

Aug. 27, 1940.

J. F. TIMMONS

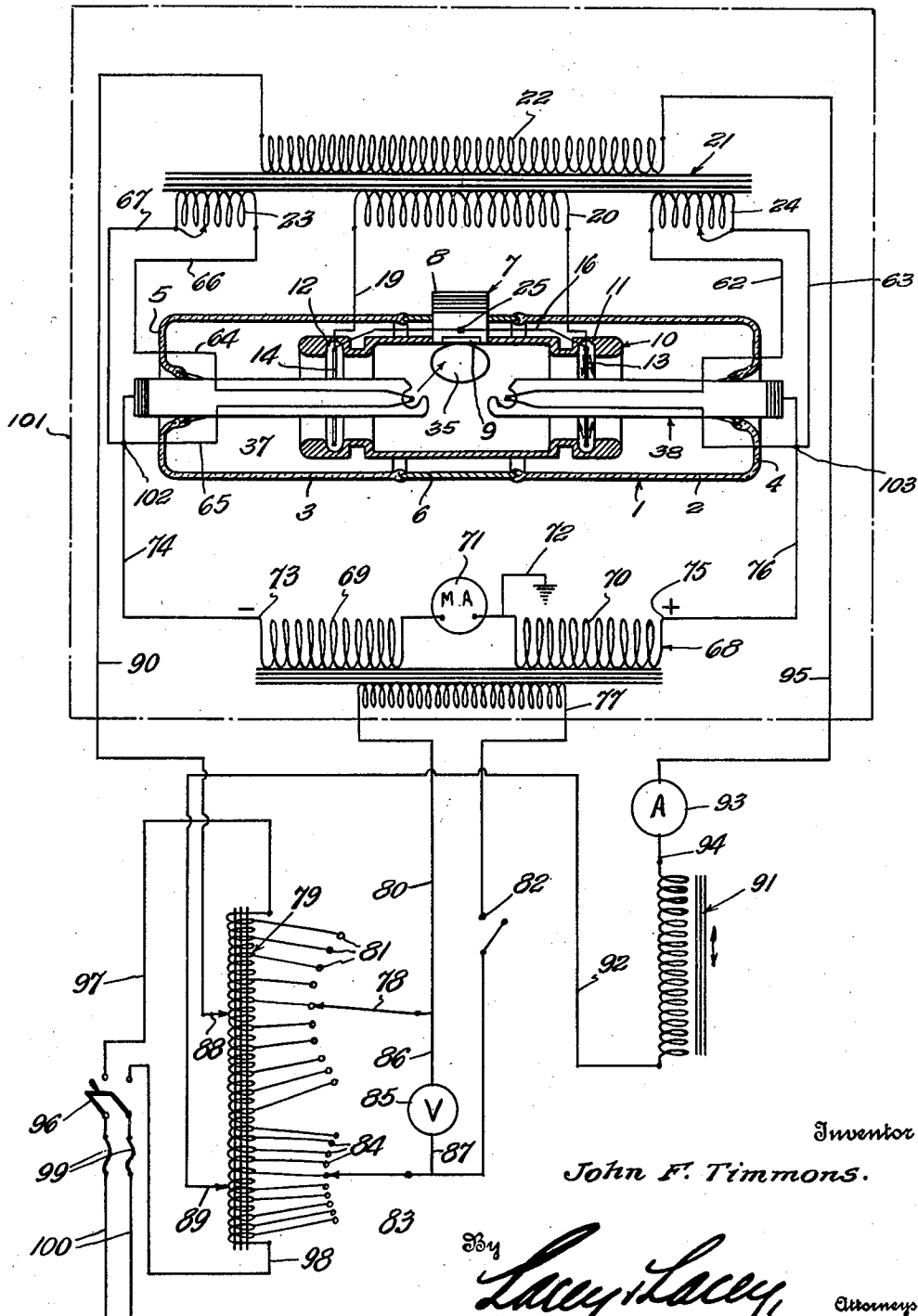
2,213,112

X-RAY TUBE

Filed July 28, 1937

6 Sheets-Sheet 1

Fig. 1.



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Fig. 2.

Fig. 3.

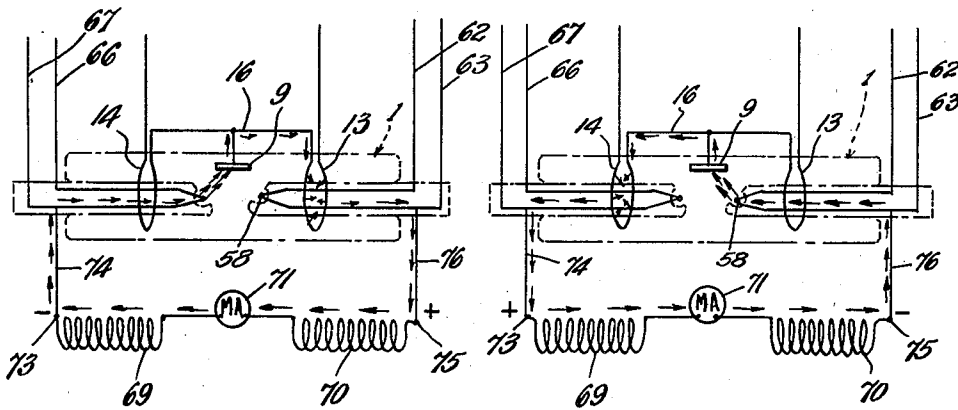


Fig. 4.

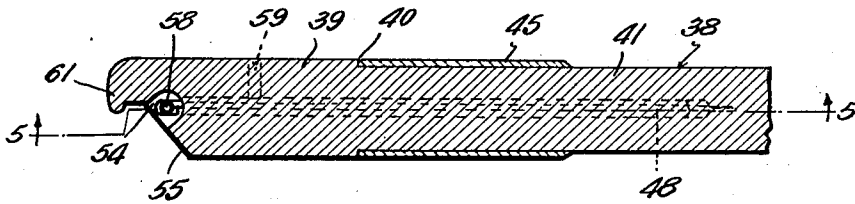


Fig. 5.

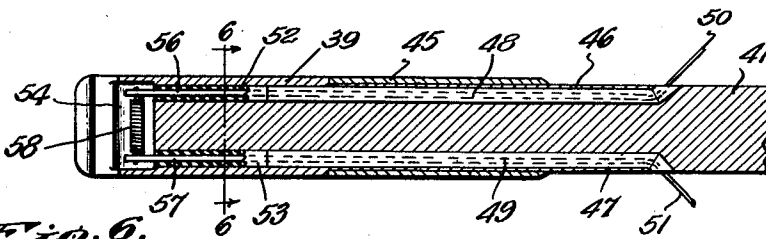
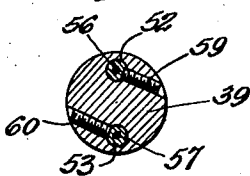


Fig. 6.



