LESTER

WWI

TRANSMITTING EQUIPMENT FOR THE ABSORPTION MEASUREMENT PROJECT

NATIONAL BUREAU OF STANDARDS
WASHINGTON, D.C.

COMPLETE INSTALLATION OF STATION W[illegible] TRANSMITTER THIRD FROM LEFT AND THE [illegible] RIGHT ARE STAND BY UNITS CONTROL EQUIPM[illegible] MASTER RACK

INTERSERVICE RADIO PROPAGATION LABORATORY
NATIONAL BUREAU OF STANDARDS
WASHINGTON, D.C.
Organized under U.S. Joint Communications Board

19 April 1945

OPERATING MANUAL FOR WWI TRANSMITTERS

Contents

		Page
I.	Purpose of the equipment	1
II.	Operating schedule	2
III.	Transmitter, type A	2
	A. Transmitter, type A, operating instructions	2
	B. Parts list, transmitter, type A	3
	C. Additional parts	5
	D. Transmitter, type A, service notes	6
IV.	Transmitter, type B	8
	A. Transmitter, type B, operating instructions	8
	B. Parts list, transmitter, type B	9
	C. Miscellaneous parts	12
	D. Transmitter, type B, service notes	12
V.	Control equipment	15
	A. Automatic keying device	15
	B. Transmitter control unit	16
	C. Receiver	17
VI.	Power wiring	17
	A. Power system parts list	17
VII.	Antenna system	18
	A. Antenna system parts list	18
Photograph of equipment.		

I. Purpose of the Equipment

The function of the equipment described in this report is to emit radio waves of five frequencies in the 2-9 Mc range, day and night, continuously over a period of years. These waves are emitted at Beltsville, Maryland, and are received at Sterling, Virginia, where the field intensities are recorded continuously. These measurements provide data from which an analysis of the absorption of radio waves reflected from the ionosphere at vertical incidence may be made. Because the absorption is higher at the lower frequencies, two types of transmitters are employed. Transmitter, type A, used in the 4-9 Mc range, operates at a power output of approximately 200 watts; while transmitter, type B, used in the 2-3 Mc range, supplies 400 watts of output power. The call letters WWI have been assigned to the National Bureau of Standards for all transmissions in connection with this project. For the purposes of analysis of the data it is desirable to have regular intervals of a few minutes duration during which no transmission takes place. It is also necessary to identify the carriers at regular intervals. Control equipment, therefore, has been designed to operate the station on a regular schedule.

(over)

II. Operating Schedule

At all times of the day and night station WWI broadcasts a continuous carrier, which is interrupted at regular intervals as follows:

> Beginning on the hour and every five minutes thereafter there is a keying interval of twenty seconds during which the station call letters are transmitted in International Morse Code.
>
> Beginning on the hour and every twenty minutes thereafter the carrier is off the air for five minutes, with the exception of the keying interval indicated above.

III. Transmitter, Type A

Three type A transmitters operate continuously in the 4, 6, and 7 megacycle bands, while a fourth is used as a standby transmitter. With the exception of the plug-in type coils and crystals, the four transmitters are identical in every respect (Fig. 1). Each transmitter contains four integral units and connections between units are of the plug-and-jack type so that any unit may be removed or replaced in a short time (Fig. 2). The circuits employed are conventional (Fig. 3). The oscillator-amplifier unit consists of a 6L6 crystal-controlled oscillator and a single 813 class C power amplifier (Figs. 4 and 5). The low-voltage power supply is the source of all the oscillator-stage supply voltages and provides the amplifier stage with filament voltage and fixed grid bias (Figs. 7 and 8). Plate and screen voltages for the power amplifier are obtained from the high-voltage power supply (Fig. 10). The panel meters serve as a check on the operation of the transmitters and as an aid in servicing. The transmitter is keyed in the cathode circuit of the oscillator.

A. Transmitter, Type A, Operating Instructions

The location of the controls and switches is shown in Figs. 1 and 2. The main power plug K_{16} plugs into the receptacle in the channel. Switches S_3 and S_2, which control filaments and bias supply, should be thrown on, allowing about a minute for the tube filaments to heat up. The oscillator plate supply switch S_1 should be turned on and oscillator plate condenser C_1 tuned through resonance as indicated by the dip on the reading of the oscillator plate current meter M_1. The current should change sharply on one side of the minimum value and slowly on the other. The proper setting of C_1 is for plate current slightly greater than the minimum value on the low capacity or slowly changing side of the dip. It is essential that switch S_2 which controls the amplifier grid bias be on before the high voltage is turned on. The variac control T_6 should be turned to less than half scale, thus reducing the power amplifier plate voltage so that an excessive amount of plate current will not flow when the amplifier is detuned. The high-voltage switch S_4 should then be turned on.

The power amplifier tuning condenser C_4 is then tuned for minimum plate current. Next, the antenna tuning unit C_{17} is tuned for maximum antenna current. The power amplifier and oscillator should then be retuned. When the transmitter is properly tuned, the variac control T_6 should be advanced until the power amplifier plate voltage reaches its normal operating value.

B. Parts List, Transmitter, Type A.

Condensers

C_1 - 150-μμf variable - National TMC 150.
C_2 - 0.0001-μf mica, 1000-volt
C_3 - 0.002-uf mica, 1000-volt.
C_4 - 100-μμf variable, 6000-volt - National TMA-100A.
C_5, C_6 - 0.01-μf mica, 600-volt.
C_7, C_8 - 0.002-μf mica, 600-volt.
C_9 - 0.005-μf mica, 5000-volt - Radio Wire Television K3763.
C_{10} - 1-μf Dykanol, 1000-volt - Cornell-Dubilier TLA-10010.
C_{11}, C_{12}, C_{13}, C_{14} - 2-uf Dykanol, 600-volt - Cornell-Dubilier TLA-6020.
C_{15} - 2-μf Dykanol, 3000-volt - Cornell-Dubilier TJU-30020.
C_{16} - 4-μf Dykanol, 3000-volt - Cornell-Dubilier TJU-30040.
C_{17} - 230-μμf variable, 6000-volt - National TMA-230A.

Fuses

F_1 - 15-amp. fuse plug with receptacle.
F_2 - 7½-amp. - Littlefuse 1338.
F_3 - 1/16-amp. 1000-volt - Littlefuse 2013.
F_4 - 1/4-amp. 5000-volt - Littlefuse 3022.

Pilot Bulbs

J_1 - 60 ma. - Mazda 48.
J_2, J_3, J_4, J_5 - 120-volt, 6-watt - Mazda S-6.

Connectors

K_1 - 2-contact female, cable mounting, - Amphenol MC2F.
K_2 - 2-contact male, chassis mounting - Amphenol PC2M.
K_3 - 8-contact male, chassis mounting - Amphenol PO8M.
K_4 - 8-contact female, cable mounting - Amphenol 08F1.
K_5 - 8-contact male, cable mounting - Amphenol 08M.
K_6 - 8-contact female, chassis mounting - Amphenol PO8F.
K_7, K_8 - phone jack, single closed-circuit.
K_9, K_{10}, K_{11} - phone plug.
K_{12} - duplex convenience outlet.
K_{13} - 110-volt male plug.
K_{14} - 110-volt female cable mounting plug.
K_{15} - 110-volt recessed chassis mounting male plug.
K_{16} - heavy-duty 110-volt male plug - GE 59197.
K_{17} - phone jack adapted for use in circuit.

Inductances

L_1, L_2 - 2.5 Mh. RF choke - Bud CH920-W.
L_3 - oscillator tank coil for operating frequency.
L_4 - amplifier tank coil for operating frequency.
L_5 - link to antenna tuning unit.
L_6 - 8-mh. RF choke - Bud CH1215.
L_7 - 1-mh. 300-ma. RF choke - National R-300U.
L_8, L_9 - 12-h. 150-ma. filter choke - Thordarson T17C00-B.
L_{10} - 22-h. 35-ma. filter choke - Thordarson T18C92.
L_{11} - 12-h. 300-ma. filter choke - General Electric 69G51.
L_{12} - 12-h. 300-ma. filter choke - General Electric 69G51.
L_{13} - coil for antenna tuning unit - same as L4.

Meters

M_1 - 0-100 ma. d.c. - Triplett 327A.
M_2, M_3 - 0-25 ma. d.c. - Triplett 327A.
M_4 - 0-300 ma. d.c. - Triplett 327A.
M_5 - 0-3000 volt d.c. with multiplier - Triplett 327A.
M_6 - 0-15 volt a.c. - Triplett 337A.
M_7, M_8 - RF ammeter with suitable range - Triplett 347A.

Resistors

R_1 - 50,000-ohm, 1-watt.
R_2, R_3 - 1000-ohm, 10-watt.
R_4 - 50,000-ohm, 100-watt adjustable - IRC type HAA.
R_5 - 25,000-ohm, 50-watt adjustable - Ohmite 0585.
R_6 - 75,000-ohm, 200-watt adjustable - Ohmite 1372.
R_7 - external resistor supplied with M_5.
R_8 - 10-ohm, 10-watt.

Switches

S_1, S_2 - d.p.s.t. toggle switch - 5-ampere - Radio Wire Television 12814.
S_3 S_4 - d.p.s.t. toggle switch - 10-ampere - Radio Wire Television 12816.
S_5 - door interlock - Bud SW1270.

Transformers

T_1 - 10-volt, 8-amp. filament supply - Thordarson T19F96.
T_2 - oscillator supply - Thordarson T13R16.
T_3 - grid bias supply - Thordarson T13R12.
T_4 - 2.5-volt, 10-amp. filament supply - Thordarson T19F90.
T_5 - high-voltage power supply - GE 78G301.
T_6 - variac General Radio type 100Q.

Relay

U_1 - 110-volt a.c. "break" keying relay - Leech 1177ABF.

Crystal

X_1 - quartz crystal for operating frequency, with holder.

C. Additional Parts.

Tubes

1 - type 6L6.
1 - type 813.
1 - type 5Z3.
1 - type 80.
2 - type 866.

Tube Sockets

2 - 8-prong - Amphenol RSS8.
2 - 4-prong - Amphenol RSS4.
1 - 7-pin giant - RCA 9929.
2 - rectifier tube sockets - National XM-10.

Plug-in Coil Assemblies

2 - 3-inch ribbed coil forms - National XR-10A.
1 - oscillator coil socket - National XB-16.
1 - oscillator coil plug base - National PB-16.
2 - amplifier and antenna coil mounting plugs - National PB-15.
2 - amplifier and antenna coil bases - National XB-15.

Enclosed Cabinet Rack

1 - 66½" cabinet - Bud CR-1772.

Metal Panels

3 - 5¼" enclosed meter panels - Bud PS439.
1 - 10½" panel - Bud PS1255.
1 - 3½" panel - Bud PS1251.
1 - 5¼" panel - Bud PS1252.
3 - 8 3/4" panels - Bud PS1254.

Chassis

3 - 10"x17"x3" black crackle finish - Bud CB-655.
1 - rack shelf for high-voltage power supply - Bud CB-1976.

Mounting Brackets

3 pr. - 6½" high, 10" deep - Bud MB-448.
1 pr. - 6½" high, 13" deep - Bud MB-460.
1 pr. - supporting angles for rack shelf - Bud SA-1349.

Insulators

2 - antenna feed-through - Johnson 10060.
1 - high-voltage feed-through - Johnson 42J.
12 or 16 - 3/4" stand-off - National GS10.
10 - 1½" stand-off - Birnbach 432.
4 - 1" narrow stand-off for 813 socket.

Miscellaneous Parts

1 - interstage shield - Bud IS-1247.
1 - 1" jewel assembly, red - Dialex 910CF.
1 - 1" jewel assembly, amber - Dialex 910CF.
1 - 1" jewel assembly, green - Dialex 910CF.
1 - 1" jewel assembly, blue - Dialex 910CF.
3 - insulated shaft couplings - National TX-9.
1 - pilot light base for 60-ma. bulb.
3 - panel bearings for condenser shaft - Bud PB-531.
3 - 2 3/4" tuning dials - Bud D-1732.
1 - Buckwheat coal blower (Sears).

D. Transmitter, Type A, Service Notes.

Trouble	Probable Cause
Oscillator has plate current but will not oscillate.	Faulty keying relay U1; cracked or dirty crystal X1; open pilot light in grid circuit J1; open grid coil L1; open grid resistor R1; coil L3 will not tune to crystal frequency; leaky or shorted coupling condenser C2.
Oscillator has no plate current.	Faulty keying relay U1; control equipment out of adjustment; keying relay U1 energized; defective 6L6 tube; no supply voltage; coil L3 is not plugged in socket; defective plate current meter M1; defective choke L6; faulty connection in plate or cathode circuit.
No plate voltage on oscillator	Open coil L3 or L6; open meter M1; defective connection in connectors, K3, K4, K5, K6 or K7 or supply cable; open filter choke L8 or L9; defective 5Z3 tube; defective transformer T2; open switch S1; shorted bypass condenser C6.

Trouble	Probable Cause
Oscillator plate voltage is present but no screen voltage.	Open bleeder resistor R4; open resistor R2; shorted bypass condenser C5.
813 tube has no grid current.	Oscillator not working; open coupling condenser C2; defective 813 tube; open grid meter M2; defective meter jack K8; defective grid choke L2; faulty connection in grid circuit; no filament voltage.
813 tube has no filament voltage.	defective filament transformer T1; open filament resistor R8; open circuit in connectors K3, K4, K5, K6 or supply cable.
Filament transformer T1 and resistor R8 get hot.	Shorted meter jack K17.
813 tube has no plate current.	Defective 813 tube; no excitation; no screen voltage; no plate voltage; no filament voltage.
No screen voltage on 813 tube but plate voltage is present.	Open resistor R3; open meter M3; open screen fuse F3; open bleeder R6 in high-voltage power supply; defective contact on bleeder R6.
No plate or screen voltage on 813 tube.	Defective 866 tube; no filament voltage on 866 tube; open switch S3 or S4; defective interlock switch S5; back door is not completely closed; defective high-voltage transformer T5; defective filter choke L11 or L12; open fuses F1 and F2; defective variac T6.
813 screen, grid, and plate currents low.	low excitation; weak tube.

Trouble	Probable Cause
No grid bias voltage on 813 tube.	Defective grid coil L2; defective meter jack K8; open meter M2; open connection in connectors K3, K4, K5, K6, K7 or supply cable; open filter choke L15; defective 80 tube; open bleeder R5; defective transformer T3; defective switch S2.
813 plate current high. Blows fuse F4.	Shorted bypass condenser C9; shorted coupling condenser C2; plate circuit not tuned to oscillator frequency; no grid bias.
813 screen current high.	Shorted bypass condenser C3; shorted coupling condenser C2.
Transmitter does not load up on antenna.	Link coupling L5 on coil L4 out of adjustment; open antenna current meter M7 or M8; antenna tuning unit not tuned to transmitter frequency; wrong coil plugged in L13 socket; faulty connection to transmission line.

IV. Transmitter, Type B.

Two type B transmitters were built for operation in the 2-3 megacycle range. The two transmitters are perfectly identical with the exception of the plug-in type coils and crystals (Fig. 12). Each transmitter is made up of five integral units. Connections between units are of the plug-and-jack type which makes it possible to replace any unit in a short time (Fig. 13). The power amplifier unit consists of two 813 tubes operating in push-pull (Figs. 15 and 16). An 807 tube operating in class C serves as buffer and a 6J5 as oscillator (Figs. 18 and 19). All the supply voltages for the oscillator-buffer unit as well as the filament and grid bias for the power amplifier are furnished by the low-voltage power supply (Figs. 21 and 22). The oscillator supply voltage is well regulated by the circuit using the 2A3 tube, 6SJ7 tube, and the 1-watt neon bulb. (Fig.14). Plate and screen voltages for the power amplifier are obtained from the high-voltage power supply (Fig. 24). The transmitter is keyed in the grid circuit of the buffer stage by the blocked grid method of keying. The eleven panel meters serve as an aid in checking the operation and adjustment of the transmitter.

A. Transmitter, Type B, Operating Instructions.

The location of the controls and switches is shown in Figs. 12 and 13. The main power plug K24 plugs into the receptacle in the channel. The

master switch S5 should now be thrown on. Switches S1 and S2 which control the filaments of the 866 and 813 tubes along with the oscillator and buffer supply voltages may now be turned on.

The oscillator plate condenser C1 should now be tuned through resonance indicated by a dip on the reading of the oscillator plate current meter M1. The current should change sharply on one side of the minimum value and slowly on the other. C1 should be adjusted for a value of plate current slightly greater than minimum on the slowly changing or low-capacity side. The buffer plate condenser C2 may then be tuned for minimum value reading on the buffer plate meter M4. The power amplifier grid condenser C3 is then tuned to resonance as indicated by a maximum reading on power amplifier grid current meter M7. Readjustment should now be made on the oscillator and buffer tuning.

It is essential that switches S1 and S2 be on before the high voltage is turned on. The variac control T3 should be turned to less than half-scale in order to keep the plate voltage low to prevent an excessive amount of plate current from flowing while the amplifier is detuned. The high-voltage switch S3 may then be turned on.

The power-amplifier tuning condenser C4 is then tuned for minimum plate current. The antenna tuning condenser C5 is then tuned for maximum antenna current. With the transmitter properly tuned the variac control T3 should be advanced until the power amplifier plate voltmeter M6 reads 2000 volts. The coupling between antenna tuning coil L5 and link coil L6 should be adjusted for best efficiency and loading.

B. Parts List, Transmitter, Type B.

Condensers

C_1 - 150-μμf variable - National TMC150.
C_2 - 300-μμf variable - National TMA300.
C_3 - split stator, 100-μμf per section - National TMC100D.
C_4 - split stator, 110-μμf per section - Hammarlund TCD110-H.
C_5 - 230-μμf variable - National TMA230A.
C_6 - 0.00002 mica.
C_7 - 0.005-μf, mica.
C_8 - 0.002-μf, mica.
C_9 - 0.005-μf, mica.
C_{10} - 0.005-μf, mica.
C_{11} - 0.005-μf, mica, 1000-v.
C_{12} - 0.002-μf, mica.
C_{13} - 0.002-μf, mica.
C_{14} - 0.002-μf, mica.
C_{15} - 0.005-μf, mica, 1000-v.
C_{16} - 0.005-μf, mica, 1000-v.
C_{17} - 0.002-μf, mica.
C_{18} - 0.005-μf, mica, 2500-v.
C_{19} - 2-μf Dykanol, 1000-v. - Cornell-Dubilier TLA-10020.

Condensers (continued)

C_{20} - 2-µf Dykanol, 1000-v. - Cornell-Dubilier TLA-10020.
C_{21} - 2-µf Dykanol, 600-v. - Cornell-Dubilier TLA-6020.
C_{22} - 2-µf Dykanol, 600-v. - Cornell-Dubilier TLA-6020.
C_{23} - 2-µf Dykanol, 3000-v. - Cornell-Dubilier TJU-30020.
C_{24} - 4-µf Dykanol, 3000-v. - Cornell-Dubilier TJU-30040.

Fuses

F_1 - 15-amp. cartridge-type fuse.
F_2 - 3/8-amp., 5000-v. - Littlefuse 3023.
F_3 - 1/16-amp., 1000-v. - Littlefuse 2013.
F_4 - 1/8-amp., 1000-v. - Littlefuse 2014.

Pilot Bulbs

J_1 - 60-ma. - Mazda #48.
J_2, J_3, J_4 - 120-volt, 6-watt - Mazda S-6.

Connectors

K_1 - 8-contact male chassis connector - Amphenol P08M.
K_2 - 8-contact female cable connector - Amphenol 08F1.
K_3 - 8-contact male cable connector - Amphenol 08M.
K_4 - 8-contact female chassis connector - Amphenol P08F.
K_5 - 4-contact female chassis connector - Amphenol P04F.
K_6 - 4-contact male cable connector - Amphenol 04M.
K_7 - 4-contact female cable connector - Amphenol 04F1.
K_8 - 4-contact male chassis connector - Amphenol P04M.
K_9 - 2-contact male chassis connector - Amphenol PC2M.
$K_{10, 11, 12, 13, 14, 15, 16}$ - phone plug.
$K_{17, 18, 19, 20, 21, 22, 23}$ - phone jack adapted for circuit.
K_{24} - 117-volt male plug - heavy-duty - GE59197.
K_{25} - duplex convenience outlet.
K_{26} - 2-contact 117-v. female cable connector - GE1351 connector body.
K_{27} - 2-contact 117-v. male chassis mounting plug - GE2291 motor base.

Inductances

L_1 - oscillator tank coil - Bud OCL-160.
L_2 - buffer tank coil - Bud OEL-160.
L_3 - P.A. grid coil - Bud OCL-160.
L_4 - P.A. tank coil - Bud MCL-160.
L_5 - antenna tuning coil - Bud MLA-1.
L_6 - variable link assembly - Bud AM-1964.
$L_{7, 8, 9, 10}$ - 2.5-mh. RF choke - Bud CH920-W.
L_{12} - 2.5-mh. 300-ma. RF choke - National R-300U.
L_{13} - 4-mh. 600-ma. RF choke - National R-152.
$L_{14,15}$ - 12-h. 150-ma. filter choke - Thordarson T17C00-B.
$L_{16,17}$ - 22-h. 35-ma. filter choke - Thordarson T18C92.
$L_{18,19}$ - 20-h. 500-ma. choke - G.E. 69G49.

Meters

M_1 - 0-25 ma. d.c. - Triplett 327-A.
M_2 - 0-10 ma. d.c. - Triplett 327-A.
M_3 - 0-25 ma. d.c. - Triplett 327-A.
M_4 - 0-100 ma. d.c. - Triplett 327-A.
M_5 - 0-15 volt a.c. - Triplett 337-A.
M_6 - 0-3000 volt d.c. (with ext. resistor) - Triplett 327-A.
M_7 - 0-25 ma. d.c. - Triplett 327-A.
M_8 - 0-50 ma. d.c. - Triplett 327-A.
M_9 - 0-500 ma. d.c. - Triplett 327-A.
$M_{10, 11}$ - 0-2.5 amp. RF - Triplett 347-A.

Resistors

R_1 - 10,000-ohm - 25,000-ohm, 1-watt.
R_2 - 10,000-ohm, 2-watt.
R_3 - 50,000-ohm, 10-watt.
R_4 - 250-ohm, 5-watt.
R_5 - 35,000-ohm, 10-watt.
R_6 - 20,000-ohm, 10-watt.
R_7 - external series resistor supplied with M_6.
R_8 - 50,000-ohm, 100-watt adjustable - IRC type HAA.
R_9 - 25,000-ohm, 50-watt adjustable - Ohmite 0585.
R_{10} - 0.5-megohm, 1-watt.
R_{11} - 10,000-ohm, 10-watt.
R_{12} - 25,000-ohm, 10-watt.
R_{13} - 10,000-ohm potentiometer.
R_{14} - 50,000-ohm, 10-watt.
R_{15} - 50,000-ohm, 200-watt adjustable - Ohmite 1371.
R_{16} - 7-ohm, 20-watt.

