Digital Computer Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

SUBJECT: HIGH-SPEED (5965) FLIP-FLOP

To: Group 62 Engineers and Group 63 Engineers

From: Hal Boyd

Date: February 24, 1953

Abstract: In this E-Note is presented a collection of data taken on the preliminary circuit of a high-speed, high-reliability, 5965 duo-triode flip-flop, that was designed to drive 7AK7 gate tubes. The procedure used in the design of this flip-flop is explained in E-525 entitled "The Normalized Flip-Flop Chart." A circuit schematic of the flip-flop, from which all data was taken, is shown in Figure 1, attached.

1.0 P.R.F. Response Characteristics

The curves shown in Figure 2 were obtained by complementing the flip-flop with a continuous train of 0.1 μsec pulses with various loads on both flip-flop outputs. The lower curves define the transition from the region of either inoperation or frequency division, to the region of absolute operation. The upper curve (45° line at 5 megacycles) defines the transition from the region of operation to the region in which both output levels coincide. In this latter region the flip-flop's memory is destroyed and the flip-flop assumes a third stable state in which counting is not reliable.

For 20-volt triggers with a range from 13 to 30 volts, the flip-flop can drive up to 100 μμf/side (6-7, 7AK7 gate tubes per side) up to a maximum continuous p.r.f. of 4 megacycles.

2.0 Counting Characteristics

Figure 3 was read directly from the output waveforms of the flip-flop while complementing at 1 Kc with 0.1 μsec pulses. 15-volt and 25-volt negative triggers were used for complementing the flip-flop, and the output waveforms were observed with no load and with a load of 100 μμf on each output of the flip-flop. Note that no additional delay would be necessary for use of the flip-flop in counting applications.

3.0 Variation of critical voltages with low I_b tubes

The worst combination of tube sides for the flip-flop tube is with one side of high I_b and the other of low I_b. The most critical voltages are the output levels, E_{o1}, and E_{o2}, the flip-flop tube's cathode voltage, E_k, the "on" tube's grid voltage, E_{gon}, and the "off" tube's grid voltage, E_{goff}. The manner in which these voltages vary as one tube side's I_b varies is shown in Figure 4.

The I_b of the tube side in question was varied by its filament voltage. In the experiment, provision was made for switching the tube side from a tube testing circuit to the flip-flop circuit. Hence, at each filament voltage the I_b at 120 volts E_b and $E_c = 0$ was measured, and, at that same filament voltage, the behavior of the tube in the flip-flop was noted and the critical voltages were measured. The results were verified when, later, low I_b 5965's were available.

4.0 Supply Voltage Variations

Nominal Voltage	Limits	% Change	Output Levels
+150	+210	40%	+5 to -25
	0	100%	0 to -48
	$-\lvert >300 \rvert$	100%	+.5 to -50
-150	-125	16.7%	+2.5 to -25
	-100	33.3%	+2.5 to -15

The above data is presented in terms of output voltage levels because failure of the flip-flop was arbitrarily taken as the point at which either output level falls within the range of from 0 to -25 volts; whereas flip-flop failure with respect to gate tubes defines a range of from 0 to -15 volts.

5.0 Resistor and diode tolerances

Tolerances on resistors and diodes were taken one at a time, and the limits were defined by the point at which either output level falls within a range of from 0 to -25 volts. Figure 5 gives the maximum tolerance of each component, all others being held constant and within the tolerances shown on Figure 1.

6.0 Marginal Checking

Various components of the flip-flop were varied one at a time, and marginal checking voltages were determined for a number of values of each component. The marginal check voltage was inserted in the flip-flop at the spot marked "marginal check voltage" on Figure 1. The marginal checking voltage is centered, or has its base line, at -150 volts, and is taken to be the displacement from -150 volts. The manner in which the marginal checking voltage varies with percentage variations of each component is shown in Figures 6-12 inclusive. The solid curves indicate the picking up of a component on the same side of the flip-flop as the marginal checking voltage; whereas, the dotted curves are for components on the opposite side of the flip-flop.

<u>Drawings:</u>

SA-53718-1
SA-54002
SA-48396-G to
48405-G incl.

Signed ____________
Hal Boyd

Approved ____________
R.L. Best, Section Leader

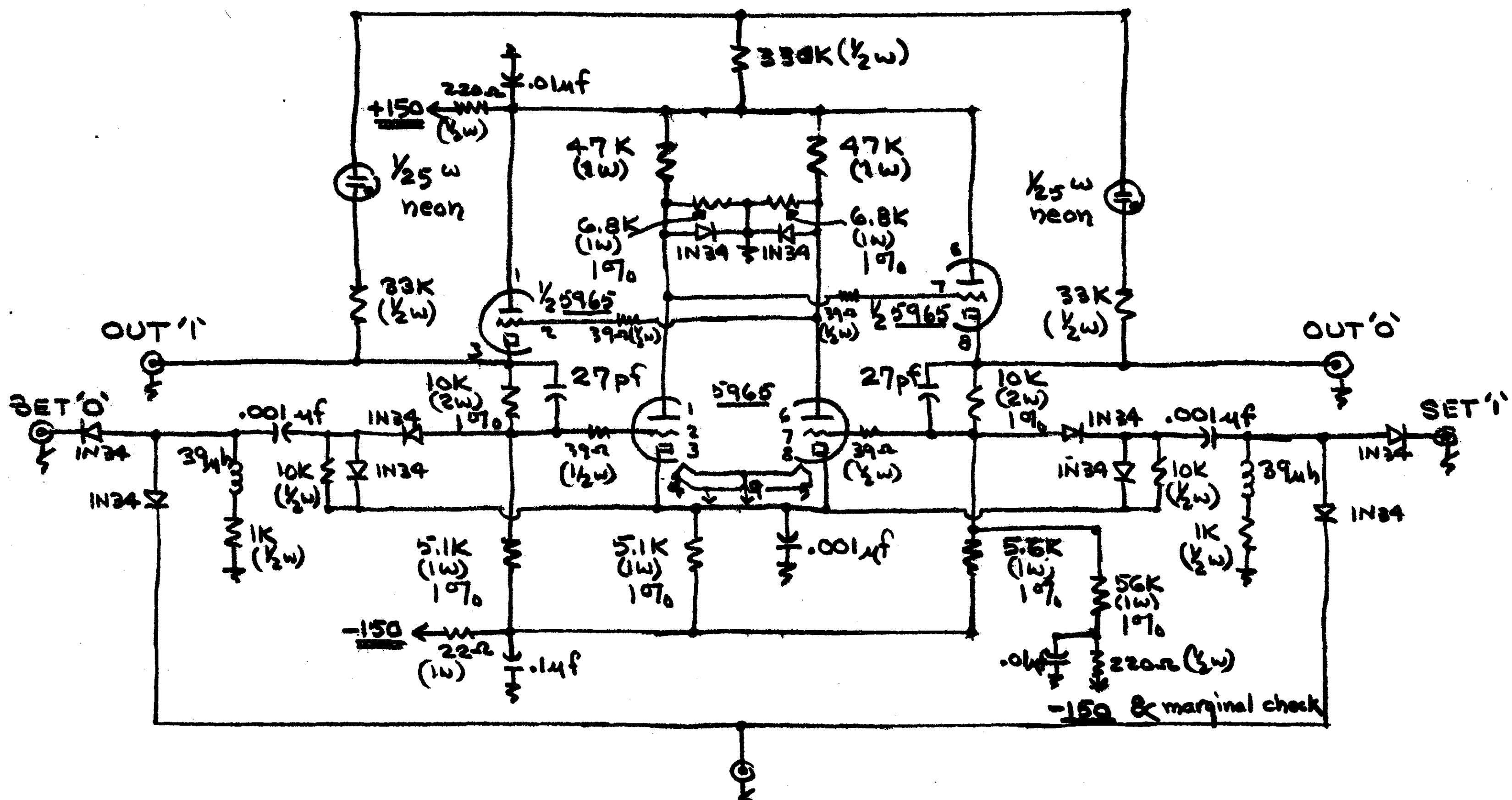
Approved ____________
N.H. Taylor, Group Leader

