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REPORT NO. R-2398:

DATE NOVEMBER 8, 1944:

FR-2398

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Date: 25 AUG 2011
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SUBJECT

REPORT ON

THE DEVELOPMENT OF A MAGNETRON TRANSMITTER

FOR JAMMING IN THE RANGE OF 80 to 380 MEGACYCLES:

[redacted]

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8 November 1944

NRL Report No. R-2398
Problem No. S 195 R-S

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NAVY DEPARTMENT

Report on

The Development of a Magnetron Transmitter for Jamming in the Range of 80 to 380 Megacycles

Naval Research Laboratory
Washington, D. C.

No. of Pages: 27 Text: 7 Plates: 20

Authorization: BuShips ltr. S-S67-5(924-6), S-920-5109 to Dir., NRL dated 2 July 1943.

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A. H. Taylor, Supt., Radio Division

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A. H. VanKeuren, Rear Admiral, USN, Director,

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Illustrations

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1.0 Abstract:

1.1 The development of the equipment described in this report was undertaken as one of the steps to provide countermeasures equipment covering a frequency range from 80 to 1000 megacycles. This transmitter covers the portion of that range between 80 and 380 megacycles with a nominal output of 150 watts. Random noise modulation of the carrier is used to provide the jamming signal. The transmitter is similar to the Model TDY equipment developed by Radio Research Laboratory and General Electric Company for the range of 350 to 800 megacycles.

2.0 Introduction:

2.1 The transmitter uses a type ZP590 or a type ZP599 water-cooled magnetron tube as an oscillation generator. These tubes have split anodes and make use of a fixed magnetic field applied externally to obtain a negative resistance characteristic. The tubes are the same size and similar in construction with the exception that the ZP599 has a larger filament. The transmitter was originally built around the ZP590 tube and the transmitter requirements were made to correspond with the capabilities of this tube. When the ZP599 tube became available, it was substituted for the ZP590. Due to its larger filament, the ZP599 is capable of producing more power and also has less tendency to oscillate in a double mode than the ZP590. Power supply limitations in the present equipment limit the power output to that obtainable from the ZP590. The tube is an experimental type and the principal objectives of the transmitter development were to determine its frequency range and output capability and its performance characteristics when modulated with random noise voltage.

3.0 Description:

3.1 The equipment is made up of an oscillator unit, a modulator unit and a high voltage power supply unit, each housed in a separate cabinet. Photographs of the three units are shown in Plates 10 & 11. The units are interconnected by separate high voltage and low voltage cables. Interlocks are provided to prevent danger to operators if cabinet doors are opened. A power line input of 115 volts, 60 cycles, 2000 watts is required.

3.2 The oscillator is contained in a standard relay rack cabinet 65 inches high 21-1/2 inches wide and 15 inches deep. The weight is 256 pounds. In addition to the magnetron tube and tuning lines, the unit contains a detector circuit for observation of modulation on a cathode ray oscilloscope. An enclosed water cooling system with heat exchanger is located in this cabinet. A control inside the cabinet is provided for adjusting the rate of flow. Front panel controls include oscillator tuning, output coupling and magnetron filament current. Photographs of the oscillator are shown in Plates 12 & 13.

3.3 The modulator is contained in a relay rack cabinet 28 inches high, 21-1/2 inches wide and 15 inches deep. The weight is 165 pounds. This unit includes the noise generator-modulator chassis and a rectifier chassis to supply voltage for the low power stages. Front panel controls are provided for adjusting noise voltage amplitude, for selecting half-wave or full

[redacted]

wave modulation, for varying modulation bandwidth, and for selecting C.W. or M.C.W. operation. Photographs of the modulator unit are shown in Plates 14 to 18.

3.4 The high voltage power supply is contained in a cabinet of the same dimensions as the modulator. The weight is 248 pounds. The unit includes the rectifier supplying the plate voltage for the oscillator and modulator and the relays for power control. Front panel controls include power switch, plate voltage switch and plate voltage amplitude control. Photographs of the power supply unit are shown in Plates 19 & 20.

4.0 <u>Analysis of Circuit Operations:</u>

4.1 The ZP590 tube has a split anode which is connected to a variable quarter wave transmission line. This line determines the frequency of oscillation since the tube operates as a negative resistance magnetron. The tube is loaded by a variable tap on one of the lines. The two transmission lines are each hollow concentric tubes, water passing through the two inner conductors up to the anode and returning through the outer conductors. Water enters and leaves the lines at zero potential R.F. points. A schematic diagram of the oscillator is shown in Plate 1.

4.2 The source of modulation for the magnetron is a 931 photo tube which generates noise when light is focused on it. The noise output can be controlled by varying the light intensity. The signal passes through several stages of high frequency compensated amplifiers to the final modulator tubes. In the amplifier are four Pi section filters, selection of which cuts off the noise spectrum at 1.5 Mc., 2.0 Mc., 3.0 Mc. or 4.4 Mc. For full-wave modulation, two 813's are connected in parallel, and the pair are connected in series with the magnetron. For half-wave modulation, four 813's are connected in parallel except for their grids. One pair has the grids grounded and comprises the c.w. operating current control. The other pair is fixed biased to cut-off and is driven by the noise amplifier. Because the magnetron transmission line shorting bar must be grounded, it is necessary to apply the modulation between the filament of the ZP-599 and ground. Thus a low capacity filament transformer is required to minimize loss of high frequencies. A schematic diagram of the modulator is shown in Plate 2.

4.3 The power supply is a conventional bridge rectifier using four 836 tubes. However, unlike conventional supplies, it has a floating ground point. High voltage negative is connected to the filament of the ZP599 and high voltage positive is connected to the plates of the 813's. Since the cathodes of the 813's are connected to ground (through a bias resistor) and the magnetron transmission line shorting bar is grounded, the ground point of the power supply depends on the division of voltage between the modulator and the magnetron. A schematic diagram of the power supply is shown in Plate 3.

5.0 <u>Testing Methods:</u>

5.1 Power output of the unit was measured by use of a water-cooled resistance load. Frequency of operation was determined both by an absorption wavemeter and a heterodyne frequency meter. The waveform of the R.F. signal was observed on a high frequency cathode ray oscilloscope.

5.2 The modulator was tested by measuring power output by use of an R.F. ammeter and a non-inductive resistor. Frequency response was determined by use of a video frequency signal generator and vacuum tube voltmeter. When used with the oscillator, modulation was observed on an oscillograph using a detected R.F. signal. Modulation bandwidth was checked by measuring the output of a receiver as the receiver was tuned through the spectrum.

6.0 Results Obtained:

6.1 A power-frequency curve is shown on Plate 4, power, voltage and efficiency vs. current curves are shown on Plate 5, and spectrum curves are shown on Plates 6, 7, 8, and 9.

6.2 The drop in power output at low frequencies is due to the fact that the oscillator could not be loaded heavily without causing the frequency to jump to a value for which the transmission lines were 3/4 wave in length rather than 1/4 wave in length.

6.3 From the voltage-current curve it may be observed that 100% modulation is not possible with magnetrons, since there is a minimum voltage and current at which oscillation is stable. If modulation which extends into this region is attempted, the oscillator will be unstable, since it will break into and out of oscillation whenever the video signal drives the oscillator into this region.

6.4 The spectrum analysis was taken with a ZP599 tube. Part of the reason for the poor frequency response is due to the large capacity in the plate circuit of the modulator tubes. Besides having four tubes in parallel, there is the capacity of two filament transformers across the modulator. Two filament transformers were necessary because of the large filament in the ZP599 tube.

6.5 A difficulty yet to be overcome in the operation of magnetrons is the tendency to oscillate at more than one frequency, especially at a frequency for which the transmission lines become three-quarters wave in length. For the ZP590 tube this is particularly troublesome at frequencies below 150 mc., where the Q of the lines is higher for the 3/4 wave length mode than for the 1/4 wave length mode. It was found that the tendency for double moding depended on amplitude of filament current, polarity of filament current (in some cases where DC was used on the filament), degree of loading, and character of the load (resistive, inductive, or capacitive.). If the filament current was reduced much below 35 amperes, the tendency for double moding was pronounced. Under some conditions of loading, 1/4 wave oscillation occurred with D.C. of one polarity on the filament, and both 1/4 wave and 3/4 wave oscillations occurred with the opposite polarity on the filament. With alternating current on the filament, this effect produced only 1/4 wave on one half of the cycle, and both 1/4 wave and 3/4 wave oscillations on the other half of the cycle. With other conditions of loading it was possible to

 [redacted]

produce both 1/4 and 3/4 wave oscillations on both halves of the cycle, 1/4 wave alone on both halves of the cycle, or predominantly 3/4 wave on both halves of the cycle. With the ZP599 tube this double moding effect was not noticed, and it is believed that this is due to the large filament power of this tube (3 to 4 times that of the ZP590). It was found that the tightness of coupling to the load was an important factor in determining mode of oscillation, loose coupling being favorable to 1/4 wave oscillation. It was found that adding a small capacitance (20-30 uuf) across the transmission lines near the tube almost completely eliminated the 3/4 wave mode, as well as decreasing the length of line required for a given frequency. Frequencies above 300 mc. could not be obtained with this capacitor in the circuit.

6.6 It was observed that the magnetron tubes used have a very short life, the operating period not exceeding 8 hours for any tube. This was due not to loss of filament emission but rather to electronic bombardment of the elements resulting in fracture of the seals. It has not been possible to take a complete set of measurements on a single tube type because of the difficulty in procurement and the short life. For this reason, the "power runs" shown in the curves are for the ZP590 tube and the modulation characteristics are for the ZP599.

7.0 Conclusions:

7.1 The tube is limited in its operation at the lower frequencies by the double oscillation mode present with the resonant line used for frequency control. For frequencies below 150 megacycles a capacitor with the transmission line or a coil and capacitor arrangement for tuning is recommended.

7.2 Due to the voltage characteristic of the magnetron, a high percentage of modulation without distortion is not achieved. For countermeasure use with noise modulation, this factor need not be considered. The results obtained are therefore satisfactory.