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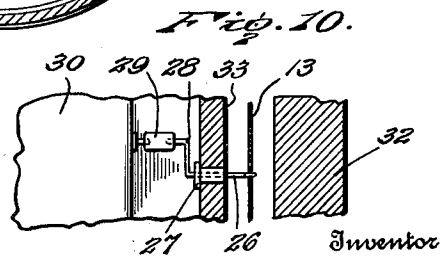
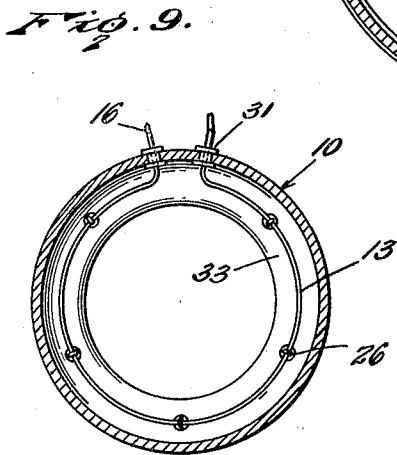
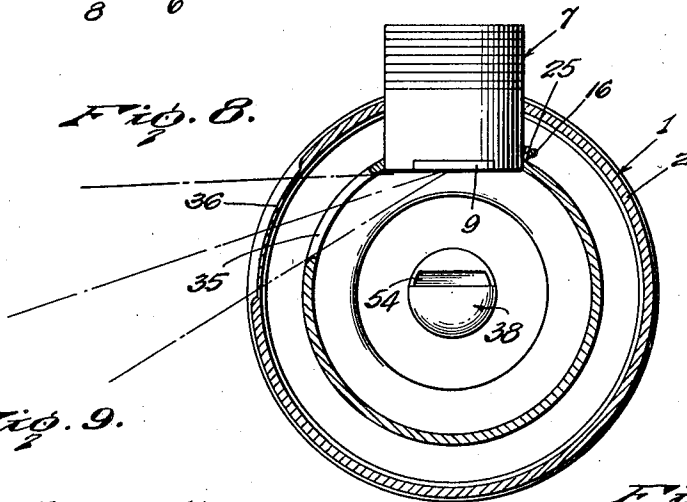
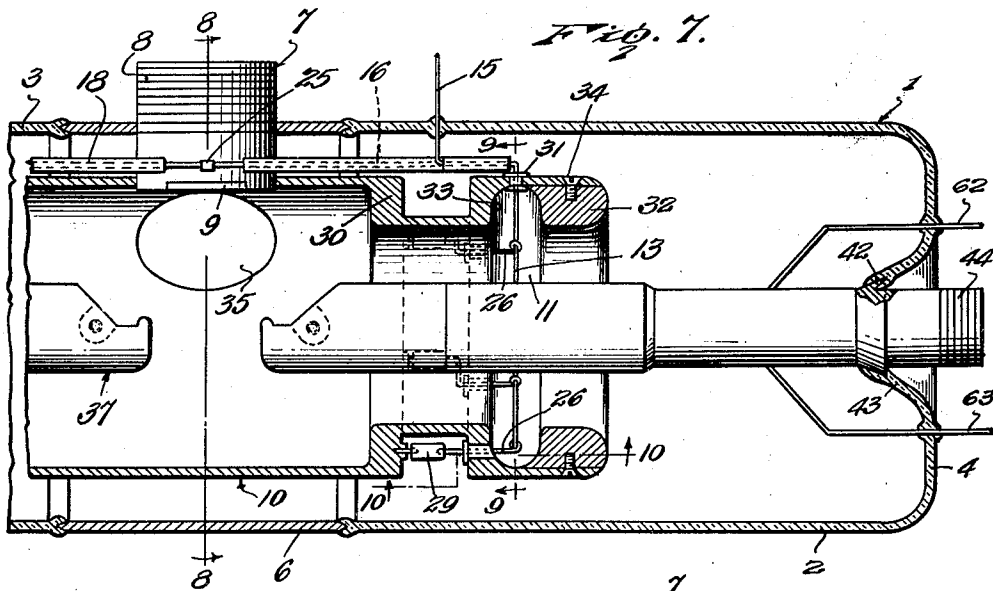
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X-RAY TUBE

