Report No. R-2183



FR-2183

# REPORT NO. R-2183

DATE 20 November 1943



SUBJECT

Japanese Radar Equipment C.E.E. No. 211 Captured on Guadalcanal



NAVAL RESEARCH LABORATORY

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Navy Department

Report on

Japanese Radar Equipment

FR-2183

C.E.E. No. 211

Captured on Guadalcanal

Naval Research Laboratory

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Washington, D.C.

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1. INTRODUCTION.

As described in the letter of reference (b), the subject equipment was shipped from Guadalcanal to this laboratory for examination in September, 1942. The shipment was received November 11, 1942. Three essentially complete radar systems, all alike, were received. A photograph of the system as found on Guadalcanal is shown in Plate 1, and photographs of the system as set up at this laboratory are shown in Plates 2, 3, and 4. One system was put together from parts of the three systems received; tests of operational performance, electrical characteristics, and analyses of components were made. A preliminary report was made in the letter of reference (f), on 2 February, 1943.

1-1. Authorization. The tests of this equipment were directed and authorized by the Bureau of Ships letter of reference (a), assigning Problem X102C, priority A. This letter specifically requests that the susceptibility to standard forms of countermeasures be determined. This letter and additional references pertinent to this problem are listed below:

Ref. (a) BuShips ltr C-S67-5(920-T), Serial C-920-5111, dated 15 Dec. 1942, assigning Problem X102C.
Ref. (b) Secret ltr from COMGEN 1st MARDIV, 082/271, AE-0054, to COMSOPAC AREA and SOPAC FORCE, dated 8 Oct., 1942, forwarded to NRL with 1st Endorsement by COMSOPAC dated 21 Oct., 1942, S67, Serial 00929a.
Ref. (c) Conf ltr PAC 22 orf, S67 (1) from COMINCH Pacific Fleet to VCNO, dated 5 October 1942.
Ref. (d) Conf Enemy Materiel Report No. 75 from Headquarters, Allied Air Forces, South West Pacific Area, Directorate of Intelligence, dated 30 November, 1942.
Ref. (e) Secret ltr S-S67/36(370), Ser. 1039, from NRL to Chief of Naval Operations, dated 12 January 1943, enclosing preliminary description of Japanese Radar equipment.
Ref. (f) Secret ltr S-S67/36(370), Serial 1116, dated 2 Feb., 1943, from NRL to BuShips, reporting results of tests and examination to date.
Ref. (g) Translation of Captured Japanese Documents; Navy Dept. Intelligence Report Serial #52, issued April 26, 1943 by Intelligence Division, Office of CNO, Op-16-FE ONI. Monograph Index Guide No. 701-700. See also Appendix III of this (NRL) Report.
Ref. (h) Secret ltr S-S67-5/EF37(378), Serial 2039 from NRL to BuShips dated November 1943, Subject: Radar Countermeasures - Tests against Japanese Radar, C.E.E. No. 211.

[redacted]

2. OBJECT OF TESTS.

The object of these tests was to determine the capabilities of the subject radar equipment for detection and ranging, and also to determine its susceptibility to standard forms of countermeasures. Secondary objectives were determination of whether the Japanese equipment incorporated any novel or unusual features or components representing worthwhile advances in design, and the procurement of any intelligence information possible regarding the situation in Japan with respect to availability of critical materials.

3. ABSTRACT.

3-1. Preliminary Analysis. The Japanese radar equipment captured at Guadalcanal was set up at the Naval Research Laboratory after the various circuits had been traced out and diagrammed. Translation of nameplates and of the Japanese instruction book by ONI translators assisted in the analysis of the circuits and the determination of the proper functions of the various controls.

3-2. Laboratory Performance Tests. The transmitter power output was measured, and the receiver characteristics were ascertained by bench tests. During these tests the effect of various conventional types of jamming signals was determined for each of the two types of receivers.

3-3. Operational Performance Tests. An antenna was constructed according to data furnished on the original Japanese antenna, and the complete system was operated at the Naval Research Laboratory Chesapeake Bay Annex. Observations on ships, planes, and fixed land targets were made. Operational countermeasures tests were carried out at the Chesapeake Bay Annex, using both air-borne, ship-borne, and fixed or land-based jamming transmitters. The results of those countermeasures tests whose security classification would not permit inclusion in this report are reported in the letter of reference (h).

3-4. Tests of Component Parts. Component parts of particular interest were thoroughly investigated. The transmitting tubes were completely analyzed both as to construction and materials. The characteristics of the RE-3 receiving tubes and two types of cathode ray tubes were determined. Construction of a high voltage power supply filter capacitor whose size was remarkably small for its ratings was analyzed by an American manufacturer of similar type capacitors. Spectrochemical analysis of some of the metal parts was made by the National Bureau of Standards.

3-5. Disposition of Equipment. The equipment remains in operation at the Chesapeake Bay Annex, where it is available for use in whatever special tests may be desired by any branch of the armed forces.

[redacted]

4. CONCLUSIONS.

4-1. General Construction and Mechanical Design. The construction and workmanship of the Japanese Radar equipment as a whole is decidedly poor, and it was found that constant attention and nursing were required to maintain good performance, or even to keep the system in operation. Failure of components was frequent, and the lack of neatness in construction and wiring made servicing difficult. Apparently no attempt at simplicity of design was made; the pulse-generating, synchronizing, and monitoring circuits in particular are so complicated as to present a difficult maintenance problem. The equipment is very large and heavy, with no evidence of attempts to economize on material, and the general design is inferior. It is probable that many of the special devices used in our radar systems, such as duplexers, transmission line rotating joints, and the use of "synchro" motors and generators in antenna control systems had not yet been developed for radar use by the Japanese at the time this captured equipment was manufactured (first three months of 1942).

4-2. Performance. Performance of the system, though somewhat better than was expected from analysis of the individual units, was definitely mediocre and far from equal to that of the best U.S. Naval search radar equipment in existence at the time the capture was made. The transmitter power is far lower than that of U.S. equipment.

4-3. Transmitter. The transmitter, rated (according to the translated Japanese instructions) at 5 kw pulse power output, delivers this power only with very careful tuning and adjustment; the output under average or service adjustment would probably be on the order of 2.5 to 3 kw. Output power as high as 4.7 kw was obtained during the laboratory tests, but only with considerable difficulty. Stability is poor, adjustments critical, and spark-over frequent.

4-4. Receiver Type 29-17-2. Of the two receivers obtained with the equipment, that designated in this report as type 29-17-2 - apparently the original receiver designed as part of the subject equipment - is of conventional design, but construction is very poor. Sensitivity is 7 to 8 db less than that of the latest 200 mc receivers developed at the Naval Research Laboratory. The i.f. bandwidth is greater than necessary, so that the sensitivity of the receiver is not fully utilized. There are no anti-jam features.

4-5. Receiver Type NEC-NO-1736. The receiver designated NEC-NO-1736, a larger receiver of excellent mechanical construction, with some evidences of German design, is slightly less sensitive than the type 29-17-2. However, the bandwidth is somewhat less than that of the type 29-17-2, so that the performance is as good or better than that of the other type. This receiver likewise had no special anti-jam features, and r.f. jamming in conventional fashion was found to be quite effective. The dynamic range was found to be limited, definite i.f. overloading occurring at full gain with a 300 microvolt input signal. The stability of this receiver, however, is extremely good, as a result of perhaps excessive use of decoupling and shielding.

4-6. Antenna. Although the antenna for this equipment was not shipped to the Naval Research Laboratory, the information furnished regarding the original Japanese antenna allowed a practical duplicate to be built. The general design does not indicate familiarity with the most approved recent practices in this country. The one-quarter wavelength spacing of the radiators from the mesh reflector is not good design; the one-tenth wavelength spacing used quite generally in this country with non-resonant reflectors has proved better. No duplexing is used, necessitating separate antennas for transmitting and receiving. Instead of the antenna alone being rotated (which would require a rotary joint in the transmission line), the entire house containing the complete equipment, including antennas, was rotated by a 5 h.p. motor.

4-7. Vacuum Tube Types. The transmitting tubes, Japanese type TR-593-A, resemble closely the (American) G.E. types GL-8002 and GL-434, and are excellent tubes mechanically andelectrically, although not as well adapted to radar transmitting application as the latest special radar transmitting types used in U.S. Naval radar equipment. The German type RE-3 tube used in one of the receiver types was analyzed and found to be an excellent tube, though by no means extraordinary, for its use as a video and i.f. amplifier. The cathode ray tubes type SSE-75-G and SSE-120-G were analyzed and found to possess no unusual features. Other tube types used were closely similar or identical to standard U.S. types, with the exception of types 6302, VR-135-50, and DC-762. These types do not have any unusual features or characteristics, however.

4-8. Analysis of Components. The very compact power supply filter capacitor which occasioned much interest (rated 4 mfd., 15 kv D.C., in a container very much smaller than U.S. types of equivalent rating) was found to be, by U.S. standards, very much over-rated, and by no means superior (in fact, inferior) to capacitors manufactured in this country. The glass of some Japanese insulators was found to be closely similar to Corning #774 pyrex. Analysis of metals and alloys used in the transmitting tubes and other parts indicated that aluminum and copper were used liberally, indicating either a plentiful supply or willingness to use these materials unsparingly because the radar equipment may not then have been in sufficiently large production to warrant use of substitute materials.

[redacted]

## 5. DESCRIPTION OF JAPANESE RADAR EQUIPMENT.

5-1. Type Designation and Dates of Manufacture. The translated Japanese instruction book designates this equipment as "No. 1 Electric Wave Detector, Model 1 Transmitter". Three essentially complete systems were received. The individual units of the systems carried serial numbers and dates as follows:

No. 9 - January, 1942.
No. 29 - February, 1942.
No. 35 - March, 1942.

This equipment has been assigned Captured Enemy Equipment No. 211.

5-2. Installation. The photographs of Plates 5 through 14 show some of the units and spare parts as they were received at the Naval Research Laboratory in November 1942. Plates 2, 3, and 4 show the system as set up at the Chesapeake Bay Annex of this laboratory. In the actual installation on Guadalcanal, shown in Plate 1, the entire equipment was mounted in a house on a rotating mount. The antenna was mounted on the side of this house, and the whole assembly rotated as desired by a five horsepower electric motor.

5-3. General Characteristics. Characteristics of the equipment, as set forth in the instruction book, are as follows:

(a) Frequency range: 97-103 mc.
(b) Peak power output: 5 kw.
(c) Repetition rate: 1000 per sec.
(d) Pulse length: 20 microseconds.
(e) Range: 100 km.
(f) Power supply: 200 volts ($\pm$ 10%)
AC, 3 phase, 50-60 cycles, 4 kw.

Plate 15 is a block diagram of the equipment.

5-4. System Components. Each system consists of the following units:

(a) Synchronizing unit.
(b) Modulator unit.
(c) Transmitter.
(d) Video amplifier and sweep generator unit.
(e) Indicator unit.
(f) Monitor unit.
(g) Receiver.
(h) Antenna (not received at NRL).

5-5. Synchronizing Unit. The synchronizing oscillator is the controlling unit of the equipment. Plates 16 through 20 are photographs of this unit. The circuit is shown in Plates 21 and 22.

[redacted]

Plates 23, 24, and 25 show the oscillographic wave-forms at various points in the circuits. The heart of the unit is the 15 kc sine wave generator. The output of this generator (V301) is first "squared" (V305), then divided (V306 and V307) by use of the "blocking oscillator" type of counter circuit, which results in a 1 kc voltage. Outputs from this unit are as follows:

(a) 1 kc pulses for synchronizing main indicator sweep.
(b) 1 kc pulses for blanking main indicator return trace.
(c) 1 kc sawtooth voltage, to provide horizontal sweep for monitoring oscilloscopes.
(d) 1 kc pulses to synchronize the modulator unit (keyer).
(e) 15 kc pulses used as timing markers on the main indicator sweep.

5-5-1. Interconnections between this unit and the monitor unit (paragraph 5-10), sweep generator (paragraph 5-8), modulator (paragraph 5-6), and main indicator oscilloscope (paragraph 5-9) are made by means of the front panel jacks and patch cords shown in Plate 5.

5-6. Modulator. The modulator unit is shown in Plates 26 through 30, and the circuit diagram is given in Plate 31. This unit "keys", or pulses, the oscillator unit of the transmitter. The keying tube is a thyratron (Japanese type XC728A) which is triggered by a pulse derived from the synchronizing unit. The keying voltage, of about 500 volts amplitude, is developed across R32 in the cathode lead of the thyratron, and is applied to the grid-cathode circuit of the transmitter oscillator. The thyratron is extinguished by the action of the "quenching" capacitor (C28, 29), which is discharged between pulses by the bleeder R30, 31. Provision is made for switching in a spare thyratron. Since the failure of the last of the Japanese tubes of this type (XC728A), a Westinghouse type KU627 has been successfully used in this unit.

5-7. Transmitter. Plates 32 and 33 show the general construction and appearance of the transmitter, which is the largest and heaviest of the units.

5-7-1. Aluminum is used liberally in construction of the cabinet. The transmitter is contained in a cabinet by itself, and the transmitter power supplies in another. These two cabinets are bolted together to form a single unit, with power supply below and transmitter above (Plates 32 and 33). The r.f. circuits are diagrammed in Plate 34 and the power supply and control circuits in Plate 35.

5-7-2. The transmitter is a master-oscillator power-amplifier type, using 4 large air-cooled triodes in push-pull circuits. Copper is used almost wastefully in circuit construction.

[redacted]

The tube type is designated as TR-593-A by the Japanese, and a discussion of its characteristics will be found in paragraph 7-3.

5-7-3. The oscillator is of somewhat unique construction, as shown in the photograph of Plate 36. The oscillator unit is to the left of the vertical center shield panel. A "high Q" plate tank circuit, of the concentric line type with capacity loading, is employed. This is shown in detail in Plates 37 and 38. The filament circuit is tuned with a coil-condenser arrangement. The grids connect through series coil and condenser circuits to "ground" (actually to points on the outer can of the plate tank circuit); the d.c. grid return is to the output of the pulse modulator. The oscillator is operated at d.c. plate voltage of 2500 volts maximum, and is grid keyed with a pulse of 10 to 20 microseconds at a 1000 cycle repetition rate. The oscillator r.f. output circuit is capacity coupled to the amplifier grid circuit.

5-7-4. The r.f. amplifier, shown to the right of the shield panel in Plate 36, uses a push-pull circuit with the same tube type used in the oscillator. Grid and plate circuits are of the "linear" type, with copper tubes of about 7/8 inch diameter. Neutralization is accomplished in the customary manner using adjustable condensers. Grid and plate r.f. lines are tuned with variable capacitors and movable shorting bars. The output coupling is inductive; power is fed to the antenna by an open wire balanced transmission line.

5-7-5. The monitor pick-up unit, diagrammed in Plate 39, is a diode detector unit providing a video output pulse corresponding to the envelope of the transmitter output; this pulse is applied to the vertical deflector of one of the monitor cathode ray tubes (paragraph 5-10), contained in a small box in the lower right section of the amplifier compartment.

5-7-6. The power supply and control circuits occupy the entire lower half of the transmitter cabinet. Detail of the power supply is shown in Plates 40, 41, and 42. The transmitter power supply is a three-phase full-wave duplex rectifier with half voltage output for the oscillator and full voltage (about 5 kv) for the amplifier. A switch in the primary circuit allows selecting taps on the transformer primaries to give either full voltage output for the normal radar operation, or reduced (half) voltage output for operation during tune-up or other transmitter adjustment.

5-7-7. A second three-phase rectifier serves as bias supply; this supply uses only three instead of six rectifiers as in the transmitter plate supply. All rectifiers in these supplies are of the mercury vapor type, similar to the U.S. types 866 and 816.

5-7-8. All high-voltage circuits are protected with overload relays, with re-set buttons on the power supply panel. All important circuits are metered with three-inch panel type meters. A large blower for cooling mounts at the rear of the supply unit; air ducts distribute the air to the tubes, and a vane-operated switch cuts off the power supply when the blower is not operating.

5-7-9. A three phase induction voltage regulator, which operates automatically, is built into the transmitter power supply. The induction regulator is operated by a small three phase motor controlled by a contact-making voltmeter. This is a standard type of regulating system. The contact making voltmeter is shown in the photograph of Plate 41; it is the unit just to the right of center.

5-8. Video Amplifier and Sweep Generator. The video amplifier and sweep generator unit is shown in Plates 43, 44, and 45; and the circuit diagram is given in Plates 46 and 47. The video amplifier uses a pentode tube in a conventional circuit. The sweep generator is synchronized by a 1 kc pulse from the synchronizing oscillator unit; the pulse from this latter unit is coupled through a cathode-follower stage (V-1) to a blocking oscillator type of pulse generator (V-2). The pulse generated by V-2 is used to operate the sweep generator stage, V-3; this stage is arranged to give balanced output, which is amplified by a push-pull amplifier (V4 and V5). The wave-forms at various points in the sweep generator are diagrammed in Plate 48.

5-9. Main Indicator Oscilloscope. Plates 49, 50, and 51 are photographs of the indicator unit. The schematic circuit diagram is given in Plate 52.

5-9-1. The indicator uses a type SSE-120-G tube (screen diameter 120 mm). This tube is further discussed in paragraph 7-5. There are two optional types of display. One is the conventional type "A" display - linear horizontal time base sweeping from left to right, with echoes showing as vertical upward "pips" and range markers every 10 km in the form of downward pips. The second form of presentation utilizes the same time base, but the echo signals ("negative" pulses) are applied to the intensity control grid of the cathode ray tube; in addition, a ripple voltage taken from the power supply rectifier circuit is applied to the vertical deflectors, so that the horizontal trace is broadened to about 1/2 inch. The echo signals appear as vertical dark lines on the trace. This type of presentation is interesting, but seems to offer no particular advantage over the more conventional type "A" display; in fact, the latter has been found to allow detection of weaker signals.

5-9-2. The main indicator oscilloscope unit contains only the cathode ray tube, its high voltage power supply, and the focus and intensity controls. Sweep circuits, centering controls, and video amplifiers are contained in the separate unit described in paragraph 5-8. Front panel jacks and patch cords allow interconnection with this unit and with the synchronizing unit (range

[redacted]

marker pulses). A silicon steel magnetic-electrostatic shield encloses a portion of the tube (see paragraph 7-8-1 (k) ).

5-9-3. A glass range scale is fastened in front of the tube screen; this is seen in the photograph of Plate 49. The scale is calibrated to 100 km in 10 km steps. The length of the time base may be adjusted to fit this scale by means of the centering, sweep amplitude and phasing controls. The range marker pips may be aligned with the scale marks by adjustment of these controls. The markers may be removed by pulling out the proper patch cord, although it is possible to apply the range markers and video echo signals simultaneously. The range determination accuracy possible with this unit is rather poor - probably about plus or minus 1 km. This degree of accuracy is sufficient for early warning or search use, but not for most effective fighter direction. There is no built-in range calibration equipment, and if the 15 kc master synchronizing oscillator should be appreciably off-frequency, the ranging would be in error by a proportionate amount.

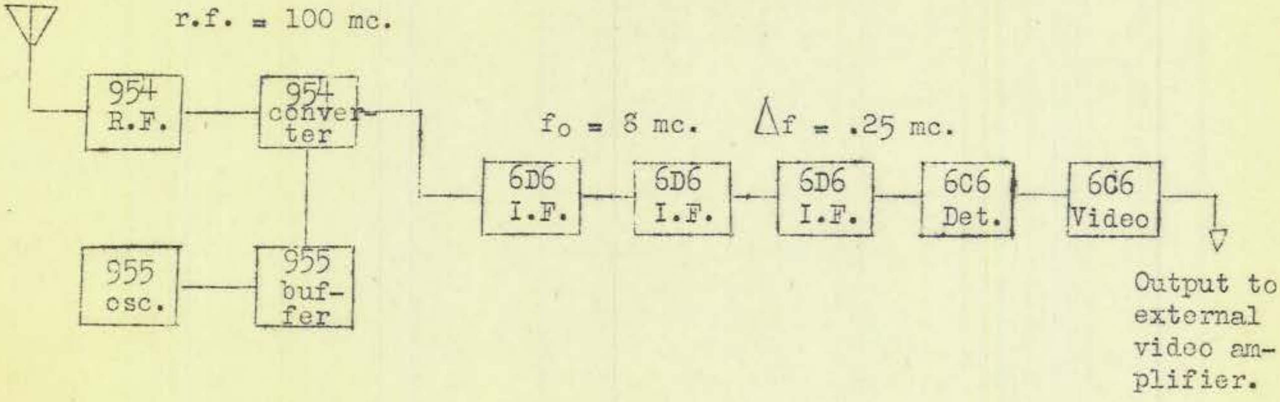
5-9-4. The high voltage power supply for the tube is of conventional half-wave type with resistance capacity filter. The rectifier tube type DC-762-A is similar to the type 879 (2X2) used in this country.

5-10. Monitor. The monitor unit is shown in Plates 53 thru 55. This unit uses four 3 inch cathode ray tubes, Japanese type SSE-75-G. These tubes are almost identical with the American type 906 (3AP1). The circuit of the monitor unit is given in Plates 56 and 57. The horizontal deflectors are all provided with a 1 kc sawtooth time base voltage by V201 of the synchronizing unit. The four vertical deflectors receive voltages from receiver video output, transmitter r.f. monitor pick-up (paragraph 5-7-5), modulator output pulse, and range marker pulses. The modulator synchronizing pulse is also applied to the monitor scope along with the range markers, these two voltages being mixed in the plate circuits of V5 and V6, Plate 21. The video voltage from the receiver output is amplified by V2 and V3.

5-10-1. Proper adjustment of focusing, intensity, and spot centering of the four cathode ray tubes has been found to be very difficult, since adjustment of the controls for any one of the four tubes affects the voltages on all the other tubes, and the voltages all require readjustment as the equipment warms up. For this reason the value of the monitoring unit has been slight.

5-11. Radar Receiver Type 29-17-2. Of the two different types of radar receivers captured on Guadalcanal, the smaller, designated in the translated instruction book (reference (g), Enc. A) as "Mark I, Mod. 1," seems to be the one originally designed as a unit of the "No. 1 Electric Wave Detector" (see paragraph 7-9-1). This receiver, shown in the photographs of Plates 58 through 63, is referred to in this report as type 29-17-2, a number found on one of the nameplates.

5-11-1. Plate 64 is a schematic circuit diagram of this receiver. A block diagram of the circuit is given below:




The tuning range is 87 to 105 mc. The antenna coil is arranged for balanced input line. The acorn tubes used in the high frequency stages, designated type UN-954 and UN-955, are of Japanese manufacture, but are exact duplicates of the types 954 and 955 used in this country, except that certain constructional features seem to be copied after the very earliest tubes of this type. The types 6C6 and 6D6 are likewise duplicates of the American tubes of the same type numbers.

5-11-2. The high frequency circuits are of conventional design, except for the 954 buffer stage which reduces reaction on the oscillator frequency by strong input signals.

5-11-3. The intermediate frequency amplifier is also conventional in design except for the rather elaborate decoupling networks in the plate and screen grid return leads. The intermediate frequency is approximately 8 mc, and the bandwidth is 250 kc.

5-11-4. The second detector is of the square-law type using a 6C6 "sharp cut-off" type pentode. Another 6C6 following the second detector is used as a triode-connected video amplifier. There are three output leads; one is for headphones, one is marked "1000 ohm" and the third is marked "100 ohm". The output is fed into the video amplifier and sweep generator unit described in paragraph 5-8; this unit contains an additional stage of video amplification. The plate and filament power for the receiver are supplied from a separate unit.

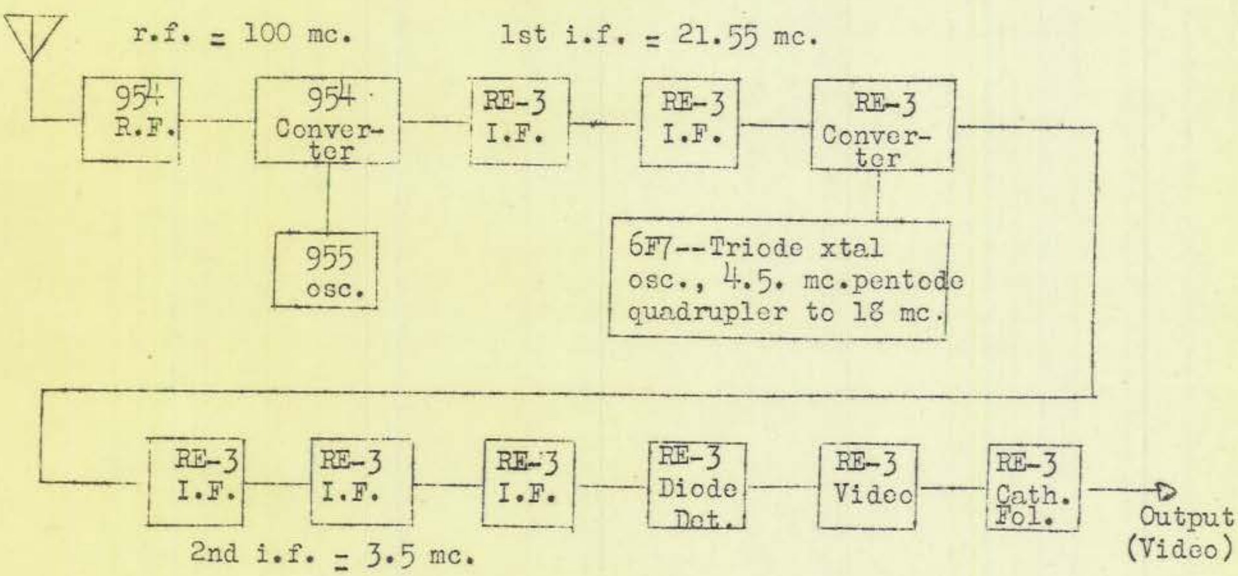
5-11-5. The design of this receiver is entirely conventional, but the wiring and circuit construction are poor. The sensitivity is fair. The results of sensitivity measurements and

[redacted]

other tests of the characteristics of this receiver are given in paragraph 7-2.

5-12. Radar Receiver Type NEC-NO-1736. This is the larger of the two radar receiver types. The construction is shown in the photographs of Plates 65 through 72. The design and workmanship are superior to those of the smaller receiver. It is believed that this receiver may be of German design, although there has been some difference of opinion among observers. The type RE-3 tubes used in the intermediate frequency and video amplifiers are a German type. Engineers familiar with German components have recognized condensers and resistors as being German types. However, the acorn type tubes in the radio frequency stages are Japanese copies of the American acorn tubes, and the receiver was evidently manufactured by the Nippon Electric Company (NEC). Two Australian engineers who visited this laboratory en route from England stated that the Germans would have designed the receiver more compactly.

5-12-1. Plate 73 is the schematic circuit diagram of the receiver, and Plate 74 is a list of the components values. The Japanese characters of this list refer to the manufacturer's type designation. The circuit is of the double superheterodyne type. A block diagram showing tube types used and frequency conversions is given below:




The tuning range is 89 to 116 mc. The type RE-3 tube is used in all except the radio frequency stages and the second local oscillator stage. This tube is connected for pentode, triode, or diode operation as required. The practice of using this single tube

[redacted]

type for all classes of service is typically German. The characteristics of this tube as a pentode are reported in paragraph 7-4.

5-12-2. The radio frequency circuits, using the acorn tube types are of conventional design. Separate controls are used for tuning the radio frequency amplifier, converter, and high frequency oscillator. The converter is followed by two stages of amplification at 21.5 mc. The second local oscillator uses the dual type 6F7 triode-pentode (an American type used in some broadcast and "short-wave" receivers in the period of about 1935 to 1937). The triode section of this tube is used as a crystal oscillator at approximately 4.5 mc. The milliammeter seen on the receiver front panel (Plate 65) is in the crystal oscillator plate circuit. The pentode section acts as a frequency quadrupler to provide a signal at 18 mc for heterodyning with the first i.f. signal. This is mixed with the 21.5 mc signal to give the second i.f. frequency of 3.5 mc. There are three stages of amplification at this frequency, followed by the detector, a diode-connected RE-3. This is followed by a pentode RE-3 video amplifier and a triode-connected RE-3 cathode follower. Two output terminals are provided, as shown at the lower left corner of Plate 73. The power supply is a separate unit.

5-12-3. Measurements of the receiver characteristics and susceptibility to standard forms of jamming signals were made and are reported in paragraph 7-2. The sensitivity is slightly less than that of the smaller receiver (type 29-17-2). The stability is excellent, as a result of the almost excessive use of decoupling and shielding. The unit-type construction allows removal and replacement of a complete i.f. unit, local oscillator unit, or video unit without disturbing any of the other units. This feature would allow quick resumption of operation in case of local circuit failure, if spare units were available. The radio frequency section is of plug-in type. It is shown partially withdrawn in the photograph of Plate 67, and completely removed in Plate 68. This feature may indicate that r.f. units for other frequency ranges may be used with the same basic receiver, although no such units were found on Guadalcanal.

5-13. Antenna. The antenna was not shipped from Guadalcanal, but a sufficiently complete description of it was provided so that it was possible to set up an equivalent structure at this laboratory. This description was provided in the report of reference (d), and in Enclosure B, of reference (b).

5-13-1. The antenna constructed at this laboratory is shown in Plates 3 and 4. It consists of two complete Sterba arrays, each five half-waves long, horizontally polarized, placed in front of a mesh reflecting screen. The upper array is used for transmitting, the lower for receiving. The arrays are each center fed, with balanced transmission line. The upper array is fed with an open wire line of about 400 ohms impedance. The lower array feeds a balanced shielded line of about 100 ohms impedance. The electrical diagram of one of the arrays is given in Plate 75, which is a reproduction of Enclosure B of reference (b).

5-13-2. It is calculated that the horizontal beam-width of this antenna is about 18 degrees, with a secondary lobe of about 25 percent at 33 degrees, and one of about 10 percent at 65 degrees. The power gain is calculated to be about 15 db over an isotrope. The measured horizontal beam-width of the antenna shown in Plates 3 and 4 is 23.0 degrees. Plate 75A is a plot of the measured horizontal pattern. The following are given in the report of reference (b) as the characteristics of the antenna; these were stated to have been obtained by analysis of Japanese blueprints captured on Guadalcanal:

Antenna lobe 20 degrees horizontal.
Antenna lobe 15 degrees vertical
Side lobe at 90 degrees and 45 degrees.
Antenna 5.5 meters high by 8.0 meters wide,
(18 ft. by 26 ft.)
Five half-waves bays located one-quarter wave in front of screen.
Two wire feed to transmitter.
Receiving antenna identical located one-half wavelength below.

It is noted that the side lobe angles here given differ considerably from those calculated at this laboratory, and the vertical beam width-given is much sharper than would be expected from the antenna design. The figure given for the horizontal directivity is in good agreement with the value calculated at this laboratory, however.

5-13-3. The spacing between the elements of the arrays and the screen reflector is one-quarter wavelength, instead of one-tenth wavelength, which in this country has been demonstrated to give better results.

5-13-4. The use of two separate arrays indicates ignorance of the practicability of employing a duplexing device to make possible the use of a single antenna for transmitting and receiving.

## 6. RADAR PERFORMANCE TESTS.

These tests were made at the Chesapeake Bay Annex of this laboratory, where the antenna described in paragraph 5-13 was operated on a Mark XI mount. This location overlooks a 10 mile wide section of Chesapeake Bay, so that propagation conditions are comparable to those at sea or at a coastal location. The antenna

[redacted]

height above the water level at this location is approximately 120 feet; it was necessary to place the antenna about 60 feet back from the edge of the cliff, as shown in the diagram of Plate 76. It is probable, however, that there was little or no ground-reflected interference for targets out beyond two or three miles. Because of the pulse length of the equipment it is not possible to detect objects at much closer than two miles. The type NEC-NO-1736 receiver was used during these tests because the operation of the type 29-17-2 receiver was erratic and unstable.

6-1. Aircraft Targets. Tests on aircraft targets have not been as extensive as might be desired; controlled tests were confined to observations of a single Navy type SBD flying at various altitudes. Further data has been obtained from random observations on miscellaneous aircraft. The SBD, a single engined two-place carrier-type scout bomber, was tracked to distances as tabulated below (nautical miles):

| Altitude | Max. Range (Average) |
| --- | --- |
| 200 ft. | $7\frac{1}{2}$ miles |
| 1000 ft. | 16 miles |
| 5000 ft. | 16 miles |
| 10000 ft. | 17 miles |

Observations on random aircraft have been recorded consistently at ranges out to about 30 to 35 miles, and occasionally to from 50 to 65 miles. The plane types and altitudes in these cases were not known. The Navy type SC-2 radar at this location consistently detects planes at 70 miles.

6-2. Surface Craft. Random observations on freighters have been made at ranges out to between 6 and 7 miles. The Baltimore to Norfolk passenger boat was tracked to 6 miles; at the same time, this boat was followed to 9 miles on the U.S. Navy type SC-2 200 mc radar equipment. The SC-2 normally will range this boat to about 12 miles, indicating that propagation conditions may have been poor at the time of this test. The SC-2 has a pulse power of about 150 kw, and a receiver 3 to 5 db better than the Japanese receivers. The SC-2 antenna has 12 dipole elements whereas the Japanese antenna has 10 elements (see paragraph 5-13); the SC-2 is 2 elements high by 6 wide. Both antennas have horizontal polarization. The higher frequency of the SC-2 gives it a fundamental advantage over the Japanese radar for detection of surface targets.

6-2-1. Tests were made to determine whether landing barges of about 105 ft. size (Navy type LCT) could be detected with the Japanese radar. With the barge out beyond the "minimum observable range", no echo was seen. With the barge at about two mile range, a slight flutter was observed at the right edge of the transmitter pulse, but this range is too close to allow an echo to be seen as distinctly separate from the transmitter pulse. These

[redacted]

same barges were followed out to 5 nautical miles on the SC-2.

6-2-2. The height of the antenna location has an important effect on detection range for surface targets; the maximum detectable range will vary as the square root of the antenna height, for short ranges at which the effect of the earth's curvature is not important. Therefore the surface target ranges given in this report should be corrected to take into consideration the antenna height at any specified enemy location.

6-3. Fixed Land Targets. Two landmarks are frequently used as "standard" targets for determining radar performance at the Chesapeake Bay Annex. These are the Annapolis radio towers, at a range of about 20 miles, and Sharp's Island lighthouse, range about 7 miles. The former target gives a saturation echo on the SC-2 radar, with receiver noise just showing, and the latter gives an echo with about 5 or 6 to 1 signal to noise ratio. Neither of these targets are detectable with the Japanese radar equipment.

6-4. Operational Countermeasures Tests. Because of the security classification of the results of operational tests of actual countermeasures against the Japanese radar, they are not included in this report, but are fully reported in the letter of reference (h).

## 7. TESTS OF UNITS AND COMPONENTS.

The following units and components of the Japanese radar equipment were specifically examined and tested:

(a) Transmitter.
(b) Receivers (2 types).
(c) Transmitter tubes, type TR-593A.
(d) Receiver tubes, type RE-3.
(e) Cathode ray tubes, types SSE-75-G and SSE-120-G.
(f) High voltage filter condenser.
(g) Glass stand-off insulator.
(h) Metal parts (spectrochemical analysis).

7-1. Transmitter Power. The pulse power output of the transmitter was determined by measuring the average power output, using a dummy load, and dividing the figure obtained by the product of pulse length (seconds) and repetition rate (pulses per second).

7-1-1. The dummy load used was a high-vacuum lamp of a low r.f. loss type especially constructed at this laboratory for r.f. power measurement. A photronic cell and microammeter combination was used in conjunction with the lamp, and a power calibration of the microammeter was made by energizing the lamp with 60 cycle power measured by a precision wattmeter. The lamp was then incorporated in a tuned circuit which was coupled to the transmitter

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output circuit, in the same manner used for coupling the antenna transmission line. The coupling was adjusted for maximum output, the various tuning controls being readjusted as necessary during the process.

7-1-2. The product of pulse length by repetition rate (duty cycle) was measured directly by employing an instrument (duty cyclemeter) designed at this laboratory for that purpose, in connection with the measurement of power output of experimental transmitters. This instrument contains an r.f. detector (diode), a video amplifier, and an electronic circuit by means of which the duty cycle is indicated by the reading of a microammeter. The accuracy of this instrument has been checked against measurements of pulse length and repetition rate by direct methods, and the probable error found to be on the order of 5 percent or less.

7-1-3. Using these methods of measurement, a maximum pulse power output of 4.7 kw was obtained, but only by very careful adjustment. Operation at this output level is unstable, adjustments are critical, and flash-over is frequent. It is probable that the output under usual operating conditions is not more than 2.5 to 3 kw.

7-2. Receiver Characteristics. Measurements were made in the laboratory to determine the sensitivity, selectivity, and other characteristics of the two receiver types described in paragraphs 5-11 and 5-12.

7-2-1. Curves plotted from data taken during these measurements are reproduced as Plates 77 through 84. In addition to sensitivity and bandwidth, those characteristics which are important in determining the effect of radar jamming signals were measured.

7-2-2. The bandwidth, or selectivity, of the type NEC-NO-1736 receiver, is given by the curves of Plates 78 through 81. It was found that the overall i.f. response was "double humped", as shown in Plate 80. Apparently the selectivity of the r.f. stages is appreciable, since the receiver's overall bandwidth depends on whether the r.f. circuits are tuned to the "center" of the i.f. response or to one of the "humps". Plate 78 gives the overall bandwidth for the former condition, while Plate 78 is for the latter condition. Tuning the r.f. section to one of the "humps" of the i.f. response gives the greatest receiver sensitivity, and hence represents the way the receiver would most likely be tuned in actual service. The bandwidth is thus 0.17 mc. This represents the frequency difference between points 3 db up on the response curve (since these curves represent input voltage for constant output instead of vice versa). The bandwidth of the type 29-17-2 receiver, measured in the same way, was 0.25 mc. The i.f. response was not "double humped", however.

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7-2-3. The sensitivity was determined by the method indicated in Plate 77, which is data taken on the type NEC-NO-1736 receiver (paragraph 5-12). $E_n$ is the "equivalent noise voltage", found by measuring the voltage of the cw input signal required to increase the receiver power output to twice that obtained with no signal input (i.e., that due to the receiver and antenna noise alone). The value of $E_n$ divided by the square root of the band-width gives the noise voltage per megacycle. For a perfect receiver, this figure would be 0.55 microvolts per megacycle, for 70 ohm impedance. The ratio of the figure actually obtained to this ideal figure is called the "noise factor", and is customarily used as a means of rating the sensitivity of a receiver. This figure for the type NEC-NO-1736 is found to be 19.5 db with the r.f. section tuned for "broad-band" operation, and 18.3 db for the "narrow band" condition. The figure for the type 29-17-2 receiver is 13.7 db, although instability of this receiver made accurate measurement difficult. This noise factor is about equal to that of U.S. Navy 200 mc radar receivers in use at approximately the time the Japanese equipment was captured (Navy type SC). These U.S. Navy receivers used the same acorn tube types, but the design is actually superior to that of the Japanese receiver since with the same tubes it should be possible to obtain a lower noise factor at the lower frequency of the Japanese radar. The noise factor of the more recent U.S. Navy 200 mc receivers, using improved tubes and circuits, is 7 to 8 db better than the more sensitive of the Japanese receivers.

7-2-4. The image rejection ratio of both receivers was found to be approximately 80 db.

7-2-5. Plate 82 is a set of curves showing the overload characteristics of the i.f. amplifiers of the type NEC-NO-1736 receiver, for various conditions of tuning and i.f. gain. Complete overload occurs at 300 microvolts input (last i.f. tube blocks). The type 29-17-2 receiver i.f. overloads with 500 microvolts input, the second detector blocking in this case.

7-2-6. The modulated r.f. input voltage required to block the video amplifier was 20 microvolts for the type NEC-NO-1736 receiver, and 25 microvolts for the type 29-17-2.

7-2-7. The behavior of the two receivers with conventional types of jamming signals is given by the curves of Plates 83 and 84. The data for these curves was obtained by using two signal generators whose mixed output was fed into the receiver. One generator was pulse modulated, to provide an artificial "echo" signal, and the other was modulated or operated "c.w." as an artificial jammer. The value of jamming signal voltage to echo signal voltage required for effective jamming was determined; this ratio, termed the "dynamic range", is plotted as a function of the artificial echo signal voltage. As would be expected, this ratio is greatest for a cw jamming signal and least for a "noise" modulated

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signal. The values of these ratios allow calculation of how much power a jamming transmitter must have in order to effectively jam these receivers, for assumed values of echo signal input, distance between jammer and radar, antenna elevations, and other similar arbitrary conditions.

7-3. Transmitting Tubes, Type TR-593-A. The construction of the Japanese transmitting tubes, type TR-593-A, is shown in plates 85 through 89. The tube is a forced-air cooled triode, and is used both as an r.f. oscillator and as r.f. power amplifier.

7-3-1. The static tests conducted on this tube were made with the filament operated at 7.5 volts. The results of the measurements are given in Table 1. The average filament heating current is 16 amperes. The filament emission current obtained with a plate potential of 4000 volts is about 9 amperes. The grid emission current is not high enough to cause any operating difficulties in circuits using this type tube. The cut-off ratio (cor) is about 12. This is measured as the ratio of plate voltage to grid bias voltage for one milliampere of plate current (Plate potential 3000 volts).

7-3-2. The interelectrode capacitances of the tube were measured by a substitution method at a frequency of 500 kilocycles per second. The average capacitances are:

| | |
|---|---|
| Grid to plate | 5.6 mmfd. |
| Grid to filament | 7.92 mmfd. |
| Plate to filament | 0.87 mmfd. |

Table 2 lists the results of capacitance measurements on four samples chosen at random.

7-3-3. The following specifications for the tube were translated from the instruction book:

Type forced-air-cooled three element tube
$E_f$ 7.5 V.A.C.
$I_f$ 16.0 A
$E_p$ 4500 V (max. 5000 V.)
Amp. factor 16
Transconductance 4000 micromhos
Output 1000 watts

From the static characteristic curves, shown in Plate 90, the following information was obtained:

| | |
|---|---|
| Amplification factor | - 17 |
| Plate resistance | - 6000 ohm for operation at $E_p = 3000$ v. $I_g = -170$ V. |
| Transconductance | - 2750 micromhos for $E_p = 3000$ V $E_g = -170$ V |

[redacted]

7-3-4. The filament temperatures of four tubes were measured by the use of an optical pyrometer:

| Tube Serial | Temperature (degrees centigrade) |
|---|---|
| 3473 | 1377 |
| 2897 | 1498 |
| 2931 | 1492 |
| 3612 | 1417 |

This measurement is slightly lower than the actual temperature because of the absorption of the radiation by the glass envelope.

7-3-5. The TR-593-A characteristics were compared with those of several American tube types. It was found to closely resemble the General Electric Company tube type GL-8002. The comparison of electrical and physical dimensions are shown in Table 3.

7-3-6. The tube is constructed very well and is mechanically rigid. Most of the welds on the internal structure are spot welds of good quality. The only defective work on the tube was some faulty butt welds on the tube leads. Several of these came apart with little applied force. Plates 85, 86, 87, 88, and 89 illustrate the dimensions and construction of the tube. Some miscellaneous observations are listed in Table 4.

7-3-7. Plate 87 illustrates the probable procedure used in assembling the tube. The following discussion is based upon experience in the construction of similar American tubes. The tube was sealed with a regular type Housekeeper seal. The Housekeeper copper-sleeve was beaded with nonex glass (similar to Corning #772) on the inside only, then a nonex 50 mm tube was sealed to it. A moulded nonex base, with the tube elements sealed in place, was set on the copper glass assembly and machine sealed to it. A friction fit copper shield was attached to cover the inside of the copper to glass seal. The tube was then put on the pumps and sealed off. The plate end of the tube was tinned with soft (lead-tin) solder. The radiating fins were machined from a cast block. A copper sleeve was probably shrink-fitted to the fins, then held in position by the use of a lock pin. The inside of the sleeve was tinned so that a good electrical and thermal contact could be made when the tube was warmed to melt the solder and set in place in the copper sleeve. The exposed metal of the copper to glass seal was covered with black lacquer. The draw handles used on the tubes were of various designs. Some handles were screwed in place and the bent ends coupled with sleeves on one tube, another type had "u" bend handles fastened by brass cross pins in the radiator.

7-3-8. This tube is excellent both mechanically and electrically for applications in which high values of pulse powers are not necessary - i.e., for high duty cycle service. However,

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its performance as a radar transmitting tube does not approach that of the latest radar transmitting tube types now manufactured in this country. The reasons are indicated in paragraphs 7-3-1 and 7-3-4; the filament temperature, and hence the emission per watt of filament power are definitely "conservative".

7-4. Receiving Tubes, Type RE-3. The type RE-3 tubes used in the video and i.f. circuits of the larger receiver (type NEC-NO-1736; see paragraph 5-12) were examined, and characteristics of a pair of samples were determined. Plate 91 is a photograph of the tube. It is a pentode type with 6.3 volt heater; all grids are brought out to terminals. The control grid terminal is the "end cap". The pin terminals at the other end of the tube are heater, cathode, screen grid, suppressor grid, and plate. These are supported in a brown phenolic insulating material which appears to be of good quality; it is probably "low loss" for frequencies up to about 50 megacycles.

7-4-1. The tube is normally operated in an "inverted" position, with the grid cap down. The small knob on which the tube in the center of the photograph (Plate 91) rests is used as a handle for insertion and removal of the tube.

7-4-2. The measured characteristics of samples of the RE-3 are given in the curves of Plates 92 thru 96. The maximum transconductance of the samples averaged about 2000 micromhos. Some of the samples differ quite markedly in actual characteristics, as will be noted from inspection of the curves.

7-4-3. The tube capacities were measured and found to have approximate average values as follows:

$C_o$ (Plate to all other electrodes) - 3.4 mmfd.
$C_i$ (Grid to all other electrodes) - 4.1 mmfd.

These capacitances are quite low, considering the transconductance value.

7-4-4. This tube is very well suited to its use as a video and i.f. amplifier. In size it is intermediate between the U.S."acorn" types and the standard "G" or "GT" glass tubes. The transconductance is high, though not so high as that of the U.S. types 6AC7 and 6AG7 (9000 and 7000 micromhos, respectively), which are commonly used as video amplifiers. The transconductance of the RE-3 is, on the other hand, higher than that of the acorn pentode types 954 ($G_m$ = 1400) and 956 ($G_m$ = 1800). Actually there is no U.S. standard tube type with characteristics closely similar to those of the RE-3, and the physical outline of this tube, and its type of base and socket, are quite radically different from standard U.S. types.

7-5. Cathode Ray Tubes. The two types of cathode ray tubes used in the Japanese radar equipment were examined and characteristics determined. The types are designated SSE-75G and SSE-120G. The type numbers apparently refer to the diameter of the screen in millimeters. The type SSE-75G is very similar to the U.S. type 3AP1 (formerly type 906; screen diameter 3 inches). The SSE-120G is not similar to any U.S. type. Plate 97 is a photograph of these tubes.

7-5-1. The data obtained in tests of two samples of the SSE-75G is given in Table 5. The markings indicating "satisfactory" characteristics, or "failure to comply with specifications" refer to specified characteristics of the U.S. type 3AP1.

7-5-2. Only one sample of the SSE-120G was available for tests; the data on this sample is given in Table 6. Designations "satisfactory" or "failure to comply with specifications" refer to specified characteristics of the U.S. type 5BP1. Deflection sensitivity of this tube is low compared to that of the 5BP1, and the position of the spot with deflector plate leads open is excessively off center, indicating poor "gun" construction. This tube has a screen of approximately $4\frac{1}{2}$ inches diameter (120 mm), and has a five pin base. There are also five cap terminals on the neck of the bulb, and the four deflecting plates and second anode are brought out to these terminals. This tube is used in the main indicator unit (paragraph 5-9). The screen is of the medium persistence type with green fluorescence.

7-6. High Voltage Filter Condenser. A high voltage filter condenser which was much smaller in size than American condensers of the same rating was analyzed by the Insulation Research Section, Pittsfield Works Laboratory, of the General Electric Company. The results of this analysis are contained in the General Electric Company's confidential data folder No. 65126, dated 27 January, 1943. A discussion of the results of the analysis is contained in a letter of 25 February 1943, from Mr. L.E. Gregory, Capacitor Section, General Electric Company. Copies of these documents are attached to this report as Appendix I.

7-6-1. As noted in Appendix I, the voltage rating of the Japanese capacitor was considerably greater than it would have been by U.S. standards; the materials used in its construction were inferior, and in fact the total volume occupied was not used efficiently. A condenser designed according to best U.S.A. practice and using the same stress per unit thickness of dielectric would have up to 62% greater capacity for the same volume.

7-7. Glass Radio-Frequency Stand-Off Insulators. A large number of cylindrical glass stand-off insulators, of about one inch diameter and in lengths of about 3 inches were used as supports for the antenna elements. Similar but larger insulators were used in the radio frequency circuits of the transmitter. The glass from one of these insulators was examined, and a sample was sealed to a piece of Corning #774 pyrex glass. A good bond resulted, indicating

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that the Japanese glass was molded pyrex similar to the Corning #774, since few dissimilar glasses will weld without subsequent cracking or severe strains due to expansion differences.

7-8. Spectrochemical Analysis of Radio Parts Samples. Metal parts from various components of the captured equipment, particularly the type TR-593-A transmitting tubes, were sent to the laboratories of the National Bureau of Standards for qualitative and semi-quantitative analysis. The analysis was made by the spectrometric method; the complete report of the Bureau of Standards is reproduced as Appendix II.

7-8-1. The results of the analyses are summarized below. The following designations are used to indicate very approximately the amount of each element in the alloys.

VS - Very Strong
S - Strong
M - Moderate
W - Weak

In general, the designations VS and S correspond to major constituents (greater than 1%), and M and W to minor constituents (1 to 0.1%).

| Name of Article | Constituents | Classification | Special Properties |
|---|---|---|---|
| (a) Draw Handles of TR-593A | Cu Zn Pb<br>VS VS M | Yellow Brass<br>70% Cu - 30% Zn | ----- |
| (b) Handle Coating TR-593A | Sn Ni<br>S M | Nickel Plate | Non-Corrosive |
| (c) Support Rods of TR-593A | Ni Mn Co Fe<br>VS M M W | 98-99% Nickel Base Alloy | Corrosion Resistant |
| (d) Internal Shield of TR-593A | Mo<br>VS | Molybdenum | ----- |
| (e) Lead Wire of TR-593A | W<br>VS | Tungsten | ----- |
| (f) Grid Wire of TR-593A | Mo<br>VS | Molybdenum | ----- |
| (g) Shield at base of grid wire TR-593A | Mo<br>VS | Molybdenum | ----- |
| (h) Filament Wire TR-593A | W Th<br>VS S | Thoriated Tungsten | Low Work Function |

[redacted]

| Name of Article | Constituents | Classification | Special Properties |
|---|---|---|---|
| (i) Metal top of insulator for transmission line | Cu Zn Fe Pb<br>VS VS S S<br>Sn Ni<br>S M | Pb-Ni-Bronze.<br>Fe generally left out of American Bronze.<br>Corresponds to Navy Composition M, or red brass: 85% Cu, 5% Zn, 5% Sn, 5% Pb. | |
| (j) Fuse Clip | Cu Sn P<br>VS S M | Phosphor Bronze | |
| (k) Cathode Ray Tube Shield | Fe Si<br>VS N | Silicon Steel | |
| (l) Cathode Ray Shield Paint | Al Co<br>VS M | Probably $Al_2 O_3$<br>(Ordinary aluminum paint) | |
| (m) Transmitter Panels | Al Cu Fe Si<br>VS S S M | Duralumin | |
| (n) Radiating Fin of TR-593A | Al Cu Fe Ni<br>VS S S S<br>Si Zn<br>S S | Al casting, alloy not similar to American alloys. | |

7-8-2. Those alloys that contain aluminum show evidence of being made from scrap material because of the nature and percentages of impurities present. It is probable that a large source of molybdenum is available because of its liberal use in the construction of the TR-593A.

7-9. Translation of Captured Documents and Nameplates. As indicated in Appendix III, a Japanese document descriptive of the radar installation on Guadalcanal was found with the captured equipment, and has been translated by the Office of Naval Intelligence. This translation is Enclosure A of reference (g), paragraph 1-1. Appendia III is a copy of reference (g) less the enclosures, which comprise a total of 47 typed pages (Enclosure A, 31 pages; Enclosure B, 16 pages).

7-9-1. Enclosure (A) of reference (g) is a fairly complete radar manual, containing a description of the operation of the equipment, instructions for tuning and adjusting, and discussion of the most probable circuit failures, procedure for locating trouble, and recommended remedies. There are frequent sketches and diagrams to illustrate the text, although complete circuit diagrams are not given. The first 21 pages are devoted to the transmitter and modulator. Pages 22, 23, and 24 are headed "Mark I Mod. 1 Receiver". The receiver described is the small "Japanese designed" unit; see paragraph 5-11. This is conclusive evidence

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that the small receiver is the one originally designed to be used with the other captured units. There is no mention of the larger receiver in the "manual". The remaining pages of Enclosure (A) describe the indicator unit, synchronizing unit, and monitor.

7-9-2. As noted in Appendix III, the original Japanese document of Enclosure (B), reference (g), appeared to have been a notebook kept by a Japanese radar technician, and most of the notes seem to have been copied from a radar manual. It is also thought possible (Appendix III) that "the radar described in Enclosure (B) was designed for shipboard rather than shore use", because of the technician's reference to repairs made aboard the heavy cruiser KINUGASA. That the radar equipment referred to in Enclosure (B) is of different design is indicated by the difference in rated line voltage - 220 volts a-c for the radar captured on Guadalcanal and described in Enclosure (A), and 110 volts a-c for the radar referred to in Enclosure (B). Furthermore, Appendix III states that the equipment mentioned as being repaired on the KINUGASA is identical with that described in the pencilled notes thought to have been copied from a manual.

7-9-3. An analysis of these notes of Enclosure (B), by an engineer of this laboratory who is familiar with the characteristics of the Guadalcanal equipment, confirms the proposal that the equipment described is of a different type. The most significantly different feature of this equipment is that the pulse repetition rate is 1500 cycles per second, while that of the radar captured on Guadalcanal is 1000 c.p.s. In other respects this "shipboard" equipment is similar to the shore-based type; the pulse length is given as $\frac{2}{100,000}$ second - i.e., 20 microseconds. Unfortunately the notes of Enclosure (B) deal solely with the operation of the indicator, monitor, and synchronizing circuits, and the radio frequency of operation is not given. However, the long pulse length (20 microsecond) indicates that the equipment is of the "search" type, and possibly operates at the same frequency (97-103 mc) as the shore based equipment.

7-9-4. The fact that Japanese shipboard radar equipment operates at 1500 cycle per second pulse repetition rate may be useful tactical information. Any intercepted enemy radar signals using this repetition frequency may be tentatively assumed to be from a Japanese warship.

7-10. Translation of Nameplates. The nameplates identifying the various controls and terminals of the units were translated by personnel of the Office of Naval Intelligence. In addition, nameplates on some of the circuit components and the main nameplates of the units were translated on those units which carried them. Translations of typical circuit components nameplates are given in Table 7.

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8. CONCLUSIONS.

8-1. General Construction and Mechanical Design. The construction and workmanship of the Japanese Radar equipment as a whole is decidedly poor, and it was found that constant attention and nursing were required to maintain good performance, or even to keep the system in operation. Failure of components was frequent, and the lack of neatness in construction and wiring made servicing difficult. Apparently no attempt at simplicity of design was made; the pulse-generating, synchronizing, and monitoring circuits in particular are so complicated as to present a difficult maintenance problem. The equipment is very large and heavy, with no evidence of attempts to economize on material, and the general design is inferior. It is probable that many of the special devices used in our radar systems, such as duplexers, transmission line rotating joints, and the use of "synchro" motors and generators in antenna control systems had not yet been developed for radar use by the Japanese at the time this captured equipment was manufactured (first three months of 1942).

8-2. Performance. Performance of the system, though somewhat better than was expected from analysis of the individual units, was definitely mediocre and far from equal to that of the best U.S. Naval search radar equipment in existence at the time the capture was made. The transmitter power is far lower than that of U.S. equipment.

8-3. Transmitter. The transmitter, rated (according to the translated Japanese instructions) at 5 kw pulse power output, delivers this power only with very careful tuning and adjustment; the output under average or service adjustment would probably be on the order of 2.5 to 3 kw. Output power as high as 4.7 kw was obtained during the laboratory tests, but only with considerable difficulty. Stability is poor, adjustments critical, and spark-over frequent.

8-4. Receiver Type 29-17-2. Of the two receivers obtained with the equipment, that designated in this report as type 29-17-2 - apparently the original receiver designed as part of the subject equipment - is of conventional design, but construction is very poor. Sensitivity is 7 to 8 db less than that of the latest 200 mc receivers developed at the Naval Research Laboratory. The i.f. bandwidth is greater than necessary, so that the sensitivity of the receiver is not fully utilized. There are no anti-jam features.

