RECTIFIERS
MISCELLANEOUS ELECTRON TUBE TYPE
(FORMERLY TUNGAR)
DESCRIPTION

1. GENERAL

1.01 This section covers the Tungar Rectifiers per the following specifications: KS-5191, KS-5191-01, KS-5192, KS-5193, KS-5194, KS-5197, KS-5280, KS-5281, KS-5282, KS-5364, KS-5395, KS-5420 and KS-5443, used for charging storage batteries in telephone and telegraph power plants, P.B.X.'s, etc.

1.02 Each rectifier consists of a transformer and one or more rectifier bulbs which permit current to flow in only one direction thereby producing a pulsating direct current which may be used for charging batteries. With the larger capacity rectifiers, means of regulating and controlling the output current are provided in the rectifier, and choke coils to decrease the ripple in the current output are usually furnished with full-wave rectifiers.

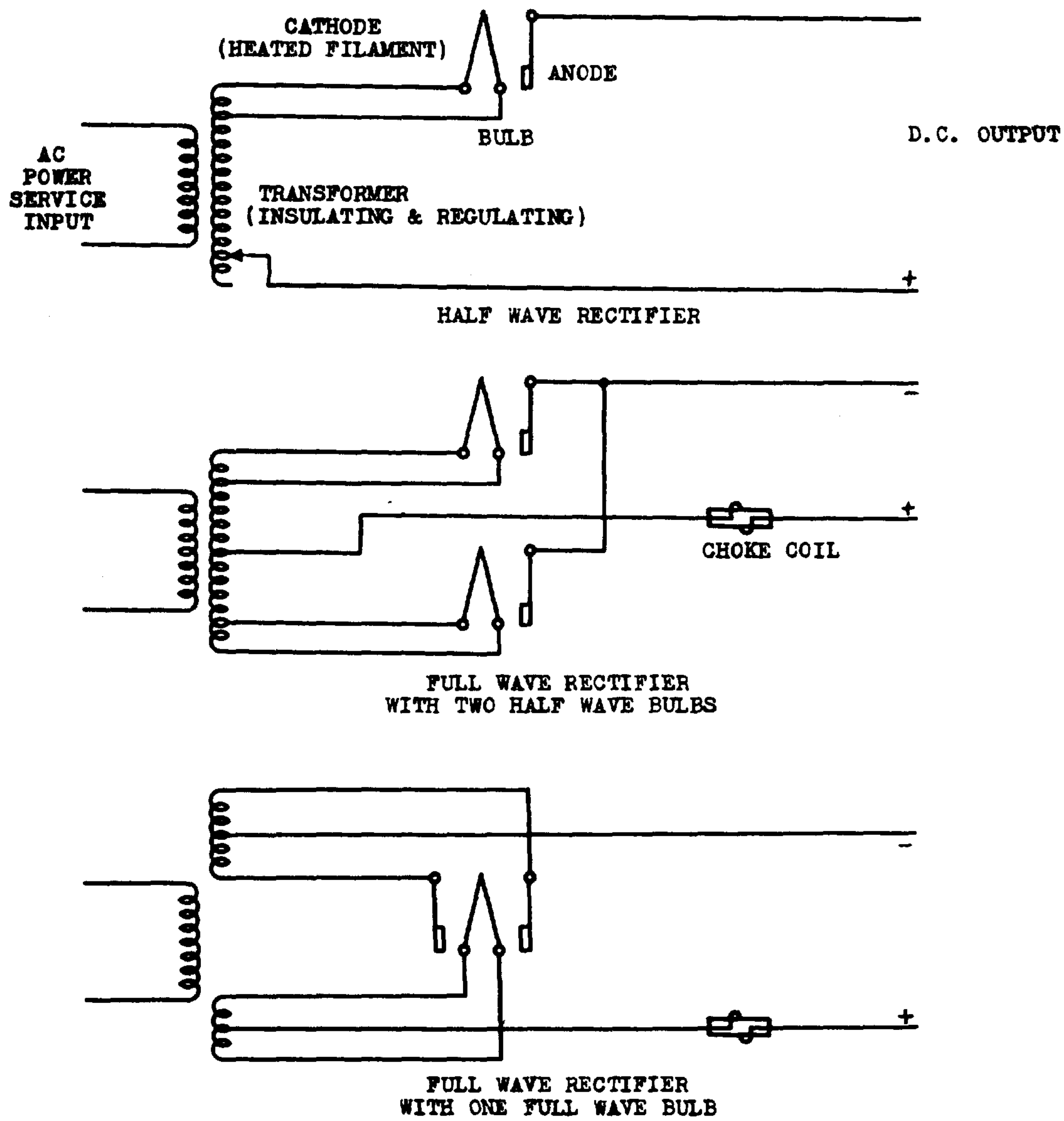

FIG. 1 - SCHEMATIC RECTIFIER CIRCUITS

1.03 Three methods of mounting rectifiers are employed, depending upon the size of the unit, its application, and the general arrangement of adjacent equipment. Units of small capacity are generally mounted on a shelf or on top of a cabinet and enclosed in a sheet metal case having a hinged top which provides access to the equipment. A typical example of this type of unit is shown in Fig. 4. Large capacity units are arranged for either wall type mounting (Figs. 2, 5 & 6), or panel mounting (Fig. 3). In both the latter types the front of the case forms a panel on which the rectifier controls, meters, switches etc. are mounted. In wall mounted rectifiers the sides of the case are hinged to provide access to the equipment within as the back of the case is very close to the wall. In the case of panel mounted rectifiers, access to the inside of the case is through the back since this type of rectifier is usually mounted on the regular power panel framework.

