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A device for determining the electrical characteristics of common industrial electronic tubes

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A Device for Determining
the Electrical Characteristics
of Common Industrial Electronic Tubes

By

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I. Introduction

Many tube checkers designed for radio receiving tubes have been developed. Most of the devices for testing these tubes do little more than check the emission of the cathode.[1] This is usually accomplished by applying

1. Terman:
Measurements in Radio Engineering 176-178 (1935)

alternating voltage to the plate of the tube undergoing the test and reading the direct-current component of the plate current. In this case, the control grid bias voltage is usually set at a fixed value although sometimes facilities for varying the bias are provided. If the tube is of the multi-grid type, all the grids except the control grid are connected to the plate, thereby eliminating their effects on the operation of the tube.

Since mutual conductance is of great importance in determining the functioning of a tube, instruments for measuring it have been devised. To do this, a known alternating voltage is applied to the grid, and a meter calibrated to read mutual conductance directly, measures the resulting alternating component of the plate current. Only in the most elaborate checkers is there any attempt made to place the tube under working conditions while testing.

In the electronics laboratory there is a need for many different types of industrial tubes in order that experiments and research can be performed. However, no one device has been introduced with which the characteristics and working performance of these tubes can be determined.

True, the manufacturers of industrial tubes have elaborate instruments with which all kinds of tests on the tubes can be made, but a separate instrument is used for each type of tube. These are far too extensive and expensive for the majority of colleges and small industries.

A device for comparing the simultaneous emission[2] of two shield-grid thyratrons has been developed, but only the critical values of grid potential and the emission characteristics for one fixed value of plate voltage can be obtained and only on a very few tubes.

2. Radio News 20-21 (March, 1943)

In testing industrial tubes, the situation is quite different from that of testing radio receiving tubes, for the latter do not vary in either structural design or electrical requirements as do the industrial types. The external features, the connections in particular, of receiving tubes are similar, and the voltages and currents necessary for their operation are comparatively small whereas the structural features of industrial tubes follow no pattern, and the required voltages and currents vary over a wide range.

This investigation was undertaken for the purpose of developing a device by which tests can be made and data obtained on the more generally used thyratrons, kenotrons, phanotrons, and pliotrons.

These tests and data consist of filament continuity; shortcircuits; the determination of static characteristics; critical values of grid voltage in the case of gas-filled tubes and controlling effects of the grid in vacuum tubes; emission; and the information obtainable from placing the tubes under approximate working conditions, various values of plate voltage and load resistance being available.

II. Description of Apparatus

In brief, the apparatus consists of two power supplies which furnish rectified grid and plate voltage, and methods for varying them; a control for the filament voltage; a system of switches through which these voltages are applied to the various test sockets; and meters for reading filament voltage and current, plate voltage and current, and control and shield grid voltages.

The grid power supply is a symmetrical voltage-doubling rectifier[3,4,5,6,7,8], employing a 25Z5 dual-diode tube requir-

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3. Schulz and Anderson:
   Experiments in Electronics and Communication Engineering 207-209 (1943)

4. Muller, Garman, and Droz:
   Experimental Electronics 104-105 (1942)

5. Fink:
   Engineering Electronics 257 (1938)

6. Reich:
   Theory and Applications of Electron Tubes 566 (1944)

7. A. R. R. L.
   The Radio Amateur's Handbook 183 (1947)

8. Albert:
   Fundamental Electronics and Vacuum Tubes 193-194 (1938)

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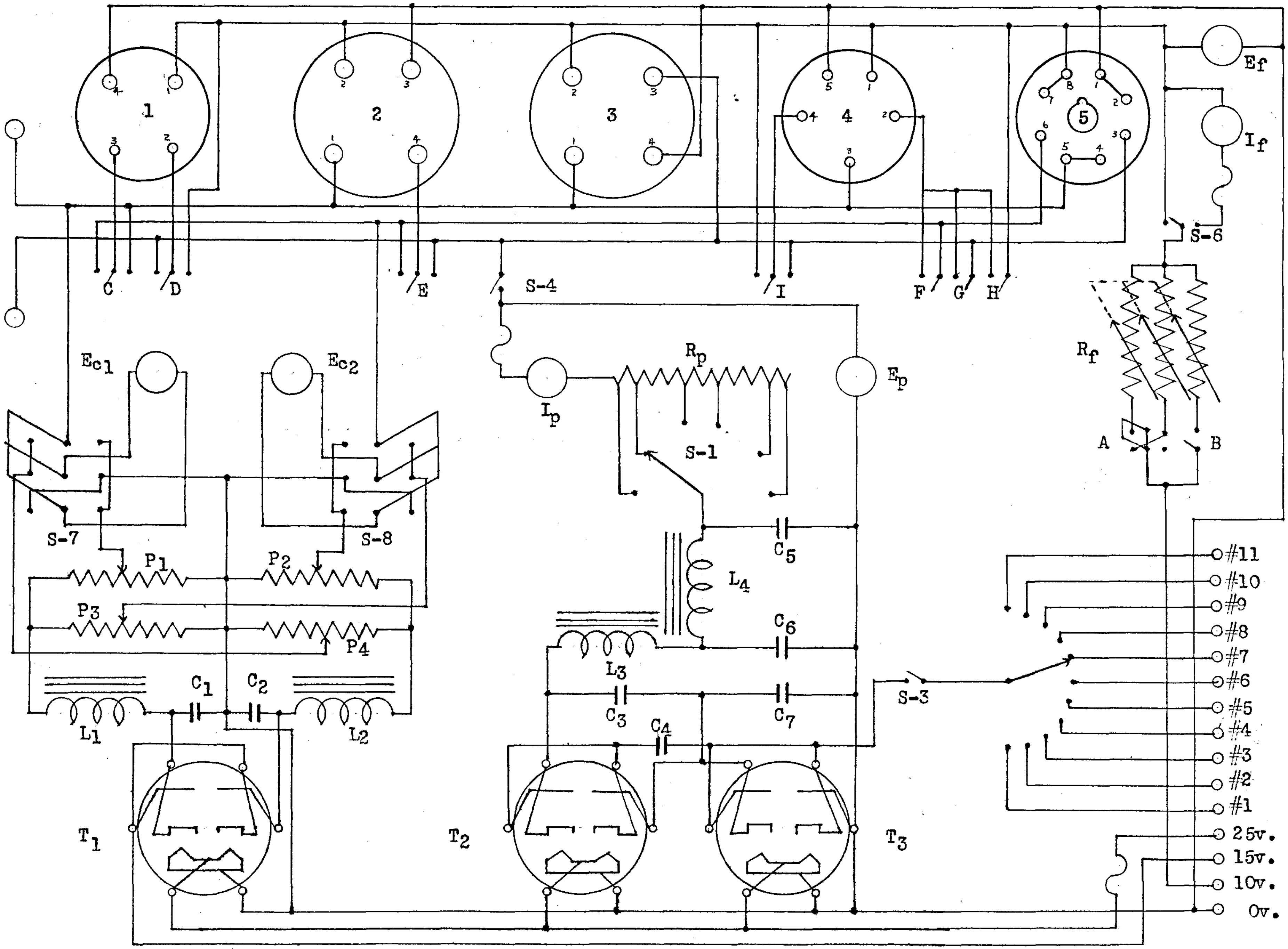
ing a 25-volt heater voltage. Since this is a symmetrical doubler, it gives both a positive and a negative potential equal to $\sqrt{2}$ times the effective a.c. input voltage. By the use of 500 ohm potentiometers and switches, controlled values of either positive or negative bias can be applied to the control and shield grids of the tube under test.

