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OPERATION INSTRUCTIONS FOR THE COLD ELECTRON SOURCE

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Final Report - Part II

DEPARTMENT OF ELECTRONICS AND INSTRUMENTATION
UNIVERSITY OF ARKANSAS
GRADUATE INSTITUTE OF TECHNOLOGY
LITTLE ROCK, ARKANSAS

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Part II
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Final Report
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M K Testerman

M. K. Testerman, Head
Electronics and Instrumentation

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Date

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HIGH VOLTAGE

OPERATION INSTRUCTIONS FOR THE COLD ELECTRON SOURCE

R. W. Raible, B. E. Gilliland and W. G. Hinson

I. MULTIPLIER ION SOURCE

A. Theory of Operation

The basic resistance strip multiplier, shown schematically in Figure 1, consists of two plane-parallel, resistive surfaces. These surfaces consist of a semiconducting coating over an insulating base wherein the active surface possesses the proper volume resistivity. Equal potential gradients are established along each surface by applying equal potential differences across the strip's long dimension. The potential of one surface (field strip) is maintained more positive than that of the other surface (dynode strip) at comparable lengths along the strip. The entire structure is placed in a uniform magnetic field of about 200 gauss normal to the electrostatic field. An electron released from the dynode strip at any point will describe a trochoidal path whose initial direction is determined by the equipotential at its point of origin. It will return to the dynode strip with an impact energy corresponding to the difference in potential between its points of origin and impact. This energy is large enough to give a secondary emission ratio greater than unity. Thus, each electron will release more electrons at its point of impact, and these electrons will continue along the strip in a similar fashion.

The total gain in electron current along the strip is a function of the magnetic and electrostatic field strengths and the length of the dynode.

The electrons exiting the multiplier fall through a potential established by the dynode to control grid voltage. Since the electrons depart the dynode at different points, their average energy is 40 to 80 volts with respect to the dynode exit voltage, with an energy spread of up to 200 volts. Thus, the electron energy is 40 to 80 volts above the dynode-control grid voltage. The electrons ionize the residual gas in the system and are repelled by the second pulling out grid of the mass spectrometer. The ions are thus admitted to the mass spectrometer while the electrons are collected either on the system walls, the control grid, or the first pulling out grid.

Primary, or source, electrons are provided by a tantalum photocathode irradiated by a deuterium lamp. This electron current is on the order of 10^{-9} amperes. The photocathode is biased via a photoresistor-resistor divider network such that the primary current can be varied to maintain a constant electron multiplier output current. The control signal used to vary the primary current is derived from the control grid (Figure 1). NOTE: Normally the input voltage gradient between the field strip and dynode is greater than zero. Also, the photocathode would be negative with respect to the dynode so that the photoelectrons are attracted to the dynode. In this multiplier the protrusion of the photocathode into the multiplier between the dynode and field strip greatly perturbs the electrostatic fields. Thus, it was found that the system was more nearly "optimum" when the field strip and dynode were tied together at the input and the photocathode was biased somewhat positive with respect to the multiplier input. The control circuit, however, is able to adjust the photocathode voltage such that it is positive or negative with respect to the dynode so that a wide range of control is achieved.

The addition of the deflection plates at the multiplier output was required to counteract the curving of the electron beam by the magnetic field. The input isolation grid, negatively biased, effectively shields the photocathode from the endcap, allowing a high percentage of the photoelectrons to enter the multiplier.

B. Operation Procedures

1. Introduction

The multiplier ion source is mounted on a stainless steel baseplate complete with knife-edge sealing groove and may be attached to existing vacuum systems by means of a suitable interface. (NOTE: THIS SOURCE PERFORMS SATISFACTORILY ONLY IN ION PUMPED VACUUM SYSTEMS. OIL DIFFUSION PUMPED SYSTEMS GREATLY SHORTEN SOURCE LIFE.)

The deuterium lamp (Beckman Cat. No. 96280) is attached to the end plate using the holder shown in Figure 1. The adjustable mask permits normal control of the multiplier gain.

