Dec. 12, 1950 C. R. STEVENS 2,534,077

MULTIUNIT ELECTRON DISCHARGE TUBE

Filed March 21, 1947 3 Sheets-Sheet 1

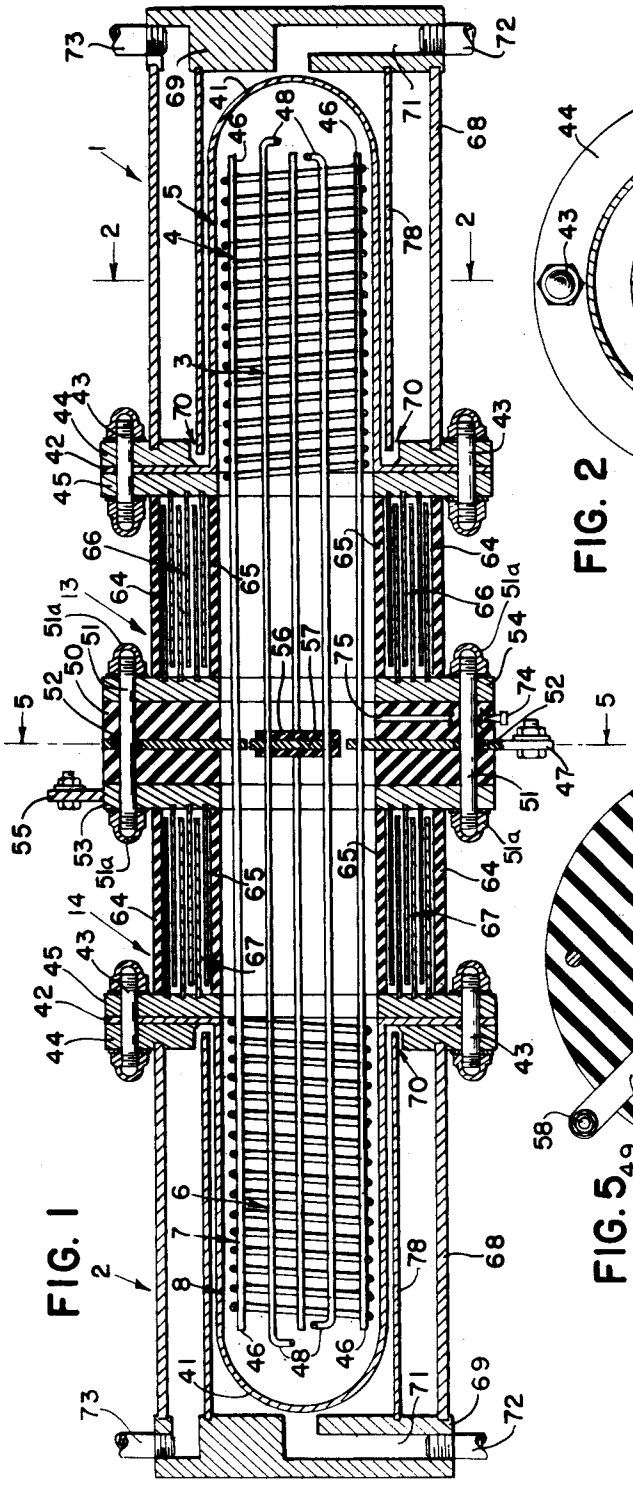


FIG. 1

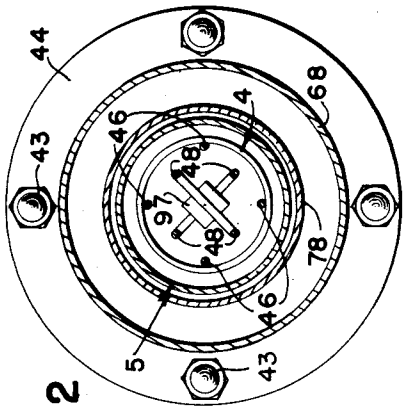


FIG. 2

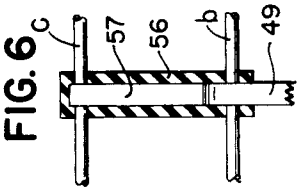


FIG. 6

