Westinghouse Electric & Manufacturing Company

East Pittsburgh, Pa.

January 4, 1932

WESTINGHOUSE RESEARCH LABORATORIES DATA LETTER NO. 2

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GASEOUS DISCHARGE TUBES

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Description, ratings, sizes and typical circuits of available developmental and standard Grid-Glow Tubes, Gaseous Discharge Rectifiers and Glow Lamps.

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CONTENTS

GENERAL

GRID-GLOW TUBES

The Westinghouse Grid-Glow Tubes, or grid controlled gaseous discharge relays, have an extremely wide range of usefulness. This is owing to their sensitivity, high speed of operation, durability as rapid duty contactors and general adaptability for automatic operations. In addition, the rectifying property of the tubes permits of special applications which are altogether impossible with metallic contact relays. The applications of the various types of the Grid-Glow Tubes range all the way from ultra sensitive uses, such as flame detection, to the control of large spot welders, with present tubes. The following list of some of the more important present and contemplated applications will indicate the variety of uses to which the tubes are adaptable.

Production Line Control - operation from the capacity of small metal objects in production line chutes.

Oil Burner Safety Control Device - operating from the conductivity of the furnace flame.

Cable Testing - operating from the leakage of imperfectly insulated cable.

Photo Tube Amplifier - operating from the minute currents passed by a photo tube.

High Voltage Relay - operating from the electrostatic potential set up in conductors in the near neighborhood of high voltage leads.

Voltage Regulation - of A-C. feeder lines or of A-C. or D-C. generators.

Time Delay Relays - operating from the slow change in voltage across a condenser in series with a high resistance.

Temperature Control - operating from contacting with a bi-metallic strip or the column of a mercury thermometer.

Relay for Indicating Meter - operating from contact of the pointer with a stop pin.

The Stroboglow - which operates from a momentary glow or flash of the tube. This is for the viewing of rotating or vibrating objects.

Remote Position Control - operating from the unbalance between a manual and a remote motor-controlled potentiometer.

Vibratory Apparatus Control - which delivers periodic current at below line frequency from periodic applications of grid voltage.

Theatre Light Dimming Control - this may be by use of the tubes directly in series with the lights or by the use of a three legged reactor saturated from the tube circuit.

Manual or Automatic Motor Speed Control - operating from the variable field or armature voltage obtained by selecting, by means of the tubes, various fractions of each A-C. voltage wave.

Spot Welder Control - operating by periodic interruption of the A-C. supply by means of grid control of the tubes.

The Grid-Glow Tubes have some resemblance to the ordinary three electrode vacuum tube, both in construction and in operation. Like the vacuum tubes they contain three electrodes spaced relatively to one another and sealed in an air tight glass container. Also, they function as grid controlled rectifiers.

However, the resemblance ceases here. In the vacuum tube the current is carried between the principle electrodes entirely by megative electrons emitted from the filament. The Grid-Glow Tubes, on the other hand, are filled with neon gas at a few millimeters pressure or with mercury vapor. The conduction of current, then, is in the form of a glow or arc discharge through this gas. Passage of current through glows or arcs does not consist of a flow of electrons alone. The current is carried jointly by electrons moving toward the anode and by positive ions moving toward the cathode. Their relative distributions vary continuously over the length of the discharge, electrons being most abundant at the anode and positive ions at the cathode. At some intermediate point, they are present in approximately equal numbers. The positive ions render a valuable service in neutralizing the negative space charge such as is prevalent in the operation of vacuum tubes where it accumulates in proportion to the current and causes a high tube resistance. The voltage drop of the hot cathode gaseous discharge tube is of a low constant value, only sufficient to ionize the gas content, so that the efficiency is considerably higher than that of the vacuum type. A tube of the same physical size can, then, control considerably more power.

In the vacuum tube where all the carriers of electricity are electrons, a negatively charged grid will in general receive no current since the negative carriers are repelled by it. In a glow discharge or an arc, however, the grid will always receive current excepting at one critical value of potential, this being the particular value which causes electrons and positive ions to arrive at the grid in equal numbers.

The function of the grid in the Grid-Glow Tubes is merely to "Trigger Off" the tube. When the grid is given the proper potential in relation to the anode-cathode potential, the tube breaks down and current is conducted in the form of a glow, or arc, discharge. Once this is started, the tube voltage drop reaches a low constant value throughout the period of conduction and the grid is no longer effective in controlling the discharge. Hence, the tube possesses a lock-in characteristic when used with D-C. sources. This is desirable in certain applications where the grid is used to block the discharge until some disturbance imposes a voltage surge upon the grid which allows the tube to break down. The anode potential must then be interrupted to stop the discharge. The tubes are generally used with A-C. sources where the discharge is periodically extinguished, and the grid control restored, by the reversal of the anode-cathode voltage. Thus grid control is never lost for more than one half cycle.

With regard to the speed of operation of these tubes, the breakdown or ionization time varies from 1 to 50 microseconds and the de-ionization time (the time for restoration of grid control after the tube has been conducting) is not in excess of one thousandth second.

The various Grid-Glow Tubes may be classified with respect to the type of cathode; into (1), the cold cathode type, (2), the hot cathode or filament type and (3), the mercury-pool cathode type in which a keep-alive arc maintains a thermionic cathode spot on the pool and keeps the vapor in an ionized state in the vicinity of the pool.

In the operation of tubes of the first class, electrons are emitted from the cathode due to the positive ion bombardment, breakdown of the tube being possible because of a small everpresent ionization of the gas. A higher tube voltage drop and consequent higher power loss is involved in the use of this type of tube and hence it is used mainly for the control of small amounts of power in sensitive relay applications.

In tubes of class (2) and class (3), electrons are emitted thermionically from the cathode (from the "cathode spot" in the case of the mercury pool tube) and they, therefore, have a low anode-cathode voltage drop. Although some cathode power for electron emission is required constantly during the use of tubes of the latter two types, one or the other is used wherever appreciable amounts of power are to be handled. They are sometimes termed "power" Grid-Glow tubes.

An important difference, however, exists between tubes of class 2 and class 3. This is that the maximum current passed by the hot cathode tube must never exceed the electron emitting power of the filament because, whenever this is exceeded, the tube voltage rises and the resulting positive ion bombardment of the filament rapidly destroys the coating, while in the case of the mercury-pool tube, the emission increases in proportion to the current drawn and the only injury which may be worked by high currents is that due to excessive heating of tube parts. This type thus has an advantage in applications where the current rises to very high values momentarily.

However, two disadvantages are involved in the use of the mercury-pool type of tube. These are: (1) Special care must be taken in shipment because of the unconfined mercury. (2) Difficulties are involved in starting the keep-alive arc. No tubes of the mercury-pool type are listed herein although developmental work is being carried forward on two sizes.

Also Grid-Glow Tubes may be classified, with regard to the plate voltage-grid voltage control characteristics, into the positive and negative control types, the difference between which will be noted from the characteristics given herein.

Fig. 1a shows photographs illustrating the physical construction of the various designs of Grid-Glow Tube. In all cases the grid is an open structure interposed as a barrier between cathode and anode. After breakdown the discharge takes place through the openings in the grid. It is not at all necessary that these openings lie in a direct line between anode and cathode.

One of the tubes, the DKU-618, contains a fourth electrode which surrounds a certain portion of the anode in the near vicinity of the grid. This electrode is always connected to the cathode through a resistance of from 2 to 10 megohms. The tube is not critical to the value of this resistance since the electrode has little to do with the control of the tube, its function being primarily that of prolonging life.

Mercury-pool Grid-Glow Tubes contain a total of 6 electrodes. Besides the principal electrodes, anode, cathode and grid, two small keep-alive anodes are necessary to maintain a continuous arc to the pool in operating with A-C. sources. The remaining electrode, associated with a small separate pool, is used only in starting the keep-alive arc. For starting, a low voltage is applied to this electrode and the tube tilted so as to draw an arc between the small pool and the main cathode pool of the tube.

Fig. 2 shows dimensioned drawings of the bases with which the tubes are equipped.

GASEOUS DISCHARGE RECTIFIERS

These tubes are very similar in all respects to the Grid-Glow Tubes discussed above, excepting that they do not contain a third control electrode or grid. The anodes and cathodes and, in fact, all parts of the tube in some cases are identical to those used in the construction of the Grid-Glow Tubes.

The manner in which these tubes may be used requires no particular mention here. In general they should find applications wherever standard rectifier apparatus, as listed in the general catalog, does not have suitable ratings. The voltage ratings of the tubes herein listed are far in excess of that permissible on Rectigon bulbs. Also the range of current ratings extends much higher than that of present standard Rectigon bulbs. See Fig. 1_b for photographs illustrating tubes of this type.

