Western Electric

RADIO TRANSMITTER

D-156000

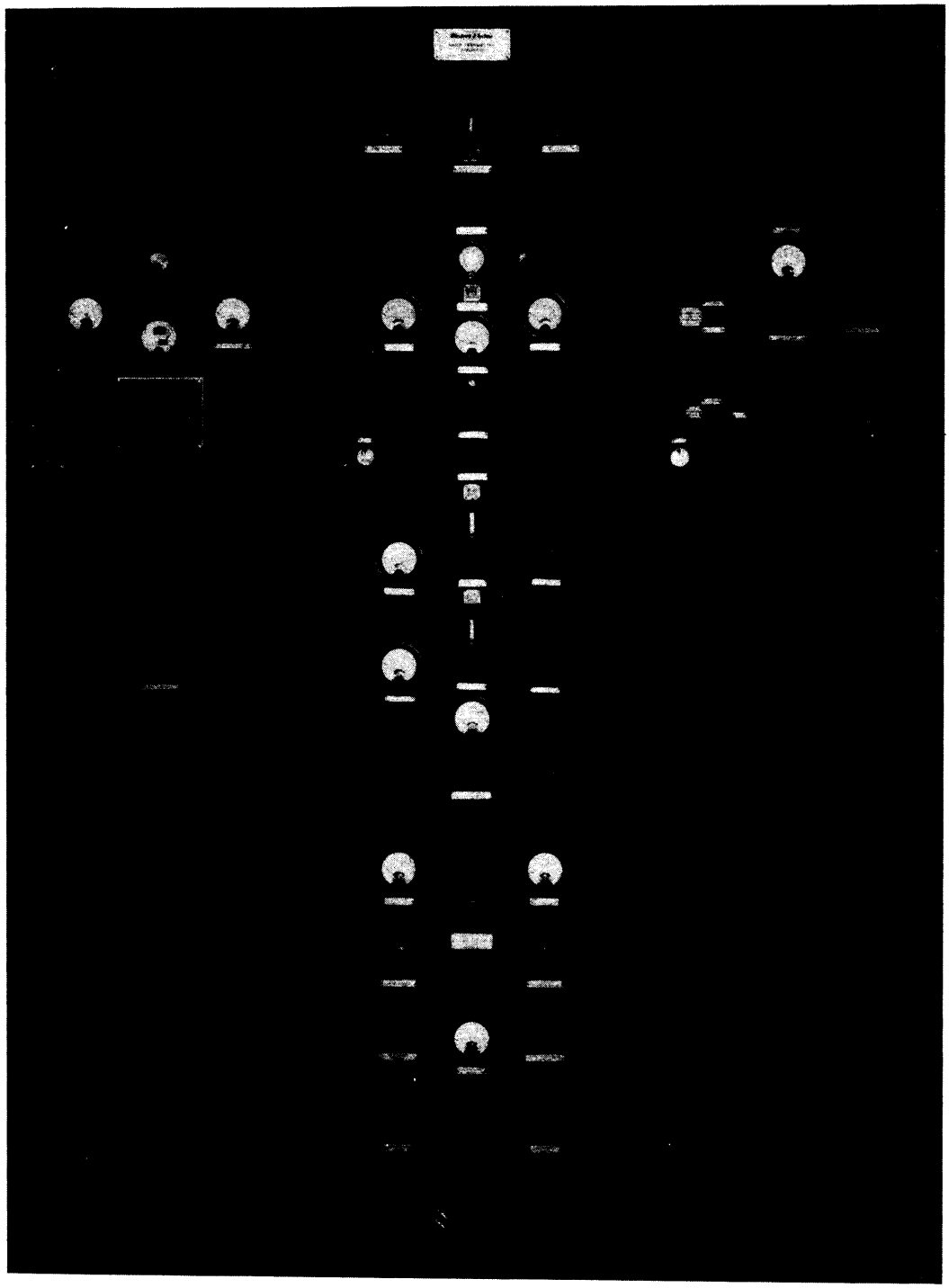
Volume I — General Description

Volume II — Installation Instructions

Volume III — Description, Operation and Maintenance

Instruction Bulletin No. 985

Issue 2



D-156000 Radio Transmitter - Front View 89725

Volum I.

GENERAL DESCRIPTION OF
WESTERN ELECTRIC D-156000 RADIO TRANSMITTER

1. GENERAL

The D-156000 Radio Transmitter is a short wave transmitter incorporating the best engineering features which the present state of the art will permit. It is designed for transoceanic telephony in the frequency range from 4,500 to 22,000 kilocycles. The complete D-156000 transmitter provides for the transmission of two telephone channels in a so-called twin-channel single sideband system and alternatively, one conventional double sideband channel. Consequently it may be used in any communication service within its frequency range requiring either single or double sideband transmission. Unless otherwise specified the transmitter is supplied equipped for twin-channel single sideband service. If desired the equipment for the second single sideband channel may be omitted. The double sideband equipment is only supplied if specifically ordered. The necessary cabling for these optional arrangements is complete and the units may be added at any time.

In the twin-channel single sideband system the radio transmitter and receiver provide two independent transmission bands extending from 100 to 6,000 cycles on opposite sides of a common reduced carrier and the two telephone channels, each about 3,000 cycles wide, are positioned in these bands by modulators in the wire terminal equipment at the control centers. Thus, considerable flexibility is available for the disposition of the communication channels to reduce interference or inter-channel cross talk. Usually the two channels are separated from each other by one channel width. If one radio transmission band is not used, the full width of the other band may be used for high fidelity transmission such as that required for a broadcast program circuit.

The twin-channel single sideband with reduced-carrier has definite advantages over a normal double sideband system. Foremost is the improvement of 9 decibels in signal-to-noise ratio which is obtained on the basis of equal transmitter peak amplitudes. The ability to transmit two independent telephone channels through one equipment offers important advantages. The reduction of distortion at the receiver at times when the carrier fades selectively is a desirable improvement resulting from the single sideband method of transmission.

Certain requirements must be met and certain methods of operation must be identical in both single sideband transmitter

id receiver in order that the system will function properly. The D-156000 Radio Transmitter is designed to operate with a D-99945 Radio Receiver. This transmitter provides for twin-channel operation by placing one channel on each side of a carrier normally reduced 10 decibels below the reference amplitude for single-channel operation and 20 decibels for twin-channel operation. Reference amplitude is by definition the amplitude of one of two equal tones which load a transmitter to its envelope peak output. The envelope peak output is determined by the allowable distortion in the transmitter, which usually sets the distortion limits for the system. Distortion is of prime importance in a twin-channel system because it determines the allocation of the communication channels and the type of privacy that may be employed. For connections with systems employing band splitting privacy the maximum intra-channel distortion product generated by two tones of reference amplitude should be at least 25 decibels below one of the two tones. To limit interchannel cross talk to a satisfactory value, the nearest edge of one of the two channels is ordinarily translated one bandwidth from the carrier.

In order to avoid certain difficulties in the generation of the conversion frequency supply to the third modulator it is desirable to use the upper sideband from this modulator on the higher frequencies and the lower sideband on the lower frequencies. Consequently the transmitter is arranged so that channel A is the upper sideband for radiated frequencies of 10,000 kilocycles and higher and is the lower sideband for radiated frequencies less than 10,000 kilocycles. Channel B is the other sideband in both cases. Obviously this same sideband turnover at 10,000 kilocycles must take place in the receiver.

Due to the low temperature coefficient quartz crystals and the use of voltage regulators in the power supply to the oscillators the frequency stability of the D-156000 transmitter is exceedingly good. The use of a resistance type of circuit with no tuned reactances for the high frequency oscillator contributes materially to the fine stability.