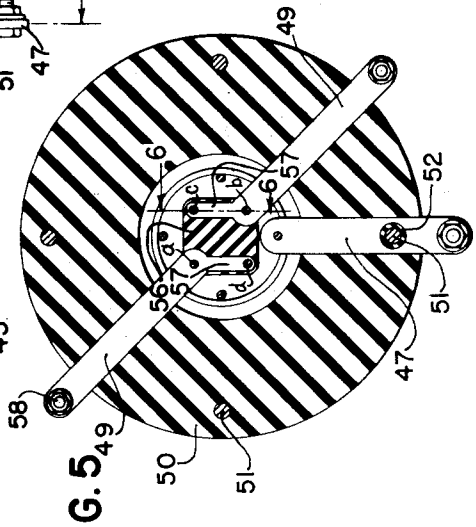


FIG. 5

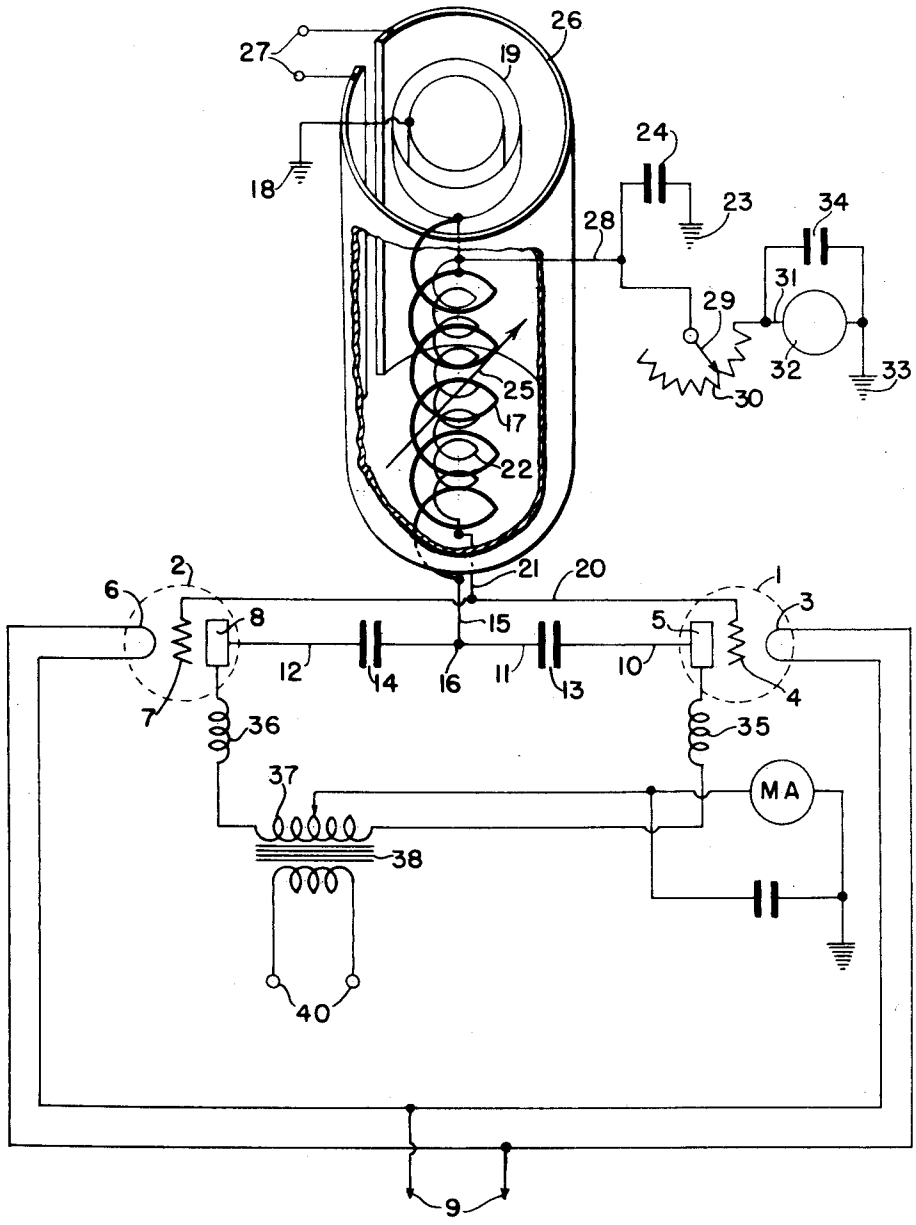
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FIG. 3

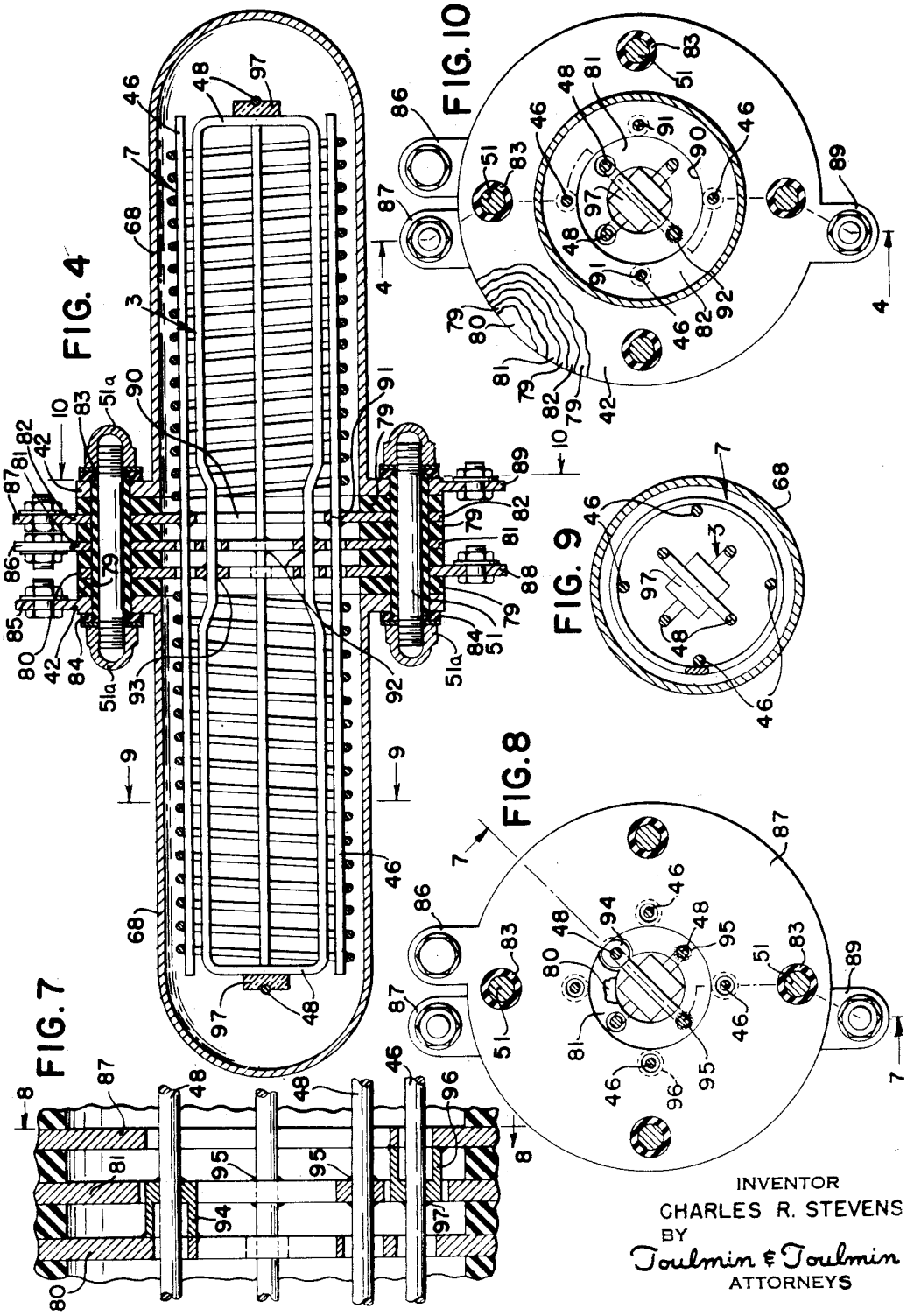


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Patented Dec. 12, 1950 2,534,077

