Dec. 23, 1969 G. W. SWANSON 3,486,060

COOLING APPARATUS WITH LAMINAR FLOW FOR ELECTRON PERMEABLE WINDOWS

Filed Sept. 6, 1967 2 Sheets-Sheet 1

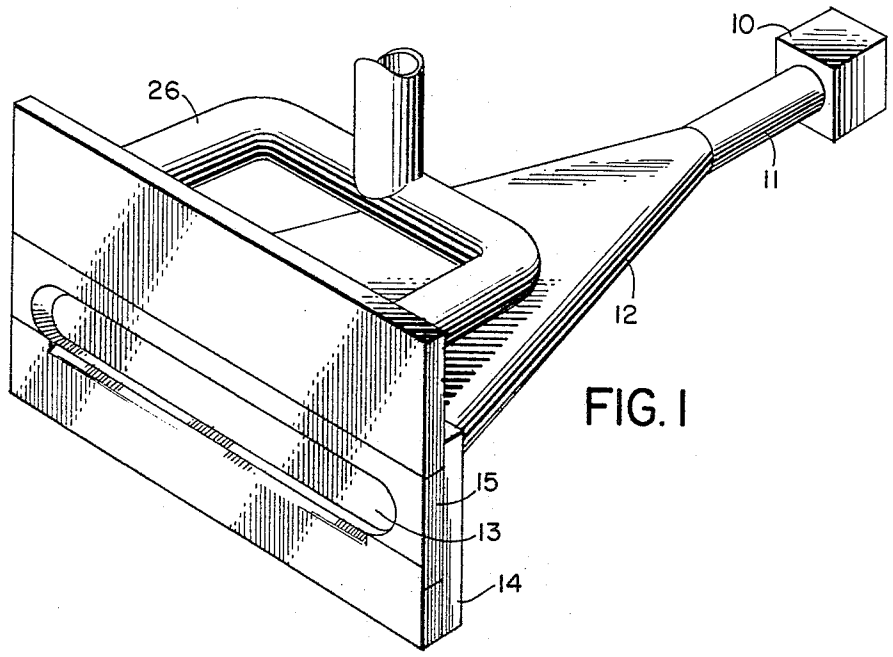


FIG. 1

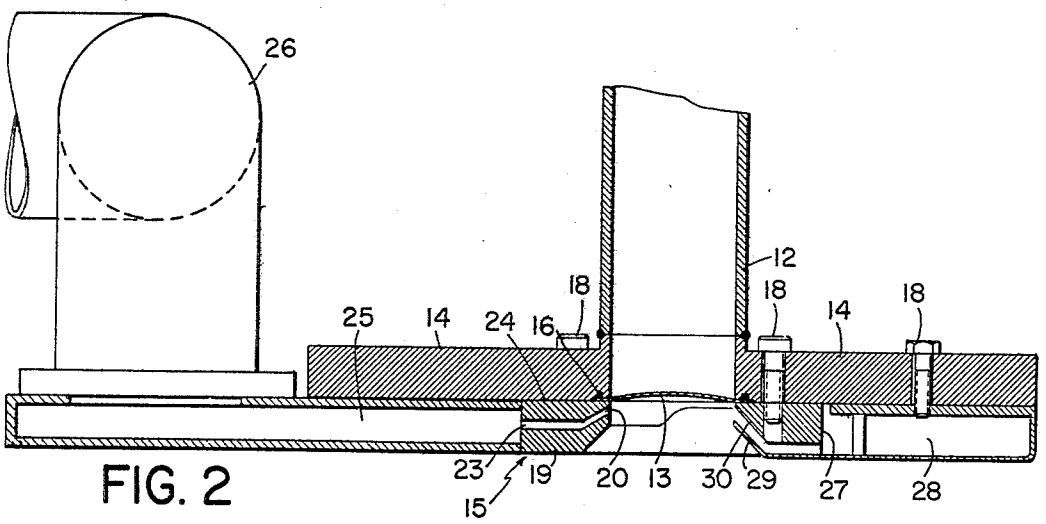


FIG. 2

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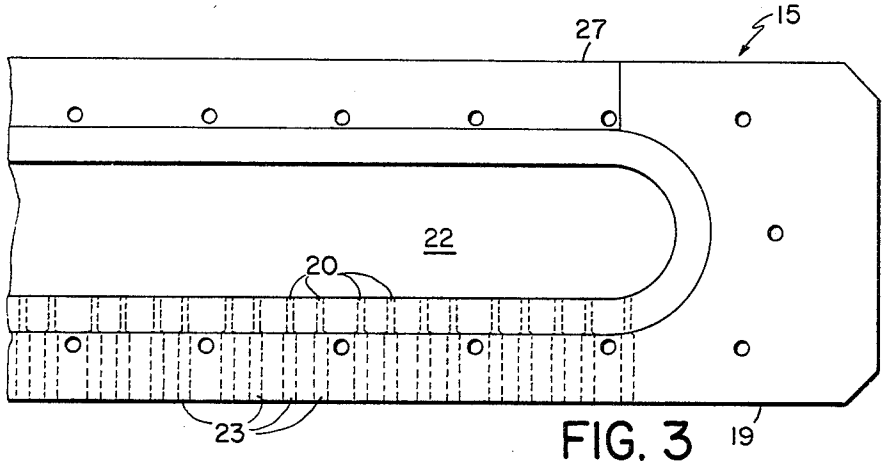


