Oct. 1, 1963 R. C. MARKER ET AL 3,105,916

RADIATION BEAM WINDOW

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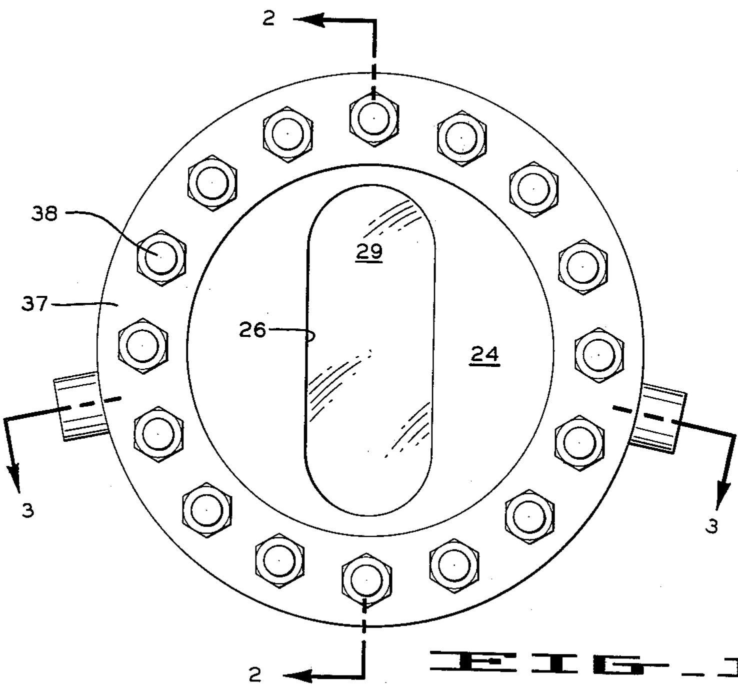

FIG. 1

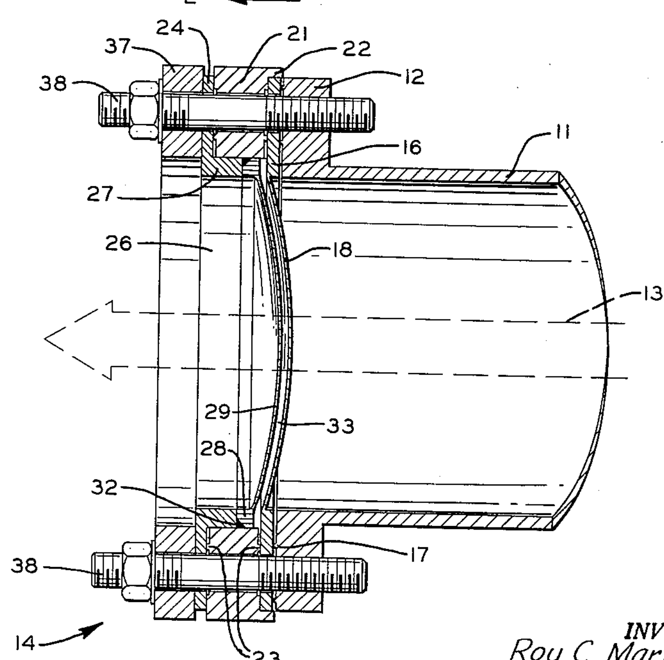

FIG. 2

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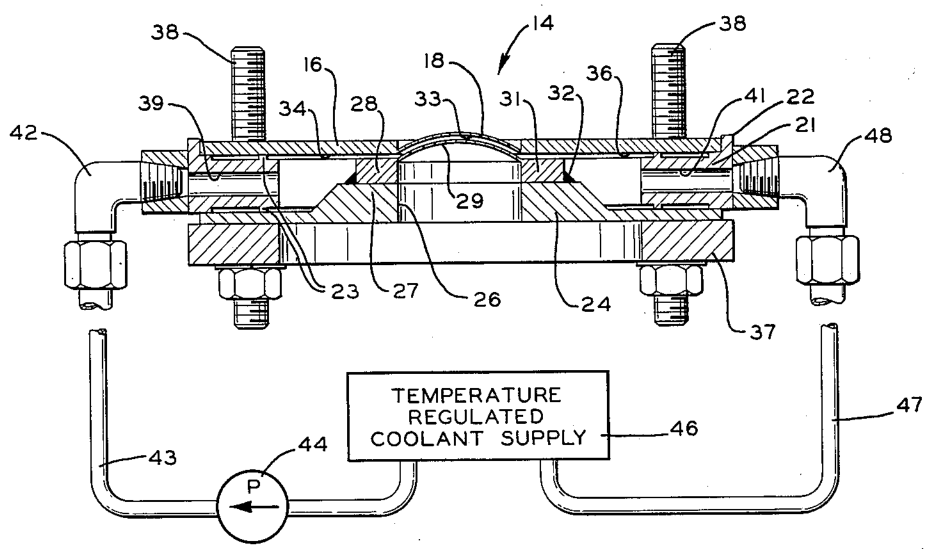