UNITED STATES PATENT OFFICE

2,534,077

MULTIUNIT ELECTRON DISCHARGE TUBE

Charles R. Stevens, Toledo, Ohio, assignor, by mesne assignments, to Reconstruction Finance Corporation, Cleveland, Ohio, a corporation of the United States

Application March 21, 1947, Serial No. 736,233

12 Claims. (Cl. 250—27.5)

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The present invention relates to frequency translating systems including oscillation generating circuits, but more particularly to the thermionic tube apparatus employed in such systems and associated reactive elements.

In the art of frequency conversion or generation of oscillations, dealing with the translation of relatively high frequency current, symmetry of circuits and parts thereof is highly desirable. All causes of extraneous electrical disturbances must be avoided and tubes should be accurately matched and properly positioned, particularly when they have a balanced function within the system. Circuits of this character usually employ reactive elements such as condensers, inductances, etc., and it is necessary that these elements be symmetrically positioned with respect to the tubes. Heretofore, the positioning of these reactors was a matter of mere skill and judgment which might be the cause of variations in the frequency being translated or generated.

The primary object of the invention is to provide an improved tube unit for use in frequency translation circuits, the unit providing an accurate balance of the thermionic devices and their immediate associated reactive elements.

Another object is to provide improved tube apparatus for use in high frequency circuits and in which the elements of the tube or tubes are constrained to fixed positions which will promote the electrical balance of the associated circuits.

Still another object is to provide an improved combination of a tube or tubes together with a condenser reactance or reactances all parts of which including the electrodes of the tubes are so arranged with respect to one another that electrical balance within the associated circuit is effected without depending on the skill or judgment of the fabricator of the apparatus or of the operator in obtaining the balanced operating conditions.

In the case of large load apparatus involving thermionic tubes, the latter are usually of complicated design, expensive to make and assemble and in addition, difficult to take apart for inspection and replacement purposes. The problem is made even more difficult when double unit tubes are employed surrounded by water jackets for increasing the load carrying capacity.

Accordingly, another object of the invention is to provide tube apparatus for use in frequency translating systems carrying large loads, such apparatus being made of simple parts, readily assembled and disassembled, in fact, these parts

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may be made out of ordinary machined elements. In accordance with this object water jackets are provided about any one or all of the tubes in such manner that the jacket may also be assembled or disassembled from its tube unit and without affecting the ease with which the parts of the tube or tubes may be disassembled.

The above objects are attained in brief by providing a double tube unit in which the tubes are placed end to end but spaced apart to receive one or more of the reactive elements. The water jackets are so arranged and secured to the tubes in such manner that they may be readily added to or taken away from the tube structure, still leaving the facility of disassembling the tube and the reactive elements. The invention will be better understood when reference is made to the following description and the accompanying drawings, in which:

Figure 1 represents a longitudinal section of the entire tube and reactive element assembly.

Figure 2 is a cross sectional view taken along line 2—2 in Figure 1 and showing the electrode configuration and arrangement of the elements of the double tube unit.

Figure 3 represents a schematic view of a typical convertor and circuit in which the improved tube apparatus and associated reactive elements can be used to advantage.

Figure 4 is a longitudinal sectional view of a modified form of the improved double ended tube and one in which the intermediate condenser elements have been omitted, also the water jackets. The view is taken along line 4—4 in Fig. 10.

Figure 5 is a sectional view cutting across the middle portion of the tube shown in Figure 1 at the line 5—5.

Figure 6 is an enlarged cross sectional view of a detail taken along line 6—6 in Figure 5 and showing the manner in which the heavy cathode wires or rods are connected together.

Figure 7 is an enlarged fragmentary sectional view showing a modified structure for making connections with the cathode and grid elements from the exterior of the tube. This section is taken at the line 7—7 in Fig. 8.

Figure 8 represents a section taken along line 8—8 in Fig. 7 but in smaller size.

Figure 9 is a transverse section across one of the end tubes in Fig. 4 at the position 9—9.

Fig. 10 represents a view taken along line 10—10 in Figure 4.

In order to explain the character of the improved tube, a typical circuit will now be de-

scribed in which the tube offers special advantages. The system shown in Figure 3 has been disclosed and claimed in my co-pending application 677,448, filed June 18, 1946, and entitled "A Convertor." It was explained in the said application that the system employs a pair of multi-electrode thermionic tubes 1 and 2, vacuum, gas or vapor filled and in which the discharge is controllable by an electrostatically charged member. Within the tube 1 there is a cathode 3 which may be indirectly or directly heated, a control grid 4 and an anode 5. There are corresponding electrodes in the tube 2 and these electrodes have been given the characters 6, 7 and 8 respectively. The cathodes 3 and 6 may be connected in parallel to any suitable source of current, alternating or direct as indicated at 9. The two anodes are connected together through a high frequency circuit represented by the conductor 10, 11 and 12 and the interposed condensers 13 and 14. A lead 15 is taken from a tap 16 on the conductor 11 to a relative large vertically positioned tank coil 17 which is grounded at its upper end, as indicated at 18 through a condenser 19. The grids 4, 7 are connected together by an equipotential conductor 20 from which a lead 21 is taken to a second coil 22, also preferably positioned in a vertical position and contained within the large coil 17. The coil 22 is grounded as indicated at 23 through a condenser 24.

