Oct. 20, 1959 M. J. ZUNICK 2,909,686

X-RAY TUBE

Filed June 29, 1955 2 Sheets-Sheet 1

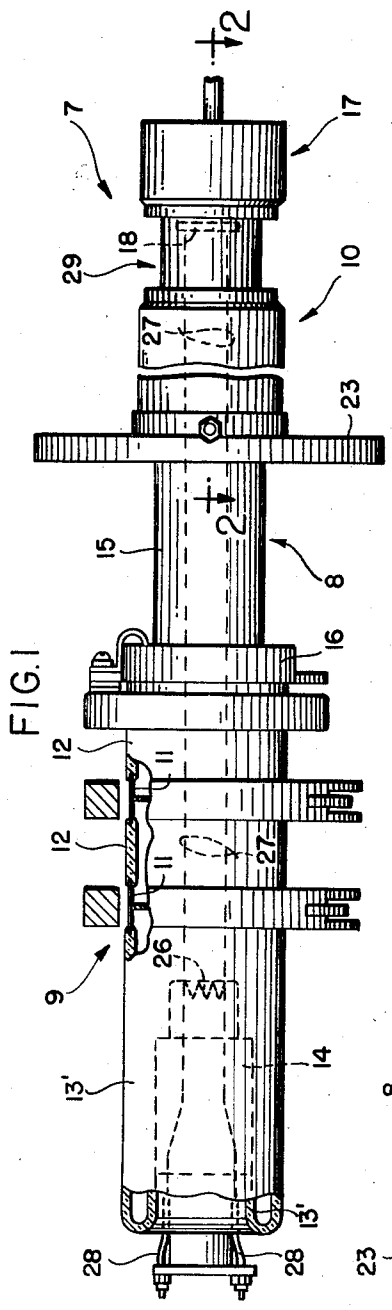


FIG. 1

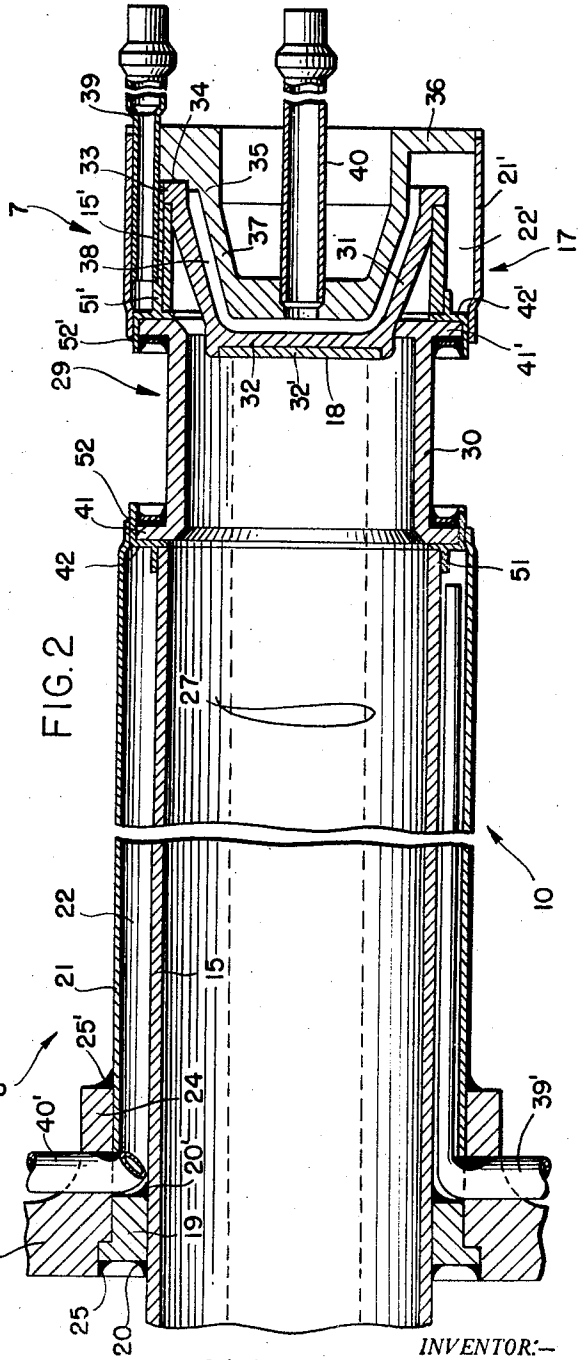


FIG. 2

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FIG. 3

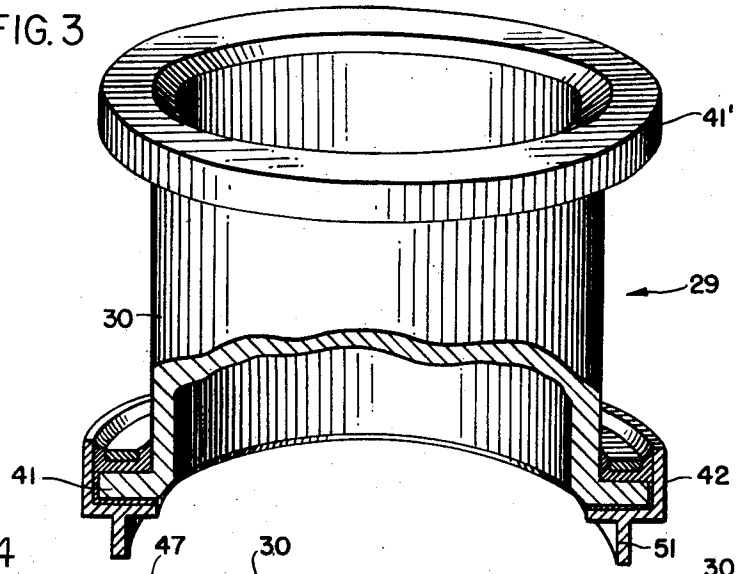


FIG. 4

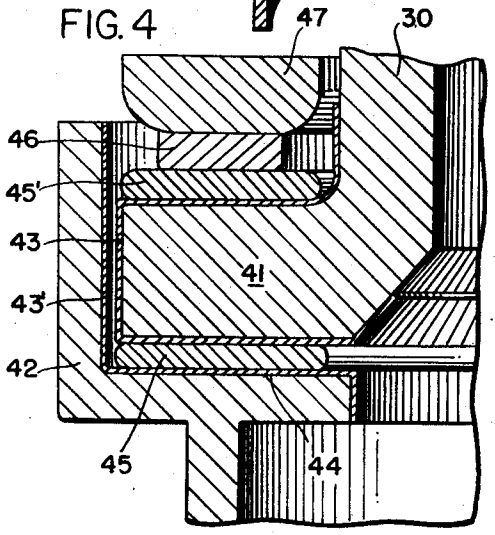
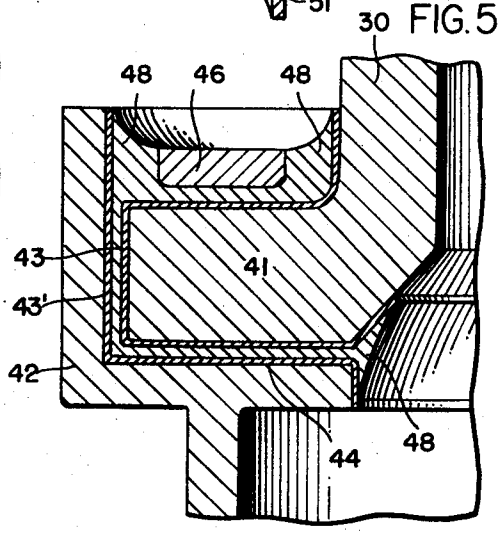


FIG. 5



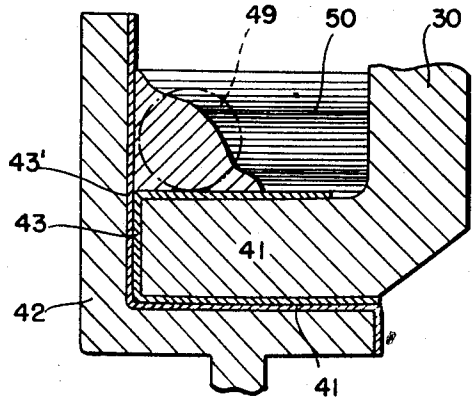


FIG. 6

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X-RAY TUBE

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Application June 29, 1955, Serial No. 518,886

2 Claims. (Cl. 313—59)

The present invention relates in general to electronics, and has more particular reference to X-ray generating tubes.