Great attention in the design of this transmitter has been given to the elimination of sources of noise modulation from the power supplies. Heater type unipotential cathodes are used throughout the low power equipment. Rectified and filtered dc is used on the filaments of the medium power amplifiers and the filaments of the two tubes in the final amplifier are supplied from transformers whose secondary voltages have a quadrature relationship. The alternating current supply wires in the interconnecting cable have been carefully shielded where they are in proximity to leads into which hum might be

introduced. These refinements in design all contribute to a satisfactory single sideband signal-to-noise ratio.

The outstanding characteristic of the D-156000 Radio Transmitter is its reliability, achieved through painstaking attention to conservative electrical and mechanical design. In all components mechanical and electrical ruggedness are emphasized. Stability of gain is a great importance in a radio transmitter. Regulated supplies for the low power equipment, oscillators, modulators and amplifiers achieve high stability in that portion of the equipment. Voltage regulators also are used for the grid bias and screen supplies of amplifiers 3 and 4. The use of large capacity fans for ventilating the transmitter compartments results in materially reducing the effects of warm-up when starting the transmitter.

To the operator of radio transmitting equipment the protection of operating personnel is of paramount importance. While it is practically impossible to design a safety system that cannot be rendered ineffective by intentional tampering no effort has been spared to make the D-156000 transmitter as safe as it can be made. A specially designed mechanical interlock system prevents access to the transmitter compartment with power on. As an added precaution a special screw was designed for fastening the meters in place on the mats so that they may not be removed without first removing the power and operating the locks on the mats. As a precaution against accidental contact with potentially dangerous voltages appearing on the low power rectifier transformer terminals while testing the low power equipment, shields are provided over these terminals and provision is made for seals on the screws fastening these shields in place. Where applicable, provisions are also made for seals on the key locking system. Finally, a certain method for the operator to assure himself of the safety of the equipment is provided in a prod, grounded through a flexible chain, with which the operator may make contact to questionable portions of the circuit.

Accidental contact with the blades of the fans from the top of the transmitter is prevented by a rugged screen placed over the fan openings.

The ability to transmit a high quality single sideband signal depends to a great degree on the perfection of the filter used to separate the wanted from the unwanted sideband in the first modulation step. The use of the second channel of the twin system imposes still greater requirements on these filters. The filters used in this transmitter employ quartz crystal elements and their excellent design is reflected in the performance of the transmitter.

The optional double sideband featur of the D-156000 Radio Transmitter permits the use of this transmitter in a service where the correspondent is not equipped for single sideband reception. This feature might be desirable where the transmitter is used in a branched service with more than one correspondent. The change from single to double sideband is accomplished instantly by operating a relay in the transmitter, either locally at the transmitter, or remotely from the control terminal. No other adjustments or changes are required. A wobbler is provided by means of which the double sideband carrier is wobbled ± 250 cycles. This gives additional privacy for double sideband transmission. It may be stopped in its mid-position by means of an ingenious control from the front of the transmitter.

2. GENERAL DESCRIPTION

The Western Electric D-156000 Radio Transmitter is a moderate power transmitter for use in the frequency range from 4,500 to 22,000 kilocycles. A modification can be made in the transmitter to permit operation in the frequency range from 4,000 to 20,000 kilocycles if this range is more desirable.

A transfer switch in the output of the final amplifier permits the operation of the transmitter through the self contained matching network into a balanced open wire transmission line of 600 ohms nominal impedance or directly into a balanced concentric transmission line of approximately 200 ohms impedance. The latter arrangement is normally used when a D-156000 transmitter is used as a driver of a succeeding power amplifier. The transmitter may be adjusted from the front for operation on any one of six frequencies.

The transmitter is housed in two steel cabinets. One cabinet is a single relay rack in width so as to accommodate a single tier of 19 inch panels. The other cabinet is twice as wide so as to accommodate two tiers of apparatus. These cabinets when assembled, compose one unit whose base dimensions are 5 ft. 3/4-inch by 2 ft. 3 inches. The height of the cabinets is 7 ft. 0 inches. However, a wooden base 1-9/16 inches thick is placed under the transmitter and the output insulators extend about 3 inches above the top. The overall height is then just under 7 ft. 5 inches. The three doors at the rear of the transmitter swing open 90° and the width of each door is 19 inches. Operating controls are on the front. ES-761267 shows the base dimensions and ES-761264 is an outline front view of the transmitter. Photograph No. 89725 is a front view of the transmitter and 89722 is a rear view with the doors open and shield covers removed.

The cabinets are finished with a medium dark gray lacquer having finely divided aluminum particles in suspension. Control knobs are dull black bakelite and nameplates are dull chromium with black letters.

Power Requirements

Rectifier and power equipment for supplying all circuits from a 230 volt, three phase source are contained in the transmitter. The transmitter will perform satisfactorily with the supply voltage between 220 and 235 volts. Operation at 240 volts will reduce the filament life of the vacuum tubes in the final amplifier to one half the life at 230 volts. In case the mean line voltage of the supply does not stay within the limits of 220 to 235 volts it is necessary to provide a means of adjusting the supply voltage to within this range. A suitable device is the American Transformer Co. "Transtat" Spec. No. 29286. This has a rated output of 5.75 k.v.a. continuous, 3 phase, 230 volts 50/60 cycles. Adjustable for any input line voltage between 190 and 260 volts.

The equipment normally supplied is for 60 cycle operation. Fifty cycle equipment can be provided. The full load drawn is approximately 5 kilowatts. A separate interlocked service switch is provided which may be mounted as desired. The dimensions of the switch are shown on ES-761268. A polarized, one side grounded, 110-120 volt outlet should be available in the vicinity of the transmitter for supplying power for testing the low power portion of the transmitter with the doors of the transmitter open. Not more than 500 watts is required for these tests. The external power connections are shown on ES-761266. The 230 volt, 3 phase power leads from the service switch connect to the fuse block on panel A of rectifier 4. This block is about 33 inches above the floor and 16 inches from the rear on the extreme right hand side of the set when viewed from the rear. This is shown on photograph No. 89720. Terminals 25 and 26 on the distribution panel shown at the bottom of photograph No. 89720 are to be connected to the jaw and blade of one pole of the service switch. The opening of this switch disconnects the 115 volt test supply from the 230 volt system when testing with the doors open.

Circuit

The schematic block diagram ES-794932 shows the general arrangement of the apparatus.

Audio Input

The audio input impedance of the D-156000 transmitter is 600 ohms and it is arranged for an input of + 5 VU speech and a test tone input of one milliwatt.

Terminals 1 and 2 of the low frequency unit distribution panel are the input terminals for the "A" channel. Terminals 3 and 4 are the input terminals for the "B" channel. Terminals 5 and 6 are the input terminals for the test tone and terminal 7 is the terminal of the control circuit for operating the test tone keying relay. Terminal 8 is the terminal of the control circuit for the test tone generator. Terminal 16 is the terminal for remotely operating the single to double sideband transfer relay. These terminals all appear on the distribution panel of the low frequency unit which is on the left when the transmitter is viewed from the rear. These terminals are about 9 inches above the floor and are shown in photograph No. 89717.

Modulators

Three steps of modulation are employed to obtain the final sideband. Separate modulators and filters are employed for each channel in the first step of modulation. The same conversion frequency is used for each of these modulators, and band pass filters employing quartz crystal elements select the upper sideband from one modulator and the lower sideband from the other. The passed band of these filters is equivalent to a 100 to 6,000 cycle audio input band for each channel.

The first modulators are balanced and are equipped with an adjustment by means of which a high degree of carrier suppression can be maintained. An adjustable gain carrier re-supply amplifier provides the required amplitude of carrier for transmission

Conversion frequencies for the first two steps of modulation are derived from a 625 kc quartz crystal controlled oscillator. The 125 kc subharmonic of the oscillator frequency is obtained from the associated multivibrator. This supplies the first modulators and the carrier re-supply amplifier. The 2,500 kc conversion frequency for the second modulator is obtained from a harmonic generator which is driven by the same 625 kc oscillator.

