# Automatic ionosphere recorder

National Research Council of Canada. Radio Branch

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NATIONAL RESEARCH COUNCIL OF CANADA

ELECTRICAL ENGINEERING AND RADIO BRANCH

# AUTOMATIC IONOSPHERE RECORDER



OTTAWA

JUNE, 1946

# AUTOMATIC IONOSPHERE RECORDER

## PRA-132

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NATIONAL RESEARCH COUNCIL OF CANADA

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# AUTOMATIC IONOSPHERE RECORDER

## I

## GENERAL DESCRIPTION

A.I.R. is an Automatic Ionosphere Recorder which measures the virtual heights of the ionosphere layers, from 40 Km. to 1000 Km. over a frequency range of 1 mc. to 16 mc. A camera takes a six inch record on 35 mm. film, a complete sounding of the ionosphere taking just over two minutes.

Three modes of operation are provided: manual, clock, or continuous. With clock operation, records can be taken at 5, 15, 30 or 60 minute intervals.

### Physical Dimensions

The complete recorder consists of two racks, the camera unit, and the clock with its selector box. (See Photo. 1 and Fig. 1).

| | | | | | | |
|---|---|---|---|---|---|---|
| Rack 1 measures | 48" high | by 20" wide | by 22" deep, | weight | approx. 300 lb. |
| Rack 2 " | 26" " | " 20" " | " 22" " , | " | approx. 150 lb. |
| Camera, (Unit F) | 11" " | " 25" " | " 25" " , | " | approx. 100 lb. |

Rack 1 contains the transmitter, receiver and associated power supply.
Rack 2 contains the scanner chassis " " " "
The Camera unit consists of the camera, camera scope and film cassette.

### Power Requirements

The equipment will operate from 100 to 125 volts 60 cycles, but operates best at 117 volts and draws approximately 12 amperes. For mobile use Onan 2 K.V.A. gas electric plants supply the power.

### Power Output and Sensitivity

The transmitter works into an antenna load of approximately 550 ohms and has a power output of up to 3 kw. peak. The pulse width is variable from 50 to 100 microseconds. The receiver has a bandwidth of 20 kc. and a power sensitivity of 10 microvolts for twice noise level.

Height Measuring System

Echoes from the ionosphere appear as blank spots on the sweep line of the camera C.R. tube. The height measuring scale is a linear series of narrow blank spots at 50 Km. intervals on the same sweep line. When the image of this sweep is focused on 35 mm. film being drawn past the lens at a constant speed the blank spots produce white lines on the resulting negative. Frequency markers are produced by mechanically blanking the sweep at logarithmic intervals.

The final record is a grid with horizontal height lines at 50 Km. intervals and vertical logarithmic frequency markers dividing each band into ten divisions. The height and critical frequency of an ionospheric layer can thus be easily determined.

## II

## CIRCUIT DESCRIPTION

(a) Transmitter Chassis (Unit A, Rack#1) - See Fig. 3.

(i) The transmitting tubes V1 and V2 are 152TH's and form a push-pull Hartley oscillator. The grid to plate feedback condensers are the vacuum type, to withstand the high voltage.

(ii) The modulator is two 807's, V4 and V5, in parallel, cathode modulating the transmitter. The 807's are driven by V3, a 6SN7 Kipp relay, which is triggered by a positive pip from the multivibrator in Unit D, rack #2.

The grids of the transmitter tubes are at ground potential and the cathodes are held at +600 volts. This keeps the transmitter cut off until the modulator pulse drives the cathodes to nearly ground potential, allowing the transmitter to oscillate for the duration of the modulator pulse. The filament transformer for V1,V2, is of the low capacity to ground type, which presents only a small load across the modulator.

The pulse power for the transmitter is taken from C3, which is connected between plate and cathode of the transmitter, in order that the transmitter current does not have to pass through the modulator tubes.

(iii) V6 and V7 form a transmit-receive switch, permitting the use of a single antenna for both transmitting and receiving. This T-R switch consists of two tubes used as cathode followers isolating the receiver input from the antenna, during pulses, due to the self-biasing action of the grids. Incoming signals can be received with only about a 10% decrease in gain compared to a separate antenna.

(b) Receiver-Motor Control Chassis (Unit B, Rack #1) See Fig. 5.

(i) Tube functions

V1 - R.F. Amplifier
V9 - local oscillator
V2 - mixer
V3 - 1st I.F. amplifier 455 kc.
V4 - 2nd " " " "
V5 - 3rd " " " "
V6 - 2nd detector-differentiator
V7 - video amplifier
V8 - voltage regulator for oscillator
V10 - resistance coupled buffer between Osc. V9 and receiver mixer V2.
V11 - " " " " " " " motor-control mixer V12.
V12 - Untuned mixer to motor control
V13 - I.F. amplifier for motor control 455 kc.
V14 - discriminator
V15 - first section - voltage amplifier.
second section in parallel with first section V16- infinite impedance detector.
V16 - second section - A.F. amplifier.
V17 - V18 - push pull 60 cy. amplifier driving transmitter - condenser motor.

(ii) Receiver

The receiver is a conventional superhet. with one R.F. stage and a 20 kc. broad-band I.F. channel. Differentiation is provided in the 2nd detector to show only the leading edge of echoes and give a clearer photographic record. No A.V.C. is used.

The two buffer stages V10 and V11 provide isolation between the receiver mixer and the motor control mixer and also load the local oscillator as little as possible.

(iii) Motor Control

In the motor control a probe near the antenna feeds some transmitter R.F. to grid No.3 of V12, and R.F. from the local oscillator V9 is fed through buffer V11 to grid No.1 of V12. These two R.F. signals mix in V12 and when their frequency difference is approximately 455 kc., that of I.F.T. No.5, a voltage is fed to the control grid of V13, the motor control I.F. amplifier. I.F.T. No.5 has a band width of approximately 20 kc.

The output of V13 is fed into the paralleled primaries of I.F.T. No.6 and I.F.T. No.7. I.F.T. No.6 is peaked at 448 kc. and I.F.T. No.7 is peaked at 462 kc. each being 7 kc. on either side of 455 kc. V14 is a duo-diode frequency discriminator with one plate connected to the output of I.F.T. No.6 and the other plate to the output of I.F.T. No.7.

The output of the discriminator is amplified by V15, detected by V15 and V16 and finally appears as a variable D.C. bias on grid No.2 of V16. Some 60 cy. is also fed into grid No.2 of V16, is amplified, and drives the pair of 6V6's, whose output is coupled to the field of the "drag-cup" transmitter-condenser drive motor.

(iv) The Receiver-Transmitter following sequence

The motor follower control, a pot. controlling the gain of V16, is adjusted so that the transmitter-condenser motor drives the trans-cond. at a little under 1 R.P.M. The receiver condenser drives at 1 R.P.M. and since the receiver frequency at the start of each band is slightly lower than the transmitter frequency, the receiver "catches" the transmitter frequency and the motor control "latches on" before the camera starts to record. The recorded frequency ranges on the four bands are 1-2, 2-4, 4-8, and 8-16 mc, but there is an overlap at each end of each band and it is in this overlap section at the beginning of each band that the receiver overtakes the transmitter in frequency. A cam-driven switch on the receiver condenser shaft controls the camera recording period. If the transmitter frequency is lower than that of the receiver, the resultant I.F. frequency fed through I.F.T. No. 5 to I.F.T. No.6 and No.7, is greater than 455 kc. and I.F.T. No. 7 produces the most voltage through its side of the discriminator diode and finally drives grid No.2 of V16 more positive, thus driving the transmitter-condenser motor faster and picking up the frequency lag between transmitter and receiver.

The reverse action is true to a lesser degree when the transmitter frequency is higher than the receiver frequency.

(c) Power Supply for Transmitter, Receiver and Motor Control
Unit C. Rack #1.

The power supplies shown in Fig. 6 are quite conventional. It will be noted that a 300 volt regulated supply is provided to furnish well regulated power to the critical stages of the receiver and motor control.

(d) Scanner Chassis. Unit D, Rack #2. See Fig. 7.
This chassis contains 17 tubes and one C.R.T.

(i) Multivibrator

V1 & V2 form a multivibrator which triggers and brightens the sweep, triggers the modulator and calibrator.

(ii) Sweep

V3 is a saw tooth generator. Its grid is driven by a negative square wave of sweep duration from V2 and it drives the grid of V4 with a positive saw-tooth voltage. V4 is a sweep generator driving the two C.R. tube magnetic sweep deflection coils in series.

S1 is a D.P.S.T. switch which halves the time constants of the multivibrator V1-V2, giving two sweep lengths, one 500 Km. and the other 1000 Km.

(iii) V12 is a Miller time base, giving a linear saw tooth of voltage. The V11 diode in the plate circuit of V12 can be biased by the Range pot. to pass any portion of the triangular saw tooth to V13. V13 squares and amplifies this triangular saw tooth voltage and the resultant square wave is fed through a differentiating circuit to grid No.1 of V14. V14 is a Kipp relay whose square wave output duration is controllable by the Strobe Length Pot. The output of this Kipp is fed to V15. V15 is a cathode follower which acts as a buffer between the Kipp and the output. This cathode follower then feeds out to the monitor C.R.T. a narrow strobe variable in width, and variable in time from the beginning of the sweep. This gives an effective method of using the leading edge of the strobe to measure ionospheric layer heights manually, and also to feed out on the strobe any echoes for polarization measurements.

(iv) Height Markers

V5, 1st section, is a LC oscillator, at 3000 cycles, triggered by a negative square wave from the multivibrator.
V6 is a negative resistance circuit which sustains the train of oscillations in the LC oscillator.
V5, 2nd section, is a cathode follower feeding the grid of V7.
V7 is a squaring amplifier whose differentiated output is fed through a negative pass diode to the grid of V9.
V9 is a pip amplifier which feeds into the cathode of the camera C.R. tube and also through the Calibration Pips switch to the grid of V10.
V10 is a video amplifier whose output is connected to both camera and monitor C.R. tubes through diodes V17.

(v) Frequency Markers

V16 is a Kipp relay mechanically triggered by the Frequency Marker microswitch and pins on the receiving condenser cam. The output of the Kipp feeds a short negative pulse to the grid of the camera C.R. tube every time the Frequency Marker microswitch closes, and this pulse blanks out the sweep for a short period.

Since the pins actuating the microswitch are spaced logarithmically on the receiver cam, vertical blank lines are thus produced on the film record, dividing each band into ten logarithmic frequency divisions.

(e) Scanner Power Supply Unit E Rack #2. See Fig. 8.

This unit supplies the power requirements of the scanner chassis and the camera C.R. tube. The circuits are very similar to those of the transmitter-receiver power supply.

(f) Camera (Units F, G & H)

The camera unit is in three parts. The camera, the film cassette, and the camera scope.

The camera C.R. tube is a 5FP7 long persistance tube, used because of its photographic properties, namely, blue flash and flat face. The sweep is vertical, starting at the top of the tube. All power, sweep, voltage, and video, is fed to the camera scope from rack #2. The camera holds 100 ft. of 35 mm. film which is driven past the lens at three inches per minute, producing a six inch record during the two minute recording period. A counter is incorporated to record the number of inches of film used. A late addition to the camera is a clock dating system, similar to the one used by the Carnegie ionospherists on the British 249 recorder. Other controls on the camera are film cutter and selector switch. This switch has "continuous", "off", and "record", positions.

(g) Clock

The minute hand of an eight day spring-wound clock makes contact with twelve separate contacts placed at the five minute points on the clock face. These twelve contacts are connected through the clock selector switch, battery, and relay, to actuate N.R. #1 at 5, 15, 30 and 60 minute intervals, as selected. NR #1 is the turn-on relay for the recorder.

## III

## MODES OF OPERATION

The selector switch on Unit B rack #1 selects either of three modes of operation.

(i) Clock - The clock actuates NR#1 at the chosen interval; the recorder takes one complete record and turns itself off. This is the common method of operation.

(ii) Manual - In manual operation a push button replaces the clock, the recorder takes one record and turns itself off.

(iii) Continuous - In continuous operation a push button turns on the recorder, as in manual operation, but the recorder does not turn itself off. Instead it continues to take a continuous series of records, with no spacing between them, until the same push button is pressed again, turning off the recorder.

## IV

## LIST OF SWITCHES AND RELAYS AND THEIR FUNCTIONS

The switching sequence of this recorder is complicated and interlocking and no attempt will be made to describe it here. However, the functions of the various relays and switches will be described briefly.

N.R. = notching relay. These relays are of the multiple pole double throw type and switch to one position when voltage is applied to the coil. Voltage must be broken and applied again to switch to the other position.

T.D. = Time delay relay. These are paragon time delays of the electric clock driven type and can be adjusted to give any delay of from one to sixty seconds.

M.S. = Micro switch - both make and break types used.

N.R.#1 - is the notching relay which turns on and turns off the AC mains supply to the recorder.

N.R.#2 - is the notching relay which in one position controls the recording period and in the other controls the band switching.

T.D.#1 - turns on the high voltage circuits 45 seconds after N.R.#1 closes.

T.D.#2 - turns off camera 30 seconds after camera motor is started by N.R.#1.

T.D.#3 - breaks the A.C. circuit to N.R.#2 two seconds after N.R.#1 closes the circuit. This is to free N.R. #2 for further switching.

T.D.#4 - (added later) flashes clock dater 15 seconds after N.R.#1 closes. This produces time and date in the middle of the blank film space between records.

M.S.#1 - is closed momentarily by the geneva wheel pin. This switch is in series with M.S.#7 and completes the turn-off circuit when cam on receiver coil turret closes M.S.#7.

M.S.#2 - closes on geneva wheel and holds on coil change motor until just before coils are about to change again.

M.S.#3 - is closed momentarily by geneva pin just after coil change and this actuates N.R.#2 to the recording position.

M.S.#4 - is closed by a cam on the receiver condenser and turns on the camera during the proper frequency range on each band.

