April 19, 1949. J. W. COLTMAN 2,467,730

VACUUM SEAL FOR WAVE GUIDES

Filed Nov. 10, 1943

Fig. 1.

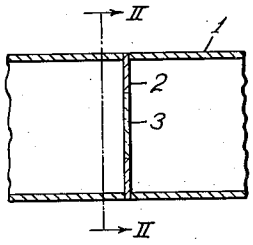


Fig. 2.

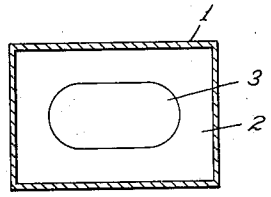


Fig. 3.

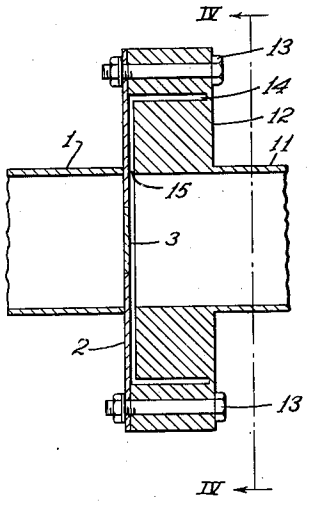
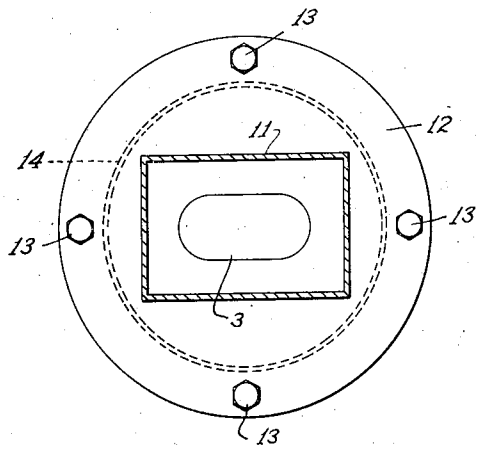


Fig. 4.



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VACUUM SEAL FOR WAVE GUIDES

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10 Claims. (Cl. 178—44)

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My invention relates to hollow conductors or guides for electromagnetic waves and, in particular, relates to arrangements for inserting vacuum-tight partitions of glass or other suitable material at a desired point in such wave-guides.

One of the most important of recent activities in the use of radio waves has been the transmission of electromagnetic waves, usually of the ultra short type, through hollow conducting guides usually in the form of metallic tubes or other metallic cylinders. The generation of electromagnetic waves of the length desired usually takes place in highly evacuated electrical discharge tubes, and while the above-mentioned wave-guides for transmitting the electromagnetic energy to work circuits may, of course, also be highly evacuated so as to form a continuous enclosure with the highly evacuated generator, it is usually convenient to conduct the waves through guides which contain air at atmospheric pressure. The transmitting of electromagnetic energy through the walls of the highly evacuated container into the wave-guide presents a problem, one solution of which has been found in the interposition of a vacuum-tight window of some material which is readily transparent to the electromagnetic waves in a portion of the wall of the evacuated part of this system. Taking a specific instance, it has been found desirable to form a glass window sealed vacuum-tight to the metallic walls of a wave guide projecting from the generator. However, the construction of such a window constitutes a problem of a very high degree of difficulty, inasmuch as it tends under ordinary conditions to form a discontinuity with a resulting reflection of the electromagnetic waves which is for many purposes highly undesirable.

While transparent windows have heretofore been interposed in wave-guides, it has, in general, been thought necessary to make the contour of the window (usually a circle) such that its periphery would fall outside the walls of the guide were the transverse dimensions of the latter kept uniform. This necessitated the provisions of enlargements of cross section in the wave guides on each side of the window; and quarter wave chokes had to be provided adjacent to each face of the window. The provision of such complicated and expensive structure is obviated by my invention.

One object of my invention is accordingly to provide means for interposing a vacuum-tight window which is transparent to electromagnetic

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radiation in a wave guide having conducting walls.

Another object of my invention is to so form a vacuum-tight partition of material which is transparent to electromagnetic waves in a conductive wave guide as to minimize reflection of the waves at the window.

Still another object of my invention is to devise a method of interposing in a wave-guide of uniform transverse dimensions a vacuum-tight window which is transparent to electromagnetic radiation and which shall be of such contour as to fall everywhere within the periphery of the wave-guide.

More specifically, it is an object of my invention to so proportion a window of low expansion glass which is sealed to form a partition in a metallic guide of approximately $\frac{7}{16}'' \times \frac{15}{16}''$ inside diameter for waves having a length of approximately 3.2 centimeters as to substantially prevent reflection of the waves at the partition.