An important object of the invention is to provide an X-ray generating tube having an improved anode configuration; a further object being to provide simplified means for cooling the anode structure.

Another important object is to provide an anode structure for an X-ray tube embodying a preferably metallic portion comprising a tubular extension of the enclosing envelope of the ray generating tube, said extension being disposed in alinement with an electron emitting cathode enclosed within the envelope, the cathode remote end of the extension carrying an anode target and a surrounding ray emitting window of novel construction forming a part of the tubular extension; a further object of the invention being to form the window as a sleeve completely surrounding and enclosing the target in all directions radially thereof; yet a further object being to provide adequate means for cooling the window structure in order to minimize the danger of damage thereto as the result of heat produced at the ray generating electron target enclosed within said window.

Another important object is to provide an improved X-ray window construction for ray generating tubes; a further object being to provide a window structure comprising a preferably cylindrical sleeve element of ray translucent metal, such as beryllium, having end flanges thereon affording means for hermetically sealing the window element in the envelope structure of an X-ray tube; a still further object being to seal one end of the sleeve-like window element to the envelope of the generating tube and to sealingly secure an anode structure to the other end of the window element in position presenting an electron target portion of the anode structure within the sleeve-like window element, whereby the anode structure is supported on the envelope of the tube by the window element; a still further object being to cool the window element at each of its opposite ends by circulating a fluid cooling medium in heat exchange relationship with respect to each of said ends through ducts formed, respectively, in the envelope portions on which the window element is secured and in the anode structure carried by the window element.

Another important object is to provide a window structure for X-ray generating tubes comprising a preferably cylindrical sleeve of ray translucent material, such as beryllium, having integral outstanding flanges formed at the opposite ends of the sleeve and each sealed in a mounting ring or ferrule of metal, such as steel, monel metal, or other metallic alloy including iron or nickel, adapted for attachment as by welding or brazing with metals of the sort commonly employed in the construction of X-ray tube envelopes and anodes.

Another important object of the present invention is to provide for soldering a metal, such as beryllium, which is readily soluble in other metals including solder or brazing material; a further object being to provide for

joining such readily soluble metal with other more difficultly soluble metals, such as steel and other alloys including iron and nickel as constituents; a still further object being to provide a sealed envelope or casing, such as the envelope of an X-ray generating tube, having an insert or window of readily soluble ray translucent material, such as beryllium, sealed to an envelope portion of difficultly soluble metal, such as steel, monel metal or other alloys embodying iron and nickel as alloy constituents; yet another object being to provide an improved X-ray tube envelope having a ray translucent beryllium window sealed in the envelope structure.

Another important object of the invention is to promote and facilitate the joining of an element comprising a readily soluble metal, such as beryllium, with another metal member substantially without contaminating the readily soluble metal element by diffusion therein of other metal during the soldering operation; a further object being to accomplish the joining of the element of readily soluble material with another metal member by initially coating the element, at the surfaces thereof to be joined, with a film of a suitable joining metal adhered thereto in any suitable fashion, as by electroplating the film upon the surfaces of the element, and by then soldering, brazing or otherwise joining the coated portions of the element to the metallic member with which it is to be joined.

Another important object is to join a beryllium element with a metal member by first coating the surfaces of the beryllium element with a film of copper, silver or like metal, and by then soldering or brazing the coated surfaces of the beryllium element to the member to which it is to be joined, by means of a suitable soldering substance, such as pure silver solder, adapted to wet the material of the plated film as well as the material of the metal member with which the beryllium element is to be joined.