M.S.#5 - is closed momentarily by the last frequency marker pin on the receiver condenser cam and actuates N.R.#2 to the coil change position.

M.S.#6 - is in parallel with M.S.#7 and breaks circuits to N.R.#2 when band #1 is in position. This is to have N.R.#2 in the proper position to start a new record.

M.S.#8 - frequency marker microswitch actuated by logarithmically spaced pins on the receiver condenser cam, triggers the frequency marker Kipp relay on the closed position.

Relay #1 - to carry current for the coil change motor.

Relay #2 - to carry current for the magnetic clutches.

## V

## ALIGNMENT DATA

An F.M. signal generator and an oscilloscope required.
For all receiver alignment connect oscilloscope to output of video.
For all motor control " " " " pin jack.

I.F. Alignment - set S.G. at 455 kc. with 40 kc. sweep into mixer grid and adjust I.F. trimmers to give characteristic broad-band flat-top trace on scope; band width should be close to 20 kc. when properly aligned.

Oscillator Alignment - S.G. amplitude modulated, connect into antenna leads.

| Osc. | S.G. |
|---|---|
| Band 1 | Set at 1 mc. and at 1st freq. marker pin adj. padder to peak. |
| " | Set at 2 mc. " " last " " " " trimmer " " |
| Band 2 | Set at 2 mc. " " 1st " " " " padder " " |
| " | Set at 4 mc. " " last " " " " trimmer " " |
| Band 3 | Set at 4 mc. " " 1st " " " " padder " " |
| " | Set at 8 mc. " " last " " " " trimmer " " |
| Band 4 | Set at 8 mc. " " 1st " " " " padder " " |
| " | " " 16 mc. " " last " " " " trimmer " " |

R.F. and Mixer Alignment - Same settings as for oscillator A.M. peak padders and trimmers; however, some sacrifice to peak settings must be made to get band changeover gain again fairly flat.

Motor Control Alignment - S.G. set at 455 kc. F.M. 40 kc. connected into R.F. probe. Oscilloscope connected to pin jack output of discriminator.

Peak I.F.T. No.5 at 455 but get 20 kc. wide flat top characteristic.

Adjust I.F.T. No.6 to peak at 448 kc. A.M. and I.F.T. No.7 to peak, at 462 kc. A.M.

Then with 455 kc. 40 kc. F.M. injection, as before, readjust I.F.T. No.6 and No.7, to give two equal crossed peaks on the oscilloscope 14 kc. apart. The optimum adjustment can only be obtained through practice.

## VI

## ANTENNA

Fig. 10 shows a plan and side elevation of a delta antenna, as constructed by N.R.C. for use with the mobile ionospheric observatory. The original design information was obtained in a letter from Cox to F.T. Davies in October 1944. Some modifications were made in the Cox design, the main one being a feed wire height of 7' above ground, rather than 6'; this to give adequate head room. The centre mast of a British type 249 recorder is used with the antenna.

Excerpt from Cox's letter:

"To obtain constant impedance we are using the delta aerial of Fig. 10. The "feeders" are single wires 6' above the ground, and it is most important that they are curved round in such a way that there is no sudden change of direction anywhere, either in the horizontal or vertical plane, as any sudden change introduces reflections, and consequently resonances. The impedance is between 400 and 800 ohms from 1 - 18 mc. With this aerial tightly coupled, the tuning curve of the transmitter is hardly altered from its shape on purely resistive load. The radiation in a vertical direction is about 6 db. down as compared with the rhombic at 4 - 6 mc., and a good 6-10 db. up on 1-1/2 - 2-1/2 mc., where the extra power is most useful. It is also something of an advantage to have low end posts, although to accommodate the bend in the feeder, several of them are necessary."

No measurements have been made on the N.R.C. antenna. However, it seems to give reasonably good gain at 1 megacycle, and the impedance characteristics appear to conform to Cox's letter.

The delta antenna now to be used with the mobile recorder uses a 103 ft. centre mast and all wire lengths have been scaled up from the dimensions of Fig. 10. This larger delta antenna is expected to give even more gain at the lower frequencies.

For communication purposes this antenna is to be used as an end-terminated tilted half rhombic. To accomplish this, three R.F. relays have been installed - one at the top of the mast to short out the normal terminating resistor of 1100 ohms, and one at each end of the antenna. One to switch in a terminating resistor to ground, the other to connect into the communications transmitter. Data on the success of this experiment will be available shortly.