GLOW LAMPS

All glow-discharge tubes have light emitting qualities. The mercury vapor type emits light of a greenish blue hue while the neon filled type gives out the characteristic orange red color seen commonly in neon advertising signs.

Although the candle power of these lamps is low as compared to incandescent lamps, the illumination given out by them is entirely sufficient to clearly define rotating or vibrating objects.

In some cases glow lamps are required to contain control grids, and also possibly hot cathodes, as in the "stroboglow" previously mentioned. However, two electrode cold cathode lamps are much more common and it is tubes of this type, especially designed for producing light, which are designated by the term "glow lamp". In the tubes listed herein one electrode is larger than the other so that a somewhat brighter flash occurs on alternate half cycles. However it is possible to construct tubes which will pass current equally well in either direction.

No mention will be made here regarding the well understood uses of these tubes excepting to state that they emit light only during the instant of passing current and in some proportion to the amount of current passed which renders them especially adaptable to such uses as stroboscopic work, television, etc.

See Fig. 1_c for photographs illustrating tubes of this type.

TUBES AVAILABLE

Table 1 lists the available tubes of the various types along with their ratings, maximum dimensions, etc. A detailed explanation of the principal ratings is given under "APPLICATION DATA - Tube Ratings".

It will be noted that only average characteristics are given on the curves shown in this publication, and that no maximum or minimum limits have been set within which the characteristics of all tubes of a given type will fall. As long as the development of any tube has not progressed to the point where these limits can be given, the tube is called developmental. With all of the Westinghouse standard tubes, limits of characteristics are furnished.

The developmental tubes listed in this publication are presented to the trade at this time since it is deemed highly desirable from all points of view that customers have the opportunity, at as early a date as is possible, of developing new applications to meet their needs. Quantities of these tubes should not be depended upon without consulting the nearest Westinghouse District Office giving, if possible, detailed requirements which it is desired that the tubes meet. In view of such information it may be considered advisable to standardize size and rating of the tubes, as well as establish suitable limits, and thus standardize the tubes at an early date, thereby assuring the customer a continuous supply.

See Figs. 1_a, 1_b and 1_c for photographs of the tubes listed and Figs. 3,4,5,6 and 7 for the control characteristics of the Grid-Glow Tubes listed.

CHARACTERISTICS

As stated above, Figures 3 to 7 inclusive show the control characteristics of the various Grid-Glow Tubes. These curves represent average characteristics only, there being an appreciable difference between individual tubes. However, for any individual tube, the control characteristics will remain substantially constant with increasing tube life.

The characteristics are taken with the grid potential referred either to the anode or to the cathode. This is somewhat of a deviation from standard vacuum tube practice. The definition of grid polarity potential depends upon the point to which this potential is referred; thus, a positive grid, with the grid voltage referred to the anode, means that the grid is positive when the anode is positive and the cathode negative. A negative grid with respect to anode means that the applied grid potential is negative to the anode when the anode is positive. Similarly, a negative grid potential referred to the cathode indicates that the grid is negative when the cathode is negative. Likewise a positive grid voltage referred to the cathode means that the grid is positive with respect to the cathode when the cathode is negative. Briefly summed up, the polarity of bias is that polarity existing under forward voltage condition on the tube.

It will be noted that for the KU-610 tube, the control characteristics are given with respect to cathode, but with an anode-grid resistor permanently connected. This, of course, has some influence upon the characteristic obtained even though the resistor value is high. The resistor is recommended for general applications since it stabilizes the control characteristic.

It should be understood that the grid may be biased to either anode or cathode depending upon the application. The characteristics given herein are plotted thus depending on the most common past use of the tube.

The breakdown voltage curves given represent the minimum plate voltage at which the tubes will ionize and pass current at a given grid bias. When the curve is given with the ordinates given in RMS voltage, this, of course, indicates that the tube breaks down at the peak of each positive half cycle. The "Positive" and "Negative" breakdown characteristics differ in that the grid bias of the former is positive throughout the major part of the working range while for the latter it is negative. Less grid current is involved in the use of the negative control tube since, with the grid negative to cathode, the grid current is very minute in any of the tubes. However, the negative control type is generally associated with mercury vapor content which introduces a temperature coefficient. It will be found that different applications will find one type or the other most suitable.

As regards ambient temperature, this has very little influence on the breakdown characteristics of the neon filled tubes, but by affecting the vapor pressure, it does influence the behavior of the mercury vapor filled tubes especially when below 20°C. At increasing ambient temperature, increasing negative bias is necessary to render the mercury vapor tube non-conducting. However, the amount of this change is not generally sufficient to be at all serious when the ambient temperature ranges from 20°C. to 60°C., since it is generally possible to provide an abundance of grid voltage to cover all conditions in this range. It should be pointed out that the vapor pressure is determined by the coolest part of the tube.

The grid-current curves given represent the values of grid current respectively before and after breakdown. These curves serve to indicate the amount of the power which is involved in the grid circuit.

Regarding the rectifiers and glow lamps, it will not be necessary to give characteristics for these other than the ratings given in Table 1. It is necessary to keep in mind that these tubes also have a constant voltage drop regardless of current value, and therefore, will be destroyed unless a current limiting resistor is placed in series with them. This should be of such value that the specified ratings will not be exceeded.

APPLICATION DATA

TUBE RATINGS

It is especially important in the operation of gaseous discharge tubes that the plate current and voltage ratings are not exceeded. The tubes have no current limiting or resistance characteristics in themselves and therefore the load must be of such proportions that the tube ratings will not be exceeded. This applies also to the grids of gaseous discharge tubes. The series resistor should limit the grid current to only a few microamperes for long tube life. Breakdown of the tube in the reverse direction should be avoided since this also shortens the tube life. In regard to the ratings given in Table 1, the maximum average plate current is determined by the permissible tube heating, the power loss in the tube being approximately in direct proportion to the current because of the constant voltage drop characteristic. This rating is the maximum continuous average current applying to either commercial frequencies or D-C. It is further defined as the maximum average current over any period of T consecutive seconds. (T as given in Table 1 is referred to as the time constant.)

The maximum crest plate current rating is determined by the maximum current which the cathode can supply for even a very short time without injury, applying especially if the cathode is of the filament type. It should be pointed out here that usually the crest value of current being passed by a tube is not 1.4 times the RMS. value. If the maximum crest current demanded of the tube in a certain application cannot be estimated, it should be determined by means of an oscillograph or a reliable crest ammeter.

In applying the tube, the average current over any period of T consecutive seconds must not exceed the average rating given and under no conditions must the crest current exceed the crest rating given even for surges of very short duration.

To illustrate the meaning of these ratings, assume the maximum crest plate current rating of a tube is 1 ampere, the maximum average plate current rating is .5 amperes, and the time constant T is 10 seconds. Then under no condition of service must 1 ampere be exceeded. Also, during no 10-second period, whenever taken, must the average tube current be more than .5 amperes.

The voltage ratings of the tubes are determined by the following factors: (a) flash back (b) grid control (c) insulation. The tubes are rated conservatively with respect to the above limiting factors. The crest voltage rating given is the highest anode-cathode voltage which the tube will safely stand in either direction. Voltage peaks exceeding this value, even momentarily, imperil the life of the tube and must be carefully guarded against. In circuits where oscillations are present, special peak voltage measuring means must be employed to measure the crest value.

An important difference exists between the filament type and the mercury-pool cathode type of tubes in that the former has a maximum emission rating which, if exceeded, increases the anode-cathode voltage drop and works rapid injury to the filament by positive ion bombardment, while the mercury-pool tube does not have this limitation. Very large peak currents may be passed through them, the only limitation being heating of the tube parts. However, this type has disadvantages in shipment and in the difficulty of starting the keep-alive arc as pointed out previously.

After shipment or other handling of the mercury vapor tube it is well to pass filament current only, for a period of 15 minutes with the tube in the normal position. This evaporates the mercury from the various tube parts and distributes it properly.

The filament of the hot-cathode tubes should always be supplied with rated current and voltage. A variation of 5% is allowed for in design. If the filament voltage is too low, or if the socket contact resistance is high, the filament will operate at below normal temperature so that it is important that the tube prongs make good contact in the socket. Such a condition results in low emission and a consequent high tube voltage drop which in turn causes bombardment of the cathode by positive ions and a further loss in emission. Too high filament voltage, on the other hand, causes evaporation of the filament. It is, then, important that the filament voltage, as measured on the filament prongs of the tube, be kept as close to the rated value as possible.

It is well to point out here that a considerable variation of filament temperature, provided the filament is still emitting, has almost no effect on the tube control characteristics.

