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E. J. SHELTON, JR
DIELECTRIC WINDOWS

2,990,526

Filed March 2, 1953

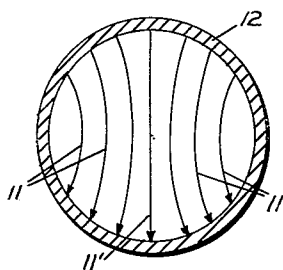


FIG. 1

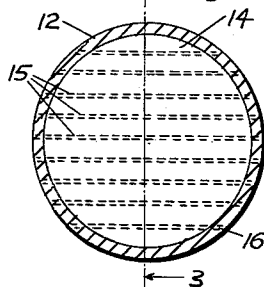


FIG. 2

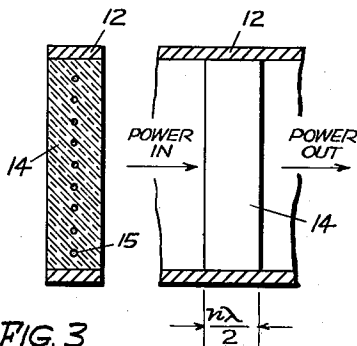


FIG. 3

FIG. 4

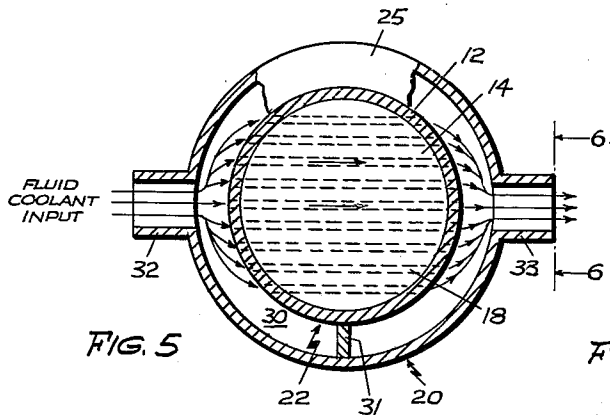


FIG. 5

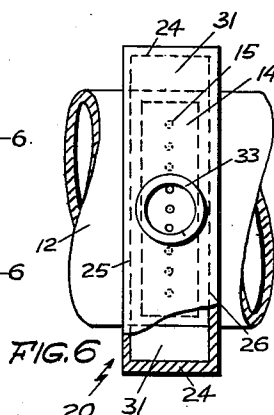


FIG. 6

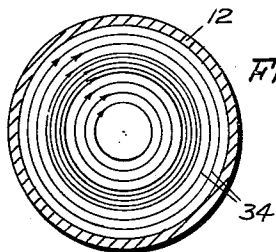


FIG. 7

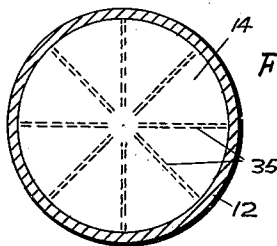


FIG. 8

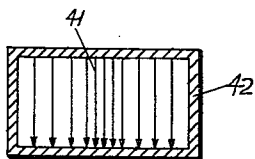


FIG. 9

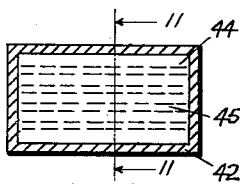


FIG. 10

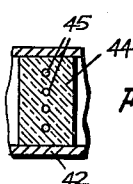


FIG. 11

INVENTOR
EARL J. SHELTON, JR.
BY *Elmer J. Gorn*
ATTORNEY

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DIELECTRIC WINDOWS

Earl J. Shelton, Jr., Natick, Mass., assignor to
Raytheon Company, a corporation of Delaware
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10 Claims. (Cl. 333—98)

This invention pertains to a novel window for use in microwave transmission lines, and more particularly relates to a fluid-cooled transmission line window having a thickness equal to an integral number of half wave lengths at the operating frequency.

The use of vacuum-tight dielectric windows for sealing a portion of a transmission line, such as in wave guide outputs for magnetrons, is well known. In previous design, such windows were made as thin as possible in order to present a minimum reflection of high-frequency energy to be transmitted through the window. At frequencies above 7500 megacycles, the thinnest window possible is an appreciable part of an electrical wave length, and matching through the window, so as to minimize reflection, becomes arduous.

The minimum thickness of such windows is determined by mechanical strength and ability to maintain a vacuum. At best, windows used at high frequency absorb considerable energy and, consequently, an undesirable amount of heat may be generated; this, in turn, reduces the power rating of the equipment. Because of the thin windows previously used, effective cooling was impracticable.

