737	.002 μf "
738	10 μμf "
739	" " "
740	.5 μf-PAPER-600 V.
741	" " " "
742	" " " "
743	" " " "
744	.1 " " "
745	" " " "
746	.5 " " "
747	10 " " "
748	0.5 μf " "
749	.001 μf MICA
750	.0025 μf MICA
L701	FILTER COIL
702	LINE FILTER CHOKE
703	" " "

L704	FILTER CHOKE-15 HY.-125 MA.
L705	R.F. CHOKE-1 M.H
L706	R.F. CHOKE 1 M.H.
L707	FILTER COIL
I701	NEON LAMP INDICATOR
V701	6AC7-I.F. AMPLIFIER
702	" " "
703	" " "
704	" " "
705	" " "
706	6AG7-FEEDBACK "
707	5U4G-RECTIFIER
708	6H6-DETECTOR
709	6AC7-VIDEO AMPLIFIER
710	" " "
711	6SN7GT " "
712	" CATHODE FOLLOWER
713	" " "
714	" " "
715	" " "
T701	SINGLE TUNED I.F. COIL
702	I.F. TRANS.
703	" "
704	POWER TRANS. N.R.L. # 339
705	I.F. TRANS.
F701	2A AUTO FUSE & HOLDER
S701	WAFER SW.
702	" "
703	SPDT TOGGLE SW.
M701	0-1 MA.

ALTERATION TABLE

b	REDRAWN	A.R.C.	5-17-43
c	MADE CCT. CHANGES	J.E.M.	6/16/43
d	CHANGED CCT. & COMPONENTS	W.D.G.	7/16/43
e	CHANGED MARKER NOTE & R7...		8/5/43
f	MADE CCT. CHANGES		...43

SYMBOLS AND THEIR EQUIV. TOLERANCES (UNLESS OTHERWISE NOTED)

SYMBOL 1	±.0005
SYMBOL 2	±.0010
SYMBOL 2½	±.0030
SYMBOL 3	±.0050
SYMBOL 3½	±.0100
SYMBOL 4	±.0250
SYMBOL 5	

DELINEATOR	A.R.C.	IN CHARGE OF RADIO DRAFTING	CHIEF DRAFTSMAN
TRACER		CRS.	
CHECKER	R.L. Ramp		

APPROVAL

RADIO ENGINEER	SUPT. OF RADIO DIVISION
H. O. LORENZEN	A. Hoyt Taylor
FOR DIRECTOR	RnDale
	COMDR. U.S.N.
BUREAU OF SHIPS	REFERENCE

U.S. NAVAL RESEARCH LABORATORY
"BELLEVUE," ANACOSTIA, D. C.

RECEIVER UNIT NO. 2

MODEL XBF EQUIPMENT
SCHEMATIC DIAGRAM

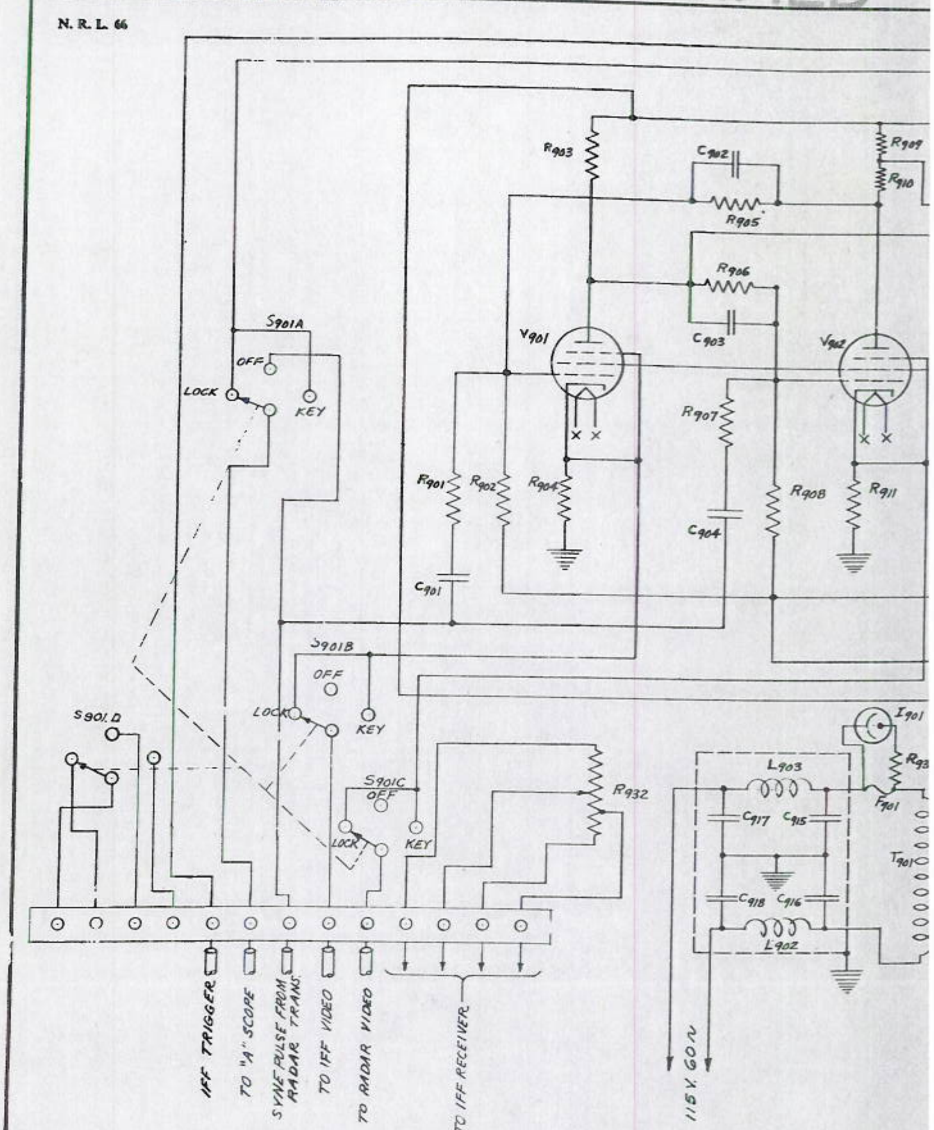
SCALE

DATE APR. 17, 1943

RA 46F 320F

PLATE 18

N. R. L. 66



LEGEND OF CIRCUIT COMPONENTS

NOTE	ALL MICA CONDENSERS 600 V.DC. RATING				RESISTORS		
C901	50 μμf MICA	L901	20 HY. 50 MA. FILTER CHOKE	R901	10K ½W.	R931	
902	100 μμf "	902	20 μh LINE FILTER CHOKE	902	120 K ½W.	932	
903	100 μμf "	903	20 μh " " "	903	6800 — 10 W.		
904	50 μμf "			904	560 - ½W.		
905	.01 μf. PAPER - 600 V.			905	330 K - ½W.		
906	250 μμf - MICA			906	330 K - ½W.		
907	250 μμf "	T901	POWER TRANSFORMER	907	10 K. - ½W.		
908	.25 μf. PAPER - 400 V.			908	120 K. - ½W.		
909	.25 μf. PAPER - 400 V.			909	2200 - ½W.	S901	S
910	250 μμf. MICA	I901	NEON IND. LAMP	910	4700 - ½W		
911	250 " "			911	56 K - ½W.		
912	250 " "			912	22 K - 2 W.		
913	4 μf. PAPER - 600 V. DC.	F901	2 A. AUTO FUSE & HOLDER	913	220 K - ½W.		
914	4 " " " "			914	680 K. - ½W.		
915	500 μμf MICA			915	100 K. - ½W.		
916	500 " "			916	500 K. - POT. - COMPOSITION		
917	.1 μf. PAPER - 600 V.			917	100 K - ½W.		
918	.1 " " " "			918	10 K. - ½W.		
		V901	6AG7	919	4700 - ½W.		
		902	6AG7	920	100 K - ½W.		
		903	6SN7GT	921	100 K - ½W.		
		904	6SN7GT	922	10 K - ½W.		
		905	6SN7GT	923	100 K - ½W.		
		906	5U4G	924	6.8 K. - 1W.		
				925	180 K. - ½W.		
				926	6800 - 1W.		
				927	10 K - 1W.		
				928	100 K - 1 W.		
				929	56 K - ½W.		
				930			

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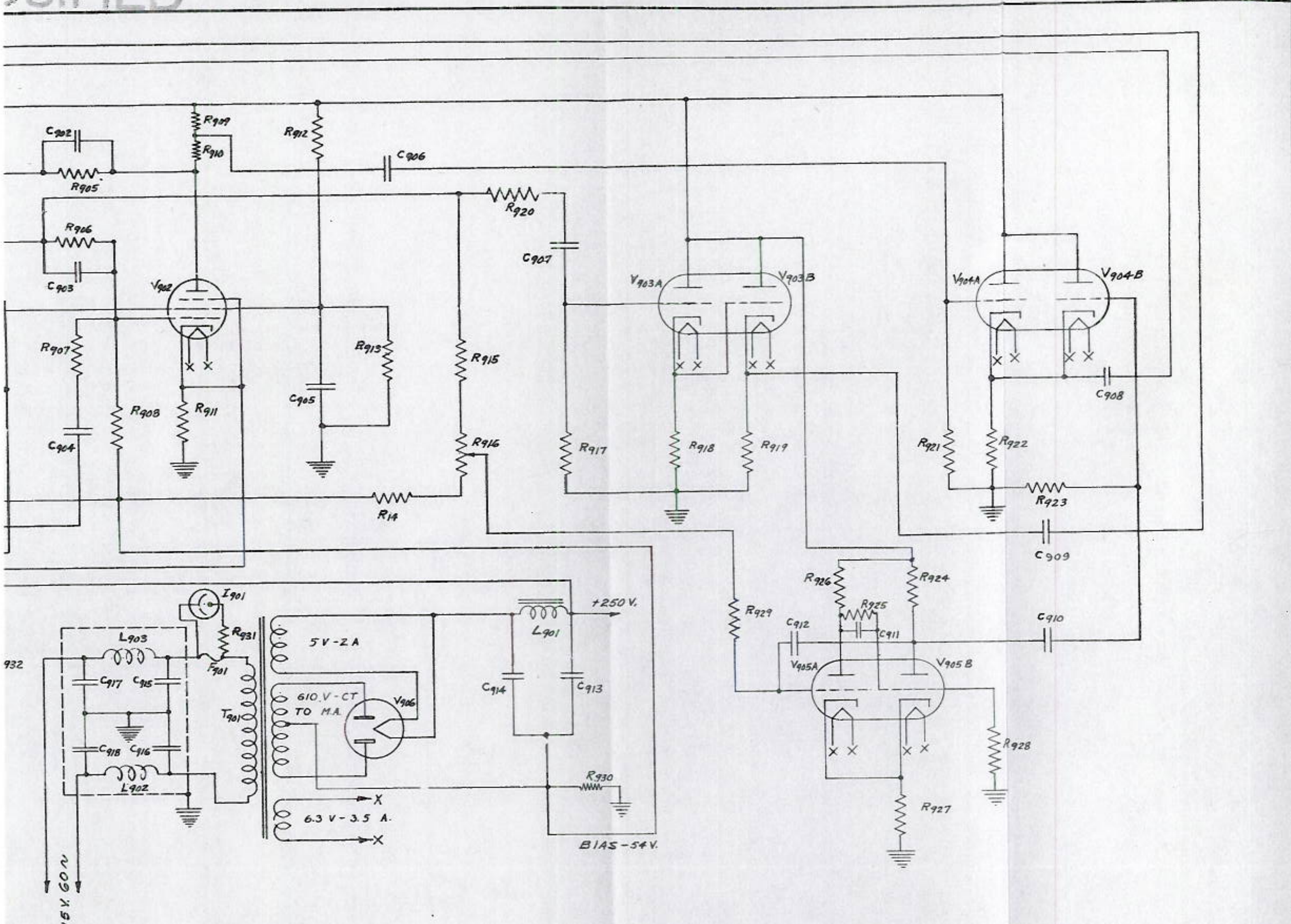


END OF CIRCUIT COMPONENTS

	RESISTORS			
	10K ½W.	R931	27K - ½W.	
2	120 K ½W.	932		
	6800 - 10 W.			
	560 - ½W.			
5	330 K - ½W.			
	330 K - ½W.			
	10 K. - ½W.			
	120 K. - ½W.			
	2200 - ½W.	S901	SPECIAL SWITCH	
	4700 - ½W.			
	56K - ½W.			
	22K - 2W.			
	220 K. - ½W.			
	680 K. - ½W.			
	100 K. - ½W.			
	500 K. - POT. - COMPOSITION			
7	100 K - ½W.			
	10 K. - ½W.			
	4700 - ½W.			
	100 K - ½W.			
	100 K - ½W.			
2	10 K - ½W.			
3	100 K - ½W.			
4	6.8 K. - 1W.			
5	180 K. - ½W.			
6	6800 - 1W.			
7	10 K - 1W.			
8	100 K - 1W.			
7	56 K - ½W.			

