Innovation, Sciences et Développement économique Canada
Office de la Propriété Intellectuelle du Canada

Innovation, Science and Economic Development Canada
Canadian Intellectual Property Office

CA 2932990 C 2020/12/15

(11)(21) **2 932 990**

(12) **BREVET CANADIEN**
CANADIAN PATENT

(13) **C**

(22) Date de dépôt/Filing Date: 2016/06/13
(41) Mise à la disp. pub./Open to Public Insp.: 2017/02/25
(45) Date de délivrance/Issue Date: 2020/12/15
(30) Priorité/Priority: 2015/08/25 (US14/835,659)

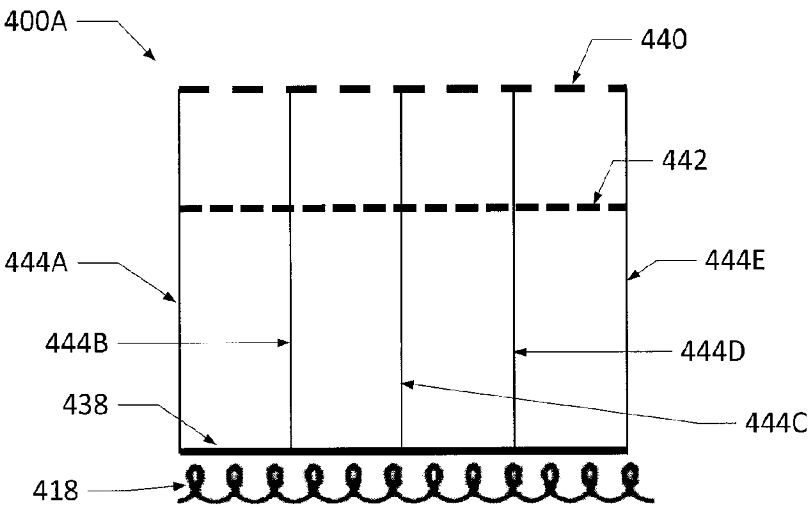
(51) Cl.Int./Int.Cl. *B64D 15/12* (2006.01), *B32B 15/00* (2006.01), *B32B 5/18* (2006.01), *B64C 1/40* (2006.01), *B64C 7/02* (2006.01), *F01D 25/02* (2006.01), *H05B 6/10* (2006.01), *C09K 3/18* (2006.01)

(72) Inventeurs/Inventors:
KHOZIKOV, VYACHESLAV, US;
LAN, JUSTIN H., US;
NESBITT, ERIC H., US;
FOLLET, JESSE I., US

(73) Propriétaire/Owner:
THE BOEING COMPANY, US

(74) Agent: SMART & BIGGAR LLP

(54) Titre : ABSORPTION DE BRUIT SYNERGETIQUE ET ANTI-GIVRAGE DESTINES AUX AERONEFS
(54) Title: SYNERGETIC NOISE ABSORPTION AND ANTI-ICING FOR AIRCRAFTS



(57) Abrégé/Abstract:
Systems and methods are provided for an inductive coil anti-icing and noise absorption system. In certain versions, the inductive coil anti-icing and noise absorption system may include an inductive coil and a skin. The inductive coil may generate electromagnetic fields and may electromagnetically couple with the skin. The skin, upon electromagnetically coupling with the inductive coil, may increase in temperature and the increase in temperature may melt or prevent the formation of ice on the skin. The skin or a portion of the skin may be porous and may allow incorporation of a sound absorbing liner. The sound absorbing liner may attenuate noise generated by the aircraft (e.g., noise generated by the aircraft engine). Certain versions may include a plurality of inductive coils and a plurality of skins.

ABSTRACT

Systems and methods are provided for an inductive coil anti-icing and noise absorption system. In certain versions, the inductive coil anti-icing and noise absorption system may include an inductive coil and a skin. The inductive coil may generate electromagnetic fields and may electromagnetically couple with the skin. The skin, upon electromagnetically coupling with the inductive coil, may increase in temperature and the increase in temperature may melt or prevent the formation of ice on the skin. The skin or a portion of the skin may be porous and may allow incorporation of a sound absorbing liner. The sound absorbing liner may attenuate noise generated by the aircraft (e.g., noise generated by the aircraft engine). Certain versions may include a plurality of inductive coils and a plurality of skins.