1.04 The principal electrical data for the various rectifiers are given in the following table.

						AC Power Service			Bulbs		
KS No.	List	Mtg.	Wave	DC Amps.	DC Volts	Fuses	Volts	Freq.	No.	Type	Cat.No.
5191	1	Shelf	Half	.4-.6-.8	175-150-120	5	105/125	60	2	Argon	12 x 825
	2							25/50			
	3					3	210/250	60			
	4							25/50			
5191-01	1	Shelf	Full	.4-.6-.8	175-150-120	5	105/125	60	1	Mercury	16 x 897
	2							25/50			
	3					3	210/250	60			
	4							25/50			
5192	1	Wall	Half	2-5-6	175-150-120	25	105/125	60	2	Argon	189049
	2					15	210/250				
	3					25	105/125	25/50			
	4					15	210/250				
	5		Full			20	105/125	60	1	Mercury	45 x 674
	6					10	190/250				
	7					20	105/125	25/50			
	8					10	190/250				
5193	1	Wall	Half	6	75	15	105/125	50/60	1	Argon	189049
	2							25/40			
	3					10	210/250	50/60			
	4							25/40			
5194	1	Wall	Full	6/12	75	15	105/125	50/60	2	Argon	189049
	2							25/40			
	3					10	210/250	50/60			
	4							25/40			
5197	1	Wall	Full	1.75-3	65-19/52	5	105/125	60	2	Argon	12 x 825
	2							25/50			
	3					3	190/250	60			
	4							25/50			
5280	1	Shelf	Full	0.5	30	3	105/125	60	1	Argon	199698
	2							25/50			
5281	1	Shelf	Half	2.5	24/30	5	105/125	60	1	Argon	195528
	2							40/50			
	3	Wall						25/30			
5282	1	Shelf	Half	2.5	40/60	10	105/125	60	1	Argon	189049
	2	Wall						40/50			
	3							25/30			
5364	1	Panel	Full	12	17/80	15	105/125	50/60	2	Argon	189049
	2							25/40			
	3					10	190/250	50/60			
	4							25/40			
5395	1	Panel	Full	1.75-3	70-19/52	5	105/125	50/60	2	Argon	12 x 825
	2							25/40			
	3					3	190/250	50/60			
	4							25/40			
5420	1	Panel	Full	30	24/30	15	190/250	50/60	2	Argon	217283
	2				12/15						
5443	1	Panel	Full	1-2	170-140	5	105/125	50/60	1	Mercury	16 x 897
	2							25/40			
	3					3	190/250	50/60			
	4							25/40			