The second modulator is also a balanced modulator. The filter following it selects the upper sideband from the modulator output. This filter is of an electrical type employing inductive and capacitive elements. The output of this filter consists of a 2,625 kc carrier and either one or two adjacent sidebands.

The conversion frequency for the third modulator is obtained through a harmonic generator from another quartz crystal controlled oscillator. This conversion frequency and consequently that of the crystal oscillator is fixed by the assigned frequency of the radiated signal inasmuch as the selected sideband from the third modulator is at the final radiated frequency. Low temperature coefficient quartz crystals are used for the 625 kc and for the high frequency oscillators. No temperature control is employed.

The low power portion of the high frequency equipment is arranged in such a way that interchangeable pretuned circuits and crystals are available by means of selector switches for six frequencies. If operation on additional frequencies is required the pretuned circuits and crystals may be removed and other units inserted without disturbing the adjustments of the units.

Continuously variable inductances are used for tuning the higher power equipment.

When used for single channel double sideband transmission the single sideband first modulators are made inactive and the channel A input is switched to the double sideband equipment. In this equipment, a 125 kc electric oscillator, the frequency of which may be wobbled $\pm$ 250 cycles drives a modulated amplifier stage. The output of this amplifier is connected to the input of the second modulator. From this point on the operation of the transmitter is the same as for single sideband transmission.

Output

Five stages of amplification follow the third modulator in the D-156000 transmitter. Pentodes are employed in the first four stages. The fifth stage of this amplifier is composed of a balanced, neutralized stage employing triodes. The output of this stage may be connected to either of two output connections by means of the "Output Transfer" switch. One position of the switch, designated as the "Antenna" position connects the output through an impedance transformation circuit to the terminals on the top of the transmitter. This output transformer can be used to match a balanced open wire transmission line of 600 ohms nominal impedance. Such a line has been used to connect the D-156000 transmitter directly to an antenna. The other position, designated as the "Amplifier" position is used to connect the D-156000 transmitter to a succeeding power amplifier through a balanced concentric transmission line of approximately 200 ohms impedance.

Interlock

A key interlock is provided on the "Output Transfer" switch. The interlock employs a "Yale" type of lock. The key of the lock can be removed only when the transfer switch is locked in the "Antenna" position, and the key must be in place in the D-156000 transmitter before the switch can be thrown to the "Amplifier" position. If a suitable lock mechanism is provided in the power amplifier this key may be utilized to prevent access to the amplifier when the "Output Transfer" switch is in a position to supply high frequency drive to the amplifier. There is then no possibility of burn or shock to persons working on the power amplifier due to high frequency voltage from the D-156000 transmitter.

The rear doors of the transmitter and the mats are provided with key operated locks so arranged that they may not be opened without keys from the key interchange lock. This keeps the door and mat keys locked in the interchange lock until the service switch is opened and the key from it inserted in the key interchange lock. Likewise the key for the switch cannot be removed from the key interlock until all the keys from the mats and door locks are in place in the key interchange lock. This arrangement prevents opening of the doors and mats before the power has been removed and then prevents applying the power before closing and locking the mats and doors.

Monitor

The monitor provided as a part of the D-156000 transmitter may be used to monitor the output of the transmitter and facilitate measurements of distortion. It may be connected to a pick-up loop in amplifier 5 or may be switched to other pick-up loops in succeeding amplifiers. The small amount of signal obtained from the monitoring loop is applied to the monitor first detector. Conversion frequency supply for this detector is obtained from a harmonic generator driven by the crystal oscillator in the transmitter proper. The output of the first detector, consisting of a reduced 2,625 kc carrier and either one or two sidebands, is then applied to the second detector 2,625 kc is supplied to the second detector from a special modulator in the low frequency unit of the transmitter. The output of the second detector is a reproduction of the signal input to the transmitter. Since the principal purpose of the monitor is to provide a means of measuring distortion in the transmitter no provision has been made in the monitor for separating th two chann ls of the twin system.

As many as six points external to the D-156000 transmitter may be connected to the monitor. A single conductor lead-covered wire should be run from the monitor in the high frequency unit of the D-156000 transmitter to each such point in the succeeding amplifiers. The exposure to the amplifier should consist of a single turn of small diameter (about 2 inches) connected to the conductor and to the lead sheath and coupled to the circuit which is to be monitored. Terminals 1 and 2 of the high frequency unit distribution panel are the monitor output terminals. These are shown on photograph No. 89720.

Amplifier Output Voltmeter

A milliameter having a 0-5 m.a. range is provided on the D-156000 transmitter. The connections to this meter are brought to terminals 9 and 10 of the low frequency unit. If a suitable rectifier type of peak voltmeter has been provided on the output of the power amplifier it may be connected through this meter so as to give an indication of the amplifier output voltage to the person adjusting the D-156000 transmitter. This will facilitate the proper adjustment of the carrier amplitude and gain of the D-156000 transmitter.

Location

The exact location of the D-156000 transmitter relative to an associated power amplifier is not important. Inasmuch as a transmission line is used to connect the output of the D-156000 transmitter to the input of the power amplifier, the units can conceivably be a considerable distance apart. However, for operating convenience a more compact arrangement would seem desirable. An arrangement with the units adjacent and with the front faces in a plane might be considered. Another convenient arrangement would be with the D-156000 transmitter facing the power amplifier.

External Connections

The following is a list of the external connections.

Panel	Terminal #	Purpose
Low Frequency Unit Distribution Panel	1) 2)	Channel A audio input
	3) 4)	Channel B audio input
	11	Ground for shields on above pairs

10. MODULATOR #1A AND #1B

C1 Western Electric Co., Condenser, Type 233A, 0.7 mf., 400 V.
C2 d-c.
C3

C4 Western Electric Co., Condenser, Type 137A, 4 mf., 200 V. d-c.

C5 Hammarlund Mfg. Co., Condenser, Dual APC, 50 mmf. each side, common rotor, made on #2592 base. Type B shaft.

J1 Western Electric Co., Jack, Type 218A.

R1 International Resistance Co., Resistor, Type BT-1, 0.3 megohm.

R2 International Resistance Co., Resistor, Type BT-1/2, 50,000
R3 ohms.

R4 Western Electric Co., Resistance, Type 38E, 20,000 ohms.

R5 International Resistance Co., Resistor, Type BT-1, 60,000 ohms.

R6 General Radio Co., Rheostat, Type 410A, 200 ohms.

R7 International Resistance Co., Volume Control, Type 11-120, 25,000 ohms.

R8 International Resistance Co., Resistor, Type BT-1/2 800 ohms.

R9 International Resistance Co., Resistor, Type F-1/2 100 ohms.
R10

R11 International Resistance Co., Resistor, Type BT-1/2 300 ohms.

R12 International Resistance Co., Resistor, Type BT-1/2 150 ohms.
R13

T1 Western Electric Co., Input Transformer, Type D-97793

T2 Western Electric Co., Input Transformer, Type D-97798

T3 American Transformer Co., Filament Transformer as per Spec. No. 19989, 115/2.1 V., single phase, 50-60 cycles, 10.7 VA.

T4 Western Electric Co., Output Transformer, Type D-97794 for Modulator #1A. Type D-97799 for Modulator #1B.

V1 Western Electric Co., Vacuum Tube, Type 259A
V2

Photograph 89717 - Rear View for Input Connections.
89720 - Rear View for Power Connections.
89722 - General Rear View.
89725 - Front View.

References:

The following references contain information of interest on single sideband systems. References (2), (3) and (4) describe fairly completely the single sideband system for which the D-156000 transmitter was designed.