HB/cs

SA-53718-1

4 MEGACYCLE 5965 FLIP-FLOP for GATE TUBE LOADING

20 volt negative 0.1 μsec trigger, nominal; range: 13-30 volts
Output levels: upper — 0 to +3, lower — -25 to -35
Maximum loading (for 20 v triggers at 4 mc): 100 pf/side (6-7, 7AK7 GT's)



All resistors ±10% except as otherwise specified

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SA-54002

RESISTOR & DIODE TOLERANCES

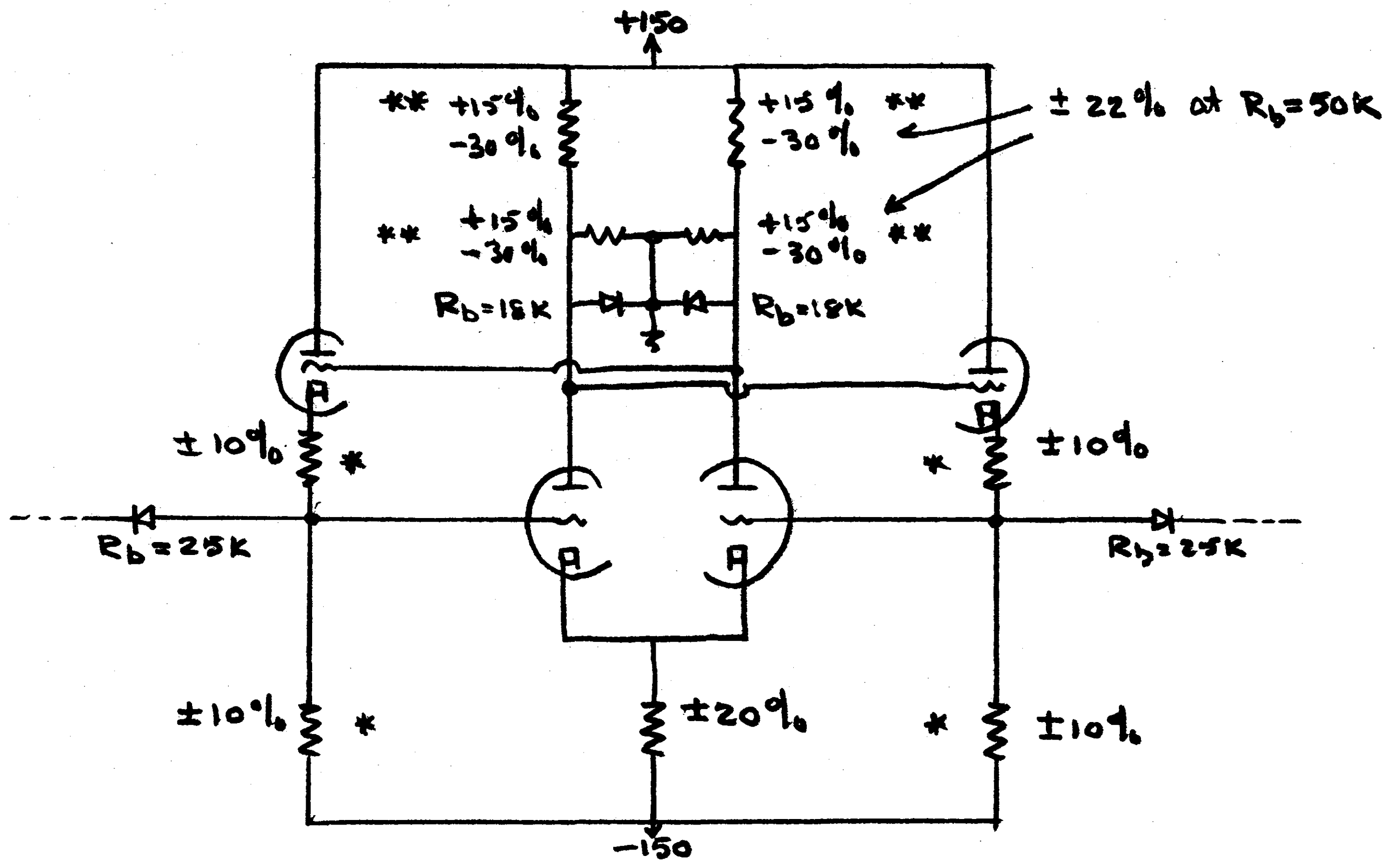

FIGURE 5

FIGURE 5

NOTES : (*) If all four resistors vary in the worst directions, then each can vary 2.5% before failure.

(**) These limits (as are all others) are defined by output levels of 0 to +3, and/or -25 to -35 volts. If -40 volts were taken as one of the limits instead of -35, then the +15% tolerance would be increased to +60%.
Also, as the plate-circuit-diode's back resistance decreases, the upper limit increases and the lower limit decreases.