R.E. Freeman

R.I. Mott

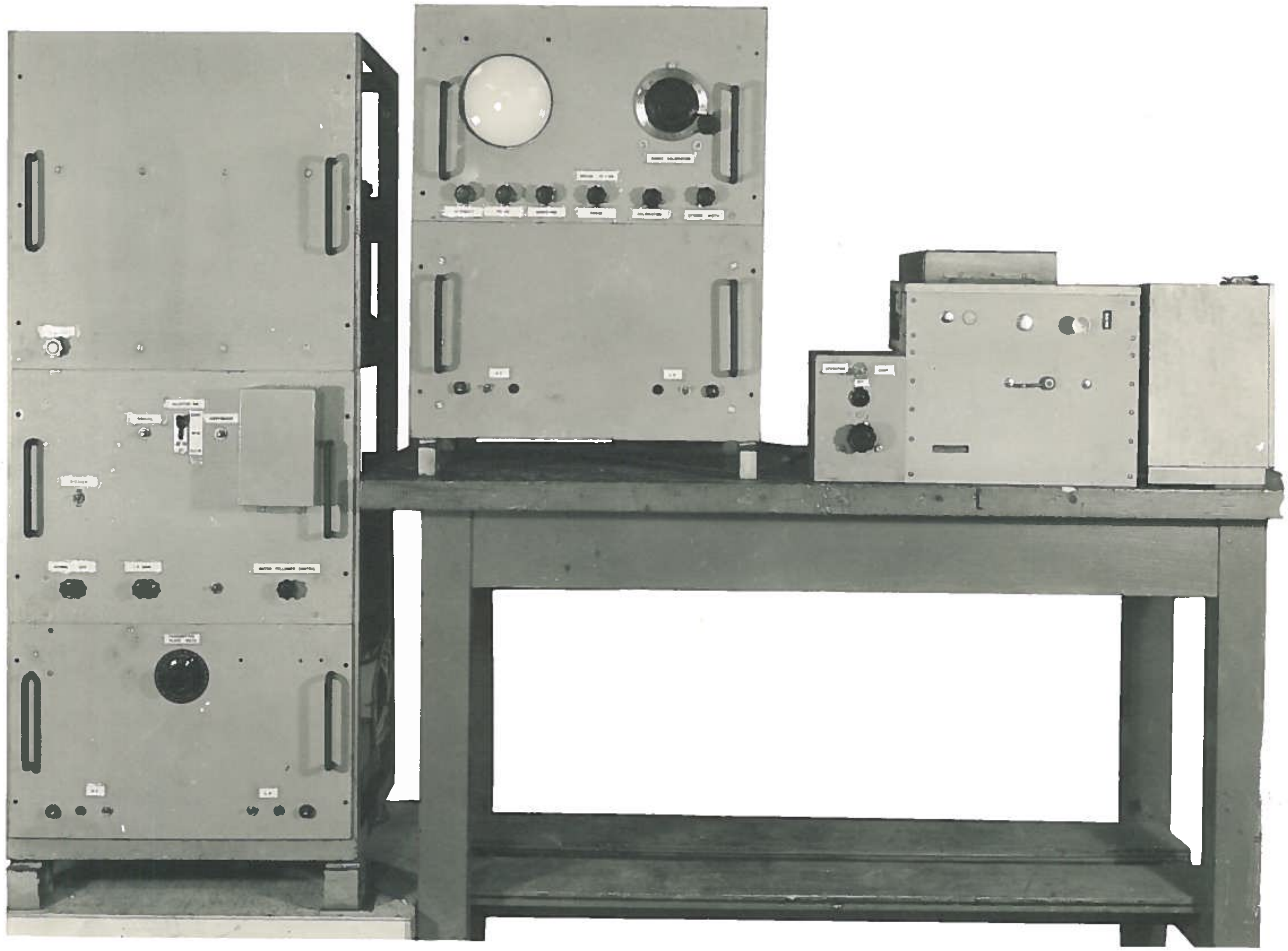


PHOTO 1 - AUTOMATIC IONOSPHERE RECORDER (COMPLETE)
FRONT VIEW

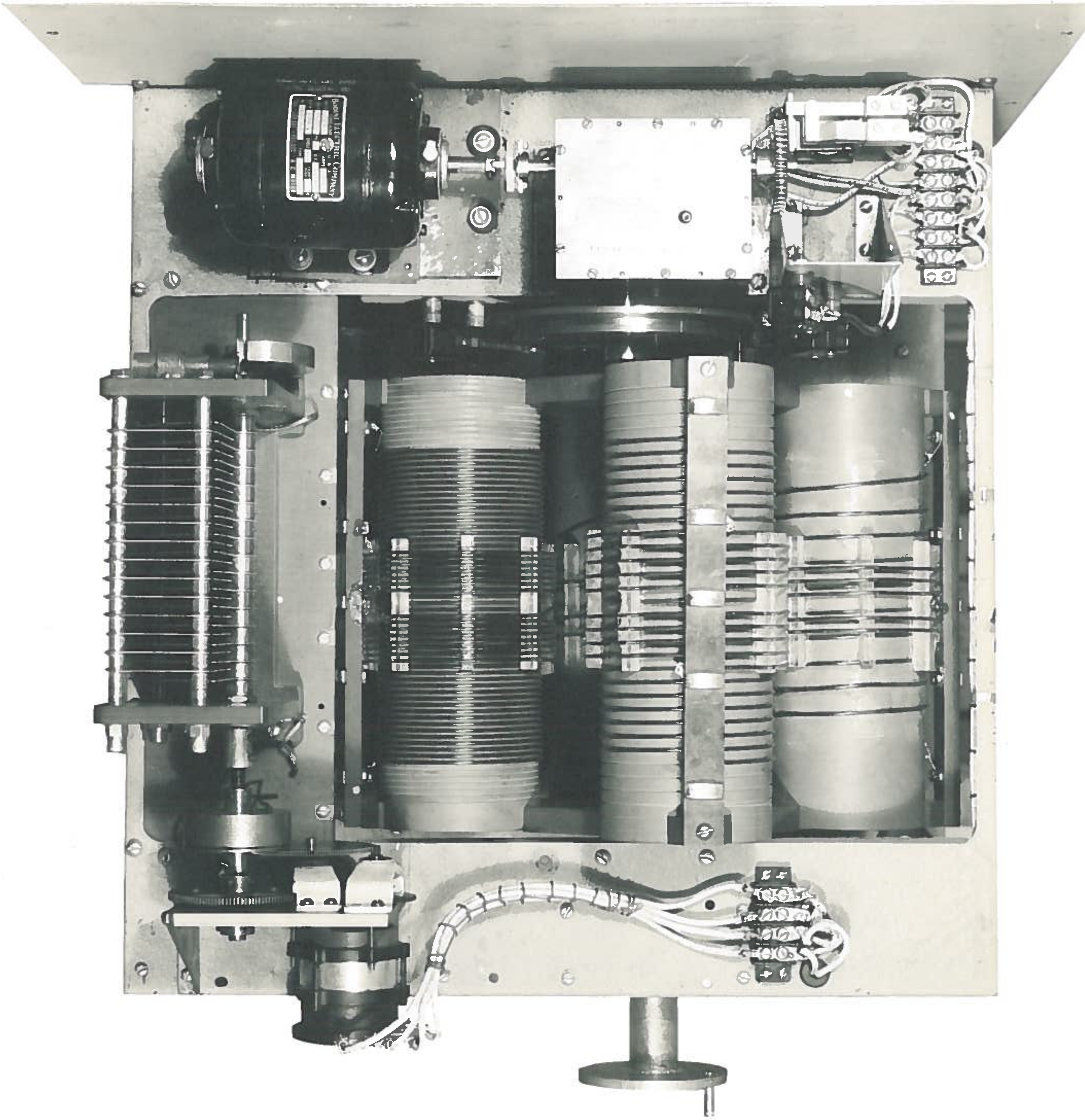


PHOTO 2 - UNIT A - TRANSMITTER AND MODULATOR
TOP VIEW

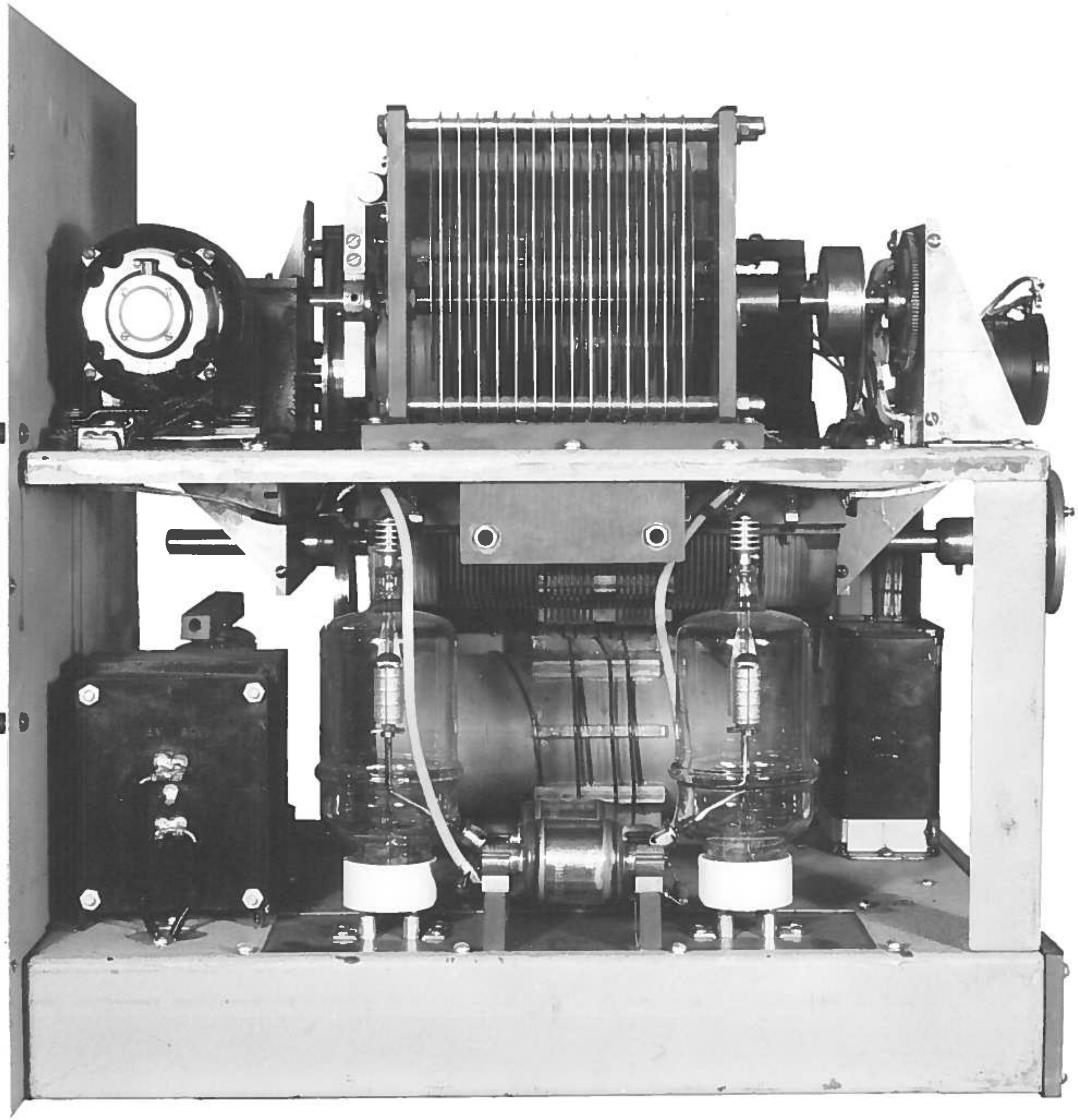


PHOTO 3 - UNIT A - TRANSMITTER AND MODULATOR

SIDE VIEW

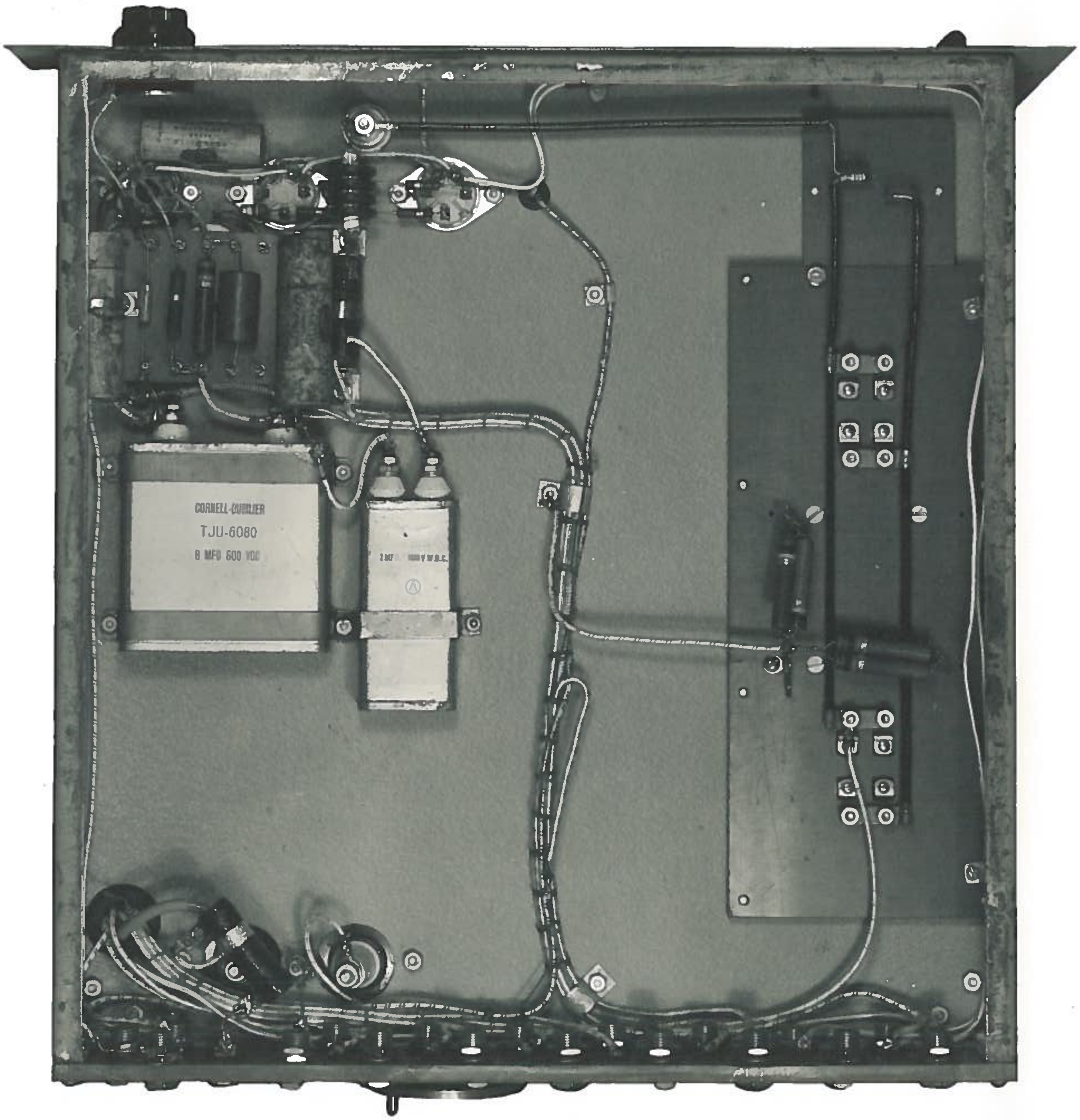



PHOTO 4 - UNIT A - TRANSMITTER AND MODULATOR

BOTTOM VIEW

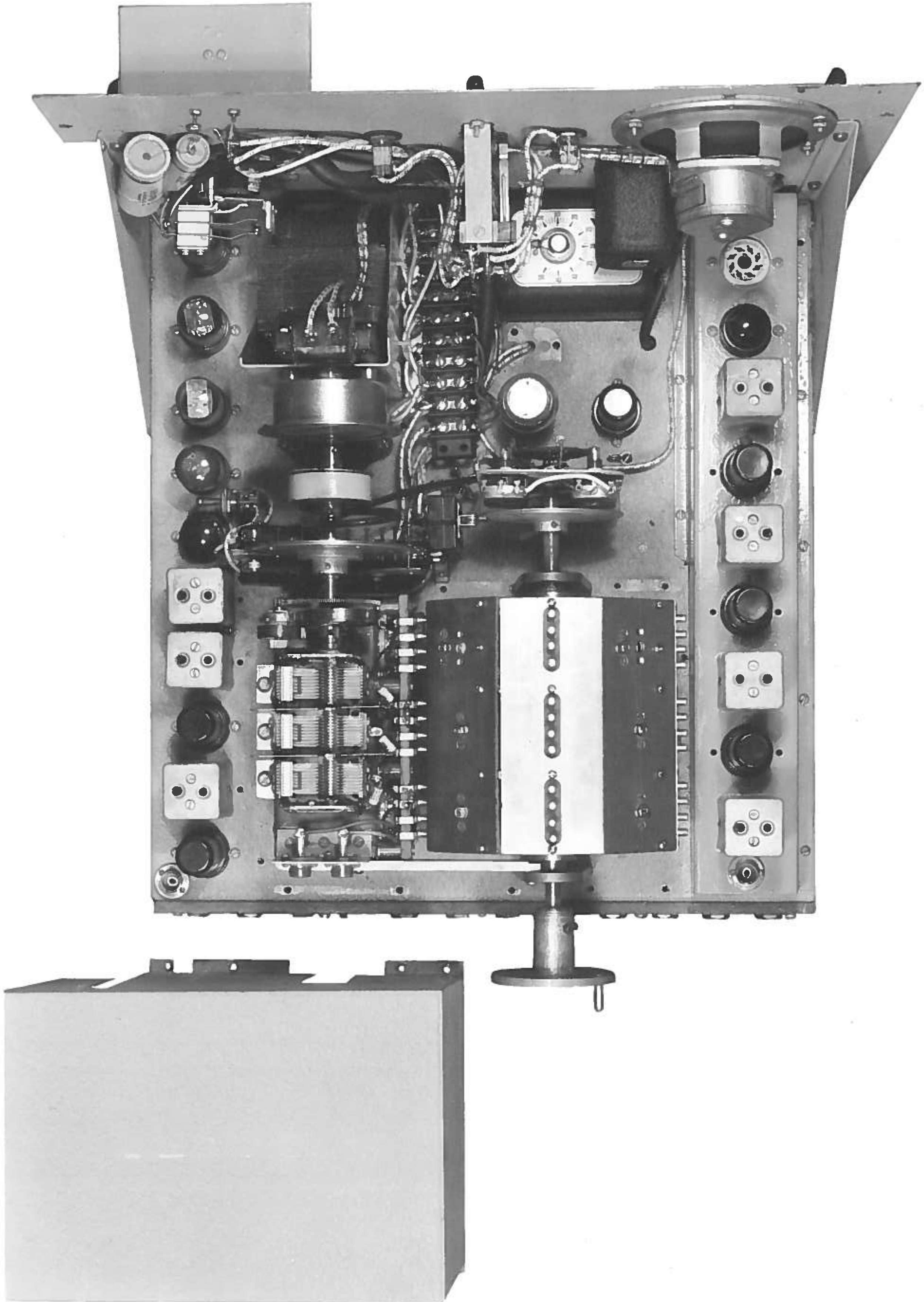


PHOTO 5 - UNIT B - RECEIVER AND MOTOR CONTROL