Briefly stated, a preferred embodiment of the invention may comprise an X-ray generating tube having a sealed envelope providing a tubular metallic portion forming an extension of the envelope in alinement with an envelope enclosed electron emitting cathode. The cathode remote end of the extension may be sealed to one end of a beryllium sleeve, on the opposite end of which an anode structure is sealingly secured and supported in position presenting an X-ray generating electron target in alinement with the cathode and within the beryllium sleeve, whereby X-rays, generated as the result of impingement on the target of cathode emitted electrons, may be transmitted outwardly of the envelope through said beryllium window sleeve in all directions radially of the ray generating target. The envelope extension to which the window sleeve is attached, as well as the anode structure supported on the sleeve, may both be formed with ducts for the circulation of a cooling fluid in heat exchange relation with respect to the opposite ends of the window sleeve, said opposite ends having outwardly extending flanges sealed in ferrules of metal, such as steel. These flanges of readily soluble beryllium may be sealed in the steel ferrules substantially without contaminating the material of the ray translucent window element by first coating the same with a layer of metal, such as copper, as by electroplating a film of copper on the flanges, and by then silver soldering the plated flanges in the ferrules. The ferrule at one end of the window element may then be welded or otherwise sealingly attached to the envelope extension, after which the anode structure may be sealingly mounted, as by welding the same to the ferrule at the extension remote end of the window element.

The foregoing and numerous other important objects, advantages, and inherent functions of the invention will

become apparent as the same is more fully understood from the following description, which, taken in connection with the accompanying drawings, discloses preferred embodiments of the invention.

Referring to the drawings:

Fig. 1 is a side view of an X-ray generating tube embodying the present invention;

Fig. 2 is an enlarged sectional view taken substantially along the line 2—2 in Fig. 1;

Fig. 3 is a perspective view partially sectionalized of a ray translucent window element forming a part of the tube structure shown in Figs. 1 and 2;

Fig. 4 is an enlarged sectional view taken through a portion of the window element and a metal ferrule in which the element is to be sealed, the parts being shown in position immediately prior to the commencement of the sealing operation;

Fig. 5 is a view of the parts illustrated in Fig. 4, showing the same in sealed condition upon completion of the sealing operation; and

Fig. 6 is a sectional view, similar to Fig. 5, illustrating a modified arrangement embodying the invention.

To illustrate the invention the drawings show an X-ray generator tube 7 comprising a tubular structure forming a sealed envelope 8, said envelope preferably embodying a cathode enclosing portion 9 and a tubular anode carrying portion 10 disposed in coaxial alinement at the opposite ends of the envelope structure. The cathode enclosing portion 9 may comprise alternate metal and glass sections 11 and 12, sealed together in end-to-end relationship and including a preferably glass end section 13 supporting and enclosing an electron emitting cathode structure 14 within the envelope, said end section 13 having reentrant portions 13' providing an annular edge extending within the envelope and conventionally sealed with the cathode structure 14, whereby to support the same firmly upon said reentrant portions, preferably concentrically within the envelope end portion 13.

The metal envelope sections 11 may carry electronic lenses within the envelope portion 9 in concentric alinement with respect to the electron emitting cathode structure 14, in manner shown in U.S. Letters Patent No. 2,336,774 of December 14, 1943. The metal portions 10 of the envelope structure may conveniently comprise a tubular element 15 of metal, such as steel, sealingly connected at one end in a preferably metal junction ring 16, which is secured to the cathode enclosing portion 9 of the envelope at the end thereof remote from the cathode carrying and enclosing end section 13, the tubular element 15 extending in concentric alinement with respect to the envelope portion 9 and the cathode structure supported therein.

At its cathode remote end, the tubular element 15 carries an X-ray generating anode structure 17 forming an anode target 18 in concentric alinement with respect to the electron emitting cathode. Spaced from the junction ring 16, the tubular element 15 carries a mounting ring 19 of metal which may be circumferentially sealed upon the element 15, as by welding or brazing, as shown at 20 and 20', said mounting ring providing a peripheral seat, outwardly of the tubular element 15, for sealingly securing an end of a preferably metallic jacket sleeve 21, disposed in position extending concentrically around the tubular element 15 between the mounting ring 19 and the cathode remote end of the element 15, thereby providing a cylindrical space 22 within the jacket sleeve 21 and around the tubular element 15.