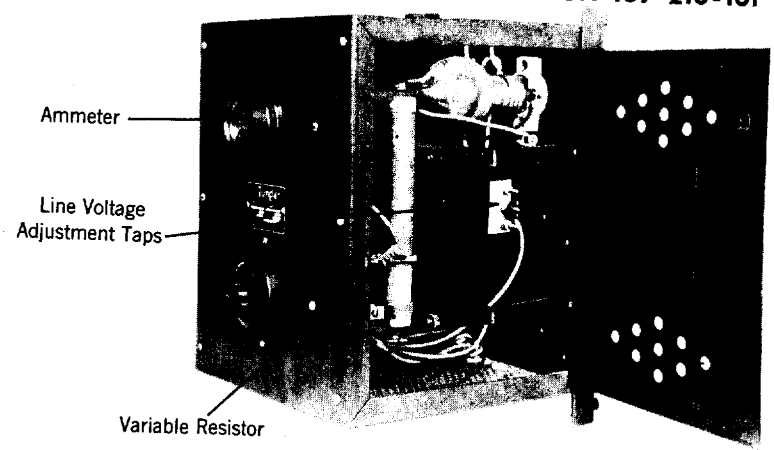

FIG. 2 - WALL MOUNTED RECTIFIER KS-5192, LIST 1

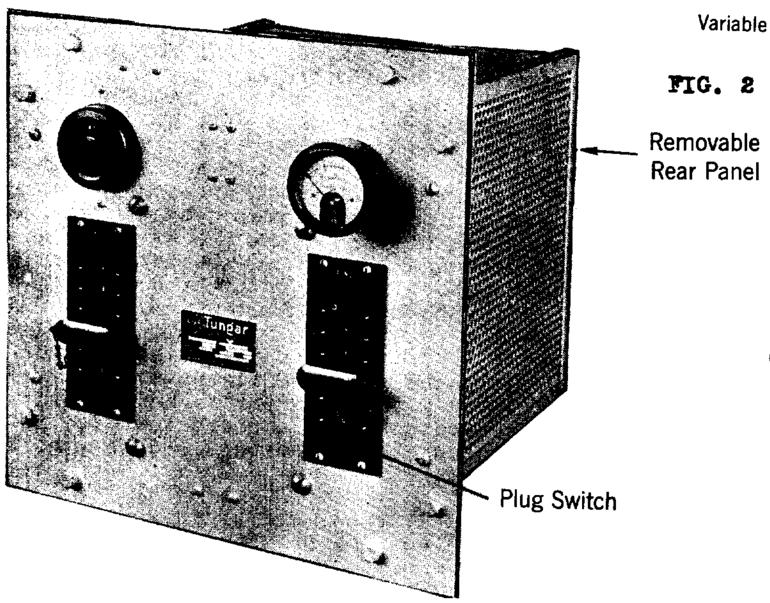

FIG. 3 - PANEL MOUNTED RECTIFIER KS-5364

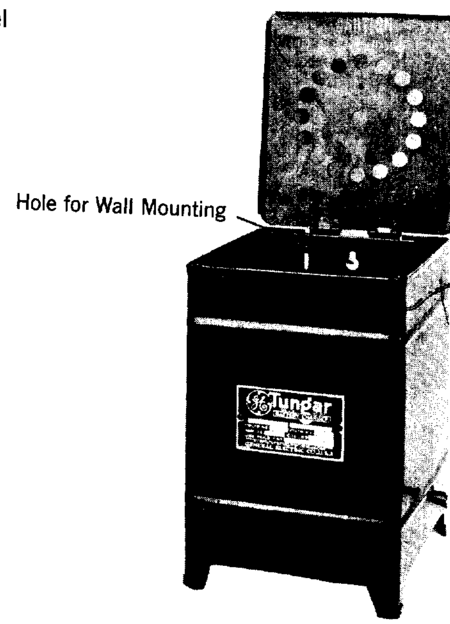

FIG. 4 - SHELF MOUNTED RECTIFIER

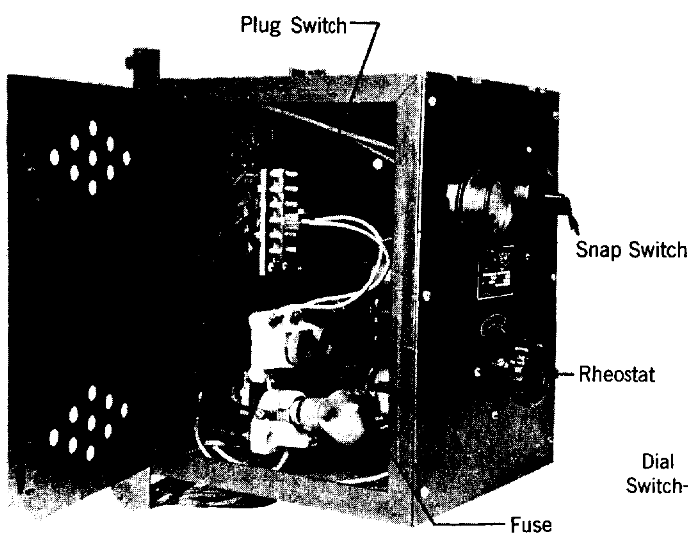

FIG. 5 - WALL MOUNTED RECTIFIER KS-5197

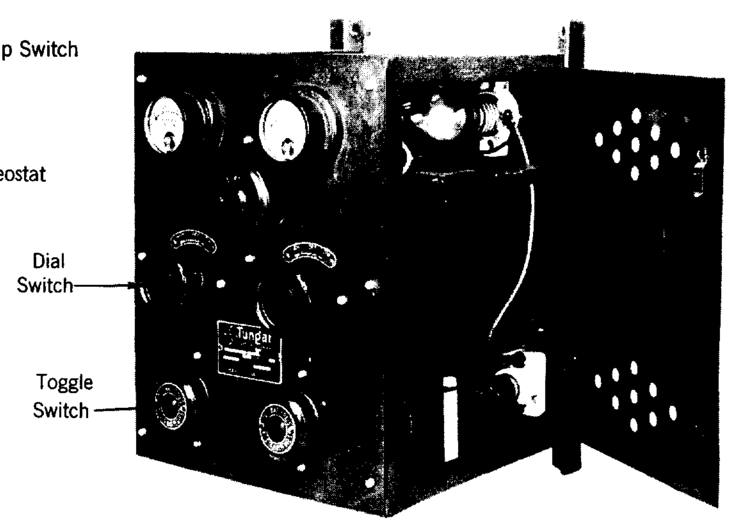

FIG. 6 - WALL MOUNTED RECTIFIER KS-5194

2. DESCRIPTION OF APPARATUS

Rectifier Bulb

2.01 Theory of Operation - The Tungar bulb contains a graphite plate (anode) and a tungsten filament in the form of a short helical coil (cathode), which is heated while the bulb is operated. The combination of a cold plate and a hot filament in a vacuum will serve as a rectifier since, when the plate is positive with respect to the filament, electrons emitted by the filament because it is heated to the point of incandescence, are attracted to the plate and this electron stream is a small electric current. When the plate is negative with respect to the filament, the electrons are repelled by the plate and thrown back upon the filament so that no electron stream exists and consequently no electric current. Therefore, with alternating voltage impressed upon the plate, current will flow from the plate to the filament during that part of the cycle when the plate is positive with respect to the filament and will not flow during that part of the cycle when the plate is negative.

Tungar bulbs, however, instead of being of the vacuum type are filled with gas at low pressure (about 1.5 pounds absolute or a vacuum of 27 inches of mercury). In the case of the older types of bulbs, this gas is the inert atmospheric gas argon whereas in the lately developed high voltage types of bulbs, the gas is mercury vapor. When the electrons emitted by the filament are attracted to the plate they attain high velocities but in this path they collide with molecules of gas and cause the gas to become ionized. This ionized gas provides a path for current and an arc is formed between the elements. Along the arc, relatively heavy currents are permitted to flow from plate to filament. By proper regulation of the gas in the tube the amount of this ionization is controlled and the arc is diffused. A concentrated arc such as is used primarily to furnish light would cause excessive heating