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NRL Report No. R-2398

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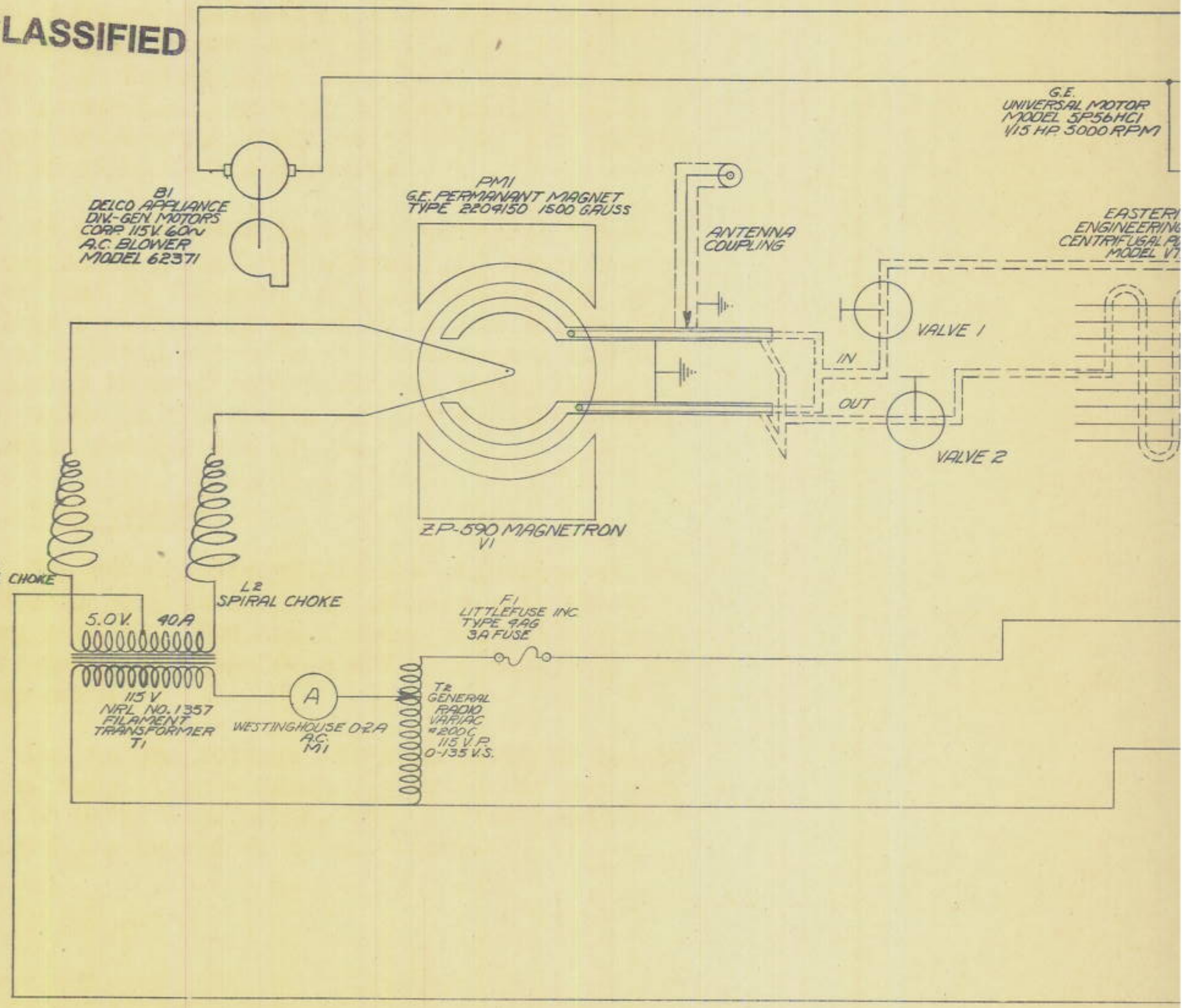
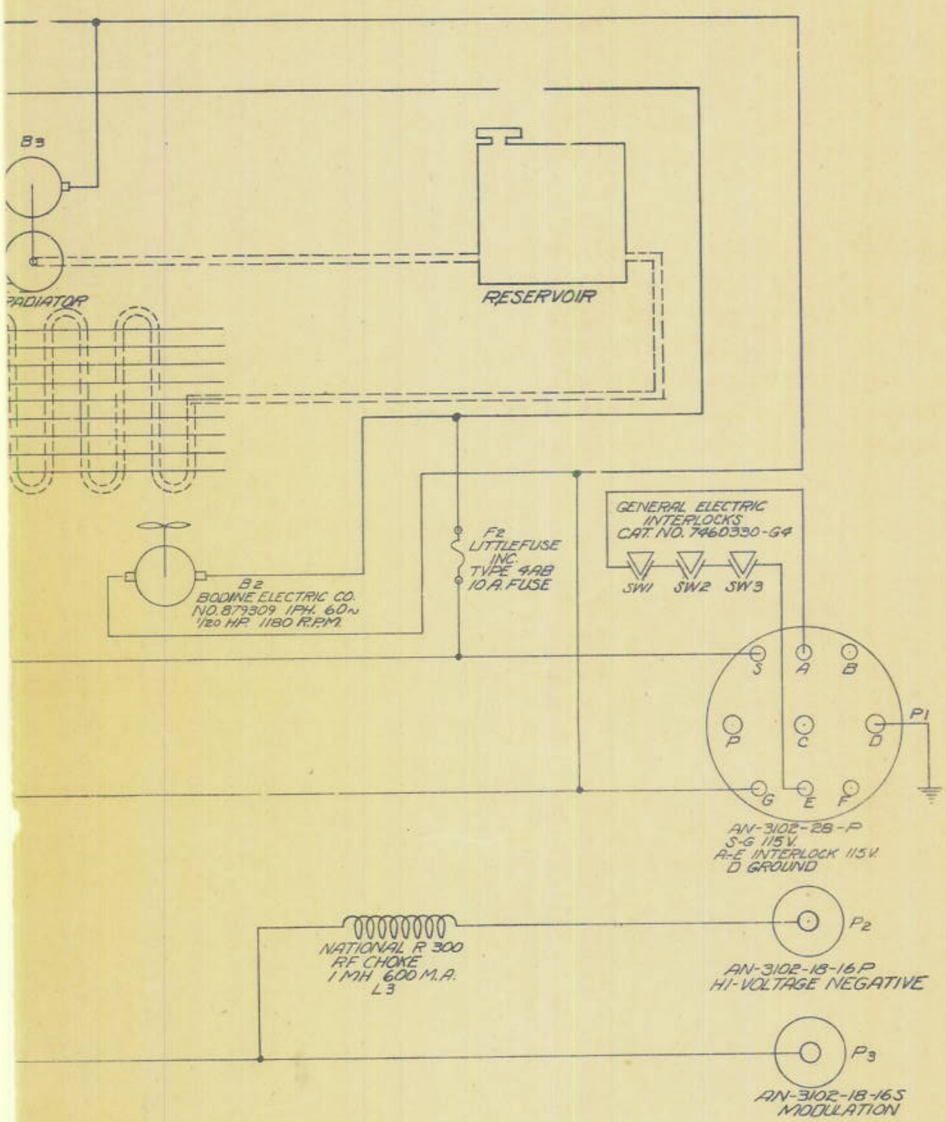

G.E.
UNIVERSAL MOTOR
MODEL 5P56HC1
1/15 HP. 3000 RPM
B1
DELCO APPLIANCE
DIV.-GEN. MOTORS
CORP. 115V. 60~
A.C. BLOWER
MODEL 62371
PM1
G.E. PERMANANT MAGNET
TYPE 2204150 1500 GAUSS
ANTENNA
COUPLING
VALVE 1
IN
OUT
VALVE 2
ZP-590 MAGNETRON
V1
L1
SPIRAL CHOKE
L2
SPIRAL CHOKE
5.0 V. 40 A
115 V
NRL NO. 1357
FILAMENT
TRANSFORMER
T1
A
WESTINGHOUSE 0-2A
A.C.
M1
F1
LITTLEFUSE INC.
TYPE 4AG
3A FUSE
T2
GENERAL
RADIO
VARIAC
#200C
115 V.P.
0-135 V.S.



ALTERATION TABLE	
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SECRET

SYMBOLS AND THEIR EQUIV. TOLERANCES (UNLESS OTHERWISE NOTED)

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

		IN CHARGE OF RADIO DRAFTING	CHIEF DRAFTSMAN
DELINEATOR	B.T. SMITH	CRS.	[signature]
TRACER			
CHECKER			

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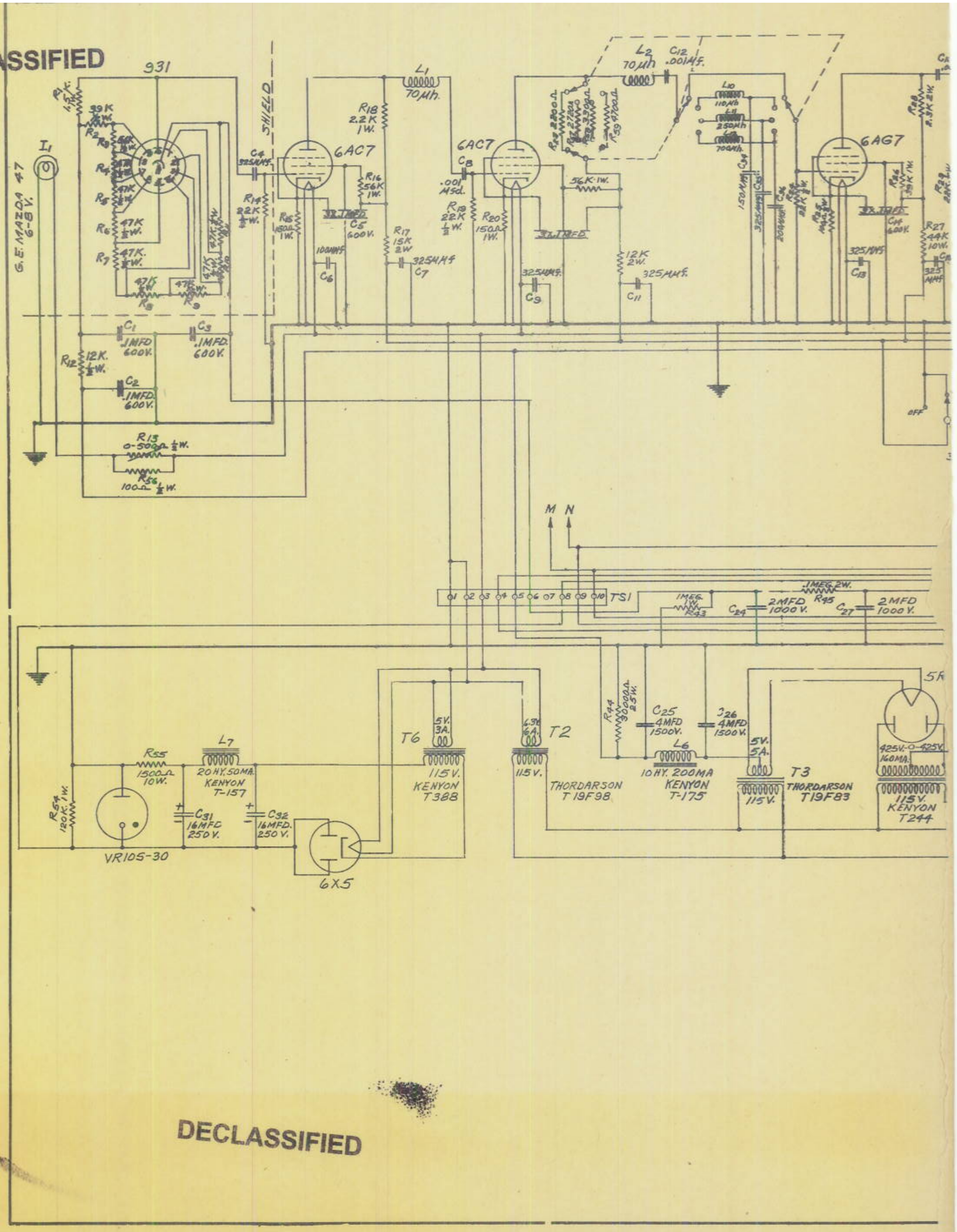
"BELLEVUE," ANACOSTIA, D. C.