A mounting flange 23 having a hub 24 may be firmly secured upon the mounting ring 19 and the ring connected end of the jacket sleeve 21, the hub 24 being sized to snugly embrace the mounting ring and the ring connected end of the jacket sleeve; and the hub may be welded or otherwise circumferentially secured on the mounting ring and to the jacket sleeve, as indicated at 25 and 25'. The flange 23 may serve as convenient means for mounting the X-ray generating tube in position on or in a tube support structure of any suitable, preferred or convenient character.

The cathode structure 14 may conventionally comprise an electron emission element 26, supported thereon in position to emit a stream or beam of electrons 27 in a direction coaxially through the tubular envelope element 15 toward the anode target 18. The emission element 26 preferably comprises an electron emitting filament adapted to be energized by connection with a suitable source of filament energizing power, outwardly of the envelope, as through electrical conductors 28 connected with the emission filament within the envelope and extending thence outwardly through suitable conductor seals.

It should be understood that an X-ray generating tube functions to produce X-rays at the anode target 18 by the impingement thereon of electrons generated at and emitted by the emission element 26 and directed as an electron stream 27 upon the target under the influence of electrical potential applied between the emission and target elements. X-rays generated at the target means 18, by electron impact thereon, may be delivered thence outwardly of the envelope in all directions radially of the target 18; and the present invention especially contemplates the provision of a ray translucent window 29, as a part of the anode structure 17 supported on the cathode remote end of the tubular element 15, said window being of sleeve-like configuration and enclosing the anode target in fashion permitting X-rays to be emitted from the target through the window in all radial directions.

As shown, the window 29 preferably comprises a cylindrical sleeve 30 of material having low ray absorbing characteristics, whereby to transmit X-rays from the anode target 18, outwardly of the envelope, without appreciably diminishing the intensity and character of the rays. To this end, the window preferably comprises a sleeve of beryllium, which is a metal that is translucent, indeed substantially transparent, to X-rays. The sleeve-like window 30 is sealed at one end to the cathode remote end of the tubular element 15, the anode structure 17 being sealed to the other end of said sleeve-like window.

The operation of an X-ray generating tube is always accompanied by the generation of substantial quantities of heat, especially where the tube is designed for high voltage operation. The heat produced by the operation of an X-ray tube is generated principally at the anode target 18 as the result of electron impact thereon at high velocity. The disposition of the X-ray window 30 in position closely encircling the electron target exposes the window to the deleterious action of the heat generated at and emitted by the target, such deleterious action being appreciably enhanced when the generating tube is operated intermittently, whereby the anode structure, including the closely adjacent window, is alternately exposed to the heat generated at the anode when the device is in operation, and the relatively low temperature conditions of the order of normal atmospheric temperature to which the device may cool down during intervals when the device is not in operation. In order to minimize the deleterious effects of heat upon the window 30, the present invention provides means for maintaining the same, at all times during the operation of the ray generating tube, at a safe, relatively low temperature to thereby prevent impairment of the window element and the hermetic seals by means of which the same is secured to the tubular envelope element 15 and to the anode structure 17.

To these ends, the anode structure 17 may comprise a hollow shell member 31, preferably made of copper and having conical side walls and an end wall 32, the end of the shell 31 remote from the wall 32 being open. The anode structure may provide means for mounting the shell on the cathode remote end of the tubular element 15 in position presenting the wall 32 in the path of the electron beam 27, the cathode facing surface of said

wall preferably carrying a plate or button 32' forming the electron target 18. At its open end, the shell member 31 may form a rim 33 sized to snugly fit within a seat 34 formed in an end member 35.

The end member 35 may comprise a circular flange portion 36 containing the seat 34 and a central frusto-conical portion 37 adapted to extend concentrically within the conical side walls of the shell member 31 and behind the end wall 32 thereof to define a chamber 38 surrounding the frusto-conical surfaces of the portion 37 within the hollow shell 31. The chamber 38 may be connected centrally and marginally, respectively with conduits 39 and 40, for the circulation of a cooling fluid to and from the chamber 38 and in heat exchange relationship with the wall portion 32 of the shell member behind the electron target 18, to continuously cool the same during operation of the generating tube.