of the filament which would in a short time burn out the bulb and therefore, it is necessary to have the arc diffused. When the plate repels the electrons because it is negative with respect to the filament, there is no bombardment of the gas molecules in the space between the elements and,therefore, the gas in this space is not ionized, and as a result no current flows.

The current output of a single half-wave Tungar bulb consists of the positive half of an alternating current wave for one half of the cycle and zero current for the other half. When two half-wave bulbs are connected so that the plate of one is positive when the plate of the other is negative, or when a two anode full-wave rectifier bulb is used, both halves of the alternating current wave are rectified. Figure 7 shows the output of each bulb of a full-wave rectifier,the combined output of the two bulbs when charging a battery directly, the combined output of both bulbs when charging a battery with a choke coil in series, and, for purposes of comparison, the alternating input current wave which is being rectified.

2.02 Filament Heating - The emission of electrons from the filament of the bulb is necessary to start and to maintain rectification. To provide this emission, the filament is heated by passing current through the wire, which consumes between 10 and 60 watts depending upon the size of the bulb. After the bulb starts to rectify a blue halo forms about the filament. This is glow discharge and is caused by the ionization of the gas around the filament. When the bulb is in this condition, it will continue to function even though the heating current of the filament be discontinued, because the heat generated by the arc will be sufficient to insure the proper emission, but in this case the rectifier would not be self-starting after power failure. Furthermore, the arc tends to concentrate upon one or two turns of the filament with the result that these turns are greatly overheated and fuse in a very short time. It might appear that operating without the filament heating would result in more efficient operation of the rectifier. However, the potential drop between the plate and the filament is greatly increased when the filament is not heated from a separate source and the loss so incurred exceeds the power required to heat the filament.