TOP VIEW

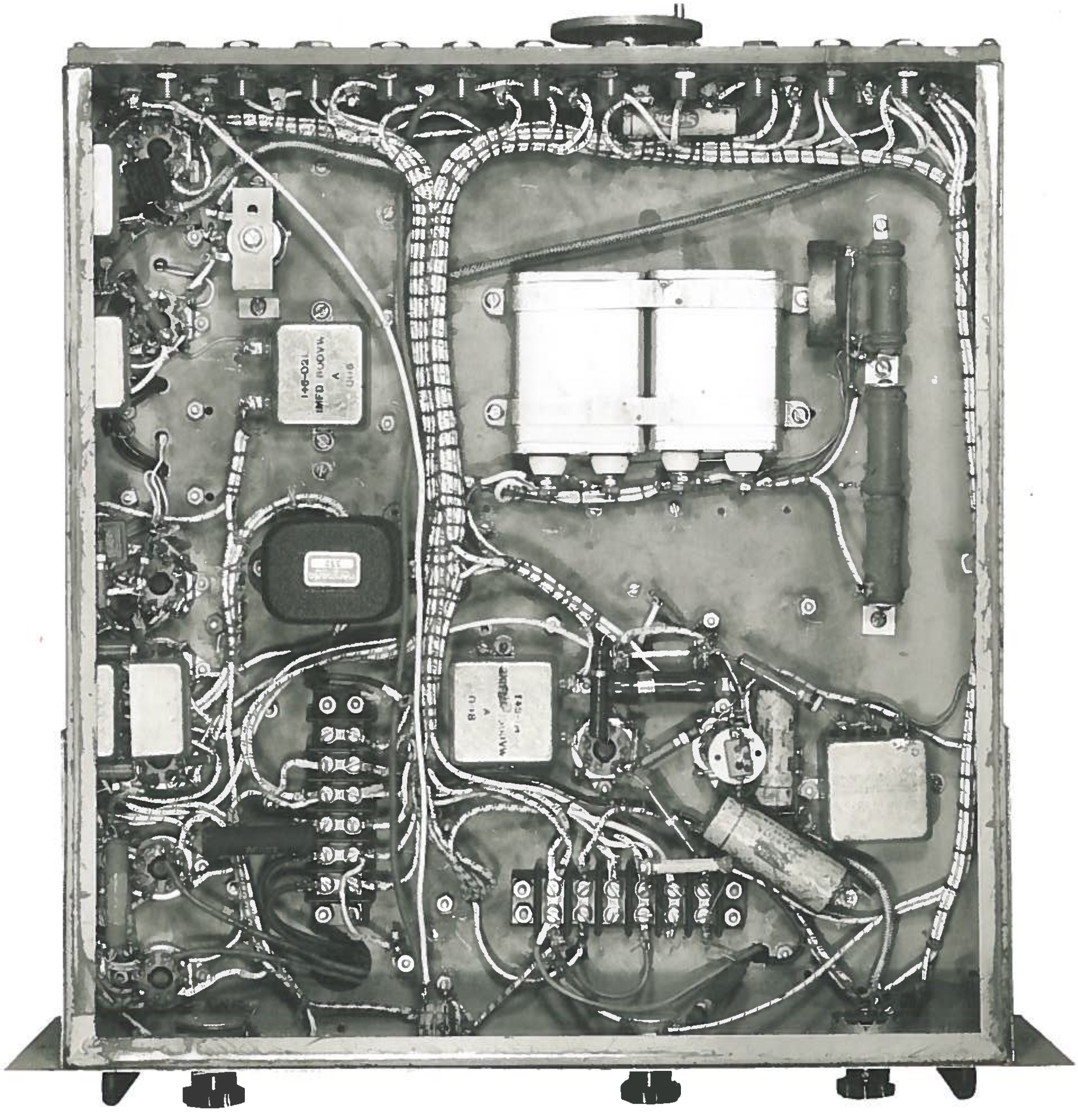


PHOTO 6 - UNIT B - RECEIVER AND MOTOR CONTROL

BOTTOM VIEW

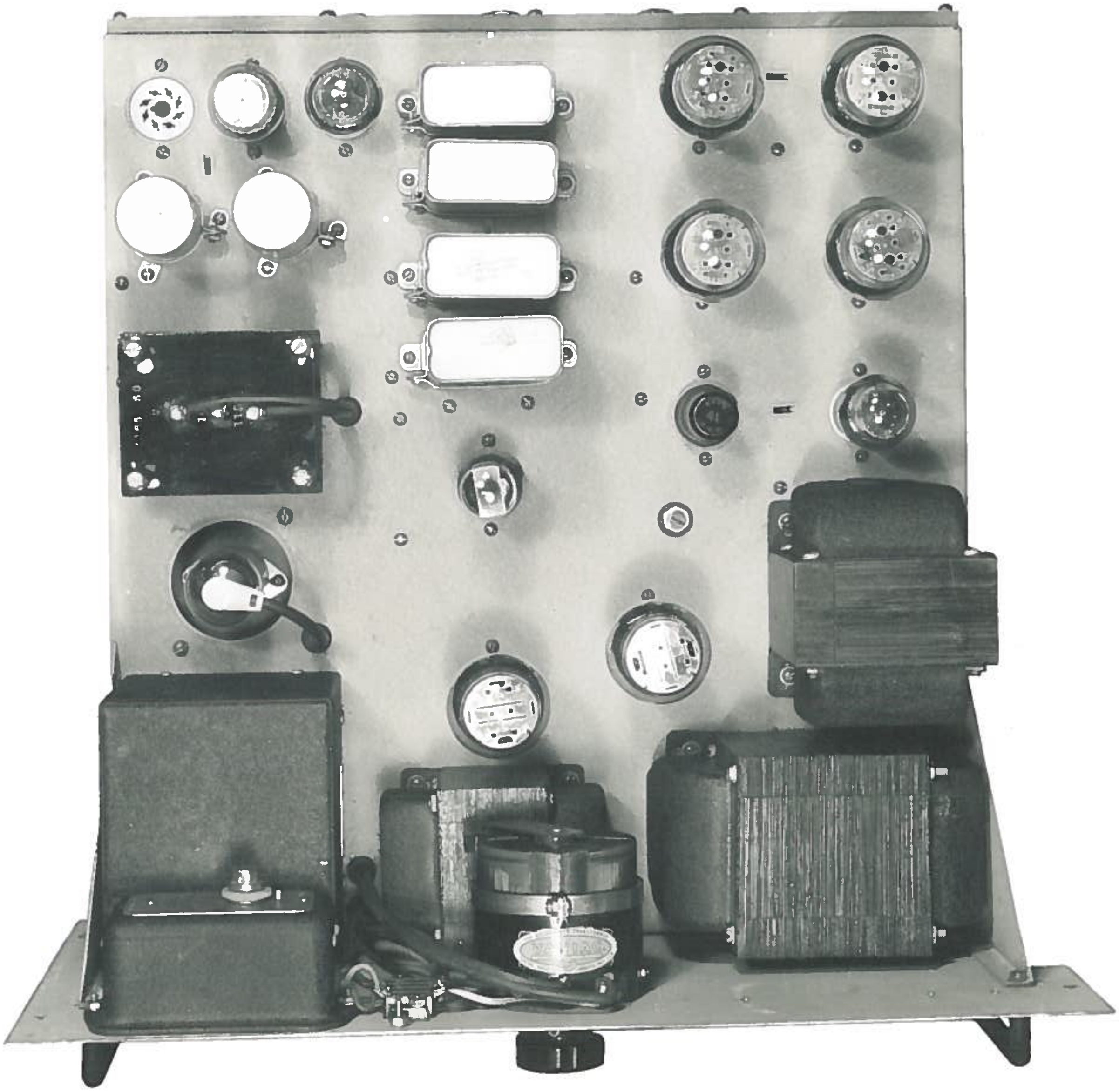


PHOTO 7 - UNIT C - POWER SUPPLY FOR RACK NO. 1
TOP VIEW

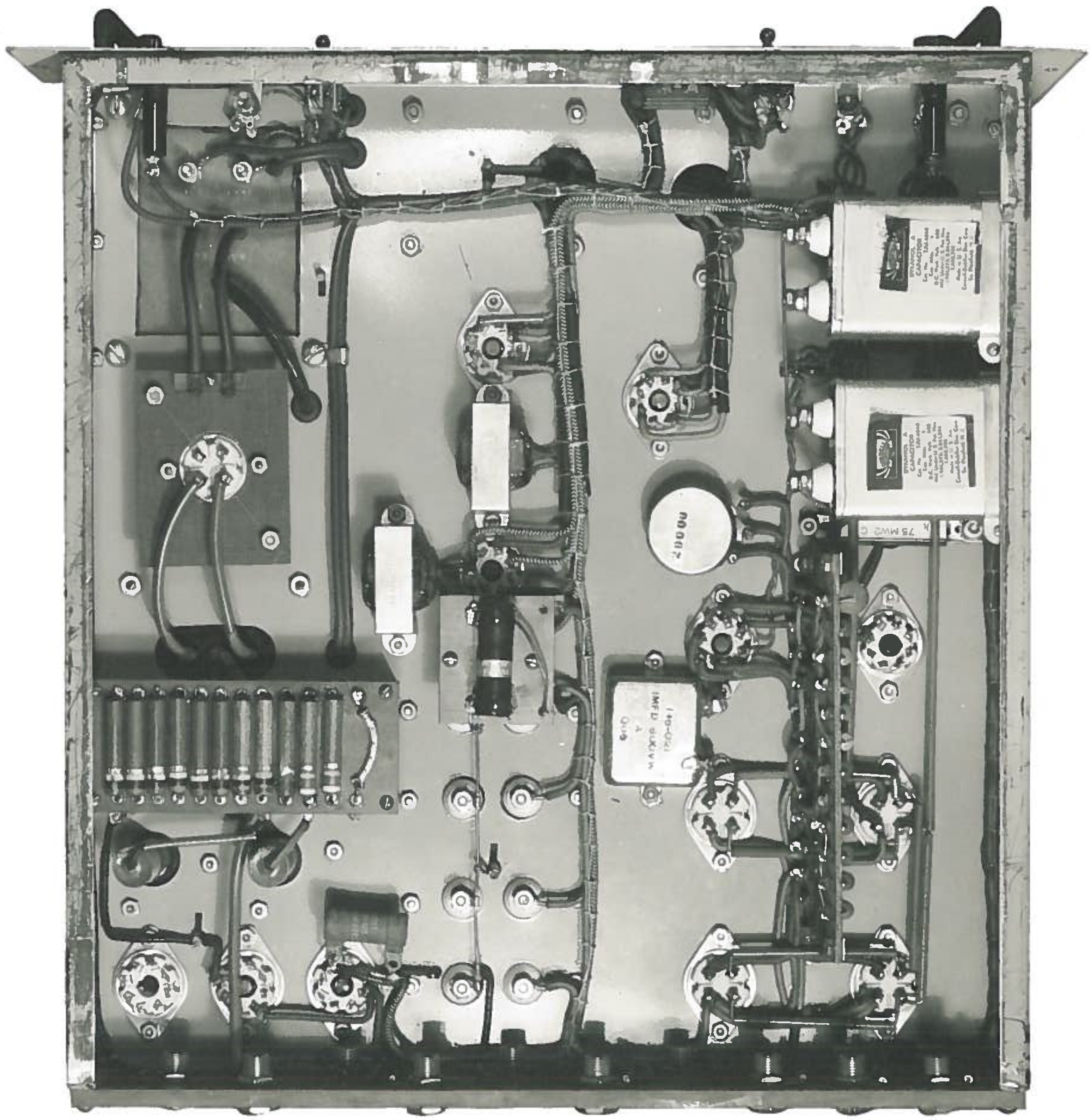


PHOTO 8 - UNIT C - POWER SUPPLY FOR RACK NO. 1
BOTTOM VIEW

PHOTO 9 - SCANNER - UNIT D

TOP VIEW

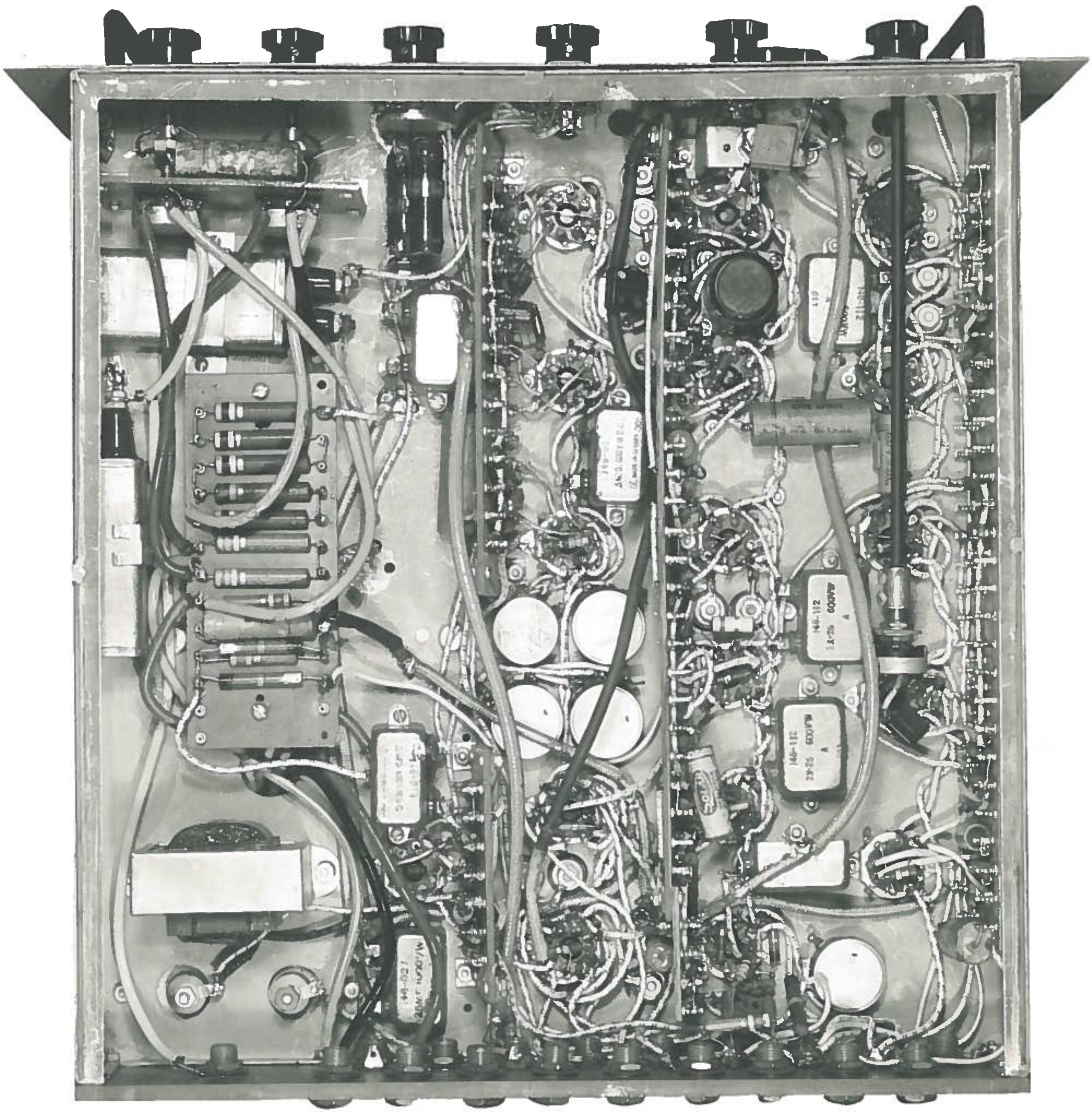


PHOTO 10 - SCANNER - UNIT D
BOTTOM VIEW

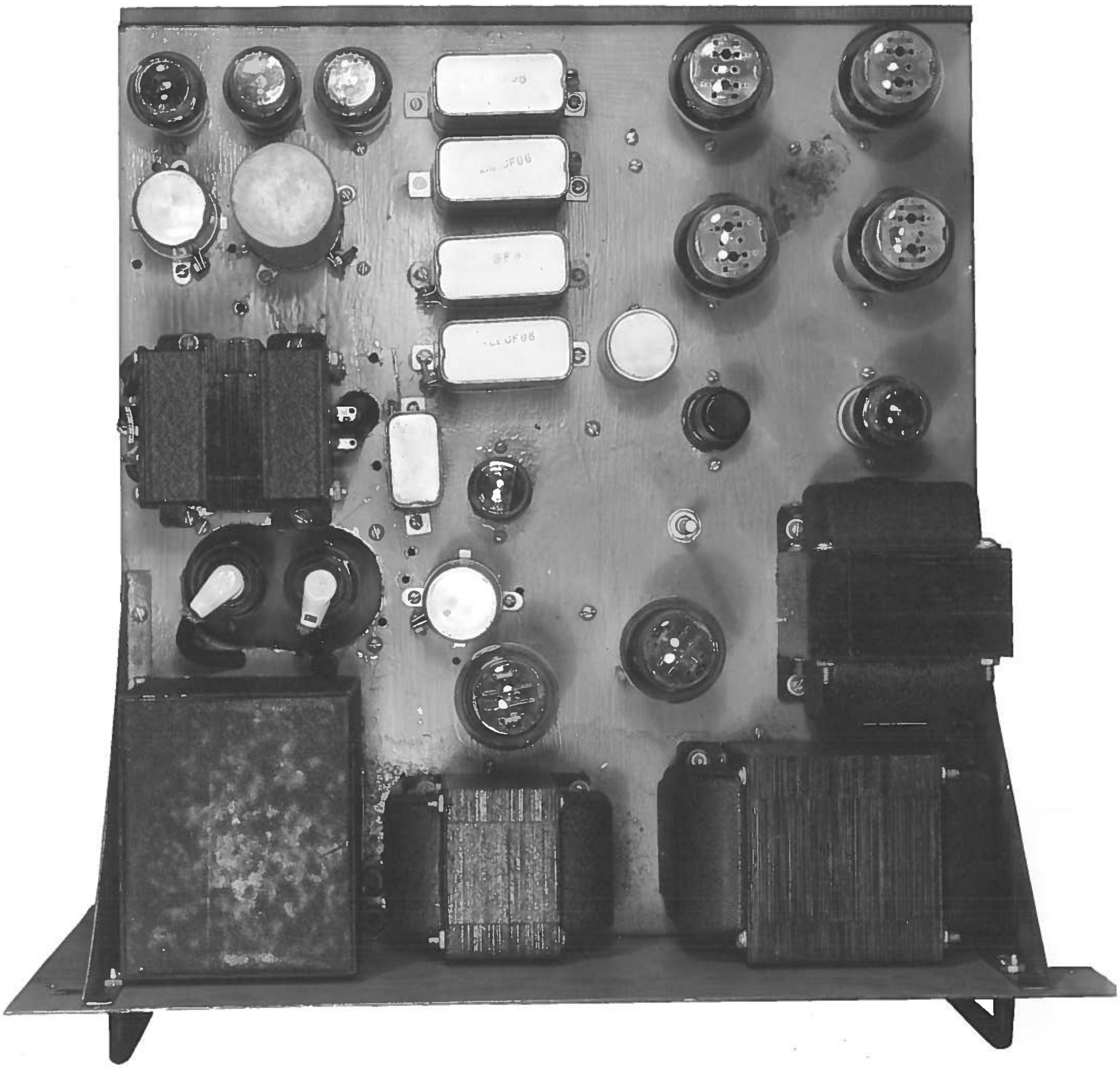


