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(54) **Titre : PANNEAU EN COUCHES ACOUSTIQUE ET METHODE**
(54) **Title: ACOUSTIC SANDWICH PANEL AND METHOD**

(57) **Abrégé/Abstract:**
A sandwich panel including a core having a first major side and an opposed second major side, the core defining cavities, a first liner sheet connected to the first major side, the first liner sheet defining apertures, wherein each aperture provides fluid communication with an associated cavity, and a bulk absorber material and/or a thermal conductor material received in at least a portion of the cavities.

ABSTRACT

A sandwich panel including a core having a first major side and an opposed second major side, the core defining cavities, a first liner sheet connected to the first major side, the first liner sheet defining apertures, wherein each aperture provides fluid communication with an associated cavity, and a bulk absorber material and/or a thermal conductor material received in at least a portion of the cavities.

ACOUSTIC SANDWICH PANEL AND METHOD

FIELD

This application relates to sandwich panels and, more particularly, to sandwich panels having a perforated liner sheet for sound suppression.

BACKGROUND

Sandwich panels are typically formed from a core sandwiched between two liner sheets. The core may be relatively thick, yet lightweight, as compared to the liner sheets. The liner sheets may be relative thin, yet stiff. Therefore, sandwich panels typically possess relatively high strength and stiffness at relatively low weight. As such, sandwich panels are widely used in various aerospace applications.

Like traditional sandwich panels, acoustic sandwich panels include a core sandwiched between two liner sheets. One of the liner sheets is perforated, while the other liner sheet is not perforated. The core provides bulk and defines a plurality of cavities. The apertures defined by the perforated liner sheet fluidly couple the cavities with the ambient environment. Therefore, when air flows across the perforated liner sheet of an acoustic sandwich panel, the cavities in the core act as Helmholtz resonators and attenuate the sound of the associated airflow.

Because of their relatively light weight and sound attenuating capability, acoustic sandwich panels have been used in various industries, including the aerospace industry. For example, acoustic sandwich panels are commonly incorporated into bypass gas turbine aircraft engines, such as into the inlet inner barrels, fan duct walls and/or exhaust nozzles, to attenuate the noise associated with high volume airflows.

Despite advances already made, those skilled in the art continue with research and development efforts in the field of acoustic sandwich panels.

SUMMARY

In one embodiment, the disclosed sandwich panel may include a core having a first major side and an opposed second major side, the core defining cavities, a first liner sheet connected to the first major side, the first liner sheet defining apertures, wherein each aperture provides fluid communication with an associated cavity, and a bulk absorber material received in at least a portion of the cavities.

In another embodiment, the disclosed sandwich panel may include a core having a first major side and an opposed second major side, the core defining cavities, a first liner sheet connected to the first major side, the first liner sheet defining apertures, wherein each aperture provides fluid communication with an associated cavity, and a thermal conductor material received in at least a portion of the cavities.

In another embodiment, the disclosed sandwich panel may include a core having a first major side and an opposed second major side, the core defining cavities, a first liner sheet connected to the first major side, the first liner sheet defining apertures, wherein each aperture provides fluid communication with an associated cavity, and a combination of bulk absorber material and thermal conductor material received in at least a portion of the cavities.

In another embodiment, the disclosed sandwich panel may include a core having a first major side and an opposed second major side, the core defining a plurality of cavities, a first liner sheet connected to the first major side, the first liner sheet defining a plurality of apertures, each aperture providing fluid communication with an associated cavity, a second liner sheet connected to the second major side, and a plurality of inserts received in the cavities, wherein each insert includes at least one of a bulk absorber material and a thermal conductor material.

In one embodiment, the disclosed method for manufacturing an acoustic sandwich panel may include the steps of (1) assembling a core having a first major

side, a second major side, and defining a plurality of cavities; (**2**) applying a first liner sheet to the first major side, the first liner sheet defining a plurality of apertures; (**3**) applying a second liner sheet to the second major side; and (**4**) introducing a plurality of inserts to the plurality of cavities, wherein each insert of the plurality of inserts includes a bulk absorber material and/or a thermal conductor material.

In one embodiment, there is provided a sandwich panel including a core having a first major side and an opposed second major side. The core defines a plurality of cavities. The sandwich panel further includes a first liner sheet connected to the first major side. The first liner sheet defines a plurality of apertures. Each aperture of the plurality of apertures provides fluid communication with an associated cavity of the plurality of cavities. The sandwich panel further includes a plurality of inserts received in at least a portion of the plurality of cavities. Each insert of the plurality of inserts includes a bulk absorber material and a thermal conductor material.

In another embodiment, there is provided a method for manufacturing an acoustic sandwich panel. The method involves: assembling a core having a first major side, a second major side, and defining a plurality of cavities; applying a first liner sheet to the first major side, the first liner sheet defining a plurality of apertures; applying a second liner sheet to the second major side; and introducing a plurality of inserts to the plurality of cavities. Each insert of the plurality of inserts includes a bulk absorber material and a thermal conductor material. The introducing step is performed during the assembling step.

In another embodiment, there is provided a method for manufacturing an acoustic sandwich panel. The method involves: assembling a core having a first major side, a second major side, and defining a plurality of cavities; applying a first liner sheet to the first major side, the first liner sheet defining a plurality of apertures; applying a second liner sheet to the second major side; and introducing a plurality of inserts to the plurality of cavities. Each insert of the plurality of inserts includes a bulk absorber material and a thermal conductor material. The plurality of inserts are introduced to the plurality of cavities by way of the plurality of apertures.

In another embodiment, there is provided a sandwich panel including a core having a first major side and an opposed second major side. The core defines a plurality of cavities. The sandwich panel further includes a first liner sheet connected to the first major side. The first liner sheet defines a plurality of apertures. Each aperture of the plurality of apertures provides fluid communication with an associated cavity of the plurality of cavities. The sandwich panel further includes a bulk absorber material received in at least a portion of the plurality of cavities, and a thermal conductor material received in the portion of the plurality of cavities receiving the bulk absorber material. The thermal conductor material has a thermal conductivity of at least 50 W/(m·K).

In another embodiment, there is provided a method for manufacturing an acoustic sandwich panel. The method involves: assembling a core having a first major side, a second major side, and defining a plurality of cavities; applying a first liner sheet to the first major side, the first liner sheet defining a plurality of apertures; applying a second liner sheet to the second major side; and introducing a plurality of inserts to the plurality of cavities. Each insert of the plurality of inserts includes a bulk absorber material and a thermal conductor material. The thermal conductor material has a thermal conductivity of at least 50 W/(m·K).

Other embodiments of the disclosed acoustic sandwich panel and method will become apparent from the following detailed description, the accompanying drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. **1** is a perspective view of one embodiment of the disclosed acoustic sandwich panel;

Fig. **2** is a top plan view of a portion of the acoustic sandwich panel of Fig. **1**;

Fig. **3** is a cross-sectional view of a portion of the acoustic sandwich panel of Fig. **1**;

CA 2930855 2019-10-16

Fig. **4** is a flow diagram illustrating a method for manufacturing an acoustic sandwich panel;

Fig. **5** is a graphical depiction of an example method for assembling a core in accordance with the method of Fig. **4**;

Fig. **6** is a graphical depiction of one method for introducing a bulk absorber material and/or a thermal conductor material in accordance with the method of Fig. **4**;

Fig. **7** is a graphical depiction of another method for introducing a bulk absorber material and/or a thermal conductor material in accordance with the method of Fig. **4**;

Fig. **8** is a graphical depiction of yet another method for introducing a bulk absorber material and/or a thermal conductor material in accordance with the method of Fig. **4**;

Fig. **9** is a flow diagram of an aircraft manufacturing and service methodology; and

Fig. **10** is a block diagram of an aircraft.

DETAILED DESCRIPTION

Disclosed is an acoustic sandwich panel that incorporates a bulk absorber material and/or a thermal conductor material into the cavities defined by the acoustic sandwich panel. With appropriate material and quantity selection, particularly vis-à-vis cavity size, the addition of bulk absorber material and/or thermal conductor material may augment the sound attenuating and/or heat dissipating properties of the associated acoustic sandwich panel.

Referring to Figs. **1–3**, one embodiment of the disclosed acoustic sandwich panel, generally designated **10**, may include a core **12**, a first liner sheet **14**, a second liner sheet **16** and a plurality of inserts **50**. The core **12**, the first liner sheet **14** and the second liner sheet **16** form a layered structure **20** (Fig. **3**), and the inserts **50** are positioned within the core **12** of the layered structure **20**.

While the layered structure **20** of the acoustic sandwich panel **10** is shown and described having three layers (the core **12**, the first liner sheet **14** and the second liner sheet **16**), additional layers, such as additional core layers, additional liner sheets and/or additional other layers, may be included in the layered structure **20** without departing from the scope of the present disclosure. In certain applications, the second liner sheet **16** may be optional (or rendered optional due to application) and, therefore, may be omitted from the layered structure **20** of the acoustic sandwich panel **10** without departing from the scope of the present disclosure.

The core **12** of the acoustic sandwich panel **10** may include a first major side **22** and an opposed second major side **24**. The first liner sheet **14** may be connected (e.g., adhered, welded, braised, mechanically fastened etc.) to the first major side **22** of the core **12** and the second liner sheet **16** may be connected (e.g., adhered, welded, braised, mechanically fastened etc.) to the second major side **24** of the core **12**, thereby sandwiching the core **12** between the first liner sheet **14** and the second liner sheet **16**, and forming the layered structure **20**.