The multiplier consists of a magnetic assembly (Permag Central Corporation, 5301 D Otto Ave., Des Plaines, Illinois), two coated glass strips (Corning Glass Works, Corning New York, Code 7740 polished glass plate, 4 M/square resistivity), and two Teflon insulating supports.

The deflection plates are 0.010 inch nichrome and the grids are of tungsten mesh supported by 0.010 inch nichrome rings. All junctions are made using either spot welds or indium solder.

2. Start Up

a. Deuterium Lamp

The deuterium lamp is turned on and the high voltage and filament controls adjusted for minimum stable output. This generally occurs with both controls fully counterclockwise. Additional adjustments of the filament are usually not necessary but extra light output may be obtained, if needed, by adjustment of the high voltage control.

The shutter is opened completely at first. When using a new multiplier, current output is larger than can be regulated by the control circuitry. Adjustment of the shutter is then made to bring the output into the range of the control circuit. As the multiplier strips age, additional adjustments of the shutter may be required for proper operation. This should occur only infrequently.

b. Multiplier

The multiplier power supply is turned on and the gradient potentiometer adjusted for maximum total ion current. The total ion current can be measured using the grids of the mass spectrometer as a collector.

Refer to page 8 for adjustment of the current control circuit.

The multiplier ion source is now ready for operation.

c. Maintenance

The multiplier gain, and thus the current output, tends to decay with time and replacement of the dynode strip will be necessary. The following procedure is suggested:

1. Remove collector-grid assembly by loosening hold-down screws. Release of pressure on Teflon washers will also free deflection plates. Wires should remain attached to these components.

2. Unsolder wires from the output ends of the dynode and field strip. Use a low temperature soldering iron to lessen oxidation of the indium solder. Identify wires so that correct connections can be made during reassembly.

3. Remove both multiplier supports by removing four hold-down nuts. Hold multiplier during this procedure to prevent damage to mycalex support from multiplier droppage. The multiplier is marked to indicate dynode output location. This eliminates incorrect assembly.

4. Disconnect wires from the input ends of the dynode and field strip. Identify these wires to eliminate possible confusion.

5. The dynode strip can now be removed. Generally the field strip need not be replaced since it is totally inactive except for establishing the desired electrostatic field configuration. However, it should be removed and the Teflon supports thoroughly cleaned. If any brownish deposits are noted on the Teflon, these should be removed using a non-conductive abrasive paper.

6. Replace the field strip. Using indium solder, lightly solder the entire width of each end of the new dynode strip. These contacts should be as small as possible (about 1/16 inch) to insure a greater active dynode surface area.

7. Connect the input leads, mount the multiplier on its support, replace the output leads, deflection plates and grid. A continuity check should be made. The multiplier source is now ready for use.

d. Trouble Shooting

Loss of Output - Check for continuity within multiplier ion source. Dynode or field strip leads may become disconnected.

If continuity checks reveal nothing amiss, remove source and thoroughly clean Teflon slide supports. Any deposits on these supports create spurious electrostatic fields which may disrupt multiplier operation.

Low Output Current - Deposits on dynode cause gain decay. Replace dynode strip.

e. Multiplier Feedthrough Connections as Lettered on the Instrument

A - Collector

B - Dynode Input and Field Strip Input

C - Dynode Output

D - Deflection Plate

E - Control Grid

F - Photocathode Shield Grid

G - Field Strip Output and Deflection Plate

H - Photocathode

II. CONTROL CIRCUIT

A. Theory of Operation

The operation of the control circuit is such that the electron output is regulated to a pre-set level. A grid across the output end of the multiplier assembly intercepts a part of the electron output current. This grid is returned through a current determining resistor to a positive potential. When the proper value of the electron output current leaves the multiplier, the potential of thi control grid goes negative towards its intended operating point at about ground potential. A difference amplifier senses whether or not the control grid is at, above, or below ground potential. Any deviation is amplified and changes the current through a gallium arsenide light source. As the light intensity of the source changes, the resistance of a photosensitive resistor exposed to this light source is changed in the proper direction to correct the gain of the multiplier. The photosensitive resistor controls the potential between the photocathode and the dynode strip. This method of operation allows the control circuitry to operate at or near ground potential and provides isolation from the control element which is operating several thousand volts negative with respect to ground.

