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SERIES MERCURY ARC RECTIFIER

This book covers the installation, operation and general care of the series mercury arc rectifiers manufactured by the General Electric Company and no manipulation of the apparatus, whatever, should be attempted until it has been thoroughly read.

GENERAL

The complete equipment includes the following parts:

- Constant current transformer
- Direct current reactance
- Rectifier tube
- Rectifier tube tank
- Static protector
- Exciting transformer
- Static discharger
- Switchboard panel

Segregated outfits have all the principal parts above mentioned separate from each other and installed where convenient.

Combined outfits have all parts except the switchboard panel assembled and connected together.

The constant current transformer when supplied with alternating current at constant potential and frequency (either within 5 per cent of rated value) delivers alternating potential and the rectifier tube permits only uni-directional current to flow. The current strength is such that the ampere value of the rectified current is within 5 per cent of the rated current for loads from full to one-third full load. (See below for operation with partial load taps.)

The constant current transformer insulates the secondary or load circuit and all auxiliary parts from the primary or supply circuit.

The transformer, which is shell type, has a stationary secondary and a movable primary, both encircling the center leg of the core. The moving coil is partially counterbalanced by an adjustable weight.

Standard primary coils have a tap for improving the power-factor and efficiency if the outfit is to be operated at 80 per cent rated load or less. Load current will be maintained constant within 5 per cent of rated amperes from 80 per cent rated load to one-fifth rated load when this partial load tap is used. Partial load taps cannot be furnished on series-multiple or "Scott connected" primary windings.

A blueprint sketch attached to the core or casing gives instructions for changing the connections of the primary or other windings.

Combined outfits have a small coil at the upper end of the center leg of the core. This exciting coil attached to a fuse cutout, supplies
Fig. 1. SERIES MERCURY ARC RECTIFIER (COMBINED UNIT)
(See page 3)
LIST OF PARTS (See Fig. 1)

1 Pilot or indicating lamp
2 Socket for No. 1
3 Static discharger
4 Static discharger resistance base
5 Static discharger resistance rod
6 Static discharger horn gap
7 Static discharger spark gap
8 Outgoing terminal
9 Exciting coil
10 Cutout for No. 9
11 Buffers
12 Porcelain bushings
13 Cable support
14 Top clamp
15 Top clamp set screw
16 Core
17 Core clamp
18 Supporting cable
19 Flexible connection cable
20 Guide rod
21 Guide rod support
22 Upper side rod
23 Lower side rod
24 Bottom clamp
25 Cable couplings
26 D-c. reactance core
27 D-c. reactance core clamp
28 D-c. reactance coil
29 Exciting transformer
30 Exciting transformer reactance coil
31 Exciting transformer secondary coil
32 Exciting transformer primary coil
33 Base
34 Underload series relay operating coils
35 Underload series relay contact for alarm circuit
36 Underload series relay contact for shaking circuit
37 Underload series relay terminal
38 Motor-operated contact
39 Motor-operated contact terminals
40 Balancing lever
41 Adjusting sector
42 Adjusting screw
43 Check nut
44 Shaft
45 Mechanical latch
46 Dashpot
47 Dashpot rod
48 Dashpot rod head
49 Dashpot lever
50 Dashpot support
51 Dashpot by-pass
52 Hanger or regulating weight.
53 Primary coil
54 Primary coil clamp
55 Secondary coil
56 Secondary coil clamps and supports
57 Shaking magnet
58 Shaking magnet support
59 Calibrating weight
60 Oil circulator
61 Tube tank
62 Tube tank cover
63 Tube tank lid
64 Tube tank latch
65 Valve for controlling flow of water
66 Thermometer wells for observing temperature of water
67 Thermometer indicating top oil temperature
68 Removable base end
Fig. 2. CONNECTIONS OF SINGLE-TUBE OUTFIT

Fig. 3. CONNECTIONS OF TWO-TUBE OUTFIT
alternating current at 110 volts to the exciting transformer and other auxiliary devices.

Fig. 2 and Fig. 3 indicate the general arrangement of wiring of the various parts comprising the outfit.

The direct current reactance is a device which reduces the pulsations in the rectified current and consists of a core or cores with winding or windings thereon.

![Diagram of Rectifier Tube]

The rectifier tube is the device which accomplishes the rectification from alternating to direct current and consists of an exhausted glass vessel containing one anode or positive terminal in each of the two upper arms, two mercury starting anodes and a cathode or negative terminal of mercury at the bottom.

The operation of the tube may be described as follows:

The main anodes are connected to the terminals of the transformer secondary winding. The direct current reactance and the load are connected in series between the cathode terminal of the tube and
the transformer secondary winding. The rectifier tube with its mercury arc acts as a valve to permit current to flow (with about 25 volts drop) in one direction only, viz.: from anode to cathode.

The mercury vapor, to become an electrical conductor, must be ionized. This is accomplished by the arc when running, and as follows when starting:

Tilt the tube until the mercury bridges the space between the cathode and the starting anode; current flows from the exciting transformer through this bridge. Return the tube to an upright position, thus breaking the mercury bridge and causing an arc which ionizes the mercury vapor.