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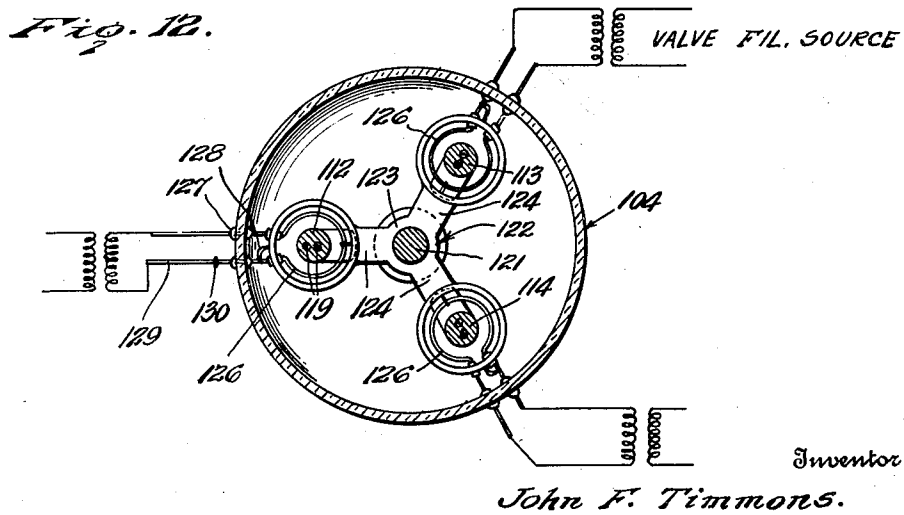
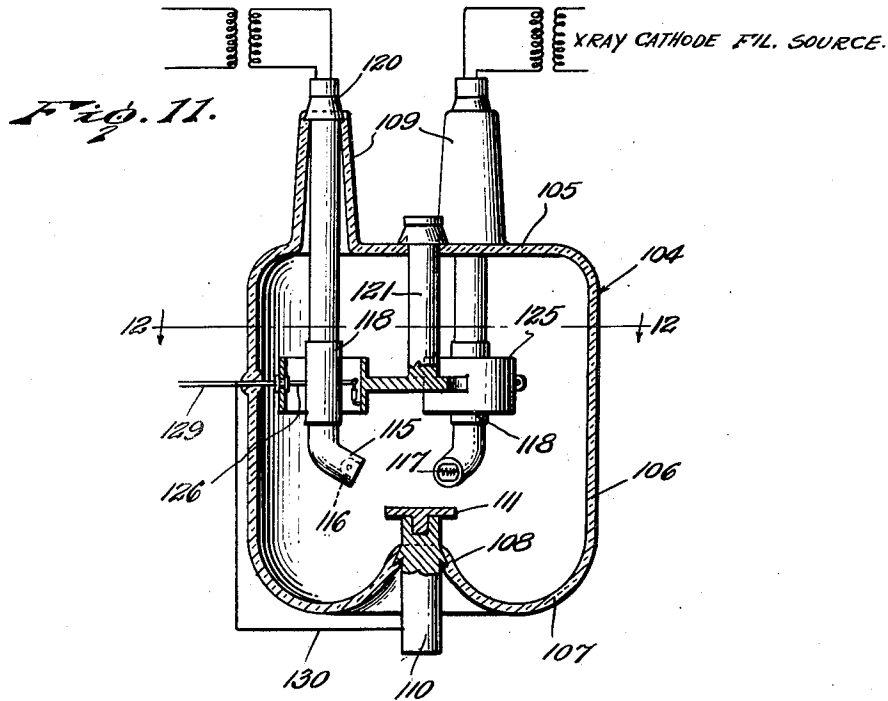
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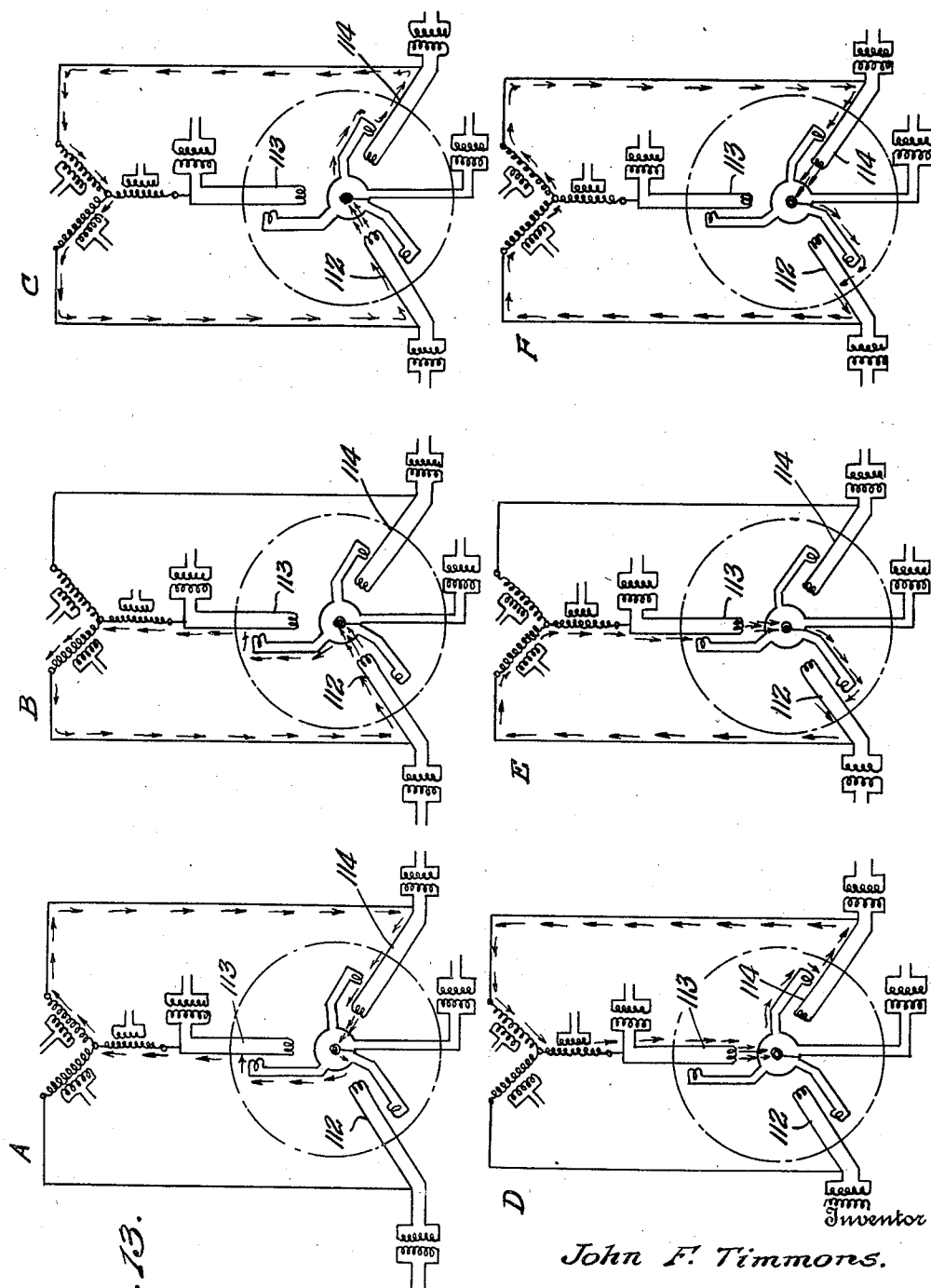


Fig. 13.

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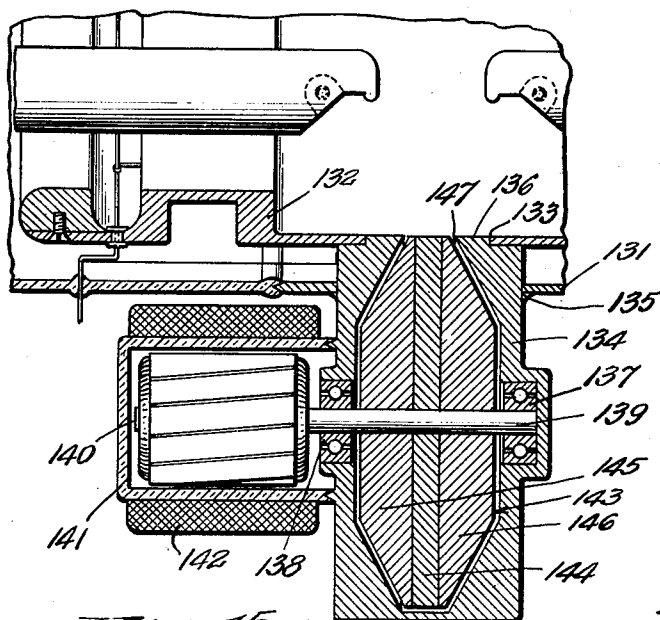


Fig. 14.

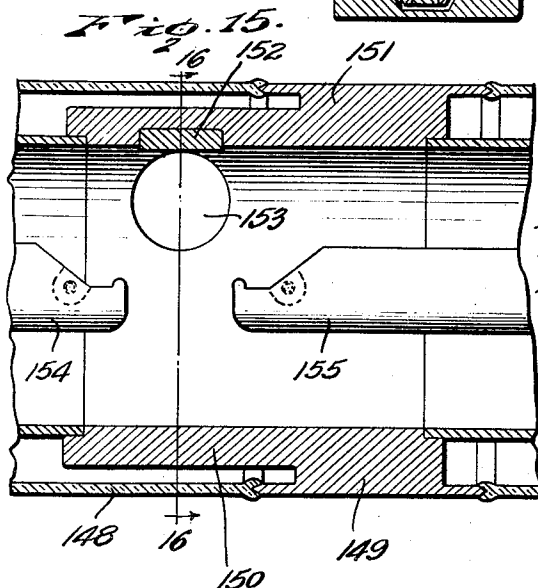


Fig. 15.