Switches

S_1 - d.p.s.t. toggle switch, 5 amp. - Radio Wire Television 12814.
S_2, S_3 - d.p.s.t. toggle switch, 10 amp. - Radio Wire Television 12816.
S_4 - door interlock switch - Bud SW1270.
S_5 - enclosed switch and fuse holder - Arrow Hart & Hegeman 27202.

Transformers

T_1 - oscillator, buffer and bias supply - Thordarson T89R28.
T_2 - 2.5-v. filament transformer - Thordarson T19F90.
T_3 - auto-transformer - General Radio 100Q Variac.
T_4 - 2.5-v. filament transformer - Thordarson T19F90.
T_5 - 2350-0-2350 high-voltage supply - G.E. 78G302.
T_6 - 10-v. filament supply - Thordarson T19F87.

Relay

U_1 - 110-v. a.c. "break" keying relay - Leach 1177ABF.

Crystal

X_1 - quartz crystal for operating frequency, with holder.

C. Miscellaneous Parts

1 - interstage shield - Bud IS-1247.
1 - 1" jewel assembly, red - Dialex 910CF.
1 - 1" jewel assembly, green - Dialex 910CF.
1 - 1" jewel assembly, blue - Dialex 910CF.
4 - insulated shaft couplings - National TX-9.
1 - pilot light base for 60-ma. bulb.
4 - panel bearings for condenser shaft - Bud PB-531.
4 - tuning dials - National type 0 scale 2.
25 ft - No. 14 twin-conductor lead-covered cable.
Miscellaneous wire and hardware.
1 - 1-watt neon bulb - adapted to circuit requirements.

D. Transmitter, Type B, Service Notes.

Trouble	Probable Cause
Oscillator has plate current but will not oscillate.	Cracked or dirty crystal X1; open pilot light, J1, in grid circuit; open grid coil L7; open grid resistor R1; coil L1 will not tune to crystal frequency.
Oscillator has no plate current.	Defective 6J5 tube; no supply voltage; coil L1 is not plugged in socket; defective plate current meter M1; defective choke coil L8; faulty connection in plate or cathode circuit; no filament voltage.
No plate voltage on oscillator.	Open coil L8 or L1; open meter M1; defective connection in connectors; K, K4, K10, K21 or supply cable open; filament in 2A3 tube open filament; transformer for 2A3 tube; open bleeder resistor R8; open filter choke L14 or L15; open 5Z3 tube; defective power transformers T1; open switch S1; shorted bypass condenser C1.

Trouble	Probable Cause
807 tube has no grid current.	Oscillator not working; defective 807 tube; no filament voltage; open resistor R2; coil C1 not plugged in socket; coil C1 open; defective meter M2; defective meter plug K11; defective meter jack K23; faulty connection in grid circuit; faulty keying relay U1 control equipment out of adjustment; keying relay U1 energized.
6J5 and 807 tubes have no filament voltage.	Defective transformer T1 open in connector K1 or K4; faulty connection in filament circuit.
807 tube has no plate current.	Defective 807 tube; no screen voltage; no plate voltage; no filament voltage.
No screen voltage on 807 tube but plate voltage is present.	Open resistor R6; defective meter M3; defective meter jack K17; defective meter plug K14; shorted bypass condenser C10.
No plate or screen voltage on 807 tube.	Defective coil L12; open fuse F4; open in connector K1 or K4; open bleeder R8; open filter choke L14 or L15; defective 5Z3 tube; defective transformer T1.
807 grid, screen, and plate currents low.	Weak 807 tube; low excitation; defective 5Z3 tube.
807 screen current high.	Shorted bypass condenser C10; defective 807 tube.
813 tubes have no grid current.	Buffer not working; wrong coil plugged in L3 socket; open coil L9; defective meter M7; defective meter jack K19; defective meter plug K13; no filament voltage;

Trouble	Probable Cause
813 tubes have no grid current (continued)	faulty connection in grid circuit; defective 813 tubes; faulty connection in connectors K5, K6, K7, K8 or supply cable; open resistor R9.
No filament voltage on 813 tubes.	Defective filament transformer T6; open in connectors K5, K6, K7, K8 or supply cable.
813 tubes have no plate current.	Defective 813 tube; open fuse F2; no excitation; no plate voltage; no screen voltage; no filament voltage; coil L4 not plugged in socket; open coil L4 or L13; defective meter M9; faulty connection in plate or filament circuit.
No screen voltage on 813 tubes but plate voltage is present.	Open coil L11; defective meter M8; defective meter jack K29; defective meter plug K28; open screen fuse F3; faulty contact of bleeder resistor R6; open bleeder resistor R6.
No plate or screen voltage on 813 tubes.	Defective 866 tube; no filament voltage on 866 tubes; open switch S2 or S3; defective interlock switch S4; back door not completely closed; defective high-voltage transformer T5; defective filter choke L18 or L19; open fuse F2 and F3; defective variac T3.
Control grid, screen grid, and plate currents low on 813 tubes.	Low excitation; defective 813 tube.
No grid bias voltage on 813 tubes.	Open coil L3; open coil L9; defective meter M7; defective meter jack K19; defective meter plug K13; faulty connection in connectors K5, K6, K7, K8 or supply cable;

Trouble	Probable Cause
No grid bias voltage on 813 tubes (continued).	open bleeder resistor R9; open choke coil L19 or L17; defective 80 tube; faulty connection in grid circuit; defective transformer T1; no filament voltage on 80 tube.
P.A. plate-current meter M9 reads high. Fuse F2 blows.	Shorted bypass condenser C18; plate circuit not tuned to oscillator frequency; P.A. tank coil will not tune to oscillator frequency; no grid bias voltage; short circuit between plate circuit wiring and ground; defective 813 tube.
P.A. screen current meter M8 reads high. Fuse F3 blows.	Shorted bypass condenser C8; short circuit between screen circuit wiring and ground.
Voltage regulator does not control oscillator voltage.	Defective 6SJ7 tube; defective neon bulb; open resistor R10, R11, R12, R13, or R14; tap, on bleeder resistor R8, set at a point of too low voltage to start the neon bulb; faulty connection in regulator circuit.
Transmitter does not load up on antenna.	Link coupling between L5 and L6 out of adjustment; open antenna current meter M10 or M11; antenna tuning unit not tuned to transmitter frequency; coil L5 will not tune to oscillator frequency; faulty connection to transmission-line; open connection in link circuit.

V. Control Equipment

Control equipment for the transmitters consists of an automatic keying device, a transmitter control unit, and a Hammarlund model HQ120 receiver (Figs. 26 and 27).

A. Automatic Keying Device.

In the automatic keying device, in Figs. 28 and 29, a revolving code wheel is used to make and break contactor K1. This causes the code wheel output terminals to be short-circuited as the dots and dashes on the code

wheel pass under contactor K1.

This device is so designed that it will not start keying the transmitters in the middle of a code group or discontinue keying them, after the 20-second keying interval, until a complete code group (which consists of the call letters WWI) has gone under contactor K1. This is accomplished by use of a holding relay which is energized by contactor K2 falling into a cam just before a code group on the code wheel reaches contactor K1. The circuit through the holding relay coil is opened by contactor K3, which is pushed open by a bakelite pin on the side of the code wheel. This happens just after a complete code group has gone under contactor K1. With the relay in a relaxed position the circuit from contactor K1 to the code-wheel output terminals is open. When the holding relay is energized by contactor K2 one set of its contacts completes the circuit from contactor K1 to the code-wheel output terminals, another set of its contacts serves to keep the contactor of cam C in the transmitter control unit short-circuited. Another set of contacts is necessary to lock the holding relay.

If contactor K1 is in the middle of a code group at the end of the 20-second keying interval (controlled by the transmitter control unit), the holding relay, which has a set of contacts short-circuiting the contactor of cam C in the transmitter control unit (Fig. 31), will prevent the transmitter control unit from stopping the keying interval until the complete code group has gone under contactor K1. After a complete code group has gone under contactor K1 the bakelite pin on the side of the code wheel will push contactor K3 apart to take the energy off the holding relay and discontinue the keying interval.

The code wheel and cam are motor-driven.

B. Transmitter Control Unit.

A photograph and circuit diagram of the transmitter control unit are shown in Figs. 30 and 31. When relay 2 is energized by the contactor of cam C, 110 volts is applied to the keying-motor input terminals by one set of the relay contacts. The other set of contacts, on relay 2, short-circuits the contactors of cams A and B, which puts 110 volts on the transmitter relays to cut the transmitters off the air until the keying device short-circuits the code input terminals.

When the code input terminals of the transmitter control unit are short-circuited by the automatic keying device the coil of relay 1 is energized. This breaks the circuit and takes the 110 volts off the transmitter relays, therefore causing the transmitters to be keyed according to the dots and dashes on the code wheel in the automatic keying device.

The 5-minute interval when the transmitters are off the air is controlled by cams A and B. The contactors of these two cams are connected in series. Both contactors have to be closed for the transmitters to be off the air. When the contactor falls into cam A, it closes, and 110 volts is put on the transmitter relays, which causes the transmitters to go off the air. Five minutes later the contactor falls into cam B. This removes

the 110 volts and puts the transmitters back on the air. The cams are driven by a Telechron clock motor.

The Telechron clock and cam mechanism may be set to the correct time by loosening the set screw on the motor side of the shaft coupling. The cams may then be revolved by turning the shaft coupling in a counter-clockwise direction facing the clock motor shaft. The cams should be revolved until the contactor falls into cam A; at the same time the contactor of cam C will fall in. The control unit is now set for the beginning of an off-the-air interval. (See operating schedule). If another setting is desired the cam mechanism may be rotated further. After this setting is passed, five minutes may be added to the time every time the contactor of cam C falls in. The mechanism should be left a few seconds on the fast side. The set screw should now be tightened and the control unit put in operation. The 110-volt a-c line plug may be taken out and left out for the number of seconds the unit is found to be fast. The time may be checked with WWV.

When the manual keying switch on the front panel of the control unit is turned on, the transmitters will continuously key the station call letters. The other switch on the front panel is an on-off switch which when turned off will remove the power from everything in the unit except the Telechron clock motor. The three pilot lights tell what is going on in the unit. When the red light is on, the transmitters are off the air. The green light indicates that the control unit is turned on. When the amber light is on, the transmitters are keying.

C. Receiver.

The Hammarlund model HQ120 receiver is used for monitoring the transmitters. A schematic of this receiver can be seen in Fig. 32.

VI. Power Wiring

The power wiring runs from the circuit breaker on the main WWV switchboard through the channel and is brought out through the metal channel plates in which are mounted five 30-ampere receptacles (Fig.30). An extra length of wire is left in the channel to allow for the plates being removed. The circuit breaker will trip when a load requiring more than 35 amperes is connected to one phase.

A. Power System Parts List

350 ft. No. 3 insulated wire.
50 ft. No. 4 insulated wire.
6 General Electric SP52C15 galvanized covers.
6 General Electric SP52151 galvanized boxes.
6 General Electric 59197 polarity caps.
6 GE 996 receptacles.
6 GE 997 flush plates
6 - 3/4-inch close nipples.
5 - 1/2-inch close nipples.

1 - 1-inch close nipple.
6 - 3/4-inch bushings.
5 - 1/2-inch bushings.
1 - 1-inch bushing.
12 - 3/4-inch locknuts.
10 - 1/2-inch locknuts.
2 - 1-inch locknuts.

VII. Antenna System.

Half-wave doublet antennas with a height of one-quarter wavelength above ground are used in order to get good vertical radiation. A map of this antenna system is shown in Fig. 35. All of the antennas except the 2-Mc one point in the direction of the receiving station. The 2-Mc antenna is broadside to the receiving station. Radiation patterns for the antennas are shown in Fig. 37. Fig. 36 shows the construction details. Wire connectors are used at the point where the transmission line connects to the antenna. The connectors are of a type which can conveniently be disconnected to insert ammeters at the center of the antenna for the determination of radiated power.

Resonant lines are used in order that frequencies may be changed quickly and conveniently by retuning the transmission line.

A. Antenna System Parts List.

2 - 160-ft wooden masts with guy wires and hardware.
2 - 82-ft wooden masts with hardware.
9 - 65-ft wooden poles with hardware.
1 - 35-ft wooden pole with hardware.
10 - 19-ft wooden poles with hardware.
7 - 15½-ft wooden poles with hardware.
10 - 6'x4"x3" cross-arms with braces and hardware.
4 - 8'x4"x3" cross-arms with braces and hardware.
16 - 2'x4"x3" cross-arms with braces and hardware.
1 - 3'x4"x3" cross-arm with braces and hardware.
600 ft - No.10 galvanized iron wire.
1400 ft - No. 10 Copperweld wire.
1500 ft - No. 12 Copperweld wire.
10 - eye bolts, 3/8" shank.
10 - screw eyes, 3/8" shank.
30 - turnbuckles, 3/8" screw diameter, 11½" open.
10 sets - Johnson #52 feed-thru insulators.
30 - 7½" strain insulators - Pyrex 67017.
36 - 4" standoff insulators with hole - Radio Wire Television 16800.
18 - 6" standoff insulators.
50 - compression-type strain insulators - Knox 500.
20 - 6" spreader insulators.
20 - wire connectors.
Miscellaneous hardware.

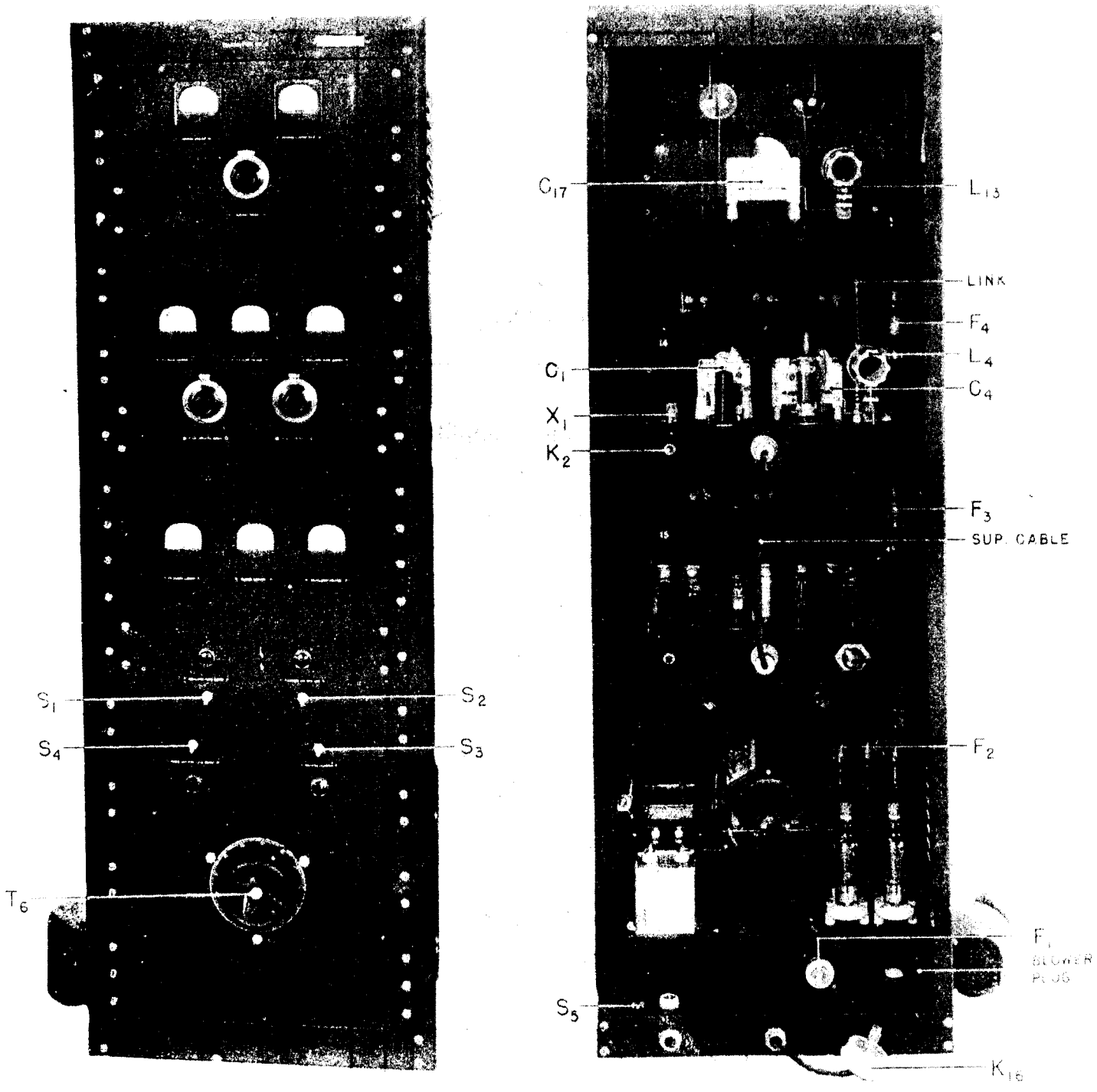
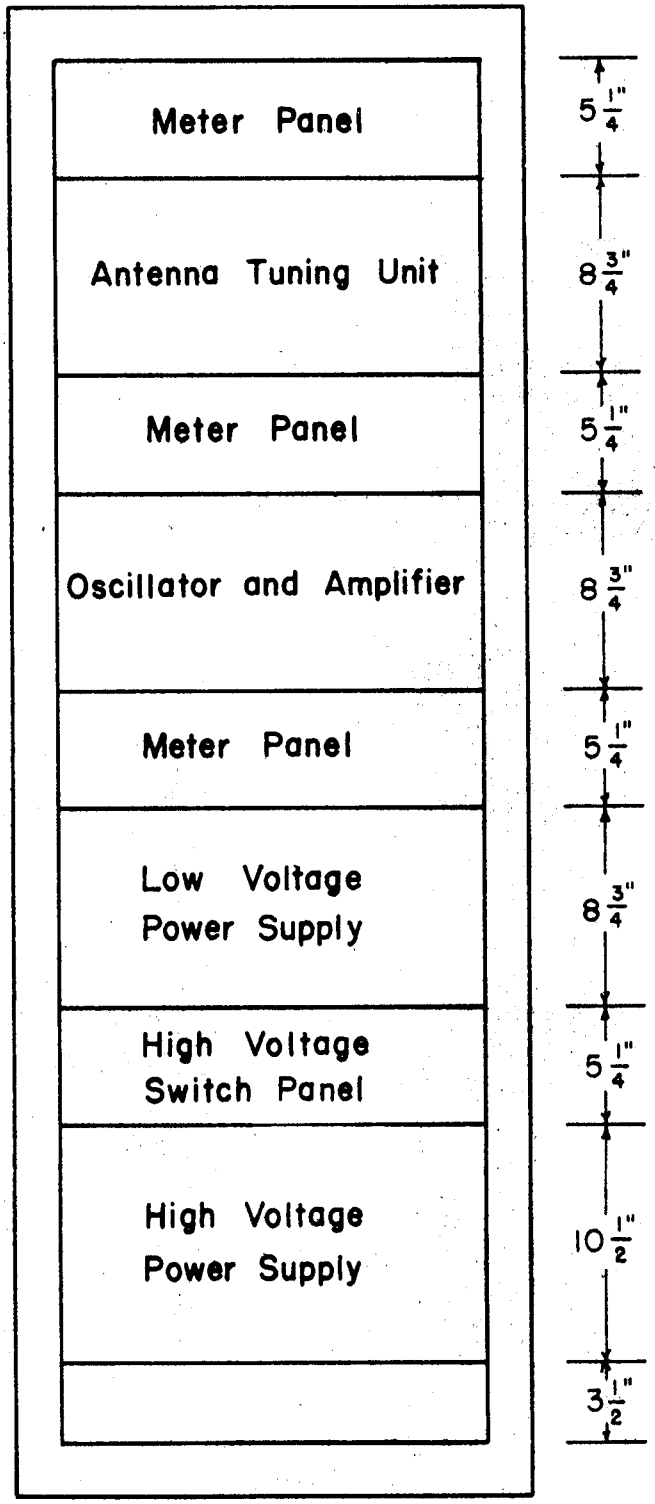


FIG. 1 - FRONT AND REAR VIEW OF TRANSMITTER TYPE A WITH BACK DOOR REMOVED

TRANSMITTER TYPE A
PANEL LAYOUT



SCALE 1" = 8"