As soon as the initial ionization is accomplished, the potential from the portion of the transformer secondary winding included in the circuit will cause current to flow through an arc from the anode which at that time is positive to the cathode.

The current flowing through the arc leaves the tube by the cathode. The bright spot which plays on the surface of the mercury at the cathode is commonly called the cathode spot.

Current will flow from this anode only so long as it is positive to the cathode, i.e., during that half cycle of the alternating current supply. During the next half cycle, the arc will carry current from the other anode to the cathode. In succeeding half cycles, current flows from the anodes alternately and the current through the cathode is uni-directional.

The arc from anode to cathode readily transfers from anode to anode so as always to flow from that one which is positive. One of the anodes is always positive to the cathode except during the time when there is no potential difference between anodes. During this time, the arc is maintained by the energy which has been stored in the direct current reactance.

The exciting of the tube is accomplished by a small specially designed transformer whose action is similar to that of the main transformer. (Fig. 5.)

An indicating lamp is supplied for each tube operating in oil and is so connected as to glow brightly during normal operation.

A standard street series socket and receptacle is used with each lamp. Combined outfits have shunts in parallel with the lamps, segregated outfits may or may not have these shunts. Pilot lamp Cat. No. 132212 (spherical bulb) must always have a shunt.

As the carbon filament lamps formerly supplied with the segregated outfits fail, it will be necessary to replace them with 9.6-ampere 40-watt (or lower) MAZDA lamps or new pilot lamp and shunt, since the manufacture of the old carbon filament lamp has been discontinued.
The lamp must have a film cutout inserted between short circuiting clips on the socket except when a shunt is used, in which case a piece of insulating matter may be used.

The exciting transformer supplies current for the exciting arc in the tube, to start the main arc and should be left in circuit during the operation of the outfit to aid in maintaining operation under unfavorable conditions.

![Diagram](image)

**Fig. 5. CONNECTIONS OF THREE COIL (TYPE Y-148) EXCITING TRANSFORMER**

The exciting transformer consists of core, primary and secondary coils and reactance core and coil. Between primary and secondary is a magnetic shunt whose adjustment limits the current in the starting arc.

The tube tank affords a place for supporting the rectifier tube, means for insulating and protecting it and also for controlling its operating temperature.

The tube tank consists of an iron tank with lid and cover, cooling coil with pipe connections, thermometer wells and regulating needle valve, wooden lining with supports for carrier and tube holder, shaking mechanism for tilting the tube in starting, and leads and contacts for electrical connections to tubes. A thermometer is attached to the cover of the tank in a position to indicate the temperature of the oil in the upper part of the tank.
The construction of the tube carrier and holder may be readily understood from Fig. 6. The holder is pivoted and has a pin to engage with a fork in the tube shaking mechanism.

Auxiliary devices used with tanks include shaking magnets, oil circulators and oil heaters. The first permits starting to be controlled by a pull button switch or by automatic devices from a distance, the second assists in maintaining suitable operating temperature by establishing vigorous circulation of oil, and the third is used together with the second for bringing up oil temperature preparatory to starting when it is below 16 deg. C. at the bottom of the tank and they have a special snap switch which enables both to be operated together or the circulator alone.

Static dischargers are provided to protect the tube and other parts of the apparatus from excessive electrical stresses which may be set up under certain conditions and which occur occasionally at starting when the tube is cold. The effect is more marked with old tubes.
The static dischargers consist of horn gaps in series with resistance, the horns operating to open the circuit after discharge. The resistance is shunted by a spark gap across which the discharge can pass in case the resistance is damaged.

**Switchboard panels** are equipped with the following parts: primary switches and fuses, secondary or load switches, ammeter with protecting cover in rectified circuit and pull button switch for controlling circuit of tube shaking magnet.

**Horn type lightning arresters** with series resistance should be used as they are especially adapted not only for protection from

![Fig. 7. HORN TYPE LIGHTNING ARRESTER](image)

lightning but also to dissipate surges which may be set up by the grounding of the line.

The resistance in series with the horns prevents short circuiting during the period of discharge and enables the horns effectively to open the circuit. The arrester should be located in the station on the line side of the arc circuit outgoing switches so as to protect all the apparatus in the rectifier circuit from disturbances occurring on the line.

**Automatic Shaking Devices**

To make the outfit self-starting when the supply line is closed, after an interruption of the primary supply, or to shake the tube when the cathode spot is in the starting anode, the operation of the shaking magnet is controlled by a commutator whose operation is in turn
controlled by a series relay in the load circuit. This series relay, called the “underload series relay” or “operation indicator” has its operating coil connected directly in series with the indicating lamp and is so constructed as to close a circuit if the load current drops below one-half normal. The closing of this circuit energizes the motor-operated contact and completes the circuit to the shaking magnet of the corresponding tube tank. The motor-operated contact consists of a contact of commutator type driven through a worm and wheel by a small motor.

An additional contact on the underload series relay permits control of an auxiliary alarm circuit when desired.