By increasing the thickness of the window to an integral number of half wave lengths at the mean operating frequency, the window acts as a series-tuned circuit in the transmission network, or a transformer with an impedance transformation of one, and produces substantially no reflection at the frequency to which it is tuned.

Furthermore, with a window of increased thickness, it is mechanically feasible to introduce means into the window for cooling the same.

The cooling of the window is accomplished by introducing a plurality of thermally-conductive elements in the window. In one embodiment, a series of heat-conducting wires or rods are inserted through the window transversely to the electric field of the high-frequency wave passing through the window. These rods, which make contact with the boundary of the transmission line, conduct away heat from the interior of the window to said boundary and thence to a heat sink such as the ambient atmosphere surrounding said boundary.

In another embodiment, a fluid type jacket, which may include the boundary of said transmission line, surrounds the line in the vicinity of the window. A series of tubular recesses or ducts is formed in said window normal to the electric lines of force. A coolant is allowed to flow through the jacket and the ducts, thereby removing heat generated within the window.

FIG. 1 is a diagram depicting the electrical field configuration for the TE_{11} mode in a cylindrical wave guide;

FIG. 2 is a plan view, partly in section, of a first embodiment of a cooled dielectric window mounted within a cylindrical wave guide;

FIG. 3 is a section view taken along line 3—3 of FIG. 2;

FIG. 4 is a fragmentary longitudinal view of the wave guide and window of FIG. 2;

FIG. 5 illustrates a second embodiment of a dielectric window which is fluid cooled;

FIG. 6 is a section view taken along line 6—6 of FIG. 5;

FIG. 7 is a diagram illustrating the lines of electric intensity for the TE_{01} mode in a cylindrical wave guide;

FIG. 8 is a plan view of a third type of dielectric

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window mounted within a cylindrical wave guide operating in the mode illustrated in FIG. 7;

FIG. 9 represents the electrical field distribution for the TE_{01} mode in a rectangular wave guide;

FIG. 10 is a view illustrating the dielectric window similar to that shown in FIG. 2 and mounted in a rectangular wave guide; and

FIG. 11 is a section view taken along line 11—11 of FIG. 10.

In FIG. 1, the configuration of the electric lines of force 11 within a wave guide 12 of circular cross section is shown for the TE_{11} mode. This mode is often used since it has the lowest cutoff frequency of all TM and TE waves in a cylindrical guide and this mode can be used in a smaller tube for the same frequency.

As shown in FIG. 1, the diametric line of electric force 11' connecting points on the periphery of the wave guide of equal potential is substantially linear, but the lines of force become increasingly curved as the distance from said diametric line increases. For purposes of this invention, however, the lines of electric force may all be considered linear.

Referring to FIGS. 2 to 4, a discoidal ceramic window 14, which is preferably any number of half wave lengths thick at the mean operating frequency, is mounted within the wave guide 12 substantially normal to the direction of energy flow within the guide. The window is preferably made from an alumina type ceramic although other types of ceramics may be used successfully. Although the window is referred to as made of ceramic, it is possible to utilize any material which is transparent to microwaves and which may be firmly sealed to the wall of the wave guide. The ceramic window shown in FIGS. 2 and 3 is sealed to the inner wall of guide 12 by any of the well-known ceramic-to-metal sealing techniques. Illustrative methods of sealing ceramics to metal may be found in chapter 16 of "Materials Technology for Electron Tubes," by Kohl, published in 1951 by Reinhold Publishing Corporation. Since the invention does not reside in the sealing technique, a description of the manner of bonding the ceramic to the metal guide appears unnecessary.

The window 14 contains a plurality of thermally-conductive wires or rods 15 which may be molded into the ceramic or inserted into tubular ducts drilled into the edge of the ceramic disc. The rods should be made of a material having a high thermal conductivity, such as silver, copper, or aluminum. As shown in FIG. 2, the rods also pass through apertures 16 in the wall of the wave guide; however, as shown in FIG. 8 (to be described later) it is not necessary that the guide wall be apertured. It is necessary only that a good thermal contact be made between the ends of the rods and the wave guide wall. If the drilling technique is to be used and if the rods are to pass through the wall of the guide, the ceramic disc is preferably first bonded to the guide and then the entire assembly drilled.