1. A. H. Reeves "The single sideband system applied to short-wave telephone links", Jour. I.E.E. (London), Vol. 72, pp. 245-279, September 1933.
2. F. A. Polkinghorn and N. F. Schlaack "A single sideband short-wave system for transatlantic telephony", Proc. I.R.E., Vol. 23, pp. 701-718, July 1935. (Bell System Monograph B-872).
3. A. A. Oswald "A short-wave single sideband radiotelephone system", Proc. I.R.E., Vol. 26, pp. 1431-1454, December 1938. (Bell System Monograph B-1113).
4. A. A. Roetken "A single sideband receiver for short-wave telephone service", Proc. I.R.E., Vol. 26, pp. 1455-1465, December 1938. (Bell System Monograph B-1114).
5. N. Koomans "Single sideband telephone applied to the radio link between The Netherlands and The Netherlands East Indies", Proc. I.R.E., Vol. 26, pp. 182-206, February 1938.

The equipment described in this bulletin
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by

BELL TELEPHONE LABORATORIES

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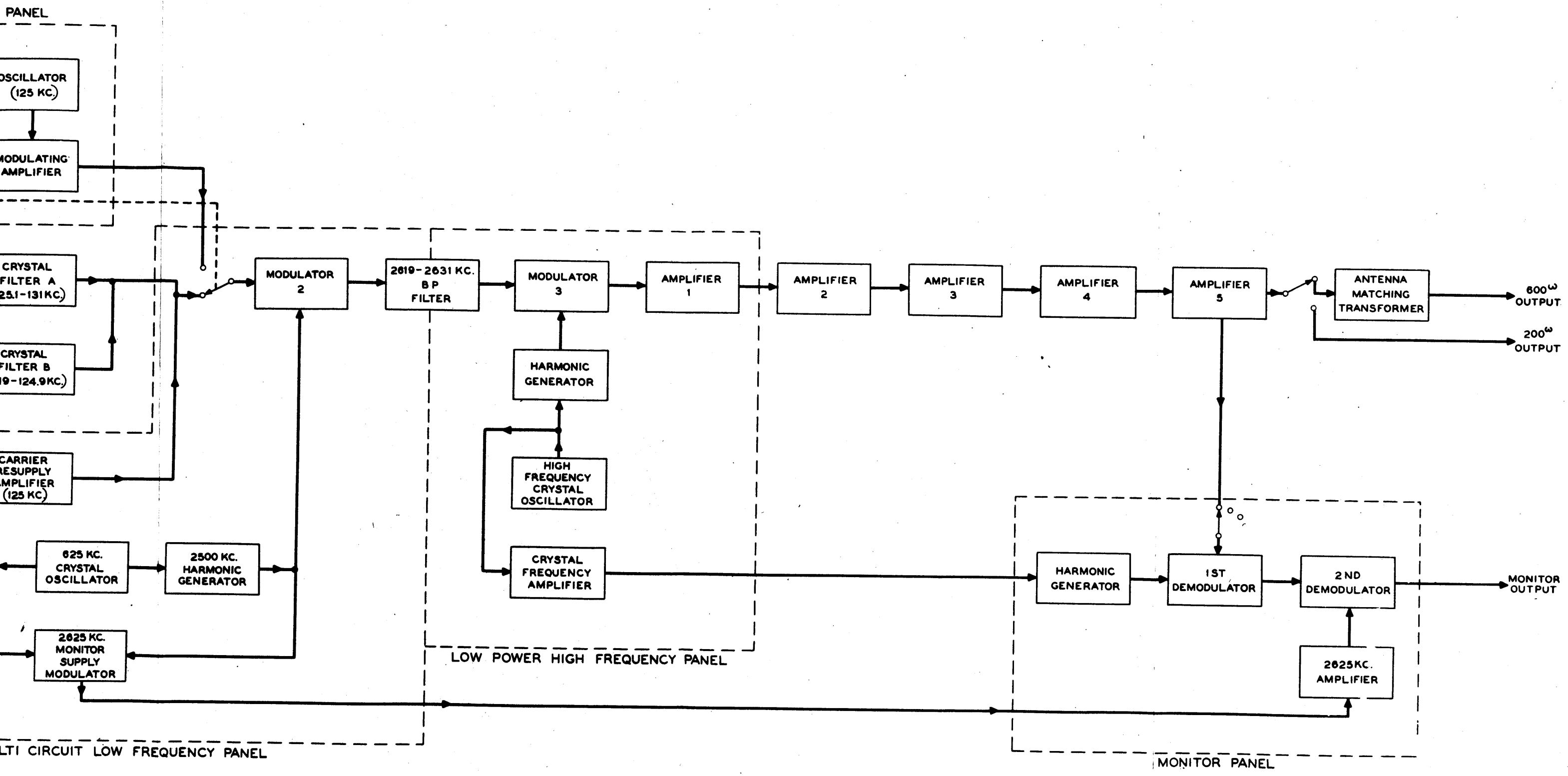
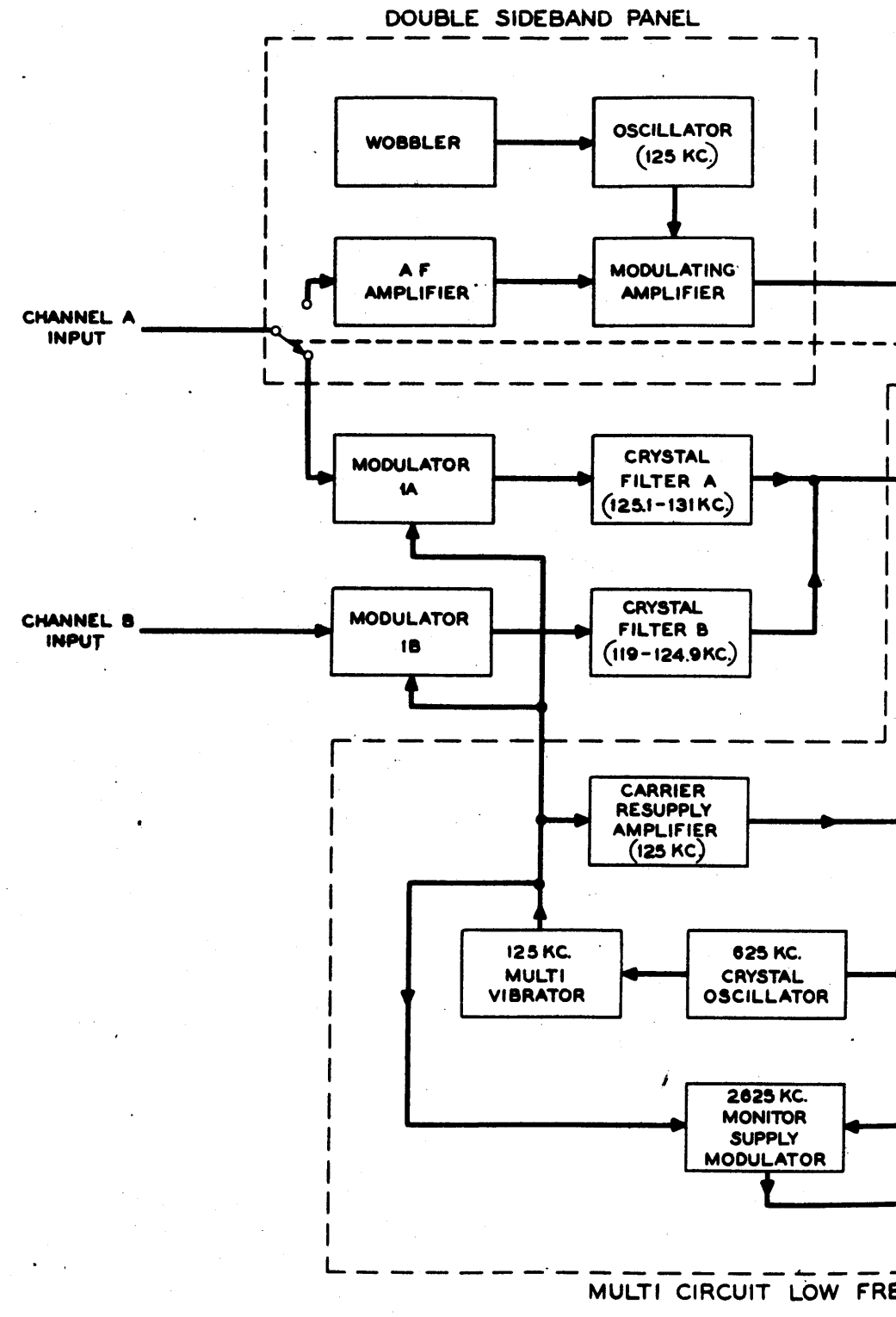
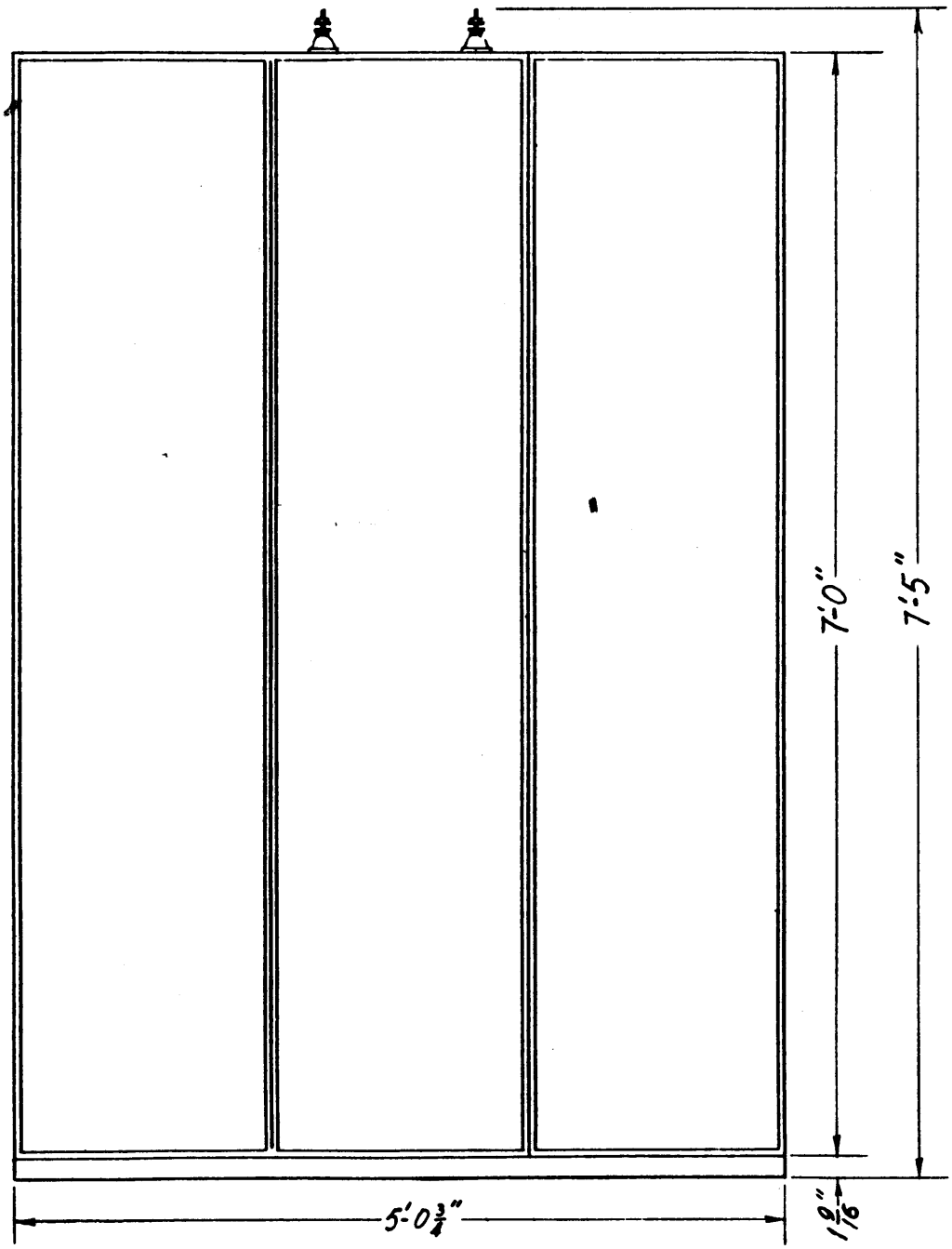
Printed in U. S. A.