**CAPACITIES AND STYLES OF OUTFITS**

Rectifier outfits are built in all sizes from 6-light (at 6.6 amp.) and 12-light (at 4 amp.) to 100 lights, for frequencies from 25 to 133 cycles, for primary voltages up to 13,200 volts, and for load currents of 4, 5 and 6.6 amperes.

Standard capacities are 25-, 50- and 75-light; standard frequencies are 25 and 60 cycles; standard primary voltage is 2200 and standard load currents are 4 and 6.6 amperes.

The 100-light size (segregated) is often built up of two 50-light outfits side by side with common base and casing, the parts being symmetrically arranged.

The capacity of the outfits is indicated by the rating of the rectified voltage, which is based on 90 volts per lamp, e.g., 4500 volts is the rating of a 50-light outfit, 6750 volts is the rating of a 75-light outfit.
UNPACKING—INSTALLATION—CONNECTIONS

For convenience in shipping, the rectifier outfit is packed in several cases. In unpacking, care should be taken that no parts are overlooked.

Install the outfit on a suitable foundation in a dry, ventilated place so situated that air can circulate freely about it. There should be enough head room so that there will be at least 12 inches free air space over the horns of the static dischargers.

When lifting the outfit, always apply stress in line with the arrows (see Fig. 8), never at an angle to these lines. As a further precaution against bending the side rods, always have the spreader in place between them.

When installing outfits, place the lower part on the foundation, assemble the upper part on the lower and level carefully. Two levels are permanently attached to the top of the transformer to indicate when the outfit is properly placed. Make the electrical connections between the parts by the brass union couplings attached to the leads. Always use two wrenches when tightening the couplings.

![Fig. 9. BRASS UNION COUPLING WITH COPPER DISK AND INSULATING COVER](image)

Make sure that the copper disk is in place between the halves of the coupling. Corresponding halves bear similar marking.

Brass tags are also attached to leads and other parts during shipment. These may or may not bear the same marking as the couplings, but in every case the same marking appears on both of the parts between which connection is to be made. The tags should be removed after connections are made.

Reference to Fig. 2 and Fig. 3 may be made. When connections have been made in accordance with the marking of the various parts, it will be found that they are in general accord with the figures.

**BEFORE MOUNTING THE STATIC DISCHARGER ON THE TOP OF THE TRANSFORMER, REMOVE THE EYEBOLTS AND SPREADER AND REPLACE THE LONG HEXAGONAL NUTS UNDER THE SPREADER BY THE SHORTER NUTS FURNISHED WITH THE SHIPMENT.**

A few outfits are equipped with lifting hooks on the side rods and have no eyebolts nor spreaders.
Make sure that the resistance rods have not been damaged in shipment. Turn the horns of the horn gaps upward and set both horn gaps and spark gaps to the values shown in the table following. Tighten the set screws to insure permanency of setting.

**RESISTANCE AND SETTING OF GAPS FOR STATIC DISCHARGERS**

<table>
<thead>
<tr>
<th>Lights Capacity</th>
<th>No. of Tubes</th>
<th>Resistance</th>
<th>Setting in Inches</th>
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<tr>
<td></td>
<td></td>
<td>No.</td>
<td>Cat. No.</td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>2</td>
<td>60028</td>
</tr>
<tr>
<td>25</td>
<td>1</td>
<td>2</td>
<td>46620</td>
</tr>
<tr>
<td>50</td>
<td>1</td>
<td>4</td>
<td>46620</td>
</tr>
<tr>
<td>50</td>
<td>2</td>
<td>4</td>
<td>46620</td>
</tr>
<tr>
<td>75</td>
<td>2</td>
<td>8</td>
<td>60928</td>
</tr>
<tr>
<td>100</td>
<td>2</td>
<td>8</td>
<td>46620</td>
</tr>
</tbody>
</table>

Place the pilot lamps in their sockets at the top of the static discharger.

If the outfit is equipped for automatic shaking, attach the underload series relay to the static discharger support and make the necessary electrical connections.

Carefully remove all packing from the transformer, fill the dashpot with a mixture of half transil oil and half cylinder oil (included in the shipment) place the hanger weight in position and adjust the by-pass valve or the spring in the piston valve so that the moving coil will fall over its whole range in from two to three seconds. Final adjustment should not be made until the proper amount of regulating weight has been put in place. The proper amount of weight must be found by trial with the outfit operating its regular load.

Move the coil up and down several times to make sure that movement is not hindered by friction between the coil and core and place the casing around the outfit.

Remove the packing and any dirt from the tube tank. Examine the shaking mechanism to make sure that it works freely and see that the contacts at the bottom of the tank closely engage those on the tube carrier. Look to the adjustment of the shaking magnet and be sure that all set screws or nuts are tightened and that the ends of the cotter pins are properly spread apart. The magnet should be so set that the plunger may travel about 1/8 inch before picking up the shaking mechanism and that the limit of travel in the tank is reached when the plunger of the magnet reaches the upper limit of its travel. The spring in the tank should bring the shaking mechanism smartly back to the starting position when the magnet is not energized.
Put the thermometer in place and fill the tank with transil oil strained through several thicknesses of cheese cloth. Oil the bearings of the oil circulating motor and motor of the motor operated contact at the start and oil from time to time thereafter so that they will run freely and not overheat.