For reasons similar to those given above, it is absolutely essential that the hot-cathode tubes pass no plate current until the filament is thoroughly heated. Table 1 lists the advisable amount of filament heating time for the various tubes. In many applications it is possible to meet this condition by energizing the filaments a sufficient time before the plate circuit is closed or before, as may be definitely known, the plate circuit will be called upon to operate. In other circuits, where manual operation cannot be depended upon, it is necessary to install a time delay relay in the plate circuit which does not complete this circuit until the filament has been energized for sufficient time. Also, it is possible to apply negative bias to the tube so as to prevent plate current during the filament heating period. A very few applications only of plate voltage with the filament cold are sufficient to strip the filament of the oxide coating.

The mercury-pool tubes do not have this particular feature, and plate current can be passed through them as soon as the "keep-alive" means are put into operation. However, it should be pointed out here for comparison that the starting of the keep-alive means of mercury-pool tubes is not as simple as switching on the filament current of the hot-cathode tubes. To start the keep-alive arc it is necessary to tilt the tubes, apply high potential, or equip the tube with a mechanism for drawing the arc initially after which it maintains itself.

MOUNTING OF TUBES

Tubes of the smaller sizes are equipped with Westinghouse industrial bases and have all of the connections brought out through the four prongs of this base. Thus the tubes can be conveniently mounted and neat panel arrangements are possible. It is necessary to use double-end construction on the larger sizes bringing the anode lead out at the top of the tube. All the tubes are designed for mounting in a vertical position.

The tubes have a very rigid internal construction and will withstand a reasonable amount of mechanical shock, but where excessive vibration is present a shock absorbing mounting should be used.

Care should be taken to provide a suitable protecting housing whenever the location of mounting is such that breakage of the tubes may result from contact with missiles, tools, etc., or the location is subjected to moisture, dust and dirt deposits, oily vapors, or the splattering of liquids. Particularly, the splattering of liquids on the hot tubes is to be avoided since breakage of the glass is likely to result.

Tube apparatus must be protected as much as possible against these conditions.

The designer of tube apparatus for a given application must see to it that the apparatus is suitable in view of conditions associated with the particular application.

However, in providing housing for the tubes, care must be taken that adequate air ventilation is provided for cooling. This is important from the standpoint of injury to the tubes and also from the influence of large temperature changes upon the operating characteristics of the mercury-vapor tubes, whenever these are desired to remain especially constant in operation. Here, in some cases, it will even prove worth while to provide separate or external means to prevent extremes of temperature or to hold the temperature essentially constant.

CIRCUIT PRECAUTIONS

In designing and installing Grid-Glow Tube circuits, it is well to be on guard against high frequency and voltage surge effects, both from without and within the circuit. In some cases these interfere markedly with the normal operation of the circuit, generally by interference with grid circuits. Some common causes of such disturbances are electrostatic and magnetic influence of foreign circuits, the action of A-C. magnetic fields, transformer voltage surges, action of one tube in influencing another, etc. Such disturbances can generally be easily eliminated entirely or minimized by proper electrostatic and magnetic shielding, or by the use of non-magnetic materials, etc.

Another possible source of difficulty is in the leakage of the grid circuit insulation. Often the value of the control currents are very small so that leakage currents of a few microamperes upset the circuit considerably. This applies specially to the smaller and more sensitive tubes.

In regard to the selection of grid control means, it should be kept in mind that in practice the control characteristics of grid equipped gaseous discharge tubes are not as stable and dependable as those of the vacuum type amplifier since it is extremely difficult to eliminate all disturbing factors. Therefore, all care should be given to providing ample grid-bias change for control of the tube. This applies to off-on control or relay action of the tubes. Whenever using these tubes for magnitude, or variable output, control, it is, of course, necessary to use them with A-C. sources. The type of grid control highly to be preferred for such use is by phase shift of an A-C. grid bias which is taken from the same source as the plate voltage. This type of control is explained in detail under "Circuits". It will be noted that the grid-bias control characteristics of the tubes can here shift a considerable amount without materially changing the point of breakdown of the tube, provided the A-C. grid voltage is chosen of sufficient magnitude.

As discussed under "Tube Ratings" the circuit must always provide that the tube ratings are not exceeded. This will contribute greatly toward long operating life.

In all tube circuits, easily adjustable means should be provided to compensate for some changes in the characteristics with life and especially for the differences between individual tubes. This applies principally to the more exacting circuits. A great many circuits are not critical to the ordinary changes and differences in control characteristics.

Tube replacement costs, especially where the larger and more expensive types are used, may seem at first to be a drawback, but should be considered together with direct and indirect advantages to be gained by their use. Where tubes are carrying current only intermittently, the replacement cost may be nominal or even negligible as compared to other means. In other cases of constant duty, the replacement costs involved may be amply repaid by the advantages gained. In addition, it must be kept in mind that as larger quantities of tubes are involved, the manufacturing cost will be considerably less in the future.

In making tube applications and in the design of circuits, the effects of tube failure in service should receive serious consideration, and whenever the seriousness warrants, provision should be made for a duplicate tube in service or for automatic "cut over", or replacement. In a voltage control circuit recently designed, several pairs of tubes work in parallel relation to furnish field excitation and whenever part of the tubes may become broken, or fail otherwise, the load is taken by the remaining tubes.

SHOCK AND FIRE HAZARD

Tube grid-control circuits frequently may carry dangerously high voltages and, on account of the smallness of the control parts and their resemblance to radio parts, the individual may be inclined to use insufficient caution. Also, of course, the plate circuits often involve voltages and power capacity sufficient to cause severe personal injury. Special effort should be made to promote safety.

Suitable protection should always be employed to prevent overloading of apparatus, especially tubes. This can frequently be done by incorporating suitable features in the control circuit.

TYPICAL CIRCUITS AND METHODS OF USE OF GRID-GLOW TUBES

COLD-CATHODE GRID-GLOW TUBE, DKU-618

The smallest, and in general, the most sensitive of the Grid-Glow Tubes, is the DKU-618. This is owing not so much to the amount of the grid-voltage change which is required to control the tube, as it is to the very minute grid currents involved in its operation. It is used generally only where a very sensitive means, such as changes in resistances in the order of megohms or capacities in the order of a few millionths of a microfarad, are desired to operate a relay, or where the current which can be delivered by this tube is sufficient to meet the requirements of a certain application and it is not desired to use the hot-cathode type because of the necessity of supplying filament heating energy.

As noted in Table 1 the voltage drop of the DKU-618 is 170 volts. It is generally used on 440 volts A-C. obtained with a small transformer. An increase in the supply voltage materially decreases the life of the tube. At approximately 800 volts peak value the tube loses grid control. All of the control circuits shown employ the tube by varying the potential of the grid from one position to another between that of anode and cathode. The most generally useful means of accomplishing this is to employ very high impedances in the order of megohms, between grid and anode and between grid and cathode, one of these being the variable and controlling element. A decrease in value of the anode impedance or an increase in the cathode impedance will cause the tube to break down. See the characteristics given in Figures 3 and 4.

Also the grid of the tube may be left floating electrically, when it will assume a negative potential sufficient to raise the breakdown voltage of the tube to about 800 volts, the exact value of which will depend upon the insulation, capacity, "pickup", etc. of the grid lead. Then, upon application of the proper potential to the grid, the tube may be made to break down and pass current.

Figures 8 to 12 inclusive illustrate the various methods, which are commonly used to control the tube. From the foregoing description these circuits will be for the most part self-explanatory. The source E is generally 440 volts A-C., but in all circuits not using capacity elements the voltage may be D-C. of the proper polarity if lock-in operating qualities are desired in the circuit. In the use of

D-C. sources as explained previously, the anode-cathode potential of the tube must be reduced to zero to stop the plate current and restore grid control to the tube.

In Figure 10 the resistors R_1 and R_2 may be such elements as a flame, a photo-electric tube or similar high resistors, the changes in which are to cause operation of the tube.

In Figure 11, the condensers C_1 and C_2 may be composed of such elements as metal objects in production line chutes and small plates built into the side of the chute, or of the human hand and metal objects, etc.

In Figure 12 the voltage E_g may be from any variety of sources such as generated voltages, battery voltages, surge voltages, etc.

In general, when using the tube in circuits of the above type, it is preferable from the standpoint of tube life to place in series with the grid as high an impedance as is permissible without impairing the overall performance.

The above circuits have been given for the cold cathode tube alone although some of them will be found applicable, with suitable modifications, for use with other Grid-Glow Tubes also. Conversely, it will be found possible to use the cold-cathode tubes in some of the circuits given below for the power Grid-Glow Tubes. An instance of this is phase shift control.

POWER GRID-GLOW TUBES

An examination of the control characteristics of the various "Positive" and "Negative" control power Grid-Glow Tubes will immediately suggest applications. Resistance control characteristics of the KU-610 tube are given directly.