FIG. 3

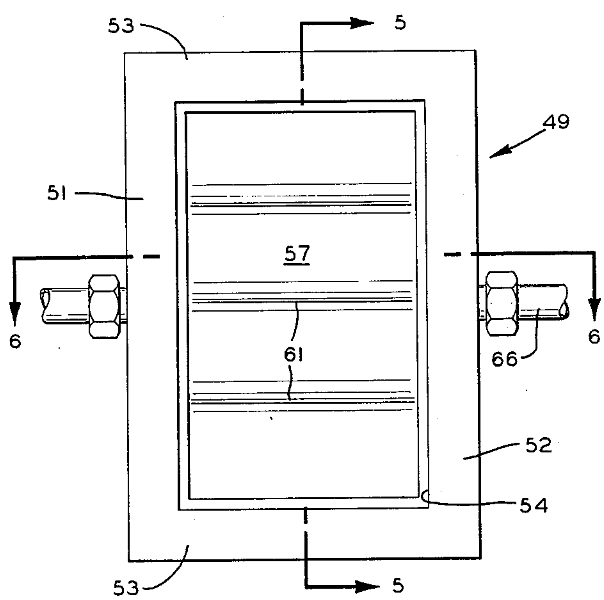

FIG. 4

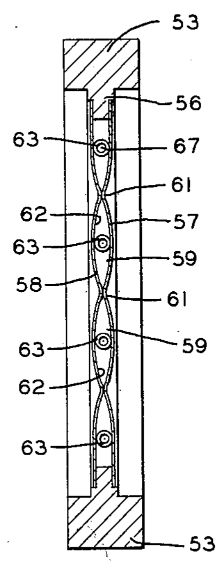

FIG. 5

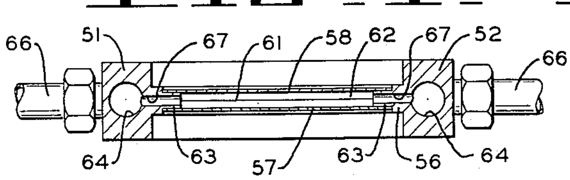

FIG. 6

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RADIATION BEAM WINDOW

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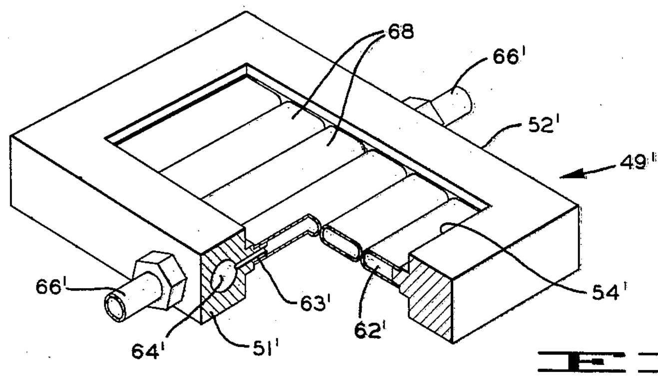

FIG. 7.