Connect the water supply pipes to the cooling coil. The water should enter by the end connected to the turn of the coil lowest in the tank.

Set up the switchboard panel and wire in accordance with the diagrams furnished with it.

![Diagram]

**Fig. 10. RECTIFIER TUBE CONNECTIONS**

The transformer, panel supports, ammeter protecting case and any parts with which the operator may come in contact should be thoroughly grounded.

Instructions for handling tubes are given on page 19 and following.

Connections are shown in Fig. 2 and Fig. 3.

**OPERATION AND ADJUSTMENTS**

When the tubes are properly attached to the carriers and inserted in the tank, the following routine should be adopted for daily operation.

**Starting**

1. Make sure that the coils of the transformer are latched apart and the load short circuiting plug is in, then insert the primary plug switches or close the primary oil switch and shake the tubes until the outfit starts and the coils unlatch.
2. Run the outfit with the load short-circuited ten minutes to warm the tubes thoroughly.
3. Make sure that the load plugs are in place and start the load by quickly withdrawing the short circuiting plug.
   If an arc persists in the tube of the short circuiting switch, open the primary switch, latch the coils apart and again start but with the short circuiting switch open.
4. Regulate the temperature of the oil by adjusting the flow of water through the cooling coil.
   If necessary to replace the tubes during a run, open the primary switch, latch the coils apart, change the tubes and start as usual.

**Shutting Down**
1. Open the primary and load switches.
2. Shut off the water.
3. Latch the coils apart.

**Adjustment**

The secondary current may be varied by changing the amount of regulating weight; an increase of weight causes a decrease of current and vice versa.

At the factory, the outfit is adjusted to deliver constant current within the limits above specified. The adjustment is made by turning the adjusting screws on the balancing levers. If the screw is turned to throw the upper end of the adjusting sector outward and the lower end inward, the load current at light load will be less than at heavy load. If the screw be turned in the opposite direction, the current at light load will be less than at heavy load. **THIS ADJUSTMENT SHOULD NOT ORDINARILY BE CHANGED.**

As in all installations of electrical apparatus all parts should be kept clean. It is very important that the coils shall be kept clean, as an excessive accumulation of dirt will impair the ventilation.

**Faults in Operation**

If the indicating lamp fails to glow, one or more of the following conditions exist:
(a) The cathode spot has jumped over into the starting anode and current is leaving the tube through the starting anode and exciting transformer winding.
(b) The load circuit is open, the tube has dropped its load or the primary supply has failed.
(c) The indicating lamp has failed.

The first, which may be cured by shaking the tube (unless some connections are loose), may be due to any of the following causes or conditions:
Fig. 11. SHIPPING CRATES FOR 2, 4 AND 6 MERCURY ARC RECTIFIER SERIES TUBE
1. It may form there when starting.
2. A faulty tube.
3. Too high or low oil temperature.
4. Momentary drops in primary voltage, on a loaded set.

If the current is below normal and the coils are not together, the regulating weight is too heavy. If the coils are together with this condition, the outfit is too heavily loaded, the primary voltage is too low or the primary frequency is too high. It should be noted, however, that after the regulating weight has been once adjusted, a deteriorated tube will give similar results.

If the current is above normal and the coils are not separated by more than the distance required to operate one-third load under normal conditions, the regulating weight is too light. If the coils be

---

**Fig. 12. TUBE CLOSET**

Not drawn to scale. All are inside dimensions, except view showing door

- **R**, roof to keep oil from dripping on lower shelves
- **S**, shelf for papers
- **T**, tube
- **L.S.**, lower shelves
- **B**, tube supporting bracket
- **D.P.**, drip pan
- **T.C.**, tube carrier in drip-pan
- **F.P.**, floor pan to catch oil drippings
- **S.S.**, supporting strips, 1 in. by 1/2 in. iron
separated by more than this distance with this condition, the outfit is too lightly loaded, the primary voltage is too high or the primary frequency is too low.

If the outfit is too heavily loaded when operating on the partial load tap, or too lightly loaded when operating on the full load tap, the connection should be changed. The connection on the exciting coil cutout of combined outfits must be changed as well as that on the primary coil.

Further faults of operation are discussed under the section on tubes.

**TUBES**

**Unpacking and Examination**

Rectifier tubes are packed in special shipping crates. (See Fig. 11.)

Careful examination of the rectifier tubes and crates should be made before accepting goods from the common carrier, paying attention to the following points:

1. Examine the crates and tubes generally to see if they have been broken. The tubes can be readily seen through the slats. If the crates have been damaged and the tubes broken, call the attention of the agent to it and accept goods as "Received in defective condition with crate and contents broken," stating the number of tubes broken and the number not broken.