FIG. 3

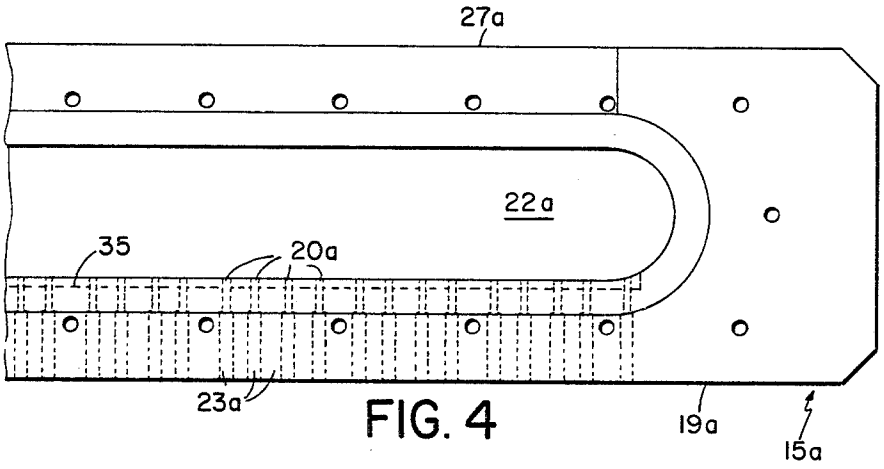


FIG. 4

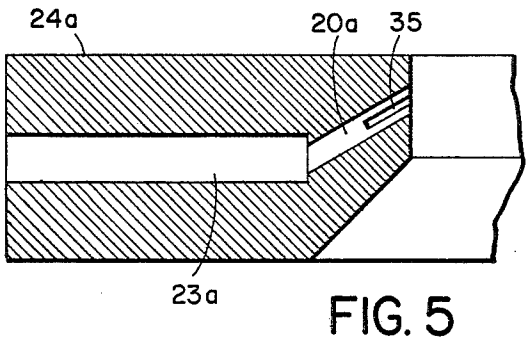


FIG. 5

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United States Patent Office 3,486,060
Patented Dec. 23, 1969

3,486,060

COOLING APPARATUS WITH LAMINAR FLOW FOR ELECTRON PERMEABLE WINDOWS

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Filed Sept. 6, 1967, Ser. No. 665,752
Int. Cl. H01j 33/08
U.S. Cl. 313—74 6 Claims

ABSTRACT OF THE DISCLOSURE

An apparatus for the cooling of electron transmissive windows used in high voltage electron accelerators which uses a multiplicity of in-line orifices extending the length of the window for forcing, at a substantially uniform delivery rate without turbulence, a low quantity, high velocity stream of cooling gas across the window. The orifices are formed as an integral part of the window frame and positioned such the gas stream cools the window below its melting point. A further novel feature is incorporated in the exhaust manifold which positively extracts the gas after it has passed over the window.

Background of the invention

Various types of apparatus for cooling electron transmissive windows in electron accelerators have been built and used in the past. One such device is shown in U.S. Patent to D. M. Robinson, No. 2,820,165 issued Jan. 14, 1958 wherein there is described a single jet for forcing cooled helium against the electron transmissive window. A second system is shown in the U.S. Patent to D. D. Miller No. 2,898,492 issued Aug. 4, 1959. This patent teaches that if an elongated air discharge slot is positioned adjacent to the window and large quantities of low velocity air are forced through this slot across the window face substantial cooling of the window is realized. Both of these techniques have been used successfully in the past.

However, with higher power electron beam accelerators and large window areas these systems have been found lacking. The present invention was devised to overcome all the difficulties encountered in the prior art systems and provides suitable cooling for higher beam energy transmission and for larger beam window areas. Moreover since the present invention is incorporated in and forms an integral part of the window frame the positioning of external apparatus is avoided. This assures that each window is cooled in the same manner and to the same degree as any other window. This feature also eliminates the necessity of repositioning or dismounting of the cooling apparatus thus aiding in the ease of repair or replacement of defective windows.