SYNERGETIC NOISE ABSORPTION AND ANTI-ICING FOR AIRCRAFTS

TECHNICAL FIELD

The disclosure relates generally to aircrafts and, more particularly, to aircraft anti-icing, de-icing, or both, and noise absorption.

BACKGROUND

Ice may form on surfaces of an aircraft. Currently, aircraft engines may include anti-icing or de-icing systems that feature a swirl system that uses hot gases to transfer heat to a leading edge of an engine nacelle to anti-ice and/or de-ice the engine nacelle. Such a swirl system may be pressurized and thus, to maintain the needed pressure, may need to be located within a pressurized chamber separate from other aircraft components. The pressurized system may be incompatible with other aircraft components, such as aircraft acoustic treatment, and thus any space used for the swirl system may be space that is not used for the other components. Such a system may also need to be placed in the engine inlet of an aircraft engine (i.e., the portion of the nacelle forward of the engine fans) as ice build-up tends to occur most on a leading edge.

SUMMARY

Systems and methods are disclosed herein providing a noise absorption and an anti-icing, de-icing, or both anti-icing, de-icing system.

In a first aspect, there is described an apparatus comprising: a portion of a nacelle comprising a skin, wherein: the skin comprises a ferromagnetic porous facesheet configured to electromagnetically couple with an electromagnetic field to generate heat, a ferromagnetic porous inner sheet disposed apart from and behind the porous facesheet, and a non-ferromagnetic backsheet coupled to the porous facesheet

CA 2932990 2020-01-17

and the porous inner sheet, wherein the porous facesheet is made of a first smart susceptor configured to couple with an inductive coil at a first resonant frequency to be heated to a first temperature, and wherein the porous inner sheet is made of a second smart susceptor configured to couple with the inductive coil at a second resonant frequency to be heated to a second temperature different from the first temperature; at least a portion of the skin forms a flow surface of the nacelle; and the skin at least partly defines a cavity.

The backsheet may allow air to flow through the porous facesheet to reduce noise without the air flowing into other regions of the engine nacelle. In some such implementations of the apparatus, the porous facesheet may further include a ferromagnetic metal.

In certain additional such implementations of the apparatus, the porous facesheet may include or be coated with the ferromagnetic metal and/or alloy and at least a portion of the skin may be located on a leading edge of the nacelle. In certain additional such implementations of the apparatus, the skin may further include a support component between the porous facesheet and the backsheet. The support sections may strengthen the skin. In certain such implementations, the support component may be a honeycomb. Honeycomb may allow weight efficient strengthening of the skin, allowing strength to be added with little increase in weight.

In certain additional such implementations of the apparatus, the portion of the skin that is porous may include at least one of a plurality of perforations, mesh, a porous mat, or a regular or irregular cross-linked structure made of a ferromagnetic metal and/or alloy wire, sponge, or other porous media.

In certain additional such implementations of the apparatus, the portion of the skin that is porous may be configured to attenuate noise.

In certain additional such implementations of the apparatus, the apparatus may further include an inductive coil located at least partly within the cavity and configured to be electromagnetically coupled to the porous facesheet and the porous innersheet.

In certain such implementations of the apparatus, the inductive coil may be a first inductive coil and the apparatus may further include a second inductive coil located at least partly within the cavity. The two (or more) inductive coils may be configured to electromagnetically couple with two (or more) portions of the skin. The different sections of the skin may be optimally electromagnetically coupled to inductive coils of different inductances. Having two (or more) inductive coils may allow portion of the skin to be optimally electromagnetically coupled. In certain such implementations, the skin may be a first skin, the ferromagnetic metal may be a first ferromagnetic metal and/or alloy, and the apparatus may further include a second skin such that the second skin at least partly defines the cavity, the second skin may be made of the first ferromagnetic metal and/or a second ferromagnetic metal, the first inductive coil may be configured to be electromagnetically coupled to the first skin, and the second inductive coil may be configured to be electromagnetically coupled to the second skin. In certain such implementations, the second skin may be non-porous. The second skin may be non-porous to reduce aerodynamic drag of the engine nacelle.

In certain additional such implementations of the apparatus, the apparatus may further include a support structure within the nacelle such that the support structure may partly define the cavity and the skin may be located forward of the support structure. In such examples, the cavity, formed by at least the support structure and the skin, may be pressurized.