8-5. Receiver Type NEC-NO-1736. The receiver designated NEC-NO-1736, a larger receiver of excellent mechanical construction, with some evidences of German design, is slightly less sensitive than the type 29-17-2. However, the bandwidth is somewhat less than that of the type 29-17-2, so that the performance is as good or better than that of the other type. This receiver likewise had no special

[redacted]

anti-jam features, and r.f. jamming in conventional fashion was found to be quite effective. The dynamic range was found to be limited, definite i.f. overloading occurring at full gain with a 300 microvolt input signal. The stability of this receiver, however, is extremely good, as a result of perhaps excessive use of decoupling and shielding.

8-6. Antenna. Although the antenna for this equipment was not shipped to the Naval Research Laboratory, the information furnished regarding the original Japanese antenna allowed a practical duplicate to be built. The general design does not indicate familiarity with the most approved recent practices in this country. The one-quarter wavelength spacing of the radiators from the mesh reflector is not good design; the one-tenth wavelength spacing used quite generally in this country with non-resonant reflectors has proved better. No duplexing is used, necessitating separate antennas for transmitting and receiving. Instead of the antenna alone being rotated (which would require a rotary joint in the transmission line), the entire house containing the complete equipment, including antennas, was rotated by a 5 h.p. motor.

8-7. Vacuum Tube Types. The transmitting tubes, Japanese type TR-593-A, resemble closely the (American) G.E. types GL-8002 and GL-434, and are excellent tubes mechanically and electrically, although not as well adapted to radar transmitting application as the latest special radar transmitting types used in U.S. Naval radar equipment. The German type RE-3 tube used in one of the receiver types was analyzed and found to be an excellent tube, though by no means extraordinary, for its use as a video and i.f. amplifier. The cathode ray tubes type SSE-75-G and SSE-120-G were analyzed and found to possess no unusual features. Other tube types used were closely similar or identical to standard U.S. types, with the exception of types 6302, VR-135-50, and DC-762. These types do not have any unusual features or characteristics, however.

8-8. Analysis of Components. The very compact power supply filter capacitor which occasioned much interest (rated 4 mfd., 15 kv D.C., in a container very much smaller than U.S. types of equivalent rating) was found to be, by U.S. standards, very much over-rated, and by no means superior (in fact, inferior) to capacitors manufactured in this country. The glass of some Japanese insulators was found to be closely similar to Corning #774 pyrex. Analysis of metals and alloys used in the transmitting tubes and other parts indicated that aluminum and copper were used liberally, indicating either a plentiful supply or willingness to use these materials unsparingly because the radar equipment may not then have been in sufficiently large production to warrant use of substitute materials.

[redacted]

Table 1

Static Tests of Type TR-593-A Tubes

| Tube Serial Nos. | Date | Hrs. | $I_f$ | $I_c$ | $I_k$ | $E_c$ | Cor. | Remarks |
|---|---|---|---|---|---|---|---|---|
| 3285 | 12/5/42 | 0 | 16.15 | 0/100 | 10 | 250 | 12.0 | |
| 2968 | 12/5/42 | 0 | 15.0 | 0/100 | 6 | 240 | 12.5 | |
| 3612 | 12/5/42 | 0 | 16.10 | 0/100 | 9 | Internal Sparkover | | |
| 3473 | 12/1/42 | 20 | 16.0 | 0/100 | 9 | 275 | 10.9 | |
| 2897 | 12/1/42 | 20 | 16.7 | 35/100 | 9 | 251 | 12 | |
| 3420 | 12/1/42 | 20 | 15.8 | 50/25 | 9 | 255 | 11.7 | Will not cut off completely |
| 3358 | 12/1/42 | 20 | 16.25 | 50/37 | 9 | 261 | 11.5 | Will not cut off completely |
| 3911 | 11/26/42 | Filament seal broken in transmitter. | | | | | | |
| 2192 | 11/24/42 | Filament open when it was unpacked. | | | | | | |
| 3239 | 11/24/42 | Went gassy in amplifier. | | | | | | |
| 2052 | 11/26/42 | Internal arcing. | | | | | | |
| 3264A | 11/24/42 | Filament seal broken during unpacking. | | | | | | |
| 3376 | 12/5/42 | 0 | 15.85 | 0/100 | 11.0 | | | Internal sparking |
| 7727 | 12/5/42 | 0 | 16.5 | 50/95 | 5.1 | 256 | 11.7 | |
| 2456 | 12/5/42 | 0 | 16.0 | 0/100 | 7.5 | 230 | 13.0 | |
| 3145 | 12/5/42 | 0 | 16.1 | 0/100 | 9.0 | 238 | 12.6 | |
| 2450 | 12/5/42 | 0 | 16.1 | 0/100 | 9.0 | 262 | 11.5 | |
| 3201 | 12/5/42 | 0 | 16.3 | 0/100 | 7.8 | 244 | 12.3 | |
| 2931 | 12/5/42 | 0 | 15.85 | 0/100 | 8.7 | 228 | 13.2 | |

[redacted]

Table 2

Interelectrode Capacitance
of TR-593A Tube

| Tube Serial No. | $C_{pk}$ | $C_{pg}$ | $C_{gk}$ |
|---|---|---|---|
| 3612 | .84 | 5.4 | 8.22 |
| *2968 | .81 | *11.5 | 8.06 |
| 2931 | .86 | 4.72 | 7.82 |
| 3285 | .97 | 692 | 7.56 |

*Tube number 2968 was defective in that the inner plate corona shield was too close to the grid support ring.

[redacted]

Table 3

Comparison of TR-593-A Tube
With Two Other Types

| Tube Characteristic | TR-593-A | GL-8002 | ZP-434 |
|---|---|---|---|
| Filament Voltage | 7.5 volts | 16 | 11 |
| Filament Current | 16 amperes | 39 | 32 |
| Filament Emission | 9 amperes | -- | 40 |
| Amplification Factor | 16 | -- | 25 |
| Interelectrode Capacitances | | | |
| Grid to Plate | 5.68 | 9 | 9 |
| Grid to Filament | 7.92 | 8 | 10 |
| Plate to Filament | .87 | 0.5 | 0.5 |
| Direct Plate Voltage | 5000 (Max.) | 3500 volts | 1500 V. |
| Plate Input | -- | 3000 watts | -- |
| Plate Dissipation | -- | 1200 watts | -- |
| Output | 1000 watts | -- | -- |
| Maximum Length | *4-5/8" | 4-11/16" | |
| Maximum Diameter | *2" | 1-7/8" | |

*Dimensions without radiating fins.

[redacted]

Table 4

Miscellaneous Information
on TR-593-A Tube

Effective diameter of grid - 11.45 mm

Diameter of filament helix - 8.68 mm

Diameter of filament wire - 0.56 mm

Diameter of grid wire - 0.19 mm

Grid wire spacing - 2.21 mm

Inner diameter of plate - 30.35 mm

| | TR-593-A | GL-8002 |
|---|---|---|
| Grid-Filament Spacing | 1.39 mm | 1.53 mm |
| Grid-Anode Spacing | 9.45 mm | 2.14 mm |

[redacted]

CATHODE RAY TUBE TEST DATA

Table 5

[redacted]

Sheet No. 1

Enclosure to accompany NRL ltr

Date Tubes Received Mfr. N.E.C. Type No.

Date Tubes Tested Apr. 17, 1943. JAN 1A Specification Dated SSE-75-G

| JAN 1A Ref. | TESTS | Serial Number | | | |
|---|---|---|---|---|---|
| | | 4612 | | 2941 | |
| F-6i | Heater Current | 2.1 | | 2.1 | |
| F-8b | 1st Anode Current | 140.0 | | 7.0 | |
| F-8b | Cathode Current | 145.0 | | 15.0 | |
| F-8c | Gas Cross Test | S | | S | |
| F-8d | Base Alignment | 10° | | 15°* | |
| F-8d(1) | Align. Def. Axis | 4°* | | S | |
| F-8d(2) | Align. Base with Bulb | S | | S | |
| F-8e | Cathode Illumination | | | | |
| F-8f | Screen Quality | S | | S | |
| F-8f(2) | Light | S | | S | |
| | Grid #1 Current ua | -6.5 | | 0 | |
| | Resistance: H-k Control Grid | S | | S | |
| F-8g( ) | Line Width "A" | 0.48 | | 0.38 | |
| F-8g( ) | Line Width " " | 0.56 | | 0.48 | |
| F-8h( ) | Position of Spot | 11.0 | | 9.0 | |
| F-8i | Cathode Emission Check | S | | S | |
| F-8j | Grid Cutoff | 37 | | 48 | |
| F-8k | Focusing Voltage : Ec = 75% Eco | 295* | | 310* | |
| F-8k | Focusing Voltage : Ec = 0 to Eco | 265-295* | | 310-310 | |
| F-8m | Deflection Factor 1D2 Volts/in | 149* | | 144* | |
| F-8m | Deflection Factor 3D4 Volts/in | 119 | | 121 | |
| F-8n | Deflection Linearity Factor | 5% | | 1% | |
| | Voltage Breakdown | | | | |
| | Spot Displacement | | | | |
| F-2 | Grid Leakage | | | | |
| F-2 | 1st Anode Leakage | | | | |
| F-8p(1) | Heater-Cathode Leakage | | | | |
| F-8p(2) | Grid Current | | | | |
| F-8q(1) | Capacitance: Control Grid - all uuf | 5.76 | | 6.42 | |
| F-8q(2) | Capacitance: Cathode - all | | | | |
| F-8q(3) | Capacitance: D1 - D2 | | | | |
| F-8q(4) | Capacitance: D3 - D4 | | | | |
| F-8q(5) | Capacitance: D1 - all | 4.12 | | 3.90 | |
| F-8q(6) | Capacitance: D3 - all | 5.28 | | 5.62 | |
| F-8q(7) | Capacitance: D1 - all except D2 | | | | |
| F-8q(8) | Capacitance: D2 - all except D1 | | | | |
| F-8q(9) | Capacitance: D3 - all except D4 | | | | |
| F-8q(10) | Capacitance: D4 - all except D3 | | | | |
| F-8s | Vibration: 10 G | | | | |
| | Anode #2 Current ua | 15.0 | | 7.0 | |
| F-5d | Overall Length Inches | 11.56 | | 11.53 | |
| F-5d | Overall Diameter Inches | 2.94 | | 2.99 | |

"S" indicates satisfactory. * indicates failure to comply with specifications. (JAN 3AP1)

Negative Grid Current Indicates Grid Emission.

CATHODE RAY TUBE TEST DATA

Table 6

[redacted]

Sheet No. 1

Enclosure to accompany NRL ltr

Date Tubes Received Mfr. N.E.C. Type No. SSE-120-G

Date Tubes Tested JAN 1A Specification Dated

| JAN 1A Ref. | TESTS | Serial Number | | | |
|---|---|---|---|---|---|
| | | 2114 | | | |
| F-6i | Heater Current Amps | 2.2 | Ef = 2.5 | volts | |
| F-8b | 1st Anode Current ua | 21.5 | | | |
| F-8b | Cathode Current ua | 20.0 | | | |
| F-8c | Gas Cross Test | S | | | |
| F-8d | Base Alignment | | | | |
| F-8d(1) | Align. Def. Axis | S | | | |
| F-8d(2) | Align. Base with Bulb | S | | | |
| F-8e | Cathode Illumination | | | | |
| F-8f | Screen Quality | S | | | |
| F-8f(2) | Light | S | | | |
| | Grid #1 Current ua | -5.0 | | | |
| | Resistance: HK-Control Grid | S | | | |
| F-8g( ) | Line Width "A" mm | 0.36 | | | |
| F-8g( ) | Line Width B " mm | 0.55 | | | |
| F-8h( ) | Position of Spot mm | 13* | | | |
| F-8i | Cathode Emission Check | S | | | |
| F-8j | Grid Cutoff | 33 | | | |
| F-8k | Focusing Voltage : Ec = 75% Eco | 35° | | | |
| F-8k | Focusing Voltage : Ec = 0 to Eco | 310-350 | | | |
| F-8m | Deflection Factor 1D2 Volts/in | 88.8* | | | |
| F-8m | Deflection Factor 3D4 Volts/in | 79.0* | | | |
| F-8n | Deflection Linearity Factor % | 4.0 | | | |
| | Voltage Breakdown | | | | |
| | Spot Displacement | | | | |
| F-2 | Grid Leakage | | | | |
| F-2 | 1st Anode Leakage | | | | |
| F-8p(1) | Heater-Cathode Leakage | | | | |
| F-8p(2) | Grid Current | | | | |
| F-8q(1) | Capacitance: Control Grid - all | | | | |
| F-8q(2) | Capacitance: Cathode - all | | | | |
| F-8q(3) | Capacitance: D1 - D2 | | | | |
| F-8q(4) | Capacitance: D3 - D4 | | | | |
| F-8q(5) | Capacitance: D1 - all | | | | |
| F-8q(6) | Capacitance: D3 - all | | | | |
| F-8q(7) | Capacitance: D1 - all except D2 | | | | |
| F-8q(8) | Capacitance: D2 - all except D1 | | | | |
| F-8q(9) | Capacitance: D3 - all except D4 | | | | |
| F-8q(10) | Capacitance: D4 - all except D3 | | | | |
| F-8s | Vibration: 10 G | | | | |
| | | | | | |
| F-5d | Overall Length Inches | 16.79 | | | |
| F-5d | Overall Diameter Inches | 4.70 | | | |

(JAN 5BP1)

"S" indicates satisfactory. * indicates failure to comply with specifications.

Negative Grid Current Indicates Grid Emission.

Table 7

Translations of Typical Nameplates
Captured Japanese Radar Equip-
ment - C.E.E. No. 211

| | |
|---|---|
| Ammeter<br>Nippon Electric Co.<br>No. 100568<br>December 1941 | 4 mfd - 8 KV<br>Tokyo Electric Co.<br>No. 6054, 1216<br>Model OP 603 |
| All small tubes made<br>by Tokyo Electric Co. | Meters, Shunts, and<br>Multipliers made by Nippon<br>Electric Company (NEC) |
| 3 mfd - 3 KV<br>Tokyo Electric Co.<br>No. 2751, 1216<br>Model OP 604 | 2 KV 2 Mfd<br>Nippon Tsushin Koggo<br>(NTK)<br>Jan. 1942 P-10 |
| Voltmeter<br>Kogawa Denki Koggo K.K.<br>( ? )<br>Nov. 1941 | Indicator Sweep Unit<br>Naval Technical Institute<br>February 1942<br>No. 29 |
| Time Delay Relay<br>Hitachi Factory<br>December 1941<br>No. 484088 | Jap. Receiver<br>Naval Technical Institute<br>January 1942<br>No. 9 |
| Modulator Power Transformer<br>Nippon Electric Co.<br>No. 22455<br>Nov. 1941 Low Voltage | Modulator<br>Nippon Electric Co.<br>Jan. 1942<br>No. 9 |
| High Voltage Condenser<br>Nippon Tsushin Kogyo K.K.<br>(Sanyosha Factory)<br>Made Jan. 1942<br>No. 82 | Modulator Power Transformer<br>High Voltage<br>Nippon Electric<br>Nov. 1941<br>No. 22516 |

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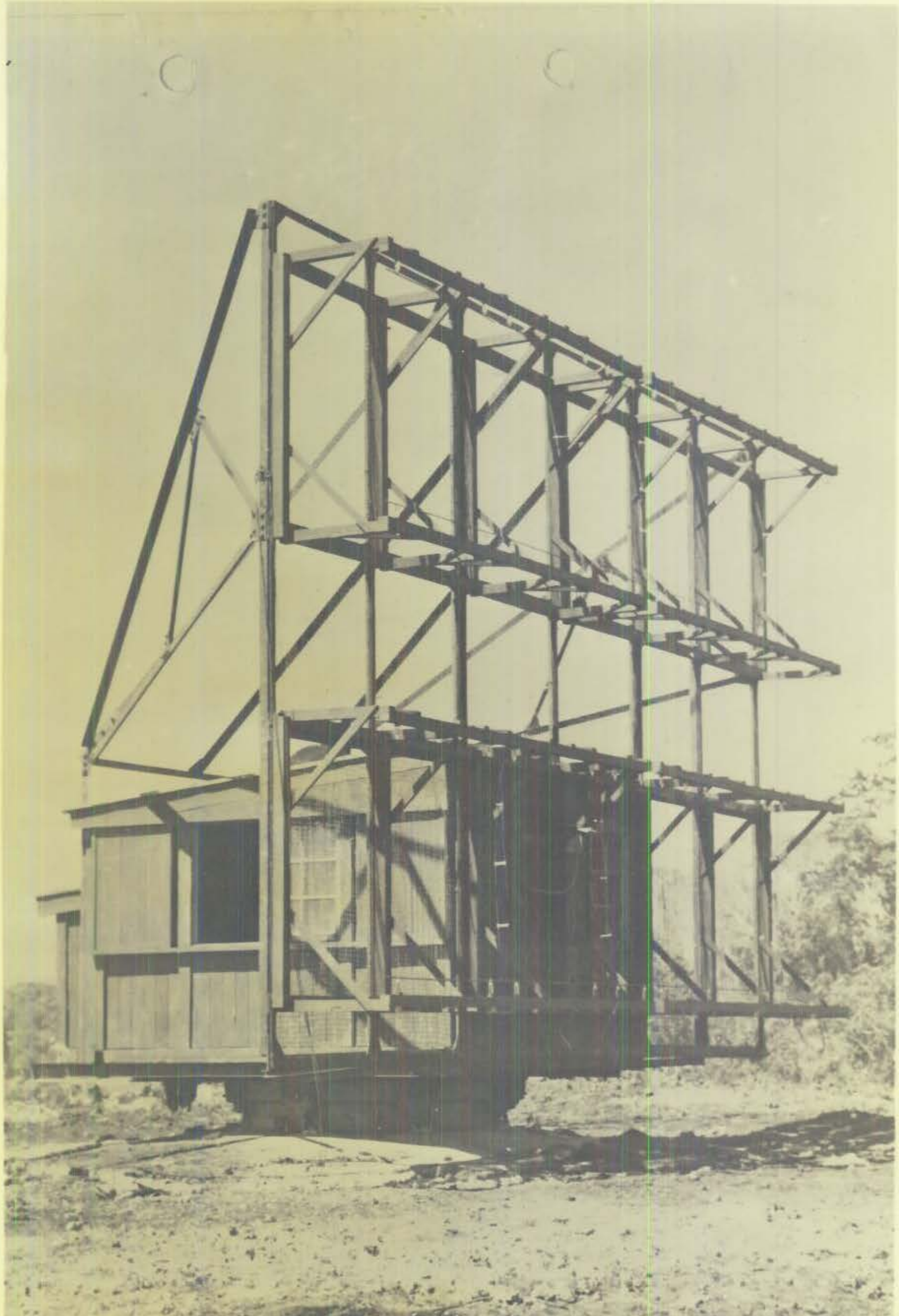

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PLATE I

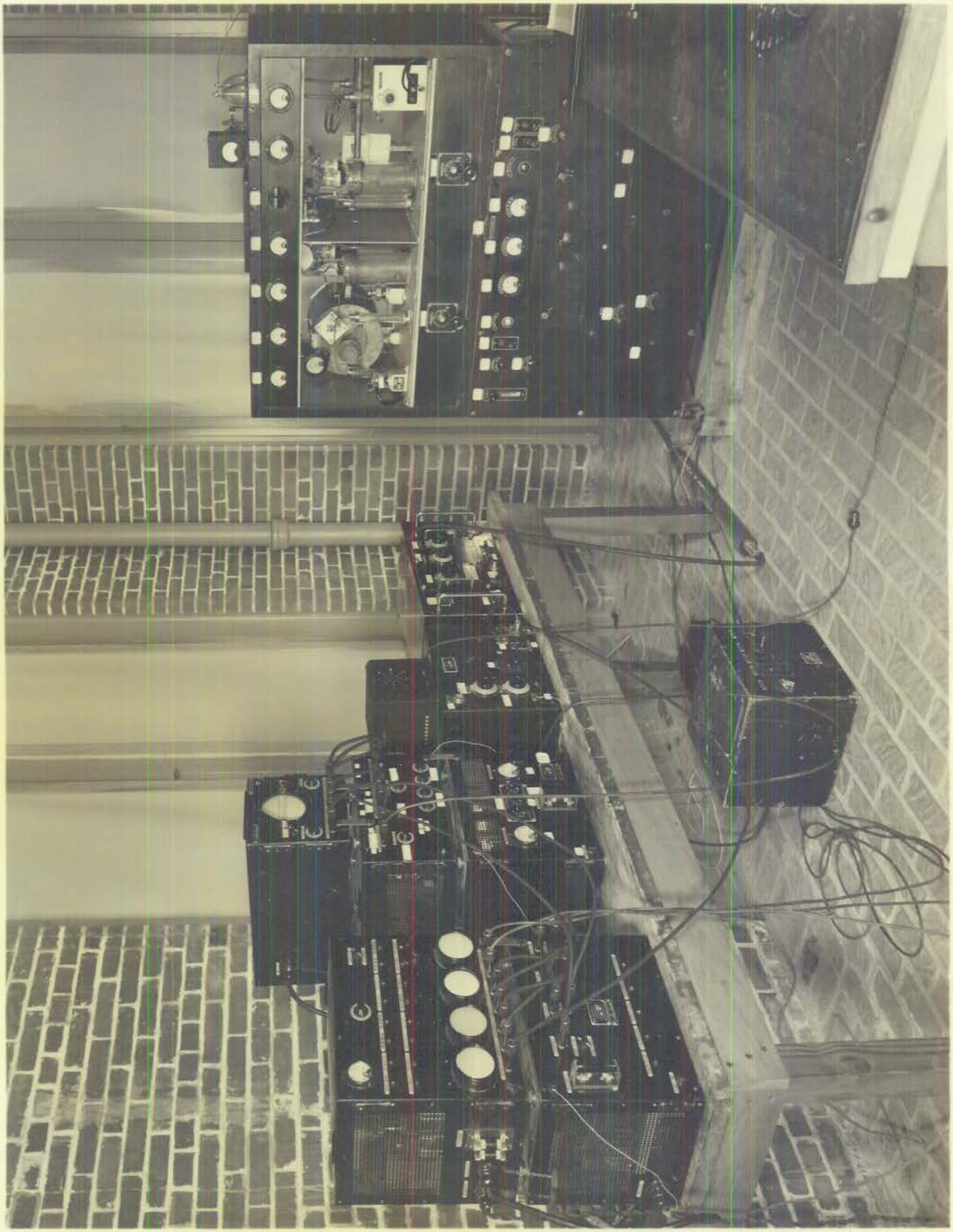

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PLATE 2

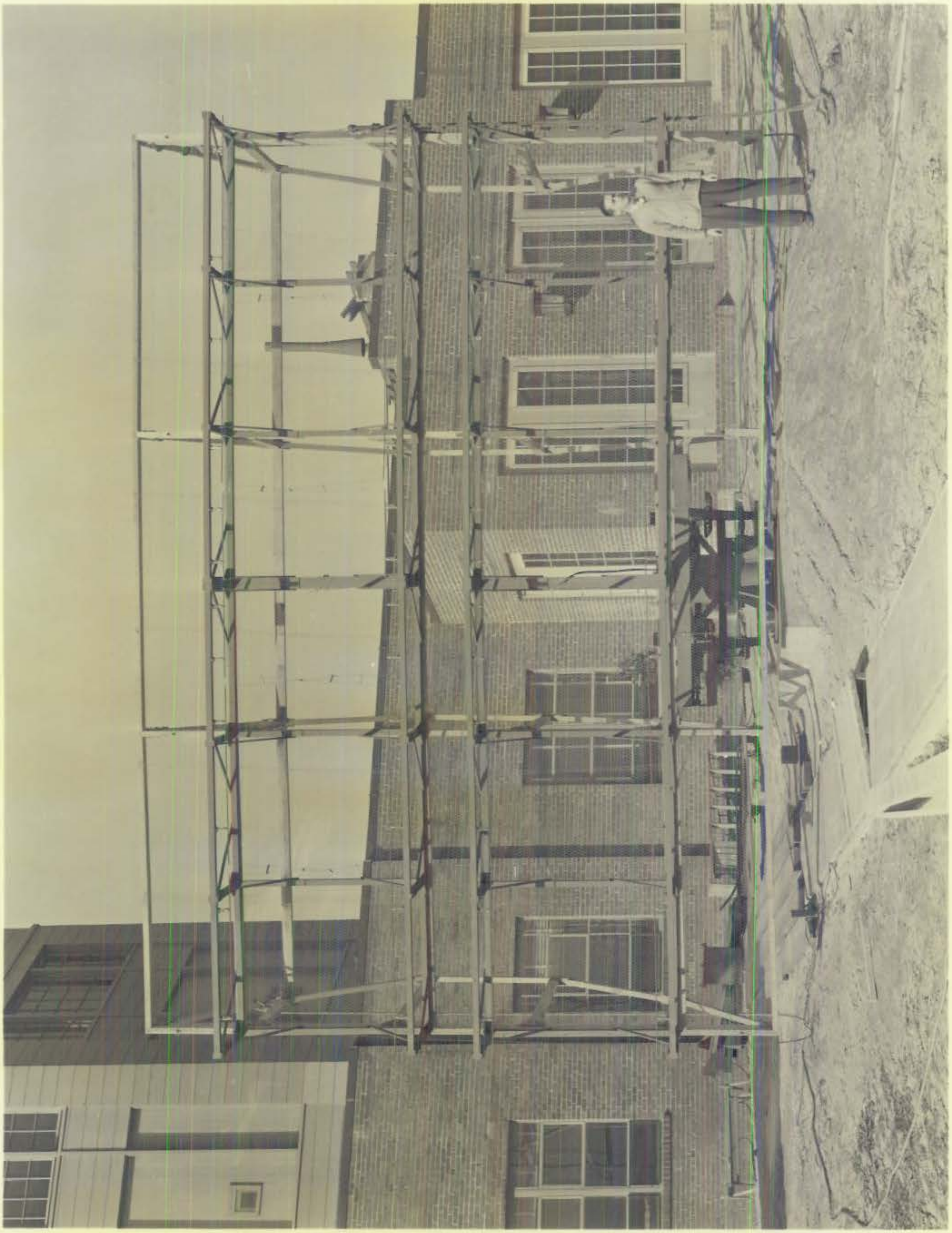





PLATE 3

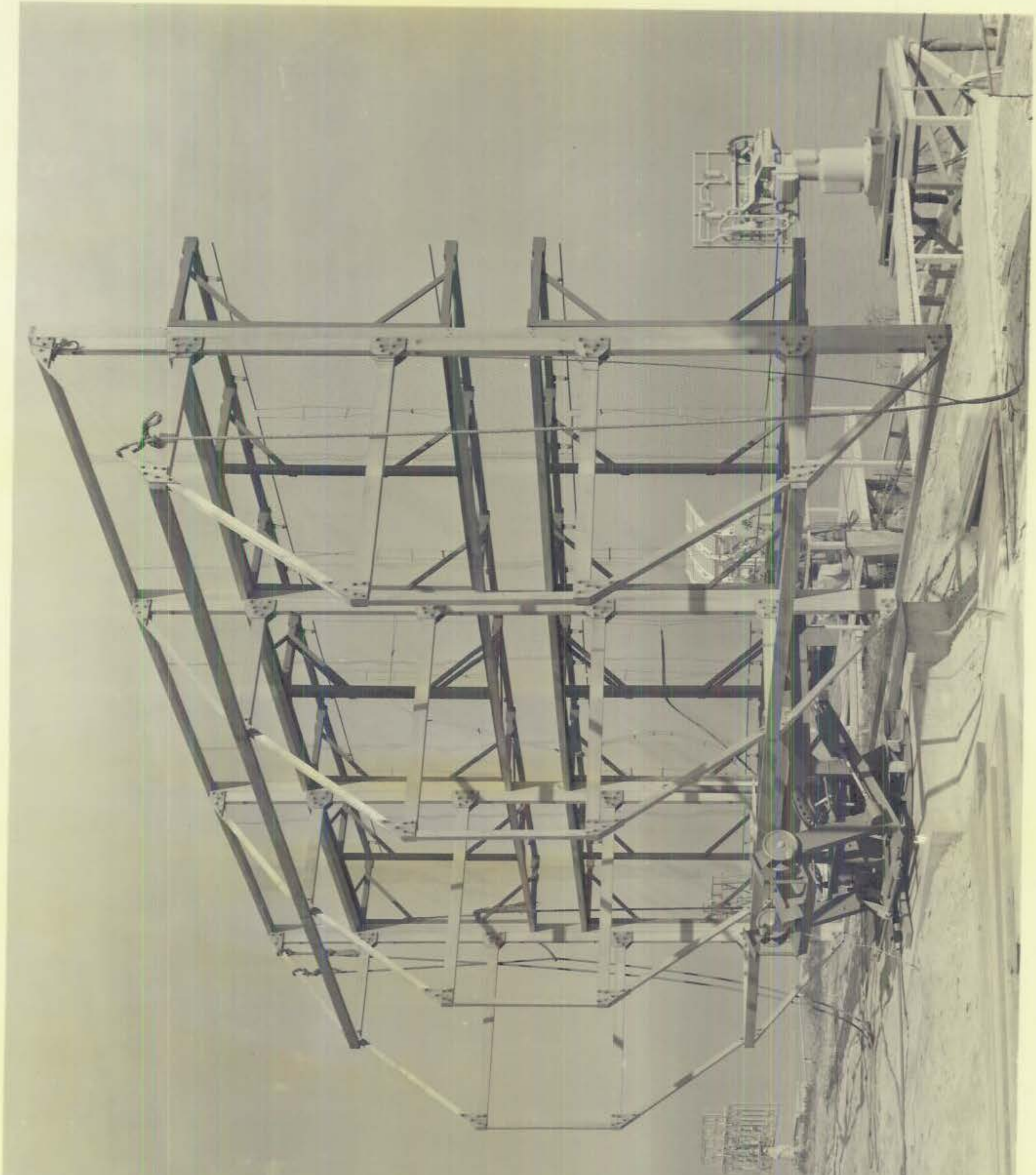

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PLATE 4

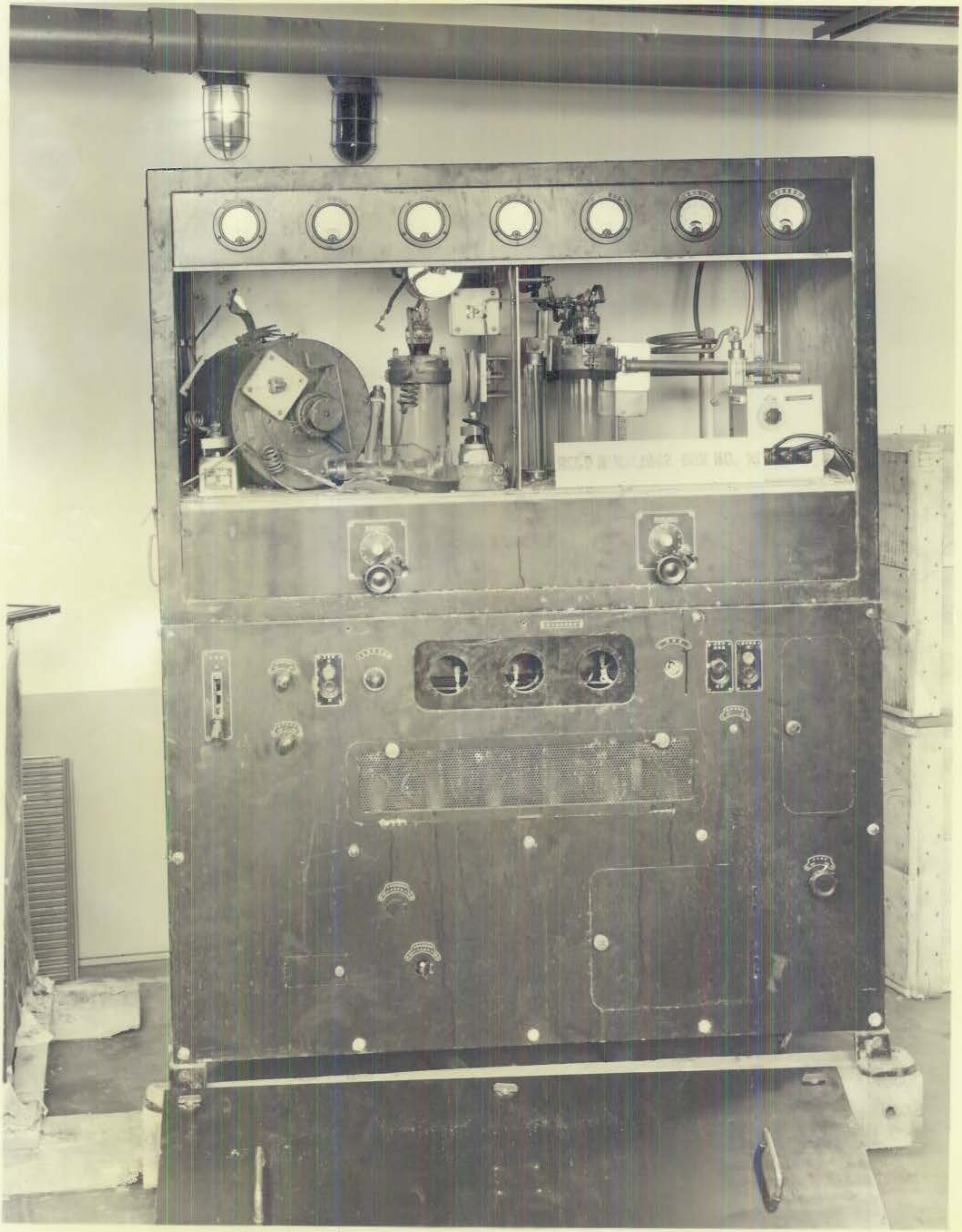

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PLATE 5

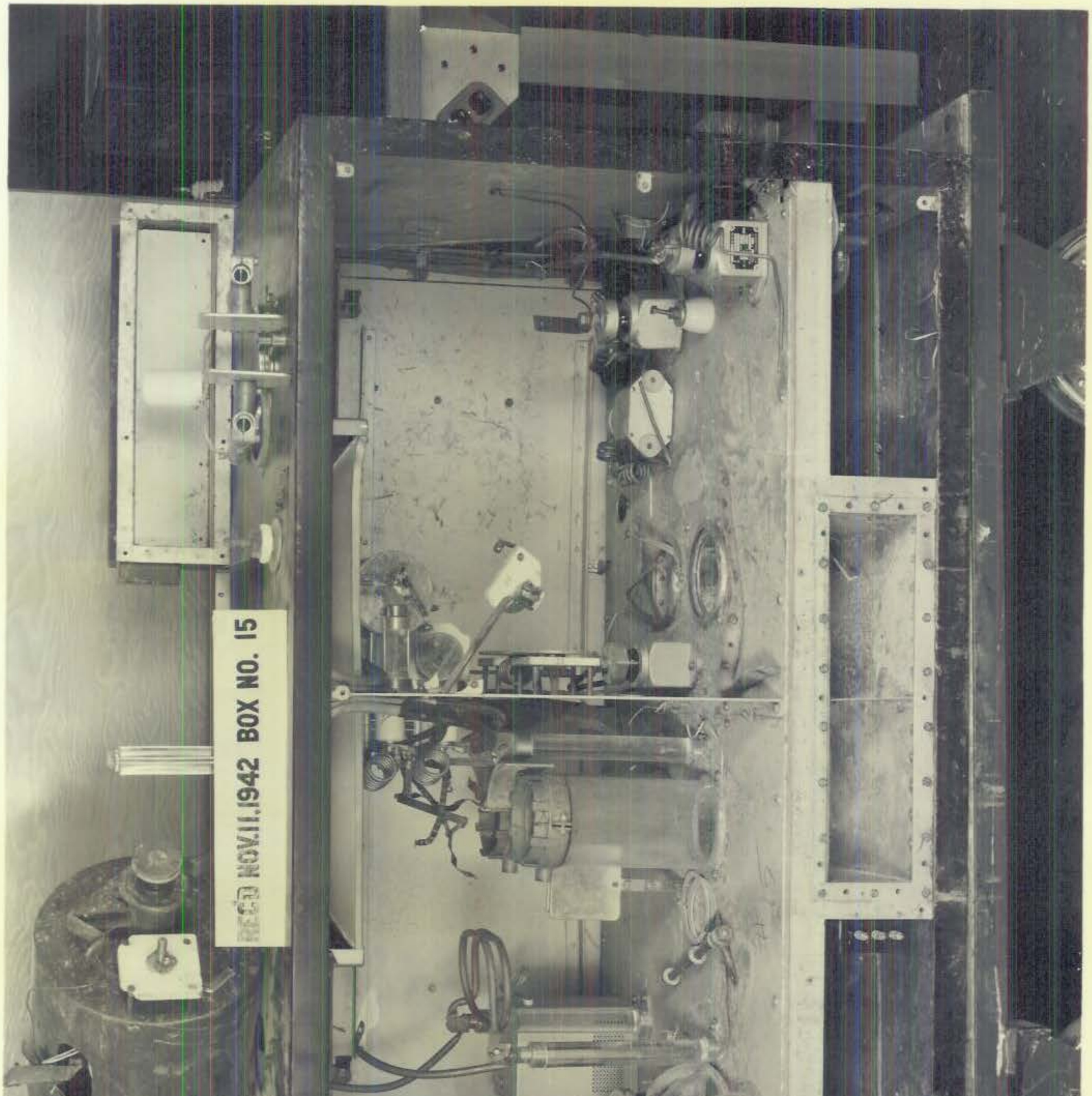


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PLATE 6

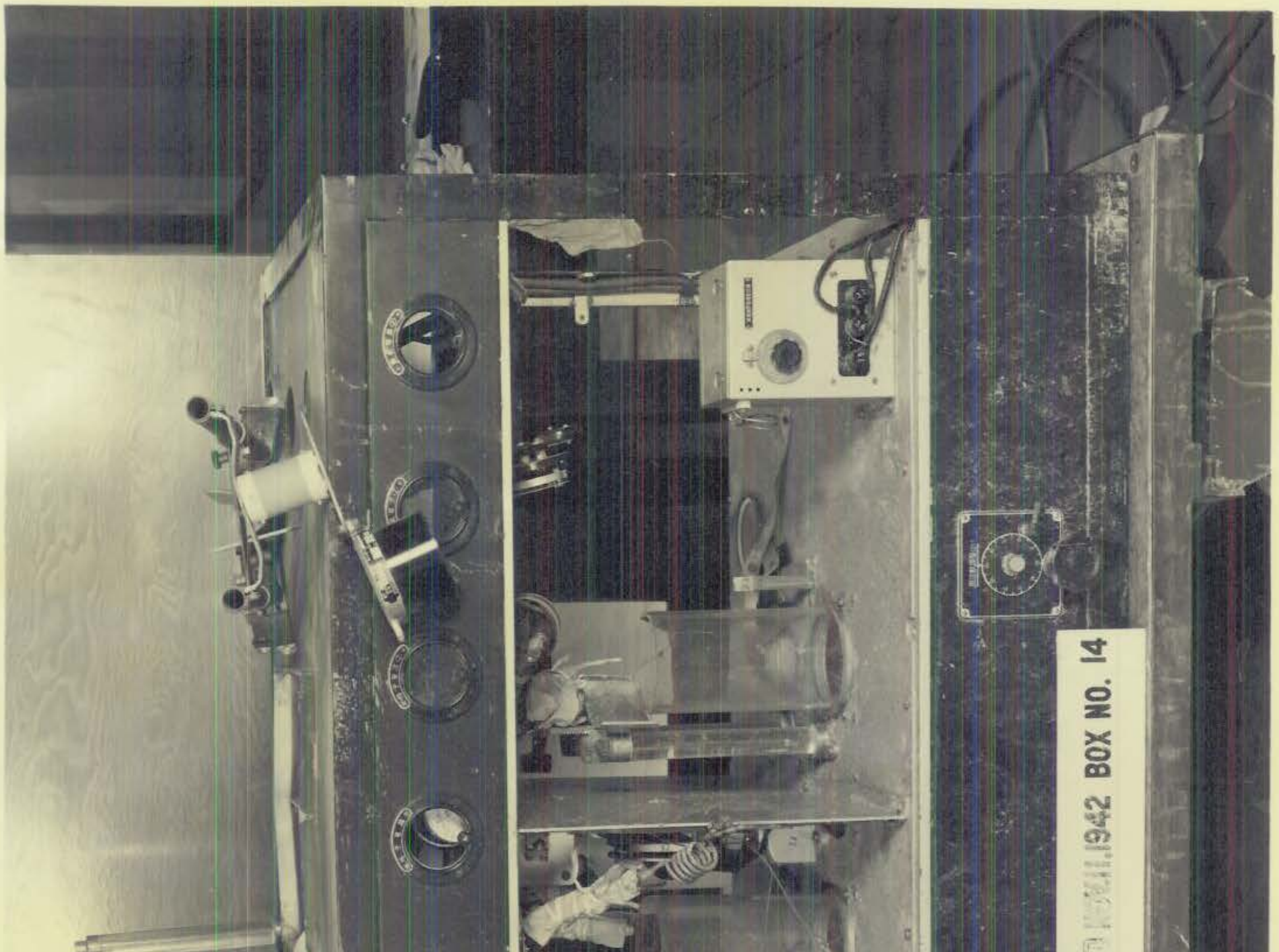






PLATE 7


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PLATE 8

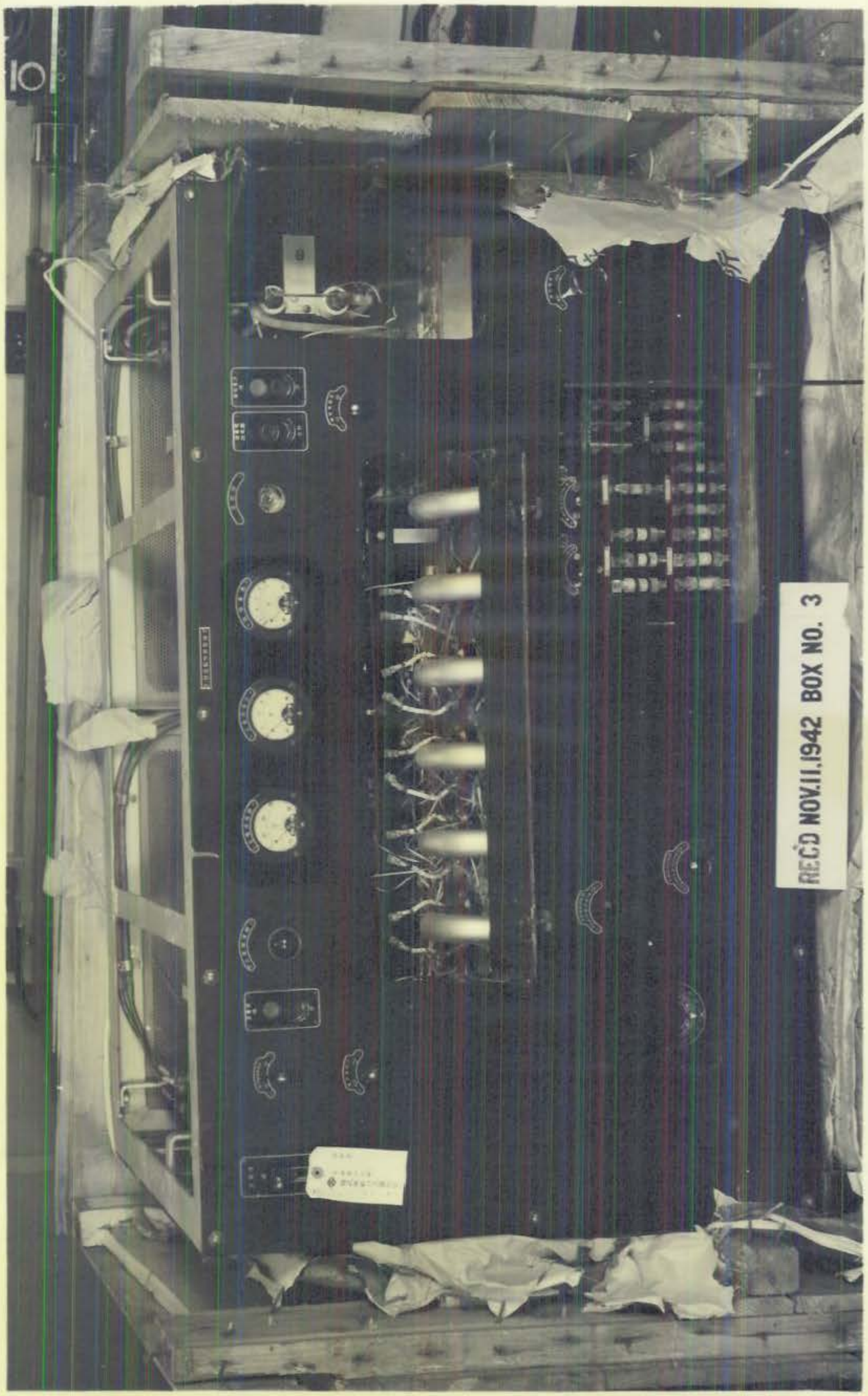






PLATE 9


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PLATE 10

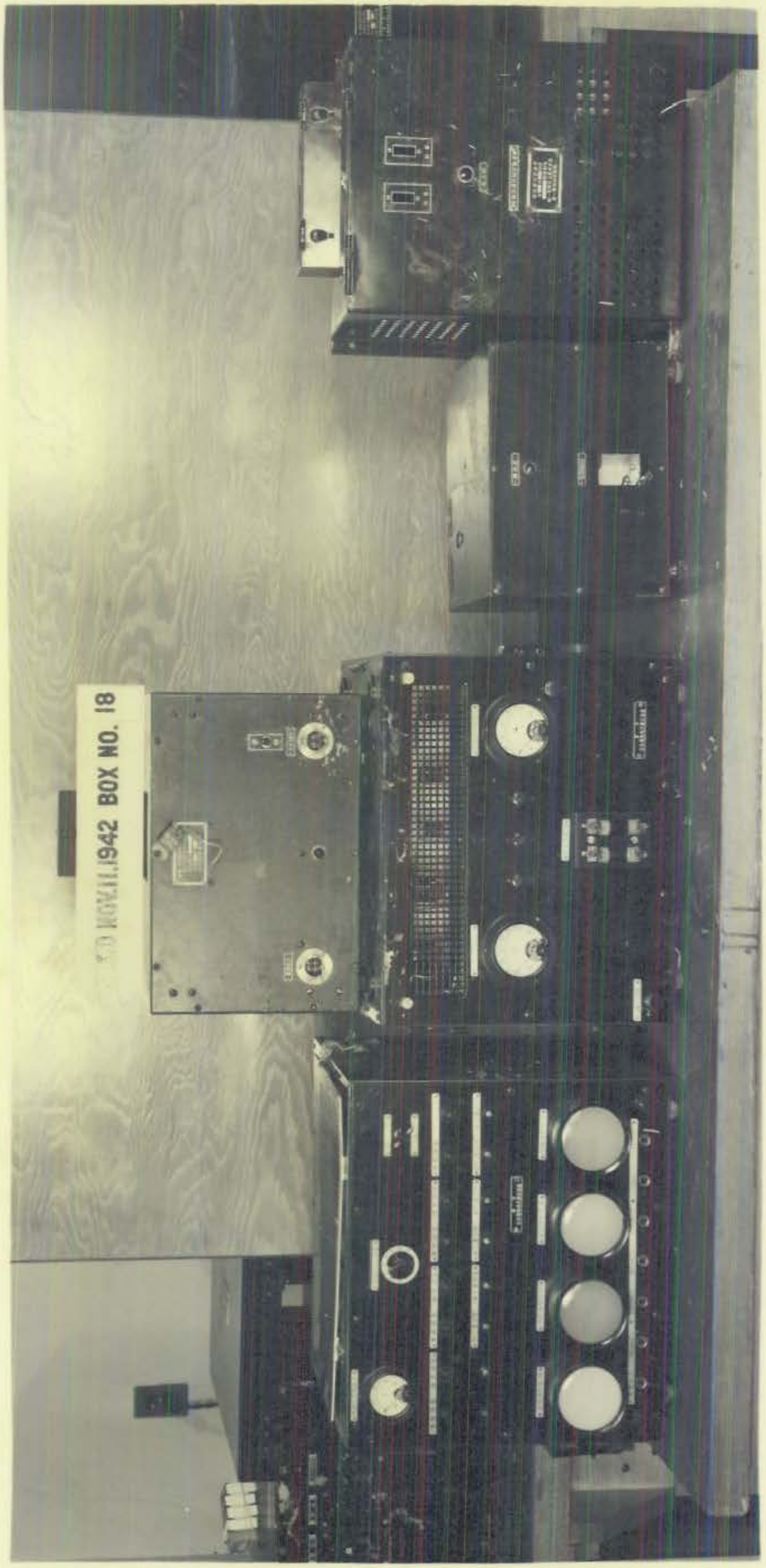


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PLATE II


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PLATE 12






PLATE 13


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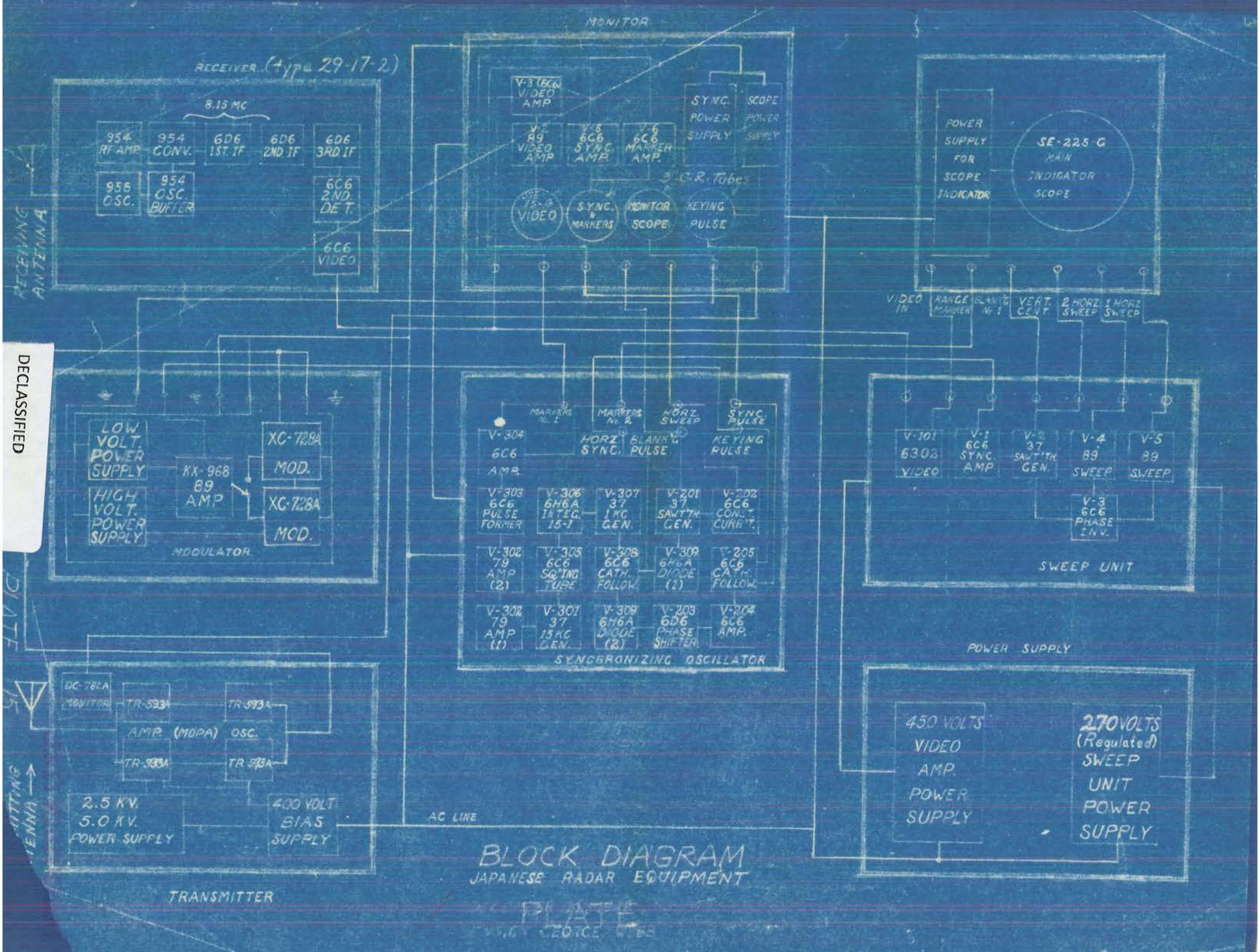
PLATE 14

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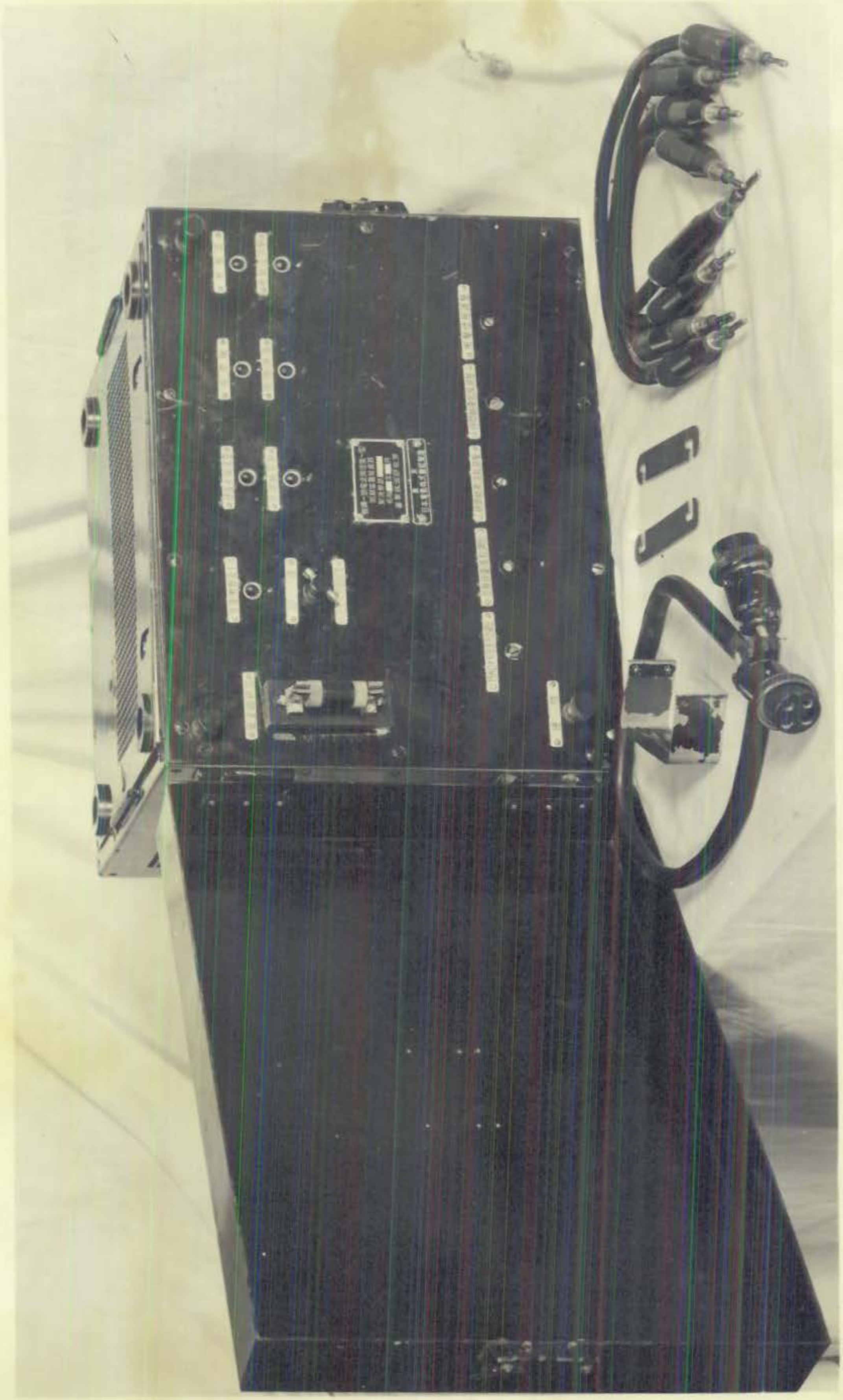

