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PRODUCTION TESTING OF VACUUM TUBES

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IN THE manufacture of radio tubes, one of the most important operations is the final electrical test to reject all inoperative tubes and those outside of a range which are not satisfactory for set operation. Four or five years ago, when the production of vacuum tubes was just commencing on a large scale, the general procedure of testing was to check each tube individually for the following characteristics:

1. Filament current.
2. Emission.
3. Plate current.
4. Gas current.
5. Electrical leakage.
6. Amplification constant.
7. Plate resistance.
8. Mutual conductance.

As the productions increased, the task became so great that means had to be devised for simplifying this operation. It was found that the tubes could be held within the desired characteristics by checking a few of the essential characteristics of the tube. The limits for these essential tests were determined by target diagrams. The essential characteristics which are now checked on all tubes are:

1. Emission.
2. Plate current.
3. Gas current.
4. Electrical leakage.

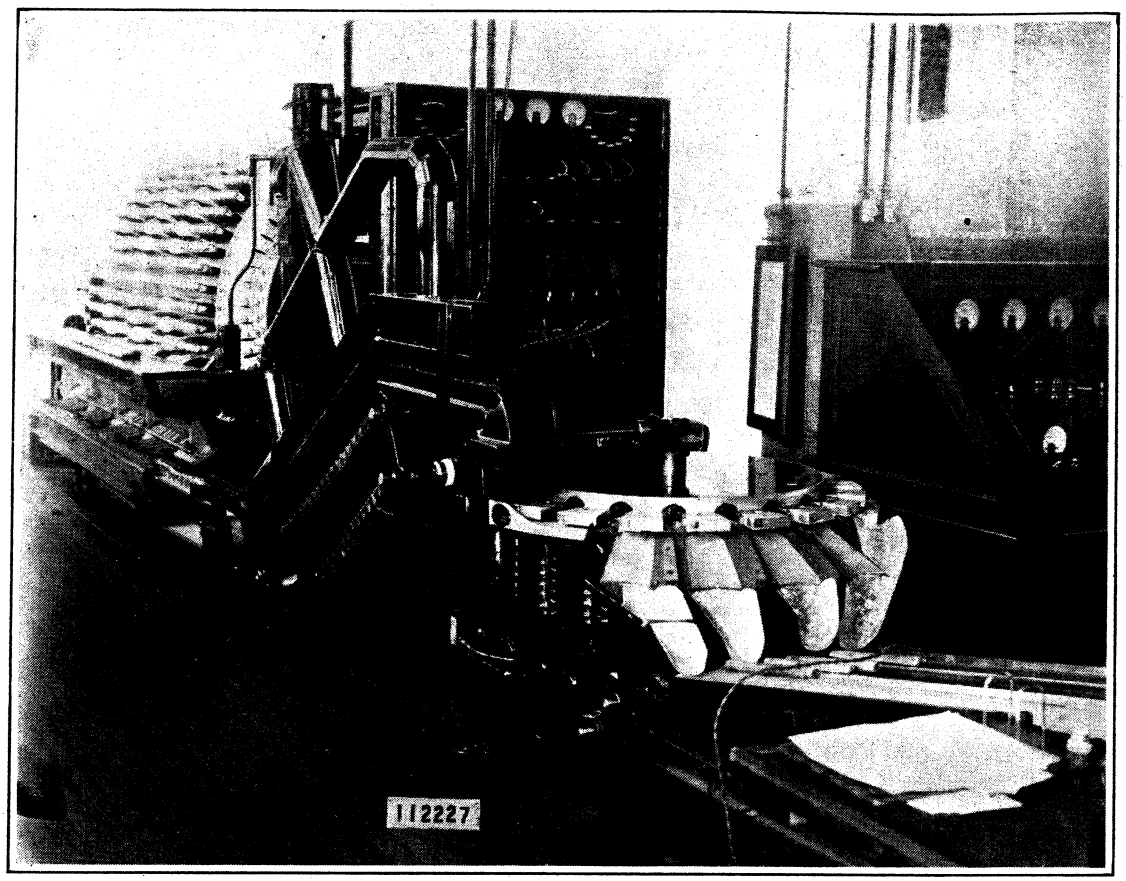
The filament current is not ordinarily tested because of the fact that it can be held within very narrow limits by checking the wire before it is used in tubes. Likewise, the amplification constant, plate resistance and mutual conductance are not ordinarily read, because the dimensions of the grids and plates are checked before assembly and a very close check is kept on the centering of the elements. Hence by a proper setting of the emission, plate current and gas limits, the tubes can be maintained within the desired limits for the other characteristics.