The anode structure 17 may also comprise mounting components including a sleeve member 15', preferably of metal such as steel, similar to the material of the tubular envelope element 15, the sleeve member 15' encircling the shell member 31 and being brazed or otherwise integrated at one end with the rim 33 of the shell member. The mounting component 21' may comprise a relatively thin sheet metal jacket sleeve, of material such as steel, similar to the material of the jacket member 21. The jacket member 21' may be welded or otherwise sealingly secured to the peripheral edge of the flange portion 36 of the end member 35 in position concentrically enclosing the sleeve member 15', whereby to define a cylindrical space 22' between the sleeves 15' and 21', said cylindrical space being in open communication on one side with the conduit 40 and on the other side with the fluid circulation chamber 38.

In order to seal the sleeve-like window element 30 to the cathode remote end of the tubular envelope element 15 and to the anode structure 17, it may be formed with integral outstanding flanges 41, 41' at its opposite ends, attachment rings or ferrules 42, 42' being integrally connected, as by soldering, with said flanges. The ferrules preferably comprise monel or other suitable metal of a sort adapted to be solderingly connected with the material of the window member 30 and also capable of being readily integrated with the preferably steel envelope and jacket members 15 and 21 of the X-ray tube and with the corresponding mounting components 15' and 21' of the anode structure 17.

The window element 30 preferably comprises beryllium, which is difficult to join with other metals by usual soldering techniques, because of the high affinity of beryllium for the usual silver or copper-silver solder employed in such joining operations. Undesirable contamination of the beryllium element by the alloying thereof with the solder, during the soldering operation, is an especially difficult problem, particularly in view of the fact that relatively large solder fillets are required to obtain the desired vacuum tightness in the soldered joint; and this problem is particularly troublesome where beryllium windows of relatively large area have to be soldered in place.

In order to obviate the foregoing difficulty, the surfaces of the flanges 41, 41' may be electroplated with a film or layer 43 of metal, such as copper or silver. If desired, a like film 43' of copper or silver may be applied, as by electroplating the same upon the surfaces of the metal members or ferrules 42, 42' with which the flanges 41, 41' of the beryllium window element are to be sealed. The coated surfaces of the beryllium element may then be sealed to the facing surfaces of the members with which it is to be sealingly connected, as by means of pure silver solder, or other suitable solder adapted to wet and alloy with the material of the beryllium coating layer 43 and with the surface material of the metal member with which the beryllium element is to be integrated. No flux is required in such a soldering operation. The solder may indeed wet the material of the beryllium element beneath the layer 43, to a limited extent, through the coating film 43, whereby the solder may become integrated with the beryllium flanges 41, 41' without, however, excessively contaminating the beryllium, or indeed contaminating the ray transmitting window portions of the element 30 which extend between the end flanges 41, 41'.

Beryllium, when heated, forms an oxide surface coating which can not be wetted by the solder without the employment of fluxing material to dissolve the oxide at soldering temperatures. It has been found, for example, that beryllium may be oxidized to a depth of as much as 1/32" when heated to soldering temperature for even short periods of time. Accordingly, to prevent the formation of oxide during the soldering operation, the flanges of the beryllium element may be electrified, as aforesaid, with copper or silver, to an approximate depth of the order of 0.0005".

The flanges of the beryllium element may be plated by conventional methods. The element 30 may then be mounted at one end within a ferrule 42, said ferrule, if desired, and preferably through not essentially, having also been coated with copper or silver either by electroplating or in a hydrogen furnace. Only those portions of the beryllium element and of the metal members 42, 42' which are to be secured together need or should be plated. The ferrules 42, 42' may comprise any suitable metal, including steel, monel metal or a metallic alloy including iron or nickel, and may provide each a seat 44 for receiving and supporting the corresponding flange of the window element within the ferrule.