2. Examine the tubes in the crates for mercury in the anode arms of one or more of the tubes. If there is mercury to any appreciable depth (1 in. or more) in the arms of any of the tubes, and the arms of other tubes are broken off or have a small hole knocked out of the end, receipt for "Tubes in defective condition, crate turned over contrary to instructions on shipping labels, mercury in anode arms and arms broken," stating the number of tubes defective and the number good.

Any mercury which has gotten over into the arms of the tubes should be returned to the condensing chamber by tipping the crate so as to run the mercury down into the cathode and then slowly inverting so as to run it into the condensing chamber, where it will do no damage in ordinary handling.

Remove the tubes from the crates and carefully examine for vacuum by running the mercury into the cathode and starting anode arms. If the vacuum is good, no gas bubbles will be entrapped by the mercury and when the mercury is run back into the condensing chamber a sharp metallic click will frequently be heard.

From examination of returned tubes, it is apparent that too little attention is paid to the following paragraph on handling of tubes.

In handling crates and removing tubes great care must be exercised or else the following is liable to occur: Sealing tips may be broken by striking crate or by mercury hammer, if the mercury is thrown
violently about the condensing chamber, if mercury is suddenly thrown into any of the arms of the tube or if it be in any of the arms and the tube is violently jarred.

If examination shows defective tubes, the nearest District Office of the General Electric Company should be notified and the tubes returned within ten days after acceptance from the transportation company, to the District Warehouse. (In the Boston and New York Districts, tubes should be returned direct to the factory at West Lynn, Mass.) If these conditions are met, new tubes will be supplied.

**Fig. 13. TUBEBracket (Cat. No. 108593)**

The rectifier tube must be dried out (see "Preparation of Tubes for Service") and reported on (if necessary) to the General Electric Company within ten days after receipt. If found defective, it should be reported, otherwise it will be included in the first year's (or later six months') tube adjustment, if the tubes which failed during this period do not meet their guaranteed average life.

**Stock of Tubes**

Rectifier tubes are delicate and liable to injury. It is recommended that a closet be provided for the storage of tubes.

The tube bracket shown in Fig. 13 is very satisfactory for supporting tubes.

Extra tube carriers and drip trays (Fig. 14) make changes of tubes much easier and quicker and should be in every station.
Preparation of Tubes for Service (Fig. 15)

If the vacuum in the tube is good, run all the mercury out of the anode arms, tapping gently to jar any off the anodes. If even a small globule of mercury is left on the glass above the anode, it is likely to cause a puncture through the glass to the platinum and the tube may be ruined.

Attach the tube to the carrier and tube holder as shown in Fig. 15.

In attaching the anode leads to the terminals on the carrier, make sure that sufficient length of lead is left to allow free movement of the holder within its limits, and that the lead does not rest against the anode arm, but goes up vertically for at least $\frac{1}{2}$ in. above.

Carefully insert in the tank, start the outfit with the load short circuited and run about an hour. The heat developed will drive away from the anodes any mercury not previously removed.

Raise the tube carrier and observe the condensation of mercury on the glass. In a good tube, the mercury will rest in small globules on the glass and both mercury and glass will be clean. In a poor tube, a heavy dark deposit or mirroring on the glass indicates that the tube is slowly leaking due to some damage in shipment or handling.
Good tubes dried out as above specified are ready for use and should be tried on load at the earliest opportunity and then stored in an upright position to keep the mercury from the anodes. One or more tubes ready for service should be always kept on hand.

**Care of Tubes in Service**

Tubes should be given the following treatment every two weeks on 50 light single tube sets, every three weeks on 75 light sets and every four weeks on 50 light two tubes in series sets.

Remove tube from holder or carrier and wash, removing all deposits from the arms, etc.

Give tubes a heat treatment for 15 minutes at 100 deg. C., which may be done in an oven, boiling in water or steam, 10 to 15 minutes should be taken to raise tubes from room temperature to 100 deg. C. and about the same time to cool off, as too rapid a change in the temperature of the glass will set up excessive stresses, frequently cracking glass and ruining the tube. If the tubes are treated for too long a period, the vacuum in the tube will be lowered too much causing an excessive amount of gas in the tube, which will not combine with the mercury while running in short circuit and the tube will arc from anode to anode destroying it if allowed to continue.
Failure of Rectifier Tubes

Tubes may be lost from one or another of the following causes:

1. They may be broken or otherwise damaged in shipment by rough or careless handling, cracking the glass and producing a slow leak.

2. The anode seals may be cracked on air cooled tubes if the tube is turned so as to run the mercury down into the anode arms immediately after the tube has been run, for the glass will be hot and the mercury cold.

3. Tubes may be damaged by forcing the tube carrier with tube down into the tank, producing mercury hammer and cracking the cathode or starting anode arms.

![Diagram of Rectifier Tubes](image)

Fig. 16

NOTE.—If an attempt is made to start a tube in which the vacuum is completely gone, it will not start, but there will be a burnt track of mercury oxide deposited between the cathode and starting anode arms. If the vacuum is partially gone, the tube may arc from anode to anode and the heat developed in the arms usually will be sufficient to melt or crack the glass.