ZP 590 MAGNETRON TRANSMITTER
OSCILLATOR UNIT
SCHEMATIC

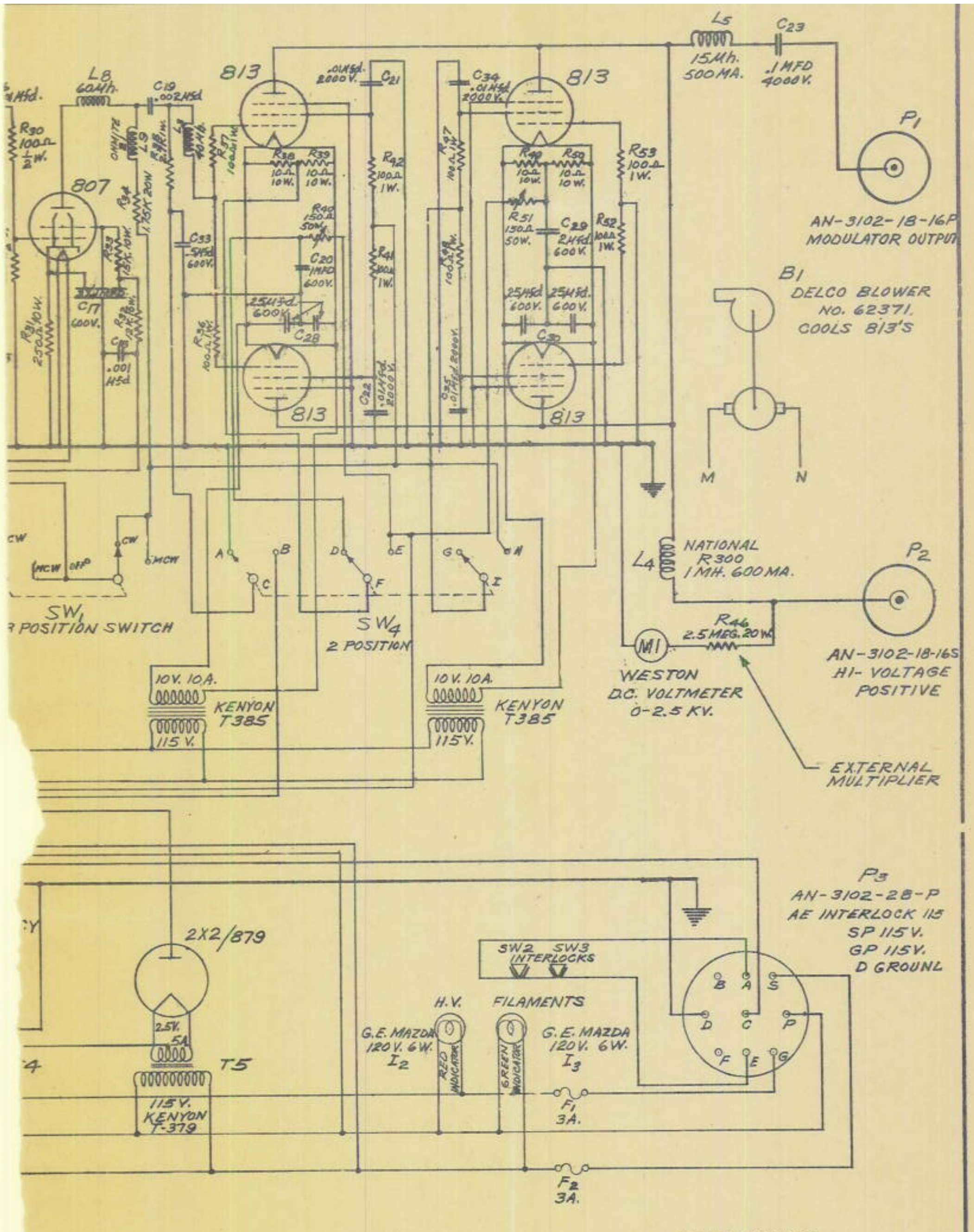
SCALE DATE

PLATE I

RA 35F 267B



931
SHIELD
6AC7
6AC7
6AG7
G.E. MAZDA 47 6-8V.
I_1
L1 70μh.
L2 70μh
C12 .001MF.
R18 2.2K 1W.
R16 56K 1W.
C4 325MMF.
R14 22K ½W.
R15 150Ω 1W.
C5 600V.
C6
R17 15K 2W
C7 325MMF
C8 .001 Mfd.
R19 22K ½W.
R20 150Ω 1W.
56K 1W.
C9 325MMF.
12K 2W.
C11 325MMF.
C13 325MMF
C14
R27 44K 10W.
C1 .1MFD 600V.
C2 .1MFD 600V.
C3 .1MFD 600V.
R12 12K ½W.
R13 0-500Ω ½W.
R56 100Ω ½W.
M
N
TS1
R43 1MEG. 1W.
R45 1MEG. 2W.
C24 2MFD 1000V.
C27 2MFD 1000V.
R44 3000Ω 25W.
C25 4MFD 1500V.
C26 4MFD 1500V.
L6 10HY. 200MA KENYON T-175
T6 5V. 3A. 115V. KENYON T388
T2 6.3V 6A. 115V. THORDARSON T19F98
T3 5V. 5A. 115V. THORDARSON T19F83
425V. 425V. 160MA. 115V. KENYON T244
R55 1500Ω 10W.
L7 20HY. 50MA. KENYON T-157
C31 16MFD 250V.
C32 16MFD. 250V.
R54 120K 1W.
VR105-30
6X5
OFF



ALTERATION TABLE

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SYMBOLS AND THEIR EQUIVALENT TOLERANCES (UNLESS OTHERWISE NOTED)

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

PLATE 2

REFERENCE DRAWINGS

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ZP590 MAGNETRON TRANSMITTER
MODULATOR UNIT
SCHEMATIC

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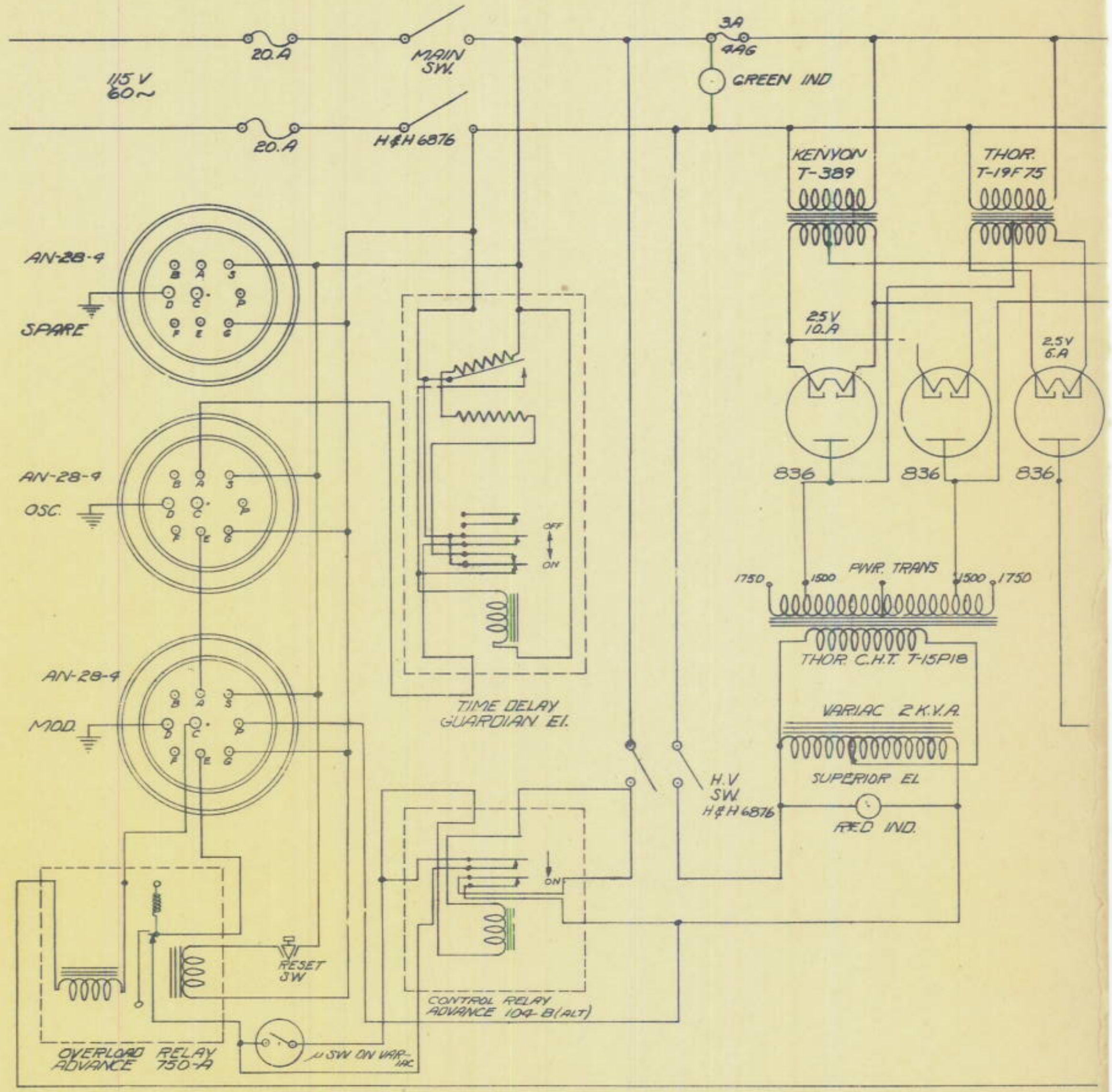

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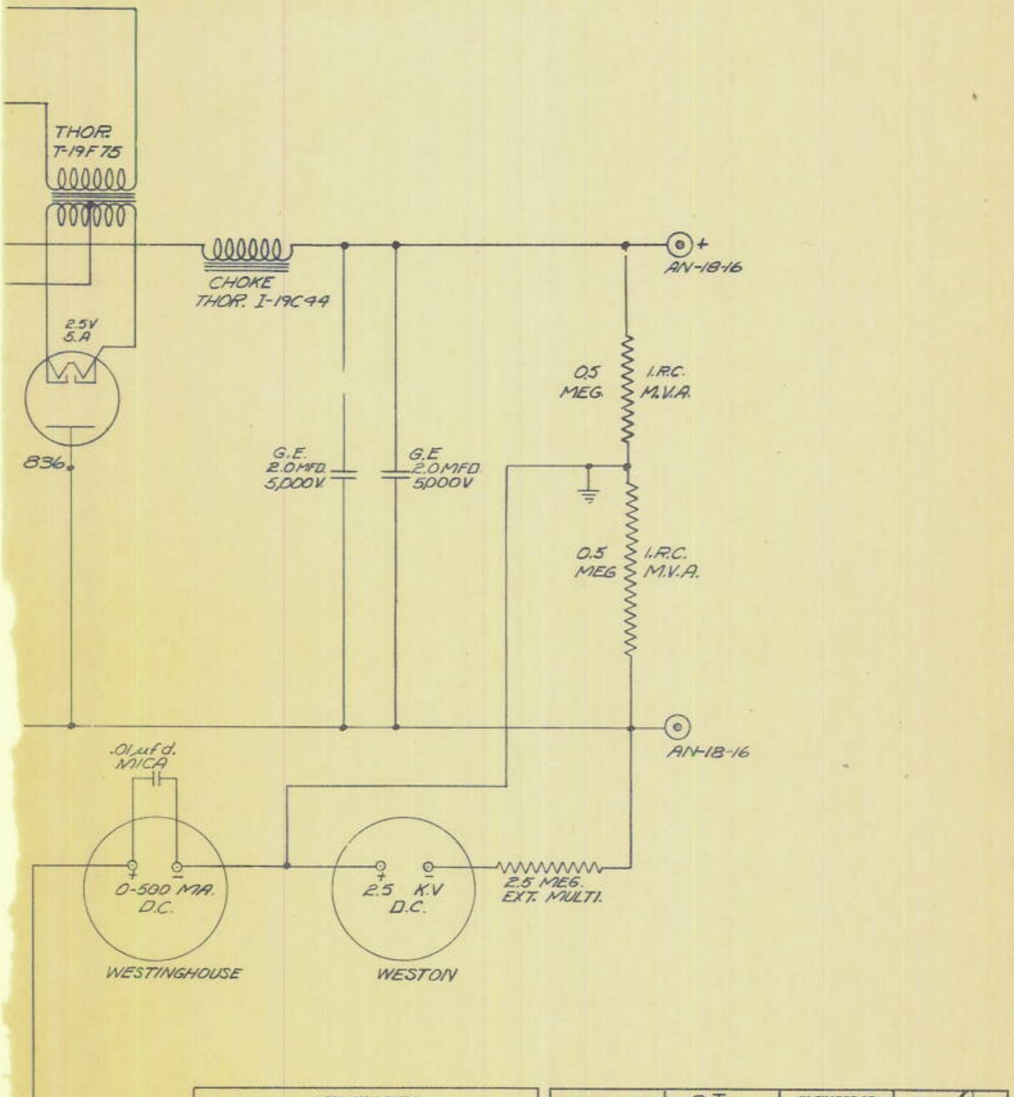

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"BELLEVUE," ANACOSTIA, D. C.