However, some experience has been gained with certain types of circuits which should be of very general use. Therefore, information is given in the following which will be of aid in making applications of these types.

PHASE-SHIFT CONTROL

An especially important use of the tubes is with what is generally termed "Phase-shift Control". This method permits of applying a continuously variable voltage to a D-C. circuit from an A-C. circuit in spite of the non-continuous control characteristics of the tubes themselves. However, the tubes have the inherent ability to rectify and also can be made conducting at any moment by means of the grids.

The variable voltage feature, then, is accomplished by chopping off, as it were, the desired fraction of each positive half wave as illustrated in Fig. 13 where the shaded portion represents the part of the A-C. voltage wave during which current is passed by the tube. The impetus given the current by each rectified wave can thus be varied through wide limits.

Suppose we consider, as applied to a Grid-Glow Tube, a cycle of line voltage Ep as shown in Figure 14. Let us plot, simultaneously with the positive half-cycle of this, the corresponding grid-bias potential U at which the tube will break down. (This characteristic may be taken directly from the characteristics shown in Figures 3,5 or 7 for various tubes). At any given value of Ep, a grid bias voltage with respect to cathode which is more positive than U will cause the tube to break down, when it will pass current until the point O is reached where Ep becomes less than the normal tube voltage drop, and the tube glow is extinguished.

Now if we superimpose upon the above figure a sinusodial "grid-bias" voltage of the line frequency, Figure 15, it will be seen that at some point P the grid potential will become more positive than the critical value and the tube will break down and pass current throughout the remainder of the voltage wave as shown shaded. It will be apparent that by suitable shift of this grid-bias voltage, practically all or none at all of the wave may be made use of.

Convenient methods of shifting this grid voltage, which lend themselves both to manual and to automatic methods of control are illustrated by the simple circuits shown in Figures 16 and 17.

In these circuits any of the factors R, L, or C may be used to control phase shift as illustrated by the vector diagram, Figure 18. In this the voltage A to B, Figure 16, is represented by the vector AB, the grid voltage by V_g, the resistance drop by IR and the condenser voltage by IXc. The vector diagram of Figure 17 is, of course, similar to Figure 18. Θ represents the angle of phase shift between grid and plate voltages. In a similar manner either a variable capacitance or a variable inductance can be employed for the control of phase shift.

Figures 19 and 20 show phase shift circuits for both single-wave and double-wave rectifier circuits.

It must be kept in mind that the voltage appearing across the load may play a noticeable part in the operation of phase shift circuits. With single-tube inductive circuits, the current will reduce to zero at some point between each positive half-cycle so that, at the time of breakdown, the tube voltage is sinusoidal as shown. However, with two-tube, or full-wave circuits, the inductance of the load may cause a voltage such that current persists in each tube until the cooperating tube is made conducting. Also, in feeding the armatures of D-C. shunt machines, the back-voltage of the machine is to be considered. Although such effects do not usually prove at all serious, it is thought well to make mention of them.

CONTACT CONTROL (USING TUBE AS RELAY)

Another very important and very general use of the Grid-Glow Tubes is where they are employed as simple relay devices. The closing of delicate contacts carrying very minute amounts of power may be used to control the tubes which in turn, may either actuate power contactors or handle the power directly in themselves. In addition, because of the rectifying property of the tubes, the power controlled by them may be in the form of either alternating or direct current as desired. In regard to speed of operation, entirely new possibilities are opened by the use of tubes as relays. The duration of power application may be reduced to one half cycle or even a fraction thereof by proper tube control with no harm resulting to the tubes. Such operation is, of course, entirely impractical with contactors of the ordinary types or even with motor driven rotating contacts.

An essential point to keep in mind is the use of the tubes for contact control, or in fact any other means of control, is that the grid bias must be kept sufficiently negative at all times when the tube is not desired to pass current. Suppose, in Figure 21, that Ep represents the positive half cycle of tube voltage and that Curve U represents the critical grid potential, which, if exceeded in the positive sense, will render the tube conducting. Then if a negative A-C. grid bias -Eg is applied, the tube does not pass current, while if zero bias or +Eg is applied, the tube will break down at P_1, or P_2 respectively.

Figure 22 shows a type of circuit suitable for control of various tubes by delicate contacts. Here the voltage across the contacts before closing, and the contact current after closing, must be at the lowest values possible since the former causes electrostatic attraction and the latter contact burning.

Figure 23 illustrates a type of circuit adaptable to spot welding and similar loads. In this circuit, the tubes are connected in parallel, but in reverse relation to one another so that alternating current can be controlled. The grid control features provided in Figure 23 are such that before the control contacts are closed the grid of each tube is negative in relation to its cathode, while the anode is positive, and after the contacts are closed the grid potential is reversed, or made positive, and the tubes become conducting. Figure 24 illustrates, by wave diagram, the manner of functioning of the tube control.

ORDERING INFORMATION

TUBES

All tubes should be ordered according to the type letter and number following it in Table 1.

AUXILIARY APPARATUS

SOCKETS

Industrial Socket 12.5 amp. rating S#766732
Industrial Socket 25 amp. rating S#793202
Recommended for KU-610, DKU-627, and DKI-620 as well as for larger tubes.

DKU-623 and DKI-625 mounting parts (See Fig. 2)
*Top------Coordinated Dwg. #7651887 GR.4
*Bottom---Coordinated Dwg. #7651887 GR.6

DKU-622 and DKI-624 mounting parts (See Fig. 2)
*Top------Coordinated Dwg. #7701336 GR.2
*Bottom---Coordinated Dwg. #7701336 GR.1

*Order from Chicopee Falls, Mass., by Dwg. No. as specified.

FILAMENT TRANSFORMERS

These have 115 volt, 60 cycle primaries provided with taps for ±10% to facilitate obtaining proper secondary voltage.

Secondary Voltage	Secondary Amperes	Insulated between wdgs. and to iron for:	Overall Size Inches	Style Number
2.5	14	2200 volts	4x3-1/8x3-1/4	793135
5.0	20	2200 volts	3-5/8x3-1/8x5-7/8	793136
5.0	40	2200 volts	3-1/8x5-7/8x4	793137

GRID BIAS OR PHASE CONTROL TRANSFORMER

115 or 230 volt, 60 cycle, 50 milliampere primary (winding center tapped).

115 or 230 volt, 50 milliampere secondary (winding center tapped).

Insulated between windings and to iron for 2200 volts.

Overall size - 2 x 2-1/2 x 2-3/4 inches. S#793134.

GRID RESISTORS

Megohms	Overall Size	Style Number
10	1-15/16 x 7/16 diameter	793114
4	1-15/16 x 7/16 diameter	793115
.1	1-15/16 x 7/16 diameter	793116
.05	1-15/16 x 7/16 diameter	793117

TYPE 10-K-1-A RELAY

Description and Rating	Overall Size	Style Number
Relay without coil.	4 x 3-1/2 x 2-1/2	437405-C
110 volt, 60 cycle coil which is suitable for operating with a KU-610 or larger Grid-Glow Tube.		472457

PLATE TRANSFORMER FOR DKU-618 GRID-GLOW TUBE

115 volt, 60 cycle primary.
440 volt secondary.
Overall size 2-1/8 x 2-3/4 x 2-1/4 S#695796-B

CONDENSERS

Capacity	Overall Size - Inches	Style Number
.00004 Mfd. Fixed	1-13/16 x 1-7/16 x 3/4	761813
.00008 Mfd. Fixed	1-13/16 x 1-7/16 x 3/4	761814
.00015 Mfd. Fixed	1-13/16 x 1-7/16 x 3/4	761815
.50 Mfd.	3-1/32 x 2-5/32 x 3/4	477424
10 to 100 MMfd. Variable		793281

TELEPHONE TYPE RELAYS AND AUXILIARY RELAY

Description	Overall Size - Inches	Style Number
Slow clapper type, time delay 1/8 second	4-3/4 x 1 x 1-3/4	695634

TELEPHONE TYPE RELAYS AND AUXILIARY RELAY (Cont'd.)

Description	Overall Size - Inches	Style Number
Fast clapper type, up to 600 operations per minute; for 60 cycle rectified current use condenser S#477424 across coil.	4-3/4 x 1 x 1-3/4	793166
Auxiliary relay for working with above telephone relays. Has 110 volt, 60 cycle, coil; 110 volt, 15 ampere, or 220 volt, 10 ampere contacts.		723094

Signed: J. W. Dawson, Eng.
January 4, 1932

Approved: D. L. Ulrey, Manager
Physics Division
Westinghouse Research Lab.

