US012392578B1

(12) United States Patent
Rascon et al.

(10) Patent No.: US 12,392,578 B1
(45) Date of Patent: Aug. 19, 2025

(54) VERTICAL LAUNCH SYSTEM (VLS) INCLUDING HEAVY INERT GAS INSULATING LAYERS

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **18/635,860**

(22) Filed: **Apr. 15, 2024**

(51) **Int. Cl.**
F41F 3/04 (2006.01)
F41F 3/077 (2006.01)

(52) **U.S. Cl.**
CPC ***F41F 3/0413*** (2013.01); ***F41F 3/077*** (2013.01)

(58) **Field of Classification Search**
CPC F41F 3/00; F41F 3/04; F41F 3/0413; F41F 3/077
See application file for complete search history.

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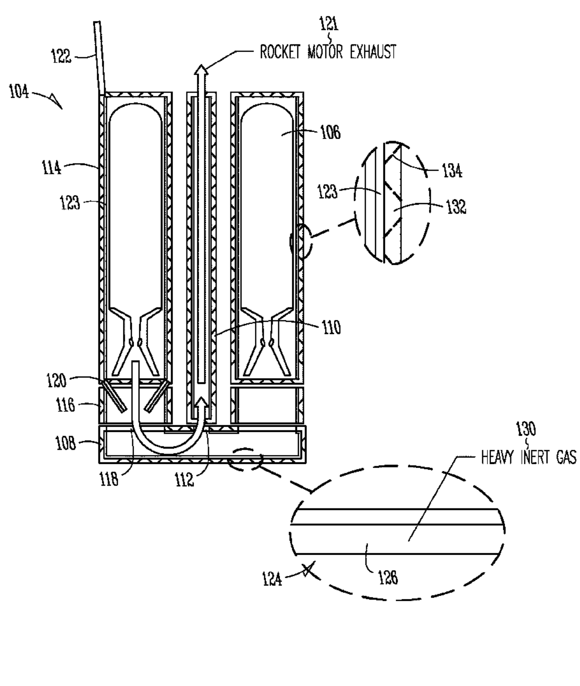
(57) **ABSTRACT**

Heavy inert gas insulation layers are provided for one or more components of a launch system for a plurality of missiles. The layer may be integrated into the walls of the components or provided in inserts attached to the components. An inert gas fills a sealed void space in the walls or the insert. The inert gas has a density of at least 1.5 Kg/m^3 and a thermal conductivity (Tcond_gas) of no greater than two-thirds of a thermal conductivity of air (Tcond_air) to form the heavy inert gas insulation layer. The inert gas may be Argon, Krypton, Xenon or a synthetic gas and is suitably held at a pressure of 760 Torr (1 atmosphere) or greater at sea level. The heavy inert gas insulation layer delays desensitization or inhibits premature reaction of the energetic materials inside the missiles due to high external temperatures. The insulation layers allow for more compact and dense configurations of the launch system and missiles.

20 Claims, 5 Drawing Sheets



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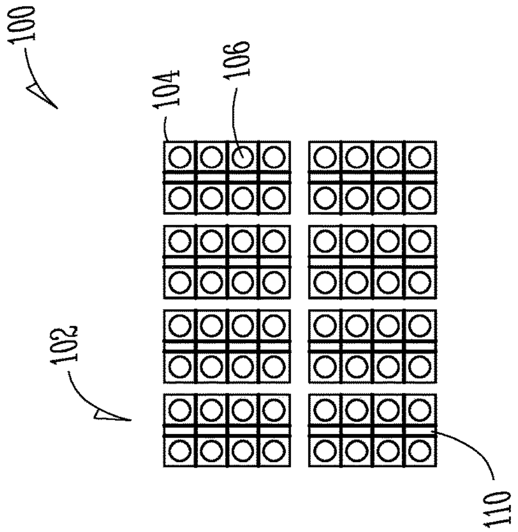
100
104
106
102
110