ZP 590 MAGNETRON TRANSMITTER
POWER SUPPLY
SCHEMATIC

SCALE DATE

SYMBOLS AND THEIR EQUIV. TOLERANCES (UNLESS OTHERWISE NOTED)

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

PLATE 3

RA 20F 259B

ZP- 590 MAGNETRON TRANSMITTER: MAGNETRON FILAMENT CURRENT = 37 AMP.
MODULATOR VOLTAGE = 1000 VOLTS. PLATE CURRENT = 300 MA.

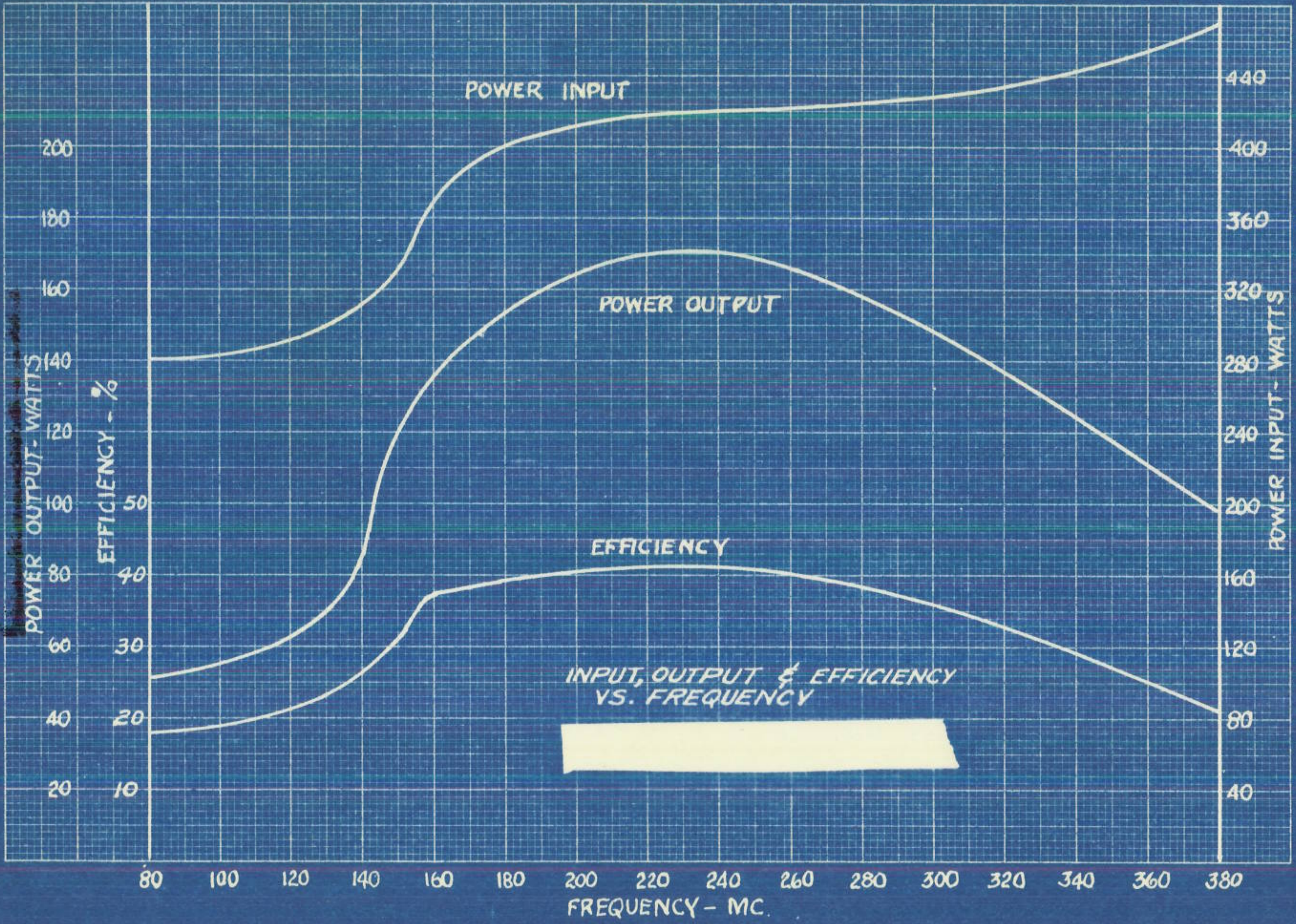

PLATE 4

ZP-590 MAGNETRON TRANSMITTER: MAGNETRON FILAMENT CURRENT = 39 AMP.
FREQUENCY = 229 MC.

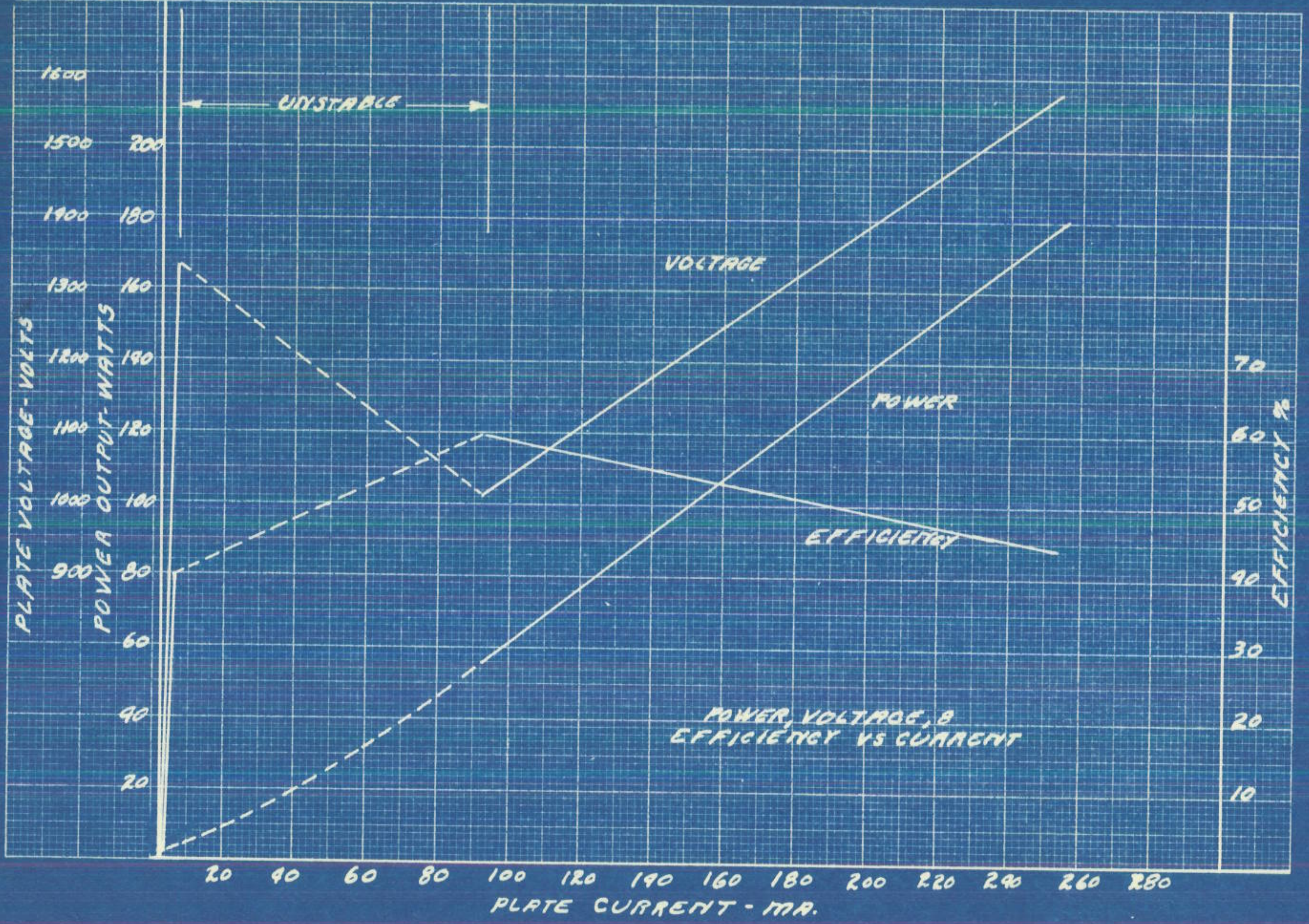

PLATE 5

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Z-P-590 MAGNETRON TRANSMITTER: USING Z P-599 TUBE, FILAMENT CURRENT = 37 AMP. IP = 300 MA. FREQUENCY = 237 MC. MODULATOR VOLTAGE = 1000 V.

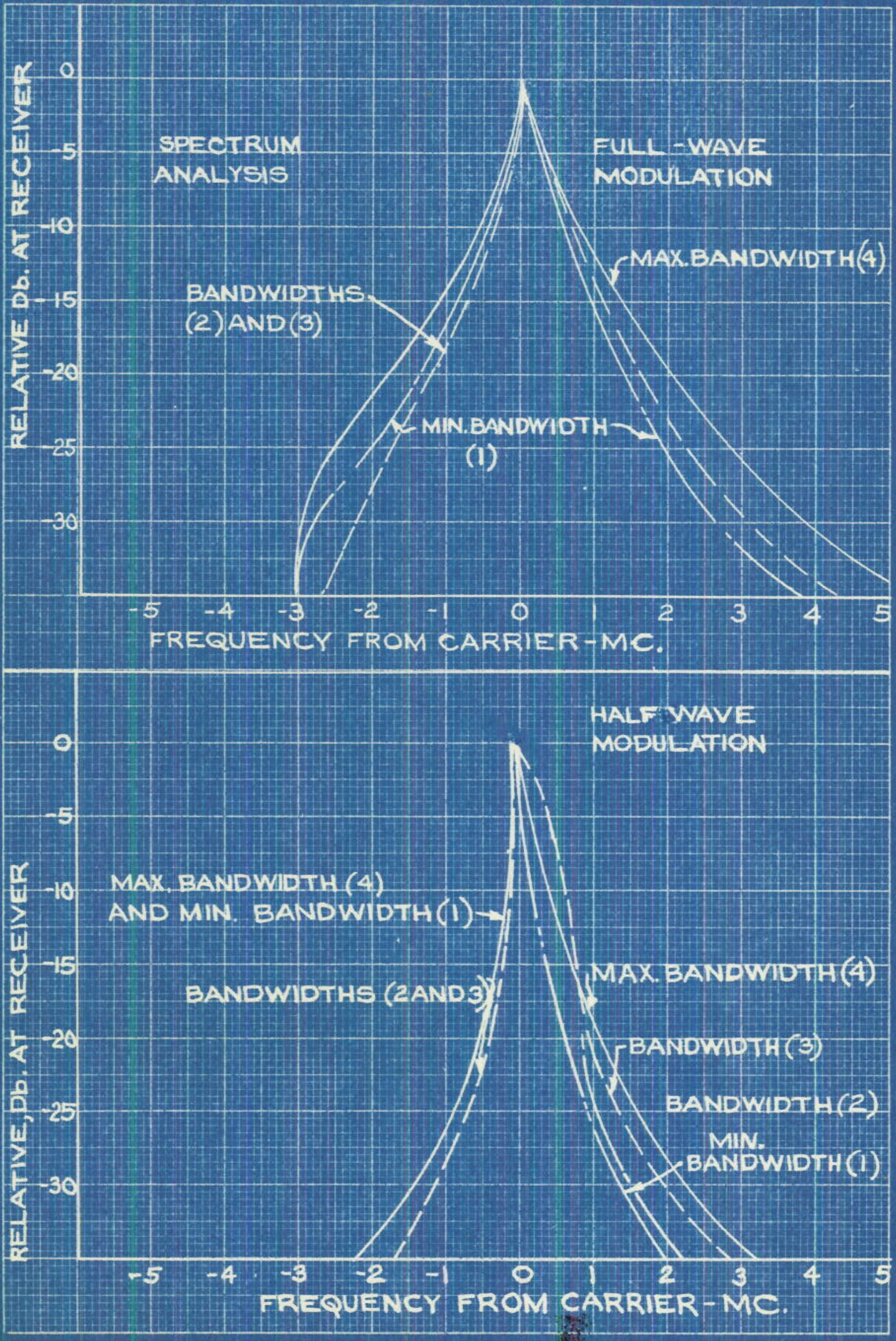


PLATE 6

ZP-590 MAGNETRON TRANSMITTER: USING ZP-599 TUBE, FILAMENT CURRENT = 37 AMP. Ip. 300 MA. FREQUENCY = 184 MC. MODULATOR VOLTAGE = 1000 VOLTS.

