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Fletcher et al.

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[54] **STRAIN ARRESTOR PLATE FOR FUSED SILICA TILE**

[76] Inventors: **James C. Fletcher,** Administrator of the National Aeronautics and Space Administration, with respect to an invention of **Murat H. Kural,** Sunnyvale, Calif.

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[52] **U.S. Cl.** **428/109;** 403/28; 403/179; 428/214; 428/212; 428/447; 428/77; 428/416

[51] **Int. Cl.²** **E06B 9/26**

[58] **Field of Search** 403/28, 30, 179; 52/759; 161/170, 166, 206

[56] **References Cited**

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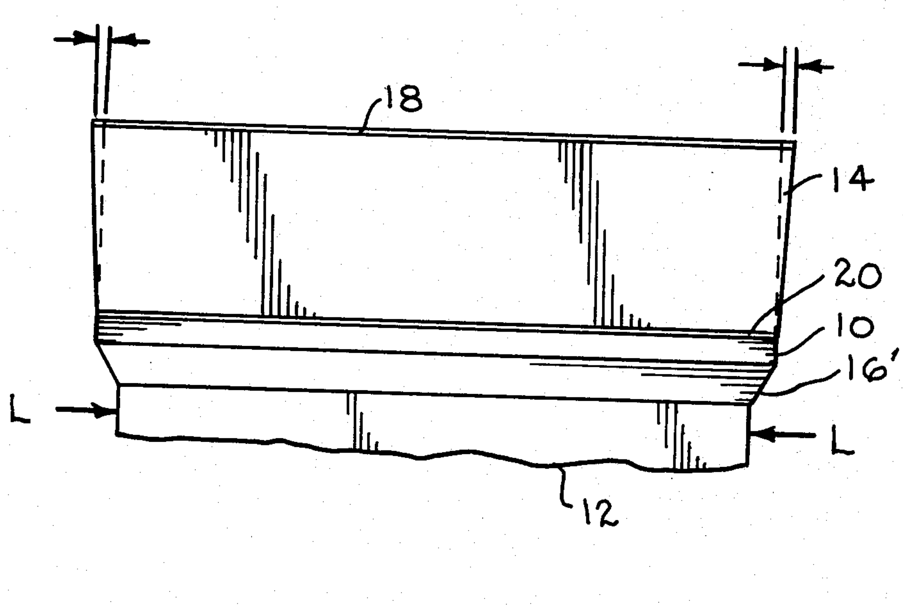
[57] **ABSTRACT**

The invention is an improvement in the technique of attaching rigid thermal insulator tiles to metallic sub-panels or structural members on the exposed surfaces of space craft or other frameworks. Heretofore this has been done by a flexible bond, but it has been found that at temperatures below the glass transition range such bonds lose their flexibility and transfer more strains to the insulator tiles. Since the tiles are relatively weak and frangible, the effect of transmitted strains, whether mechanical or thermal, is cracking and spalling of the insulation material.

The problem is solved by the inventor's incorporation with the flexible bond a strain arrestor plate, disposed adjacent the insulator tile and secured thereto with an adhesive which may be either a flexible bond or a hard bond. In addition to high strength and high stiffness, the strain arrestor plate must have a coefficient of thermal expansion preferably matching that of the rigid insulator tiles. Since most rigid thermal insulators are made of low expansion materials, Invar may be used for the plate, where weight is not a problem, but the preferred material is the lighter weight combination of fibers cast in a thermosetting resin. The preferred material is graphite fibers in an epoxy resin, built up in layers with various fiber orientations to obtain the desired strength, stiffness and thermal properties.

The strain arrestor plate is also amenable to attachment to the structural substrate by mechanical connectors.