The cross-sectional thickness T_1 of the core **12** of the acoustic sandwich panel **10** may be relatively thick, as compared to the cross-sectional thicknesses T_2, T_3 of the first liner sheet **14** and the second liner sheet **16** (e.g., $T_1 > T_2$ and $T_1 > T_3$). In one expression, the cross-sectional thickness T_1 of the core **12** may be at least **1.5** times greater than the cross-sectional thickness T_2 of the first liner sheet **14**. In another expression, the cross-sectional thickness T_1 of the core **12** may be at least **2** times greater than the cross-sectional thickness T_2 of the first liner sheet **14**. In another expression, the cross-sectional thickness T_1 of the core **12** may be at least **5** times greater than the cross-sectional thickness T_2 of the first liner sheet **14**. In another expression, the cross-sectional thickness T_1 of the core **12** may be at least **10** times greater than the cross-sectional thickness T_2 of the first liner sheet **14**. In another expression, the cross-sectional thickness T_1 of the core **12** may be at least **20** times greater than the cross-sectional thickness T_2 of the first liner sheet **14**. In yet another expression, the cross-sectional thickness T_1 of the core **12** may be at least **40** times greater than the cross-sectional thickness T_2 of the first liner sheet **14**. Despite being relatively thick, the core **12** may have a relatively lower density (basis weight divided by cross-sectional thickness), as compared to the densities of the first liner sheet **14** and the second liner sheet **16**.

The core **12** of the acoustic sandwich panel **10** may define a plurality of cavities **30**. Each cavity **30** may have a volume V_1, which may be bounded by the core **12**, the first liner sheet **14** and, optionally, the second liner sheet **16**. Those skilled in the art will appreciate that the volume V_1 of each cavity **30** may be a design consideration.

In one particular realization, the core **12** of the acoustic sandwich panel **10** may have a honeycomb structure **32** that includes an array of tightly packed cells **34**, with each cell **34** of the honeycomb structure **32** defining an associated cavity **30** (and cavity volume V_1). The cells **34** of the honeycomb structure **32** may be tubular and may have a cross-sectional shape, as best shown in Fig. **2**, such as hexagonal, square, rectangular, circular, ovular, or the like. The cells **34** of the honeycomb structure **32** may extend along an axis **A** (Fig. **3**) that is generally perpendicular to a plane coincident with the outer surface **36** (Fig. **3**) of the first liner sheet **14**. Therefore, the cavities **30** defined by the cells **34** of the honeycomb structure **32** may extend continuously through the core **12** from the first liner sheet **14** to the second liner sheet **16**.

While a core **12** having a honeycomb structure **32** with uniform and regular-shaped cells **34** is shown and described, those skilled in the art will appreciate that cavities **30** having various three-dimensional shapes, whether regular or irregular, may be used without departing from the scope of the present disclosure. Therefore, a honeycomb structure **32** is only one specific, non-limiting example of a suitable structure for the core **12** of the acoustic sandwich panel **10**.

Compositionally, the core **12** of the acoustic sandwich panel **10** may be formed from various materials or combinations of materials. Those skilled in the art will appreciate that material selection will depend on the intended application, among other possible considerations. As one example, the core **12** may be formed from a metal or metal alloy, such as steel, titanium, a titanium alloy, aluminum or an aluminum alloy. As another example, the core **12** may be formed from a composite, such as a carbon fiber-reinforced composite or a fiberglass composite. As yet another example, the core **12** may be formed from a ceramic material.

The first liner sheet **14** of the acoustic sandwich panel **10** may be layered over the first major side **22** of the core **12**, thereby at least partially enclosing the cavities **30** of the core **12** along the first major side **22**. Connection between the first liner sheet **14** and the core **12** may be effected using any suitable technique, the selection of which may require consideration of the composition of the core **12** and the composition of the first liner sheet **14**. Examples of techniques that may be used to connect the first liner sheet **14** to the core **12** include, but are not limited to, welding, braising, soldering, bonding, adhering and/or mechanically fastening.

Compositionally, the first liner sheet **14** of the acoustic sandwich panel **10**, which may be single ply or multi-ply, may be formed from various materials or combinations of materials. The composition of the first liner sheet **14** may be the same as, similar to, or different from the composition of the core **12**. As one example, the first liner sheet **14** may be formed from a metal or metal alloy, such as steel, titanium, a titanium alloy, aluminum or an aluminum alloy. As another example, the first liner sheet **14** may be formed from a composite, such as a carbon fiber-reinforced composite or a fiberglass composite. As yet another example, the first liner sheet **14** may be formed from a ceramic material.

The first liner sheet **14** of the acoustic sandwich panel **10** may be perforated. Specifically, the first liner sheet **14** may define a plurality of apertures **40** extending therethrough. Each aperture **40** of the first liner sheet **14** may provide fluid communication with an associated cavity **30** in the underlying core **12**. While a single aperture **40** per cavity **30** is shown in Figs. **1**–**3**, in an alternative construction, two or more apertures **40** per cavity **30** may be formed in the first liner sheet **14**.

Thus, as best shown in Fig. **3**, each aperture **40** may fluidly couple an associated cavity **30** with an airflow **F** moving across the first side **15** (Fig. **3**) of the acoustic sandwich panel **10**. Therefore, the fluid communication between the airflow **F** and the cavities **30** in the core **12** of the acoustic sandwich panel **10**—by way of the apertures **40** of the first liner sheet **14**—may allow the cavities **30** to function as Helmholtz resonators, thereby attenuating the sound of the airflow **F**.

The second liner sheet **16** of the acoustic sandwich panel **10** may be layered over the second major side **24** of the core **12**, thereby enclosing the cavities **30** of the core **12** along the second major side **24**. Connection between the second liner sheet **16** and the core **12** may be effected using any suitable technique, the selection of which may require consideration of the composition of the core **12** and the composition of the second liner sheet **16**. Examples of techniques that may be used to connect the second liner sheet **16** to the core **12** include, but are not limited to, welding, braising, soldering, bonding, adhering and/or mechanically fastening.

Compositionally, the second liner sheet **16** of the acoustic sandwich panel **10**, which may be single ply or multi-ply, may be formed from various materials or combinations of materials. The composition of the second liner sheet **16** may be the same as, similar to, or different from the composition of the core **12**. Also, the composition of the second liner sheet **16** may be the same as, similar to, or different from the composition of the first liner sheet **14**. As one example, the second liner sheet **16** may be formed from a metal or metal alloy, such as steel, titanium, a titanium alloy, aluminum or an aluminum alloy. As another example, the second liner sheet **16** may be formed from a composite, such as a carbon fiber-reinforced composite or a fiberglass composite. As yet another example, the second liner sheet **16** may be formed from a ceramic material.

Unlike the first liner sheet **14** of the acoustic sandwich panel **10**, which is perforated, the second liner sheet **16** may not be perforated. Therefore, the second liner sheet **16** may not provide fluid communication between the cavities **30** of the core **12** and the environment outside of the acoustic sandwich panel **10**.

At this point, those skilled in the art will appreciate that only a portion of an acoustic sandwich panel **10** is shown in Figs. **1–3**, and that the overall size and shape of the acoustic sandwich panel **10** may depend on the end application. Additionally, while the acoustic sandwich panel **10** is shown in Figs. **1–3** as being a substantially planar structure, non-planar acoustic sandwich panels **10** (e.g., curved acoustic sandwich panes **10**) are also contemplated. For example, the disclosed acoustic sandwich panel **10** may be used as a wall panel forming the inlet inner wall, fan duct and/or exhaust nozzle of a bypass gas turbine aircraft engine and, therefore, may be sized, shaped and contoured accordingly.

As best shown in Fig. **3**, a plurality of inserts **50** may be inserted into the cavities **30** of the core **12** of the acoustic sandwich panel **10**. Each cavity **30** of the core **12** may house an insert **50**. However, advantage may still be gained by providing only some (but not all) cavities **30** of the core **12** with inserts **50**. As one example, at least **10** percent of the cavities **30** of the core **12** may house an insert **50**. As another example, at least **25** percent of the cavities **30** of the core **12** may house an insert **50**. As another example, at least **50** percent of the cavities **30** of the core **12** may house an insert **50**. As another example, at least **75** percent of the cavities **30** of the core **12** may house an insert **50**. As another example, at least **90** percent of the cavities **30** of the core **12** may house an insert **50**. As yet another example, about **100** percent of the cavities **30** of the core **12** may house an insert **50**.

In a first implementation, the inserts **50** of the acoustic sandwich panel **10** may be (or may include) a bulk absorber material. Without being limited to any particular theory, it is believed that the presence of bulk absorber material (inserts **50**) in the cavities **30** of the core **12** may further promote sound attenuation, particularly with respect to an airflow **F** moving across the first side **15** (Fig. **3**) of the acoustic sandwich panel **10**.

