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(54) **MISSILE STRUCTURE**

(57) The present invention concerns a missile structure. More particularly, but not exclusively, this invention concerns a hybrid missile structure. The missile structure comprises an outer structural element, an inner structural element, and an insulating layer disposed between the outer structural element and the inner structural element. An intermediate structural element links the outer structural element and the inner structural element. The outer structure comprises a composite material, and the inner structure comprises a metal material.

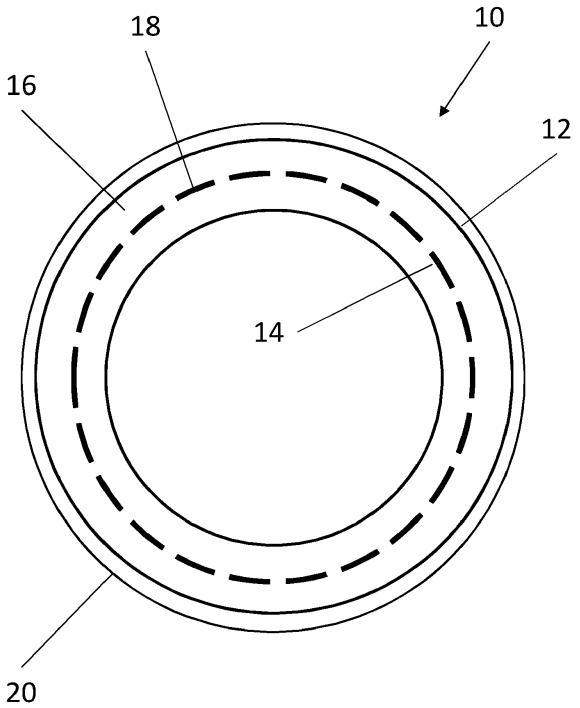

Fig. 1

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Description

Field of the Invention

[0001] The present invention concerns a missile structure. More particularly, but not exclusively, this invention concerns a hybrid missile structure.

Background of the Invention

[0002] Missiles experience a wide range of conditions once they have been deployed. For example, the forces involved in propelling a missile are significant, and the structure of the missile must be suitably strong to be able to tolerate significant loading without damage to or destruction of the missile. Also, missiles may experience significant temperatures due to aero-thermal heating during deployment, for example temperatures in excess of 1000 degrees Celsius. This requires the provision of insulation, to prevent the internal components of the missile overheating during deployment. Typical missile structures may be "hot" structures or "cold structures". Hot structures typically comprise a load bearing external structure, with a layer or layers of insulation provided inside of the load bearing external structure. A cold structure typically comprises an internal load bearing structure surrounded by a layer or layers of insulation outside the internal load bearing structure. Both arrangements require a significant thickness of insulation to be provided, which may reduce the internal payload space of the missile, and/or increase the outer diameter of the missile to an unwieldy size and have negative implications on the mass of the missile.

[0003] The present invention seeks to mitigate the above-mentioned problems. Alternatively or additionally, the present invention seeks to provide an improved missile and missile structure.

Summary of the Invention

[0004] The present invention provides according to a first aspect, a missile structure, the missile structure comprising an outer structural element, an inner structural element, an insulating layer disposed between the outer structural element and the inner structural element, and an intermediate structural element linking the outer structural element and the inner structural element, wherein the outer structural element comprises a composite material, and the inner structural element comprises a metal material.

[0005] The present arrangement provides a hybrid approach to a missile structure compared to the prior art. The outer structural element comprising a composite material, the inner structural element comprising a metal material and the intermediate structural element may cooperate to provide enhanced load-bearing capabilities as compared to prior art arrangements. In particular, the intermediate structural element mechanically couples the outer structural element and the inner structural element such that loading forces may be shared between the inner structural element and the outer structural element. The intermediate structural element may be the insulating layer. The insulating layer may comprise a material such as ceramic foam which has substantial load bearing capacity, such that forces may be transferred between the inner structural element and the outer structural element. The insulating layer may comprise a material with a high resistance to compression, to allow the transfer of forces between the inner structural element and outer structural element. The intermediate structural element may be distinct from the insulating layer. The intermediate structural element may comprise a metal or composite material. The intermediate structural element may extend through the insulating layer to link the outer structural element to the inner structural element. The intermediate structural element may comprise one or more ribs which extend through the missile structure, parallel to a longitudinal axis of the missile structure, and/or perpendicular to a longitudinal axis of the missile structure. The intermediate structural element may be mechanically fastened to one or both of the outer structural element and inner structural element by a fastener, welding, or adhesive. The missile structure may comprise a plurality of intermediate structural elements linking the outer structural element and the inner structural element.