Fig. 1

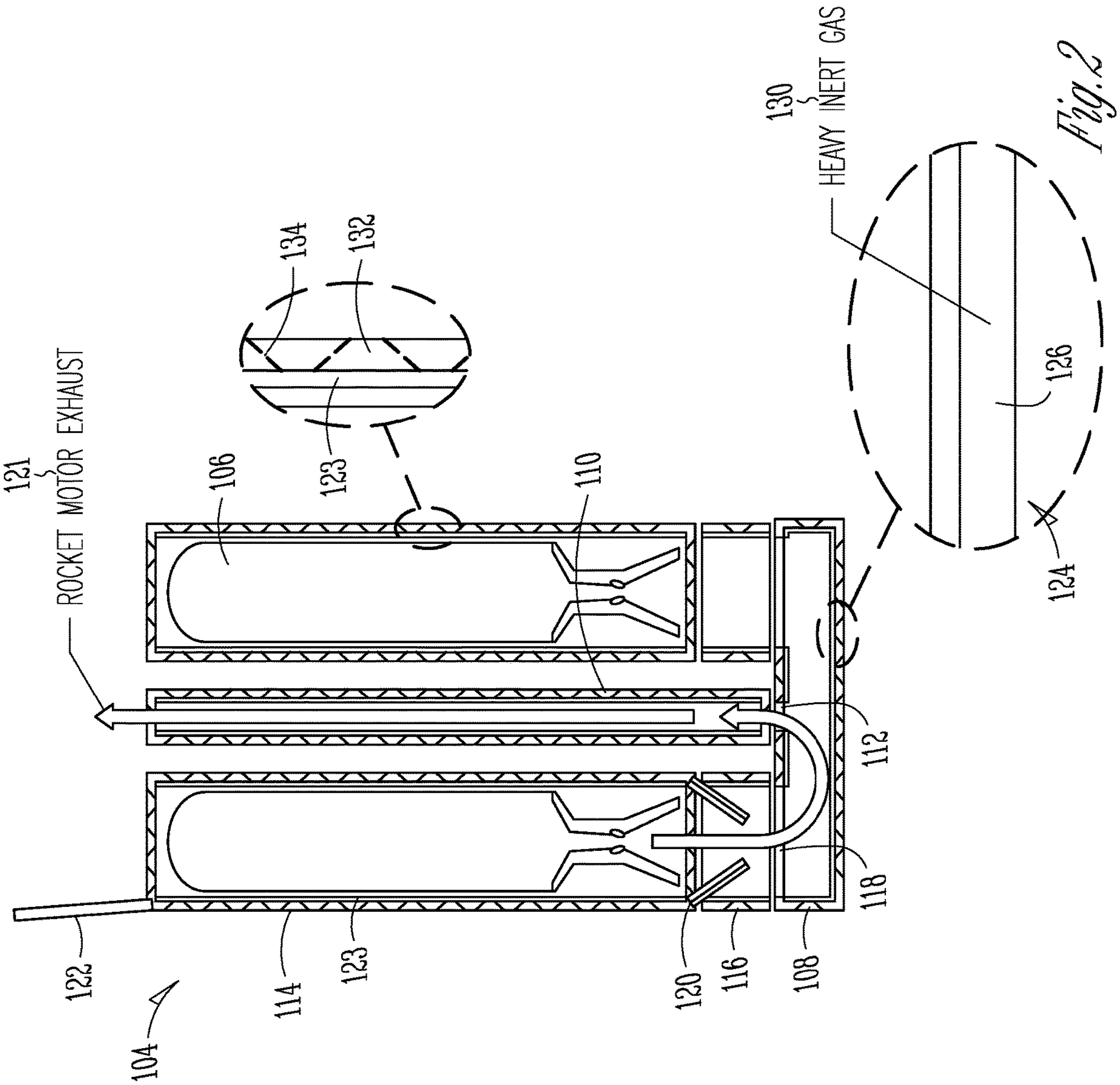
121
ROCKET MOTOR EXHAUST
106
123
134
132
130
HEAVY INERT GAS
126
110
124
112
118
120
116
108
114
123
122
104