Various bulk absorber materials (including combinations of bulk absorber materials) may be used as the inserts **50** of the acoustic sandwich panel **10**. As one specific, non-limiting example, the bulk absorber material may be aluminum oxide fibers, such as SAFFIL® aluminum oxide fibers commercially available from Saffil Ltd. of Cheshire, United Kingdom. Other non-limited examples of suitable bulk absorber materials include carbon fiber batting, ceramic batting, fiberglass batting (e.g., PYROLOFT® batting from Albany International Corp. of Albany, New York), aramid fibrous material, such as KEVLAR® para-aramid fibers (E. I. du Pont de Nemours and Company of Wilmington, Delaware) and NOMEX® meta-aramid fibers (E. I. du Pont de Nemours and Company), polyimide fibrous material (e.g., PYROPEL® felt from Albany International Corp.), polyurethane foam, polyester foam, polyimide foam, metal (e.g., copper or nickel) foam, aluminum and ceramic open cell foams, silicon rubber foam, and ceramic tiles (e.g., aluminum oxide and/or silicon dioxide).

Thus, suitable bulk absorber materials come in various physical forms, such as, but not limited to, foams, fibers, matting, batting, felted materials, woven fabrics and non-woven fabrics. Therefore, when the inserts **50** of the acoustic sandwich panel **10** are (or include) bulk absorber material, the inserts **50** may be provided in various physical forms. Merely for illustrative purposes, the inserts **50** are shown in Fig. **3** as simple blocks (one per cavity **30**). However, as used herein, the term “insert” (singular or plural) refers to all of the bulk absorber material and/or thermal conductor material within an associated cavity, regardless of whether the insert is a single mass of material (e.g., a monolithic body) or comprised of multiple separate pieces (e.g., a clump of fibers).

At this point, those skilled in the art will appreciate that a sound attenuating quantity of the bulk absorber material (insert **50**) may be used, and that the sound attenuating quantity may be dictated by, among other things, the size of the cavities **30** in the core **12** of the acoustic sandwich panel **10** and the composition of the bulk absorber material (inserts **50**).

To achieve a sound attenuating quantity of bulk absorber material, the bulk absorber material may occupy at least a portion of the volume V_1 of each cavity **30** of the core **12** of the acoustic sandwich panel **10**. In other words, each insert **50** may have a bulk volume V_2, and the volume V_2 of each insert **50** may be greater than zero and less than (or equal to) the volume V_1 of the associated cavity **30**. In one expression, the volume V_2 of each bulk absorber insert **50** may be at least **10** percent of the volume V_1 of the associated cavity **30**. In another expression, the volume V_2 of each bulk absorber insert **50** may be at least **20** percent of the volume V_1 of the associated cavity **30**. In another expression, the volume V_2 of each bulk absorber insert **50** may be at least **30** percent of the volume V_1 of the associated cavity **30**. In another expression, the volume V_2 of each bulk absorber insert **50** may be at least **40** percent of the volume V_1 of the associated cavity **30**. In another expression, the volume V_2 of each bulk absorber insert **50** may be at least **50** percent of the volume V_1 of the associated cavity **30**. In another expression, the volume V_2 of each bulk absorber insert **50** may be at least **60** percent of the volume V_1 of the associated cavity **30**. In another expression, the volume V_2 of each bulk absorber insert **50** may be at least **70** percent of the volume V_1 of the associated cavity **30**. In another expression, the volume V_2 of each bulk absorber insert **50** may be at least **80** percent of the volume V_1 of the associated cavity **30**.

In a second implementation, the inserts **50** of the acoustic sandwich panel **10** may be (or may include) a thermal conductor material. Without being limited to any particular theory, it is believed that the presence of thermal conductor material (inserts **50**) in the cavities **30** of the core **12** may improve heat dissipation by way of the acoustic sandwich panel **10**, particularly when an airflow **F** is moving across the first side **15** (Fig. **3**) of the acoustic sandwich panel **10**.

Various thermal conductor materials may be used as the inserts **50** of the acoustic sandwich panel **10**. As used herein, "thermal conductor material" refers to any material having a thermal conductivity of at least **10** W/(m·K). In one expression, the thermal conductor material (inserts **50**) may have a thermal conductivity of at least **50** W/(m·K). In another expression, the thermal conductor material (inserts **50**) may have a thermal conductivity of at least **100** W/(m·K). In another expression, the thermal conductor material (inserts **50**) may have a thermal conductivity of at least **150** W/(m·K). In another expression, the thermal conductor material (inserts **50**) may have a thermal conductivity of at least **200** W/(m·K). In another expression, the thermal conductor material (inserts **50**) may have a thermal conductivity of at least **250** W/(m·K). In yet another expression, the thermal conductor material (inserts **50**) may have a thermal conductivity of at least **300** W/(m·K).

Compositionally, use of various thermal conductor materials is contemplated. As one general, non-limiting example, the thermal conductor material may be a metal or metal alloy. As one specific, non-limiting example, the thermal conductor material may be steel. As another specific, non-limiting example, the thermal conductor material may be titanium or a titanium alloy. As another specific, non-limiting example, the thermal conductor material may be nickel or a nickel alloy. As yet another specific, non-limiting example, the thermal conductor material may be aluminum or an aluminum alloy. Use of non-metallic thermal conductor materials is also contemplated.

The thermal conductor material (inserts **50**) may be used in various physical forms. As one specific, non-limiting example, the thermal conductor material (inserts **50**) may be in the form of wire or tubing. As another specific, non-limiting example, the thermal conductor material (inserts **50**) may be in the form of mesh. Other forms, such a powders, solid mass, monolith and the like, are also contemplated.

Various quantities of the thermal conductor material (insert **50**) may be used. The specific quantity used may be dictated by need (e.g., amount of heat dissipation required), as well as the size of the cavities **30** in the core **12** of the acoustic sandwich panel **10** and the composition (thermal conductivity) of the thermal conductor material (inserts **50**).

When inserted into the cavities **30** in the core **12** of the acoustic sandwich panel **10**, the thermal conductor material will occupy at least a portion (volume V_2) of the volume V_1 of each cavity **30**. In one expression, the volume V_2 of each thermal conductor insert **50** may be at least **2** percent of the volume V_1 of the associated cavity **30**. In another expression, the volume V_2 of each thermal conductor insert **50** may be at least **5** percent of the volume V_1 of the associated cavity **30**. In another expression, the volume V_2 of each thermal conductor insert **50** may be at least **10** percent of the volume V_1 of the associated cavity **30**. In another expression, the volume V_2 of each thermal conductor insert **50** may be at least **20** percent of the volume V_1 of the associated cavity **30**. In another expression, the volume V_2 of each thermal conductor insert **50** may be at least **30** percent of the volume V_1 of the associated cavity **30**. In another expression, the volume V_2 of each thermal conductor insert **50** may be at least **40** percent of the volume V_1 of the associated cavity **30**. In another expression, the volume V_2 of each thermal conductor insert **50** may be at least **50** percent of the volume V_1 of the associated cavity **30**.

In a third implementation, the inserts **50** of the acoustic sandwich panel **10** may be (or may include) a combination of bulk absorber material and thermal conductor material. Without being limited to any particular theory, it is believed that the presence of both bulk absorber material (inserts **50**) and thermal conductor material (inserts **50**) in the cavities **30** of the core **12** may further promote sound attenuation and may enhance heat dissipation and, therefore, may be particularly advantageous in the construction of aircraft engines, such as the fan duct walls of bypass gas turbine aircraft engines.

In one variation of the third implementation, the bulk absorber material component of an insert **50** may be compositionally different from the thermal conductor material component of that insert **50**. For example, an insert **50** may be introduced to a cavity **30** by separately introducing a bulk absorber material and a thermal conductor material. Alternatively, a composite insert **50** may be prepared, such as by incorporating (e.g., wrapping, weaving, impregnating, etc.) the thermal conductor material into the bulk absorber material (or vice versa), prior to introduction into the cavity **30**.

In another variation of the third implementation, the bulk absorber material component of an insert **50** and the thermal conductor material component of that insert **50** may be compositionally one and the same. For example, a bulk absorber/thermal conductor insert **50** may be a metal foam, such copper foam and/or nickel foam, which may function both as a bulk absorber material and a thermal conductor material.

The quantity of bulk absorber/thermal conductor material used for each insert **50** may depend on various factors, including specific application, size of the associated cavities **30** and the composition of the inserts **50**. In one expression, the volume $\mathbf{V_2}$ of each bulk absorber/thermal conductor insert **50** may be at least **10** percent of the volume $\mathbf{V_1}$ of the associated cavity **30**. In another expression, the volume $\mathbf{V_2}$ of each bulk absorber/thermal conductor insert **50** may be at least **20** percent of the volume $\mathbf{V_1}$ of the associated cavity **30**. In another expression, the volume $\mathbf{V_2}$ of each bulk absorber/thermal conductor insert **50** may be at least **30** percent of the volume $\mathbf{V_1}$ of the associated cavity **30**. In another expression, the volume $\mathbf{V_2}$ of each bulk absorber/thermal conductor insert **50** may be at least **40** percent of the volume $\mathbf{V_1}$ of the associated cavity **30**. In another expression, the volume $\mathbf{V_2}$ of each bulk absorber/thermal conductor insert **50** may be at least **50** percent of the volume $\mathbf{V_1}$ of the associated cavity **30**. In another expression, the volume $\mathbf{V_2}$ of each bulk absorber/thermal conductor insert **50** may be at least **60** percent of the volume $\mathbf{V_1}$ of the associated cavity **30**. In another expression, the volume $\mathbf{V_2}$ of each bulk absorber/thermal conductor insert **50** may be at least **70** percent of the volume $\mathbf{V_1}$ of the associated cavity **30**. In another expression, the volume $\mathbf{V_2}$ of each bulk absorber/thermal conductor insert **50** may be at least **80** percent of the volume $\mathbf{V_1}$ of the associated cavity **30**.