[0006] The outer structural element comprising a composite material and the insulating layer may cooperate to provide enhanced thermal resilience compared to prior art arrangements. The intermediate structural element may reduce the thermal diffusion through the insulating layer, and/or may reduce or absorb stress created within the missile structure as a result of thermal diffusion through the missile structure with the resultant differences in thermal expansion. The present arrangement may allow the missile structure to be reduced in thickness and/or weight in comparison to prior art arrangements, for example hot structures or cold structures. A reduction in thickness and/weight of the missile structure may allow for a greater missile payload, and/or increases in missile performance such as maximum range or speed. Such an arrangement may be particularly advantageous for hypersonic missiles, which are subject to significant heating aero-thermal heating effects during deployment and also significant mechanical stresses and strains during deployment. A hypersonic missile in this context is as conventionally understood by a skilled person, namely a missile that travels at or above Mach 5.

[0007] The missile structure may comprise at least part of a missile housing or body. The missile structure may comprise a tube, for example a cylindrical tube. The tube may comprise a circular or oval cross-section. The tube cross-section may vary along the length of the missile.

[0008] The inner structural element may define a space into which missile components, for example payload, guidance components, fuel, and/or propelling components may be housed. The inner structural element may

comprise one or more attachment points for attachment of additional missile components. The provision of an inner structural element comprising a metal material may make it straightforward to mount or otherwise attach missile components to the inner structural element.

[0009] The missile structure may comprise a missile control surface, for example a wing or fin, or a propulsion system component, for example a nozzle or combustion chamber.

[0010] The inner structural element may comprise a heat sink for components attached to, or located proximate to, the inner structural element. The inner structural element comprising a metal material may make the inner structural element particularly well suited to being a heat sink.

[0011] The outer structural element may comprise a composite material including a ceramic matrix composite, for example composite material comprising ceramic fibres embedded in a ceramic matrix. Such materials may include oxide-oxide ceramic matrix composites, or non-oxide ceramic matrix composites. For example, such materials may include Alumina (AL2O3/AL2O3) when an oxide-oxide ceramic matrix composite, or C/C, S/SiC, SiC/SiC, C/C-Si for non-oxide ceramic matrix composites. The outer structure may comprise an ablative layer. The ablative layer may be destroyed or otherwise removed from the outer structural element when the missile structure is deployed, potentially providing improved thermal resilience to the missile structure.

[0012] The missile structure may comprise an active cooling system, for example the missile structure may comprise one or more coolant channels through which coolant is passed in order to remove heat from the missile structure. The coolant may be a fuel for a missile comprising the missile structure. Alternatively or additionally the missile structure may comprise one or more channels or cavities in which phase-change material is present, such that during heating of the missile structure the phase-change material absorbs heat and changes phase.

[0013] The intermediate structural element may comprise a metal material, a composite material, or a combination of a metal material and a composite material.

[0014] According to a second aspect of the invention there is also provided a missile comprising a missile structure according to the first aspect of the invention. Any of the missile structure features described in relation to the first aspect of the invention may apply to the missile according to the second aspect of the invention.

[0015] It will of course be appreciated that features described in relation to one aspect of the present invention may be incorporated into other aspects of the present invention. For example, the method of the invention may incorporate any of the features described with reference to the apparatus of the invention and *vice versa.*

Description of the Drawings

[0016] Embodiments of the present invention will now be described by way of example only with reference to the accompanying schematic drawings of which:

Figure 1 shows a cross-sectional view of a missile structure according to a first embodiment of the invention;

Figures 2 and 3 shows part of a missile structure according to a second embodiment of the invention;

Figure 4 shows a missile comprising a missile structure according to that shown in any of figures 1, 2, or 3; and

Figure 5 shows part of a missile structural according to a third embodiment of the invention.