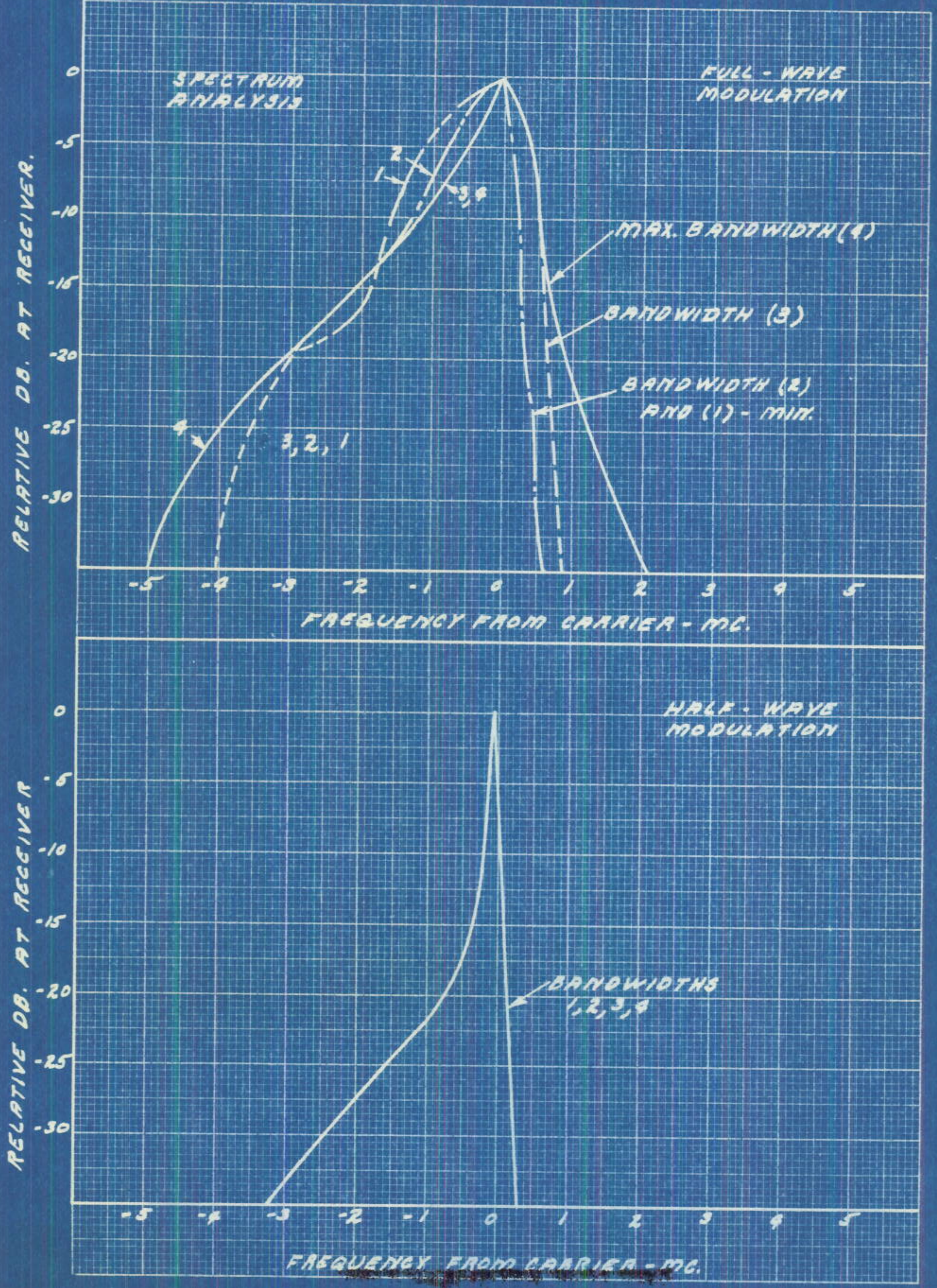
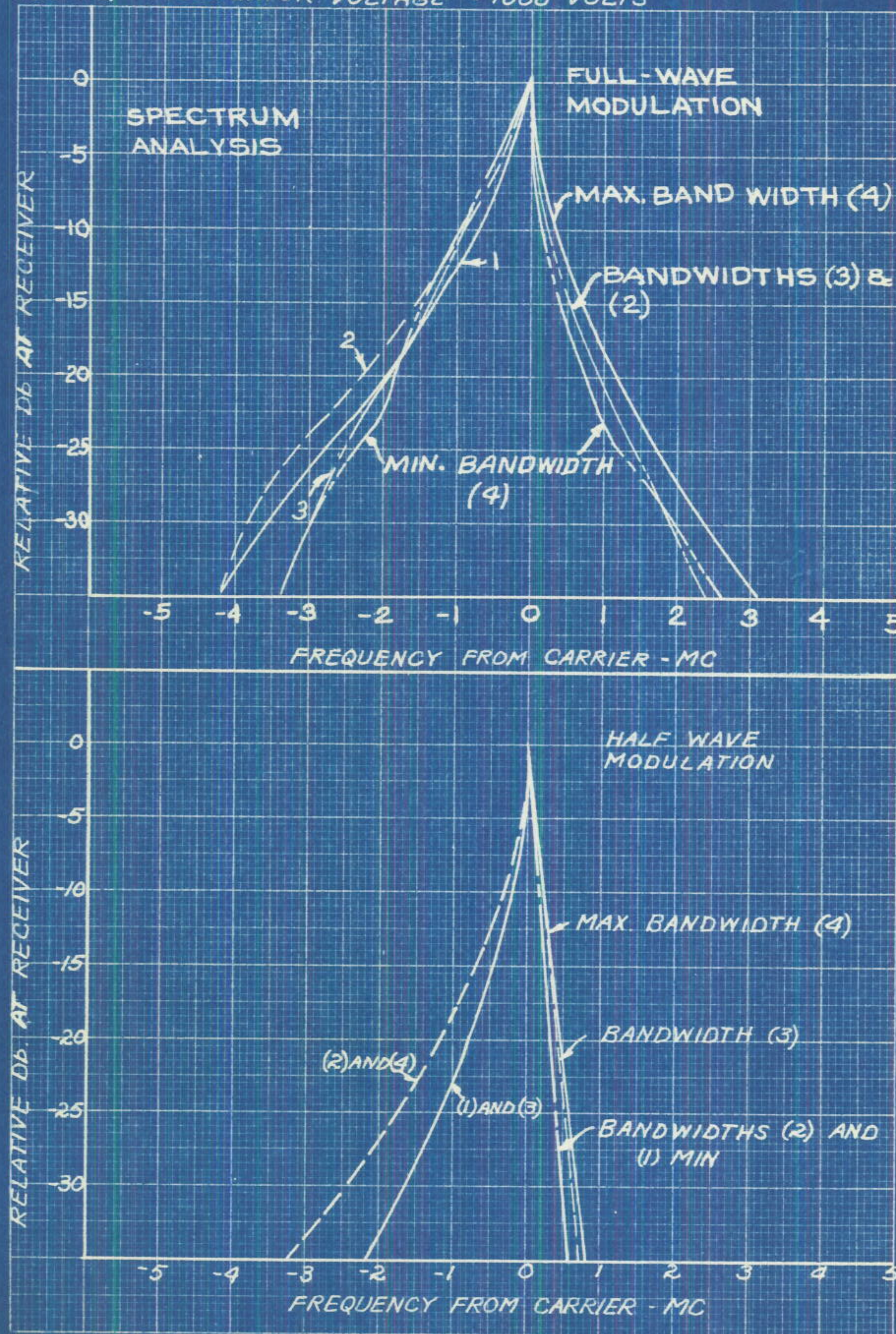


PLATE 7.

ZP-590 MAGNETRON TRANSMITTER: USING ZP-599 TUBE
FILAMENT CURRENT = 37 AMP. IP = 300 ma. FREQUENCY = 133 mc. MODULATOR VOLTAGE = 1000 VOLTS



[redacted]

PLATE 8

ZP-590 MAGNETRON TRANSMITTER: USING ZP-599 TUBE
FILAMENT CURRENT = 37 AMP. I_p = 300 MA. FREQUENCY = 78.5 MC. MODULATOR VOLTAGE = 1000 VOLTS