FIG. 2

TRANSMITTER TYPE A
CIRCUIT DIAGRAM

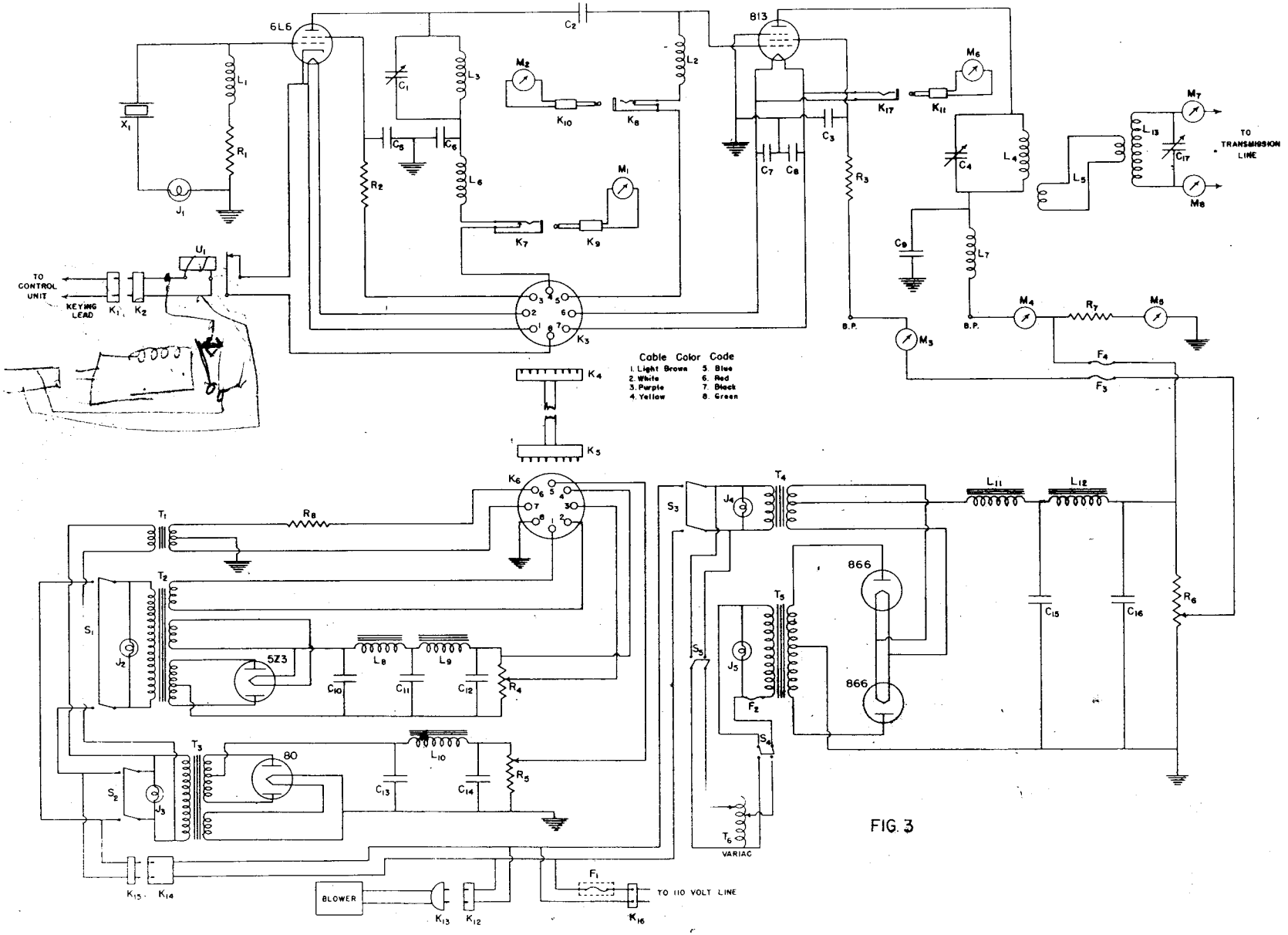
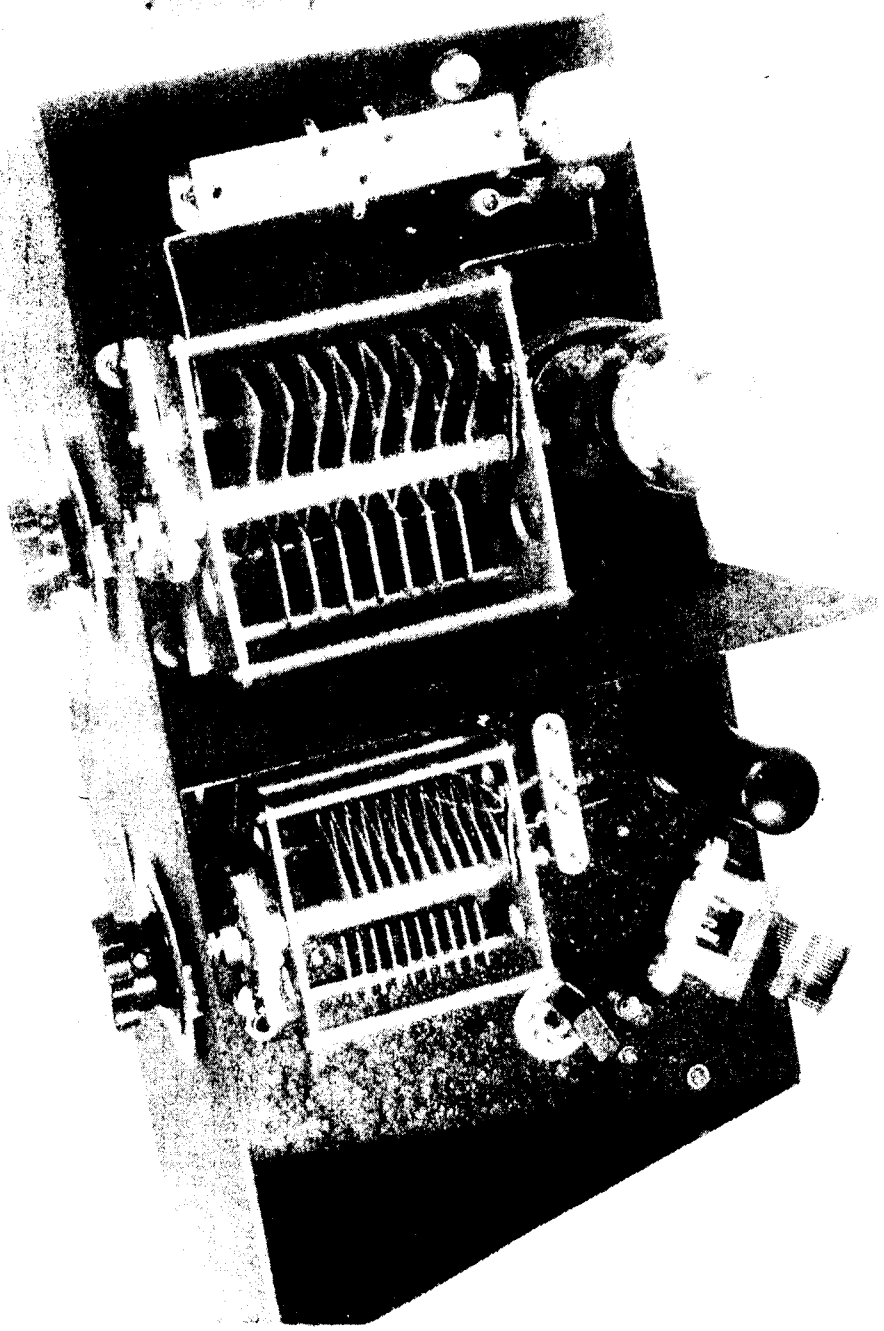


FIG. 3



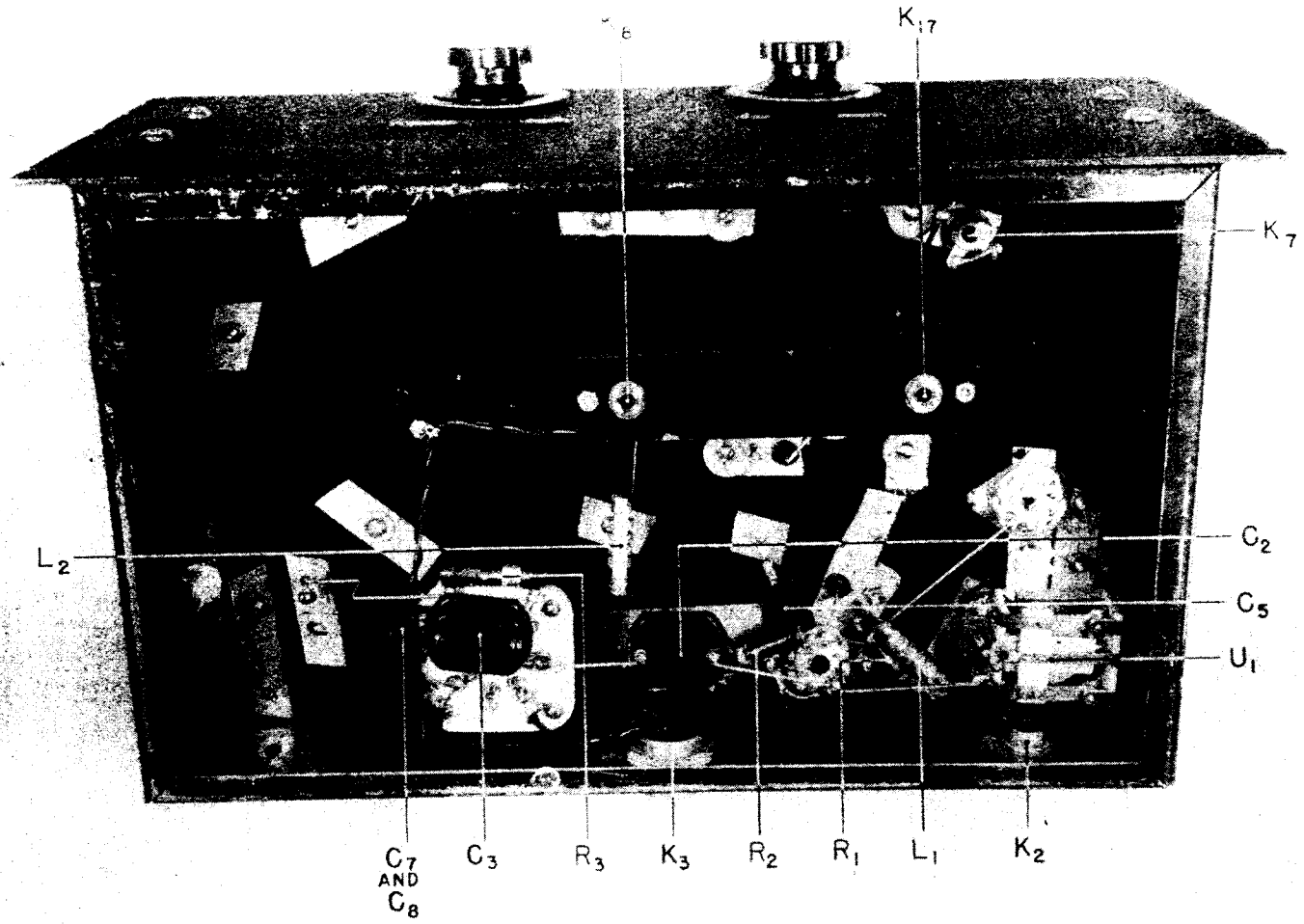
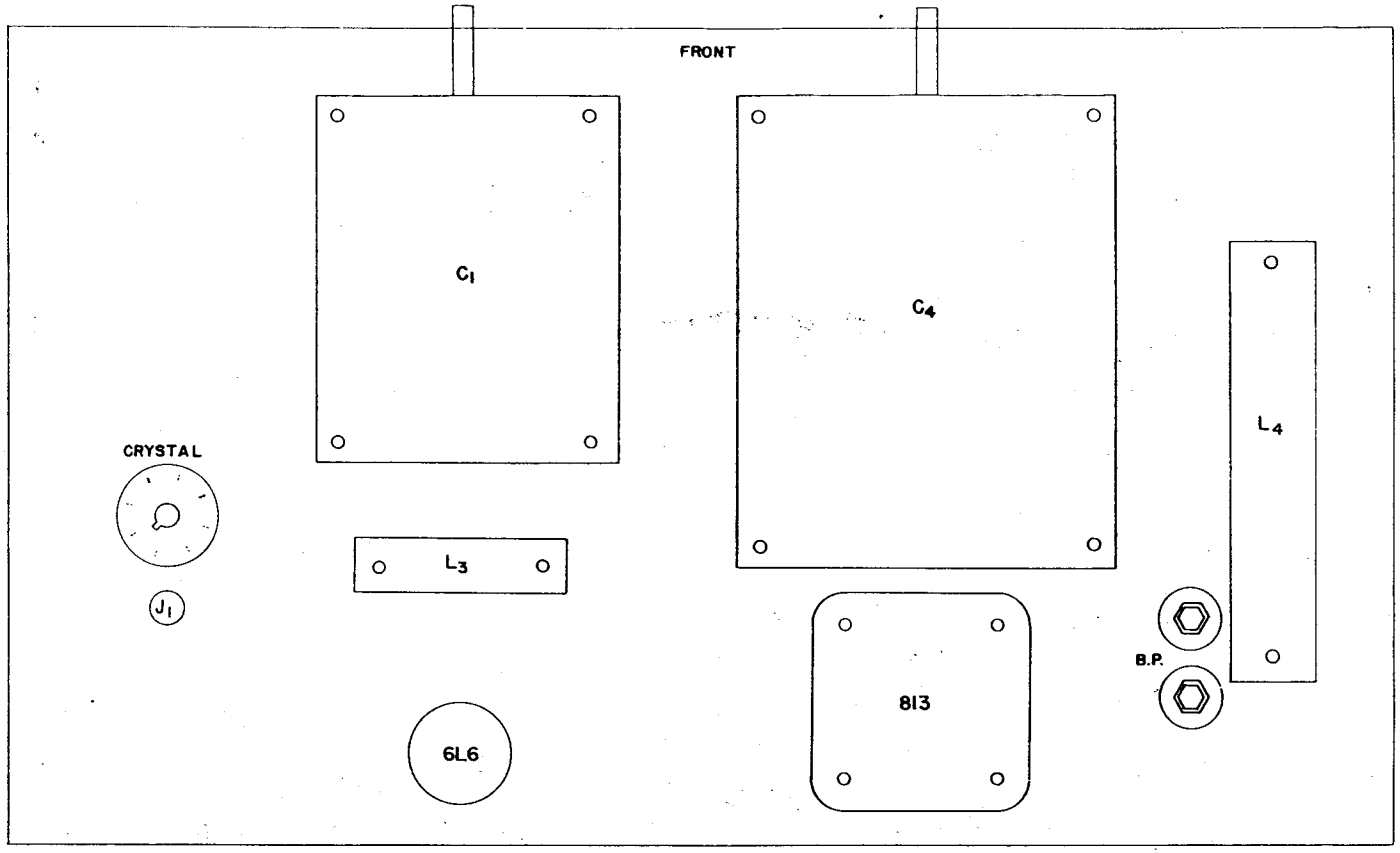


