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INSTRUCTION NOTES FOR 184-INCH CYCLOTRON DEFLECTOR HIGH VOLTAGE PULSE GENERATOR MODEL IV (2L7044), TRIGGER AMPLIFIER (2L6952), DEFLECTOR REGULATOR (2L6974), REGULATOR DELAY (2L6932), AND DEFLECTOR POWER SUPPLY (3Z1574)

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THEORY OF OPERATION

GENERAL: The deflector H.V. pulse generator exists for the sole purpose of supplying an electrostatic kick to the ions at the radius corresponding to their maximum energy in the cyclotron. This kick, properly timed with the oscillator f.m. cycle, deflects the ions into a magnetic deflector, whence they spiral out of the tank and are used outside the cyclotron proper for experiments. Drawing 2L6502A shows the position and interconnections between the various components in the system.

PULSE GENERATOR: The basic circuit in this type of pulse generator is shown in Fig. 1. The circuit action is such that the trigger fires the switch tube, transferring the energy from the storage capacitor into the primary of the pulse transformer. In the interval between pulses, the storage capacitor is recharged through the isolation device by the power supply. The cycle is then repeated.

Main Pulse Transformer: The pulse transformer is constructed to give a maximum rate of rise of voltage in the transformer secondary or deflector bar circuit. This voltage is approximately 140 kv push pull or 280 kv total for proton operation. The factor limiting the rate of rise of secondary voltage, the transformer leakage inductance, is made as small as possible by reducing the number of turns to a minimum. Reducing the number of turns to a minimum lowers the primary impedance to a very low value, approximately 2 ohms. Therefore,

in order to develop any voltage across this low primary impedance, the rest of the elements in the primary circuit must have a very low internal impedance, and these parts are grouped around the primary in such a way as to keep the lead inductance to a minimum. High core losses due to the high voltage, 5.5 kv per turn, and the speed of magnetization of the iron make water cooling necessary.

STORAGE CAPACITOR: These capacitors are especially constructed for pulse service, having extra wide low inductance internal connectors. They are filled with mineral oil instead of pyranol to give better heat transfer from the capacitor element to the outside case. Because of the rapid rate of discharge of these capacitors, excessive heat is generated in the dielectric. This heat is removed by forced air cooling.

SWITCH TUBE: The 5C22 Hydrogen Thyratron used for the switch tube in this generator passes a peak current of about 300 amperes. Much higher pulse currents are needed to energize the transformer primary with the deflector load, hence 8 of these tubes per transformer or 16 in all are needed to drive the circuit. To allow these tubes to operate in parallel, and share the load adequately, two steps are necessary. One is the use of special resistors in series with each thyratron plate lead, while the other is the simultaneous triggering of all the units with a specially designed trigger amplifier. Immediately after the main pulse, a voltage reversal (negative voltage) appears on the thyratron plates. This rapid reversal might cause a breakdown to occur between the thyratron plate and grid, destroying the tube's usefulness. Because of this adverse effect, clamping diodes are used on the transformer primary, removing all but the first 2 or 3 microseconds of the negative plate voltage surge. Because of this very short surge, that cannot be simply removed, the plate voltage at which these

tubes may be operated in this device is limited to 12 kv.

ISOLATION DEVICE: The isolation device has a double task, each part of which opposes the other. First, the isolation device must allow enough current to pass to charge up the storage capacitor in the interval between pulses, and secondly, it must not allow enough current to pass to keep the switch tube ionized after the main pulse. This function may be performed by a variety of methods, e.g., resistors or chokes properly chosen. For the main pulse generator, a voltage regulator tube is used. This regulator tube is emission limited during the charging cycle and is cut off for several milliseconds when the main pulse takes place, allowing the thyratrons sufficient time to deionize. The regulator also eliminates any variation in pulse amplitude due to power supply fluctuations.

TRIGGER AMPLIFIER: The purpose of this circuit is to provide simultaneous triggering of the 16 5C22's in the main pulser. This circuit is basically the same as that in Figure 1. In this case, the transformer is wound step down to match the 16 paralleled 50 ohm grid cables, and a resistor is used as the isolation device.

CIRCUIT DESCRIPTION

MAIN PULSE GENERATOR (2L7044A) (Figures 2, 3 and 4): V1-16, the main switch tubes, discharge C1-8, pulse storage capacitors, into the primary of T1 and T2, the main pulse transformers. R17-24, in series with the main discharge, act to balance the load between the paralleled tubes (V1-16). V1-16 are triggered from the Deflector Pulse Trigger Amplifier (2L6952) through R1-16, cable impedance matching resistors. Thyrite 9-24 by-passes to ground any high voltage pulses appearing in the grid circuit due to grid plate arcs in the main switch tubes (V1-16). Filament power for V1-16 is supplied from the 240 volt a.c. mains

through T3 and T4. Thyrite 1-6 and capacitors C12-15 prevent any high voltage pulses induced from the main pulse circuit from traveling back into the power line where they could result in destructive arcs.

Regulated d.c. power to recharge the storage capacitors, C1-8, enters the unit through PG 9210 from where it is generated in the Regulated Power Supply (3Z1574, 2L6974, and 2L6932). V10, V11, C9, R35, and T7 are parts of a resonant charging circuit used during tests of the pulse generator. When the regulated power supply is connected they are not in use. Diodes V12-13 act to drain the negative charge off C1-8 left immediately after the main pulse. An insulating transformer, T6, supplies the filament power to V12-13. C10-11 and Thyrite 7-8 by-pass to ground any high voltage pulses coupled into the primary of T6 through the interwinding capacity. The Blower to cool C1-8 is equipped with a switch, S1, and an air vane interlock. Door interlocks and a grounding hook are provided for safety. R33-34 form a voltage divider to transmit information concerning V1-16 plate voltage to the control room. R36-39 are special voltage dividers built to transmit an indication of the output pulse to the control room. Cooling water for T1 and T2 enter the rack from a regulated water supply. Before passing through T1 and T2, the water is first filtered to prevent blocking the small openings in the transformer cooling system.