8 Claims, 3 Drawing Figures



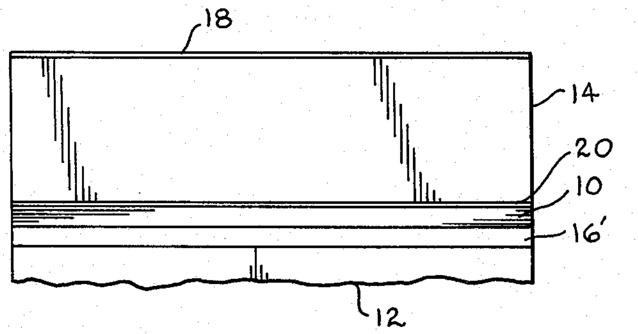
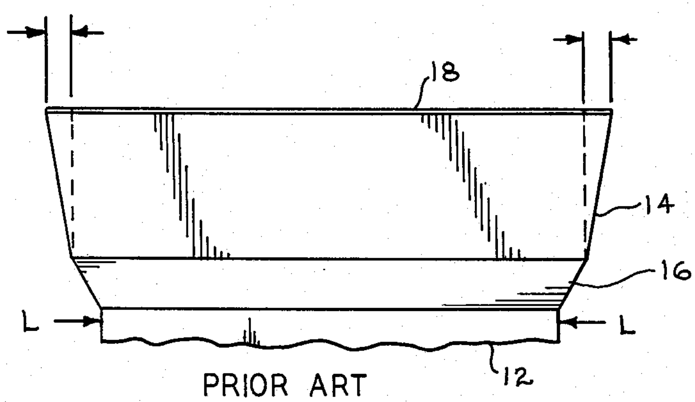


Fig-1



PRIOR ART

Fig-2

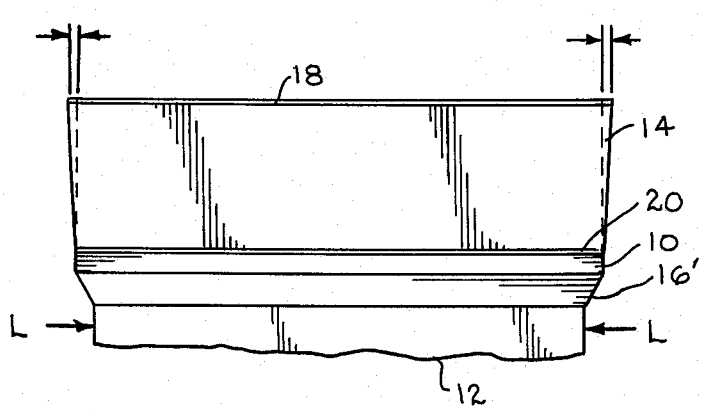


Fig-3

STRAIN ARRESTOR PLATE FOR FUSED SILICA TILE

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435, 45 U.S.C. 2457).

BACKGROUND OF THE INVENTION

1. Field of Invention

The present invention lies in the general field of attachment systems between dissimilar materials, more particularly between a structural material and a non-structural material. More specifically, the present invention may be categorized as an improvement to a flexible bond system (strain isolator system) between a low strength rigid thermal insulator and a high strength structural member, typically of metal.

2. Prior Art and Objects of the Invention

It is sometimes necessary to protect a structure from high or low temperatures by the use of thermal insulators interposed between the structural member and the heat (cold) source. While the insulating tiles may be made of various materials, for extreme temperatures the most common are refractory materials such as silica, and they share the common properties of relatively low strength, extremely high temperature resistance, and low thermal coefficient of expansion as compared to most metals. These insulators cannot be used for load-bearing, and they must be secured to the protected structure by a bond which will minimize transfer of strains from the metal structure to the tile.

Ordinarily this requirement of avoiding strain (load) in the low strength insulator is met by the use of a bond having a strain isolation capability, i.e., a flexible bond. However, at some very low temperatures of interest in the operation of space craft, e.g., −250° F. or temperature below the glass transition range, the known flexible bonds lose most of their flexibility and begin to behave as rigid connectors. As such, they permit enough strain to be passed through from the metal structure to the insulators so that the latter become cracked and spalled, causing a loss in their effectiveness. This result obtains whether the transferred strain is mechanical or thermal in nature, and whether it takes the form of a shock or is gradual in nature, as when the structure being protected contracts (or expands) as its temperature falls (or rises in the latter case).