2.03 Pick-Up Voltage - In order to cause any current to flow between the heated filament and the plate, it is necessary that the plate have impressed upon it a potential sufficient to make the plate positive with respect to the filament. This ranges from 10 to 20 volts. When charging a storage battery, the negative end of the storage battery is so connected that the negative potential of the battery is impressed upon the plate. Consequently, the alternating current potential that must be impresed upon the plate is increased by the voltage of the battery. This fact accounts for the phenomenon that when a rectifier used to charge batteries of different voltages is connected to a higher voltage battery after charging a lower voltage battery,frequently no output current flows with the same setting that gave a reasonably large charging current for the lower voltage battery. When charging the lower voltage battery,the voltage impressed upon the plate was greater than the sum of the pick-up voltage plus the battery voltage and, therefore,was sufficient to start the rectifier, but when the rectifier was switched to the higher voltage battery the alternating current potential was less than the sum of the pick-up voltage plus the battery voltage and, therefore, no current could flow. By increasing the potential impressed on the plate, the rectifier can be made to start and to charge the higher voltage battery.

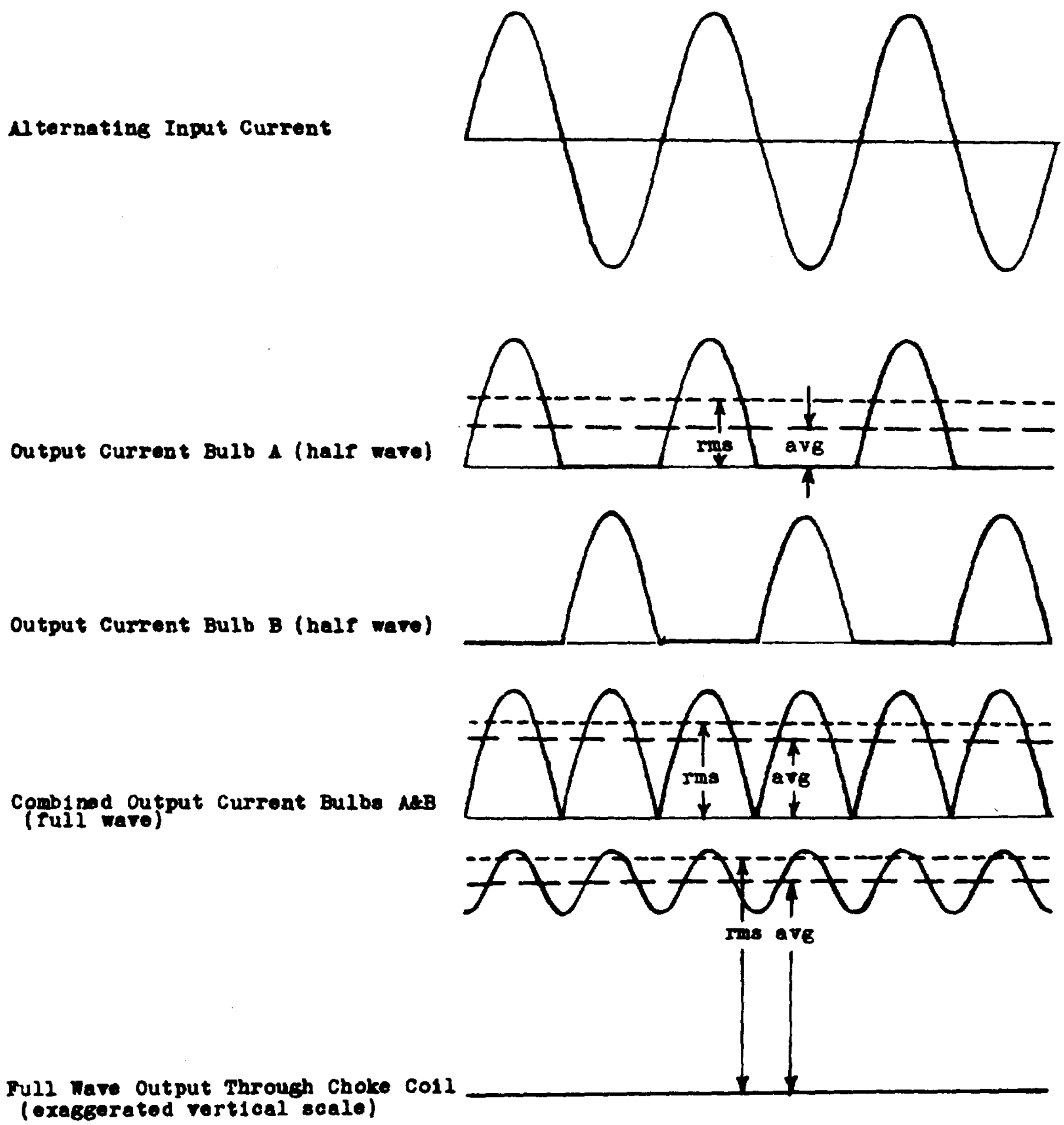

FIG. 7 - RECTIFIER OSCILLOGRAMS

2.04 Arc Drop - After rectifying action has started the voltage drop between the plate and the filament decreases to a value lower than the pick-up voltage. This is called the arc drop, and when the filament is separately heated, it ranges from 6 to 10 volts. However, if the filament heating current is discontinued, the emission is somewhat decreased and a space charge between the plate and the filament occurs. As a result of this condition, the arc drop increases from the usual 6-10 volts to as high as 20 volts, and when any appreciable current is flowing in the rectifier, the wattage lost through this increased voltage drop in the tube is usually greater than the wattage which would be required for heating the filament. When very small currents are passed by the bulbs such as when only a voltmeter is connected across the output terminals of the rectifier, the arc drop is very large and consequently the no load output voltage as read on a permanent magnet type DC meter is usually lower than the voltage of the battery to be charged.