A diagram of the high voltage power supply and control circuit is shown in Figure 2. Figure 3 is a diagram of the power supply, and Figure 4 is a photograph of the high voltage power supply and control circuit.

B. Operating Procedures for Mass Spectrometer and Ion Gauge Applications

1. Insert AC plug and connect cables, making sure the chasis is at system ground.
2. Switch the control circuit to the off position.
3. Switch power on.
4. DC light control voltage (M1 in Figure 2) should read approximately 5 volts.
5. Turn hydrogem lamp ON. (Turn the filament on first and then the high voltage.)
6. Within 30 seconds the photocathode voltage (M2 in Figure 2) should rise to approximately 150 to 200 volts. Adjust the dynode gradient potentiometer to maximum output electron current.

7. Output electron current should be approximately 1 micro-ampere or greater when the collector is at ground potential.
8. Switch control circuit to ON position.
9. Output current should be regulated to approximately 1 micro ampere when operating as an ion gauge.
10. Photocathode voltage (M2 in Figure 2) should be 50 to 225 volts. The control voltage should be between 2 volts and 15 volts. If not, adjust the mask at the light source until midrange values are reached.
11. Allow a warmup period of 30 minutes.
12. Periodically check meters to insure that they are in specified ranges.

C. <u>Trouble Shooting</u>

If abnormalities occur and it is not evident where the trouble lies, there are a few observations that can be made under various conditions that should isolate the problem. The initial test that should be performed is as follows:

Power switch on.

Control switch off.

DC light control volts approximately 5-6 volts.

Photocathode voltage approximately 150 volts.

1. If DC light control voltage is in error:
   a. Check ± 15 volt supplies.

b. Use a voltmeter with at least a 10 megohm impedence and measure the input to the control circuit (Pt.1, Figure 4) to insure it is at 0 volts.

c. Adjust the potentiometer (Pt. 2, Figure 4) that applies a DC bias to the operational amplifier and notice if the DC light control volts change. Adjust for approximately 0 volts out of the amplifier so that the DC voltmeter reads 5.5 volts.

d. Place oscilloscope probe on the emitter of the 2N697 transistor and check for oscillation. The gain of the operational amplifier can be decreased if necessary to eliminate unstable operation.

e. If the above procedure does not provide the correct readings on the meters then a thorough inspection of all wiring and connections should be performed.

2. If the DC light control voltage is correct and the photocathode voltage is in error:

a. Use caution and measure the high voltage at the first zener diode (Pt. 3, Figure 4).

b. With the power supply off, disconnect one of the leads to the photocell (Pt. 4, Figure 4) and measure the resistance. It should be 1 megohm or greater.

c. Measure the impedence of the resistor (470K) and the 2 megohm potentiometer to insure continuity. (See Figure 4)

d. Reconnect the photocell and turn the supply on. Adjust the 2 megohm potentiometer and notice if the photocathode voltage changes.

e. Repeat steps 1.c., 1.d., and 1.e.

Power switch ON.

Control switch ON.

DC volts 2 - 15 volts.

Photocathode voltage 100 - 225 volts.

D_2 Lamp "ON".

3. If either voltage is incorrect adjust the light mask and note the voltage reactions. If the DC light control voltage and photocathode voltage is too small then the light should be decreased. If both are too large then more light is needed. Circuit adjustments should not be attempted in this mode of operation since the control circuit would attempt to compensate for any change made.

4. If, after all tests and adjustments have been made, it appears that the output current level is too small, the high voltage may be increased by removing the short that is placed around one of the zener diodes on the high voltage board (Pt. 5, Figure 4). This may decrease the lifetime of the glass slides in the multiplier.

5. If trouble still exists, inspect the multiplier assembly (see the section on Trouble Shooting in Part I of this report on page 6.