Fig. 2

300

THERMAL CONDUCTIVITY (W/mK)	
PHENOLIC RESIN	1–1.5
AIR	0.026
ARGON	0.017
KRYPTON	0.0087
XENON	0.0052

Fig. 3A

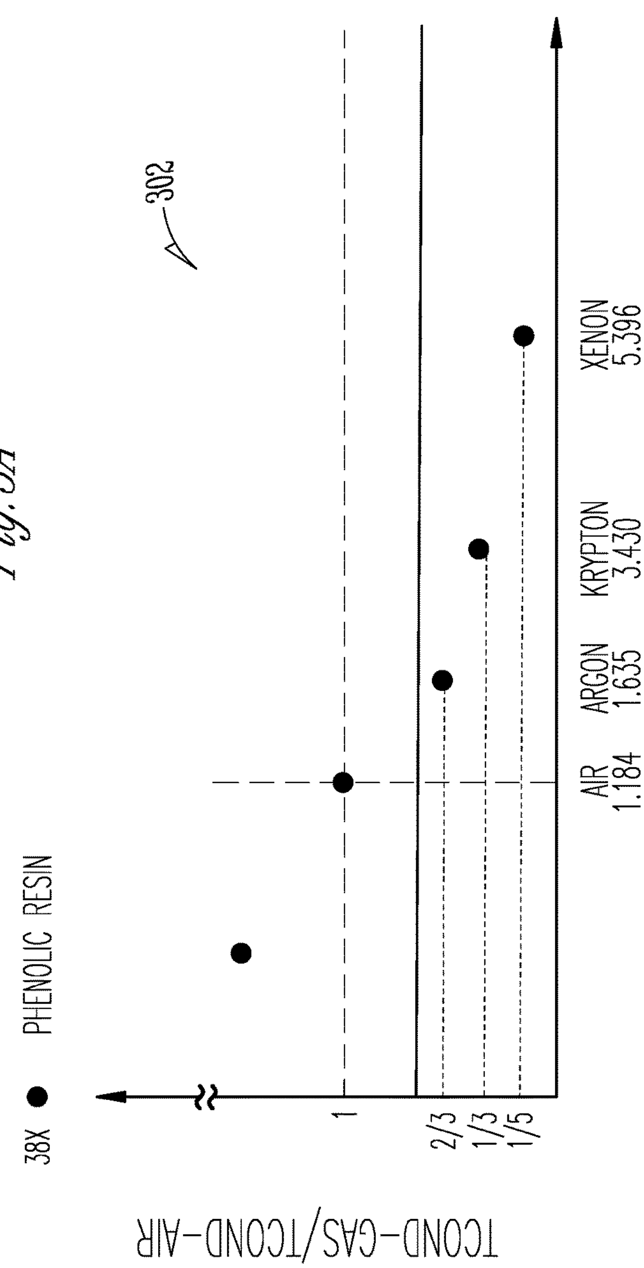

Fig. 3B

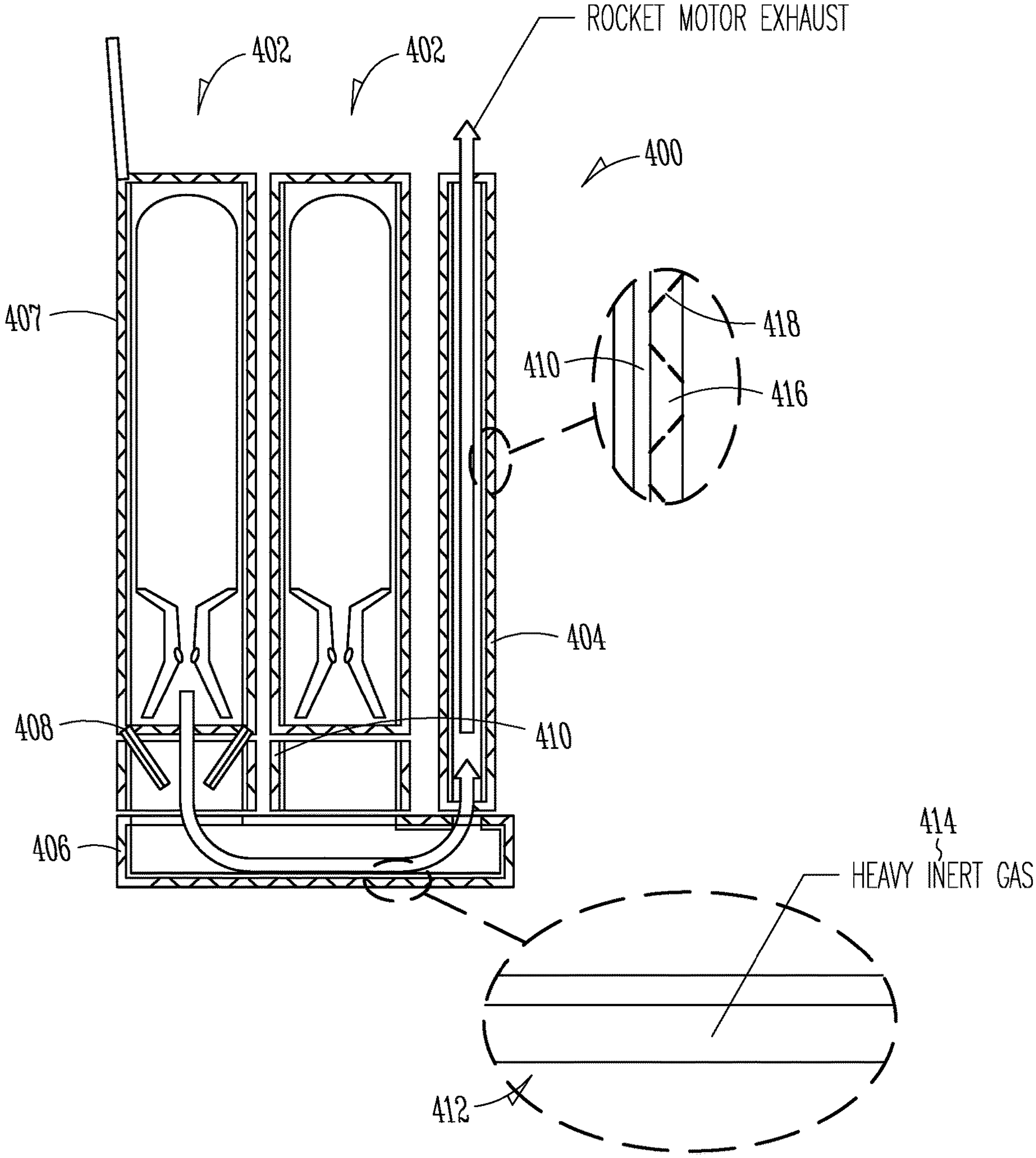
ROCKET MOTOR EXHAUST
402
402
400
407
418
410
416
404
408
410
406
414
HEAVY INERT GAS
412