ALTERATION TABLE

b	CHANGED NUMBER SERIES	6/24/43 Q.R.B.
C	CHGD. TERM. BOARD & SWITCH	8/7/43 M.H.H.

SYMBOLS AND THEIR EQUIV. TOLERANCES (UNLESS OTHERWISE NOTED)

SYMBOL 1	±.0005
SYMBOL 2	±.0010
SYMBOL 2½	±.0030
SYMBOL 3	±.0050
SYMBOL 3½	±.0100
SYMBOL 4	±.0250
SYMBOL 5	

DELINEATOR	W. L. CISSEL.	IN CHARGE OF RADIO DRAFTING	CHIEF DRAFTSMAN
TRACER		CRS	
CHECKER	R. L. RAMP.		

APPROVAL

RADIO ENGINEER	SUPT. OF RADIO DIVISION
H. O. LORENZEN	A. Hoyt Taylor
FOR DIRECTOR	COMDR. U. S. N.
BUREAU OF SHIPS	REFERENCE

U. S. NAVAL RESEARCH LABORATORY
"BELLEVUE," ANACOSTIA, D. C.

I. F. F. CONTROL UNIT

MODEL XBF EQUIPMENT
SCHEMATIC DIAGRAM

SCALE

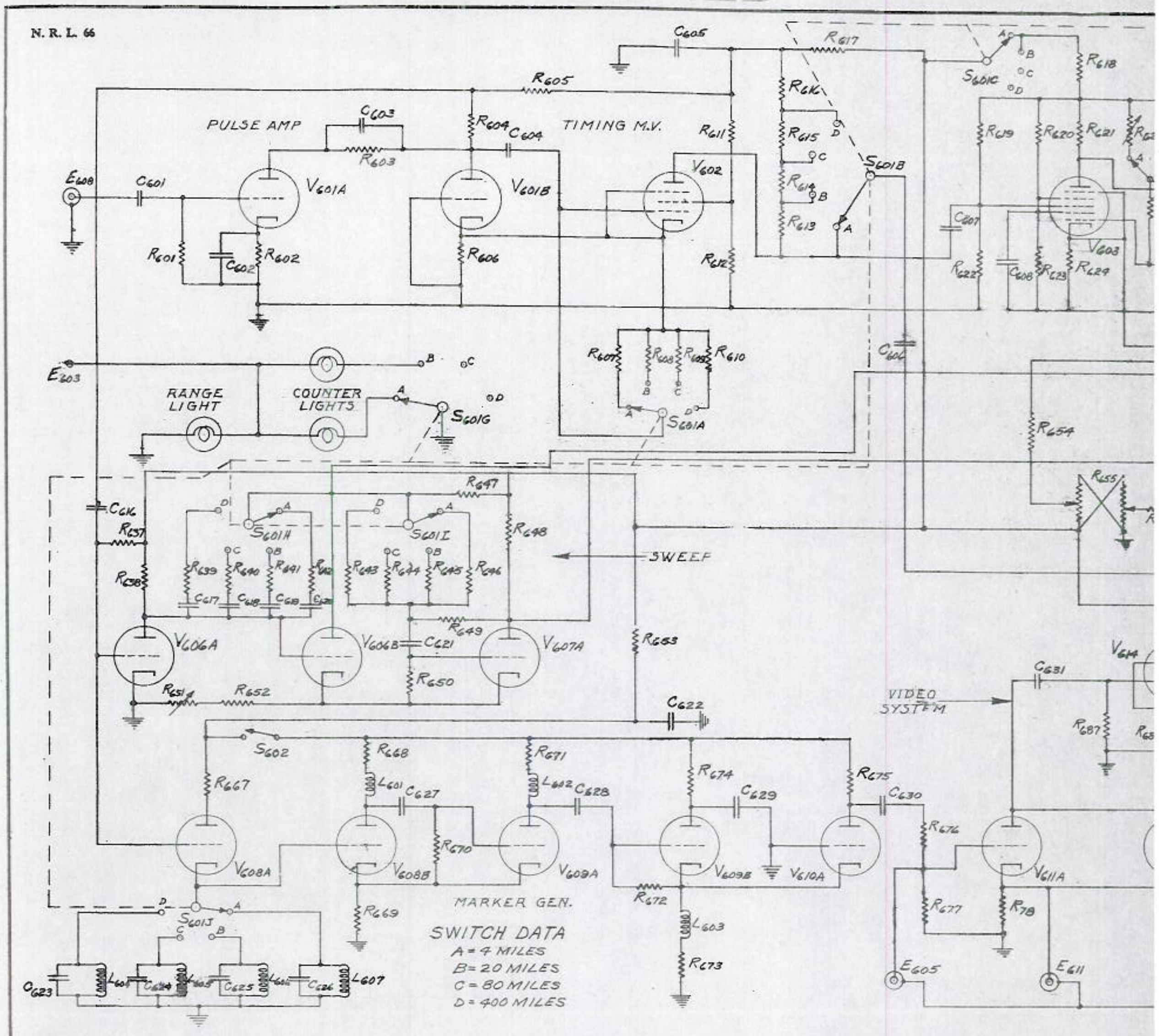
DATE MARCH 20, 1943

C

RA 23F 247C

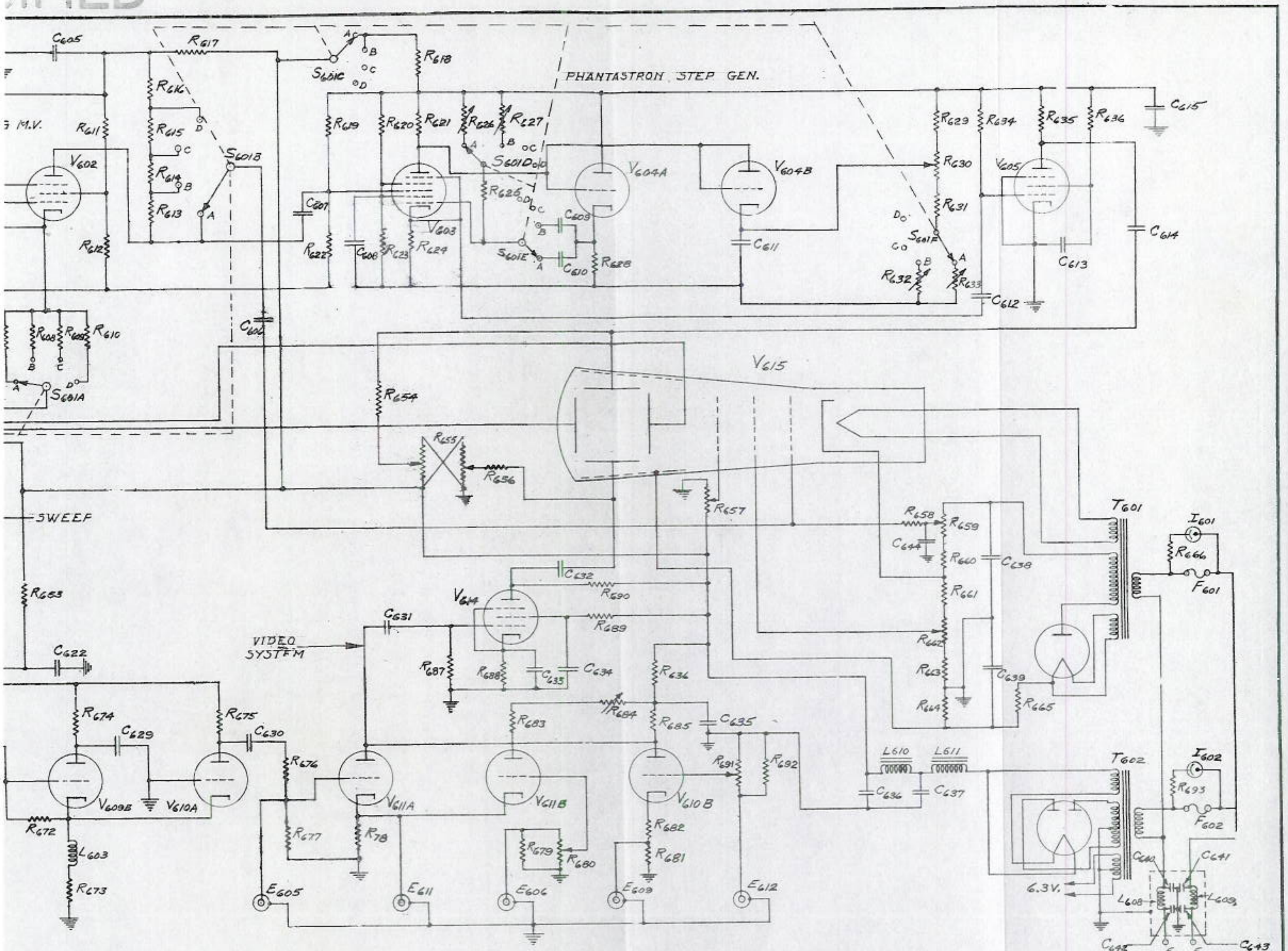
PLATE 19

N.R.L. 66



	CONDENSERS				INDUCTANCES						
C601	500 μμF. MICA	C636	10 μF. 600 V.	L601	2.5 MH.	R621	1M. ½W.	R656	1M. ½W.	R691	
602	" " "	637	" " "	602	" "	622	4.7K. " " -W.W.	657	500K. ½W. POT.	692	
603	100 " "	638	.1 μF. 2000 V.	603	" "	623	5.7 " 2 " -W.W. ±5%	658	1M. ½W.	683	
604	.0025 μF. "	639	" " "	604	350 MH.	624	10 K. ½W. ±5%	659	100K. " POT.		
605	10 μF. 600 V.	640	500 μμF MICA	605	160 "	625	1M. " -W.W.	660	220K. "		
606	.1 μF. 2000 V.	641	" " "	606	40 "	626	100K. " POT. -W.W.	661	1M.-I.R.C. TYPE MVG		
607	100 μμF. MICA	642	.1 μF. 450 V.	607	8 "	627	" " " " "	662	1M 1W. POT.		
608	4 μF. 450 V.	643	" " "	608	20 μh.	628	27K. 2W.	663	3.3M.-I.R.C. TYPE MVG	V601	
609	475 μμF. MICA	644	.1 " 2000 V.	609	" "	629	12 " 1 " -W.W.	664	5M.-I.R.C. " "	602	
610	90 " "			610	12 H.-.2A.	630	20 " 5 " -W.W.	665	120K. ½W.	603	
611	.5 μF. 450 V.			611	" " "	631	3K. 1 " -W.W.	666	27 " "	604	
612	.25 μF. 450 V.					632	3K 1W. POT.-W.W.	667	15 " 2W.	605	
613	.5 μF. "		UNIT TERMINALS			633	" " " " "	668	4.7 " ½W.	606	
614	.05 μF. 600 V.	E601	115 V. 60 ~			634	1M ½W.	669	1.5 " "	607	
615	10 μF. "	602	115 V. 60 ~		RESISTORS	635	27K. 2W.	670	1M "	608	
616	.1 " "	603	6.3 V. .75A.	R601	27K. ½W.	636	10K. "	671	4.7K. "	609	
617	.02 " "	605	MARKERS TO REMOTE P.P.I.	602	3.3 " " "	637	1M. ½W.	672	1.5K. "	610	
618	.004 " MICA	606	RADAR SIGNAL INPUT	603	10 " " "	638	680K. 1W.	673	4.7 " 1W.	611	
619	950 μμF MICA	608	SYNC. PULSE FROM IFF	604	1 " " "	639	5.6K. ½W.	674	12K. 2W.	612	
620	200 " "	609	IFF VIDEO SWITCH	605	12 " " "	640	180Ω "	675	8.2 " ½W.	613	
621	.001 μF. "	611	RADAR VIDEO SWITCH	606	1.2 " 1W.	641	150Ω "	676	680Ω "	614	
622	10 μF. 600 V.	612	IFF SIGNAL	607	1.5M. ½W.	642	0	677	68Ω "	615	
623	.09 μF. 450 V.			608	270K " "	643	100K. ½W.	678	470Ω "		
624	.01 " MICA			609	56 " " "	644	120 " "	679	220Ω "		
625	.0025 μF. MICA			610	10 " " "	645	150 " "	680	2K. " POT.		
626	400 μμF. "			611	56 " " "	646	120 " "	681	56 " "	S601	[illegible]
627	.01 μF. "			612	47 " " "	647	68 " "	682	47Ω "	602	[illegible]