The mutual inductance between the coils 17 and 22 can be adjusted in any suitable manner as indicated by the arrow 25. A work circuit 26 of preferably one turn or less is in inductive relation with the coils 17, 22 in order to constitute a high frequency voltage step-down transformer to provide low voltage, high frequency energy at the terminals 27 of which one may be grounded if desired. A conductor 28 is connected to the upper end of the grid coil 22 and connects with the movable tap 29 of the variable resistor 30. A conductor 31 is connected between one end of the resistor 30 and a milliammeter 32 to ground 33. A condenser 34 of suitable capacity may be shunted across the meter.

High frequency chokes 35, 36 are connected respectively to each of the anodes 5, 8, the opposite ends of the chokes being connected together with a secondary coil 37 of a voltage step-up transformer 38. The latter is supplied with current, preferably a 60 cycle outlet as indicated at 40.

A circuit as described is very useful in converting the relative low frequency current of the supply mains 40 to considerably higher frequency available at the output terminals 27. The frequency conversion factor is determined by the mutual inductance between coil 17 and 22. It has also been explained that the partial or unit turn 26 which is inductively related to the coils 17, 22 provides a voltage step-down effect so that the voltage of the high frequency current available at the terminals 27 is not unreasonably high and may be adjusted to any desired value. Thus the currents translated within the oscillatory circuit including the coils 17, 22 and also the tubes 1 and 2 and condenser 19, are relatively large but the attendant voltage is relatively low so that insulation difficulties are reduced as is also the possibility of initiating an uncontrolled glow or arc discharge in the tubes 1 and 2.

In dealing with large current values, the manner of properly positioning the various parts of the circuit including the coils 17, 22, the condenser 19 and the electrodes within the tubes 1 and 2 is very important. The coils 17 and 22 are preferably arranged in a vertical position, and the condenser 19 which may comprise a pair of concentrically arranged cylinders is positioned directly above the upper edge of the partial turn 26, the latter being also constituted of a split cylinder. The axis of the cylinders 19 is preferably in line with the axis of the two coils 22, 17 and of the single turn cylinder 26 so that all of these elements present a symmetrical arrangement. The condenser 24 is preferably positioned above the cylinder 26 and at the side of the cylinder away from the slot.

The tubes 1 and 2 are preferably equidistantly spaced on opposite sides of the coils. The conductors 10, 11, 12 and 20 extend preferably in a horizontal direction, i. e. at right angles to the axis of the coils 22 and 17 so that the condensers to which these conductors are connected are positioned accordingly.

It is highly desirable in order to eliminate any extraneous electrical disturbances due to unbalance of the system that the electrodes within the tubes 1, 2 be positioned in strictly symmetrical relation with respect to one another and it is equally important that the condensers 13 and 14 be equidistantly positioned from the respective tubes and the contained elements.

The present invention is directed more especially to apparatus including the tube structures 1 and 2, also the condensers 13 and 14 which will accurately position the elements of these tubes and the condensers symmetrically in place, at the same time permitting ready replacement of any of the elements without affecting this symmetrical arrangement of the parts. Referring now to Figure 1, the anodes 5 and 8 are shown as cylindrical members closed at the extreme ends as indicated at 41 by hemispherical portions and terminating at their inner ends in an outwardly extending flange 42. These flange portions are clamped by means of bolts 43 between rings 44 and 45 both of which are preferably made of metal. Each ring 45 has an inner diameter approximately the same as the inner diameter of the anode.

The grids 4 and 7 are constituted of four or more heavy stay rods 46 about which the respective grid wires are wound to a cylindrical shape. As can be seen in Figure 1 the stay rods of the two respective grids are integrally joined together because both grids are at the same potential in the exemplary circuit shown in Figure 3. The grids are intended to receive heavy control currents and a bar 47 of substantial size may be brought out to the exterior.

The filaments 3 and 6 or other cathode structure shown in the circuit of Figure 3 are at the same relative potential with respect to one another so that these elements can be connected together. Thus in the improved tube, the cathode may comprise a pair of elongate U-shaped heavy wires or rods 48 joined together at the center. Leading-in conductors 49 may be taken from opposite sides of the filament or cathode member, these conductors being positioned remote from one another, preferably at diametrally opposite positions. The metal out of which the anode, grid and cathode are made may be relatively inexpensive and easily worked. The cathode may, if desired, have an active electron admitting coating such as an oxide or alkaline earth, but in general, I prefer to employ metal in its bare state such as nickel.

One of the most important problems in tubes

of this type is to maintain symmetry of position between the various electrodes. In the tube structure described which in effect requires the two tubes to be rigidly maintained in an end-to-end position, it is impossible to get the electrodes out of line with one another. However, extreme care must be exercised in applying the leading-in conductors 47 and 49 to connect with the respective electrodes at the exact mid-electrical position. A seal by which this can be accomplished is shown in Figure 5. A pair of abutting heavy discs 50 of insulating and slightly flexible material, such as hard rubber, is provided, these discs having openings therethrough to receive the bolts 51. One of the discs is preferably thicker than the other and is provided with three radially extending grooves which tightly receive the bar conductors 49, 47. At the outer surfaces of the discs, there is a pair of metal plates 53, 54, these plates being clamped together by bolts 51 at the nuts 51*a*. This clamping effect is sufficient to squeeze the discs slightly together, causing any minute voids between the conductors 47, 49 and the grooves of the discs to close and become sufficiently hermetically tight to permit the tube to operate without appreciable ionization. One of the bolts is received by a sleeve 52 of insulating material where it passes through the grid conductor. If desired, the conductor 47 can be moved entirely away from the position of the bolt so as to minimize electrical disturbances. A heavy conductor 55 is secured to one of the plates and it will be noted that the same structure is effectively connected to the other of the plates by the bolts 51.