4. The cathode spot may form in or jump over into the starting anode and if allowed to remain there too long, the mercury may be vaporized out of the starting anode, the glass heated sufficiently to crack it or the baffle plate may be burned and the glass considerably blackened, ruining the tube.

5. The connections between tube and tube carrier may be incorrectly made by crossing the cathode and one of the starting anode leads. The effect on the tube will be the same as in 4 above.
6. Leaks may develop at the seals or elsewhere, the glass may be punctured through to the platinum through the flare or through some point in the anode arm so as to permit air or oil to enter the tube thereby destroying it and making it inoperative.

7. Overloading, momentary low primary voltage due to switching, arcing grounds or the crossing of the load circuit with other circuits very greatly shortens the life of the tubes.

**Static Protectors**

Static protectors (see Fig. 16) are small bell shaped devices designed to go over the ends of the anode arms of rectifier tubes. They are used to prolong the operative life of rectifier tubes, but they should not be put on until the tubes do not give satisfactory service, as the rate of deterioration on tubes is generally faster with static protectors than without. Furthermore, the tubes seem to be somewhat more liable to puncture when static protectors are used.

A small glass bushing must be slipped over the anode lead, the protector slipped over the same lead and the leads from the protector and anode twisted together. No metallic part of the protector should touch the glass of the anode arm.

Static protectors have only to do with the normal operation of the tube under load, and as far as is known have nothing to do with the discharges which occasionally occur across the static discharger when the tube is old or sometimes even when new tubes are started up cold with the oil temperature below 16 deg. C. at the bottom of the tank.

**Current Fluctuations**

The following conditions may produce excessive current variations and may even cause the outfit to drop its load.

1. Improper oil temperature.
2. A deteriorated tube.
3. Badly grounded circuit, arcing grounds or crosses with other circuits.
4. Too great a load on the outfit, allowing slight variations to cause the coils of the transformer to come together.
5. Low primary voltage, momentary or continued.
6. Varying load. Broken lamp globes or improperly adjusted lamps may cause continued feeding and resultant fluctuations in current.
7. One or more lamps connected to the circuit with the polarity reversed.
8. Static inductive effects of high voltage transmission lines on arc circuits. This effect is especially pronounced if one of the phases of the high voltage lines happens to be temporarily grounded.
Temperatures of Oil

Under normal conditions of operation, and when correct primary voltage, frequency and load current are maintained, the temperature of the oil in which the tubes are operated should be kept within the limits specified, the minimum being at the bottom of the tank.

<table>
<thead>
<tr>
<th>No. of Lights Capacity</th>
<th>No. of Tubes per Circuit</th>
<th>OIL TEMPERATURES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Deg. C.</td>
</tr>
<tr>
<td>25</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>50</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>50</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>75</td>
<td>2</td>
<td>16</td>
</tr>
</tbody>
</table>

To maintain these temperatures, the temperature of the cooling water must be at least 5 deg. C. lower for 4-amp. outfits and 8 deg. C. lower for 6.6-amp. outfits. The best results will be secured if the temperature is kept between 24 and 29 deg. C.

If the temperature is allowed to exceed the limits shown, the current may become unsteady, causing the lamps to feed too frequently, and the tube may be destroyed. Lowering the oil temperature will generally remedy the trouble unless the tube has become damaged. Thermometers for indicating temperatures of oil and water are now supplied with mercury columns. Spirit thermometers have been found inaccurate, in some cases to a considerable degree.

Tube Records and Settlements

It is generally advantageous to keep records of rectifier outfits and tube life, as thereby in many instances trouble may be averted and the operation and tube life greatly improved. The General Electric Company will, on application to the nearest District Office, supply record sheets (Form 10517).

One sheet should be used for each tube and will cover, normally, a month’s run. All changes of outfit or load should be entered, and a record of the total hours run should be carried to the sheet covering the subsequent run.

The first tube settlement on new outfits is made at the end of the first year’s operation. After this time settlements are made at the end of any six months’ period, if the guarantee is not met. There are few cases where the guaranteed average tube life for the first year or six months’ period is not more than met. In case the guaranteed average is not met and a settlement is desired, a report must be submitted covering the operation of the tubes, a record of the serial numbers with hours “run” and hours “resting” of all tubes in service at the
start and end of the period, and the tubes which have failed during the period under consideration must be returned for examination at the factory if any settlement is expected. The report must include serial numbers and the life of the failed tube, together with their log sheets properly filled in.

TESTING THE ARC CIRCUIT

The following tests are recommended in order that trouble on the circuit may be promptly located and for the purpose of reducing the interruptions in service to a minimum.

(a) Service Test

Use a direct current voltmeter for this test, which should be rated approximately 50 per cent above the rated rectified voltage and have about 100 ohms resistance per volt rating.
Take the following observations very shortly after starting and before shutting down, also at any other time if necessary to locate trouble.

1. Voltage across the circuit, which divided by 86 will give the approximate number of luminous arc lamps on the circuit.