Fig. 4

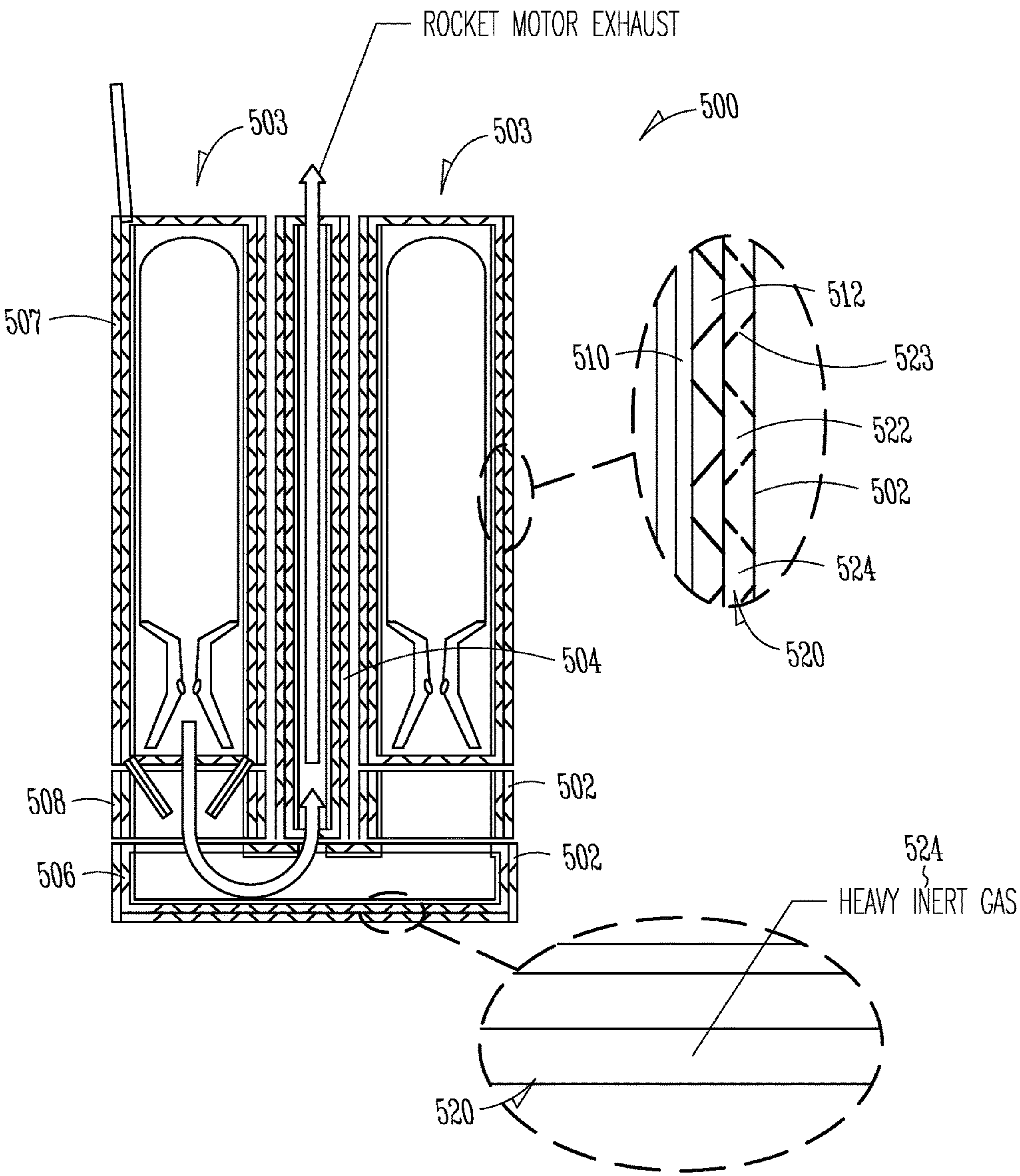
ROCKET MOTOR EXHAUST
500
503
503
507
512
510
523
522
502
524
520
504
508
502
506
502
524
HEAVY INERT GAS
520

Fig.5

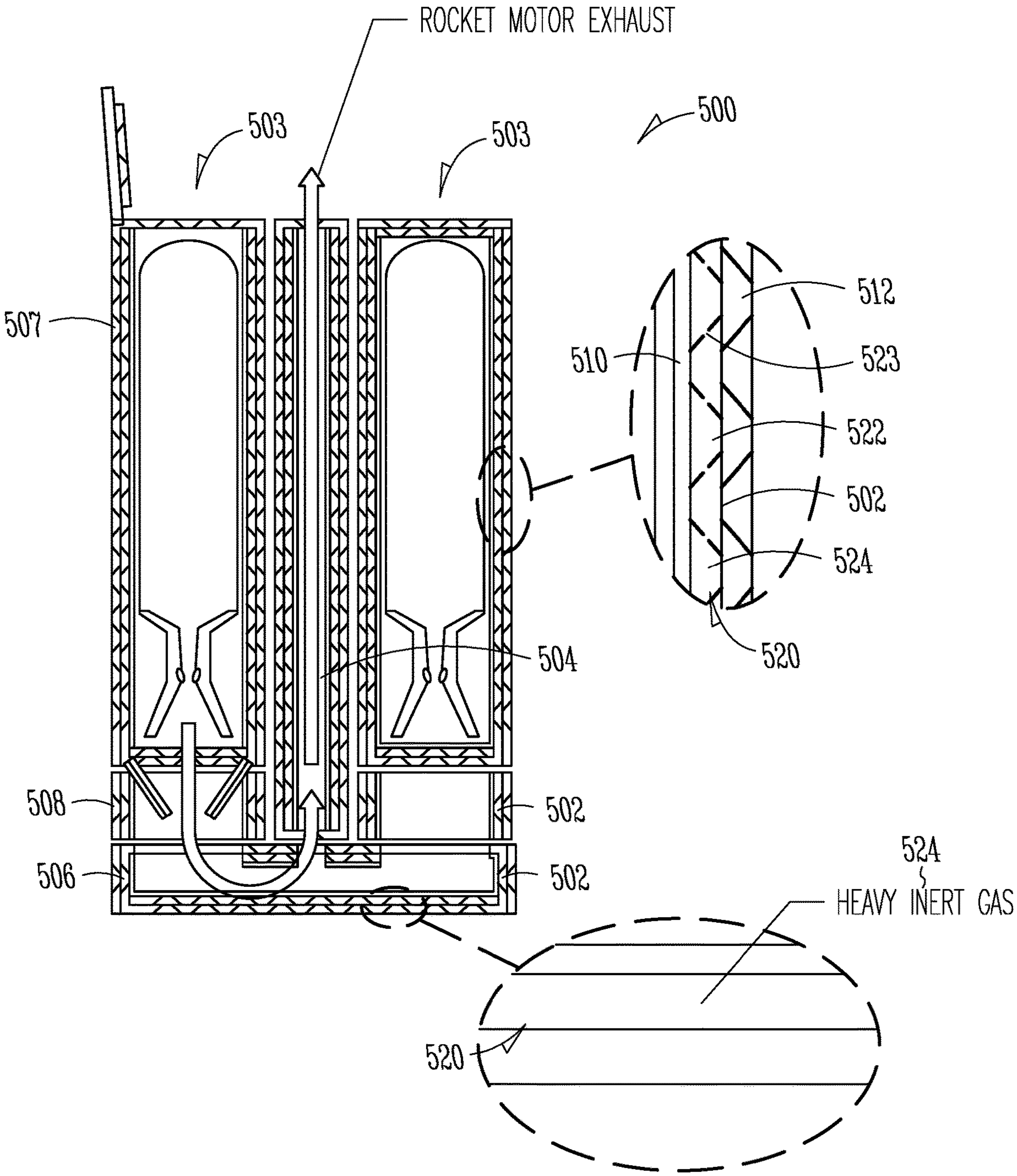
ROCKET MOTOR EXHAUST
503
503
500
507
510
512
523
522
502
524
520
504
508
502
506
502
524
HEAVY INERT GAS
520

