Westinghouse
ELECTRONIC TUBES

PHANOTRONS

HALF WAVE MERCURY VAPOR RECTIFIER TUBES

KI-626
WL-866
WL-866A
WL-869A
WL-871
WL-872
WL-872A

WESTINGHOUSE LAMP DIVISION

WESTINGHOUSE
ELECTRIC & MANUFACTURING COMPANY

SPECIAL PRODUCTS SALES DEPARTMENT

BLOOMFIELD, N. J.

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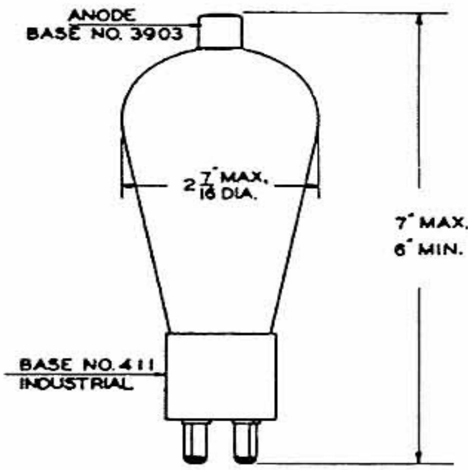
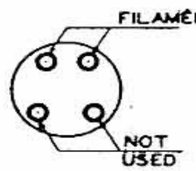
DECEMBER 21 1936

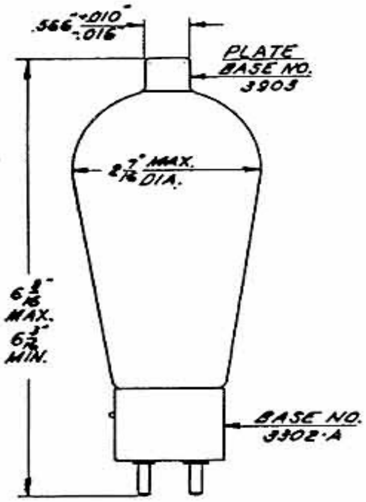
BULLETIN TD-54

—OUTLINES—

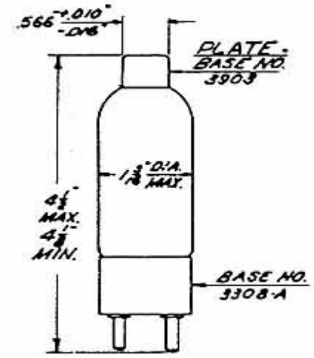


KI-626





TYPES WL-866
& WL-866-A



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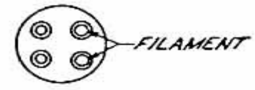