628	100 μμF. "			613	1K. " "	648	47 " "	683	4.7K. 1W.		
629	.1 μF. 450 V.		FUSES	614	" " "	649	220 " "	684	5 " 1W. POT.		
630	.005 μF. MICA	F601	1A. (AUTO TYPE)	615	" " "	650	1M. "	685	3.9 " ½W.	T601	
631	.1 μF. 450 V.	602	5A. (AUTO TYPE)	616	4.7K. 1W.	651	10K. 1W. POT.	686	" " 1W.		
632	.05 μF. 600 V.			617	3K. 5W.	652	820Ω ½W.	687	330 " ½W.	T602	[illegible]
633	.005 " MICA		INDICATORS	618	2K. " "	653	5K. 5W.	688	100Ω "		
634	.1 " 600 V.	I601	.1W. NEON LAMP	619	47K. 2W.	654	1M. ½W.	689	40K. 5W.		
635	10 μF. "	602	.1W. " "	620	15K. 5W.-W.W. ±5%	655	500K, ½W. DUAL POT.	690	3.9 " 1W.		

[redacted]



CES	R621	1M. ½W.	R656	1M. ½W.	R691	1K. ½W. POT.
	622	4.7K. " " -W.W.	657	500K. ½W. POT.	692	68Ω ½W.
	623	5.7 " 2 " -W.W. ±5%	658	1M. ½W.	693	27K. "
	624	10 K. ½W. ±5%	659	100K. " POT.		
	625	1M. " -W.W.	660	220K. "		
	626	100K. " POT. -W.W.	661	1M.-I.R.C. TYPE MVG		
	627	" " " " "	662	1M 1W. POT.		TUBES
	628	27K. 2W.	663	3.3M.-I.R.C. TYPE MVG	V601	6SN7
	629	12 " 1 " -W.W.	664	5M.-I.R.C. " "	602	6AG7
	630	20 " 5 " -W.W.	665	120K. ½W.	603	6SA7
	631	3K. 1 " -W.W.	666	27 " "	604	6SN7
	632	3K 1W. POT.-W.W.	667	15 " 2W.	605	6AG7
	633	" " " " "	668	4.7 " ½W.	606	6SN7
	634	1M ½W.	669	1.5 " "	607	"
	635	27K. 2W.	670	1M "	608	"
	636	10K. "	671	47K. "	609	"
	637	1M. ½W.	672	1.5K. "	610	"
	638	680K. 1W.	673	4.7 " 1W.	611	"
	639	5.6K. ½W.	674	12K. 2W.	612	5U4G
	640	180Ω "	675	8.2 " ½W.	613	RKR72
	641	150Ω "	676	680Ω "	614	6AG7
	642	0	677	68Ω "	615	5CP1
	643	100K. ½W.	678	470Ω "		
	644	120 " "	679	220Ω "		
	645	150 " "	680	2K. " POT.		SWITCHES
	646	120 " "	681	56 " "	S601	5 WAFER RANGE SWITCH
	647	68 " "	682	47Ω "	602	MARKER SWITCH
	648	47 " "	683	4.7K. 1W.		
	649	220 " "	684	5 " 1W. POT.		TRANSFORMERS
	650	1M. "	685	3.9 " ½W.	T601	H.V. TRANSF.-SEC. WINDINGS
	651	10K. 1W. POT.	686	" " 1W.		2400V.@2MA.; 2.5V.@3A.; 6.3V.@.6A
	652	820Ω ½W.	687	330 " ½W.	T602	L.V. TRANSF.-SEC. WINDINGS
	653	5K. 5W.	688	100Ω "		1000V.@200MA.; 5V.@3A.; 6.3V.@7.1A
V.	654	1M. ½W.	689	40K. 5W.		
W.W.±5%	655	500K, ½W. DUAL POT.	690	3.9 " 1W.		

ALTERATION TABLE

b	MADE CIRCUIT CHANGES 6-24-43 CHANGED NUMBER SERIES	O.P.B.
c	MADE CIRCUIT CHANGES 7-15-43	PHE+IGC
D	MADE CIRCUIT CHANGES 8-2-43	MHH
e	REDRAWN MADE CIRCUIT CHANGES 9-28-43	RRB

SYMBOLS AND THEIR EQUIV. TOLERANCES (UNLESS OTHERWISE NOTED)

SYMBOL 1	±.0005
SYMBOL 2	±.0010
SYMBOL 2½	±.0030
SYMBOL 3	±.0050
SYMBOL 3½	±.0100
SYMBOL 4	±.0250
SYMBOL 5	

DELINEATOR	RRB	IN CHARGE OF RADIO DRAFTING	CHIEF DRAFTSMAN
TRACER		C.R.S.	[signature]
CHECKER			

APPROVAL

RADIO ENGINEER	SUPT. OF RADIO DIVISION
B. E. Boyer	A. Hoyt Taylor
FOR DIRECTOR	R. Dale, COMDR. U.S.N.
BUREAU OF SHIPS	REFERENCE

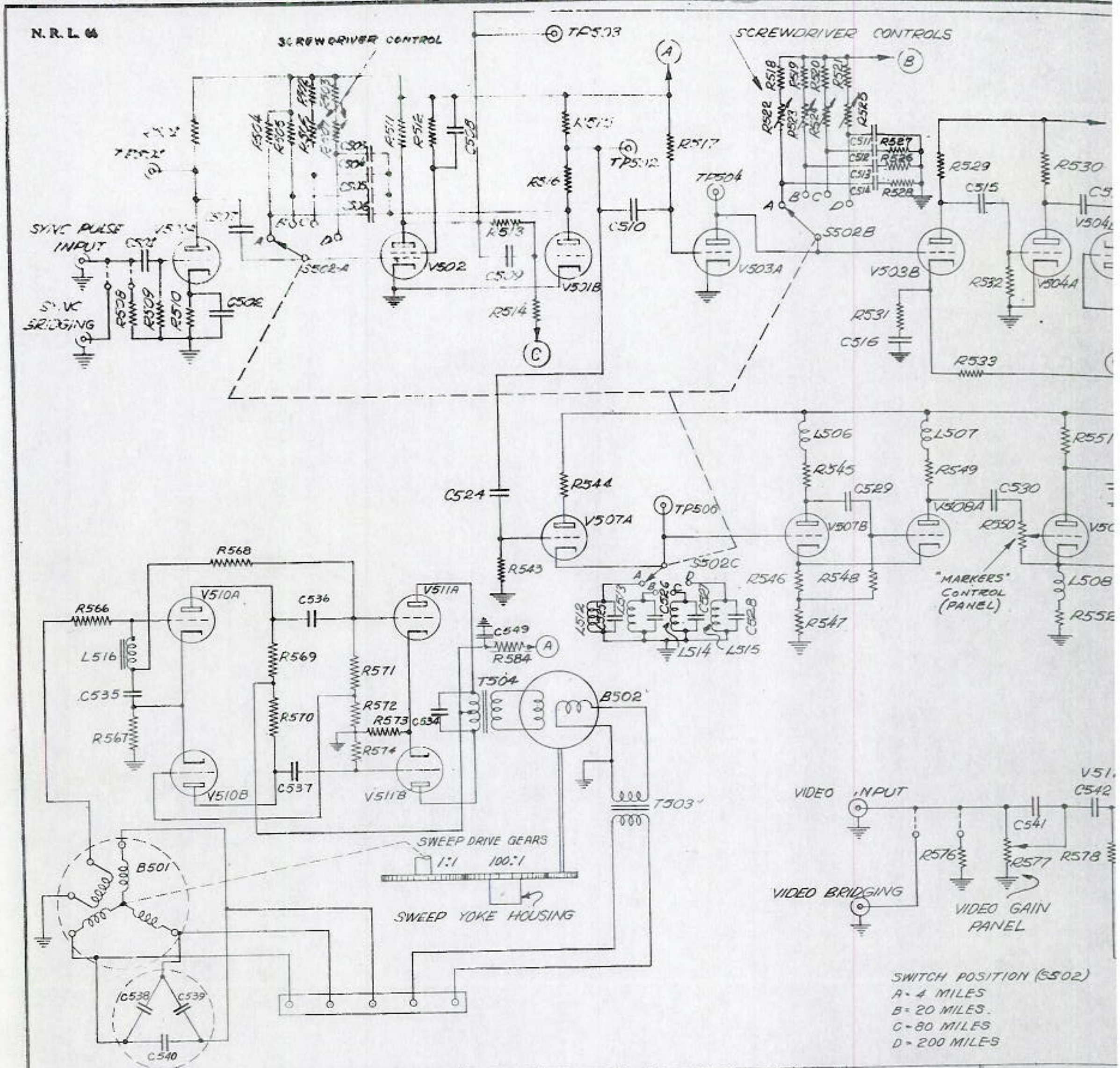
U. S. NAVAL RESEARCH LABORATORY
"BELLEVUE," ANACOSTIA, D. C.