Other objects of my invention will become apparent upon reading the following description taken in connection with the drawing, in which:

Figure 1 is a view in longitudinal cross-section of a continuous wave-guide which is provided at one point of its length with a partition embodying the principles of my invention;

Fig. 2 is a cross-sectional view of the same structure along the lines II—II in Fig. 1;

Fig. 3 is a view similar to Fig. 1 of a wave-guide arranged for detachable connection to another wave-guide and provided with a partition embodying the principles of my invention; and

Fig. 4 is a sectional view along the lines IV—IV in Fig. 3.

Referring to Figs. 1 and 2, 1 is a wave-guide which may be of metal such as copper and which may be of rectangular cross-section $\frac{7}{16}'' \times \frac{15}{16}''$ in inside dimension. At any desired point in the wave-guide 1, is positioned a partition 2 which may be a plate of an alloy such as approximately 18% cobalt, 30% nickel and the remainder iron or any other metal known in the arts to form suitable vacuum-tight seals to the window material used. Sealed to the partition 2 is a window 3 which may be of quartz or of any suitable glass, for example, G-704-P glass of the Corning Glass Company of Corning, New York. The window 3 is of smaller cross-section than the wave-guide 1 and of different peripheral configuration. The partition 2 is welded or otherwise attached to the metallic wall portion 1 after the glass is sealed in place in it. The glass 3 may

have the form of a plate and the portions of the metallic wall portion 1 which are within the interior of the wave-guide 1 are preferably of the same thickness.

The portions of the wave-guide 1 on the respective sides of the window 3 may be maintained at different pressures; for instance one portion may be at the highest attainable vacuum while the other portion may contain air at atmospheric pressure.

I have found that by suitably shaping and proportioning the glass window 3 in relation to the wave guide 1, it is possible to substantially prevent reflections of the electromagnetic waves in passing from the evacuated portion through the window to the interior of the other portion. As will be apparent to those skilled in the art the transmission of electromagnetic waves in the window 3 and in the wave guide portions on the opposite sides thereof follows the well-known equations of Clark Maxwell and the magnitudes of both transmitted and reflected waves for any size, shape and substance of the guide, partition and window may be calculated by using proper parameters and boundary conditions in these equations. Conversely it is possible to determine boundary magnitudes which will render the reflected wave, for example, zero. However, I have found it relatively easy in many instances to seal glass into an opening in the partition 2 which is made in some shape easy to machine and of approximately the dimensions desired, let us say with length and breadth enough less than those of the wave-guide 1 so that welding or brazing the partition 2 to the latter will not injure the glass. I then use the wave-guide to transmit the desired waves and measure the amount of reflection from the desired face of the window. I make several such units with one window dimension (e. g. overall length) different; and by measuring reflection from each, I can plot a curve of reflection vs. the variable dimension. I find that there exists a value of this variable dimension which gives a minimum reflection, and that this minimum reflection is extremely small (e. g. .05% of the power) for windows of the general form described.

While I do not wish to be limited by this theory, it is my opinion that once a non-reflecting system has been attained for a given wave-length, a non-reflecting system for a different wave-length may be made by using the same materials with linear dimensions scaled to the ratio of the new to the old wave-length.

To give a particular instance of the proportioning of a window, I have found reflection to be minimized if the window 3 is made of Corning G–704–P glass, having lower and upper edges parallel to the long dimension of the wave-guide 1, and having opposite ends in the form of semi-circles. For the transmission of a 3.2 centimeter wave in the above-described wave-guide, the distance between the parallel edges of the window is preferably 0.250 inch and the extreme length of the window 0.504 inch while its thickness is 0.050 inch.

In Figs. 3 and 4 I show the structure for a window in a wave-guide which is adapted to be removably attached to another section of wave-guide. The latter may, of course, be an integral portion of an oscillation generator or other circuit component. The wave-guide portion 1 is attached to a partition-plate 2 embracing a window 3 similar to that already described for Fig. 1. The edges of the partition 2 are, however, extended beyond the confines of the wave-guide portion 1 to form a circular plate. A wave-guide portion 11 having the same cross-sectional dimensions as portion 1 is provided with a flange 12 adapted to cooperate with the extended partition 2 to form a bolted flanged connection. Bolts 13 passing through suitable holes in flange 12 and plate 2 are provided to hold the two tightly together, the engaging faces of the flange and plate being machined to a true fit.

In the flange 12 is cut a circular groove 14 having a depth equal to one quarter wave-length of the radiation to be transmitted through the guide 1. The face of flange 12 inside this circular groove 14 is cut so as to be spaced away from the face of plate 2 by a distance about equal to the width of groove 14 to form an annular slot 15. The radial length of the slot 15 is made such that it also is equivalent to a quarter-wave-length. This structure will be recognized by those skilled in the micro-wave art as a quarter-wave choke. This arrangement makes it possible to removably connect two sections of wave-guide, either of which may be a portion of any larger circuit component. Reflection at the window may, of course, be minimized by proportioning dimensions as in the case of Fig. 1.