Fig. 1

Circuit Diagram



Legend

Socket #1	Standard UX socket
Socket #2	Super Jumbo socket
Socket #3	Jumbo socket
Socket #4	Standard 5-prong socket
Socket #5	Standard octal socket
T_1, T_2, T_3	25 Z 5 tubes
S-1	6-tap selector switch
S-2	11-tap selector switch
S-3, B, F, G, H	S.P.S.T. toggle switches (6a. 125 v.)
S-4,S-5,S-6,C,D,E,I	S.P.D.T. toggle switches (6a. 125 v.)
S-7, S-8	3 P.D.T. toggle switches (6 a. 125 v.)
C_1, C_2	20 μfd., 450 v. dry electrolytic capacitors
C_4	16 μfd., 450 v. dry electrolytic capacitor
C_3, C_7	20 μfd., 900 V. dry electrolytic capacitors
C_5, C_6	2 μfd., 1500 v. dry electrolytic capacitors
L_1, L_2	30 Henry, iron-core, chokes
L_3, L_4	15 Henry, iron-core, chokes
P_1, P_2, P_3, P_4	500 ohm, wire-wound, potentiometers
Rf	3 ganged rheostat (8 ohms per banch)
Rp	Plate resistor (250,500,1000,1500,200 ohm taps)
Ef	Filament voltmeter (0 - 15 v.a.c.)
Ep	Plate voltmeter (0 - 150, 0 - 1500 v.d.c.)
E_{c1}	Control grid voltmeter (0-30 v.d.c.)
E_{c2}	Shield grid voltmeter (0-30 v.d.c.)
I_f	Filament ammeter (0-10 a.a.c.)
I_p	Plate ammeter (0-100 m.a., 0-10 a.d.c.)