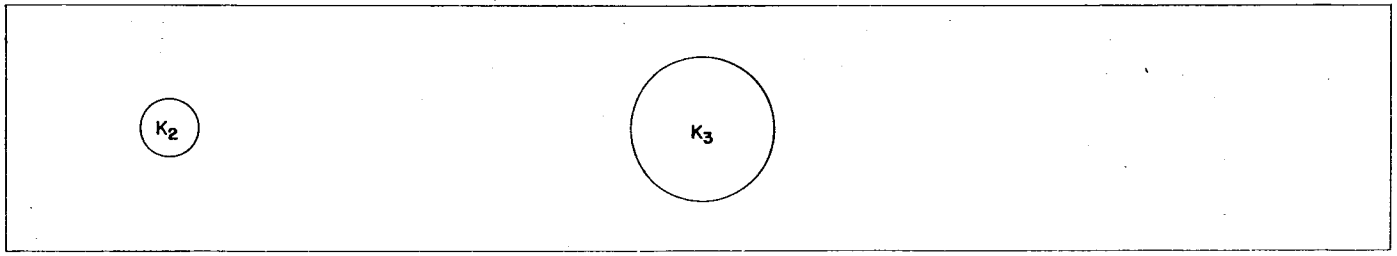
FIG. 5 - BOTTOM VIEW OF TRANSMITTER TYPE A OSCILLATOR-AMPLIFIER STAGE

TRANSMITTER TYPE A

OSCILLATOR - AMPLIFIER STAGE



TOP VIEW



BACK VIEW

FIG. 6

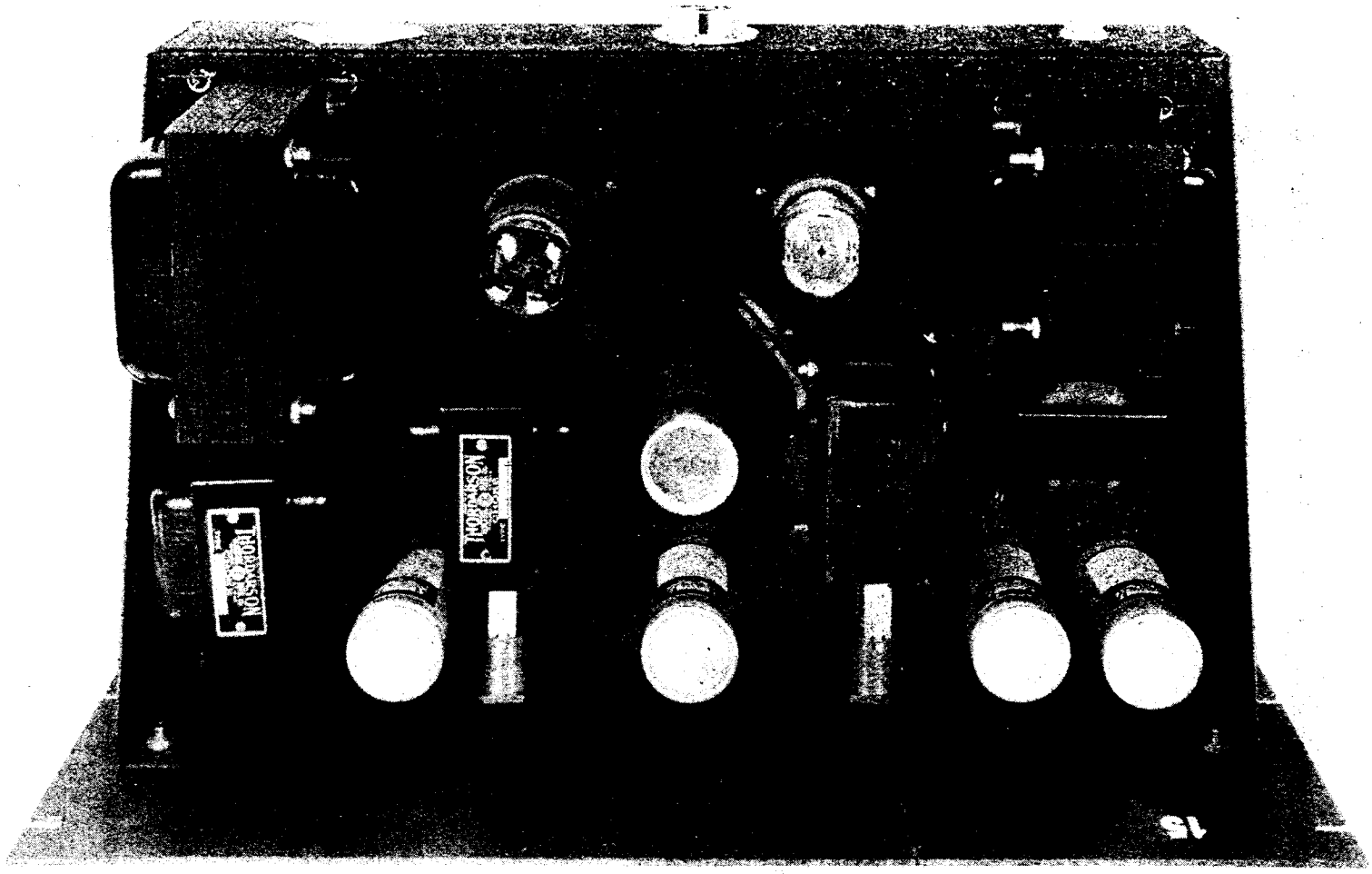


FIG. 7—TOP VIEW OF TRANSMITTER TYPE A LOW VOLTAGE POWER SUPPLY

Transmitter Type A
Low Voltage Power Supply

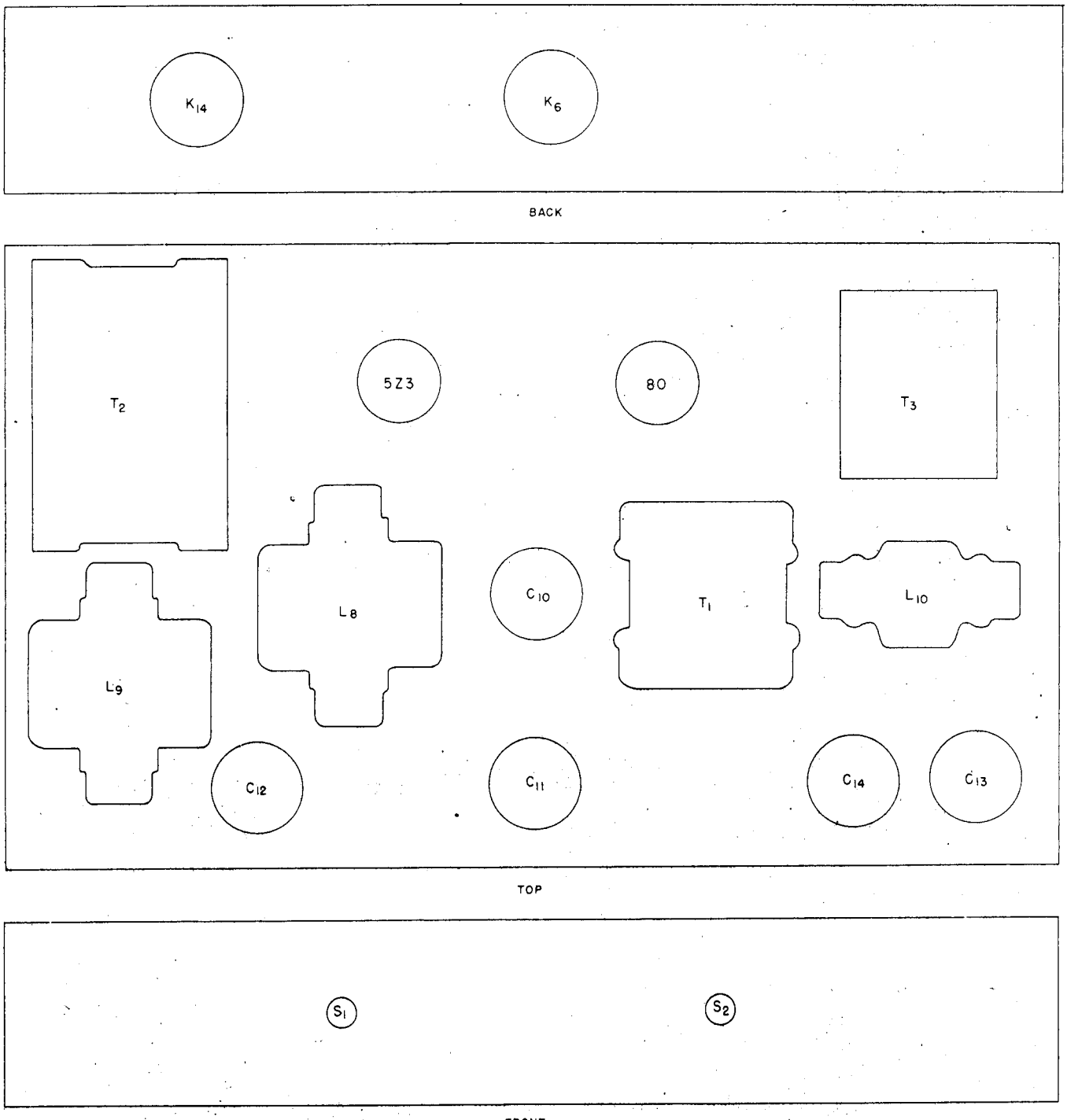


FIG. 9

TRANSMITTER TYPE A
HIGH VOLTAGE POWER SUPPLY

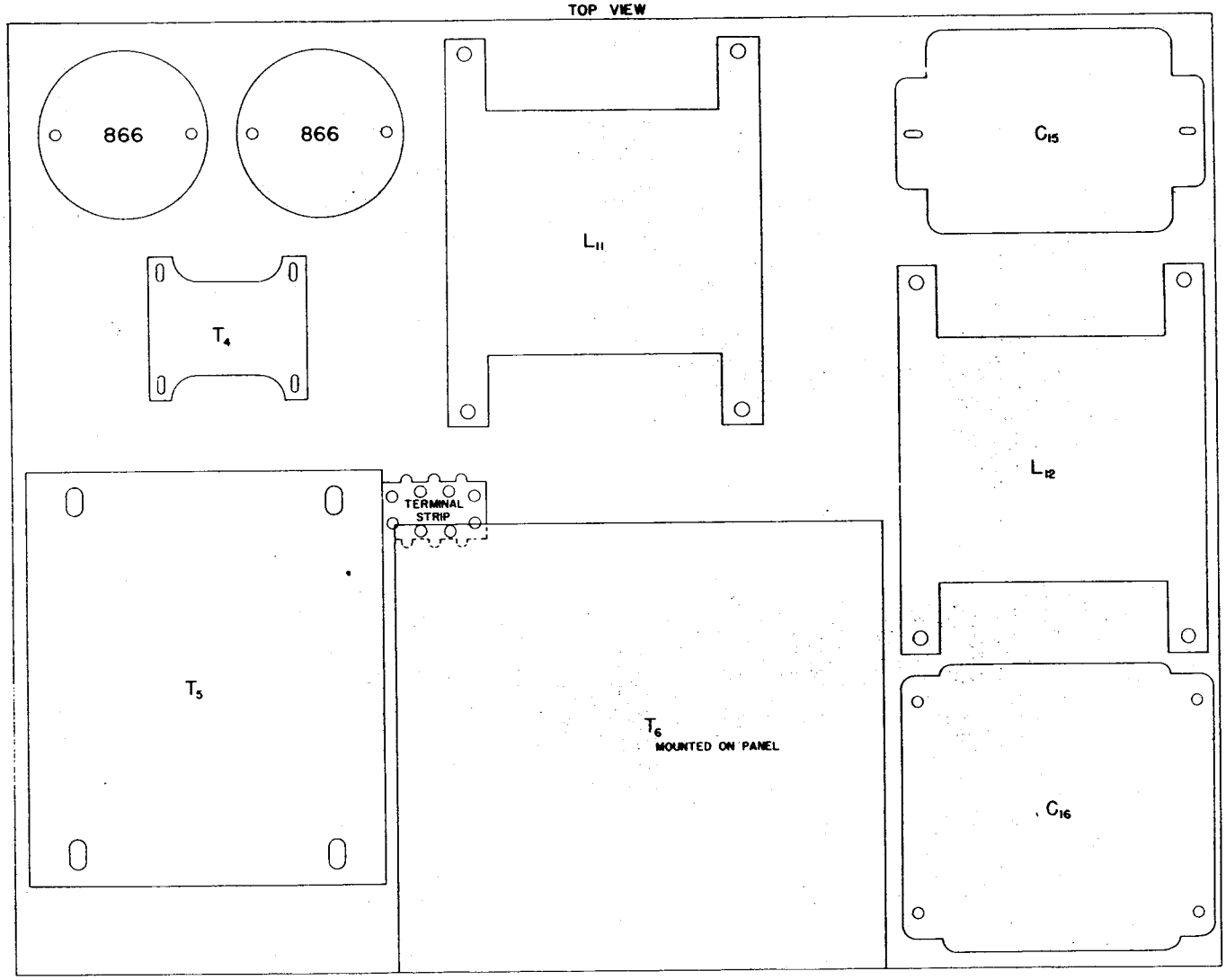


FIG.10

TRANSMITTER TYPE A
ANTENNA TUNING UNIT

TOP VIEW

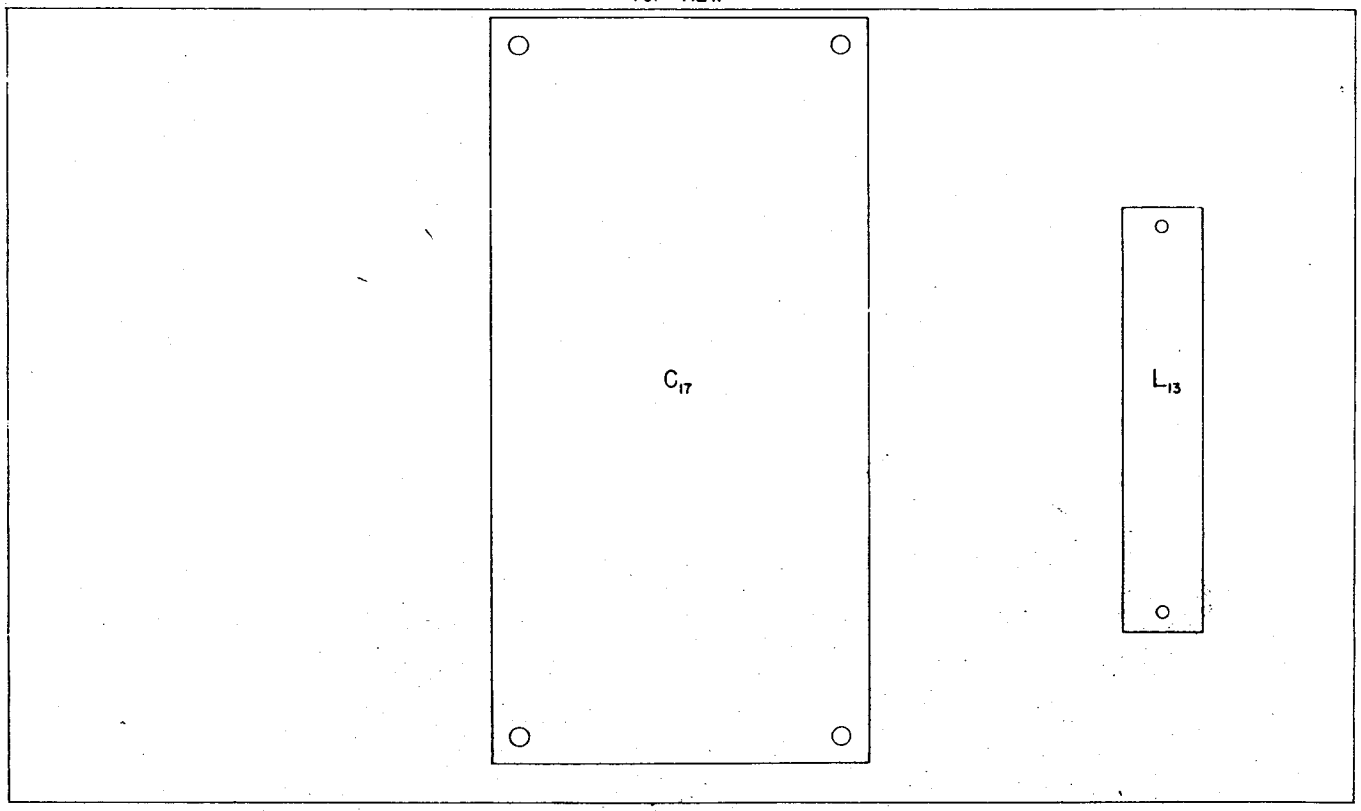
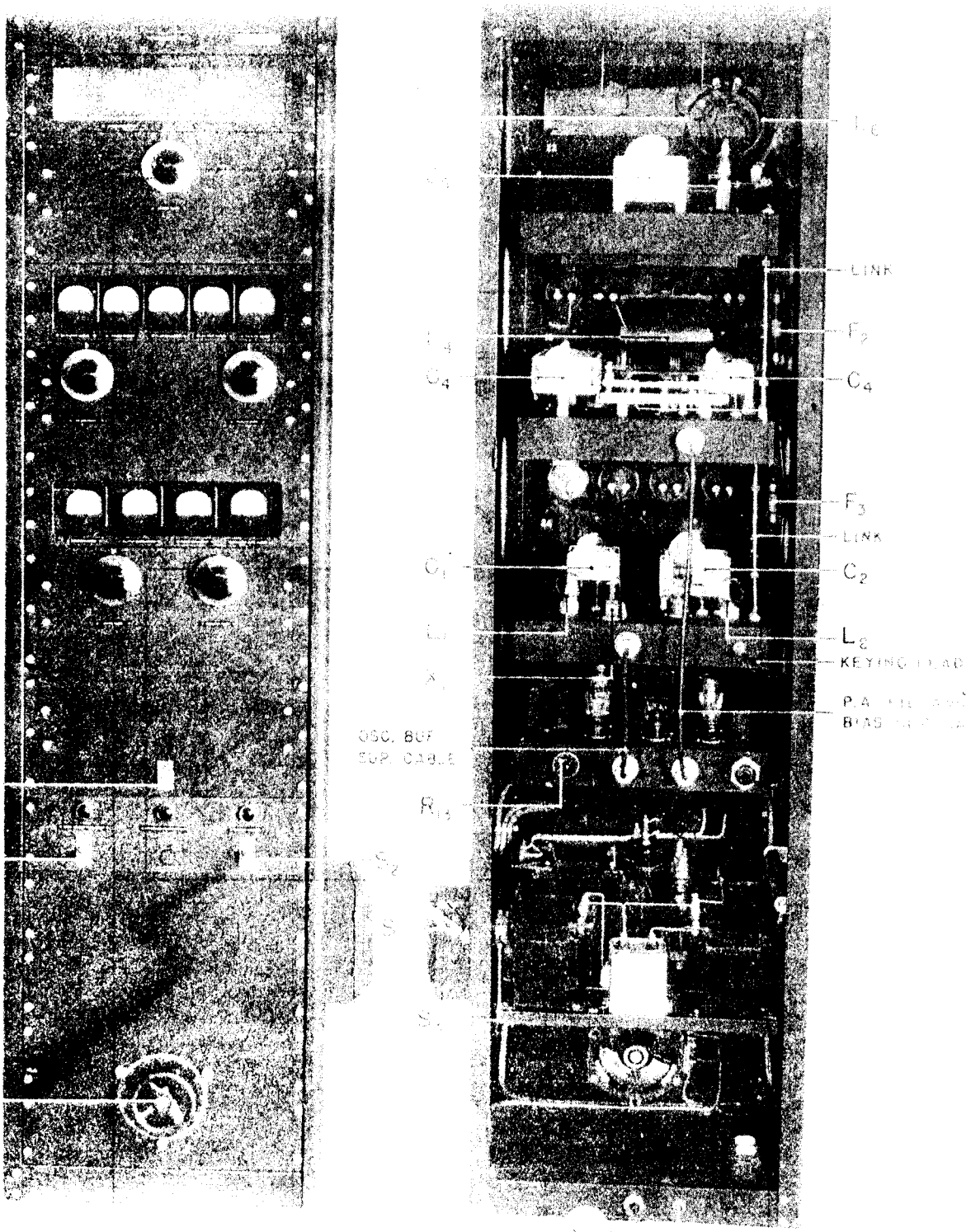
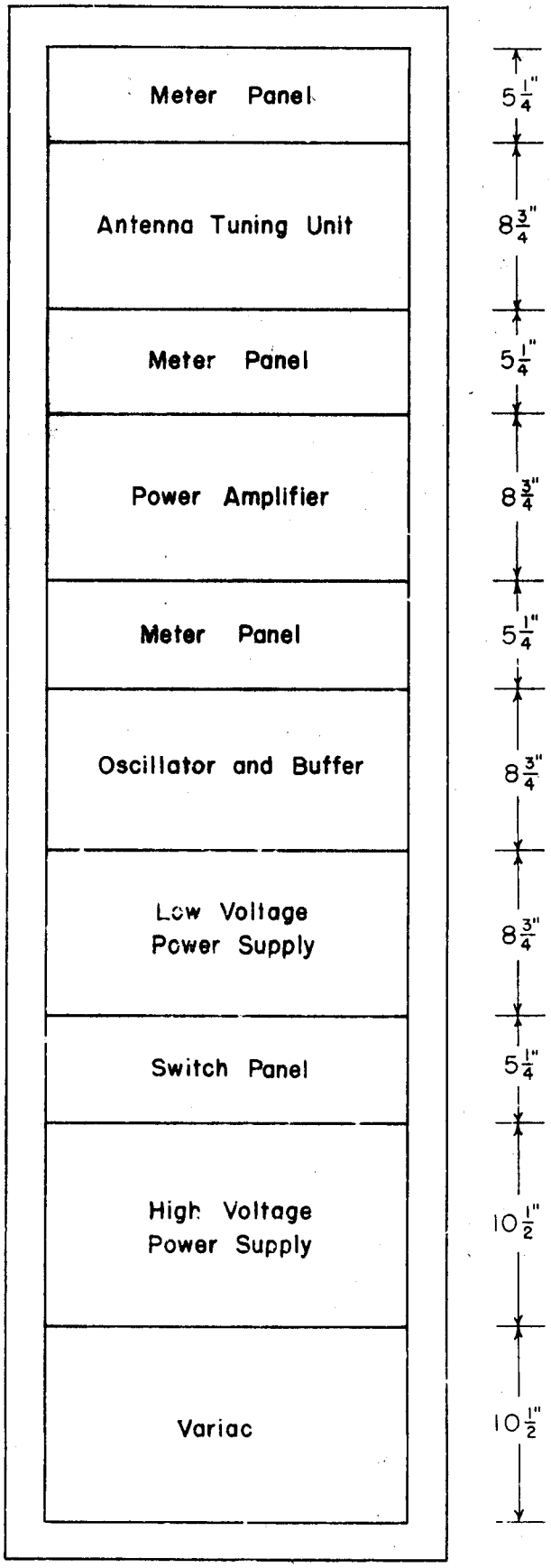


FIG. 11


LINK
C_4
F_3
LINK
C_2
L_2
KEYING LEAD
OSC. BUF
SUP. CABLE
R_1

TRANSMITTER
TYPE B
PANEL LAYOUT



SCALE 1"=8"

FIG. 13

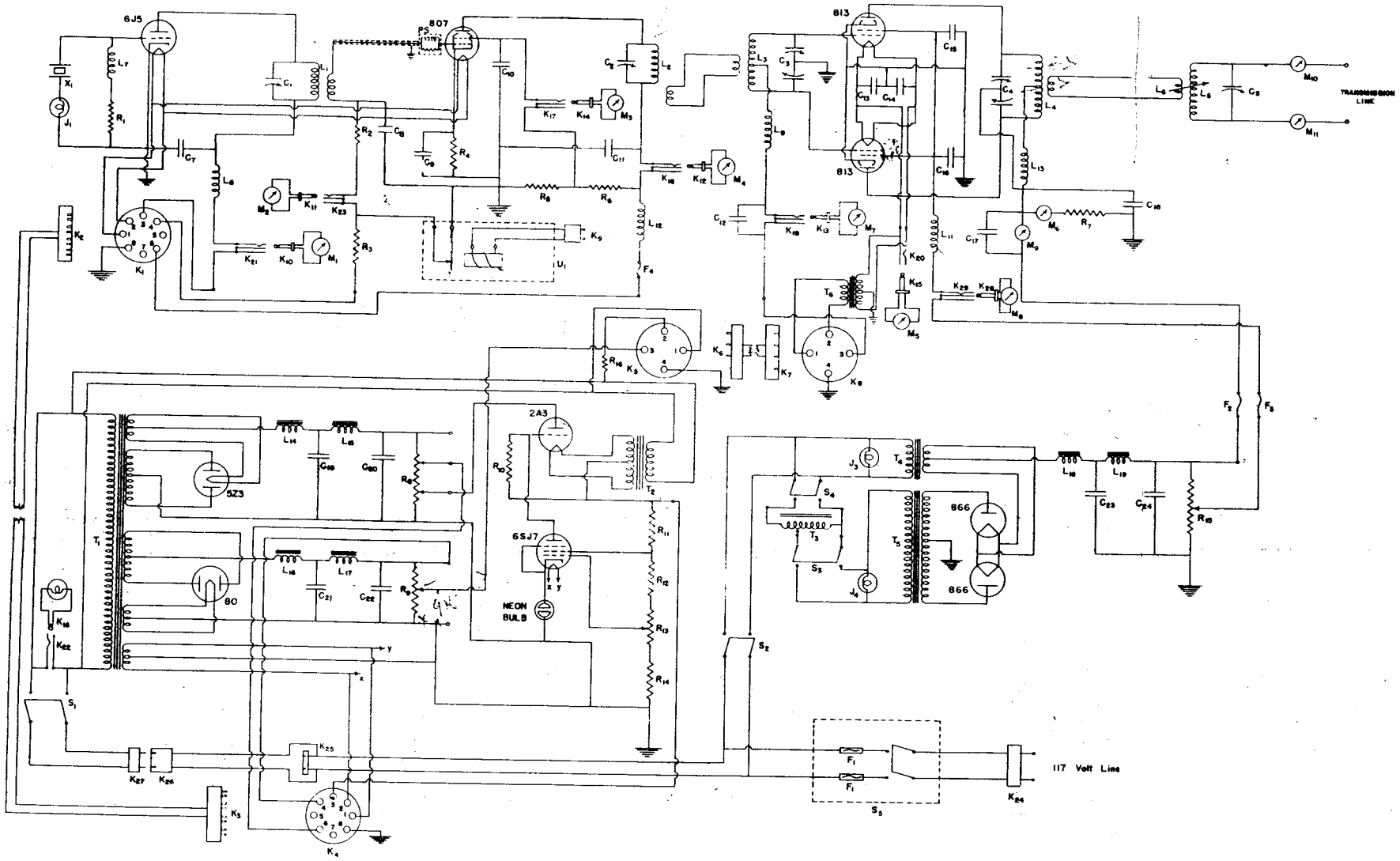
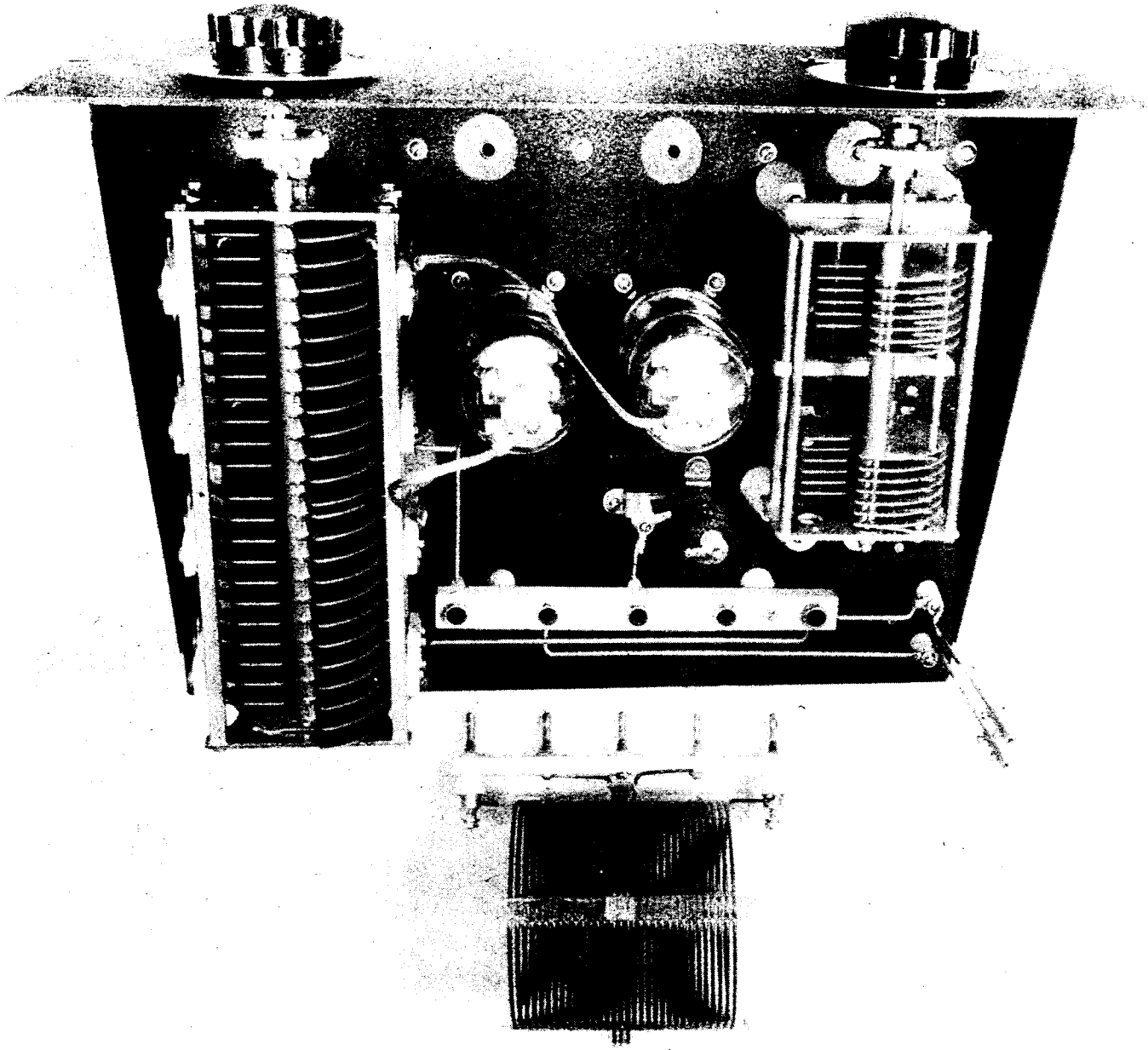