PHOTO 11 - POWER SUPPLY FOR SCANNER - UNIT E
TOP VIEW

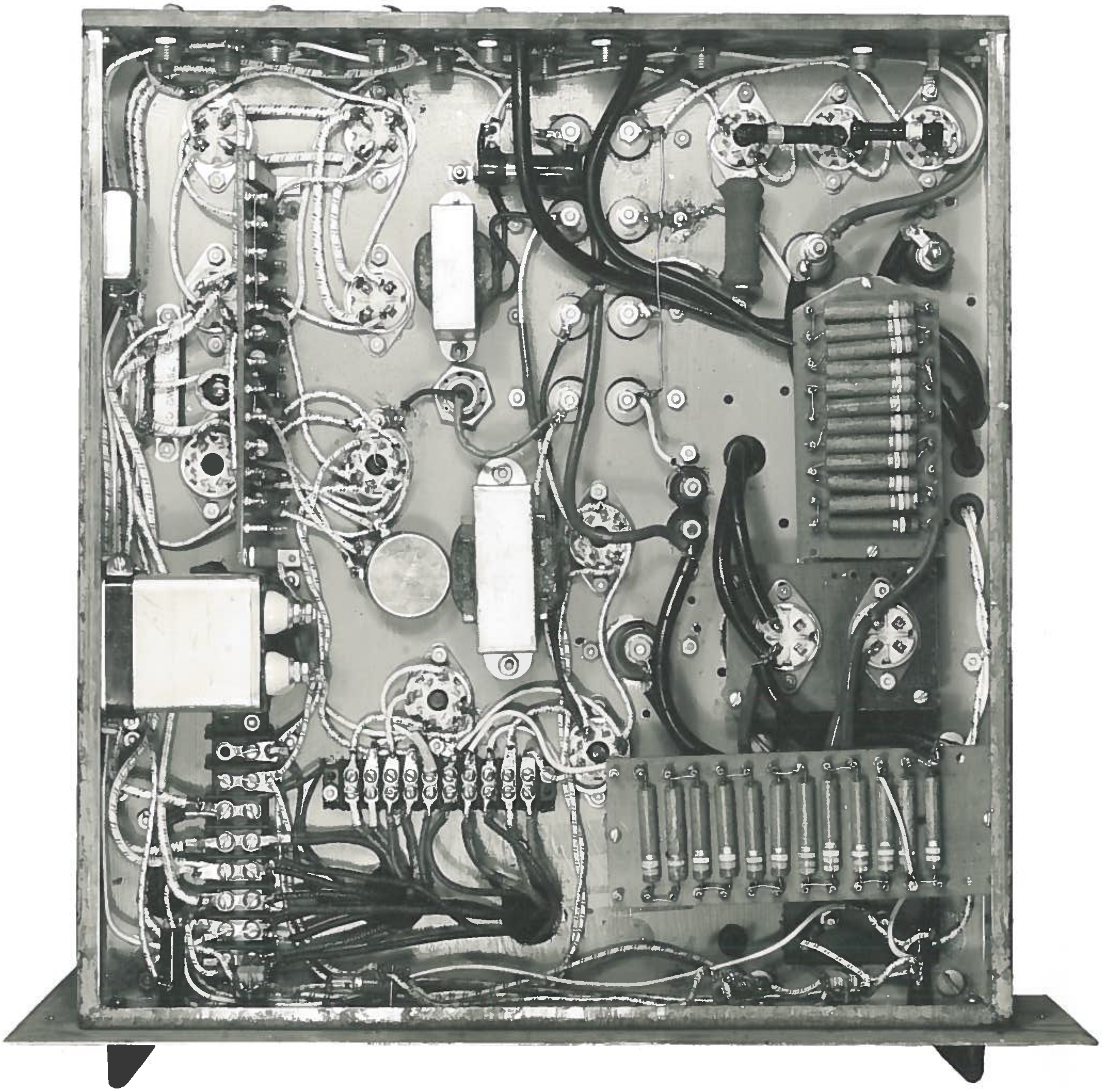


PHOTO 12 - POWER SUPPLY FOR SCANNER - UNIT E
BOTTOM VIEW

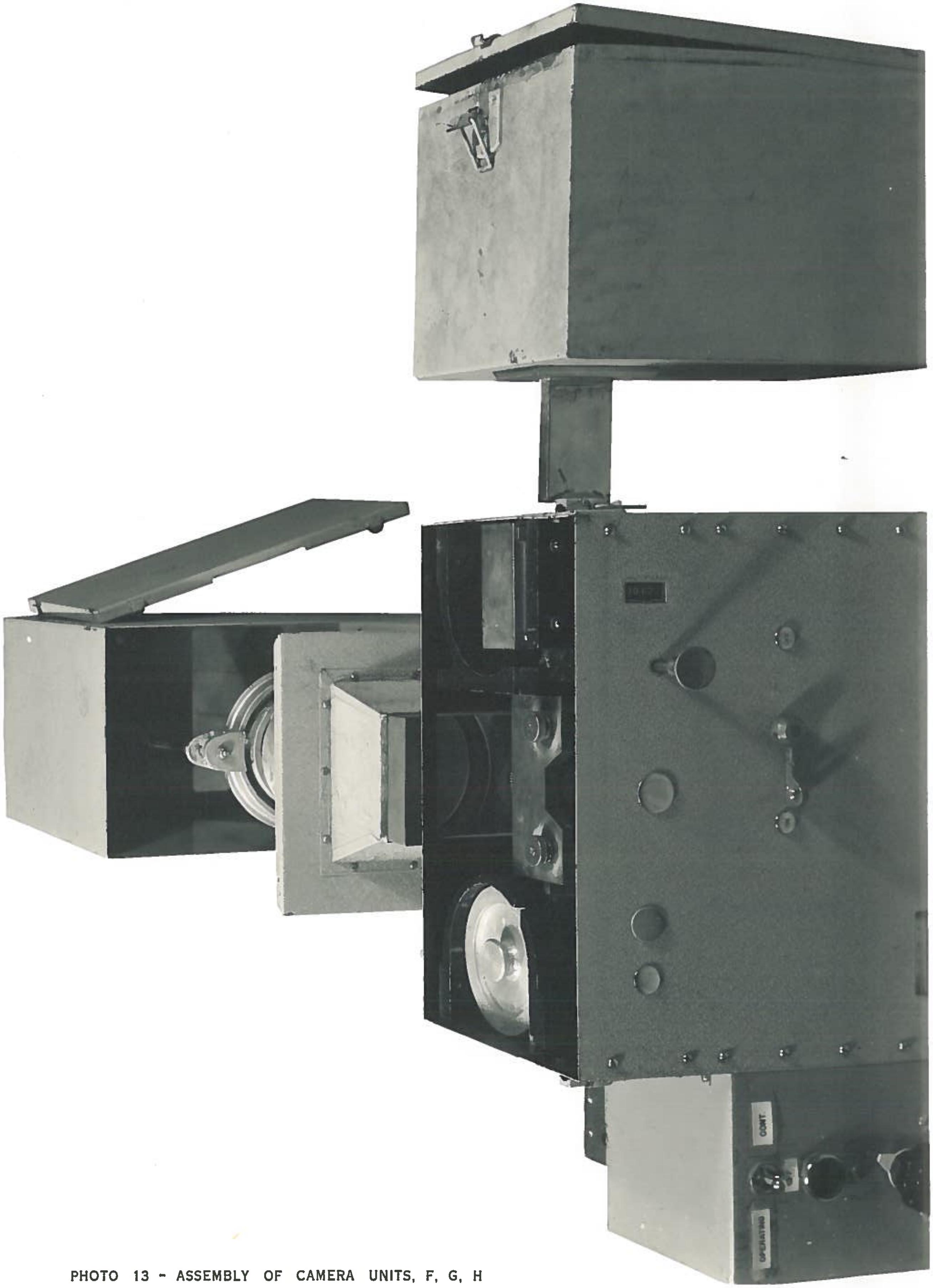



PHOTO 13 - ASSEMBLY OF CAMERA UNITS, F, G, H

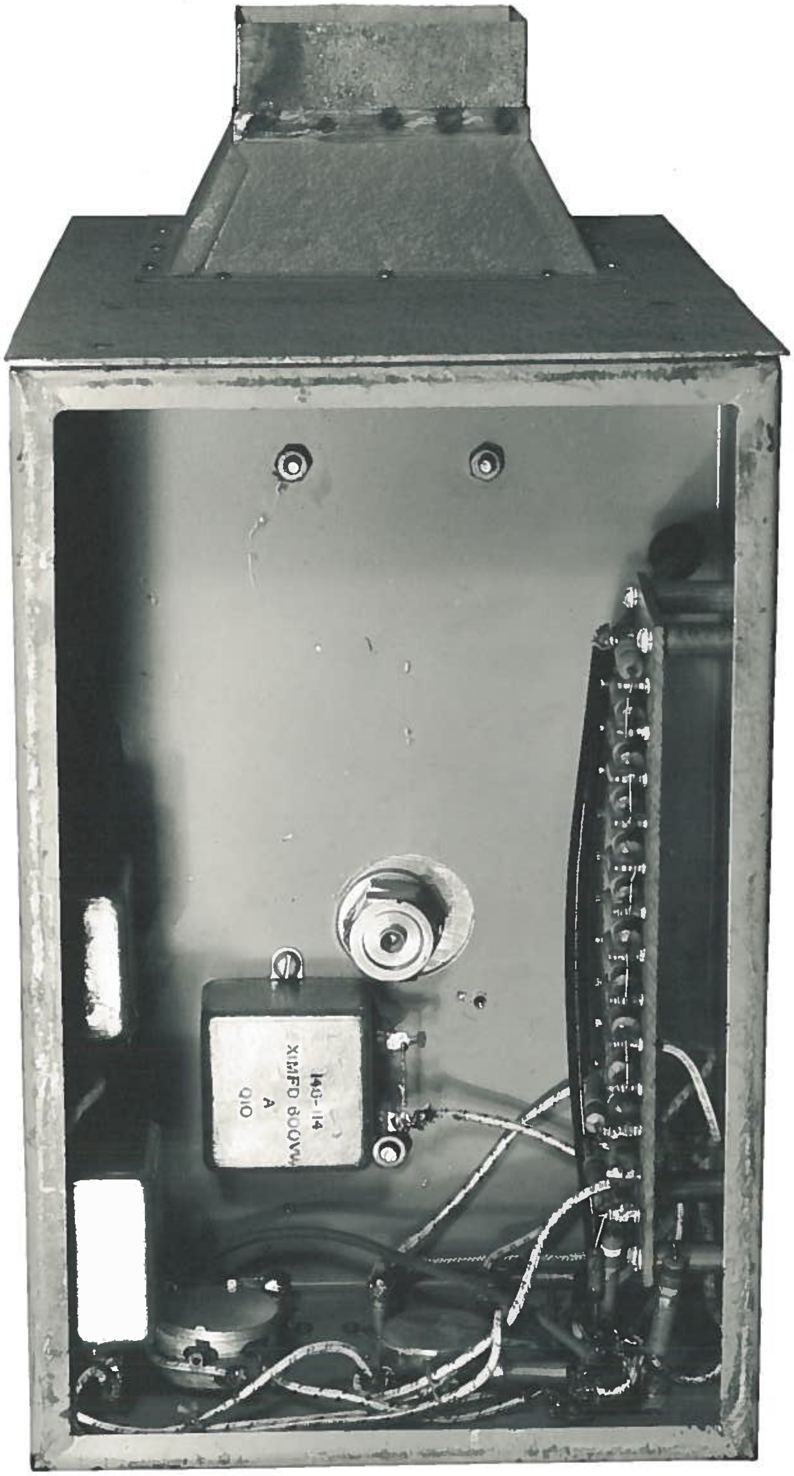


PHOTO 14 - CAMERA SCOPE, UNIT G
BOTTOM VIEW

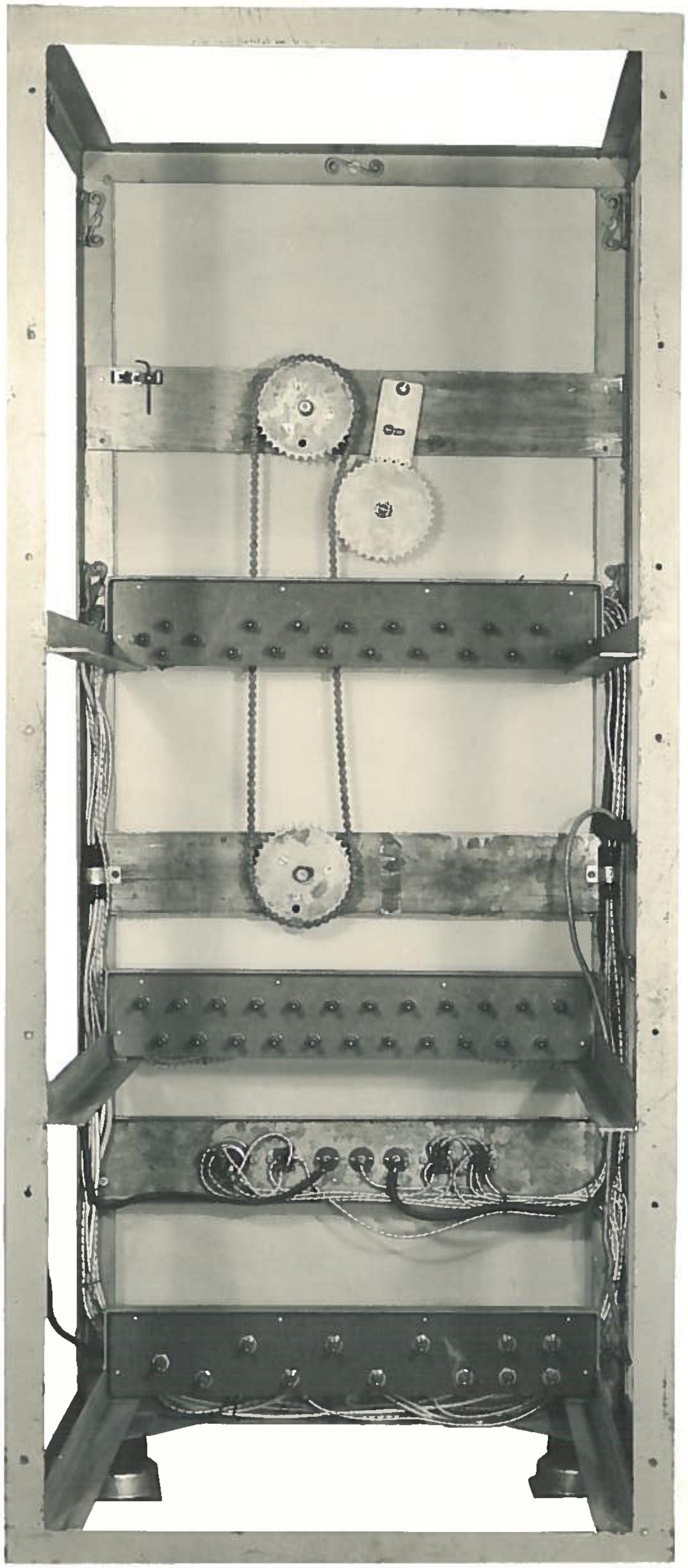


PHOTO 15 - RACK NO. 1
FRONT VIEW

INTER-RACK WIRING
REAR VIEW

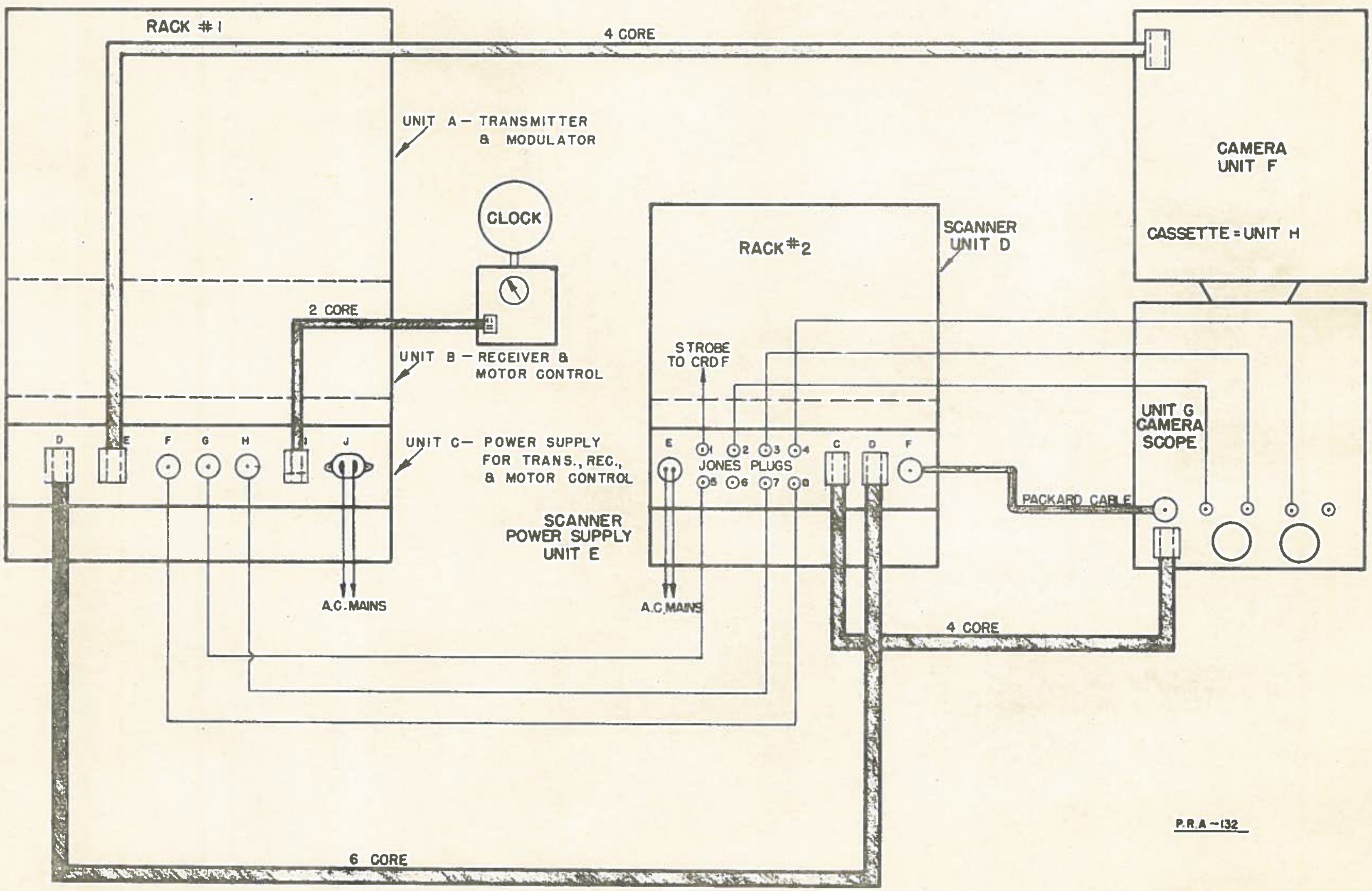
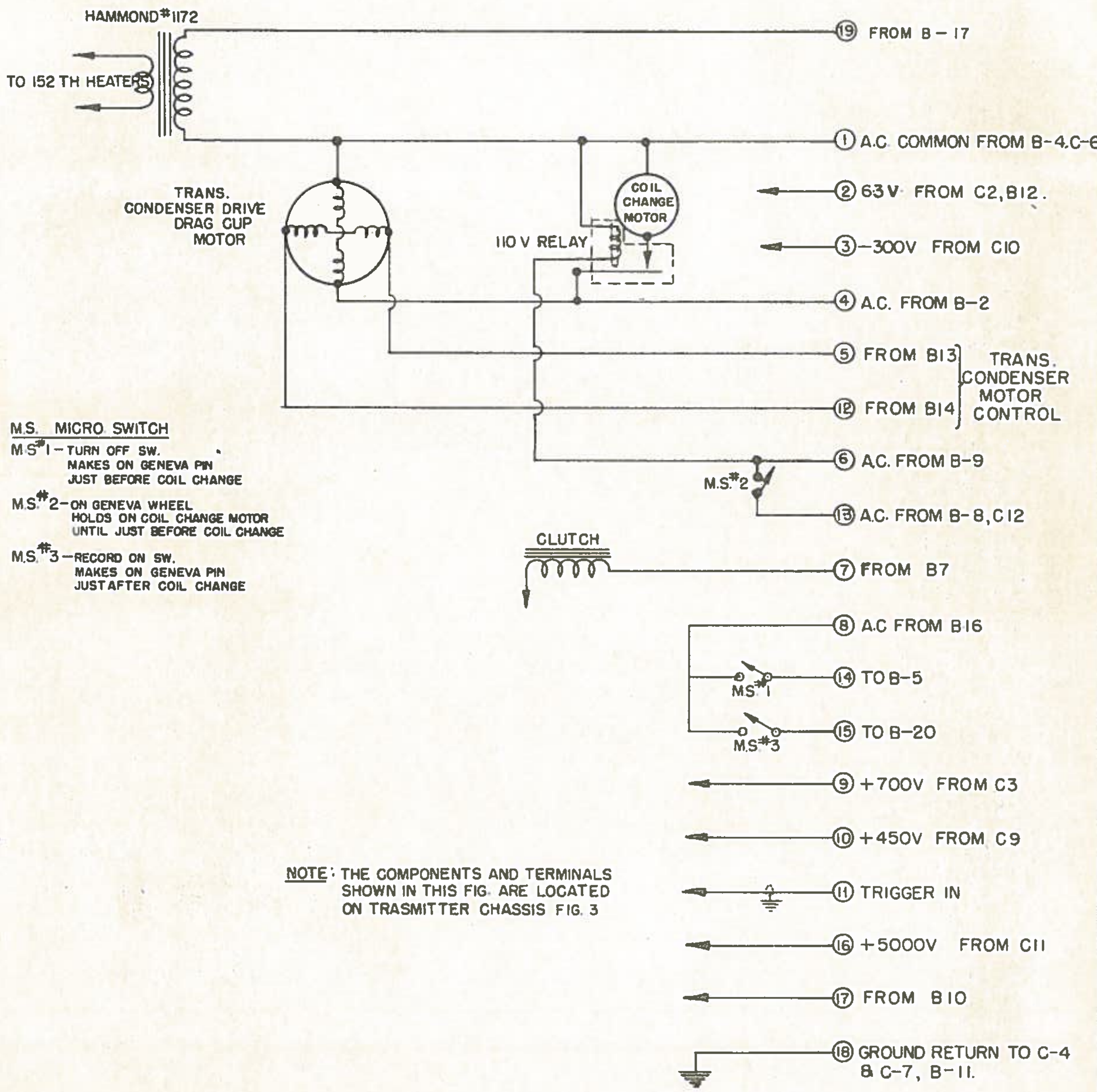