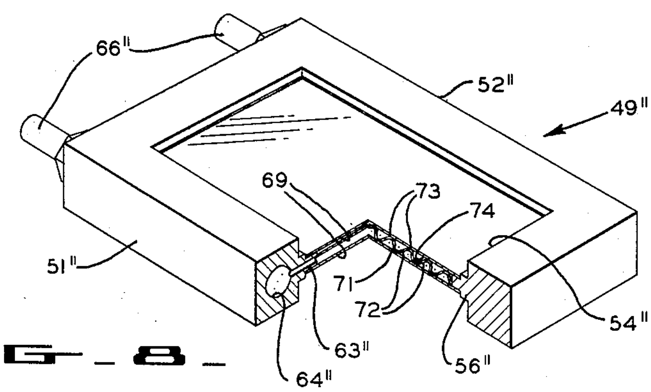

FIG. 8.

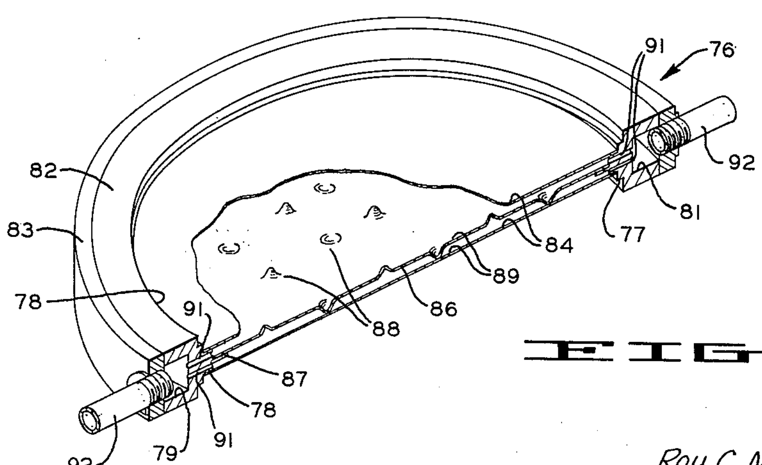

FIG. 9.

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United States Patent Office

3,105,916
Patented Oct. 1, 1963

3,105,916

RADIATION BEAM WINDOW

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Filed Sept. 8, 1960, Ser. No. 54,737
4 Claims. (Cl. 313—33)

This invention relates to improvements in a radiation beam window, and more particularly to thin windows of the class providing for the passage of a radiation beam between hermetically separated regions.

In various forms of apparatus in which radiation beams are generated, transmitted or received, it is frequently necessary to provide for the passage of the beam through a gas-tight structural wall. Very material savings in time and expense accrue from such an arrangement wherein the interior of the accelerator tank does not have to be re-evacuated with each change of the target.

Thus, in the operation of a charged particle accelerator, the irradiation of a target situated outside the accelerator vacuum tank may well be desired. A typical example of this type of operation occurs in the use of an electron linear accelerator to sterilize food by irradiation thereof. The food material, which is generally packaged prior to the irradiation, cannot be placed in vacuum in many instances and a beam exit window must therefore be provided on the accelerator.

Other operations requiring the use of an accelerator beam window may occur when a target substance is liquid, gaseous or volatilizable by bombardment and in instances where the beam is to be delivered to a target housing having internal pressures differing from that of the accelerator.

To minimize beam attenuation, scattering and the production of secondary radiations, it is desirable that a minimum amount of matter be present in the beam path. For similar reasons, windows formed of material of low atomic number are preferred. Thus, a beam window would ideally be formed of a low density foil having just sufficient thickness to withstand the pressure differential between the opposite sides of the window.

In practice, however, considerable allowance must be made for thermal effects in the window resulting from the heating action of the beam thereon. Such allowance may take the form of providing an increased window thickness or may consist of using high strength, but more dense, materials. As hereinbefore noted, either such provision has deleterious effects on the beam.

It is therefore much more desirable that thermal effects in the window be minimized through the provision of cooling means. The cooling provisions heretofore available however have not been fully satisfactory for use with beams of appreciable power rating. Some heat removal occurs through thermal radiation from the window and through gas convection adjacent the surface thereof, but the conduction of heat to the periphery of the window is usually a somewhat more efficient process and accordingly has been a primary means of limiting the window temperature. To maximize such conduction, coolant channels have sometimes been disposed around the periphery of the window.