As shown more particularly in Figs. 4 and 5, the flanges of the beryllium element may each be sized to fit more or less freely in the seat formed by the ferrule with which it is to be connected. The solder may be formed as a pair of flat rings 45 and 45', the ring 45 being applied upon the seat 44 beneath the flange 41, while the other solder ring 45' may be assembled on top of the flange within the surrounding wall of the ferrule. A bonding ring 46 of monel or other suitable metal may be mounted in the assembly upon the solder ring 45'. A weighting member 47 comprising a ring of appreciable mass is preferably applied upon the bonding ring 46 in order to hold the assembly in place during the soldering operation, said weighting member being adapted to apply substantial thrust, of the order of ten pounds, upon the bonding ring 46; and the ring engaging portions of the weighting member may be and preferably are coated with magnesium oxide or other suitable anti-soldering material to prevent it from becoming attached to the assembly during the bonding process. Since the weighting ring has to be applied around the medial portions of the window element, between the spaced apart end flanges 41, 41', said weighting ring of necessity may be of expanding sectional character to allow the same to be assembled around the window element. For like reasons, the bonding ring 46 may also be formed in sections for assembly in position encircling the member 30.

The foregoing soldering assembly may then be heated in an evacuated chamber, as by means of a high frequency induction coil, in order to fuse the solder. During the soldering operation, the assembly is preferably maintained under vacuum conditions of the order of 1–5 microns, soldering being accomplished by the melting of the solder rings 45 and 45' in contact with the adjoining surfaces of the parts being connected. The fused solder may flow between said surfaces to form layers of solder therebetween and also to form substantial solder fillets 48 and 48' between the joined parts, thereby sealing the same hermetically together. The bonding ring 46 aids in applying the thrust of the weighting member 47 to cause the solder to flow between the parts being joined and to form the fillets 48 on opposite sides of the bonding ring,

said ring being allowed to remain as an integral part of the joint at the conclusion of the soldering process.

As shown more particularly in Fig. 6, the bonding ring 46 may be omitted and the solder may be provided in the form of a single ring 49 adapted to be applied upon the flange 41, snugly adjacent the surrounding wall of the ferrule 42. The assembly may then be heated in an evacuated chamber, as by means of a high frequency induction coil, while maintaining the soldering assembly under low pressure conditions of the order of 1–5 microns, soldering being accomplished by the melting of the solder ring to form a substantial fillet of solder 50 hermetically sealing the parts together by the formation of complex alloys, which include not only the solder and the material of the coatings 43 and 43', but also the material of the member 42 and of the flange 41 in the immediate vicinity of the joint. If the flange 41 be sized to fit loosely within the ferrule 42, the solder may penetrate downwardly, during the soldering operation, between the ferrule 42 and the peripheral edge of the flange 41 and integrally unite the parts throughout the entire width of the flange. After a ferrule 42 has thus been soldered to the flange 41 at one end of the window element, the same may be inverted and the ferrule 42' attached to the flange 41' at its other end by a repetition of the foregoing soldering procedure.

Each of the ferrules 42, 42' may be formed with an integral, preferably cylindrical flange 51, 51' sized to snugly encircle the tubular members 15 and 15', which cylindrical flanges may be integrated one with the cathode remote end of the tubular envelope member 15, and the other with an end of the anode mounting sleeve 15', whereby to sealingly secure and mount the window element 30 at one end thereof on the tubular member 15 in coaxial alinement therewith, and to sealingly secure the anode structure 17 upon the other end of the window element 30 in coaxial alinement therewith. After the window element has thus been secured upon the tubular member 15, and before the anode structure has been mounted and secured upon the window element, the jacket sleeve 21 with flange 23 secured thereto may be applied slidingly over the window element into position around the tubular member 15 and sealed in place, as at 25, on the previously attached mounting ring 19. The flange remote end of the jacket sleeve 21 is formed to snugly embrace the outer surfaces of the ferrule 42 and may be soldered or otherwise sealed thereto, as at 52. The space 22 thus formed between the jacket sleeve 21 and the tubular envelope member 15 extends between the mounting ring 19 and the window carrying ferrule which is sealed to the cathode remote end of the envelope member 15.

A suitable cooling fluid may be circulated from a source thereof outwardly of the X-ray tube through the chamber 22, as by means of conduits 39' and 40', which may be connected with the chamber 22, as through the hub 24 of the flange 23. The cooling fluid inlet pipe 39' preferably opens in the chamber 22 adjacent the window mounting ferrule 42 which forms the end of said chamber, so that cooling fluid may be applied directly in heat exchange relation with respect to the ferrule and the flange 41 which is secured thereto, the cooling fluid flowing thence toward the ferrule remote end of the chamber 22 for discharge therefrom through the conduit 40'.