The rods are arranged within the window substantially perpendicular to the electric lines of force. As previously stated, the electric lines of force for the TE mode (shown in FIG. 1) are somewhat curved. It has been found in practice that the lines may be considered as parallel to the diametric line of force 11' and that the rods may be made linear and parallel to one another. It is possible, of course, to so position the rods that they are everywhere normal to the electric lines of force. In this case, slightly curved rods would be used in the ceramic disc. This refinement is only required in unusual cases where extremely high accuracy is required.

Window 14 is designed to maintain a vacuum in the wave guide 12 on one side of the window. The window has several applications, the most frequent of which is in wave guide output circuits for magnetrons in which the

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section of the line in FIG. 4 to the left of the window is adapted to be coupled to a magnetron or other evacuated high-frequency generator (not shown). The window thus serves to maintain the vacuum in the generator while effectively transmitting a considerable portion of the generated power to an output circuit (not shown) which is subjected to ordinary pressures.

Although the method of cooling a ceramic window by thermally-conductive rods is effective, the cooling may be improved by a fluid-cooled arrangement, such as shown in FIGS. 5 and 6. The ceramic window 14 is mounted within the cylindrical wave guide 12, as in the case of the assembly shown in FIGS. 2 to 4. The ceramic window is provided with a series of tubular recesses or ducts 18 which may be formed in accordance with methods previously described. The wall or boundary of the wave guide also contains apertures which are in alignment with the recesses in the window, as shown in FIG. 5. Surrounding a wave guide 12 in the region of the window is a housing 20 which cooperates with the wall of the wave guide 12 to form a fluid-tight jacket 22. The housing shown in FIGS. 5 and 6 is cylindrical and has three mutually perpendicular sizes, 24, 25, and 26, two of which are soldered or otherwise connected to the wall of the guide (see FIG. 5). The space 30 between the housing 20 and the wave guide 12 is adapted to receive a cooling fluid which flows in through an inlet port 32, through tubular ducts 18 in the window, and out through an outlet port 33 as shown by the arrows in FIG. 5. The fluid is continually circulated by means of the usual pump (not shown) which is connected to the inlet and outlet ports. In order to achieve satisfactory cooling, substantially all the cooling fluid should flow through ducts 18 rather than along the wall of wave guide 12. The cooling fluid is prevented from flowing in a closed path through the comparatively large space 30 (where the fluid would be much less effective than when flowing through ducts 18) by means of a pair of diametrically opposed fins 31, 31 or other objects which are capable of impeding the flow of said fluid.

The cooling arrangements previously described and illustrated are particularly suitable for use in guides in which propagation of the TE_{11} mode is desired. Should it be desired to propagate a mode other than this TE_{11} mode, it is necessary to alter the configuration of the array of thermally-conductive elements within the window. FIG. 7 illustrates the instantaneous electrical field configuration for the TE_{01} mode in a cylindrical wave guide 12. The electric lines of force 34 are now a series of concentric circles. If a substantially reflectionless window is required, it will be necessary to use an arrangement of thermally-conductive means such as shown in FIG. 8 in which a series of radial thermally-conductive elements 35 are located in the edge of the discoidal window. The elements of FIG. 8 are shown, for purposes of illustration, as rods similar to those used in the window of FIGS. 2 and 3. These rods may join in the center but may stop just short of the center, as shown in FIG. 8. It is possible to use a fluid-cooled arrangement for this mode, just as in the case of the TE_{11} mode, except that the cooling ducts are arranged radially. If fluid cooling is to be used for the mode shown in FIG. 7, it is necessary to provide apertures in the wave guide wall and to provide a housing of the type generally shown in FIGS. 5 and 6.

The principle of this invention is equally applicable to rectangular wave guides, one of which is shown in FIGS. 9 and 10. In FIG. 9, the electric field distribution for the TE_{01} mode in rectangular wave guide 42 is shown and constitutes a plurality of parallel lines 41 parallel to the short dimension of the guide through the central cross section. The dielectric window 44 which, in this case, is rectangular to conform to the wave guide boundaries, is sealed to the guide wall by a ceramic-to-metal sealing technique already discussed in general.

The thickness of the window 44, like that shown in FIGS. 2 to 4, is preferably an integral number of half

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wave lengths at the normal operating frequency of the system. The thermally-conductive elements 45, which may be rods or fluid-carrying ducts, are arranged parallel to the long dimension of the wave guide through the central cross section or normal to the electric lines of force for this TE_{01} mode.

Since the electric lines of force for the TE_{0m} mode—where m is the number of transverse half wave patterns existing along the long dimension of the guide through the center of the cross section—are linear, the same arrangement of thermally-conductive elements (wires or fluid-carrying ducts) may be used for either the TE_{02} , TE_{03} , TE_{04} , etc. modes.

