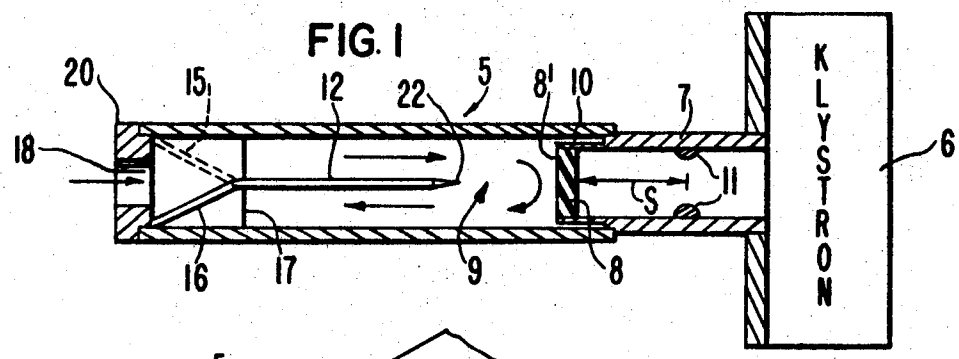
May 20, 1969 G. D. ROSSINI 3,445,789

HIGH-POWER WAVEGUIDE WATERLOADS FOR R.F. ENERGY

Filed June 29, 1967

FIG. 1



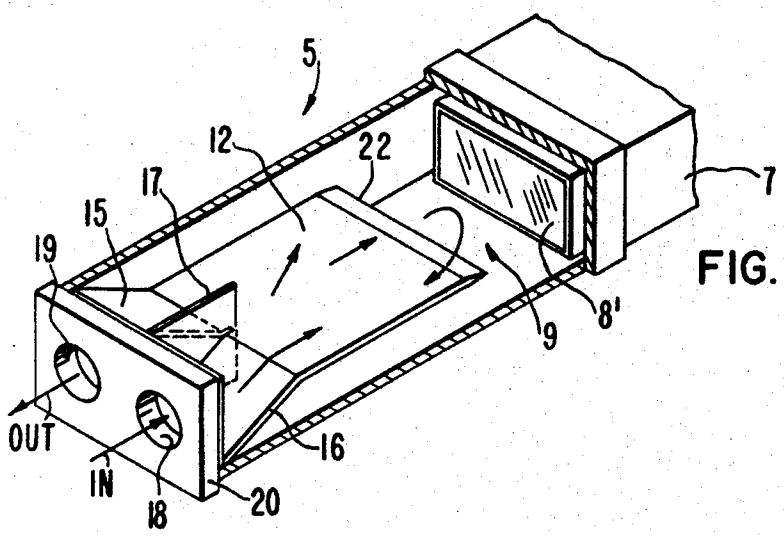


FIG. 2

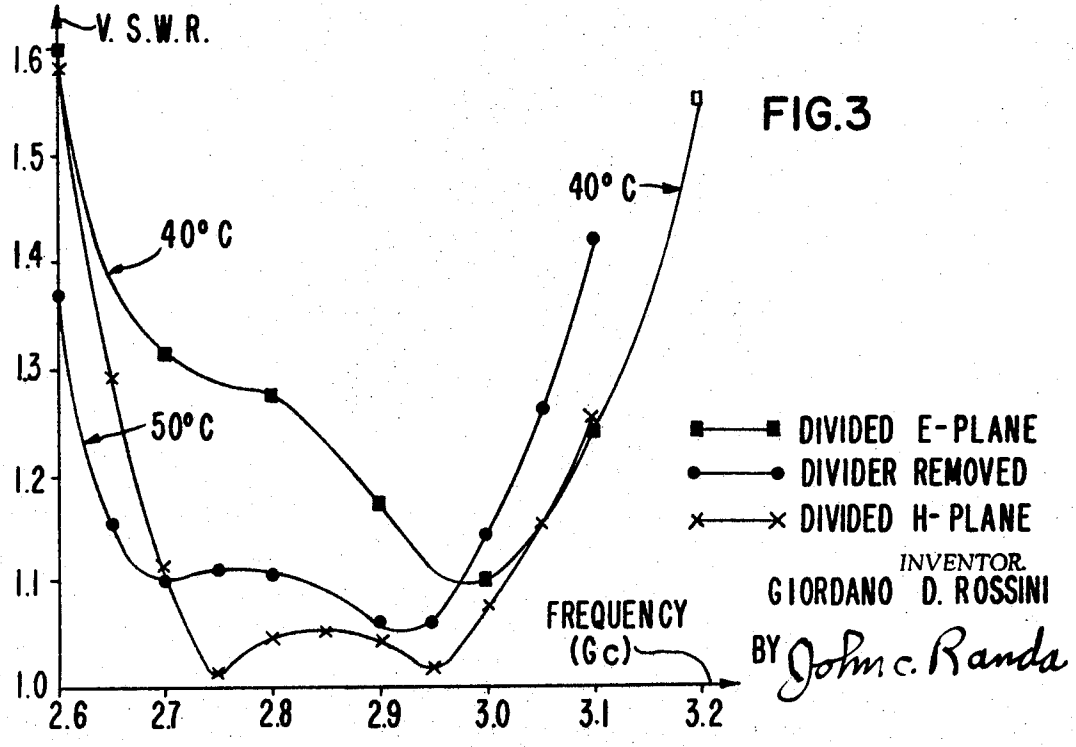


FIG. 3

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HIGH-POWER WAVEGUIDE WATERLOADS FOR R.F. ENERGY

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U.S. Cl. 333—22 3 Claims

ABSTRACT OF THE DISCLOSURE

An improved waveguide waterload for R.F. energy, preferably in the microwave spectrum is realized by introducing an H-plane septum into the waterload flow chamber portion of the waterload such that the coolant liquid flow pattern is turbulent in the vicinity of the downstream end portion of the window. The reactive effects of the H-plane are minimal in comparison to an E-plane septum with a resultant low V.S.W.R. for the waterload in conjunction with an extremely compact design which is particularly suitable for use anywhere in the microwave spectrum.

CROSS REFERENCE TO RELATED APPLICATIONS AND PATENTS

U.S. Letters Patent 3,289,109 by R. B. Nelson issued Nov. 29, 1966 and U.S. patent application Ser. No. 474,414 by Floyd O. Johnson filed July 23, 1965, both of which applications are assigned to the same assignee as the present invention are directed to basic high frequency high-power waveguide waterloads of the type with which the present invention is in general concerned with. The Nelson and Johnson waterload teachings may advantageously be incorporated herein and conversely the teachings of the present invention may advantageously be incorporated in the waterload of the present invention.

BRIEF DESCRIPTION OF THE PRESENT INVENTION

In the aforementioned Nelson and Johnson waterloads the basic concepts of utilizing $n\lambda_g/4$ thick ceramic electromagnetic wave permeable and fluid impervious windows disposed between the waveguide R.F. input channel and the fluid coolant flow channel portions of the waterload are given. The advantages of incorporating broadbanding and residual reflection cancellation iris susceptance means as well as re-entrantly disposing the window within the fluid coolant flow channel portion are also taught together with other basic design techniques in the aforementioned Nelson and Johnson references. This invention represents an