Summary of the invention

The present invention relates to a cooling apparatus designed for cooling large area, electron transmissive windows. Broadly speaking, the present invention accomplishes this result by providing along one side of the window a multiplicity of angled in-line orifices positioned to direct high velocity, non-turbulent air streams across the electron, transmissive window face for cooling purposes.

A modification of the present invention provides for inter-connecting the discharge ends of the orifices with a slot for diffusing the ejected air streams so that laminar flow is achieved across a greater portion of the window area than was realized by prior art apparatus.

The invention further provides for means for generating at the window side opposite the orifices a low pressure area to assist in and assure the positive removal of the gas after its passage over the window. This feature also removes any deleterious gases, such as ozone that may be created by the beam after it has passed into the air, and reduces the turbulence normally encountered in these systems thus allowing for the processing of the material passing under the beam.

Brief description of the drawings

FIGURE 1 is a perspective view of an electron beam accelerator utilizing the invention;

FIGURE 2 is a sectional view of the window portion of the accelerator of FIGURE 1;

FIGURE 3 is a planar view of a window retaining frame showing the orifices of the invention; and

FIGURE 4 shows a modification of the invention; and

FIGURE 5 shows the details of the modification depicted in FIGURE 4.

Description of the preferred embodiments

Referring now to the drawings and more particularly to FIGURE 1, there is shown schematically an electron accelerator such as is manufactured by High Voltage Engineering Corporation. This accelerator is capable of producing a highly energetic and narrow beam of electrons.

A cathode **10** produces a cloud of electrons (not shown) which are formed into a beam and directed down an acceleration tube **11** through a flared vacuum chamber **12** to window **13**. If the electrons have a sufficient energy imparted thereto by their passage down tube **11** they will pass through the electron transmissive window **13** which is comprised of a relatively thin foil of suitable material such as aluminum or titanium. Because such windows have a finite thickness they absorb part of the energy of the beam and become heated. Such heating can cause localized melting or erosion with subsequent rupture of the window and decay of the vacuum in chamber **12**. Thus cooling to a temperature below the melting point of the window material is required.

The present invention accomplishes such cooling in a highly reliable and effective manner by forcing a thin laminar flow of air into contact with and across the face of the window such that optimum cooling is realized.

The detailed structure of the present invention required to accomplish this result is shown in FIGURES 2 and 3. Referring simultaneously to both these figures it is seen that the window edges are contained between a flange **14**, provided on the vacuum chamber **12**, and a window frame **15** bolted to flange **14** by a plurality of bolts **18**. To assure a good vacuum seal between the window, the frame and the flange a soft gold or indium wire seal **16** is provided between flange **14** and window **13**. The window frame **15** is of a shape and size to securely fit across the mouth of chamber **12** and is usually rectangular with a centered elongated opening **22** as shown in FIGURE 3. Extending along one long side **19** of frame **15** there is provided a multiplicity of in-line uniformly

spaced orifices **20** generally of cylindrical shape and angled to direct a flow of air across the window face when the window is belled into the chamber **12** under the combined influence of the vacuum in chamber **12**, and the external atmosphere.

A typical frame has an overall length of approximately 26 inches and a width of about 5 inches. The opening **22** in this frame is about 20 inches long with a one inch radius on each end. This window will accommodate an eighteen inch beam. For effective cooling of a window affixed in this frame, 38 substantially evenly spaced orifices each $\frac{3}{32}$ of an inch in diameter are required.

Because the window **13** is depressed towards the cathode **10** under the influence of the external atmosphere it is necessary, in order to assure a smooth laminar flow of gas across the window face, that these orifices each be angled upwards with respect to the top surface **24** of the frame. Thus the entire line of orifices looks towards the concave window **13** at a very slight angle. It was empirically found that any angle between 25 and 30° would provide a smooth laminar flow across the window face.

For ease of manufacture and attachment to the input plenum **25**, blind passageways **23**, parallel to surface **24**, connect orifices **20** to the plenum **25**.

An air supply pipe **26** is connected between plenum **25** and an air supply source such as a compressor (not shown). The compressor used may be for example a Spencer turbo compressor manufactured by Spencer Turbine Company. The only requirement for the compressor being that it be capable of effecting a laminar, low quantity, high velocity flow of cooling gas across the window **13**. When cooling gas is passed from the source through the pipe **26** into plenum **25** an increase in the pressure occurs in the plenum due to the constrictions caused by orifices **20**. Thus when the cooling gas is forced into plenum **25** under the influence of the compressor a resultant increase in pressure occurs as the gas passes through orifices **20** to create a high velocity, low quantity cooling gas stream across the window face.