Detailed Description

[0017] Figure 1 shows a cross-sectional view of part of a missile structure 10 according to a first embodiment of the invention. The missile structure 10 is a cylindrical missile structure and comprises an outer structural element 12, an inner structural element 14, an insulating layer 16 disposed between the outer structural element 12 and the inner structural element 14, and an intermediate structural element 18 linking the outer structural element 12 and the inner structural element 14. The outer structural element 12 comprises a ceramic matrix composite. Such materials may include Alumina (AL2O3/AL2O3) when an oxide-oxide ceramic matrix composite, or C/C, S/SiC, SiC/SiC, C/C-Si for non-oxide ceramic matrix composites. The inner structural element 14 comprises a metal structure, in this case a steel structure. The skilled person will appreciate that various other metals may be used, for example aluminium alloys or titanium alloys. The insulating layer 16 comprises a foam material. In alternative embodiments, many other suitable materials may be used for the insulating layer, for example, cork or aerogels, ceramic foam, or a microporous material depending on the degree of insulation required for the specific embodiment in question. The insulating layer may also comprise separate layers of different materials. The intermediate structural element 18 comprises a metal material, in this case a steel web structure. In alternative embodiments, the intermediate structural element may comprise any other suitable metal material, or may comprise a ceramic matrix composite. The intermediate structural element 18 extends through the insulating layer 16, mechanically connecting the outer structural element 12 and the inner structural element 14. In figure 1, the connection between the outer structural element 12 and the inner structural element 14 cannot be seen, but the skilled person will appreciate that another "slice" of the missile would show such connection. This results in forces experienced by any of the outer structural element 12, inner structural element 14, and intermediate structural element 18, to be transferred be-

tween all of the structural elements. The inner structural element 14 encloses an inner space of the missile structure, in which further missile components may be housed. The inner structural element 14 may be physically connected to, and/or located proximate to those further missile components such that the inner structural element 14 acts as a heat sink, removing heat from those further missile components. In the embodiment shown, the missile structure is passive, without any additional cooling systems associated with the missile structure. In an alternative embodiment, an active cooling system may be associated with the missile structure. For example, the missile structure may include one or more cooling channels for a coolant, for example a liquid coolant or phase change coolant to be passed through. The inner structural element 14 may also include (not shown) one or more attachment points. The attachment points may be used to attach other missile components, for example payload or propulsion mechanisms, to the inner structural element.

[0018] The outer structural element 12 comprises an ablative coating 20. Such coatings include intumescing paints or pyrolysing ablators, and the skilled person will select the coating according to specific requirements of the specific embodiment, in particular the surface shear environment where the coating is located. The ablative coating 20 is removed from the outer structural element 12 when exposed to enough heat during missile deployment. The ablative coating 20 therefore acts as a sacrificial layer, protecting the outer structural element 12 during missile deployment.

[0019] Figures 2 and 3 show a schematic cross-sectional view of a part of a missile structure according to a second embodiment of the invention. As only a part of the missile structure is shown and the view is schematic, the curvature of the missile structure is not shown, but would be easily understood by a skilled person. A missile structure 110 comprises an outer structural element 112, and inner structural element 114, an insulating layer 116 disposed between the outer structural element 112 and inner structural element 114, and an intermediate structural element 118 connecting the outer structural element 112 and outer structural element 114 by extending through the insulating layer 116. As can be seen in figure 2, the intermediate structural element 118 does not extend across all of the outer structural element 112 and inner structural element 114 as shown, but in other positions in the missile structure 110 the mechanical connection would be seen. In alternative embodiments, the intermediate structural element 118 may extend across the whole of the inner structural element 114 or outer structural element 112. Increasing the coverage in such a way may improve the thermal insulation and/or thermal isolation between the outer structural element 112 and the inner structural element 114. The various components described with reference to figures 2 and 3 may comprise any of the materials described for similar components shown in figure 1. The skilled person will also appreciate that the intermediate structural element may still be arranged to cooperate with the inner structural element and outer structural element without there being a direct mechanical connection between the various structural elements. Instead, the insulating layer may comprise enough structural rigidity to assist in the transfer of forces between the various structural elements, such that the advantage of a stiffer and stronger missile structure is provided. Taking such an arrangement further, the intermediate structural element may also be the insulating layer disposed between the outer structural element and inner structural element, for example a ceramic foam which has both the required insulating and structural properties to provide both functions.

[0020] Figure 4 shows a missile 400 comprising a missile structure 10 according to the first embodiment of the invention.