DEFLECTOR PULSE TRIGGER AMPLIFIER (2L6952D) (Figures 5 and 6): C3, the pulse storage capacitor, is discharged into the primary of T3, the impedance matching transformer, by V3, the switch tube, sending a trigger to the grids of the main pulse tubes in the Deflector High Voltage Pulse Generator through 16 separate RG 58U cables. A trigger for V3 arrives through PG1 from the Deflector Trigger Amplifier (2L4502). R3 is a cable impedance matching resistor, while R4 and the

Thyrite drain off any charges remaining on the grid circuit after the main pulse. R2 acts as the isolating device between the power supply and V3, the switch tube, allowing sufficient current to flow from the d.c. power supply (plate transformer T1, filament transformer T2, rectifier tubes V1 and V2, filtering choke and capacitors, L1, C1, and C2, and bleeder R1) to charge C3 during the interval between pulses. T4 supplies filament current to V3. T5 is a variac used to adjust the amplitude of the output trigger pulse. F1 gives the usual protection against overloads. LT1, R5, and LT2 are indicating lights to show that the power from the a.c. mains is present.

REGULATED POWER SUPPLY (2L6974):

General Description: The regulator consists of V1, a type 880 triode, used as a series regulator tube. A voltage-regulator-amplifier (GE type GVD11B5, 2V9473) contains a 500 volt regulated standard and a direct coupled amplifier to supply the error signal to the grid of V1. V2 (type 836) is a high vacuum diode used as a clamp to prevent the grid of V1 from going positive. A delay pulse from chassis 2L6932 supplies a negative pulse to the grid of V1 through transformer T1. This delay is adjustable from 100 to 2000 μsecs.

V1 (type 880) is both water and air cooled. The water flow should be 10 plus gallons per minute. The high voltage and the V1 filament voltage are connected to the flow switch interlock so that no voltages can be applied to the 880 before proper water flow is established. A blower mounted on the top of the cabinet forces air on the glass seals of V1. This blower must be turned on before voltages are applied to V1.

Resistors R1, R2 and R3 limit the discharge current from C1 and the power supply in case of a short circuit.

Transformer T2 is a high reactance type with a 12.6 volt 320 ampere second-

ary used to supply the filament of V1. The secondary voltage is adjusted by a variac on the primary. This voltage should be set to 9.5 volts as read on Meter 1. This reduced filament voltage limits the charging current to approximately 6 amperes and also increases the expected life of V1.

High Vacuum Diode (V2) acts as a clamp to prevent the grid of V1 from going positive.

Voltage Regulator and Amplifier (2V9473): The voltage-regulator-amplifier is a GE type GVD11B5 which has a regulated 500 volt supply as a standard reference. V108 and V107 in conjunction with the VR tubes V109 and V110 constitute this regulated standard. V106 and V103 form the direct coupled amplifier which supplies the signal to the grid of V1 (2L6974). To remove the regulated supply and amplifier unit from the cubicle first loosen the four wing nuts on the two sides and remove the cover. Remove the copper strap on the stand-off insulator in the lower left corner and the leads from the terminal block in the upper right corner. Remove the wing nut on the under edge of the chassis. The whole unit now can be removed by lifting up and out. A spare unit has also been modified so that it mounts in this same manner.

R8 and R7 select a portion of the standard voltage to compare with the portion of the load voltage developed across R9 in series with R10. Different values of R9 can be used to give different ranges of output voltage. With R9 equal to .5 megohms the output voltage can be adjusted from 10.5 kv to 20.5 kv. With R9 equal to 1 meg the range is approximately 5 kv to 10.5 kv. R8 is a helipot which is driven by an Einco M1-1 selsyn. The control selsyn is mounted in the control room.

The meter on the side of the regulated supply and amplifier unit indicates when the system is operating properly. The meter pointer is kept within the two

range marks by adjusting the high voltage d.c. supply to the regulator to be approximately 3 kv higher than the regulated output.

Delay Chassis (2L6932): The delay chassis supplies a negative pulse to the grid of the type 880 triode. This cuts the 880 off for a time adjustable up to 2000 μsec. by R3. A trigger is supplied to V1 through the pulse transformer T1. This is the same trigger that triggers the deflector pulse trigger amplifier. Section 1 of V1 and section 2 of V2 form a one shot multivibrator. Section 1 of V2 is a cathode follower clipper and supplies a 100 v peak - square wave to the grid of V3. The transformer T3 in the cathode circuit of V3 supplies the output pulse. This pulse is inverted by T3. The secondary insulation to ground and primary is rated for 15 kv d.c. This transformer is a special high inductance primary type built by Electro Engineering Corp.

The output pulse is approximately 1300 volts peak and can be adjusted from 100 to 2000 μsec. Transformer T2 and tube V4 supply heater and plate voltage for the entire chassis. R 16 and R17 provide a divider for the purpose of viewing the output pulse on an oscilloscope.

NOTE: The secondary is above ground (high voltage). Make this check with all high voltages turned off.

Transformer T4 is a 25 kv insulation transformer to supply 115 v a.c. to T3 and the voltage regulator amplifier.

High Voltage Supply (3Z1574): The high voltage supply consists of a 3 phase bridge rectifier using GL575A type tubes. The input to the high voltage transformer is 230 volts 3 phase adjustable by a motor-driven variable transformer. The output voltage is 16.5 kv at 1.5 amps with the high voltage connected delta-wye and 10 kv at 2.5 amps with a delta-delta connection.

Figure 7 shows the regulator and power supply cubicles and the motor-driven variacs.

Figure 8 shows the power supply cubicle with the lower door open. The jumpers at the top of the opening are for changing from delta-wye to delta-delta.

Figure 9 shows the regulator cubicle with the doors open.