FIG. I

## TRANSMITTER SWITCHING CIRCUITS

### UNIT A




M.S. MICRO SWITCH

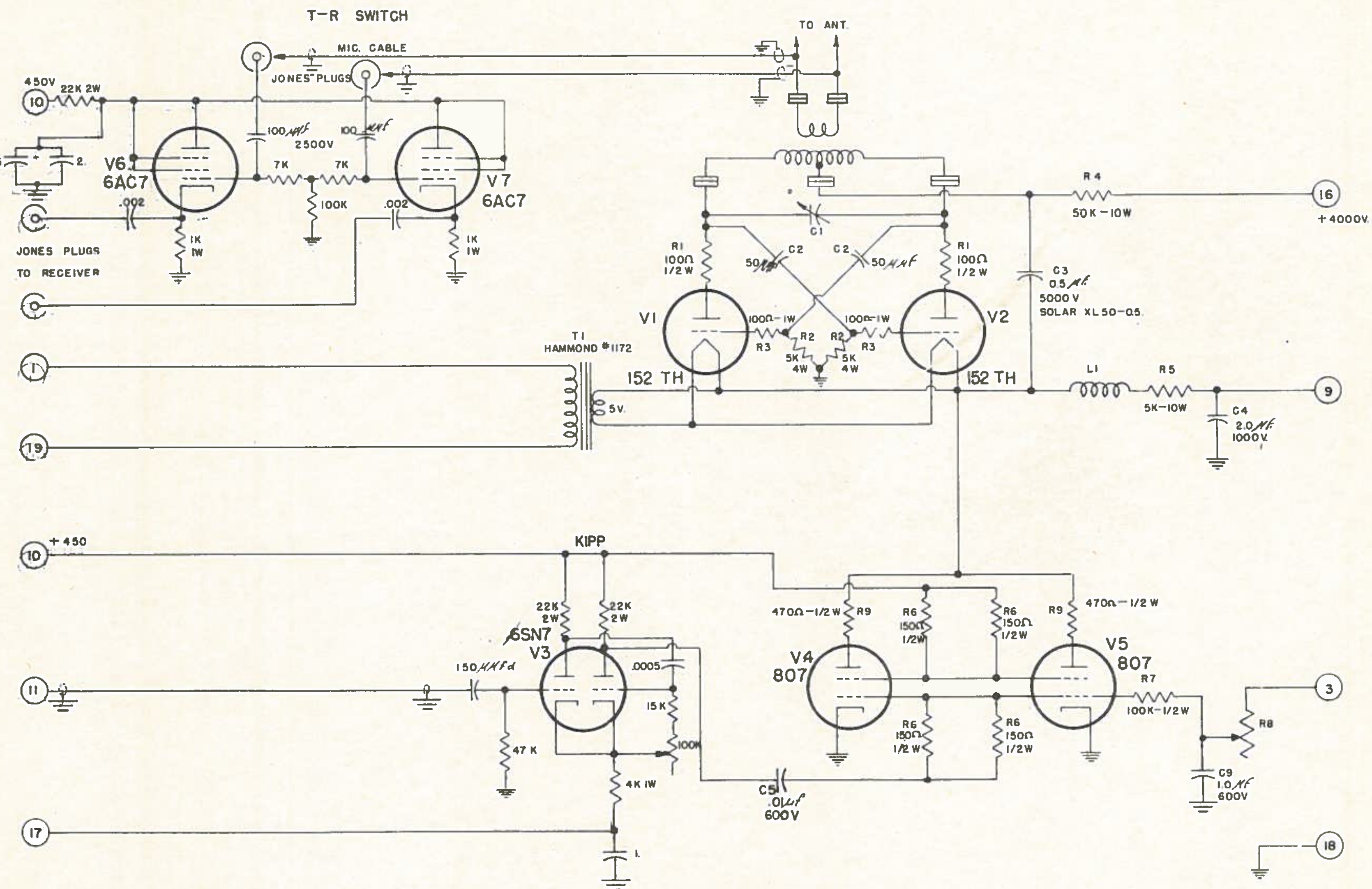
M.S.#1 – TURN OFF SW. MAKES ON GENEVA PIN JUST BEFORE COIL CHANGE

M.S.#2 – ON GENEVA WHEEL HOLDS ON COIL CHANGE MOTOR UNTIL JUST BEFORE COIL CHANGE

M.S.#3 – RECORD ON SW. MAKES ON GENEVA PIN JUST AFTER COIL CHANGE

NOTE: THE COMPONENTS AND TERMINALS SHOWN IN THIS FIG. ARE LOCATED ON TRASMITTER CHASSIS FIG. 3

FIG. 2




NOTE: PIN CONNECTIONS ARE NO. AND ENCIRCLED.