In some implementations, an aircraft including the apparatus may be provided. The aircraft may include a fuselage, a wing coupled to the fuselage, an engine coupled to the wing and/or the fuselage, such that at least one of the fuselage, the wing, and/or the engine may include the apparatus.

In another aspect, there is described an apparatus comprising: a portion of a nacelle comprising a skin, wherein: at least a portion of the skin is porous, wherein the portion of the skin that is porous is configured to attenuate noise; at least a portion of the skin forms a flow surface of the nacelle; the skin at least partly defines a cavity; the portion of the skin that is porous comprises a porous facesheet and the skin further comprises a backsheet coupled to the porous facesheet; and the apparatus further comprises an inductive coil located at least partly within the cavity and configured to be electromagnetically coupled to the skin, wherein the skin is configured to increase in temperature when electromagnetically coupled to the inductive coil, characterized in that the skin is comprised of a ferromagnetic metal, wherein the skin further comprises a ferromagnetic metal component, at least partly comprised of the ferromagnetic metal, disposed between the facesheet and the backsheet.

In another example, there is described a method comprising: receiving a skin comprising at least a ferromagnetic porous facesheet, a ferromagnetic porous inner sheet disposed apart from and behind the porous facesheet, and a non-ferromagnetic backsheet, wherein the porous facesheet is made of a first smart susceptor configured to electromagnetically couple with an electromagnetic field at a first resonant frequency to be heated to a first temperature, and wherein the porous inner sheet is made of a second smart susceptor configured to electromagnetically couple with the electromagnetic field at a second resonant frequency to be heated to a second temperature; and coupling the skin to an engine to form at least a portion of an engine nacelle, wherein at least a portion of the skin forms a flow surface of the engine nacelle.

In certain such implementations of the method, the method may further include installing an inductive coil within a cavity of the engine nacelle and electrically connecting the inductive coil to a power supply. In certain such implementations, the method may further include positioning at least a portion of the skin within **1**-**2** inches of at least a portion of the inductive coil. In certain additional such implementations, the skin may be a first skin, the inductive coil may be a first inductive coil, the ferromagnetic porous facesheet may be a first ferromagnetic metal, and the method further include coupling a second skin to the engine such that a portion of the second skin may include the first ferromagnetic metal and/or a second ferromagnetic metal, installing a second inductive coil within the cavity of the engine nacelle such that at least a portion of the second skin is within **1** foot of at least a portion of the second inductive coil, and electrically connecting the second inductive coil to the power supply or a second power supply. In certain other additional such implementations, the power supply may be a first power supply and the method may further include connecting the second inductive coil to the second power supply.

There is also described a method comprising: moving a vehicle with an engine, wherein the engine includes a nacelle and at least a portion of the nacelle comprises a skin comprising a ferromagnetic porous facesheet, a ferromagnetic porous inner sheet disposed apart from and behind the porous facesheet, and a non-ferromagnetic backsheet, wherein the porous facesheet is made of a first smart susceptor configured to electromagnetically couple with an electromagnetic field at a first resonant frequency to be heated to a first temperature, and wherein the porous inner sheet is made of a second smart susceptor configured to electromagnetically couple with the electromagnetic field at a second resonant frequency to be heated to a second temperature; flowing air through the porous facesheet; and attenuating noise by, at least, the flowing of air through the porous facesheet.

There is also described a method comprising: receiving a skin comprising at least a porous facesheet and a backsheet, wherein at least a portion of the skin is comprised of a ferromagnetic metal; and coupling the skin to an engine to form at least a portion of an engine nacelle, wherein at least a portion of the skin forms a flow surface of the engine nacelle; installing an inductive coil within a cavity of the engine nacelle; and electrically connecting the inductive coil to a power supply, wherein the skin further comprises a ferromagnetic metal component, at least partly comprised of the ferromagnetic metal, disposed between the facesheet and the backsheet.

There is also described a method comprising: moving a vehicle with an engine, wherein the engine includes a nacelle and at least a portion of the nacelle comprises a skin; flowing air through a porous portion of the skin, wherein the skin is comprised of a ferromagnetic metal; and attenuating noise by, at least, the flowing of air through the porous portion of the skin, wherein the skin further comprises a porous facesheet and a backsheet and flowing air through the porous portion of the skin comprises flowing air through the porous facesheet, and wherein the skin further comprises a ferromagnetic metal component, at least partly comprised of the ferromagnetic metal, disposed between the facesheet and the backsheet and the method further comprises: generating an electromagnetic field with an inductive coil; electromagnetically coupling, with the electromagnetic field, the inductive coil to the ferromagnetic metal component; and increasing, by electromagnetically coupling the inductive coil to the ferromagnetic metal component, a temperature of the ferromagnetic metal component.