Fig. 6

VERTICAL LAUNCH SYSTEM (VLS) INCLUDING HEAVY INERT GAS INSULATING LAYERS

BACKGROUND

Field

This disclosure relates to vertical launch systems for multiple missiles, rockets or other projectiles, and more particularly to the provision and management of thermal insulation in the launch system.

Description of the Related Art

Vertical launch systems (VLS) are configured to store and launch, in rapid succession, multiple projectiles (e.g., guided projectiles, rockets, missiles or the like). It is important that the launch system support firing the projectiles with minimal time delay between launches. In many cases, the launch system is re-loaded and fired multiple times until it must be taken out of service. The number of times the launch system can be re-used is another important factor. The launch system itself is typically supported on a land vehicle or ship. The form factor in both the density of projectiles and the depth of the launch system matters. Furthermore, the launch system must be configured to delay desensitization or inhibit premature reaction of the energetic material due to high external temperature. The provision and management of thermal insulation in the launch system impacts each of these factors.

An exemplary VLS module includes a plurality of missile cells, each cell configured for containing a missile and launching a missile out a top thereof, a common exhaust plenum and at least one exhaust tube connected via at least one first passageway to the common exhaust plenum. Each missile cell has an upper region (e.g., a launch tube or launch canister) for releasing a missile during launch and a lower region connected via a second passageway and an aft cover with the common exhaust plenum to transfer exhaust gases from the missile into the common exhaust plenum and through the exhaust tube and out of the module. The aft cover is configured to open during missile launch and otherwise close to block the reverse flow of exhaust gases from the common exhaust plenum back into the cells. At least the lower region of each cell, the common exhaust plenum and at least one exhaust tube have inner surfaces covered with an insulating layer of a burn resistant material. The inner surfaces of the upper region are suitably covered with an insulating layer of burn resistant material to support reuse of the module. The upper and lower regions of each cell, the aft cover, the common exhaust plenum and the exhaust tubes typically have a double-walled construction in which the inner and outer walls are typically supported by ribs or a corrugated structure. The space between the walls is filled with air.

SUMMARY

The following is a summary that provides a basic understanding of some aspects of the disclosure. This summary is not intended to identify key or critical elements of the disclosure or to delineate the scope of the disclosure. Its sole purpose is to present some concepts of the disclosure in a simplified form as a prelude to the more detailed description and the defining claims that are presented later.

The present disclosure provides heavy inert gas insulation layers for one or more components of a launch system for a plurality of missiles. The layer may be integrated into the walls of the components or provided in inserts attached to the components. The heavy inert gas insulation layer delays desensitization or inhibits premature reaction of the energetic materials inside the missiles due to high external temperatures. The insulation layers allow for more compact and dense configurations of the launch system and missiles.

In an embodiment a vertical launch system (VLS) module includes a plurality of missile cells in which each cell is configured for containing a missile and launching a missile, a common exhaust plenum and at least one exhaust tube connected via at least one first passageway to the common exhaust plenum. Each missile cell has an upper region (e.g., a launch tube or launch canister) for releasing a missile during launch and a lower region connected via a second passageway and an aft cover with the common exhaust plenum to transfer exhaust gases from the missile into the common exhaust plenum and through the exhaust tube and out of the module. The aft cover is configured to open during missile launch and otherwise close to block the reverse flow of exhaust gases from the common exhaust plenum back into the cells. At least the lower region of each cell, the common exhaust plenum and at least one exhaust tube have inner surfaces covered with an insulating layer of a burn resistant material. At least one and suitably all of the upper region, lower region, common exhaust plenum and exhaust tube have a double-walled structure that defines a sealed void space that is filled with an inert gas that has a density of at least 1.5 Kg/m^3 and a thermal conductivity (Tcond_gas) of no greater than two-thirds of a thermal conductivity of air (Tcond_air) to form a heavy inert gas insulation layer.

In an embodiment, the inert gas is selected from Argon, Krypton, Xenon or a synthetic gas. The inert gas in the sealed void space is held at a pressure of 760 Torr (1 atmosphere) or greater at sea level.

In an embodiment, the hollow metal shell includes a corrugated structure between the inner and outer walls that provides structural support. The corrugated structure includes openings therein to contiguously define the sealed void space.

In an embodiment, the thermal conductivity of the inert gas being less than one one-hundredth the thermal conductivity of the burn resistant material.