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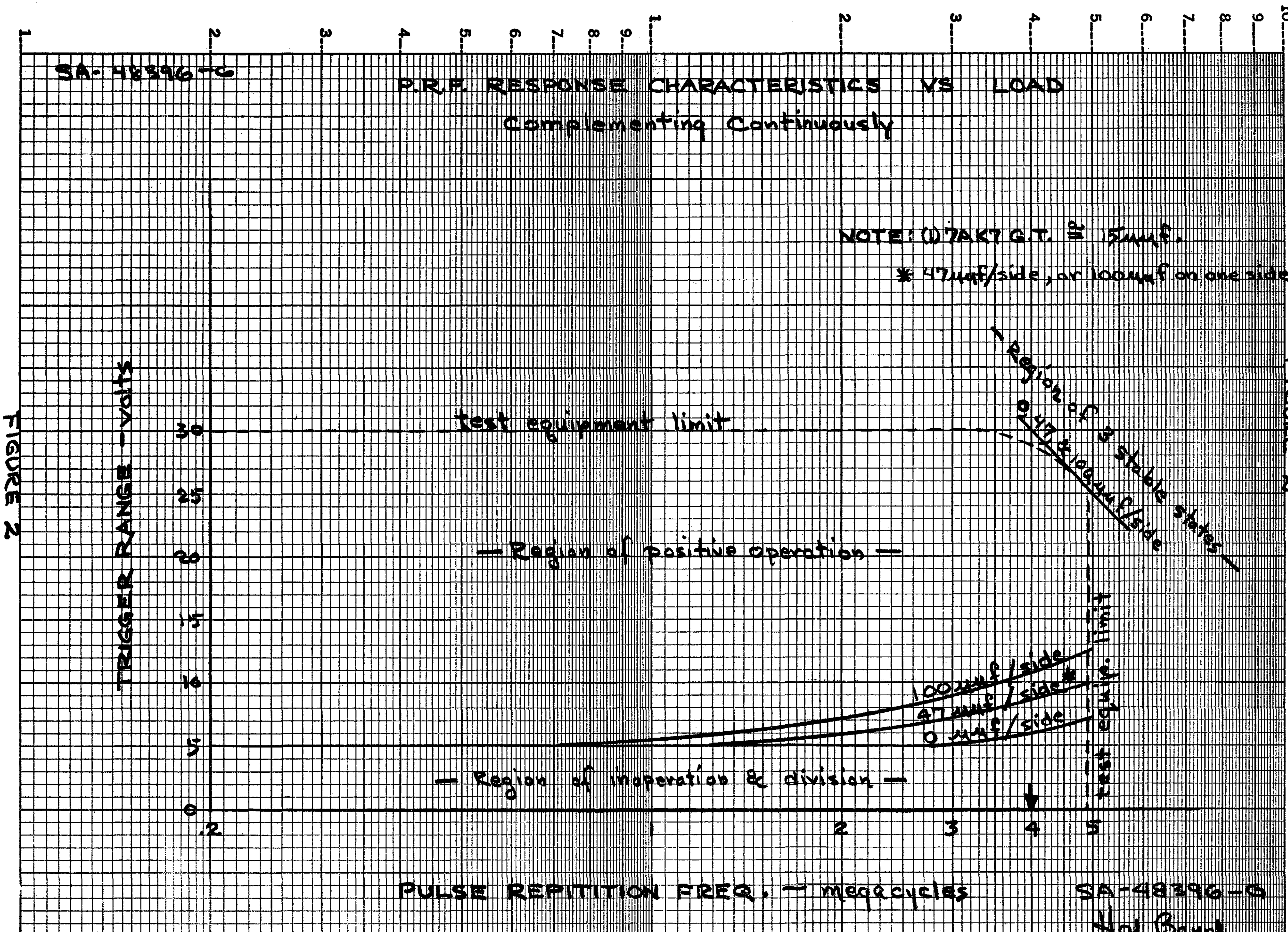

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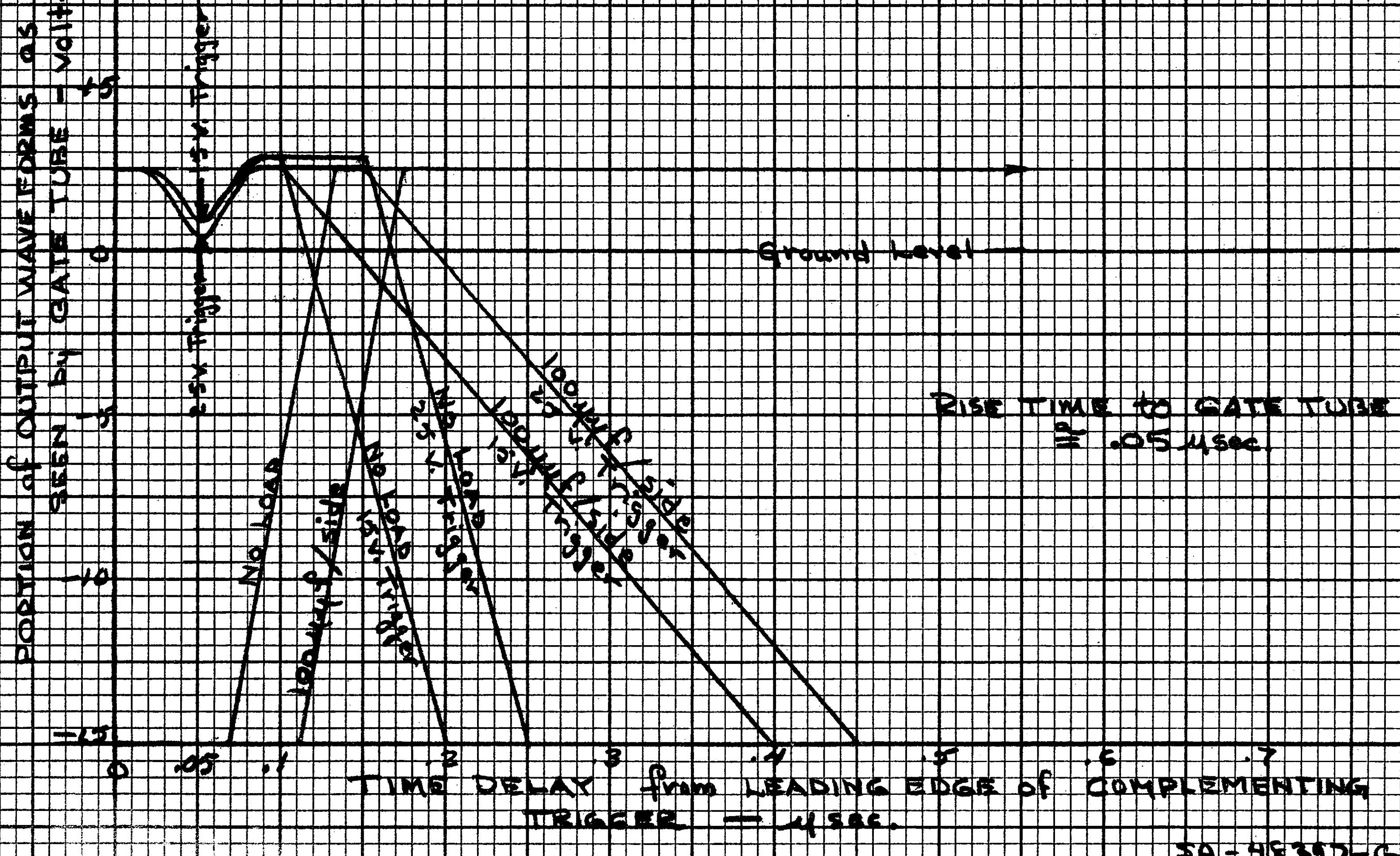
SA-48397-G