D-156000 RADIO TRANSMITTER
BLOCK DIAGRAM

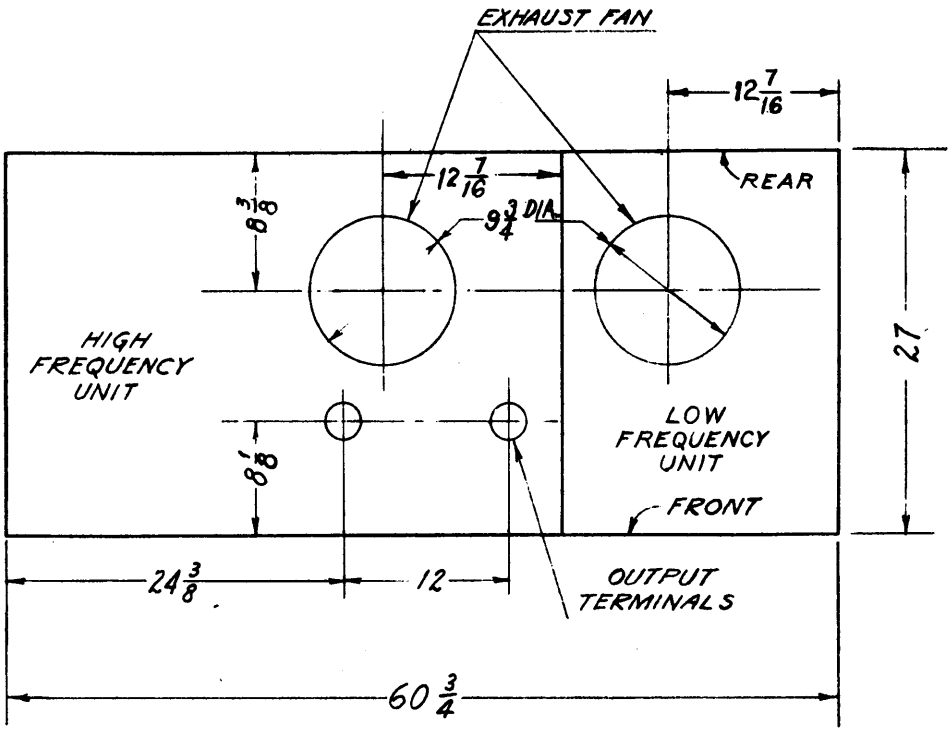


ES-794932
Issue 1

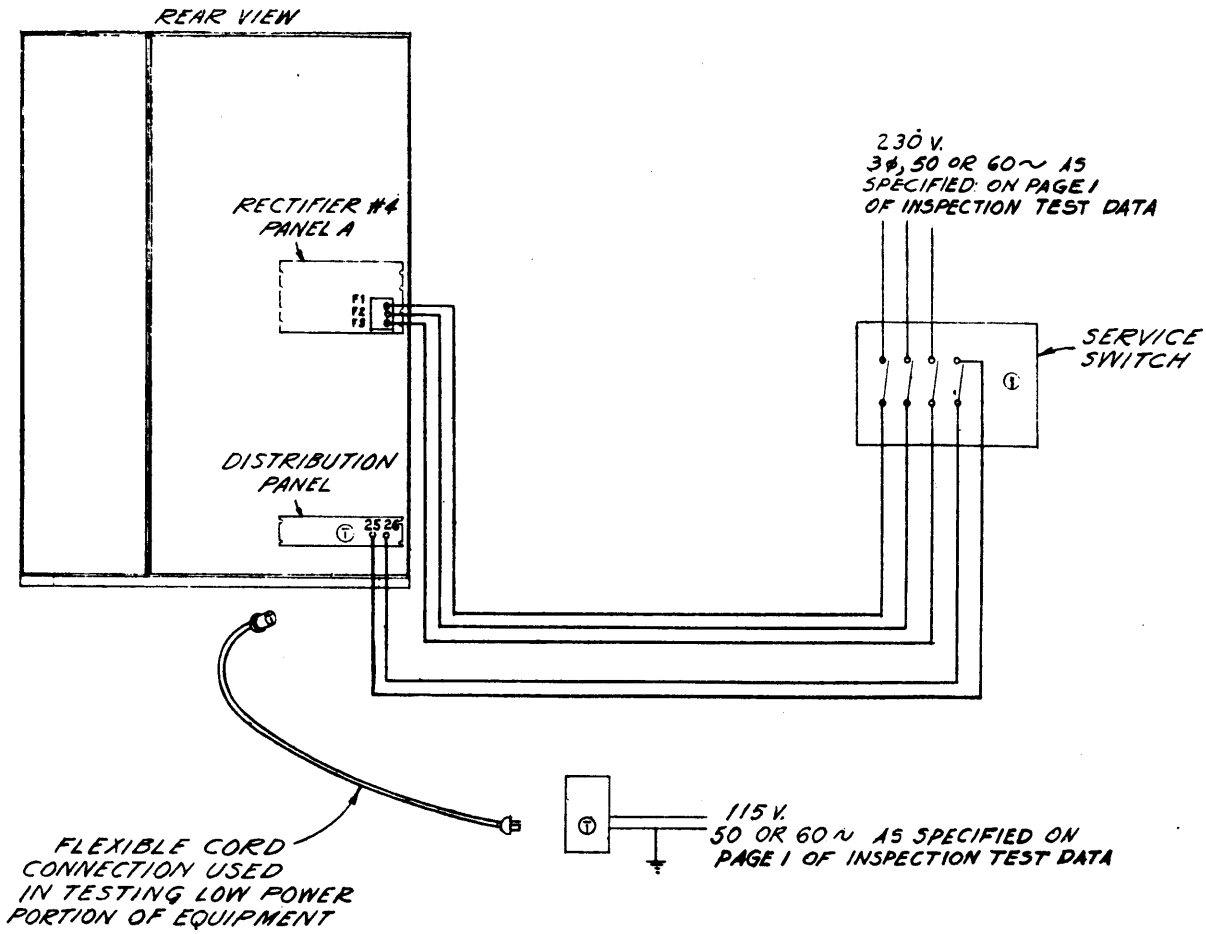

DOUBLE SIDEBAND PANEL
WOBBLER
OSCILLATOR (125 KC)
A F AMPLIFIER
MODULATING AMPLIFIER
CHANNEL A INPUT
MODULATOR 1A
CRYSTAL FILTER A (125.1-131KC)
CHANNEL B INPUT
MODULATOR 1B
CRYSTAL FILTER B (119-124.9KC)
CARRIER RESUPPLY AMPLIFIER (125 KC)
125 KC. MULTI VIBRATOR
625 KC. CRYSTAL OSCILLATOR
2625 KC. MONITOR SUPPLY MODULATOR
MULTI CIRCUIT LOW FRE

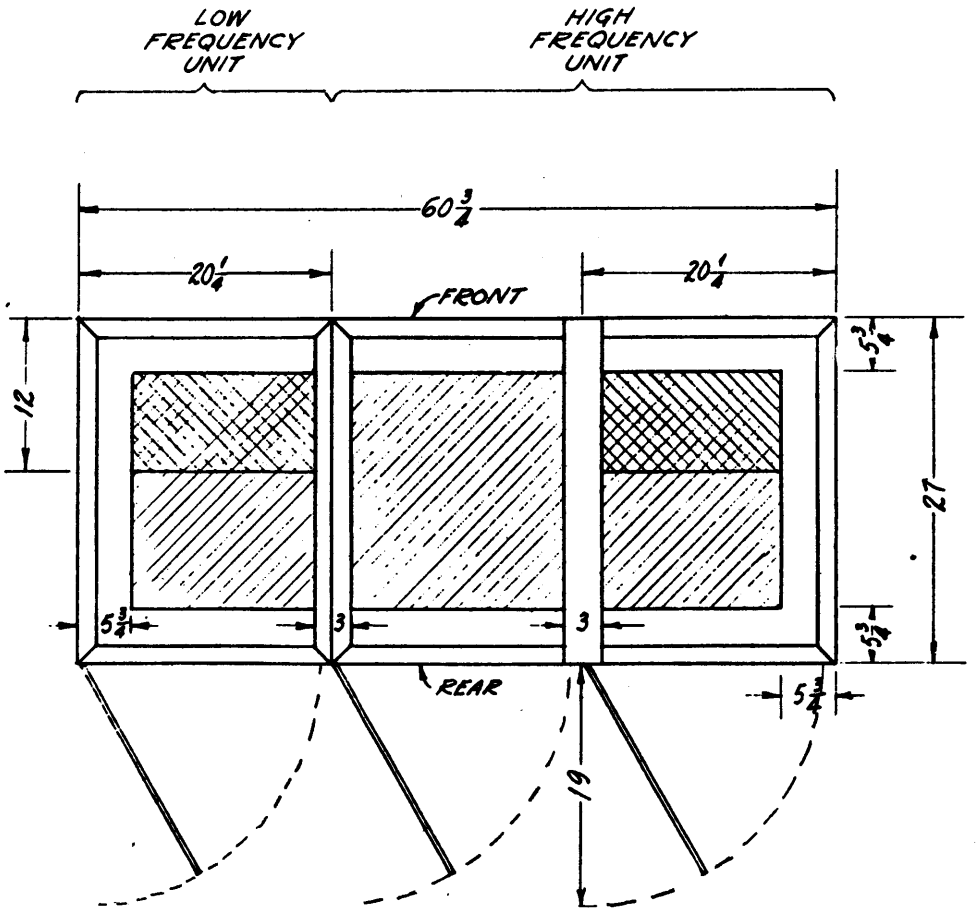


D-156000
RADIO TRANSM.
OVERALL
FRONT DIMENSIONS



D-156000
RADIO TRANSM.
TOP
LAYOUT


REAR VIEW
230 V.
3φ, 50 OR 60~ AS
SPECIFIED ON PAGE 1
OF INSPECTION TEST DATA
RECTIFIER #4
PANEL A
F1
F2
F3
SERVICE
SWITCH
DISTRIBUTION
PANEL
25
26
115 V.
50 OR 60 ~ AS SPECIFIED ON
PAGE 1 OF INSPECTION TEST DATA
FLEXIBLE CORD
CONNECTION USED
IN TESTING LOW POWER
PORTION OF EQUIPMENT