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PLATE 16

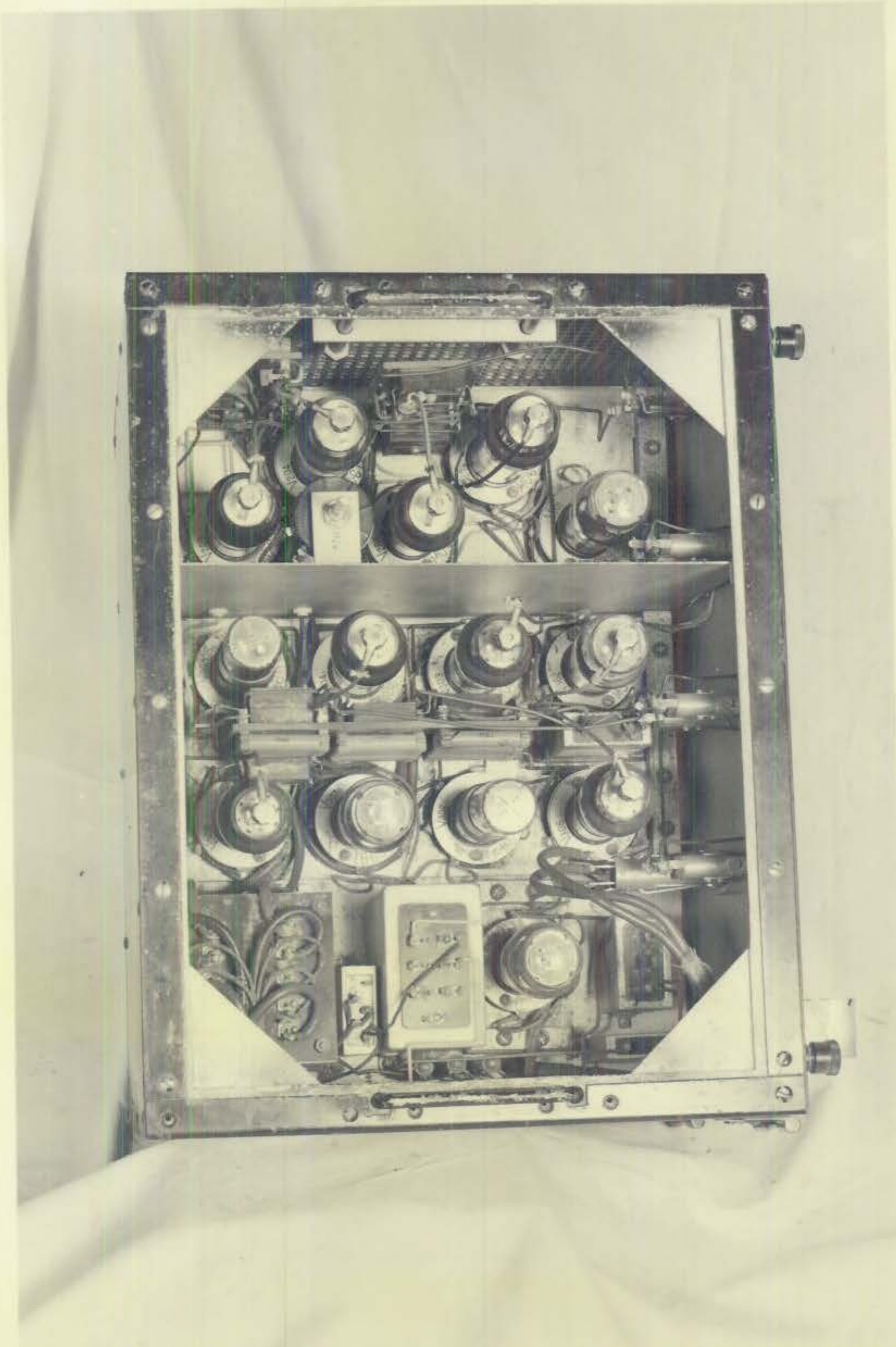

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PLATE 17

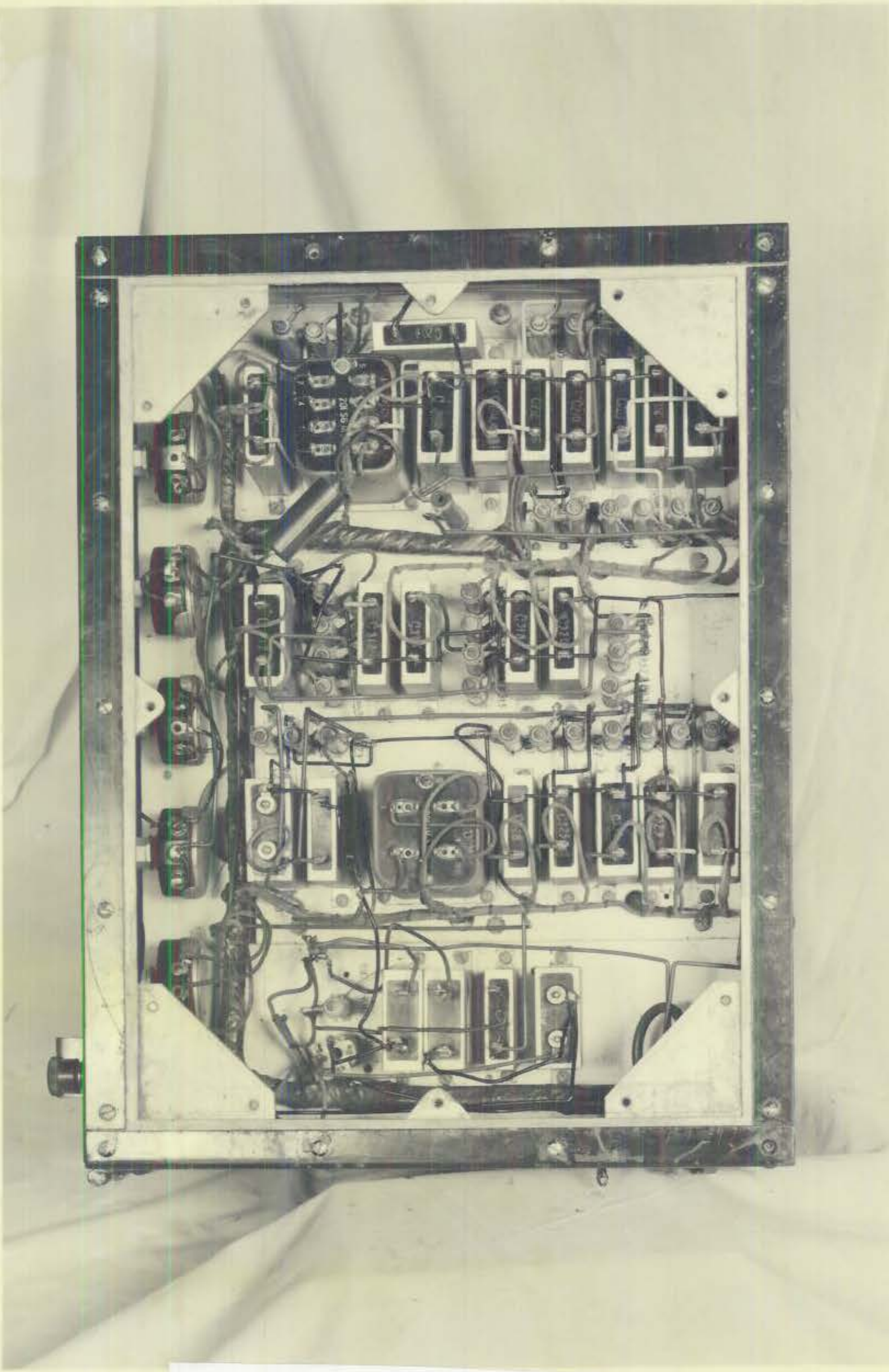

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PLATE 18

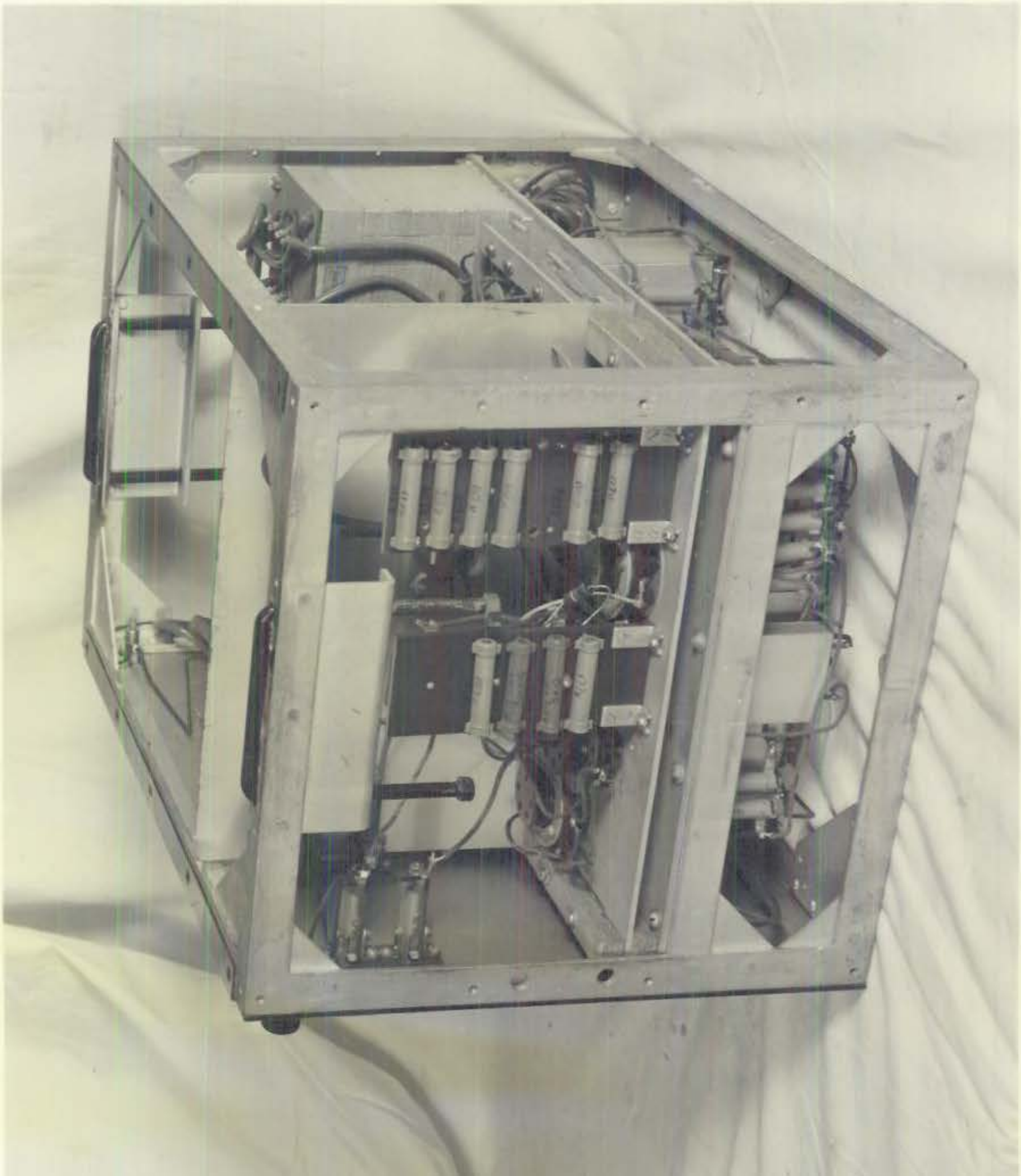

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PLATE 19

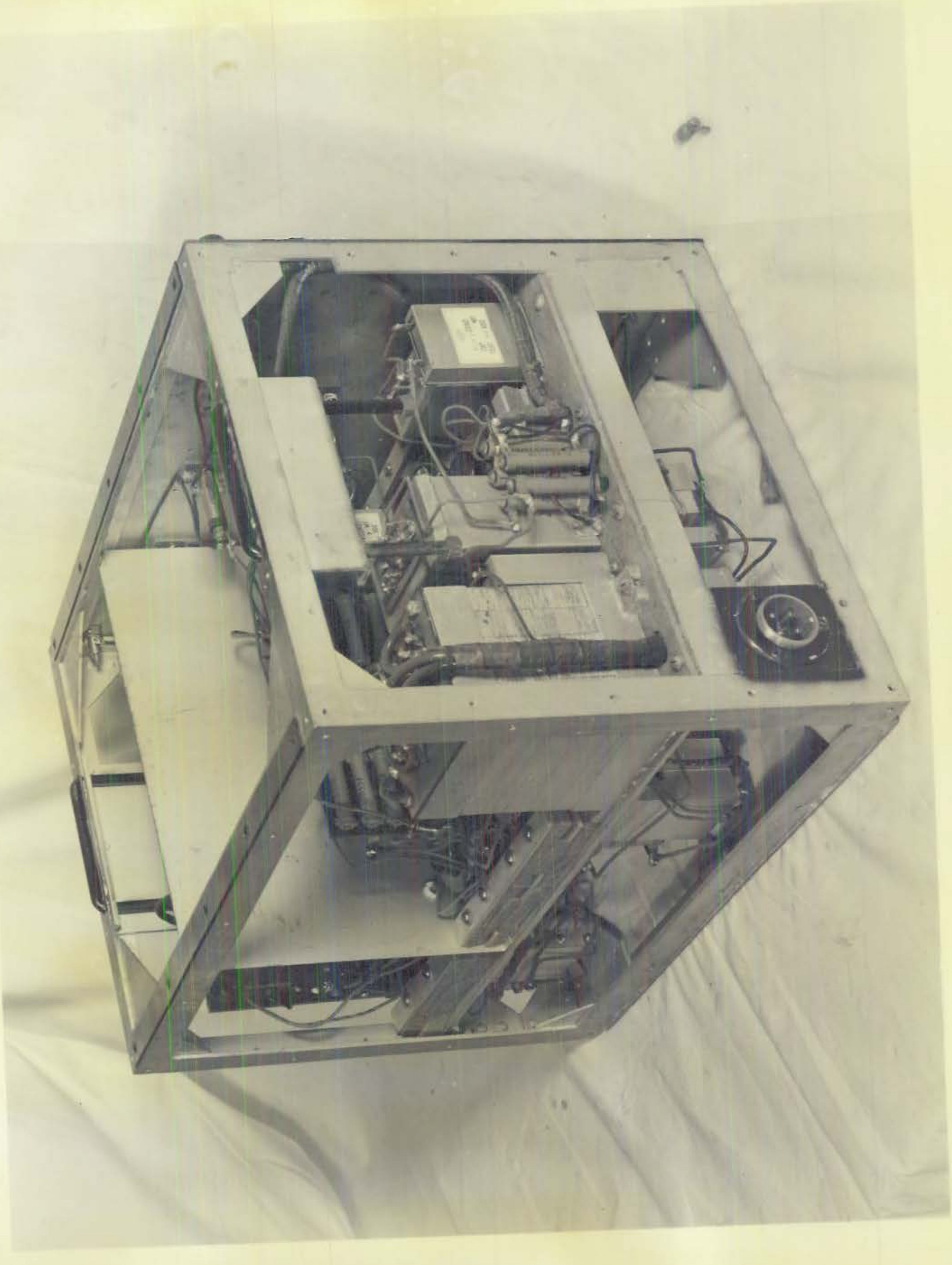





PLATE 20

# SYNCHRONIZING OSC. UNIT
## JAPANESE RADAR EQUIPMENT

12/4/42

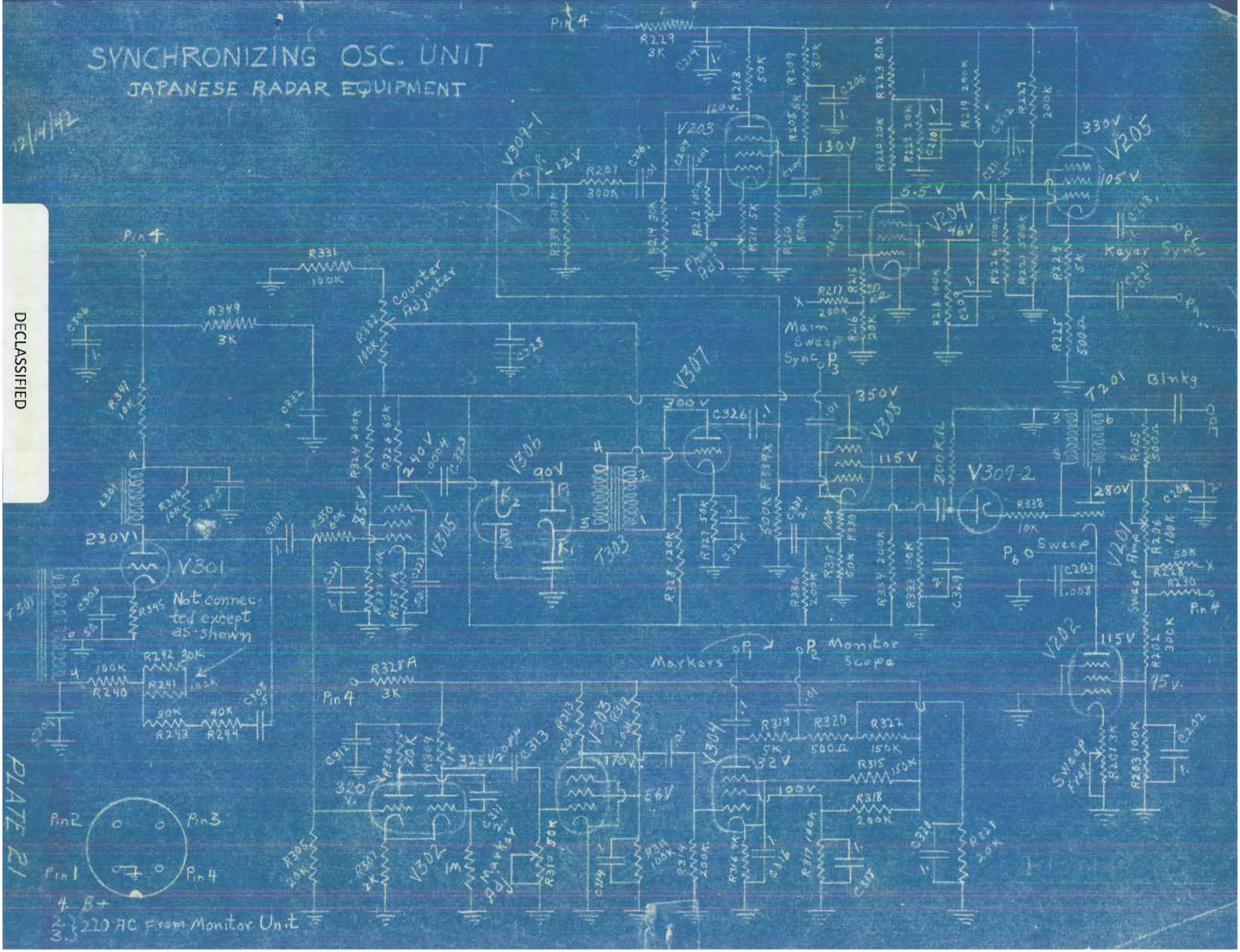


PLATE 21

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## FILAMENT SUPPLY


## OUTPUT TERMINALS

P1 – Marker Voltage #1
P2 – Marker Voltage #2
P3 – Horizontal Sweep Sync.
P4 – Sync Voltage
P5 – Keying Voltage - Modulator
P6 – Horizontal Sweep - Monitor Scopes
P7 – Blanking Voltage " "

## TUBE TYPES

| | |
|---|---|
| V-201 | 37 |
| V-202 | 6C6 |
| V-203 | 6D6 |
| V-204 | 6C6 |
| V-205 | 6C6 |
| V-301 | 37 |
| V-302 | 79 |
| V-303 | 6C6 |
| V-304 | 6C6 |
| V-305 | 6C6 |
| V-306 | 6H6-A |
| V-307 | 37 |
| V-308 | 6C6 |
| V-309 | 6H6-A |

Base connections same as U.S. types except for 6H6 A →

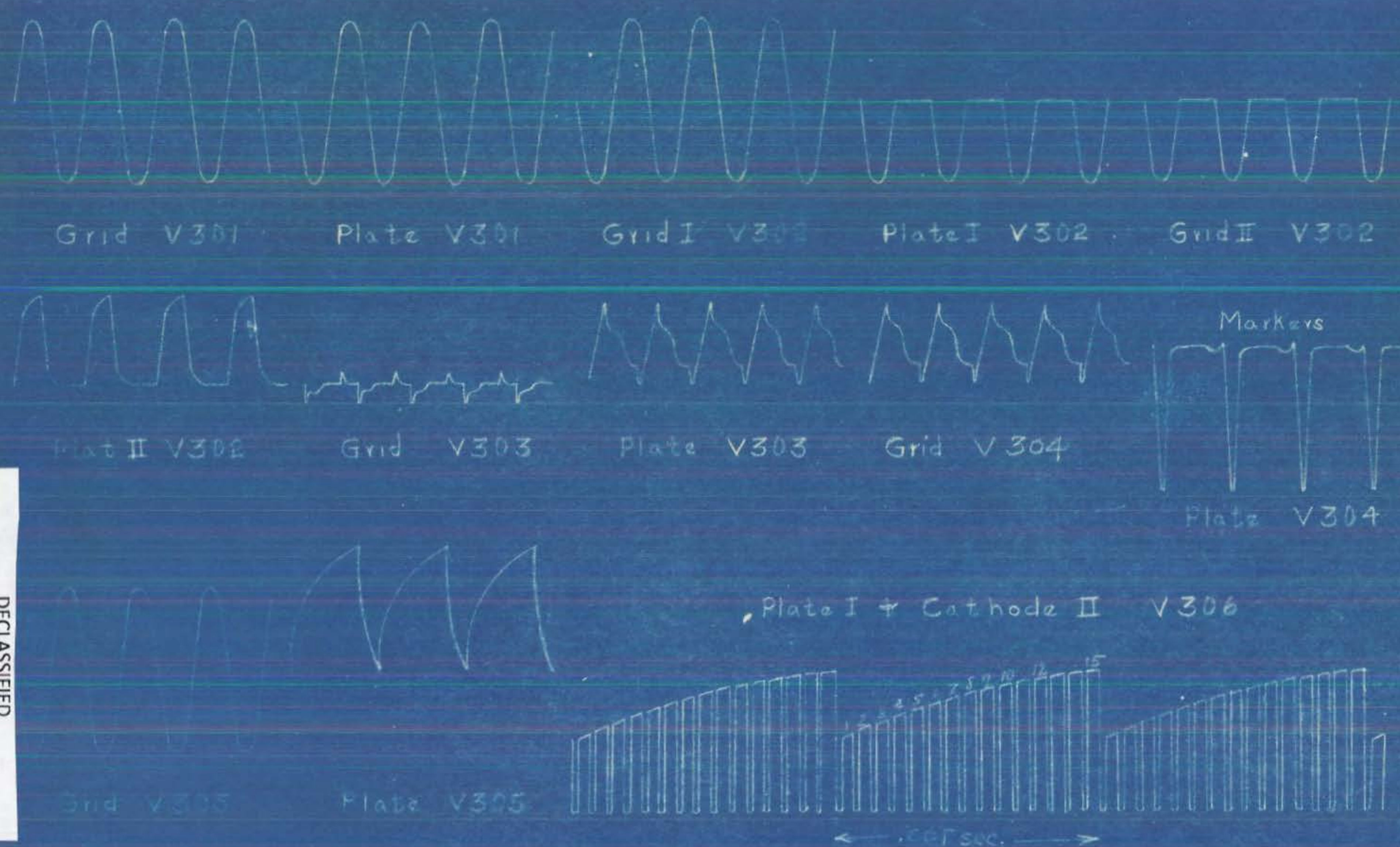
6H6-A


Top view of socket

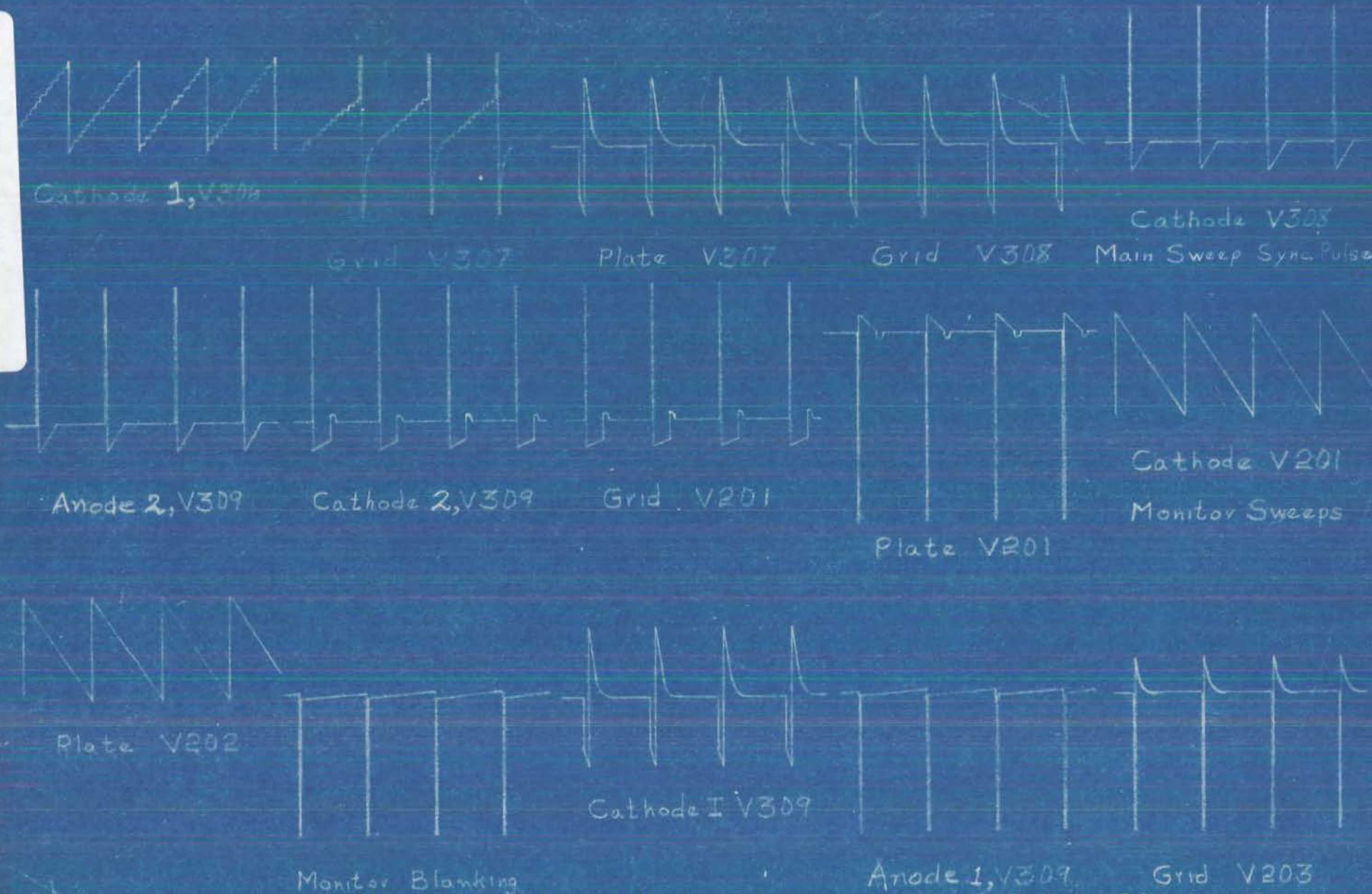
1. Filament
2. Plate 2
3. Cathode 2
4. Shield
5. Cathode 1
6. Plate 1
7. Filament

SYNCHRONIZING OSCILLATOR UNIT
JAPANESE RADAR EQUIPMENT

PLATE 22




OSCILLOGRAPH WAVE-FORMS - SYNCHRONIZING OSC. UNIT
JAPANESE RADAR EQUIPMENT
FREQUENCY OR RECURRENCE RATE 15 KC./SEC. IN ALL CASES.




OSCILLOGRAPH WAVE-FORMS-SYNCHRONIZING OSC UNIT
JAPANESE RADAR EQUIPMENT
FREQUENCY OR RECURRENCE RATE 1Kc/SEC-ALL CASES

PLATE 24


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PLATE 26

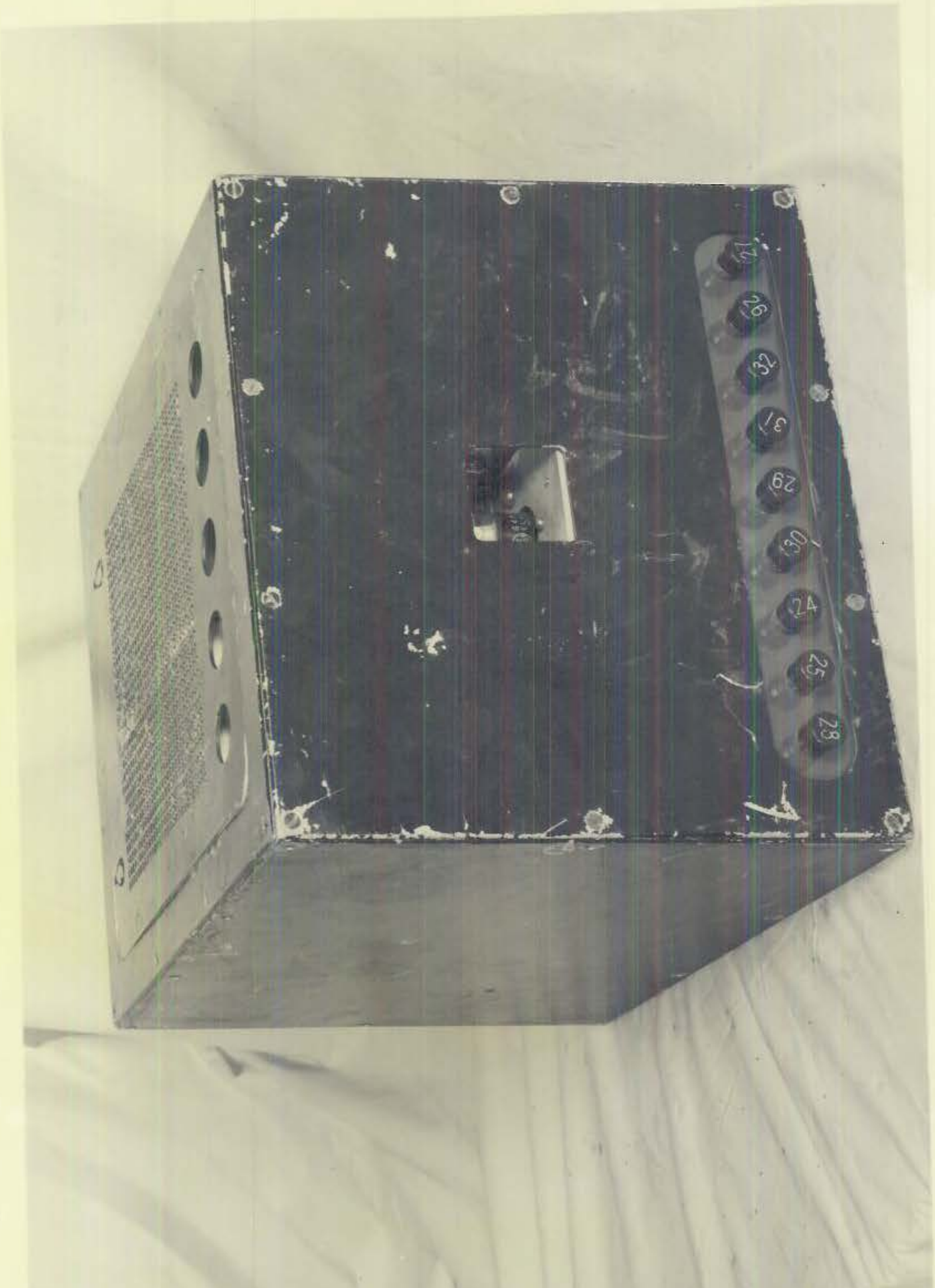


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PLATE 27

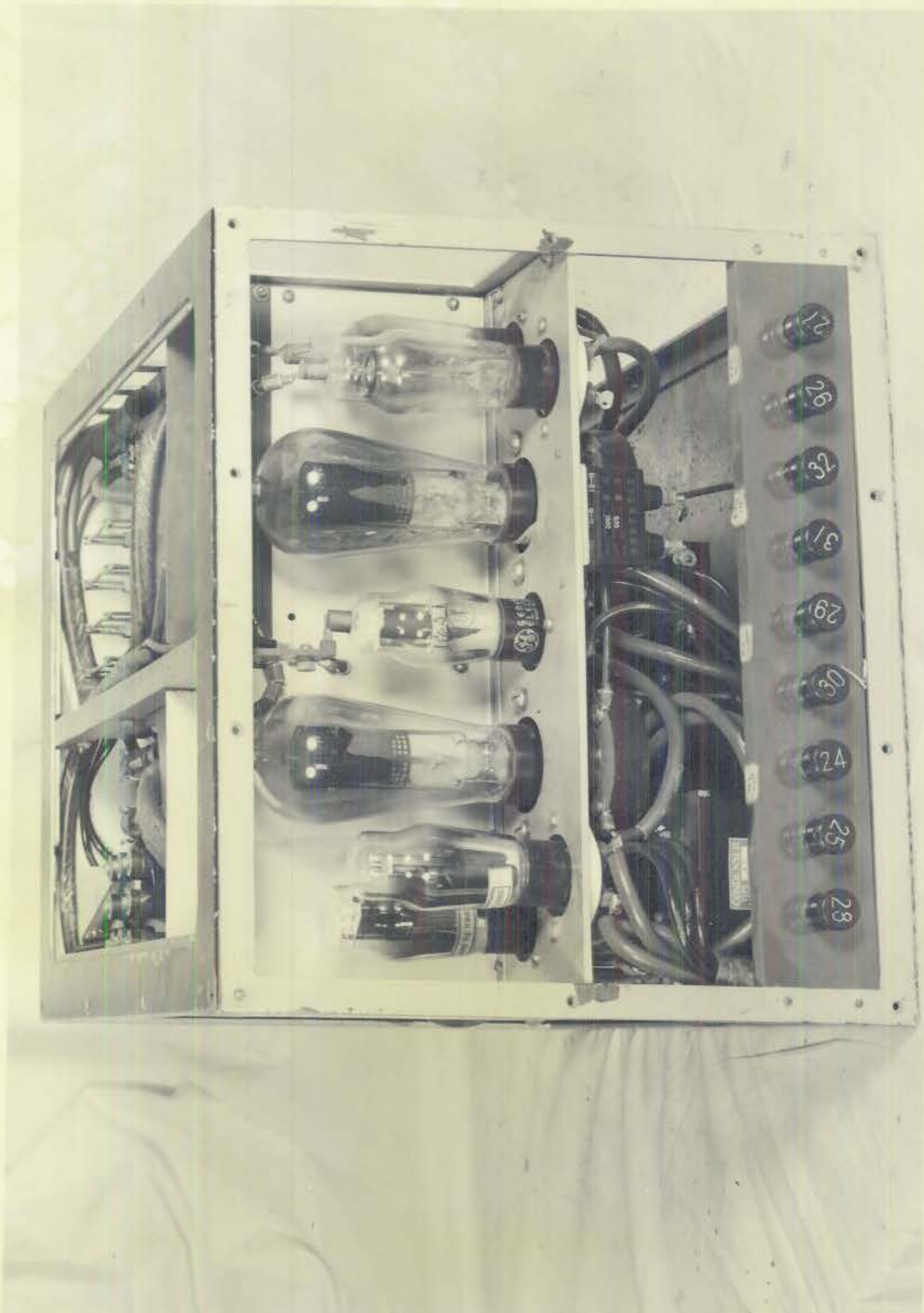





PLATE 28

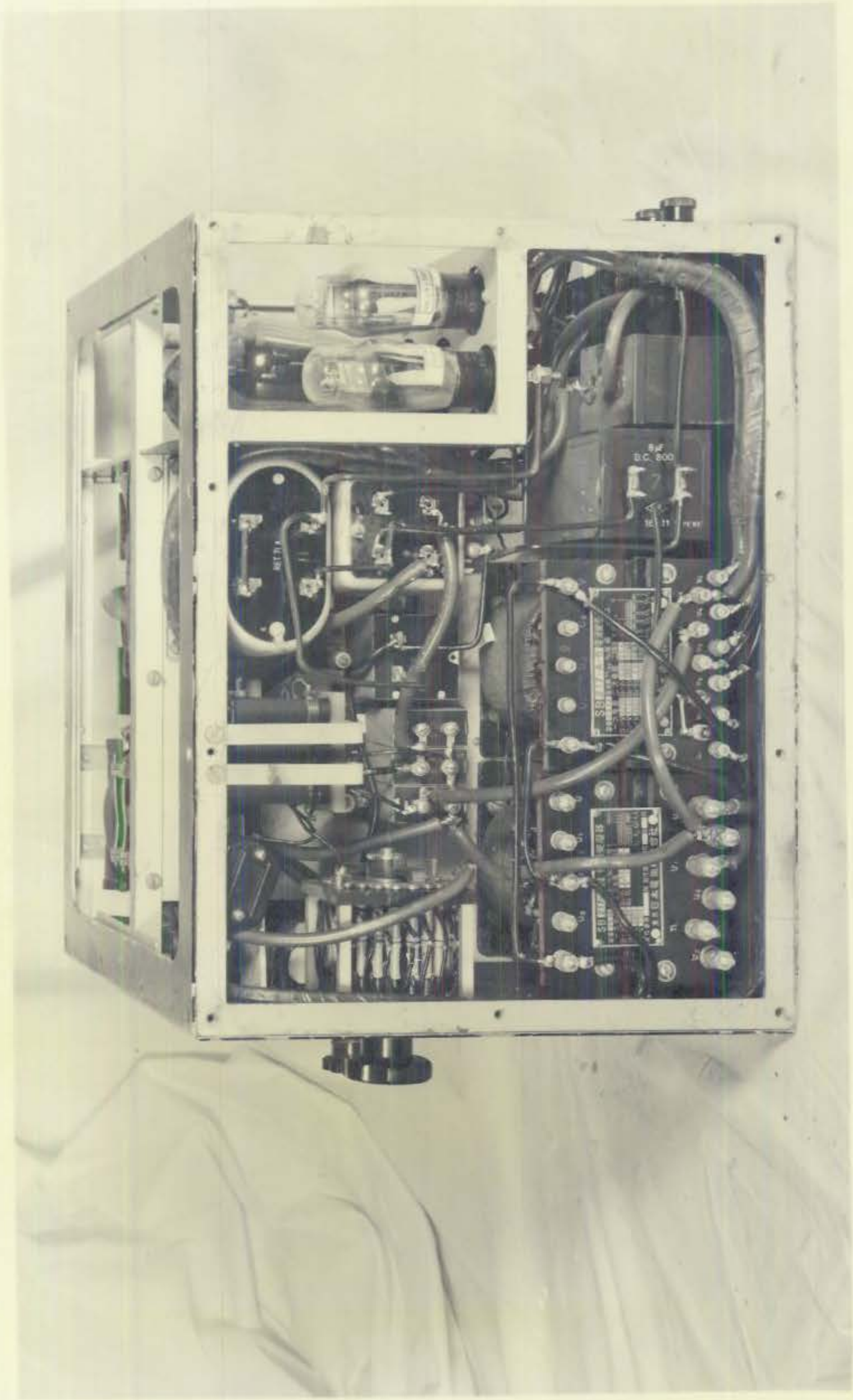

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PLATE 29

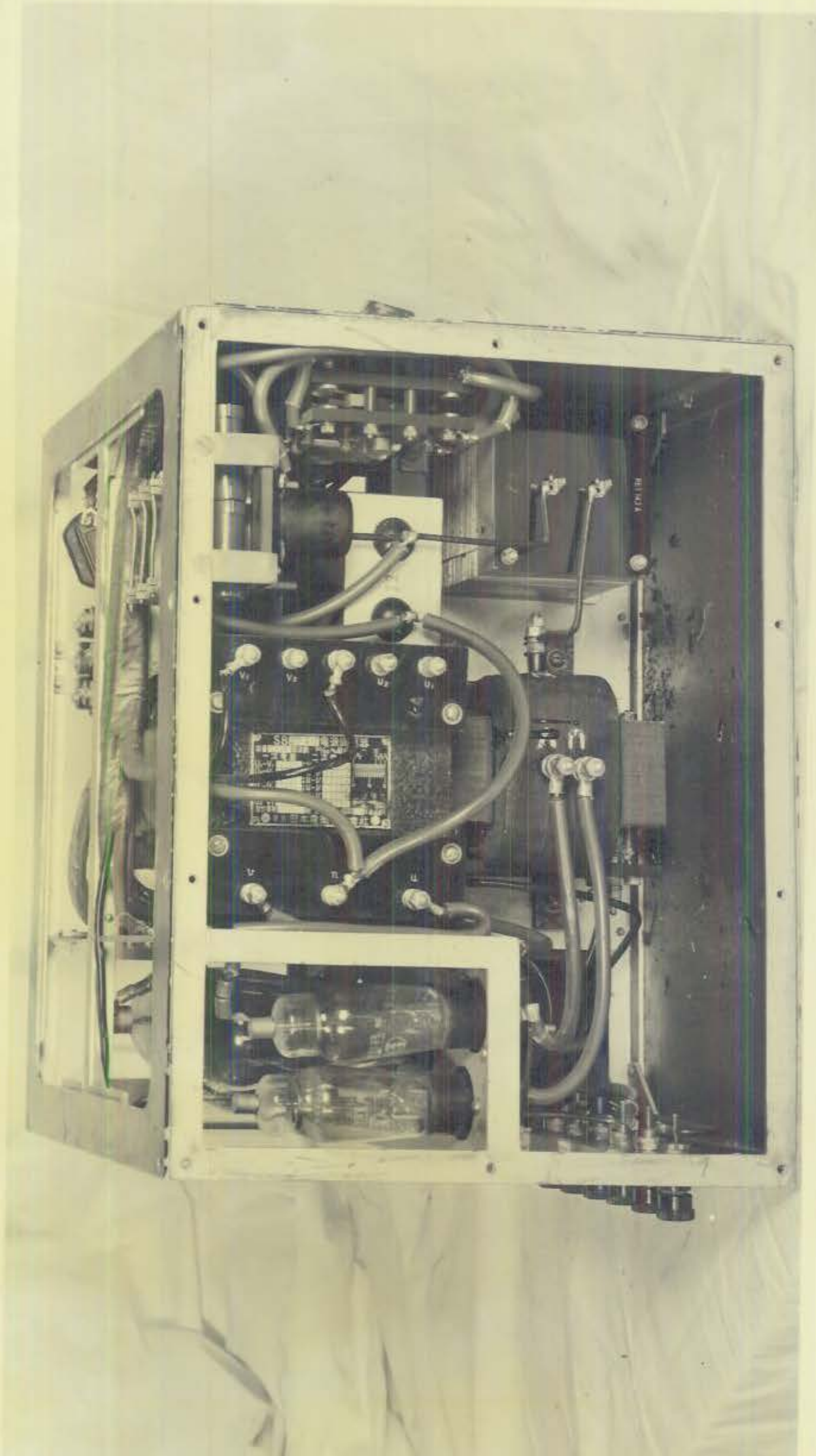
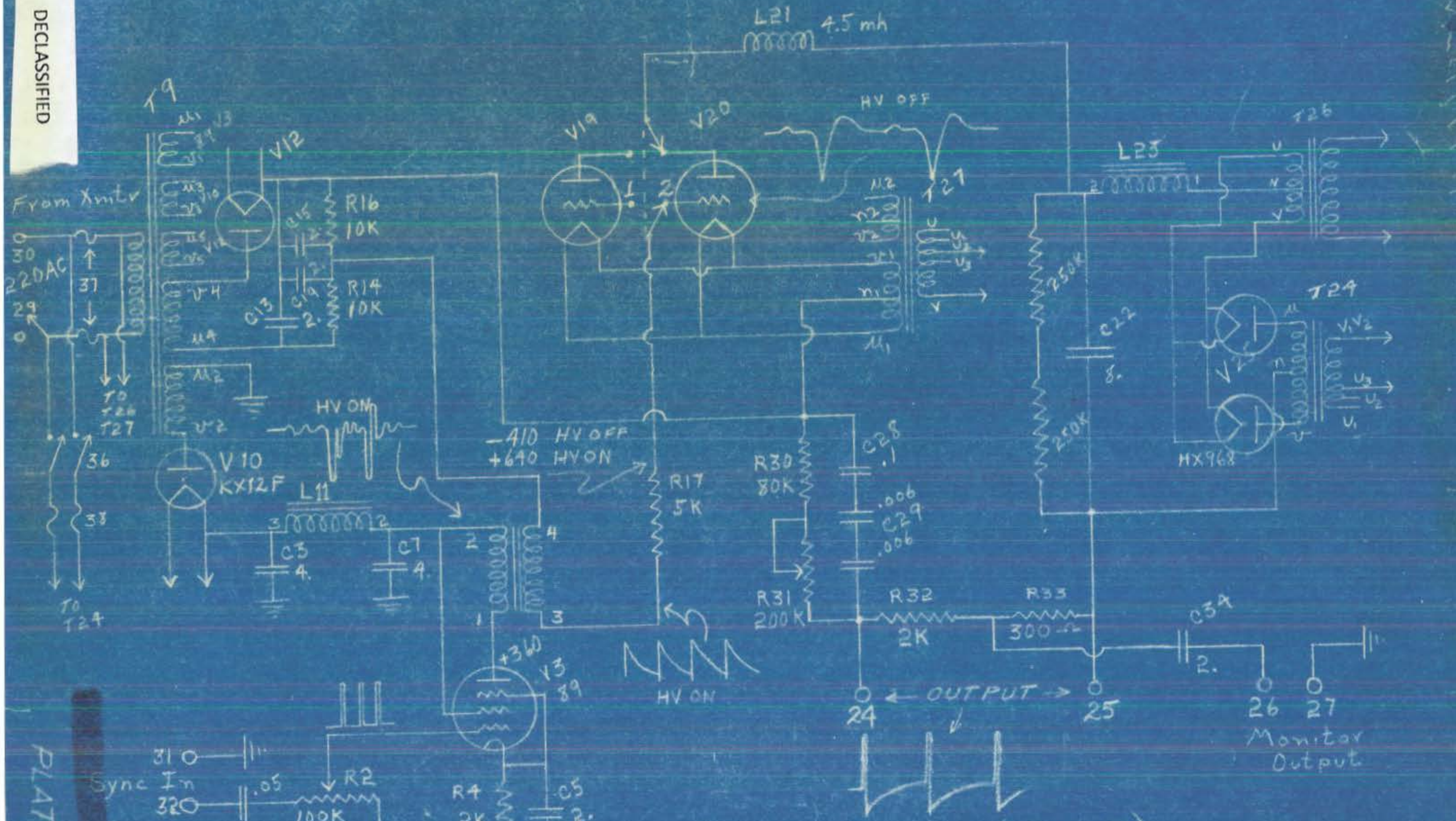






PLATE 30




MODULATOR UNIT (KEYER)

JAPANESE RADAR EQUIPMENT

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PLATE 31

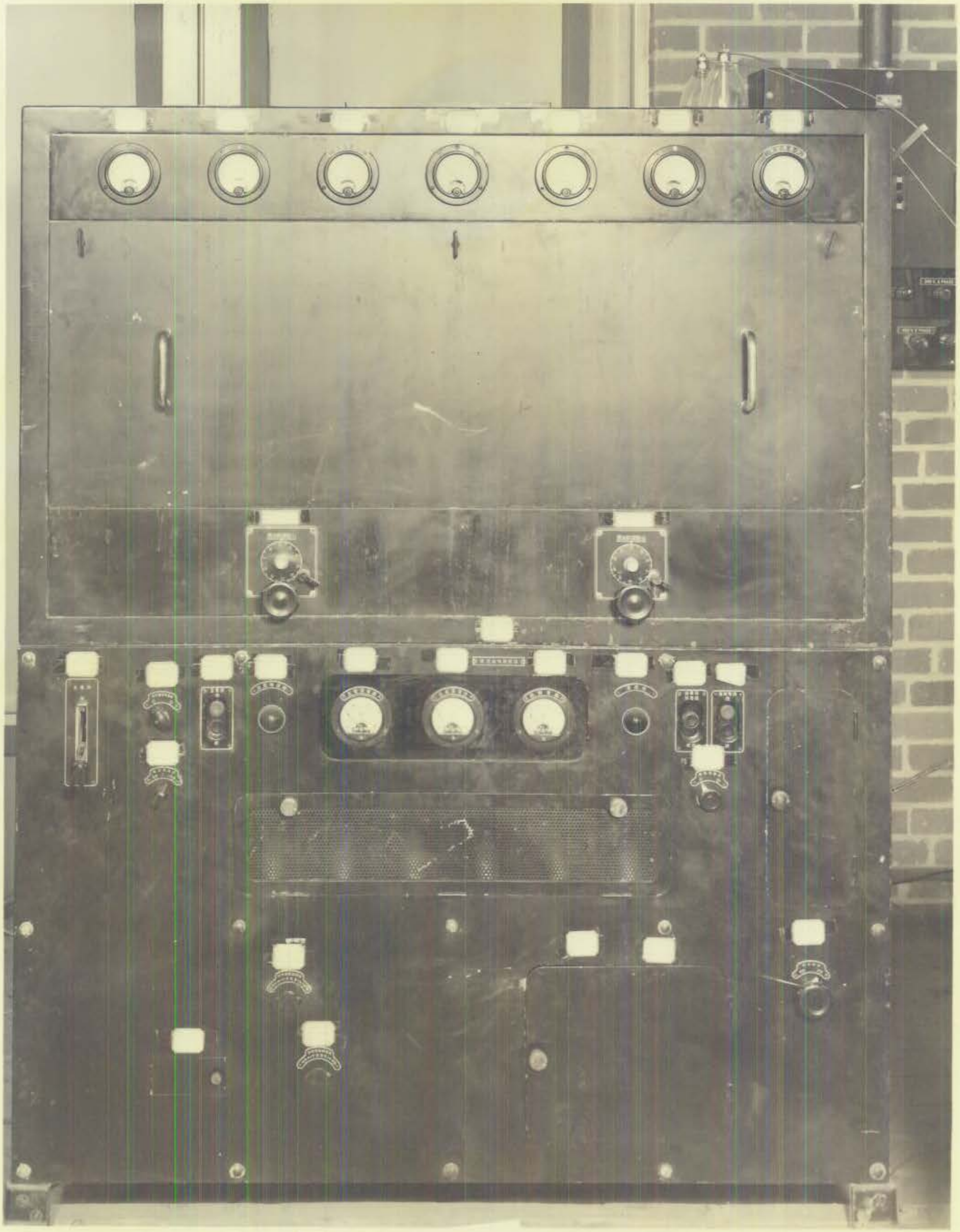

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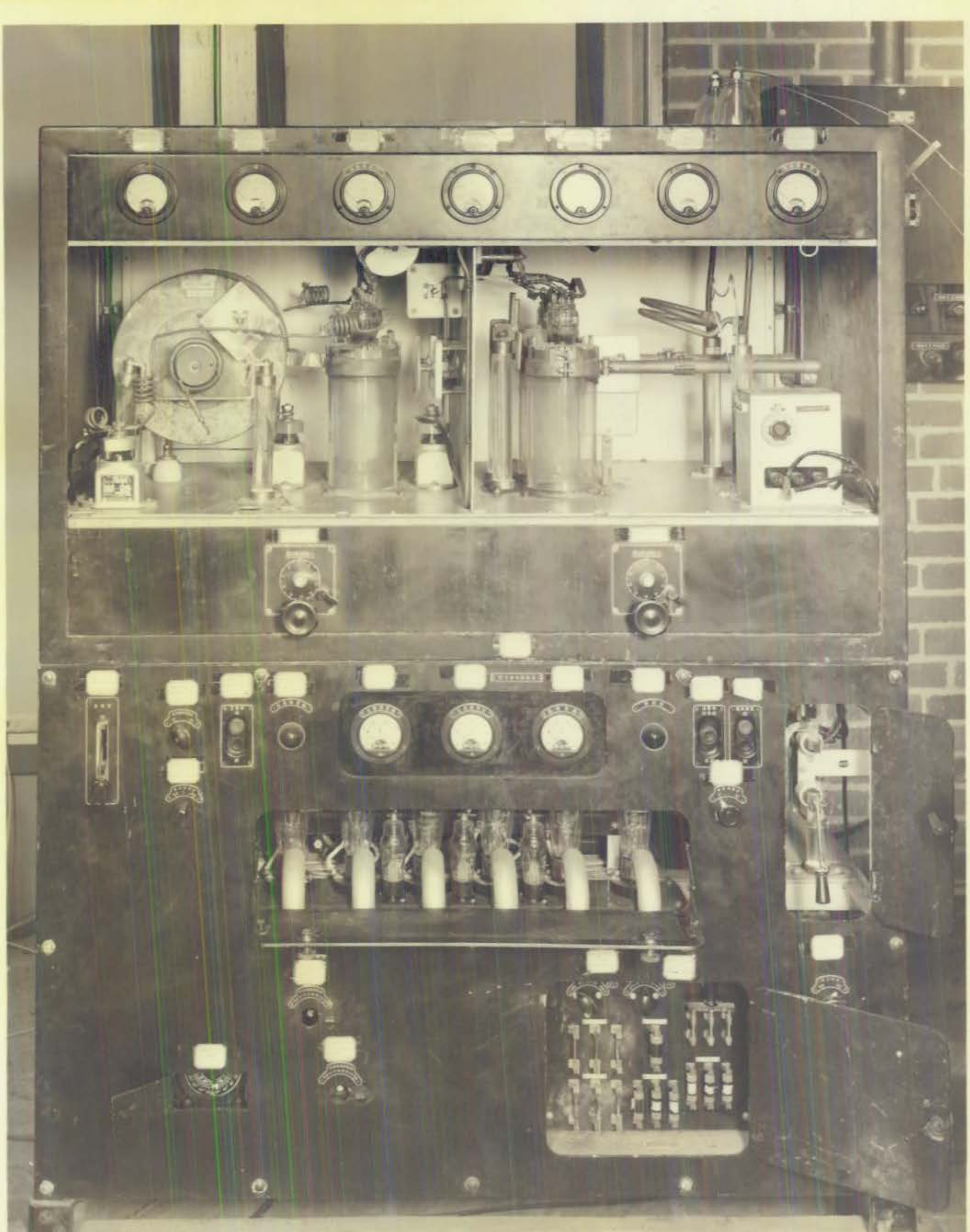
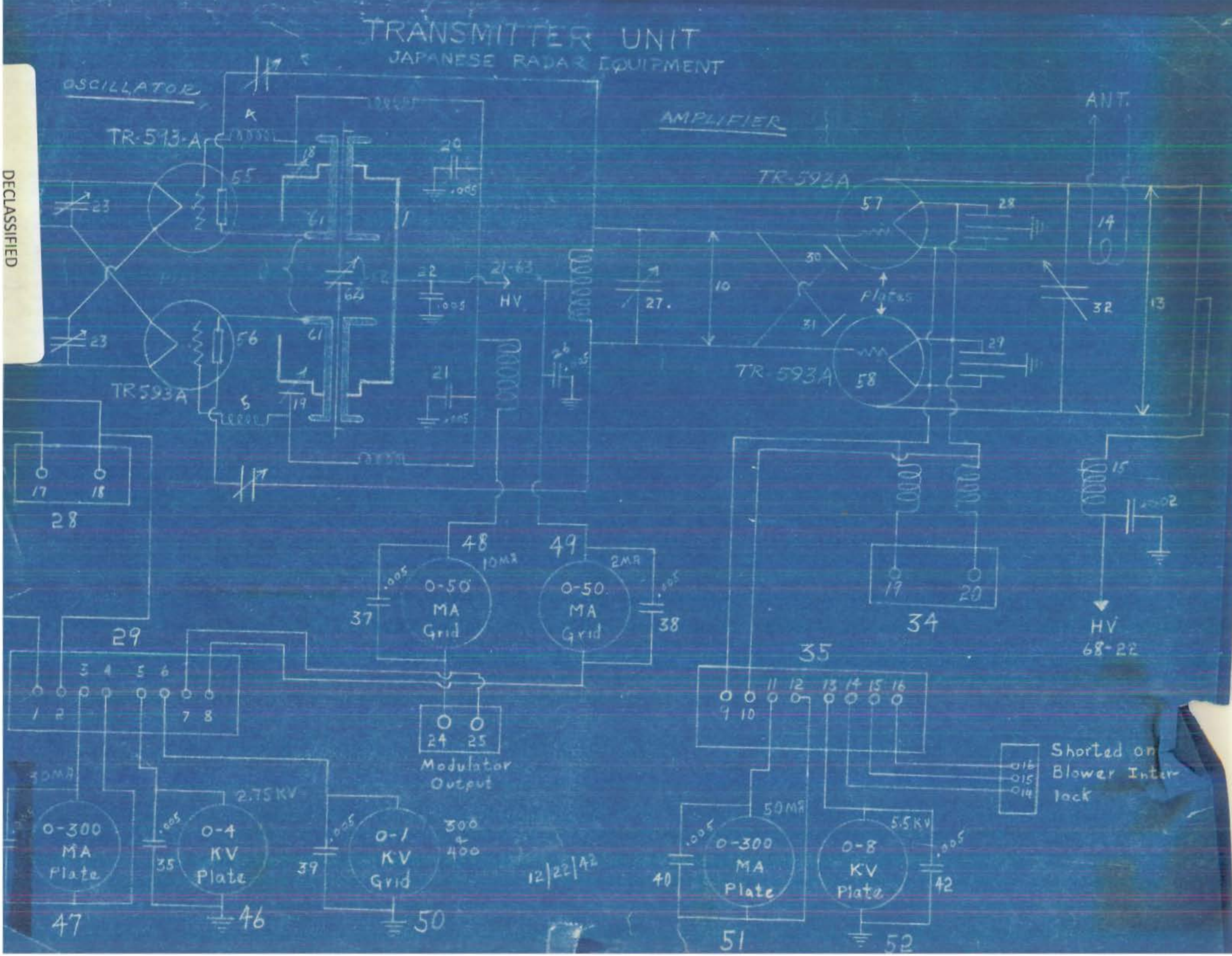
PLATE 32