The method of testing for these essential characteristics has been to have numerous girls with separate test sets checking every tube and discarding all those outside of limits. As the production gradually increased, the number of test sets necessary became very large. The time required to keep all these sets operating alike, the calibration of meters and the replacing of batteries was a considerable task. It can be realized that even when extreme care is taken to see that everything is all right, there is a possibility of some time elapsing before a meter off calibration, a wrong battery setting, or a circuit which does not always have perfect contact, is discovered. Likewise, the test girls are liable to make slips occasionally, due to carelessness or fatigue.

Because of these facts, work was started on a machine which would automatically test the tubes and sort them into the following classifications necessary for efficient factory operation:

1. Broken filaments and all types of short circuits.
2. Gassy and low emission tubes as well as any tubes having electrical leakage between the various elements.
3. Tubes outside the specified range for plate current.
4. Good tubes.

By a classification of defects as described above, it is possible for the factory engineers to get back at the source of trouble causing these rejects and make the necessary corrections. At the same time, the good tubes are picked out of the defective tubes and sent to the packers. This machine consists of an electrical control board, connected by means of a cable to the mechanical apparatus which connects the tubes in succession to the various test circuits. Connected with the mechanical apparatus is the automatic loading device and moving belts which convey the defects and good tubes away



This is a general view of the testing unit and electrical control board

from the machine. The loading is accomplished by having a belt divided into sections and timed to move at the same speed as the machine. The bulbs are placed in individual sections on the machine by the divided belt. It is necessary, however, to provide some means to locate the pins and insert them in the socket at each individual section. This is accomplished by rotating the tube by means of a rubber pad until the pin in the base hits a stop. The large and small pins of the tube are now lined up with the socket and the tube is pushed in by means of a metal slide set at an angle and equipped with springs.

THE AUTOMATIC TESTER

THE fundamental idea in connection with this tester is that tubes are placed automatically in a socket and by means of a rotating disk, equipped with contact rings and brushes, are successively connected with specially designed electrical circuits to test for the desired characteristics. The circuits are also designed to be set normally to throw out a tube, and a good tube releases the relays deënergizing the ejector circuit. The arrangements of the contacts are such that the test circuits are first connected up allowing the meters and relays to come to a fixed position before the ejector circuit is connected in. This serves a double purpose. It makes for greater speed in testing because of the fact that the ejector circuit is not connected in while the meters and relays are becoming stabilized. It also permits the system to be operated with all the circuits set at "danger," as in a railway block signal system.

The ejecting mechanism consists of three solenoids located opposite the various chutes into which the defects are sorted. The tube is ejected by the solenoid moving forward and a cam engages an incline track located on the solenoid, pushing the tube out of the socket. The good tubes must clear the three defect positions and are then pushed out mechanically by means of a fixed incline track operating a cam connected to the tube socket.

The first circuit is designed to eject the following defects:

1.		Open filaments.
2.	(minus)	Filament to plate shorts.
3.	(plus)	Filament to plate shorts.
4.	(minus)	Filament to grid shorts.
5.	(plus)	Filament to grid shorts.
6.		Plate to grid shorts.

The essential features of this circuit are: two telephone relays, a protective resistance, and a power control relay which operates the solenoid. When a good tube is in the socket, current flows through these telephone relays and breaks a contact which opens the circuit to the power control relays, thereby allowing the tube to pass this position. If the tube is open circuited or short-circuited, no current flows through these relays, and the contact on these relays remains closed, thereby energizing the power control relays which closes a circuit energizing the solenoid which ejects the tube. The protective resistance is simply to prevent the storage battery from being short circuited when a minus filament to grid short circuit occurs.

The second circuit removes the following defects:

1. Gassy tubes.
2. (minus) Filament to plate leakers.
3. (plus) Filament to plate leakers.
4. Grid to plate leakers.
5. Low emission.

as well as removing

1. (minus) Open filaments.
2. (minus) Filament to plate shorts.
3. (plus) Filament to plate shorts.
4. (minus) Filament to grid shorts.
5. (plus) Filament to grid shorts.
6. (minus) Grid to plate shorts.

as a further check on circuit number one.