When the described window was exposed to a 3 ma./in.^{2}, 500 kv. beam, it was found that optimum cooling occurred when 50 cubic feet per min. was passed over the window with an orifice exit velocity of approximately 3000 feet/min. Windows cooled with the described flow have lasted in excess of 10,000 hours and have yet to exhibit any indications of potential failure. Based on these tests the reasonable life of windows cooled using the described quantities, velocities, etc. should be in excess of 30,000 hours. Additional tests have shown that for larger beam transmissive windows that the number of orifices, and that the quantity of the cooling gas must be proportionally increased. Thus, for example, a window capable of accommodating a 48 inch beam would require 114 orifices, and a quantity of 150 cubic feet per min. This increase in quantity assures that the exit velocity of the orifice mouth remains a constant 3000 feet/min.

As can be shown by gas dynamic analysis the flow of gas from each orifice spreads out after it leaves the orifice such that the entire active surface of the window, i.e. that potiron of the window through which the beam passes, is covered by a thin layer of flowing gas. Because of the angle of and spacing between the orifices the flowing gas molds itself to the window surface and transports away the heat generated in the window by the beam passing therethrough.

Removal of the spent gas was found to be enhanced by contouring the inner face **30** of the opposite side **27** of the frame **15** by beveling it such that the gas flowing over the window is not impeded when it reaches the exhaust side **27** of the window frame. The removal of the heated gas is further aided by providing positive exhaust means such as a manifold **28** and an exhaust fan (not shown) along side **27**. The positive exhaust action of this manifold is increased by forming its remote edge **29** so that it parallels the contour of inner face **30**. The exhaust fan (not shown) which is coupled to the manifold **28** creates a subatmospheric pressure in the manifold which positively draws the spent gas and any deleterious gases such as ozone that may be created by action of the beam into the manifold and away from the window face. This also permits the disposal of such gases at a remote safe location.

When processing bulky objects, such as panels, turbulence in the air stream is of little concern. However, when processing powders, liquids, thin films or the like it becomes vital that turbulence, which could disturb the material being processed, be eliminated. The described manifold with its contoured remote edge and positive exhaust eliminates and prevents any such turbulence from occurring.

FIGURES 4 and 5 show different views of a modified embodiment of the invention. This modification comprises the addition of a slot coupling the orifices at their discharge end. Tests indicate that this slot improves the cooling effect of the gas being forced over the window face.

FIGURE 4 depicts a window frame **15A** substantially the same as frame **15** of FIGURE 3. This frame **15A** also has 38 angled orifices **20A** along its input side **19A** and a window opening **22A**. Again each orifice is $\frac{3}{32}$ of an inch in diameter and at an angle of between 25 and 30° with respect to the top surface **24***a*. Each orifice **20A** also intercepts a parallel passageway **23***a*. The improvement is however found in the $\frac{1}{32}$ inch wide slot **35** which couples each orifice **20***a* to the adjacent orifice. This slot permits a more uniform flow of gas across the window without a significant loss of velocity.

It should be understood that slight variations in quantity of gas used and in the exit velocity of the gas at the orifice mouth, can be made without going beyond the scope of the invention. Tests have indicated that velocities between 2800 ft./min. and 3200 feet are suitable and quantities between 40 c.f.m. and 60 c.f.m. can be used.

Having now described the present invention and various modifications and embodiments thereof, and since further embodiments may now become apparent to those skilled in the art it is desired that the invention described herein be limited only by the appended claims.

I claim:

1. In a high voltage electron accelerator apparatus comprising a cathode for forming an electron beam, an accelerator for accelerating said beam through said apparatus, an electron transmissive exit window sealing said apparatus from the atmosphere and a frame for holding said window on said apparatus, the improvement comprising means for effecting a laminar, low quantity, high velocity flow of cooling gas across saild window, said means comprising a plurality of in-line orifices in said frame, a plenum coupled to said orifices and a compressor air supply pipe coupled to said plenum to supply a laminar, low quantity, high velocity flow of cooling gas across said window to cool said window below its melting temperature.

2. The apparatus of claim **1** wherein the exit portions of said orifices are at an angle with respect to the direction of said beam and said window to direct said cooling gas against said window.

3. The apparatus of claim **2** wherein each of said orifices are spaced with respect to the next adjacent orifice so that the gas flow emitting therefrom blankets the electron beam transmissive portion of said window with a quantity of high velocity laminarly flowing cooling gas sufficient to maintain said window at a temperature below its melting temperature when said electron beam is passing through said window.

4. The apparatus of claim **1** wherein said means further comprises an exhaust manifold affixed to said frame to

extract the cooling gas after it has flowed across said window.

5. The apparatus of claim 1 wherein the inner face of the side of said frame parallel to said orifices is contoured to prevent any impedance in said flow of gas across said window.

6. The apparatus of claim 1 wherein said means further comprises an exhaust manifold having its remote edge, closest to the window, bent to parallel the inner face of the side of said frame parallel to said orifices thereby aiding in the removal of gases flowing over said faces.

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U.S. Cl. X.R.

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