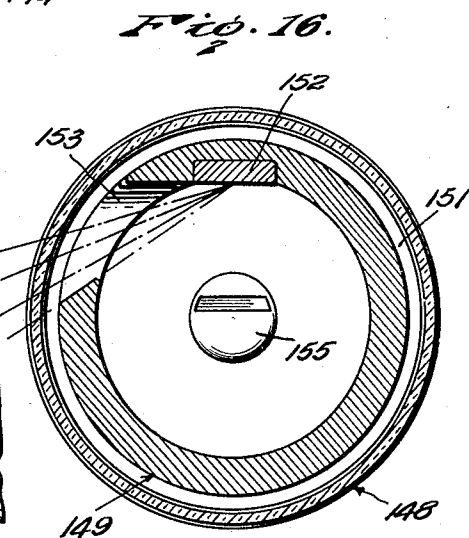


Fig. 16.

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UNITED STATES PATENT OFFICE

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X-RAY TUBE

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Application July 28, 1937, Serial No. 156,211

5 Claims. (Cl. 250-144)

This invention relates to improvements in X-ray tubes and more particularly to a self-contained full wave self-rectifying X-ray tube.

Up to the present time the X-ray tubes of the hot cathode type have never been known to be more than half wave rectifiers. It will be readily understood by those versed in the art that half wave radiographic equipment using such tubes, which is sometimes erroneously called self-rectifying equipment, is limited in effectiveness and capacity to handle high energy outputs, for the reason that the focal spot on the target will be required to be large, as the tube is only passing current through one half the cycle. Moreover, the transformer employed for supplying the high tension current to the terminals of the tube would, of necessity, be of great capacity in order to provide good voltage regulation.

During operation of a half wave rectifying X-ray tube connected to an alternating current supply in a conventional circuit, the amplitude or intensity of the voltage during the inverse or unused portion of the cycle may exceed that during the used portion by such an amount as to damage the tube or its energy supplying circuits. That is, either the filament source, the high tension transformer, or the insulating material may breakdown. To overcome the possibility of damage from this extreme inverse voltage during the unused portion of the cycle when the tube is not rectifying, i. e., that period when the cathode is positive in respect to the anode and all the electrons from the cathode are suppressed, it has been the custom of some workers in the art to increase the size of wire and iron in the high tension transformers and to add more insulating material. This, of course, requires that more weight and a larger housing be employed if the unit is equipped with a shock proof housing.

Various attempts have been made to solve the problem of inverse peak voltage in half wave X-ray equipment, in that various forms of inverse suppressers have been employed in efforts to correct this situation. To accomplish this, it is generally necessary to dissipate in the suppressers an equal or greater amount of energy than is actually used in the production of X-rays during the useful portion of the cycle. The poorer the source of alternating current, the more objectionable becomes this inverse problem, and the use of inverse suppressers merely doubles the load on the already over-taxed source. A poor alternating current source can be caused by many factors such as too small a distributing transformer, too small size conductors in the supply

line, or too long a distance from the distribution transformer to the unit, or any combination of the above mentioned faults. Another cause of poor alternating current supply could be that of a too small generator capacity, such as power units comprising small portable gasoline engines driving small alternators.

Equally as objectional as the inverse suppression problem with the half wave or self-rectifying equipment, is the unwanted necessity of a double size focal spot. This is due to the necessity of double current during the one-half of the cycle to equal the full wave output.

The use of my present invention overcomes all of these objections above noted and embodies many improvements which will be present due to the inherent nature of construction and operation for the reason that my improved tube is its own full wave rectifier. Full wave rectification is conventionally accomplished with either one or the other of two methods. In the first method, two rectifying valve tubes and a center tap transformer are used. It is necessary that the transformers develop twice the voltage to be used for X-ray generation. In the second method, four rectifying valve tubes are used in a bridge circuit with a high tension transformer which supplies just the operating voltage.

My improved X-ray tube will replace the conventional X-ray tube and the rectifying valve tubes so that one tube will replace three tubes in the first described conventional form of full wave rectification. With reference to the second method, my improved X-ray tube will replace five tubes. That is to say, the four valve tube rectifiers employed in the bridge circuit and the one X-ray tube may be dispensed with when my improved X-ray tube is used. The second method employing five tubes is the most conventional and is almost universally employed for high power X-ray work.

In addition, it is accepted that the full wave type of rectification is the most satisfactory method of eliminating any suppressers with their inherent weaknesses, also any objectionable inverse and also eliminating the necessity of employing objectionably large focal spots. Moreover, the use of four valve tubes, for rectification, and an X-ray tube sealed in one housing with ample insulation and all the necessary current supplying sources, makes for such a large unit that satisfactory manipulation and positioning is almost impossible. Needless to say, the weight factor is objectionable and hinders portability.

Therefore, my invention seeks to provide a self-

contained full wave self-rectifying X-ray tube wherein the necessary rectifying elements are incorporated within the same evacuated chamber as the X-ray electrodes so as to permit the accomplishment of the full wave rectification and the simultaneous production of X-rays within said single evacuated chamber.

Another object of the invention is to provide a self-contained full wave self-rectifying X-ray tube which will be adapted for use in polyphase X-ray systems and which will employ elements sufficient to permit polyphase full wave rectification and simultaneous production of X-rays.

Another object of the invention is to provide an improved X-ray tube of the class described which will embody a new and novel construction and particularly a highly efficient arrangement of elements within the tube.

Another object of the invention is to provide an X-ray tube of this character which will embody rectifying and X-ray producing elements within a single evacuated envelope so that the amount of external components required for proper operation of the tube will be reduced to a minimum.

A further object of the invention is to provide a self-contained full wave self-rectifying X-ray tube employing elements which will serve the purpose of both anodes and cathodes.

Another object of the invention is to provide an X-ray tube the use of which will permit a great increase in the life of the cable usually employed for carrying the high voltage current for the reason that strain on the cable ordinarily caused by inverse peak voltage will not be present.

And as a still further object the invention seeks to provide a device of this character wherein the target employed is capable of being rotated so that heating of the target such as is caused by an electronic bombardment from the cathodes will be reduced to a minimum so that the metal surface under the stream of electronic bombardment continuously changes, permitting the use of a much smaller focal spot.

My invention is illustrated in the accompanying drawings, wherein:

Figure 1 is a longitudinal sectional view of one embodiment of my improved X-ray tube and showing it as it would appear properly connected ready for operation, the high and low tension current supply sources and allied equipment being shown diagrammatically.

Figure 2 is a diagrammatic view showing the electronic flow which takes place within the tube during the first half of the cycle.