Fig. 2. The Apparatus

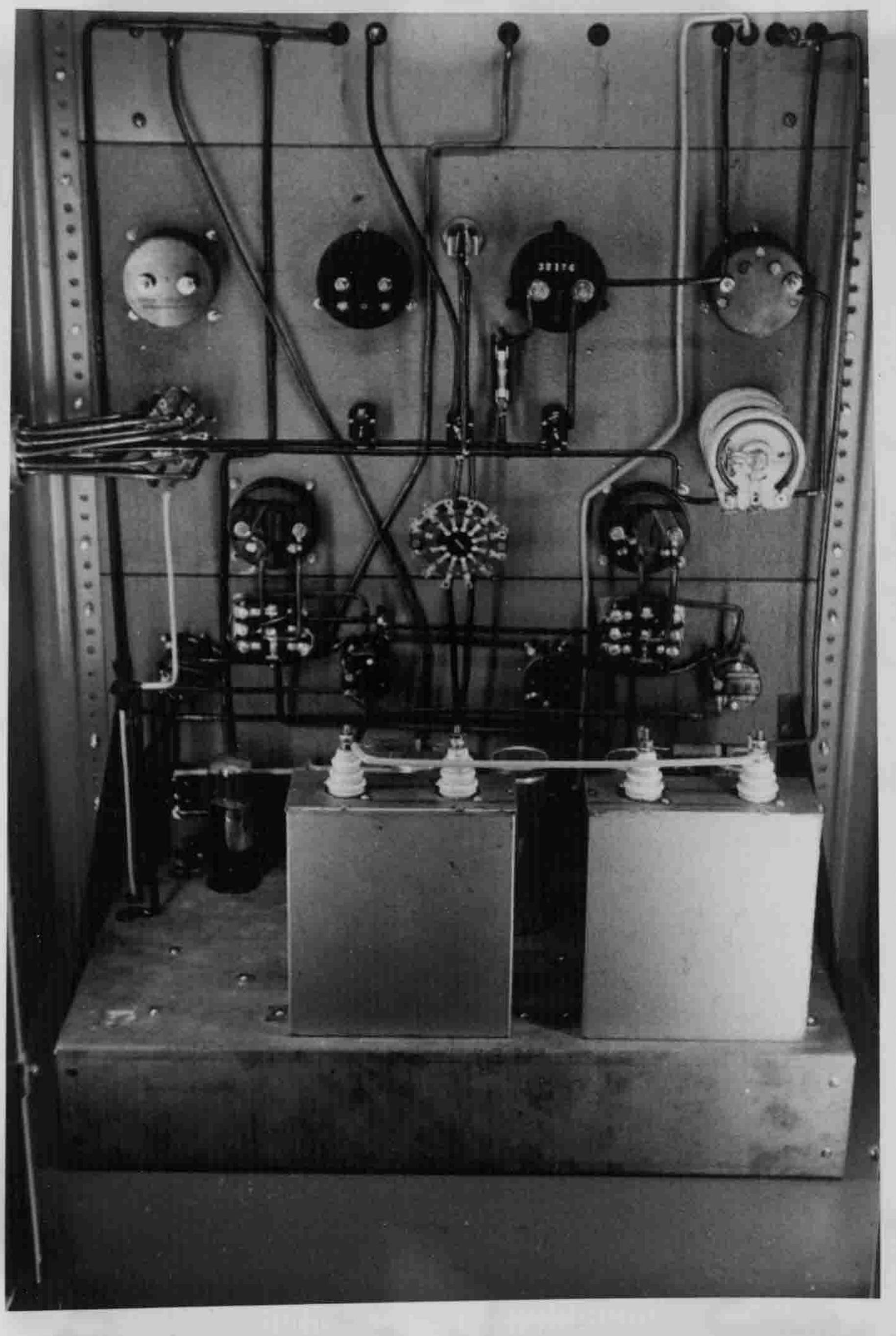


Fig. 3. Rear View of Apparatus

A 15-volt input to the doubler is sufficient for most purposes.

To obtain the necessary plate voltage a fundamental voltage-quadrupling rectifier[9,10,11] is employed, using two

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9. Schulz and Anderson:
   Experiments in Electronics and Communication Engineering
   209-210 (1943)

10. Reich:
   Theory and Applications of Electron Tubes 566-567 (1944)

11. A. R. R. L.
   The Radio Amateur's Handbook 184 (1947)

25Z5 tubes. In this circuit the negative side of the rectified voltage is grounded, therefore being at zero potential and giving a positive potential equal to $4 \times \sqrt{2}$ times the effective a.c. input voltage.

Various values of this input voltage from zero to 250 volts is obtained by means of an 11-tap selector switch between the supply transformer and the quadrupler.

To reduce the ripple in the rectified voltage, low-pass filters[12,13,14,15,16,17,18] are used. Two single-section

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12. Schulz and Anderson:
   Experiments in Electronics and Communication Engineering
   116-119, 197-200 (1943)

13. Muller, Garman, and Droz:
   Experimental Electronics 90-92 (1942)

14. Electrical Engineering Staff, M.I.T.
   Applied Electronics 272-287, 289-300, 303-307 (1943)

15. A. R. R. L.
   The Radio Amateur's Handbook 46-47, 177-179 (1947)

16. Reich:
    Theory and Applications of Electron Tubes 574-590 (1944)

17. Fink:
    Engineering Electronics 235,256 (1938)

18. Albert:
    Fundamental Electronics and Vacuum Tubes 181-192 (1943)

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condenser-input filters are connected to the voltage doubler, one to the positive side and one to the negative, while a two-section condenser-input filter is employed on the positive side of the quadrupler.

In the filament circuit, a variable resistor consisting of three parallel branches controls the filament voltage. By means of switches, either one or two of the branches can be eliminated depending on the required voltage and resulting current. The a.c. input to the resistor is 10 volts.

Due to the variety of designs among industrial tubes, several switches are necessary in order that the various voltages may be applied to the proper prongs of the tubes being tested.

To simulate actual working conditions, load resistances ranging from 250 to 2000 ohms are provided. The values are changed by means of a selector switch.

This tube tester is designed to be used in conjunction with a type 200, 250 volt-60 cycle, 10 K.V.A. auto-transformer made by the Kelley-Koett Manufacturing Company. This transformer is designed to operate on either 110 or 220 volts.

When a 110-volt input is used, the maximum voltage obtainable from the transformer is 125 volts, and 250 volts for a 220-volt input. For running tests on the majority of tubes the 220-volt input will be employed.

III. Instructions for Operation

Because of the fact that rather high voltages are developed in the tube tester, certain precautionary measures must be strictly followed.

The master switch on the input side of the transformer must be open

(1) While setting the various controls and switches;

(2) While placing a tube in one of the test sockets or taking it out; and

(3) While doing any work on the tester.

All the potentiometers and selector switches should be turned all the way to the left in the off position, and the switch settings rechecked before the master switch is closed.

The ammeter in the filament circuit must be cut out until after the surge current has subsided.

The plate circuit switch must be left open until the prescribed heating time has elapsed so no potential will be applied to the plate until the tube is properly heated. It should be in the off position before a tube is taken out of a test socket.

Never enter the cabinet for at least ten minutes after the master switch is opened thus allowing the filter condensers time to discharge.

In the case of some tubes, the maximum plate voltage is 650 volts or less. To get more readings in this lower range, an input to the transformer of 110 volts instead of the usual 220 volts can be used, and the leads from the transformer to the tester can be connected to the lower voltage binding posts. The leads may be so arranged for any tube when more readings are desired over a lesser range provided they are kept in the proper order. When using a 110-volt input to the transformer care must be taken to keep the heater voltage for the power supplies at 25 volts and the filament voltage at 10 volts.