A more complete understanding of embodiments will be afforded to those skilled in the art, by a consideration of the following detailed description of one or more embodiments. Reference will be made to the appended sheets of drawings that will first be described briefly.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. **1** illustrates an example aircraft in accordance with the disclosure.

Fig. **2** illustrates an example aircraft engine in accordance with the disclosure.

Figs. **3**A-C illustrate a portion of an example aircraft engine with various inductive coil anti-icing and noise absorption systems in accordance with the disclosure.

Figs. **4**A-C illustrate various example skin configurations in accordance with the disclosure.

Fig. **5** illustrates a flowchart detailing an example operation of an inductive coil anti-icing and noise absorption system in accordance with the disclosure.

Fig. **6** illustrates a flowchart detailing an assembly process of an aircraft component containing an inductive coil anti-icing and noise absorption system in accordance with the disclosure.

Embodiments described herein are best understood by referring to the detailed description that follows. It should be appreciated that like reference numerals are used to identify like elements illustrated in one or more of the figures.

DETAILED DESCRIPTION

Aircrafts may include anti-icing and/or de-icing systems. Currently, aircrafts may include an anti-icing system that contains a swirl system that uses hot gases to transfer heat to an engine nacelle to anti-ice the engine nacelle. Such a swirl system may be pressurized and thus, to maintain the needed pressure, the swirl system may need to be contained within the engine nacelle in a pressurized portion of the engine nacelle.

Aircraft engine nacelles may also include acoustic treatment to lower sound levels within and outside of the aircraft. The acoustic treatment may be incompatible with the swirl system and thus may only be positioned in areas of the aircraft not occupied by the swirl system. However, to maximize noise reduction, it may be desirable to include acoustic treatment in areas of the aircraft that may also require anti-icing. A certain such area is the engine inlet of an aircraft engine, where both anti-icing and noise reduction treatment would be beneficial. Current systems lead to an either or situation where devoting greater space to anti-icing systems leads to having less of such space available for noise reduction systems.

Fig. **1** illustrates an aircraft in accordance with the disclosure. In Fig. **1**, aircraft **100** includes an engine **102**, a fuselage **104**, an engine **106**, and a tail **108**. The aircraft **100** may be any type of aircraft.

The engine **102** may be any type of aircraft engine that may benefit from anti-icing and noise reduction features. Non-limiting examples of such engines include turbofans, turboprops, and turbojets. For the purposes of this disclosure, “anti-ice” or “anti-icing” may refer to either or both of the prevention of ice formation on as well as the melting of any ice that has built up on any surface of the aircraft. The fuselage **104** may be any type of aircraft fuselage. The wing **106** and the tail **108** may be control surfaces of the aircraft **100**. The wing **106** and the tail **108** may include flaps. One, some, or all of the engine **102**, the fuselage **104**, the wing **106**, and the tail **108** of the aircraft **100** may include versions of the inductive coil anti-icing system as described herein. Additionally, noise absorption features integrated within the inductive coil anti-icing system may also be present.

In certain examples, the inductive coil anti-icing system, with or without integrated noise absorption features, may be located on an engine nacelle. Fig. **2** illustrates an aircraft engine in accordance with the disclosure. The aircraft engine **102** may include a nacelle **210** and an engine fan **246**. The aircraft engine **102** in Fig. **2** may be, for example, a turbofan engine.

Fig. **2** also includes a leading edge region **212**. The leading edge region **212** may be at least part of the portion of the nacelle **210** before the engine fan **246**. In certain examples, perforation based noise treatments applied to engines may be located within the leading edge region **212**. That is, the noise treatment may be located upstream, as defined by the airflow, of the engine fan **246**. In certain examples, perforation based noise treatments may be effective upstream of the engine fan **246**.

The features of the engine nacelle within the leading edge region may be further illustrated in Figs. **3**A-C. Figs. **3**A-C illustrate the leading edge region **212** of Fig. **2** in further detail. Figs. **3**A-C illustrate a portion of an aircraft engine with various inductive coil anti-icing and noise absorption systems in accordance with the disclosure.