Figure 3 is a diagrammatic view showing the electronic flow through my improved tube during the other half of the cycle.

Figure 4 is a detail sectional view of one of the electrodes employed.

Figure 5 is a detail longitudinal sectional view on the line 5—5 of Figure 4, looking in the direction indicated by the arrows.

Figure 6 is a vertical detail sectional view on the line 6—6 of Figure 5.

Figure 7 is an enlarged detail sectional view showing substantially one half of my improved X-ray tube with all the components properly mounted therein.

Figure 8 is a vertical sectional view on the line 8—8 of Figure 7.

Figure 9 is a detail vertical sectional view on the line 9—9 of Figure 7.

Figure 10 is an enlarged detail sectional view on the line 10—10 of Figure 7.

Figure 11 is a detail sectional view of a modified form of my X-ray tube intended for use with polyphase current supply.

Figure 12 is a horizontal sectional view on the line 12—12 of Figure 11.

Figure 13 discloses a plurality of diagrams showing electronic flow at various intervals during three-phase operation.

Figure 14 is a detail sectional view of a modified form of my invention and showing particularly an X-ray tube employing a rotatable target.

Figure 15 is an enlarged detail sectional view showing another modified arrangement.

Figure 16 is a vertical sectional view on the line 16—16 of Figure 15, looking in the direction indicated by the arrows.

Referring now more particularly to the accompanying drawings wherein, as will be seen, similar numerals of reference designate similar parts throughout the various views, the numeral 1 indicates in general the envelope of my improved X-ray tube. The envelope is preferably formed with tubular sections 2 and 3 which are formed of glass and are turned inwardly at their outer corresponding ends to define end walls 4 and 5. It should be understood that the envelope may be of any desired material suitable for the work and may be formed in any desired shape. The portions 2 and 3 are adapted to be connected at their inner corresponding ends by a metal band or ring 6 which has its opposite edges sealed to the meeting edges of the glass sections 2 and 3. As will be seen in Figures 1 and 7 of the drawings, the glass is adapted to fit about the feathered edge of the metal band 6 so that an effective seal will be provided.

Mounted in the band 6 and adapted to extend radially with respect to the axis of the envelope is a target support 7 which is provided throughout its outer portion with cooling vanes 8. The target 9 is mounted on the target support 7 within the envelope and, as will be seen clearly in Figures 1 and 7 of the drawings, the target support 7 also provides a support for an inner sleeve 10, which extends concentrically of the envelope therein throughout the meeting portions of said envelope. The inner sleeve is formed of metal or any other suitable material and has grooves 11 and 12 formed near its opposite ends. As best seen in Figures 1 and 7 of the drawings, the grooves 11 and 12 are adapted respectively to receive cathodes 13 and 14 which, as particularly seen in Figure 7, comprise wires of tungsten or other suitable material adapted to have one end portion 15 led out through the wall of the groove in the end portion of the sleeve and through the wall of the section 2 of the envelope. The wire which extends through the wall of the envelope defines one terminal which is adapted to be connected with a terminal of a low tension current supply. The arrangement of the cathode or filament is particularly well seen in Figure 9 of the drawings, wherein it will be noted that the other terminal, designated at 16, is led through a tube 17 of insulating material to the target support 7. The wire 16 is welded or otherwise suitably secured at 25 to the target support 7 and projects to extend through a tube of insulating material 18 to define a terminal of the cathode or filament wire which is carried in the groove 12. The opposite terminal of the wire 14 in the groove 12, as shown at 19, is led through the envelope in a similar manner to the wire 15 and is connected to the opposite terminal of the low tension supply which, as will be seen in

Figure 1, comprises a secondary 20 of a low tension transformer shown generally at 21. The low tension transformer includes a primary 22 and additional secondaries 23 and 24. It will be understood that when the secondary 20 is energized in the normal manner, current will flow through the wire 15 and through the cathode filament wire 13 and through the wire connecting said cathode filament wires 13 and 14, which wire is indicated at 16, to the cathode filament wire 14 and thence through the wire 19 back to the other terminal of the secondary 20. The cathode filament wires 13 and 14 will be illuminated to incandescence.

As best seen in Figures 7, 9 and 10, the cathode wires 13 and 14 are mounted in the grooves 11 and 12 respectively in the following manner: Supporting wires 26 have outer end portions looped about the filament wire, for example, the filament wire 13, and said supporting wires 26 are adapted to extend through insulating bushings 27 in the end portion of the inner sleeve and said wires are adapted to be offset, as shown at 28, and have their inner end portions anchored in a glass bead 29 which is appropriately secured to a shoulder 30 on the inner sleeve. As clearly seen in Figures 7 and 9 of the drawings, the wires 15 and 16 extend through the thin portion of the end of the sleeve and are supported in said thin portion, which thin portion defines the groove 11 by means of insulating grommets 31. It will now be understood that the cathode filament wire will be effectively supported within the groove and will be so supported that changes in temperature, which will be caused by rapid heating and cooling, will not cause strain on the cathode filament wire and the supports therefor. An inner lining for the outer end of the inner sleeve, such as shown at 32, cooperates with a shoulder 33 on the inner sleeve to define the groove 11 and said inner lining 32 is adapted to be held in place by means of set screws 34. It should be understood that the lining is placed in position after the filament cathode wire 13 has been properly installed. The purpose of the groove 11 with the cathode filament wire 13 therein is to permit focusing of an electronic bombardment from the cathode filament wire, when heated, to an electrode to be presently described. Moreover, the inner lining 32 defines a shield for the cathode filament wire 13 and thereby serves to protect the envelope from being bombarded by a flow of electrons from the cathode filament wire, which bombardment would cause heating of the envelope.

As seen in Figures 7 and 8 of the drawings, the inner sleeve 10 is provided with an opening 35 which is disposed in offset center relation to the target support 7 and said opening is adapted to be alined with a window 36 in the envelope 1. The window 36 is preferably formed by grinding the surface of the envelope 1 or, more specifically, the ring 6, to such thinness as to permit practically unrestricted flow of X-rays from the target through an object to a film. If desired, a plate of different metal properties may be set into the ring 6 and this plate reduced in thickness to such an extent that the X-ray bombardment will not be impeded. The metal in question would, of course, be of very low atomic number. Mounted in the envelope 1 is a pair of electrodes which I shall designate at 37 and 38. The electrodes are of identical construction and, therefore, a description of one will suffice for both. As best seen in Figures 1, 4 and 7, the