TRANSMITTER UNIT
JAPANESE RADAR EQUIPMENT
OSCILLATOR
AMPLIFIER
TR-593-A
TR593A
TR-593A
TR-593A
55
56
57
58
Plates
HV
21-63
HV
68-22
ANT.
28
29
34
35
17
18
19
20
24
25
Modulator Output
0-50 MA Grid
0-50 MA Grid
10MA
2MA
0-300 MA Plate
0-4 KV Plate
0-1 KV Grid
0-300 MA Plate
0-8 KV Plate
2.75 KV
300 - 400
50MA
5.5KV
47
46
50
51
52
48
49
37
38
35
39
40
42
Shorted on Blower Inter-lock
12/22/42

# CONTROL SYSTEM

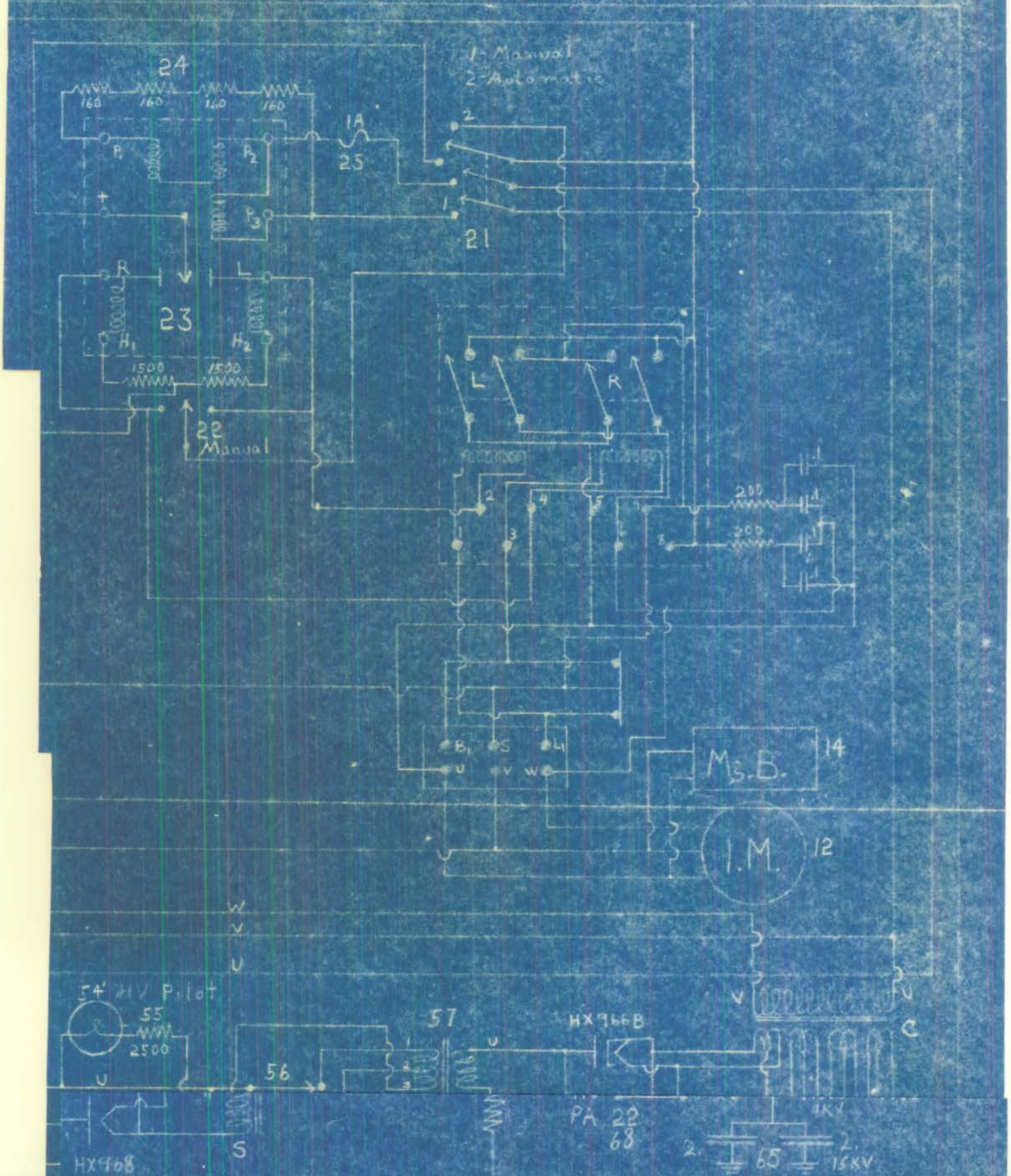
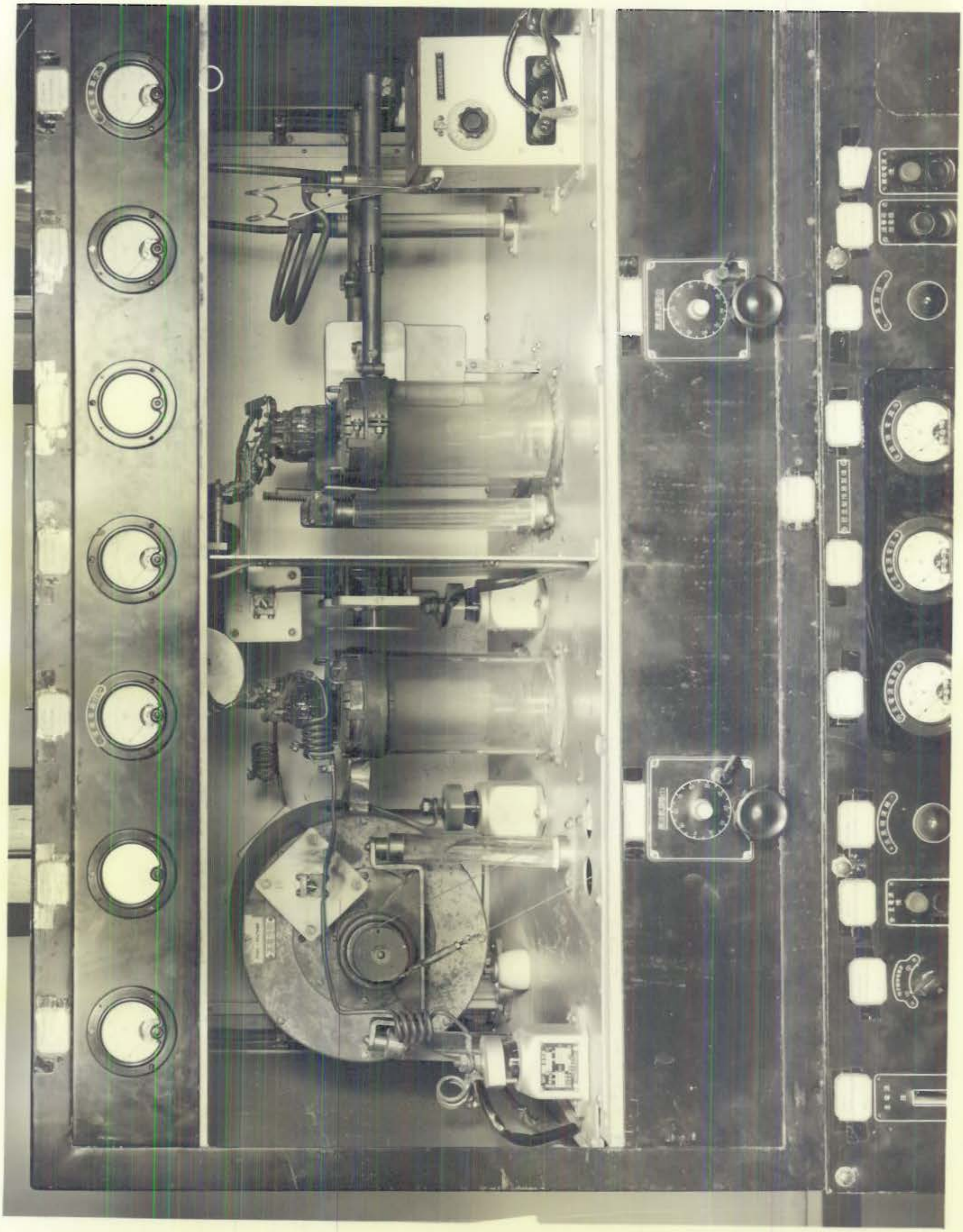



PLATE 35



[redacted]

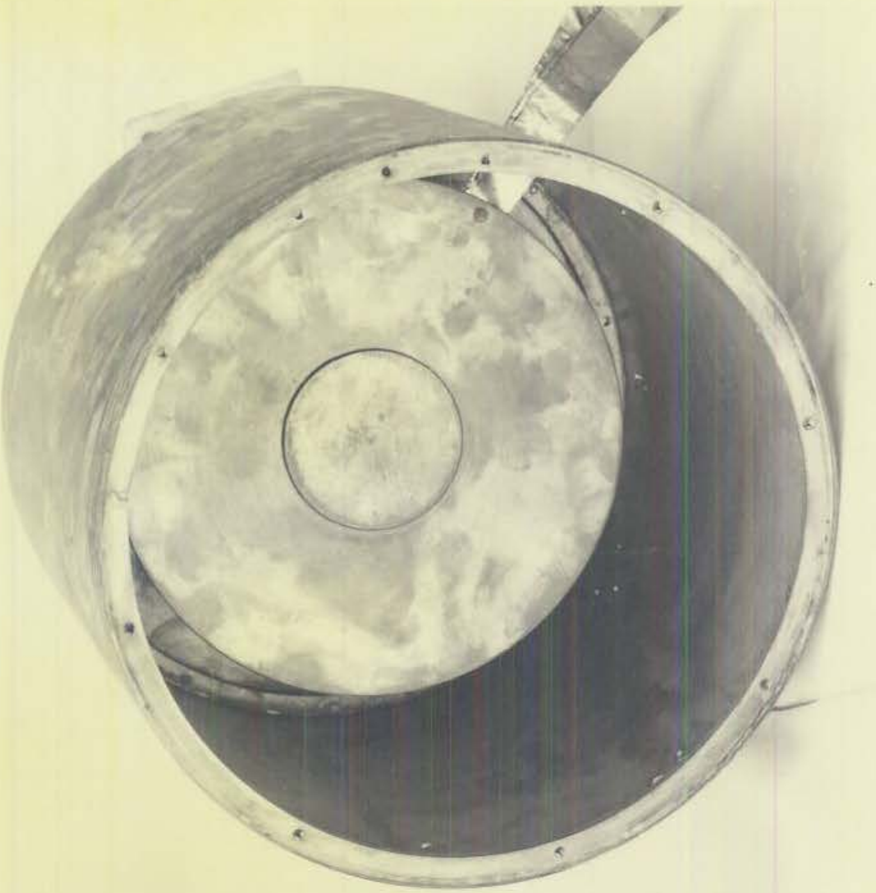
DECLASSIFIED

PLATE 36

DECLASSIFIED

[redacted]

PLATE 37

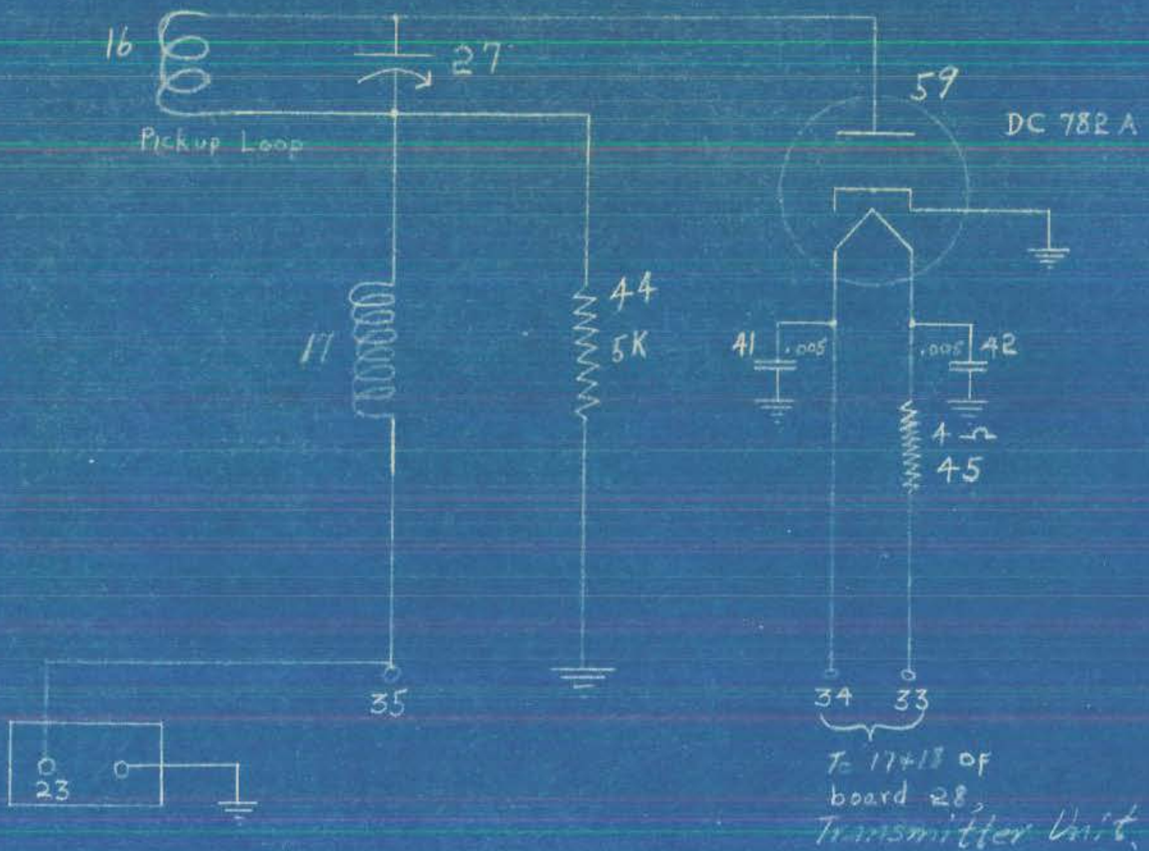


[redacted]

DECLASSIFIED

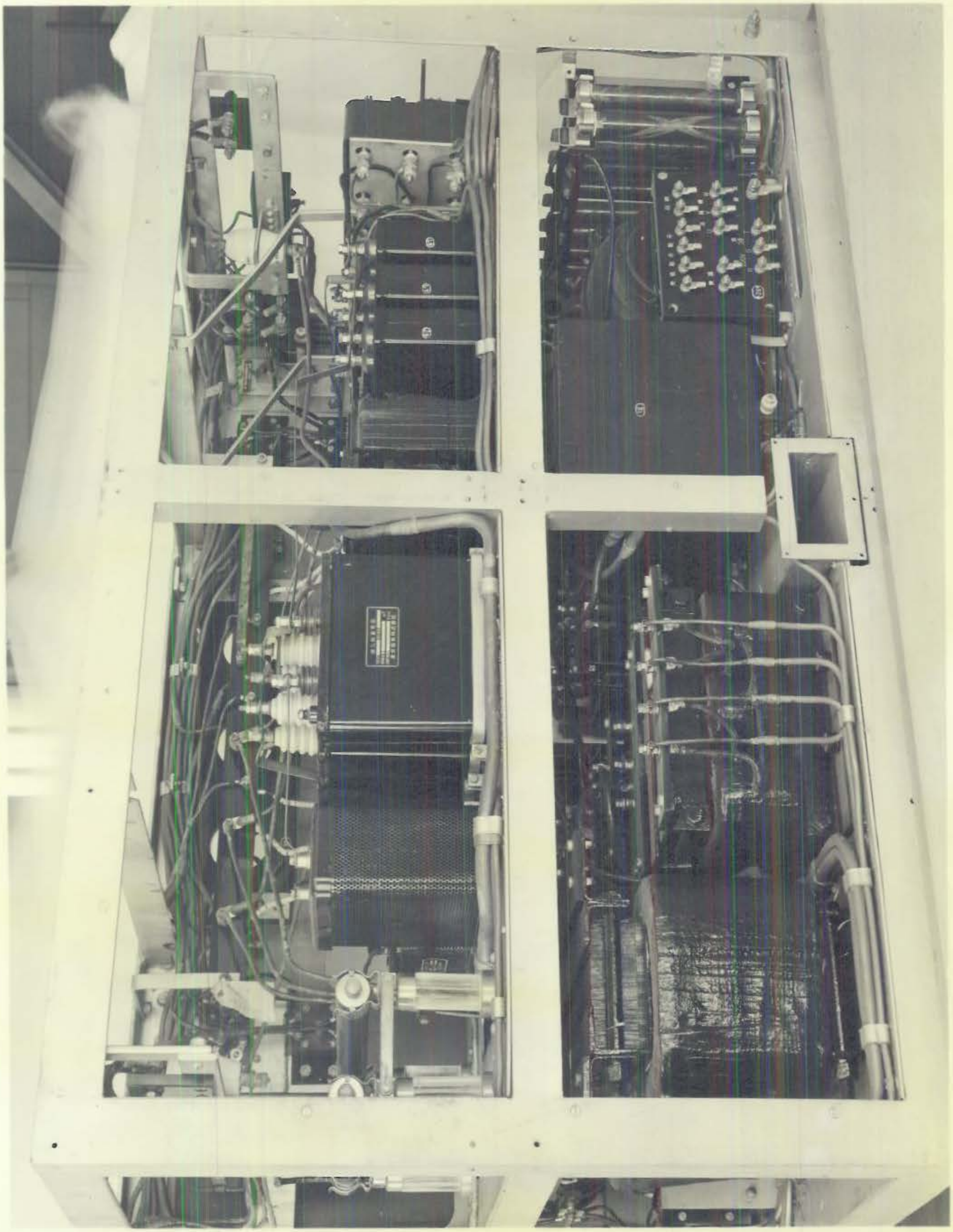
PLATE 38

MONITOR PICK-UP UNIT
JAPANESE RADAR EQUIPMENT
*Located near Transmitter Power Amplifier*




DECLASSIFIED

PLATE 39 [redacted]



[redacted]DENTIAL

DECLASSIFIED

PLATE 40

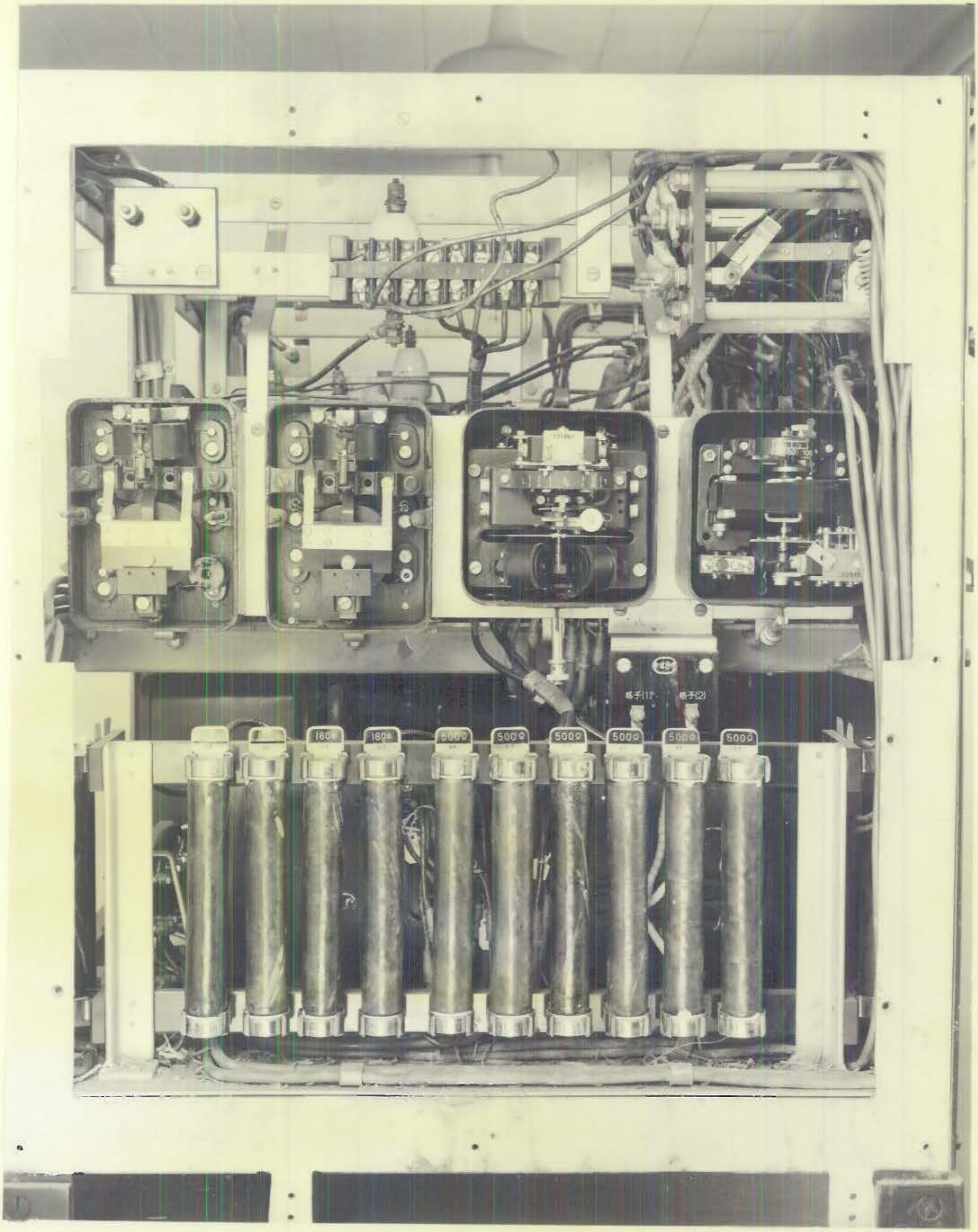
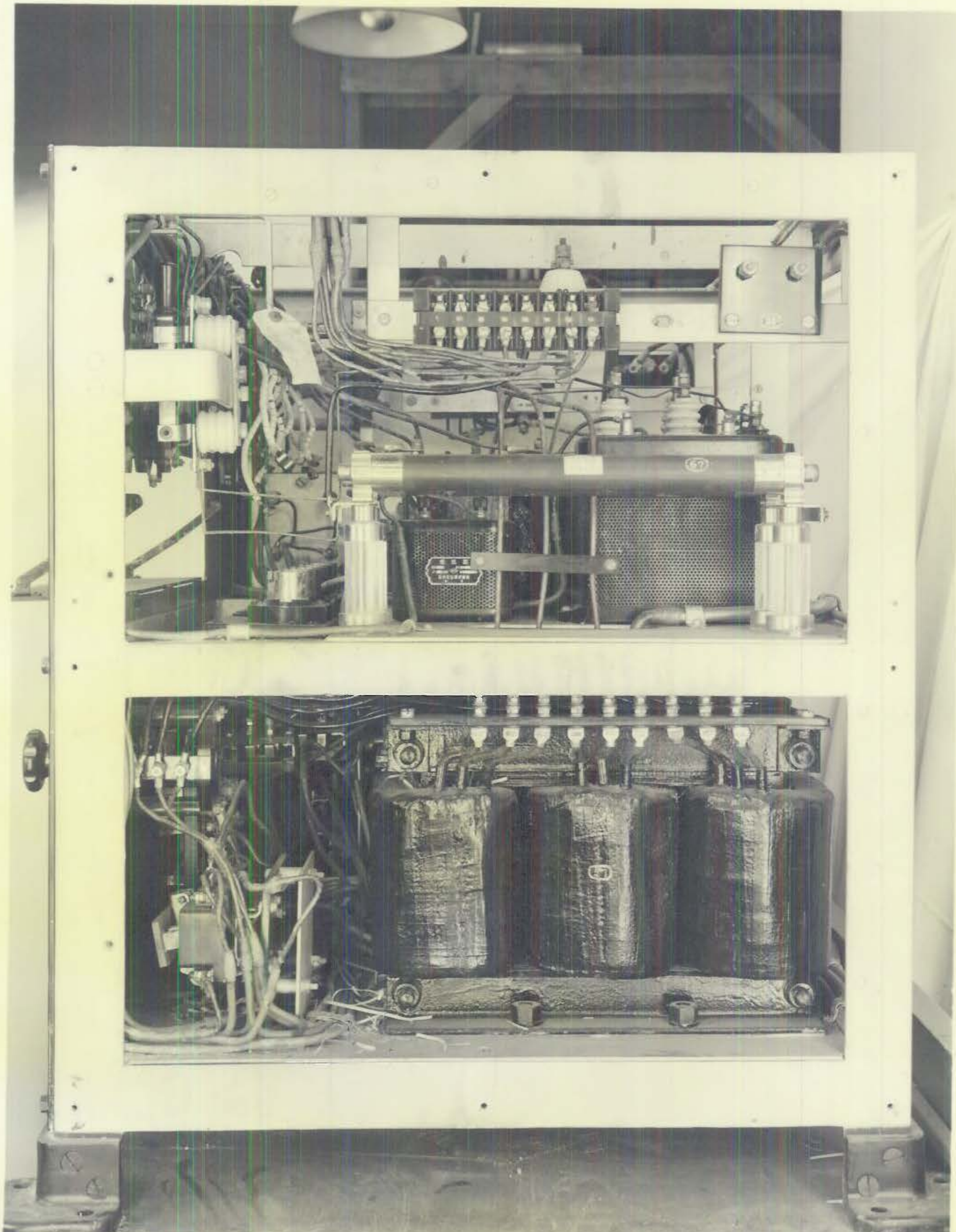







PLATE 41



[redacted]

DECLASSIFIED

PLATE 42

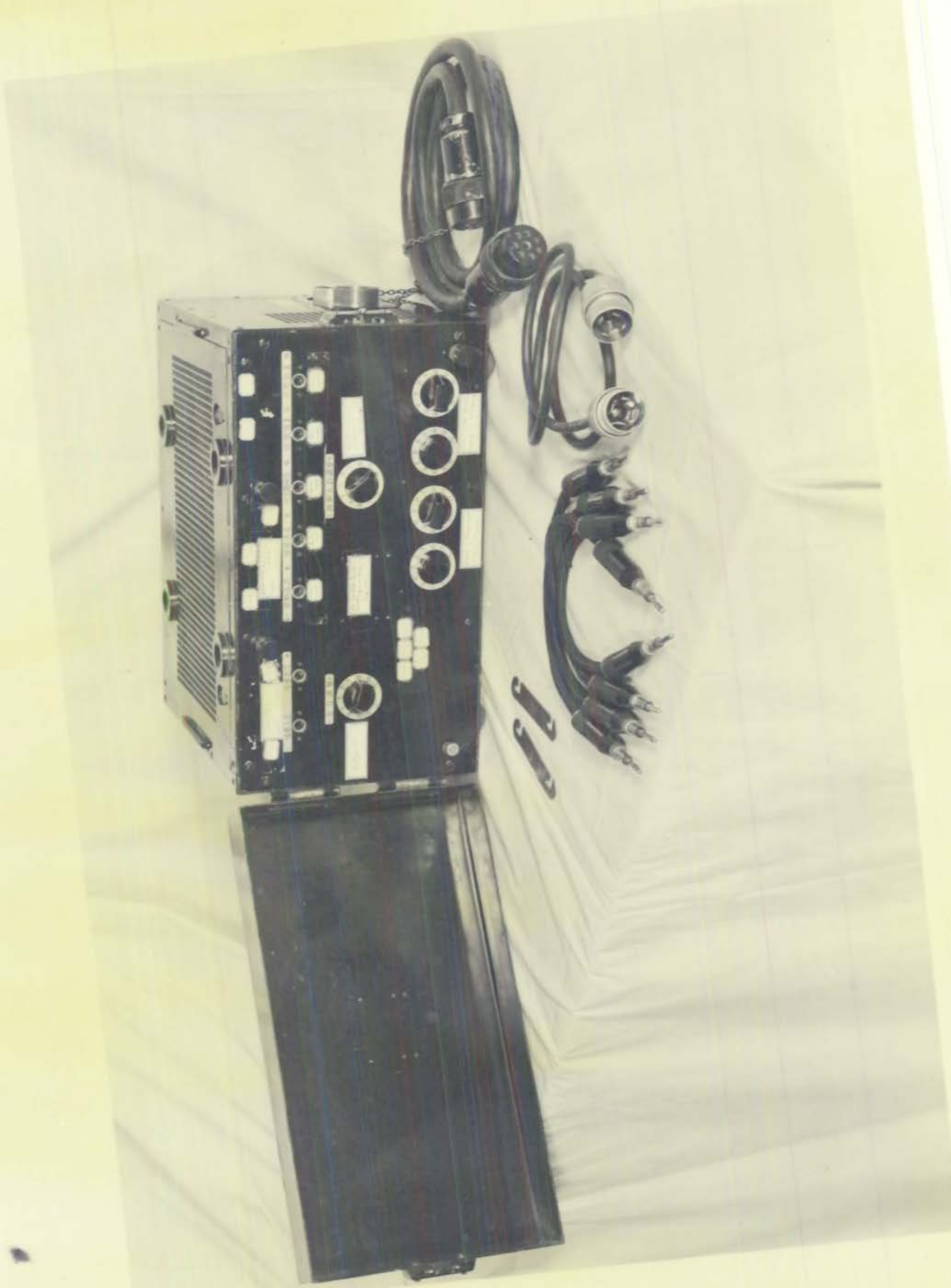
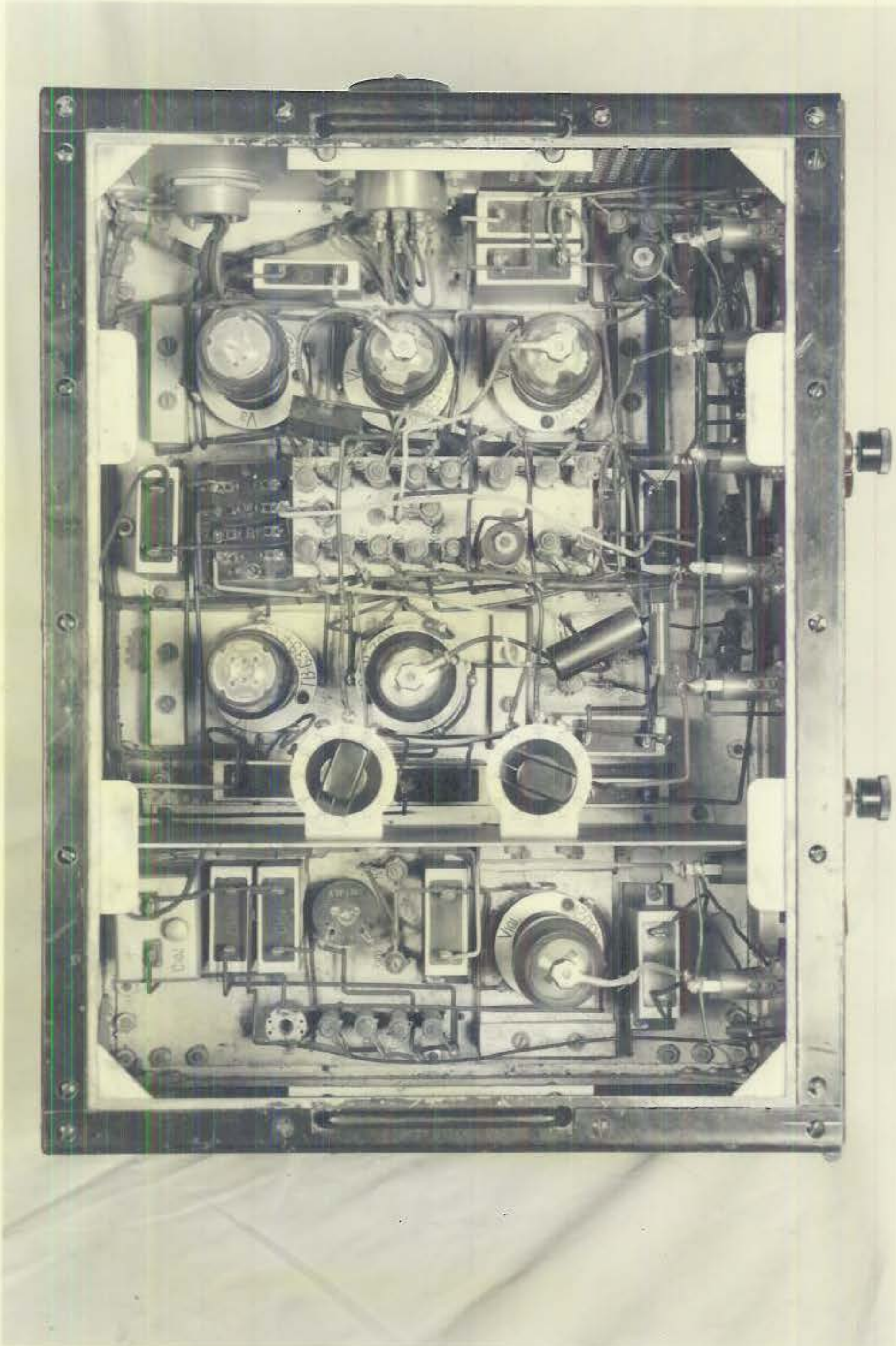


PLATE 43



~~CONFIDENTIAL~~

DECLASSIFIED

PLATE 45

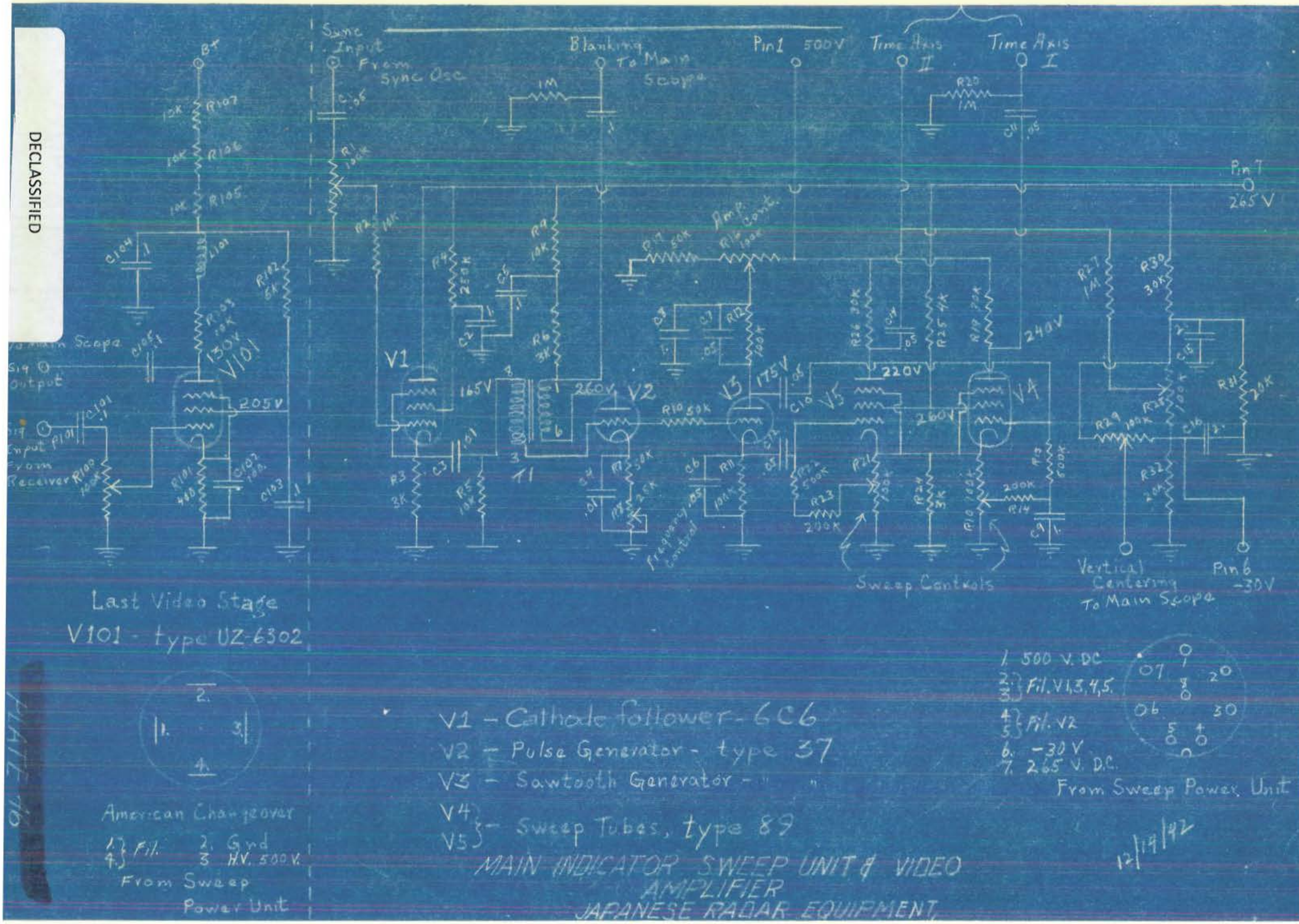
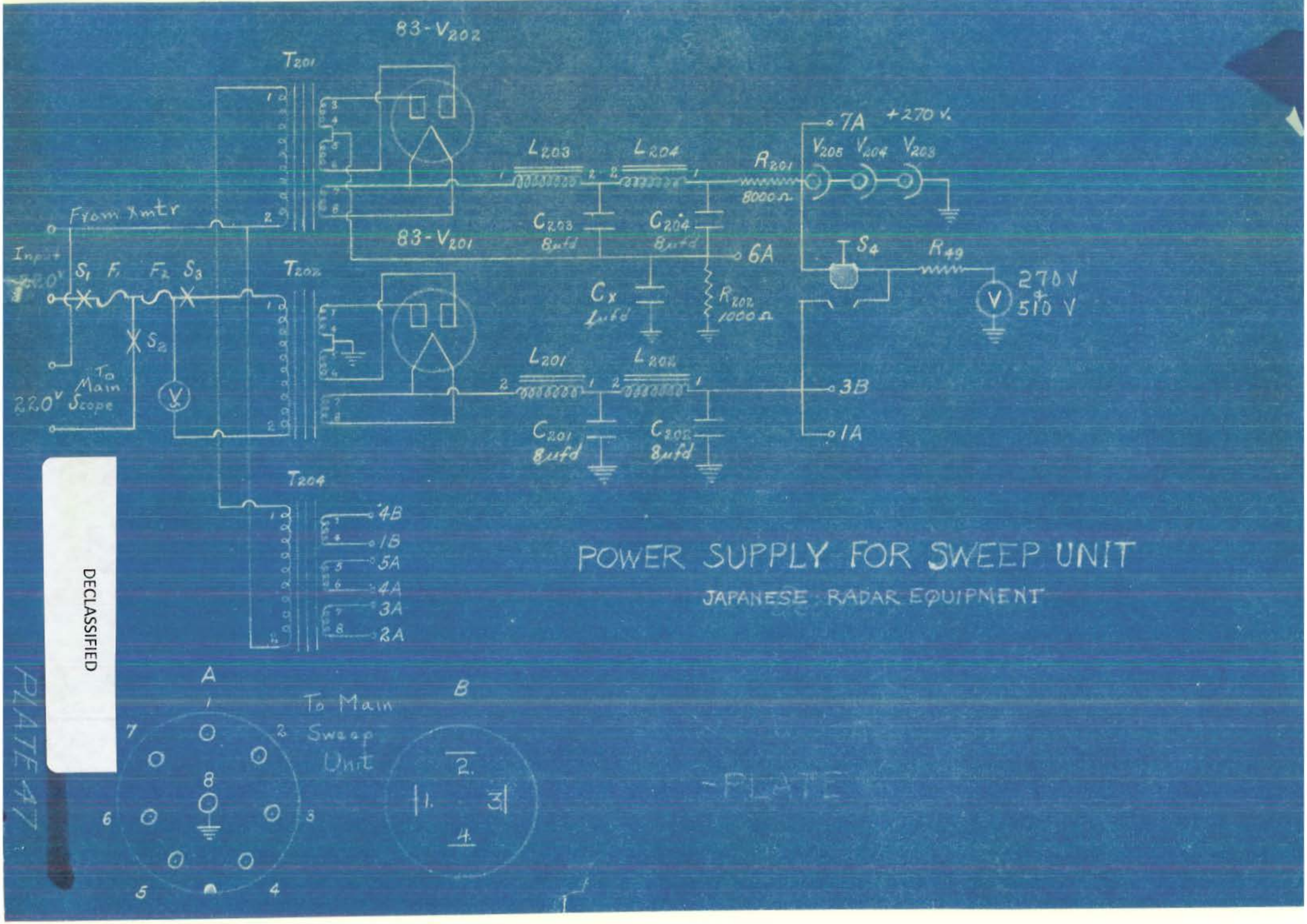

Sync Input From Sync Osc
Blanking To Main Scope
Pin 1 500V
Time Axis II
Time Axis I
Pin 7 265 V
B+
To Main Scope Sig Output
Sig Input From Receiver
V101
205V
130V
V1
V2
V3
V4
V5
165V
260V
175V
220V
240V
Amp. Cont.
Frequency Control
Sweep Controls
Vertical Centering To Main Scope
Pin 6 -30V
Last Video Stage
V101 - type UZ-6302
American Changeover
1, 4 Fil.
2. Grd
3 H.V. 500 V.
From Sweep Power Unit
V1 - Cathode follower - 6C6
V2 - Pulse Generator - type 37
V3 - Sawtooth Generator - "
V4, V5 - Sweep Tubes, type 89
1. 500 V. DC
2, 3 Fil. V1,3,4,5.
4, 5 Fil. V2
6. -30 V
7. 265 V. D.C.
From Sweep Power Unit
12/19/42
MAIN INDICATOR SWEEP UNIT & VIDEO AMPLIFIER
JAPANESE RADAR EQUIPMENT

PLATE 46

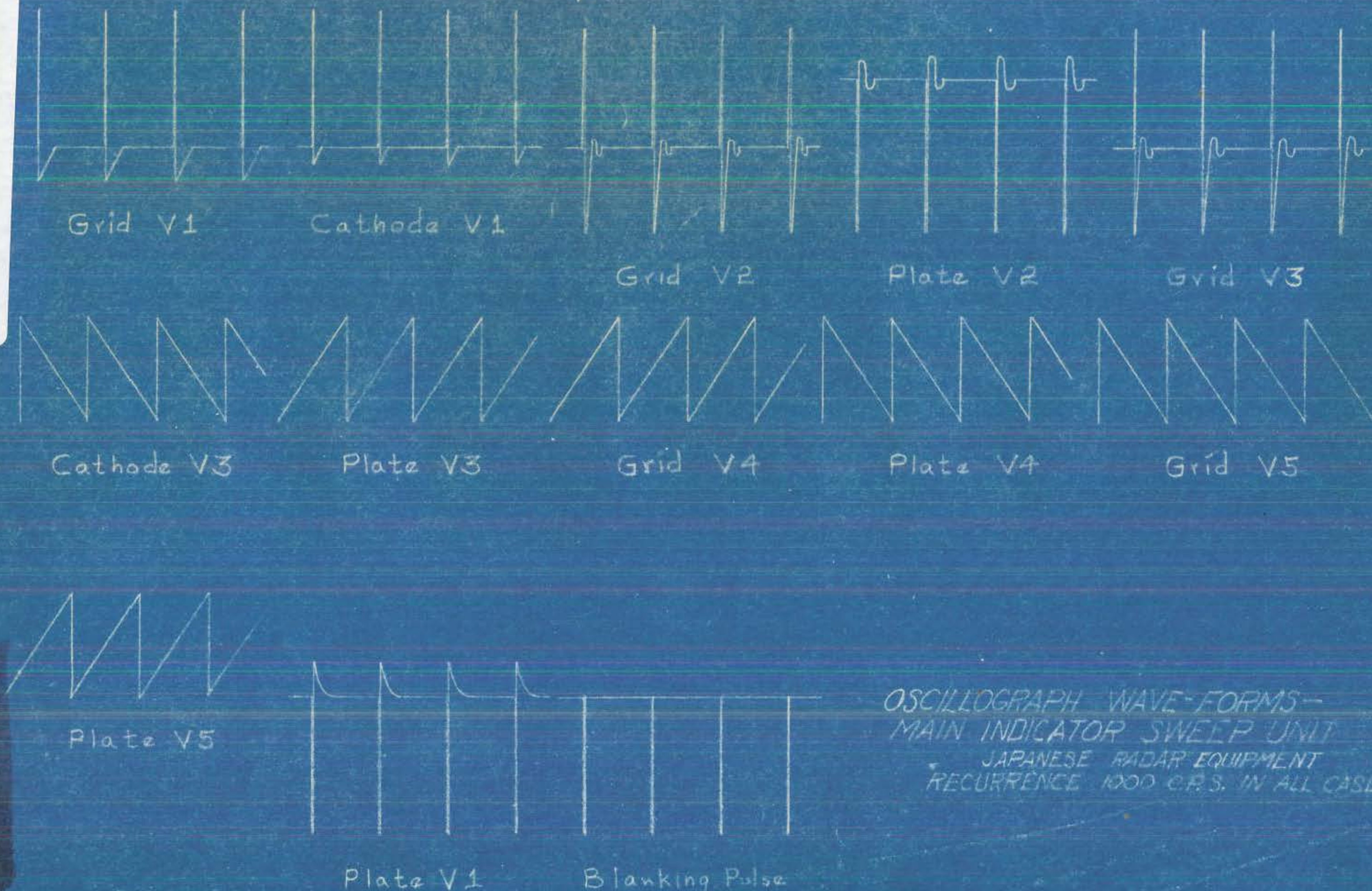



# POWER SUPPLY FOR SWEEP UNIT

JAPANESE RADAR EQUIPMENT

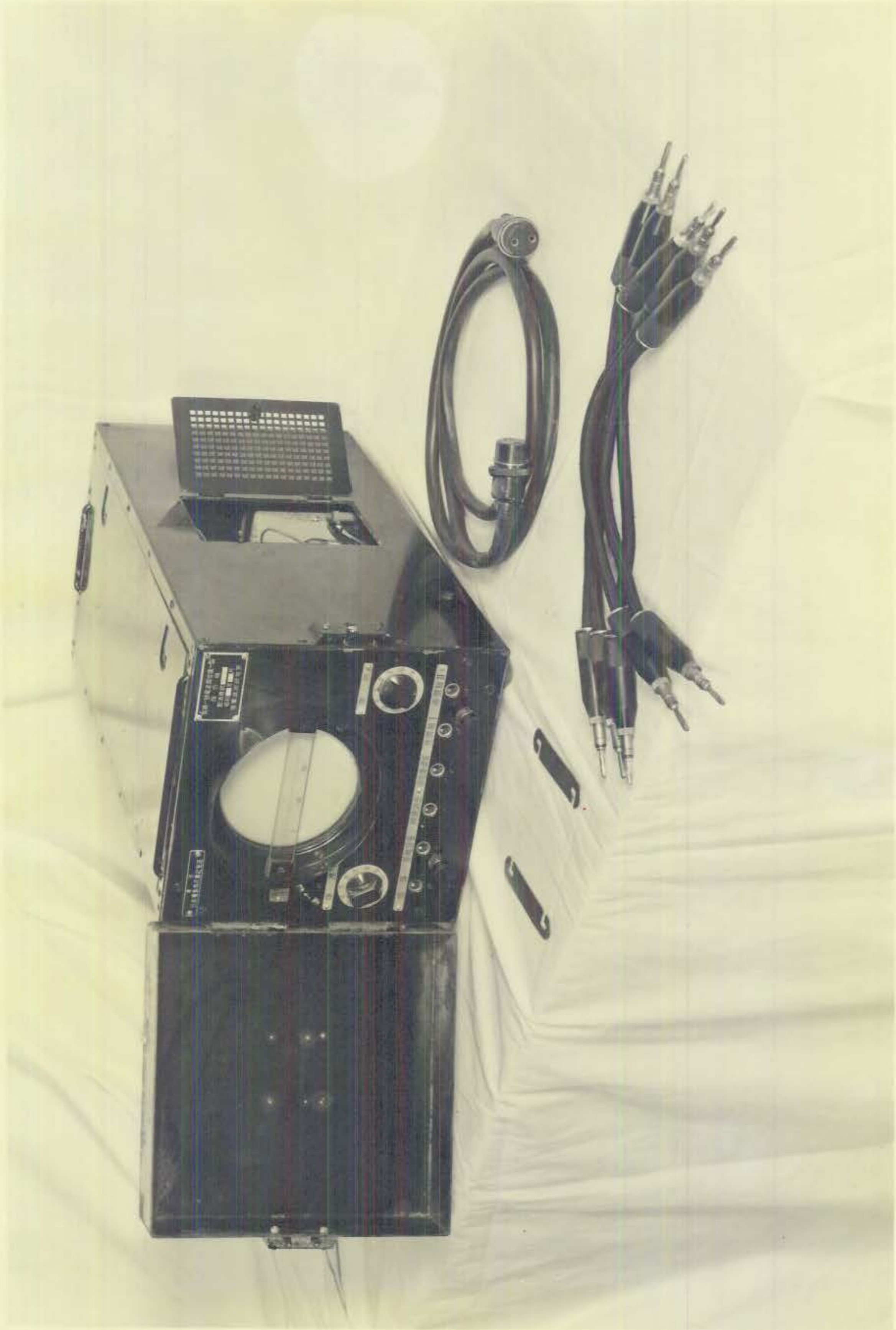
PLATE 47

DECLASSIFIED




OSCILLOGRAPH WAVE-FORMS—
MAIN INDICATOR SWEEP UNIT
JAPANESE RADAR EQUIPMENT
RECURRENCE 1000 C.P.S. IN ALL CASES.