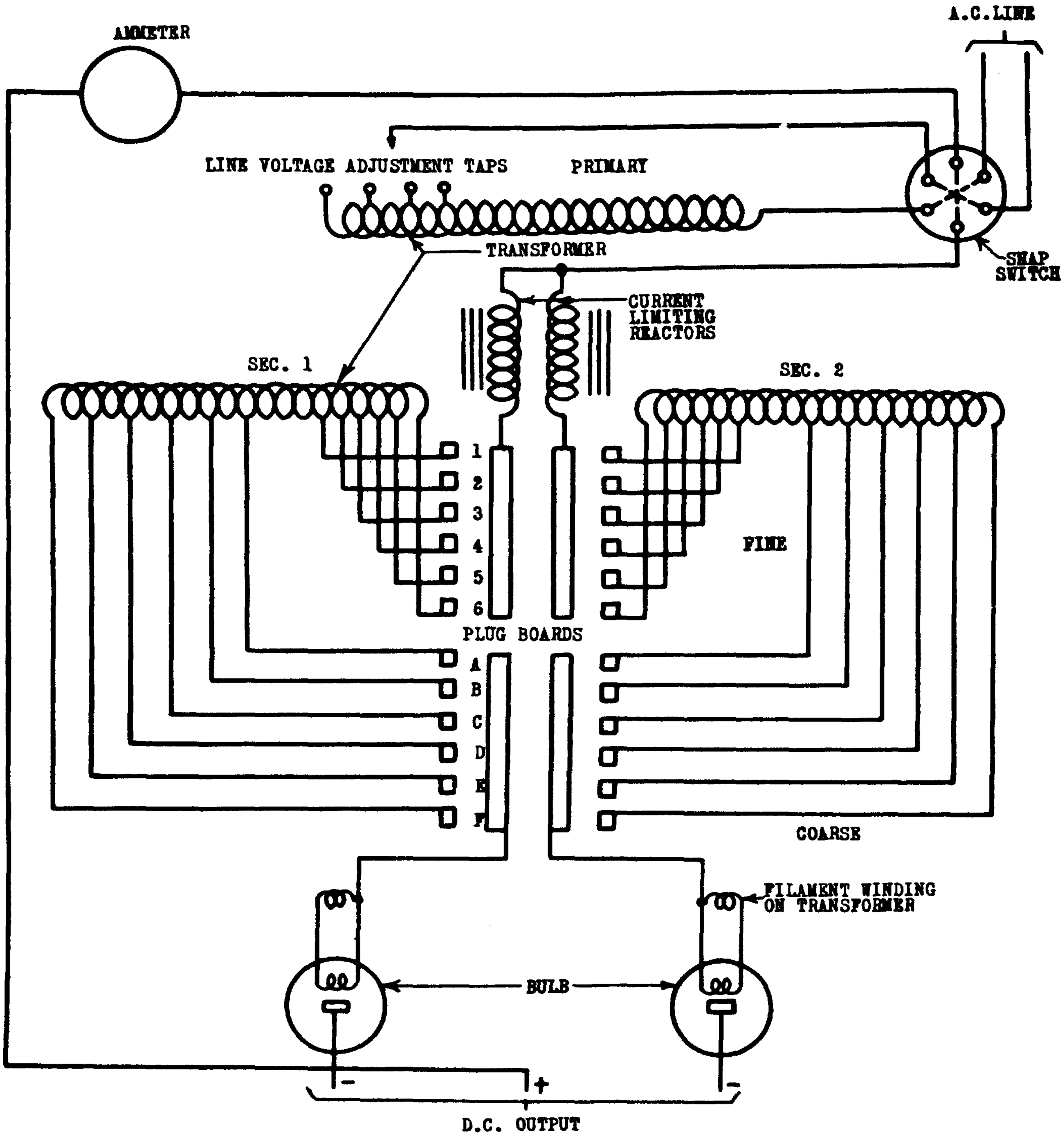

FIG. 8 - WIRING DIAGRAM OF KS-5364 RECTIFIER

2.05 Flashover - A flashover of a rectifier bulb is the result of the breaking down of its rectifying properties and the passing of current in the direction from filament to plate instead of the normal direction from plate to filament. This is caused by the plate having impressed upon it, a negative potential in excess of the inverse peak voltage. For telephone applications, in the case of argon filled bulbs this is not over about 300 volts and in the case of mercury bulbs not over about 500 volts. These values vary with the load on the bulb, being higher for low outputs. The peak voltage delivered by the transformer is as high as 2 or 3 times the voltage of the battery being charged and this fact accounts for the use of two argon bulbs in series on high voltage batteries. During the period of flashover, the illumination of the bulb is greatly increased; the color of the light in an argon filled bulb changes from yellow to a bluish white; and if the flashover continues for an appreciable time, the light may be seen to flicker.

In the manufacture of the Tungar bulbs great care must be exercised to insure that no gasses other than the argon or mercury vapor are left in the bulbs since these other gasses reduce the current output, increase the losses and in some cases disintegrate the elements. In order to insure that the last trace of foreign gas is removed, a quantity of magnesium is placed in each bulb during its manufacture, and when the bulb has been completed and is being tested this magnesium is fired. The magnesium combines with the unwanted gasses in the bulb and the products of this combination as well as excess magnesium find their way to the inside surface of the bulb where they produce either a mirror-like or a sooty appearance. The appearance of the bulb has no effect upon its operation. Sometimes some of the magnesium is left on the elements or is redeposited there during shipment. As the presence of magnesium on the elements decreases the inverse peak voltage of the bulb and increases the tendency of the bulb to flashover, new bulbs intended for operation on other than low voltages should be aged by operation for a time at low voltage or carrying small loads at a higher normal voltage to drive off any remnants of magnesium that might remain on the elements.