improvement in the fluid coolant flow channel portion of a waveguide waterload incorporating one or more of the Nelson and Johnson teachings. It permits the waterload designer to considerably reduce the design complexity and size of the fluid coolant flow channel portion of the waterload without losing the power handling capabilities thereof or introducing undesirably high V.S.W.R. or causing undesirably small bandwidths. The basic design involves the introduction of an H-plane septum in the fluid coolant flow channel which divides the flow channel into a bidirectional flow channel in the vicinity of the septum and produces a generally curvilinear fluid flow pattern past the downstream end face of the window. Experimental analysis of this H-plane design in comparison to an E-plane septum design resulted in a considerable reduction in V.S.W.R. and enhancement of the waterload bandwidth characteristics. An H-plane septum with the downstream end portion split to provide a pair of oppositely tapered ramp portions with an E-plane divider provides an extremely simple mechanism for introducing and extracting the coolant fluid into and from the H-plane septum region.

It is therefore an object of the present invention to provide an improved high frequency high-power waveguide waterload.

A feature of the present invention is the provision of a waveguide waterload having an electromagnetic wave permeable and fluid impervious dielectric window disposed between a waveguide R.F. input channel portion and a fluid coolant flow channel portion with an H-plane septum dividing the flow channel downstream from the window to provide bidirectional fluid flow paths in the septum region and generally curvilinear fluid flow past the downstream window face normal to the plane of the H-plane septum.

These and other features and advantages of the present invention will become more apparent upon a perusal of the following specification taken in conjunction with the accompanying drawings wherein:

FIG. 1 is a fragmentary sectional view of a waterload incorporating the teachings of the present invention.

FIG. 2 is a partially cutaway perspective view of the waterload depicted in FIG. 1.

FIG. 3 is an illustrative graphical portrayal of V.S.W.R. vs. frequency for different flow channel end portion designs showing the advantages of the present invention.