RANGE INDICATOR
MODEL XBF EQUIPMENT
SCHEMATIC

SCALE DATE 3-25-43

RA 55F 238E

PLATE 20



R501	100K - ½ W.
R502	470K - ½ W.
R503	560K - ½ W
R504	470K - ½ W.
R505	470K - ½ W.
R506	200K POT - CARBON
R507	200K POT-CARBON
R508	68 - ½ W.
R509	100K - ½ W.
R510	10K - ½ W.
R511	5K-W.W. - 25 W.
R512	30K - 5W.
R513	390K - ½ W.
R514	120 K - ½ W
R515	5600 - 1 W.
R516	5600 - 1 W.
R517	470K - ½ W.
R518	470K - ½ W
R519	470K - ½ W.
R520	470K - ½ W
R521	470K - ½ W.
R522	200K POT-CARBON
R523	200K " "
R524	200K " "
R525	200K " "
R526	5.6K - ½ W.
R527	1500 ½ W.
R528	22K - ½ W.
R529	100K 1W.

R530	20K - 2W.
R531	220Ω - 1 W.
R532	470K - ½ W.
R533	2200 - ½ W.
R534	2500 - 2 W
R535	470K - ½ W.
R536	180 - 1 W.
R537	33K - 10W
R538	100K - "MEGOMAX"
R539	100K - "
R540	10MEG. - "
R541	100K "
R542	27K - ½ W.
R543	1MEG. - ½ W.
R544	15K - 2W
R545	4700 - ½ W
R546	1500 - ½ W
R547	1800 - ½ W.
R548	1MEG. - ½ W.
R549	4700 - ½ W.
R550	2K POT-CARBON
R551	27K - ½ W.
R552	3900 - ½ W.
R553	220K - ½ W.
R554	4700 - 1W.
R555	50K - POT-W.W.
R556	6K " "
R557	150K - 1W.
R558	10K POT-W.W.

R559	4700 - 2W.
R560	5K - 10W.
R561	2500 - 5W.
R562	2K - 10W.
R563	70K - 10W.
R564	27K - ½ W.
R565	20K - 2W
R566	22K - ½ W.
R567	330 ½ W.
R568	680K ½ W.
R569	56K - 2W.
R570	56K - 2W.
R511	120K - ½ W.
R512	22K - ½ W.
R573	560K - 1 W.
R574	180K - ½ W.
R576	68 - ½ W.
R517	5K POT-CARBON
R578	120K ½ W.
R579	3K - W.W. - 10W
R580	.12M - ½ W.
R581	.22M - ½ W.
R582	6.8K - ½ W.
R583	15Ω - 25W POT.
R584	680Ω 10W.

C501	250μμf - MICA - 600V.
C502	250μμf " "
C503	.01μf " "
C504	.005μf " "
C505	.002μf " "
C506	500μμf " "
C507	50μμf " "
C508	100μμf " "
C509	50μμf " "
C510	.1μf - PAPER - 600V.
C511	.05μf - MICA - 600V.
C512	.02μf " "
C513	.005μf " "
C514	.001 μμf-MICA"
C515	.1μf - PAPER - "
C516	.0015μf - MICA - "
C517	.1μf - PAPER - "
C518	.1μf - OIL FILLED - 7500V.
C519	.1μf - " " "
C520	500μμf MICA - 600V
C521	500μμf " "
C522	.1μf - PAPER - 600V
C523	.1μf " "
C524	.1μf " "
C525	700μμf MICA "
C526	.0035μf "
C527	.0094μf "
C528	.022μf "
C529	.05μf - PAPER - 600V.

C530	100μμf - MICA - 600V.
C531	.1μf - PAPER - "
C532	.1μf - " "
C534	.05μf " "
C535	.025μf " 800V.
C536	.05μf " 600V.
C537	.05μf " "
C538, C539, C540	TRIPLE SECTION .6-.6-.6 μf-PAPER-90V.AC SYNCHRO CAPACITOR
C541	10μμf - MICA - 600V.
C542	.1μf - PAPER - "
C543	.01μf - G.E. PYRONOL - 600V.
C544	1.0μf - PAPER - 600V.
C545	10μf - " "
C546	10μf - " "
C547	4μf - " "
C548	4μf - " "
C549	4μf " "
C550	10μf " "
V501	6SN7GT TUBE
V502	807 "
V503	6SN7GT "
V504	6SN7GT "

V505	807 TU
V506	7BP7 C.R
V507	6SN7GT
V508	6SN7GT
V509	6SN7GT
V510	6SN7GT
V511	6SN7GT
V512	6AC7
V513	6SN7GT
V514	5U4G
V515	RKR72
V516	VR150-30
L501	SWEEP COIL 32 MH
L503	FOCUS "
L504	20μh
L505	20μh
L506	2.5 Mh.
L507	2.5 Mh.
L508	2.5 Mh.
L509	12 H. - 2
L510	12H - 20
L511	200 H. -
L512	8 MH 10
L513	40 MH 10
L514	160 MH 10
L515	400 MH 1
L516	200H

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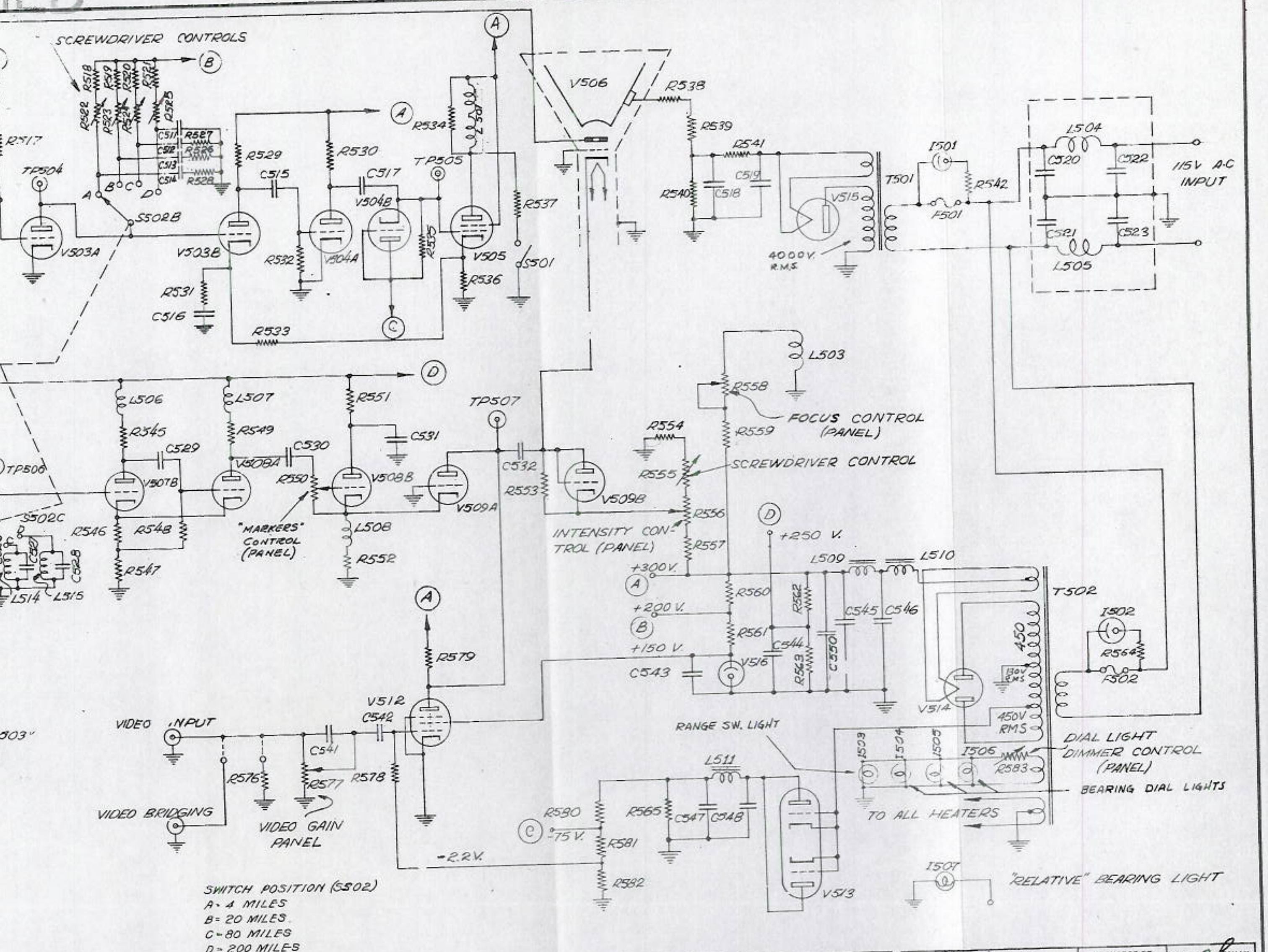


250μμf-MICA-600V.	C530	100μμf-MICA-600V.	V505	807 TUBE		
250μμf " "	C531	.1μf-PAPER- "	V506	7BP7 C.R. TUBE	TP	TEST POINT
.01μf " "	C532	.1μf- " "	V507	6SN7GT "	I501	NEON LAMP
.005μf " "			V508	6SN7GT "	I502	" "
.002μf " "	C534	.05μf " "	V509	6SN7GT "	I503	MAZDA #44 LAMP
500μμf " "	C535	.025μf " 800V.	V510	6SN7GT "	I504	" " "
50μμf " "	C536	.05μf " 600V.	V511	6SN7GT "	I505	" " "
100μμf " "	C537	.05μf " "	V512	6AC7 "	I506	" " "
50μμf " "	C538	TRIPLE SECTION .6-.6-.6	V513	6SN7GT "	I507	" " "
.1μf-PAPER-600V.	C539	μf-PAPER-90V.AC SYNCHRO	V514	5U4G "		
.05μf-MICA-600V.	C540	CAPACITOR	V515	RKR72 "	T501	H.V. TRANSFORMER
.02μf " "			V516	VR150-30 "		N.R.L. #403
.005μf " "	C541	10μμf-MICA-600V.			T502	L.V. TRANSFORMER
.001 μμf-MICA "	C542	.1μf-PAPER- "	L501	SWEEP COIL FOR C.R. TUBE		N.R.L. #382
.1μf-PAPER- "	C543	.01μf-G.E. PYRANOL-600V.		32 MH	T503	MOTOR TRANS.-PRI.
.0015μf-MICA- "	C544	1.0μf-PAPER-600V.	L503	FOCUS " " " "		115V. A-C. SEC. 75V.
.1μf-PAPER- "	C545	10μf- " "	L504	20μh.	T504	AUDIO TRANS.
.1μf-OIL FILLED-7500V.	C546	10μf- " "	L505	20μh.		
.1μf- " " "	C547	4μf- " "	L506	2.5 Mh.	B501	SYNCHRO CONTROL
500μμf-MICA-600V	C548	4μf- " "	L507	2.5 Mh.		TRANS.-TYPE 5CT
500μμf " "	C549	4μf " "	L508	2.5 Mh.	B502	2-PHASE DIEHL MOTOR
.1μf-PAPER-600V	C550	10μf " "	L509	12H. - 200 MA.		
1μf " "			L510	12H - 200 MA.	F501	AMP. AUTO FUSE
1μf " "			L511	200H. - 5 MA.	F502	AMP. " "
700μμf MICA "			L512	8 MH 10 MA.		
.0035μf "	V501	6SN7GT TUBE	L513	40 MH 10 MA.	S501	SPST TOGGLE SW.
.0094μf "	V502	807 "	L514	160 MH 10 MA.		"DECENTER"
.022μf "	V503	6SN7GT "	L515	400 MH 10 MA.	S502	3 POLE, 4 POSITION
.05μf-PAPER-600V.	V504	6SN7GT "	L516	200H		WAFER SW.