Fig.14 TRANSMITTER TYPE B CIRCUIT DIAGRAM



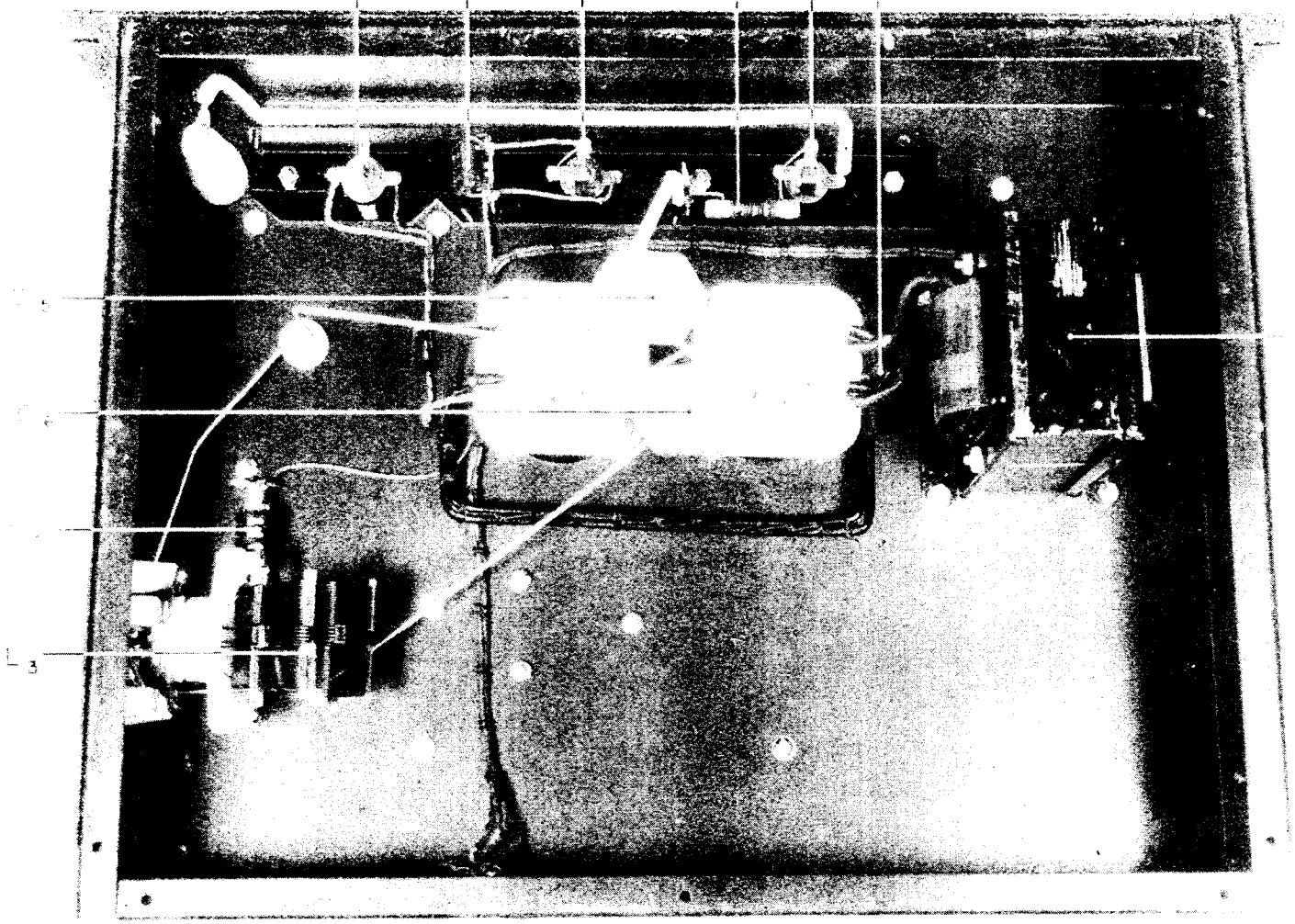
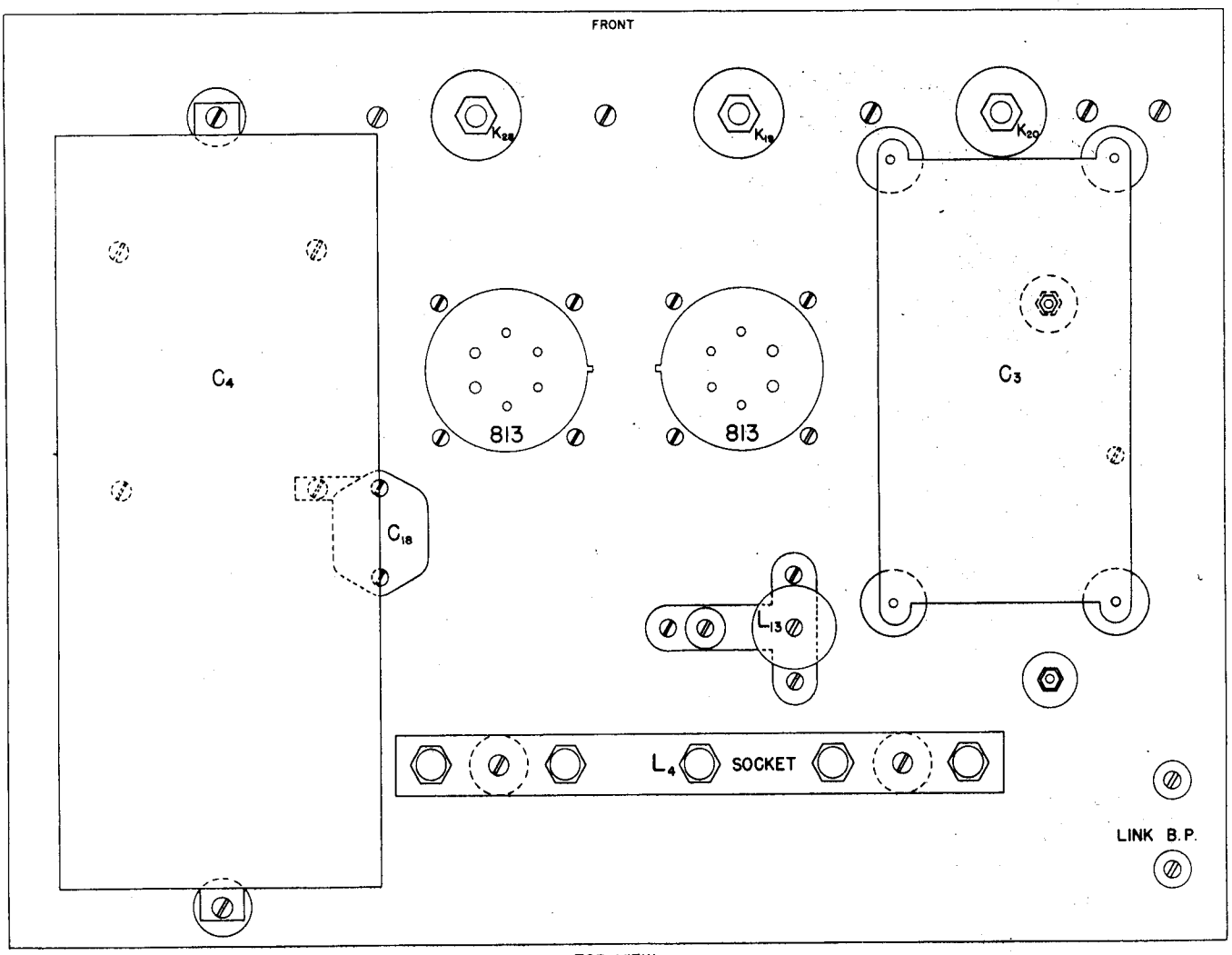
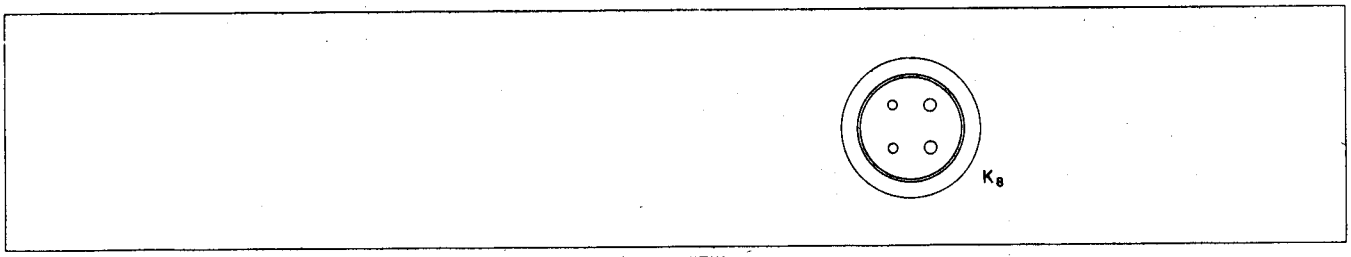


FIG. 8 - BOTTOM VIEW OF TRANSMITTER TYPE B POWER AMPLIFIER STAGE

TRANSMITTER TYPE B P.A. UNIT



TOP VIEW



BACK VIEW

FIG. 17

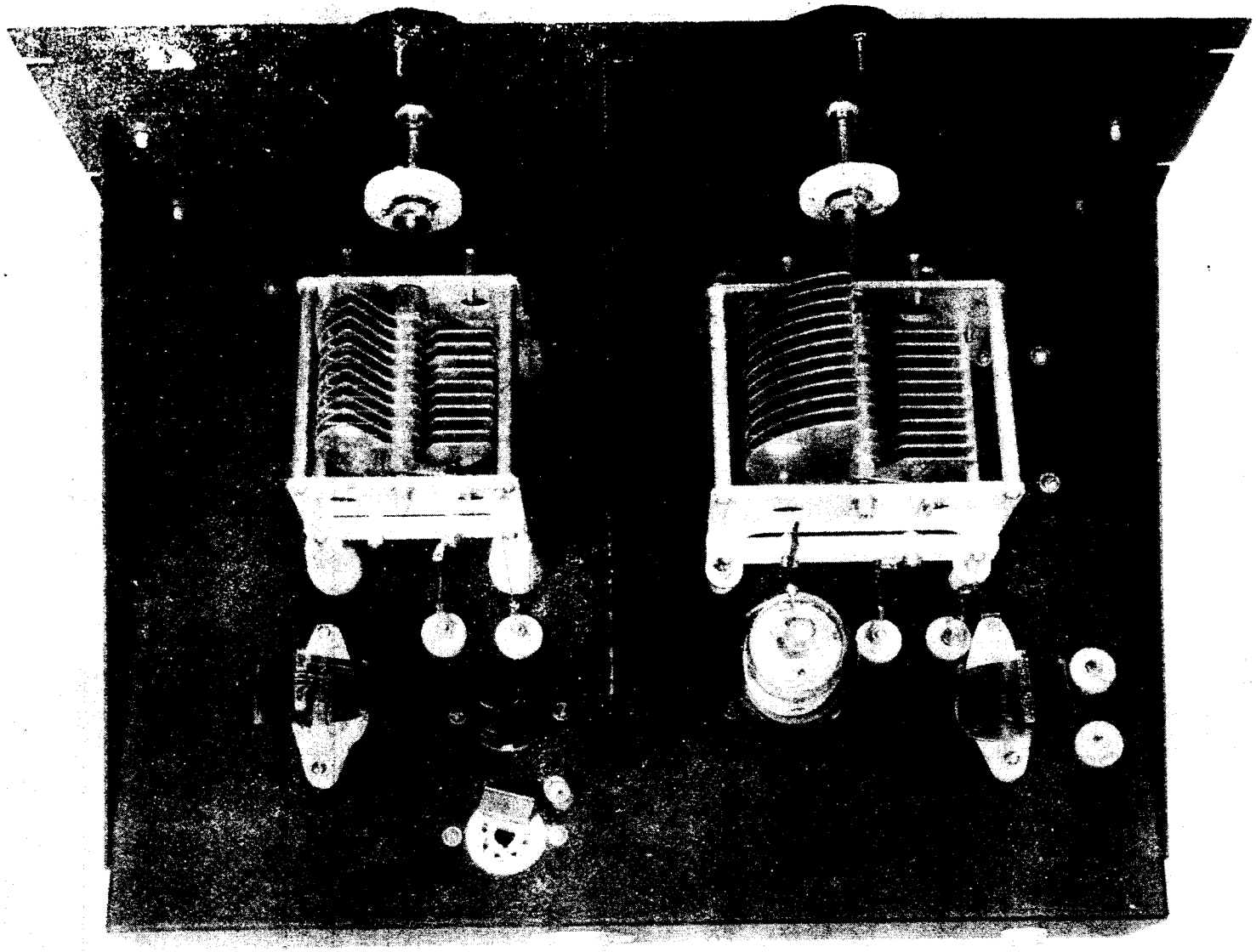


FIG. 18—TOP VIEW OF TRANSMITTER TYPE B OSCILLATOR-BUFFER STAGE. COILS ARE THE PLUG-IN TYPE.

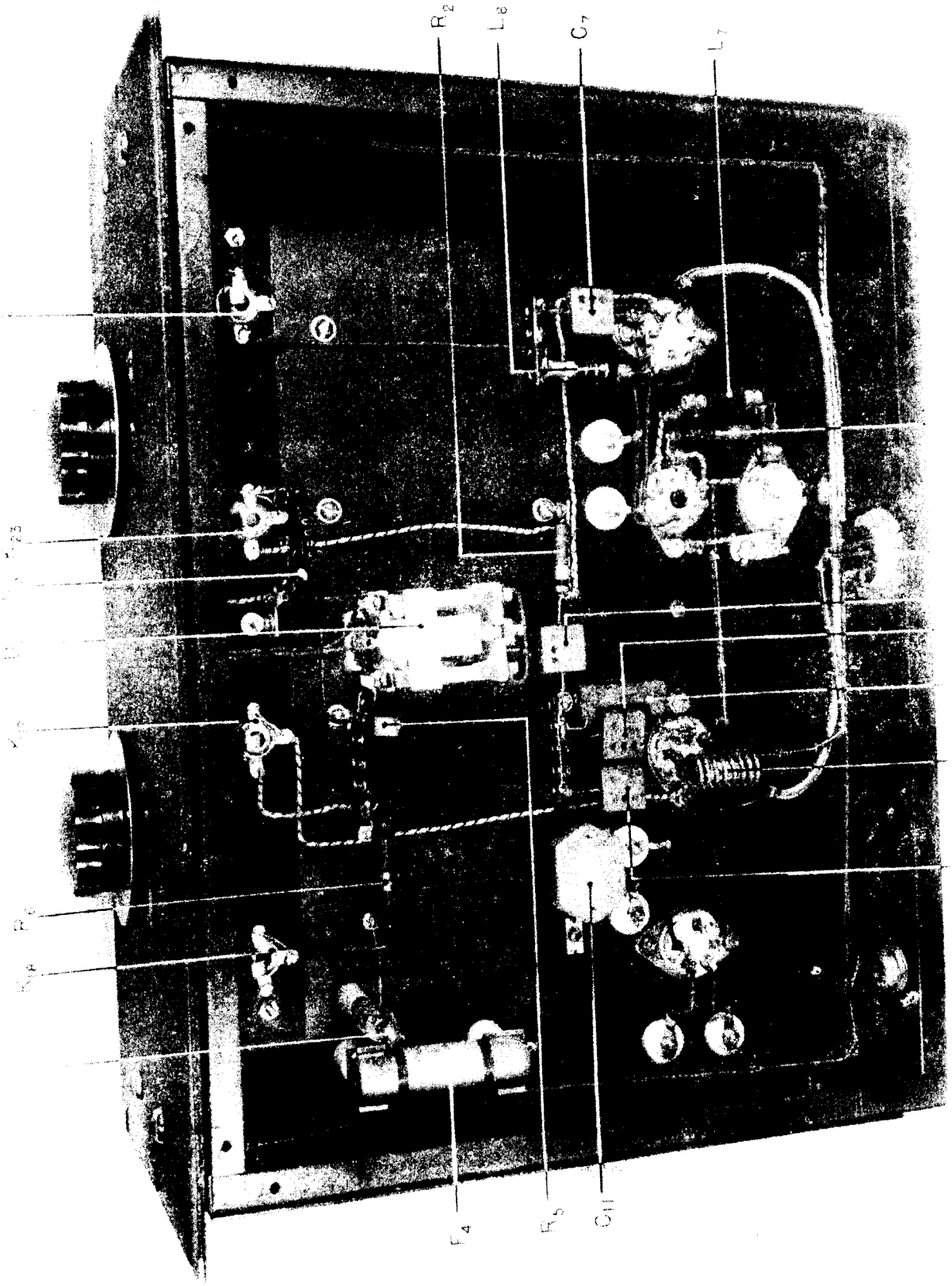
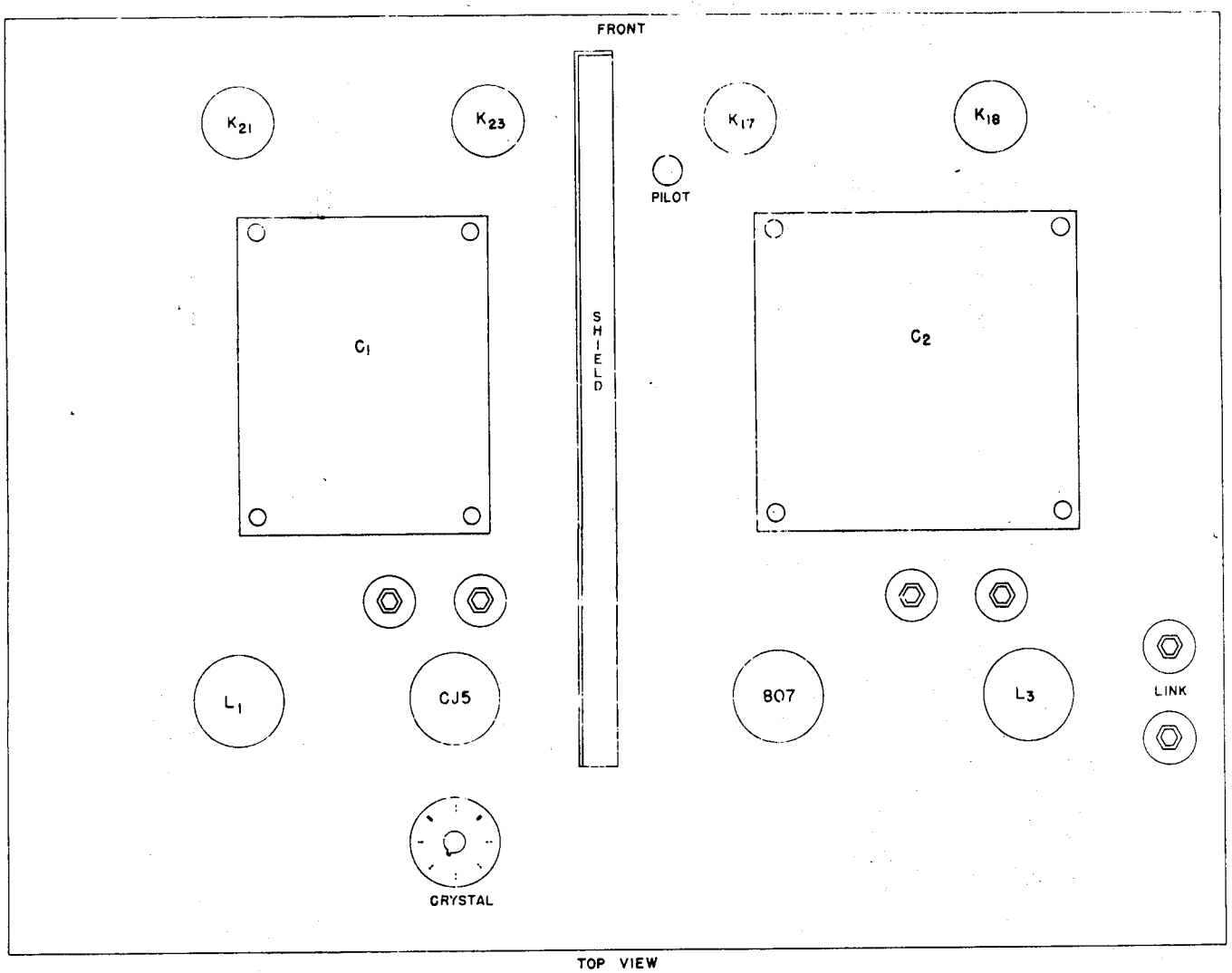


