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Carl

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[45] **Nov. 5, 1974**

[54] **INTEGRATED WINDOW, ANTENNA, AND WAVEGUIDE WITH PLASMA ALLEVIATION**

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[73] Assignee: **The United States of America as represented by the Secretary of the United States Air Force,** Washington, D.C.

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[52] **U.S. Cl.** .... **343/705,** 343/784, 343/872, 333/98 R, 325/65

[51] **Int. Cl.** **H01q 1/28**

[58] **Field of Search** .... 343/784, 783, 705; 333/22 F, 98, 98 P; 313/35; 325/65

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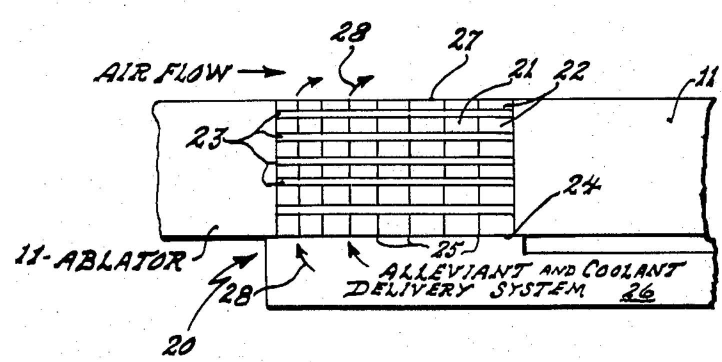
[57] **ABSTRACT**

A method and an apparatus for cooling an electromagnetic wave permeable antenna window, and for alleviating a boundary layer of dense plasma, particularly for use in high performance reentry space vehicles having a sharp or conical configuration. The window, in a shock mounting, is of multilayered construction, having alternating shock absorbent bonded layers with channels or apertures spaced throughout. Gas, such as silicon tetrafluoride or sulfur hexafluoride, flows through an associated waveguide and is introduced, through the channels or apertures, into and through the window. As the coolant gas passes through the window, the window is cooled and does not ablate. Shear forces are used to maintain the window/ablator mold line. The gas then flows into the boundary layer of dense plasma, reducing the electron concentration of the plasma, and increasing the capability of transmitting or receiving electromagnetic waves.