Flashovers are also caused by disconnecting the rectifier from the AC power supply without first disconnecting it from the battery, particularly if the rectifier charges the battery through a choke coil. In such cases, the inductive kickback from the coil raises the potential above the inverse peak value and the bulb flashes over. A flashover frequently destroys a bulb because the resultant arc concentrates on one or two turns of the filament and fuses it. Power failures do not usually cause bulb failures through flashover because the interruption of the power is not as rapid as that caused by the operation of a switch in the rectifier supply line. The characteristics of the power line from the generating station cause the voltage to decrease steadily over a period of several cycles instead of instantaneously, and the kickback is consequently much less severe.

Transformer

2.06 General Design - Rectifiers for telephone service are equipped with insulating transformers, that is, transformers with the primary windings entirely separate and insulated from the secondary windings, thus avoiding short circuits if both primary power supply and secondary load circuits are grounded as is usually the case. Each transformer has two or more secondary windings, one for the excitation of the filament and the others to provide the proper plate voltage for the operating range of the rectifier. If readings are taken with the bulbs lighted but no output current except that taken by the meter, voltages of several times the battery charging voltage required may be obtained with AC instruments and lower than the battery voltage with permanent magnet meters, although, if the rectifier were connected to a battery, the current output to charge that battery would be within the operating range of the rectifier.

2.07 Line Voltage Adjustments - All of the rectifiers with the exception of the KS-5191 and KS-5191-01 are equipped with line voltage adjustment taps on the transformer primary so that the rectifier for a nominal 115 volt service will have taps for use when the service voltage is nearer 105 or 125. Similarly, the 230 volt rectifiers are equipped with transformer taps for 210 and 250 volts with an additional tap on some of the rectifiers for 190 volt service. When a rectifier is installed, the line voltage adjustment tap closest to the actual normal line voltage is connected to the service lead.