[redacted]ATE 48



[redacted]ENTIAL

DECLASSIFIED

PLATE 49

~~CONFIDENTIAL~~

DECLASSIFIED

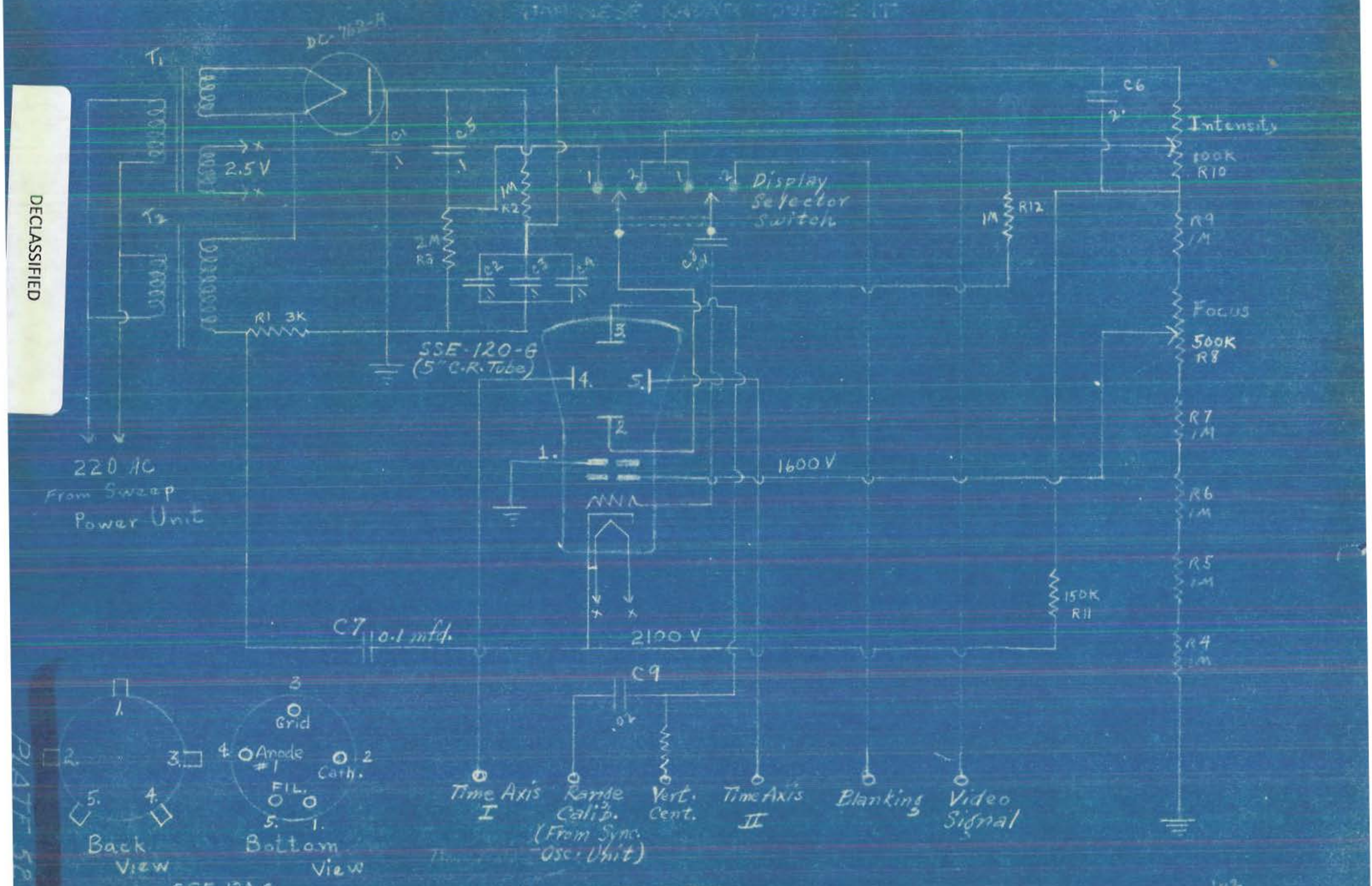
PLATE 50

[redacted]

DECLASSIFIED

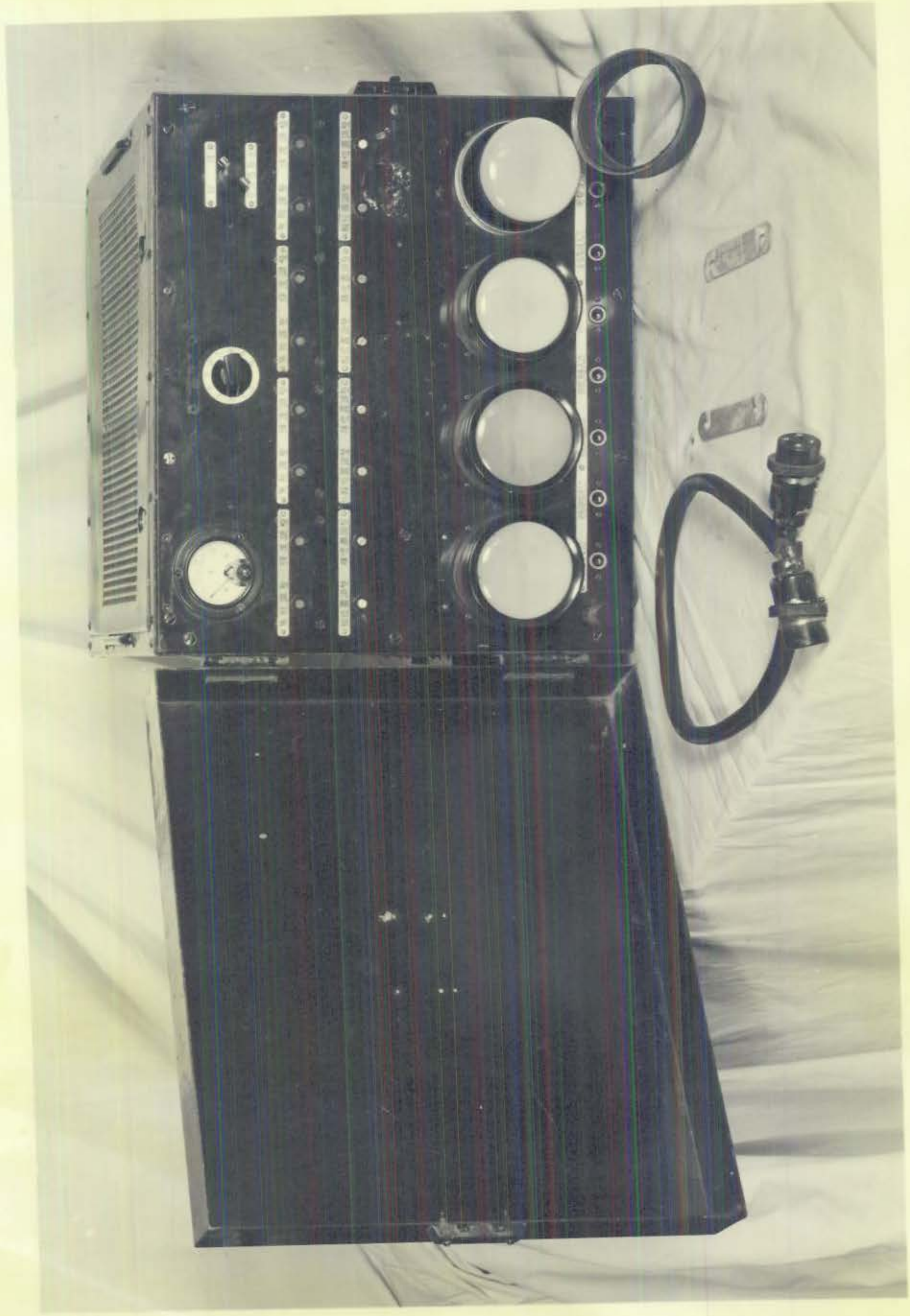
PLATE 51

DECLASSIFIED




MAIN INDICATOR OSCILLOSCOPE
JAPANESE RADAR EQUIPMENT

PLATE 52



[redacted]



PLATE 53

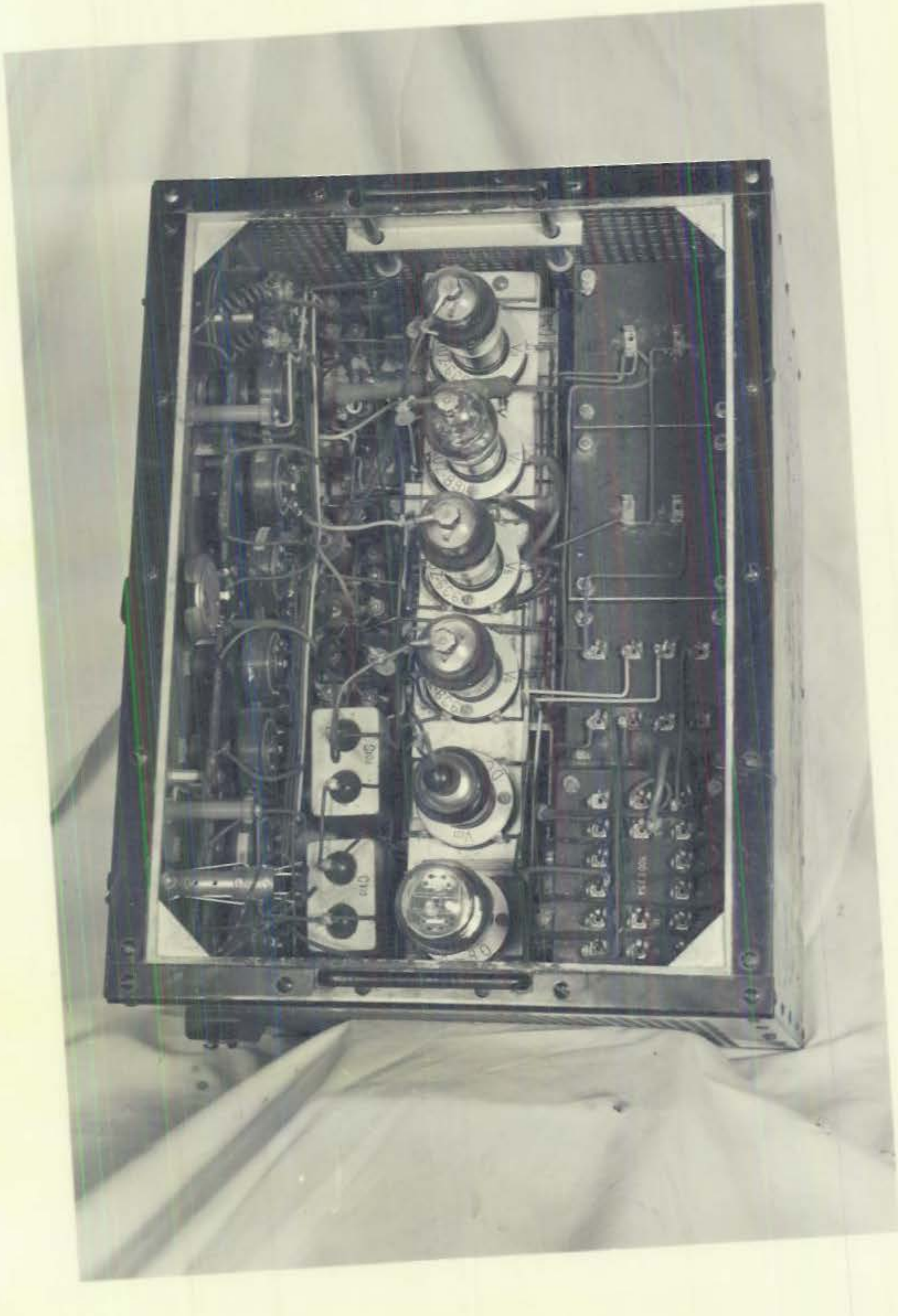
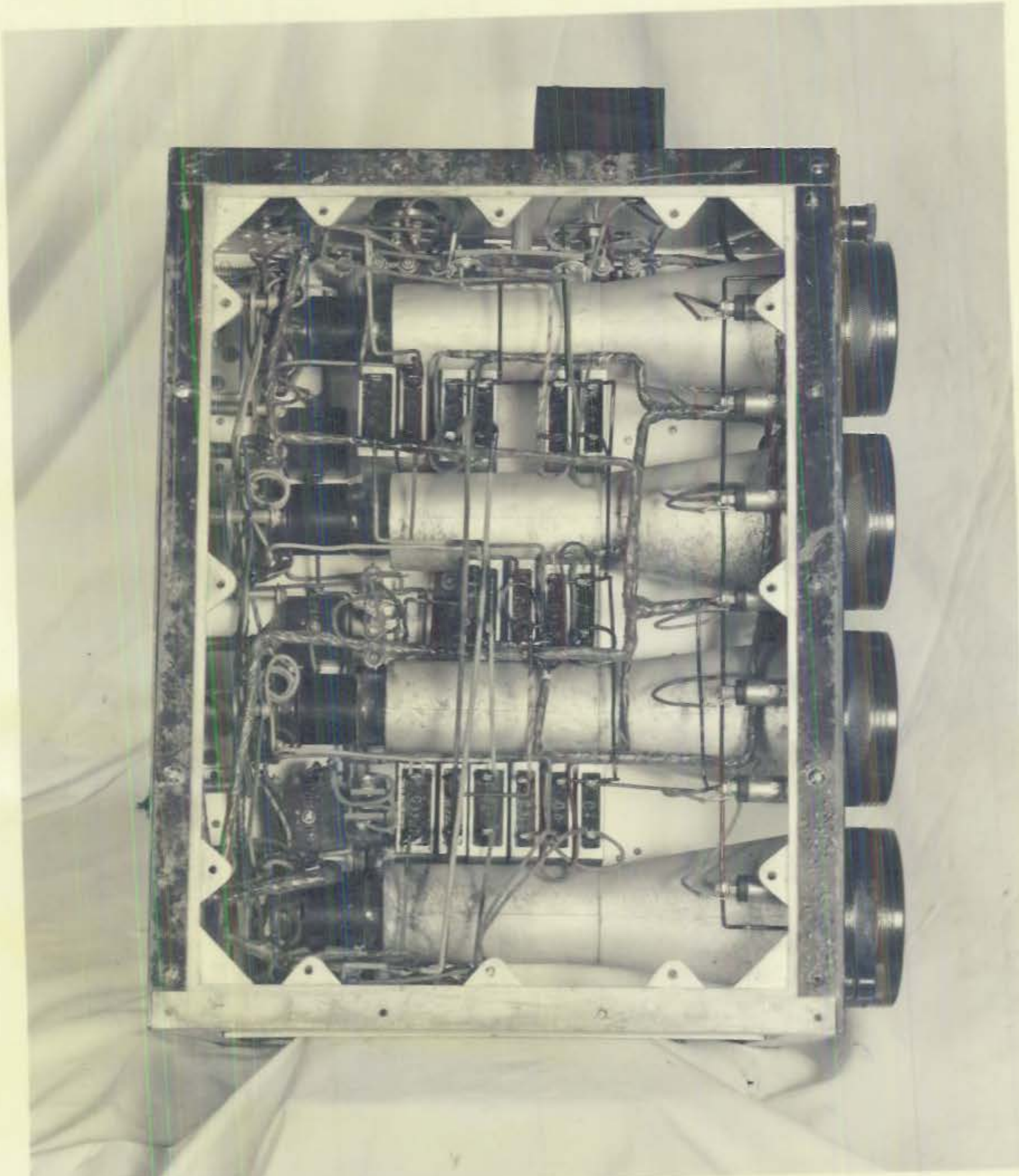


PLATE 54

[redacted]

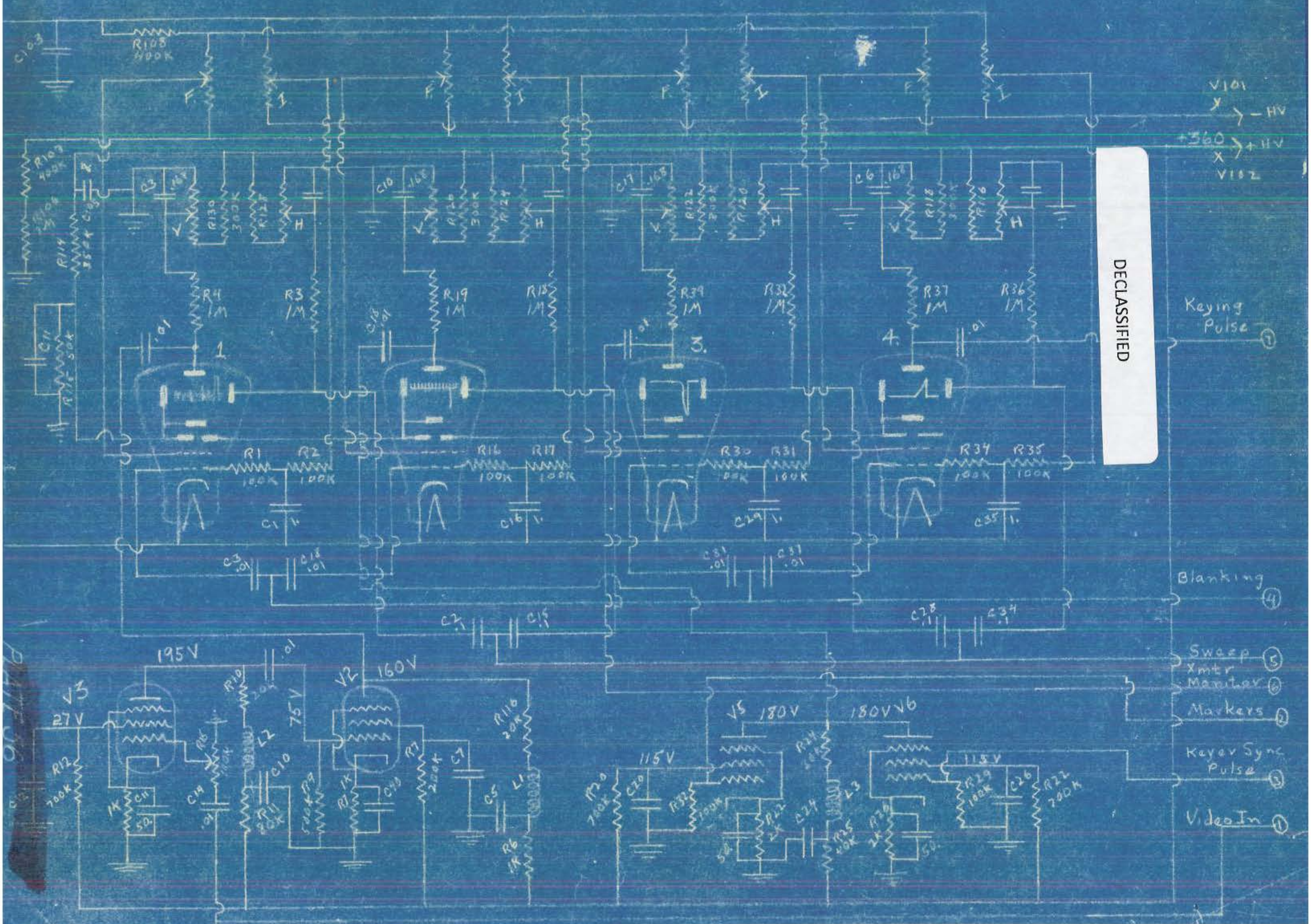


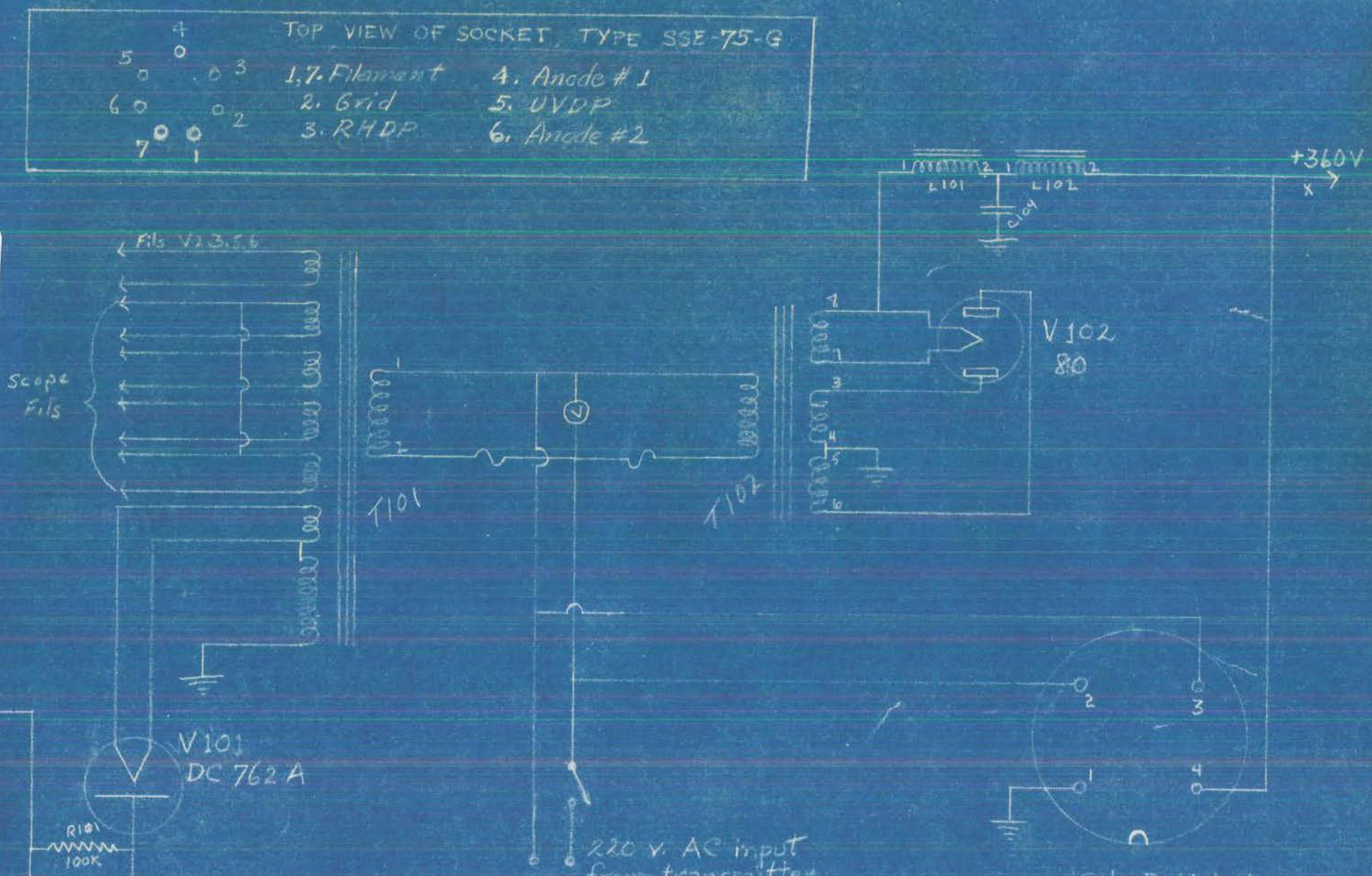
[redacted]

DECLASSIFIED

PLATE 55

# MONITOR UNIT
## JAPANESE RADAR EQUIPMENT

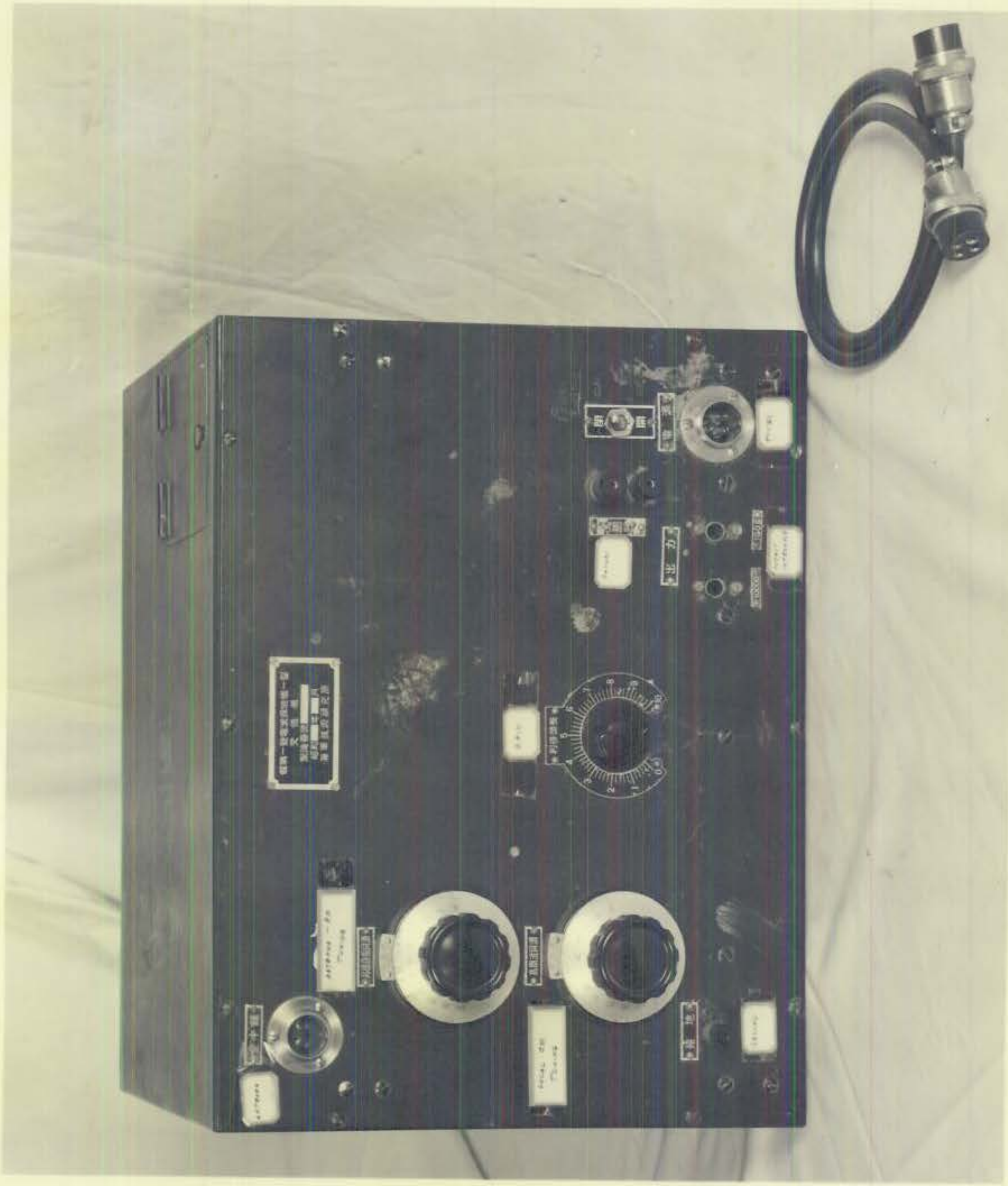





MONITOR POWER SUPPLY
CONTAINED IN MONITOR UNIT
JAPANESE RADAR EQUIPMENT

[redacted]

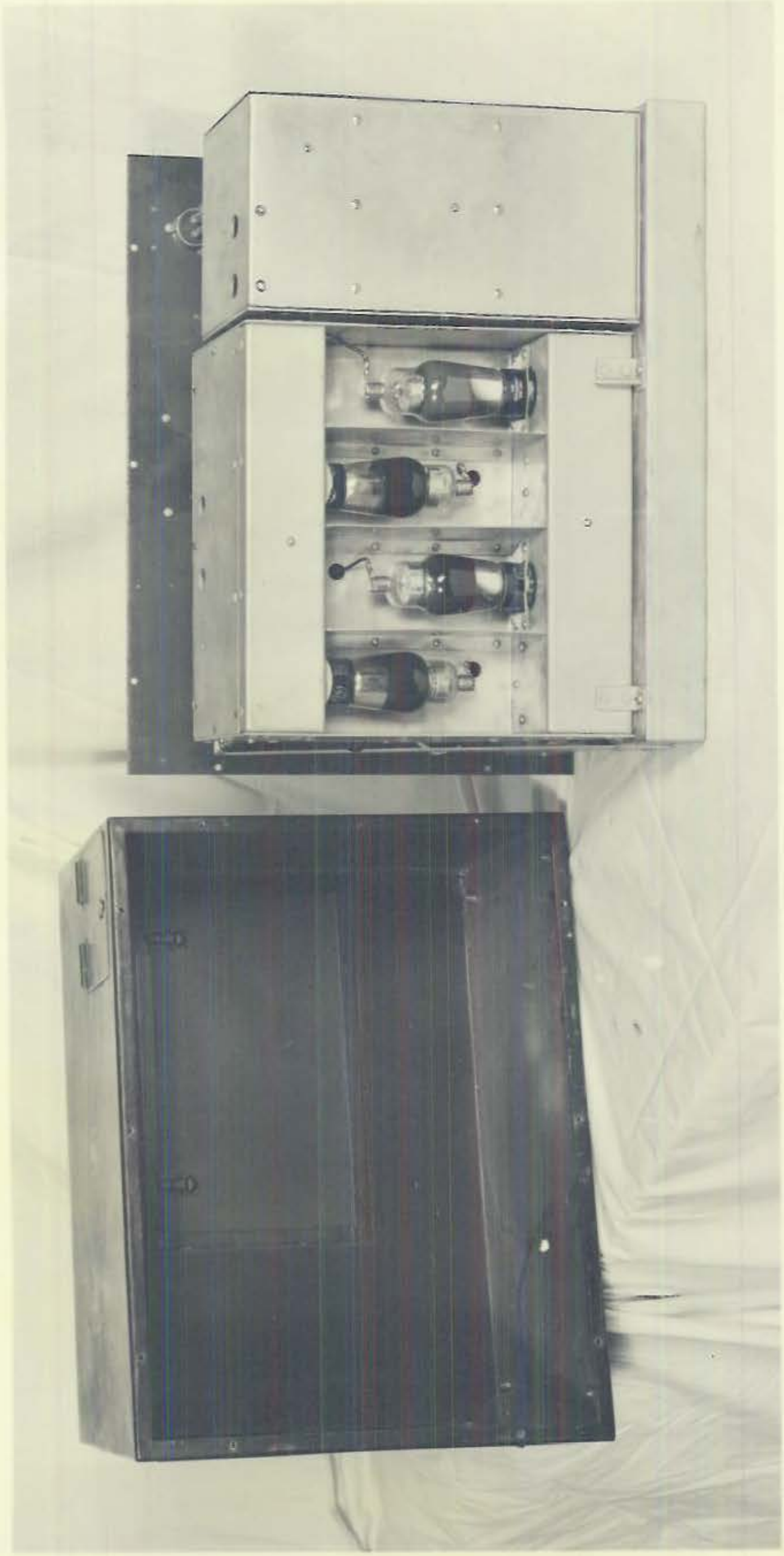
PLATE 57



[redacted]

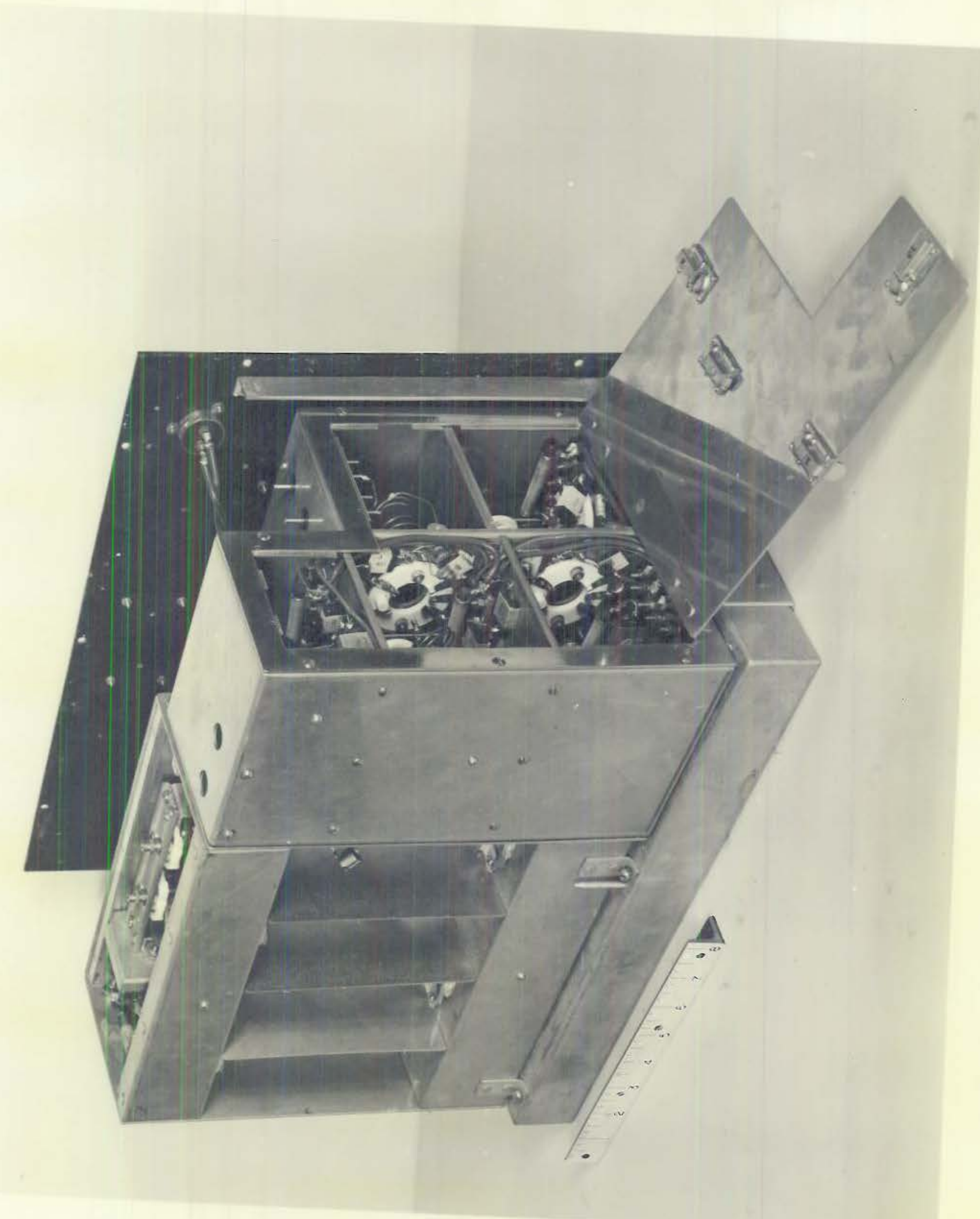
DECLASSIFIED

PLATE 58



[redacted] DECLASSIFIED

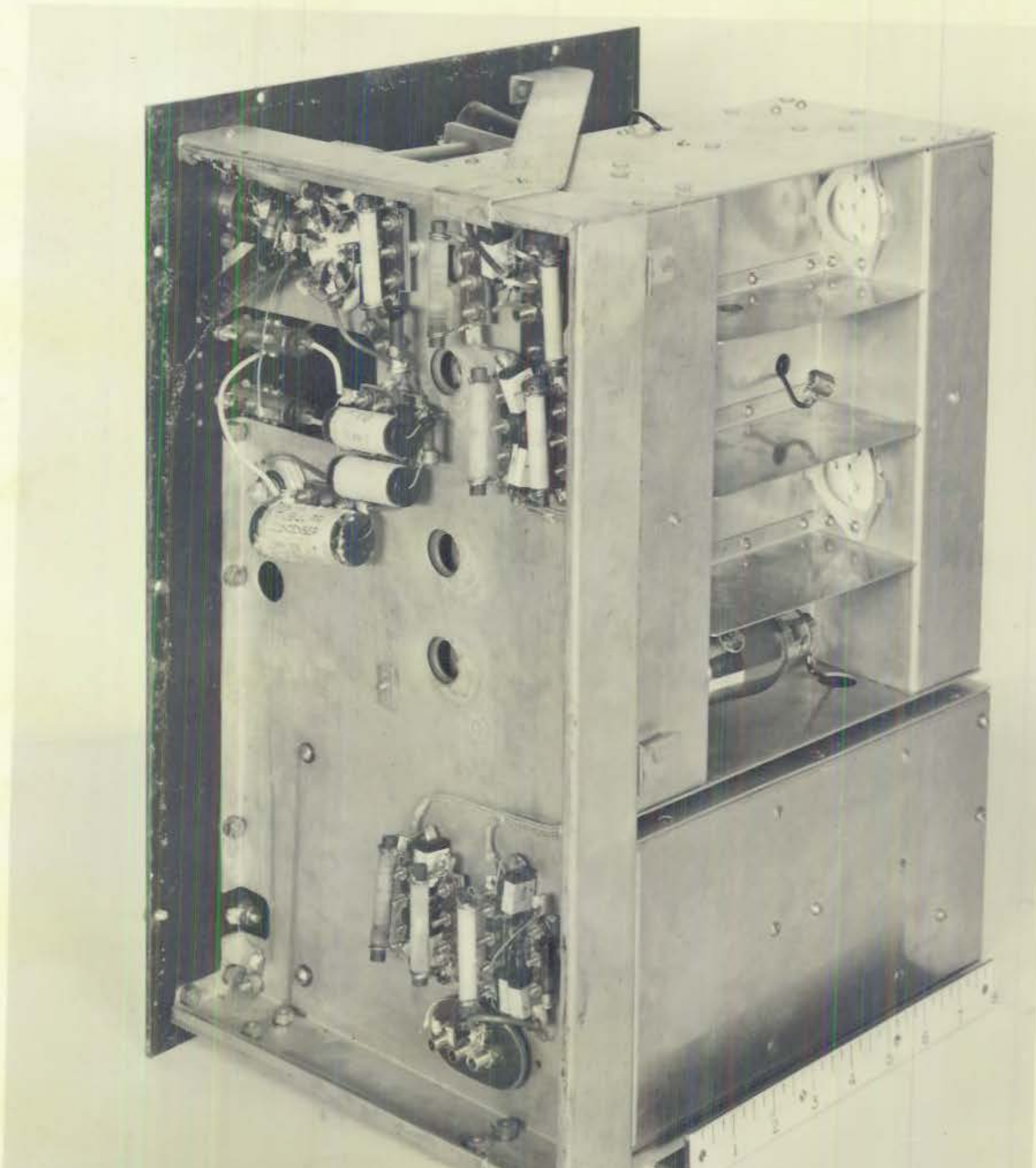
PLATE 59



[redacted]

DECLASSIFIED

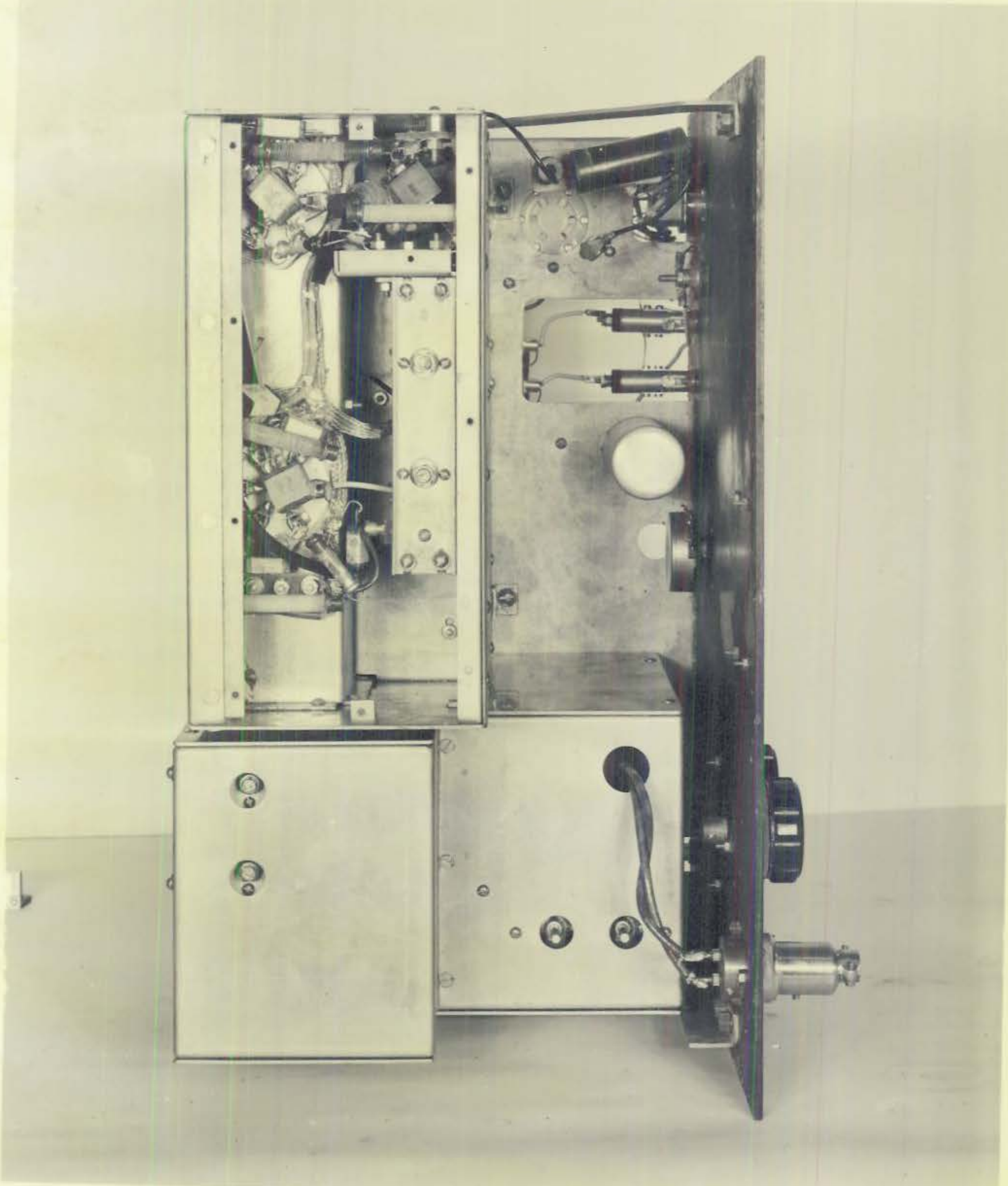
PLATE 60



[redacted]ENTIAL

DECLASSIFIED

PLATE 61



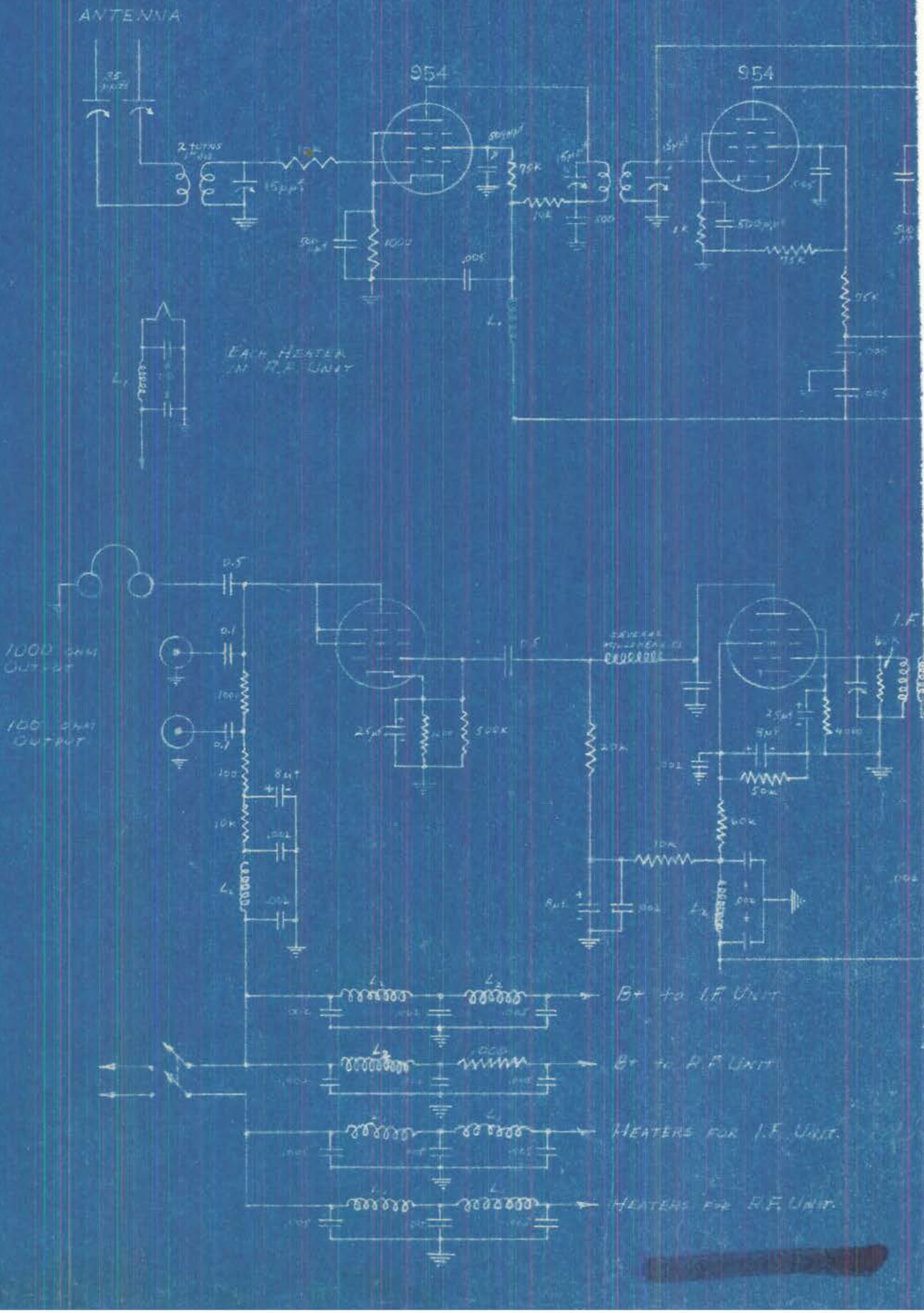
[redacted]

DECLASSIFIED

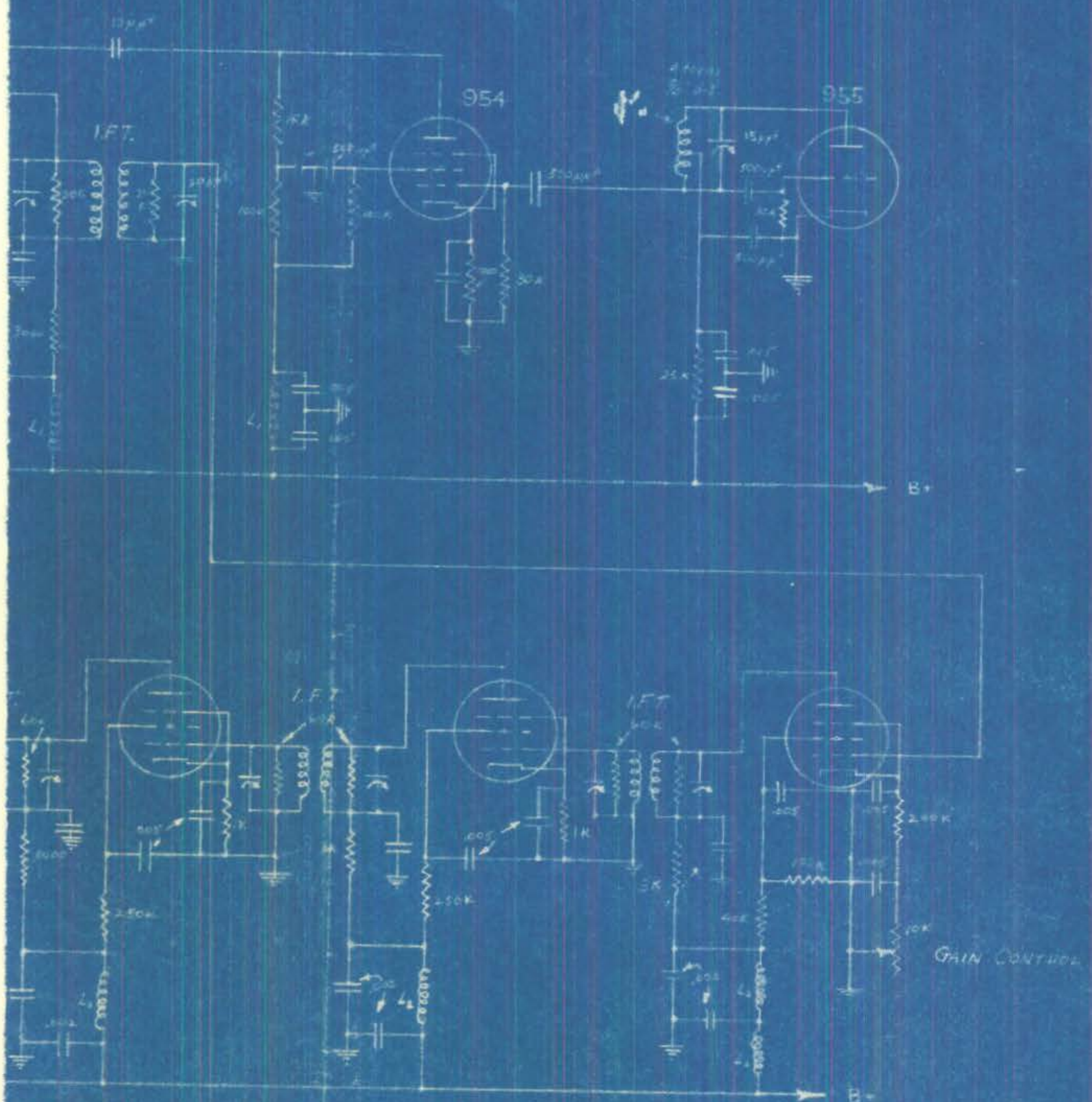
PLATE 62

[redacted]FIDENTIAL

PLATE 63



ANTENNA
954
954
EACH HEATER IN R.F. UNIT
1000 OHM OUTPUT
100 OHM OUTPUT
B+ to I.F. UNIT
B+ to R.F. UNIT
HEATERS FOR I.F. UNIT
HEATERS FOR R.F. UNIT

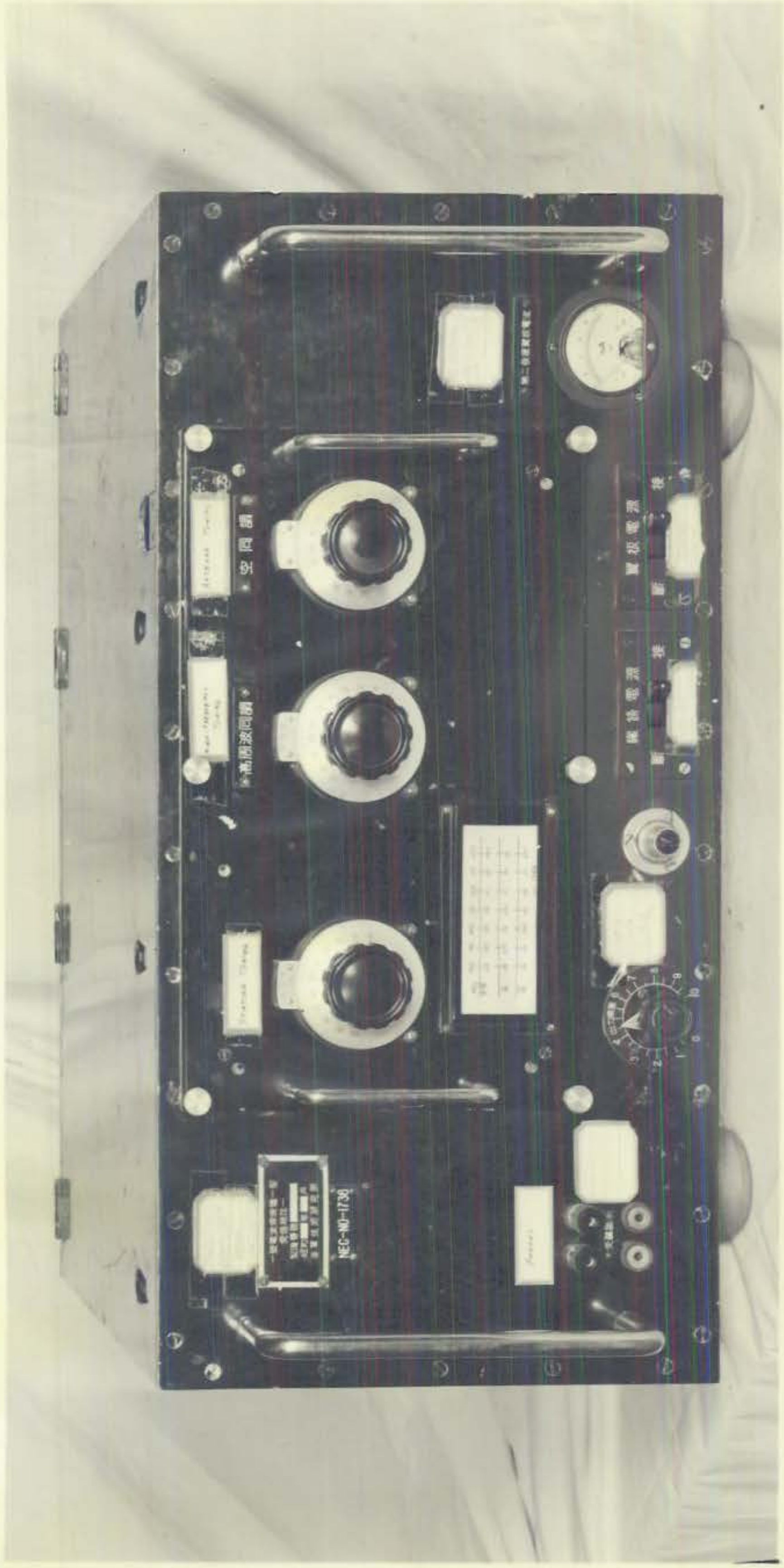



I.F.T. : 25 turns #26 enameled wire, 3/8" form, air core. Coils 3/8" apart.
L1 : 60-70 turns #24 wire, 1/2" form.
L2 : 150 turns #30 wire, 1/4" form.

JAPANESE RECEIVER
29-17-2
GUADALCANAL RADAR C.E.E. No. 211

DECLASSIFIED

PLATE 64



[redacted]

DECLASSIFIED

PLATE 65

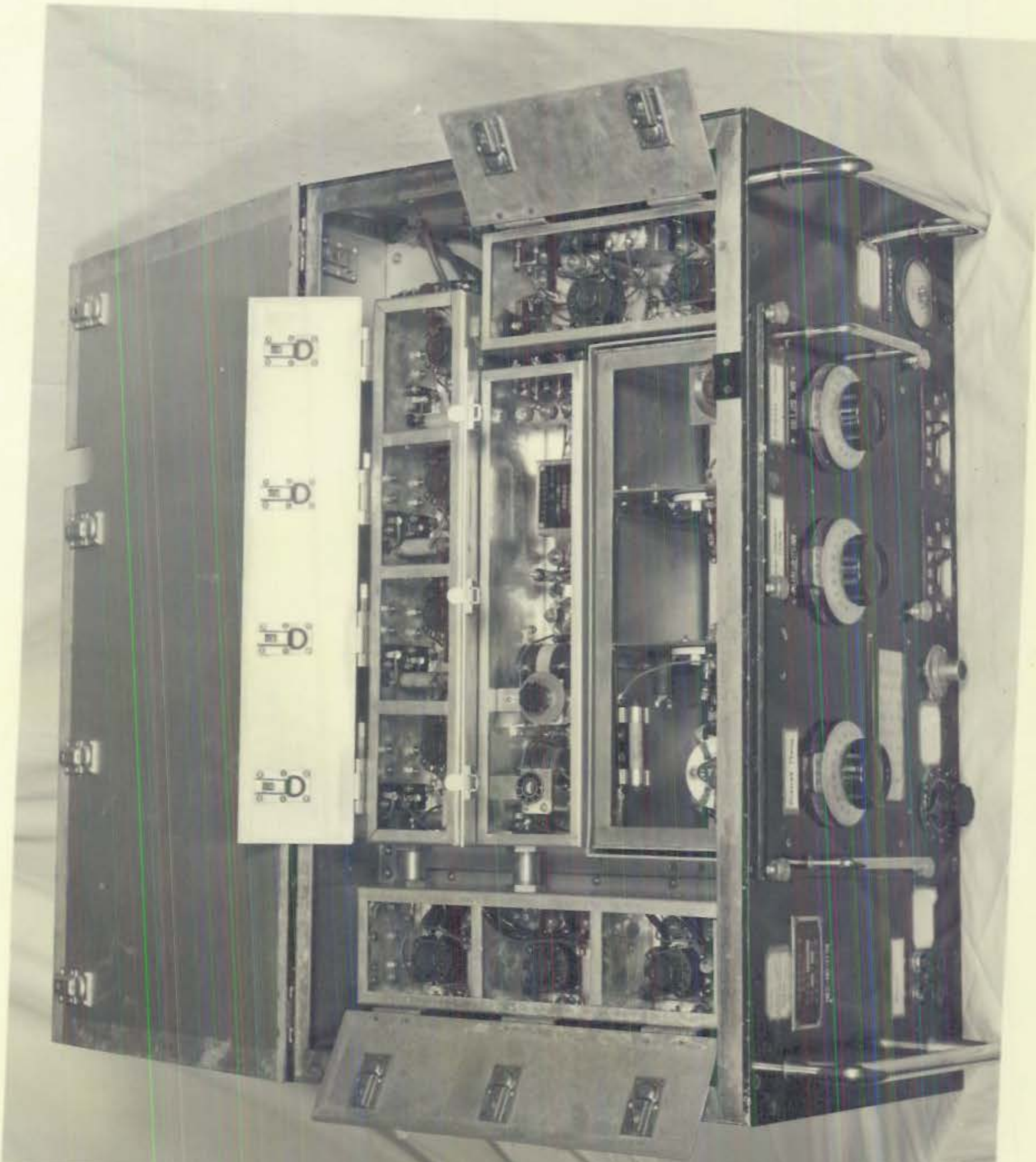
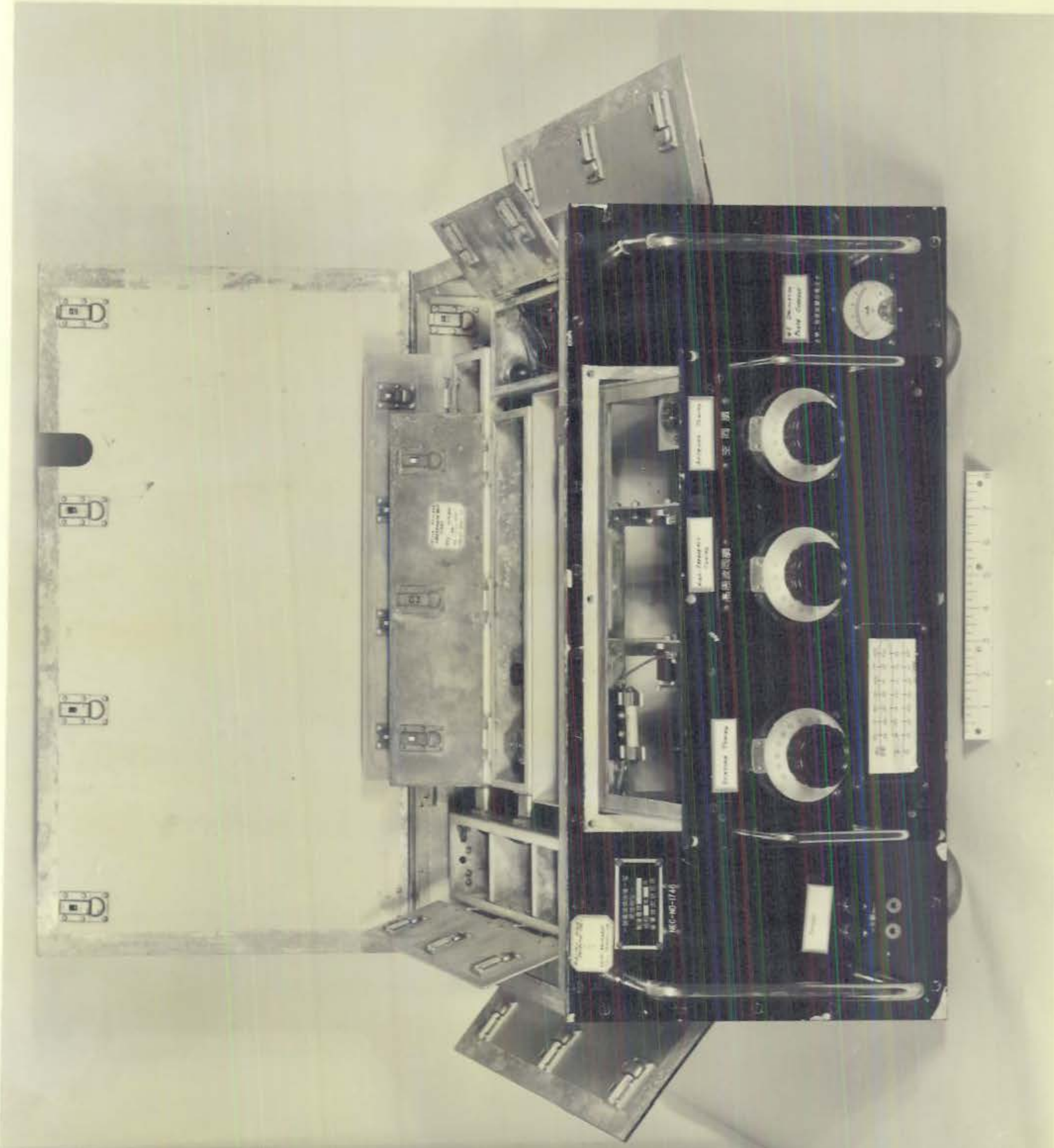