ALTERATION TABLE

b	MADE CIRCUIT CHANGES	8-2-43	A.R.C.
c	MADE CIRCUIT CHANGES	9-16-43	A.R.C.

SYMBOLS AND THEIR EQUIV. TOLERANCES (UNLESS OTHERWISE NOTED)

SYMBOL 1	±.0005
SYMBOL 2	±.0010
SYMBOL 2½	±.0030
SYMBOL 3	±.0050
SYMBOL 3½	±.0100
SYMBOL 4	±.0250
SYMBOL 5	

		IN CHARGE OF RADIO DRAFTING	CHIEF DRAFTSMAN
DELINEATOR	JJA	CRS.	
TRACER			
CHECKER			

APPROVAL

RADIO ENGINEER	SUPT. OF RADIO DIVISION
H. O. Lorenzen	A. Hoyt Taylor
FOR DIRECTOR	Rudolph, COMDR. U.S.N.
BUREAU OF SHIPS	REFERENCE

U. S. NAVAL RESEARCH LABORATORY
"BELLEVUE," ANACOSTIA, D. C.

PPI INDICATOR UNIT
FOR
MODEL XBF EQUIPMENT
SCHEMATIC DIAGRAM

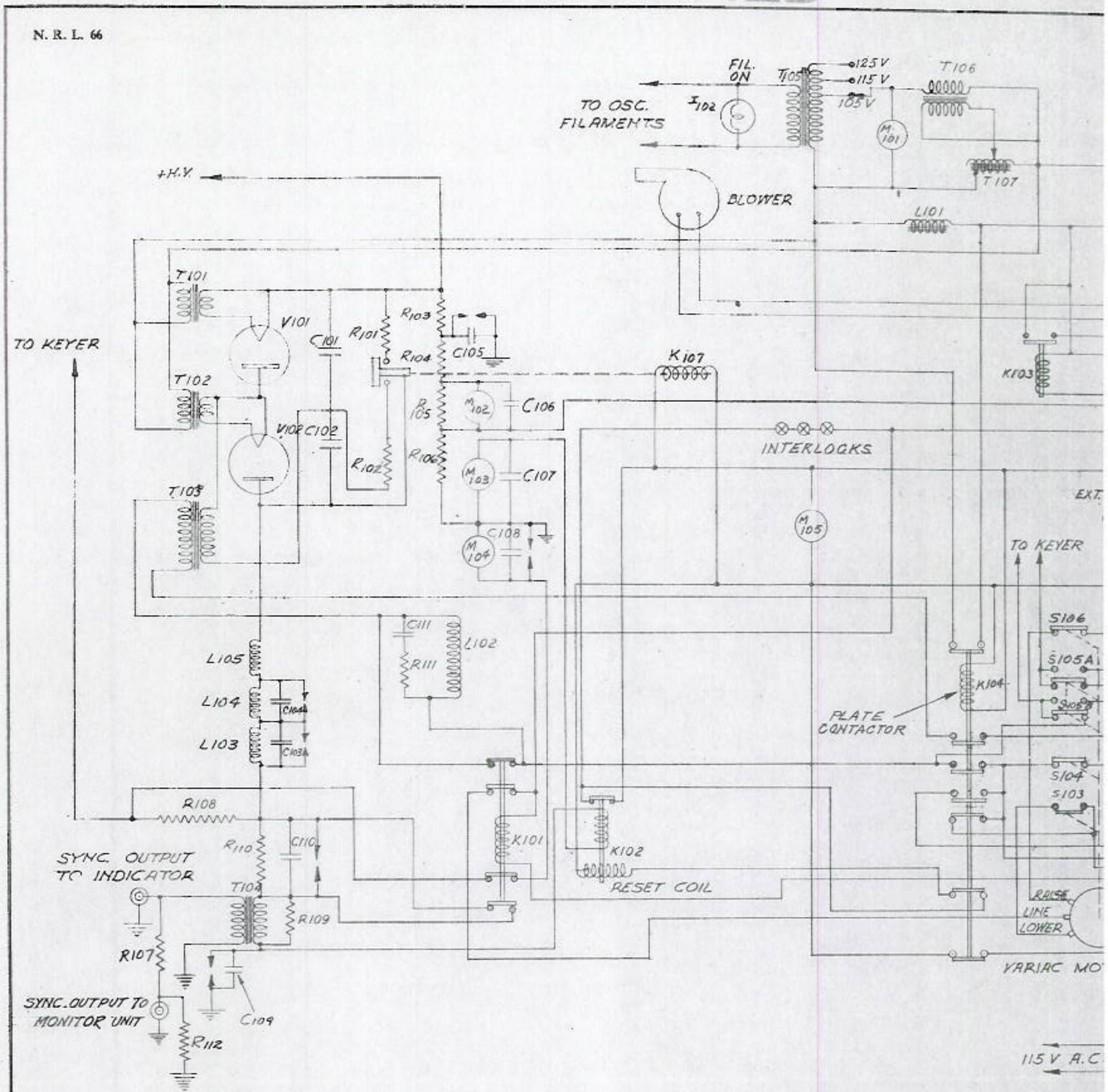
SCALE

DATE 7-5-43

RA 60F 277C

PLATE 21

N. R. L. 66



NOTE: I401 NOT CONNECTED ON NRL MODEL

R101	5 K 100WATT
102	5 K 50WATT
103	20M (4TYPE MFA RES)
104	50K-2W
105	22,000 Ω 5 W 22K
106	22000 Ω 5 W 22K
107	270 Ω 1WATT
108	10 K 2WATT
109	1 Ω 10W NON-IND
110	1.0 M 5W (1000V.)
111	
112	56 Ω 1WATT
C101	3MF 10,000 V
102	" "
103	.625MF 2,000 V
104	" "
105	1.0MF 1000 V
106	.01MF 1000 V MICA
107	" " "
108	" " "
109	10.0MF "
110	4 MF 1500 V
111	
401	.01MF 1000V MICA

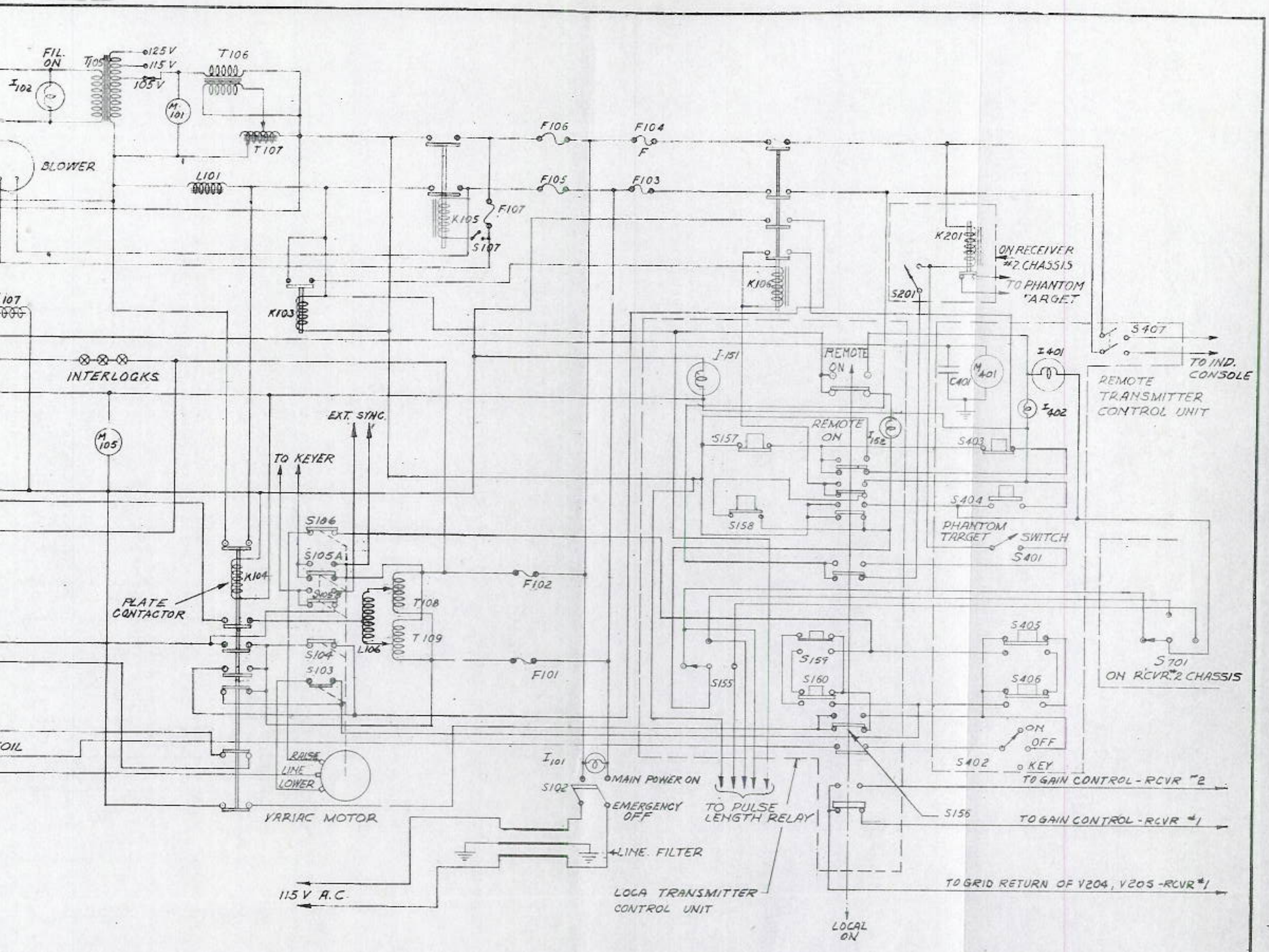
L101	20 MH. 15AMP.
102	250 MH. 300 MA
103	6.3 µH. 1.5 A
104	25 " 1.5A
105	12.5 " 1.5A
106	20 MH.-15 AMP. C.T.
T101	5V 6.5A SEC., INS. 20KV.
102	" " " " "
103	8000V. RMS. 150MA. D.C.
104	PULSE TRANSFORMER
105	PRIM. 105-115-125 SEC. 15V.-84A.
106	20V. 13 AMP. SEC.
107	200-C G.R. VARIAC
108	2 KVA VARIAC
109	2 KVA VARIAC
K101	KEYING RELAY
102	PLATE OVERLOAD RELAY
103	FILAMENT TIME DELAY RELAY
104	PLATE CONTACTOR RELAY
105	FILAMENT CONTACTOR

	RELAY
K106	RECEIVER INDICATOR POWER RELAY
107	SHORTING BAR RELAY
201	PHANTOM TARGET RELAY
S102	LINE SWITCH (50 AMP.)
103	LOWER LIMIT & OVERLOAD RESET SWITCH
104	PLATE RELAY RESET SWITCH
105	KEYER STARTING SWITCH
106	UPPER LIMIT SWITCH
107	OSCILLATOR FILAMENT SWITCH
155	LOCAL PULSE LENGTH SWITCH
156	REMOTE-LOCAL SWITCH
157	LOCAL PLATE VOLTAGE OFF SWITCH
158	LOCAL PLATE VOLTAGE ON SWITCH
159	LOCAL PLATE VOLTAGE RAISE SWITCH
160	LOCAL PLATE VOLTAGE

	LOWER SWITCH
S201	LOCAL PHANTOM TA ET SWITCH
401	REMOTE PHANTOM TARGET SWITCH
402	KEYING SWITCH
403	REMOTE PLATE VOLTA OFF SWITCH
404	REMOTE PLATE VOL ON SWITCH
405	REMOTE PLATE VOLT RAISE SWITCH
406	REMOTE PLATE VOL LOWER SWITCH
407	EMERGENCY OFF SW
701	REMOTE PULSE LEN SWITCH
	FUSES
F101	OSC. PLATE - 30 AMP.
102	OSC. PLATE 30 AMP.
103	REG.-IND. PWR.-15A
104	" " "
105	OSC. FIL. - 20AMP.
106	" " " "
107	BLOWER - 5AMP.