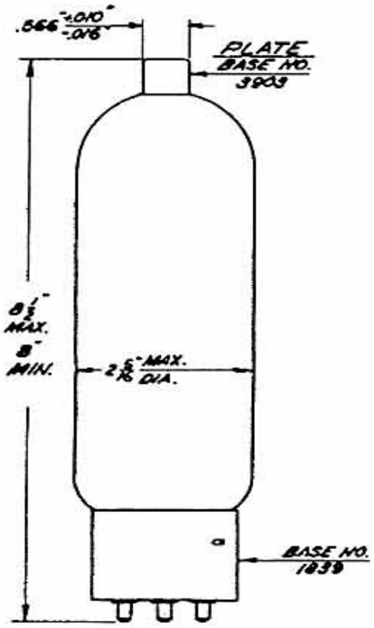

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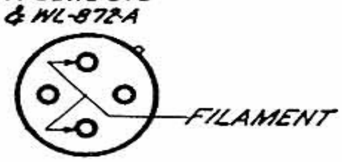
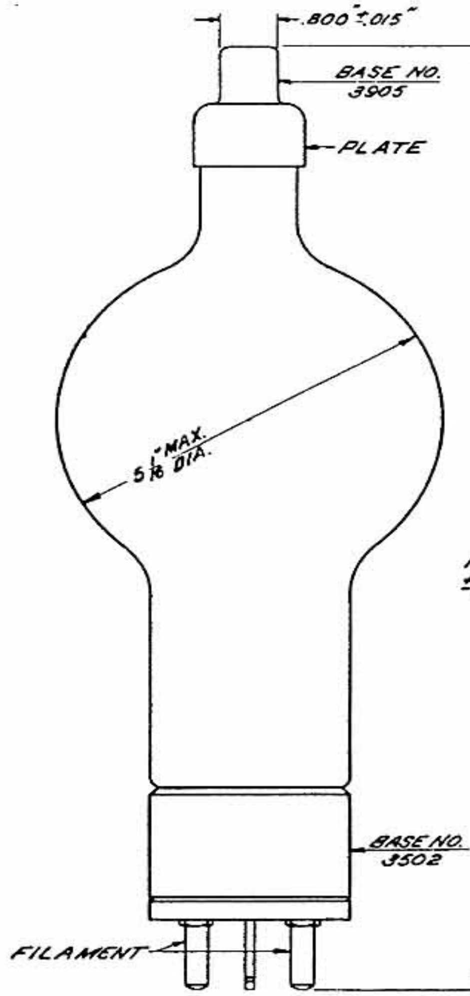




TYPE WL-869-A

WESTINGHOUSE HOT-CATHODE MERCURY-VAPOR RECTIFIER TUBES

CHARACTERISTICS AND RATINGS

Tube Type	KI-626	WL-866	WL-866A	WL-869A	WL-871	WL-872	WL-872A	
Filament Characteristics								
Potential	2.5	2.5	2.5	5.0	2.5	5.0	5.0	Volts
Current	6.0	5.0	5.0	18.0	2.0	10.0	6.75	Amperes
Heating time	10.	30.	**30.	60.	**10.	**30.	30.	Amperes
Maximum Peak Inverse Voltage								
(at 150 Cycles or Less.)								
2500 Volts (Ambient Temperature	15-60							C°
(Cond. Mercury Temp.	25-70							C°
(Optim.Cond.Merc.Temp.	35-45							C°
5000 Volts (Ambient Temperature	15-50	0-50	15-60		0-50	0-55	15-60	C°
(Cond. Mercury Temp.	25-60	10-65	25-70		10-60	10-65	25-70	C°
(Optim.Cond.Merc.Temp.	35-45	35-45	35-45		35-45	30-40	35-45	C°
7500 Volts (Ambient Temperature		0-50				0-50		C°
(Cond. Mercury Temp.		10-60				10-60		C°
(Optim.Cond.Merc.Temp.		35-45				30-40		C°
10000 Volts (Ambient Temperature			15-50	15-50			15-50	C°
(Cond. Mercury Temp.			25-60	25-60			25-60	C°
(Optim.Cond.Merc.Temp.			35-45	40-50			30-40	C°
20000 Volts (Ambient Temperature				15-50				C°
(Cond. Mercury Temp.				25-60				C°
(Optim.Cond.Merc.Temp.				30-40				C°
(at 1000 Cycles or Less.)								
5000 Volts (Ambient Temperature			15-60					C°
Maximum Plate Current								
Instantaneous or Crest	1.2	1.0*	1.0*	10.0	0.5	5.0	5.0	Amperes
Average or D.C. Value	0.3	0.25*	0.25*	2.5	0.125	1.25	1.25	Amperes
Approx. Tube Voltage Drop	15.	15.	10.	10.	10.	15.	10.	Volts
Maximum Overall Length	7.	6-9/16	6-9/16	14-3/8	4-1/2	8-1/2	8-1/2	Inches
Maximum Overall Length	6.	6-3/16	6-3/16	14-1/8	4-1/8	8.	8.	Inches
Maximum Diameter	2-7/16	2-7/16	2-7/16	5-1/16	1-3/16	2-5/16	2-5/16	Inches

**A 15-minute pre-heating time is always required if the tube is used in the region of 0-15°C.

* These values may be doubled for operating below 200 Volts Maximum Peak Inverse Voltage, at condensed mercury temperatures not exceeding the limits shown above.