2.08 Control Taps - One method of controlling the output of a rectifier is to control the voltage impressed upon the plate of the tube and, since this method is more efficient than to limit the current by means of a series resistance, most rectifiers are equipped with taps on the transformers for regulating the output. KS-5193, KS-5194, KS-5197, KS-5281, KS-5282, KS-5364, KS-5395 and KS-5443 rectifiers are all equipped with voltage control taps on the secondary winding of the transformer. The KS-5193, KS-5194 and KS-5364 rectifiers are equipped with both coarse and fine adjustment taps on the secondary winding of the transformer, the full range of the fine adjustment taps including approximately as many turns as between two adjacent coarse taps. By selection of the proper secondary tap or a combination of fine and course secondary taps the charging current delivered by the rectifier can be controlled within close limits. The KS-5420 rectifier is also equipped with taps for regulating the output but these taps appear on the primary winding rather than the secondary because of the large currents that would have to be handled on the secondary winding. When changes are made in the primary excitation of the transformer as in the KS-5420 rectifier, the filament supply must come from a separate transformer so that a decreasing or increasing of the plate transformer voltage will not cause a similar change in the filament voltage. A decrease in the filament voltage as explained above under "Filament Heating" would cause early failure of the rectifier bulb, and an excessive current due to high voltage would produce a similar result.

Control of Output

2.09 Plug switches consisting of jack boards and short-circuiting plugs are used to select the transformer taps of the KS-5443, KS-5420, KS-5395 and KS-5364 rectifiers. A somewhat similar arrangement of pins and flexible leads is used in the KS-5197 unit. With the exception of the latter rectifier where the pin board is enclosed in the case, all plug boards are on the face of the rectifier with ready access from the front for making the necessary changes.

2.10 Dial switches are used to select the proper transformer taps on the KS-5193 and KS-5194 rectifiers. The dial switches themselves are mounted within the case, but the operating handles extend through to the front of the rectifier where they are readily accessible. In the case of the full-wave rectifier, care should be exercised to have the dial switch controlling one half-wave in the same position within one step as the dial switch controlling the other half-wave so that the rectifier will be balanced.

2.11 Toggle switches are used in addition to the dial switches on the KS-5193 and KS-5194 rectifiers to provide a coarse adjustment approximately equivalent to all of the taps carried to the dial switch so that the operation of the toggle switch is approximately equivalent to a complete revolution of the dial switch. In the case of the full-wave rectifier, these toggle switches should likewise be in similar positions to keep the load on the two rectifier bulbs balanced.

2.12 A rheostat with a handwheel is used to give fine control of the output of the KS-5395 and KS-5197 rectifiers. This rheostat and handwheel is in addition to the plug switch (see 2.09) which regulates the coarse adjustment. The rheostat is mounted within the case and the handwheel extends through to the front where it is readily accessible for reducing the current from the nearest larger value attainable with the transformer taps to the desired value.

2.13 Rod type rheostats with a slider are furnished in the KS-5192, KS-5280, KS-5281 and KS-5282 rectifiers. These rheostats are all mounted within the case since these rectifiers are used in locations where it is rarely, if ever, necessary to readjust the current. Consequently, the less expensive method adjustment is provided. These rectifiers are all for fairly low currents and, therefore, the losses in the rheostat are not excessive.

2.14 No control of any kind is provided for the KS-5191 or KS-5191-01 rectifiers.

Operating Switch

2.15 An operating switch is furnished with the KS-5420, KS-5395, KS-5364, KS-5197, KS-5194 and KS-5193 rectifiers. In all cases the switch is a three-pole single throw snap switch. Two of the poles are used to control the AC power service input to the rectifier, one pole being placed in each side of the single phase line. The other pole is used in the positive DC output lead where it closes or opens the charging circuit at the same time that the power service is connected or disconnected from the rectifier. The use of this switch prevents bulb flashover which might occur if the battery potential should accidentally be left on the bulb when the AC power is turned off.

Ammeter

2.16 In order to read the output current of the rectifier, the KS-5193, KS-5194, KS-5197, KS-5364, KS-5397 and KS-5420 rectifiers are equipped with ammeters. These ammeters are of the permanent-magnet movable-coil (D'Arsonval) type, since this is the only common type which will read the average current supplied to the battery. All other meters read the square root of the mean squared currents which in the case of alternating current or ordinary direct current is satisfactory, but when rectified direct currents are involved, these readings may become as high as twice the average current. The average currents are the values effective for battery charging while the r.m.s. values represent the heating currents for fuses, resistance wattage calculations etc.

2.17 In the case of the older rectifiers, it was the practice to place the ammeter in the negative or anode lead which necessitated the use of two ammeters for full-wave rectifiers (KS-5194). The total current output of these rectifiers is the sum of the two ammeter readings. This was necessary because each of these half-wave portions had separate provision for adjusting the current. With the more modern rectifiers of the panel mounted type, a single ammeter is supplied connected in the common output lead so that the output of both tubes flows through the ammeter. This is possible in these rectifiers because the regulating devices are so connected and operated that it is impossible to unbalance these rectifiers and thereby secure incorrect reading of the meters.