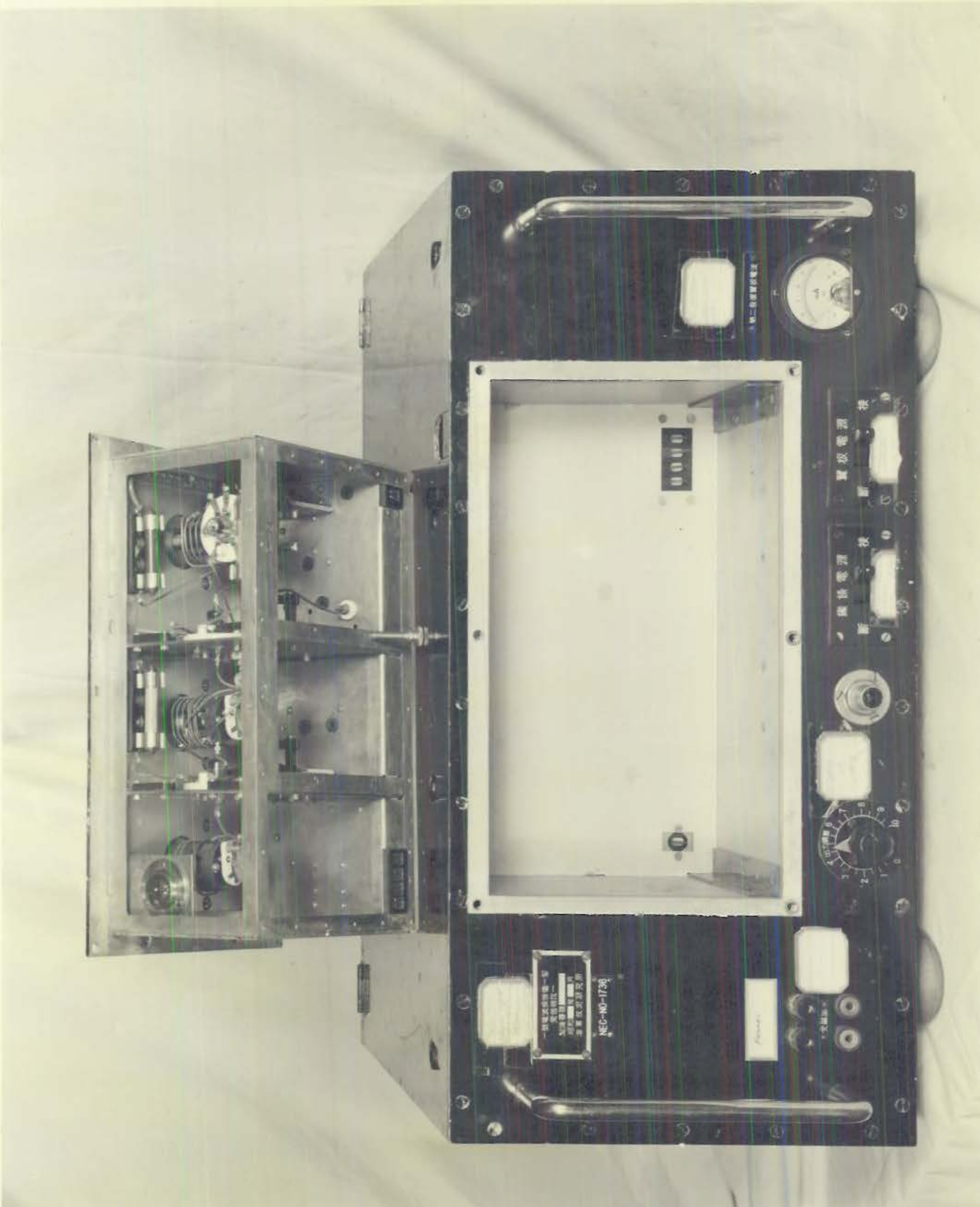
PLATE 66



[redacted]IDENTIAL

DECLASSIFIED

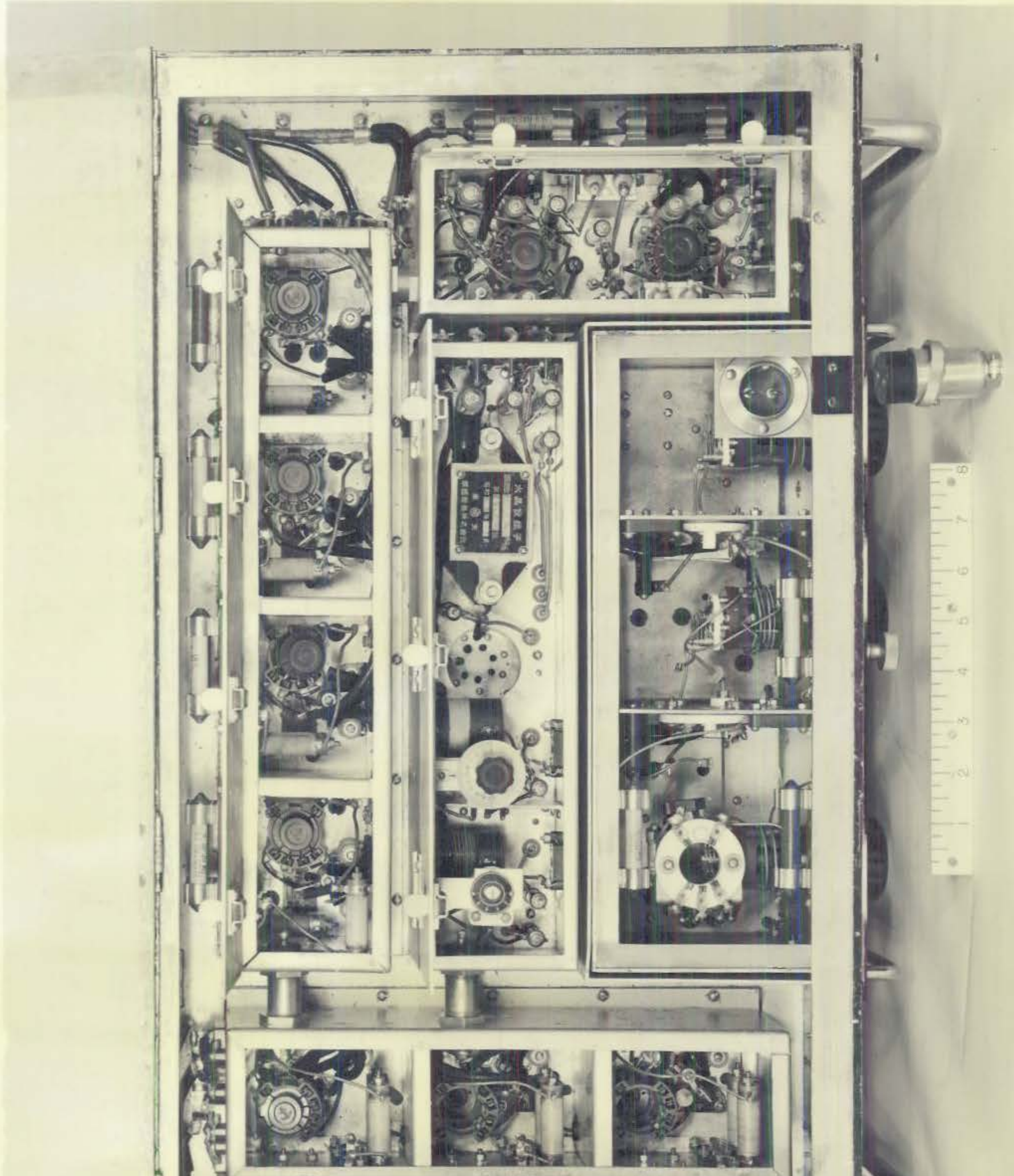
PLATE 67



CONFIDENTIAL

DECLASSIFIED

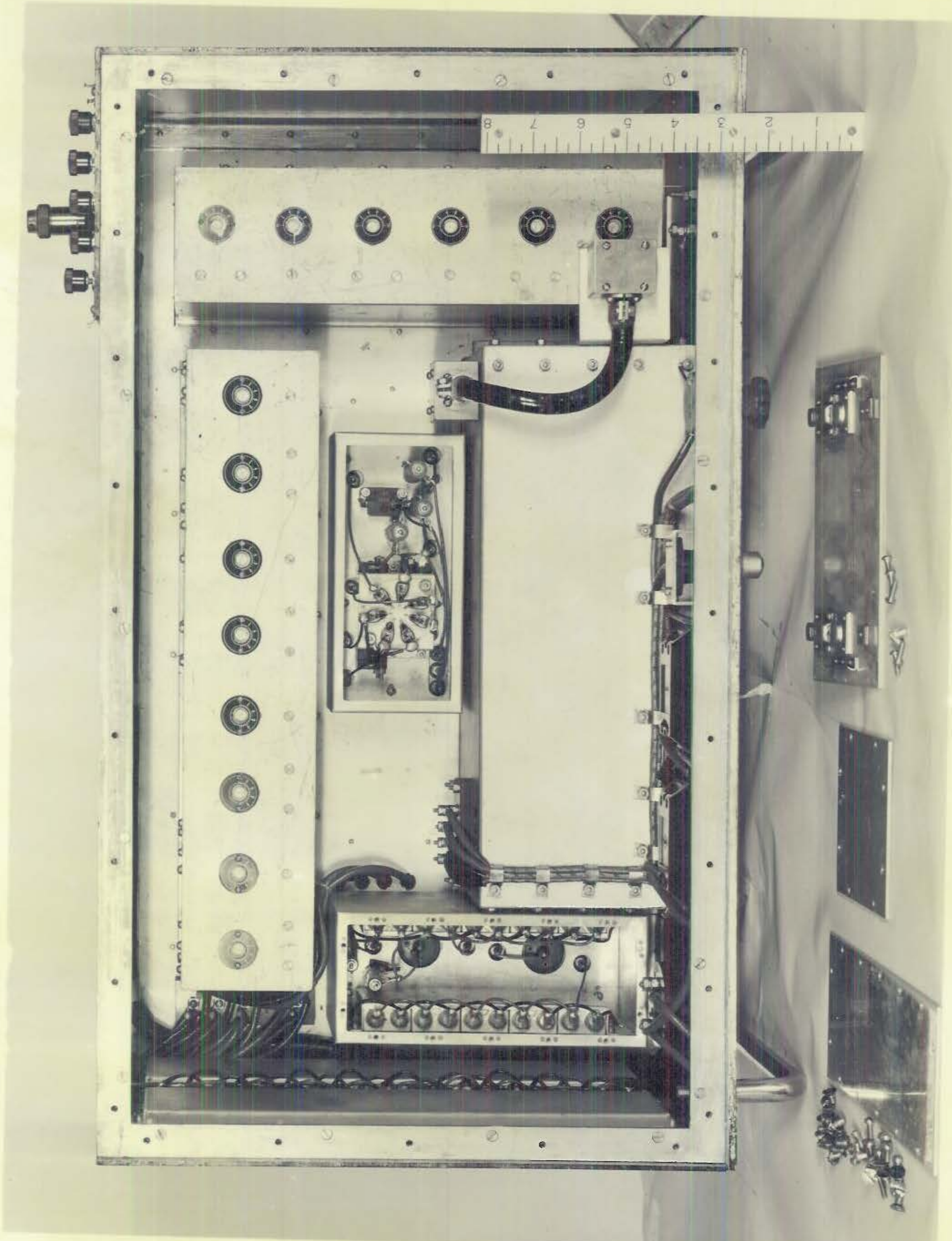
PLATE 68



CONFIDENTIAL

DECLASSIFIED

PLATE 69



CONFIDENTIAL

DECLASSIFIED

PLATE 70

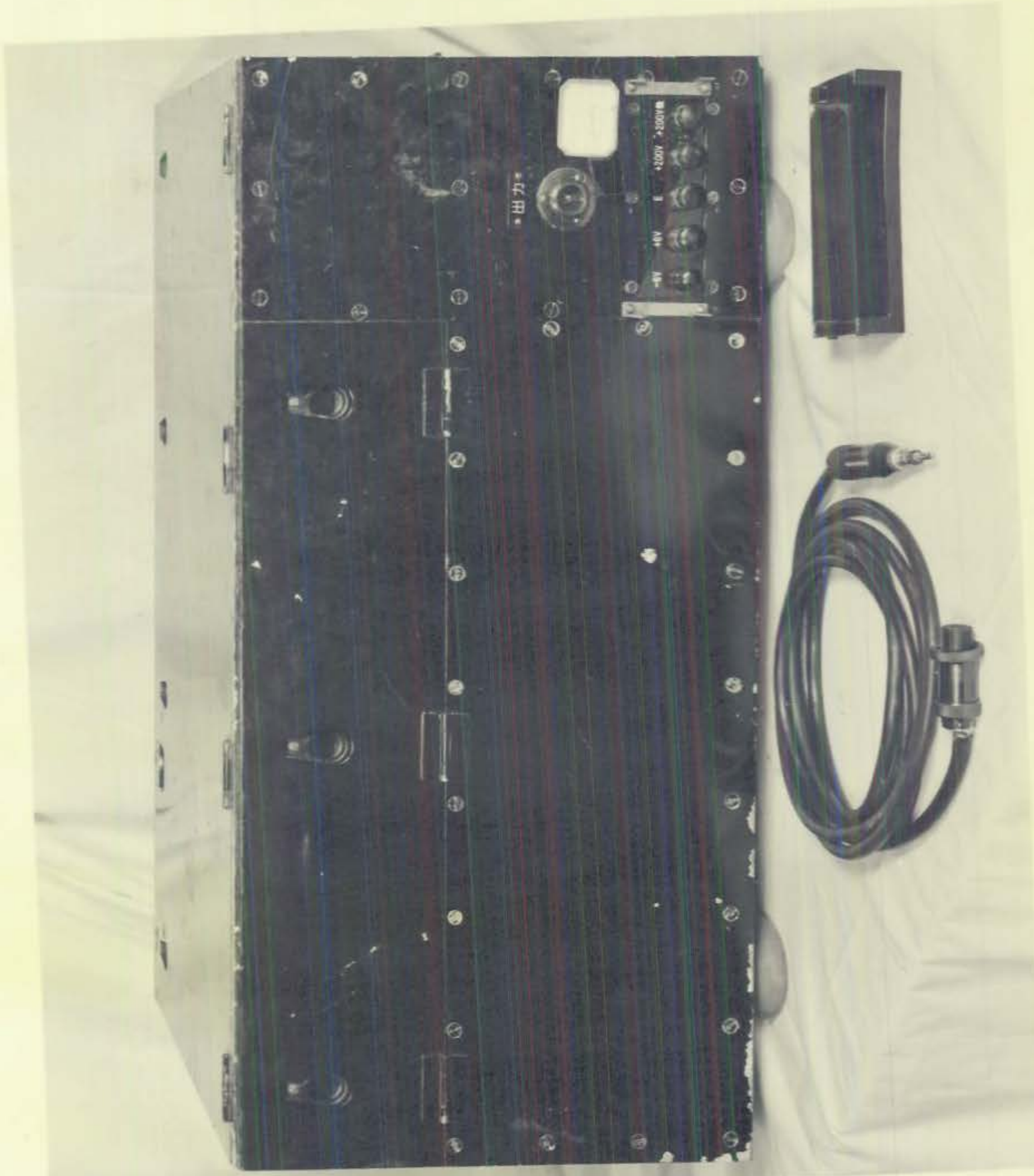
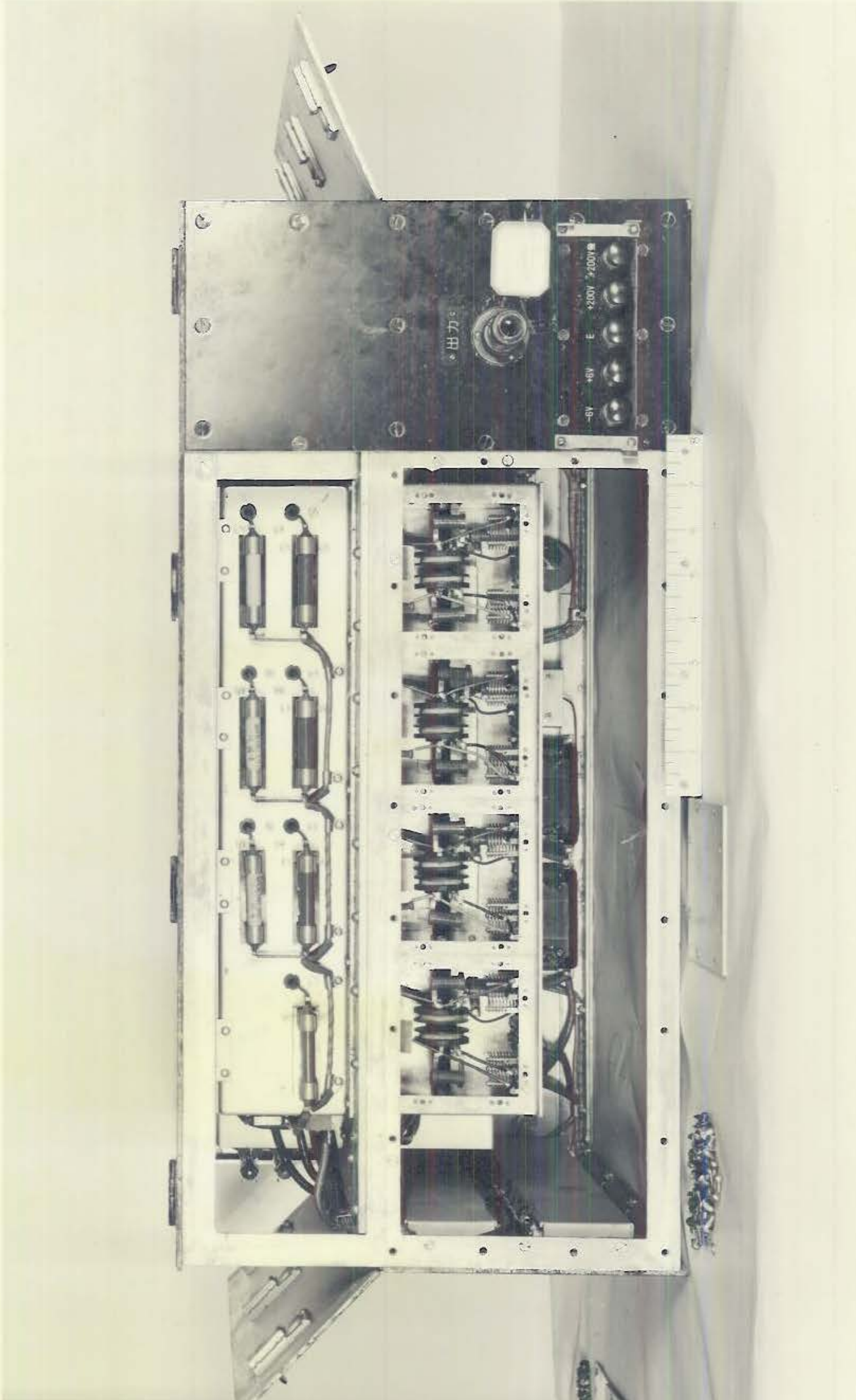




PLATE 71



CONFIDENTIAL

PLATE 72

DECLASSIFIED

CIRCUIT DIAGRAM - RADAR RECEIVER NEC-NO-1736

1st LOCAL Osc. 1st CONVERTER R.F. Amplifier - 97-103 mc.

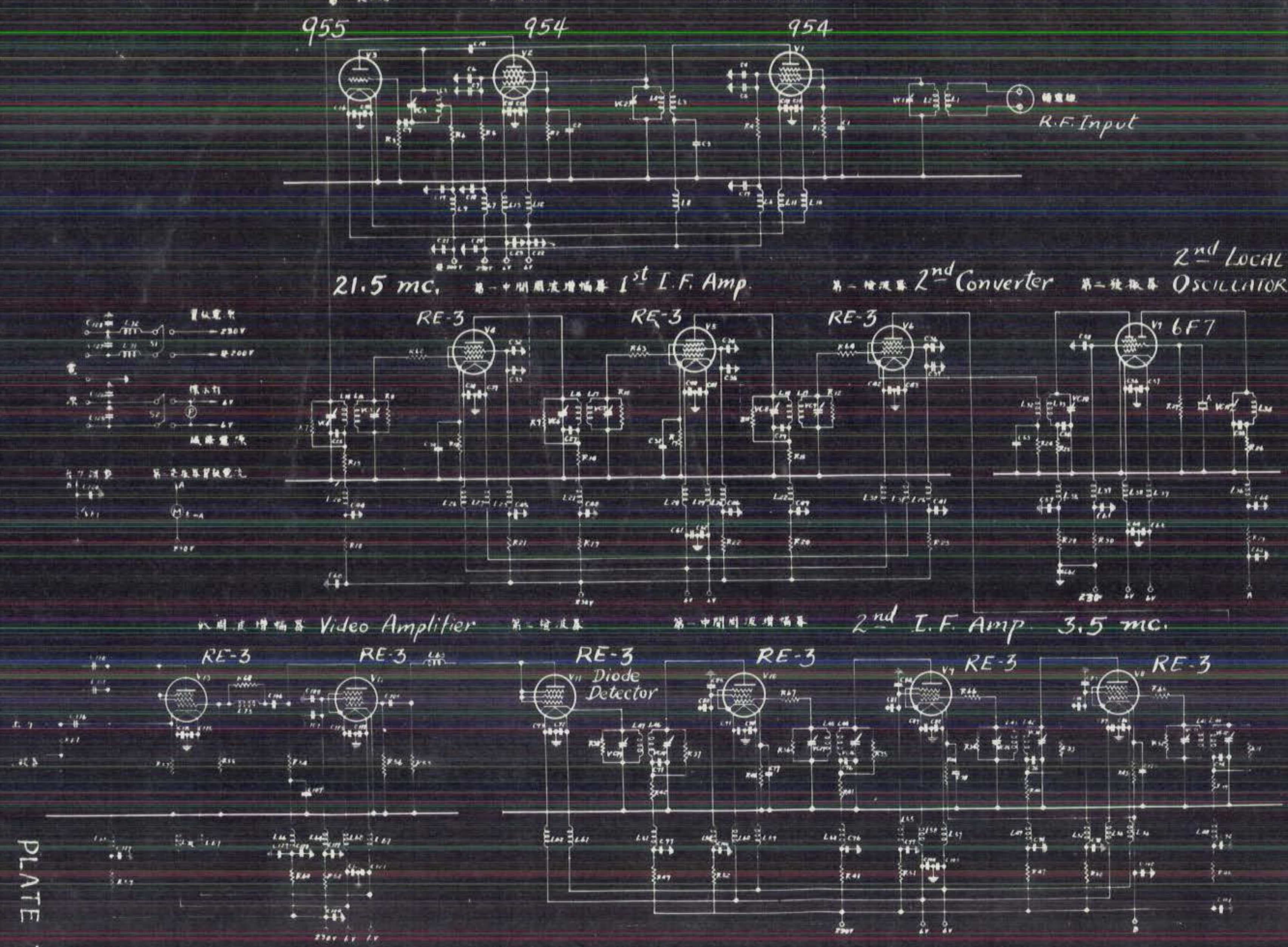



PLATE 73

# PARTS LIST & CIRCUIT VALUES, RECEIVER NEC-NO-1736

## R.F. Section

| 符号 | 品名 | 定数 | 摘要 |
|---|---|---|---|
| V 1 | UN 7?? | | [illegible] |
| V 2 | | | |
| V 3 | UN 7?? | | |
| VC 1 | [illegible] | 10 PF | |
| VC 2 | | | |
| VC 3 | | | |
| C 1 | [illegible] | 0.001 PF | |
| C 5 | | 0.5 PF | |
| C 6 | [illegible] | 0.002 PF | |
| C 7 | [illegible] | 0.5 PF | |
| C 8 | [illegible] | 0.001 PF | |
| C 9 | | 1 PF | |
| C 11 | | 0.002 PF | |
| R 1 | [illegible] | 600 Ω | [illegible] |
| R 2 | | 1 KΩ | |
| R 3 | | 10 KΩ | |
| R 4 | [illegible] | 50 KΩ | |
| R 5 | | 100 KΩ | |
| R 6 | | 5 KΩ | |
| L 1 | [illegible] | | |
| L 3 | [illegible] | | |
| L 5 | [illegible] | | |
| L 6 | [illegible] | | N 16114 |
| L 10 | [illegible] | | |

## 1st I.F. & 2nd Det.

| 符号 | 品名 | 定数 | 摘要 |
|---|---|---|---|
| V 4 | KE | | |
| V 5 | | | |
| V 6 | | | |
| VC 4 | [illegible] | 50 PF | |
| C 25 | [illegible] | 0.01 PF | |
| C 27 | [illegible] | 0.01 PF | |
| C 29 | [illegible] | 0.01 PF | |
| C 30 | [illegible] | 0.01 PF | |
| C 33 | [illegible] | 0.5 PF | |
| C 34 | [illegible] | 0.01 PF | |
| C 35 | [illegible] | 0.5 PF | |
| C 36 | [illegible] | 0.01 PF | |
| C 37 | [illegible] | 0.5 PF | |
| C 38 | [illegible] | 0.002 PF | |
| C 50 | | 0.01 PF | |
| R 67 | [illegible] | 100 Ω | [illegible] |
| R 7 | [illegible] | 100 KΩ | |
| R 13 | | 1 KΩ | |
| R 17 | | 250 Ω | |
| R 18 | | 5 KΩ | |
| R 21 | | 10 KΩ | |
| R 23 | | 100 KΩ | |
| L 14 | [illegible] | | N 16116 |
| L 20 | [illegible] | | N 16114 |
| L 26 | [illegible] | | |

## 2nd Local Osc.

| 符号 | 品名 | 定数 | 摘要 |
|---|---|---|---|
| V 7 | [illegible] | | [illegible] |
| VC 10 | [illegible] | 50 PF | |
| VC 11 | | 20 | |
| C 55 | [illegible] | 0.01 PF | |
| C 59 | | 0.002 PF | |
| C 62 | | 0.01 PF | |
| R 14 | [illegible] | 1 KΩ | [illegible] |
| R 17 | | 1 MΩ | |
| R 18 | | 5 KΩ | |
| R 20 | | 10 KΩ | |
| L 14 | [illegible] | | N 16114 |
| L 30 | [illegible] | | N 16114 |
| L 32 | [illegible] | | |
| X | [illegible] | 45 MC | |

## 2nd I.F. Amplifier
第二中間周波増幅器

| 符号 | 品名 | 定数 | 摘要 |
|---|---|---|---|
| V 8 | KE-3 | | |
| VC 12 | [illegible] | 50 PF | |
| C 74 | [illegible] | 0.01 PF | |
| C 81 | [illegible] | 0.5 PF | |
| C 84 | [illegible] | 0.01 PF | |

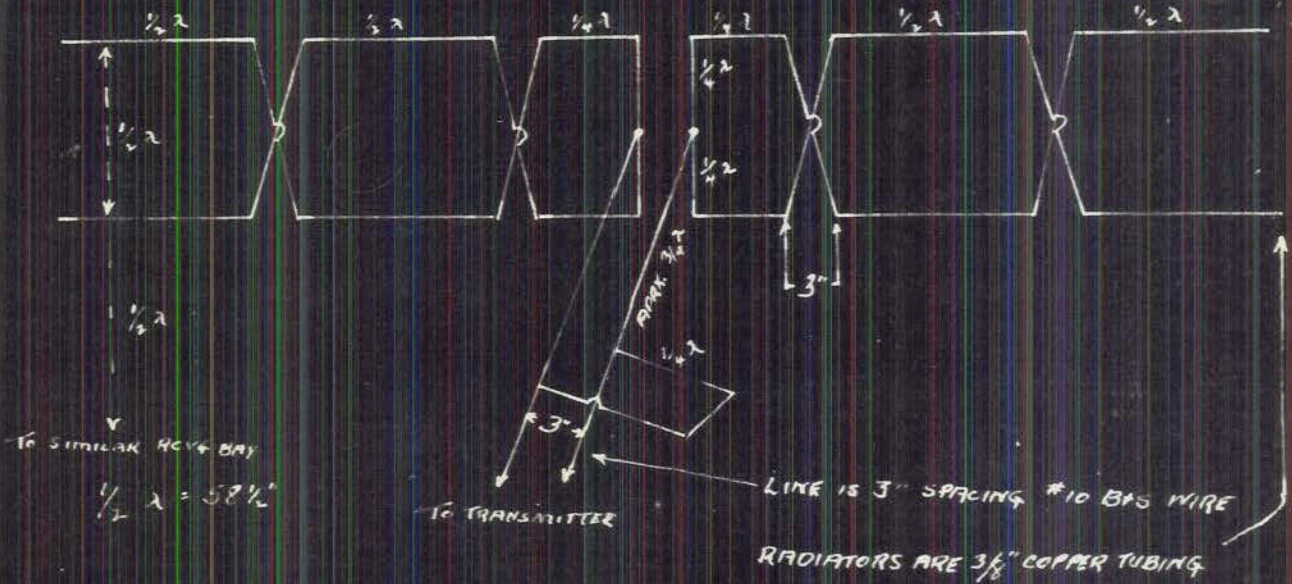
## (continued)

| 符号 | 品名 | 定数 | 摘要 |
|---|---|---|---|
| C 94 | [illegible] | 0.01 PF | |
| C 98 | | 0.002 PF | |
| C 101 | | 0.01 PF | |
| R 30 | [illegible] | 1 KΩ | [illegible] |
| R 39 | [illegible] | 1 KΩ | |
| R 43 | | 250 Ω | |
| R 50 | | 300 Ω | |
| R 65 | [illegible] | 100 Ω | |
| L 40 | [illegible] | | N 16112 |
| L 48 | [illegible] | | N 16114 |
| L 56 | [illegible] | | |

## Video Amplifier

| 符号 | 品名 | 定数 | 摘要 |
|---|---|---|---|
| V 9 | [illegible] | | |
| C 105 | [illegible] | 0.002 PF | |
| C 109 | [illegible] | 0.002 PF | |
| C 116 | [illegible] | 2 PF | |
| C 117 | [illegible] | 0.002 PF | |
| R 55 | [illegible] | 10 KΩ | [illegible] |
| R 57 | | 1 K | |
| R 61 | C-05 | 1 KΩ | |
| L 66 | [illegible] | | N 16114 |
| L 67 | [illegible] | | |
| L 73 | [illegible] | | |
| VR 1 | [illegible] | | [illegible] |
| C 126 | [illegible] | 2 PF | |
| C 125 | [illegible] | 0.01 PF | |
| M | [illegible] | 1 MA | MC-? |
| S 1 | [illegible] | | |
| S 2 | [illegible] | | |
| F | [illegible] | 2 V 0.1 A | [illegible] |
| J 1 | [illegible] | | N 16117 |
| J 2 | [illegible] | | |

Japanese RADAR Antenna on Guadalcanal.



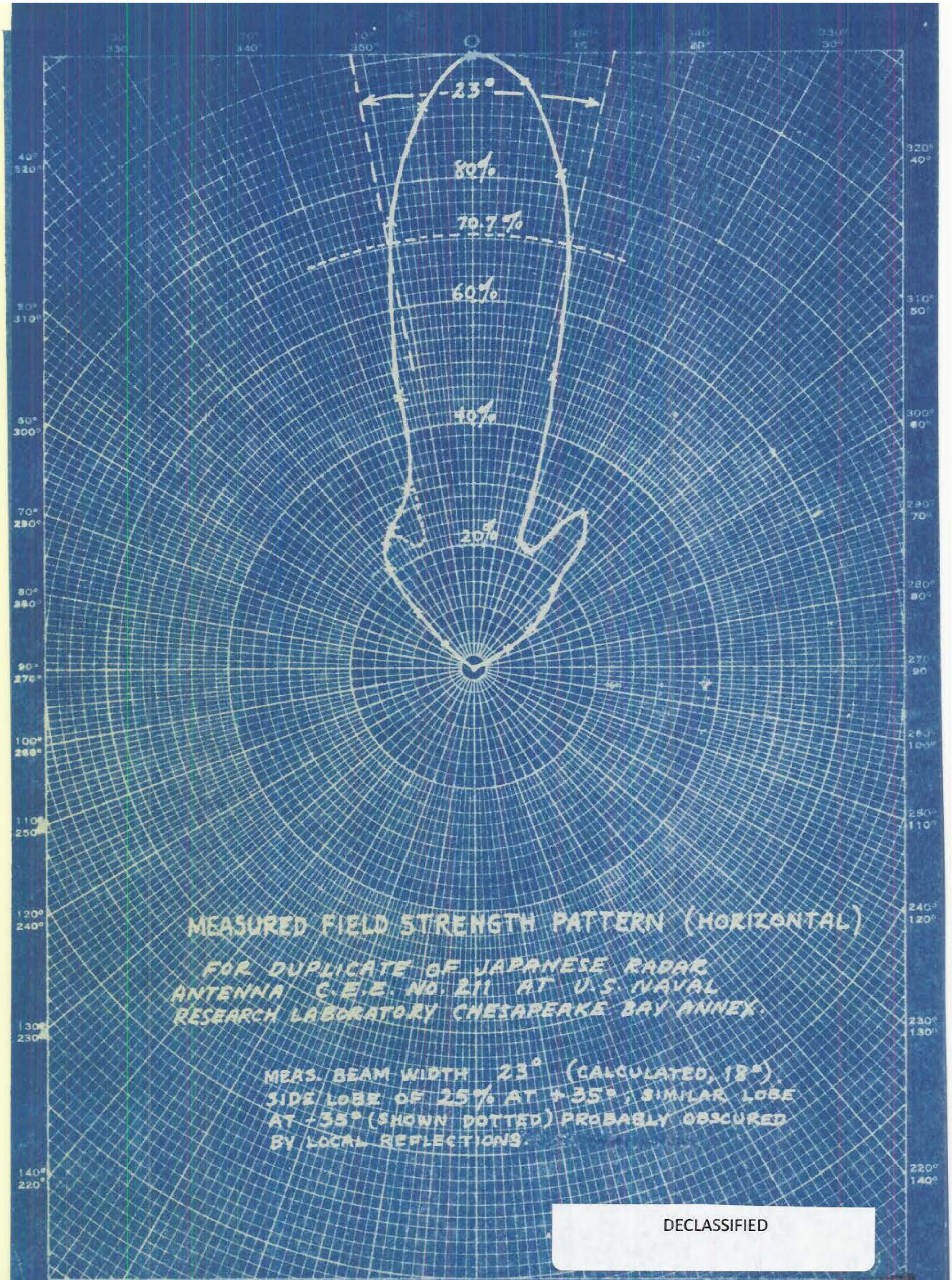

Receiving antenna is similar to the transmitting antenna and is located 1/2 wave below it. Top bay is transmitting and bottom receiving. Receiving antenna evidentally had "Q" bars for matching impedances between transmission line to antenna and coupling line to receiver. Receiver coupling line consists of a pair of #8 solid copper conductors, insulated by spacers, and protected overall by a sheath of copper with an outer covering of lead; outside dimensions approximately 1".

The complete antenna system is mounted on a combined wood and steel frame with the elements about 1/4 wave from a reflecting screen. The screen is an ordinary galvanized wire affair with 1" holes.

The antenna is horizontally polarized.

(Enclosure B. of reference b.)

PLATE 75




DECLASSIFIED

[redacted]

PLATE 75A

# SENSITIVITY
of
Japanese Receiver NEC-No.-1736

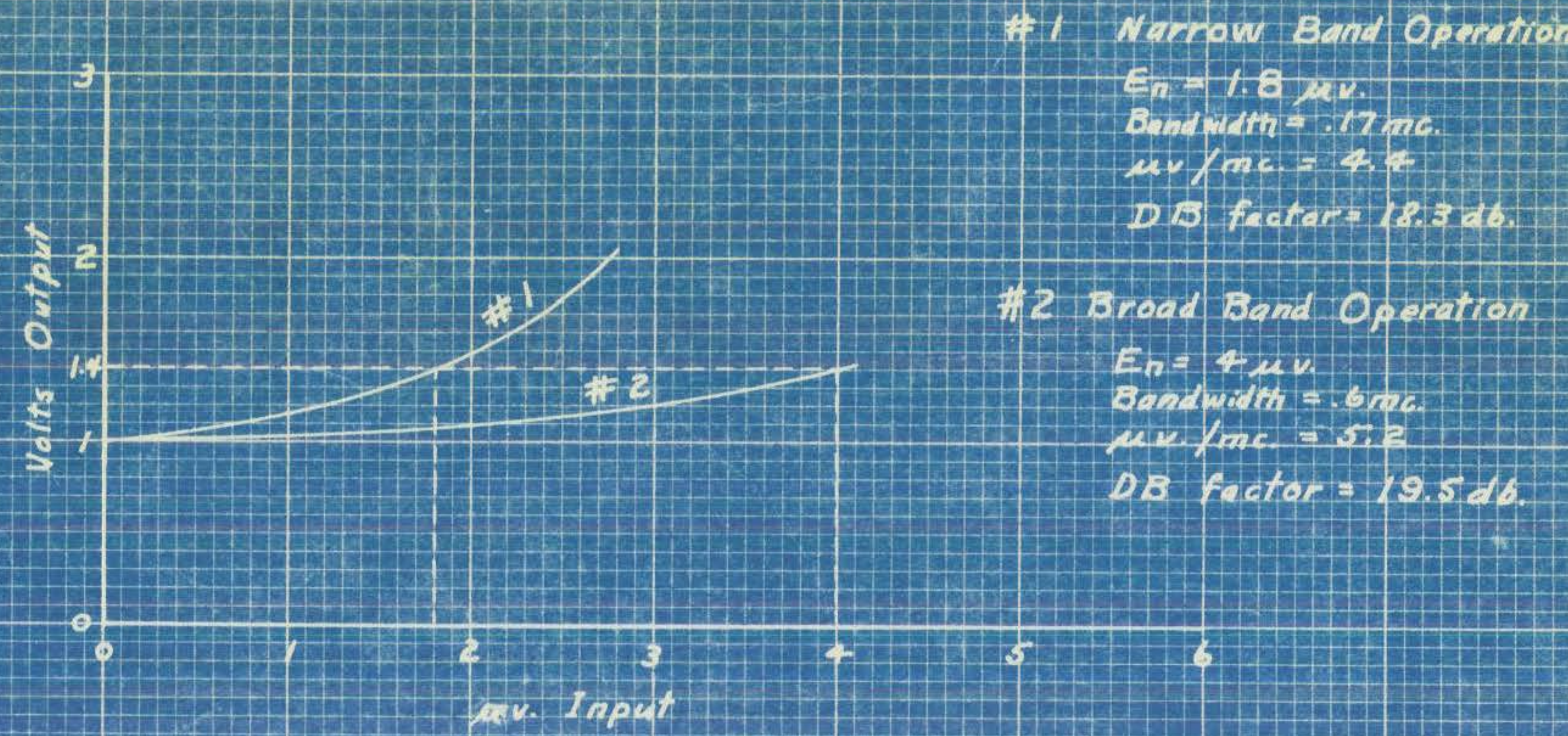





PLATE 77

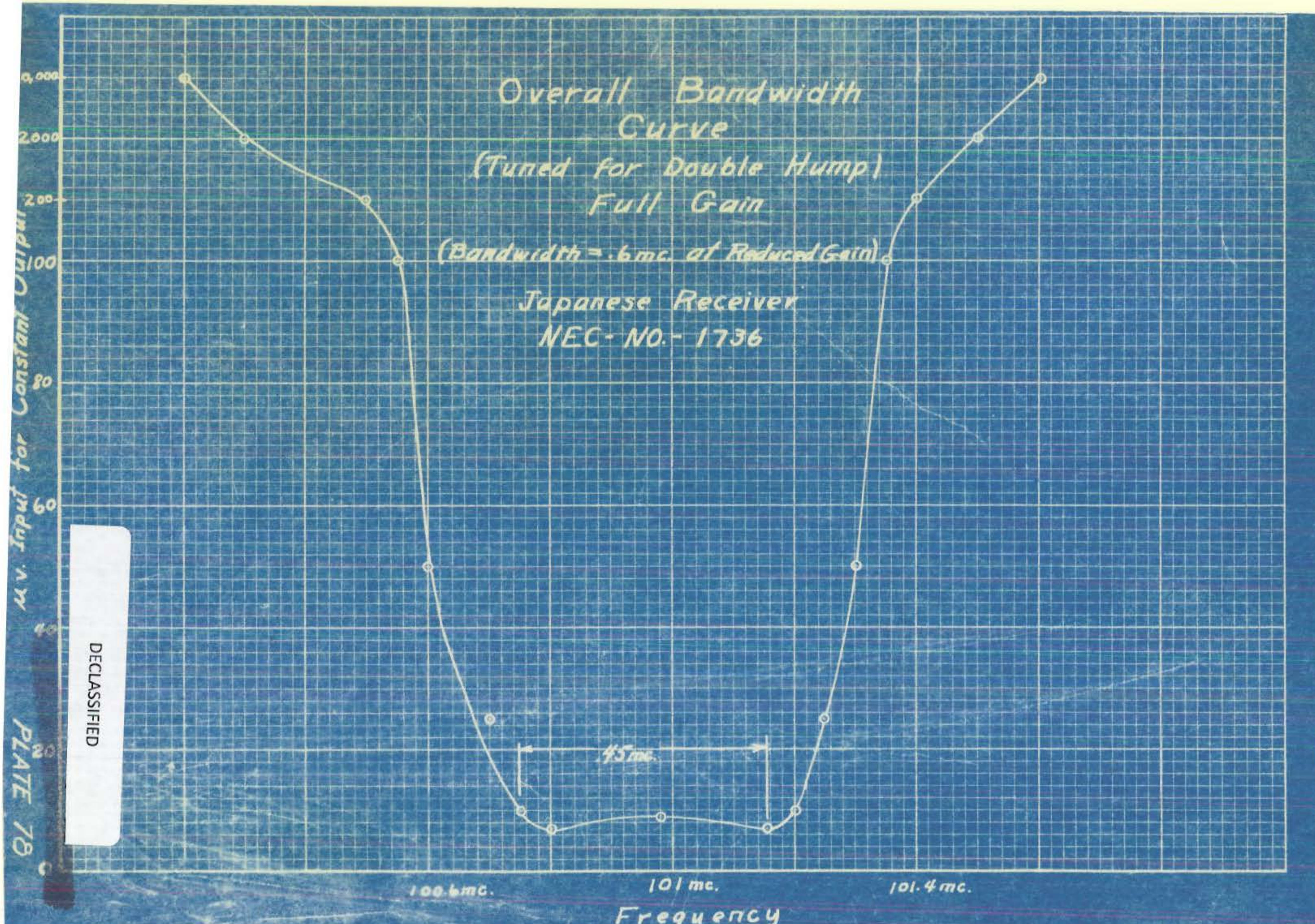

Overall Bandwidth
Curve
(Tuned for Double Hump)
Full Gain
(Bandwidth = .6mc. at Reduced Gain)
Japanese Receiver
NEC-NO.-1736
45mc.
2,000
200
100
80
60
20
0
M.v. Input for Constant Output
100.6mc.
101 mc.
101.4 mc.
Frequency

PLATE 78

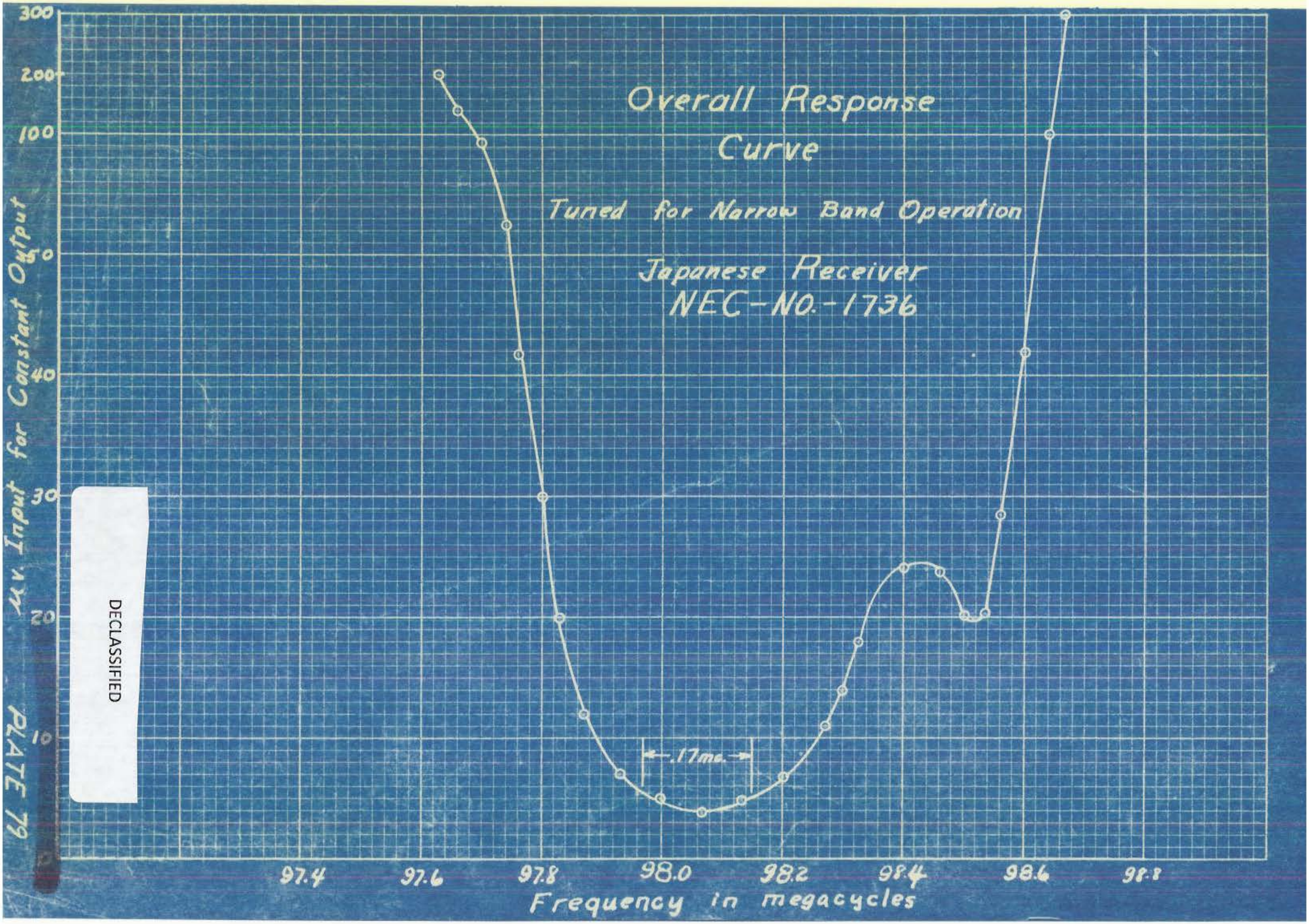



PLATE 79

DECLASSIFIED

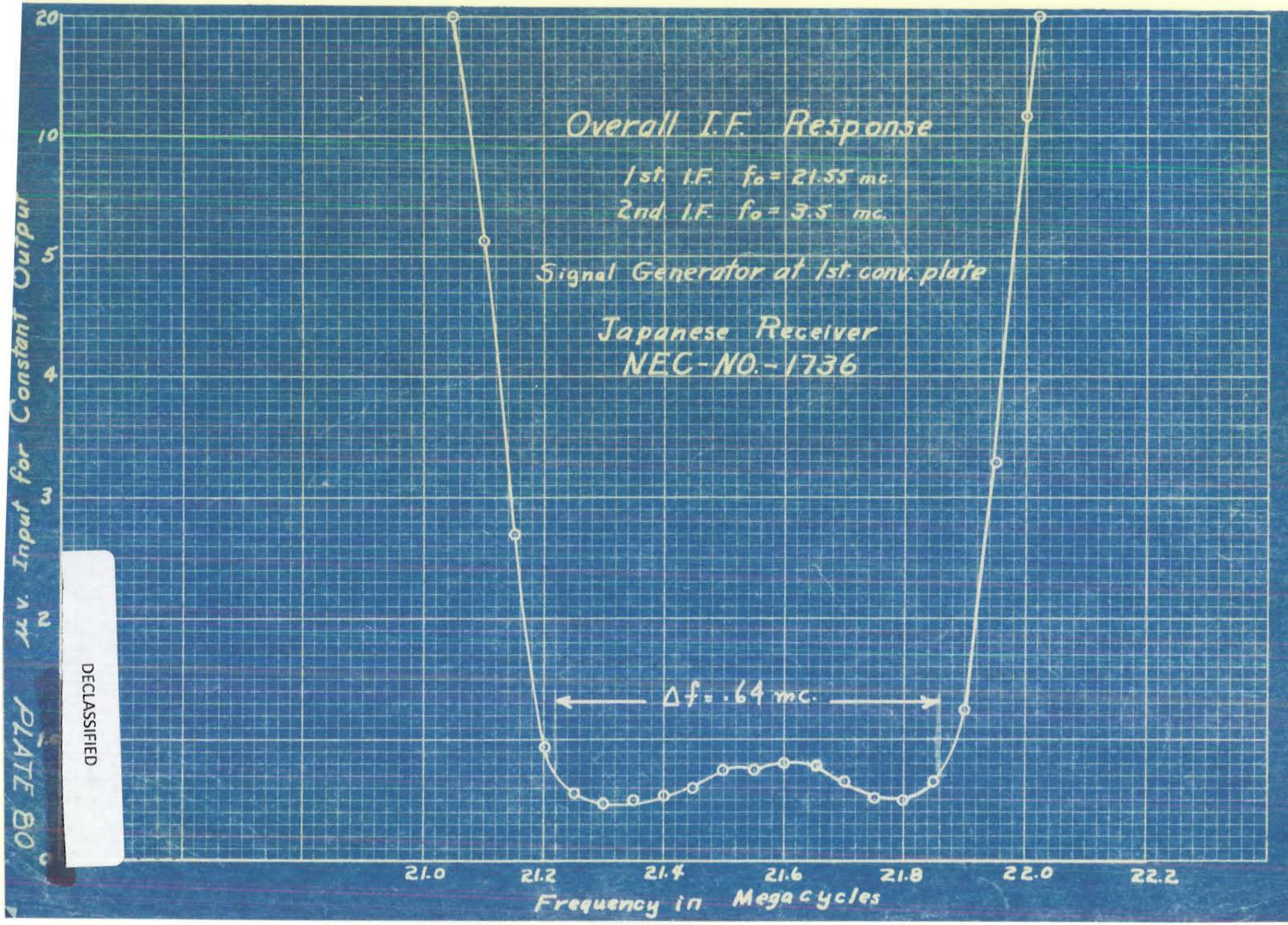

Overall I.F. Response
1st. I.F. $f_o$ = 21.55 mc.
2nd. I.F. $f_o$ = 3.5 mc.
Signal Generator at 1st. conv. plate
Japanese Receiver
NEC-NO.-1736
Δf = .64 mc.
μv. Input for Constant Output
20
10
5
4
3
2
21.0
21.2
21.4
21.6
21.8
22.0
22.2
Frequency in Megacycles

PLATE 80

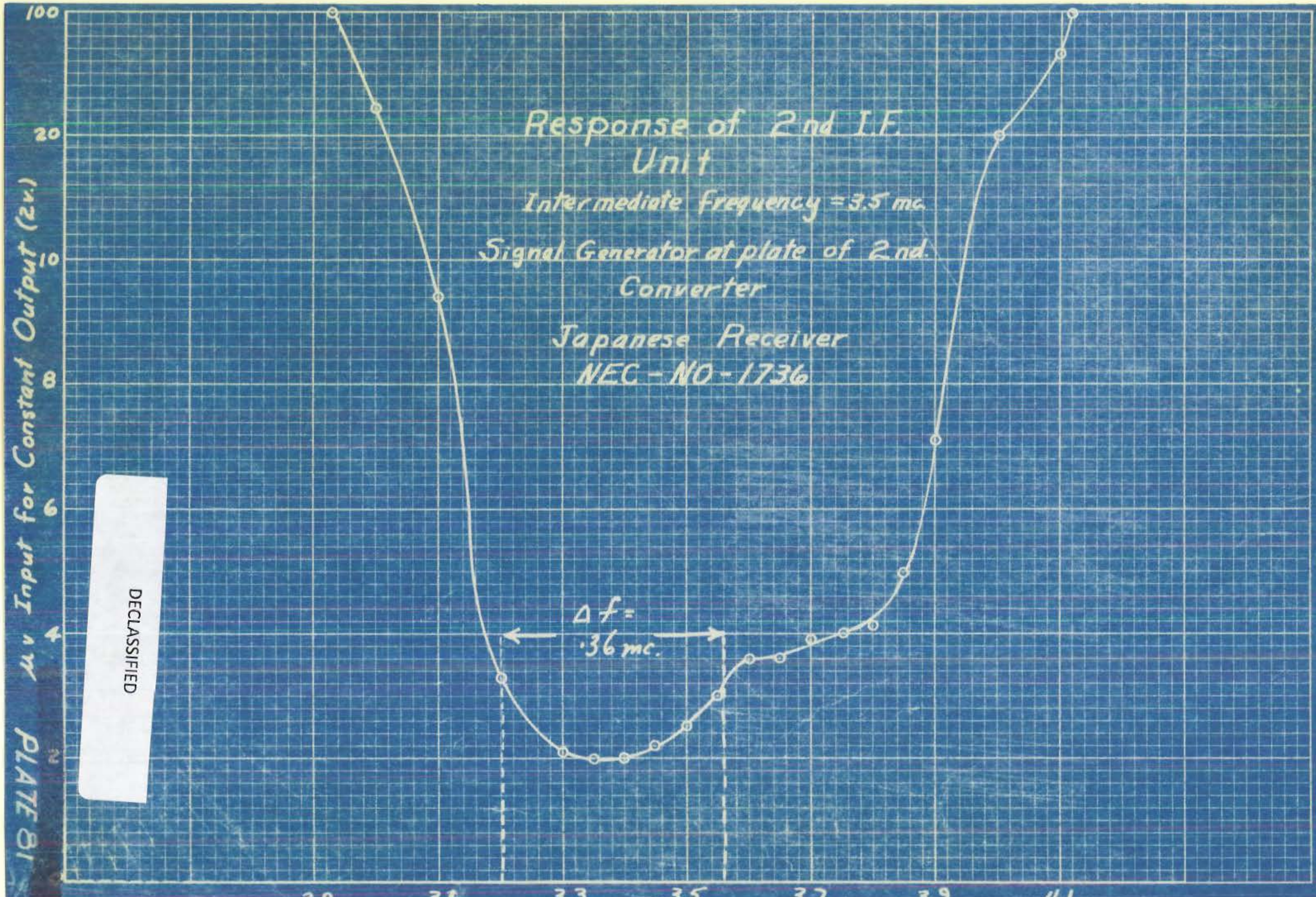
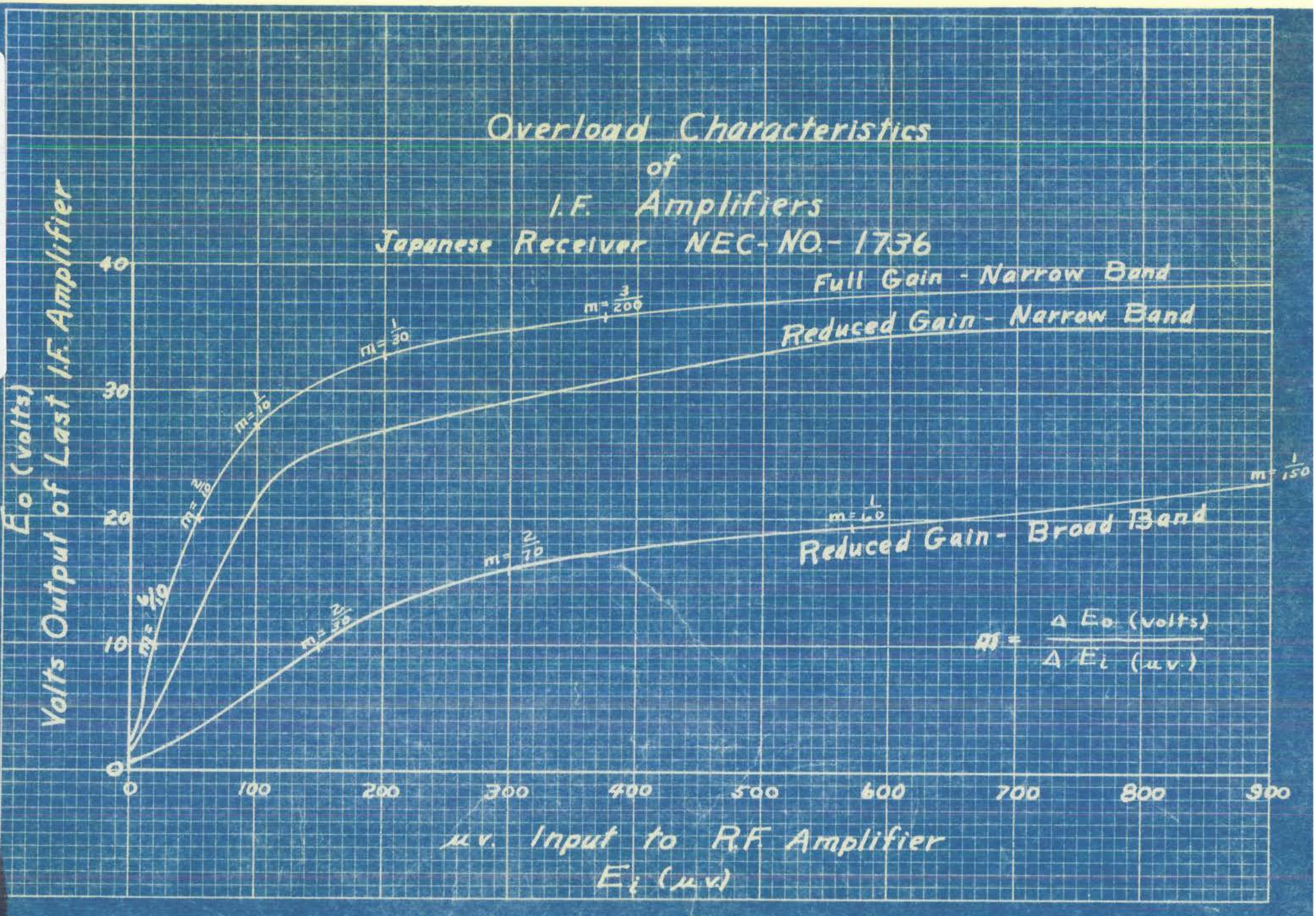

Response of 2nd I.F.
Unit
Intermediate Frequency = 3.5 mc.
Signal Generator at plate of 2nd.
Converter
Japanese Receiver
NEC - NO - 1736
Δf =
·36 mc.
100
20
10
8
6
4
2
2.9
3.1
3.3
3.5
3.7
3.9
4.1
Frequency in Megacycles
μv Input for Constant Output (2v.)
DECLASSIFIED