V1 - type 880 triode, series regulator

F1 - flow switch and meter for cooling water to V1

C1 - 25 kv capacitor bank

T2 - filament transformer for V1

T4 - 25 kv insulation transformer 240 v/115 v - 500 VA

Reg - regulated supply and d.c. amplifier

Delay - 100-2000 μsec delay chassis

M1 - V1 filament voltmeter

Motor - selsyn to set output voltage

S1 and S2 - door interlock switches

V - blower tube to direct air on V1

MAINTENANCE NOTES FOR DRAWING 2L7044 AND 2L6952

1) For aid in trouble shooting, typical waveforms are shown on 2L6952D and 2L6502A, the circuit schematics.

2) The 5C22 hydrogen thyratrons on the main unit have been selected to give satisfactory performance in this circuit. Because of variations in the spacing of the internal tube elements and hydrogen gas pressure, some replacement tubes will spark at the operating voltage for protons. Therefore it is recommended that only tubes that have been checked out in a circuit similar to the main pulser be

used as replacements.

3) T6 in the Deflector High Voltage Pulse Generator has been modified to hold a higher voltage by removing all the metal parts near the insulated secondary winding. Replacements should be given this same treatment.

4) L1 in the Deflector Pulse Trigger Amplifier has been modified to enable it to hold more voltage by rearranging the leads and dipping the whole choke in paraffin or beeswax.

5) The setting on the variac in the Deflector Pulse Trigger Amplifier has been adjusted for optimum trouble-free triggering of the thyratrons in the main pulse circuit. If this chassis is replaced, the variac on the new unit should be set to the same position as that on the old.

6) The handle on the water filter must be turned periodically to clean any residue from the filter element. Once a month will be sufficient.

7) Blower air filters should be replaced whenever they become fouled with dust.

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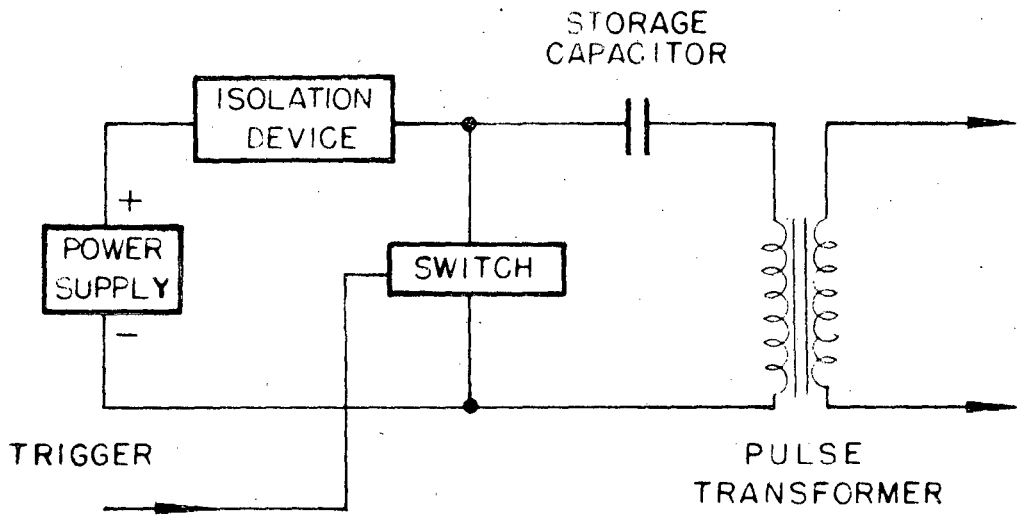