electrode 38 is of substantially circular form and is provided with an enlarged inner end portion 39 defining a shoulder 40 and a reduced major portion 41. The reduced portion 41 is adapted to be mounted in the end wall 4 and, as best seen at 42, the portion 41 is provided with an outwardly extending sealing ring which is adapted to be sealed to an inwardly extending central portion 43 of the end wall 4 of the envelope. The glass of the central portion 43, at its inner extremity, will surround the ring 42 and will provide an air-tight seal so that the electrode 38 will be effectively sealed within the envelope 1. The portion 41 extends outwardly of the envelope and is provided with cooling vanes 44. The cooling vanes 44 will cooperate with the reduced major portion 41 to permit the conducting of heat to the exterior of the envelope. Surrounding the reduced major portion 41 and abutting the shoulder 40 is a sleeve 45 which will be of a metallic material suitable for receiving an electronic flow. It will be seen, in Figure 7, that the sleeve 45 is located concentrically of the cathode filament wire 13 in position to receive a bombardment of electrons from said cathode filament wire. By referring to Figures 4 and 5 of the drawings, it will be seen that the electrode 38 is formed with openings 46 and 47 which extend throughout the major portion of the length of the electrode. The openings 46 and 47 are located preferably in parallel spaced relation and are adapted to receive the insulating sleeves 48 and 49 which surround conductors 50 and 51. The conductors 50 and 51 extend outwardly within the electrode and have sleeves 52 and 53 which are formed of suitable insulating material and which terminate at a recess 54 formed in an obliquely disposed wall 55 formed in the inner end of the electrode. The conductors are connected with supporting members 56 and 57 and said supporting members are adapted to support a filament 58 which will be made of tungsten or other suitable material. As best seen in Figure 6 of the drawings, the sleeves 52 and 53 which support the members 56 and 57, are held in place by means of set screws 59 and 60, which set screws prevent shifting of the members 56 and 57 or any distortion of the filaments. The oblique end wall 55 is extended to define a shield 61 which serves the purpose of directing a bombardment of electrons toward the target and not in the direction of the opposite electrode. Undesirable interaction between the electrodes will thus be prevented. The conductors 50 and 51 are extended through the end wall 4 of the envelope 1 and are connected to the low tension secondary 24 by means of conductors 62 and 63. It will be understood, of course, that a duplicate construction is present at the opposite end of the envelope and that the conductors, indicated at 64 and 65, are connected to the secondary 23 by means of wires 66 and 67. The electrodes 37 and 38, as will be understood from the description hereinabove, will serve the purpose of both cathodes and anodes. That is to say, the filaments 58 serve to define cathodes which are adapted to cooperate with the common target or anode 9 while the portion which encloses the cathodes 58 and wires therefor, together with their sleeves 45, cooperate to define anodes for cooperation with the cathode filament wires 13 and 14. It will be further understood, therefore, that the cathodes 58 cooperate with the common target or anode 9 to provide X-ray production while the sleeves 45 and the cathode filament

wires 13 and 14 will cooperate to provide a full wave rectifier. That is to say, the cathode filament wire 13 will cooperate with the sleeve 45 on the electrode 38 to rectify one-half of the cycle while the cathode filament wire 14 will act with the sleeve 45 on the electrode 37 to rectify the other half of the cycle.

A high tension transformer of the center tapped variety is indicated at 68 and said transformer will have secondary sections 69 and 70 which have their inner end terminals connected through a milliammeter 71. One of the inner terminals may be grounded, as shown at 72. The secondary 69 has its outer terminal 73 connected to the electrode 37 by means of a conductor 74 while the section 70 of said transformer will have its outer terminal 75 connected to the electrode 38 by means of a conductor 76. The terminals 73 and 75 have plus and minus indications thereon but it will, of course, be understood that the polarity will change at each alternation. The transformer 68 has a primary 77 and said primary has one terminal connected to a variable switch 78 of an auto-transformer 79 by means of a conductor 80. The variable switch 78 is adapted for selective connection with taps 81 which are connected to the auto-transformer to permit broad voltage regulation. The other terminal of the primary 77 is connected through a single pole switch 82 to a variable switch 83 adapted for selective connection with taps 84, which taps are connected to the auto-transformer in a manner to permit fine voltage regulation. A volt meter 85 is connected across the output of the auto-transformer in parallel therewith by means of conductors 86 and 87. The auto-transformer has taps 88 and 89 thereon and the tap 88 is connected to one terminal of the primary 22 of the low tension transformer 21 by means of a conductor 90 while the tap 89 is connected to one terminal of a voltage regulator choke 91 by means of a conductor 92. The voltage regulator choke has a movable core which may be shifted for varying the current therethrough and said choke has its other terminal connected to a terminal of an ammeter 93 by a conductor 94. The other terminal of the ammeter 93 is connected to the other terminal of the primary 22 by means of a conductor 95. The filament current fed to the primary 22 may be read from the ammeter 93. A supply switch is shown at 96 and said supply switch has jaws which are connected to the input terminals of the auto-transformer by means of conductors 97 and 98. The switch may be fused, as shown at 99, and is connected to an alternating power current line of suitable constants by means of conductors 100.

As shown at 101 in dotted lines in Figure 1 of the drawings, the high and low tension transformers are adapted to be enclosed in an oil filled head with my improved X-ray tube so that a single medium will serve to insulate and cool the transformers and the tube itself. It is pointed out that the cooling medium will act on the flanged portion 8 of the target support 7 for effectively cooling the target support and the inner sleeve 10. That is to say, heat developed in the inner sleeve will be led to the cooling medium through the target support 7 which, as stated, has the cooling vanes 8 thereon. The cooling medium will also act upon the cooling vanes 44 of the electrodes 37 and 38 so that said electrodes will be effectively prevented from reaching too high a temperature. It should be

understood that, although I have indicated diagrammatically the presence of the oil head 101, by proper construction of the vanes 44 and 8, it may be possible to operate my improved tube with air as a cooling medium.

In operation, the switch 96 is first closed for energizing the auto-transformer 79. Current will be led through the conductors 90, 92 and through the choke 91 and a meter 93 and conductor 95 to the primary 22 of the transformer 21 so that said primary will be effectively energized. Upon energization of the primary 22, the secondaries 20, 23 and 24 will be energized. It is desired to state that the secondaries are insulated above ground. That is to say, they are insulated so as to be capable of carrying the extremely high potential current used in X-ray work without a flash over. The secondaries 20, 23 and 24 are, of course, effectively insulated from each other to stand greater than full voltage. The secondary 23 will supply low tension current to the cathode 58, which is carried in the electrode 37, by means of the conductors 66 and 67. The secondaries 20, 23 and 24 may each be adapted to provide voltage adjustment which may be necessary when replacing one tube with another. Similarly, the secondary 24 will supply, through the conductors 62 and 63, low tension current to the cathode 58 which is mounted in the electrode 38. The cathode 58, as will now be seen, will be heated to incandescence by the current flowing from the secondaries 23 and 24. The secondary 20 supplies, through the wires 15 and 19 and the connecting wire 16, alternating current to the cathode filament wires 13 and 14, which are mounted inside the inner sleeve 10 so that these filament wires will also be heated to incandescence. It should be noted that, although I have shown the cathode filament wires 13 and 14 as being electrically connected in series, these wires may be connected in parallel, if desired, without departing from the scope of my invention. The wire 16 is connected to the target support 7 so that the cathode filament wires 13 and 14 will be electrically connected to said target 9 in order that any high tension potential imposed upon the cathode filament wires will be common to each of said wires and to the target.