[0021] Figure 5 shows part of a missile structure according to an alternative embodiment of the invention. The missile structure 210 is similar to that as described with reference to figure 3, and where like elements exist, the same numbering is used, with the first digit being replaced by "2". The missile structure 210 comprises an outer structural element 212, an inner structural element 214, an insulating layer 216 disposed between the outer structural element 212 and the inner structural element 214, and an intermediate structural element 218. The intermediate structural element extends between and mechanically connects the outer structural element 212 and inner structural element 214 together. It will be easily appreciated that the missile structure 212 may comprises a plurality of intermediate structural elements disposed in a spaced relationship to one another. Increasing the number of structural elements used may improve the structural rigidity of the missile structure.

[0022] Whilst the present invention has been described and illustrated with reference to particular embodiments, it will be appreciated by those of ordinary skill in the art that the invention lends itself to many different variations not specifically illustrated herein. By way of example only, certain possible variations have been described.

[0023] Where in the foregoing description, integers or elements are mentioned which have known, obvious or foreseeable equivalents, then such equivalents are herein incorporated as if individually set forth. Reference should be made to the claims for determining the true scope of the present invention, which should be construed so as to encompass any such equivalents. It will also be appreciated by the reader that integers or features of the invention that are described as preferable, advantageous, convenient or the like are optional and do not limit the scope of the independent claims. Moreover, it is to be understood that such optional integers or features, whilst of possible benefit in some embodiments of the invention, may not be desirable, and may therefore be absent, in other embodiments.

Claims

1. A missile structure, the missile structure comprising an outer structural element, an inner structural element, an insulating layer disposed between the outer structural element and the inner structural element, and an intermediate structural element linking the outer structural element and the inner structural element, wherein the outer structural element comprises a composite material, and the inner structural element comprises a metal material.

2. A missile structure as claimed in claim 1, wherein the intermediate structural element extends through the insulating layer.

3. A missile structure as claimed in claim 1 or claim 2, wherein the intermediate structural element extends through the insulating layer and is mechanically fastened to either or both of the outer structural element and inner structural element.

4. A missile structure as claimed in claim 1, wherein the intermediate structural element is the insulating layer.

5. A missile structure as claimed in any preceding claim, wherein the missile structure comprises at least part of a missile housing or body.

6. A missile structure as claimed in any preceding claim, wherein the missile structure comprises a tube.

7. A missile structure as claimed in any preceding claim, wherein the inner structural element defines a space into which missile components may be housed.

8. A missile structure as claimed in any preceding claim, wherein the inner structural element comprises one or more attachment points for attachment of additional missile components.

9. A missile structure as claimed in any preceding claim, wherein the missile structure comprise a missile control surface or a propulsion system component.

10. A missile structure as claimed in any preceding claim, wherein the inner structural element comprises a heat sink for components attached to, or located proximate to, the inner structural element.

11. A missile structure as claimed in any preceding claim, wherein the outer structural element comprises a composite material including a ceramic matrix composite.

12. A missile structure as claimed in any preceding claim, wherein the outer structural element comprises an ablative layer.

13. A missile structure as claimed in any preceding claim, further comprising an active cooling system.

14. A missile structure as claimed in any preceding claim, wherein the intermediate structural element comprises a metal material, a composite material, or a combination of a metal material and a composite material.

