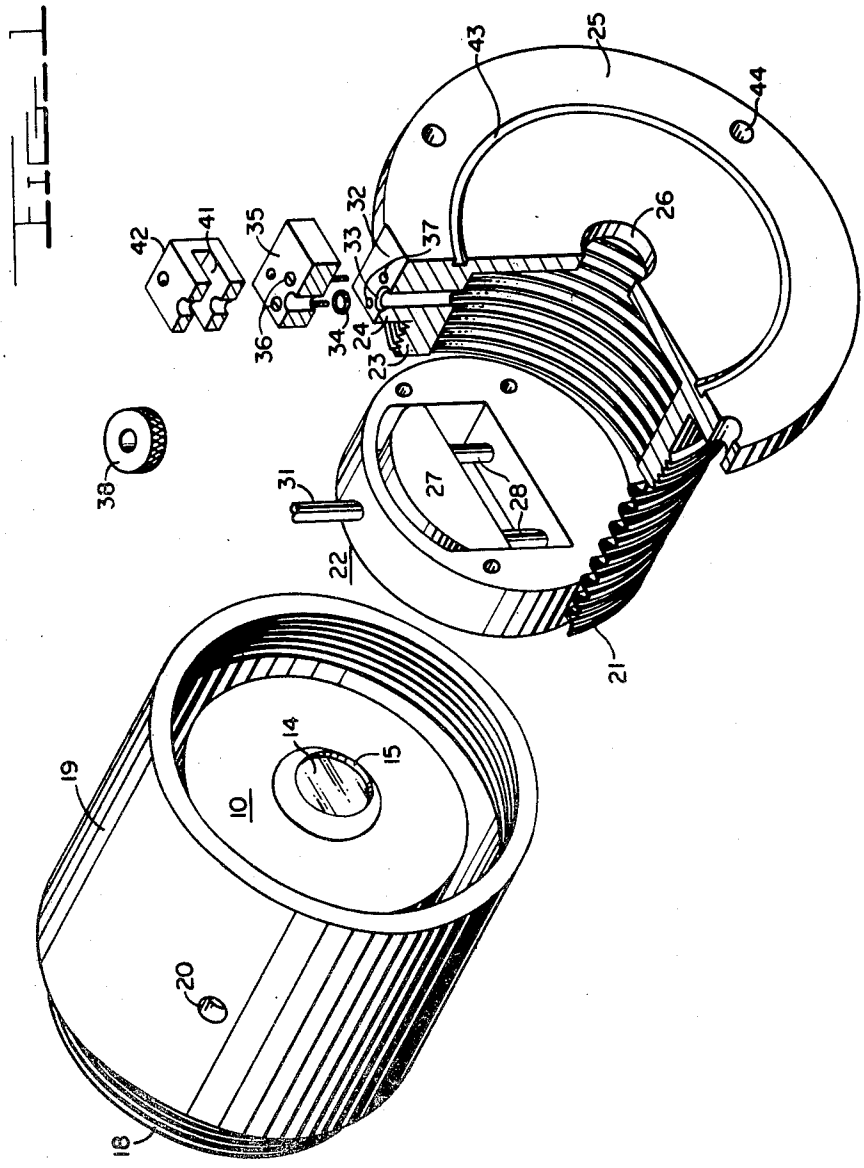
July 13, 1965 J. A. SOULES 3,194,624

METHOD OF EVACUATING AN X-RAY TUBE HAVING A THIN WINDOW

Original Filed May 22, 1962 2 Sheets-Sheet 1

FIG. 1



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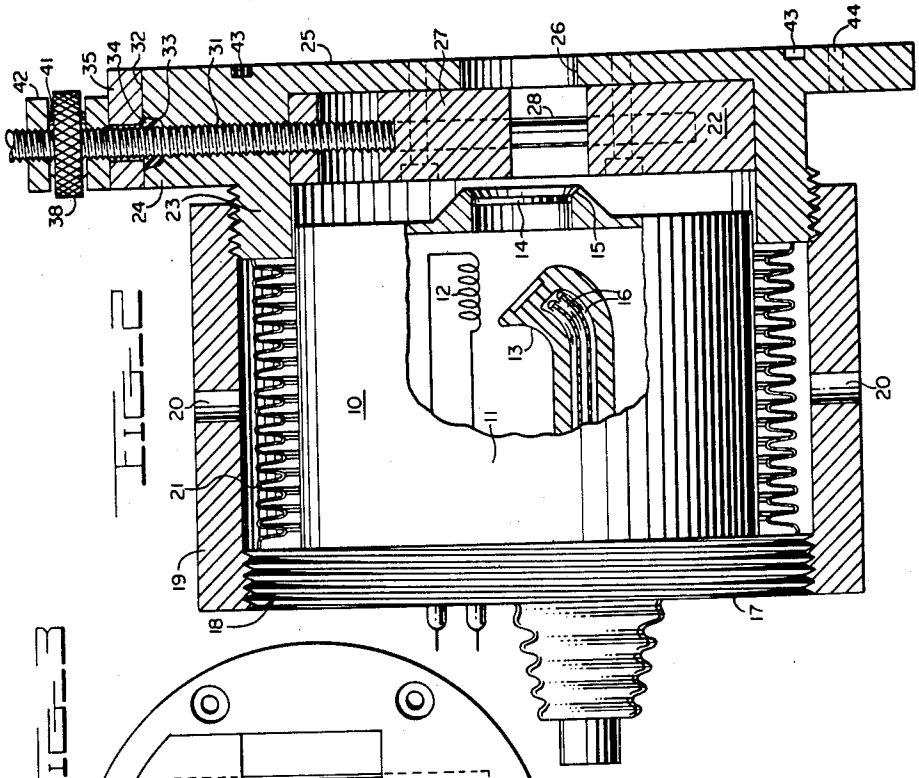


FIG. 2

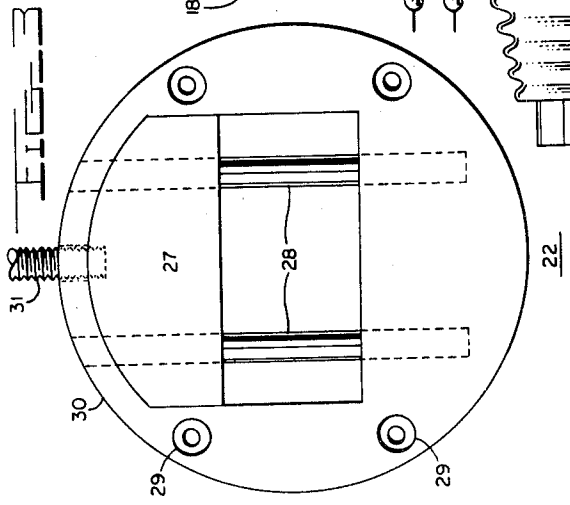


FIG. 3

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METHOD OF EVACUATING AN X-RAY TUBE HAVING A THIN WINDOW

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Original application May 22, 1962, Ser. No. 196,837, now Patent No. 3,135,889, dated June 2, 1964. Divided and this application Mar. 30, 1964, Ser. No. 371,165

4 Claims. (Cl. 316—18)

(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This application is a division of application Serial Number 196,837, filed May 22, 1962, now Patent Number 3,135,889, patented June 2, 1964.

The present invention relates to X-ray tubes useful as a source of soft X-rays and more particularly to a method of evacuating an X-ray tube having a thin window.

Heretofore most usage of X-rays has been in the hard X-ray range below 10 Angstroms which penetrate the subject being examined. More and more emphasis is being placed on research or studies which make use of the soft X-ray region between 10 and 100 Angstroms, in which the X-rays have a low penetrating power. The hardness of X-rays produced by an X-ray tube depends on the impressed voltage, and the amount of useful X-rays emanating from the tube depends on the exit window. Thick windows absorb most soft X-rays produced, therefore soft X-ray production requires very thin windows. Also, an extremely high vacuum is required in an X-ray tube to provide a clean anode and therefore a uniform and constant X-ray spectral distribution. Pressure differentials between the X-ray tube and the surrounding medium require sufficiently thick windows to prevent breakage thereof. Therefore, the production of soft X-rays depends strongly on the window which can be used in the X-ray tube, and the type of material and thickness of the tube window, as well as the X-ray tube, depends on the ability of the window to withstand the high temperatures and vacuum pressure experienced in degasifying the metal parts within the tube and subsequent operation of the tube for continuous operation.