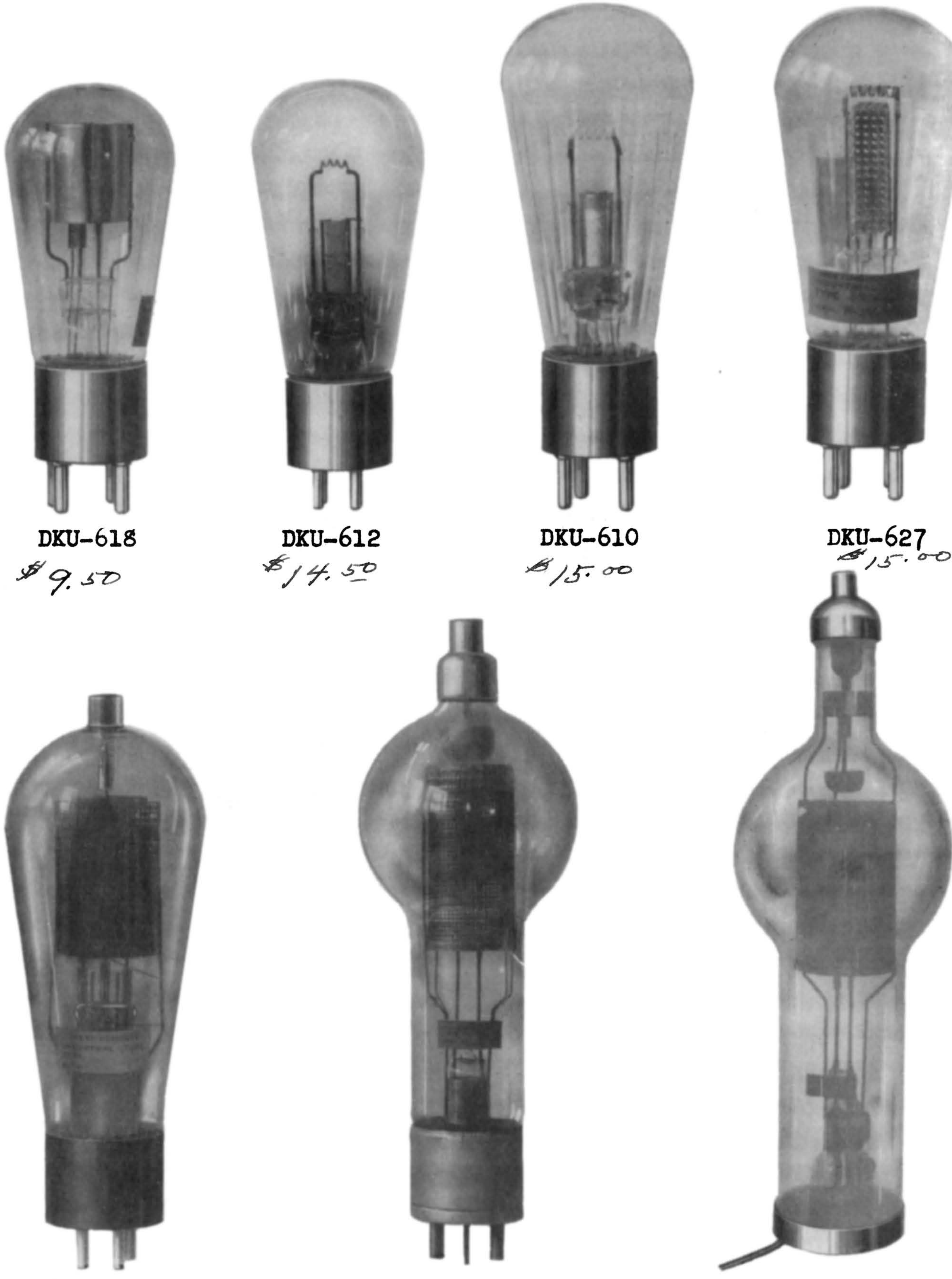
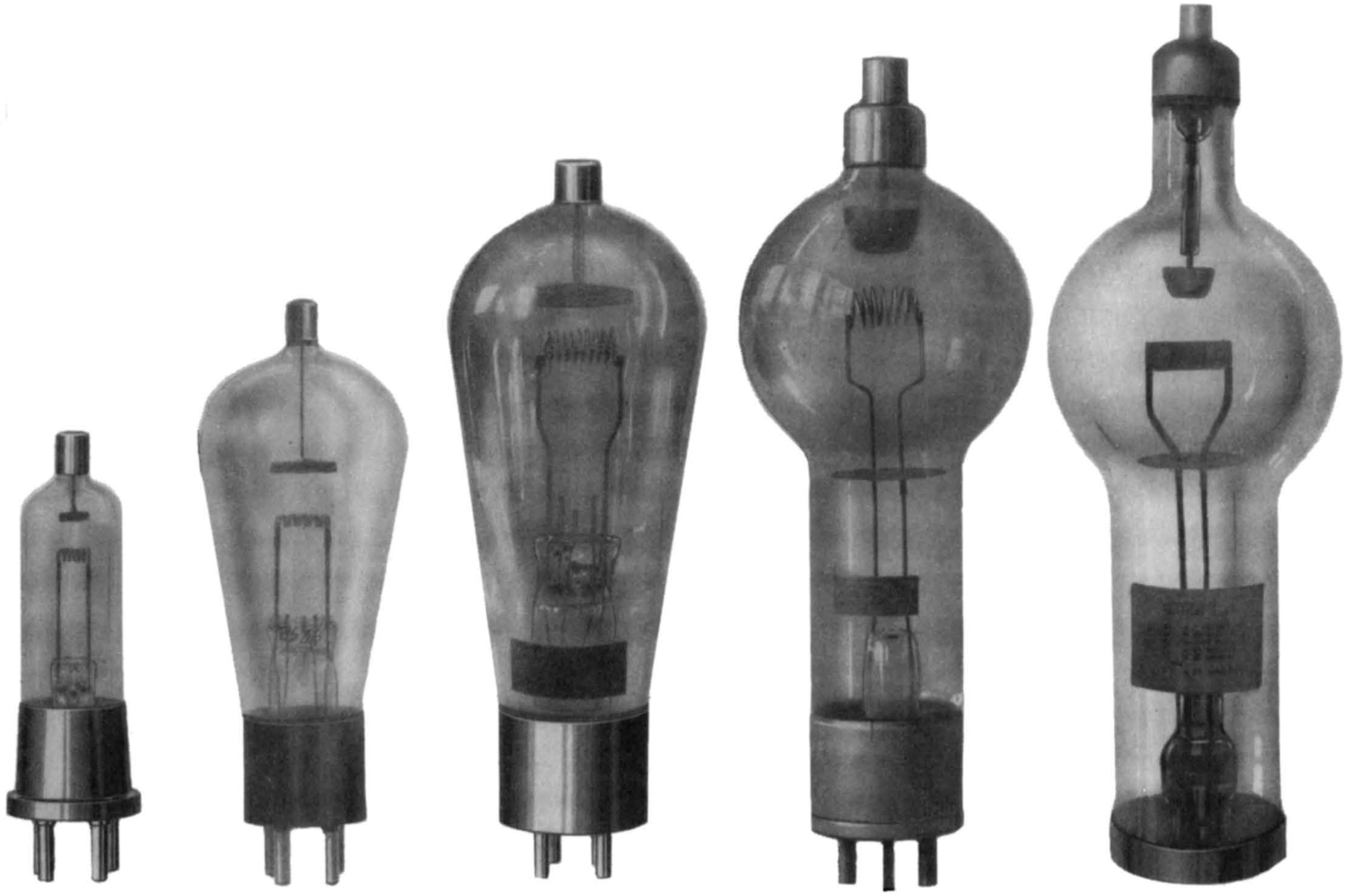