In none of these tube types is the base shell connected to a filament lead within the base.

Additional data and information on these and other Westinghouse electronic tubes may be obtained by request to the Westinghouse Lamp Division, Westinghouse Electric & Manufacturing Company, Special Products Sales Department, Bloomfield, New Jersey.

GENERAL INFORMATION

The Westinghouse hot-cathode mercury-vapor rectifier tubes, KI-626, WL-866, WL-866A, WL-871, WL-872A and WL-869A, are designed for use in suitable rectifying devices to supply d.c. power from a.c. supply lines. Full wave rectification is accomplished by using two or more of these tubes in suitable rectifier circuits. The directly heated cathodes are made in the form of ribbon filaments of the coated types.

The types KI-626, WL-871, WL-866 and WL-872 are most suitable for use in telegraph or other similar applications where they are not in the proximity of radio-frequency fields, or in locations subject to effects which would interfere with their normal operation. The tube types WL-866A, WL-872A, and WL-869A have been designed especially for telephone service and for other rectifier installations where the tubes may be subject to extraneous electrical fields. Also, the voltage ratings for the tubes with the suffix letter "A" are higher in some cases than for the other corresponding types. The weights of the various tubes are given in the following tabulation:

Type of Tube	Net Wt. per Tube	Gross Tubes	Wt. of Package Pounds	ozs.
KI-626	3ozs.	12	12	0
WL-866	3 "	12	13	8
WL-866A	4 "	12	13	8
WL-869A	20 "	1	8	3
WL-871	1 "	50	16	0
WL-872	7 "	6	22	0
WL-872A	8 "	6	22	0

INSTALLATION

The Westinghouse hot-cathode mercury-vapor rectifier tubes are designed to fit standard sockets and mounting equipments which have been especially designed for the various types. Suitable mountings for these types of tubes are tabulated below:

Type of Tube	Filament or Cathode Mounting	Plate or Anode Contact
KI-626	S#766732	S#829334
WL-871	UX Socket	S#829334
WL-866	UX Socket	S#829334
WL-866A	UX Socket	S#829334
WL-872	S#841995	S#829334
WL-872A	S#841995	S#829334
WL-869	S#831780	S#781288
WL-869A	S#831780	S#781288

All connections in the socket and filament circuit should be of low resistance and of adequate current carrying capacity. The mountings should be located so as to hold the tube in a vertical position with the filament end down. There should be no excessive vibration, and the tube should be handled carefully when placed into its socket. The bulb becomes very hot during operation, and free circulation of air should be provided. Any metallic objects or drops of liquid should be prevented from coming in contact with the bulb.

When first received, the new hot-cathode mercury-vapor rectifier tube should be tested in the equipment in which it will later be used, and the procedure which is described below should be followed each time the tube is turned upside down or whenever mercury has come in contact with either the filament or plate electrodes. A deposit of mercury on the filament or plate reduces the arc-back voltage considerably, and a proper treating schedule should be carried out to prevent permanently ruining the tube. After the mercury has been redeposited by this pretreatment process, the tube should be mounted in a spare rack near the rectifier equipment so that the tube is held in its operating position with the filament end down. Care should be taken not to lay the tube on its side even while changing tubes in the rectifier unit. If a new tube is found to be in a broken or inoperative condition, a claim should immediately be filled out and filed with the transportation company.

As a class, these tubes are designed to operate within the specified ambient temperature and condensed mercury temperature ranges corresponding with the maximum plate potential ratings. Operation at ambient temperatures below the recommended limit may have a considerable adverse effect on tube life.

The ambient temperature is the temperature of the air which encompasses the bulb. This temperature should be measured by means of several thermometers placed at different points around and opposite the filament base at a distance of a few inches. If the tube is used in a location where the circulation of air is restricted, the temperature should be taken adjacent to the filament base and with the thermometer shielded so that the effects of directly radiated heat are eliminated. If forced air circulation is used, the ambient temperature should be measured by a thermometer in the cooling air stream before the air reaches the tubes. Forced ventilation may be used if necessary from the standpoint of tube safety factor and life.