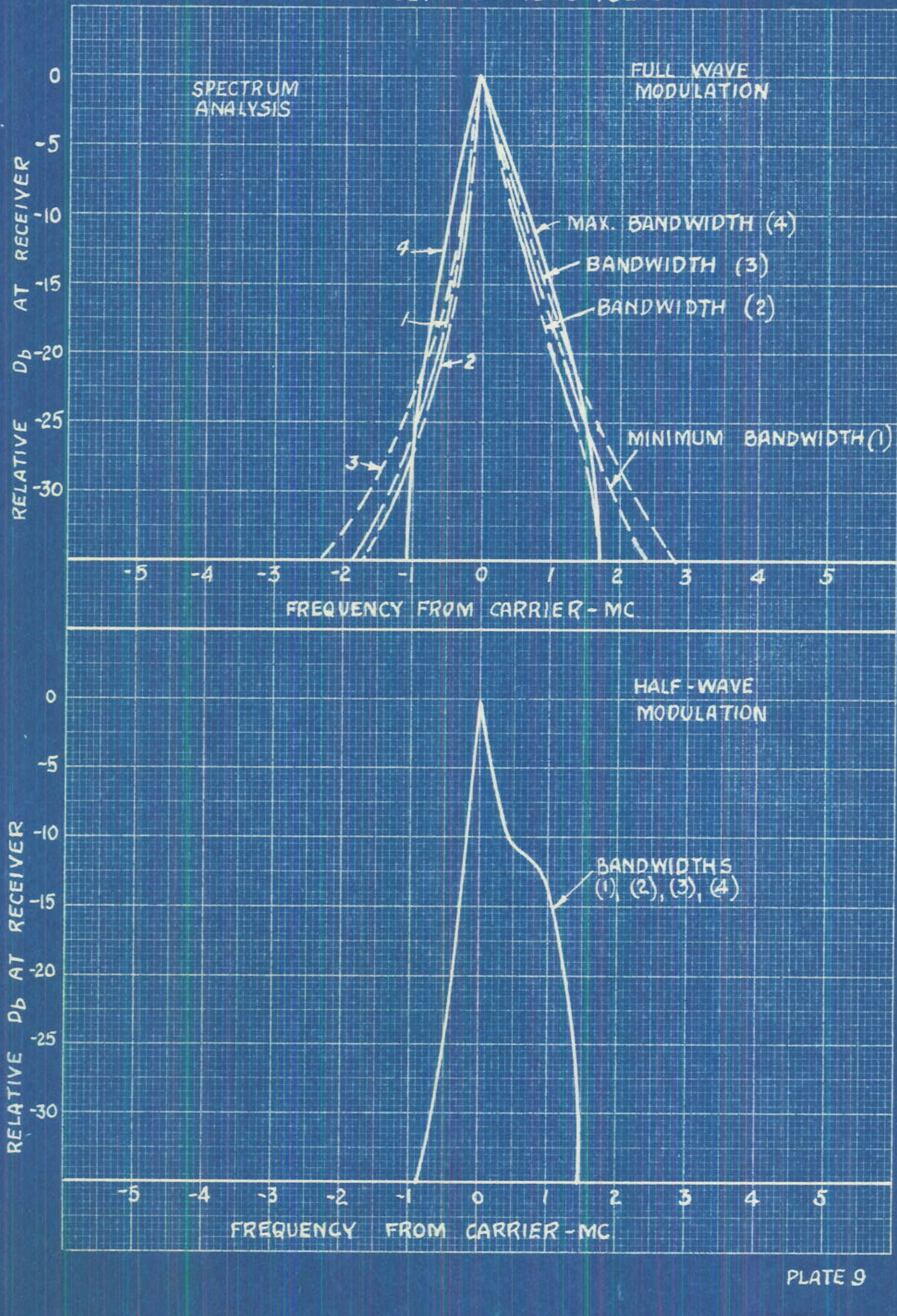


PLATE 9

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THREE UNITS - OBLIZUE VIEW

PLATE 10

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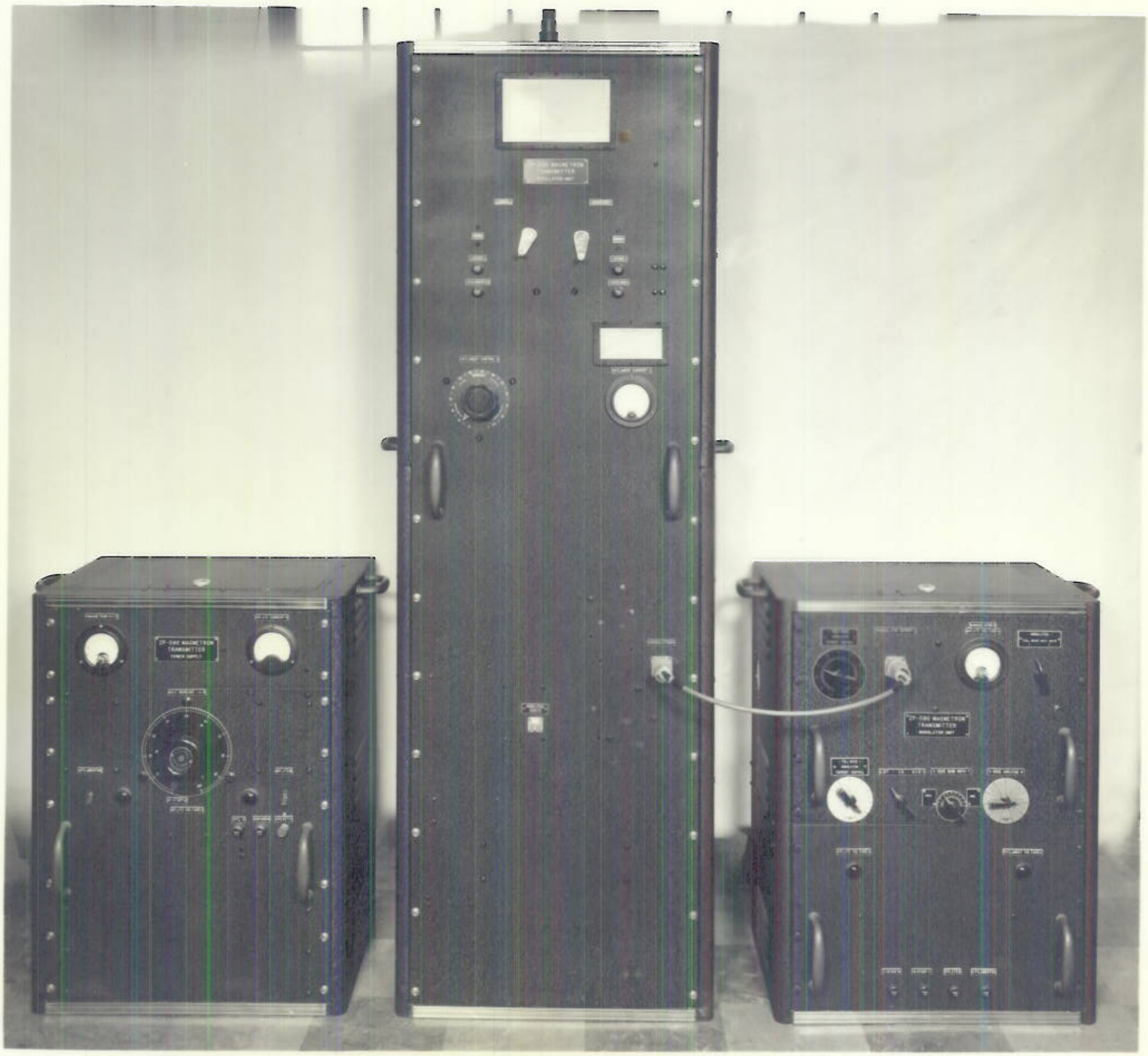

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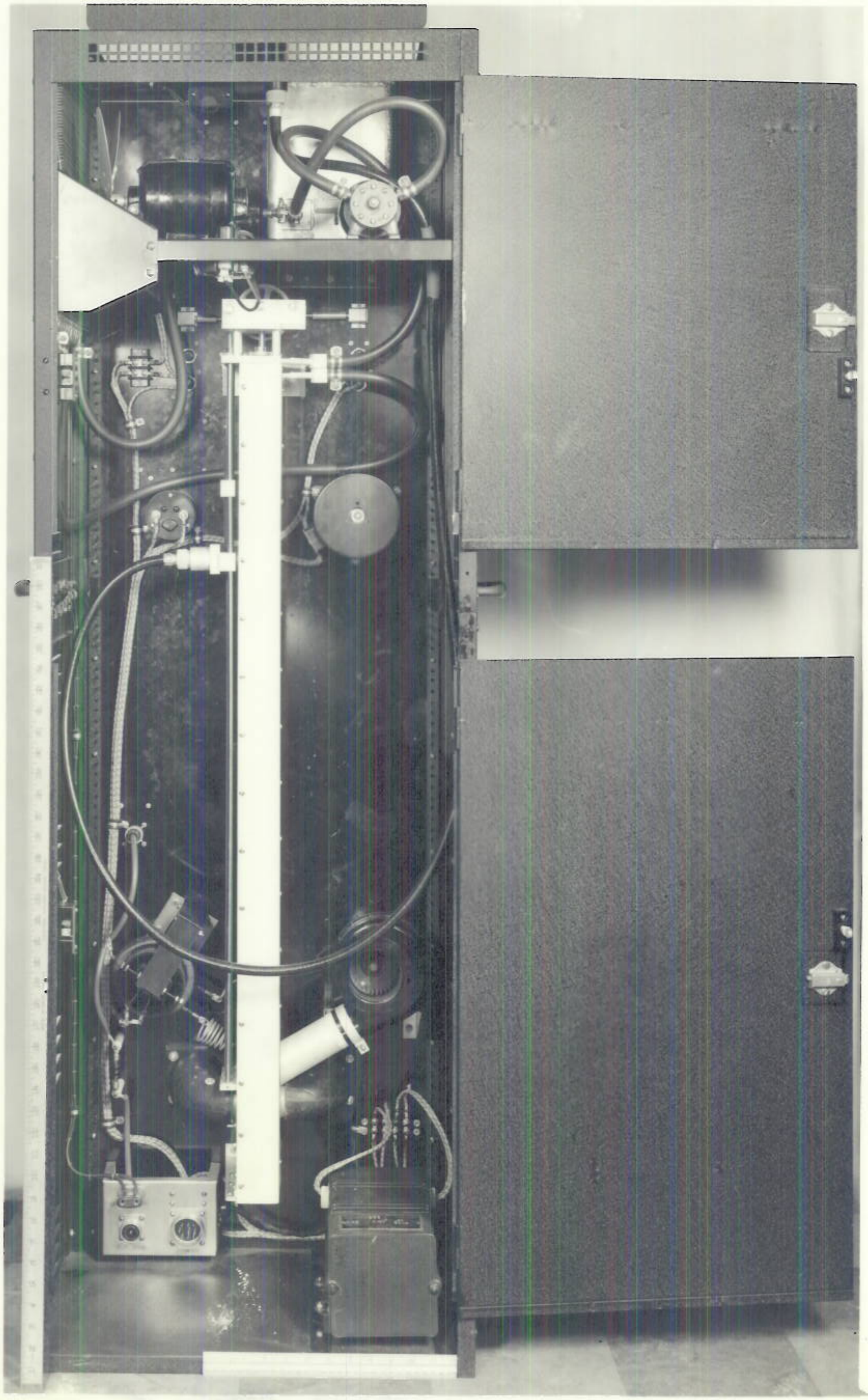
THREE UNITS - FRONT VIEW

PLATE 11



OSCILLATOR REAR VIEW

PLATE 12

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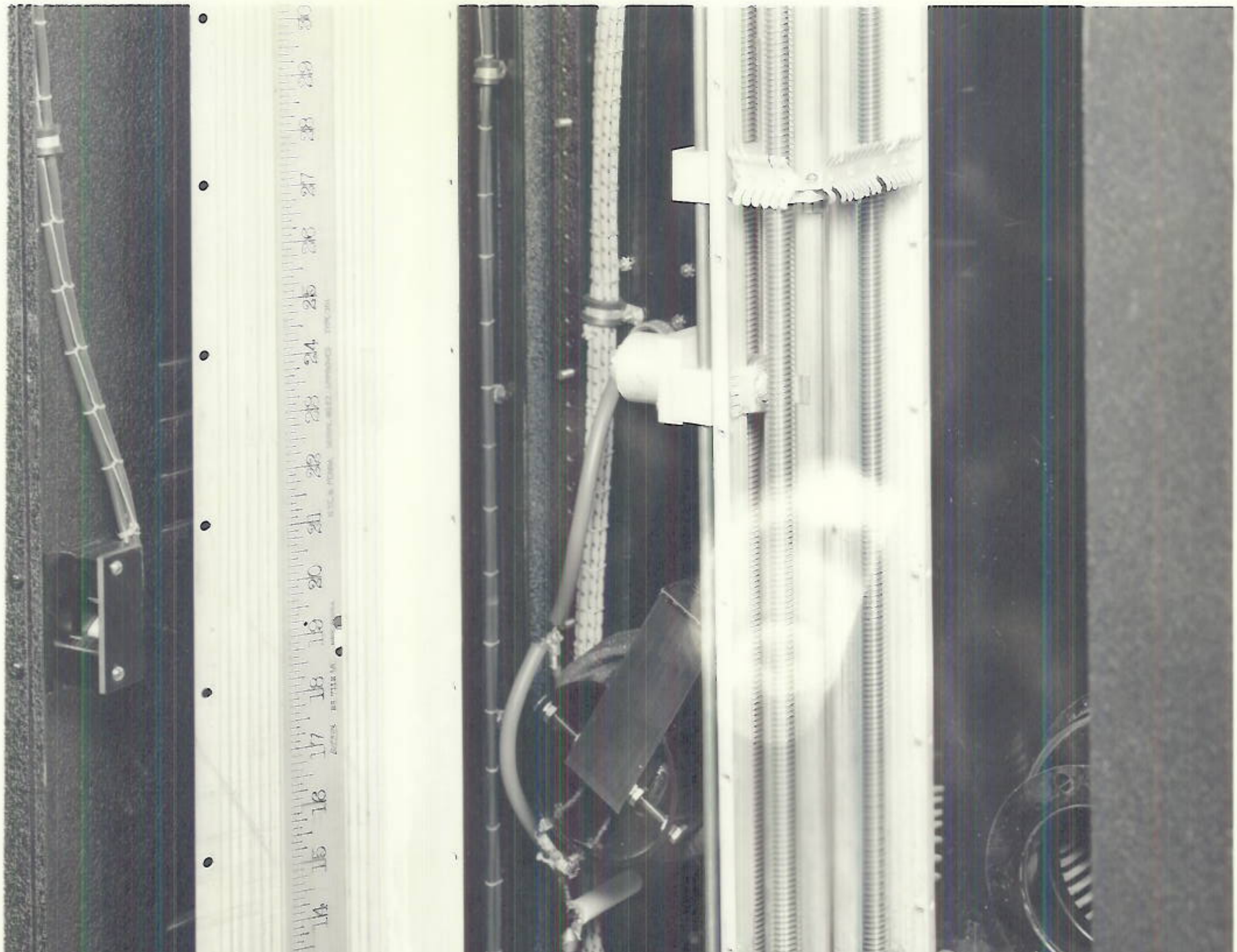