2. Voltage positive side of the circuit to ground followed by voltage negative side of the circuit to ground. The smaller these readings are, the better the insulation of the circuit. When the sum of these two readings approaches 50 per cent of the circuit voltage trouble may be expected and the circuit should be immediately inspected and repaired. When the sum of the ground readings is above 50 per cent of the circuit readings or when equal to the circuit readings, there is a ground on the circuit which can be readily located between two lamps by calculation.

3. If no voltmeter is available, use a pair of well insulated jumpers. First ground the positive side of the circuit and observe if any arc is drawn when breaking the circuit. Repeat with the negative side, and if an arc is drawn on breaking the connections to ground, there is evidently a ground on the line and by leaving one side grounded and going over the circuit, the lamps between the ground on the line and the ground in the station will be out and the ground will probably be found between the lamps burning and the lamps out.

**Fig. 18.** TYPE N ARC CIRCUIT INDICATOR
(b) Non-Service Test

This test is for the purpose of giving visual indications whether or not the circuit remains closed during the time that it is not in service, also for the purpose of determining whether there are any dead grounds on the circuit. This test should be made at about noon and about one hour before starting up. Connections are shown in Fig. 17.

In making tests in accordance with the instructions above, the ordinary voltmeter with air insulated resistance is not very satisfactory for the reason that it is practically impossible to insulate between terminals and between the supports of the resistance. In such a case, results will be inconclusive because the leakage resistance over some part of the resistance holder or container may not be appreciably higher than the resistance itself. This leakage resistance will vary with the amount of moisture in the air and also with the amount of dust collected.

To overcome this difficulty, the Type N arc circuit indicator (Fig. 18) is recommended.

A front connected voltmeter is mounted on a wooden support and attached to a frame carrying an oil insulated resistance. The terminals of the resistance are rubber insulated and have large leakage distances. The resistance is so arranged that a section may be connected on each side of the voltmeter.

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Volts Rating</th>
<th>Cat. No.</th>
<th>Volts Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>129309</td>
<td>1500</td>
<td>129312</td>
<td>7500</td>
</tr>
<tr>
<td>129310</td>
<td>2500</td>
<td>129313</td>
<td>10,000</td>
</tr>
<tr>
<td>129311</td>
<td>5000</td>
<td>148707</td>
<td>15,000</td>
</tr>
</tbody>
</table>

**UNDERGROUND CIRCUITS**

The lead covering on underground cables should be bonded where the cable is opened up to go to a lamp or into the station so that the lead covering will form a complete metallic circuit. If this is not done, unsatisfactory service may be expected on arc circuits operated by rectifiers or even direct current generators.

The lines should be installed so as to stand an insulation test between arc lighting circuit and ground as called for by the American Institute of Electrical Engineers.

**SUPPLY PARTS**

Orders for supply parts or any inquiries regarding rectifier transformers or outfits should include the serial number of the outfit. Transformers have their serial number stamped on their name plates and
on the end of one of their side rods. Tube tanks of segregated sets bear a name plate and a serial number. Switchboard panels bear a name plate and serial number. The serial number of the panel should be used only when reference is made to it, other inquiries should refer to the transformer or tank number.

Inquiries or correspondence regarding the parts of the outfit should use titles shown in this book when possible.

Further information will be furnished on application.
## General Electric Company
### Principal Offices, Schenectady, N. Y.