10 Claims, 5 Drawing Figures



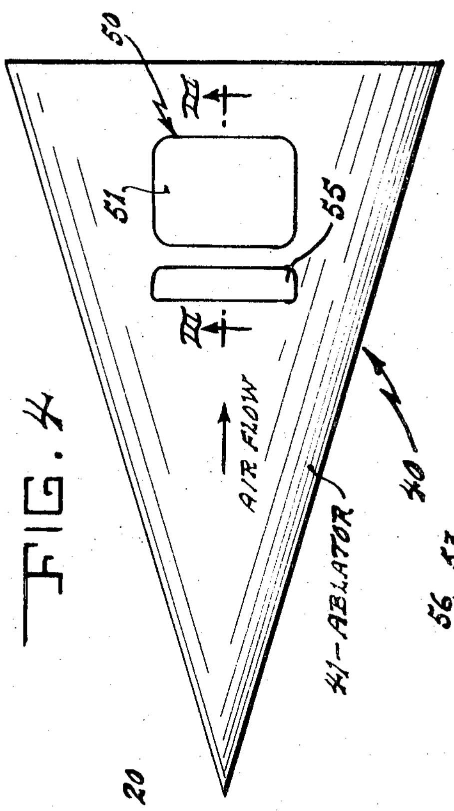


FIG. 4

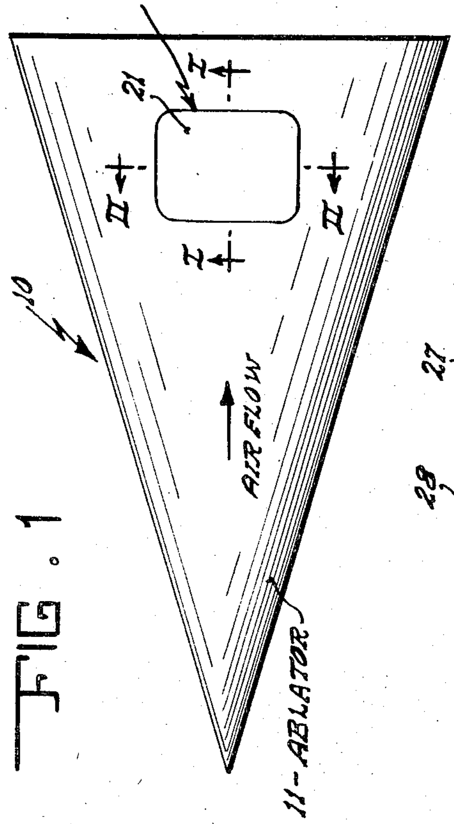


FIG. 1

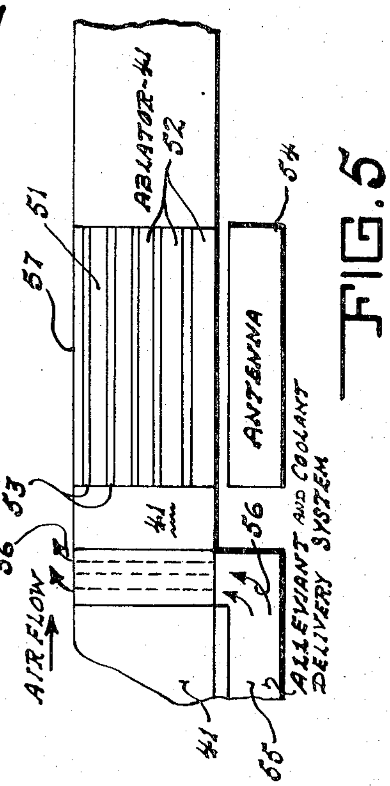


FIG. 5

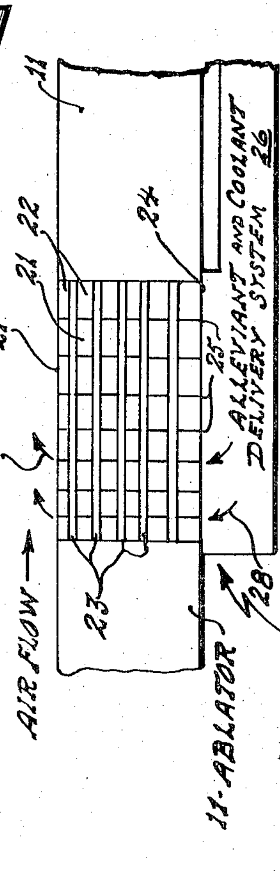


FIG. 2

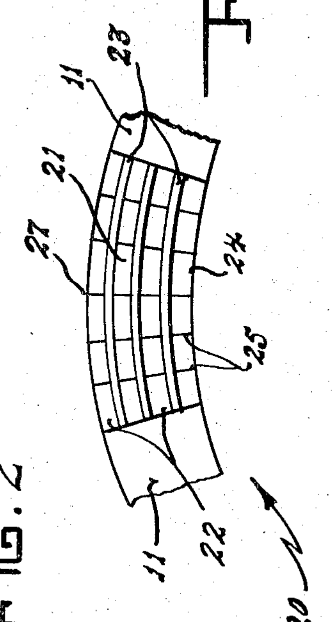


FIG. 3

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INTEGRATED WINDOW, ANTENNA, AND WAVEGUIDE WITH PLASMA ALLEVIATION

BACKGROUND OF THE INVENTION

This invention relates to a method and an apparatus for cooling an electromagnetic wave permeable antenna window, and, additionally, for alleviating a boundary layer of dense plasma.

This invention is particularly well suited for use, generally, in high thermal and high shear environments and, more specifically, in high performance reentry space vehicles having a sharp or conical configuration.