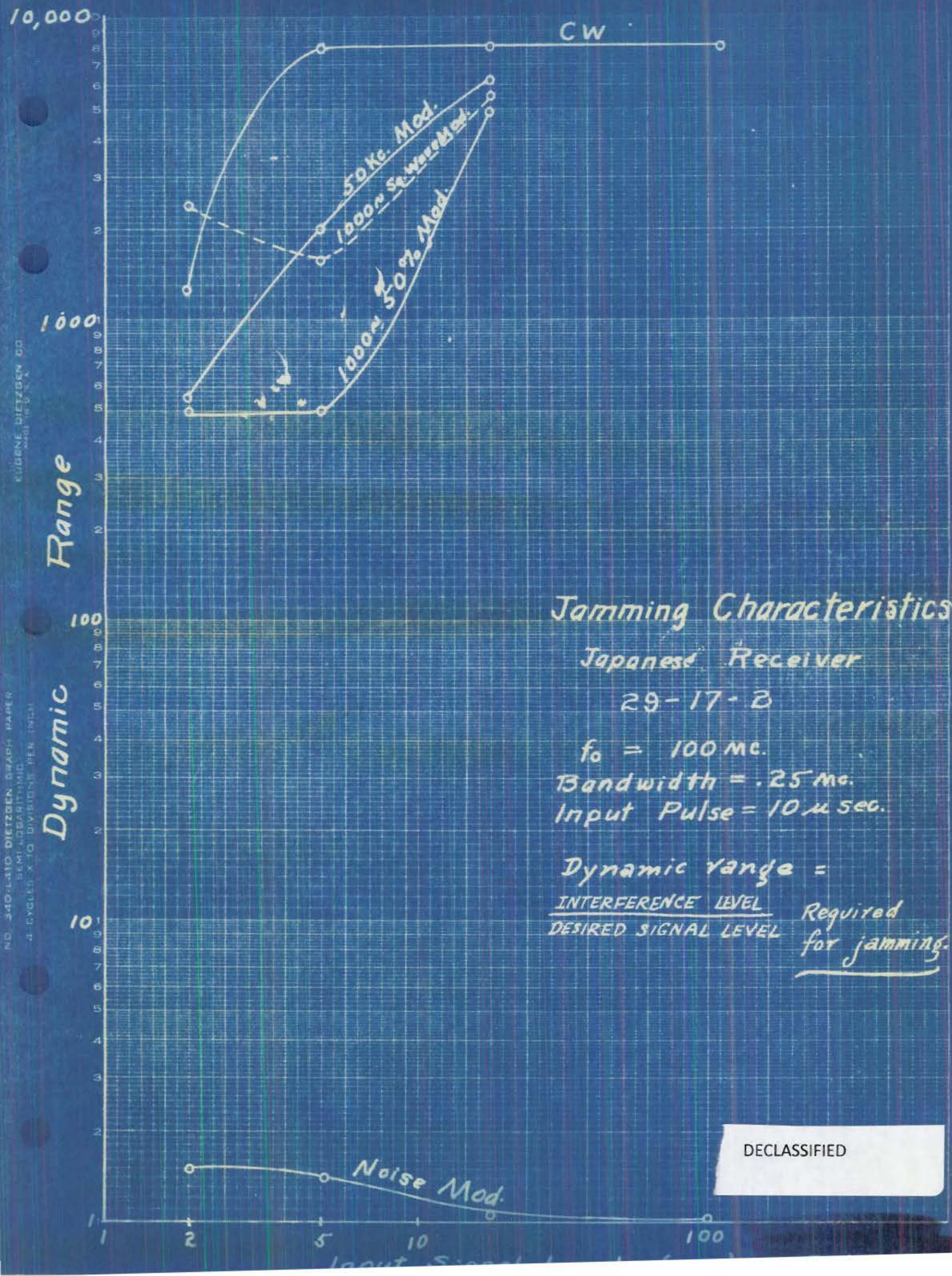
PLATE 81

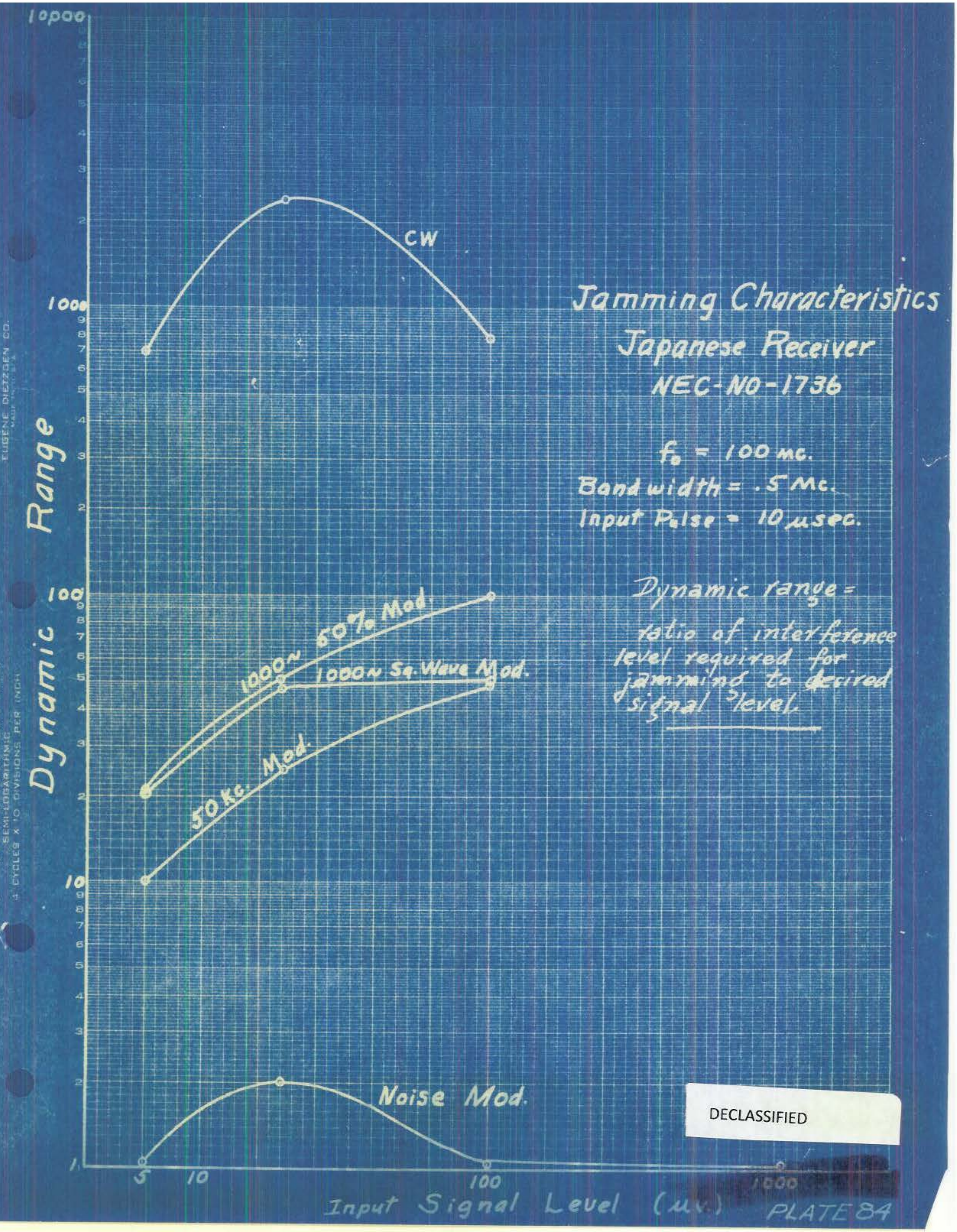


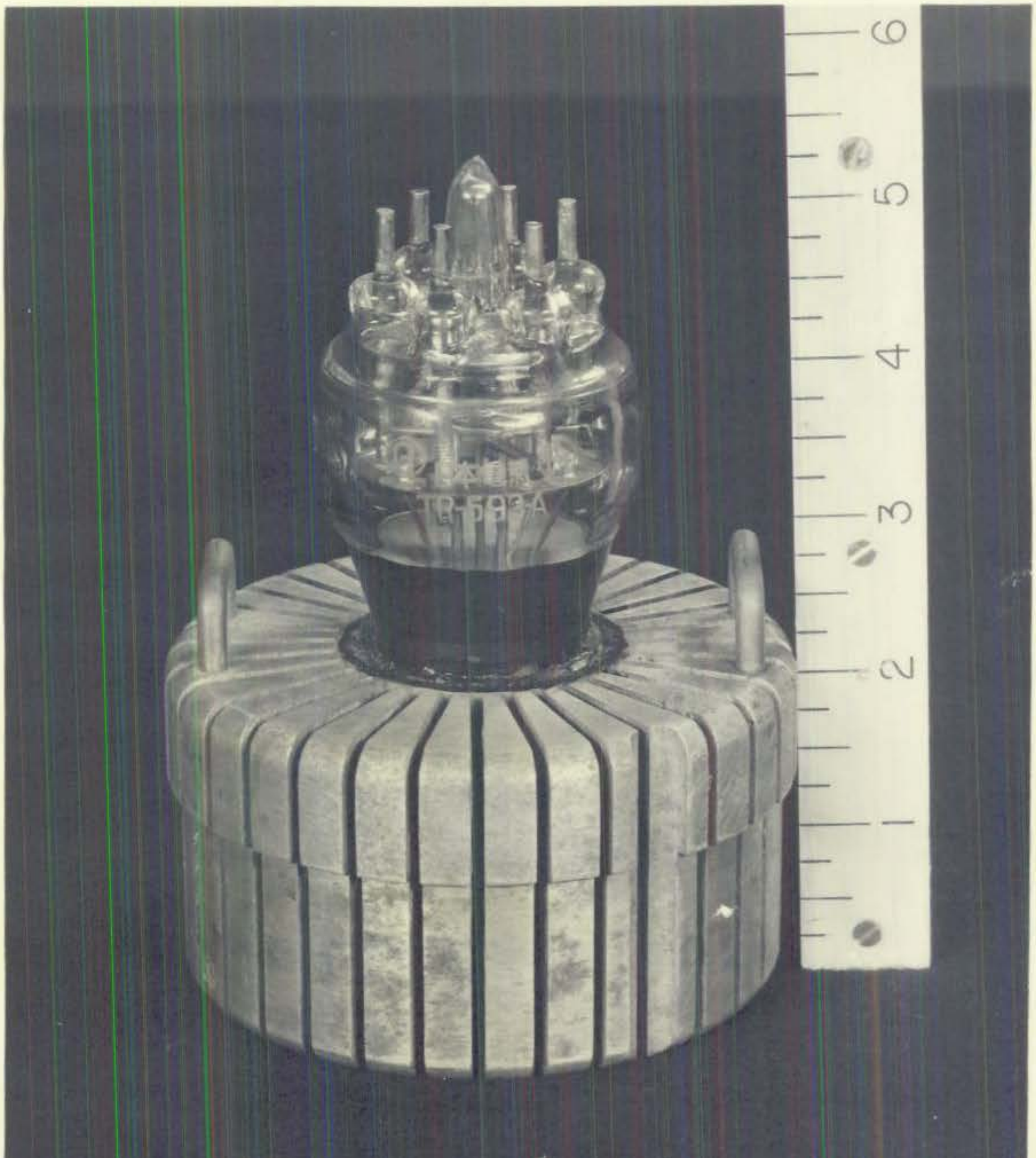

DECLASSIFIED

[redacted]

PLATE 82


10,000
1000
100
10
1
2
5
10
100
Dynamic Range
CW
50 Kc. Mod.
1000~ Sq. wave Mod.
1000~ 50% Mod.
Noise Mod.
Jamming Characteristics
Japanese Receiver
29-17-B
$f_0$ = 100 Mc.
Bandwidth = .25 Mc.
Input Pulse = 10 μ sec.
Dynamic range = INTERFERENCE LEVEL / DESIRED SIGNAL LEVEL Required for jamming.

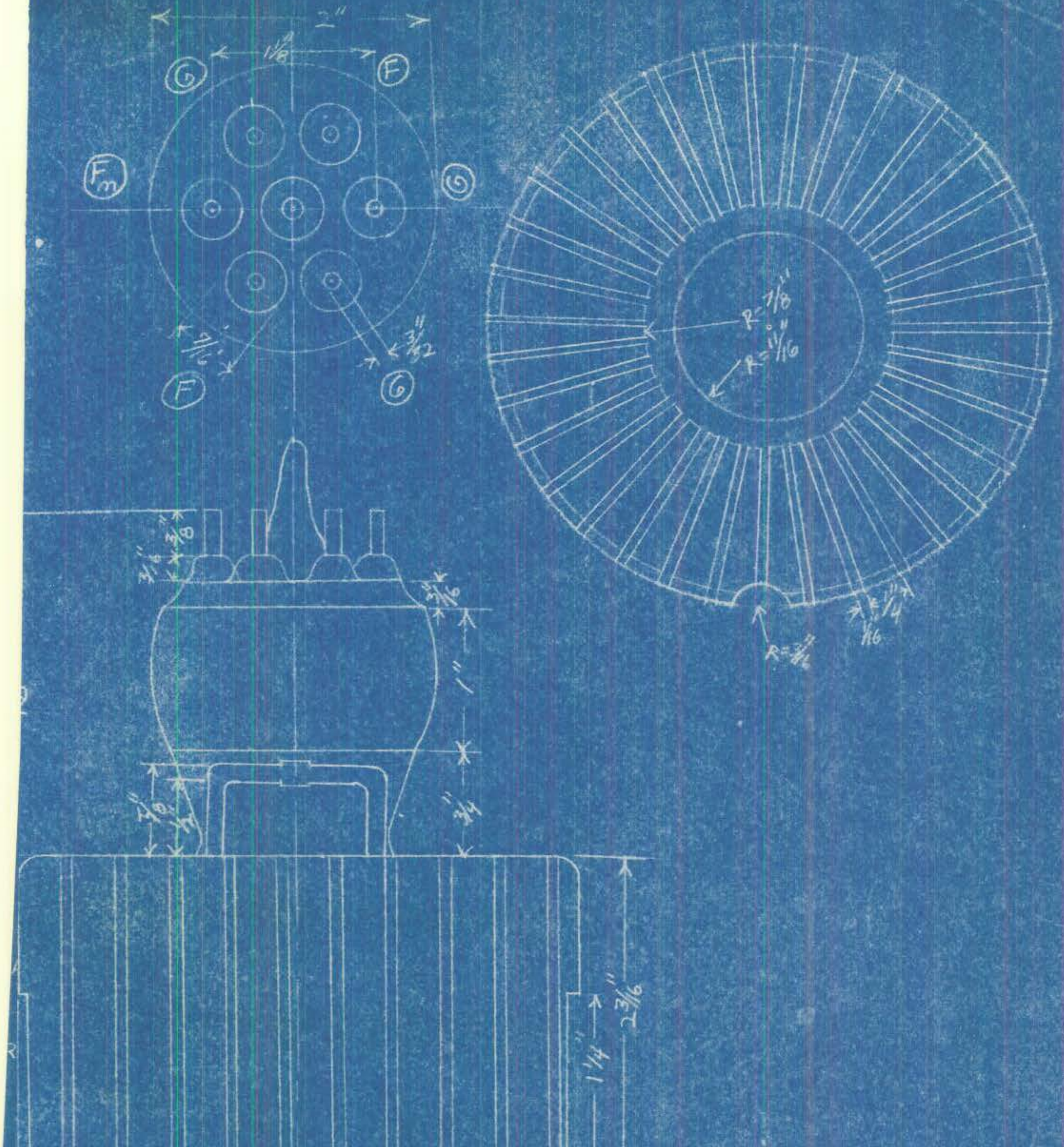

Jamming Characteristics
Japanese Receiver
NEC-NO-1736
$f_0$ = 100 mc.
Band width = .5 Mc.
Input Pulse = 10 μsec.
Dynamic range = ratio of interference level required for jamming to desired signal level.
CW
1000~ 50% Mod.
1000~ Sq. Wave Mod.
50 Kc. Mod.
Noise Mod.
Dynamic Range
Input Signal Level (μv.)
10,000
1000
100
10
1
5
10
100
1000
NO. 340-L410 DIETZGEN GRAPH PAPER SEMI-LOGARITHMIC 4 CYCLES X 10 DIVISIONS PER INCH
EUGENE DIETZGEN CO. MADE IN U.S.A.
PLATE 84




[redacted]TIAL

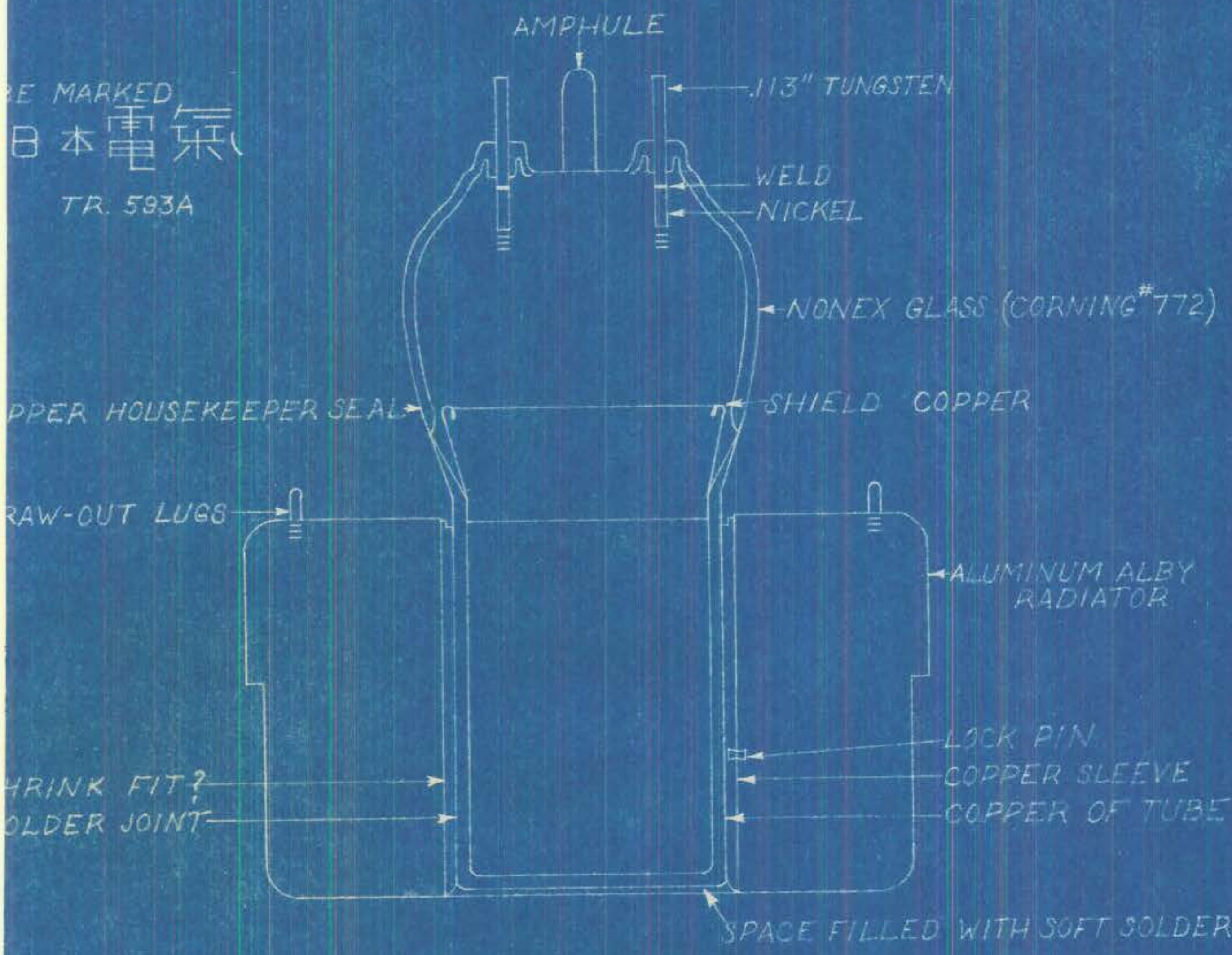
DECLASSIFIED

PLATE 85



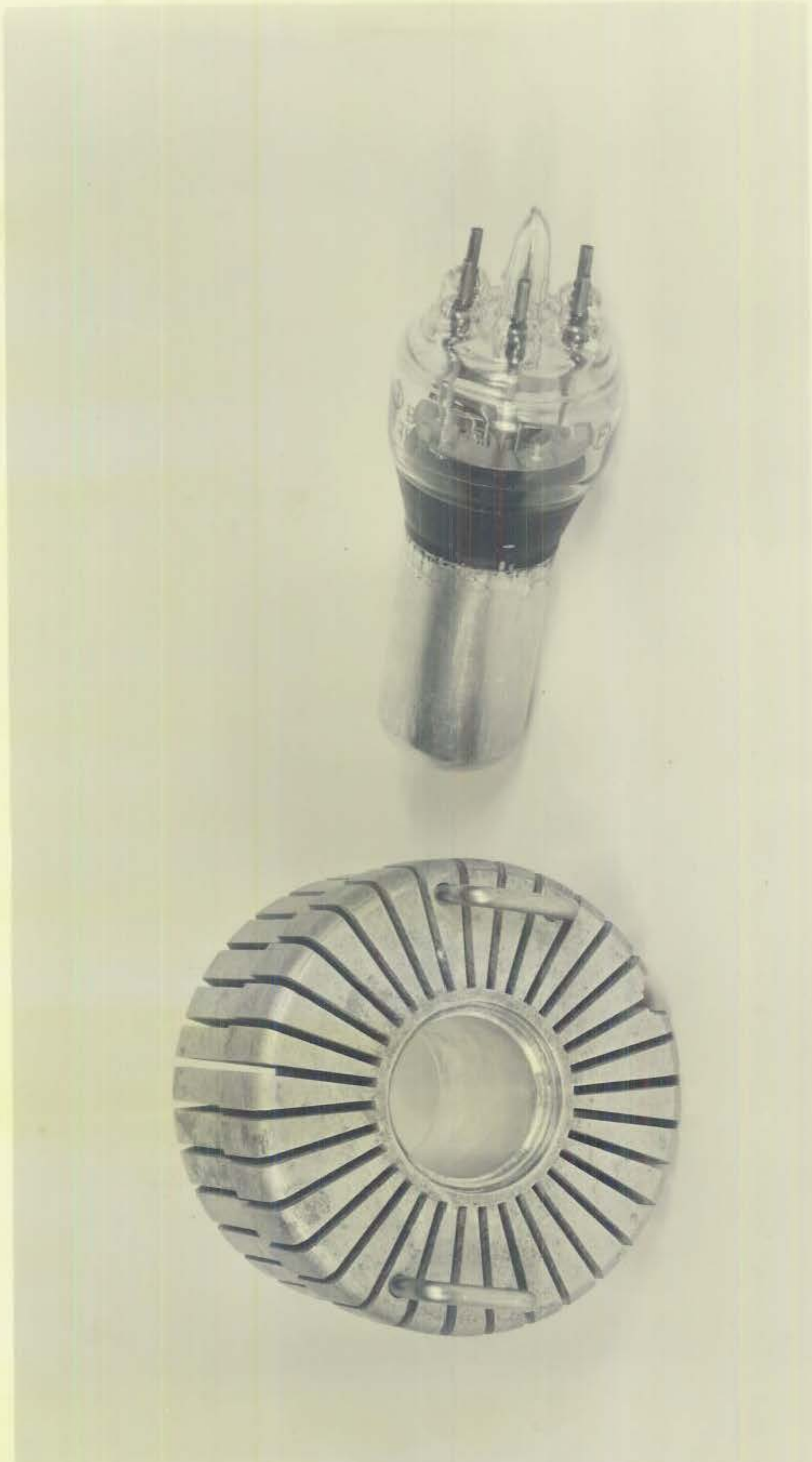

OUTLINE
TR-593-A TUBE

PLATE 86




DECLASSIFIED

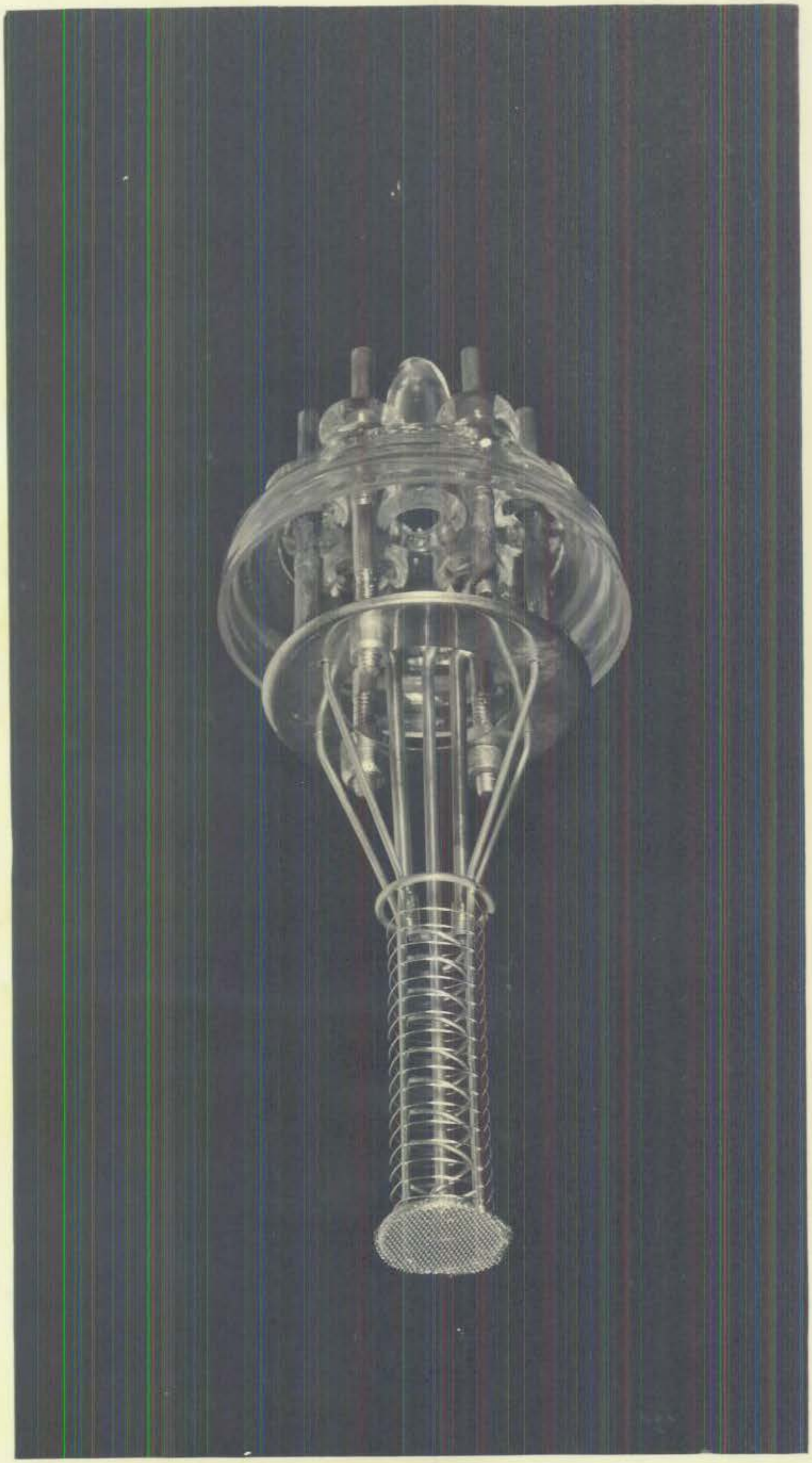
PLATE 87



[redacted]

DECLASSIFIED

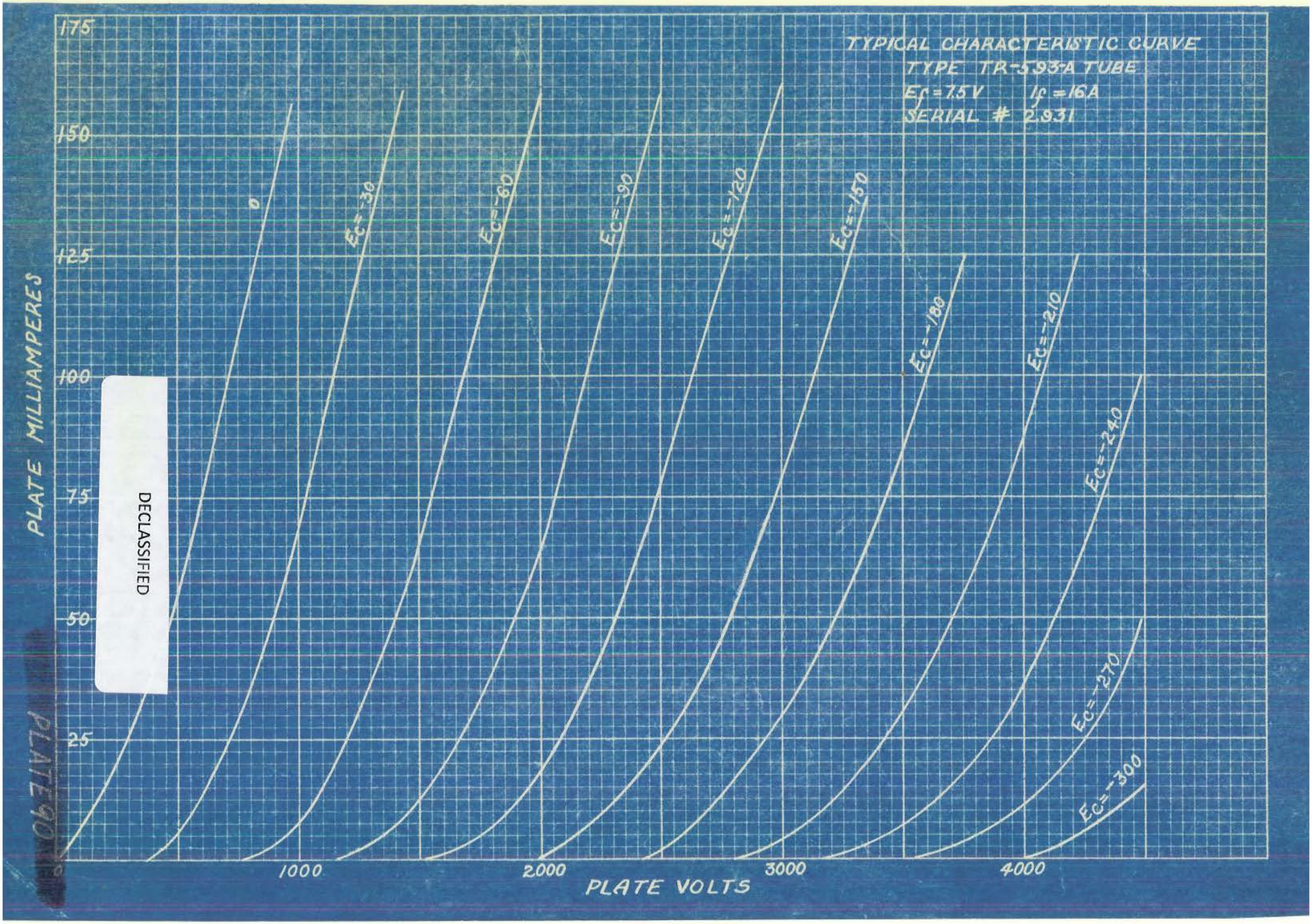
PLATE 88



[redacted]IDENTIAL

PLATE 89

DECLASSIFIED

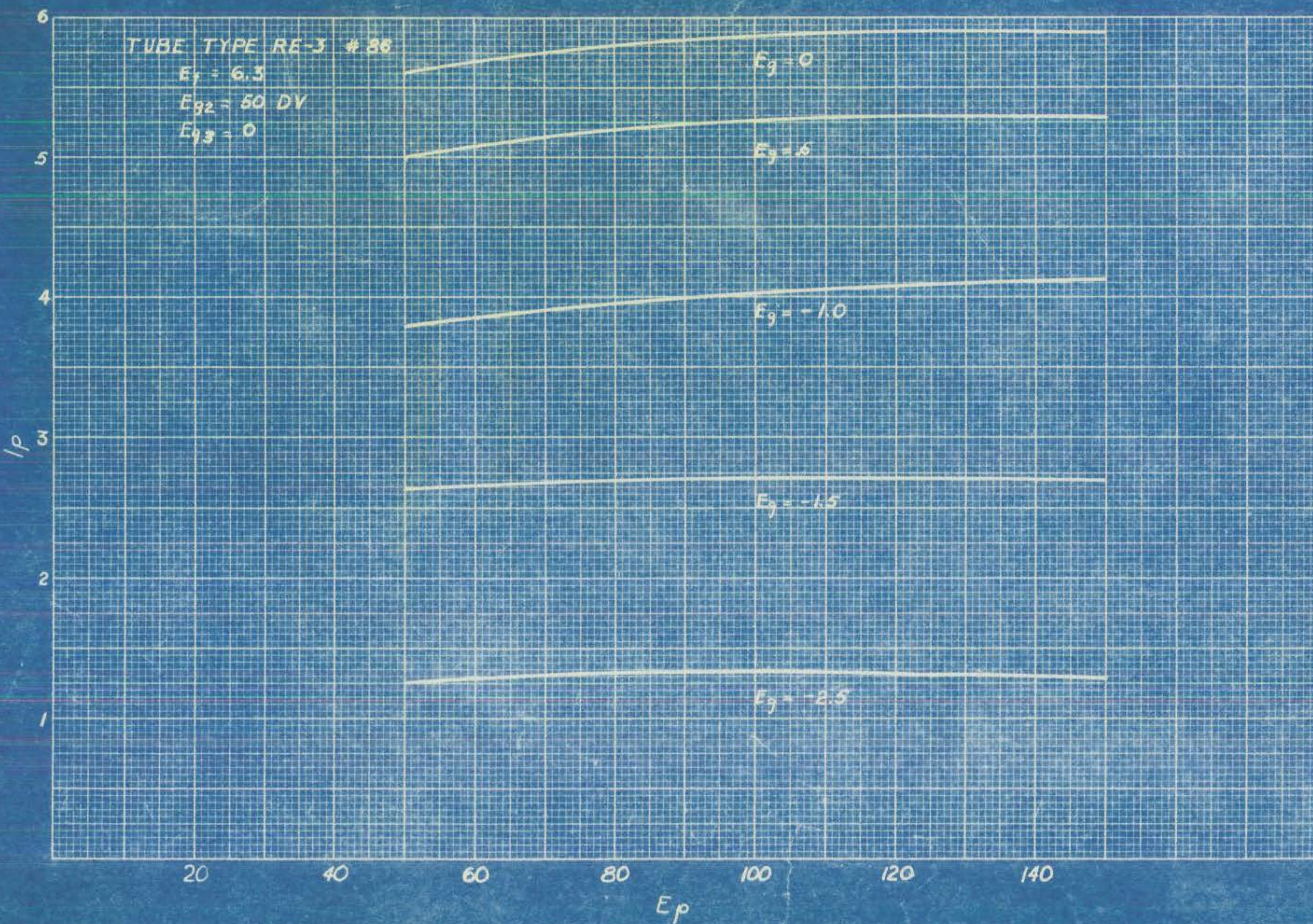


TYPICAL CHARACTERISTIC CURVE
TYPE TR-593-A TUBE
Ef = 7.5 V  If = 16 A
SERIAL # 2931
0
Ec = -30
Ec = -60
Ec = -90
Ec = -120
Ec = -150
Ec = -180
Ec = -210
Ec = -240
Ec = -270
Ec = -300
PLATE MILLIAMPERES
175
150
125
100
75
50
25
0
PLATE VOLTS
1000
2000
3000
4000
DECLASSIFIED
PLATE 90


[redacted]ENTIAL



PLATE 91




DECLASSIFIED

[redacted]

PLATE 92

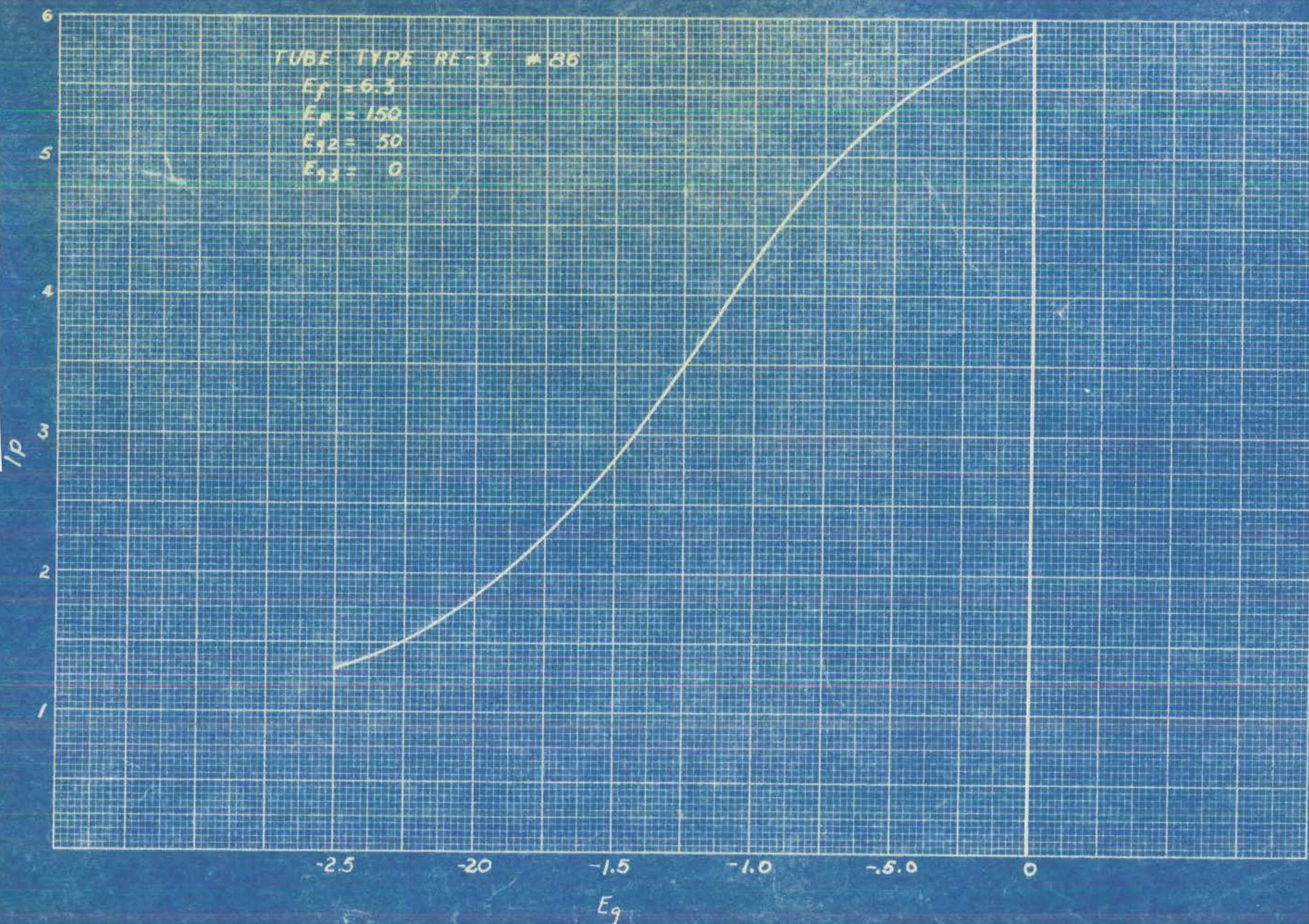

TUBE TYPE RE-3 # 86
$E_f$ = 6.3
$E_p$ = 150
$E_{g2}$ = 50
$E_{g3}$ = 0
Ip
6
5
4
3
2
1
-2.5
-20
-1.5
-1.0
-.5.0
0
$E_g$

PLATE 93

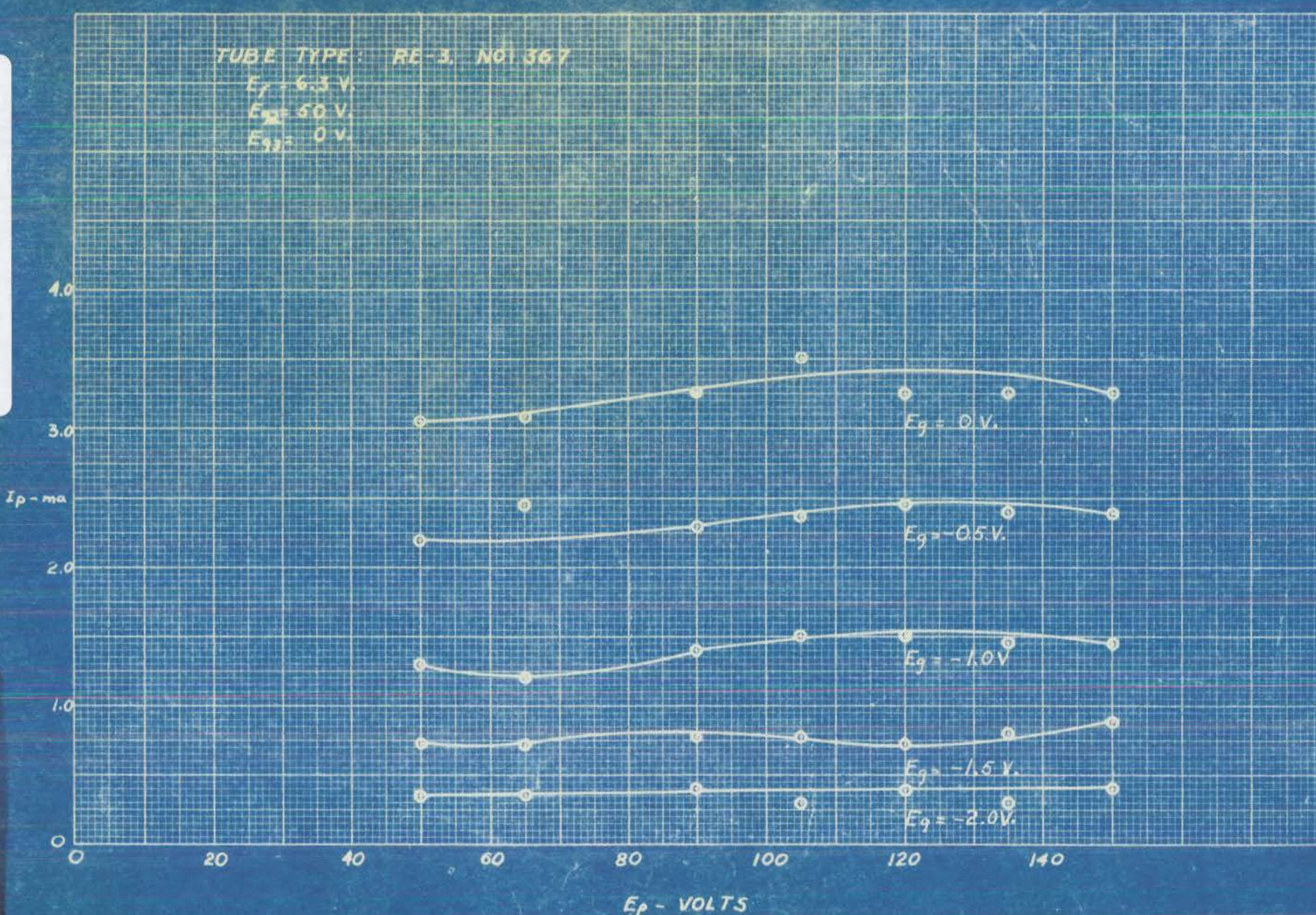
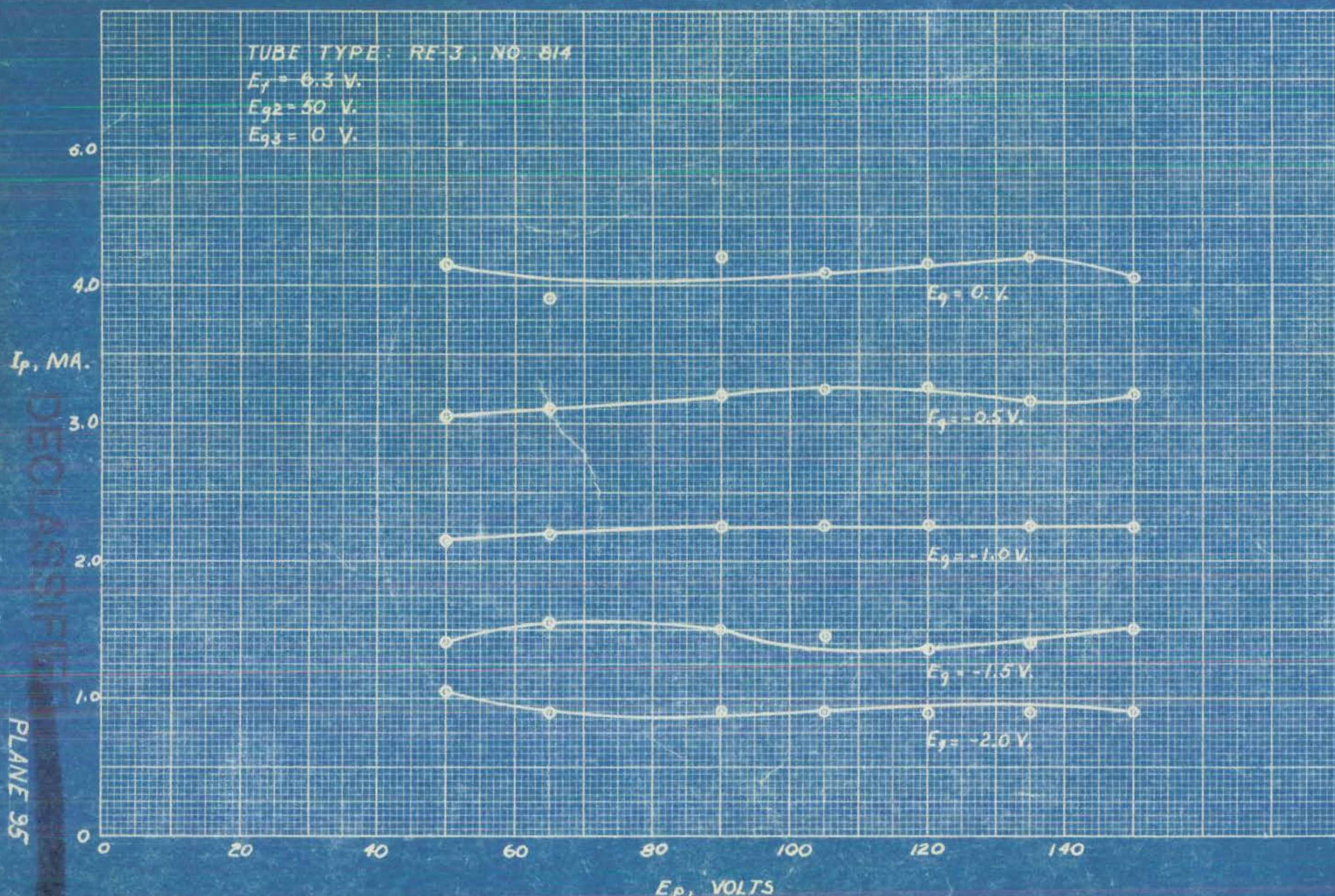

TUBE TYPE: RE-3, NO. 367
$E_f$ = 6.3 V.
$E_{g2}$ = 50 V.
$E_{g3}$ = 0 V.
$E_g$ = 0 V.
$E_g$ = -0.5 V.
$E_g$ = -1.0 V
$E_g$ = -1.5 V.
$E_g$ = -2.0 V.
$I_p$ - ma
$E_p$ - VOLTS
0
1.0
2.0
3.0
4.0
20
40
60
80
100
120
140

PLATE 94


TUBE TYPE: RE-3, NO. 814
$E_f$ = 6.3 V.
$E_{g2}$ = 50 V.
$E_{g3}$ = 0 V.
$I_p$, MA.
0
1.0
2.0
3.0
4.0
6.0
0
20
40
60
80
100
120
140
$E_p$, VOLTS
$E_g$ = 0. V.
$E_g$ = -0.5 V.
$E_g$ = -1.0 V.
$E_g$ = -1.5 V.
$E_g$ = -2.0 V.



PLANE 95

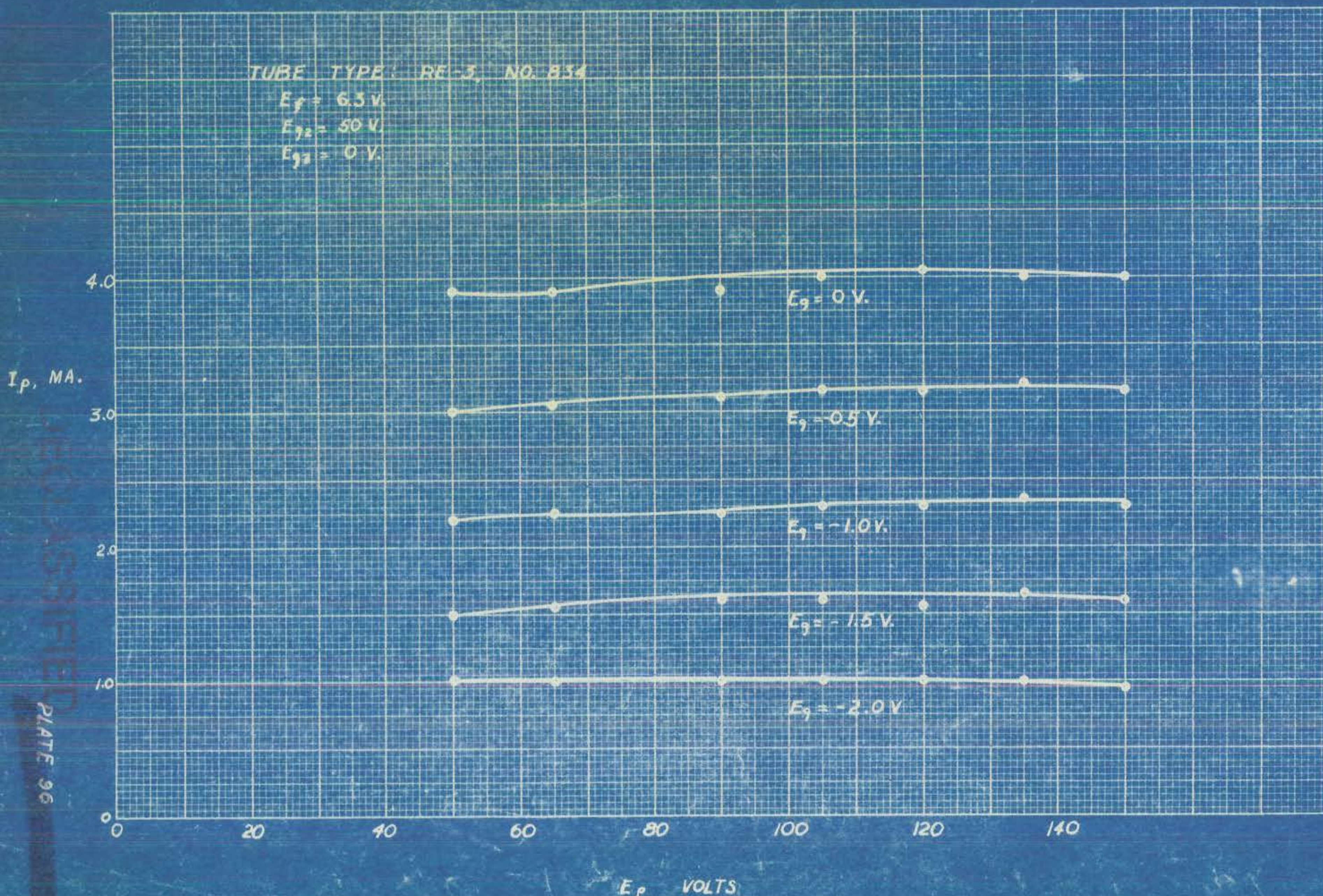

TUBE TYPE: RF-3, NO. 834
$E_f$ = 6.3 V.
$E_{g_2}$ = 50 V.
$E_{g_3}$ = 0 V.
$E_g$ = 0 V.
$E_g$ = -0.5 V.
$E_g$ = -1.0 V.
$E_g$ = -1.5 V.
$E_g$ = -2.0 V.
$I_p$, MA.
4.0
3.0
2.0
1.0
0
0
20
40
60
80
100
120
140
$E_p$ VOLTS



PLATE 96


[redacted]

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PLATE 97

(Copy)

C-S67/36(371) February 25, 1943

Mr. D.R. Hull
Lt. Commander, U.S.N.
Naval Research Lab.
Anacostia Station
Washington, D.C.

Dear Sir:

Our detailed examination of the capacitor described in your communication of December 9, 1942 is covered by the attached confidential data folder #65,126.

The following comments and observations are offered with the idea that it may help you to better judge the relative merits of Japanese and American made capacitors. Frequent reference is made to G.E. design practice. This is for the sake of convenience and also because we feel that G.E. design practice is fairly representative of the capacitor industry in the U.S.A.

The main points of difference between the Japanese capacitor and the average U.S.A. built capacitor were found to be as follows:

1. The paper used in the Japanese capacitor contained a filler. Both the density and the dielectric constant of the paper was from 35 per cent to 40 per cent higher than for papers normally used in the U.S.A.

2. The normal operating stress on the Japanese capacitor was about double that usually used in U.S.A. practice.

3. Electrical characteristics of the Japanese capacitor were poor.

4. Space or volume of the Japanese capacitor was not used efficiently.

Comments on Item #1

The mu-f capacity of the Japanese capacitor was approximately 20 per cent greater than we would expect from the same thickness and



[redacted]

area of U.S.A. materials.

The use of high density, high dielectric constant paper was obviously for the purpose of increasing mu-f capacity and decreasing size.

The use of high density, high dielectric constant papers will not give any appreciable increase in mu-f capacity per unit volume, where castor oil or Pyranol impregnation is used.

Attention is called to the fact that present Navy Specifications prohibit the use of fillers in papers. See RE-13A-488E, paragraph D3-b.

General Electric practice has been to use a paper in the general density range of .95 to 1.05. Our experience has been that high density papers are extremely difficult to thoroughly dry and impregnate. Consequently, we usually obtain poor electrical characteristics, including short life when high density papers are used.

One favorable characteristic of high density paper is that the short time breakdown strength or ability to withstand voltage surges might be expected to be higher than for lower density papers. Our experience would indicate a maximum increase of five per cent for a paper with the same density as that used in the Japanese capacitor.

<u>Comments on Item #2</u>

Normal operating stress on the Japanese capacitor was found to be approximately 2000 volts per mil of dielectric. The usual U.S.A. practice is 1000 volts per mil--see Navy Specifications RE-13A-488E paragraph D3-b.

Paragraph F-10 of the same Specification also requires that capacitors be capable of withstanding 1000 hours life test at double rated voltage. In other words, the Japanese have used a normal rating which is equivalent to the Navy Specification life test rating.

Nothing in our examination of the Japanese capacitor gave us any reason to believe that it was any better than U.S.A. built capacitors with the same dielectric thickness.

<u>Comments on Item #3</u>

Mu-f capacity versus temperature of the Japanese capacitor is shown in H-8372426. For characteristics of G.E. oil impregnated capacitors, see H-8351069. The curve for 25F394 more nearly repre-

[redacted] 

sents the average design than the curve for 26F377. It will be noted that the capacity-temperature coefficient for G.E. capacitors is less than for the Japanese capacitor.

Change of mu-f capacity with change of voltage is a peculiar characteristic for which we have no explanation, with the possible exception that it may result from the filler used in the paper dielectric. G.E. mineral oil and Pyranol impregnated capacitors do not show this characteristic.

Power factor versus temperature is shown on H-8372428. For comparison with G.E. designs, see H-8351072. It will be noted that power factor of the Japanese capacitor is considerably higher than for G.E. designs, and especially so in the range of 50 to 100° C.

Power factor versus voltage is shown on H-8372429. G.E. mineral oil filled capacitors do not show any change of power factor with change of voltage except at 100° C where there is a very slight increase in power factor with an increase of voltage.

G.E. Pyranol impregnated capacitors (see H-8372429) show a characteristic similar to that of the Japanese capacitor at 75 and 100° C. This characteristic is very pronounced on the Japanese capacitor at all temperatures.

On G.E. Pyranol impregnated capacitors we attribute this characteristic to the molecular structure of Pyranol. In the case of the Japanese capacitor it is probably due to the molecular structure of the filler used in the paper.

Insulation resistance versus temperature is shown on H-8372430. We do not have a G.E. curve which is directly comparable. However, we would normally expect our capacitor to have an insulation resistance of about five to six times that of the Japanese capacitor.

The comparatively high power factor and low insulation resistance are both indicators that inferior life might be expected.

We, of course, have no way of determining the life of the capacitor from a single sample. However, based on our experience with capacitors we would predict that the life of the Japanese capacitor, when operated at normal voltage would not exceed the following values:

| | |
|---|---|
| 1000 - 1500 hours | Ambient 60° C |
| 200 - 300 hours | Ambient 75° C |
| 5 - 10 hours | Ambient 90° C |

[redacted]

Comments on Item #4

As shown in our Laboratory report, the foil used was 3-1/8" wide and the paper 3-3/4" wide. The container height and bushing construction were such that 3-3/4" wide foil and 4-3/8" wide paper could have been used. This would make it possible for the Japanese to put about 2.28 mu-f in the same size container.

Furthermore, the inside height of the Japanese capacitor was six inches. One and one-half inches of this height was required for bushings. For the same test and voltage rating, G.E. design practice would be to use a bushing one-half inch high on the inside.

This naturally leads to the question: how many mu-f could be obtained in this size container with G.E. design practice and using the same stress per mil of dielectric that was used on the Japanese capacitor? The answer is approximately 2.54 mu-f with mineral oil impregnation and 3.7 mu-f with Pyranol impregnation.

This would indicate up to 62 per cent greater mu-f capacity with G.E. design practice on the great majority of our applications, since we use Pyranol impregnation on practically all applications except those that require a low capacity-temperature coefficient.