In the following table, the prescribed filament voltage for each tube is given along with the approximate current that can be expected if the filament is operating properly. The plate voltage given is the maximum for that particular tube and should not be exceeded. In the columns headed "Control Grid Voltage" and "Shield Grid Voltage", the approximate range is denoted from positive to negative. Under "Switch Positions", "U" signifies the up position and "D", the down position, of the toggle switches lettered A through I. "High" and "Low" in the plate ammeter column specifies whether the high, 10 ampere, scale or the low, 100 milliampere, scale is to be used.

Before placing a tube under test, it is advisable to consult the manufacturer's tube manual for more detailed information than can be given here.

This tester is designed to check only one tube at a time.

TABLE I

Tube Type & No.	Filament Voltage	Approv.Fil. Current	Heating Time	Max.Plate Voltage	Control Grid Volt.	Shield Grid Volt.	Switch Positions A	B	C	D	E	F	G	H	I	Socket No.	Plate Ammeter	Remarks
THYRATRONS																		
GL-3C23	2.5 v.	7.0 a.	15 sec.	1250 v.	0 to -10		U	U	D			D	D	D		1	High	
FG-17	2.5 v.	5.0 a.	5 sec.	2500 v.	0 to -12		U	U	D			D	D	D		1	High	
FG-27-A	5.0 v.	4.5 a.	60 sec.	1000 v.	0 to -15		U	U	D	D		D	D	D		1	High	
FG-33	5.0 v.	4.5 a.	5 min.	1000 v.	8 to -12		U	U	D	D		D	D	D		1	High	
FG-57	5.0 v.	4.5 a.	5 min.	1000 v.	0 to -10		U	U	D	D		D	D	D		1	High	
FG-67	5.0 v.	4.5 a.	5 min.	1000 v.	14 to - 8		U	U	D	D		D	D	D		1	High	
FG-81-A	2.5 v.	5.0 a.	5 sec.	500 v.	0 to - 8		U	U	D			D	D	D		1	High	Use 110 v input to transformer
FG-95	5.0 v.	4.5 a.	5 min.	1000 v.	8 to -14	0 to -5	U	U	U	D		D	D	D		1	High	
FG-97	2.5 v.	5.0 a.	5 sec.	1000 v.	6 to -20	0 to -5	U	U	U			D	D	D		1	High	
FG-98A	2.5 v.	5.0 a.	5 sec.	500 v.	0 to -16	0 to -5	U	U	U			D	D	D		1	High	Use 110 v input to transformer
FG-154	5.0 v.	7.0 a.	10 sec.	500 v.	2 to -16	0 to -5	U	U	U	D		D	D	D		1	High	Use 110 v input to transformer
FG-178-A	2.5 v.	2.25 a.	6 sec.	500 v.	0 to -12		U	D	D			D	D	D-		1	High	Use 110 v input to transformer
GL-393-A	2.5 v.	7.0 a.	15 sec.	1250 v.	0 to - 9		U	U				D	D	D		5	High	
GL-502-A	6.3 v.	0.6 a.	10 sec.	650 v.	1 to - 4	0 to -5	D	D				D	D	D		5	Low	Use 110 v input to transformer
GL-884	6.3 v.	0.6 a.	30 sec.	350 v.	0 to -30		D	D				D	D	D		5	Low	Use 110 v input to transformer
GL-885	2.5 v.	1.4 a.	30 sec.	350 v.	0 to -30		D	D				D	U	D	U		Low	Use 110 v input to transformer

TABLE I (continued)

Tube Type & No.	Filament Voltage	Approv.Fil. Current	Heating Time	Max.Plate Voltage	Control Grid Volt.	Shield Grid Volt.	Switch Positions A	B	C	D	E	F	G	H	I	Socket No.	Plate Ammeter	Remarks
GL-2050	6.3 v.	0.6 a	10 sec.	650 v.	0 to - 5	0 to - 5	D	D				D	D	D		5	Low	Use 110 v input to transformer
GL-2051	6.3 v.	0.6 a	10 sec.	350 v.	0 to - 5	0 to - 5	D	D				D	D	D		5	Low	Use 110 v input to transformer
GL-627	2.5 v.	6.0 a.	10 sec.	1250 v.	4 to -16		U	U				D	D	D		2	High	
GL-672	5.0 v.	6.0 a.	5 min.	1500 v.	20 to -25	0 to - 5	U	U			U	D	D	D		2	High	
KU-610	2.5 v.	6.5 a.	10 sec.	500 v.	30 to -15		U	U			D	D	D	D		2	Low	Use 110 v input to transformer
KU-627	2.5 v.	6.0 a.	10 sec.	1250 v.	8 to -16		U	U				D	D	D		2	High	
KU-628	5.0 v.	11.5 a.	40 sec.	1250 v.	0 to -20		U	U				D	D	D		2	High	Do not use Filament Ammeter
KU-629	2.5 v.	2.6 a.	30 sec.	350 v.	0 to - 6		U	D				D	D	U	D	4	Low	Use 110 v input to transformer
WL-632-A	5.0 v.	6.0 a.	5 min.	1500 v.	20 to -20	10 to -20	U	U	U	D		D	D	D		1	High	
KU-636	2.5 v.	7.0 a.	10 sec.	350 v.	0 to - 5		U	U				D	D	D		2	High	Use 110 v input to transformer
WL-672	5.0 v.	6.0 a.	5 min	1500 v.	20 to -20	10 to -20	U	U			U	D	D	D		2	High	
KU-676	5.0 v.	9.5 a.	5 min.	2500 v.	5 to -15		U	U				D	D	D		2	High	
WL-677	5.0 v	9.5 a.	5 min.	3000 v.	0 to -20		U	U				D	D	D		2	High	
KENOTRONS																		
FP-85-A	10.0 v.	5.0 a.					U	U				D	D	D		1	Low	
FP-400	4.0 v.	2.25 a.		125 v.			U	D				D	D	D		1	Low	Use 110 v input to transformer
GL-8020	5.0 v.	6.0 a.		650 v.			U	U				D	D	D		1	High	Use 110 v input to transformer