[redacted]

DECLASSIFIED



		LOWER SWITCH		
V	S201	LOCAL PHANTOM TARG-	I101	MAIN POWER ON
VER INDICATOR		ET SWITCH	I102	FIL. ON
R RELAY	401	REMOTE PHANTOM	I151	PLATE VOLT ON
NG BAR RELAY		TARGET SWITCH	I152	LOCAL ON
OM TARGET RELAY	402	KEYING SWITCH	I401	REMOTE ON
	403	REMOTE PLATE VOLTAGE	I402	PLATE VOLT ON
		OFF SWITCH	M101	FIL. VOLTS
	404	REMOTE PLATE VOLTAGE	M102	PLATE VOLTS
		ON SWITCH	M103	PLATE CURRENT
SWITCH (50 AMP)	405	REMOTE PLATE VOLTAGE	M104	GRID CURRENT
LIMIT & OVERLOAD		RAISE SWITCH	M105	HOUR METER
T SWITCH	406	REMOTE PLATE VOLTAGE	M401	PLATE VOLTS
RELAY RESET		LOWER SWITCH		
CH	407	EMERGENCY OFF SWITCH		
R STARTING SWITCH				
	701	REMOTE PULSE LENGTH		
R LIMIT SWITCH		SWITCH		
LATOR FILAMENT		FUSES		
CH	F101	OSC. PLATE - 30 AMP		
PULSE LENGTH	102	OSC. PLATE 30 AMP		
H	103	REC. - IND. PWR. - 15 AMP		
TE-LOCAL SWITCH	104	" " "		
PLATE VOLTAGE OFF	105	OSC. FIL. - 20 AMP		
H	106	" " "		
PLATE VOLTAGE	107	BLOWER - 5 AMP		
VITCH				
PLATE VOLTAGE				
SWITCH				
PLATE VOLTAGE				

ALTERATION TABLE

b	MADE CIRCUIT CHANGES 6/24/43 O.P.S.
c	MADE CCT. CHANGES 7/15/43 C.J.O.

SYMBOLS AND THEIR EQUIV. TOLERANCES (UNLESS OTHERWISE NOTED)

SYMBOL 1	±.0005
SYMBOL 2	±.0010
SYMBOL 2½	±.0030
SYMBOL 3	±.0050
SYMBOL 3½	±.0100
SYMBOL 4	±.0250
SYMBOL 5	

DELINEATOR	CARLISLE	IN CHARGE OF RADIO DRAFTING	CHIEF DRAFTSMAN
TRACER		CRS.	[signature]
CHECKER	R.L. RAMP		

APPROVAL

RADIO ENGINEER	SUPT. OF RADIO DIVISION
H. O. LORENZEN.	A. Hoyt Taylor
FOR DIRECTOR	Rudolf
	COMDR. U. S. N.
BUREAU OF SHIPS	REFERENCE

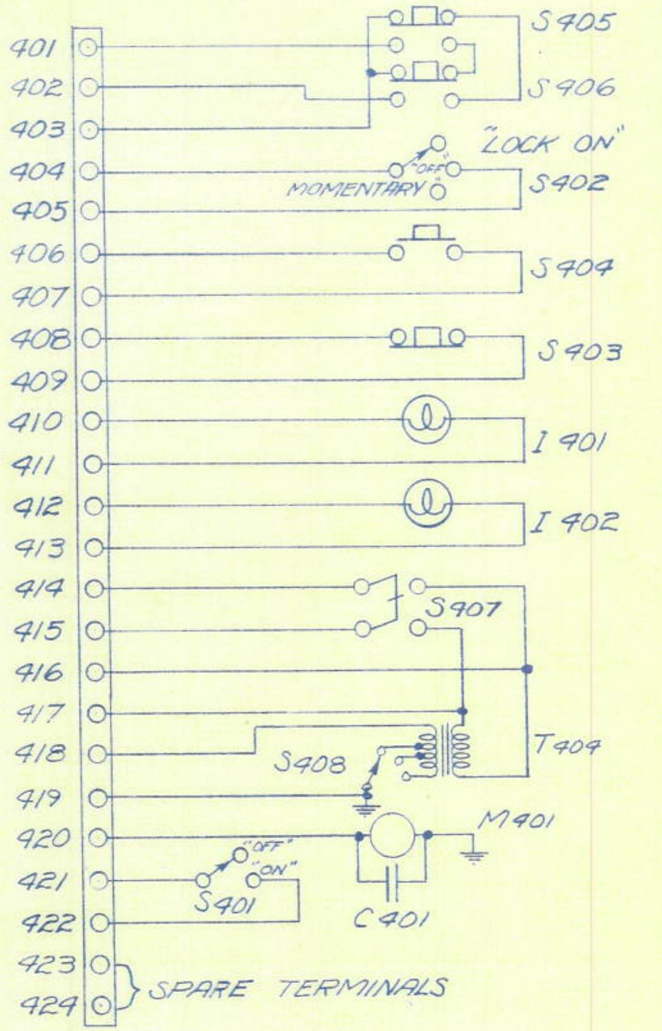
U. S. NAVAL RESEARCH LABORATORY
"BELLEVUE," ANACOSTIA, D. C.

POWER SUPPLY
FOR
MODEL XBF EQUIPMENT
SCHEMATIC DIAGRAM

SCALE DATE 4-13-43

c RA 20F 240C

PLATE 22



NOTE:
FOR OPERATION WITH MODEL XBF EQUIPMENT, CONNECT SHORTING WIRES ACROSS THE FOLLOWING PAIRS OF TERMINALS:
405 TO 403
411 TO 407

FOR OPERATION WITH MODEL XBF-1 EQUIPMENT, CONNECT SHORTING WIRES ACROSS THE FOLLOWING PAIRS OF TERMINALS:
405 TO 413
408 TO 407
411 TO 414
422 TO 414

C401 - .01µf. 1000 V. MICA
I 401 - PANEL LAMP - "CONTROL ON"
I 402 - PANEL LAMP - "HIGH VOLTAGE ON"
M 401 - PANEL METER - "HIGH VOLTAGE"
S 401 - ECHO BOX SWITCH
S 402 RADIATION SWITCH
S 403 - HIGH VOLTAGE OFF" SWITCH
S 404 - HIGH VOLTAGE ON" SWITCH
S 405 - HIGH VOLTAGE RAISE" SWITCH
S 406 - HIGH VOLTAGE LOWER" SWITCH
S 407 - "POWER ON - EMERGENCY OFF"
S 408 - DIAL LIGHT DIMMER SWITCH
T404 DIAL LIGHT POWER TRANSFORMER

ALTERATION TABLE			
b	MADE CKT. CHANGE	1-7-44	RPB
C	MODIF'D. & REDRAWN	4/3/44	B.T.

DRAWN B.T.
TRACED
CHECKED
APPROVED
IN CHARGE OF DESIGN CRS.
SUPT. DESIGN & DRAFTING DIV.
FOR DIRECTOR
COMDR. U.S.N.

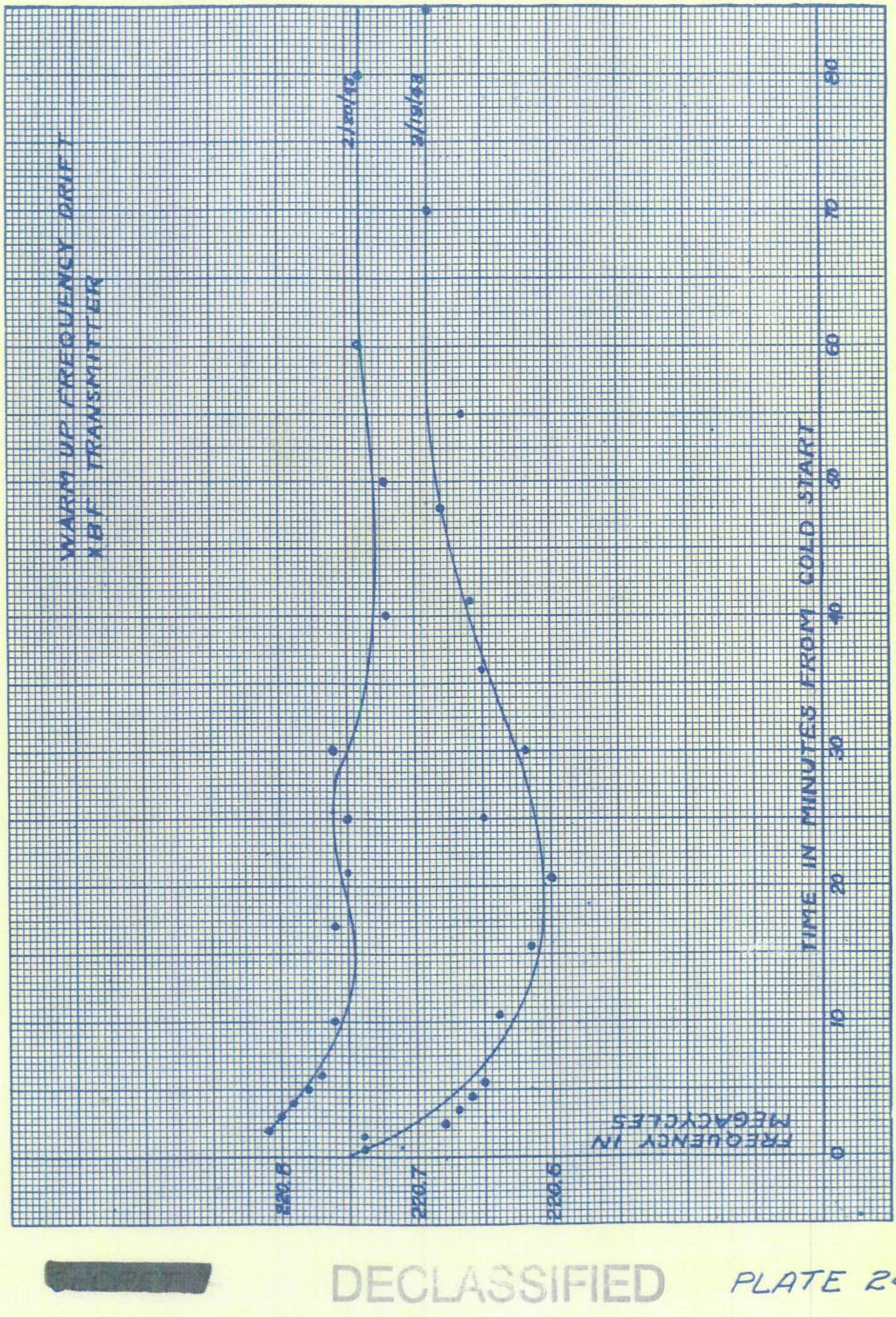
NAVAL RESEARCH LABORATORY
WASHINGTON 20, D. C.