The essential parts of this circuit are: a sensitive relay, a milliammeter, a protective relay, and the necessary batteries in the grid circuit. In the plate circuit there is a 500,000-ohm resistance, a microammeter and the necessary batteries. The filament circuit simply consists of the necessary batteries, rheostat, and voltmeter. In connection with the plate circuit there is a one-stage vacuum-tube amplifier, in the plate circuit of which there is a sensitive relay and milliammeter. The two sensitive relays referred to are connected to a power relay which operates a switch connected to the solenoid.

OPERATION OF TESTER

THE general operation of this circuit is as follows: if the tube to be tested has the required emission, the relay in the grid circuit operates so that the contact arm moves off the bottom contact and does not touch the upper contact. If the emission is below the required value, the arm of the relay does not move off the lower contact. In any one of these cases, if contact is made by this relay, the power control relay is energized, operating the ejector. The protective relay is provided to prevent an excess of current due to a short circuit from damaging the sensitive relay or milliammeter. If the current goes above the value which would cause harm to any one of these instruments, this relay opens and puts a resistance in the circuit which limits the current to the sensitive relay and milliammeter. The gas in the tube is tested in the plate circuit. If there is no ionization present, there will be no current flowing in the plate circuit, and hence the plate current of the amplifier tube will be at its normal value and the relay will be balanced between upper and lower contacts. However, if there is a current of two microamperes or over flowing in the plate circuit, the grid bias of the amplifier tube will be changed by one volt. This causes a change in the plate current of this tube and causes the contact arm to engage the upper contact, closing the power relay, thereby energizing the solenoid.

The reason the sensitive relay in this circuit is balanced between an upper and lower range is that in case the filament of the amplifying tube should burn out, or the grid or plate voltage fail, the contact arm would automatically engage either the upper or lower contact and throw out all the tubes in this particular position. Hence it will be seen that if a tube has the required emission and the gas current is not above the desired limit and has no leakage between the filament to plate, or grid to plate, the tube is allowed to pass by this position. Electrical leakage is determined and taken care of in a similar manner to the gas current.

When the automatic tester was first started the preceding method of testing for gas and leakage was not used. Instead a microammeter was fitted with a shutter and when it moved over a certain amount, light was admitted to a selenium cell which in turn worked a sensitive relay. As a strong light was used it was easy to get a charge of several milliamperes in the cell circuit which worked the sensitive relay. However, it would have been impractical to try to operate a relay between a range of a tenth of a microampere which would have been necessary if this or the preceding method were not used. The cell method was not satisfactory when testing at high speeds because the sensitive microammeter was not sufficiently damped. The present method using a high resistance in the plate circuit, in conjunction with a tube amplifier, permits rapid and certain operation and can be set to throw out tubes within a tenth of a microampere of any desired value.

The third circuit operates to eject the following defects:

1. Low plate current tubes.
2. High plate current tubes.

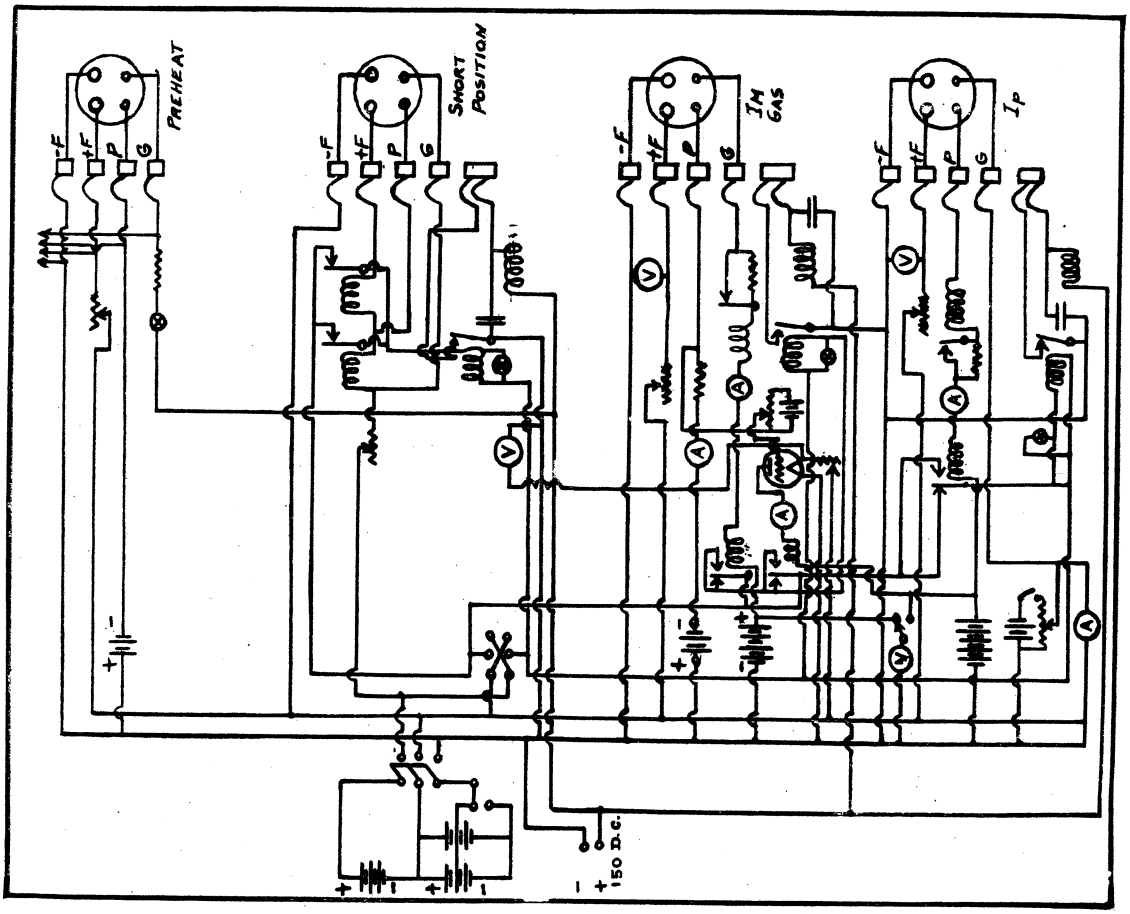
as well as

1. Open filaments.
2. (minus) Filament to plate shorts.
3. (plus) Filament to plate shorts.

The essential parts of this circuit are a sensitive relay, a milliammeter, a protective relay, the necessary batteries in the plate circuit, and the necessary batteries in the grid circuit together with the power control relay. If the tube has the proper plate current, the sensitive relay in the plate circuits operates so as not to make contact. If, however, the plate current is low, or high, contact will be made in this relay operating the power control relay which operates the solenoid and ejects the tube. It is evident that an open filament will have no plate current and also that filament plate shorts will operate the sensitive relay.

MISCELLANEOUS POINTS

ONE of the problems that came up in conjunction with this machine was to develop a socket which would stand several thousand insertions an hour and



Circuit diagram of connections employed in the tester

last under steady use. The standard commercial sockets were tried and would not last a day and continue to give good contact. After numerous trials a socket having the four contacts set in slides, and the tension to these contacts supplied by an annular rubber ring, was developed which would supply positive contact and last several months without replacement.

Signal lights are provided on this machine to indicate the operation of the various circuits. These lights are simply connected across the line to the power control relay.

The sensitive relays referred to are essentially meters, but instead of having a pointer, they have a contact arm which makes contact between an upper and lower range and may be adjusted to suit the desired conditions. A spring is provided to hold the movable arm to the lower contact. Hence, the contact is normally closed and must be opened to allow the tube to pass. These relays are special high-torque relays which have been developed for this particular purpose and can be set to work within one-twentieth of a milliampere.

As all the circuits are so designed that a failure in the test apparatus throws all the tubes out at one defect position, it is impossible for a defective tube to be packed.

This machine will operate satisfactorily at speeds up to 8000 an hour. With this machine no operators are required either to load or unload, and by the old manual testing method, the maximum limit per operator is around 225 per hour.

The same general procedure as outlined can be adapted to various uses such as testing resistances, transformers, condenser units or almost any electrical apparatus. It is evident however that before a machine of this type can be used to any economic advantage the number of units to be tested must run into considerable figures. In many cases this can be overlooked due to the more uniform product which the manufacturer is enabled to turn out.

THE RADIO CLUB OF AMERICA

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1. Manuscripts should be submitted typewritten, double-spaced, to the Chairman of the Papers Committee.* In case of acceptance the final draft of the article should be in the hands of the Chairman on or before the date of delivery of the paper before the Club.

2. Illustrations should invariably be in black ink on white paper or tracing cloth. Blueprints are inacceptable.

3. A brief summary of the paper, embodying the major conclusions, is desirable.

*For 1929 the Chairman of the Papers Committee is Mr. L. G. Pacent, 91 Seventh Avenue, New York City.

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