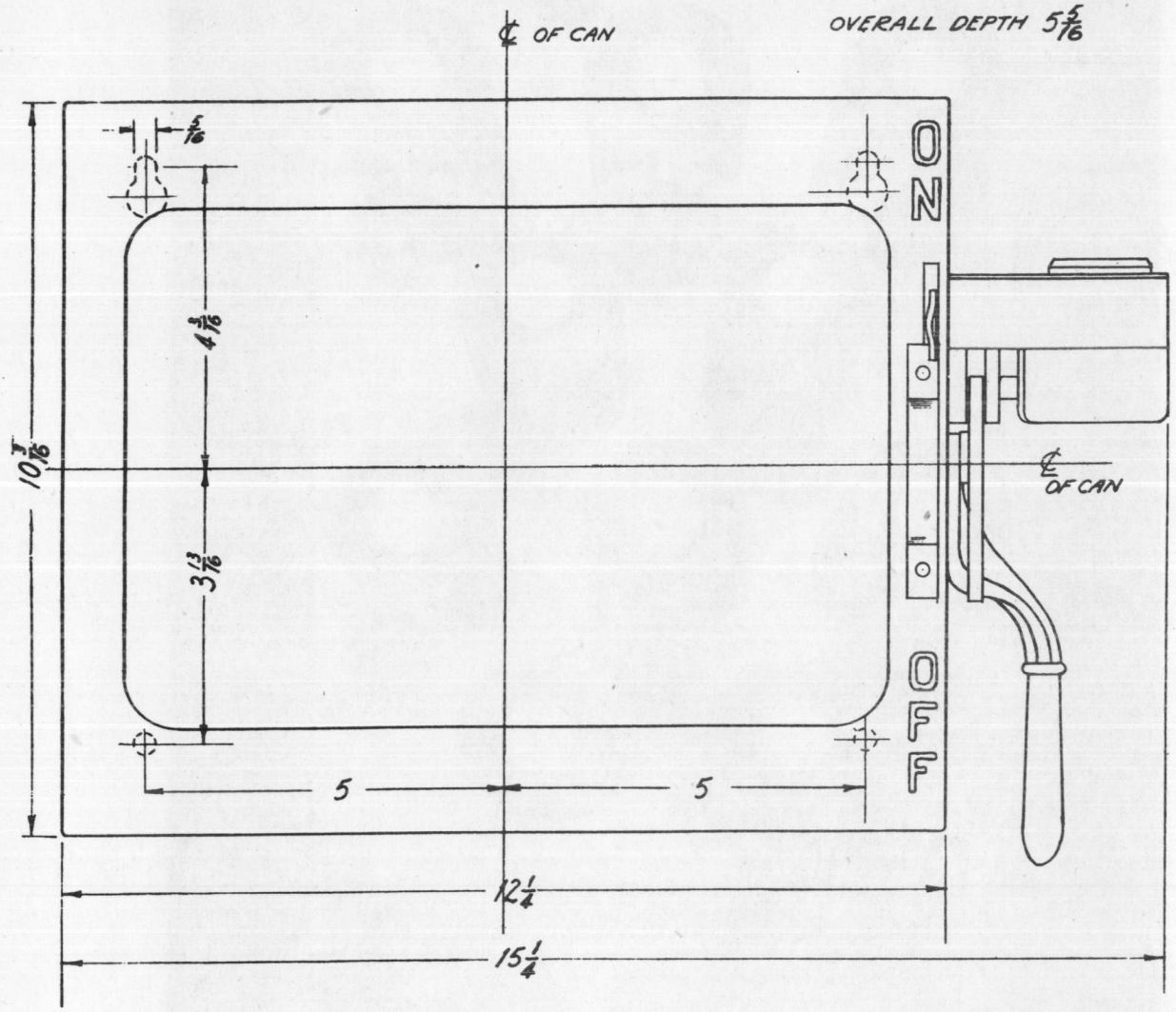


AREA AVAILABLE FOR CONDUIT ENTRANCE

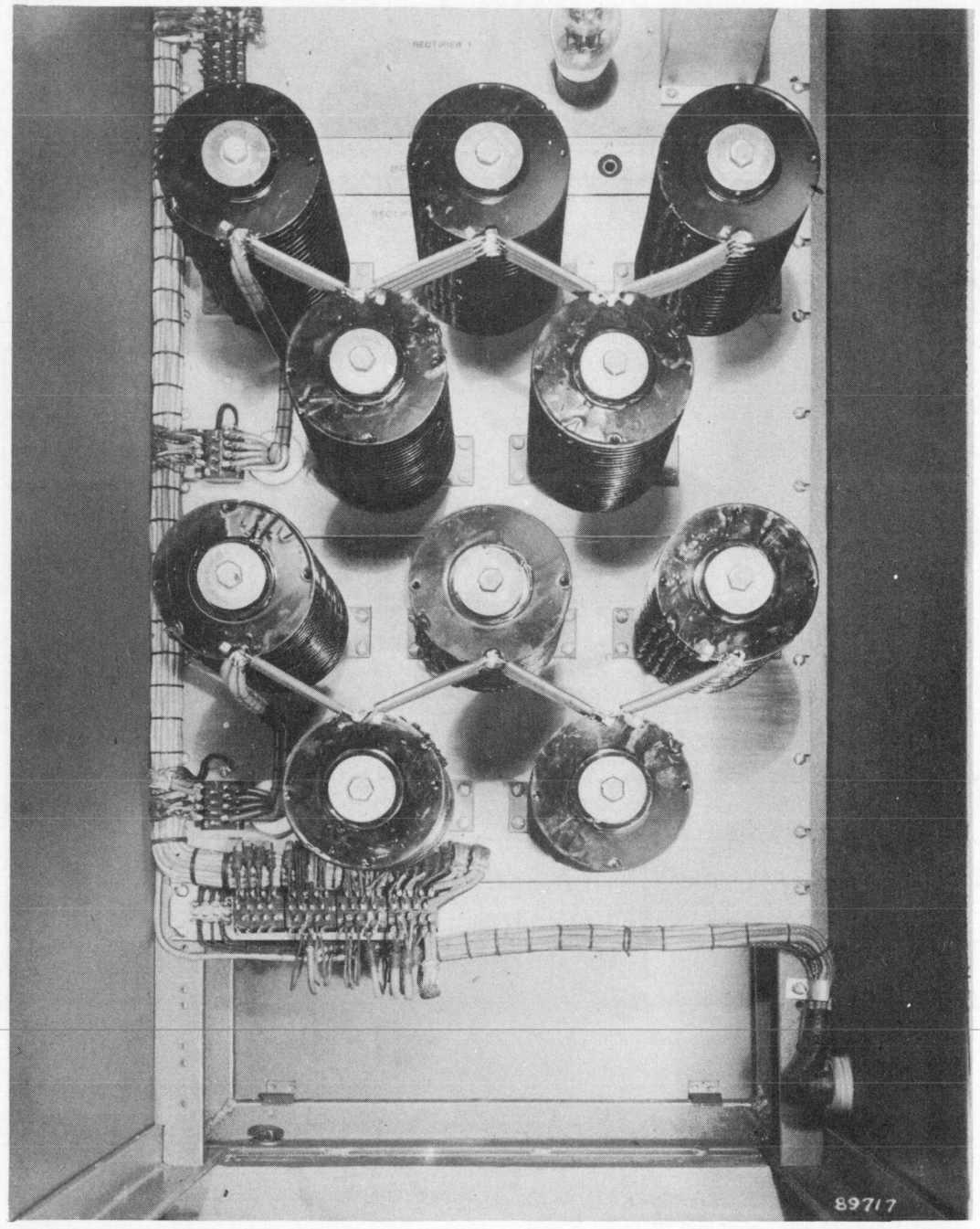
PREFERRED AREA

AVAILABLE AREA

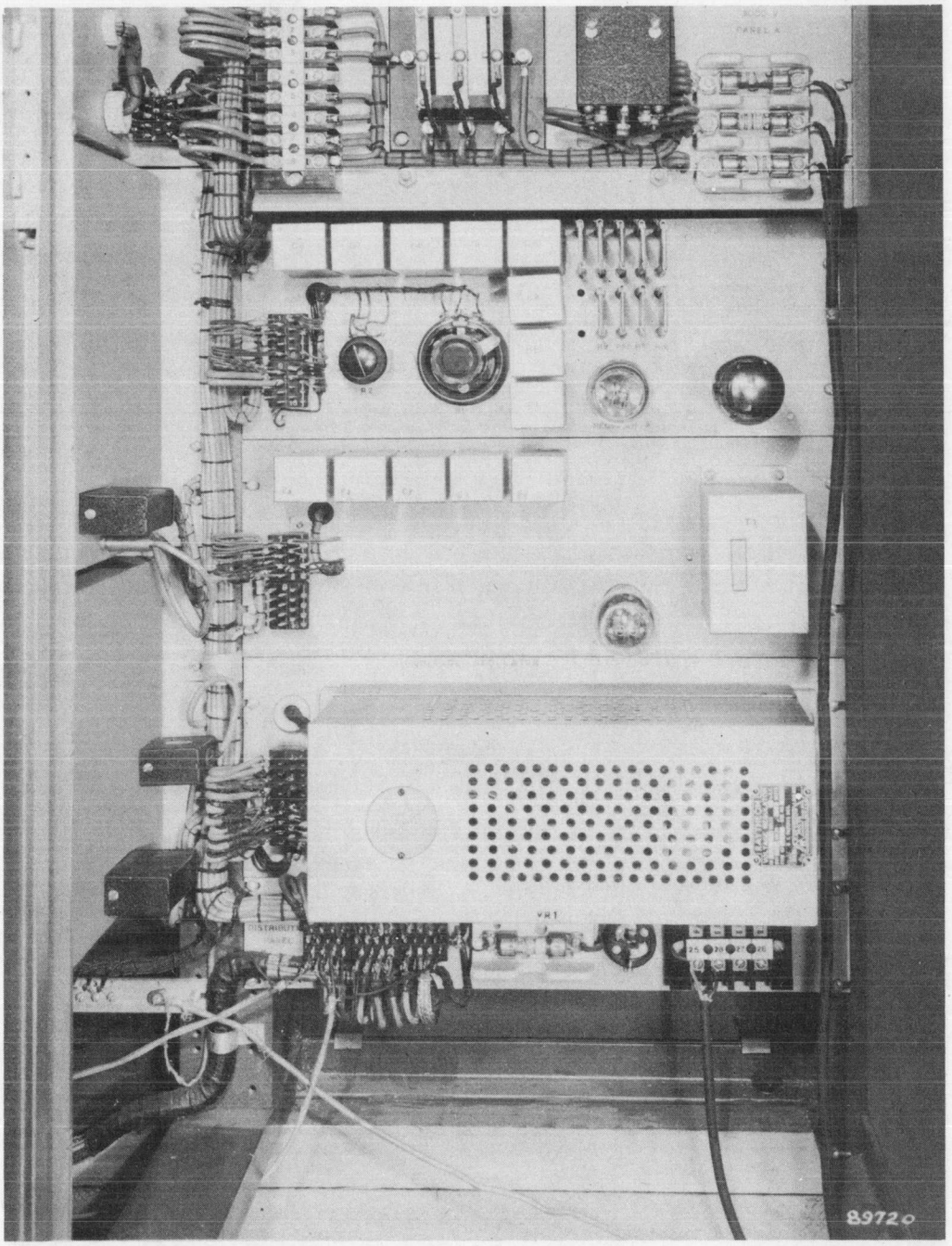
D-156000
RADIO TRANSM.
BASE
LAYOUT