TABLE I (continued)

Tube Type & No.	Filament Voltage	Approv.Fil. Current	Heating Time	Max.Plate Voltage	Control Grid Volt.	Shield Grid Volt.	Switch Positions A	B	C	D	E	F	G	H	I	Socket No.	Plate Ammeter	Remarks
WL-579-B	2.5 v	6.0 a.		300 v.			U	U				D	D	D		2	Low	Use 110 v. input to transformer
RO-585	3 to 5 v	1.1 a.		500 v.			D	D				D	D	D		2	Low	Use 110 v. input to transformer
PHANOTRONS																		
FG-32	5.0 v.	4.5 a.	5 min.				U	U		D		D	D	D		1	High	
FG-104	5.0 v.	10.0 a.	5 min.				U	U			D	D	D	D		2	High	
GL-866-A 866	2.5 v.	5.0 a.	30 sec.				U	U				D	D	D		1	High	
GL-872-A 872	5.0 v.	7.5 a.	30 sec.				U	U				D	D	D		3	High	
WL-866-A 866	2.5 v.	5.0 a.	30 sec.				U	U				D	D	D		1	High	
WL-872-A 872	5.0 v.	7.5 a	30 sec.				U	U				D	D	D		3	High	
PLIOTRONS																		
PJ-7	4.5 v.	1.1 a		600 v.	10 to -20		D	D	D	U		D	D	D		1	Low	Use 110 v. input to transformer
PJ-8	4.5 v.	1.1 a.		600 v.	10 to -30		D	D	D	U		D	D	D		1	Low	Use 110 v. input to transformer
PJ-21	4.5 v.	1.1 a.		500 v.	30 to -30		D	D	D	U		D	D	D		1	Low	Use 110 v. input to transformer
FP-265	10.0 v.	5.2 a.		1500 v.	0 to -30		U	U				D	D	D		2	High	
FP-285	10.0 v.	3.25 a.		1250 v.	30 to -30		U	U				D	D	D		3	High	
GL-807	6.3 v.	0.9 a.		750 v.	30 to -30	Screen o to 30	D	D				U	D	D	U	4	Low	Use 110 v. input Ip too small to read
WL-203-A	10.0 v.	3.25 a.		1250 v.	30 to -30		U	U				D	D	D		3	High	
WL-211	10.0 v.	3.25 a.		1250 v.	30 to -30		U	U				D	D	D		3	High	

TABLE I (Continued)

Tube Type & No.	Filament Voltage	Approv.Fil. Current	Heating Time	Max.Plate Voltage	Control Grid. Volt.	Shield Grid Volt.	Switch Positions A	B	C	D	E	F	G	H	I	Socket No.	Plate Ammeter	Remarks
WL-460	10.0 v.	3.85 a.		1800 v.	30 to -30		U	U				D	D	D		3	High	
WL-463	11.0 v.	5.00 a.		1800 v.	30 to -30		U	U				D	D	D		3	High	
WL-468	10.0 v.	3.85 a.		1800 v.	30 to -30		U	U				D	D	D		3	High	
WL-787	6.0 v.	1.6 a.		650 v.	30 to -30		U	D			D	D	D	D		2	High	
WL-805	10.0 v.	3.25 a.		1250 v.	30 to -30		U	U				D	D	D		3	High	
WL-806	5.0 v.	9.5 a.		3000 v.	30 to -30		U	U				D	D	D		3	High	
WL-807	6.3 v.	0.9 a.		750 v.	30 to -30		D	D				U	D	D	U	4	Low	Use 110 v input to transformer
WL-809	6.3 v.	2.5 a.		1000 v.	30 to -30		U	D				D	D	D		1	Low	
WL-810	10.0 v.	4.5 a.		2000 v.	30 to -30		U	U				D	D	D		3	High	
WL-811	6.3 v.	4.0 a.		1500 v.	30 to -30		U	U				U	D	D	U	4	Low	
WL-812	6.3 v.	4.0 a.		1500 v.	30 to -30		U	U				D	D	D		1	Low	
WL-814	10.0 v.	3.25 a.		1500 v.	30 to -30		U	U				U	D	D	U	4	Low	
WL-838	10.0 v.	3.25 a.		1250 v.	30 to -30		U	U				D	D	D		3	High	
WL-845	10.0 v.	3.25 a.		1250 v.	30 to -30		U	U				D	D	D		3	Low	

IV. Results Obtainable

The high-vacuum types of industrial tubes (kenotrons and pliotrons) will be considered first in discussing the results which are obtainable with the tube tester.

In testing kenotrons, three different characteristics can be determined. First, the filament characteristic, the relation between the filament voltage and current, may be obtained by taking simultaneous readings of the meters as the filament voltage is varied. The relation between the filament voltage and the plate current, plate voltage being constant, is the emission characteristic. With the above information the filament efficiency can be calculated. This is the ratio of the plate current in milliamperes to the product of the filament voltage and current. The anode characteristic shows the effect of a change in the plate voltage on the plate current, the filament voltage remaining constant. From this data, the static plate resistance, which is the ratio of a particular applied voltage to the resulting current in amperes, can be determined. Usually these various characteristics are shown by graphs. When the emission characteristic is plotted, the limiting effects of the space charge at low plate voltages and filament emission at higher voltages can be seen.

In the case of pliotrons, the grid-plate transfer characteristic and the amplification factor can be obtained in addition to the characteristics mentioned in conjunction with the kenotrons. However, since the plate current can be controlled by means of the grid, the filament voltage is usually kept constant. The transfer characteristic is the relation between the grid voltage and the plate current for some fixed value of plate voltage. The amplification factor, mu, is the ratio of the change in plate voltage to the change in control grid voltage under the conditions that the plate current remains unchanged and the other electrode voltages are kept constant.