In service, the bulb will eventually darken, which effect represents a normal condition. The mercury-vapor produces a characteristic blue glow when the tube is operated under load. External shields or radio-frequency filters should be provided wherever the tube may be subjected to extraneous high voltage or high frequency fields when in operation. Such fields may produce a continuous glow inside the tube and thus tend to produce breakdown effects in the mercury-vapor which will adversely affect the tube performance. Radio frequency filters will tend to prevent damage from radio frequency current which might otherwise be fed back into the rectifier tube.

The transformer secondary winding should be provided with a center tap or center tap resistor, and should supply the rated filament potential at each individual socket under operating conditions. As measured at the tube terminals, the filament voltage should not fluctuate more than plus or minus 5% from the rated value. This variation should include the effects of plate power and other equipment regulation. A filament voltmeter properly calibrated should be provided and installed so that the rated filament potential can be maintained. The filament circuit is at high potential; hence, caution should be observed when the filament potential is checked by means of a voltmeter connected directly to the filament terminals.

The plate supply of the circuit should be provided with a time delay relay having an obtainable delay period of sufficient duration to allow the filaments to come up to normal temperature before plate potential is applied. Since various installations will have filament supply transformers of widely different characteristics, it is recommended that the relays be adjusted to give the maximum permissible delay. The necessary delay period will vary with the particular type of tube, but in any case, the filament must reach the normal operating temperature before plate voltage is applied.

If it should become necessary to decrease the filament heating time, the following method is recommended in testing for the proper time delay. The tests should be made in the actual circuit under consideration if possible, and if not, the characteristics of the filament circuit should be duplicated. Approximately 115 volts d.c. should be applied to the plate of one tube through a resistance of sufficient value to limit the current through the tube to 20% of its rated average value. A voltmeter should be placed between the plate and filament electrodes. The filament supply voltage should be the maximum encountered in service, and the filament rheostat should be set for rated voltage. With the d.c. plate voltage on, the filament supply switch should be closed with the tube cold and the time noted until the d.c. plate voltage reaches a constant value. The decrease in this voltage will be very rapid until this value is reached. The time noted should be increased by 50%, which will give the shortest allowable delay period for the particular installation tested. The filament and plate voltages may be applied simultaneously when the KI-626, WL-866 and WL-866A types are used at peak inverse potentials not exceeding 2100 volts.

In the case of type WL-669A, an arc-back indicator, which is a form of polarized relay, is recommended for use with each tube in the rectifier, and should be connected in series with the anode. In all cases, regardless of the service to which the tubes are put, careful handling and conservative operation will be amply repaid by the longer and more uniform tube life which will be obtained.

OPERATION

When a new tube, or one in which the mercury has come in contact with either the filament or anode, is first placed in operation, the filament only should be operated for 15 minutes. The plate voltage should be reduced so that the peak inverse plate potential is not above 20% of the peak ratings, and the circuit should be closed. After the rectifier has been operated for a period of 5 minutes, the plate potential should be gradually increased so that normal load conditions are reached in 15 minutes.

If it is not possible in a particular installation to reduce the peak inverse voltage to 20% of the normal value, practically the same effect can be obtained by applying the lowest available plate voltage for short periods of time. For example, applying plate voltage for one second and remove for five seconds. Continue the above procedure with correspondingly longer periods of time on, until satisfactory operation is obtained at normal operating voltage. Operation should be continued for 15 minutes under normal conditions. If there is any evidence of sparking in the tube, the time for reaching full voltage should be increased so that the tube can reach stable operating conditions without causing injury to itself. In some cases where a tube has been operated improperly and shows a tendency to flash occasionally, this characteristic can be overcome by following the above procedure.