A distinguishing feature of my invention is the fact that the periphery of the window 3 falls everywhere within the confines of the walls of the wave guide 1. For example, the wave-guide 1 may be of any cross-section found desirable for transmission of the electromagnetic wave, and the wave-length of the electromagnetic vibrations may be of any value corresponding with the dimensions of the guiding system. The important feature of having the overall length and width of the window such as to fall within the confines of the wave-guide should, however, be preserved in accordance with my invention.

While I have complied with the patent statutes by describing a specific embodiment of my invention, it will be evident to those skilled in the art that the principles thereof are of broader application in ways that will be self-evident.

I claim as my invention:

1. In combination with a wave-guide of conducting material and of substantially uniform cross-section, a substantially flat partition extending transverse to said wave-guide and comprising a window of material transparent to electromagnetic radiation lying in the plane of said partition and separating one portion of the interior of said wave-guide from another portion, the periphery of said window falling everywhere within the confines of said wave-guide and a rim of conducting material intervening between the transparent material and the wave guide.

2. In combination with a wave-guide of conducting material and of substantially uniform cross-section, a substantially flat partition extending transverse to said wave-guide and comprising a window of material transparent to electromagnetic radiation lying in the plane of said partition and separating one portion of the interior of said wave-guide from another portion, the periphery of said window falling everywhere within the confines of said wave-guide, the interior of said one portion being at a pressure different from the interior of said other portion and a rim of conducting material intervening between the transparent material and the wave guide.

3. In combination with a cylindrical wave-guide of conducting material and of substantial-

ly uniform cross-section, a substantially flat partition extending transverse to said wave-guide and comprising a window of material transparent to electromagnetic radiation lying in the plane of said partition and separating one portion of the interior of said wave-guide from another portion, the periphery of said window falling everywhere within the confines of said wave-guide and a rim of conducting material intervening between the transparent material and the wave guide.

4. In combination, a hollow wave-guide portion having at one end a partition embracing a window of material transparent to radiation, the edges of said partition extending radially outward from the walls of said wave-guide, a second hollow wave-guide portion having a flange at its end adapted to engage said extending edges, means for removably holding said flange and said extending edges in engagement and a quarter-wave choke at the interface between said flange and said extending edges.

5. In combination, a hollow wave-guide portion having at one end a partition embracing a window of material transparent to radiation, the periphery of said window falling everywhere within said wave-guide, the edges of said partition extending radially outward from the walls of said said wave-guide, a second hollow wave-guide portion having a flange at its end adapted to engage said extending edges and means for removably holding said flange and said extending edges in engagement.

6. In combination, a hollow wave-guide portion having at one end a partition embracing a window of material transparent to radiation, the periphery of said window falling everywhere within said wave-guide, the edges of said partition extending radially outward from the walls of said wave-guide, a second hollow wave-guide portion having a flange at its end adapted to engage said extending edges and means for removably holding said flange and said extending edges in engagement and a quarter-wave choke at the interface between said flange and said extending edges.

7. In combination, a hollow wave-guide portion having at one end a partition embracing a window of material transparent to radiation, the periphery of said window falling everywhere within said wave-guide, the edges of said partition extending radially outward from the walls of said wave-guide, a second hollow wave-guide portion of the same cross-sectional dimensions as the first said portion having a flange at its end adapted to engage said extending edges, and means for removably holding said flange and said extending edges in engagement.

8. In combination, a hollow wave-guide portion having at one end a partition embracing a window of material transparent to radiation, the periphery of said window falling everywhere within said wave-guide, the edges of said partition extending radially outward from the walls of said wave-guide, a second hollow wave-guide portion of the same cross-sectional dimensions as the first said portion having a flange at its end adapted to engage said extending edges, means for removably holding said flange and said extending edges in engagement and a quarter-wave choke at the interface between said flange and said extending edges.

9. In combination, a cylindrical hollow wave-guide portion having at one end a partition embracing a window of material transparent to radiation, the periphery of said window falling everywhere within said wave-guide, the edges of said partition extending radially outward from the walls of said wave-guide, a second hollow wave-guide portion of the same cross-sectional dimensions as the first said portion having a flange at its end adapted to engage said extending edges, and means for removably holding said flange and said extending edges in engagement.

10. In combination, a cylindrical hollow wave-guide portion having at one end a partition embracing a window of material transparent to radiation, the periphery of said window falling everywhere within said wave-guide, the edges of said partition extending radially outward from the walls of said wave-guide, a second hollow wave-guide portion of the same cross-sectional dimensions as the first said portion having a flange at its end adapted to engage said extending edges, means for removably holding said flange and said extending edges in engagement and a quarter-wave choke at the interface between said flange and said extending edges.

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