PARTIAL PARTS LIST

Part	Manufacturer
Photoresistor CL-503	Clairex Corp., 1239 Broadway, New York, N. Y.
GaAs Light Source LED-9	General Electric Corp., Semiconductor Products Dept., Electronics Park, Syracuse, New York
Operational Amplifier P65A1	Philbrick Researches, Inc., Allied Dr. at Route 128, Dedham, Mass.
Rectifier AW 200	Mallory Semiconductor Co., 424 South Madison, DuQuoin, Illinois
Reference Transistor GERA1	General Electric Corp., Semiconductor Products Dept., Electronics Park, Syracuse, New York
Dynode and Field Strips Code 7740 Glass with high resistance coating	Corning Glass Works, Corning, New York
Deuterium Lamp 96280	Beckman Instruments, Inc., Scientific and Process Instruments Div., 2500 Harbor Blvd., Fullerton, California
Multiplier Assembly	Permag Central Corp., 5301 D Otto Avenue, Rosemont, Des Plaines, Illinois

FIGURE I

SCHEMATIC OF MULTIPLIER ION SOURCE CONNECTED AS TRIODE ION GAUGE

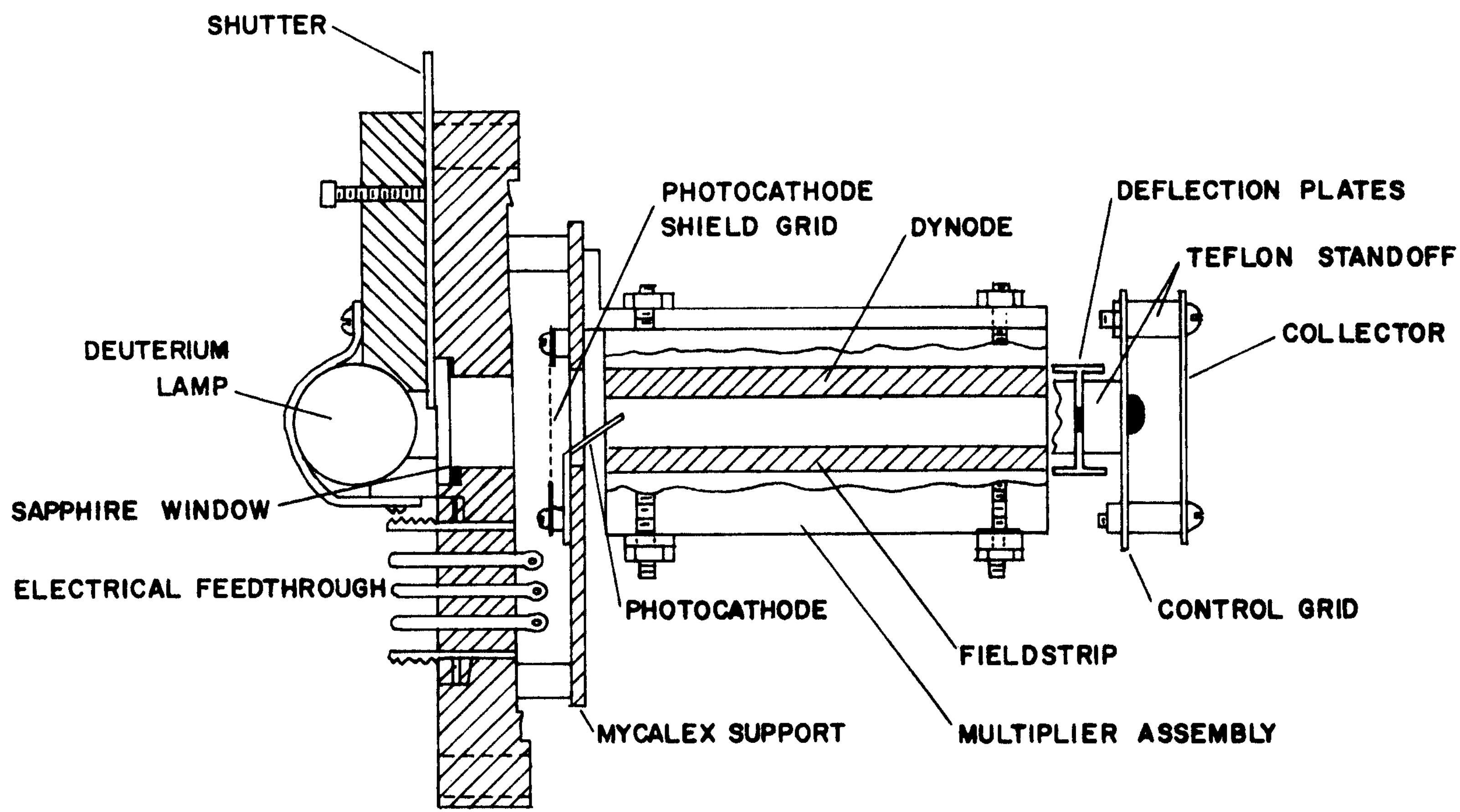


FIGURE 2

HIGH VOLTAGE POWER SUPPLY AND CONTROL CIRCUIT

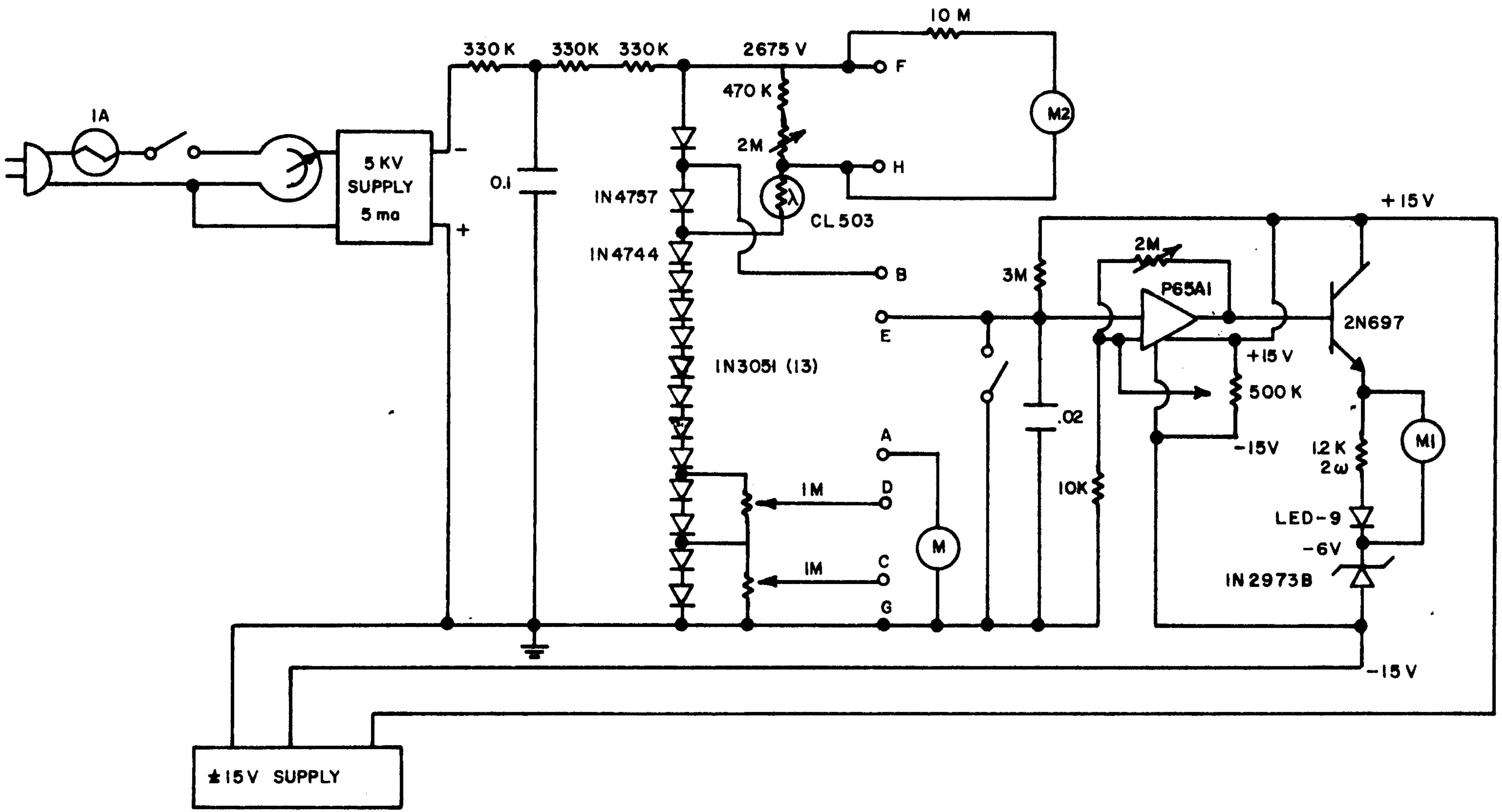
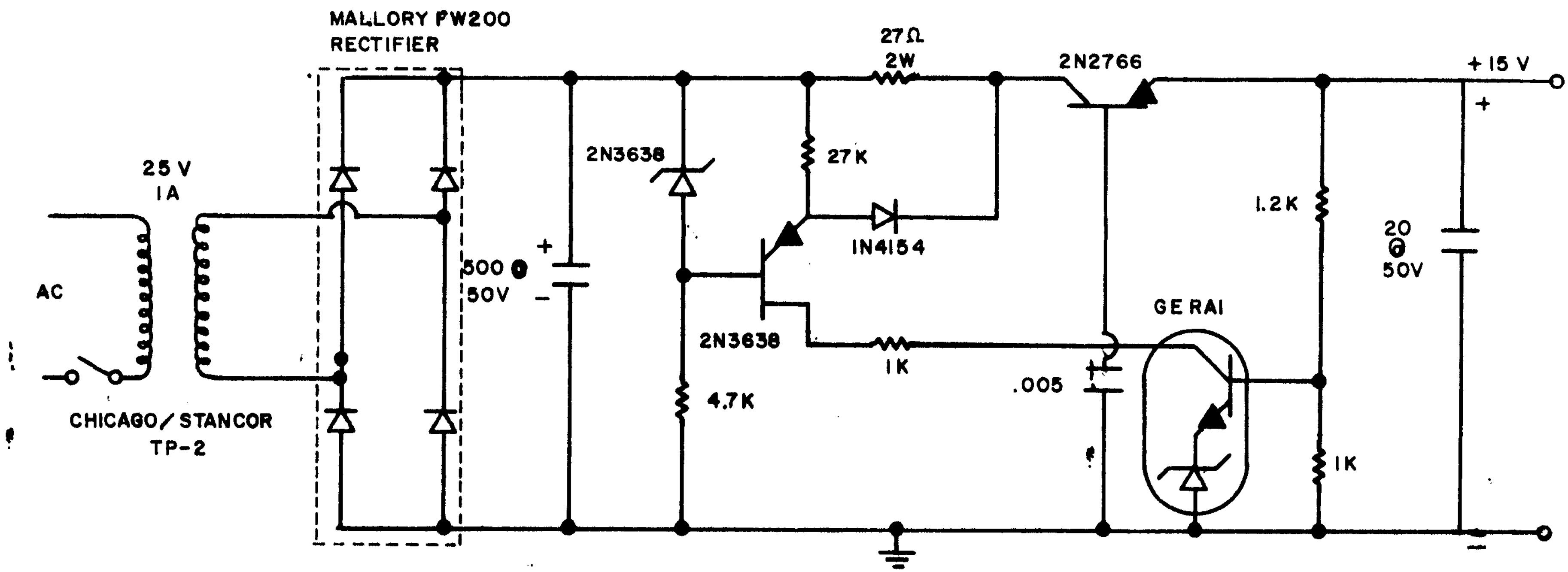