Electromagnetic wave permeable windows are not new. They have been made of glass, mica and, more recently, of alumina ceramic. They have been vacuum sealed or otherwise affixed to antennas, such as the horn type, and to output waveguides. Their use has been extended, in fact, to cooling structures, but as far as is known, without great success. Cooling, for example, by air, water and even specific gases, has been attempted at or contiguous to the periphery of the window. The results have been uneven cooling of the window, particularly at the center thereof, and resultant cracking of the window. Even where cracking did not occur, the structure of the window or of the coolant carrier, or both, resulted in significant loss of transmission of electromagnetic waves from the antenna or output waveguide.

In addition, in connection with the use of electromagnetic permeable windows in antenna or output waveguides for use in airborne vehicles, particularly sharp or conical configurated high performance reentry vehicles, there is the problem of dense plasma which can prevent, or at least severly limit, propagation or transmission of electromagnetic waves to or from the vehicle. This transmission limitation is well-known not only to those skilled in the art, but also to the general public and to commercial communications mass media, such as television, which often refers to this phenomena, in connection with coverage of space flights, as "communications interference" or "communications blackout" caused by "a plasma layer" or "a plasma sheath."

My invention cools electromagnetic wave permeable windows without deleterious effect and, concurrently, eliminates or at least minimizes the problem of transmission limitation caused by the dense plasma in, near, or about the window, when the window is used in an airborne vehicle.

SUMMARY OF THE INVENTION

My invention pertains to a method and an apparatus for cooling an electromagnetic wave permeable antenna window and for alleviating a boundary layer of dense plasma. More particularly, this invention relates to an integrated electromagnetic wave permeable window, antenna, and waveguide, with plasma alleviation, for use, for example, in high performance reentry space vehicles having a sharp or conical configuration.

Thus, an object of my invention is to provide a novel electromagnetic wave permeable window for use with an antenna or a waveguide.

Another object of my invention is to provide an electromagnetic wave window which can be simply and economically constructed and which can be efficiently cooled without any deleterious effect.

Still another object of my invention is to provide an electromagnetic wave permeable window which can be used in high thermal and high shear environments.

A further object of my invention is to provide an electromagnetic wave permeable window for use in high performance reentry space vehicles having a sharp or conical configuration.

A still further object of my invention is to provide a novel method of cooling an electromagnetic wave permeable wave window.

An additional object of my invention is to provide a method for alleviating a boundary layer of dense plasma in, near and about an electromagnetic wave permeable window to eliminate, or at least uminimze, the problem of transmission limitation caused by said dense plasma.

These, and still other, objects of my invention will become readily apparent after a consideration of the description of my invention and reference to the drawings.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a top plan view, in schematic form, of a portion of a sharply configurated reentry space vehicle showing an embodiment of my invention;

FIG. 2 is a cross-sectional view, in schematic form, taken along line I—I of FIG. 1;

FIG. 3 is also a cross-sectional view, in schematic form, but taken along line II—II of FIG. 1;

FIG. 4 is a top plan view, in schematic form, of a portion of a sharply configurated reentry space vehicle showing another embodiment of my invention; and

FIG. 5 is a cross-sectional view, in schematic form, taken along line III—III of FIG. 4.

DESCRIPTION OF THE EMBODIMENTS

With reference to FIG. 1, wherein a portion of a sharply configurated reentry space vehicle **10** is shown, the electromagnetic wave permeable window **21** is flush, or essentially level with, the ablative surface or shield **11** of space vehicle portion **10.** Window **21** is a part of an integrated window-antenna-waveguide assembly **20,** of which the antenna and waveguide component parts are not shown in FIG. **1.**

In FIG. **2,** the ablative surface or shield **11,** the window **21,** and the antenna-waveguide portion of the integrated window-antenna-waveguide assembly **20,** and their relative positioning are better seen. The window **21** is at the antenna (or output waveguide) interface **24** and said window is of the multilayered type, i.e., layered construction, with alternating bonded layers, such as **22** and **23,** preferably of fused silica layers with less dense layers which are sintered until bonds are formed.