Heretofore, X-ray tubes have been used for spectrographic or crystalline analysis in which the X-ray tube and the vacuum chamber, in which the X-rays are used, are made into one integral system. In such a system, the X-ray tube and vacuum chamber are operated at the same vacuum pressure. This has the disadvantage that the X-ray anode cannot be kept clear and the spectral distribution is generally not uniform or constant.

The X-ray tube of the present invention makes use of a gate valve in combination with an X-ray tube which has a very thin tube window. The combination can be used to produce soft X-rays and to protect the window against damage if the tube is removed from the vacuum system within which the tube is normally used. The combination also permits evacuation of an X-ray tube to an ultra-high vacuum pressure of about 10^{-9} mm. Hg and baking of the combination at very high temperatures during degassing of the tube. Further, the combination permits operation of the X-ray tube at a pressure different from that of the vacuum system or chamber within which the X-ray tube is used.

It is therefore an object of the present invention to provide a method by which an X-ray tube having a very thin window can be evacuated to an extremely high vacuum in atmospheric pressure.

Still another object is to provide an X-ray tube which will withstand high temperature during degassing or use without deleterious effects on the tube window.

While still another object is to provide an X-ray tube operable in a vacuum system in which the pressure in the tube is much lower than that of the vacuum system within which the X-ray tube is operated.

The nature of this invention as well as other objects and advantages thereof will be readily apparent from consideration of the following specification relating to the annexed drawings, in which:

FIG. 1 is an exploded view shown in perspective which illustrates the relative parts of the invention;

FIG. 2 is a side view partly cut away to better illustrate the parts; and

FIG. 3 is an end view of the gate valve assembly.

Now, referring to the drawings, there is shown by illustration an X-ray tube 10 provided with a metal envelope 11, or any other suitable material, comprising a cathode unit 12 and an anode unit 13 positioned relative to each other and adjacent to an X-ray exit window 14. The anode comprises a suitable target such as tantalum molybdenum or tungsten to provide an X-ray source which is directed through a very thin foil window 14 of Al_2O_3 or other low X-ray absorbing material. The window is sealed in a special opening in one end of the tube which is formed with a sharp, shaped, right angular corner 15. The X-ray tube is provided with an electrical source of less than 10,000 volts, not shown, for simplification of the drawings, suitable for producing soft X-rays having wavelengths between two and one hundred Angstrom units. The tube is also provided with suitable means for securing the cathode and anode in place and is provided with a tubular passage 16 to the anode through which water is forced to cool the anode during use. The base 17 of the X-ray tube is larger in diameter than the envelope and is provided with right-hand threads 18 of about thirty-two threads to the inch on the outer edge to which one end of a coupling 19 is secured by screw threads. The coupling 19 is provided with holes 20 therein within which a spanner wrench fits to rotate the coupling. One end of a stainless steel bellows 21 is secured to the base between the envelope and the coupling and extends therebetween along the envelope.