DETAILED DESCRIPTION

Turning now to FIG. 1 there is depicted a waveguide waterload **5** incorporating the teachings of the present invention. The waterload **5** may be used in many well-known ways such as a dummy load for absorbing R.F. energy during testing of microwave sources such as the klystron **6** depicted in block form and coupled to the input waveguide channel portion **7** of the waterload.

Another use would be as a calorimeter for accurately measuring the R.F. power output of a microwave source in a manner well-known in the art as well as other usages which are well known to those skilled in the art. In brief, the waterload **5** as depicted in FIGS. 1 and 2 includes an R.F. input channel portion **7** preferably with an end flange **8** for facilitating coupling to a microwave source.

The R.F. input channel portion is terminated with an $n\lambda_g/4$ dielectric window **8** which preferably protrudes re-entrantly into the flow channel portion **9** to enhance cooling of the interface **10** between waveguide and window as explained in more detail in the aforementioned Johnson application. The $n\lambda_g/4$ window **8**, where n is any odd integer as determined at a frequency within the operating passband of the waterload and preferably $n=1$ or 3 as determined at the center frequency f_0 of the passband of the waterload is broadbanded via inductive iris means **11** disposed upstream from the window in a manner to cancel residual reflections from the window and enhance the operating bandwidth. The inductance susceptance technique taught by Johnson wherein the susceptance means **11** is inductive in nature and has a net spacing S from the window which corresponds to

$$S=(.4\lambda_g+n\lambda_g/2)\pm.1\lambda_g$$

where $n=-1, 0, 1, 2, 3$, etc. as determined at f_0 and wherein the inductive susceptance means **11** has a net normalized susceptance value B/Y_0 falling within the limits $B/Y_0=.1$ to $.7$ as determined at f_0 where B is net susceptance means value in mhos and Y_0 is the reciprocal of the waveguide characteristic impedance is preferred although other known mechanisms may be utilized. The specific values being determined preferably at the output coolant flow temperature desired by the particular user of the waterload using any suitable lossy coolant fluid, e.g., tap water, de-ionized H_2O or any other commercially available fluids. The window material is preferably selected from ceramics such as alumina (Al_2O_3), single

crystal sapphire, beryllia, etc. although obviously not limited thereto. Preferably, the relative dielectric constants of air ϵ_0), window material (ϵ_1), and lossy coolant fluid (ϵ_2) are selected such that $\epsilon_1=\sqrt{\epsilon_0\epsilon_2}$ at f_0 for $\lambda_g/4$ windows to obtain a theoretical zero reflection coefficient if desired. However, it is to be understood that the H-plane septum approach in the fluid coolant flow channel portion of the waterload may be used independently of the above specific design concepts given by way of providing a preferred embodiment. Any conventional materials such as OFHC copper, stainless steel etc. may be used to form the waveguide and flow channel portions of the present invention in conjunction with conventional metal joining techniques such as e.g., brazing.

Turning now to the downstream end portion of the waterload, the flow channel region **9**, there is incorporated an H-plane septum **12** disposed parallel to the broad walls of rectangular shaped fluid coolant flow channel portion **9** such as to form bididectional fluid flow paths in the septum region as indicated by the directional arrows. The septum is spaced from the downstream window face **8'** such that the coolant fluid flows in a generally curvilinear flow path past the downstream window face normal to the plane of the septum as shown. This approach eliminates any cavitation boiling due to non-turbulence or dead water spots in the vicinity of the window without having to introduce slanted input-output flow pipes such as taught, for example, by Nelson or Johnson and without having to sacrifice V.S.W.R. and waterload bandwidth as well as power handling capabilities to any deleterious degree for the design of concern. The input and output fluid coolant flow ports and associated piping can be located in the confines of the transverse cross-sectional plane of the flow channel if desired. The resultant waterload **5** as depicted in FIGS. 1 and 2 is extremely compact in overall size and very simple in design as is readily apparent upon examination of the waterload depicted in FIGS. 1 and 2.

The downstream end of the septum **12** is split down the middle to provide a pair of oppositely tapered ramps **15, 16** which are separated by an E-plane divider **17** in the tapered regions as shown. Liquid fluid coolant is introduced via an input fluid coupling input port such as an annular aperture **18** in the end wall **20** of the flow channel and extracted via output fluid coupling port such as an annular aperture **19** as shown. Any suitable coupling pipes or the like (not shown) may obviously be used to introduce and extract the coolant liquid. The coolant fluid will be restricted to the half-section portion in the vicinity of the divider and then spread out over the flow channel broad wall cross-sectional area in the septum region as indicated by the directional areas and will cover the entire window cross-section including the re-entrant sides or interface portions **10** without any dead spots where cavitation boiling can occur.