The examples of the inductive coil anti-icing systems described in Figs. **3**A-C may all be compatible with aircraft noise treatments, such as perforation based noise treatments. Accordingly, such systems may more efficiently use the space available on an aircraft, such as space available on an aircraft engine, by having the same space be occupied by a system that performs the dual role of anti-icing and noise abatement.

Note that while Figs. **3**A-C illustrate a cutaway of a portion of an engine nacelle, the various components illustrated in Figs. **3**A-C may extend across the entire engine nacelle (e.g., may extend across the entire circumference or a portion of the circumference of an engine nacelle) or may be applied to other areas of the aircraft such as the control surfaces or the fuselage.

Fig. **3**A highlights an example of an inductive coil anti-icing and noise absorption system located within a leading edge of an engine nacelle. Engine nacelle leading edge **212**A of Fig. **3**A includes a first skin **316**, a second skin **314**, a first inductive coil **320**, a second inductive coil **318**, a power source **322**, electrical connections **324** and **326**, a capacitor **328** (as well as additional capacitors where certain such additional capacitors may be configured to decouple), a non-ferromagnetic nacelle skin **330**, bulkhead **332**, and a controller **350**. The first skin **316** and the second skin **314** may partly define a cavity that may contain the first inductive coil **320** and the second inductive coil **318**. Certain examples may also include the bulkhead **332** and the bulkhead **332** may also partly define the cavity. In certain examples, the first skin and/or the second skin may form a portion of the engine nacelle. In certain such examples, the first skin and/or the second skin may not form the entirety of the engine nacelle. Such examples may locate elements of the system described herein within the portion of the engine nacelle formed by the first skin and/or the second skin.

The first skin **316** may be a single component (e.g., one sheet of metal) or may be multiple components (e.g., multiple sheets of metal coupled together). At least a portion of the first skin **316** may be ferromagnetic metal. For the purposes of this disclosure, “ferromagnetic metal” may refer to ferromagnetic materials made from one type of metal or to ferromagnetic materials made an alloy (in other words, a ferromagnetic alloy). Certain examples may include components made from both ferromagnetic metals and ferromagnetic alloys. Such examples may include systems with multiple skins or panels. The multiple panels in such examples may include at least one ferromagnetic metal panel and at least one ferromagnetic alloy panel. For examples of the first skin **316** assembled from multiple components, at least a portion of one of the components may be ferromagnetic metal. In certain such examples, the ferromagnetic metal may contain ferromagnetic metals such as INCONEL™, nichrome, graphite based materials, or other types of material. Such materials may be available from a variety of vendors. Non-limiting examples of appropriate ferromagnetic metals include alloys containing chrome, steel, iron, aluminum, nickel, cobalt, and titanium, but other examples may use other ferromagnetic metals. Certain examples may include one ferromagnetic metal, or multiple different ferromagnetic metals. Any ferromagnetic metal may be used with the systems and apparatus of this disclosure, including ferromagnetic metals with magnetic susceptibilities leading to certain current densities at certain frequencies as appropriate, as to be understood by one skilled in the art. In certain examples, current densities of the ferromagnetic metal may be proportional to frequency. Appropriate magnetic susceptibility may include magnetic susceptibilities of less than **2**, less than **5**, less than **10**, less than **20**, and up to **10**,**000**, or above **10**,**000**. In certain such examples, a higher magnetic susceptibility may allow for a lower frequency. Lower frequencies may be used, if desired, due to, for example, electromagnetic interference considerations. Certain examples may select the ferromagnetic metal based on a combination of the magnetic susceptibility, the frequency, the available materials, and other considerations (such as environmental,

CA 2932990 2020-01-17

packaging, reliability, etc.). The ferromagnetic metal may be a smart susceptor that may be tuned to be heated to specific temperatures when electromagnetically coupled. A smart susceptor may be a ferromagnetic metal with a known Curie temperature at which susceptibility of the metal and/or alloy to a magnetic field may start to decrease.

The first skin **316** may at least partially define a cavity. The cavity may be an interior form of, for example, the engine nacelle and may at least partially contain a first inductive coil. Inductive coils described within this disclosure may be pancake, sandwich, solenoid, etc. configurations of inductive coils. The first inductive coil **320** may, when powered, produce a first electromagnetic field. The ferromagnetic metal within the first skin **316** may couple with and/or capture the first electromagnetic field produced by the first inductive coil **320**. When the metal within the skin **316** captures the first electromagnetic field, heat may be generated. The heat may prevent the formation of ice or melt any ice on the outside surface of the first skin **316** (e.g., the surface of the skin exposed to airflow).