The long conduction path and small cross-section inherent in the thin window design severly limit the heat transfer which can be obtained by the foregoing means. For example, a 6 mev. electron beam having an average current value of 0.7 ma. and a diameter of 0.3 inch which beam is impinged upon a nickel window of 0.005 inch thickness will produce a power density of the order of 2270 watts per square inch in the window. The resultant

temperature differential along a radius of the area of the window which intercepts the beam may be calculated to be 1720° C. While at temperatures of *xxx* this magnitude thermal radiation will obviously assist in the heat dissipation, the actual temperature differential will still remain excessive inasmuch as only 40° C. temperature differential will induce a 15,000 pounds per square inch stress in a rigidly contained nickel structure. The latter value is within the range of yield stress for annealed nickel and therefore should not be exceeded.

Thus, the cooling of a thin beam window by the circulation of coolant around the periphery thereof is not an adequate technique where high beam power values are involved and a need exists for a window construction having provision for more efficient heat removal.

Accordingly the present invention is a radiation beam window having self-contained provision for efficient cooling with minimum attenuation of the beam. To effect this result, the invention provides for the passage of fluid coolant through a very large proportion of the area of the window. Specifically, the invention is a window formed of foil-like material and formed to have a spaced apart double wall construction over at least a majority of the area of the window thus providing an extensive coolant channel therein. Suitable manifolding may be provided around the periphery of the window to force a fluid coolant flow between the double walls thereof.

Preferably, the spacing between the double walls of the window is kept small and coolant is forced therethrough at high velocities. Such construction enhances heat transfer to the coolant and reduces beam attenuation to minimum values.

In order to permit the use of foils of minimum thickness in the construction of the window, it is desirable that the specific design of the window provide for strengthening of the foils, which result should be accomplished without disposing appreciable thicknesses of material in the path of the beam. This may be effected in the present invention by any of several means, examples of which will be hereinafter described in detail.

The window may, for example, be formed to have an arcuate cross section. A second means for strengthening the window against deformation utilizes a pair of undulating foils which alternately contact and separate to form the desired coolant passages. In other forms of the invention, various internal bracing means formed of thin material may be disposed between the two principal foils.

Accordingly, it is an object of the present invention to provide a radiation transmitting window having self-contained provision of the removal of heat generated by the passage of radiation through the window.

It is an object of the invention further to provide a radiation beam transmitting window for hermetically sealing the beam opening in a gas-tight structure which window is capable of withstanding severe pressure differentials and which is provided with efficient cooling means.

Another object of the invention is the provision of a gas-tight window structure for transmitting a radiation beam which structure is efficiently cooled and minimizes attenuation of the beam.

It is a further object of the present invention to provide a gas-tight structure for transmitting radiations which structure provides for the passage of fluid coolant across the path of said radiations.

A still further object of the present invention is to provide a radiation beam window formed of foil-like gas impervious material and having efficient cooling provision and strengthening provision whereby very thin materials may be employed.

Further objects and advantages of our invention will be apparent as the specification proceeds, and the new and useful features of the same will be fully defined in the claims hereto attached.

The preferred forms of our invention are illustrated in the accompanying drawings, forming part of this application, in which:

FIGURE 1 is a frontal view of a first embodiment of the invention;

FIGURE 2, a longitudinal section view of the embodiment of FIGURE 1 taken along line 2—2 thereof;

FIGURE 3, a section view of the apparatus of FIGURE 1 taken along angled line 3—3 thereof and with coolant supply elements shown in schematic form;

FIGURE 4, a frontal view of a second embodiment of the invention;

FIGURE 5, a section view of the embodiment of FIGURE 4 taken along line 5—5 thereof;

FIGURE 6, a section view of the embodiment of FIGURE 4 taken along line 6—6 thereof;

FIGURE 7, a perspective view of a third form of the invention with a portion thereof broken out to illustrate interior details;

FIGURE 8, a perspective view of a fourth form of our invention and showing a portion thereof broken out; and

FIGURE 9, a perspective view of a fifth embodiment of the invention with a portion thereof cut away to show the internal construction.

While we have shown only the preferred forms of our invention, it should be understood that various changes or modifications may be made within the scope of the claims hereto attached, without departing from the spirit of the invention.