<table>
<thead>
<tr>
<th>City</th>
<th>Office</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlanta, Ga.</td>
<td>Third National Bank Building</td>
</tr>
<tr>
<td>Baltimore, Md.</td>
<td>Munsey Building</td>
</tr>
<tr>
<td>Birmingham, Ala.</td>
<td>Brown-Marx Building</td>
</tr>
<tr>
<td>Boston, Mass.</td>
<td>84 State St.</td>
</tr>
<tr>
<td>Buffalo, N. Y.</td>
<td>Electric Building</td>
</tr>
<tr>
<td>Butte, Mont.</td>
<td>Electric Building</td>
</tr>
<tr>
<td>Charleston, Va.</td>
<td>1st National Bank Building</td>
</tr>
<tr>
<td>Charlotte, N. C.</td>
<td>Commercial National Bank Building</td>
</tr>
<tr>
<td>Chattanooga, Tenn.</td>
<td>James Building</td>
</tr>
<tr>
<td>Chicago, Ill.</td>
<td>Monadnock Building</td>
</tr>
<tr>
<td>Cincinnati, Ohio</td>
<td>Provident Bank Building</td>
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<tr>
<td>Cleveland, Ohio</td>
<td>Illuminating Building</td>
</tr>
<tr>
<td>Columbus, Ohio</td>
<td>Columbus Savings &amp; Trust Building</td>
</tr>
<tr>
<td>Dayton, Ohio.</td>
<td>Schwinn Building</td>
</tr>
<tr>
<td>Denver, Colo.</td>
<td>First National Bank Building</td>
</tr>
<tr>
<td>Des Moines, Iowa</td>
<td>Hippee Building</td>
</tr>
<tr>
<td>Duluth, Minn.</td>
<td>Fidelity Building</td>
</tr>
<tr>
<td>Elmira, N. Y.</td>
<td>Marine National Bank Building</td>
</tr>
<tr>
<td>Erie, Pa.</td>
<td>Fort Wayne Electric Works</td>
</tr>
<tr>
<td>Fort Wayne, Ind.</td>
<td>Hartford National Bank Building</td>
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<tr>
<td>Hartford, Conn.</td>
<td>Traction Terminal Building</td>
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<tr>
<td>Indianapolis, Ind.</td>
<td>Heard National Bank Building</td>
</tr>
<tr>
<td>Jacksonville, Fla.</td>
<td>Miners Bank Building</td>
</tr>
<tr>
<td>Joplin, Mo.</td>
<td>Dwight Building</td>
</tr>
<tr>
<td>Kansas City, Mo.</td>
<td>Bank &amp; Trust Building</td>
</tr>
<tr>
<td>Knoxville, Tenn.</td>
<td>124 West Fourth Street</td>
</tr>
<tr>
<td>Los Angeles, Cal.</td>
<td>Sutter Building</td>
</tr>
<tr>
<td>Louisville, Ky.</td>
<td>Randolph Building</td>
</tr>
<tr>
<td>Memphis, Tenn.</td>
<td>Public Service Building</td>
</tr>
<tr>
<td>Milwaukee, Wis.</td>
<td>410 Third Ave., North</td>
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<tr>
<td>Minneapolis, Minn.</td>
<td>Second National Bank Building</td>
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<tr>
<td>Nashville, Tenn.</td>
<td>Stahlman Building</td>
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<td>New Haven, Conn.</td>
<td>Maison Blanche Building</td>
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<tr>
<td>New York, N. Y.</td>
<td>30 Church Street</td>
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<tr>
<td>Niagara Falls, N. Y.</td>
<td>Gluck Building</td>
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<td>Omaha, Neb.</td>
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<td>Philadelphia, Pa.</td>
<td>Witherspoon Building</td>
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<td>Pittsburgh, Pa.</td>
<td>Oliver Building</td>
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<tr>
<td>Portland, Ore.</td>
<td>Electric Building</td>
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<tr>
<td>Providence, R. I.</td>
<td>Turks Head Building</td>
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<tr>
<td>Richmond, Va.</td>
<td>Virginia Railway &amp; Power Building</td>
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<tr>
<td>Rochester, N. Y.</td>
<td>Grote Building</td>
</tr>
<tr>
<td>St. Louis, Mo.</td>
<td>Pierce Building</td>
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<tr>
<td>Salt Lake City, Utah</td>
<td>Newhouse Building</td>
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<tr>
<td>San Francisco, Cal.</td>
<td>Rialto Building</td>
</tr>
<tr>
<td>Seattle, Wash.</td>
<td>Colman Building</td>
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<tr>
<td>Spokane, Wash.</td>
<td>Paulsen Building</td>
</tr>
<tr>
<td>Springfield, Mass.</td>
<td>Massachusetts Mutual Building</td>
</tr>
<tr>
<td>Syracuse, N. Y.</td>
<td>Onondaga County Savings Bank Building</td>
</tr>
<tr>
<td>Toledo, Ohio.</td>
<td>Spitzer Building</td>
</tr>
<tr>
<td>Washington, D. C.</td>
<td>Evans Building</td>
</tr>
<tr>
<td>Youngstown, Ohio.</td>
<td>Wick Building</td>
</tr>
</tbody>
</table>

**For Michigan** Business refer to General Electric Co. of Michigan.  
**For Texas, Oklahoma and Arizona** Business refer to Soutwest General Electric Co. (Formerly Hobson Electric Co.)  
**For California** Business refer to Dime Savings Bank Building  
**For Texas, Oklahoma and Arizona** Business refer to Hulet Building  

### Partial List of FOREIGN Sales Offices

<table>
<thead>
<tr>
<th>Country</th>
<th>Office</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Electric Co., Foreign Dept.</td>
<td>Schenectady, N. Y.</td>
</tr>
<tr>
<td>General Electric Co., Foreign Dept.</td>
<td>30 Church St., New York, N. Y.</td>
</tr>
<tr>
<td>General Electric Co. of N. Y.</td>
<td>83 Cannon St., London, E. C., England</td>
</tr>
<tr>
<td>Australian General Electric Co.</td>
<td>Melbourne and Sydney</td>
</tr>
<tr>
<td>Companhia General Electric do Brazil</td>
<td>Rio de Janeiro</td>
</tr>
<tr>
<td>Cia. General Electric Sudamericana</td>
<td>Buenos Aires</td>
</tr>
<tr>
<td>Mexican General Electric Co.</td>
<td>City of Mexico</td>
</tr>
<tr>
<td>South African General Electric Co.</td>
<td>Johannesburg and Cape Town</td>
</tr>
</tbody>
</table>

For all **Canadian** Business refer to Canadian General Electric Co., Ltd., Toronto, Ont.