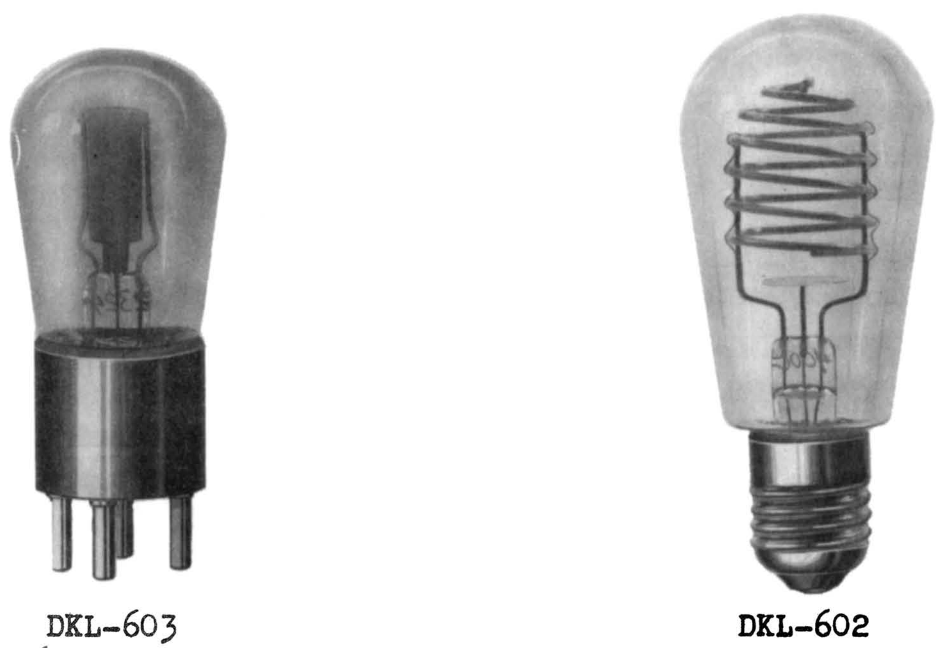
FIG.1a - GRID-GLOW TUBES

WRDL-2-22



DKI-605	DKI-626	DKI-620	DKI-625	DKI-624
15.00	$9.00	$15.50	$33.00	$51.00

FIG.1b - SINGLE-PHASE RECTIFIER



DKL-603	DKL-602
$12.50	9.00

FIG.1c - GLOW LAMPS

TABLE NO. I

AVAILABLE DEVELOPMENTAL & STANDARD GASEOUS DISCHARGE TUBES
GRID-GLOW TUBES - RECTIFIER TUBES - GLOW LAMPS

TUBE DESIGNATION		TUBE CONTENT	ANODE-CATHODE RATINGS					AVERAGE TUBE VOLTAGE DROP	CATHODE				TUBE DIMENSIONS		***** TUBE BASE
										FILAMENT					
TYPE NO.	DESCRIPTION		MAX. AVERAGE CURRENT IN AMPS.	*** T (SECS.)	MAX. CREST CURRENT IN AMPS.	RECOMMENDED R.M.S. VOLTAGE	MAX. CREST VOLTAGE		TYPE	VOLTAGE	CURRENT	HEATING TIME	OVERALL LENGTH INCHES	DIA. INCHES	
DKU-618	POSITIVE CONTROL GRID-GLOW TUBE	NEON GAS	0.015	—	.10	440****	640 F 800 r	170	COLD CYLINDER	—	—	—	5 1/2	2 1/8	411
DKU-612	" " " " "	"	0.10	10	.10	****	750 f 1500 r	22	OXIDE FIL	2.5	2.0	5 SEC.	5 1/2	2 1/8	411
* KU-610	" " " " "	"	0.40	10	.80	****	750 F 1500 r	22	" "	2.5	7.0	10 SEC.	6 1/2	2 7/16	411
DKU-627	NEGATIVE CONTROL GRID-GLOW TUBE	MERCURY VAPOR	0.64	30	1.00		1500	20	" "	2.5	6.0	10 "	6 1/2	2 7/16	411
** DKU-628	" " " " "	" "	4.00	30	6.00		5000		" "	5.0	11.0	40 "	8 1/2	3 1/4	412
DKU-623	" " " " "	" "	10.00	40	16.00		5000		" "	5.0	20.0	45 "	15	5	SEE FIG. #2
DKU-622	" " " " "	" "	25.00	30	40.00		5000		" "	5.0	40.0	2 MIN.	22	7/8	"
DKI-605	SINGLE PHASE RECTIFIER	" "	0.20	10	.30		5000		" "	2.5	2.0	5 SEC.	5	1 1/4	410
DKI-626	" " "	" "	0.64	30	1.00		1500	15	" "	2.5	6.0	10 "	6 1/2	2 7/16	411
DKI-620	" " "	" "	4.00	30	6.00		5000	15	" "	5.0	11.0	40 "	8 1/2	3 1/4	412
DKI-625	" " "	" "	10.00	40	16.00		5000	15	" "	5.0	20.0	45 "	15	5	SEE FIG. #2
DKI-624	" " "	" "	25.00	30	40.00		5000	15	" "	5.0	40.0	2 MIN.	22	7/8	"
DKL-602	SPIRAL CATHODE GLOW LAMP	NEON GAS	0.05	—	0.10	220	—		COLD SPIRAL	—	—	—	5 1/2	2 1/8	EDISON
DKL-603	POINT SOURCE GLOW LAMP	" "	0.05	—	0.10	220	—		COLD CRATER	—	—		5	1 13/16	400

* THIS TUBE IS STANDARD AS SIGNIFIED BY THE ABSENCE OF D (DEVELOPMENTAL) IN THE TYPE DESIGNATION

** FOR APPLICATIONS WHERE THE TEMPERATURE COEFFICIENT OF THE MERCURY VAPOR TYPE MAKES THE DKU-628 UNUSABLE, A NEON TUBE SIMILAR TO KU-610 IN CONSTRUCTION IS BEING DEVELOPED