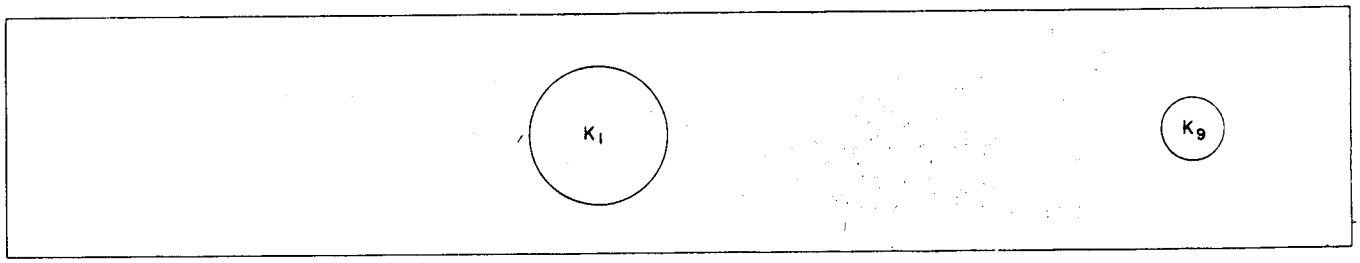
FIG. 3 — BOTTOM VIEW OF TRANSM

TRANSMITTER TYPE 8

OSCILLATOR - BUFFER STAGE



TOP VIEW



BACK VIEW

FIG. 20

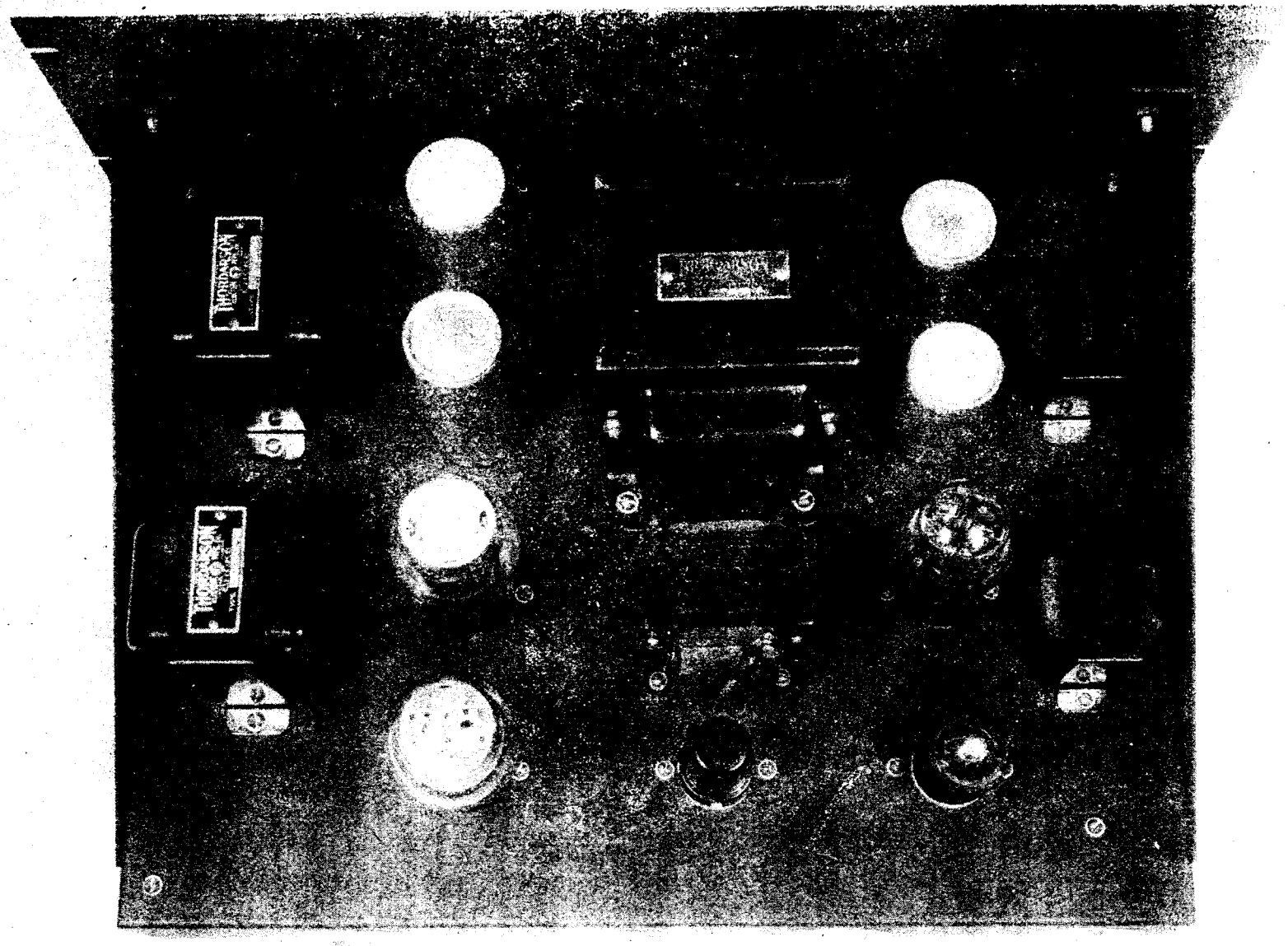
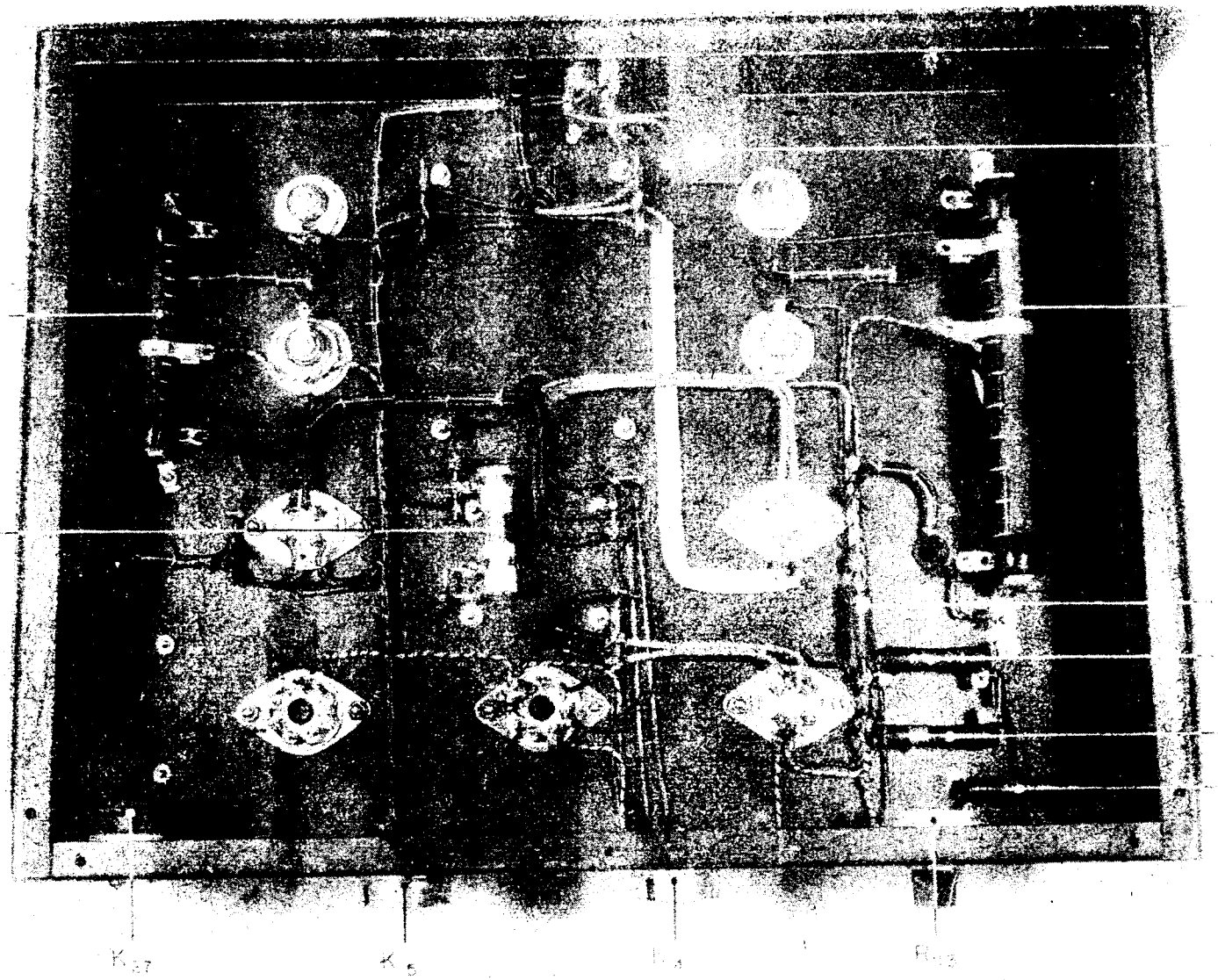
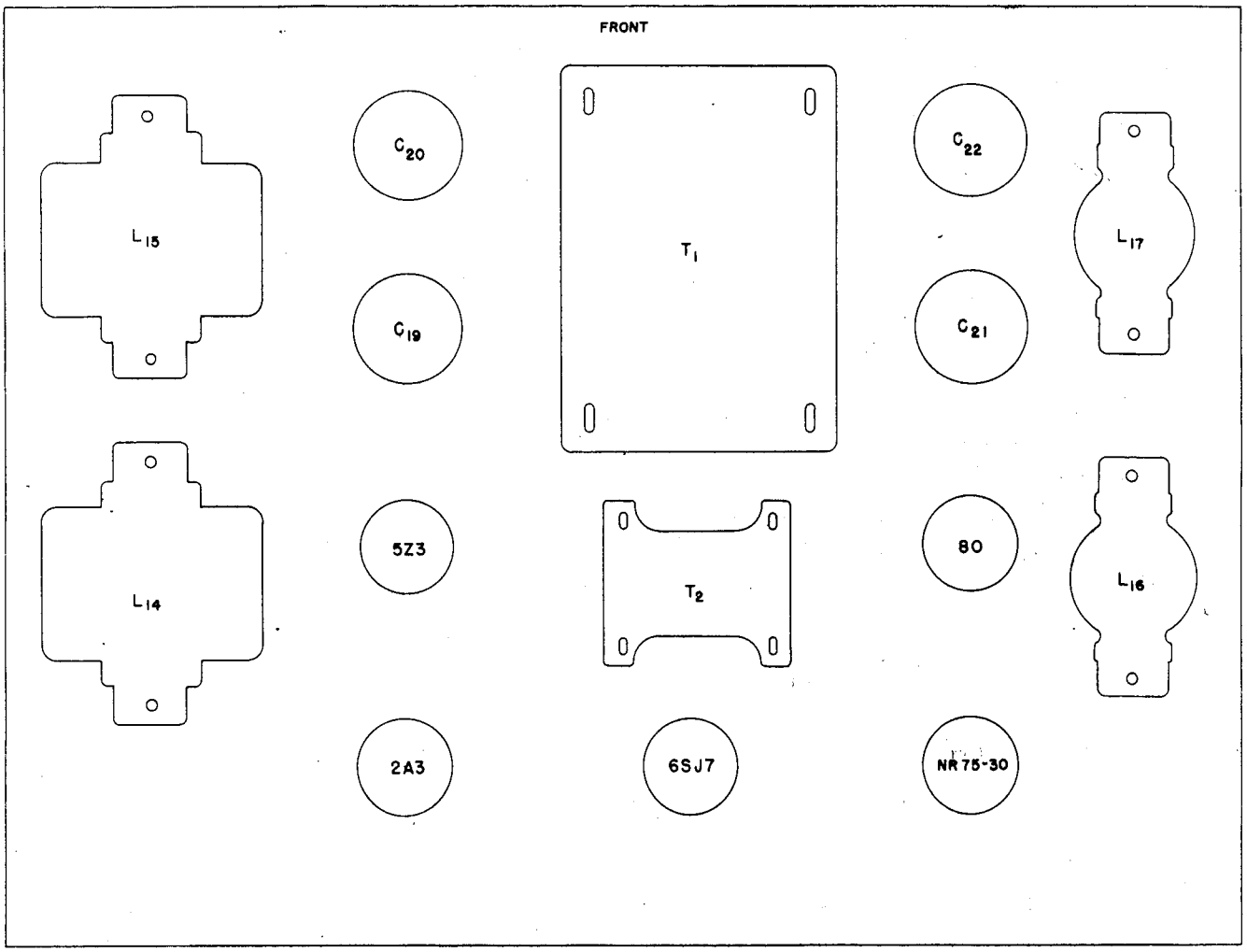


FIG. 21— TOP VIEW OF TRANSMITTER, TYPE [illegible]

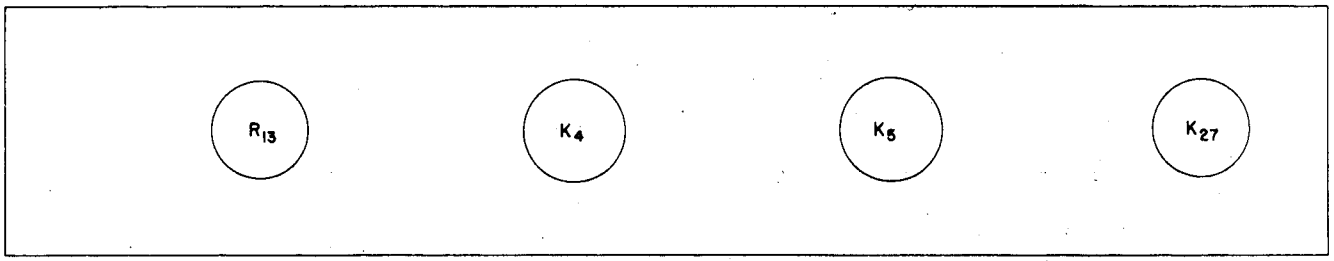


IG 22 - BOTTOM VIEW OF TRANSMITTER TYPE B LOW VOLTAGE POWER SUPPLY

TRANSMITTER TYPE B
LOW VOLTAGE POWER SUPPLY



TOP VIEW



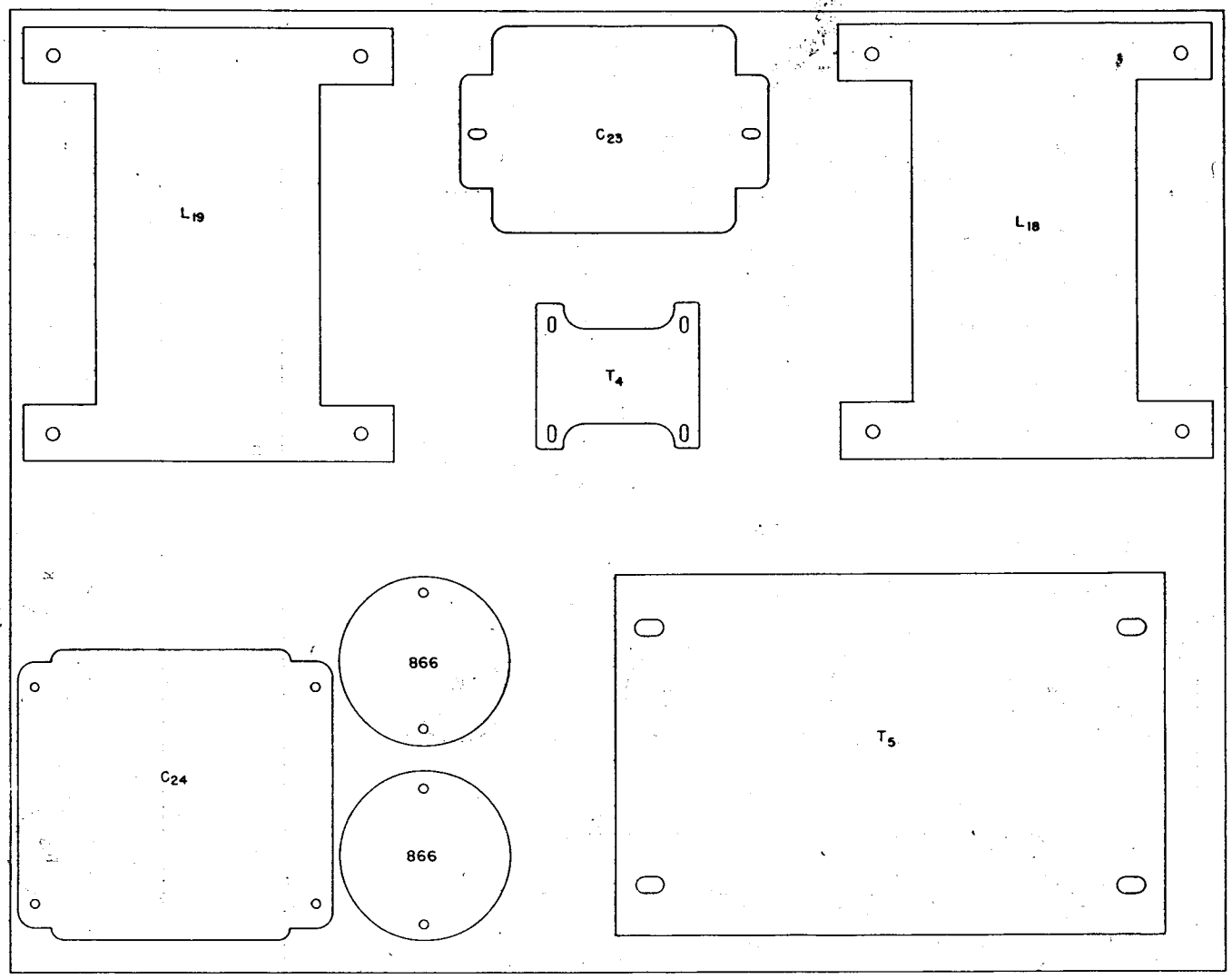
BACK VIEW

FIG. 23

TRANSMITTER TYPE B

HIGH VOLTAGE POWER SUPPLY

TOP VIEW



TOP VIEW

FIG. 24

TRANSMITTER TYPE B

ANTENNA TUNING UNIT

TOP VIEW

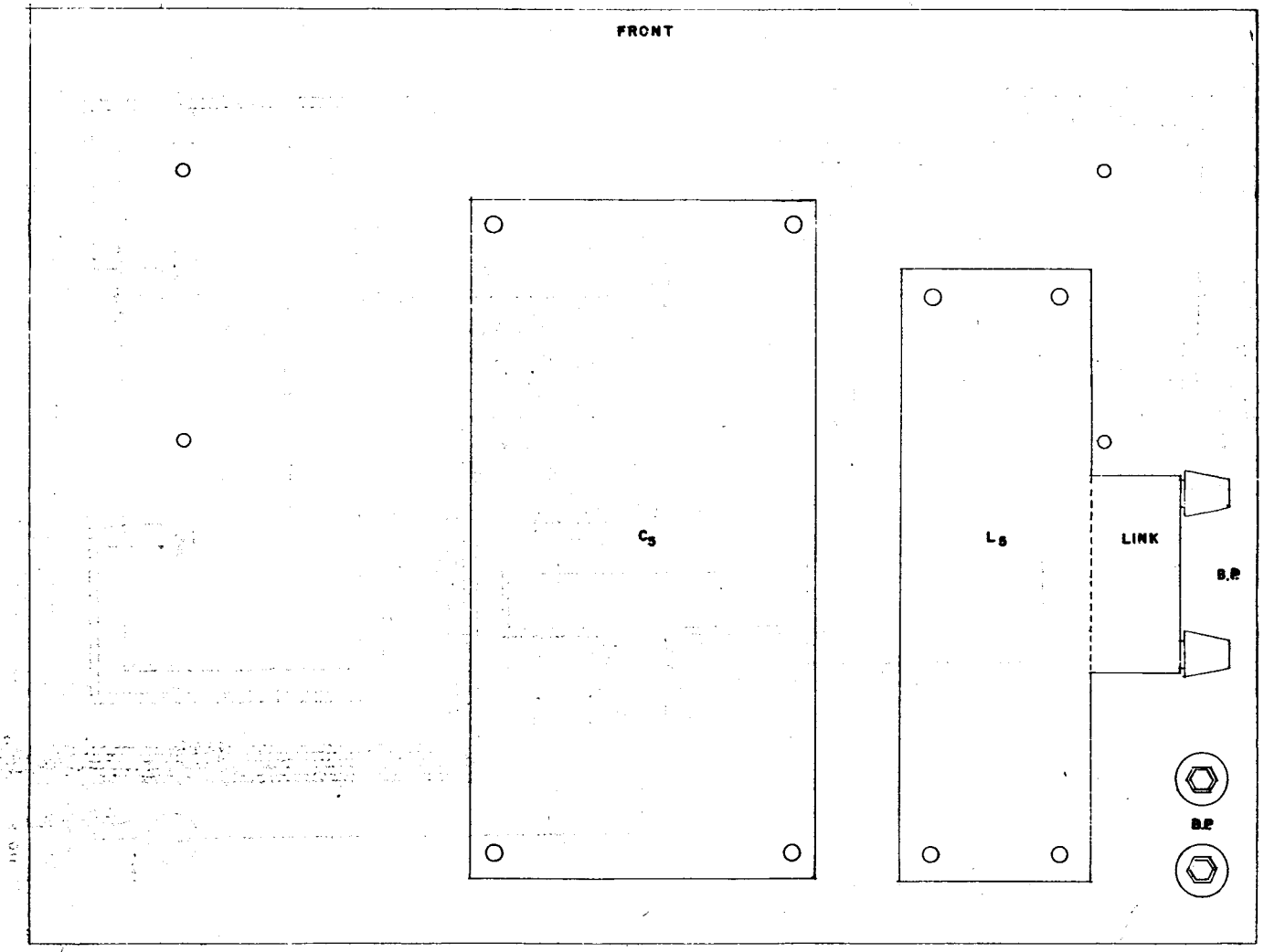


FIG. 25

WWI - Control Equipment

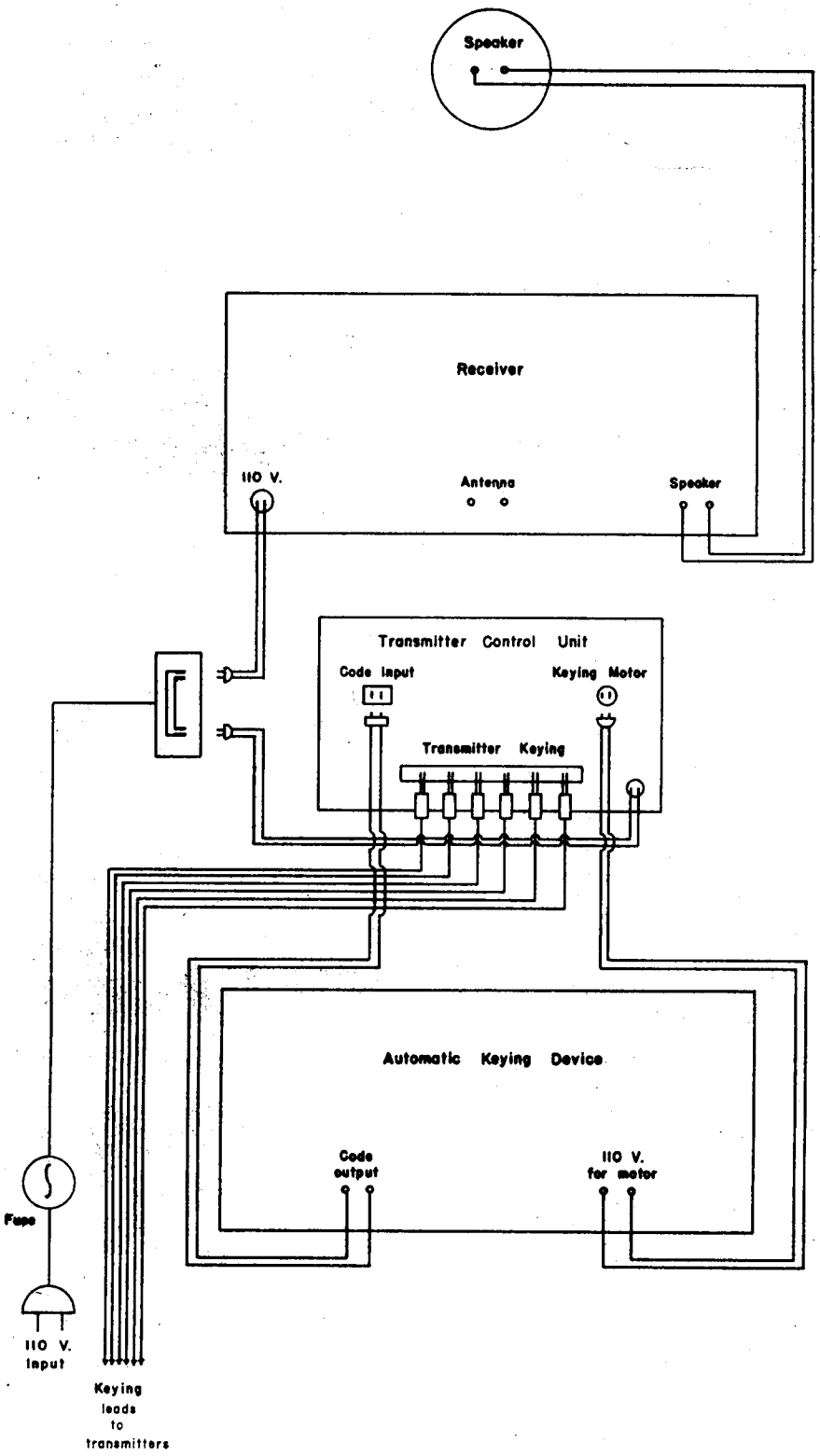


FIG. 26

CONTROL EQUIPMENT CABINET LAYOUT

SCALE 1" = 8"