Referring now to the drawing, and more particularly to FIGURES 1, 2 and 3 in conjunction, a first form of our invention is shown mounted at the beam output of an electron linear accelerator. An accelerator of this type may typically be provided with a cylindrical output tube **11** having a terminal flange **12**. The beam, indicated by arrow **13** in FIGURE 2, may be required to pass from the evacuated region within tube **11** to an external region at atmospheric pressure. Accordingly a window structure **14** must be provided at the end of tube **11** which structure must be gas impervious, capable of withstanding the pressure differential and substantially transparent to the beam.

The beam **13** might not be of circular cross section and might not be well defined in the radial direction. In addition, it may be desired to scan the beam according to some pattern. Thus, the window structure may be required to be of greater extent than the nominal beam cross-section area and can be of any of various outlines. For purposes of example, the beam transmitting area of window structure **14** is here shown to be of an elongated configuration. It should be understood, however, that the window may have various other desired configurations and is not limited to that herein described.

To mount an inner barrier across the end of beam tube **11**, an inner window disc **16** is disposed against the tube flange **12** which disc is circular and positioned coaxially with respect to the tube. Suitable sealing provision, such as an annular sharp projection **17** on flange **12**, should be provided between the tube **11** and disc **16**.

A central area of the disc **16**, in this instance an elongated area **18** having parallel sides and rounded end boundaries, is made of thinner construction than the peripheral areas of the disc in order to provide a beam transmitting element. Typically, the area **18** of the disc **16** may have a thickness of 0.015 inch where the disc is aluminum alloy and the area **18** is 3.5 inches long and 1.375 inches wide.

To impart additional strength to the foil-like area **18** of the disc **16**, the area is formed to have a smoothly curved dished configuration. The area **18** is preferably arched both with respect to the long dimension and the transverse dimension and with the convex face adjacent the evacuated beam tube **11**. The specific curvature may variously be circular, catenary or other.

An annular clamping ring **21** is disposed against disc **16** on the opposite side thereof from flange **12**, the ring being of slightly greater outside diameter than the disc and being coaxial therewith. An annular lip **22** on the ring **21** projects over the rim of the disc **16** to accurately position the disc. Annular sealing embossments **23** are formed around the side of ring **21** which faces disc **16** and also around the opposite face of the ring.

A circular outer window disc **24** is disposed coaxially against the outer face of clamping ring **21** which disc has a central opening **26** conforming to the area **18** of disc **16**. The outer window disc **24** is formed with a thickened area around the margin of opening **26** which thickened area **27** extends a short distance towards disc **16** from the side of the disc **24** facing disc **16**.

To form an extensive coolant channel across the outer face of disc **16**, an outer foil member **28** is secured to disc **24** which member has a central thin area **29** conforming in configuration and curvature with the area **18** of disc **16**. The member **28** has a thick rim **31** secured against area **27** of disc **24** by welds **32**. The member **28** is proportioned so that the thin area **29** thereof is spaced a small distance outward from the matching thin area **18** of disc **16** thus forming an internal coolant passage **33** between the two foils. The spacing may be varied somewhat according to the degree of cooling required but should be kept to the minimum consistent with adequate cooling in order to minimize the amount of matter present in the beam path. In a window of the dimensions hereinabove given, a spacing of 0.05 inch might typically be used.

In order to provide for the forcing of coolant through the channel **33**, the area **27** of disc **24** and the thick rim **31** of the foil member **28** are proportioned to contact the inner surface of clamping ring **21** at the regions adjacent the ends of the foil areas **18** and **29** so the region between discs **16** and **24** is divided into a coolant inlet chamber **34** at one side of the foils and a coolant outlet chamber **36** at the opposite side thereof.

In order to hold the foregoing elements in place on the end of beam tube **11**, an outer clamping ring **37** is disposed against disc **24** and studs **38** are transpierced through the ring **37**, disc **24**, ring **21** and disc **16** and are threadably engaged in the beam tube flange **12**, the studs being equi-angularly distributed around the flange.

Considering now provision for supplying coolant to the window and with reference to FIGURE 3 in particular, an inlet passage **39** is provided in the clamping ring **21** which passage communicates with coolant inlet chamber **34** and an outlet passage **41** is provided at the opposite side of the ring which latter passage communicates with the outlet chamber **36**. A fitting **42** is engaged in inlet passage **39** and connects with a conduit **43** leading through a pump **44** to a suitable source of fluid coolant **46**.