*** SEE PAGE 9 FOR DEFINITION OF T

**** FIRST FIGURE IS THE FORWARD RATING AND SECOND FIGURE THE REVERSE RATING

***** SEE FIG. 2

T-51727

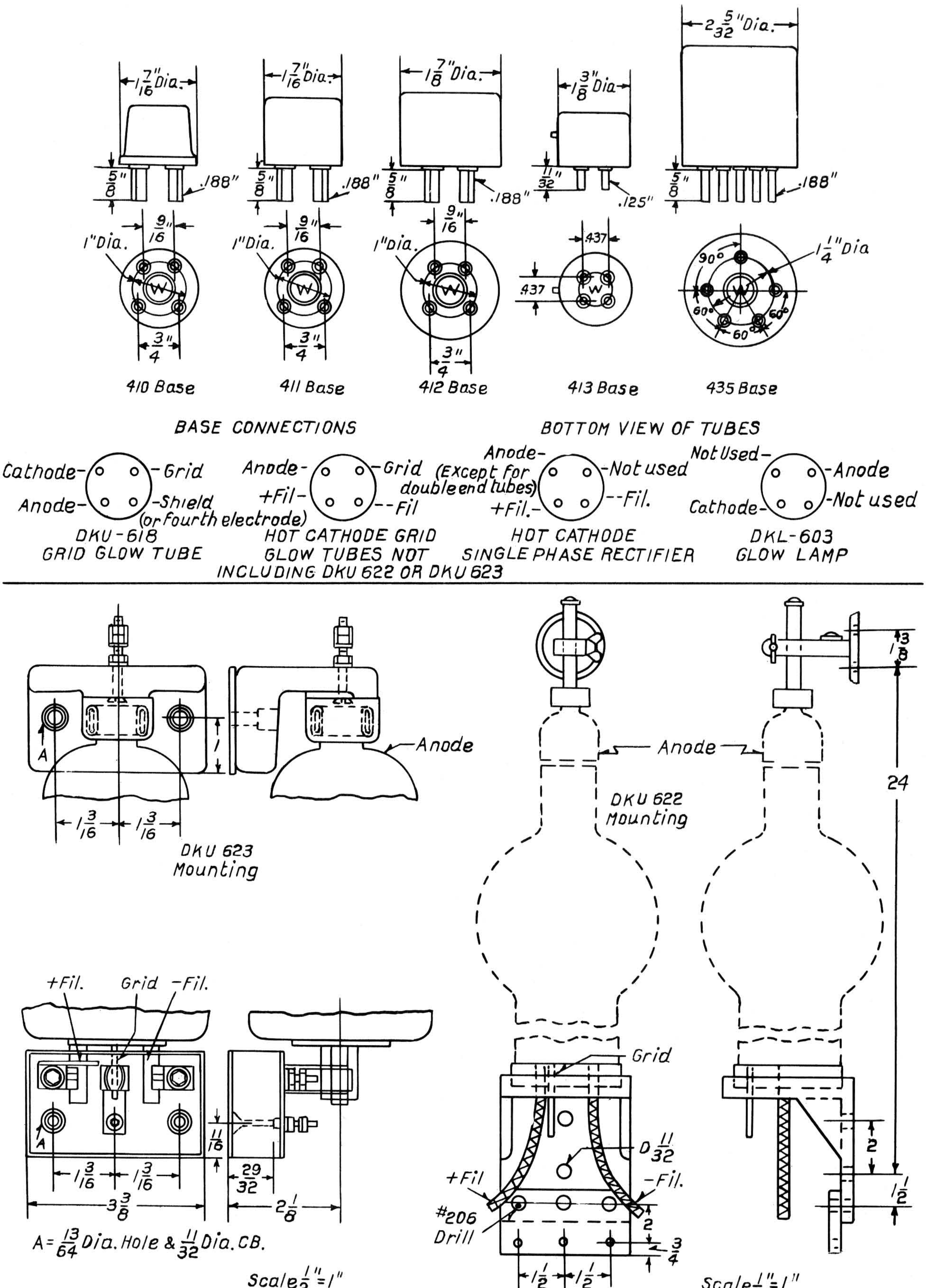


FIG. 2-DIMENSIONS OF TUBE BASES

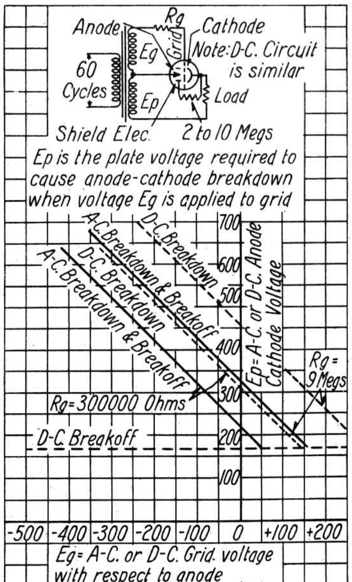


Fig. 3-DKU-618 Grid-Glow Tube Average A-C. and D-C. Characteristics

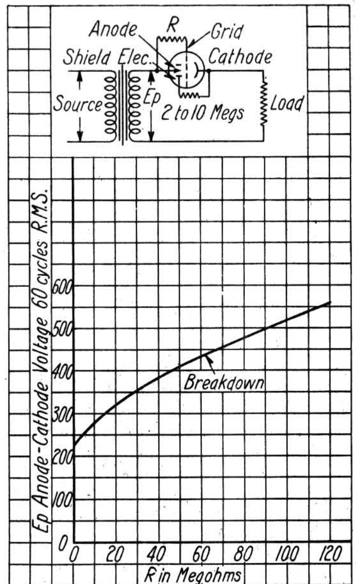


Fig. 4-DKU-618 Grid-Glow Tube Average Resistance Control Characteristics

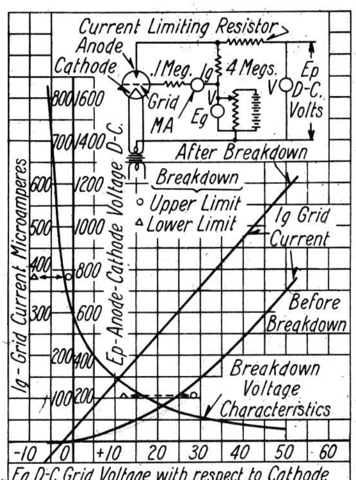


Fig. 5-KU-610 Grid-Glow Tube Average Characteristics (Typical for Positive Control Tubes)

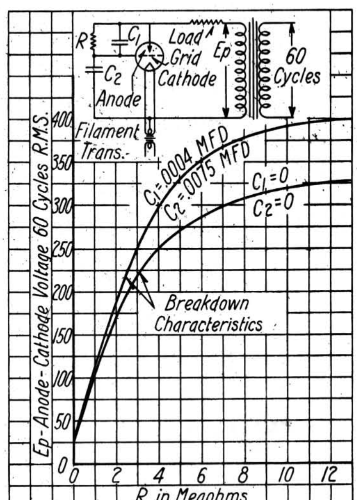


Fig. 6-KU-610 Grid-Glow Tube Voltage Resistance Control Characteristics

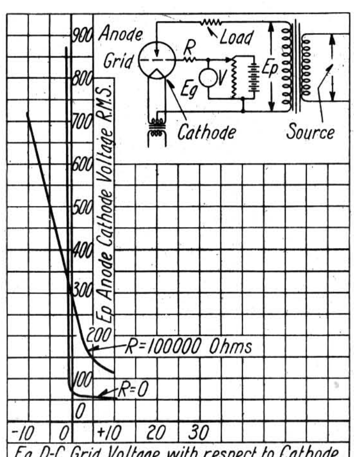


Fig. 7-DKU-622 Grid-Glow Tube Average Characteristics (Typical for Negative Control Tubes)

CIRCUITS FOR DKU 618 COLD CATHODE GRID GLOW TUBE

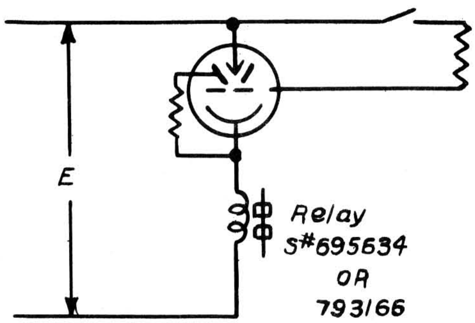


FIG. #8-SIMPLE CONTACT OR VARIABLE RES. CONTROL (SEE FIG. 4)