COUNTING CHARACTERISTICS

FIGURE 3



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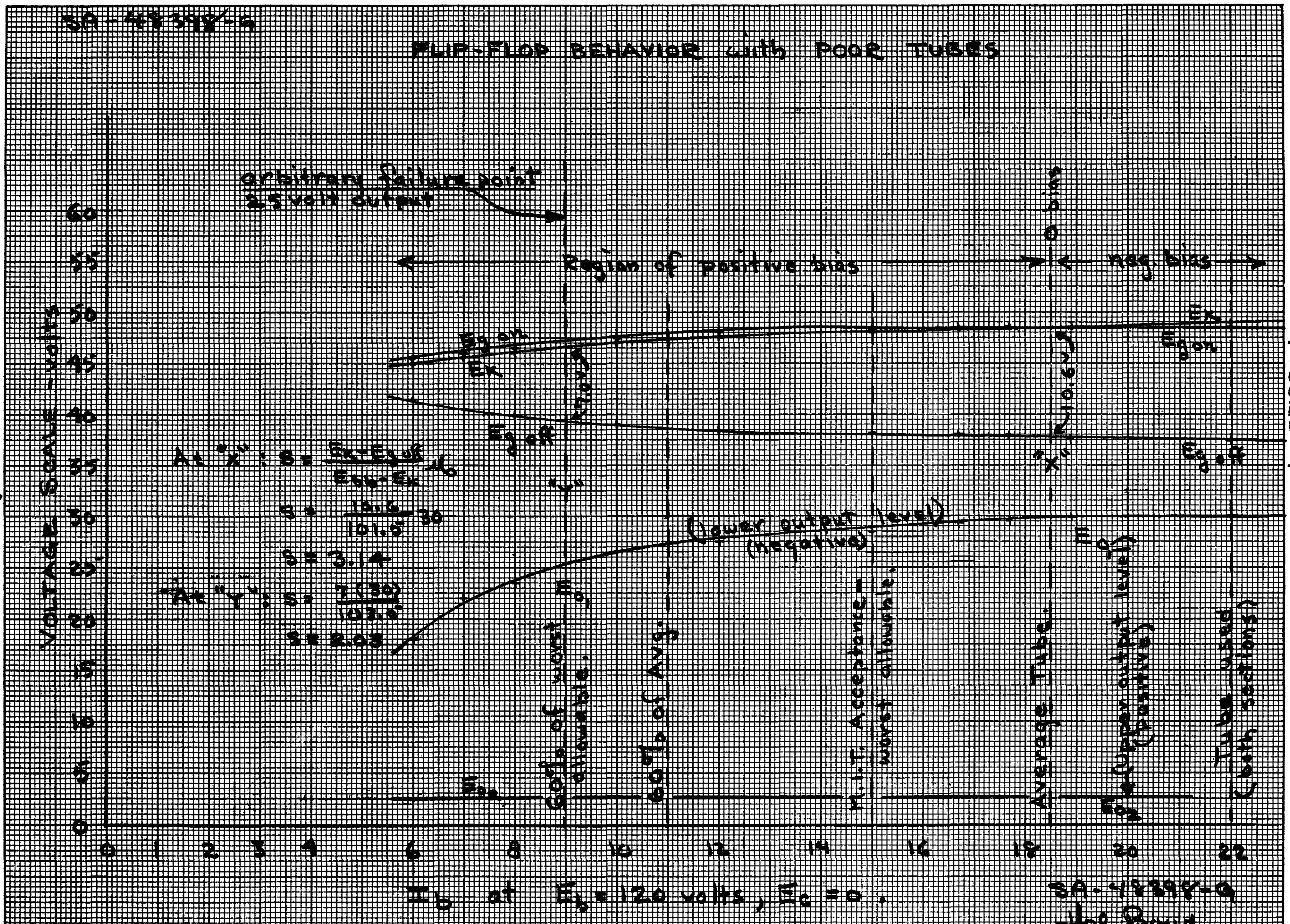

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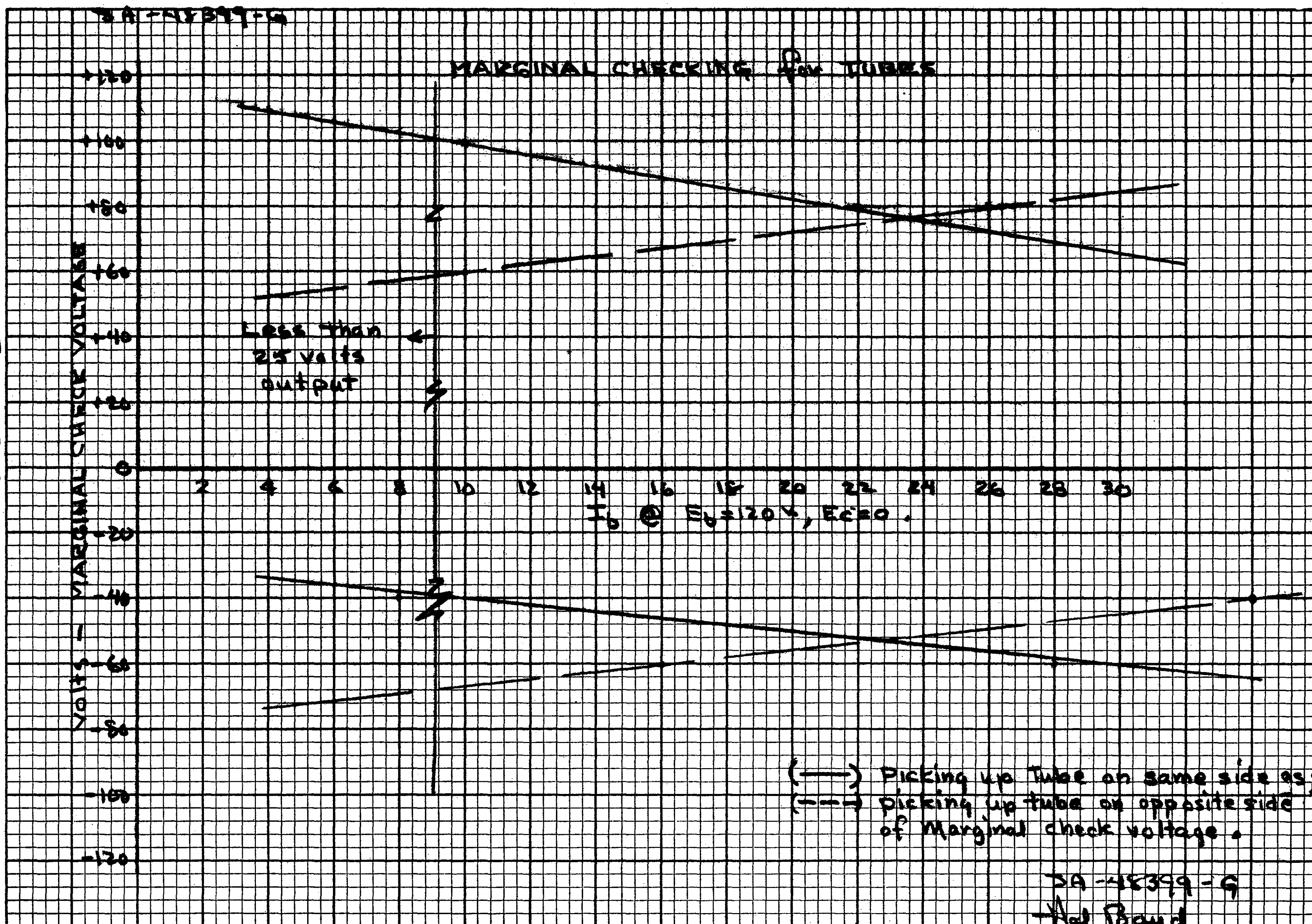