In an embodiment, inner surfaces of the upper region of each cell are covered with an insulating layer of a burn resistant material to facilitate reloading and relaunching missiles from the module.

In an embodiment, additional insulation is provided by positioning a plurality of inserts on an interior or exterior surface of at least one of the upper region, aft cover, lower region, common exhaust plenum or exhaust tube. Each insert itself includes a hollow metal shell defining a sealed void space that is filled with an inert gas.

In an embodiment, an existing launch system whose walls do not provide a heavy inert gas insulation layer can be retro-fit by positioning a plurality of inserts on an interior or exterior surface of at least one of the upper region, aft cover, lower region, common exhaust plenum or exhaust tube. Each insert itself includes a hollow metal shell defining a sealed void space that is filled with an inert gas.

These and other features and advantages of the disclosure will be apparent to those skilled in the art from the following

detailed description of preferred embodiments, taken together with the accompanying drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a top view of a VLS that includes 8 modules with each module including 8 cells;

FIG. **2** is a section view of a pair of cells coupled to the common exhaust plenum that share an exhaust tube in which heavy inert gas insulating layers are formed in the walls of the upper region of the cell, a lower region of the cell, a common exhaust plenum and a vertical exhaust tube;

FIGS. **3**A and **3**B are a table and a plot comparing the thermal conductivity of various heavy inert gases to air;

FIG. **4** is a section view of another embodiment of a VLS;

FIG. **5** is a section view of a VLS retro-fit with a plurality of heavy inert gas inserts attached to the external surfaces of the components of the VLS; and

FIG. **6** are views of a VLS retro-fit with a plurality of heavy inert gas inserts attached to the interior surfaces of the components of the VLS.

DETAILED DESCRIPTION

Heavy inert gas insulation layers are provided for one or more components of a launch system for a plurality of missiles. The layer may be integrated into the walls of the components or provided as inserts attached to the components. An inert gas fills a sealed void space in the walls or the insert. The inert gas has a density of at least 1.5 Kg/m^3 and a thermal conductivity (Tcond_gas) of no greater than two-thirds of a thermal conductivity of air (Tcond_air) to form the heavy inert gas insulation layer. The inert gas may be Argon, Krypton, Xenon or a synthetic gas and is suitably held at a pressure of 760 Torr (1 atmosphere) or greater at sea level and 25 C. The heavy inert gas insulation layer delays desensitization or inhibits premature reaction of the energetic materials inside the missiles due to high external temperatures. The insulation layers allow for more compact and dense configurations of the launch system and missiles.

Referring now to FIGS. **1** and **2**, a VLS **100** includes 8 modules **102** with each module including 8 cells **104**. Each cell is configured for containing a missile **106** and launching a missile out a top thereof. Each cell is coupled to a common exhaust plenum **108** and at least one vertical exhaust tube **110** via at least one first passageway **112** to the common exhaust plenum. In this configuration, the vertical exhaust tube **110** is placed between each pair of cells **104**, e.g., **4** exhaust tubes for an 8 cell module. A plenum is a pressurized housing containing a gas (such as air or hot exhaust gasses) at positive pressure. One of its functions is to equalize pressure for more even distribution, compensating for irregular supply or demand. It is typically relatively large in volume compared to the upper/lower regions or exhaust tube and thus has relative low velocity compared to the system's other components.

Each missile cell has an upper region **114** (e.g., a launch tube or launch canister) for releasing a missile during launch and a lower region **116** (e.g., a canister adapter) connected via a second passageway **118** and an aft cover **120** with the common exhaust plenum **108** to transfer exhaust gases from the missile into the common exhaust plenum and through the exhaust tube **110** and out of the module. The aft cover **120** is configured to open during missile launch and otherwise close to block the reverse flow of exhaust gases **121** from the common exhaust plenum back into the cells. A cell hatch **122** opens at missile launch.

At least the lower region **116** of each cell, the common exhaust plenum **108** and at least one exhaust tube **110** have inner surfaces covered with an insulating layer **123** of a burn resistant material. The inner surfaces of the upper region **114** are suitably covered with an insulating layer of burn resistant material to support reuse of the module. The surfaces of the aft cover **120** and cell hatch **122** that may be exposed to hot exhaust gases may also be covered with a layer of the burn resistant material.

The burn resistant material may be a phenolic resin selected for its resistance to erosion or corrosion in the presence of very hot combustion gases (e.g., its low char rates). The material may be a 3-ply layer having a homogeneous base layer, a char layer and an ablative layer. If the insulating material is quickly degraded and removed it is of no value. However, phenolic resin is not a very good insulating material. Its thermal conductivity is approximately 1 to 1.5 W/mK (Watts per Meter-Kelvin) whereas air is approximately 0.026 W/mK. The thermal conductivity of the resin is at least 38× that of air.

At least one and suitably all of the upper region **114**, lower region **116**, common exhaust plenum **108** and at least one exhaust tube **110** have a double-walled structure **124** that defines a sealed void space **126** that is filled with an inert gas **130** that has a density of at least 1.5 Kg/m^3 and a thermal conductivity (Tcond_gas) of no greater than two-thirds of a thermal conductivity of air (Tcond_air) to form a heavy inert gas insulation layer. The inert gas is selected from Argon, Krypton, Xenon or a synthetic gas. The inert gas in the sealed void space is held at a pressure of 760 Torr (1 atmosphere) or greater at sea level. As shown, the double-walled structure includes a corrugated structure **132** between the inner and outer walls that provides structural support. The corrugated structure **132** includes openings **134** therein to contiguously define the sealed void space. The openings **134** are a sufficient number of small holes to maintain structural integrity while allowing the heavy inert gas and vacuum to reach every individual chamber created by the corrugation to form a single contiguous sealed void space **126**. The aft cover **120** and cell hatch **122** may also be similarly configured to provide heavy inert gas insulation layers. The aft cover **120** protects the upper region from gases created by neighboring cells. The cell hatch **122** protects the cell from thermal threats during shipment or storage of the missile.