BASIC PULSE GENERATOR CIRCUIT

FIG. 1

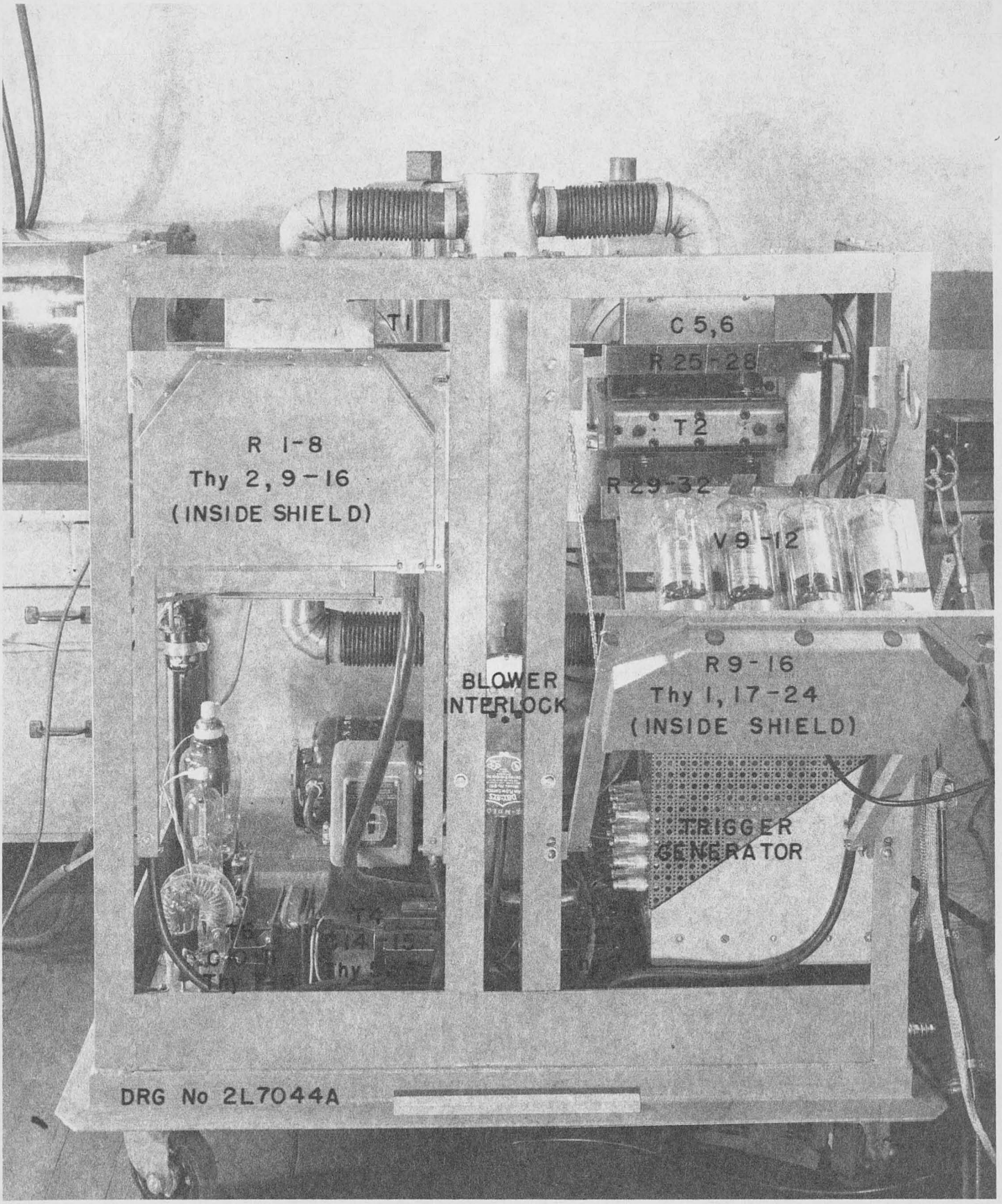

T1
C 5,6
R 25-28
T2
R 29-32
V 9-12
R 1-8
Thy 2, 9-16
(INSIDE SHIELD)
BLOWER
INTERLOCK
R 9-16
Thy 1, 17-24
(INSIDE SHIELD)
TRIGGER
GENERATOR
T4
DRG No 2L7044A

FIG. 2

OZ 460

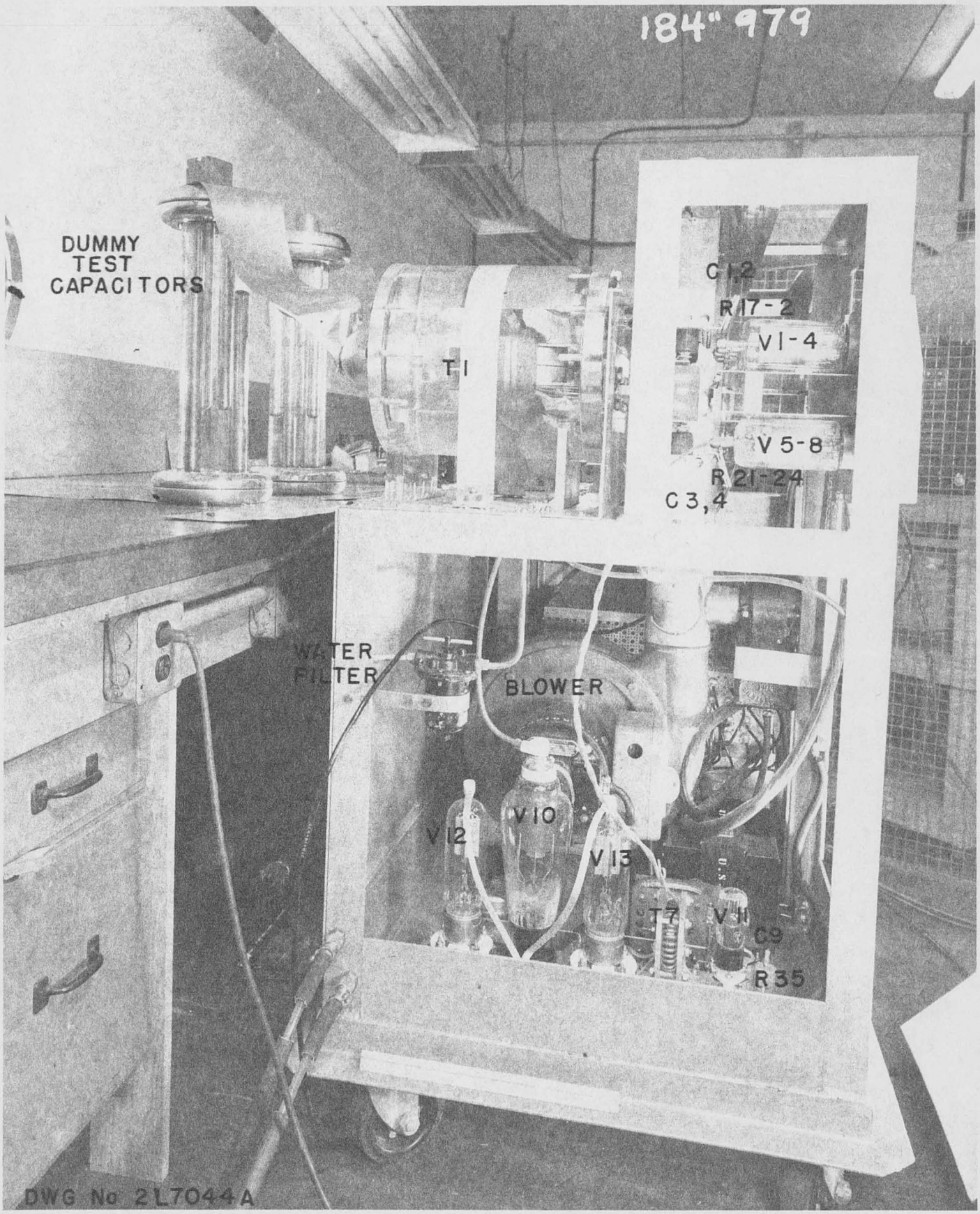

184" 979
DUMMY
TEST
CAPACITORS
T1
C1,2
R17-2
V1-4
V5-8
R21-24
C3,4
WATER
FILTER
BLOWER
V10
V12
V13
T7
V11
C9
R35
DWG No 2L7044A

