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UCRL-3237 Rev

UNIVERSITY OF CALIFORNIA
Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

MAGNET POWER SUPPLY FOR AN ALPHA-PARTICLE SPECTROMETER

George F. Schrader

March 1956

Printed for the U. S. Atomic Energy Commission

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ABSTRACT

A current-regulated power supply has been built to deliver current, continuously variable from 0 to 600 ma, into a load of 4000 ohms. The system is stable to approximately 1 part in 10,000 over long periods of time. Stability has been achieved by using a series tube type of regulator with a dc amplifier and a chopper amplifier combined to give both long-time and short-time stability.

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I INTRODUCTION

This alpha-particle spectrometer is a 180° magnetic deflecting machine with a 35-cm orbit radius, designed for a maximum field of 15,000 gauss. The coil has a total resistance of about 4,000 ohms and requires a maximum current of 600 ma. The machine may be operated with either a photographic plate or a scintillation counter as the receiver. Photographic exposures may run more than 24 hours, and the power supply for the magnet must have a long time stability, on the order of one part in 10,000, to maintain the resolution of the system. The magnet supply is operated from an unregulated line. This means that the power supply should be able to maintain the magnet current within the specified variations under long-time line variations, short-time periodic line variations, and rapid transient variations.

In order to maintain a uniform, noise-free ground for the entire system, the installation has an isolated power system, and a single ground separate from other grounds and isolated from that normally established for the incoming power lines.

II DESCRIPTION

The power supply for the unit consists of a bridge-type rectifier and a filter capable of delivering 4,000 v at 600 ma. The current (I_m) for the magnet passes from the positive end of the supply through four type 304TH V1-V4 transmitting tubes in parallel, through a 250-ohm precision oil- and water-cooled resistor which provides the signal voltage to control the unit, then passes through the current-metering system to the magnet and returns to the negative side of the power supply. (See Fig. 1.) The system is grounded at the negative end of the meters in order to keep the metering near ground potential, and to keep the controlling amplifiers at a low impedance to ground so that there will be no spurious signals picked up and transmitted to the magnet.

The signal from the 250-ohm resistor R1 is applied through a suitable amplifier to control the grid potential of the control tubes V1-V4 as described below.

A 170-volt table reference voltage is added to the signal from R1, and a potential divider consisting of R2 and R3 is placed across the two of them, forming a bridge. The legs of the bridge are formed by

(a) the signal resistor R1,

(b) the reference voltage,

(c) R2 and the section of R3 between R2 and the tap,

(d) the section of R3 between the tap and R1.

The points between which a null is to be established are the tap of R3 and the junction between R1 and the reference voltage.

If this null is established then the ratio of the voltage across R1 to the reference voltages is equal to the ratio selected on the potential divider. Thus R3 is used to select the desired magnet current.

The error voltage across the null points of this bridge is applied to two different amplifiers, each of which serves a separate function in controlling the current. The first of these is a conventional dc amplifier. The signal is applied from cathode to grid of the first stage through a 1-μf capacitor and the plate of the second tube is connected to the 304TH control tubes through a 500-v biasing supply. Normally the coupling condenser would not be used on the input to this amplifier, but since there must be a few volts bias between the grid and cathode of the first tube, and as this bias requirement varies with time and temperature by a few millivolts, it was found necessary to apply a correcting voltage to keep the bridge at an absolute null. A stabilizing amplifier was added to the circuit to supply the necessary difference between the operating bias and the null for the bridge. The error voltages are applied to a 60-cycle interupter, and the resulting ac voltage is amplified. The resulting 60-cycle wave is synchronously rectified and applied as a charging current into the coupling capacitor of the dc amplifier, thus supplying the necessary bias and correcting for any variations that would alter the null of the system. The net result is that any rapid changes in the system are corrected by the dc amplifier, and slow drifts are corrected by the stabilizing amplifier.

The magnet was found to be so inductive that it generated very high voltages upon any change in current, throwing the amplifier out of its range of operation and causing sustained oscillations. It was necessary to introduce a feedback voltage from the negative end of the magnet to the amplifier input through C1 in order to correct these surges and prevent oscillation.

III PLATE SUPPLY

The rectifier consists of four type 872 mercury vapor tubes connected as a bridge rectifier. They are supplied through adequate fuses from a 4500 v power transformer. The filter is a conventional choke input type with a substantial bleeder to discharge the capacitors when the unit is turned off and to drop the open-circuit voltage of the supply.