The heavy inert gas insulation layers provide better insulation than open-air double-walled structures. This can be leveraged to reduce spacing between the exhaust tube and cell thereby increasing the density of missiles in a given footprint. This can also be leveraged to reduce the thickness of the heat resistant layer. In particular in a 3-ply layer, the thicknesses of the homogenous and ablative layers may be reduced. The heat resistant layer is just thick enough to protect the components from the corrosive effects of the hot exhaust gasses. The heavy inert gas insulation layers may also reduce the required depth or volume of the plenum.

Referring now to Table **300** of FIG. **3**A and a plot **302** of the relative thermal conductivity of different heavy inert gases to air in FIG. **3**B, at sea level and a temperature of 25 C, air has a thermal conductivity of approximately 0.026 W/mK, phenolic resin between 1 and 1.5 W/mK and Ar, Kr and Xe have thermal conductivities of approximately 0.017, 0.0087 and 0.0052 W/mK, respectively. Ar, Kr and Xe have thermal conductivities of approximately two-thirds, one-third and one-fifth that of air. Any suitable inert gas will have a thermal conductivity (Tcond_gas) no greater than two-thirds the thermal conductivity of air (Tcond_air). This provides a substantial thermal insulating benefit over air, and a very substantial thermal insulting improvement over phenolic resin. The heavy inert gas has a density greater than 1.5 kg/m3 (by comparison air is 1.29 kg/m3). Inert gases from Group 8A of the periodic table will not react with temperature or other compounds and thus are very stable and safe over the life of the blast tube. Heavy inert gases (those having a density greater than air) include heavier particles, which transfer heat more slowly and thus are better insulators than air.

Referring now to FIG. **4**, in an alternate configuration of a VLS **400** a plurality of cells **402** are positioned side-by-side with a vertical exhaust tube **404** positioned at the edge of the module. Each cell **402** and the vertical exhaust tube **404** are coupled to a common exhaust plenum **406**. The inner surfaces of the cell **402**, common exhaust plenum **406** and vertical exhaust tube **404** are provided with an insulating layer **410** of heat resistant material as described previously. The common exhaust plenum, upper and lower regions **407** and **408** of each cell and the vertical exhaust tube each have a double-walled construction **412** that is sealed and filled with a heavy inert gas **414** to form an insulating layer. As previously described, the double-walled construction **412** may include a corrugated or similar structure **416** that provides structural support. If so, openings **418** are formed in structure **416** to form a single contiguous sealed void space in the particular component of the VLS. The aft cover and top hatch may or may not be configured as heavy inert gas insulating layers.

As shown in FIGS. **5** and **6**, an existing VLS **500** can be retro-fit by attaching a plurality of heavy inert gas inserts **502** to the external and internal surfaces, respectively, of the various components of the VLS. When attached internally, the insulating layer of heat resistant material must be removed and then re-applied after the inserts **502** are attached. In this example, the components of the existing VLS have a double-walled structure with a corrugated support structure. However, the component's double-walled structure is not sealed and is air-filled.

The existing VLS **500** includes a plurality of cells **503** that are separated by a vertical exhaust tube **504**. Each cell **503** and the vertical exhaust tube **504** are coupled to a common exhaust plenum **506**. The inner surfaces of the cell **503**, common exhaust plenum **506** and vertical exhaust tube **504** are provided with an insulating layer **510** of heat resistant material as described previously. The common exhaust plenum, upper and lower regions **507** and **508** of each cell and the vertical exhaust tube each have a double-walled construction **512** that is unsealed and filled with air. As previously described, the double-walled construction **512** may include a corrugated or similar structure that provides structural support.

As shown in FIG. **5**, inserts **502** line the external surfaces of the upper and lower regions **507** and **508** of each cell, the common exhaust plenum **506** and the vertical exhaust tube **504**. In this example, each insert **502** has a double-walled constructions **520** including a corrugated structure **522** in which openings **523** are formed to create a single contiguous sealed void space that is filled with a heavy inert gas **524**, which is held under vacuum of at least 760 Torr (1 atm) at sea level and 25 C.

As shown in FIG. **6**, inserts **502** line the internal surfaces of the upper and lower regions **507** and **508** of each cell, the common exhaust plenum **506** and the vertical exhaust tube **504**. In this example, each insert **502** has a double-walled construction **520** including a corrugated structure **522** in which openings are formed to create a single contiguous sealed void space that is filled with a heavy inert gas **524**, which is held under vacuum of at least 760 Torr (1 atm) at sea level and 25 C.

While several illustrative embodiments of the disclosure have been shown and described, numerous variations and alternate embodiments will occur to those skilled in the art. Such variations and alternate embodiments are contemplated, and can be made without departing from the spirit and scope of the disclosure as defined in the appended claims.