FIGURE 6

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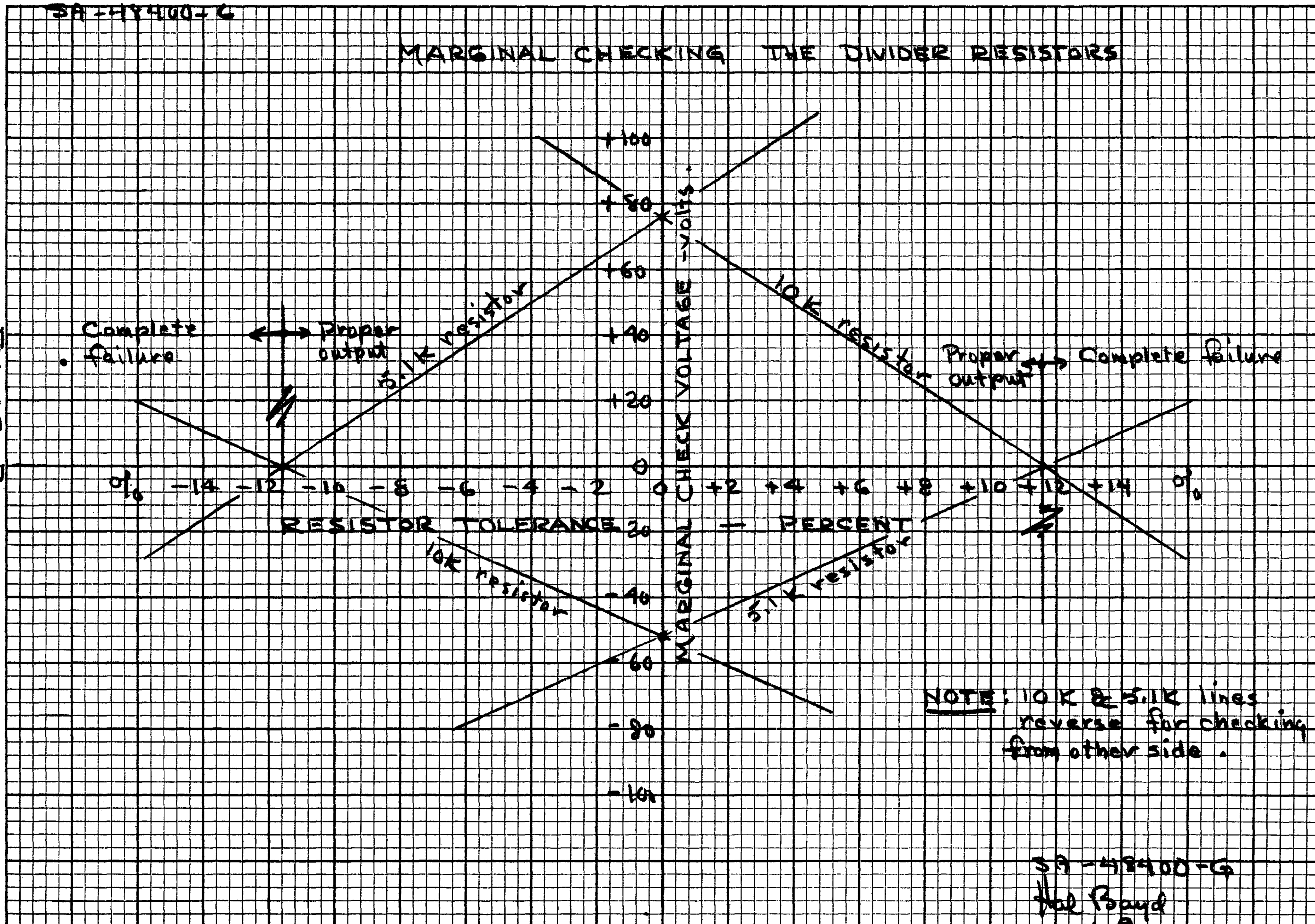
SA-48400-G
MARGINAL CHECKING THE DIVIDER RESISTORS
MARGINAL CHECK VOLTAGE - volts
+100
+80
+60
+40
+20
0
-20
-40
-60
-80
-100
RESISTOR TOLERANCE — PERCENT
% -14 -12 -10 -8 -6 -4 -2 0 +2 +4 +6 +8 +10 +12 +14 %
Complete failure
Proper output
5.1 K resistor
10K resistor
Proper output
Complete failure
10K resistor
5.1 K resistor
NOTE: 10 K & 5.1 K lines reverse for checking from other side.
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FIGURE 7