15. A missile comprising a missile structure according to any of claims 1 to 14.

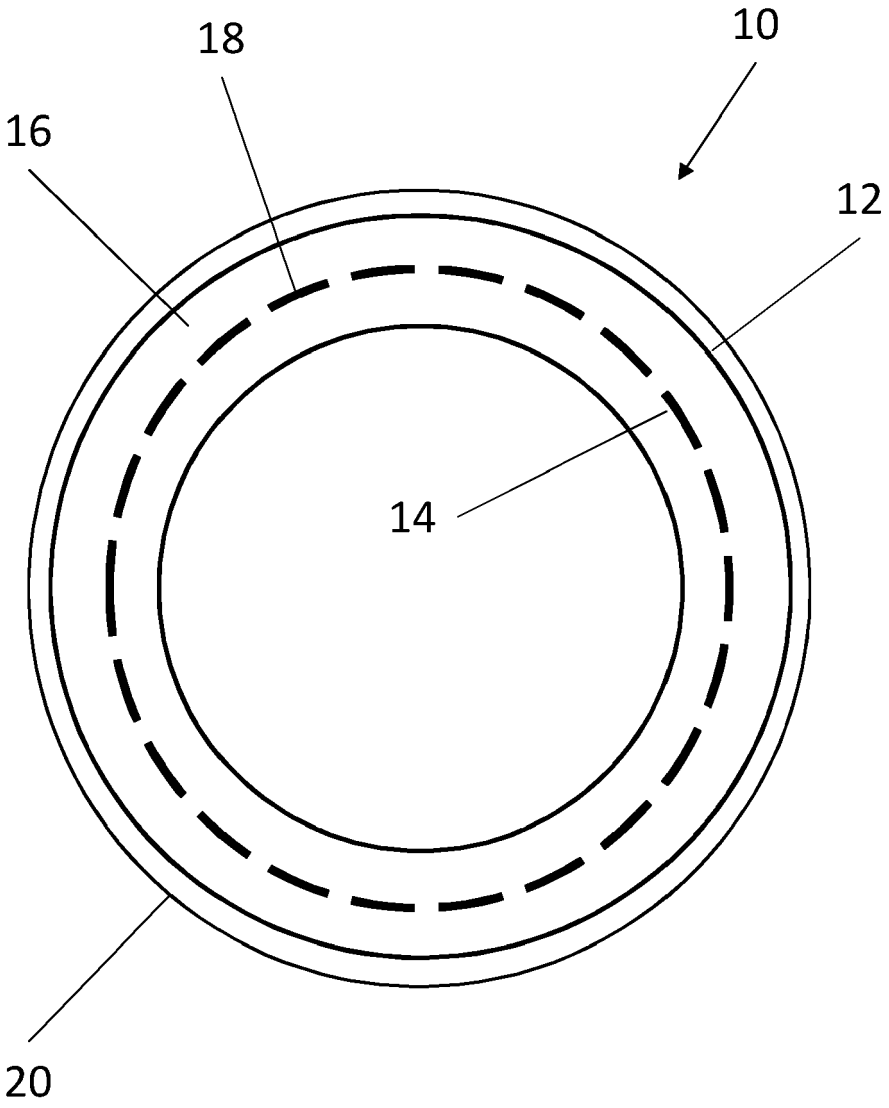

Fig. 1

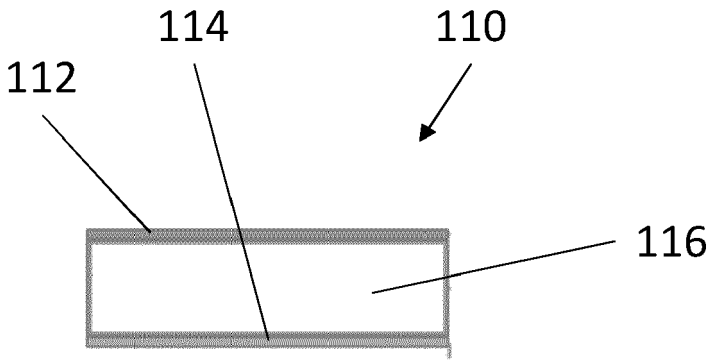

Fig. 2

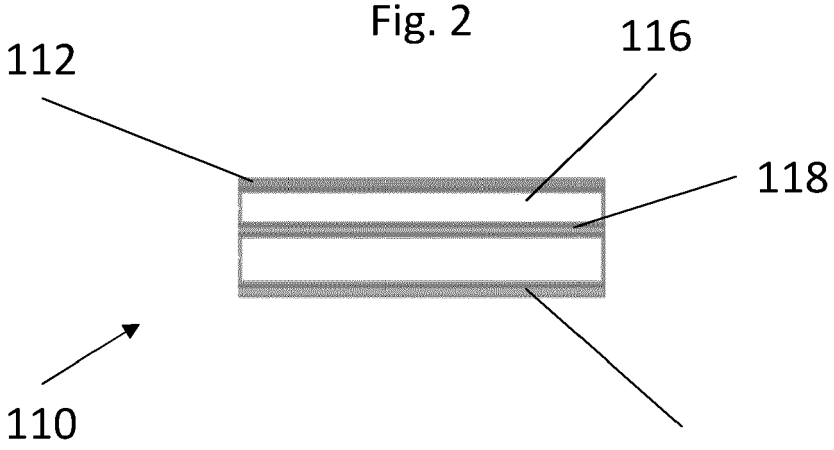

Fig. 3

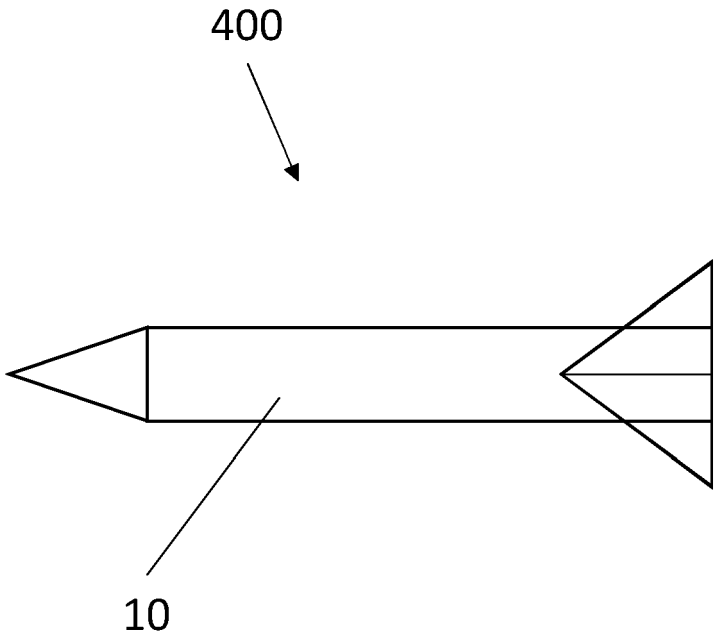

Fig. 4

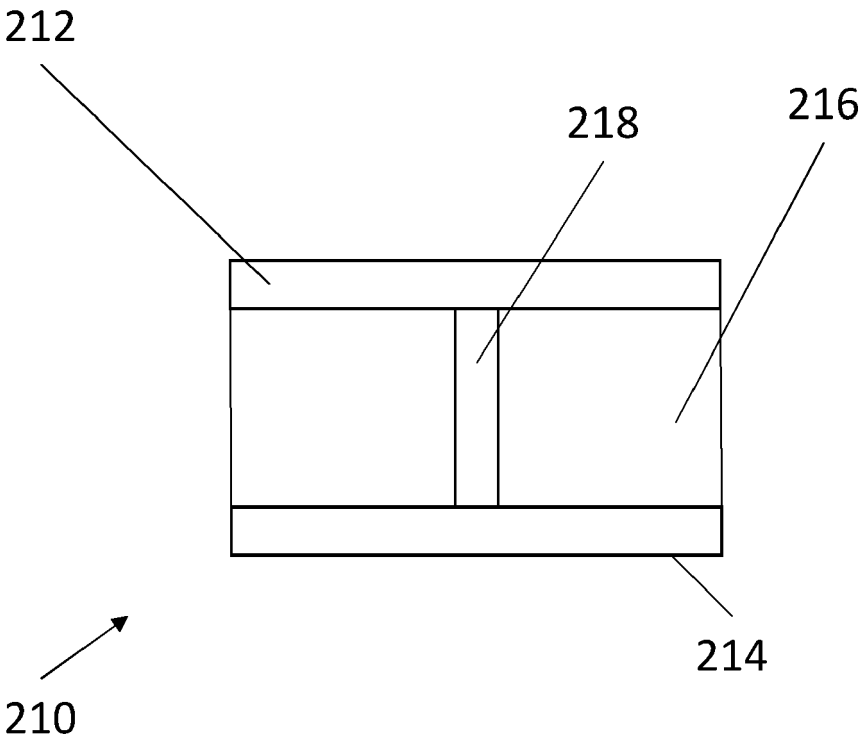

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 23 27 5003

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 2006/176677 A1 (GLOVATSKY ANDREW Z [US] ET AL) 10 August 2006 (2006-08-10) * paragraphs [0003], [0010] - [0013], [0016]; figures 1-3 *	1-10, 13-15 11,12	INV. F42B15/00 F42B15/34
Y	US 10 543 663 B2 (BOEING CO [US]) 28 January 2020 (2020-01-28) * column 2, line 49 - column 3, line 27; figures 1,2 *	11	
Y	US 2012/121892 A1 (FISCH PETER GERD [DE] ET AL) 17 May 2012 (2012-05-17) * paragraphs [0037] - [0040]; figures 1,2 *	12	
A	US 5 979 826 A (BROWN JANIS [US] ET AL) 9 November 1999 (1999-11-09) * column 3, line 31 - column 5, line 16; figures 1-4 *	1-15	
			TECHNICAL FIELDS SEARCHED (IPC) F42B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	6 June 2023	Seide, Stephan

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 23 27 5003

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