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OSCILLATOR - SHIELD REMOVED

PLATE 13

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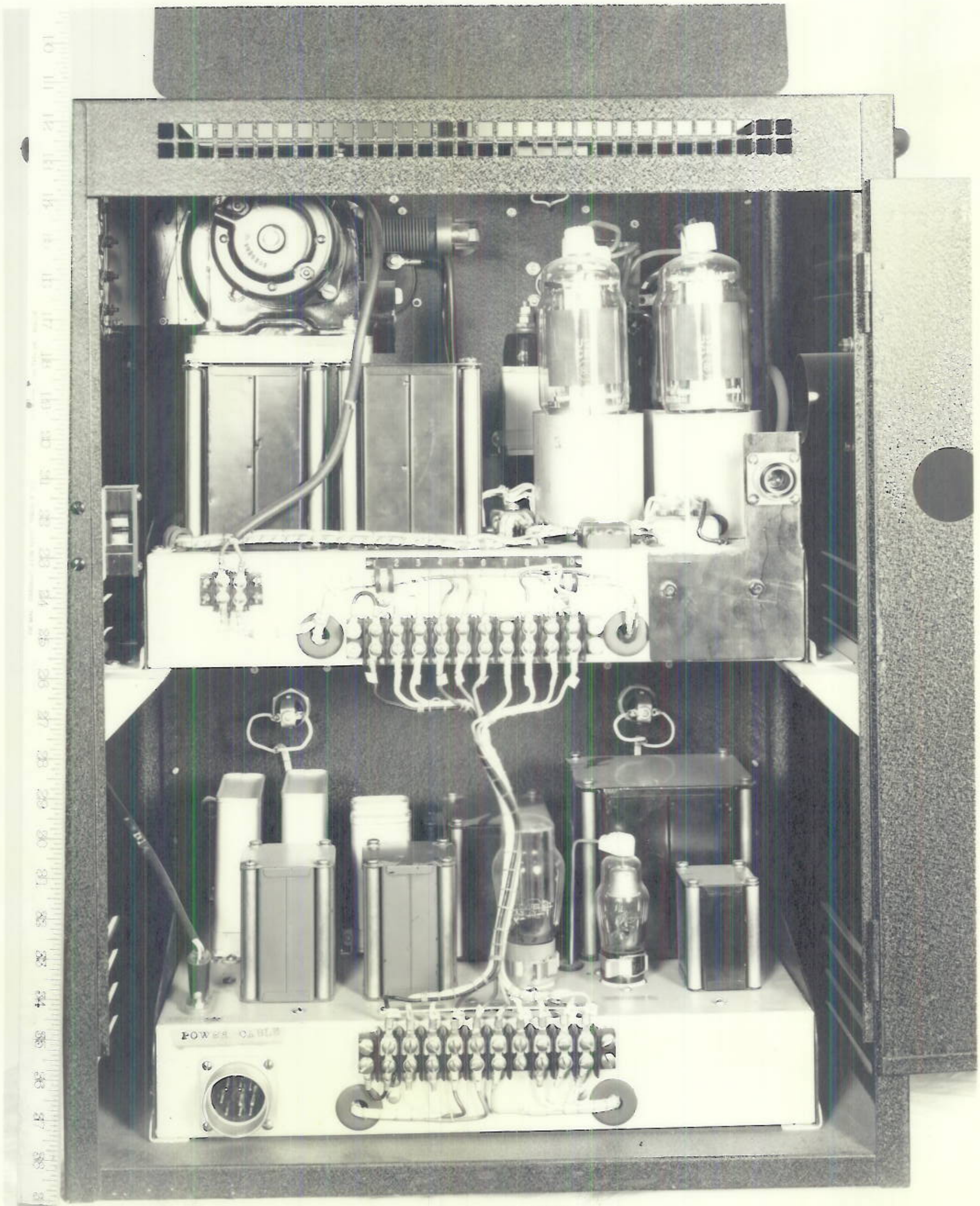

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MODULATOR - REAR VIEW

PLATE 14

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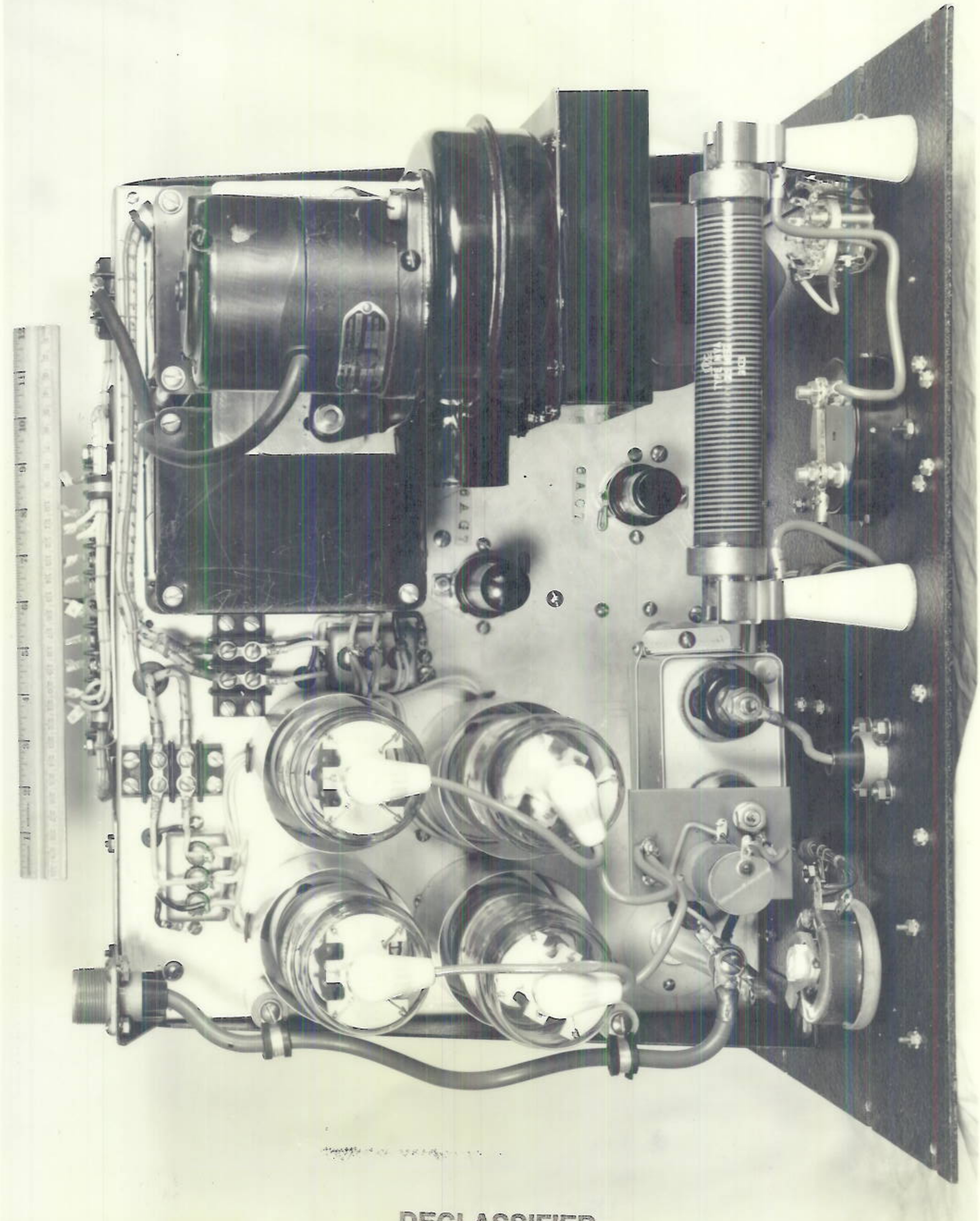

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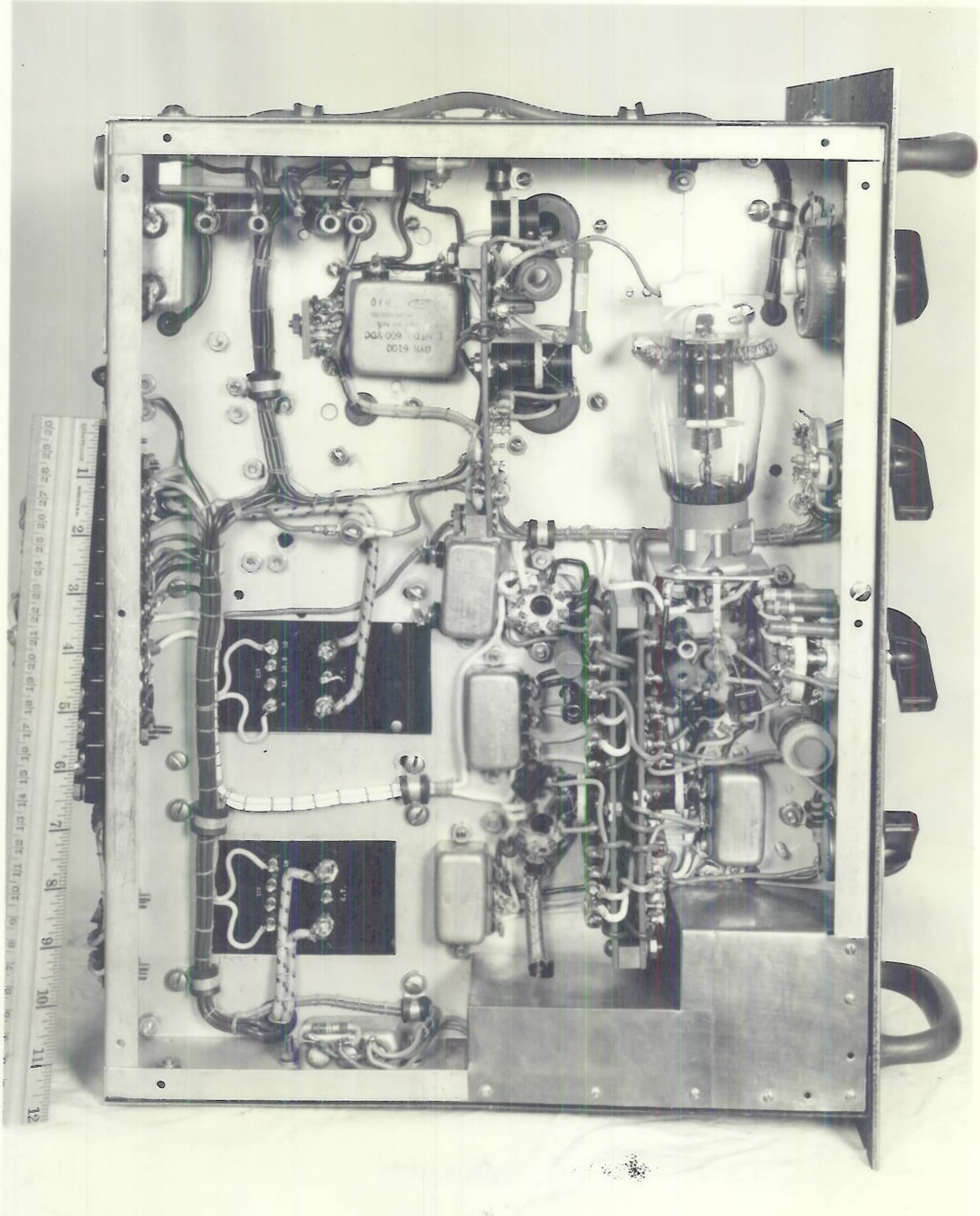
MODULATOR - TOP VIEW