The prior art seems to be wholly devoid of solutions to the problem. There are many suggestions in the prior art dealing with the protection of metallic structures by adequate thermal insulators such as asbestos, but for the most part these suggestions are concerned solely with sudden increases in temperature, e.g., those experienced by a rocket upon re-entry into the earth's atmosphere. The materials suggested are largely those which can withstand the high temperatures involved while retaining their flexibility or resiliency. None teaches or suggests a rigid insulator suitable for use with a bond at temperatures as low as −250° F.

It is therefore the principal object of the present invention to furnish an improved attachment system between a metallic load-bearing structure and a refractory insulator, one which will minimize transmission to the insulator of mechanical and/or thermal strains of the load-bearing structure at all temperatures including temperatures below the glass transition range of the bond system (adhesive and strain isolator pad).

A further object is to furnish a composite bond system between a load-bearing structure and a refractory insulator, such bond system comprising an adhesive secured to the load-bearing structures which is flexible at temperatures above the glass transition range, and a member secured to such adhesive and to the insulator, such added member being one that minimizes the transmission of mechanical and thermal strains to the insulator at all temperatures including temperatures below the adhesive glass transition range.

Another object is to furnish for use between a high-strength structural member and a low-strength insulator a strain isolation member which is attached to the other of the two members by suitable mechanical or adhesive means and which serves to minimize the transmission of mechanical and thermal strains to the insulator.

Another object is to furnish such a member which has high strength, high stiffness, and a thermal coefficient of expansion essentially equal to that of the insulator.

SUMMARY OF THE INVENTION

The above and further objects are accomplished by providing between the structural member, typically metallic, and the rigid thermal insulator a member which may be called a strain arrestor plate. While the plate may be secured to the structural member by mechanical means, the preferred means of attachment is by a bond or adhesive which is flexible at temperatures above the glass transition range; one suitable bond for this purpose is RTV-560 adhesive, a silicone rubber compound made by General Electric Company and having the characteristics of heat resistance up to 600° F. and flexibility at −150° F.

At its other face, directed toward the insulator, the strain arrestor plate may be secured to the insulator either by a flexible attachment or by a hard bond or adhesive, e.g., flexible bonds such as RTV silicone rubber compounds or hard bonds such as epoxy compounds. The strain arrestor plate itself must have a high stiffness, high strength, and a low thermal coefficient of expansion, the latter quantity being as close as possible to that of the insulator. High strength and stiffness imply that a load on the metallic structure that causes it to expand, for instance, will cause little expansion of the strain arrestor plate. Although the plate will be heavily stressed, such stresses will produce only a slight expansion or strain. The strain will be arrested, and hence the adjacent insulator cannot be stressed to produce strain in the rigid thermal insulator material.

On the other hand, the low thermal coefficient of expansion of the strain arrestor plate, ideally exactly equal to that of the refractory insulator, means that plate and insulator will expand or contract at the same rate in response to a change in temperature. The type of change in the insulator is not one that should cause alarm; indeed, it is a characteristic of refractory material that it can suffer the results of great temperature changes (especially at high temperatures) better than most materials. What should cause concern would be the result of attaching the insulator to a strain arrestor plate having a markedly different thermal coefficient of expansion. If this were done, a change in temperature would cause the strain arrestor plate to expand, for instance, at a higher rate than the insulator. Being stiffer and stronger, the plate would compel the insulator to expand more than its natural characteristics dictate, thus producing in the insulator a strain which could easily fracture it.

SHORT DESCRIPTION OF THE DRAWING FIGURES

The invention may perhaps be better understood by reference to the enclosed drawing forming a part of the present patent application, in which drawing:

FIG. 1 is an elevation of a portion of the combination of a structural member and refractory insulator as joined together by the combination of a flexible bond, a strain arrestor plate of the invention, and a flexible or a hard bond under stress-free conditions.