After the jacket sleeve 21 has thus been assembled and soldered to the ferrule 42 at one end of the window element, the anode structure 17 may be sealed to the ferrule 42' at the opposite end of the element, as by soldering the cylindrical flange 51' of the ferrule sealingly to the end of the anode supporting sleeve 15' and by soldering or otherwise sealingly securing the ferrule 42', peripherally as at 52', with the jacket sleeve component 21'. The cooling fluid inlet conduit 39' is arranged to deliver cooling fluid within the chamber 22' directly in heat exchange relation with respect to the ferrule 42' and the flange 41' of the window element which is sealed in said ferrule, cooling fluid flowing thence into the chamber 38 in heat exchange relation with the anode target supporting wall 32, and being discharged therefrom through the fluid outlet conduit 40.

It will be seen from the foregoing that devices built in accordance with the teachings of the present invention provide a ray pervious window structure adapted to transmit rays from a source in all directions radially thereof, which, so far as is known, has never heretofore been accomplished in a structure embodying a ray pervious window element of beryllium. An important feature of the present invention, accordingly, is the provision of the complete circumferential window element 30 of beryllium, the novel manner in which the window structure is mounted upon the cathode remote end of the tubular envelope member 15, including the flange 41 and ferrule 42, and the arrangement whereby the mounted end of the window is at all times in heat exchange relation with respect to cooling fluid circulated in the chamber 22.

A further important feature of the present invention is the manner in which the anode structure 17 is mounted and supported entirely upon and by the window element 30, including the flange 41' and ferrule 42', and the arrangement whereby the anode supporting end of the window is at all times maintained in heat exchange relation with respect to the cooling fluid circulated in the chamber 22'.

It is thought that the invention and its numerous attendant advantages will be fully understood from the foregoing description, and it is obvious that numerous changes may be made in the form, construction and arrangement of the several parts without departing from the spirit or scope of the invention, or sacrificing any of its attendant advantages, the forms herein disclosed being preferred embodiments for the purpose of illustrating the invention.

The invention is hereby claimed as follows:

1. An X-ray generator comprising an envelope having a tubular metal portion, a jacket sleeve surrounding said portion, a window sleeve of beryllium formed with an integral outstanding peripheral flange, at each of the opposite ends thereof, said flanges serving to radially strengthen said sleeve at its opposite ends, a pair of metal ferrules sealingly secured each to a corresponding one of said flanges, each of said ferrules providing concentric inner and outer seats, said tubular metal portion and said jacket sleeve having ends respectively sealed on the inner and outer seats of one of said ferrules, to form a chamber at one end of the window sleeve, anode means comprising a frame carrying an electron target and embodying inner and outer sleeve members having ends respectively sealed on the inner and outer seats of the other of said ferrules, to form a chamber at the other end of said window sleeve, and means to circulate a cooling fluid in each of said chambers in heat exchange relation with respect to said ferrules and the attached flanges of the window sleeve.

2. An X-ray generator comprising an envelope having a tubular metal portion, a jacket sleeve surrounding said portion, a window sleeve of beryllium formed with an integral outstanding peripheral flange, at each of the opposite ends thereof, said flanges serving to radially strengthen said sleeve at its opposite ends, a pair of metal ferrules sealingly secured each to a corresponding one of said flanges, said ferrules each providing an upstanding peripheral wall and an integral inwardly extending ledge forming a seat within said peripheral wall sized to receive a said flange, each ferrule having an integral dependent rib extending beneath said ledge inwardly of said peripheral wall, said wall and rib respectively forming inwardly and outwardly facing seats, said tubular metal portion and said jacket sleeve having ends respectively sealed on the inwardly and outwardly facing seats of a

said ferrule, to form a chamber at one end of the window sleeve, anode means comprising a frame carrying an electron target and embodying an inner and outer sleeve member having ends respectively sealed on the inwardly and outwardly facing seats of the other of said ferrules, to form a chamber at the other end of said window sleeve, and means to circulate a cooling fluid in each of said chambers in heat exchange relation with respect to said ferrules and the attached flanges of the window sleeve.

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