Referring now specifically to Fig. **4** with reference to the acoustic sandwich panel **10** shown in Figs. **1–3**, one embodiment of the disclosed method for manufacturing an acoustic sandwich panel, generally designated **100**, may begin at Block **102** with the step of assembling a core **12**. The core **12** may be assembled such that the core **12** defines a plurality of cavities **30**.

Various methods may be used to assemble (Block **102**) a core **12** without departing from the scope of the present disclosure. Referring to Fig. **5**, one specific assembly method, generally designated **200**, may begin at Block **202** with the step of providing a plurality of sheets of core material (e.g., metal, such as steel, titanium alloy or aluminum alloy). At Block **204**, the sheets of core material may be formed, such as by stamping, rolling or the like, to yield formed sheets having the designed (e.g., corrugated) cross-sectional profile. Then, at Block **206**, the formed sheets may be stacked to form the desired honeycomb structure and connected together, such as by welding.

Referring back to Fig. **4** with reference to the acoustic sandwich panel **10** shown in Figs. **1–3**, at Block **104**, a first liner sheet **14** may be applied to the first major side **22** of the core **12**. The first liner sheet **14** may define a plurality of apertures **40**, which may be positioned to align with associated cavities **30** in the core **12**. The first liner sheet **14** may be secured to the core **12**, such as by welding, braising, soldering, adhering and/or mechanically fastening.

At Block **106**, a second liner sheet **16** may be applied to the second major side **24** of the core **12**. The second liner sheet **16** may be secured to the core **12**, such as by welding, braising, soldering, adhering and/or mechanically fastening.

At Block **108**, inserts **50** may be introduced to the cavities **30** defined by the core **12** of the acoustic sandwich panel **10**. The inserts **50** may include bulk absorber material, thermal conductor material or both bulk absorber and thermal conductor material. As shown by lines **120**, **130**, **140**, **150**, the inserts **50** may be introduced at various stages of the method **100**. The method **100** may come to an end at Block **110**.

Referring to Fig. **6**, in one aspect, the inserts **50** may be introduced to the cavities **30** of the core **12** during assembly of the core **12** (see line **120** in Fig. **4**). For example, a strip **300** of interconnected inserts **50** may be positioned between two adjacent formed sheets **302**, **304**. (See Block **204** of Fig. **5**.) Then, after the strip **300** has been positioned between the formed sheets as desired, the formed sheets may be connected (e.g., by welding), as shown in Block **206** of Fig. **5**.

Referring to Fig. **7**, in another aspect, the inserts **50** may be introduced to the cavities **30** of the core **12** after assembly of the core **12**, but prior to application of the final liner sheet (e.g., the second liner sheet **16**) to the core **12** (see lines **130**, **140** in Fig. **4**). Therefore, as shown in Fig. **7**, the inserts **50** may be placed directly into pre-formed cavities **30** within the core **12**. For example, the mechanical arm **400** of a robot **402** (e.g., a pick-and-place robot) may precisely position the inserts **50** into associated cavities **30** of the core **12**.

Referring to Fig. **8**, in yet another aspect, the inserts **50** may be introduced to the cavities **30** of the core **12** after application of the final liner sheet (e.g., the second liner sheet **16**) to the core **12** (see line **150** in Fig. **4**). Specifically, as shown in Fig. **8**, once the final liner sheet has been applied, the inserts **50** may be introduced to the cavities **30** by way of the apertures **40** in the first line sheet **14**. For example, a nozzle **450** may inject inserts **50** into associated cavities **30** by way of the apertures **40**. The injection process may be monitored (e.g., timed) to ensure delivery of the desired quantity (e.g., a pre-defined length of wire and/or a pre-defined volume) of bulk absorber/thermal conductor material into each cavity **30**.

Thus, the disclosed method **100** (Fig. **4**) may yield an acoustic sandwich panel that incorporates a bulk absorber material and/or a thermal conductor material into the Helmholtz resonator cavities defined by the core of the acoustic sandwich panel.

Examples of the present disclosure may be described in the context of an aircraft manufacturing and service method **500** as shown in Fig. **9** and an aircraft **600** as shown in Fig. **10**. During pre-production, the illustrative method **500** may include specification and design, as shown at block **502**, of the aircraft **600** and material procurement, as shown at block **504**. During production, component and subassembly manufacturing, as shown at block **506**, and system integration, as shown at block **508**, of the aircraft **600** may take place. Thereafter, the aircraft **600** may go through certification and delivery, as shown block **510**, to be placed in service, as shown at block **512**. While in service, the aircraft **600** may be scheduled for routine maintenance and service, as shown at block **514**. Routine maintenance and service may include modification, reconfiguration, refurbishment, etc. of one or more systems of the aircraft **600**.

Each of the processes of illustrative method **500** may be performed or carried out by a system integrator, a third party, and/or an operator (e.g., a customer). For the purposes of this description, a system integrator may include, without limitation, any number of aircraft manufacturers and major-system subcontractors; a third party may include, without limitation, any number of vendors, subcontractors, and suppliers; and an operator may be an airline, leasing company, military entity, service organization, and so on.

As shown in Fig. **10**, the aircraft **600** produced by illustrative method **500** (Fig. **9**) may include an airframe **602** with a plurality of high-level systems **604** and an interior **606**. Examples of high-level systems **604** may include one or more of propulsion system **608**, electrical system **610**, hydraulic system **612**, and environmental system **614**. Any number of other systems may be included. Although an aerospace example is shown, the principles disclosed herein may be applied to other industries, such as the automotive and marine industries. Accordingly, in addition to the aircraft **600**, the principles disclosed herein may apply to other vehicles (e.g., land vehicles, marine vehicles, space vehicles, etc.).

The disclosed acoustic sandwich panel may be employed during any one or more of the stages of the manufacturing and service method **500**. For example, components or subassemblies corresponding to component and subassembly manufacturing (block **506**) may be fabricated or manufactured using the disclosed acoustic sandwich panel. Also, the disclosed acoustic sandwich panel may be utilized during production stages (blocks **506** and **508**), for example, by substantially expediting assembly of or reducing the cost of aircraft **600**, such as the airframe **602** and/or the interior **606**. Similarly, the disclosed acoustic sandwich panel may be utilized, for example and without limitation, while aircraft **600** is in service (block **512**) and/or during the maintenance and service stage (block **514**).

Although various embodiments of the disclosed acoustic sandwich panel and method have been shown and described, modifications may occur to those skilled in the art upon reading the specification. The present application includes such modifications and is limited only by the scope of the claims.

EMBODIMENTS IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A sandwich panel comprising:

a core having a first major side and an opposed second major side, said core defining a plurality of cavities;

a first liner sheet connected to said first major side, said first liner sheet defining a plurality of apertures, each aperture of said plurality of apertures providing fluid communication with an associated cavity of said plurality of cavities; and

a plurality of inserts received in at least a portion of said plurality of cavities, each insert of said plurality of inserts comprising a bulk absorber material and a thermal conductor material.

2. The sandwich panel of claim **1** wherein said core comprises a honeycomb structure.

3. The sandwich panel of claim **1** or **2** wherein said core has a first cross-sectional thickness and said first liner sheet has a second cross-sectional thickness, and wherein said first cross-sectional thickness is at least **1.5** times said second cross-sectional thickness.

4. The sandwich panel of any one of claims **1** to **3** further comprising a second liner sheet connected to said second major side.

5. The sandwich panel of any one of claims **1** to **4** wherein at least **10** percent of said plurality of cavities receive an insert of said plurality of inserts.

6. The sandwich panel of any one of claims **1** to **5** wherein at least **75** percent of said plurality of cavities receive an insert of said plurality of inserts.

7. The sandwich panel of any one of claims **1** to **6** wherein said bulk absorber material comprises at least one of a foam material, a felted material, aluminum oxide fibers, carbon fiber batting, ceramic batting, fiberglass batting, aramid fibrous material, polyimide fibrous material, polyurethane foam, polyester foam, polyimide foam, metal foam, ceramic open cell foams, silicon rubber foam and ceramic tile.

8. The sandwich panel of any one of claims **1** to **7** wherein each cavity of said portion of said plurality of cavities receiving an insert of said plurality of inserts has a volume, and wherein at least between **10** percent and **50** percent of said volume is occupied by said bulk absorber material.

9. The sandwich panel of any one of claims **1** to **8** wherein said thermal conductor material has a thermal conductivity of at least **50** W/(m·K).

10. A method for manufacturing an acoustic sandwich panel comprising:

assembling a core having a first major side, a second major side, and defining a plurality of cavities;

applying a first liner sheet to said first major side, said first liner sheet defining a plurality of apertures;

applying a second liner sheet to said second major side; and

introducing a plurality of inserts to said plurality of cavities, wherein each insert of said plurality of inserts comprises a bulk absorber material and a thermal conductor material, wherein said introducing step is performed during said assembling step.

11. The method of claim **10** wherein said core comprises a honeycomb structure.

12. The method of claim **10** or **11** wherein each cavity of said plurality of cavities has a volume, and wherein at least **50** percent of said volume is occupied by said bulk absorber material after said introducing step.