FIG. 3

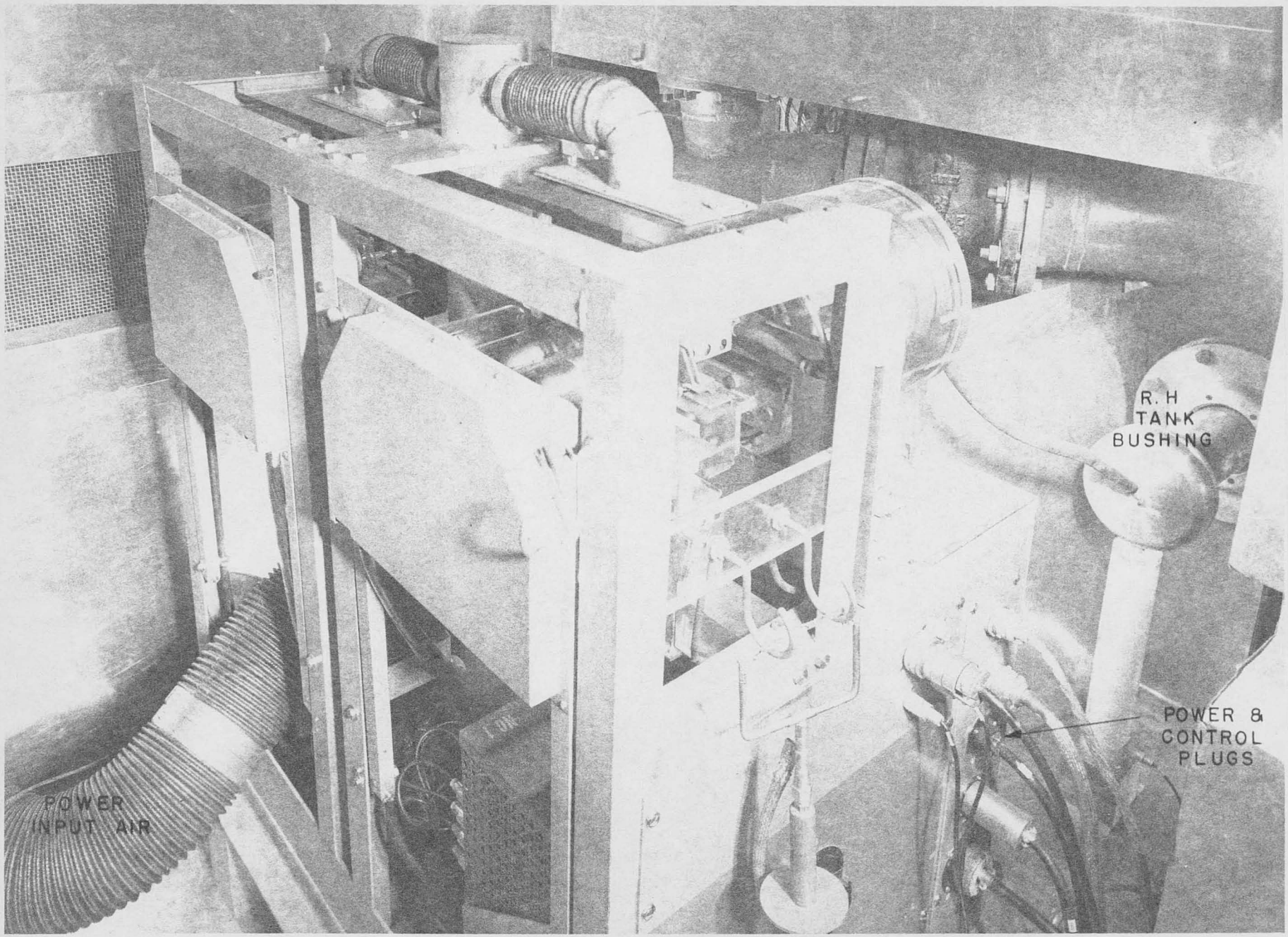


FIG. 4

OZ 466

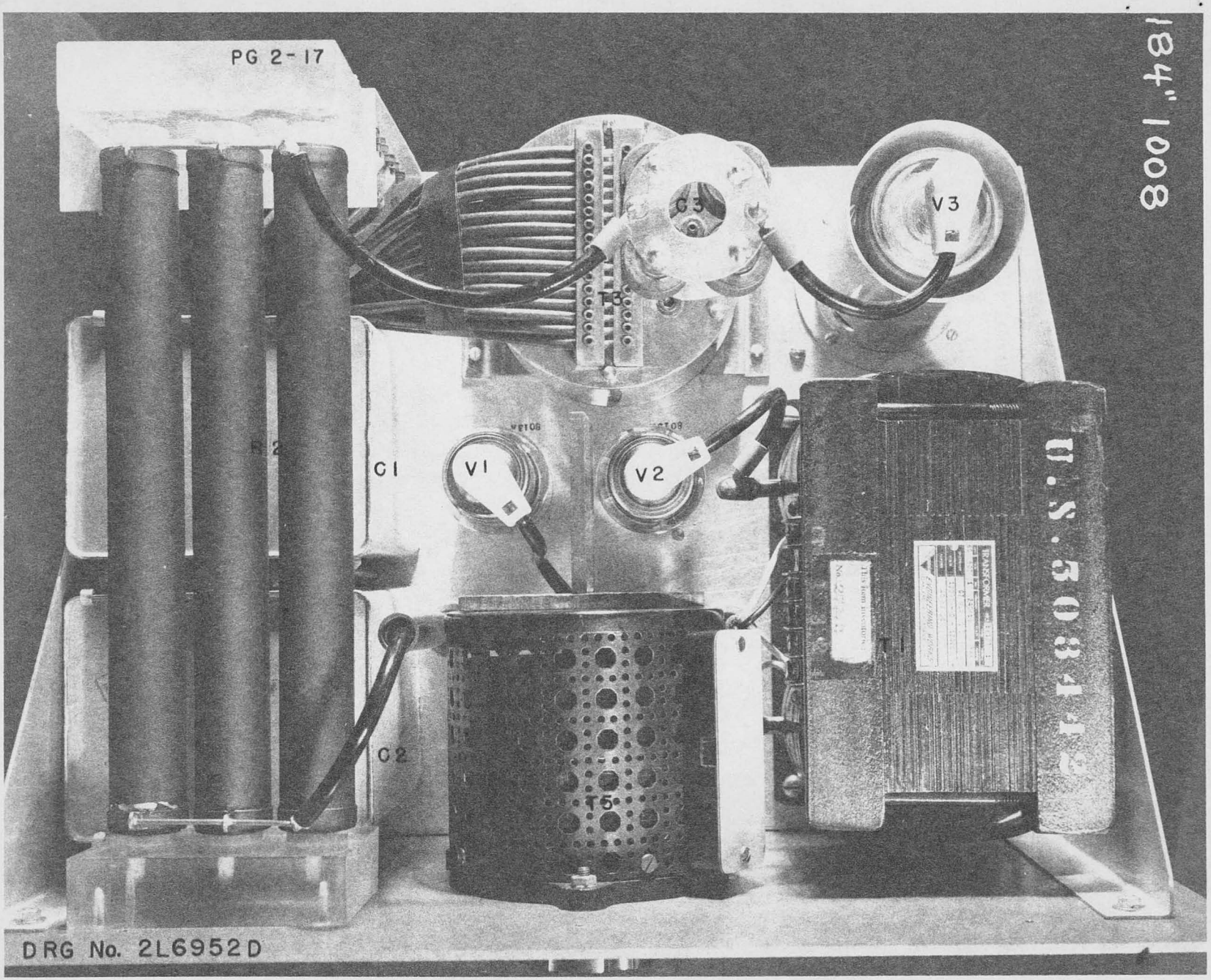