The situation in gas-filled tubes differs somewhat from that of vacuum tubes. There is no space charge since it is neutralized by the ionized gas, hence no limiting effect on emission. Also, the purpose of the grid in gas-filled tubes is that of controlling only the starting of the discharge and not the amount of emission.

Since the filament voltage of a phanotron must be kept at a fixed value and cannot be varied as is done in the case of the kenotron, some of the characteristics are eliminated; and little more than filament continuity, emission, and tube drop can be checked. Tube drop is the plate voltmeter reading during conduction.

With thyratrons, the critical values of control grid voltage, the values at which the tube fires for various applied anode voltages, can be read directly on the voltmeter at the instant discharge begins. These values plotted against the corresponding plate voltages give a graph of the control characteristics. Comparison of the effects of the control and shield grids can be made in the case of shield-grid thyratrons, and control characteristic curves can be plotted for various values of shield grid voltage.

A total of sixty-four types of industrial tubes manufactured by General Electric and Westinghouse can be checked with this tube tester. There is no doubt that similar tubes manufactured by other concerns can also be tested provided they come within the limitations of this device.

The following graphs show some of the characteristics described above and were plotted from data obtained with this tube tester.

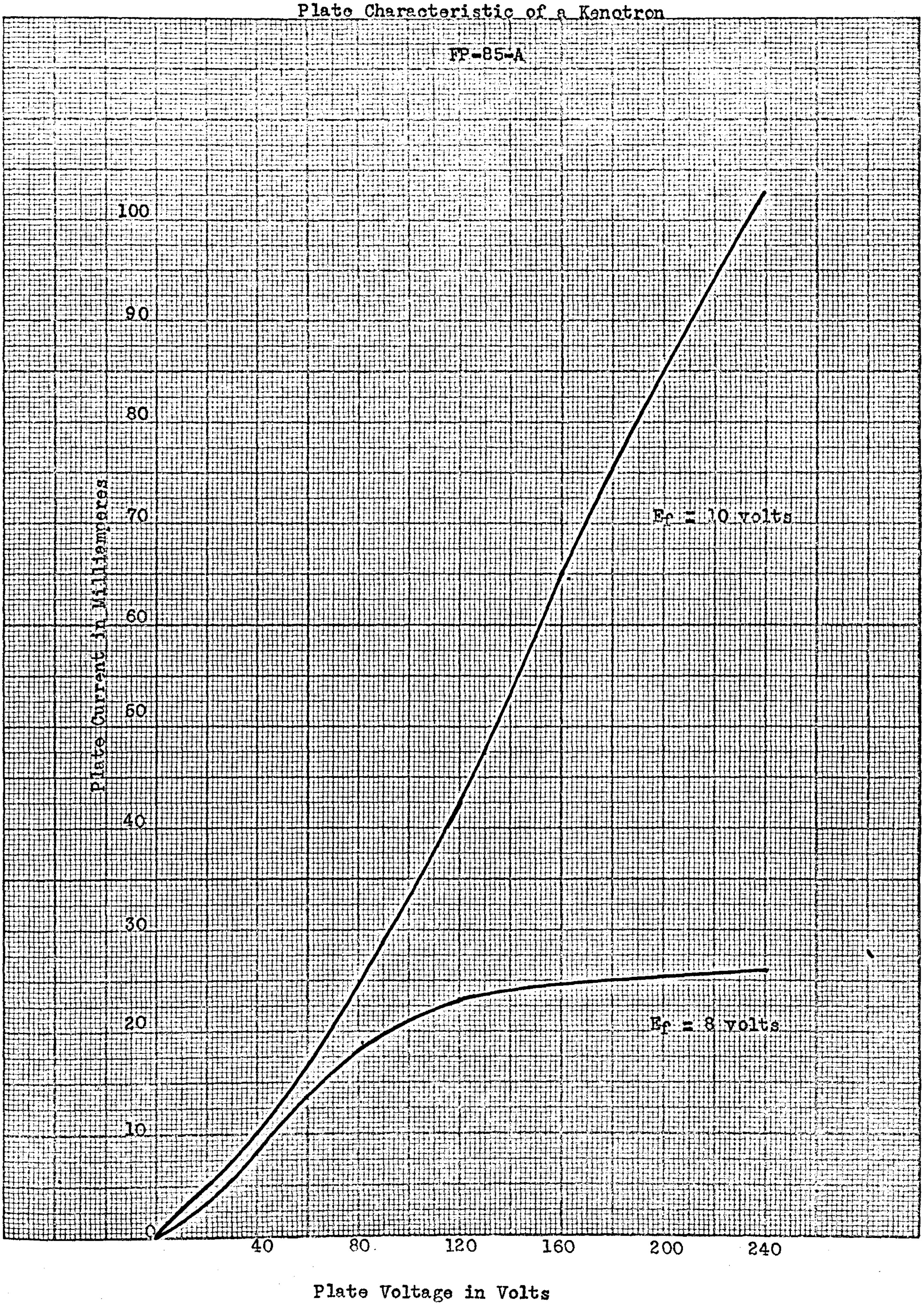
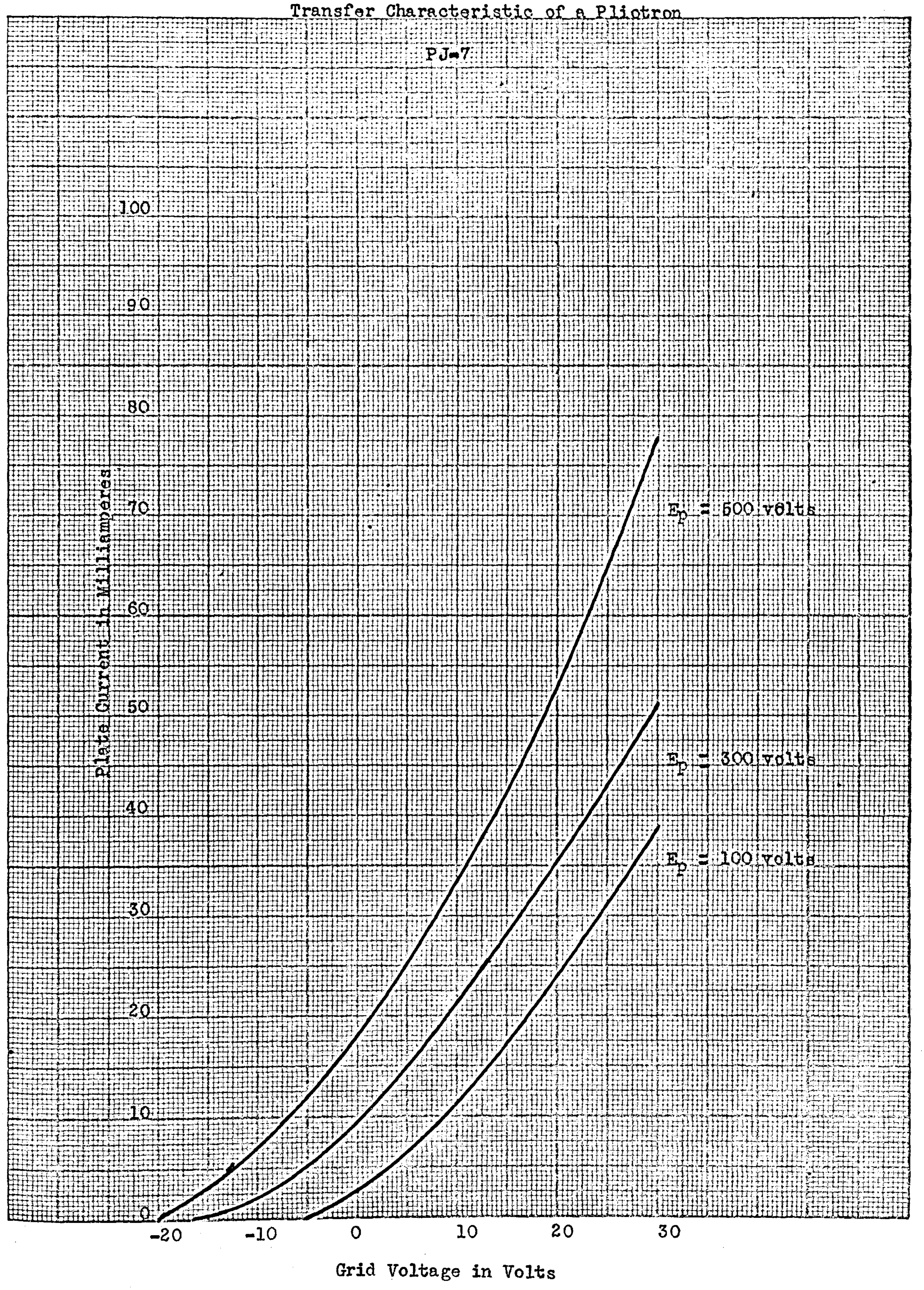
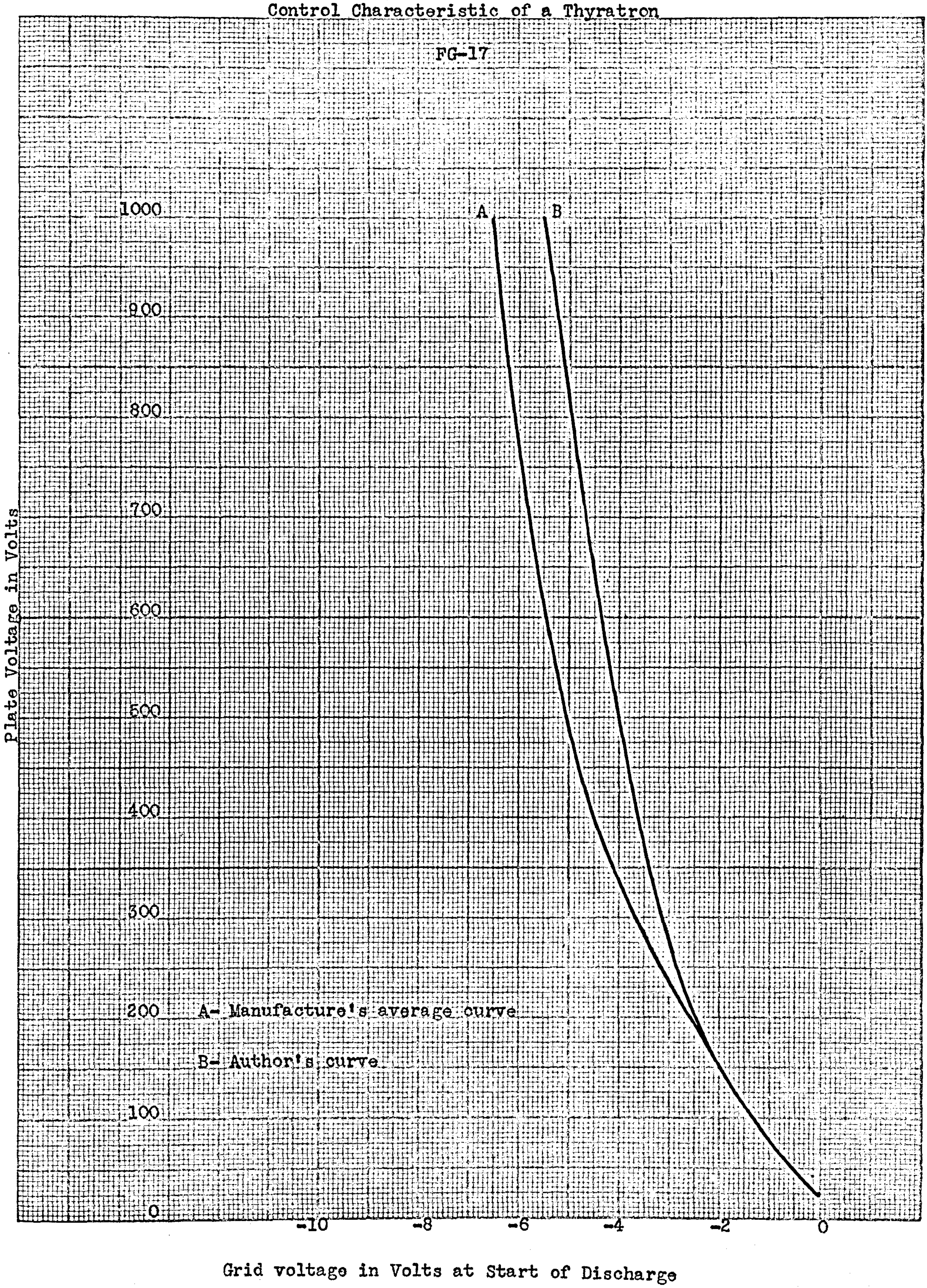