In certain examples, the first skin **316** may be porous. That is, at least a portion of the first skin **316** may include perforations. In certain examples, the perforations may be formed by, for example, holes within the first skin **316** or by having at least a portion of the first skin **316** be produced from a mesh material. In certain such examples, the first skin **316** may include at least a porous facesheet and a backsheet. The facesheet and the backshseet of the first skin **316** may be elements of an acoustic liner. In certain examples, the porous facesheet may work in conjunction with a back cavity and a non-porous backsheet or back surface to set up a Helmholtz resonator type acoustic liner. Possible configurations of the first skin **316** may be further illustrated in Figs. **4**A-C.

The second skin **314** may be similar to the first skin **316**. The second skin **314** may also be constructed from a single component (e.g., one sheet of metal) or may be multiple components (e.g., multiple sheets of metal coupled together) and at least a portion of the second skin **314** may be ferromagnetic metal. The ferromagnetic metal of the second skin **314** may be the same ferromagnetic metal of the first skin **316** or may be a different ferromagnetic metal.

The second inductive coil **318** may also be similar to the first inductive coil **320**. However, in certain examples, the positioning, length, and coil configuration of the second inductive coil **318** may differ from the first inductive coil **320**.

The second inductive coil **318** may, when powered, produce a second electromagnetic field. The ferromagnetic metal within the second skin **314** may couple with and/or capture the second electromagnetic field and generate heat. The heat generated by the second skin **314** may also prevent the formation of ice or melt any ice on the outside surface of the second skin **314**.

In certain examples, the second skin **314** may also be porous, however other examples may have a non-porous second skin **314**. A non-porous second skin may allow for noise decreasing perforations to be concentrated in areas where they reduce noise the most (e.g., on the inside of the engine nacelle) and may, for example, decrease cost and/or aerodynamic drag resulting from locating porous skins in areas where they are less useful. In certain examples, a porous first skin **316** may be located on an inside of the engine nacelle (e.g., the portion of the engine nacelle that intakes air) while a non-porous second skin **314** may be located on an outside of the engine nacelle. In such a configuration, the porous first skin **316** may be most effective at attenuating noise on the inside of the engine nacelle. On the outside of the engine nacelle, where noise attenuation through the use of a porous skin is less effective, the second skin **314** may be non-porous to decrease aerodynamic drag.

In certain examples, the second skin **314** may be constructed from a single component (e.g., one sheet of metal) or multiple components (e.g., multiple sheets of metal coupled together). In examples where either the first skin **316** and/or the second skin **314** are made of multiple components, one, some, or all of the components may include the ferromagnetic metal. When less than all of the components include the ferromagnetic metal, the ferromagnetic metal may be in thermally conductive contact with other components, such as the outer skin (e.g., the layer of the skin exposed to airflow), so as to heat the other components. As such, these other components may also be heated to prevent the formation of ice or melt any ice on the components.

The inductive coils **318** and **320**, which produce the electromagnetic fields to heat the first skin **316** and the second skin **314**, may be coupled to the power source **322** (e.g.,, be able to receive current flowing from the power source **322**). The power source **322** may be an AC power source, though other examples may use a DC power source. The power source **322** may be coupled to the first inductive coil **320** and/or the second inductive coil **318** through electrical connections. In Fig. **3**A, the power source **322** may be coupled to the first inductive coil **320** via the electrical connection **326** and may be coupled to the second inductive coil **318** via the electrical connection **324**. Additionally, the first inductive coil **320** may be electrically coupled to the second inductive coil **318** through an electrical connection. In Fig. **3**A, a capacitor **328** may be installed within the electrical connection connecting the first inductive coil **320** and the second inductive coil **318**.

The example shown in Fig. **3**A may have the first inductive coil **320** and the second inductive coil **318** may be coupled in series. In such an example, the capacitor **328** may be a compensating capacitor. In certain configurations, having two inductive coils connected in series may shift the resonant frequency of at least one inductive coil away from the optimal frequency. Such a situation may be compensated for by the installation of the compensating. The value of the compensating connector may be selected to affect the amount of current flowing within the coils.