IV REGULATING TUBES

The four control tubes are mounted on a separate chassis with a fan to keep the tube envelope and connections cool. (See Fig. 3.) This chassis also contains a current meter and a voltmeter that reads the voltage drop in the tubes. These meters are used to check the operation of the tubes so that they do not exceed their rated dissipation. The necessary supply voltage may be computed from the following figures:

1. Voltage drop in the magnet (4000 ohms at 600 ma)	2400 v
2. Voltage drop in the sampling resistors (250 ohms at 600 ma)	150 v
3. Plate supply drop, no load to full load	400 v
4. Voltage drop in control tubes for adequate control at 600 ma	1000 v
Total required supply voltage	3950 v

The maximum dissipation of the regulator tubes in running from no load to full load is $\frac{E_0^2}{4R}$, where E_0 is the supply voltage and R is the total external resistance, including the power supply impedance.

The maximum plate dissipation is then $\frac{3950^2}{4 \times 4,000} = 980$ watts.

The regulator tubes have a rated plate dissipation of 300 watts each or a total of 1200 watts. This leaves a margin of 20% for variation in the line and for unequal distribution of current between tubes.

V CONTROL AMPLIFIER

The control amplifier (the dc amplifier described in Section II) is designed with a common point to which all the components of the system are tied. (See Fig. 4.) These components are (1) the dc amplifier, (2) the reference voltage, (3) the sampling resistor, (4) the control tubes, (5) the stabilizing amplifier, all of which can be tied to a common subchassis to eliminate

the introduction of spurious signals and to prevent capacitive feed-back from the various parts of the circuit through stray capacities between power supplies and grounds. The dc amplifier is operated from its own power supply, which is voltage-regulated by the tubes V2, V3, V4, V5, and V6 (Fig. 4). This supply also provides a stable source for the reference voltage produced across V7 and V8. This reference voltage is very stable if the current in the two 85A2 voltage regulator tubes is kept at a fixed value and the tubes are adequately protected from heat and light.

The bridge circuit described in Section II is shown here by the sampling resistor connected across BP1 and BP2, the reference voltage, V7 and V8, and the potential divider R8, R9, R12, and R13. Resistors R12 and R13 are the coarse and fine current controls. A voltmeter is placed across the terminals of the sampling resistor 12 so that the current in the resistor may be read on this panel. This is a 150-v meter scaled to read 0 to 600 ma. The input to the stabilizing amplifier is made through PG1 and the output from the stabilizing amplifier comes in on PG2 and provides a charging current into the coupling capacitor C4 in the manner described in Section II.

Units V9 and V10 make up the dc amplifier. It can be seen from the voltages indicated on Fig. 2 that the plates of V10 have a possible excursion of about 450 v. That is, the voltage cannot go higher than the plate-supply voltage of 600 v or lower than about 60 or 70 volts above its cathode, which is 85 volts above the negative end of the supply. Since this excursion must be applied to the grids of the 304TH control tube, but must descend from 0 volts to above -400 v, it is necessary to place a fixed negative voltage between the plate of V10 and the output to the control tube grids (PG3). This is done with an isolated power supply of 500 v, shown across C7 of Fig. 2.

VI STABILIZING AMPLIFIER

The stabilizing amplifier (Fig. 3) is an ac amplifier for the 60-cycle square wave produced by a 60-cycle vibrator. This signal is synchronously demodulated and applied to the output terminals. The operation is as follows: During the first half of the cycle, the input capacitor C1 is allowed to charge to the error signal voltage, and the output capacitor is grounded at one end and allowed to charge to the plate voltage of V3. During the next half cycle the incoming dc signal is grounded so that a voltage appears at the grid of V1 equal to the incoming signal that has charged C1 and opposite in polarity. At the

same time C8 is detached from ground so that a voltage through R15 appears at the output terminal Pin A of PG2. This voltage is equal to the change in the input to V1 multiplied by the gain of the amplifier and is of the same polarity as the incoming dc signal. Thus voltage pulses of half-cycle duration and of the same polarity as the incoming signal are applied to the output terminal to charge the coupling capacitor described in Section II.

VII METERING

The metering is done with two shunts in series with a direct reading D'Arsonval movement. One shunt is used to read the current on a Rubicon potentiometer, and the other is bucked against a reference voltage and the difference applied to a 10 mv recorder. In this manner the drift can be monitored continuously.

Other meters are provided in the control tube chassis and on the control amplifier as previously described.

This work was done under the auspices of the U. S. Atomic Energy Commission.

FIGURE CAPTIONS

Fig. 1. Simplified schematic drawing of power supply for magnet of the alpha-particle spectrometer.

Fig. 2. Schematic of control amplifier.

Fig. 3. Schematic of stabilizing amplifier.