Again with reference to FIG. **2,** there are artifically constructed channels **25** disposed within the window **21,** from interface **24** to air flow boundary **27.** The coolant fluid **28,** in this case silicon tetrafluoride or sulfur hexafluoride gas, flows through artifically constructed channels **25,** after delivery through the conduit **26** which also serves as the delivery system for the electromagnetic wave energy.

In FIG. **3,** the flush contouring of the window **21** at the air flow boundary surface **27** can be more readily seen. It is to be noted that the alternating bonded layers **22** and **23** of window **21** are also contoured.

Window **21** is in a suitable shock mounting (not shown).

In FIGS. **4** and **5** are depicted views of another embodiment of my invention.

In this embodiment, and specifically with reference to FIG. **4**, there is a coolant fluid outlet **55** disposed adjacent to the electromagnetic wave permeable window **51**, of integrated antenna-window-waveguide assembly **50**, in ablative surface or shield **41** of space vehicle portion **40**.

In FIG. **5** is shown window **51** with alternating bonded layers such as **52** and **53**, preferably of fused silica layers with less dense layers which are sintered until bonds are formed, antenna **54**, and coolant fluid flow conduit **55**, just upstream of window **51**, as they are relatively positioned in ablative shield **41**.

It is to be noted that in this embodiment, window **51** does not have any artificially constructed channels, such as **25**, FIGS. **2** and **3**.

The coolant fluid, such as silicon tetrafluoride gas or sulfur hexafluoride gas **56**, flows through conduit **55**.

Window **51** and coolant fluid flow conduit **55** are flush with the contouring of ablative shield **41** at the air flow boundary surface **57**.

Window **51** is in a suitable shock mounting (not shown).

MODE OF OPERATION OF THE PREFERRED EMBODIMENT

As to the embodiment shown in FIGS. **1, 2** and **3**, the gas coolant **28**, such as silicon tetrafluoride or sulfur hexafluoride, is introduced through conduit **26** which in this case serves the dual purpose of coolant delivery system and waveguide. The flow of the gas coolant through the waveguide, as such, protects the waveguide from high voltage breakdown.

Coolant gas **28** leaks into electromagnetic wave permeable window **21** through artifically constructed channels **25**, cooling the window. As a result, window **21** does not ablate. Shear forces are used to maintain the window/ablator mold line or air flow boundary **27**, so that if the shearing forces are sufficiently strong, window **21** will shear at the bond lines between alternating bonded layers, such as **22** and **23**, as a particular bond line is reached and is acted upon by the shearing forces. It is here to be noted that the multilayered construction of window **21** with shock absorbent bonding layers, such as **22** and **23**, preferably of fused silica layers with less dense layers which are sintered until bonds are formed, together with the shock mounting (not shown) of window **21**, permits window **21** to withstand much higher shock levels than any known conventional solid electromagnetic wave permeable window. The layered construction, with alternating bonding layers, of window **21** serves as acoustical mismatch for the attenuation of shock waves.

Coolant gas **28**, after flowing through artifically constructed channels **25**, passes into boundary layer **27**, a region of high temperature and high electron concentration, cools that boundary layer **27** and, thereby, reduces the electron concentration, or dense plasma, and eliminates, or at least minimizes, the problem of transmission limitation caused by the dense plasma.

As to the embodiment shown in FIGS. **4** and **5**, the coolant gas **56**, such as silicon tetrafluoride or sulfur hexafluoride, is introduced through conduit **55** into boundary layer **57**, which is a region of high temperature and high electron concentration. There, the coolant gas **56**, moving downstream, cools window **51** by cooling boundary layer **57**. Additionally, and as a result of cooling of boundary layer **57**, the electron concentration or dense plasma is eliminated, or at least minimized, so that transmission of electromagnetic waves is significantly improved.