An S-band waterload was designed as depicted in FIGS. 1 and 2 using standard S-band rectangular waveguide and easily handled average powers of 200 kilowatts at a 40° C. output port fluid temperature. The coolant fluid was standard tap water at a flow rate of around 40 gal./min. or more with the septum edge **22** disposed about $2\lambda_g$ from the window face **8'** as determined with the tap water filling the flow channel. The same design could easily handle 500 kilowatts average power without encountering excessive window overheating and/or coolant fluid temperature increases which would deleteriously affect the V.S.W.R. and bandwidth characteristics. If the fluid coolant temperature is increased too far beyond the design value the effective fluid dielectric constant will change to such a degree as to introduce excessive mismatch which may exceed the users system requirements. Obviously, the waterload depicted in FIGS. 1 and 2 can be designed to accommodate R.F. energy anywhere in the microwave spectrum. The S-band waterload discussed above provided a 15% bandwidth with a V.S.W.R. of less than 1.2 as depicted in FIG. 3 for the curve denoted divided H-plane with 40° C. tap water disposed in the flow channel. The curve denoted E-plane was made for identical conditions but with the septum disposed in the E-plane instead. It was totally unacceptable from a V.S.W.R. and bandwidth standpoint. The curve denoted divider removed was run for 50° tap water and besides indicating a higher V.S.W.R. and narrower bandwidth would be unacceptable from a power handling standpoint since it would permit cavitation in the vicinity of the window due to reduced fluid flow. The distance of the H-plane edge **22** from the downstream window face **8'** can be varied as desired to either increase or decrease the flow parameters in the vicinity of the window without adversely affecting the V.S.W.R. The E-plane septum was found to introduce excessive V.S.W.R. when disposed within the same distance as the H-plane design from the window face **8'** as determined with the fluid in the flow channel which does not permit obtaining both good flow velocity in the vicinity of the window with low V.S.W.R. and a wide bandwidth as does the H-plane which did not introduce excessive wave reflection regardless of how close it was disposed to the window face **8'**. The rationale for the above result is not fully understood, therefore no further explanation will be attempted.

It is to be understood that if the divider end portion is to be dispensed with and the H-plane extended to the end wall **20** other coupling approaches such as transverse pipes or off-set apertures may be employed, if desired, without detracting from the H-plane septum concept. It is to be noted that the H-plane concept is applicable to any guide cross-section wherein the plane of the septum is disposed normal to the E-field of the dominant mode of the waveguide. In the case of the rectangular guide depicted in the preferred embodiment of FIGS. 1 and 2 this would be the TE_{10} mode and the H-plane septum thus is oriented parallel to the broadwalls **7'** of the waveguide channel **7** which means the H-plane is disposed normal to the incident E-fields of the electromagnetic wave energy to be absorbed in the flow channel **9**.

Since many changes could be made in the above construction and many apparently widely different embodiments could be constructed without departing from the scope thereof, it is to be understood that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A high frequency waveguide waterload for absorbing electromagnetic wave energy including an R.F. wave input waveguide channel disposed at the one end portion of the waterload, a fluid coolant flow channel disposed at the other end portion of the waterload and an electromagnetic wave permeable and fluid impervious dielectric window disposed therebetween and separating said R.F. wave input waveguide channel and said fluid coolant flow channel, said fluid coolant flow channel being provided with an H-plane septum which provides said fluid coolant flow channel with bi-directional fluid flow channels in septum region, said H-plane septum being axially spaced from said dielectric window within said flow channel such that coolant fluid flows from one of said bi-directional flow channels to the other in a generally curvilinear flow pattern in the vicinity of said window, and input and output fluid coupling ports for introducing coolant fluid into said flow channel and extracting coolant fluid therefrom.

2. The waveguide waterload defined in claim **1** wherein said H-plane septum is divided in the vicinity of the downsrteam end wall portion of said fluid coolant flow channel into two oppositely directed tapered portions forming ramps between the major plane of the H-plane septum and opposing wall portions of said fluid coolant flow channels, divider means disposed between said tapered portions and oriented perpendicular to said H-plane within

said flow channel for providing fluid coupling between the input and output fluid coupling ports and the bi-directional flow channels in the region of H-plane septum.

3. The waveguide waterload defined in claim 1 wherein said R.F. waveguide channel and said fluid coolant flow channel are rectangular in cross-section with said H-plane septum having its major plane disposed parallel to the broadwalls of the flow channel and normal to the incident E-fields of the dominant wave of said rectangular waveguide and to the major plane of said dielectric window.

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U.S. Cl. X.R.

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