13. The method of any one of claims **10** to **12** wherein said core has a first cross-sectional thickness and said first liner sheet has a second cross-sectional thickness, and wherein said first cross-sectional thickness is at least **1.5** times said second cross-sectional thickness.

14. The method of any one of claims **10** to **13** wherein said bulk absorber material is one of a foam and a felted material.

15. The method of any one of claims **10** to **13** wherein said bulk absorber material comprises aluminum oxide fibers.

16. The method of any one of claims **10** to **15** wherein said thermal conductor material has a thermal conductivity of at least **50** W/(mK).

17. A method for manufacturing an acoustic sandwich panel comprising:

assembling a core having a first major side, a second major side, and defining a plurality of cavities;

applying a first liner sheet to said first major side, said first liner sheet defining a plurality of apertures;

applying a second liner sheet to said second major side; and

introducing a plurality of inserts to said plurality of cavities, wherein each insert of said plurality of inserts comprises a bulk absorber material and a thermal conductor material, wherein said plurality of inserts are introduced to said plurality of cavities by way of said plurality of apertures.

18. The method of claim **17** wherein said core comprises a honeycomb structure.

19. The method of claim **17** or **18** wherein each cavity of said plurality of cavities has a volume, and wherein at least **50** percent of said volume is occupied by said bulk absorber material after said introducing step.

20. The method of any one of claims **17** to **19** wherein said core has a first cross-sectional thickness and said first liner sheet has a second cross-sectional thickness, and wherein said first cross-sectional thickness is at least **1.5** times said second cross-sectional thickness.

21. The method of any one of claims **17** to **20** wherein said bulk absorber material is one of a foam and a felted material.

22. The method of any one of claims **17** to **20** wherein said bulk absorber material comprises aluminum oxide fibers.

23. The method of any one of claims **17** to **22** wherein said thermal conductor material has a thermal conductivity of at least **50** W/(mK).

24. A sandwich panel comprising:

a core having a first major side and an opposed second major side, said core defining a plurality of cavities;

a first liner sheet connected to said first major side, said first liner sheet defining a plurality of apertures, each aperture of said plurality of apertures providing fluid communication with an associated cavity of said plurality of cavities; and

a bulk absorber material received in at least a portion of said plurality of cavities, and a thermal conductor material received in said portion of said plurality of cavities receiving said bulk absorber material, said thermal conductor material having a thermal conductivity of at least **50** W/(m·K).

25. The sandwich panel of claim **24** wherein said core comprises a honeycomb structure.

26. The sandwich panel of claim **24** or **25** wherein said core has a first cross-sectional thickness and said first liner sheet has a second cross-sectional thickness, and wherein said first cross-sectional thickness is at least **1.5** times said second cross-sectional thickness.

27. The sandwich panel of any one of claims **24** to **26** further comprising a second liner sheet connected to said second major side.

28. The sandwich panel of any one of claims **24** to **27** wherein at least **10** percent of said plurality of cavities receive said bulk absorber material and said thermal conductor material.

29. The sandwich panel of any one of claims **24** to **28** wherein at least **75** percent of said plurality of cavities receive said bulk absorber material and said thermal conductor material.

30. The sandwich panel of any one of claims **24** to **29** wherein said bulk absorber material comprises at least one of a foam material, a felted material, aluminum oxide fibers, carbon fiber batting, ceramic batting, fiberglass batting, aramid fibrous material, polyimide fibrous material, polyurethane foam, polyester foam, polyimide foam, metal foam, ceramic open cell foams, silicon rubber foam and ceramic tile.

31. The sandwich panel of any one of claims **24** to **30** wherein each cavity of said portion of said plurality of cavities receiving said bulk absorber material and said thermal conductor material has a volume, and wherein at least between **10** percent and **50** percent of said volume is occupied by said bulk absorber material.

32. A method for manufacturing an acoustic sandwich panel comprising:

assembling a core having a first major side, a second major side, and defining a plurality of cavities;

applying a first liner sheet to said first major side, said first liner sheet defining a plurality of apertures;

applying a second liner sheet to said second major side; and

introducing a plurality of inserts to said plurality of cavities, wherein each insert of said plurality of inserts comprises a bulk absorber material and a thermal conductor material, said thermal conductor material having a thermal conductivity of at least **50** W/(m·K).

33. The method of claim **32** wherein said introducing step is performed during said assembling step.

34. The method of claim **32** wherein said introducing step is performed after said assembling step.

35. The method of claim **34** wherein said introducing step is performed prior to completion of both said applying said first liner sheet step and said applying said second liner sheet step.

36. The method of claim **32** wherein said plurality of inserts are introduced to said plurality of cavities by way of said plurality of apertures.