Window **51** is structured similarly to window **21**, FIGS. **2** and **3**, except of course that it does not have artificially constructed channels **25**, FIGS. **2** and **3**. In essence, it does not ablate; shear forces are used to maintain the window/ablator mold line or air flow boundary **57**; window **51** will shear at the particular or appropriate bond line if sufficient shearing force is applied; and, window **51** will withstand much higher shock levels than conventional solid electromagnetic wave permeable windows because, in addition to the foregoing, it is also shock mounted (not shown) and its layered construction, with alternating bonding layers, serves as acoustical mismatch for the attenuation of shock waves.

While there has been shown and described the fundamental novel features of my invention, as applied to the preferred embodiments, it is to be understood that various substitutions and omissions may be made by those skilled in the art, without departing from the spirit of the invention. For example, the window may be used as waveguide window, rather than an antenna window; the configuration or periphery of the window may be circular, or otherwise configurated as necessary or desired; the artifically constructed coolant flow channels through the window may be replaced by natural channels, simply by using gas-pervious electromagnetic wave permeable materials as the bonded layers; the window laminates may be flat, rather than contoured; and the window laminates may be of pyrolytic boron nitride layers with hot pressed boron nitride as bonding layers.

What I claim is:

1. An electromagnetic wave transmitting and receiving structure, comprising:

a. an antenna;

b. an electromagnetic wave permeable window which includes:

(1). a plurality of alternating bonded layers; and

(2). a plurality of hollow channels, essentially parallel to each other and extending throughout said window.

c. means for supporting said electromagnetic wave permeable window within said antenna; and

d. a waveguide affixed to said antenna.

2. The apparatus, as set forth in claim **1**, wherein said alternating bonded layers are of fused silica and of less dense silica which has been sintered.

3. The apparatus, as set forth in claim **1**, wherein said alternating bonded layers are of pyrolytic boron nitride and of hot pressed boron nitride.

4. An apparatus for cooling an electromagnetic wave transmitting and receiving structure, and for alleviating a boundary layer of dense plasma, in a high performance reentry space vehicle, comprising:

a. an antenna;

b. an electromagnetic wave permeable window, having a plurality of alternating bonded layers of fused silica and of less dense silica which has been sintered, and having a plurality of hollow channels es-

sentially parallel to each other and extending throughout said window;
c. means for supporting said electromagnetic wave permeable window within said antenna;
d. a waveguide affixed to said antenna;
e. a coolant fluid; and
f. means for conducting said coolant fluid to said hollow channels of said electromagnetic wave permeable window.

5. The apparatus, as set forth in claim **4,** wherein the coolant fluid is silicon tetrafluoride.

6. The apparatus, as set forth in claim **4,** wherein the coolant fluid is sulfur hexafluoride.

7. The apparatus, as set forth in claim **4,** wherein the means for conducting said coolant fluid to said hollow channels of said electromagnetic wave permeable window is the said waveguide.

8. An apparatus for cooling an electromagnetic wave transmitting and receiving structure, and for alleviating a boundary layer of dense plasma, in a high performance reentry space vehicle, comprising:
a. an antenna;
b. an electromagnetic wave permeable window, having a plurality of alternating bonded layers of fused silica and of less dense silica which has been sintered;
c. means for supporting said electromagnetic wave permeable window within said antenna;
d. a waveguide affixed to said antenna;
e. a coolant fluid; and
f. means for conducting said coolant fluid to the boundary layer.

9. The apparatus, as set forth in claim **8,** wherein the means for conducting said coolant fluid to the boundary layer is a conduit upstream of said electromagnetic wave permeable window.

10. The method of cooling an electromagnetic wave transmitting and receiving structure, and of alleviating a boundary layer of dense plasma, in a reentry space vehicle having an electromagnetic wave permeable window, comprising the step of flowing a coolant fluid through hollow channels in said window.

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