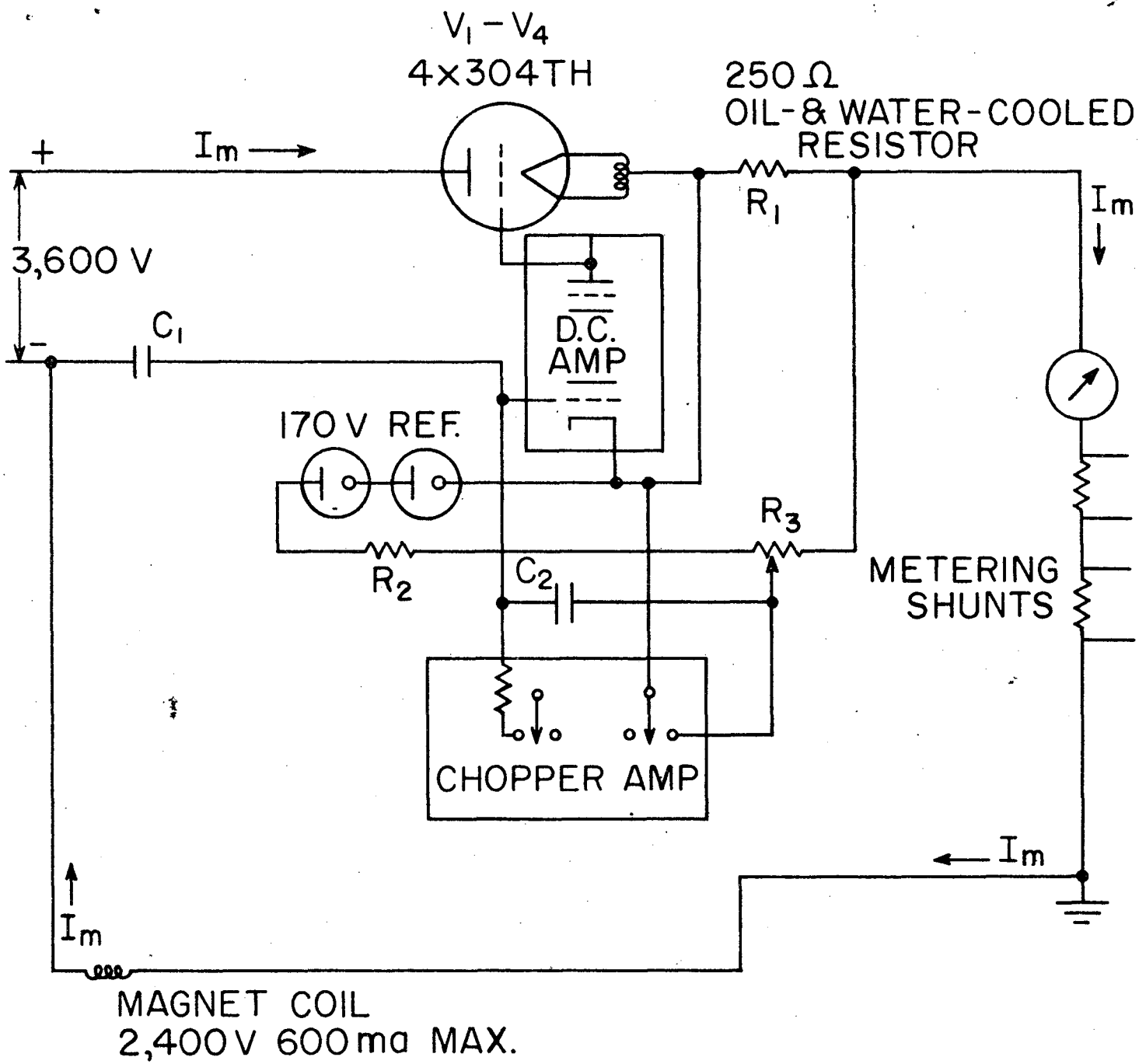

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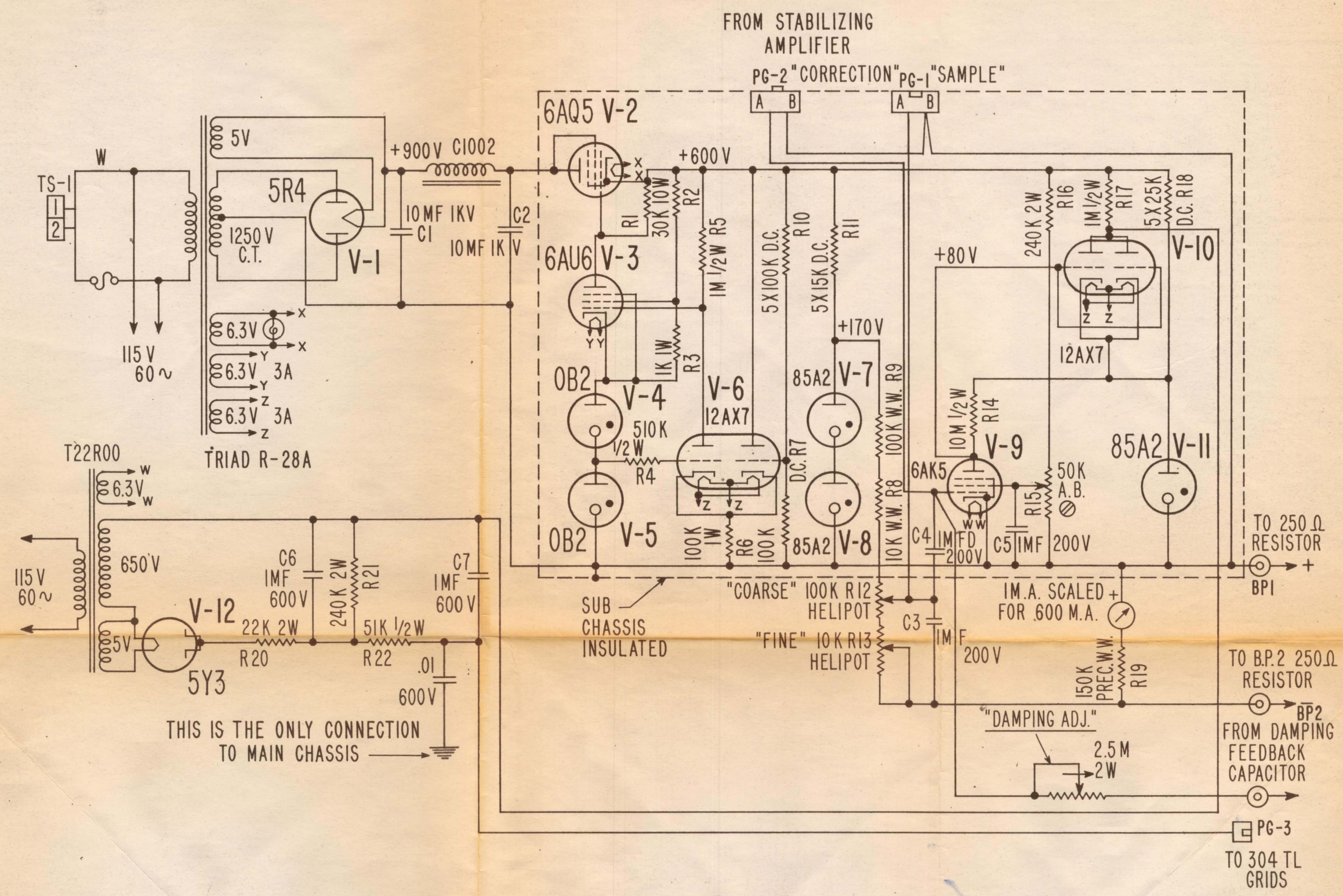
Fig. 1

24279-1


FROM STABILIZING AMPLIFIER
PG-2 "CORRECTION"
PG-1 "SAMPLE"
TS-1
W
115 V 60 ~
5V
5R4
1250 V C.T.
V-1
+900 V
C1002
10 MF 1KV C1
C2 10 MF 1K V
6.3V
6.3V 3A
6.3V 3A
TRIAD R-28A
T22R00
6.3V
650 V
115 V 60 ~
5V
V-12
5Y3
C6 1MF 600 V
22K 2W R20
240K 2W R21
51K 1/2 W R22
C7 1MF 600 V
.01 600 V
THIS IS THE ONLY CONNECTION TO MAIN CHASSIS
6AQ5 V-2
+600 V
R1 30K 10W
R2
6AU6 V-3
1M 1/2W R5
1K 1W R3
OB2 V-4
510K 1/2 W R4
OB2 V-5
V-6 12AX7
100K 1W R6
100K
D.C. R7
5X100K D.C. R10
5X15K D.C. R11
+170 V
85A2 V-7
85A2 V-8
100K W.W. R9
10K W.W. R8
SUB CHASSIS INSULATED
"COARSE" 100K R12 HELIPOT
"FINE" 10K R13 HELIPOT
C3 1MF 200 V
+80 V
240K 2W R16
1M 1/2W R17
5X25K D.C. R18
V-10
12AX7
10M 1/2W R14
V-9
6AK5
C4 1MFD 200V
C5 1MF 200V
R15 50K A.B.
85A2 V-11
TO 250 Ω RESISTOR
BP1
1M.A. SCALED FOR 600 M.A.
150K PREC. W.W. R19
TO B.P.2 250 Ω RESISTOR
BP2
"DAMPING ADJ."
2.5 M 2W
FROM DAMPING FEEDBACK CAPACITOR
PG-3
TO 304 TL GRIDS