If coolant is to be recycled, it will be found preferable to provide suitable temperature regulation at the source **46** as by heat exchangers and other means known to those skilled in the art. In this instance, a coolant return conduit **47** is provided connecting source **46** with a second fitting **48** engaged in outlet passage **41**.

The coolant employed may be either liquid or gaseous. If liquid is employed, more effective cooling may be achieved but a greater beam attenuation occurs. Gas has the advantage of minimum beam attenuation but requires more complex circulating equipment and is less effective from the standpoint of heat transfer.

The present invention may take other forms both with respect to the general configuration of the frame means and the structure of the foils. Referring now to FIGURES 4, 5 and 6 in conjunction, a second embodiment of the window is shown which is of generally rectangular configuration and in which strengthening of the foils is effected by utilizing a different curvature therein.

A rectangular frame 49 is formed by long parallel side members 51 and 52 connected at the ends by end members 53 and defining a rectangular central opening 54. Each of the component members of the frame 49 is formed with an inner section 56 of reduced thickness thus forming a sub-frame around the margin of the opening 54. The section 56 of the end members 53 is stepped to receive the end edges of a pair of rectangular foils 57 and 58.

As best shown in FIGURE 5, the foils 57 and 58 are formed with matching parallel corrugations 59 extending at right angles to the frame side members 51 and 52. The corrugations 59 are of opposite curvature on the two foils 57 and 58 so that the foils contact along parallel zones 61 and separate between the zones to define coolant channels 62 within the window. The foils 57 and 58 are bonded together along zones 61.

To support the long edges of foils 57 and 58, and to provide coolant manifolding, projections 63 are formed on sections 56 of the frame side members 51 and 52, which projections have a configuration matching the space between foil corrugations 59 and which project a short distance into each corrugation at the ends thereof. The edges of foils 57 and 58 are hermetically bonded to projections 63 and also to the stepped end of section 56 of frame end members 53.

To provide for the circulation of coolant between the foils 57 and 58, a longitudinal bore 64 is provided in each of the frame side members 51 and 52 and fittings 66 communicate therewith. A passage 67 extends through each projection 63 to communicate each end of coolant channels 62 with the bores 64. Considerations with respect to the circulation of coolant in this embodiment of the invention are similar to those discussed with reference to the embodiment of FIGURES 1, 2 and 3.

The above described corrugated construction of the foils 57 and 58, and particularly the bonding of the foils together along the spaced apart parallel zones 61 will be found to impart considerable strength to the window and to increase resistance to pressure differentials at opposite sides thereof as well as to increase resistance to internal coolant pressure.

The foregoing window structure may be constructed in a somewhat different manner with equally effective results. Referring now to FIGURE 7, there is shown a third embodiment of the invention closely related to the form of FIGURES 4, 5 and 6, but fabricated in a modified manner.

The frame 49′ and associated coolant circulating provisions may be essentially similar to that described with reference to FIGURES 4, 5 and 6. Rather than providing corrugated foils in the opening 54′ thereof, however, a series of foil tubulations 68 are employed which tubulations are preferably somewhat flattened. One such tubulation 68 extends between each pair of opposed projections 63′ on the frame side members 51′ and 52′ and is hermetically bonded to the projections.

To hermetically seal the assembly the juxtaposed edges of each adjacent pair of foil tubulations 68 are bonded together. Thus, it may be seen that the resultant structure is essentially similar to that of the second embodiment.

Referring now to FIGURE 8, a fourth modification of the invention is shown in which still another means is used to impart strength to the foil structure. In this embodiment the frame 49″ may again be similar to that of FIGURES 4, 5 and 6 except that the projection 63″ along the side members 51″ and 52″ is of uniform cross section rather than having a corrugated configuration. The coolant inlet and outlet fittings 66″ are here shown entering the end of the frame 49″ to illustrate varied possible constructions.

A pair of flat rectangular foils 69, are secured within the central opening 54″ of frame 49″, the foils being spaced apart and disposed one on each side of the subframe defined by section 56″ of the frame.