FIGURE 3
POWER SUPPLY
± 15 VOLTS



NOTE: All capacitances are in microfarads

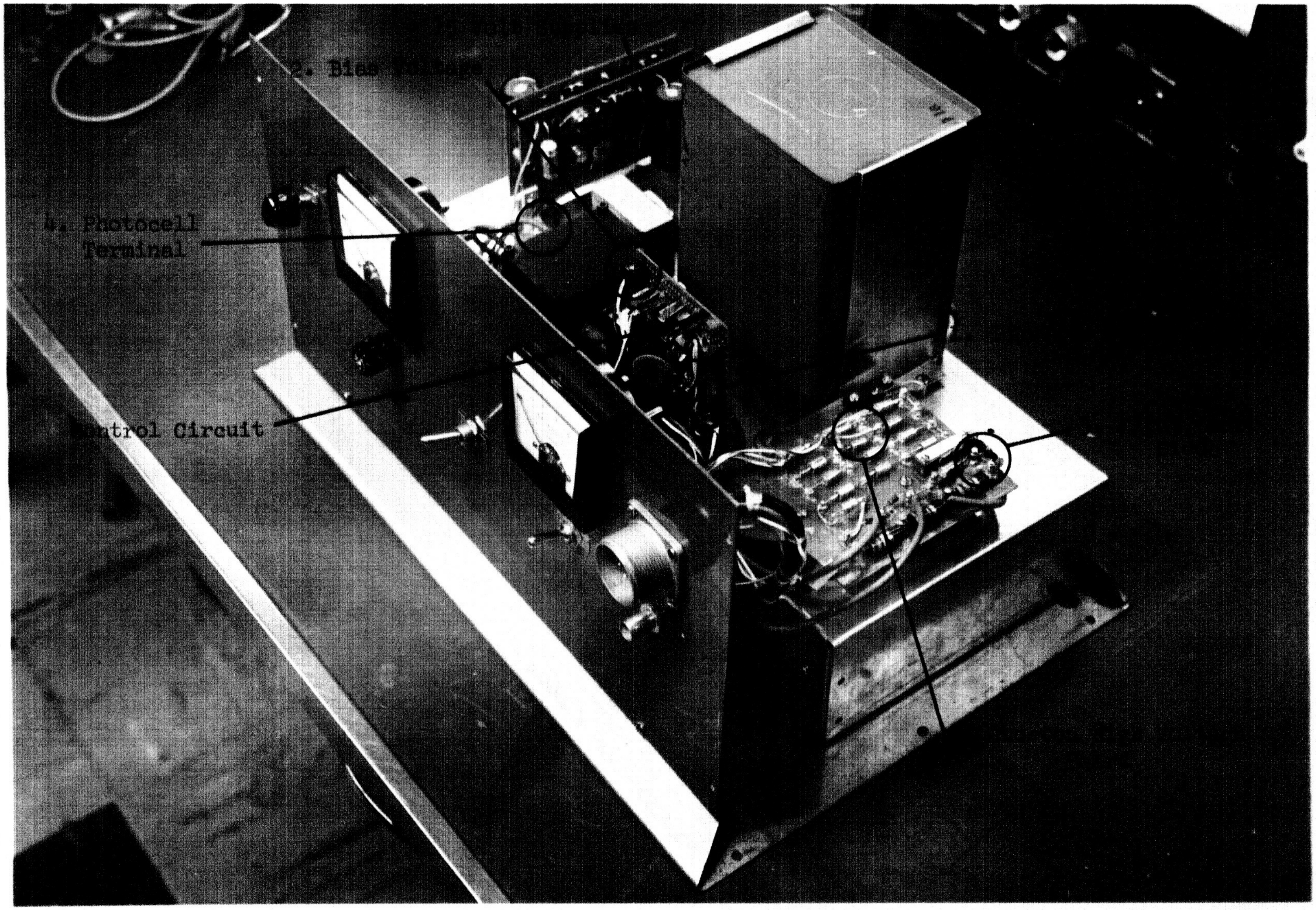


FIGURE 4

HIGH VOLTAGE POWER SUPPLY AND CONTROL CIRCUIT