Referring more particularly to Figures 2 and 5, the cathode rods 48 extend from the mid-point of the tube toward each end as explained hereinbefore and comprise a pair of U-shaped rods mounted 90° apart with respect to one another. One of these U-shaped rods is indicated at *a* in Figure 5 and the opposite leg of that rod is indicated by the mark *b*. The U-shaped rod disposed at 90° is indicated at the letters *c* and *d* respectively. These rods support a heavy plastic plate 56 and the latter is suspended exactly at the mid-point of all of the cathode rods. Extending along one edge of the plate 56 there is a conducting strip 57 which interconnects two of the corresponding legs of the angularly disposed cathode portions and these two legs are then brought out through one of the metal strips 49 which terminates in a terminal 58. Thus, the two U-shaped filament members at each end of the tube are connected in parallel through the strips 57, and inasmuch as the members at both ends of the tube constitute extensions of one another, the conductors 49, are in fact connected across the filaments at the mid-point of the cathode structure as a whole.

Thus, by properly positioning the various conductors radially with respect to the insulating discs 50, I am able to make contact at the exact mid-electrical position wtih respect to the cathode structure and also with respect to the control grid structure of the double ended tube.

The plates 53, 54 (Fig. 1) are separated from the plates 45 on each side thereof by concentrically arranged insulating cylinders 64, 65. These cylinders are secured edgewise to the plates against which they contact in any suitable manner. The adjacent faces of the plates 45 and 53, also the adjacent faces of the plates 54 and 45 are provided with circular grooves for rigidly receiving a plurality of circular metal plates indicated at 66 forming a plurality of condensers. One set (3 as illustrated) of the plates are attached to the left hand plate 54 and the opposite set of plates, forming the other side of the condenser are attached to the plate 45. Likewise, there is one set of plates of the adjacent condenser 67 secured to the plate 45 and the opposite set of plates of the same condenser are secured to the plate 53. It is apparent that the plates 66 and 67 are held in rigid concentric spaced relationship by the grooves formed in the plates to which they are attached and the connection to the condenser 66 can be made through the left hand plate 54 and the plate 45 while the opposite sides of the condenser 67 are electrically connected through plate 45 and the right hand plate 53. It is further evident that a part of the plates 66, 67 are electrically connected to the respective anodes 5 and 8 while the intermediate plates of the condensers are connected together through the plates 53, 54, the bolts 51 and the common conductor 55.

In the structure described hereinbefore the anodes, the grids, the cathodes, also the plates of the condensers 66, 67 are all arranged in rectilinear relation and the relative distances between the condensers and the various tube elements are absolutely fixed. If electrical symmetry and balance have been effected between these various electrodes and condensers by proper design, keeping in mind the various requirements of the circuit as typified in Figure 3 the same symmetry and balance is always obtainable within the structure shown in Figure 1 on account of the rigidity of the parts and of their relative positions. No leading-in conductor is necessary to connect the condensers together nor to connect them with the anodes within the tube sections, and only one leading-in conductor is necessary for the two grids as they have both been wound on the same set of stay wires. The only connections necessary to bring out from the tube are the conductors 49 which may be connected to the mains at 9 (Figure 3), conductor 47 which may be connected in parallel to the lower end of the inner coil 22, and conductor 55 which may be connected to the lower end of the outer coil 17.

In order to provide for a water cooling effect, thereby to permit the anode to dissipate greater amounts of heat and translate a larger high frequency load, I may provide a water jacket about each of the respective anodes. Metal cylinders 68 are received at their inner edges in grooves formed in the plates 44. These cylinders may be welded if desired within these grooves. At their outer edges or ends, the cylinders are received by grooves formed in a heavy metal plate 69 and the latter may be welded to the cylinders. Circular partitions 78 are also contained within grooves in the respective plates 69. These partitions have a diameter slightly larger than the outer diameter of the anodes and extend almost the entire length of the anodes to leave a small annular passageway indicated at 70 between the inner edges of the partition and the flanges 42 of the anodes. The rings 44 have an interior diameter sufficiently large as to clear the partitions whereby an annular space of fairly small size is provided between each anode and immediately adjacent surface of the partition, this space extending around the inner edge of each partition. Passageways 71 extend radially of the plate 69 and open into the space between each anode and plate. Fluid under pressure may be supplied through a pipe 72 to the passageway. It is ob-

vious that this fluid passes as a thin layer along the outer surface of each anode and then around the inner edge of each partition to fill up the space between the partition and the outer cylinder 68. The fluid is withdrawn from this space through a passageway and an outlet pipe 73.

It will be noted that the cylinders 68 and 78 are in rectangular alignment with the plates of the condensers 66, 67, also with the electrodes forming the tubes, and further, these cylinders are rigidly spaced with respect to the said elements. Consequently, the partitions of the water jacket in no way affect any electrical balance or symmetry of the electrical active portions of the structure.

It is also evident that the various parts of this structure can be readily assembled and disassembled or any particular part can be removed by simply loosening any one set of bolts 43, 51. It is simply necessary when taking the structure apart and inspecting or replacing any of the parts to re-evacuate the interior of the anodes at the plug 74. An evacuating passageway 75 extends radially through the disc 50 to the interior of the tube. When the tube has been evacuated the plug 74 can be inserted or the passageway 75 can be sealed off in any suitable and well-known manner.

If desired, an inert gas such as nitrogen, argon or helium may be introduced within the tube interior. It will be understood that the character of the circuit shown in Figure 3 is such that the grids 4, 7 must exercise a continuous control over each entire half cycle of the alternating voltage applied at the supply line 40 and for that reason the gas pressure, in case gas is used, should be such as not to permit a cumulative positive ion discharge between the electrodes. However, it will be understood that for other uses it may be desirable to have the grids 4, 7 act as an electrostatic trigger for initiating an arc or glow discharge and using, if desired, the well-known phase or voltage magnitude control of the output current.