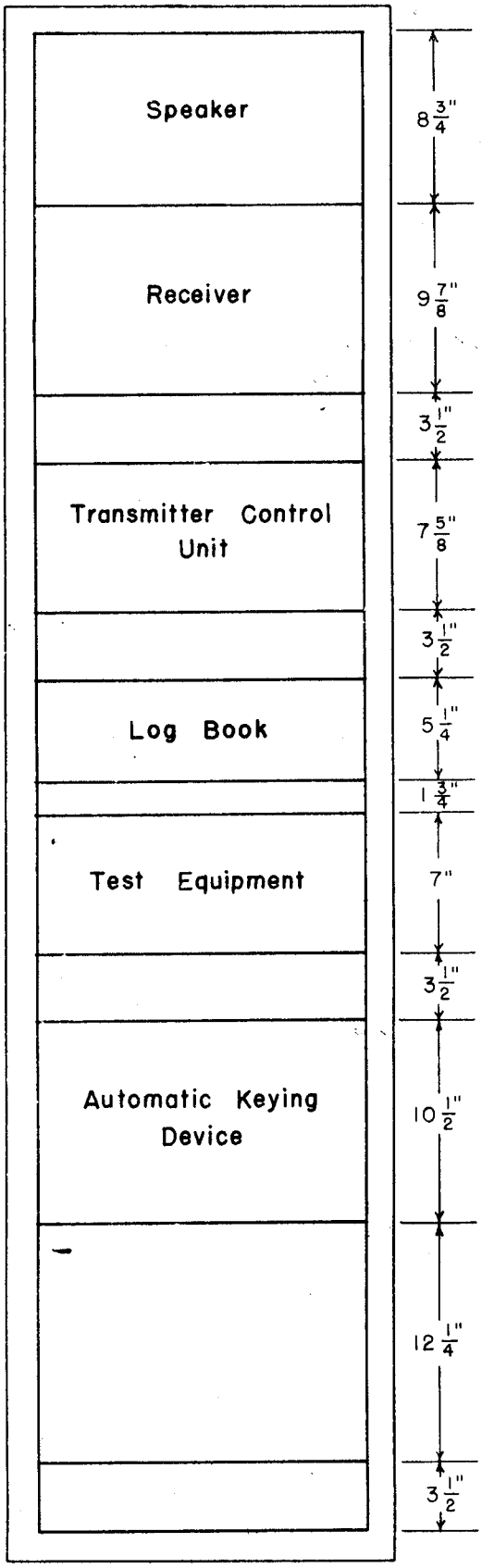


FIG. 27

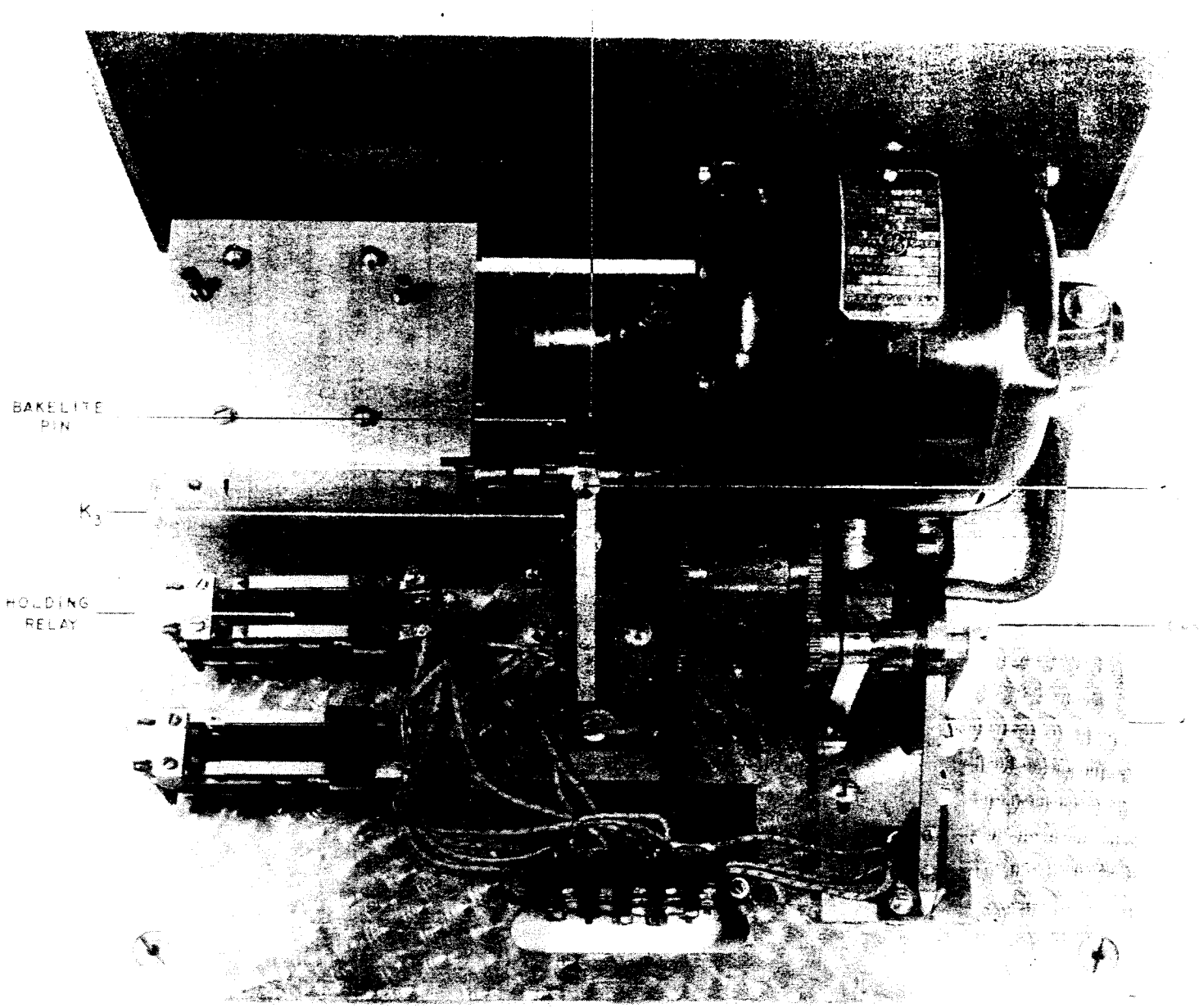


FIG. 28 — AUTOMATIC KEYING DEVICE

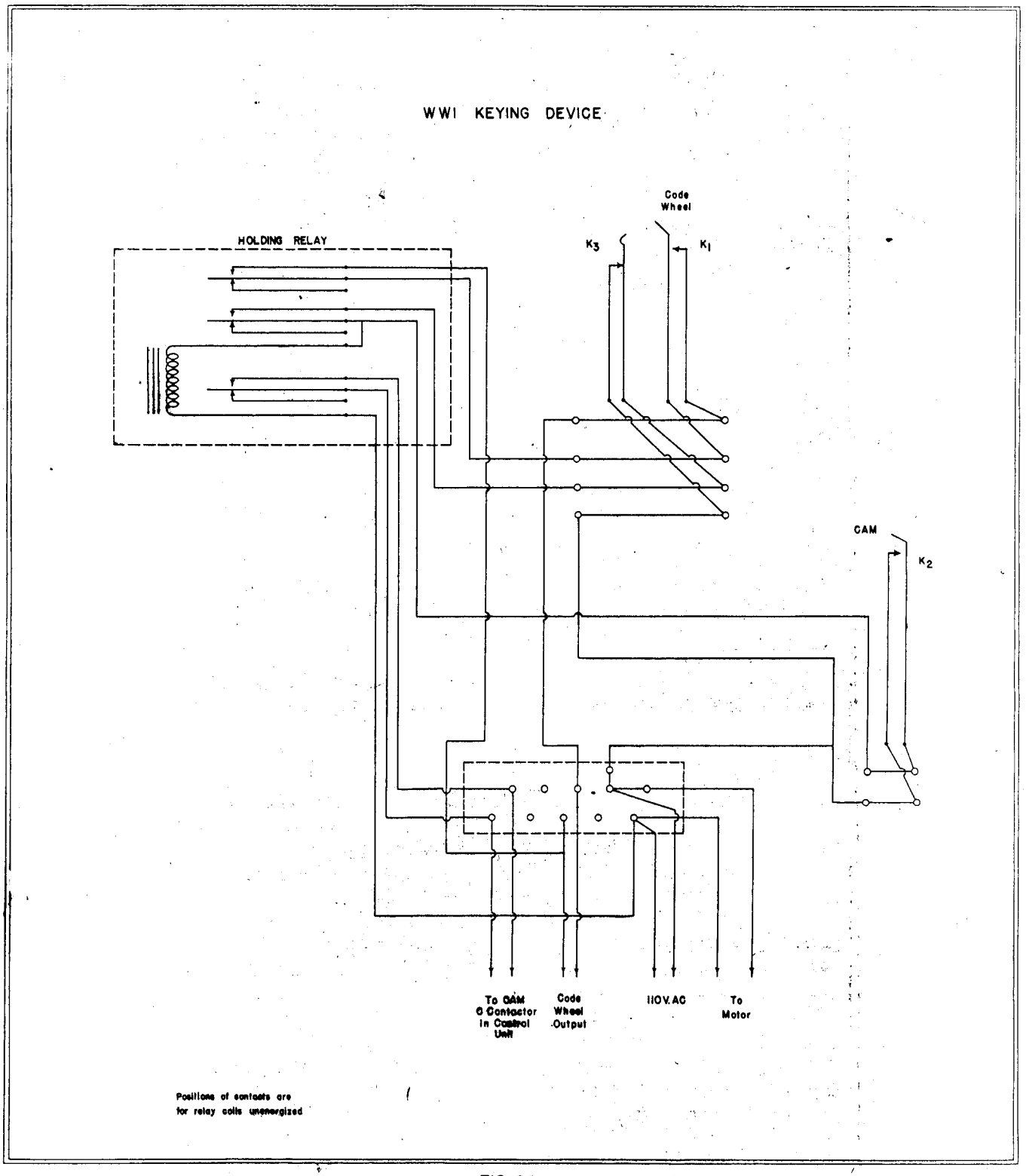

WWI KEYING DEVICE
HOLDING RELAY
Code Wheel
K3
K1
CAM
K2
To CAM & Contactor in Control Unit
Code Wheel Output
110V.AC
To Motor
Positions of contacts are for relay coils unenergized

FIG. 29

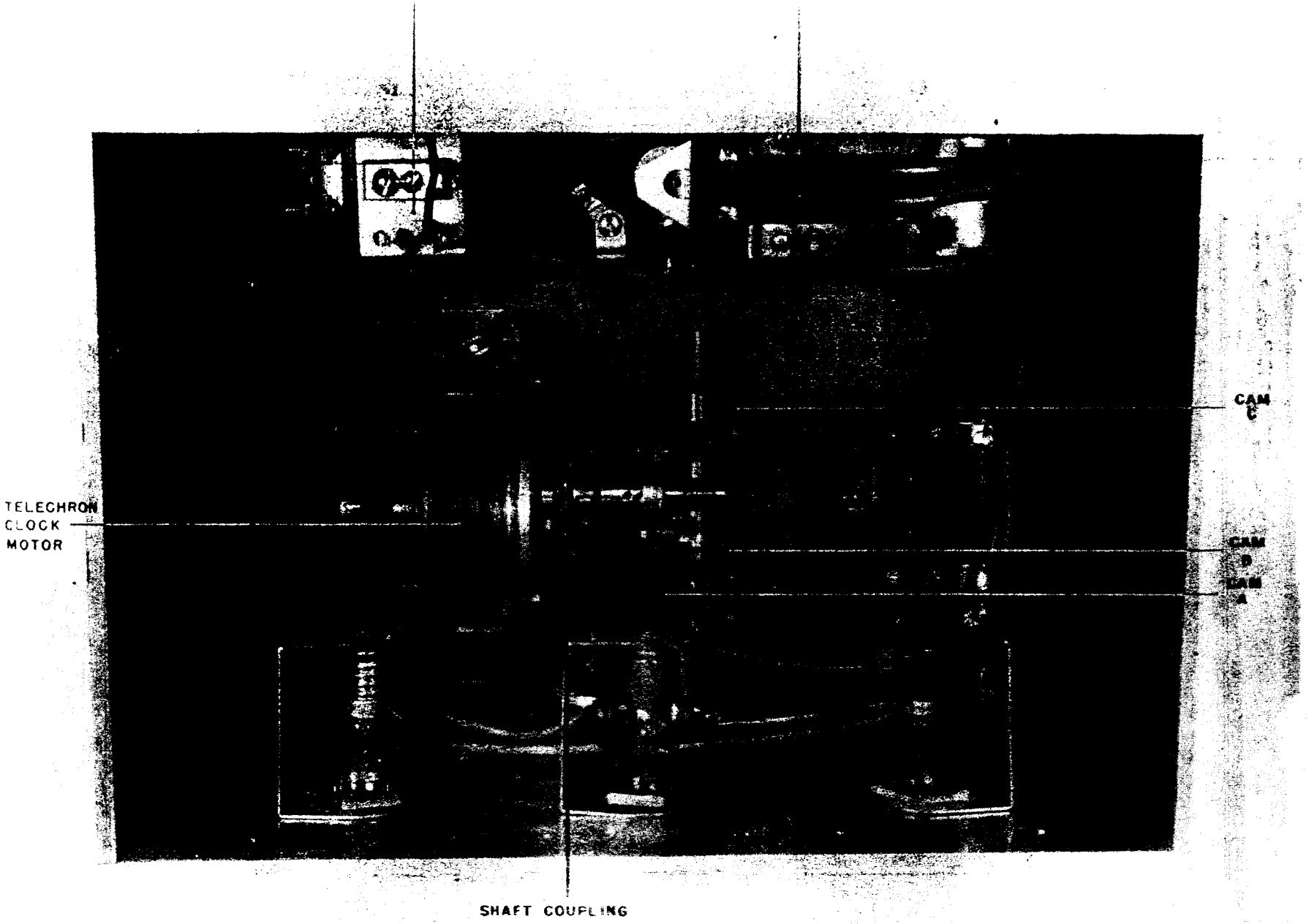


FIG. 30. - TRANSMITTER CONTROL UNIT

TRANSMITTER CONTROL UNIT

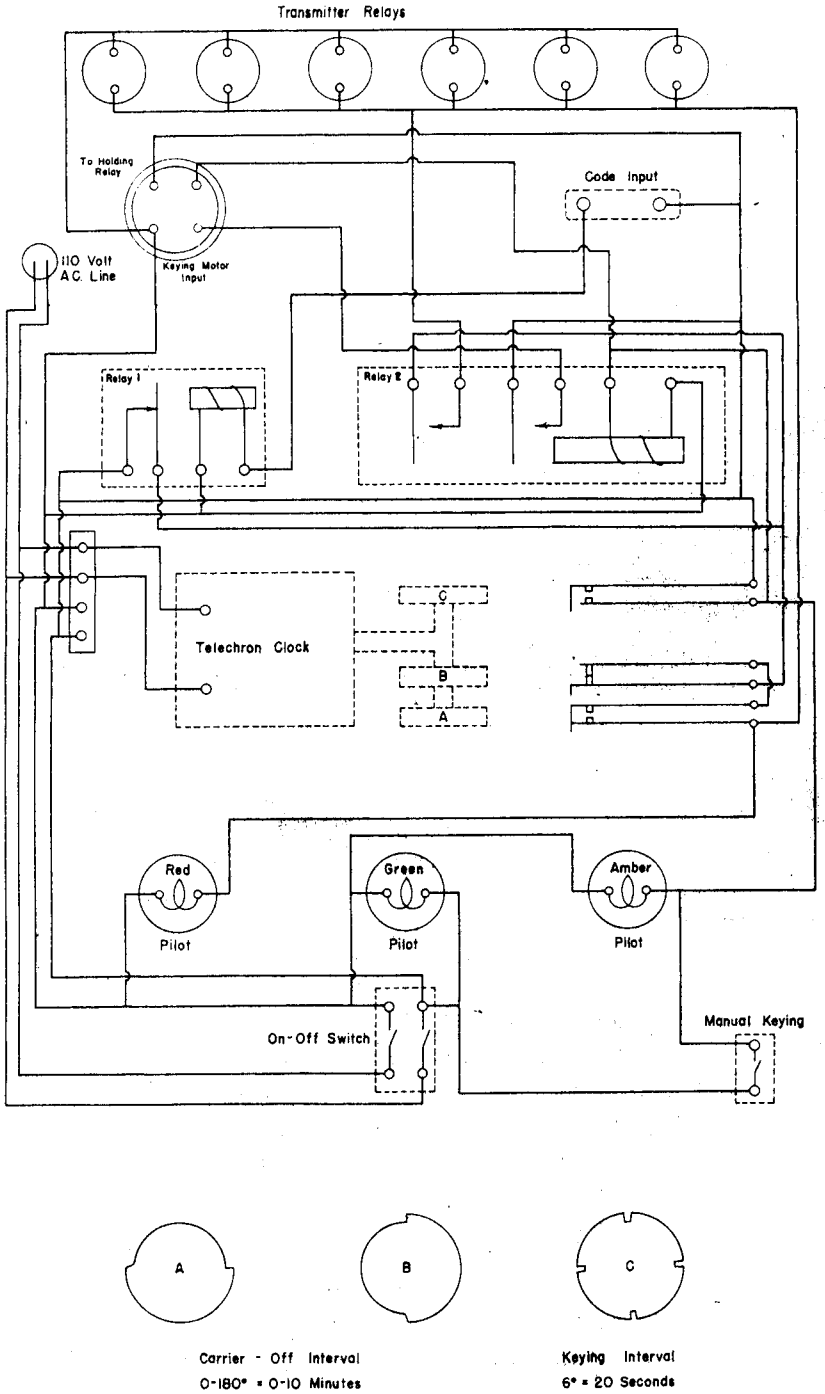


FIG. 31

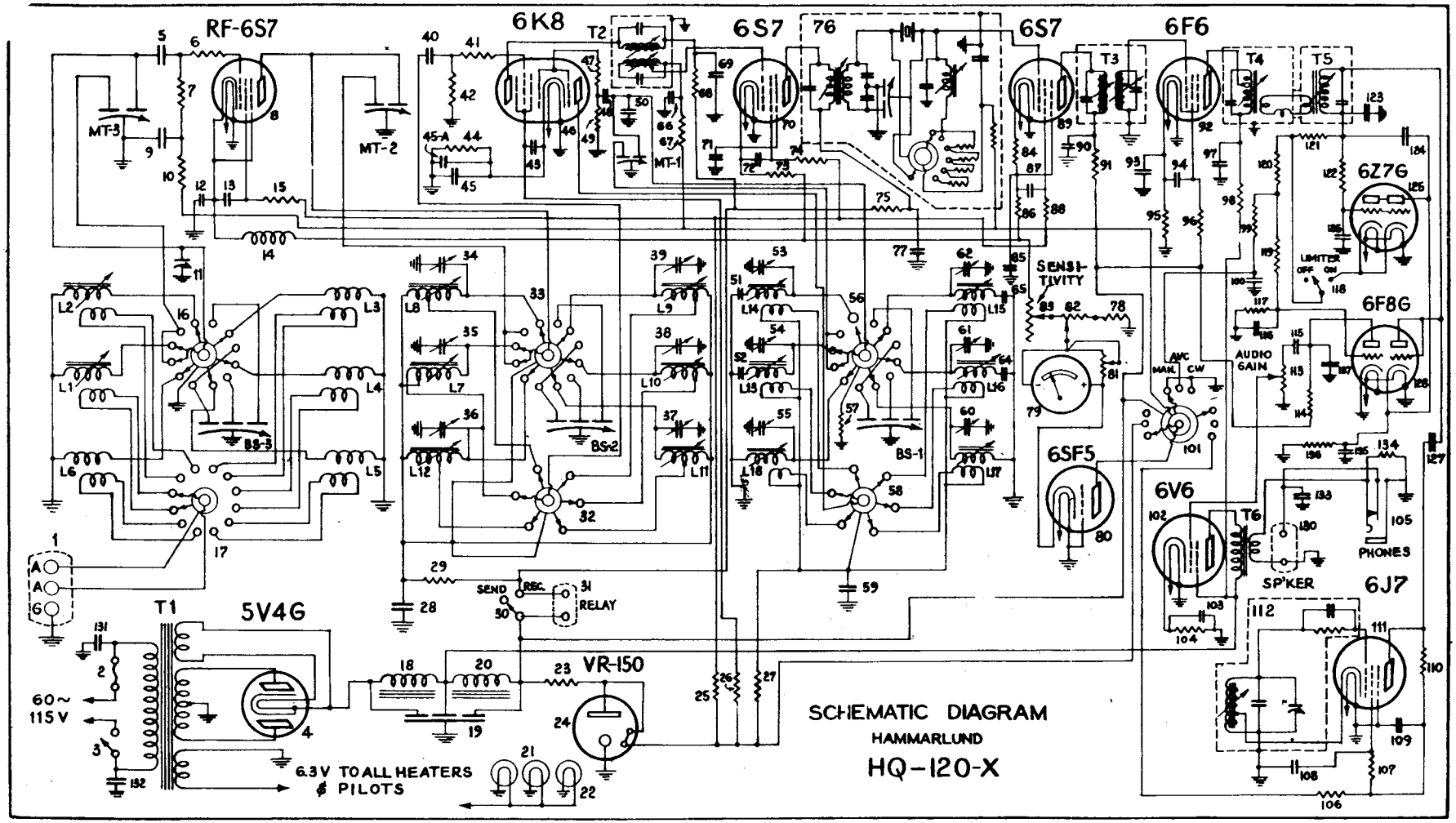

RF-6S7
6K8
6S7
6S7
6F6
T1
T2
T3
T4
T5
T6
5V4G
6SF5
6V6
6Z7G
6F8G
6J7
VR-150
MT-1
MT-2
MT-3
BS-1
BS-2
BS-3
SENSITIVITY
AUDIO GAIN
AVC MAN. CW
LIMITER OFF ON
SEND REC.
RELAY
PHONES
SP'KER
60~ 115V
6.3V TO ALL HEATERS & PILOTS
SCHEMATIC DIAGRAM
HAMMARLUND
HQ-120-X

FIG. 32

WWI LOG SHEET

Transmitter No. ________ Frequency (kc/s) ________

			Trans. Line		Power Amplifier					Buffer			Osc.		
Date	Time EWT	Observer	No.1 (amp)	No.2 (amp)	Ip (ma)	Ep volts	Isg (ma)	Ig (ma)	Ef volts	Ip (ma)	Isg (ma)	Ig (ma)	Ip (ma)	Keying check	Remarks on back