The first inductive coil **320** and the first skin **316** may form a first system. The second inductive coil **318** and the second skin **314** may form a second system. The compensating capacitor may affect an amount of current flowing through the first inductive coil **320** and/or the second inductive coil **318** such that the first system and/or the second system may be operating substantially within the resonant frequency of the first system and/or the second system.

In a certain example, the resonant frequency of the first system and/or the second system may be determined through the thickness of the first skin **316** and/or the second skin **314**, respectively. The characteristics of the first system and/or the second system, such as the resistance and the inductance of the first system and/or the second system, may be evaluated and the capacitance of the capacitor **328** may then be determined responsive to the other characteristics of the first system and/or the second system. The capacitor **328** may be an off-the-shelf capacitor or may have a custom capacitance. The capacitor **328** may be selected to have a capacitance to influence the first system and/or the second system such that the first system and/or the second system may be operating substantially within the resonant frequency of the first system and/or the second system.

The controller **350** may regulate the power source **322**. The controller **350** may, in certain examples where the power source **322** is an AC power source, determine an optimal switching frequency of the power source **322**. The controller **350** may regulate the switching frequency of the power source **322** automatically so as to "tune" the output frequency of the power source **322** to the resonant frequency of the first system and/or the second system. In other words, the controller **350** may "scan" the frequency range of the power source **322** until the controller **350** finds a spot within the frequency range where the impedance is minimal or current reaches its maximum value.

In addition, the controller **350** may also determine when to provide power to the first inductive coil **320** and the second inductive coil **318**. In certain examples, the controller **350** may provide power to the inductive coils based on a schedule such as a timetable or power providing schedule, may provide power when commanded to by an operator, or may provide power to the inductive coils when an environmental factor, such as the presence of ice on a surface of the aircraft, is detected.

Certain examples may include the nacelle skin **330** and/or the bulkhead **332**. The nacelle skin **330** may be a portion of the nacelle that does not include inductive coils positioned behind the nacelle skin **330** to heat the skin. In certain examples, the nacelle skin **330** may not include ferromagnetic metal within its composition. The bulkhead **332** may support part of the nacelle. Though certain examples may use the bulkhead **332** to fully seal, and thus pressurize, the cavity, the inductive coil anti-icing system does not require the cavity to be pressurized. Accordingly, certain examples may not include the bulkhead **332**.

Fig. **3**B highlights another example of an inductive coil anti-icing and noise absorption system located within a leading edge of an engine nacelle. Similar to Fig. **3**A to the engine nacelle leading edge **212**A, engine nacelle leading edge **212**B of Fig. **3**B may include the first inductive coil **320**, the second inductive coil **318**, the first skin **316**, the second skin **314**, the power source **322**, and the controller **350**.

However, unlike in Fig. **3**A, the first inductive coil **320** and the second inductive **318** may be coupled in parallel to the power source **322**. Electrical connector **334**A may be coupled to the power source **322** and the second inductive coil **318**. Electrical connector **334**B may be coupled to the power source **322** and the first inductive coil **320**. The electrical connector **334**A may include a capacitor **336**A and an electrical connector **334**B may include the capacitor **336**B. The first inductive coil **320** and the capacitor **336**B may form a first system. The second inductive coil **318** and the capacitor **336**A may form a second system. The capacitors **336**A and **336**B may be capacitors with capacitances chosen to equalize the impedance of the first system and the second system. Such a configuration may allow for substantially equal flow of current between the first and second system. In certain other examples, the power source **322** and the controller **350** may represent a dual-frequency power supplying system. In such examples, the controller **350** may controller the frequency of the power source **322**.

Fig. **3**C highlights a further example of an inductive coil anti-icing and noise absorption system located within a leading edge of an engine nacelle. Engine nacelle leading edge **212**C of Fig. **3**C may also be similar to the engine nacelle leading edge **212**A of Fig. **3**A. However, where Fig. **3**A includes one power source, the example of the inductive coil anti-icing and noise absorption system in Fig. **3**C includes two power sources; power sources **338**A and **338**B. The power source **338**A may be coupled to the first inductive coil **320** via the electrical connector **334**B while the power source

338B may be coupled to the second inductive coil **318** via the electrical connector **334**A.