It is generally unnecessary that the various parts of the tubes including the anodes should be denuded of gas prior or during evacuation because the voltages applied between the cathodes and anodes are usually too small to produce an excessive heat radiating discharge and furthermore the anodes are maintained at a relative low temperature by the surrounding water jackets.

From the foregoing it is evident I have disclosed a combined double ended tube and condensers which can be employed for the elements 1, 2, 13 and 14 in the system shown in Figure 3 and in which the parts of the tube and condensers can be readily inspected and replaced if desired by simply loosening an ordinary nut or an ordinary bolt. When the parts are assembled and properly tightened they will assume their positions accurately with respect to one another in order to maintain the electrical balance and symmetry in such circuits in which this electrical characteristic is highly desirable.

Instead of adapting my invention to an end to end tube structure in which the tube elements are spaced by a split condenser, it is apparent that the condenser could be eliminated and the tubes brought directly in contact with one another, but with interposed insulation, if necessary. Such an arrangement has been shown in Figure 4 and the parts of this tube have been given the same reference characters as the corresponding parts of the tube shown and described in connection with Figure 1.

The cathodes 43 in the modified structure are constituted of two pairs of U-shaped members at both ends of the combined tube structure similar to the arrangement shown and described in connection with Figure 2. However, the leading-in conductors for these cathode members are brought out from the envelope in a manner different from that shown and described in Figure 1. The anode flanges are separated from one another by means of alternate rings of insulating and metallic character. The insulating rings may be constituted of hard rubber or fiber and are indicated by the reference character 79. The interposed metal rings which may be formed of a good conducting material such as copper are designated 80, 81 and 82 respectively. All of these rings are peripherally complete and a plurality of openings, four as shown may be provided in each of the rings to receive the bolt 51 which are contained within an insulating sleeve 83. Washers 84 of insulating material may be interposed between nuts 51*a* and the anode flanges 42 so that the bolts and the nuts are completely insulated from the metal rings. Extensions 85, 86, 87, 88 and 89 are provided on the left hand anode flange, the ring 81, the ring 82, the ring 80 and the right hand flange 42 respectively. These extensions carry terminal bolts or nuts. The right hand ring 82 is provided with a large central opening indicated at 90 which clears the cathode structure 3 and in addition there are four equidistantly spaced openings indicated at 91 for snugly receiving the rods 7 of the grid and to which these rods are welded or soldered as indicated on the drawings. Thus the terminal extension 87 constitutes a connection to the grid 7 and this terminal and the associated metal connections including the ring 82 constitutes a conductor adapted to receive large control currents. The intermediate ring 81 has a number of openings therein, some of which are sufficiently large to clear the grid longitudinals 7 and also one side of the filament longitudinals 3 but other of the openings are of a size as snugly to receive the opposite side of the cathode longitudinals to which the latter are connected by a weld or solder. This connection is indicated at 92. Thus the terminal extension 86 constitutes one side of the cathode structure which, as explained hereinbefore is made up of two pairs of U-shaped members at each end of the tube and the length of which are connected in parallel.

The ring 80 as in the case of the ring 81 has various openings therein to clear the grid longitudinals 7 and also to clear the side of the filament to which the ring 81 is connected, but there are other openings which snugly receive the remaining side of the filament structure to which connection is made by a weld or solder and indicated at 93. It is apparent, therefore, that the terminal extension 88 constitutes the other and remaining side of the filament so that the cathode energizing circuit is connected across the terminals 86 and 88. The remaining terminal extensions 85 and 89 are taken from each of the anode flanges 42 so that connections to all of the active elements of the double-ended tube shown in Figure 4 are provided. If desired, the terminal extensions 86 and 87 may be positioned out of line with one another as indicated in Figure 10 so as to space these terminals a sufficient distance from one another and thereby

facilitate the making and breaking of contact to the external circuits.

It will be noted that the connections between the ring 82 and the grid, also between the rings 80, 81, and the opposite sides of the filament are spaced from one another within the tube and are not connected at the exact center of their respective elements. However, the distances between these connections are so small compared to the extreme lengths of the elements of the tube that all three rings 80, 81 and 82 are, in effect, connected substantially at the electrical center of all of the elements.

As in the case of the structure shown in Figure 1 when the nuts 51a are tightened, a slight squeezing effect is exerted on the insulating rings 79, particularly as they are made of a flexible material such as hard rubber. This pressure should be such as to assure a tight joint between all of the various rings and between the rings and the anode flanges 42. Thus the tube shown in Figure 4 is adapted to operate under fairly high vacuum conditions if desired or inert gases may be admitted to facilitate current flow, with or without cumulative ionization effect. It will be noted that the tube structure shown in Figure 4 differs from that disclosed in Figure 1, not only in the elimination of the centrally disposed condensers and the water jackets but also in the manner in which connections are taken from the electrodes within the tube to the exterior. By providing the peripherally complete metal rings 80, 81 and 82 substantially hermetic joints can be obtained between the alternate insulating and metal rings when the nuts 51a are tightened. There are no grooves in the insulating rings 79 to receive the leading-in conductors and therefore no voids to eliminate when pressure is applied at the bolts. It is obvious that if desired, the two anodes in Figure 4 may be electrically connected together, by simply running a conductor from the extensions 85, 89 or by removing the insulating washer 84 to permit the bolt 51 to constitute the interconnecting conductor. When such connections are made, the tube units would operate as a single electrical member for providing the function of translating abnormally large currents within the combined unit tube.