A gate valve assembly 22 is secured within a housing having a cylindrical portion including a threaded end 23 which is provided with twenty-four threads to the inch and an outwardly extending rim 24 with the cylindrical portion extending to an integral front wall 25 which is a continuation of the ridge and which is provided with a central aperture 26. The gate valve assembly 22 is secured in the housing by suitable bolts 29 and includes a cylindrical structure 30 with a somewhat semicircular opening in the upper portion and solid portion at the bottom. The opening in the top portion is sufficiently large to receive therein a gate valve 27 of semicircular shape which has a radial upward movement sufficient to clear the central aperture 26 in the front wall of the housing and the X-ray exit window of the tube and a sufficient downward movement to entirely cover the aperture 26 and the X-ray exit window. The gate valve 27 can be made of copper or any other suitable material and is provided with parallel passages therein through which guide rods 28 are passed to secure the gate valve for radial movement within the gate valve assembly. The guide rods 28 are passed through the upper wall of the assembly and extended downwardly into the solid bottom portion of the circular structure 30 and secured therein by screw threads or any other suitable manner. The gate valve is moved relative to the guide rods by a draw rod 31 which passes through an aperture in the circular structure 30 and then through the ridge of the housing. The gate valve is moved parallel to the front wall of the housing and can be moved to a position above the X-ray

tube window and the aperture in the housing and when lowered, the gate valve will rest on the solid bottom portion of the gate assembly and lie across the aperture and window. The gate is of such a size that it is larger than the window opening in the X-ray tube but small enough in radius that it can be raised out of the path of X-rays emanating from the target on the anode of the X-ray tube.

The stainless steel bellows is soldered or welded to the face of the threaded cylindrical end 23 and the threaded end 23 is then secured to the coupling 19 by the threads thereon. When the gate assembly is secured to the coupling, the aperture 26 of the gate assembly is in axial alignment with the window 14 and the gate valve 27 is adapted to be moved across the window proximate thereto or stored in a position out of the path of any X-rays emanating from the X-ray tube.

The top portion 32 of the gate assembly housing through which the draw rod 31 passes is milled flat and has a shallow hole 33 of larger diameter than the hole through which the draw rod passes. Any suitable gasket 34 is placed in the shallow hole 33 to provide a vacuum tight seal about the draw rod. The vacuum seal gasket is held in place by a plate 35 and screws 36 which screw into appropriately threaded holes 37 in the top flat surface of the gate valve assembly. The draw rod can be moved by any desired method; however, it is shown as having a threaded end which passes through a knurled nut 38 which is held in place within a slot 41 of a slotted element 42 which is secured to the plate 35 that holds the vacuum seal in place. As the knurled nut is rotated the draw rod will be fed through the nut to either lower or raise the gate and the nut will be restrained by the slotted element.

For the purpose of securing the X-ray tube-gate valve assembly to a vacuum system, the outer face of the solid end of the gate valve assembly has a circular groove 43 therein for receiving a gasket, not shown, and holes 44 in the outer portion through which bolts pass to secure the gate valve-X-ray tube assembly to a matching surface in the vacuum system.

In assembling the X-ray tube-gate assembly into one unit, the X-ray tube is assembled by the usual process of securing the cathode, anode, window, etc., to make up the tube. The gate assembly can be assembled by many methods, one of which will be explained. The gate valve is held in place within the cylindrical structure, then the guide rods are passed through the holes therein and the cylindrical structure is secured in the housing by appropriate bolts. The draw rod 31 is then passed through the hole in the rim and screwed into the threaded hole in the gate valve. The vacuum seal is positioned in place and then the vacuum seal plate is placed down over the draw rod and secured to the milled flat portion of the rim. The knurled nut is held in position within the slot of the slotted element and screwed onto the draw rod until the slotted element reaches the vacuum seal hold down plate, then the slotted element is secured to the vacuum seal hold down plate. The gate valve assembly housing and X-ray tube are now separately assembled. The stainless steel bellows is secured to the X-ray tube base at one end and the coupling is slid over the bellows and screwed onto the threaded end of the X-ray tube. The other end of the bellows is then secured to the face of the gate valve assembly housing and the coupling is screwed onto the threaded cylindrical portion of the gate valve assembly housing. The X-ray tube-gate valve assembly is now ready for use.

In operation and evacuation of the X-ray tube in a vacuum system, the gate valve is lifted to its open position and the X-ray tube-gate valve assembly housing is secured to a vacuum system, not shown for simplification, by the use of the holes in the wall of the gate valve assembly housing. The X-ray tube and vacuum system

are evacuated simultaneously by separate lines so that the thin X-ray tube window will have the same pressure on each side thereof until a pressure of approximately 10^{-5} mm. Hg is reached. The gate valve is then moved across the window. The coupling is then rotated to force the sharp end about the X-ray tube window into a vacuum tight fit against the gate valve. The gate valve will be held in place against the guide bars by the force applied by the end of the X-ray tube on the gate valve.