FIGURE 3

TRANSMITTER AND MODULATOR CIRCUITS
UNIT A

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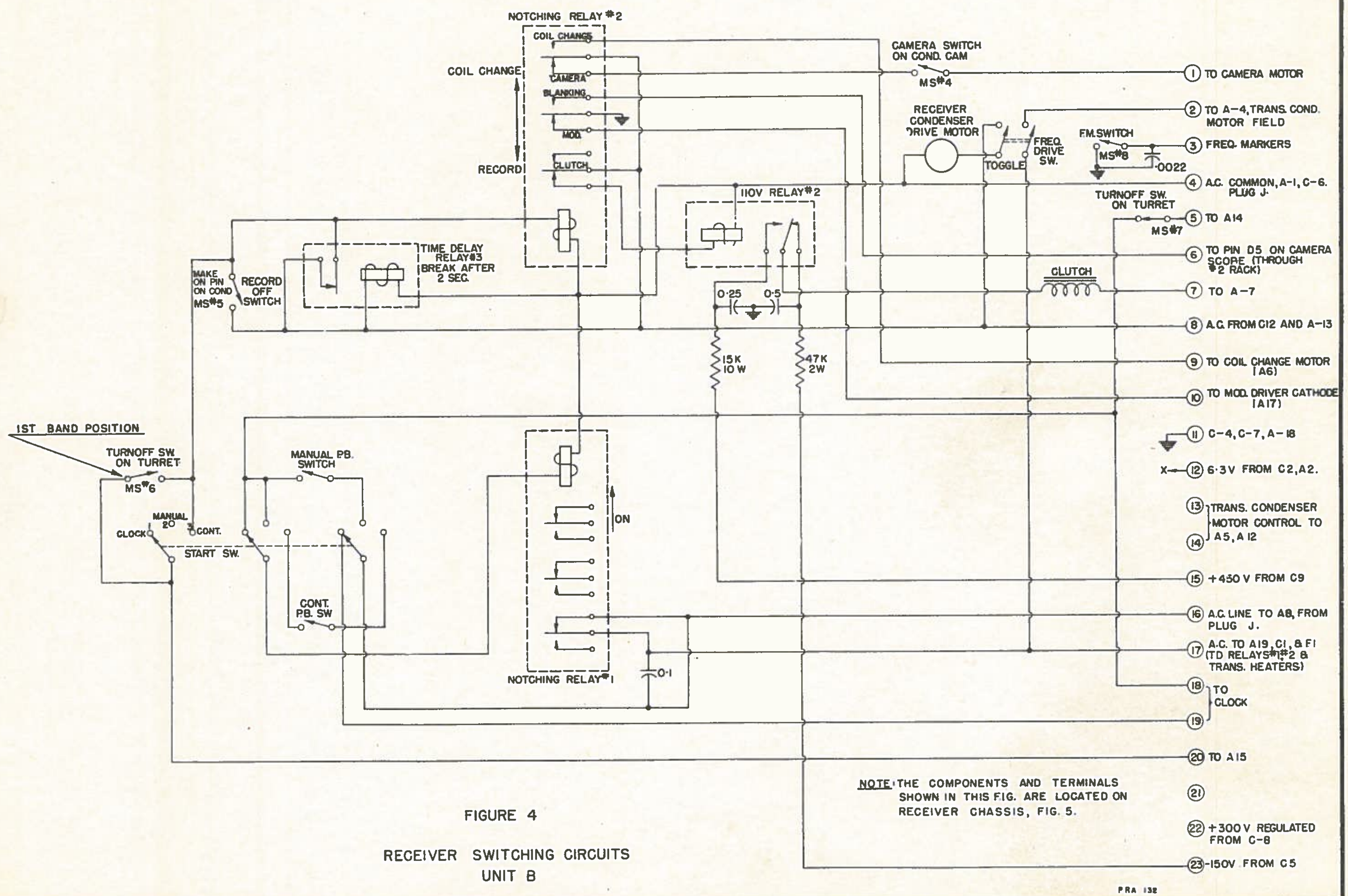


NOTE: THE COMPONENTS AND TERMINALS SHOWN IN THIS FIG. ARE LOCATED ON RECEIVER CHASSIS, FIG. 5.