By closing switch 82, the primary 77 of the high tension transformer 68 is energized from the output of the auto-transformer 79 by way of the switches 78 and 83 and the conductor 80. Variation of the input to the high tension transformer primary is accomplished by the shifting of the switches 78 and 83. The voltage input may, of course, be read on the volt meter 85. Upon energization of the primary of the transformer 77, as described, the secondary sections 69 and 70 will be energized and high tension current will flow to the electrodes 37 and 38 through the conductors 74 and 76, which conductors are connected to the conductors 67 and 63 of the low tension filament sources at 102 and 103 respectively.

Presuming all of the cathodes to be heated to the proper electronic emitting temperature and the primary of the high tension transformer 68 to be energized, the secondary sections 69 and 70 will, in turn, be energized. As seen in Figure 2 of the drawings, during the first alternation, the terminal 75 will, for sake of example, be presumed to be positive and the electrode 38 will be positively energized. At the same time, the section 69 will have its outer terminal 73 at a negative potential so that the electrode 37 will be

negative with respect to the target 9 and cathode filament wires 13 and 14. Upon positively charging the electrode 33 half wave rectification will take place for the reason that the cathode filament wire 13 will bombard the sleeve 45 surrounding the electrode 33 for effecting such half wave rectification. In view of the fact that the cathode filament wire 13 is positively charged, the target 9 and the cathode filament wire 14 will assume a positive charge from the electrode 33 as the cathode filament wires and said target are all connected by the wire 16. There will, therefore, be an electronic flow from the negative terminal 73 of the section 69 through the cathode 58 which is carried in the electrode 37 to the target 9 thence to the cathode filament wire 13 and thence back to the terminal 75 through the electrode 38 and the conductor 76. It will be noted that the cathode 58 which is carried in the electrode 38 will be positive with respect to the target 9 so that there will be no bombardment of electrons and no conduction of current during this alternation. Moreover, the filament cathode wire 14 will be positively charged with respect to the electrode 37 so that there will be no current conduction between the cathode filament wire and the electrode 37. During the second alternation of the cycle, as shown in Figure 3, the opposite action takes place. That is to say, the electrode 37 is positively charged so that the electrode 38 will be negatively charged. The cathode filament wire 14 is positively charged and, therefore, the target 9 and the cathode filament wire 13 will all be positively charged. Electronic flow will, therefore, be from the negative terminal of the transformer through the cathode 58, enclosed in the electrode 38, to the target 9 and thence to the cathode filament wire 14 and through the electrode 37 back to the positive terminal of the transformer. It will be noted in this alternation that, as the cathode 58 within the electrode 37 is positive, there will be no bombardment of electrons from this cathode to the target 9. Also, the cathode filament wire 13 is positively energized so that there will be no electronic flow from said cathode filament wire 13 to the sleeve 45 which surrounds the electrode 38. It will be seen from the foregoing description that both sides of the alternating current cycle are effectively rectified and simultaneously therewith, at each alternation of the cycle X-rays are produced from the cathode 58 to the common target 9. Need for external rectification means is obviated as all portions of the cycle are useful and there is no inverse to be suppressed and, in addition, inasmuch as X-rays are produced at each alternation of the cycle, a focal spot of relatively small diameter may be employed.

In practice, by sealing my improved X-ray tube in a head or container with its filament and high tension current sources, much space will be saved. Ready portability without sacrifice of efficiency for X-ray machines will be provided.

In view of the fact that I employ the choke 91 which is imposed in the primary circuit of the filament transformer 21, the temperature of the cathodes may be regulated so that they will be at the proper temperature for a given load through the tubes. The number of turns on the secondary coils of the filament transformer 21 are in such ratio that they will supply proper energy to the filaments, the filaments being of such cross section and length that the resulting temperature of the filaments when fed from

their respective transformer secondaries will be in proper proportion for insuring perfect tube operation at any tube load. Accordingly, great increase in filament life and efficiency is provided.

It is believed that the construction and operation of the embodiment of my invention as shown in Figures 1 to 10 will be clearly understood.

Referring now to the modification of the invention as shown in Figures 11, 12 and 13 of the drawings, I have produced an X-ray tube which is adapted for use with a three phase electric current supply. In this embodiment of the invention, I employ an envelope 104 which is, as best seen in Figure 12, of circular shape and is formed of glass. It should be understood that the envelope may be of any desired shape and of any material suitable for the purpose. The envelope 104 is provided with a substantially flat top wall 105, a circular side wall 106 and a bottom wall 107 which is provided with an inwardly and upwardly projected central portion 108. Formed integral on the top wall 105 are mounting sleeves 109. Mounted on the bottom wall 107 and sealed to the central portion 108 is a stem 110. The stem is sealed in a manner similar to that employed in the preferred form of the invention. Mounted on the stem at its inner end is a target 111. It will be understood that the target is disposed axially of the tube and that the sleeves 109 are located on the upper wall 105 of the envelope, near the wall 104 thereof, on radii one hundred and twenty degrees apart. Carried by the sleeves 109 are electrodes 112, 113 and 114 which are identical in construction. A typical electrode 112 includes an inwardly turned lower end portion 115 which is provided with a recess 116, which recess is adapted to have mounted therein a cathode 117 which accomplishes the same purpose as the cathodes 58. Carried on the electrodes 112, 113 and 114 near their lower end portion 115 are sleeves 118 of similar metallic formation to that of the sleeve 45. The electrode 112 has cathode feeding wires 119 which are adapted to pass through a cap 120, which cap seals the electrode to the sleeve 109. From the cap 120 the wires 119 are led to the secondary of the filament current supply. It should be understood that, if desired, the wires 119 may be led through the wall of the sleeve 109 and effectively sealed therein.

Mounted on the top wall 105 of the envelope is a depending mounting stem 121 which is sealed to the top wall in any appropriate manner and carries, at its lower end, a web 122 comprising a hub 123 and legs 124. The legs 124 have integrally formed thereon vertically disposed shields 125 which are adapted to carry cathode filament wires 126. The shields 125 serve the purpose of preventing electrons from the cathode wires 126 from bombarding the wall 104 of the envelope and said shields 125 also serve effectually to mount the cathode filament wires in such position that they will be in proper relation to focus electrons on the sleeves 118. It will be understood that one of the shields 125 is connected to each of the legs 124 at its free end and each of said shields is adapted to surround one of the electrodes in proper position to surround the shield 118 on said electrode. The cathode wires 126 are led through the wall 104, as shown at 27, by leads 129 and 129^a and will be effectively sealed in the glass so that proper vacuum will be retained. Each of the shields 125 is connected with one side of the filament cathode circuit by

means of conductors 128 and one of the cathode filament wires, shown at 129, is connected to the stem 110 by means of a conductor 130. Each of the cathode filament wires will have its own filament transformer. That is to say, the cathode filament wires are not connected in series as in the first described form of the invention.