FIG. 2 is an elevation of the same members as held together by only a prior art bond or adhesive, depicitng the effects of a compressive load applied to the structural member, or an increase in its temperature.

FIG. 3 is an elevation of the FIG. 1 structure including the invention, showing the effects of the same compressive load as applied in FIG. 2.

DETAILED DESCRIPTION OF THE INVENTION

For a clearer understanding of the present invention, the reader is well advised to consider first the prior art as depicted in FIG. 2. As there indicated, the parts to be secured together consist of a high strength structural member **12** and a rigid insulator tile **14**. Member **12** may be a subpanel or primary structure such as a wing or fuselage, made for instance of aluminum or beryllium. The insulator **14** is a part of a rigid surface thermal protection system adapted to protect members **12** from environmental temperatures, particularly those encountered by an operating space craft. It may be made of any one of a number of refractory materials, a preferred material being an all silica tile fabricated by Lockheed Missiles and Space Co., Inc. and designated LI-900 tile.

Joining the two parts **12** and **14** is a thick layer of flexible bond **16**. While various materials may be employed for this bond, a satisfactory material for all temperatures above the glass transition range is a sponge layer designated RM/RL-1973 combined with a layer of a 5 to 15 mil adhesive manufactured by General Electric Company and designated RTV-560 on both sides of the sponge. The sponge material and the RTV-560 adhesive are silicone rubber compounds specially developed for meeting the extreme temperature requirements found in many aerospace applications.

For the sake of completeness, it is mentioned that the refractory insulator **14** is coated with a thin coat of silicone carbide **18** to prevent moisture from being absorbed into the insulator. The coating **18** may be any water-proof material with a specific emissivity characteristic for heat conduction which will coat the tile and remain in place over the full range of temperatures to be experienced by the tile, from −250° to 2300° F.

As indicated in FIG. **2**, a compression load L or temperature decrease in the structural member **12** causes it to shorten. At the very low temperatures of concern, the otherwise flexible bond **16** also becomes shortened over its full length, although somewhat less at its upper surface, where it joins the low strength insulator **14**. The indicated strain in the insulator, although not extremely large, is nonetheless sufficient to fracture this low strength member.

FIGS. **1** and **3** show the same structural member **12**, rigid insulator tile **14** (with water-repellent glaze or coating **18**) and flexible bond as in FIG. **2**; the flexible bond has been reduced in thickness and hence has been designated **16'** to distinguish it from the thicker layer of bond **16** of FIG. **2**. In addition, the embodiment of FIGS. **1** and **3** includes the strain arrestor plate **10** of the invention, sandwiched between bond **16'** and insulator **14**. The thin layer **20** is a second bond securing strain arrestor plate **10** to insulator **14**; it may be of the same composition as bond **16'**, may be another flexible bond such as General Electric RTV-531 or may be a hard bond such as B. F. Goodrich 5 B.

FIG. **1** shows the described combination in a state of zero stress, while FIG. **3** shows the same combination under the influence of a compression load L identical in size to that applied to the structural member **12** in FIG. **2**. As may be seen by comparing the displacements of the lower surface of the insulator **14** in FIGS. **2** and **3**, the effect of the strain arrestor plate **10** is nearly to eliminate the strain which otherwise would be transmitted to insulator **14**. Most of the strain is arrested or eliminated in the strain arrestor plate **10**, which receives the full load but is only slightly strained because of its stiffness.