TRANSM. CONTROL-REM UNIT
FOR
MODEL XBF EQUIP.
SCHEMATIC DIAGRAM

SCALE
DATE JULY 13 1943

[redacted]

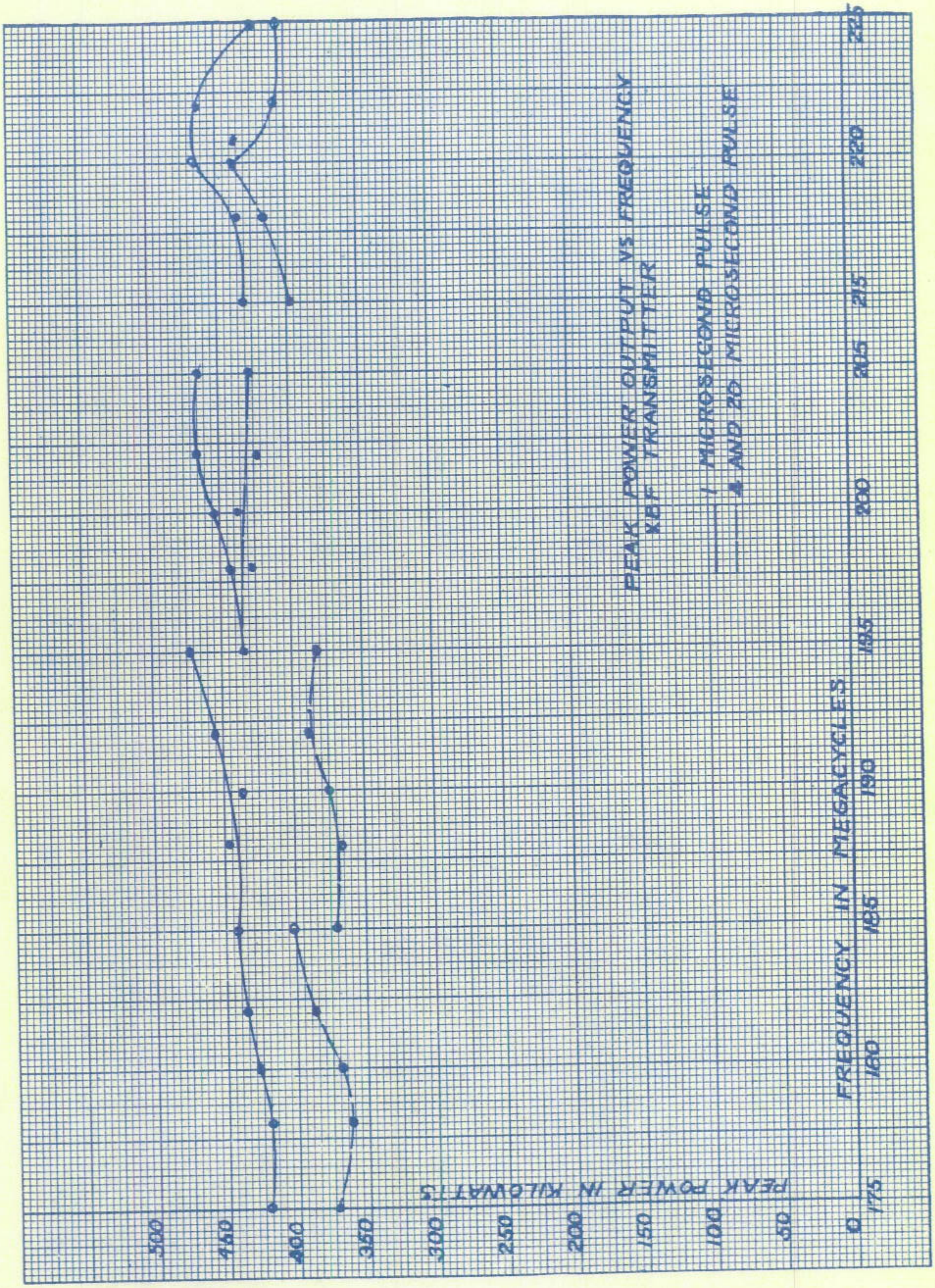
PLATE 23. RA 23A 256C



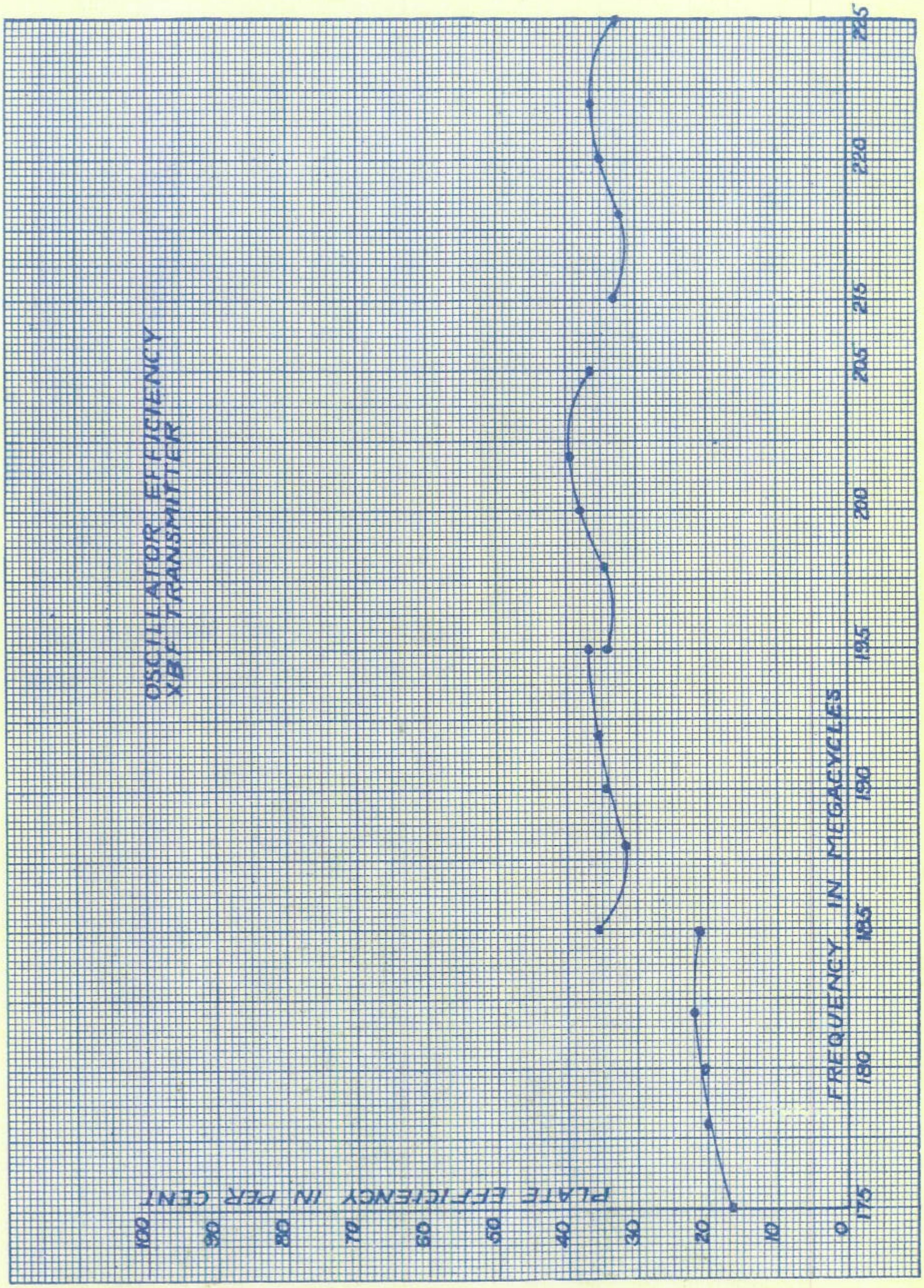
[redacted]

DECLASSIFIED

PLATE 24



[redacted] PLATE 25



[redacted]

PLATE 26

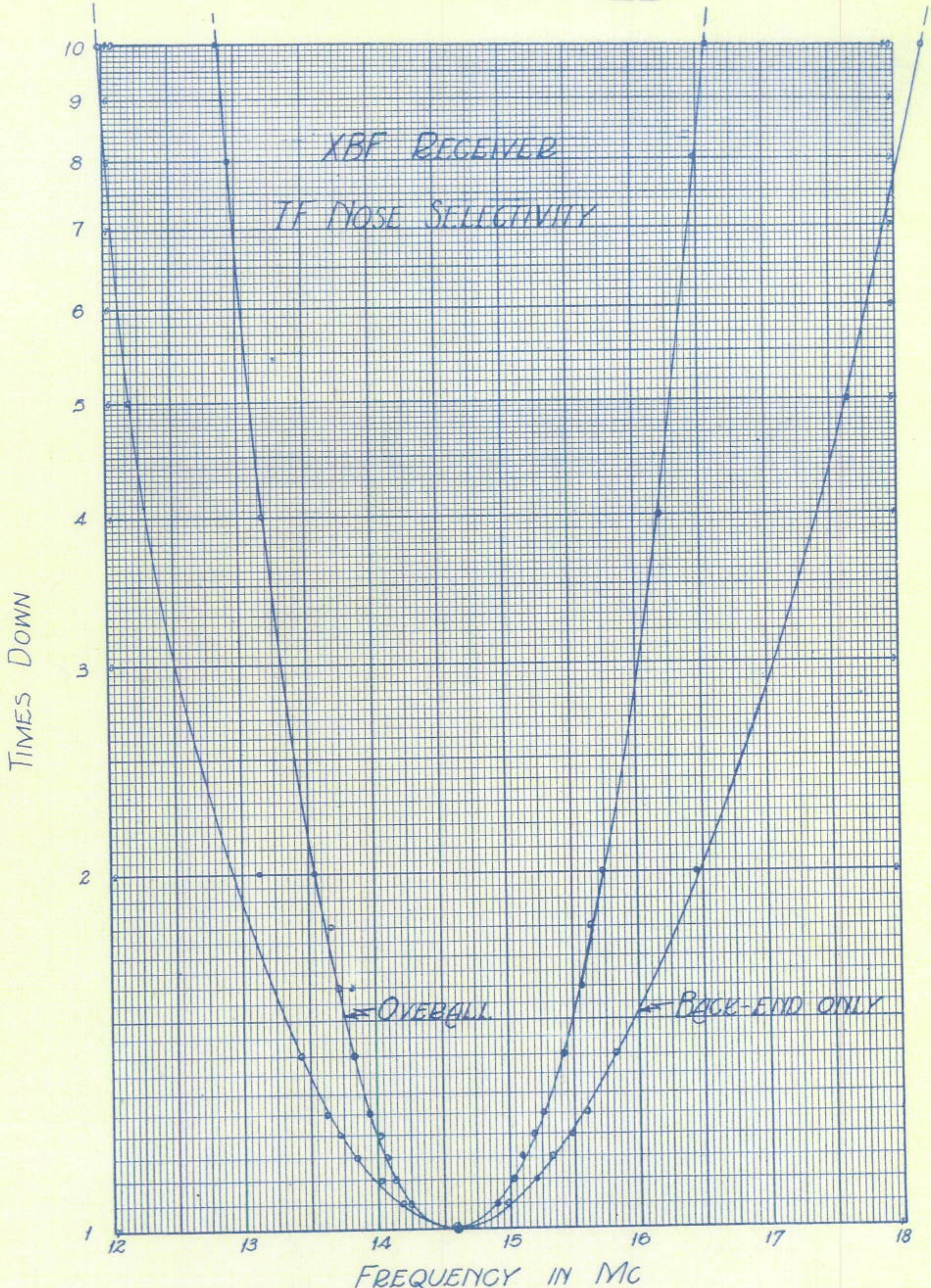
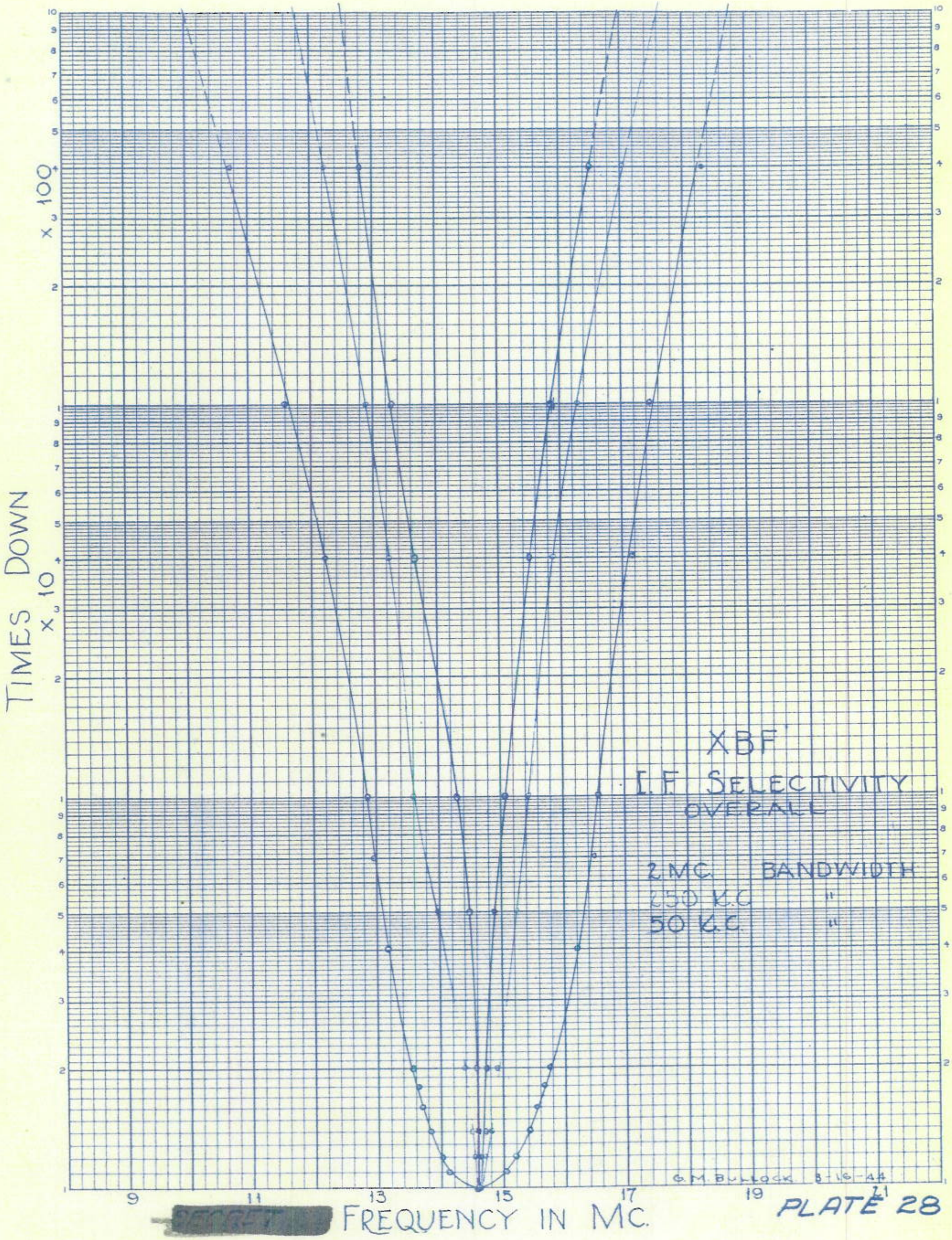