Once the gate valve is secured in place in a vacuum tight seal by the sharp end of the X-ray tube about the thin window, the vacuum pressure within the area confined by the base of the X-ray tube, the gate valve and the stainless steel bellows will be about 10^{-5} mm. Hg. Also, the area confined by the sharp end of the X-ray tube between the gate valve and the thin window will have a vacuum pressure of 10^{-5} mm. Hg. This vacuum pressure will be maintained until the end of the X-ray tube is moved away from the gate valve. The knurled nut and slotted element, the vacuum seal hold down plate, and the vacuum seal are removed from the gate valve assembly, then the X-ray tube-gate valve assembly is disconnected from the vacuum system. The X-ray tube will now have the same vacuum pressure on each side of the window due to the gate valve being in a vacuum tight seal with the end of the X-ray tube. The evacuation of the X-ray tube is continued and the tube is baked at a high temperature of about 250° C. to about 450° C., and pumped simultaneously until an ultra-high vacuum of about 10^{-9} mm. Hg is achieved. The gas flow into the X-ray tube through the thin window when the external pressure on the outside of the window is of the order of 10^{-5} mm. Hg is negligible, thus an X-ray tube can be maintained at an ultra-high vacuum without harming the thin window by outside pressure. The force applied on the window by a difference in vacuum pressure between 10^{-5} mm. Hg and 10^{-9} mm. Hg is not sufficient to harm the window. Once the X-ray tube has been evacuated to the ultra-high vacuum and removed from the baking oven, the vacuum seal and knurled nut, etc., is assembled back onto the gate valve assembly housing. The X-ray tube-gate valve assembly can now be secured to a vacuum system for operation wherein the vacuum system is pumped to 10^{-5} mm. Hg with the X-ray tube-gate assembly in place. Once 10^{-5} mm. Hg has been reached in the vacuum system, the gate valve can be opened by turning the cylindrical nut in a reverse direction to move the X-ray tube away from the gate valve and then rotating the knurled nut to raise the gate valve out of the X-ray beam path. The system is now operative with an X-ray tube that has an ultra-high vacuum pressure of about 10^{-9} mm. Hg within the tube envelope and a vacuum system which is operable at 10^{-5} mm. Hg. Thus, there will be no harmful effects on the thin window during bakeout or operaton and the X-ray tube can be removed from the vacuum system without any harmful effects on the thin window by properly securing the gate valve relative to the X-ray tube window.

Such an operational system is beneficial wherein one may wish to use an X-ray tube that can be disassembled for some reason. In disassembling the X-ray tube, atmospheric pressure must be admitted into the tube and vacuum system simultaneously at the same rate to prevent breakage of the thin window.

Thus, the device of this invention permits one to use very, very thin windows which are useful in soft X-ray research and also provides a simple, convenient manner for making X-ray tubes with an ultra-high vacuum of about 10^{-9} mm. Hg. Thin windows referred to are of about 100 to 1000 Angstroms, or 10^{-6} cm. to 10^{-5} cm. thickness.

Al_2O_3 windows as referred to herein are well known in the art and are made by hot pressing aluminum onto a steel ring of a diameter just larger than the desired window opening in the X-ray tube envelope. The aluminum is oxidized to the desired thickness and then the aluminum

is etched away by any well known process, leaving the oxidized aluminum for the window. The steel ring affords a good material for securing the window to a metal envelope and the oxidized aluminum affords a very, very thin window, as noted above.