FIG. 5

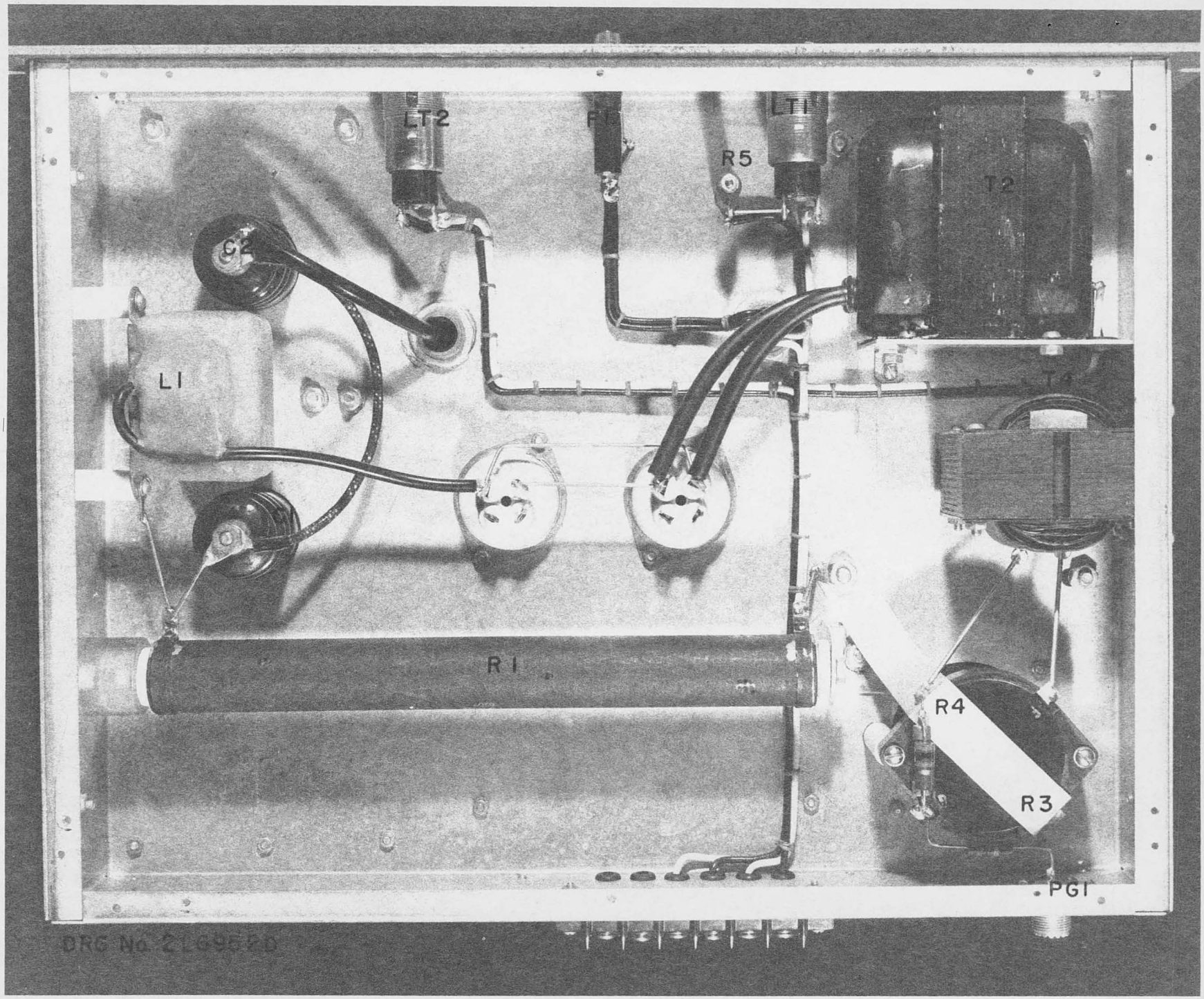


FIG. 6

OZ 464

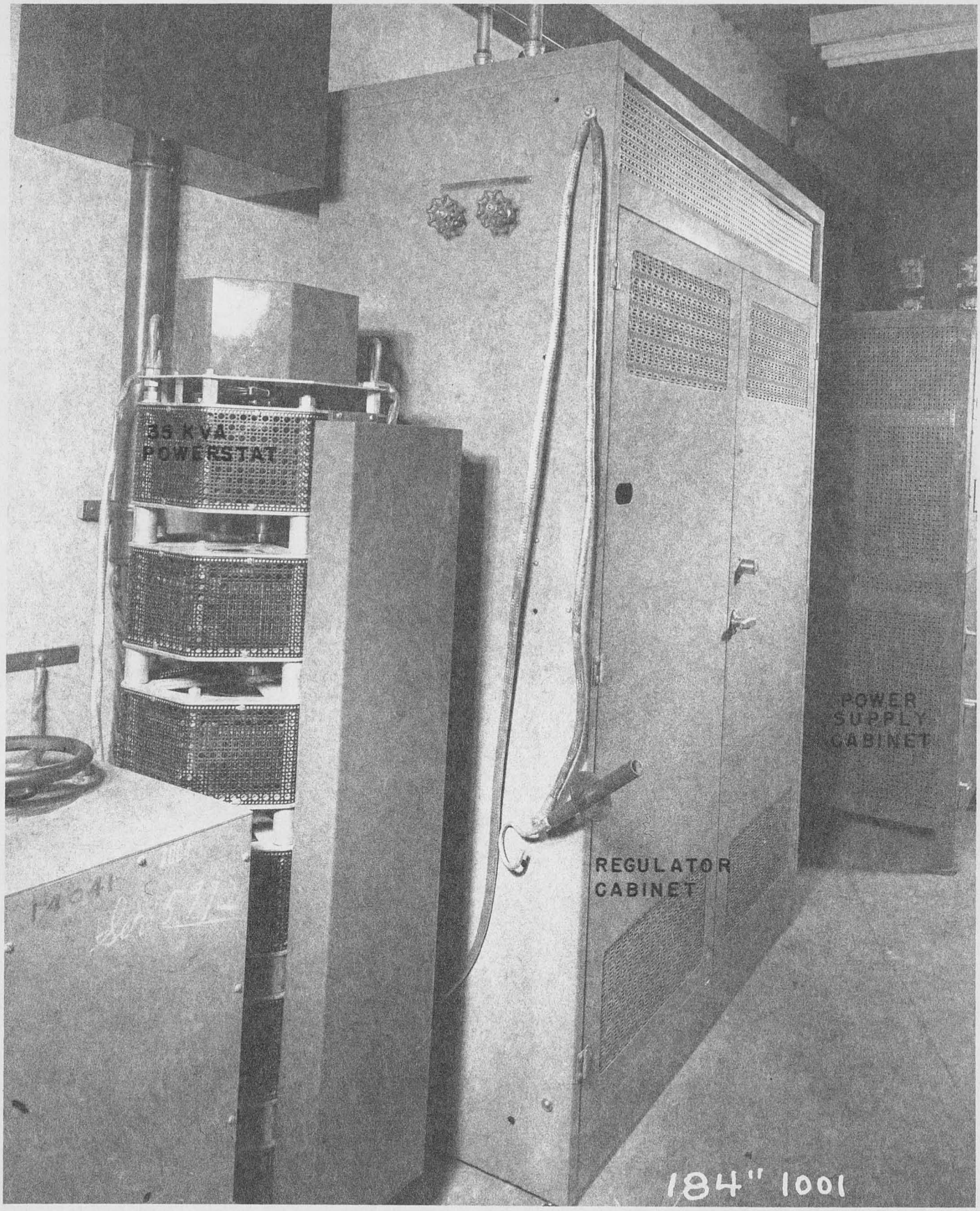