PLATE 27

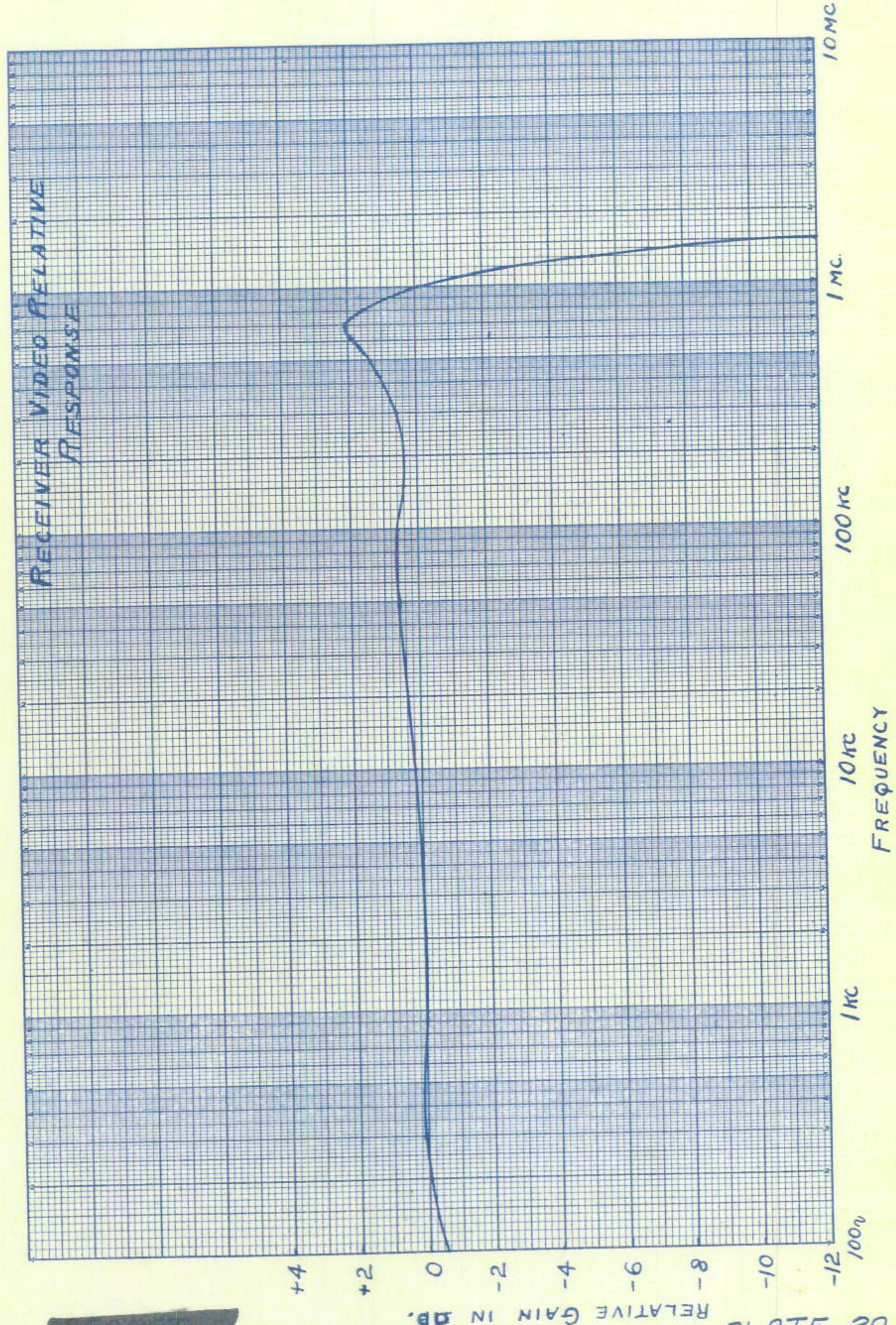
[redacted]

DECLASSIFIED



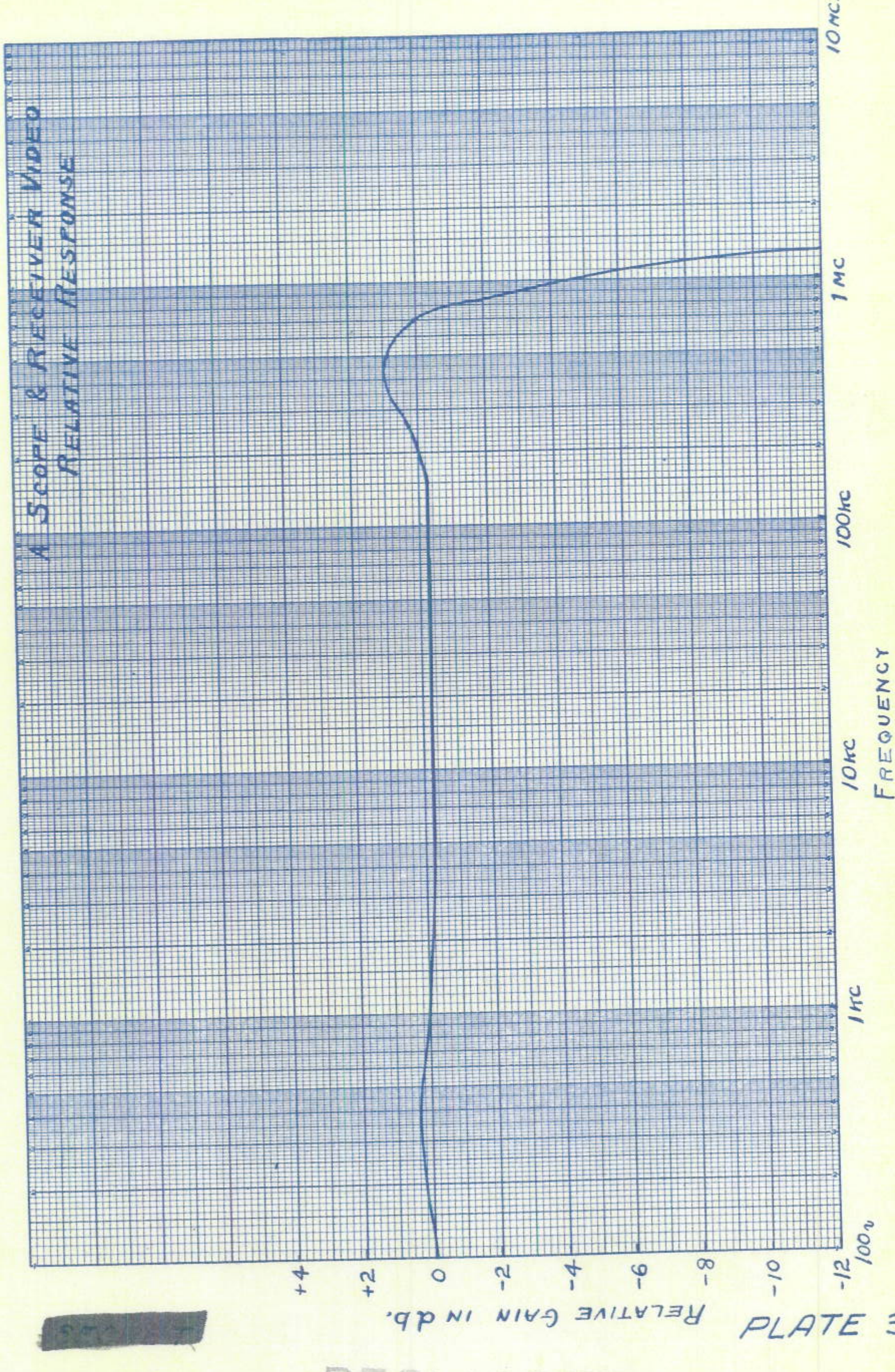
[redacted]

PLATE 28



[redacted]

PLATE 29



[redacted]

PLATE 30

DECLASSIFIED