Heretofore, there was mention that the screw threads on the base of the X-ray tube are thirty-two threads to the inch and that the screw threads on the gate valve assembly housing are twenty-four threads per inch, each of which are right hand threads. The purpose for this arrangement is to advance the X-ray tube toward the gate valve at a very slow rate. As the coupling nut screws onto the cylindrical threaded portion drawing the gate valve toward the X-ray tube at a rate of twenty-four threads per inch, the coupling is simultaneously moving the X-ray tube away from the gate valve at a rate of thirty-two threads per inch. Thus, the advance of the X-ray tube toward the gate valve is very slow, approximately 0.01042 inch per revolution. The slow advance of the gate valve toward the X-ray tube insures a good seat which is important in making a good vacuum seal between the end of the X-ray tube and the gate valve. The gate valve is assembled proximate the sharp surface of the X-ray tube and therefore requires only a very short linear movement between the two surfaces to make a vacuum tight seal or to separate the end of the X-ray tube from the gate valve for operation of the tube for X-ray production.

As noted above, the gate valve housing and gate valve assembly are made separately. This provides for better engineering and since the gate valve moves along guide rods, these guide rod openings are on the inside of the housing and do not need any vacuum seals. If these guide rods extended through the housing, seals would be required. Since the only element that passes from the outside of the housing to the inside is the gate valve draw bar, there is a requirement for only one outside vacuum seal. It is also noted that the vacuum seal can be removed without breaking the vacuum of the X-ray tube, during bakeout or during the time the X-ray tube is not assembled into a vacuum system by use of the gate valve.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A method of evacuating and baking an X-ray tube having a thin window to obtain an ultra-high vacuum pressure in said tube without damage to said window which comprises securing said X-ray tube in a vacuum system, simultaneously evacuating said X-ray tube and said vacuum system to a high vacuum pressure, sealing off said thin window with a sealing means to maintain said high vacuum pressure between said thin window and said sealing means, removing said X-ray tube from said vacuum system with said sealing means sealing off said window, further evacuating and simultaneously baking said X-ray tube at a high temperature to obtain said ultra-high vacuum in said X-ray tube, sealing off said tube evacuation and terminating said baking.

2. A method of evacuating and baking an X-ray tube having a thin window without damage to said window while obtaining an ultra-high vacuum pressure in said tube, which comprises assembling said X-ray tube, securing said assembled X-ray tube with the window end within an evacuation system, simultaneously evacuating said X-ray tube and said evacuation system to a vacuum pressure of about 10^{-5} mm. Hg, sealing off the area about said thin window by a suitable sealing means to maintain a vacuum pressure of about 10^{-5} mm. Hg between said window and said sealing means, removing said X-ray tube from said vacuum system while maintaining said vacuum pressure in said X-ray tube and adjacent to said window, further evacuating said X-ray tube and simultaneously baking said X-ray tube at a suitable temperature to obtain an ultra-high vacuum pressure, sealing off said tube evacuation and terminating said baking, and removing said X-ray tube from said baking operation.

3. A method as claimed in claim 2 wherein a baking temperature of about 250° C. to about 450° C. is maintained during the baking operation.

4. A method of obtaining an ultra-high vacuum in an X-ray tube having a very thin window and then using said tube in a vacuum system without any damage to said thin window which comprises assembling said X-ray tube, securing said assembled X-ray tube with the window end within an evacuation system, simultaneously evacuating said X-ray tube and said evacuation system about said window end of said X-ray tube to a vacuum pressure of about 10^{-5} mm. Hg, sealing off the area about said X-ray tube thin window by use of a suitable sealing means to maintain a vacuum pressure of about 10^{-5} mm. Hg between said sealing means and said thin window, removing said X-ray tube from said evacuation system while maintaining said vacuum pressure in said X-ray tube and between said window and said sealing means, further evacuating said X-ray tube and simultaneously baking said X-ray tube at a temperature of about 250° C. to about 450° C. in a baking means until an ultra-high vacuum is formed in said X-ray tube, sealing off said evacuation of said tube and removing said tube from said baking means, inserting said window end of said X-ray tube into a desired evacuation system, evacuating said system to a vacuum of about 10^{-5} mm. Hg, removing said sealing means from said window of said X-ray tube and operating said X-ray tube in said evacuation system to produce a desired X-ray source.

No references cited.

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