Plate Characteristic of a Kenotron
FP-85-A
Plate Current in Milliamperes
100
90
80
70
60
50
40
30
20
10
0
Ef = 10 volts
Ef = 8 volts
40
80
120
160
200
240
Plate Voltage in Volts


Transfer Characteristic of a Pliotron
PJ-7
Plate Current in Milliamperes
100
90
80
70
60
50
40
30
20
10
0
E_p = 500 volts
E_p = 300 volts
E_p = 100 volts
-20
-10
0
10
20
30
Grid Voltage in Volts


Control Characteristic of a Thyratron
FG-17
A
B
1000
900
800
700
600
500
400
300
200
100
0
Plate Voltage in Volts
A- Manufacture's average curve
B- Author's curve
-10
-8
-6
-4
-2
0
Grid voltage in Volts at Start of Discharge

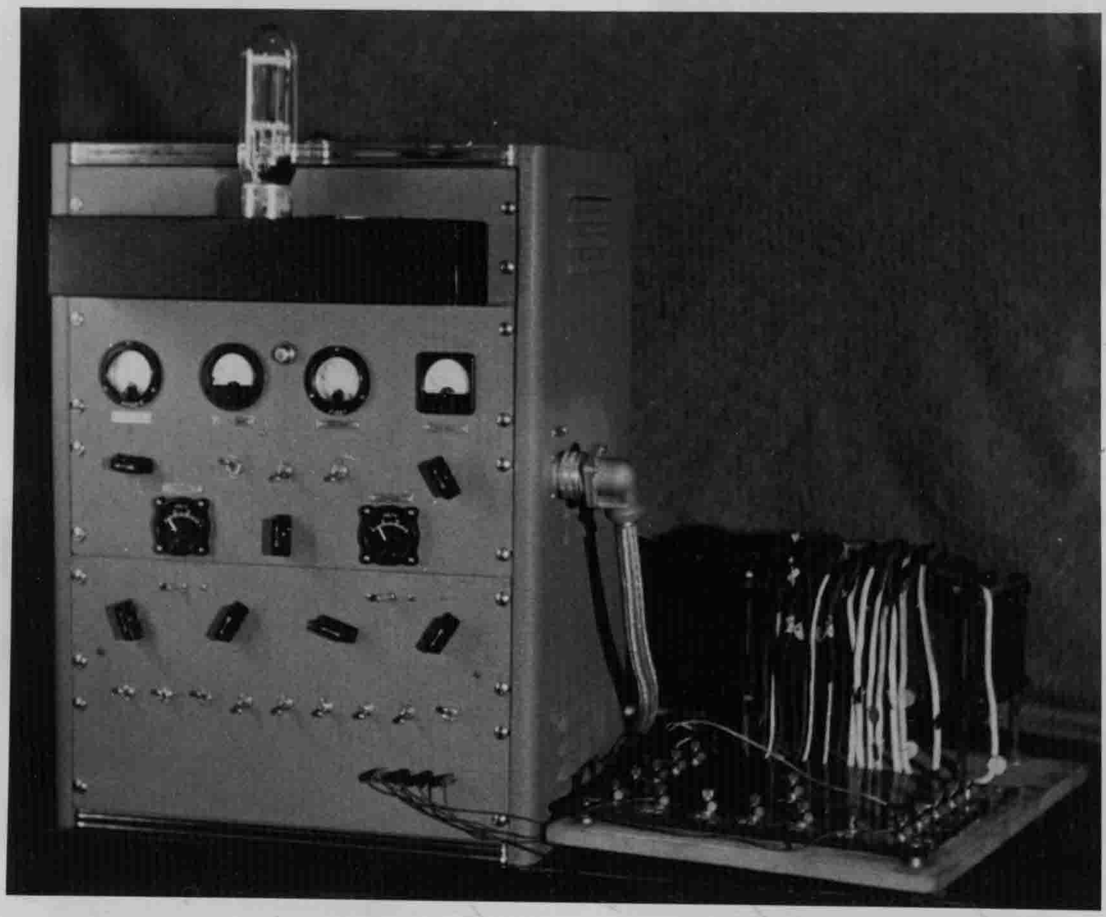


Fig. 4. The Apparatus and Transformer
Showing a Tube under Test

V. Acknowledgment

The author wishes to express his sincere thanks to the members of the Physics Department for their interest and aid, especially to Dr. C. L. Albright for suggesting this problem and for his helpful advice and suggestions during the course of the investigation.