PLATE 15



MODULATOR - BOTTOM VIEW

PLATE 16

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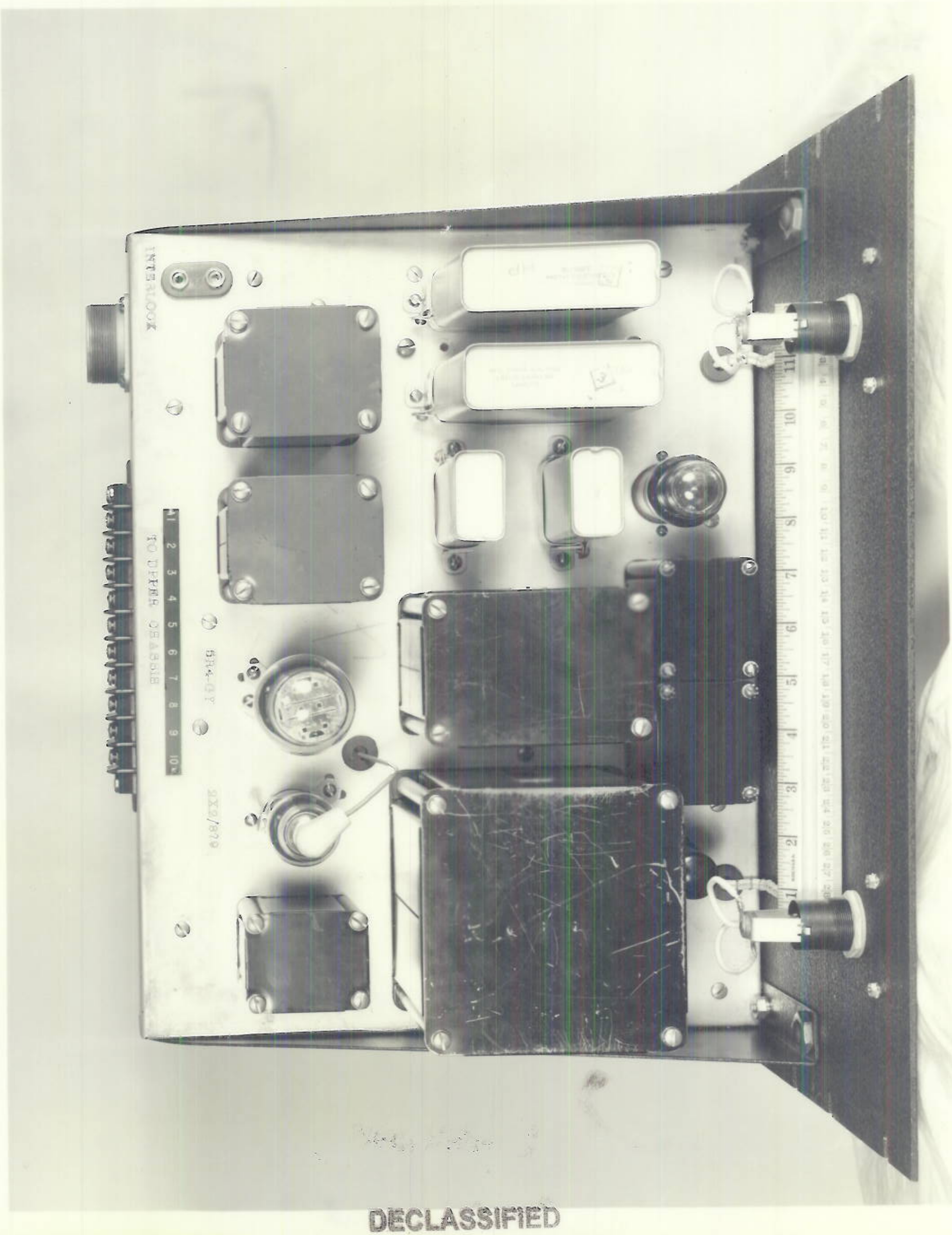


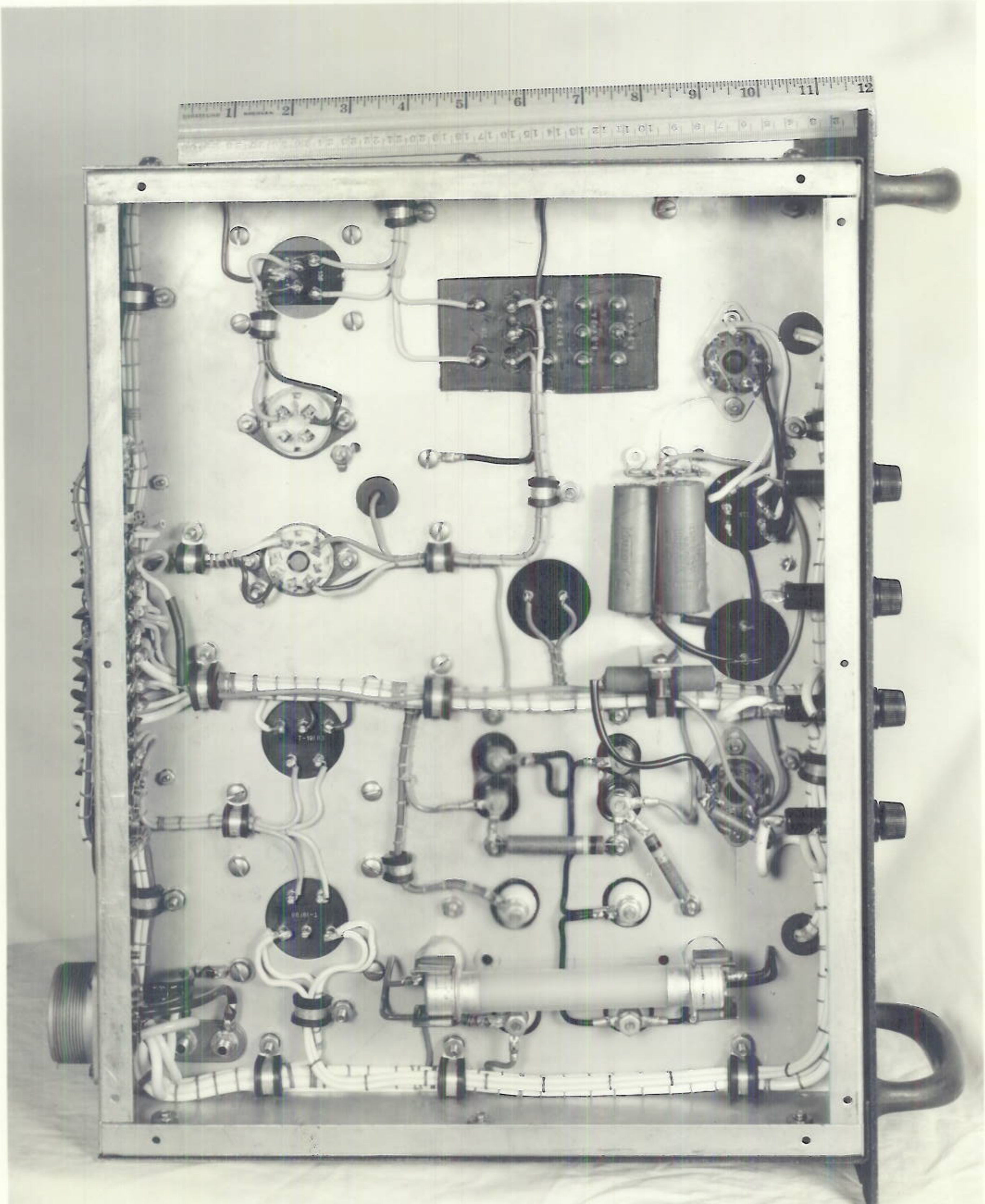
DECLASSIFIED

SECRET

MODULATOR POWER SUPPLY - TOP VIEW

PLATE 17

DECLASSIFIED



DECLASSIFIED

SECRET

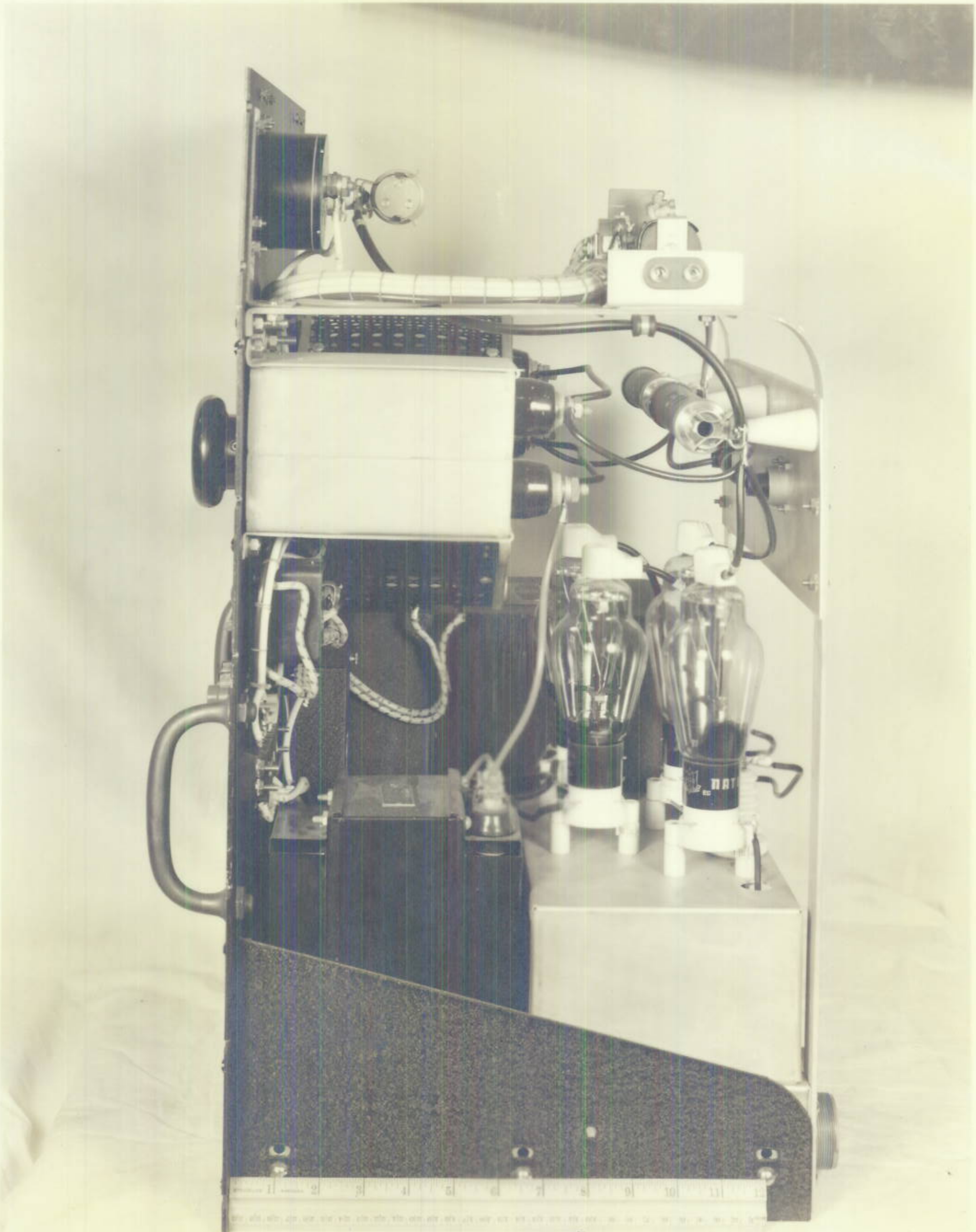
MODULATOR POWER SUPPLY - BOTTOM VIEW

PLATE 18

POWER SUPPLY - REAR VIEW

PLATE 19

DECLASSIFIED



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SECRET

POWER SUPPLY - SIDE VIEW

PLATE 20