The filament of these tubes should always be operated at rated voltage. Less than this voltage may result in a high tube drop with consequent bombardment of the cathode and eventual loss of emission. Greater than rated voltage will shorten the life of the filament. If standby operation of the equipment without plate voltage is desired, normal filament voltage should be maintained. Also, if the time off intervals are less than two hours, the filament voltage should be left on the tubes. The voltage drop in the tube is approximately constant within the rated current range of the tube.

<u>Maximum peak inverse voltage</u> is the highest peak plate voltage that a rectifier tube can safely stand in the direction opposite to that in which it is designed to pass current. In other words, it is the safe arc-back limit with the tube operating within the specified temperature range. The relations between the peak inverse voltage, the d.c. voltage, and the r.m.s. value of a.c. voltage depend largely upon the individual characteristics of the rectifier circuit and the power supply. The presence of line surges, keying surges, or any other transient or wave form distortion may raise the actual peak voltage to a value which is higher than that calculated from the sine wave voltages in the transformer. It should, therefore, be emphasized that the maximum rating of the tube refers to the actual inverse voltage and not to the calculated value. A cathode ray oscillograph or a spark gap connected across the tube is useful in determining the actual peak inverse voltage.

<u>Maximum instantaneous or crest plate current</u> is the highest peak or instantaneous current that a rectifier tube can safely carry in the direction in which it is designed to pass current. If a large condenser is used in the filter circuit next to the rectifier tube, the peak current is often as much as four times the load or average current. In order to determine accurately the instantaneous current in any circuit, the best procedure usually is to measure it with a peak form of meter or to use an oscillograph.

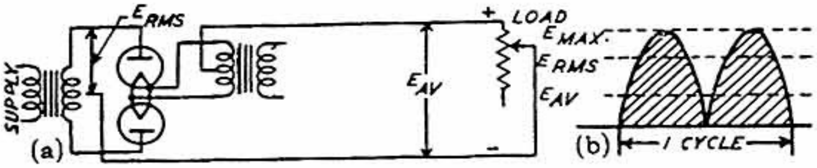
<u>Maximum average or d.c. plate current</u> is the highest value of average output current that can be safely supplied by the tube in the operating direction. The average and instantaneous current limitations must both be considered in designing rectifiers, and neither maximum limits may be exceeded even though the other limit is not reached. The average output current may be measured by the usual types of d.c. meters in the rectifier output circuit.

Several circuits particularly suited for use with these tubes are schematically given in the accompanying circuit diagrams. A summary of the approximate conditions and typical results which will usually be obtained from the use of these circuits are also tabulated for the various tubes. This also shows the main characteristics of the load current wave form, as well as the wave form of the current taken from the individual tubes in the accompanying circuits. Formulas which permit calculating the load and tube current values for these various circuits are also given for the appropriate circuits. These include the various voltage ratios as well as the current ratios both in the tube and load circuits. Where reference is made to the d.c. voltage values and to the load average values, the values represent the typical results which will be obtained from the use of these circuits. It is important to note that the tabulated values are theoretical values based upon pure sine wave conditions, and these values must be determined for each individual installation. This means that the tabulated value of d.c. voltage is the effective output voltage from the tube, and any voltage drop in the filter or any reduction in voltage occurring in the transformer must be subtracted from the value given in order to obtain the net voltage output.

The accompanying tabulation shows that the voltage output from a rectifier using tubes of these types suffers very little loss, and that the over-all efficiency of the rectifier is normally quite high. Due, also, to rather low voltage drop in the tube, the regulation of the whole rectifier is very good. It is quite obvious from the various wave-form curves that a small amount of filtering is necessary with the various six tube circuits. Also, the six tube circuits permit the obtaining of more power from the rectifier than is possible with the two or three tube circuits, and without exceeding the voltage ratings on the tubes.