Referring now to Figure 13 of the drawings, there will be seen six diagrammatic views showing the operation of this embodiment of the invention and particularly showing the electronic flow during a three phase cycle. The operation of this form of the invention is similar to that of the preferred form and it need only be stated that the relation between the target and the cathodes and anodes is such that the target is cooperating with one or more of the cathodes carried by one of the electrodes 112, 113, or 114, for producing X-rays while one or more of the cathode filament wires 126 are cooperating with one or more of the sleeves 118 for simultaneously producing rectification within the tube. It is desired to point out that in Figure 13 of the drawings, the cathode filament wires employed for rectification have been shown connected in series, for the sake of clearness. It is thought that this embodiment of the invention will now be clearly understood.

Referring now to the modification of the invention disclosed in Figure 14 of the drawings, the numeral 131 indicates a portion of an envelope which is similar to the envelope 1. Mounted in the envelope is an inner sleeve 132 which is identical in construction to that of the first described embodiment of the invention with the exception that said inner sleeve 132 has a relatively large target receiving opening 133. Fitted through the side wall of the envelope 131 and into the opening 133, is a target casing 134 which is formed of suitable metal and which will be sealed at 135 to the envelope 131. As will be seen, the casing 134 has a reduced upper end portion 136 which is adapted to fit in the opening 133 so that the inner sleeve 132 will be effectually mounted on the casing 134. The target casing, as described, will be secured to the envelope 131 so that the casing, inner sleeve and envelope will all be rigidly mounted with respect to each other and the casing 134 will serve the same purpose as the target support 7 in that said casing will aid in leading heat from the inner sleeve to the exterior of the envelope. The target casing 134 will be of circular or any other desired shape and will have side walls in which are mounted bearings 137 and 138, which bearings are adapted to journal a target mounting shaft 139 which forms an extension of a motor armature 140. The motor armature forms a portion of a motor and said armature is rotatably mounted in a housing 141 which will be of glass or any other suitable material. The housing is sealed to the target casing 134 and it should be understood that the interior of the casing 134 and the housing will be maintained at the same vacuum as the interior of the envelope. Field windings 142 are carried on the exterior of the housing 141 and cooperate with the armature for rotating the same.

Mounted on the target mounting shaft 139 within the casing 134 is a circular target shown generally at 143. The target 143 comprises tungsten disc 144 and copper discs or plates 145 and 146, which are appropriately secured to each side of the tungsten disc 144. As seen in Figure 14, the copper plates 145 and 146 are tapered or

feathered toward their edges so that they will present but little surface at the opening 147 which is formed in the casing and which permits a portion of the edge of the tungsten disc to be presented within the inner sleeve.

The operation of this form of the invention is identical with that of the first described embodiment of the invention with the exception that the motor will effectually rotate the target 143 and present a constantly changing surface to a bombardment of electrons so that the temperature of the target will be below the melting point and, at the same time, the focal spot will be small. In other words, by making the target rotatable, it may be much smaller than would be the case if it were fixed, for the reason that the load on any given section will be less.

In the modification of the invention shown in Figures 15 and 16 of the drawings, the envelope is shown at 148. The envelope is provided with a center ring 149 and said ring has an inner sleeve 150 which is connected to said ring by means of an annular web 151. A target is shown at 152 and an X-ray emitting opening at 153. The electrodes are shown at 154 and 155 and are positioned to cooperate with the common target 152. In this form of the invention, the use of an offset inner sleeve 150 will locate the target 152 and the X-ray emitting opening 153 clear of the ring 149 so that the X-rays after passing through the opening 153 in the inner sleeve 150 will have only to pass through the glass of the envelope 148. The necessity for providing a window in the ring 149 will thus be avoided. The operation of this form of the invention is identical with that of the other described embodiments. It is believed that the construction and operation of my improved self-contained full wave self-rectifying X-ray tube will now be completely understood.

Having thus described the invention, what is claimed as new is:

1. In an X-ray tube, an anode having an open end, a cathode carried in the open end, said open end having a shield, conductors extending through the anode for supplying a source of low tension current for heating the cathode, insulating sleeves about the conductors, and set screws engageable through the anode tangentially thereof and with the sleeves for holding said sleeves and conductors in a set position.

2. In an X-ray tube, an evacuated envelope, a target in the envelope, a sleeve in the envelope, a target support carrying said target, said target support mounting the sleeve within the envelope, a pair of electrodes carried in the envelope and extending into the sleeve, filaments carried by the sleeve, one of said filaments surrounding each of the electrodes, cathodes carried by the electrodes, said electrodes having anode portions, and circuit connections between the filaments and the target support, said filaments being energizable for bombarding the anode portions of the electrodes and said cathodes being energizable for bombarding the target, said sleeve having an opening for allowing X-rays to pass through the sleeve for diffusing exteriorly of the envelope.

3. In an X-ray tube, an evacuated envelope, a sleeve mounted in the envelope concentrically thereof and having grooves at its opposite ends, filaments carried in the grooves, a target support carried by the evacuated envelope and engageable with the sleeve for mounting said sleeve concentrically within the envelope, a target carried by the target support, a pair of electrodes

carried by the evacuated envelope in opposed relation therein and having anode portions extending into the sleeve, said electrodes having open inner ends, cathodes carried in the open inner ends, and circuit connections between the filaments and the target support, said filaments being energizable whereby an electronic flow will be directed toward said anode portions of the electrodes and said cathodes being energizable for directing an electronic flow toward the target, said sleeve having an opening for allowing X-rays to pass through the sleeve for diffusing exteriorly of the envelope.

4. In an X-ray tube, an evacuated envelope, electrodes therein concentrically of the envelope and in opposed relation, a sleeve surrounding the opposed end portions of the electrodes within the envelope, a target support mounting the sleeve in the envelope concentrically therein, a target carried by the target support, said sleeve having grooves at its opposite ends, filaments mounted in the grooves in surrounding relation to the electrodes, said electrodes having anode portions, supporting wires carried by the sleeve and projecting into the grooves for supporting

the filaments, cathodes carried by the electrodes, said sleeve having an opening in its side wall, circuit connections between the filaments and the target support, a source of current for the filaments, a source of current for the cathodes, and a source of high tension alternating current for the electrodes, said filaments being energizable from their filament source for bombarding the anodes with an electronic flow and said cathodes being energizable from their cathode current source for bombarding the target whereby rectification of the alternating current high tension source and the simultaneous production of X-rays will take place.

5. In an X-ray tube, an evacuated envelope, an electrode therein, a sleeve of substantially non-secondary emitting material tightly fitting about the electrode for conducting heat from said sleeve through the electrode to the exterior of the envelope whereby the tube will be cooled, and a filament surrounding the electrode and sleeve and being energizable for bombarding the sleeve with a flow of electrons.

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