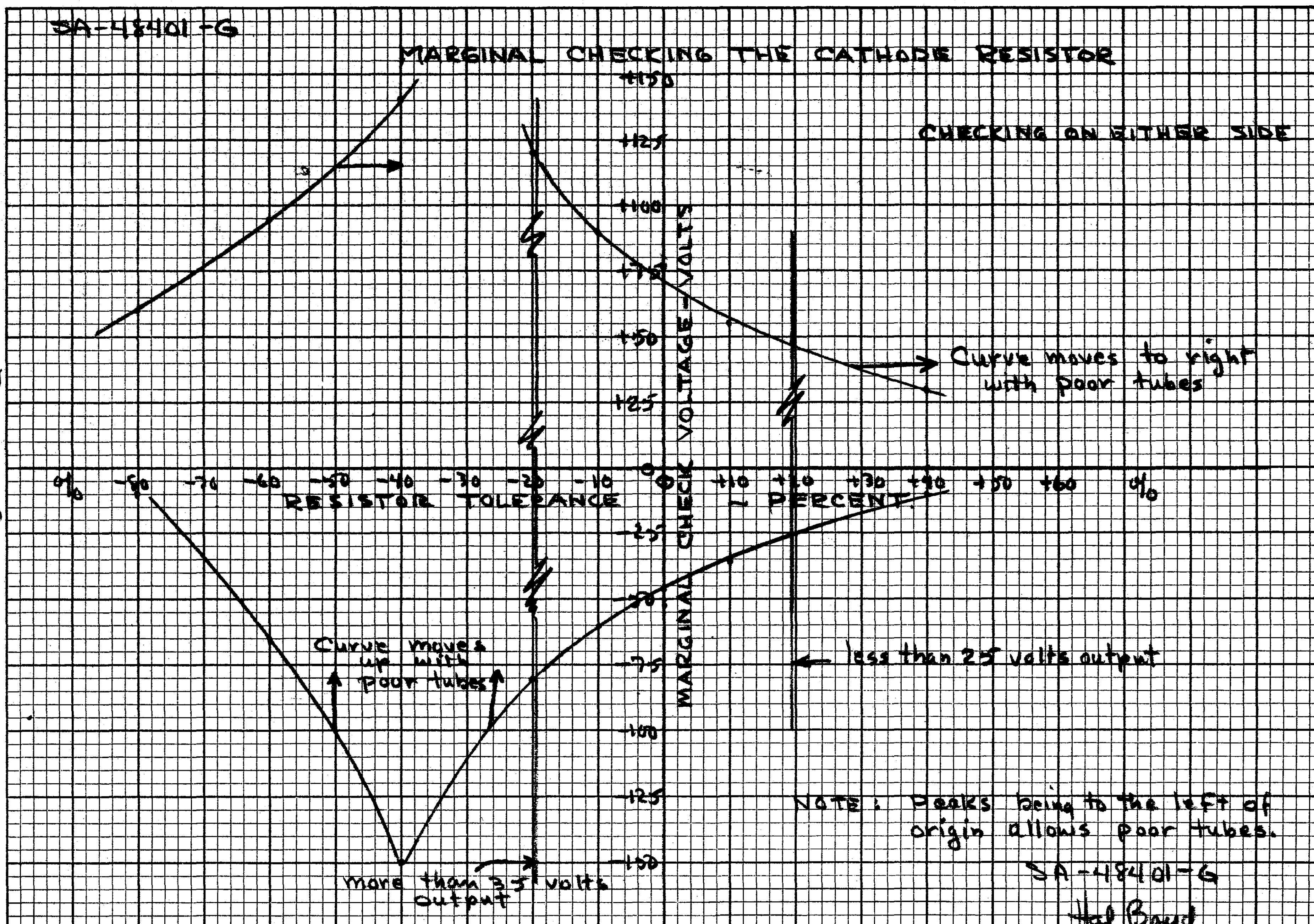

FIGURE 8

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FIGURE 6

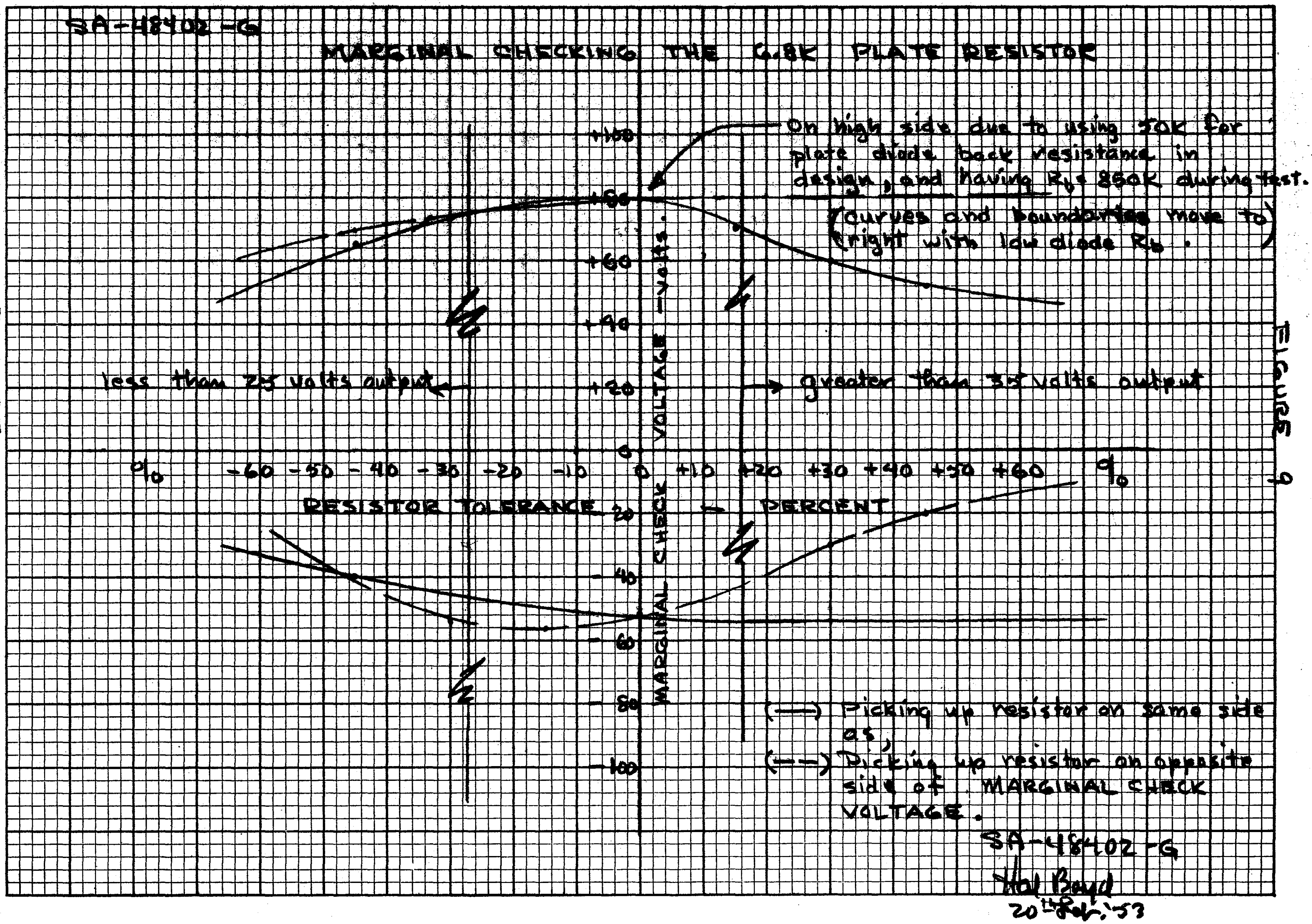

FIGURE 6

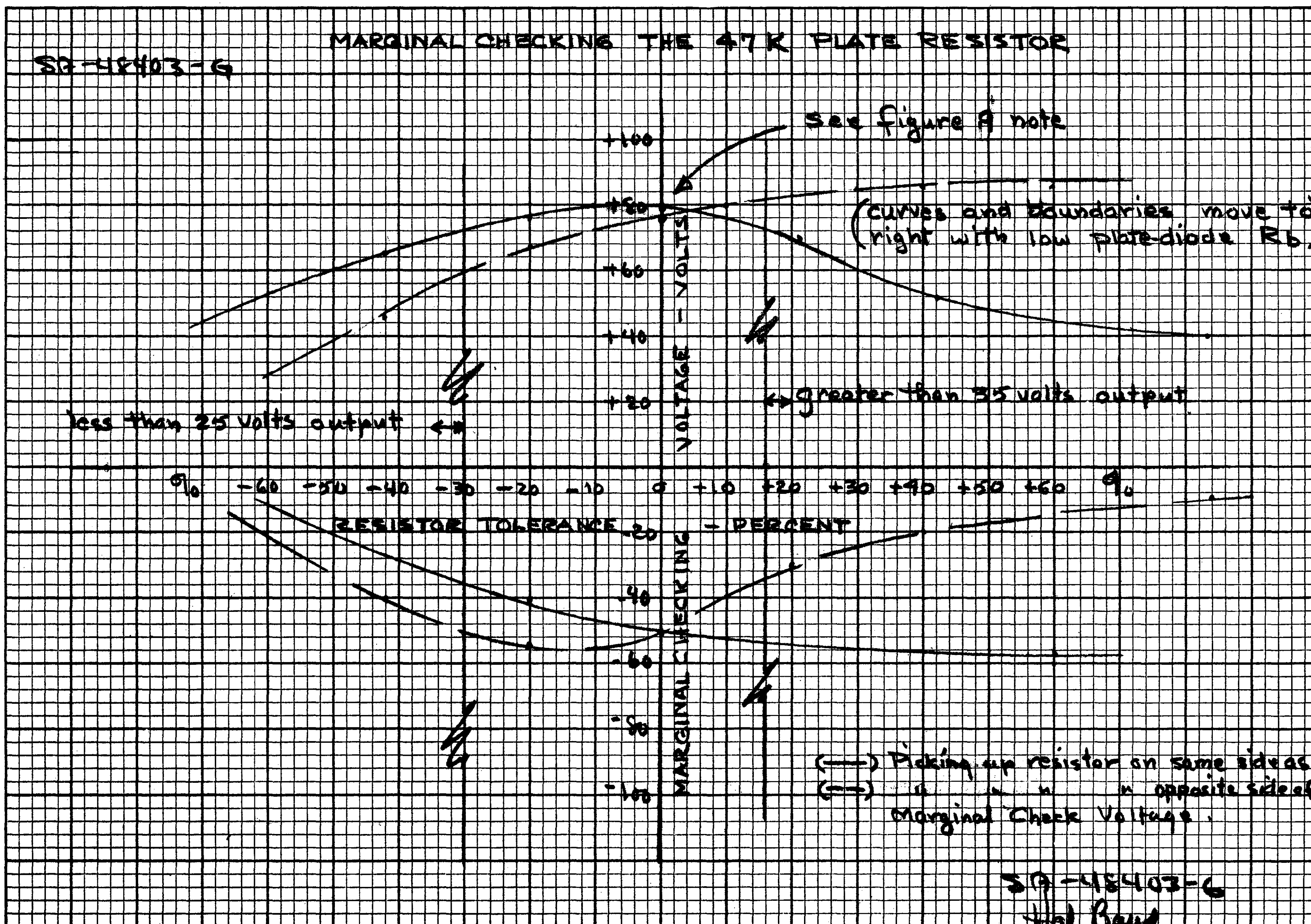

FIGURE 10

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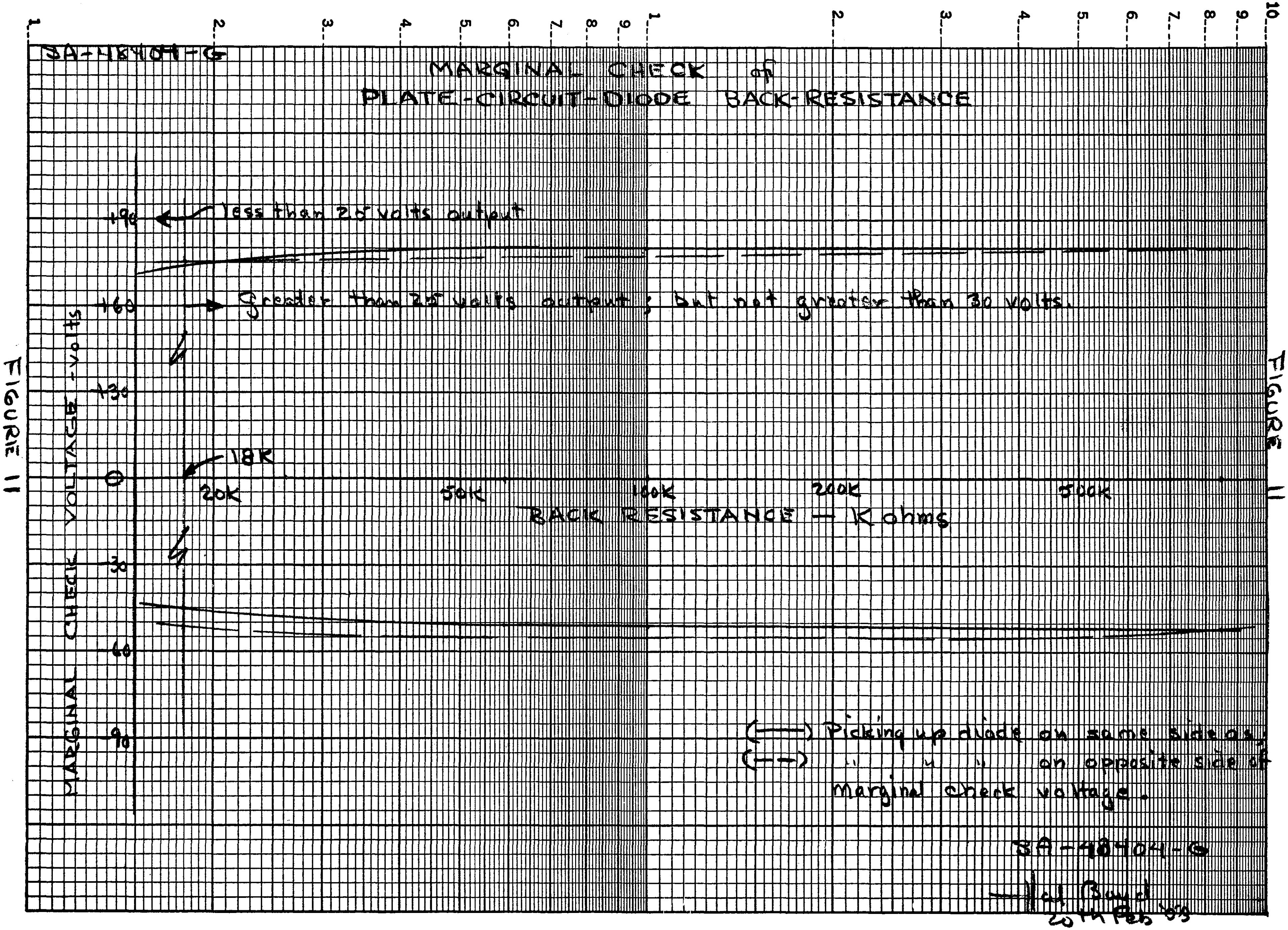
FIGURE 11
SA-48404-G
MARGINAL CHECK of
PLATE-CIRCUIT-DIODE BACK-RESISTANCE