To strengthen the foils 69, a third foil 71 is employed which third foil is disposed between foils 69 and which is formed to have parallel corrugations 72 at right angles to the frame side members 51″ and 52″. The corrugations 72 are of sufficient amplitude to extend between the two flat foils 69 and the zones 73 of contact between the corrugations and the foils 69 are bonded together to form a reinforced foil structure and to define the desired coolant channels 74 extending between the coolant passages 64″ in the frame side members 51″ and 52″.

Referring now to FIGURE 9, still another modification of the invention is shown in which a differing provision is used for purposes of strengthening the window. This embodiment is shown in circular form to illustrate the varied applications of the invention.

An annular frame structure 76 is provided, the inner portion 77 of which is of reduced thickness to form an annular sub-frame around the periphery of a central circular opening 78. To facilitate the provision of a coolant inlet passage 79 within a first portion of the frame 76 and a coolant outlet passage 81 within the opposite portion of the frame, the frame may be constructed of two segments which are welded together. Specifically, an inner annulus 82 is provided with the passages 79 and 81 machined therein in the form of grooves and an outer annulus 83 is secured around the inner annulus in coaxial relation therewith to close the grooves and define the passages.

A pair of circular foils 84 are mounted in the opening 78 of the frame 76, the foils being parallel and spaced one on each side of the portion 77 of the frame. The inner corners of portion 77 of the frame are rabbeted to receive the edges of the foils 84 and the foils are hermetically bonded thereto.

To provide for strengthening of the foils 84, a third circular foil 86 is mounted between the two foils 84 in parallel relation therewith and substantially midway therebetween. An annular projection 87 is provided around the center of frame portion 77 to form a shelf to which the edge of the third foil 86 may be bonded.

The third foil 86 is formed to have dimple protuberances 88 distributed at spaced apart points on the foil which protuberances are alternately on opposite sides of the foil. The protuberances are of sufficient extent to contact the flat foil 84 and each such protuberance is bonded to the adjacent foil 84.

The center foil 86 divides the region between foils 84 into two parallel coolant channels 89. To provide for the circulation of coolant across the channels 89, spaced apart parallel passages 91 are provided in portion 77 of the frame, each pair of such passages being spaced one on each side of the plane of the center foil 86. Such passages 91 are provided at a first side of the frame to communicate between inlet passage 79 and the channels 89 and at the opposite side of the frame to connect outlet passage 81 with channels 84. Suitable fittings 92 are mounted in the frame 76 to connect inlet and outlet passages 79 and 81 respectively with a source of coolant as hereinbefore described.

Thus, while the invention has been disclosed with respect to a limited number of exemplary embodiments, it will be apparent to those skilled in the art that many variations and modifications may be made within the spirit and scope of the invention and thus it is not intended to limit the invention except as defined in the attached claims.

We claim:

1. In a thin window structure for transmitting a radiation beam, the combination of a frame means having an extensive opening therein for the passage of said beam, a pair of foil-like sheets of gas impervious material disposed within said opening of said frame means and her-

metically sealing said opening, said sheets having matching undulations thereby being contacted at spaced apart parallel linear zones and thereby being spaced apart between said zones to form coolant channels within said opening of said frame means, and means for forcing fluid coolant through said channels.

2. In a thin window structure for transmitting a radiation beam, the combination comprising a frame means having an extensive opening therein for the passage of said beam, a plurality of parallel tubulations extending across said opening of said frame means, said tubulations being juxtaposed and bonded together to hermetically seal said opening in said frame means, and means for forcing fluid coolant through said tubulations.

3. A thin window structure for transmitting a radiation beam comprising, in combination, a frame means having an extensive opening therein for the passage of said beam, a first and a second sheet of foil-like material mounted in said opening of said frame means and hermetically sealing said opening, said first and second sheets

being spaced apart to form a coolant channel across said opening, a stiffening means disposed between said first and second sheets, said stiffening means comprising a third sheet of foil-like material having parallel corrugations extending across said opening and contacting said first and second sheets, and means for forcing fluid coolant through said coolant channel.

4. A thin window structure for transmitting a radiation beam as described in claim 3 and wherein said stiffening means comprises a third sheet of foil-like material disposed between said first and second sheets in parallel spaced apart relationship thereto, said third sheet having a plurality of dimple protuberances distributed on each side thereof which protuberances contact said first and second sheets.

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