It was explained in connection with Figure 4 that the cathode and grid rings 80 to 82 made connection to their respective electrodes in the proximity of the electrical center, thus maintaining electrical balance between the elements of the tubes when the latter are connected to highly sensitive circuits. However, in Figure 7 I have shown a structure by which the connections between the various cathode and grid conductors and their respective electrodes can be made at the exact electrical center. The cathode conductor ring 80 in this figure is provided with a series of openings through which all of the internal electrodes pass with sufficient clearance. But a hollow boss 94 is welded or otherwise secured to the ring 80 about one of the filament conductors 48, a weld or a soldered joint being applied to the end of the boss and the conductor at the exact physical anl electrical center of the tube. The boss is hollowed out on the inside so as to clear the filament conductor except at the position where connection is made. It will be noted that the physical and electrical center of the tube coincides with the cathode ring 81. The ring 80 is also provided with a second boss (not shown in Figure 7) by which the ring 80 is connected in a manner similar to that shown in Figure 7 but to the corresponding filament conductor of the other cathode structure. Thus the ring 80 serves, in effect, not only as a leading-in conductor for one side of the combined cathode structure but also as a connector to take the place of one of the strips 57 shown in Figure 5.

It will be noted that the cathode ring 81 is positioned at the exact electrical and physical center of the electrode structure as a whole within the tube so that the connections between the filament ring 80 and its portions of the cathode structure are made in line with the cathode ring 81 as shown in the figure. This ring 81 is provided with openings to clear all of the electrodes including the bosses 94, 95. However, the openings through which the two conductors 48 representing the other side of the cathode circuit pass receives these conductors snugly and a connection, weld or solder, is made between the ring 81 and these two conductors as indicated at 95. As in the case of the ring 80, the ring 81 takes the place of one of the strips 57 (Figure 5) in connecting the corresponding legs of the cathode structure together.

The grid ring 87 is also provided with a boss 96 which extends to the left and surrounds the grid conductor 46. A connection indicated at 97 is made between the left hand surface of the boss 96 and its conductor 46 at the exact electrical and physical center of the electrode structure, i. e., in line with the cathode ring 81. If desired, a second boss 96 may project from the ring 87 and positioned diametrally opposite from the first boss in order to provide two oppositely positioned connections between the ring 87 and opposite sides of the unipotential grid 46.

As in the case of the arrangement shown in Figure 1, the structures illustrated in Figures 4 and 7 also preclude the slightest misalignment between any of the parts of the tube, particularly when operating these tubes and circuits of the highly balanced type, an example of which was described in connection with Figure 3. While, I have not indicated the use of a water jacket surrounding the envelopes of the tube shown in Figure 4 and its modification in Figure 7, it will be understood that if desired, such jackets may be employed, depending upon the amount of the currents that it is desired for the tubes to handle.

It will be noted in Figures 4 and 9 that each U-shaped cathode rod element is positioned within space bounded by the control grid stay rods so that the general construction is strictly symmetrical. In Figure 4 one of the U-shaped cathode members 48 is provided with an insulator 97 having a slot for receiving the lower inter-connecting leg of the other U-shaped cathode member. In this manner the two U-shaped cathode portions at each end of the tube are secured precisely at 90° with respect to one another.

While I have shown and described my improved double-ended tube with respect to Figures 1, 4 and 7 as employing a single control grid which extends throughout the length of both anodes, it will be understood that if desired the control grid stay wires can be separated by an insulating element in order that the grids can function electrically independent of one another as for example in the case of a "push pull" circuit. In this case separate leading-in conductors (not shown) would be taken from each half of the control grids, and heavy circular plates 50 or the rings 80, 81, 82 may still be used for bringing out

the various conductors to the exterior from the ends of the double unit grid. Obviously, if desired the cathodes 43 can also be split mid-way of their length and separate conductors or metal rings taken to the exterior of the tube. It will be still further evident that when the anodes are electrically connected through the metal bolts 51 as shown in Figure 4 with the washers 84 removed and the grids and cathodes constitute integral members throughout the lengths of both anodes, the tube units are in effect connected in parallel and therefore give twice the capacity of one tube unit in translating the current. The structure shown in Figure 4 has all of the advantages of that described in Figure 1 from the standpoints of being easily made from ordinary machinable metal and readily assembled and disassembled since the assembly operation consists mainly in applying the bolts 51.

It is further apparent that instead of employing only double unit tubes, I may provide three or more anode sections with a corresponding increase in length of the contained electrodes. Each anode section would be provided with connecting flanges and the two end sections would have spherical terminating portions as shown in Figures 1 and 4. The various grid and cathode elements could be either integrally joined as shown in these two figures or could be physically and electrically separated, and leading-in conductors in the form of metal strips (Figure 5) or metal rings (Figure 4) brought out at each joint between the anode sections for connecting into any type of electrical circuit. In fact, the only limit to which the electrodes can extend is simply one of a practical limit, with the assurance that all of the elements will be maintained in fairly accurate alignment, because I have found that the joints between the leading-in conductors, the metal rings and the anode flanges can be made sufficiently tight by bolts 51 as to prevent the admission of any appreciable amounts of air. Thus, tubes of this character can be operated by a continuous control of the grid or grids and, if desired, inert gas of any suitable and well known type may be introduced to facilitate the conduction of current.

It will be understood that various modifications and arrangements in structure could be made without departing from the spirit of my invention and, accordingly, I desire to comprehend such modifications and substitutions of equivalents as may be considered to come within the scope of the appended claims.

Having thus fully described my invention, what I claim as new and desire to secure by Letters Patent, is:

1. A multi-unit tube, each unit comprising a cathode, a control grid and an external anode open at its base and closed at the opposite end, the anodes of the unit being flanged at their bases the flanges being detachably connected in fixed relation and the open ends of the anodes brought into strict rectilinear alignment, the grids of the unit being constituted of a plurality of stay rods over which the grid wires are wound, said stay rods extending integrally throughout the length of the interior of the combined anodes.

2. A multi-unit tube, each unit comprising a cathode, a control grid and an external anode having closed and open ends respectively, the control grid and cathode being contained within the respective anodes, flanges provided at the open ends of the anodes, means secured to the flanges for detachably maintaining the anodes in strict rectilinear alignment with the open ends in opposed relation, the control grid and cathode being constituted of integral elements which extend throughout the length of the interior of the combined anodes and leading-in conductors taken from the control grid and cathode at a position intermediate the flanged ends of the anodes.