35 KVA
POWERSTAT
POWER
SUPPLY
CABINET
REGULATOR
CABINET
184" 1001

FIG. 7

OZ 463

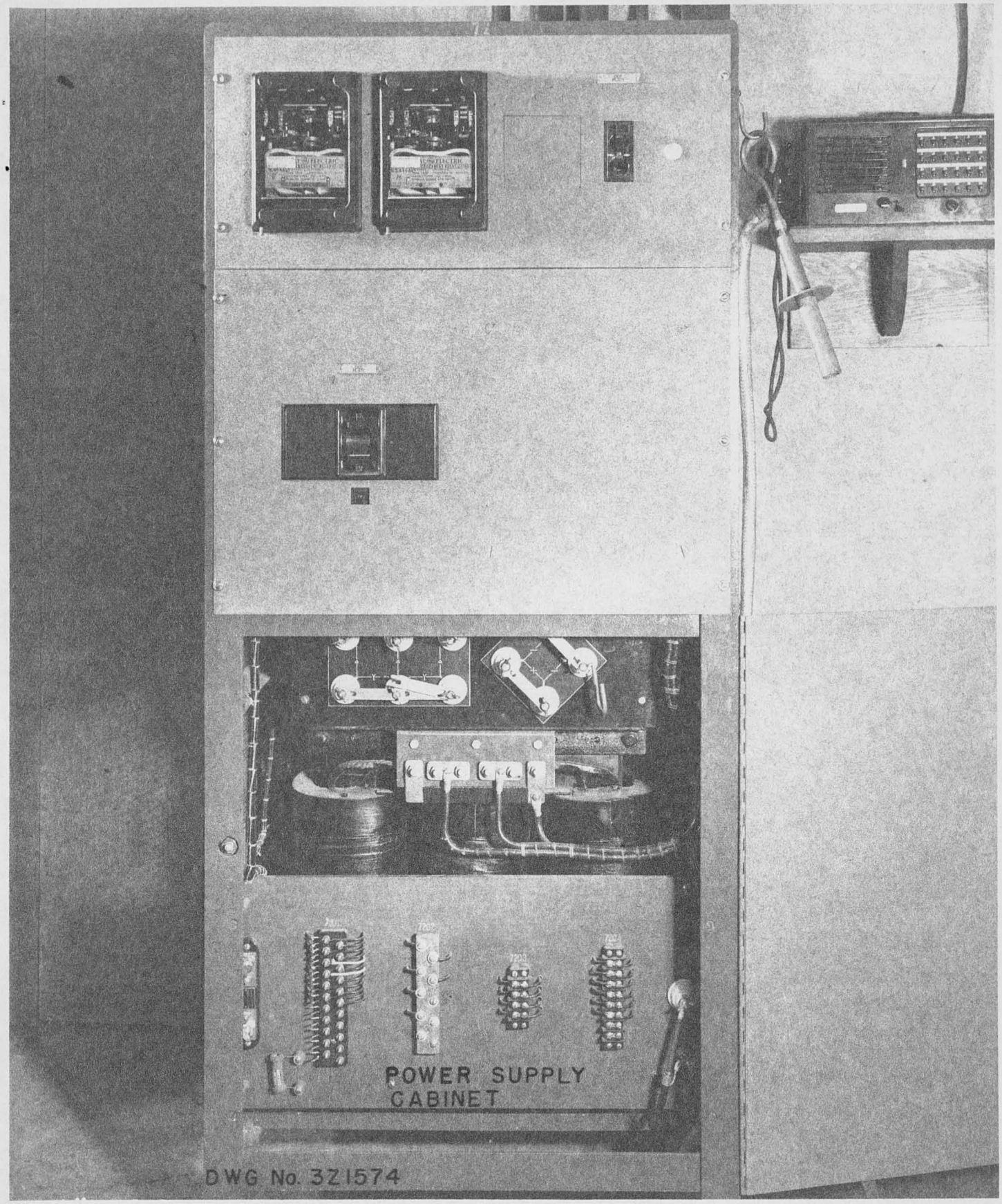