D-156000
RADIO TRANSM.
SERVICE SWITCH
MOUNTING
INFORMATION

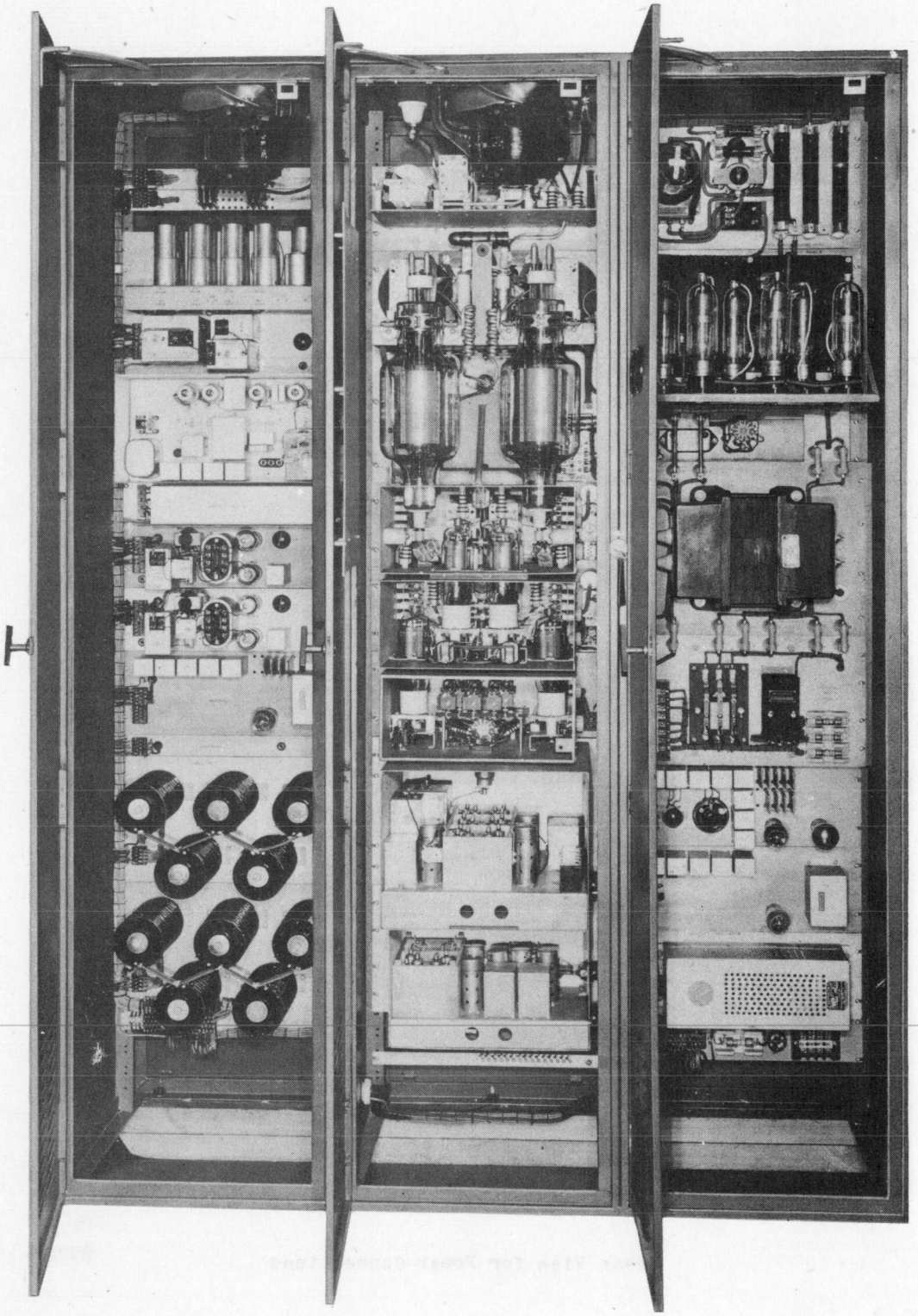


89717 Rear View for Input Connections



Rear View for Power Connections

89720



89722 D-156000 Radio Transmitter, Rear View, Doors Open