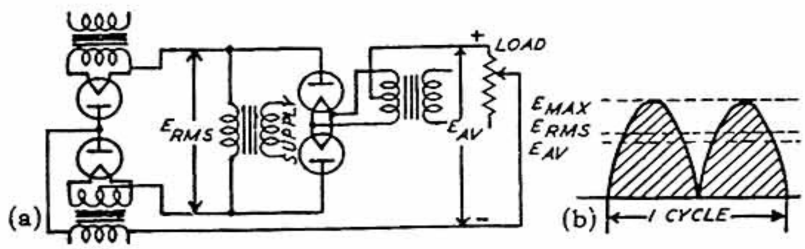
Tube Type	Circuit	Number of Tubes	Input Voltage R. M. S.	Approx. Output Volts	D. C. Output Amperes
KI-626	Single Phase Full Wave	2	1770 per tube	1590	0.6
"	" " " "	4	3535 total	3180	0.6
"	Three Phase Half Wave	3	2040 per leg	2390	0.9
"	" " Double Y Parallel	6	2040 " "	2390	1.8
"	" " Full Wave	6	2040 " "	4780	0.9
WL-866	Single Phase Full Wave	2	2650 per tube	2380	0.50
"	" " " "	4	5300 total	4760	0.50
"	Three Phase Half Wave	3	3060 per leg	3580	0.75
"	" " Double Y Parallel	6	3060 " "	3580	1.50
"	" " Full Wave	6	3060 " "	7160	0.75
WL-866A	Single Phase Full Wave	2	3535 per tube	3180	0.50
"	" " " "	4	7070 total	6360	0.50
"	Three Phase Half Wave	3	4080 per leg	4780	0.75
"	" " Double Y Parallel	6	4080 per leg	4780	1.50
"	" " Full Wave	6	4080 per leg	9560	0.75
WL-869A	Single Phase Full Wave	2	7070 per tube	6360	5.0
"	" " " "	4	14140 total	12720	5.0
"	Three Phase Half Wave	3	8160 per leg	9560	7.5
"	" " Double Y Parallel	6	8160 " "	9560	15.0
"	" " Full Wave	6	8160 " "	19120	7.5
WL-871	Single Phase Full Wave	2	1770 per tube	1590	0.25
"	" " " "	4	3535 total	3180	0.25
"	Three Phase Half Wave	3	2040 per leg	2390	0.38
"	" " Double Y Parallel	6	2040 " "	2390	0.75
"	" " Full Wave	6	2040 " "	4780	0.38
WL-872	Single Phase Full Wave	2	2650 per tube	2380	2.50
"	" " " "	4	5300 total	4760	2.50
"	Three Phase Half Wave	3	3060 per leg	3580	3.75
"	" " Double Y Parallel	6	3060 " "	3580	7.50
"	" " Full Wave	6	3060 " "	7160	3.75
WL-872A	Single Phase Full Wave	2	3535 per bube	3180	2.50
"	" " " "	4	7070 total	6360	2.50
"	Three Phase Half Wave	3	4080 per leg	4780	3.75
"	" " Double Y Parallel	6	4080 " "	4780	7.50
"	" " Full Wave	6	4080 " "	9560	3.75

Definition of terms-	Load	Tube	Transformer
	E_{av}	I_{max}	E_{rms}
	I_{av}	E_{inv}	E_{max}



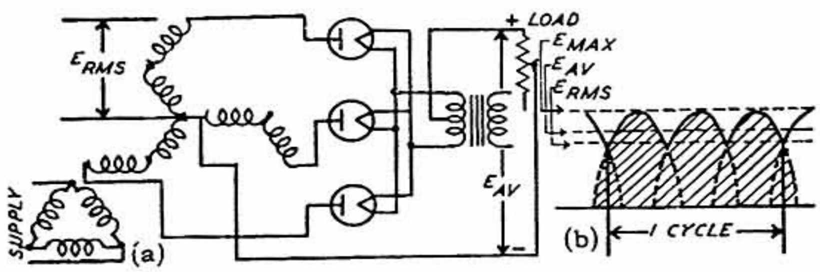
$E_{AV} = .636\ E_{MAX}$
$= .896\ E_{RMS}$
$E_{INV} = 3.14\ E_{AV}$
$I_{AV} = .636\ I_{MAX}$