In addition to its high strength and stiffness, the strain arrestor plate **10** has a low coefficient of thermal expansion, nearly equal to the 3×10^{-7} in./in.-° F. of the rigid thermal insulation tile **14**. While there are relatively few materials possessing all of the desirable attributes, the workable materials do include Invar steel and various cermets and fiber-resin combinations. Invar was not seriously considered fot the space craft application because it would add too much weight to the thermal protection system, and glass ceramics are usually low strength materials. The material finally chosen is a combination of graphite fibers (HMS) manufactured by Hercules and licensed by Courtaulds, Ltd. in an epoxy resin (X-904) manufactured by several companies including Fiberite, Hercules and DuPont. The fibers-and-resin combination is prepared in layers or plies of 0.004 inch thickness with the graphite fibers running parallel to each other. Seven plies were used to build a plate of about 0.028 inch thickness, the plies being oriented at fiber angles of 0°, ±30°, 90°, ±30° and 0°. Other ply orientations and number of plies are possible. Furthermore, graphite fibers other than HMS can be used.

using the described strain arrestor plate as in the FIG. 1 embodiment with 6-inch square insulators approximately 2.5 inches thick, structural plate **12** of 0.7 inch thickness and flexible bond system **16'** of 0.09 inch thickness, a study was made of the stresses transmitted to the insulator **14** at −200° F., and such stresses were compared with stresses transmitted to the insulator of the FIG. 2 assembly (no strain arrestor plate) at the same temperature. It was found that the principal compression with the strain arrestor plate, 31 psi, was only a fraction of the stress induced in the insulator of the assembly lacking a strain arrestor plate, 600 psi. It was evident from this data that the insulators would fail without the strain arrestor plate.

What is claimed is:

1. An improved joint between a high strength metal structural member having a relatively high thermal coefficient of expansion and an insulating tile member composed of chemically pure fused silica, the assembly being subject to temperatures ranging from −250° to

2300°F, said tile member having a thermal coefficient of expansion in the order of 3×10^{-7} in/in/°F, said joint comprising a separate, thin layer of nonmetallic adhesive bond secured to the insulating member, a strain arrestor plate being the same size in plan as the tile secured to the adhesive bond, said adhesive bond being flexible or resilient at temperatures above its glass transition range and said strain arrestor plate having a high yield strength, high stiffness, a low coefficient of thermal expansion, approximately equal to that of the insulating member, and being of such a thickness that contractions of the structural member resulting from changes in temperatures are substantially absorbed by the plate, and a second, separate, thin layer of flexible nonmetallic adhesive bond securing the strain arrestor plate to the structural member, the thin layers of adhesive bond being of sufficient thickness to securely maintain the bond throughout the temperature range.

2. The strain arrestor plate of claim **1** in which said plate is made of graphite fibers in a matrix of epoxy resin.

3. The strain arrestor plate of claim **1** in which the thickness of said plate is of the order of 0.01–0.03 inch when said refractory members have a thickness of the order of 1–10 inches.

4. The strain arrestor plate of claim **3** which is formed of laminae in which the graphite fibers are oriented at various angles between one lamina and its neighbor.

5. The improved joint specified in claim **1** in which the strain arrestor plate has a thickness of approximately 0.03 inches and the flexible adhesive bond has a thickness of approximately 0.09 inches.

6. In an insulating system for a space vehicle formed of a plurality of tile of substantially chemically pure fused silica attached to a metal substrate of the space vehicle, the tiles having a coefficient of thermal expansion markedly lower than the coefficient of expansion of the metal substrate, the improvement comprising: an intermediate member between each tile and the metal substrate forming a strain arrestor plate, said plate attached to each tile by a separate, thin layer of flexible adhesive bond, said plates attached to the metal substrate by a separate layer of adhesive bond, said plate being approximately the same size in plan as the tile, to which it is attached, said plate having a thermal coefficient of expansion approximating that of the tile and a said plate having a high modulus of elasticity and high yield strength and being of such thickness that strains resulting from contraction by the metal substrate are substantially absorbed by the strain arrestor plate, and the layer of flexible bond between the strain arrestor plate and tile.

7. The improved joint of claim **6** in which said plate is composed of graphite fibers in an epoxy resin matrix.

8. The improved joint of claim **7** in which said graphite fibers-epoxy resin plate is of the order of 0.01–0.03 inch for an insulator thickness of the order of 1–10 inches.

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