This invention is not limited to the particular details of construction, materials and processes described, as many equivalents will suggest themselves to those skilled in the art. For example, the window according to the invention is not restricted to use in wave guides operating in the modes herein shown and described but may be used in guides propagating many modes. Moreover, the window may be used in wave guides of various shapes, such as coaxial wave guides or elliptical wave guides. It is, accordingly, desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. In a transmission line, a dielectric window transparent to high-frequency waves and positioned in said line normal to the direction of propagation of energy along said line, said window further containing a plurality of spaced tubular ducts arranged substantially perpendicular to the electric lines of force within said line.

2. In a wave guide transmission line, a dielectric window transparent to high-frequency waves and positioned within said guide normal to the direction of propagation of energy along said guide, said window containing a plurality of spaced tubular ducts arranged substantially perpendicular to the electric lines of force within said guide, the ends of said ducts being positioned in thermal contact with the boundary of said guide.

3. In a transmission line, a dielectric window transparent to high-frequency waves and positioned transversely to the longitudinal axis of said line, said window containing a plurality of spaced tubular ducts arranged substantially perpendicular to the electric lines of force within said guide, and means for producing a flow of a coolant through said ducts to remove the heat generated within said window.

4. In a transmission line, a dielectric window transparent to high-frequency waves and positioned within said line normal to the direction of propagation of energy along said line, said window having a thickness equal to

$$\frac{n\lambda}{2}$$

where λ is the wave length of the operating frequency and n is any integer, said window containing a plurality of spaced tubular ducts arranged substantially perpendicular to the electric lines of force within said line, and means for producing a flow of a coolant through said ducts to remove the heat generated within said window.

5. In a wave guide transmission line, a dielectric window transparent to high-frequency waves and positioned within said guide normal to the direction of propagation of energy along said guide, said window having a thickness equal to

$$\frac{n\lambda}{2}$$

where λ is the wave length of the operating frequency and n is any integer, said window containing a plurality of spaced tubular ducts arranged substantially perpendicular to the electric lines of force within said guide, and means for producing a flow of a coolant through said ducts to remove the heat generated within said window.

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6. In a wave guide transmission line, a dielectric window transparent to high-frequency waves and positioned within said guide normal to the direction of propagation of energy along said guide, said window having a thickness equal to

$$\frac{n\lambda}{2}$$

where λ is the wave length of the operating frequency and n is any integer, said window containing a plurality of spaced tubular ducts arranged substantially perpendicular to the electric lines of force within said guide and extending through apertures in the boundary of said guide, and means for producing a flow of a coolant through said ducts to remove the heat generated within said window.

7. In a wave guide transmission line, a dielectric window transparent to high-frequency waves and positioned within said guide normal to the direction of propagation of energy along said guide, said window containing a plurality of spaced tubular ducts arranged substantially perpendicular to the electric lines of force within said guide, and means for producing a flow of a coolant through said ducts to remove heat generated within said window.

8. In a wave guide transmission line, a dielectric window transparent to high-frequency waves and positioned within said guide normal to the direction of propagation of energy along said guide, said window having a thickness equal to

$$\frac{n\lambda}{2}$$

where λ is the wave length at the operating frequency and n is any integer, said window containing a plurality of spaced tubular ducts arranged substantially perpendicular to the electric lines of force within said guide, and means for producing a flow of a coolant through said ducts to remove heat generated within said window.

9. In a wave guide transmission line, a dielectric window transparent to high-frequency waves and positioned within said guide normal to the direction of propagation

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of energy along said guide, said window having a thickness equal to

$$\frac{n\lambda}{2}$$

where λ is the wave length at the operating frequency and n is any integer, said window containing a plurality of spaced tubular ducts arranged substantially perpendicular to the electric lines of force within said guide, a housing surrounding said wave guide and combining with said guide boundary to form a fluid-tight jacket in the region adjacent said window, and means for producing a flow of a coolant through said jacket and said ducts to remove heat generated within said window.

10. In a wave guide transmission line, a dielectric window transparent to high-frequency waves and positioned within said guide normal to the direction of propagation of energy along said guide, said window containing a plurality of spaced tubular ducts arranged substantially perpendicular to the electric lines of force within said guide, a series of apertures located in the boundary of said guide and aligned with corresponding ones of said ducts, a housing surrounding said wave guide and combining with said guide boundary to form a fluid-tight jacket in the region adjacent said window, and means for producing a flow of a coolant through said jacket and said ducts to remove heat generated within said window.

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