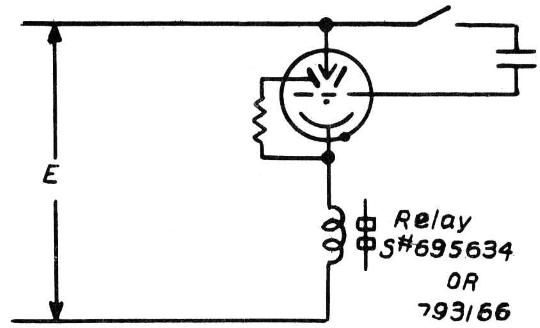


FIG. #9-SIMPLE CONTACT OR VARIABLE CAPACITY CONTROL

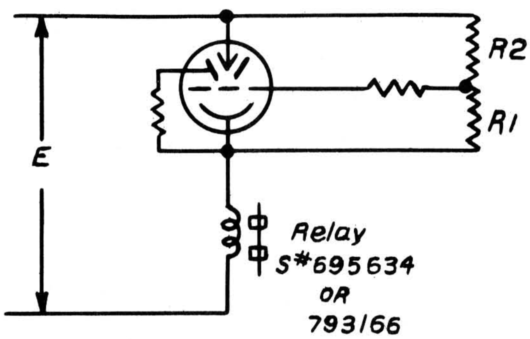


FIG. #10-RESISTANCE POTENTIOMETER CONTROL

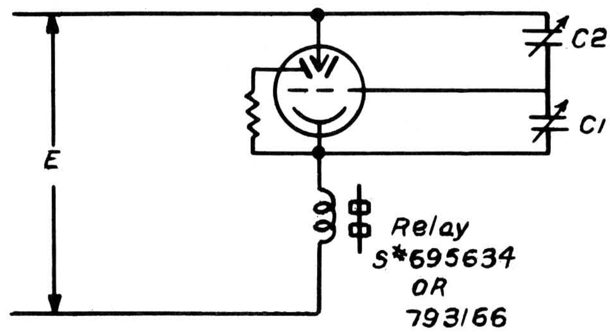


FIG. #11-CONDENSER POTENTIOMETER CONTROL

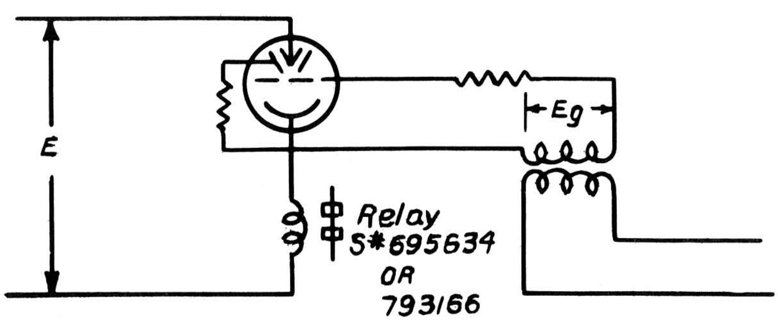


FIG. #12-EXTERNAL BIAS VOLTAGE CONTROL

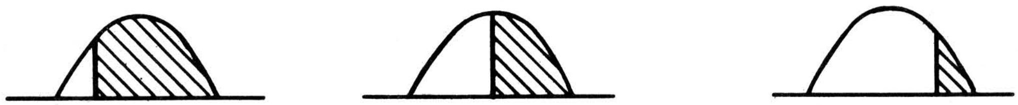


Fig. 13

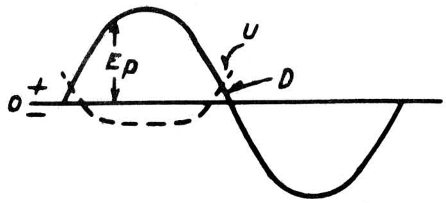


Fig 14

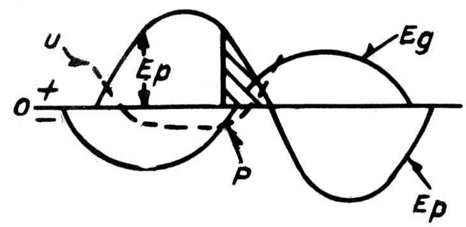


Fig. 15

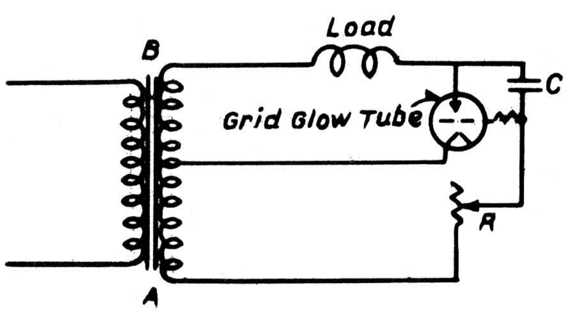


Fig. 16

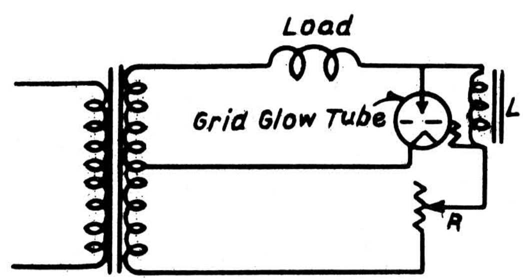


Fig. 17

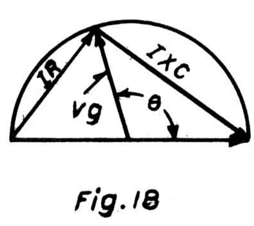


Fig. 18

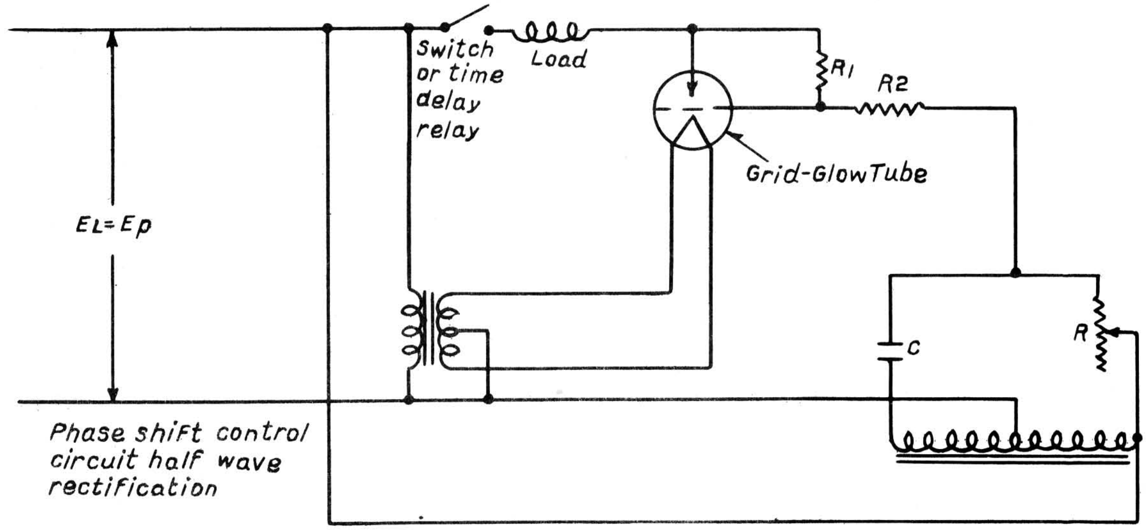
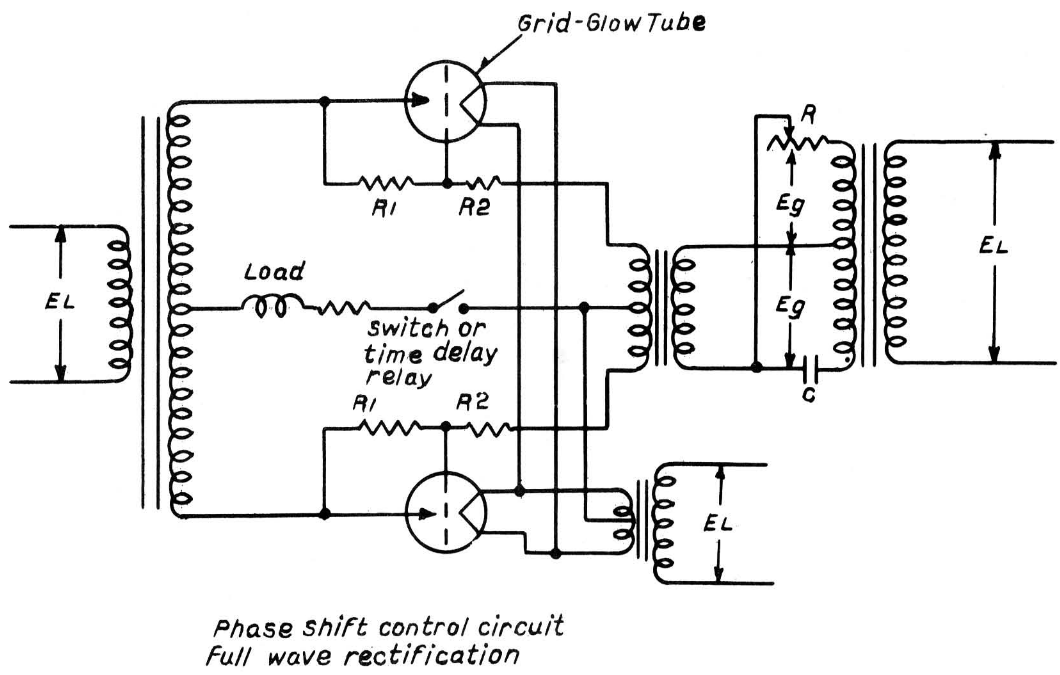


Fig. 19



Phase shift control circuit
full wave rectification

Fig. 20

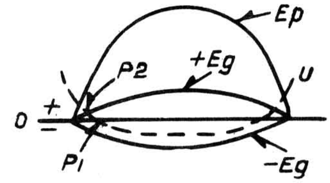


Fig. 21

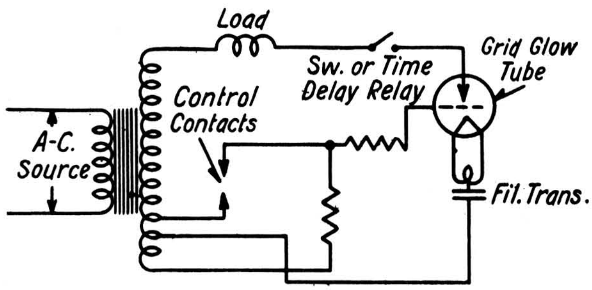


Fig. #22

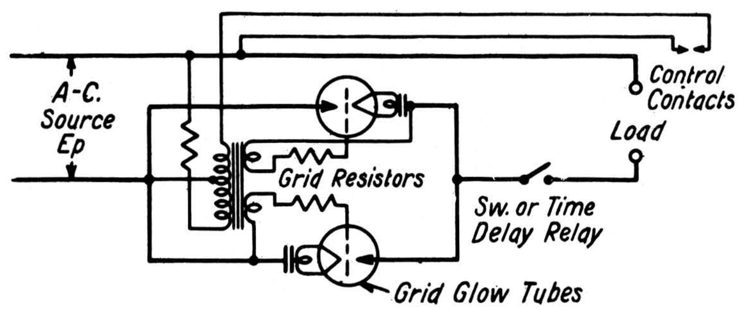


Fig. #23

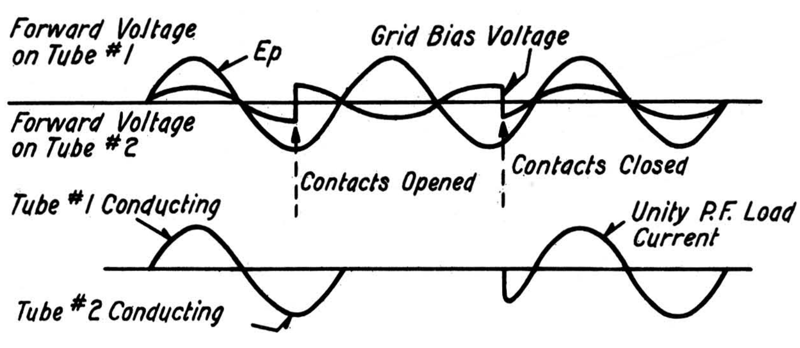


Fig. #24