+90
less than 20 volts output
+60
Greater than 25 volts output; but not greater than 30 volts.
+30
0
-30
-60
-90
18K
20K
50K
100K
200K
500K
BACK RESISTANCE — K ohms
MARGINAL CHECK VOLTAGE - volts
(——) Picking up diode on same side as
(- - -) " " " on opposite side of
marginal check voltage.
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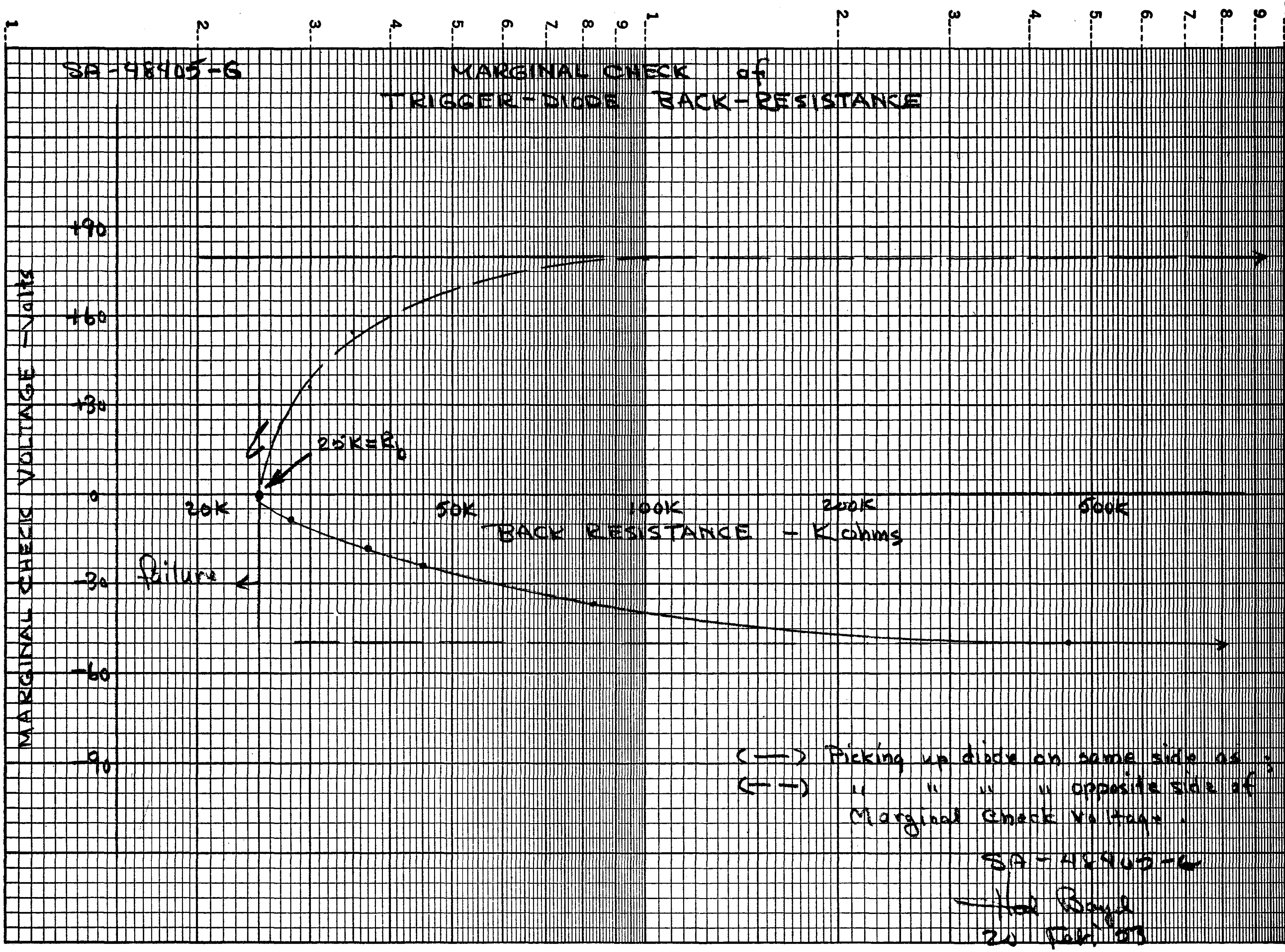
FIGURE 11



SA-48405-G
MARGINAL CHECK of
TRIGGER-DIODE BACK-RESISTANCE
MARGINAL CHECK VOLTAGE - volts
+90
+60
+30
0
-30
-60
-90
20K
50K
100K
200K
500K
BACK RESISTANCE - K ohms
25K=R0
failure
(——) Picking up diode on same side as
(- -) " " " " opposite side of
Marginal Check Voltage.
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FIGURE 12