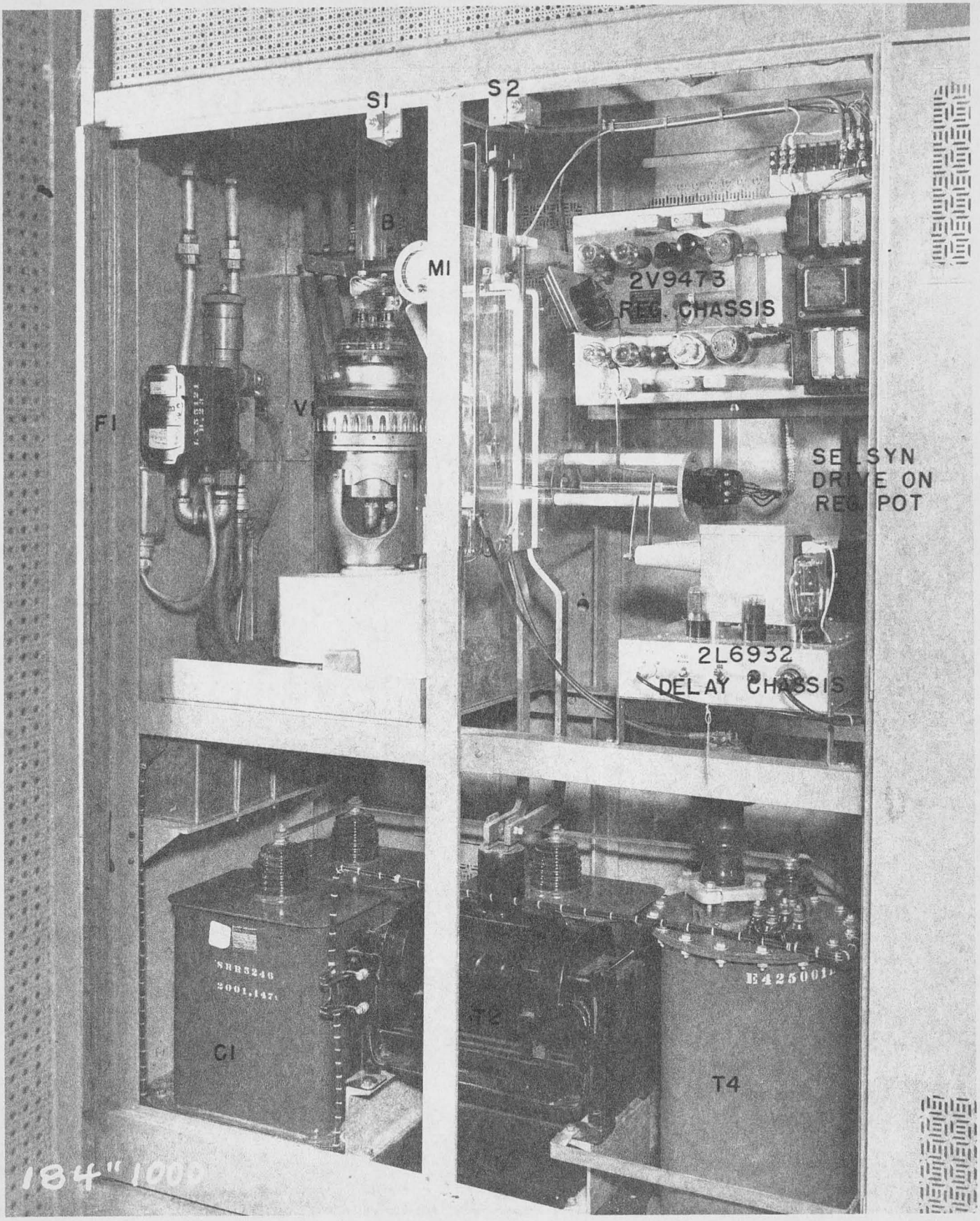


FIG. 8

OZ 461



DWG No. 2L6974

FIG. 9

OZ 462