FIG. 33

WWI POWER WIRING

110 Volt Three Phase - Four Wire System

Maximum Load - 35 Amperes per phase

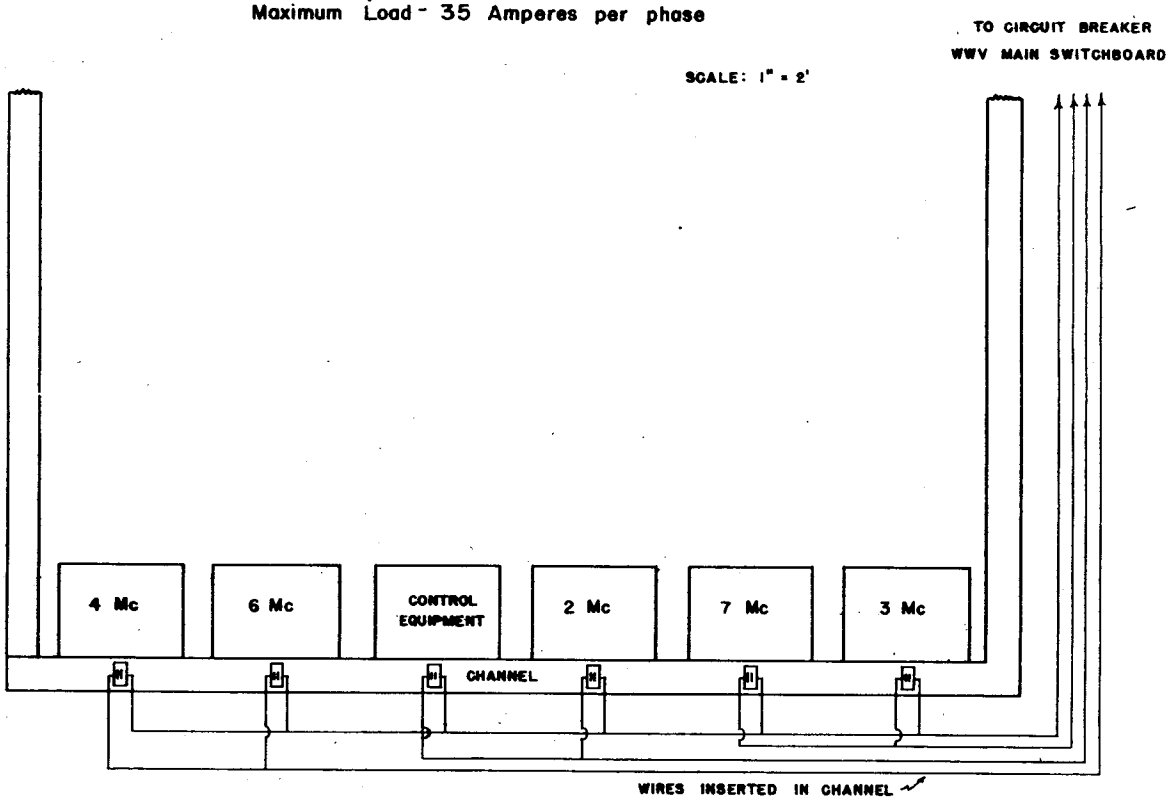
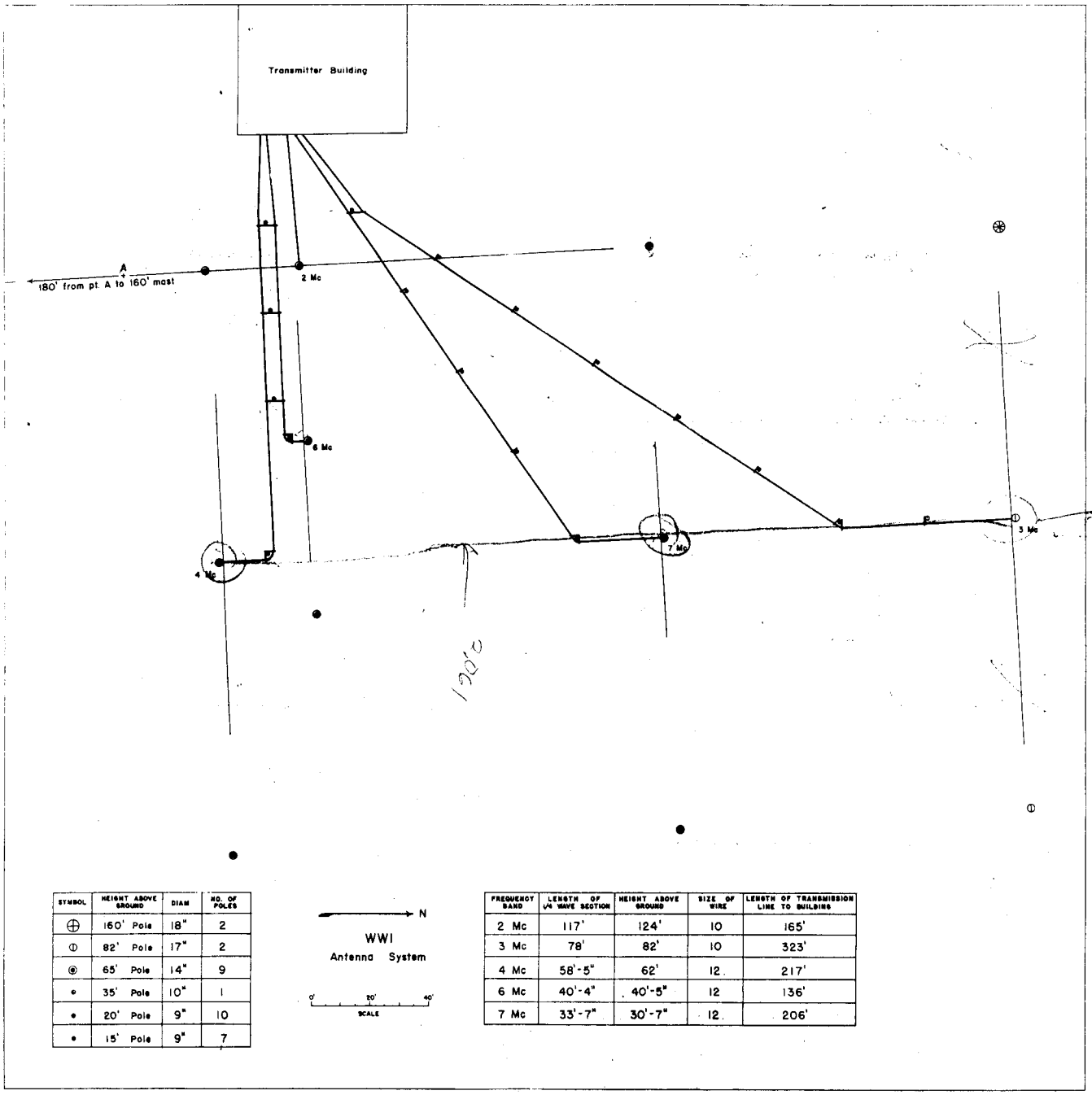


FIG. 34



SYMBOL	HEIGHT ABOVE GROUND	DIAM	NO. OF POLES
⊕	160' Pole	18"	2
⊙	82' Pole	17"	2
◉	65' Pole	14"	9
◦	35' Pole	10"	1
•	20' Pole	9"	10
•	15' Pole	9"	7

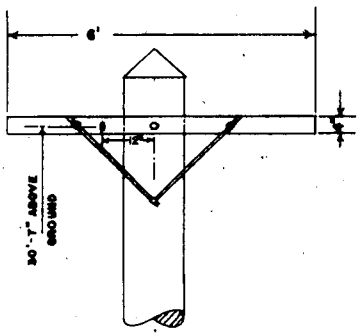
N

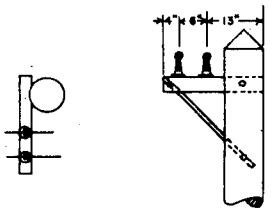
WWI
Antenna System

0' 20' 40'
SCALE

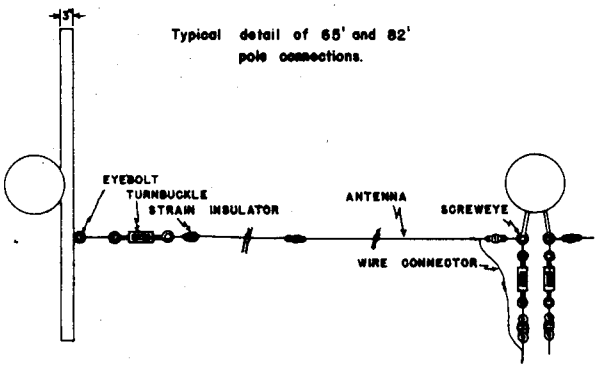
FREQUENCY BAND	LENGTH OF 1/4 WAVE SECTION	HEIGHT ABOVE GROUND	SIZE OF WIRE	LENGTH OF TRANSMISSION LINE TO BUILDING
2 Mc	117'	124'	10	165'
3 Mc	78'	82'	10	323'
4 Mc	58'-5"	62'	12	217'
6 Mc	40'-4"	40'-5"	12	136'
7 Mc	33'-7"	30'-7"	12	206'

FIG. 35

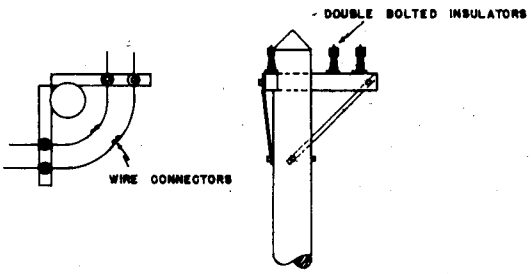




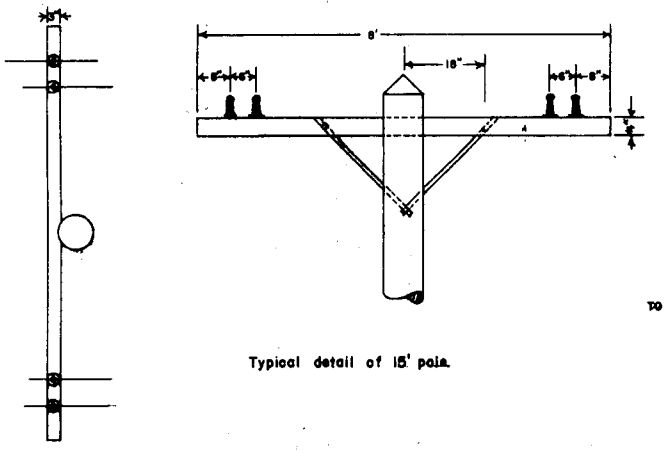
Typical Detail of 20' pole



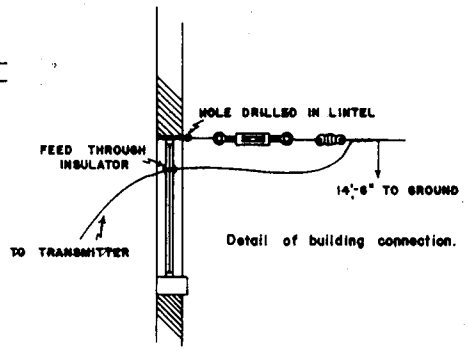
Typical detail of 65' and 82' pole connections.



Typical corner pole.



Typical detail of 15' pole.



Detail of building connection.

Construction
Details of
WWI
Antenna System.

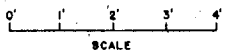


FIG. 36

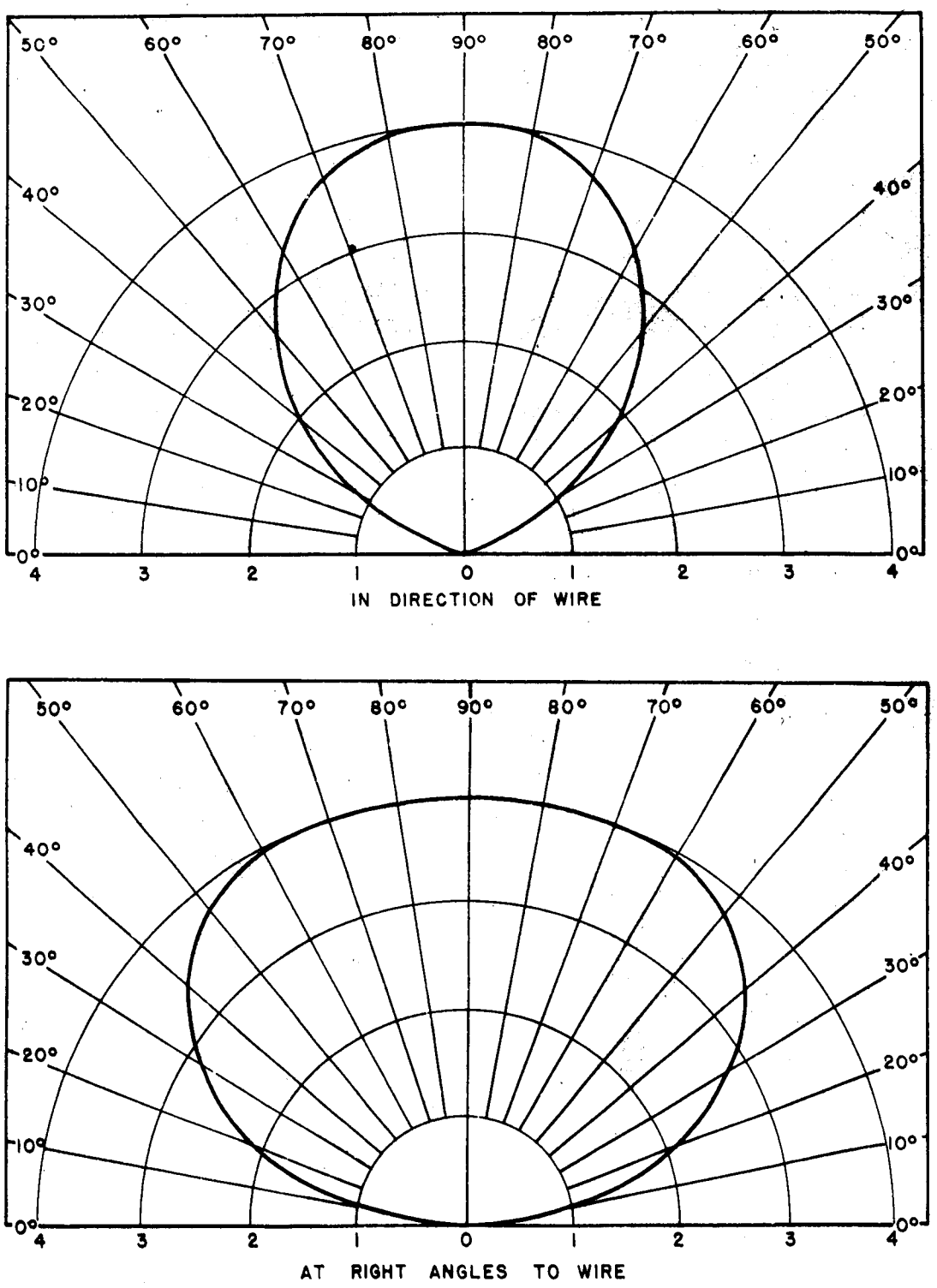


FIG. 37. THEORETICAL VERTICAL PLANE RADIATION PATTERN OF THE $\frac{1}{2}$ WAVE DOUBLET ANTENNAS $\frac{1}{4}$ WAVE ABOVE GROUND.

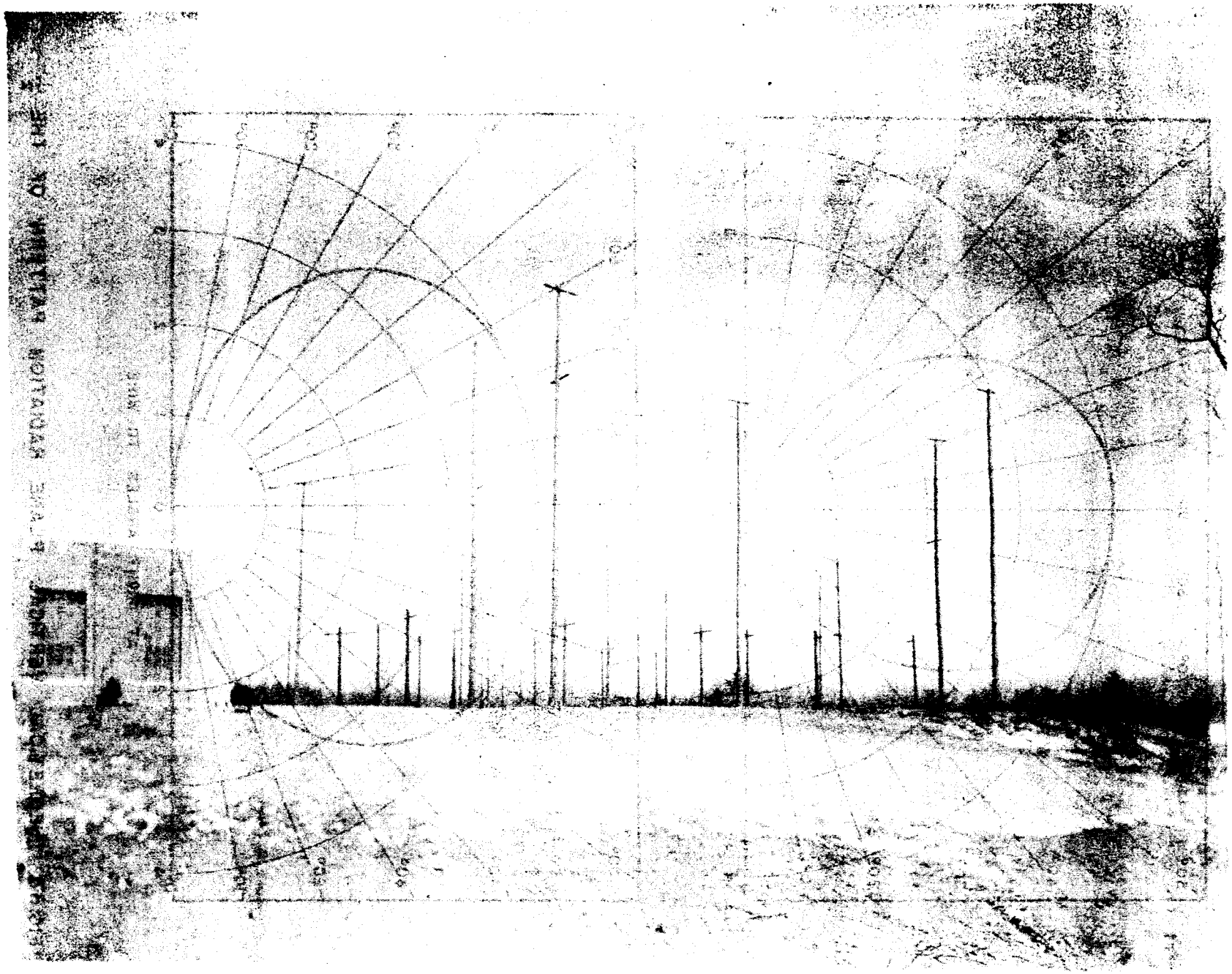


FIG. 38 - OVERALL VIEW OF ANTENNA SYSTEM SHOWING END OF TRANSMITTER BUILDING ON THE LEFT

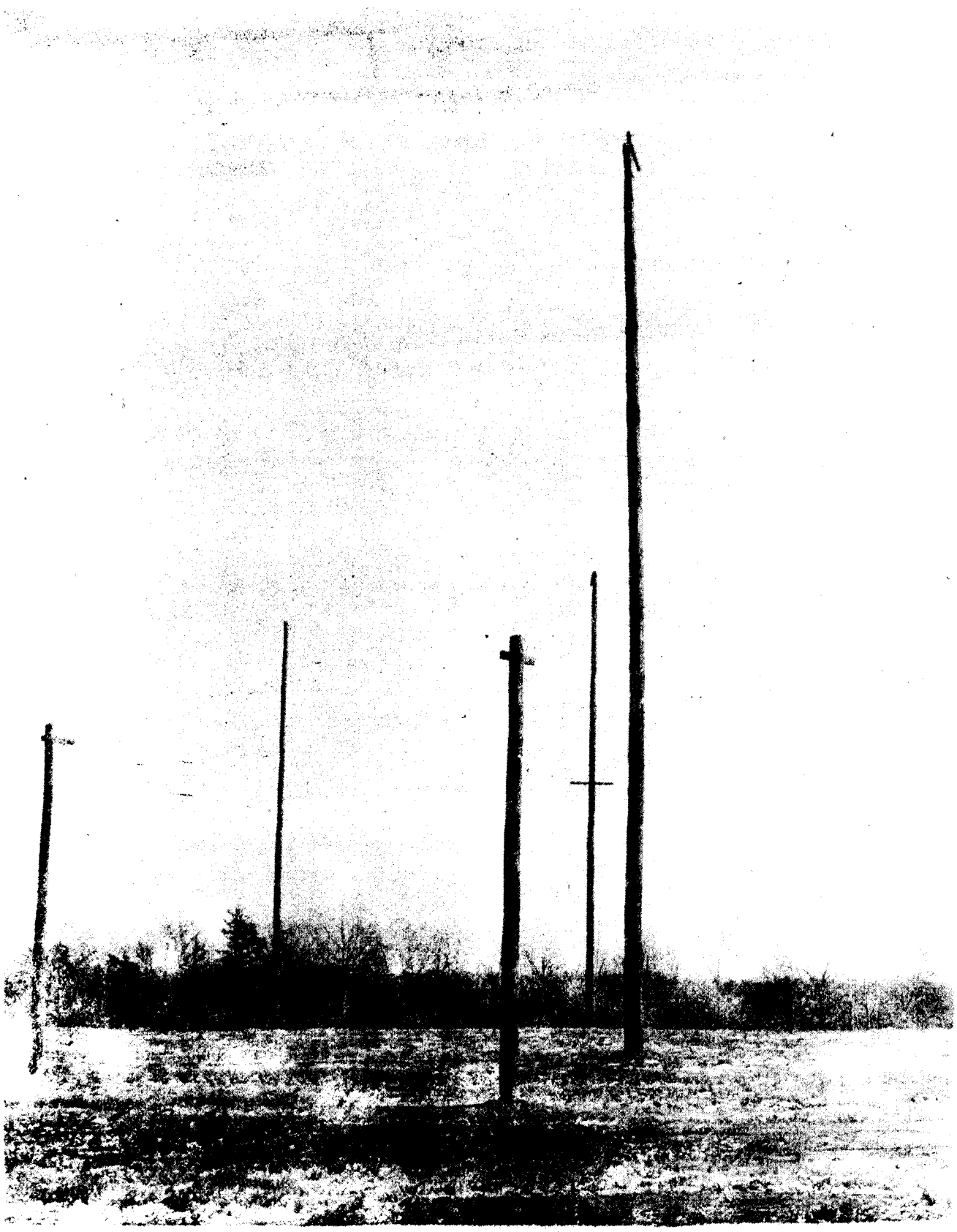


FIG. 39—VIEW SHOWING CONNECTION OF THE 2 MEGACYCLE TRANSMISSION LINE TO ANTENNA

FIG. 40—VIEW OF ANTENNA SYSTEM TAKEN FROM THE TOP OF THE TRANSMITTER BUILDING. TRANSMISSION LINES ARE SUPPORTED ON THE WOOD POLES.