If there is any additional information or any other service which we can render on this subject, please feel free to call on us.

Very truly yours,

V.E. Goodwin, Managing Engineer
LTG. ARREST., CUTOUT & CAP. DEPT.

By: L.E. Gregory
CAPACITOR SECTION

LEG/g

[redacted]

GENERAL ELECTRIC

GO-817-A (7-39)

## DATA FOLDER No. 65126

[redacted]

Subject EXAMINATION OF 2 MF, 15,000 VOLT DC TEST, JAPANESE CAPACITOR

Issued by PW LABORATORY Date 1/27/43

Return to



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Data Folder 65,126

GENERAL ELECTRIC

COMPANY

Schenectady, N.Y., U.S.A.

IRS 651
File #16

Class 5

Title Examination of 2 MF, 15,000 Volt DC Test, Japanese Capacitor.

By

Insulation Research Section

Pittsfield Works Laboratory Dept.

Information prepared for Capacitor Engineering Department

Tests made by J.F. Byrne, L. Harrop, L.J. Hogue, B.H. Nieder, R. Umhoefer

Information prepared by R.R. Umhoefer

Countersigned by F.M. Clark

January 27, 1943 Date

---

F.M. Clark
L.E. Gregory
V.E. Goodwin
J.D. Stacy

[redacted]

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Report No. 65,126 Page No. 1

CONFIDENTIAL

INSULATION RESEARCH SECTION REPORT 651
PITTSFIELD WORKS LABORATORY
January 27, 1943

I. SUBJECT: Examination of 2 MF 15000 Volt DC Test, Japanese Capacitor

II. SOURCE OF CAPACITOR:

This unit was taken from a Japanese plane, and was used on an 8000 volt DC circuit. The nameplate stated that the capacitor had been tested at 15000 volts DC.

III. OBJECT:

This unit had a much smaller volume than do capacitors of similar rating manufactured by General Electric.

This made it desirable to examine completely the electrical and construction details of this capacitor.

IV. OBSERVATIONS AND CONCLUSIONS:

A. This unit, in outward appearance, is similar in all details to a former General Electric design.

B. The workmanship is of a high quality.

C. The relatively high capacity of this unit, as compared to General Electric oil-filled capacitors, is due to a higher dielectric constant of the solid insulation.

D. The solid dielectric consists of vegetable fiber, principally mulberry with either or both manila or ramie. The dielectric constant has been increased by incorporating a clay filler in which hydrated aluminum oxide is a major constituent.

E. The liquid dielectric is mineral oil of about the grade of 10-C transformer oil.

F. Both the capacity and power factor decreases with increasing voltage.

G. The capacity increases with increasing temperatures over the range tested, -57° to 95° C.

H. At 1500 volts A-c, the power factor is a minimum and less than 0.5% between 15° and 60° C.

I. The power factor is higher than General Electric Pyranol or oil units, and also shows a greater variation with temperature.

J. The insulation resistance is low compared to General Electric capacitors.

## V. EXPERIMENTAL:

### A. Electrical Properties:

A detailed examination of the electrical characteristics at different voltages are given in test report 46506.

CAPACITY AND POWER FACTOR VS TEMPERATURE

| Test Temp. (°C) | Test Voltage (AC) | Capacity (MFD) | Power Factor (%) |
|---|---|---|---|
| -57 | 50 | 1.782 | 2.07 |
| -25 | 50 | 1.840 | 0.727 |
| 0 | 50 | 1.873 | 0.977 |
| 25 | 1500 | 1.904 | 0.461 |
| 51 | 1500 | 1.936 | 0.457 |
| 75 | 1500 | 1.963 | 0.663 |
| 95 | 1500 | 1.992 | 1.062 |

INSULATION RESISTANCE VS TEMPERATURE (500 VDC)

| Temperature (°C) | Insulation Megohms | Resistance Megohm-Microfarads |
|---|---|---|
| -43 | 5190 | 10380 |
| -25 | 4020 | 8040 |
| -8 | 2600 | 5200 |
| 5 | 1770 | 3540 |
| 25 | 740 | 1480 |
| 50 | 111 | 222 |
| 75 | 14.1 | 28.2 |
| 98 | 4.1 | 8.2 |

Curve sheet H-8372426 shows the change in capacity with temperature and voltage
Curve sheet H-8372428 shows the change in 60 cycle power factor with temperature at 1500 volts.
Curve sheet H-8372429 shows in detail the effect of voltage and temperature on the power factor.
Curve sheet H-8372430 shows the change in insulation resistance with temperature.

[redacted]

Conclusions:

1. The power factor vs temperature characteristics of this capacitor as received are not good. The minimum in the power factor at 1500 volts occurs between 15 and 60° C.

2. The power factor of this unit is higher than General Electric Pyranol or oil-filled units, and also shows a greater variation with temperature.

3. The capacity increases with increasing temperatures over the range -57° to 95° C.

4. The insulation resistance is low compared to General Electric capacitors.

B. Construction Details of Capacitor:

1. Description of Unit:

| | |
|---|---|
| (a) Nameplate: | The nameplate was stamped in Japanese letters with the exception of the rating of 2 Muf, 15000 VDC. |
| (b) Appearance: | This unit had the same appearance as a former General Electric capacitor, see photograph. |
| 2. Weight: | 2850 g. |
| 3. Container: | Tin-plate can, 6 1/4 x 2 1/2 x 7"; volume, 98.5 cu. in. |
| 4. Terminals: | Hollow, nickel-plated brass with a threaded top end. These were insulated with procelain bushings. The bushings were sealed to can by resin-coated cork gaskets (Photograph). |
| 5. Electrical contact to cover terminals: | Contact was made by two, twisted, tin-coated copper wires. Diameter, .020". The wires extended through the hollow terminal and were soldered to it at the tap. The solder sealed the hollow terminal. |
| 6. Electrical Arrangement of capacitor rolls: | The capacitor rolls were arranged in two groups in series. Each group was composed of four capacitor rolls connected in parallel by means of the twisted terminal wires. One of the wires crossed over the assembly at the center and was insulated from the rolls by a notched mica sheet. (Photograph) |

 



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7. Interior Construction: The capacitor rolls were encased in a pressboard barrier which lined the inside of the can. End movement of the capacitor rolls and pressboard liner was prevented by red fiber pieces, 1 5/8" x 3 5/8" x .055". At each end, there were two pieces between barrier and can and one between rolls and barrier.

The rolls were held to the bottom of the can by a rectangular shaped, pressboard piece aluminum riveted to the pressboard liner. (Photograph) Between the capacitor rolls and bottom of can were 6 sheets of kraft paper doubled over, 12 x 2 1/2 x .002".

8. Electrical contact to Capacitor Rolls: The terminal wires were soldered to tin-coated brass tap straps, 2 15/16 x 5/32 x .003". The taps had square corners. There were two taps to each foil, 5" apart and located 10.1 and 10.5 feet from outside end of foil.

9. Capacitor Rolls 8 in number. Each one was 7/8" x 2 1/2" x 3 3/4".

10. Insulation Between Foils: Number of sheets between foils: 5
Thickness each sheet: .00038"; width 3 3/4"
Dielectric constant: 4.9
Composition: The solid insulation was a dense, essentially non-porous paper made from mulberry fibers and either or both manila and ramie. The paper density was about 1.345. A clay-like filler was present which consisted to a large degree of hydrated aluminum oxide. The presence of potassium sulfate has been detected also.

The paper extended, 6" on inside and 12" on outside, beyond the foil. Breaks in the paper were neatly stuck together with a 1/2" overlap, the sticker had a blue color.

Conclusions: The higher capacity per unit volume, compared to General Electric oil capacitors, is due to the higher dielectric constant of the solid insulation. (4.9 as compared to 3.85 for General Electric oil impregnated kraft paper) The higher dielectric constant has been obtained by incorporating an inorganic filler with the paper fibers. The filler appears to be a clay in which hydrated aluminum oxide is a major constituent. (The dielectric constant for dry aluminum oxide is 7.7).

11. Foil: Aluminum. Length for each roll, 26.5 feet. Width, 3 1/8 in. Thickness, .00036 in. The foil had a crushed appearance on inside end of roll.

[redacted]

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Report No. 65,126 Page No. 5

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12. Effective Area: One roll, 13.8 sq. ft.
    Capacitor, 110.4 sq. ft.

13. Electrical Tests at 25°C: Capacity 1.904 MF (1500 volts AC)
    Power Factor, 0.461 percent

14. Sq. Ft. Foil Area per MF: 58

15. Cu. In. per MF of Electrical Capacity: 51.7

C. Examination of Impregnating Compound:

1. Physical Properties:

| | Japanese Impregnant | New 10-C Transformer Oil |
|---|---|---|
| Condition 25°C | Clear, fluid liquid | Fluid liquid |
| Color (ASTM) | 6, dark, red-brown | 1, pale yellow |
| Acidity (mg NaOH/g) | .06 | .014 Max. |
| Refractive Index (25°C) | 1.4998 | 1.49 about |
| Gravity (15.6°C) | .928 | .900 Max. |
| Viscosity (37.8°C) | 57 sec. | 58 sec. Max. |
| Pour | -48°C | -40 Max. |
| Flash | 136°C | 130°Min. |
| Fire | 146°C | 145°Min. |
| Saponification No. (mg KOH/g) | .84 | Less than .5 |
| Dielectric Constant (25°C) | 2.2 | 2.2 |
| " " (100°C) | 2.1 | 2.1 |
| Power Factor (60 cycle, 25°C) | 13% | .007 |
| " " " " 100°C) | 87% | .036 |
| Resistivity (100°, ohm/cm$^3$ ) | $53 \times 10^8$ | $50 \times 10^{11}$ |

Conclusions: These properties indicate the impregnating liquid to be a mineral oil of about the same grade as 10-C transformer oil. The impregnating liquid, therefore, is not a factor in producing the high capacity per unit volume of this capacitor.

2. Chemical Examination:

Attempts to determine the presence of stabilizers in the oil have been unsuccessful. The coloring matter and chemically similar material is present to about 0.6 percent. No nitrogen compounds are present, but compounds which contain sulfur have been detected. The coloring compounds have higher boiling points than most of the oil and hence are of large molecular weight and complexity. As is the case for oxidized oils, the color may be removed by fullers earth. The refined product has a light yellow color.

That inhibitors are absent or ineffective is further indicated by the poor condition of the oil. Thus the oil has a slight acidity, high power factors at 25 and 100°C and a low resistivity at 100°C.

Conclusions: No evidence for the presence of stabilizers in the impregnating oil has been found. All the physical and chemical factors noted may be explained on the basis of oxidation or deterioration of a sulfur containing oil.

rru/mp
2/2/43

R.R. Umhoefer
PITTSFIELD WORKS LABORATORY

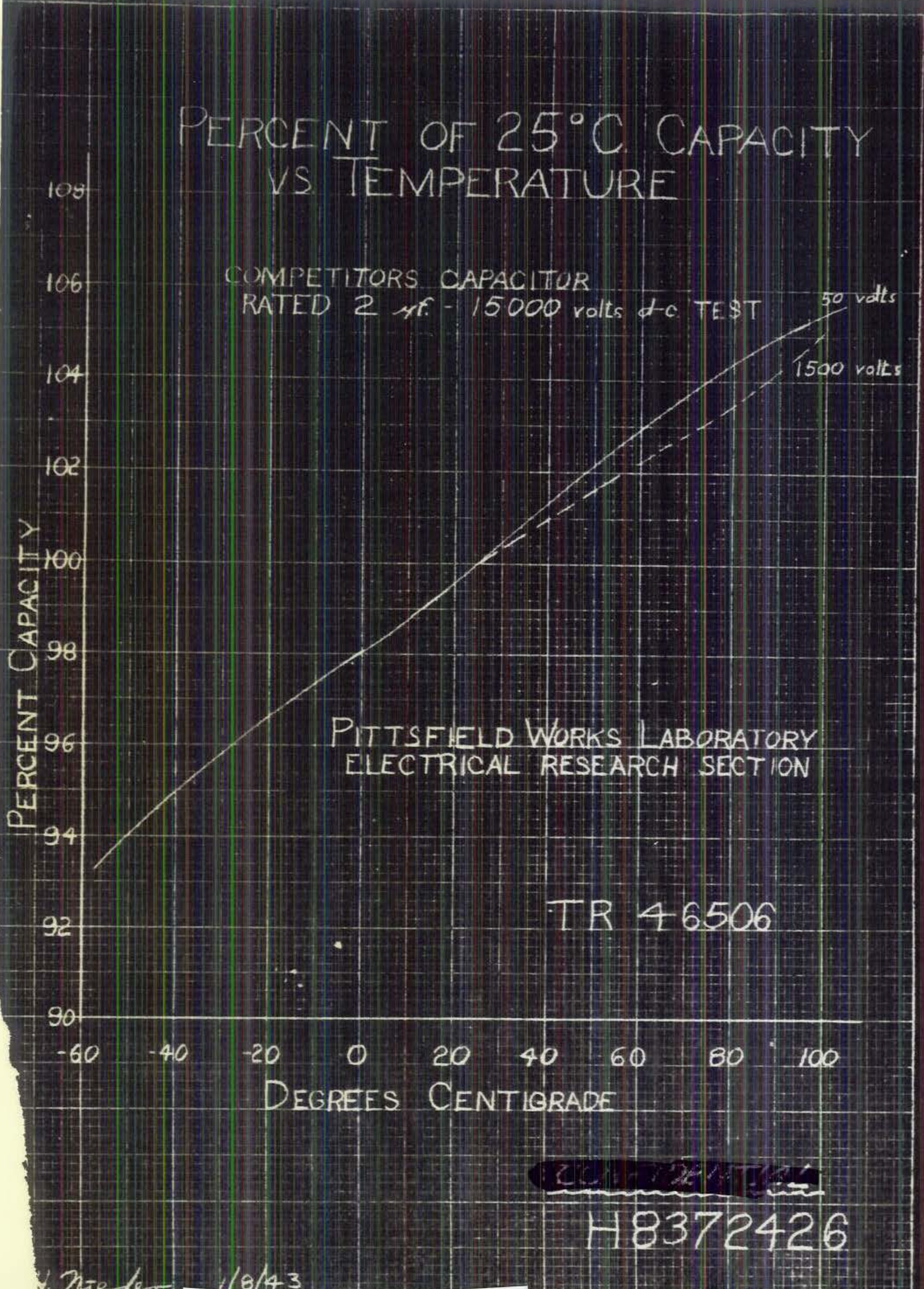
[redacted]



761730 DISASSEMBLED CAPACITOR RATED 2.0 MICROFARADS, [illegible] VOLTS D-C WORKING, 15,000 VOLTS D-C TEST. FROM JAPANESE RADAR EQUIPMENT. [redacted]

FILING NO.5700, 918 E334.1 1-8-43

APPENDIX I, PAGE 13

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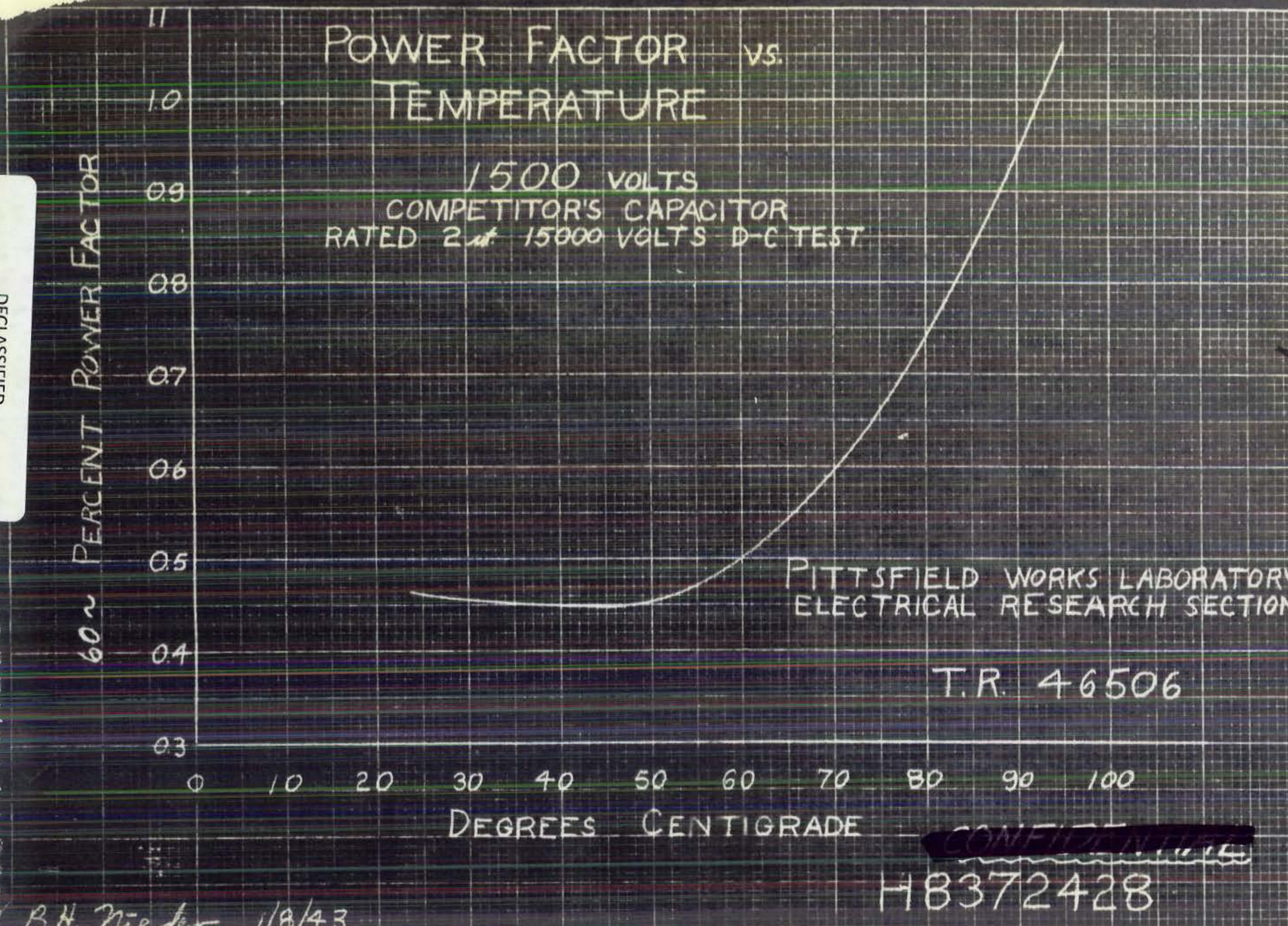
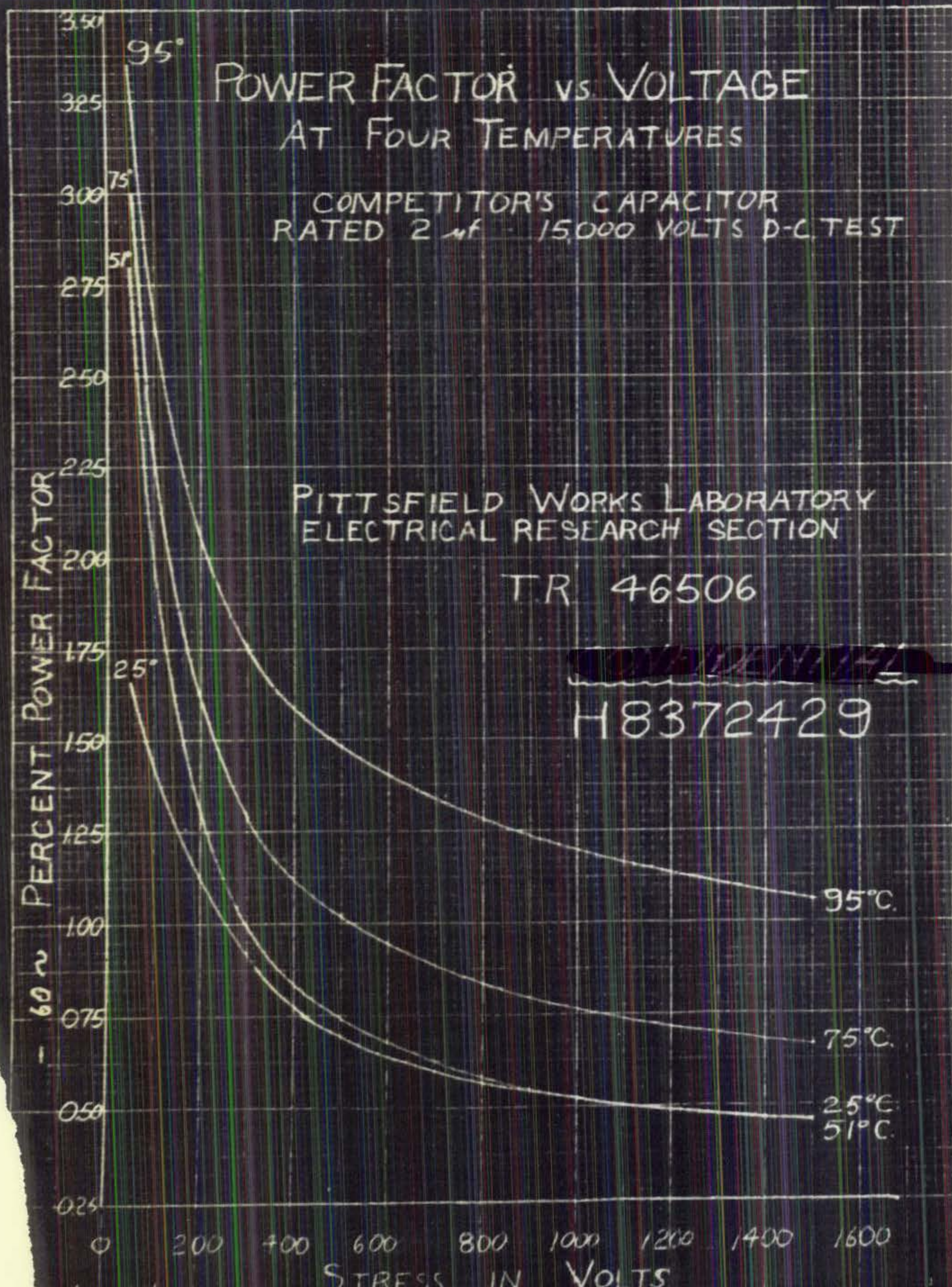
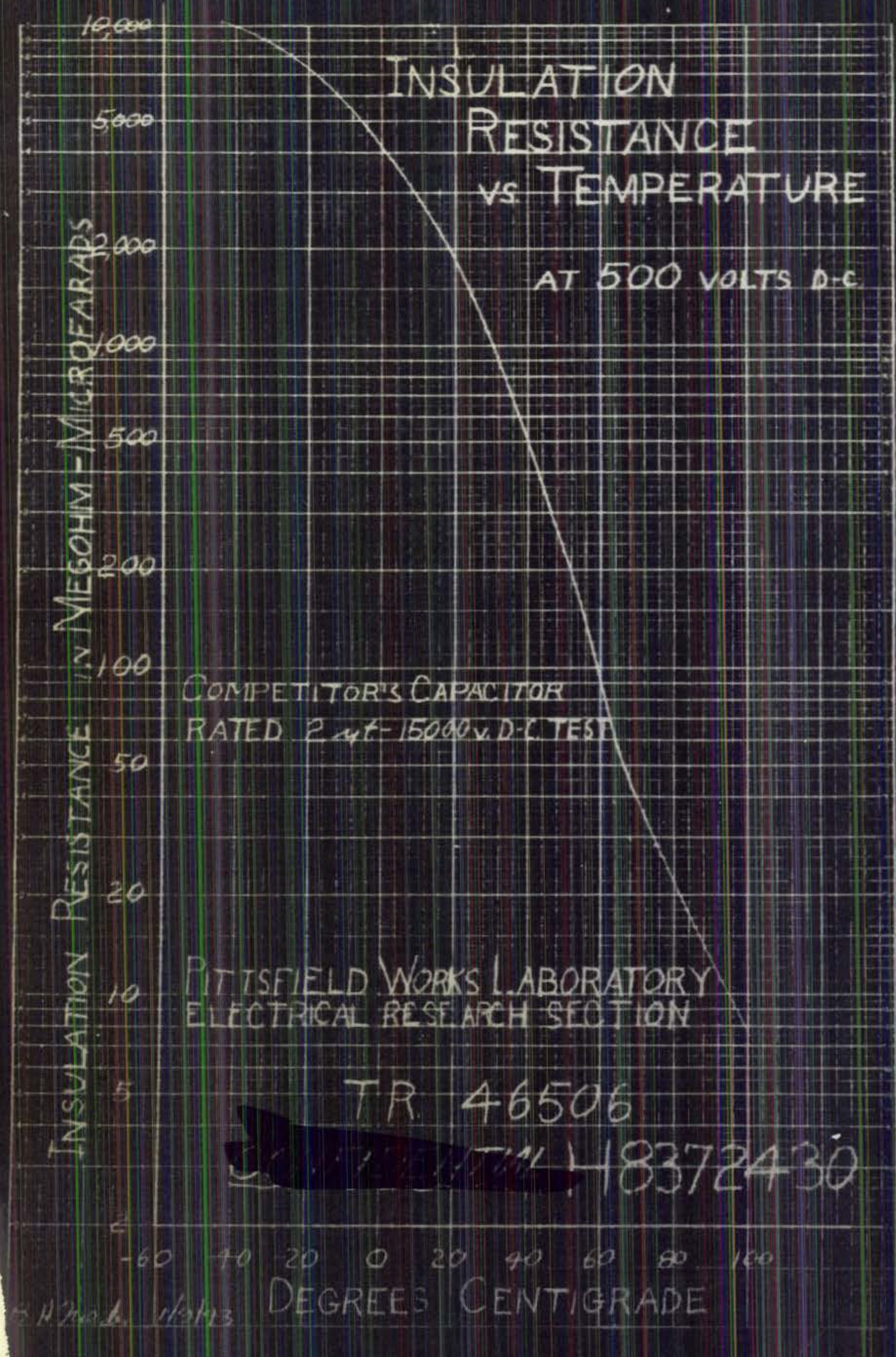
Appendix II p. 15

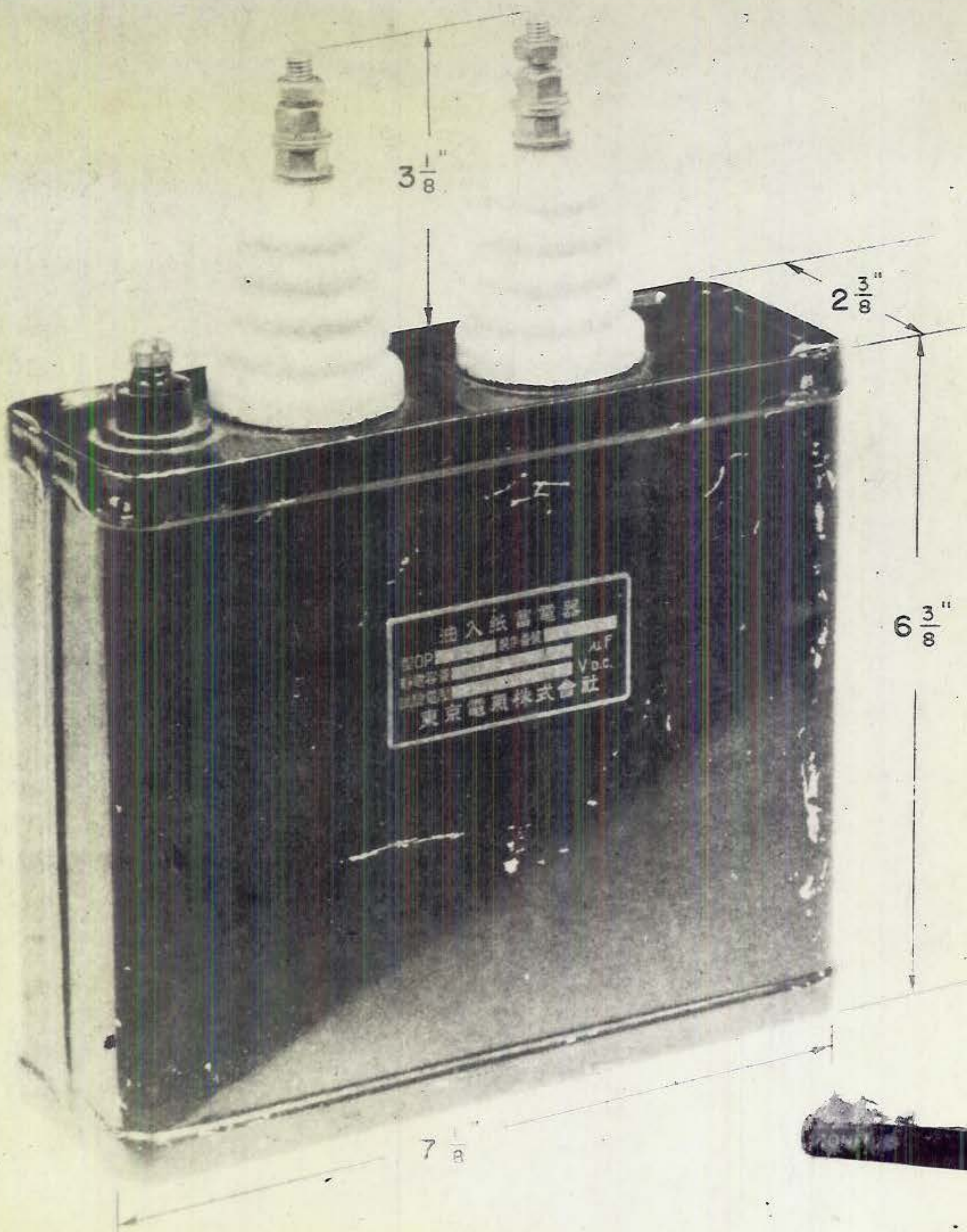





APPENDIX I, PAGE 15


POWER FACTOR vs VOLTAGE
AT FOUR TEMPERATURES
COMPETITOR'S CAPACITOR
RATED 2 μf 15,000 VOLTS D-C TEST
PITTSFIELD WORKS LABORATORY
ELECTRICAL RESEARCH SECTION
T.R. 46506
[redacted]
H8372429
60 ~ PERCENT POWER FACTOR
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
95°
75°
51°
25°
95°C.
75°C.
25°C.
51°C.
0
200
400
600
800
1000
1200
1400
1600
STRESS IN VOLTS


INSULATION RESISTANCE vs TEMPERATURE
AT 500 VOLTS D-C
INSULATION RESISTANCE IN MEGOHM - MICROFARADS
10,000
5,000
2,000
1,000
500
200
100
50
20
10
5
2
COMPETITOR'S CAPACITOR
RATED 2 μf - 15000 v. D-C. TEST
PITTSFIELD WORKS LABORATORY
ELECTRICAL RESEARCH SECTION
TR 46506
[redacted] 48372430
-60 40 20 0 20 40 60 80 100
DEGREES CENTIGRADE



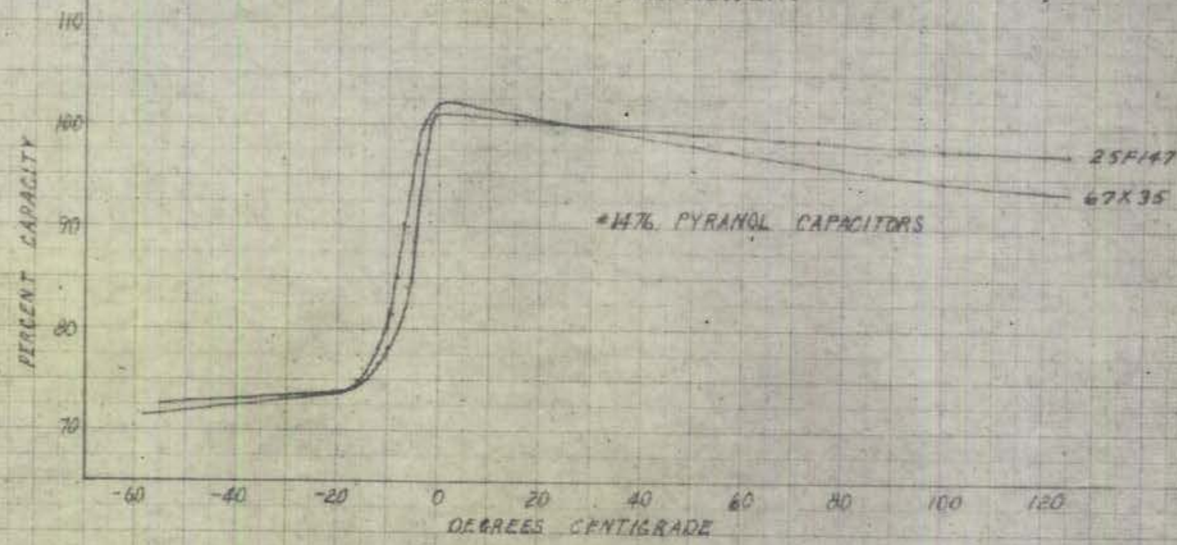

761683 CAPACITOR RATED 2.0 MICROFARADS, 8000 VOLTS D-C (WORKING), 15,000 VOLTS D-C (TEST). FROM JAPANESE RADAR EQUIPMENT.

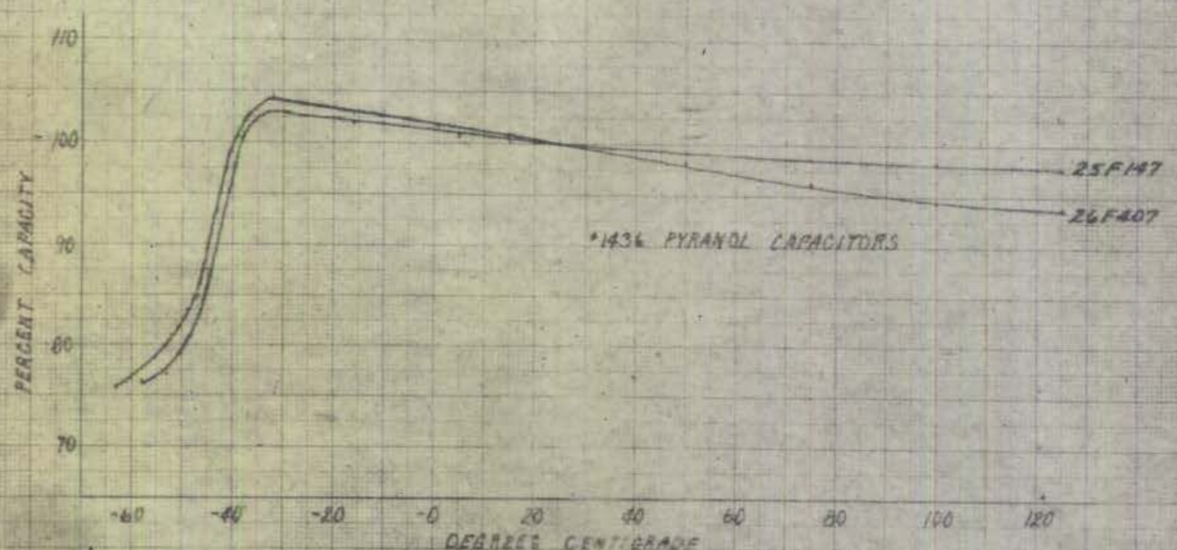
FILING NO.5700, 6900 E338.1 1-4-43

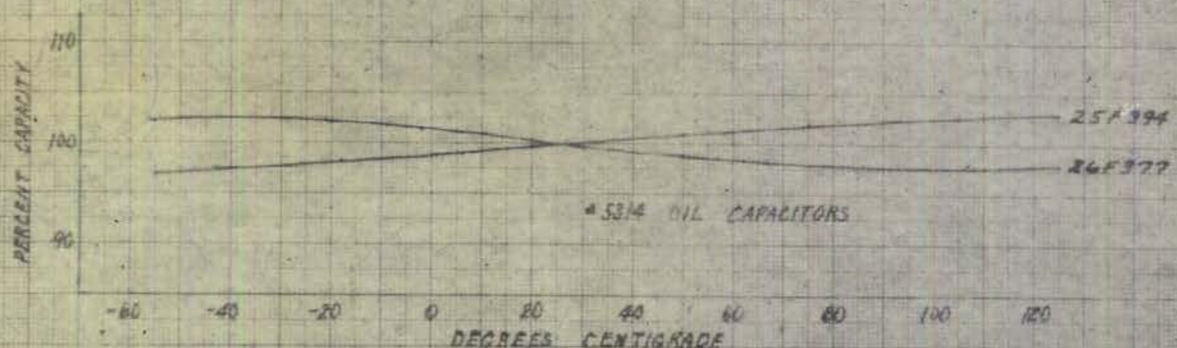
APPENDIX I, PAGE 18

PERCENT OF 25°C CAPACITY vs TEMPERATURE

RANGE FOR COMMERCIAL DESIGNS
CLASS 895 CAPACITORS



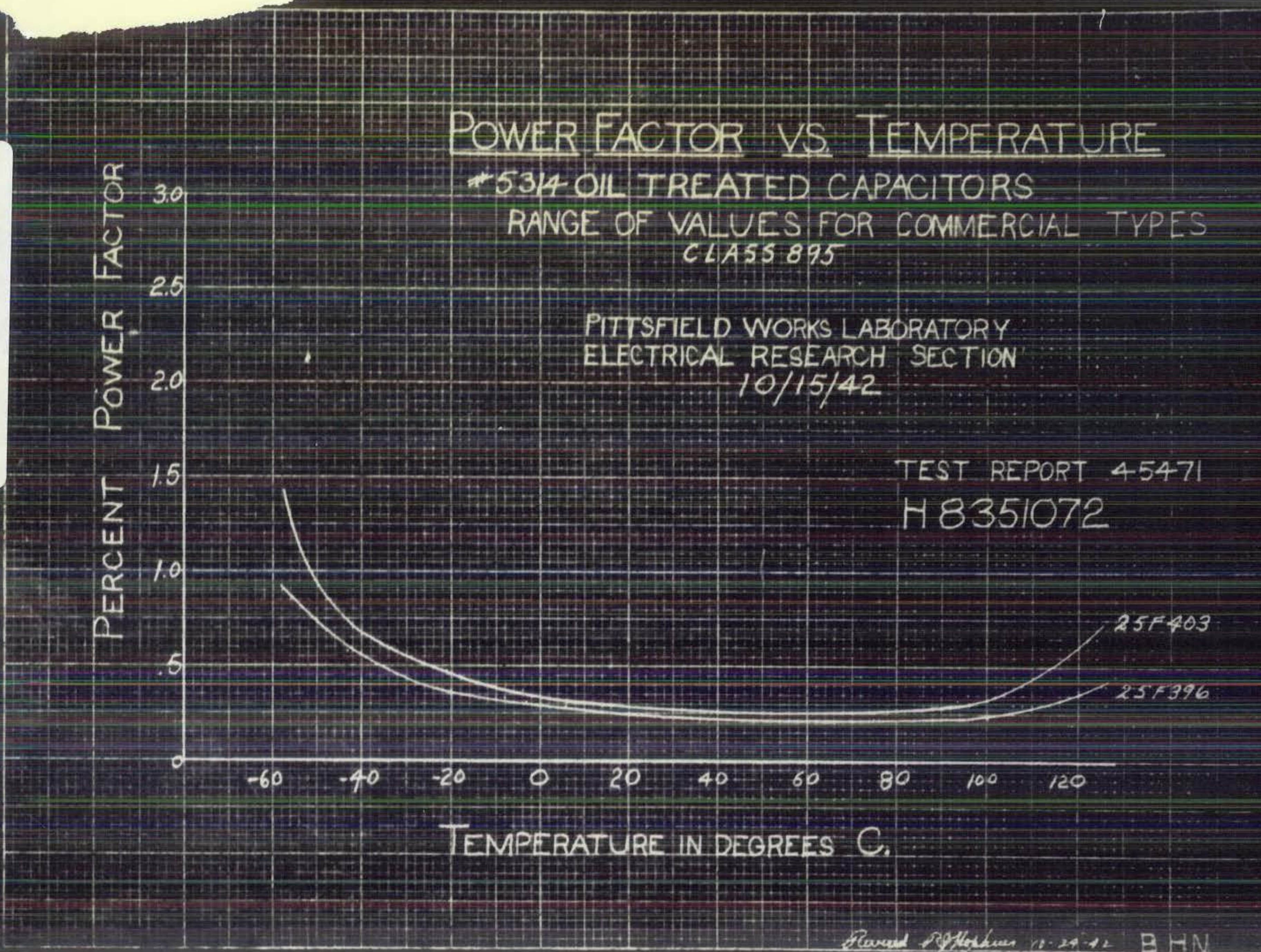



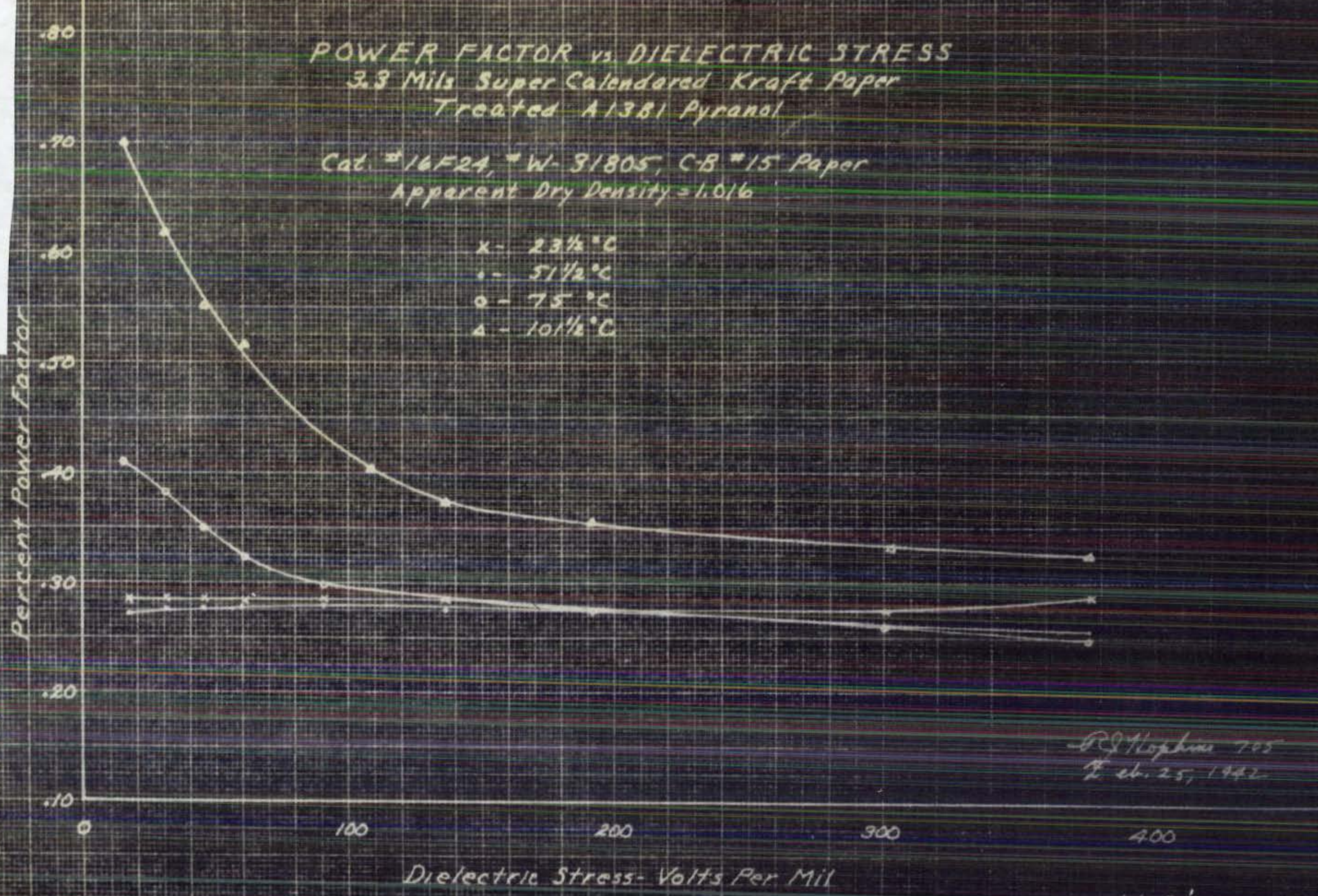




TEST REPORT 45471

H-8351069

Revised R.J. Hopkins 10-29-42
H.J. Endicott 10-10-42


POWER FACTOR VS. TEMPERATURE
#5314 OIL TREATED CAPACITORS
RANGE OF VALUES FOR COMMERCIAL TYPES
CLASS 895
PITTSFIELD WORKS LABORATORY
ELECTRICAL RESEARCH SECTION
10/15/42
TEST REPORT 45471
H 8351072
PERCENT POWER FACTOR
3.0
2.5
2.0
1.5
1.0
.5
0
-60
-40
-20
0
20
40
60
80
100
120
TEMPERATURE IN DEGREES C.
25F403
25F396
BHN




DECLASSIFIED

H-8321648

UNITED STATES DEPARTMENT OF COMMERCE
WASHINGTON

TS:AJB **National Bureau of Standards** IV-1/Tp 411-14/43

# REPORT

on
SPECTROCHEMICAL ANALYSIS
of
Twelve Samples of Radio Parts
Labelled as Shown in Table
Submitted by
United States Navy Department
Naval Research Laboratory
Anacostia Station

Date Submitted: December 26, 1942
Laboratory Nos: IV-1/ 4036-4047, Inclusive
Spectrogram Nos: W-763, W-765 and W-766
Region of Spectrum: 2400-5000 A.

The spectrograms were examined for the sensitive spectral lines of the elements as shown in the accompanying table. The qualitative scale used in reporting the relative amounts of the elements in the samples is as follows:

| Designation | Scale value | Designation | Scale value |
|---|---|---|---|
| VS | Very strong | VW | Very weak |
| S | Strong | T | Trace |
| M | Moderate | FT | Faint trace |
| W | Weak | – | Not detected |

In general, the designations VS and S correspond to major constituents (greater than 1%), M and W to minor constituents (1 to 0.01%), and VW, T, and FT to trace constituents (less than 0.01%).

The absence of a designation indicates that a test was not made for that element.

NBS Test No. IV-1/Tp 411-14/43
WASHINGTON, D. C.,
January 9, 1943

L J Briggs

Lyman J. Briggs, Director.

Inclosure.

NBS Form 81

U. S. GOVERNMENT PRINTING OFFICE 16—17900

NBS Test No. IV-1/Tp 411-14/43

TABLE OF RESULTS (1)

| Element | Sample 1 | 2 | 3 | 4 | 5 | Element | Sample 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ag | T | T | VW | T | – | Mo | VW | – | – | – | – |
| Al | W | VW | VW | W | VW | Na | | | | | |
| As | – | – | W | – | – | Nd | | | | | |
| Au | – | – | – | – | – | Ni | M | VW | M | VW | VS |
| B | VW | – | – | – | – | Os | – | – | – | – | – |
| Ba | T | T | – | T | – | P | – | – | – | M | |
| Be | – | – | – | – | – | Pb | S | M | S | VW | VW? |
| Bi | – | – | VW? | VW? | – | Pd | – | – | – | – | – |
| C | | | | | | Pr | | | | | |
| Ca | VW | VW | T | –? | T | Pt | – | – | – | – | – |
| Cb | | | | | | Ra | | | | | |
| Cd | VW | VW | – | – | – | Rb | | | | | |
| Ce | | | | | | Re | | | | | |
| Co | W | – | VW | – | M | Rh | – | – | – | – | – |
| Cr | T | T | – | T | FT | Ru | | | | | |
| Cs | | | | | | Sb | W | – | W | – | – |
| Cu | VS | VS | VS | VS | VW | Sc | – | – | – | – | – |
| Dy | | | | | | Si | W | VW | VW | VW | W |
| Er | | | | | | Sm | | | | | |
| Eu | | | | | | Sn | S | VW | S | S | – |
| Fe | W | W | S | M | W | Sr | – | – | – | – | – |
| Ga | – | –? | – | – | – | Ta | – | – | – | – | – |
| Gd | | | | | | Tb | | | | | |
| Ge | VW | VW | – | – | – | Te | | | | | |
| Hf | – | – | – | – | – | Th | – | – | – | – | – |
| Hg | –? | – | – | – | T | Ti | – | – | – | – | – |
| Ho | | | | | | Tl | – | – | – | – | – |
| In | – | – | – | – | – | Tm | | | | | |
| Ir | – | – | – | – | – | U | – | – | – | – | – |
| K | | | | | | V | – | – | – | – | – |
| La | | | | | | W | – | – | – | – | – |
| Li | | | | | | Y | – | – | – | – | – |
| Lu | | | | | | Yb | | | | | |
| Mg | VW | VW | T | VW | VW | Zn | VS | VS | VS | W | – |
| Mn | W | VW | VW | VW | M | Zr | – | – | – | – | – |

| No. | IV-1 Lab. No. | Label of Sample |
|---|---|---|
| 1 | 4036 | Handle Coating |
| 2 | " | " Base |
| 3 | 4037 | Metal top of Insulator |
| 4 | 4038 | Fuse Clip |
| 5 | 4039 | Internal Support |

BS Form 82

NBS Test No. IV-1/Tp 411-14/43

## TABLE OF RESULTS (2)

| Element | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 | Element | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ag | - | T | T | FT | VW | Mo | VS | VW | VW | - | - |
| Al | W | VS | W | VS | VS | Na | | | | | |
| As | - | - | - | - | - | Nd | | | | | |
| Au | - | - | - | - | - | Ni | W | VW | VW | VW | S |
| B | - | - | - | - | - | Os | - | - | - | - | - |
| Ba | - | T | - | - | - | P | | | | | |
| Be | - | - | - | - | - | Pb | VW | VW | -? | VW | W |
| Bi | - | - | - | - | - | Pd | - | - | - | - | - |
| C | | | | | | Pr | | | | | |
| Ca | VW | M | VW | T | T | Pt | - | - | - | - | - |
| Cb | | | | | | Ra | | | | | |
| Cd | - | - | - | - | - | Rb | | | | | |
| Ce | | | | | | Re | | | | | |
| Co | VW | -? | W | - | VW | Rh | - | - | - | - | - |
| Cr | VW | VW | W | FT | T | Ru | | | | | |
| Cs | | | | | | Sb | - | - | - | - | VW |
| Cu | T | W | W | S | S | Sc | - | - | - | - | - |
| Dy | | | | | | Si | W | M | S | M | S |
| Er | | | | | | Sm | | | | | |
| Eu | | | | | | Sn | - | W | W | VW | W |
| Fe | W | VS | VS | S | S | Sr | - | - | - | - | - |
| Ga | - | - | - | T | T | Ta | - | - | - | - | - |
| Gd | | | | | | Tb | | | | | |
| Ge | - | - | VW | - | - | Te | | | | | |
| Hf | - | - | - | - | - | Th | - | - | W | - | - |
| Hg | - | - | - | - | - | Ti | - | - | W | W | W |
| Ho | | | | | | Tl | - | - | - | - | - |
| In | - | - | - | - | - | Tm | | | | | |
| Ir | - | - | - | - | - | U | - | - | - | - | - |
| K | | | | | | V | - | - | VW | VW | VW |
| La | | | | | | W | - | - | - | - | - |
| Li | | | | | | Y | - | - | - | - | - |
| Lu | | | | | | Yb | | | | | |
| Mg | VW | VW | T | T | VW | Zn | - | VW | - | W | S |
| Mn | VW | VW | VW | W | W | Zr | - | - | W? | - | - |

| No. | IV-1 Lab. No. | Label of Sample |
|---|---|---|
| 1 | 4040 | Internal Shield |
| 2 | 4041 | Cathode Ray Shield Coating |
| 3 | " | " " " Base |
| 4 | 4042 | Back Panel of Transmitter |
| 5 | 4043 | Radiating Fin |

S Form 82

NBS Test No. IV-1/Tp 411-14/43

TABLE OF RESULTS (3)

| Element | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 |
|---|---|---|---|---|---|
| Ag | - | - | - | - | |
| Al | VW | VW | VW | - | |
| As | - | - | - | - | |
| Au | - | - | - | - | |
| B | W | - | - | - | |
| Ba | - | - | - | - | |
| Be | - | - | - | - | |
| Bi | - | - | - | - | |
| C | | | | | |
| Ca | T | T | T | T | |
| Cb | | | | | |
| Cd | - | - | - | VW | |
| Ce | | | | | |
| Co | - | - | W | - | |
| Cr | - | - | - | - | |
| Cs | | | | | |
| Cu | W | -? | -? | - | |
| Dy | | | | | |
| Er | | | | | |
| Eu | | | | | |
| Fe | VW | VW | VW | VW | |
| Ga | - | - | - | - | |
| Gd | | | | | |
| Ge | - | - | - | - | |
| Hf | - | - | - | - | |
| Hg | - | - | - | - | |
| Ho | | | | | |
| In | - | - | - | - | |
| Ir | - | - | - | - | |
| K | | | | | |
| La | | | | | |
| Li | | | | | |
| Lu | | | | | |
| Mg | T | T | T | T | |
| Mn | VW | VW | VW | VW? | |

| Element | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 |
|---|---|---|---|---|---|
| Mo | - | VS | VS | - | |
| Na | | | | | |
| Nd | | | | | |
| Ni | VW | - | - | - | |
| Os | - | - | - | - | |
| P | | | | | |
| Pb | - | VW | VW | - | |
| Pd | - | - | - | - | |
| Pr | | | | | |
| Pt | - | - | - | - | |
| Ra | | | | | |
| Rb | | | | | |
| Re | | | | | |
| Rh | - | - | - | - | |
| Ru | | | | | |
| Sb | - | - | - | - | |
| Sc | - | - | - | - | |
| Si | M | W | W | W | |
| Sm | | | | | |
| Sn | - | - | - | - | |
| Sr | - | - | - | - | |
| Ta | - | - | - | - | |
| Tb | | | | | |
| Te | | | | | |
| Th | - | - | - | S | |
| Ti | - | - | - | - | |
| Tl | - | - | - | - | |
| Tm | | | | | |
| U | - | - | - | - | |
| V | - | - | - | - | |
| W | VS | - | - | VS | |
| Y | - | - | - | - | |
| Yb | | | | | |
| Zn | - | - | - | - | |
| Zr | - | - | - | - | |

| No. | IV-1 Lab. No. | Label of Sample |
|---|---|---|
| 1 | 4044 | Lead Wire |
| 2 | 4045 | Grid Screen |
| 3 | 4046 | Grid Wire |
| 4 | 4047 | Filament Wire |
| 5 | | |

(Copy) Appendix III

Issued by the Intelligence Division

Office of Chief of Naval Operations

Navy Department

F-2 0516 INTELLIGENCE REPORT

Serial #52 Monograph Index Guide No. 701-700

From Op-16-FE ONI at Washington, D.C. Date April 26 1943.

Reference 9300

Source Captured Japanese Documents Evaluation

Subject Japan Communications Radar

## Japanese Radar

Enclosures A and B are translations of two captured Japanese documents on radar equipment.

The original Japanese document of Enclosure A is a 57-page mimeographed pamphlet on the cover of which is a notation in ink which suggests that it was prepared by the Electric Research Department of the Japanese Naval Technical Research Laboratory and was intended as a manual for the use of Japanese radar personnel. The original Japanese document of Enclosure B is 17 pages of pencil notes which appear to have been a note book kept by a Japanese radar technician. From the organization of the material, its division into sections, sub-section etc., it is possible that the technician merely copied this information from a radar manuel. The material of Enclosure A was found on Guadalcanal and was descriptive of the Japanese radar installation captured there and subsequently shipped to the Naval Research Laboratory. The two documents, however, described different types of radar equipment. The alternating current for the equipment mentioned in Enclosure A is given as 220 volts, while the alternating current described in the pencil notes of Enclosure B is 100-110 volts. It is possible, therefore, that the radar described in Enclosure B was designed for shipboard rather than shore use.

| | | |
|---|---|---|
| Op-20-G (2) | Cominch | List I - b, d, e, |
| Bur. Ships (3) | Archives | List II - y |
| Bur. Air (3) | Monograph | |
| Bur Ord | MIS (5) | |
| NRL (3) | AUS JSM (2) | |
| SONRD | NZ JSM (2) | |
| Op-16-FA (8) | | |

[redacted]

This possibility is further strengthened by a brief note in ink on a single sheet of paper which accompanied the pencil notes composing Enclosure B. The type of stationery is identical and both the pencil notes and the brief ink notation are in the same handwriting. A translation of the ink notation, which is incomplete, is as follows:

"May 12, 1942. Report of Repairs and Adjustments of Mechanical Troubles on the KINUGASA. No. 2 squad.

1. Relay for automatic voltage adjustment in the rectifier for use with the transmitter ....."

The equipment mentioned is identical with apparatus described in the pencil notes on radar, and suggests that the technician who wrote these notes had been ordered in May, 1942, to repair and adjust radar equipment on the KUNUGASA, a heavy cruiser which was later sunk off Savo Island in October, 1942.

The original Japanese document of Enclosure B was written in very poor handwriting and, in addition to the extremely technical language employed, presented difficult problems from the standpoint of translation.