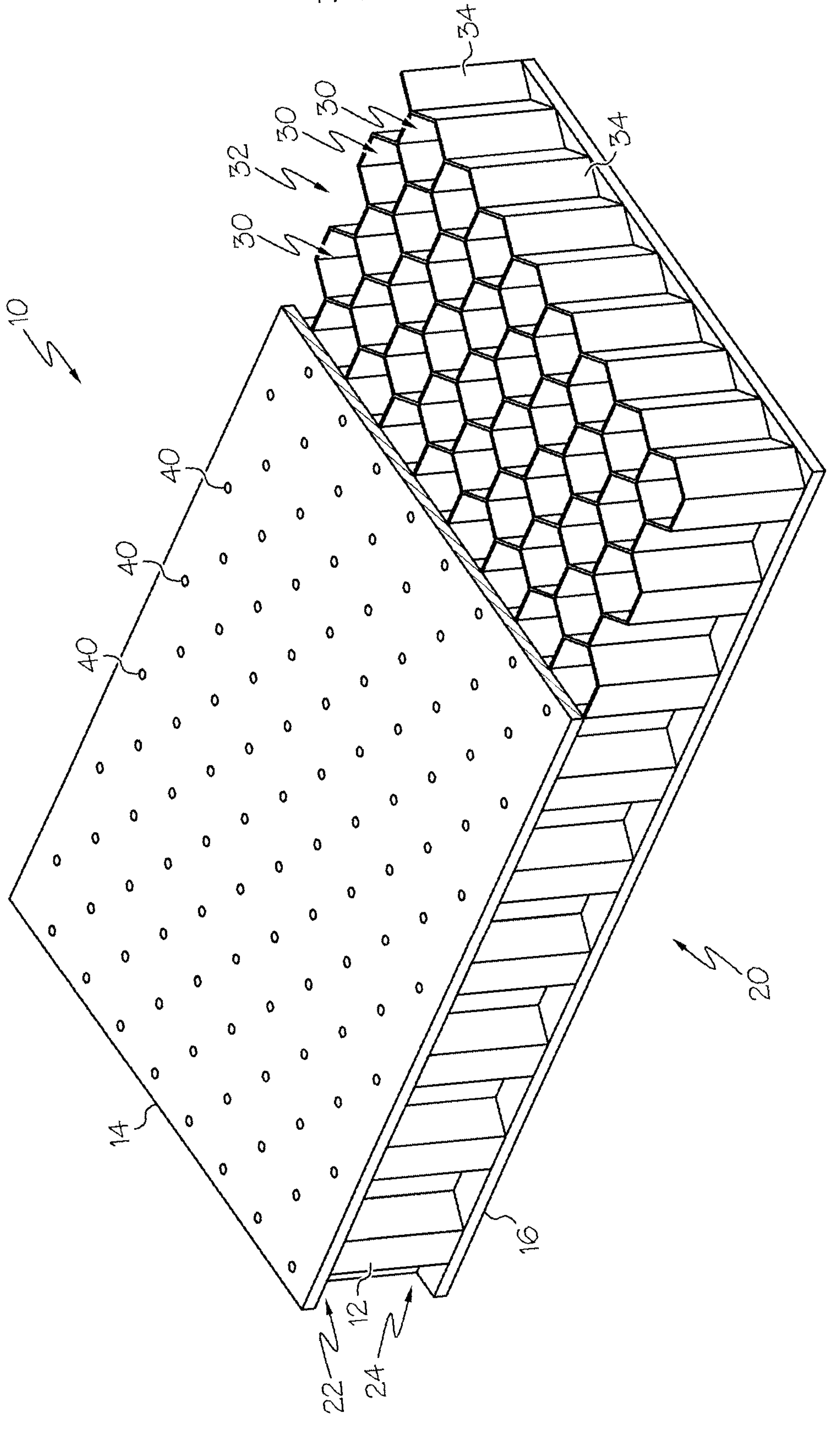


FIG. 1

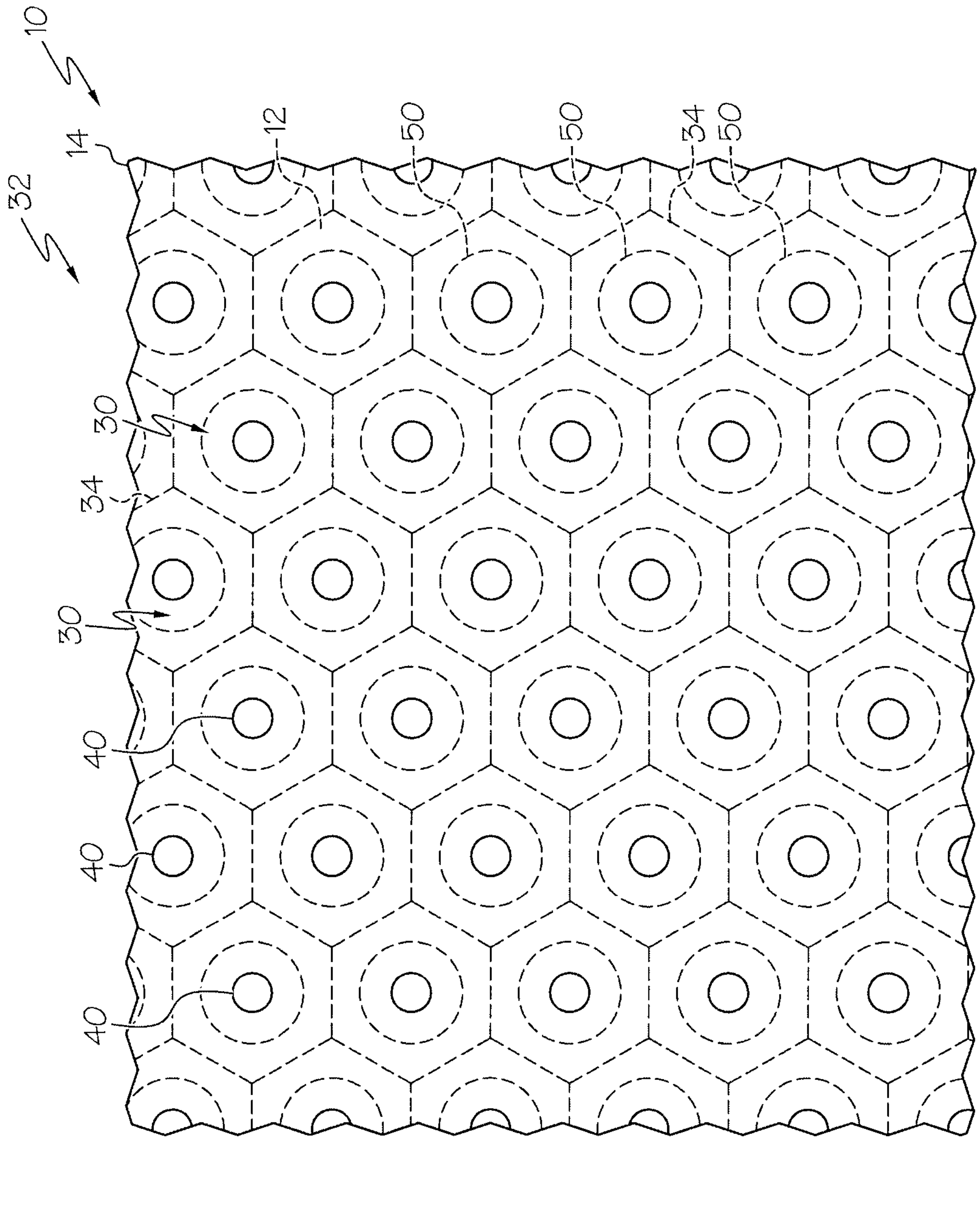


FIG. 2

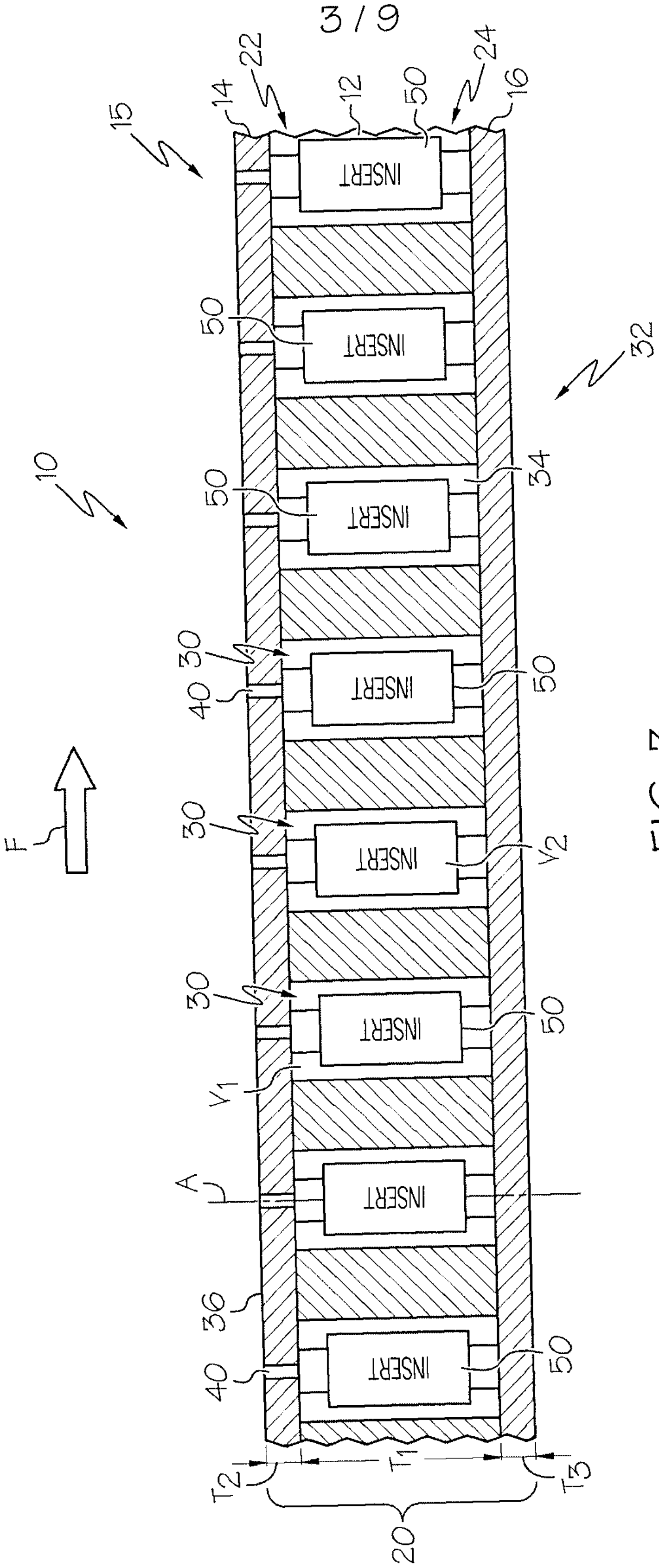


FIG. 3

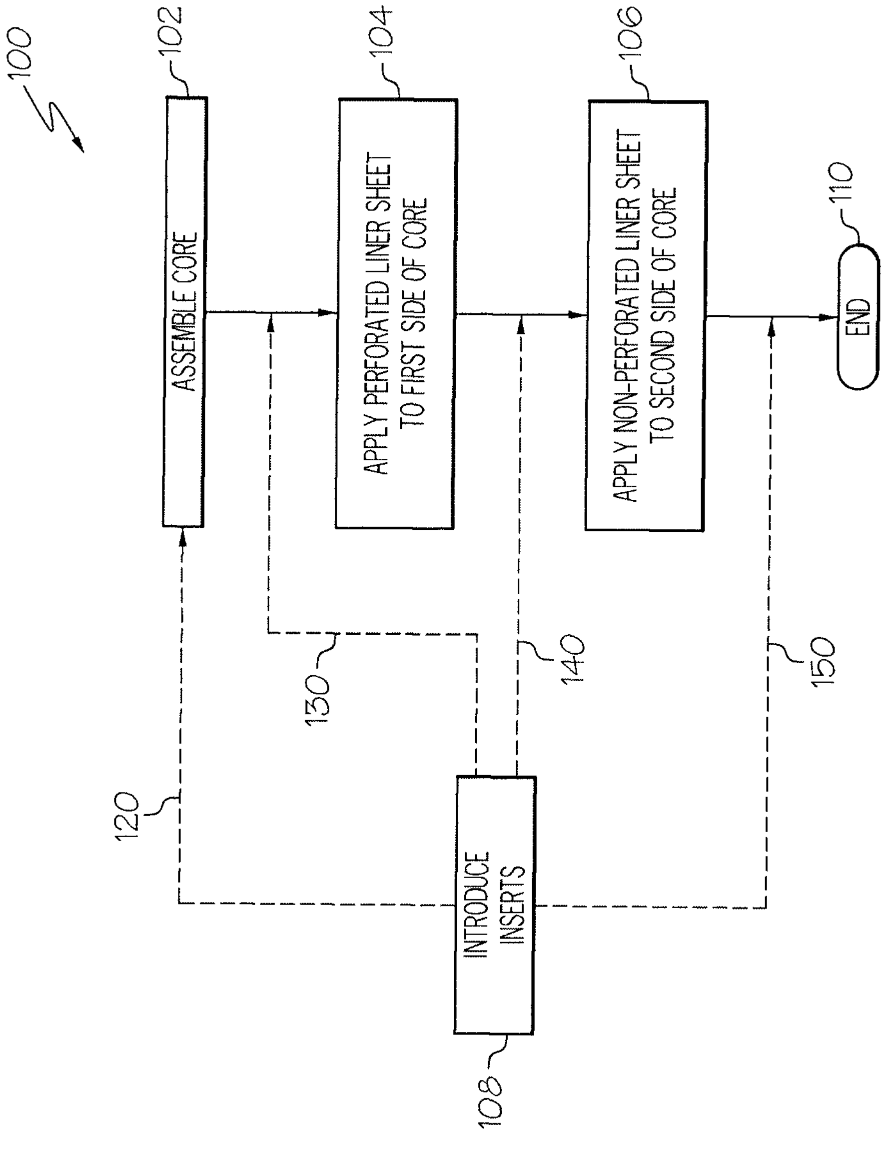

100
102
ASSEMBLE CORE
104
APPLY PERFORATED LINER SHEET TO FIRST SIDE OF CORE
106
APPLY NON-PERFORATED LINER SHEET TO SECOND SIDE OF CORE
110
END
120
130
140
150
INTRODUCE INSERTS
108