FIG. 1-13—A TWO-TUBE, SINGLE-PHASE, FULL-WAVE RECTIFIER



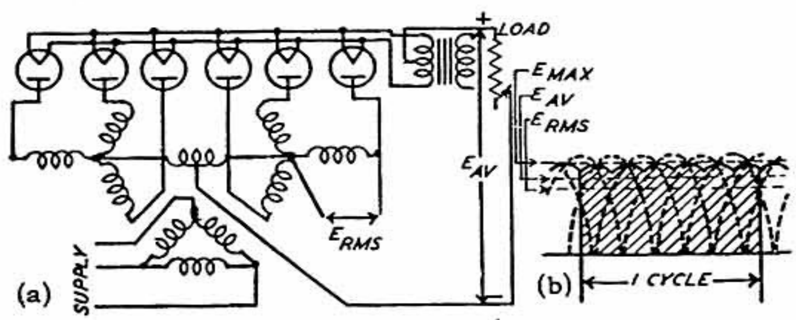
$E_{AV} = .636\ E_{MAX}$
$= .900\ E_{RMS}$
$E_{INV} = 1.57\ E_{AV}$
$I_{AV} = .636\ I_{MAX}$

FIG. 1-14—A FOUR-TUBE, SINGLE-PHASE, FULL-WAVE RECTIFIER



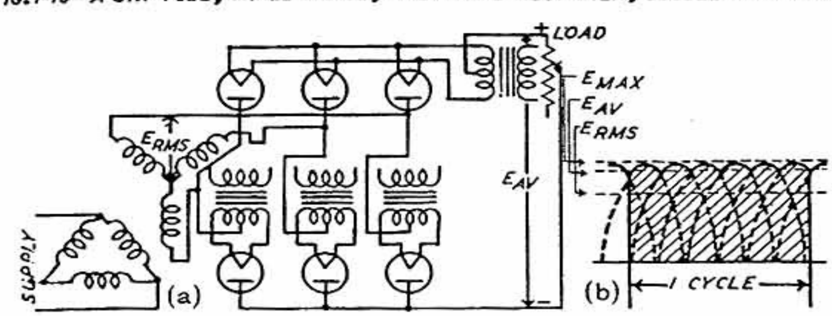
$E_{AV} = .827\ E_{MAX}$
$= 1.170\ E_{RMS}$
$E_{INV} = 2.09\ E_{AV}$
$I_{AV} = .827\ I_{MAX}$

FIG. 1-15—A THREE-TUBE, THREE-PHASE, HALF-WAVE RECTIFIER



$E_{AV} = .827\ E_{MAX}$
$= 1.170\ E_{RMS}$
$E_{INV} = 2.090\ E_{AV}$
$I_{AV} = 1.910\ I_{MAX}$

FIG. 1-16—A SIX-TUBE, THREE-PHASE, HALF-WAVE RECTIFIER, DOUBLE Y CONNECTION



$E_{AV} = 1.65\ E_{MAX}$
$= 2.34\ E_{RMS}$
$E_{INV} = 1.045\ E_{AV}$
$I_{AV} = .955\ I_{MAX}$

FIG. 1-17—A SIX-TUBE, THREE-PHASE, FULL-WAVE RECTIFIER

CURRENT RATIOS

Figure	$\frac{TUBE_{AV}}{LOAD_{AV}}$	$\frac{TUBE_{RMS}}{LOAD_{RMS}}$	$\frac{TUBE_{RMS}}{TUBE_{AV}}$	$\frac{LOAD_{RMS}}{LOAD_{AV}}$
FIG. 1-13	0.500	0.705	1.57	1.11
FIG. 1-14	0.500	0.705	1.57	1.11
FIG. 1-15	0.333	0.579	1.76	1.01
FIG. 1-16	0.167	0.280	1.72	1.02
FIG. 1-17	0.333	0.561	1.72	1.02