FIGURE 4

RECEIVER SWITCHING CIRCUITS
UNIT B

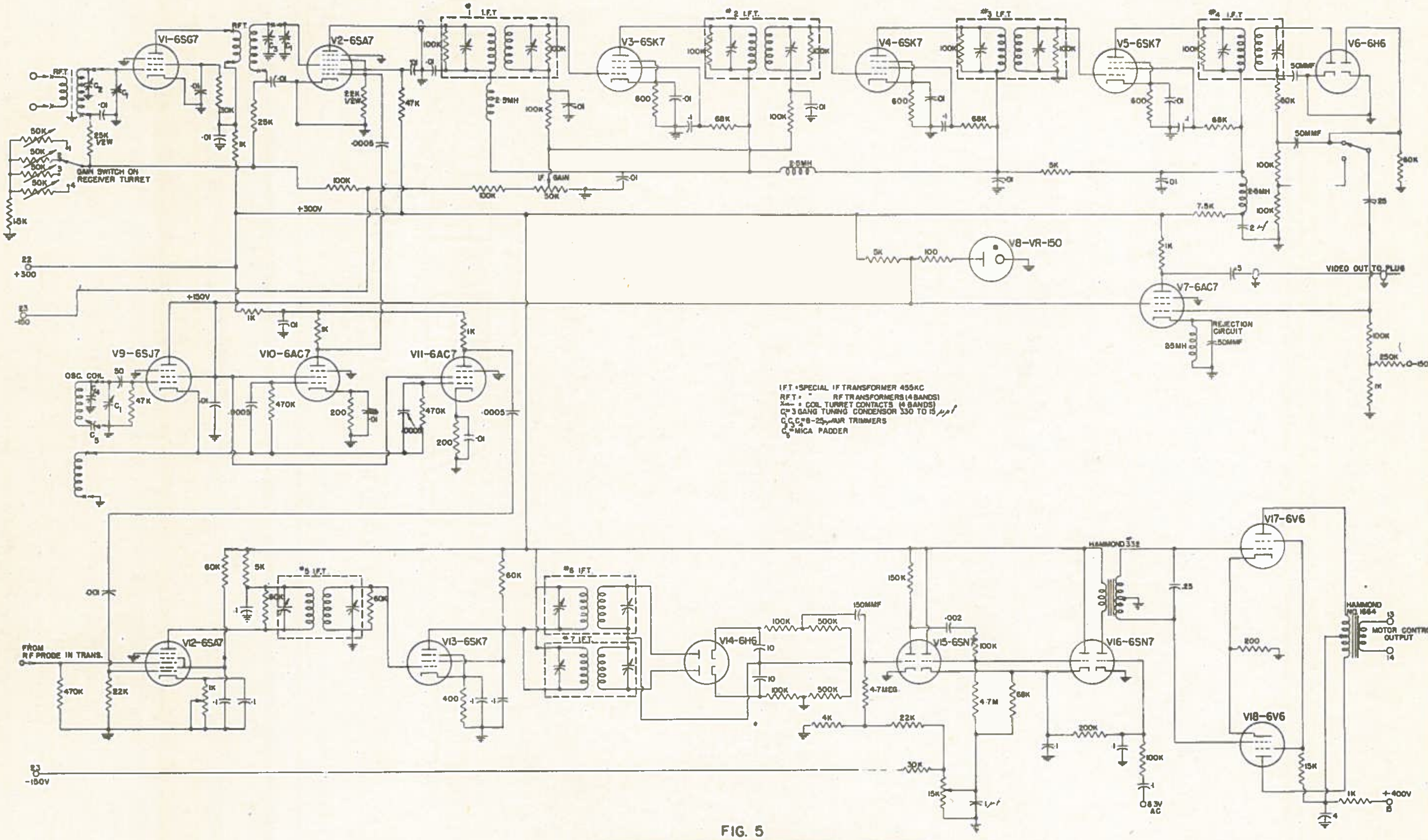


FIG. 5
RECEIVER AND MOTOR CONTROL CIRCUITS
UNIT B

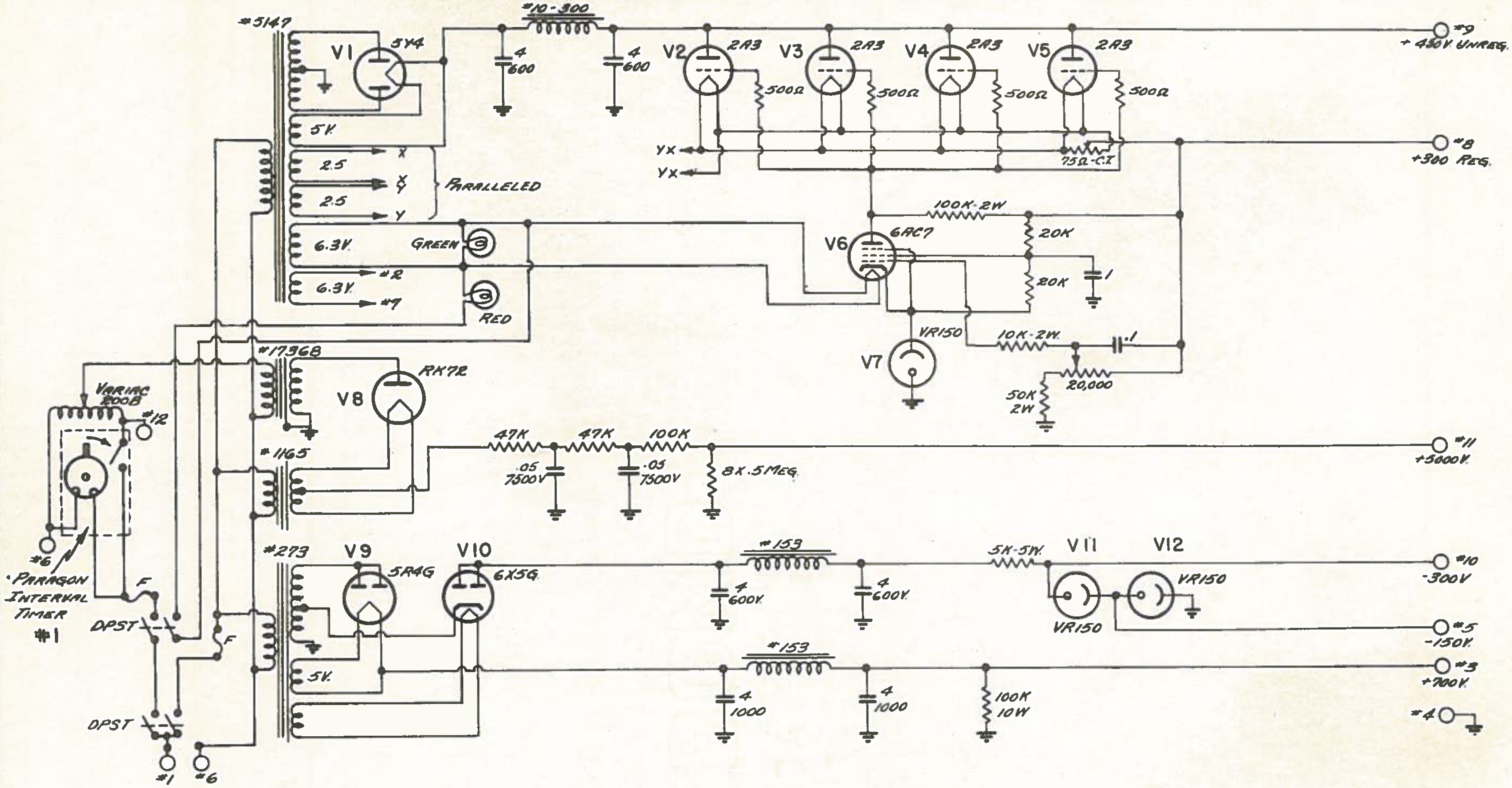


FIGURE 6

POWER SUPPLY
FOR
TRANSMITTER, RECEIVER, AND MOTOR CONTROL CIRCUITS
UNIT C

PRA 132

LE-56-45-B

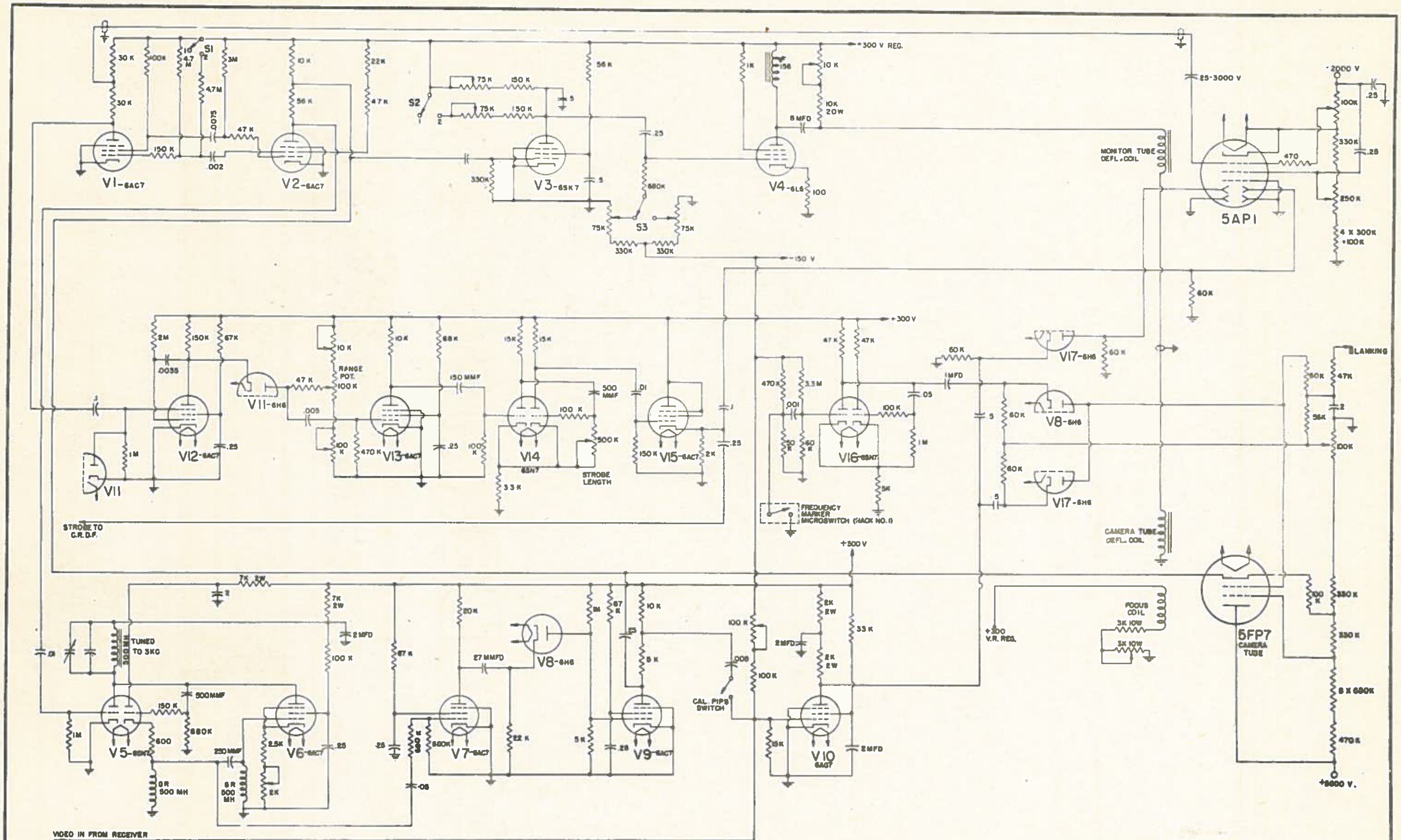

FIG. 7
SCANNER & CAMERA SCOPE CIRCUITS
UNIT D

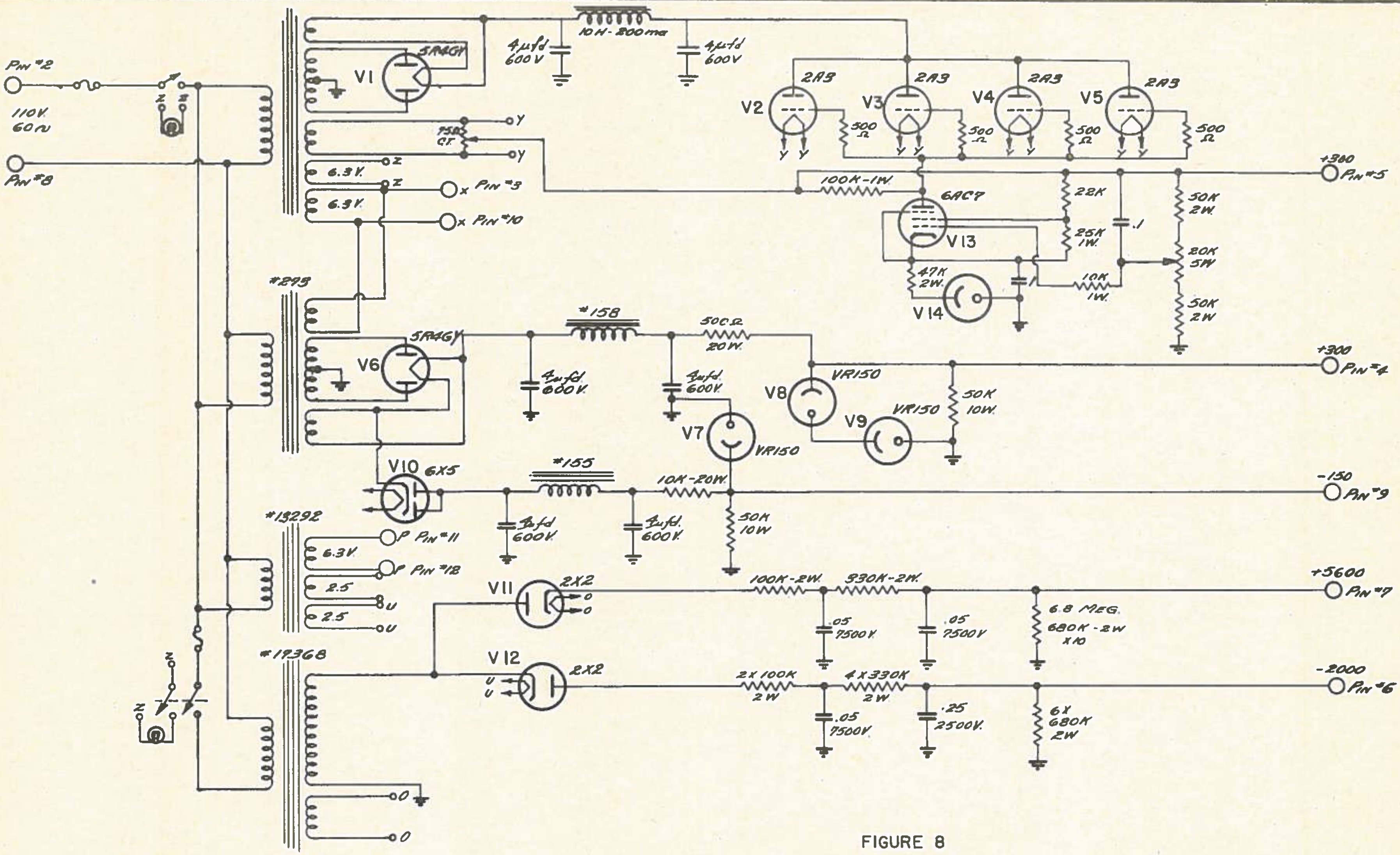


FIGURE 8

POWER SUPPLY FOR SCANNER
UNIT E

PRA 132

LE-56-46-B

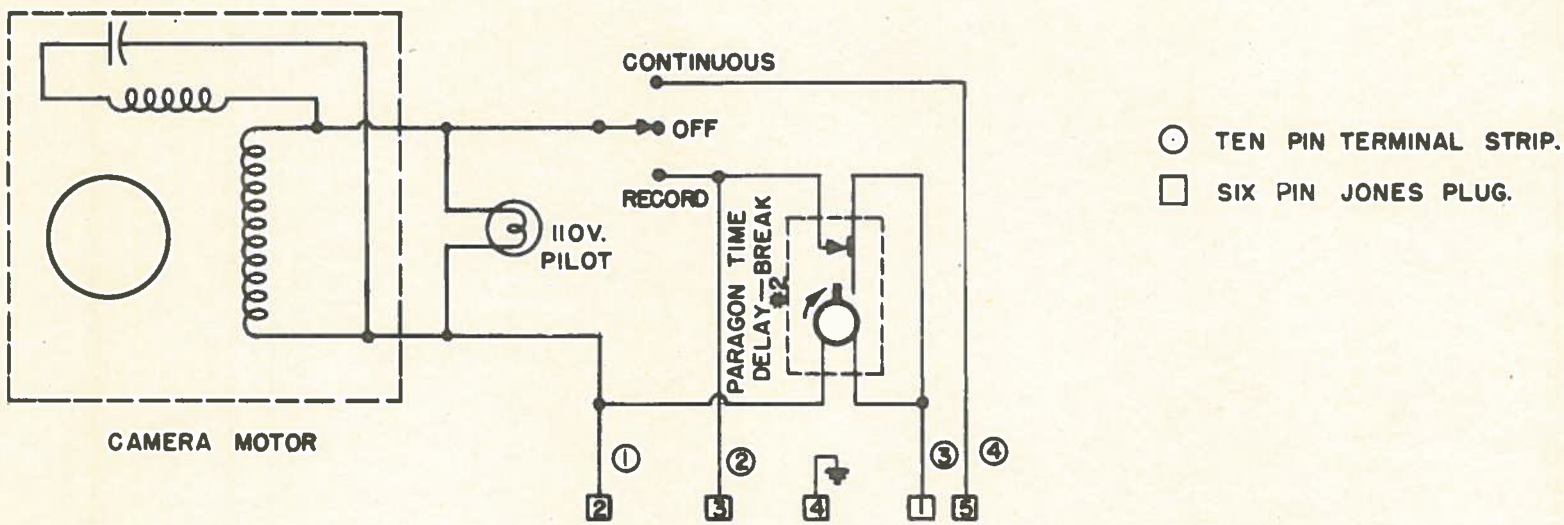


FIGURE 9

CAMERA CONTROL CIRCUITS
UNIT F

PRA —132

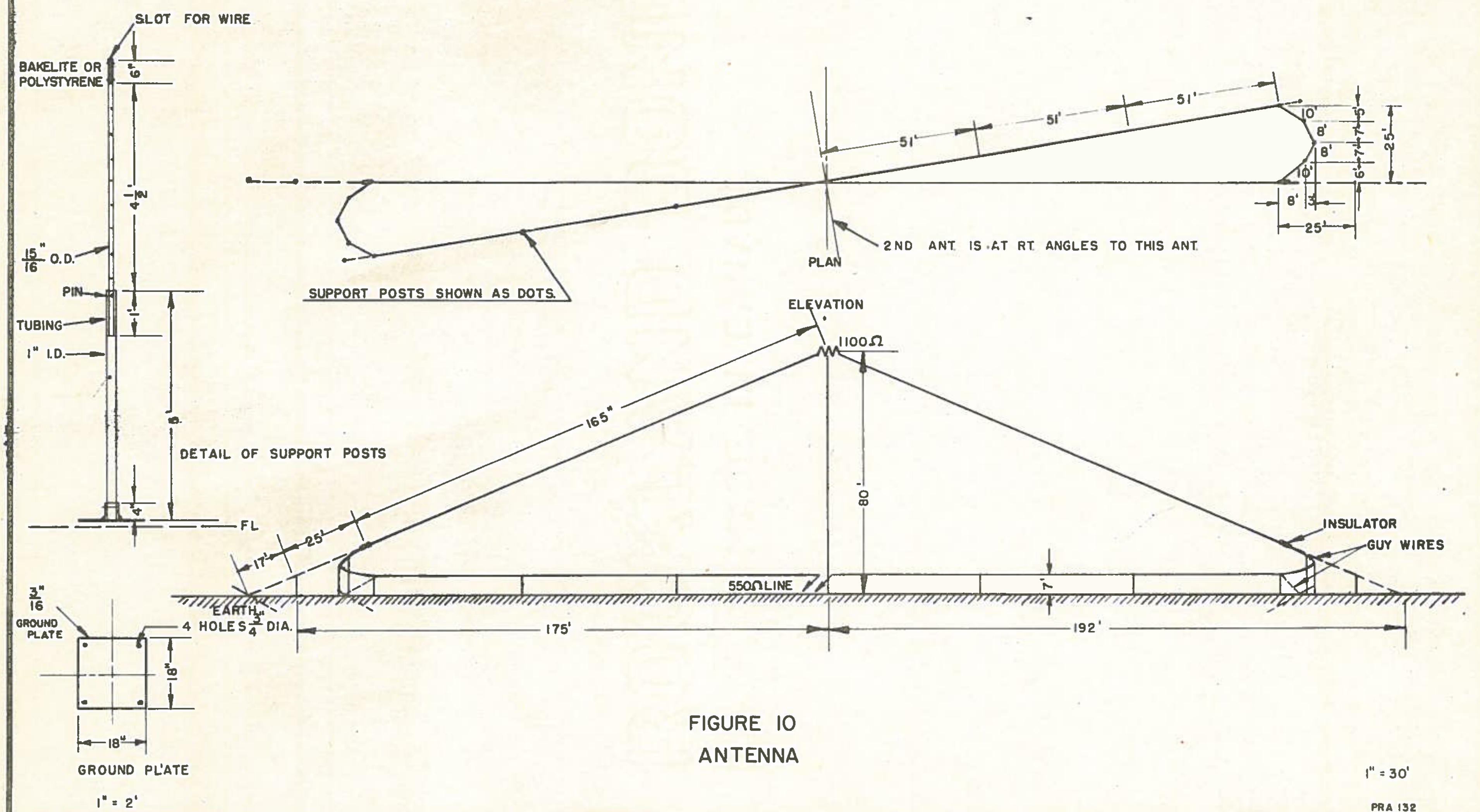


FIGURE 10
ANTENNA

LE-56-44-B