24454-3

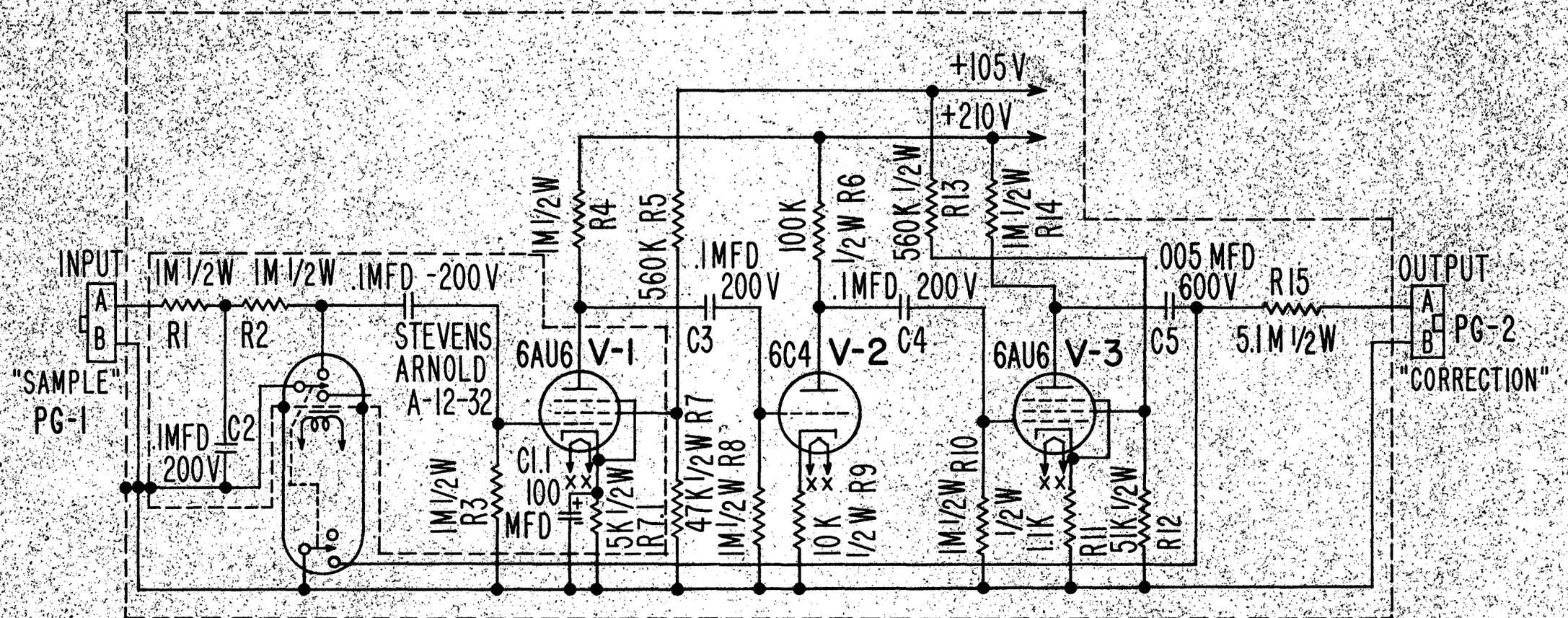

+105V
+210V
INPUT
A
B
"SAMPLE"
PG-1
1M 1/2W
R1
1M 1/2W
R2
.1MFD -200V
STEVENS
ARNOLD
A-12-32
.1MFD
200V
C2
1M 1/2W
R4
560K R5
.1MFD
200V
C3
6AU6 V-1
C1.1
100
MFD
1M 1/2W
R3
15K 1/2W
R7
100K
1/2 W R6
.1MFD 200V
C4
6C4 V-2
47K 1/2W R7
1M 1/2W R8
10K
1/2 W R9
560K 1/2W
R13
1M 1/2W
R14
6AU6 V-3
1M 1/2W R10
1/2W
1.1K
R11
5K 1/2W
R12
.005 MFD
600V
C5
R15
5.1M 1/2W
OUTPUT
A
B
PG-2
"CORRECTION"

Fig. 3

24453-2