3. A multi-unit tube, each unit comprising a cathode, a control grid and an anode, said anodes having flanges which extend exterior of the tube, and means for detachably securing said flanges together to bring the anodes in an end to end opposed relation, said anode flanges being separated by portions of condensers of circular shape, said condenser portions and anodes being arranged in rectilinear alignment.

4. A double-unit tube, each unit comprising a cathode, a control grid and a cylindrical anode, a pair of condensers of circular configuration interposed between the ends of the anodes and separating said anodes from one another, and means including spacers interposed between the adjacent ends of the anodes and condensers for detachably securing said anodes and condensers in rectilinear alignment.

5. A multi-unit tube, each unit comprising a cathode, a control grid and an anode, said anode being of the external cylindrical type and having a flanged base, a pair of circular condensers interposed between and separating the flanges of said anodes, said cathode and control grid constituting elements which extend throughout the entire length of the cylindrical anodes and of the circular condensers, and leading-in conductors electrically connected to the mid-point of the grid and cathodes, said leading-in conductors extending through a circular plate of insulating material and said plate being interposed between the inner ends of the two circular condensers, and means for detachably securing said anodes, condensers and circular plate in rectilinear alignment.

6. A double unit high current tube, each unit comprising a cathode, a control grid and a cylindrical external anode, said anodes being closed at one end and open at the other end, means for detachably securing the open ends of the anodes together in order to position all parts of the tube in rectilinear alignment, said control grid being constituted of heavy stay rods over which are wound grid wires of considerable size, said stay wires extending integrally throughout the interior of the double unit tube and the contained anodes, a leading-in conductor taken from one of the grid stay wires to the exterior of the tube at a position mid-way of the length of the combined tube and the electrical center of the extended grid, said cathode being constituted of a rod construction which extends integrally throughout the length of the interior of the double unit tube, and leading-in conductors taken from opposite sides of the cathode to the exterior of the combined tube, mid-way of the length of said tube and from the electrical center of the extended cathode.

7. A multi-unit tube, each unit comprising a cathode, a control grid and an anode, said anode being of the external cylindrical type and having a flanged base, said cathode and control grid constituting elements which extend throughout the entire length of the cylindrical anodes, leading-in conductors electrically connected to the mid-point of the grid and cathodes, said leading-in conductors constituting circular plates of metal and positioned between the anode flanges when the latter are placed end to end, said plates being

insulated from one another and insulated from said anode flanges and means for detachably securing said anode flanges and the insulated metal plates together so as to position all of the electrodes in rectilinear alignment with respect to one another, and electrical connections to said anode flanges and to said metal plates for connecting the electrodes in an electric circuit.

8. A multi-unit tube, each unit comprising a cathode, a control grid and an external cylindrical anode, said cathode and control grid being constituted of portions which extend over the entire length of each anode interior and being electrically separated from one another, leading-in conductors for each of the cathodes and control grid portions extending mid-way of the length of the tube, said conductors comprising peripherally complete rings arranged co-axial with respect to the anodes and interposed between the ends of the anode portions but insulated from one another and from said portions, and means for detachably securing the anodes and rings together to position the anodes in their contained cathode and control grid portions in rectilinear alignment.

9. A multi-unit tube, each unit comprising a cathode, a control grid and an external cylindrical anode, said cathode and control grid being constituted of portions which extend over the entire length of each anode interior and are electrically separated from one another, said anodes being provided with flanges which are placed in juxta-position but spaced apart, a plurality of alternate metal rings and rings of insulating material positioned between said anode flanges and both passing through said flanges and rings for detachably connecting the elements together and positioning the anodes in rectilinear alignment, and connections between the various rings and the cathode and control grid portions, said connections being positioned at the approximate electrical center of the double unit tube, and connections to each of said rings and the anode flanges.

10. A multi-unit tube, each unit comprising a cathode, a control grid and an external cylindrical anode, said cathode and control grid being constituted of portions which extend over the entire length of each anode interior and are electrically separated from one another, said anodes having flanges which are arranged in juxta-position but separated from one another, a plurality of alternate metal and insulating rings positioned between said anode flanges, and means for detachably securing said flanges and the rings together so as to position the anodes and contained electrodes in rectilinear alignment, and means for connecting the respective rings to each of the cathode and control grid portions, said means including extensions from one of the rings to a position mid-way of the length of the tube in order to make connection between that ring and its respective electrode at the electrical center of the tube.

11. A double unit tube, each unit comprising a cathode, a control grid and a cylindrical anode, each anode having an open and a closed end, the open ends of the anodes being arranged in opposed relationship when the anodes extend in rectilinear alignment, a plurality of condensers of circular configuration interposed between the open ends of the anodes, said condensers being positioned end to end and in substantially concentric relation with respect to said anodes when the tube is viewed from either end, and means including spacers interposed between the adjacent ends of the condensers and between the opposite end of each of said condensers and the adjacent open end of one of the anodes for maintaining the anodes and condensers in fixed rectilinear alignment.

12. A double unit tube, each unit comprising a cathode, a control grid and a cylindrical anode, each anode having an open and a closed end, the open ends of the anodes being arranged in opposed relationship when the anodes extend in rectilinear alignment, a plurality of condensers of circular configuration interposed between the open ends of the anodes, said condensers being positioned end to end and in substantially concentric relation with respect to said anodes when the tube is viewed from either end, and means including spacers interposed between the adjacent ends of the condensers and between the opposite end of each of said condensers and the adjacent open end of one of the anodes for maintaining the anodes and condensers in fixed rectilinear alignment, the grid of each unit being constituted of a plurality of stay rods over which the grid wires are wound, said stay rods extending integrally over the entire interior of the condensers and the anodes, and said cathode extending throughout the entire interior of the condensers and the anodes.

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