We claim:

1. A vertical launch system (VLS) module, comprising:

a plurality of missile cells, each cell configured for containing a missile and launching a missile out a top thereof,

a common exhaust plenum;

at least one exhaust tube connected via at least one first passageway to the common exhaust plenum;

each said missile cell having an upper region for releasing a missile during launch and a lower region connected via a second passageway and an aft cover with the common exhaust plenum to transfer exhaust gases from the missile into the common exhaust plenum and through the exhaust tube and out of the module, said aft cover configured to open during missile launch and otherwise close to block the reverse flow of exhaust gases from the common exhaust plenum back into the cells;

wherein at least the lower region of each cell, the aft cover, the common exhaust plenum and the at least one exhaust tube have inner surfaces covered with an insulating layer of a burn resistant material;

said common exhaust plenum having a double-walled structure that defines a sealed void space; and

an inert gas inside the sealed void space, the inert gas having a density of at least 1.5 Kg/m^3 and a thermal conductivity (Tcond_gas) of no greater than two-thirds of a thermal conductivity of air (Tcond_air) to form a heavy inert gas insulation layer.

2. The VLS module of claim **1**, wherein the sealed void space has a pressure of 760 Torr or greater.

3. The VLS module of claim **1**, wherein the inert gas is Argon, Krypton, Xenon or a synthetic gas.

4. The VLS module of claim **1**, wherein said common exhaust plenum has a corrugated structure within the double-walled structure, wherein the corrugated structure includes openings therein to contiguously define the sealed void space.

5. The VLS module of claim **1**, wherein the thermal conductivity of the inert gas is less than one one-hundredth the thermal conductivity of the burn resistant material.

6. The VLS module of claim **1**, wherein inner surfaces of the upper region of each cell are covered with an insulating layer of a burn resistant material.

7. The VLS module of claim **1**, wherein the upper region of each cell has a double-walled structure that defines a sealed void space that is filled with the inert gas.

8. The VLS module of claim **1**, wherein the lower region of each cell has a double-walled structure that defines a sealed void space that is filled with the inert gas.

9. The VLS module of claim **1**, wherein the aft cover for each cell has a double-walled structure that defines a sealed void space that is filled with the inert gas.

10. The VLS module of claim **1**, wherein the at least one exhaust tube has a double-walled structure that defines a sealed void space that is filled with the inert gas.

11. A vertical launch system (VLS) module, comprising:

a plurality of missile cells, each cell configured for containing a missile and launching a missile out a top thereof,

a common exhaust plenum;

at least one exhaust tube connected via at least one first passageway to the common exhaust plenum;

each said missile cell having an upper region for releasing a missile during launch and a lower region connected via a second passageway and an aft cover with the common exhaust plenum to transfer exhaust gases from the missile into the common exhaust plenum and through the exhaust tube and out of the module, said aft cover configured to open during missile launch and otherwise close to block the reverse flow of exhaust gases from the common exhaust plenum back into the cells;

wherein at least the lower region of each cell, the aft cover, the common exhaust plenum and the at least one exhaust tube have inner surfaces covered with an insulating layer of a burn resistant material;

wherein each of the upper region, the lower region, the common exhaust plenum and the at least one exhaust tube have a double-walled structure that each define a sealed void space; and

an inert gas inside each of the sealed void spaces, the inert gas having a density of at least 1.5 Kg/m^3 and a thermal conductivity (Tcond_gas) of no greater than two-thirds of a thermal conductivity of air (Tcond_air) to form a heavy inert gas insulation layer.

12. The VLS module of claim 11, wherein each of the sealed void spaces has a pressure of 760 Torr or greater.

13. The VLS module of claim 11, wherein the inert gas is Argon, Krypton, Xenon or a synthetic gas.

14. The VLS module of claim 11, wherein each of the double-walled structures include a corrugated structure having openings therein to contiguously define the sealed void space.

15. The VLS module of claim 11, wherein the thermal conductivity of the inert gas is less than one one-hundredth the thermal conductivity of the burn resistant material.

16. A vertical launch system (VLS) module, comprising:

a plurality of missile cells, each cell configured for containing a missile and launching a missile out a top thereof,

a common exhaust plenum;

at least one exhaust tube connected via at least one first passageway to the common exhaust plenum;

each said missile cell having an upper region for releasing a missile during launch and a lower region connected via a second passageway and an aft cover with the common exhaust plenum to transfer exhaust gases from the missile into the common exhaust plenum and through the exhaust tube and out of the module, said aft cover configured to open during missile launch and otherwise close to block the reverse flow of exhaust gases from the common exhaust plenum back into the cells;

wherein at least the lower region of each cell, the aft cover, the common exhaust plenum and the at least one exhaust tube have inner surfaces covered with an insulating layer of a burn resistant material;

a plurality of inserts attached to at least one of the upper region, the lower region, the common exhaust plenum or the exhaust tube, each insert having a hollow metal shell defining a sealed void space therein;

an inert gas inside the sealed void space, the inert gas having a density of at least 1.5 Kg/m^3 and a thermal conductivity (Tcond_gas) of no greater than two-thirds of a thermal conductivity of air (Tcond_air) to form a heavy inert gas insulation layer.

17. The VLS module of claim 16, wherein each of the sealed void spaces has a pressure of 760 Torr or greater.

18. The VLS module of claim 16, wherein the inert gas is Argon, Krypton, Xenon or a synthetic gas.

19. The VLS module of claim 16, wherein at least some of the inserts are positioned between the lower region, the common exhaust plenum or the exhaust tube and the insulating layer of burn resistant material.

20. The VLS module of claim 16, wherein each of the lower region of each cell, the common exhaust plenum and the at least one exhaust tube have a double-walled structure that defines a void space filled with air.

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