FIG. 4

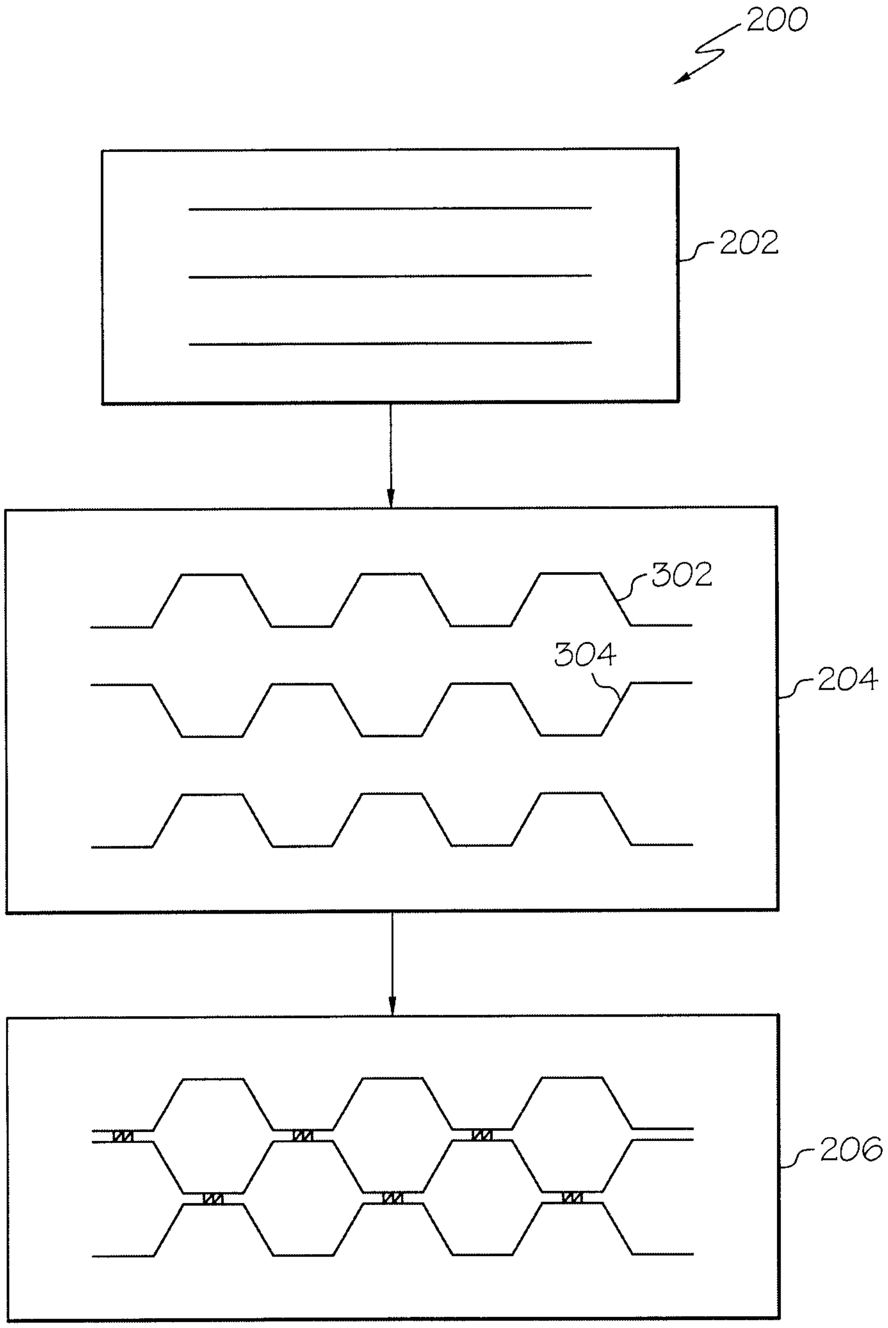


FIG. 5

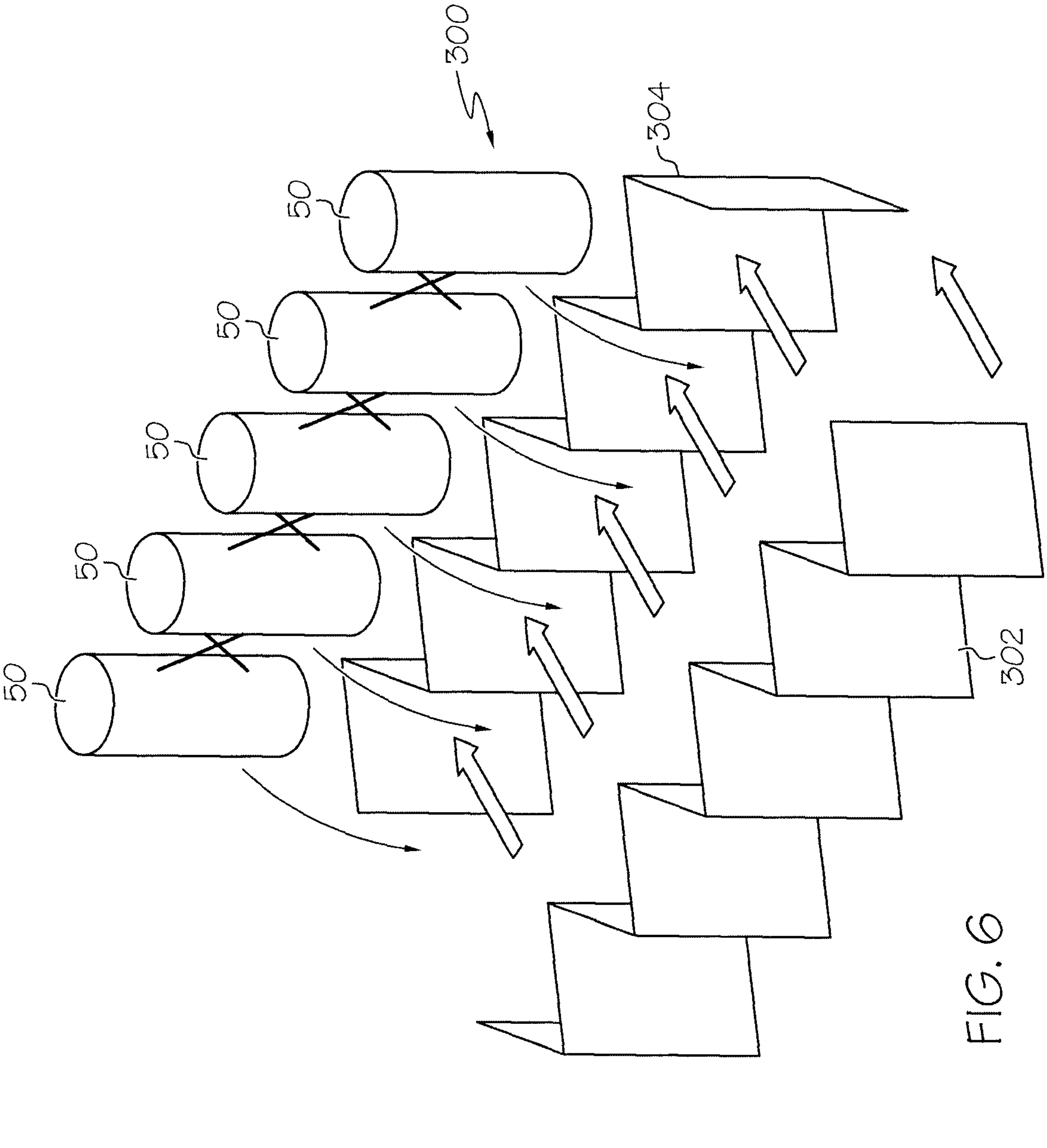


FIG. 6

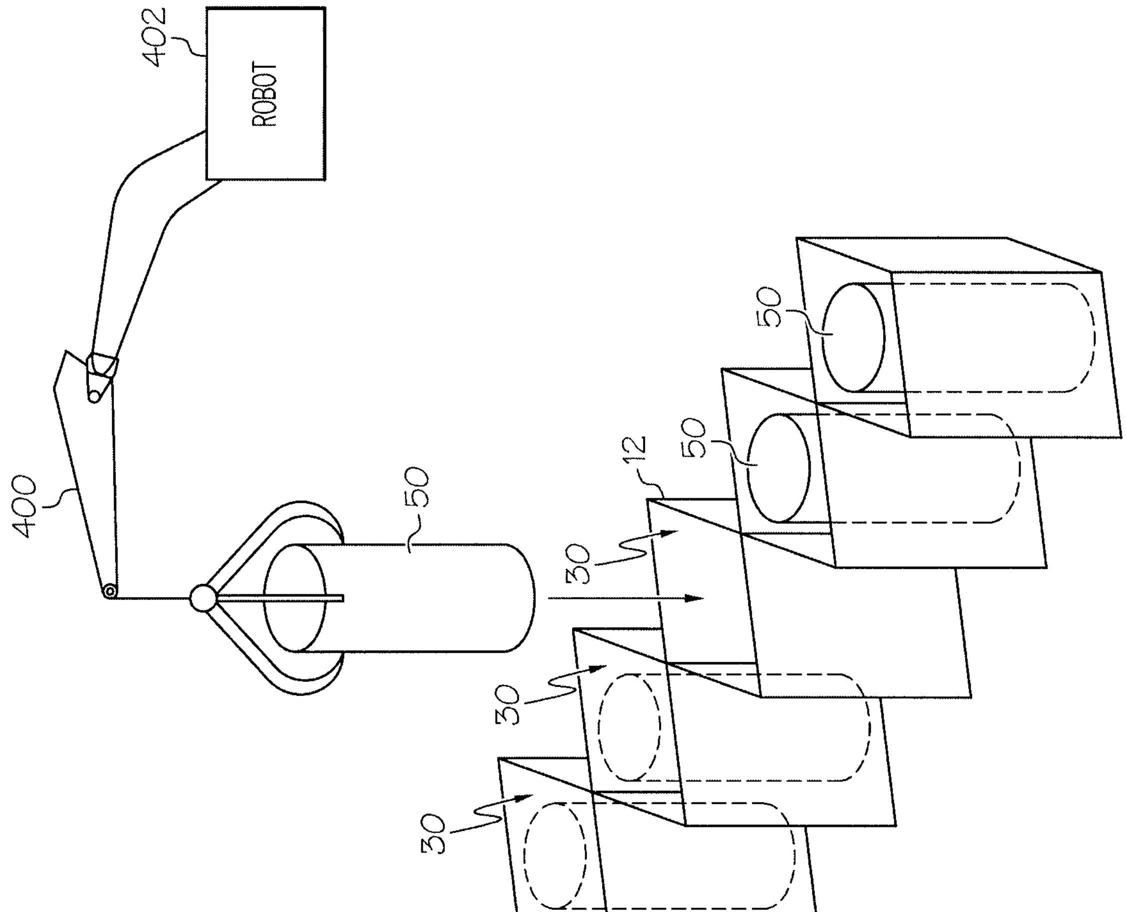


FIG. 7

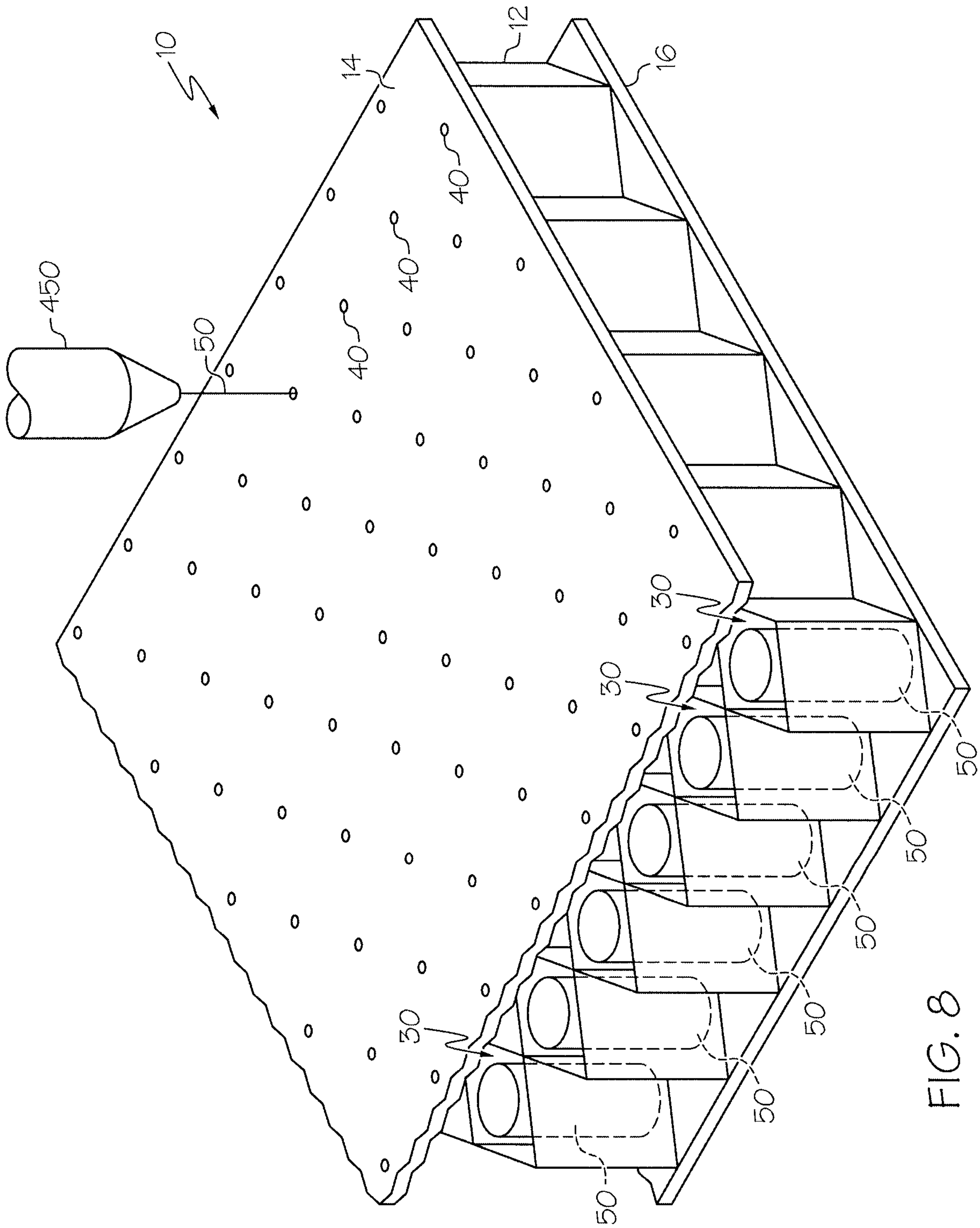
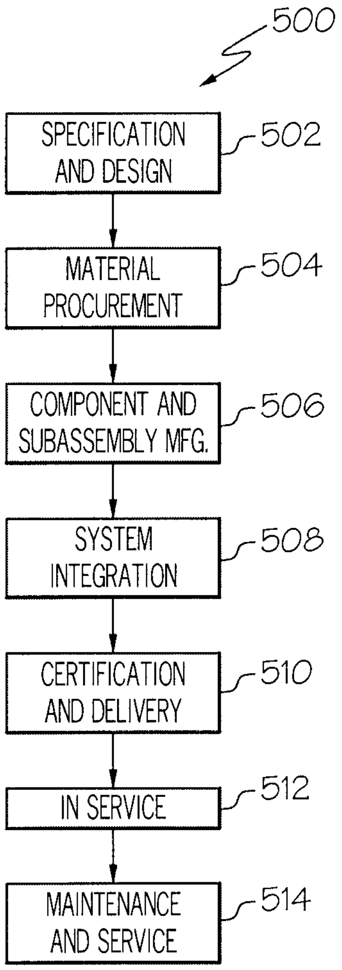
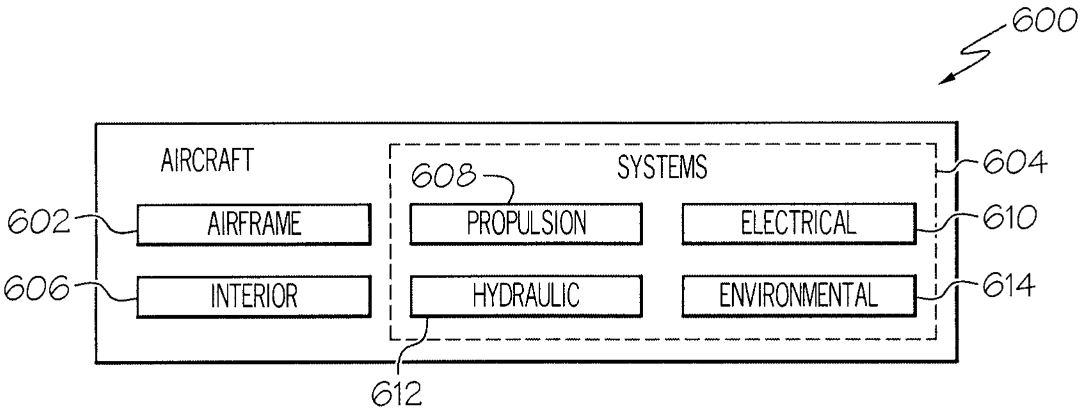


FIG. 8



500
SPECIFICATION AND DESIGN
502
MATERIAL PROCUREMENT
504
COMPONENT AND SUBASSEMBLY MFG.
506
SYSTEM INTEGRATION
508
CERTIFICATION AND DELIVERY
510
IN SERVICE
512
MAINTENANCE AND SERVICE
514

FIG. 9



600
AIRCRAFT
SYSTEMS
604
608
602
AIRFRAME
PROPULSION
ELECTRICAL
610
606
INTERIOR
HYDRAULIC
ENVIRONMENTAL
614
612

FIG. 10