The controller **350** may control the amount of power that each power source supplies to the respective inductive coil. In certain examples, the controller **350** may include algorithms determining the amount of current and/or the duration of power supplied to each inductive coil. Additionally, certain other examples may, instead of including two power sources, include a single power source configured to provide power to either of the first inductive coil **320** or the second inductive coil **318** or to both coils **318** and **320** in a dual-frequency power supplying mode. In such a configuration, the controller **350** may control the switching of the power source between providing power to either the first inductive coil, the second inductive coil, or both.

It is appreciated that the examples of the inductive coil anti-icing and noise absorption system described in Figs. **3**A-C are non-limiting. Other examples of the inductive coil anti-icing and noise absorption systems are possible. For example, other examples may include only one inductive coil or more than two inductive coils. Additionally, the inductive coils of such examples may be electromagnetically coupled to only one skin, but other examples may include inductive coils that are electromagnetically coupled to more than one skin (i.e., using the example shown in Figs. **3**A-C as an example, one inductive coil may be electromagnetically coupled to both the first skin **316** and the second skin **314**).

Additionally, the skin used in inductive coil anti-icing and noise absorption systems may also have various configurations. Figs. **4**A-C illustrate various skin configurations in accordance with the disclosure.

Skin **400**A in Fig. **4**A is such a skin configuration. The skin **400**A includes a backsheet **438**, a facesheet **440**, a septum **442**, and support components **444**A-E. Additionally, Fig. **4**A also includes an inductive coil **418** to illustrate a possible position of an inductive coil if the skin **400**A is used as part of an inductive coil anti-icing and noise absorption system.

The backsheet **438** may be a solid sheet, though other examples may include a backsheet with a porous portion or with gaps within the backsheet. The backsheet **438**, with or without support components, may structurally support the facesheet **440** and prevent at least a portion of the facesheet **440** from flexing. The support components **444**A-E may additionally aid in supporting the facesheet **440**. In various examples, the support components **444**A-E may be structural materials such as walls and/or honeycombs that may lend additional stiffness to the skin **400**A.

Referring back to the backsheet **438**, in various examples, the backsheet **438** may be constructed of a material that does not include ferromagnetic metals, but other examples may construct the backsheet **438** at least with a material that includes ferromagnetic metal. In such examples, the ferromagnetic metal may couple with and/or absorb an electromagnetic field generated by the inductive coil **418** and produce heat through coupling with and/or absorbing the electromagnetic field. The heat produced may then be conducted to the facesheet **440**.

The facesheet **440** may, in certain examples, be a porous facesheet. In other words, the facesheet **440** may be perforated. The perforations may allow air to flow through the facesheet **440**. In certain examples, the flow of air through the facesheet **440** may attenuate noise (i.e., attenuate noise generated by the engine) through techniques described herein.

In another example, the facesheet **440** may be a mesh and the perforations may be the open area of mesh. In yet a further example, the facesheet **440** may include circular or non-circular holes or other features drilled (including laser drilled), formed, or otherwise produced into the facesheet **440**.

In certain examples, the facesheet **440** may be at least partially constructed of a ferromagnetic metal. The material of the facesheet **440** may include the ferromagnetic metal or the facesheet **440** may have a non-ferromagnetic metal base material with a ferromagnetic metal layer deposited onto the base material (i.e., through a coating such as a plasma spray or a metallic aerosol spray or through deposition of the ferromagnetic metal onto the base material).

The ferromagnetic metal of the facesheet **440** may couple with and/or absorb electromagnetic waves generated by the inductive coil **418**. The ferromagnetic metal may then increase in temperature and thus increase the temperature of the facesheet **440**. The increase in temperature may melt any ice present on the flow surface portion of the facesheet **440** or prevent the formation on ice on the facesheet **440**. The facesheet **440** may increase in temperature to any temperature, including **0** degrees Celsius or above, above **5** degrees Celsius, or **10** degrees Celsius or above. The flow surface may be any surface, such as a surface of the engine nacelle, exposed to the flow of air resulting from movement of a vehicle.

The example in Fig. **4**A may additionally include the septum **442**. The septum **442**, in certain examples, may be at least partially constructed of a ferromagnetic metal. The ferromagnetic metal may be the same or may be different from the ferromagnetic metal that the facesheet **440** is constructed from and may generate heat from coupling with and/or receiving electromagnetic waves generated by the inductive coil **418**. In such examples, the inductive coil **418** may be configured to couple with both the facesheet **440** and the septum **442**. Accordingly, the inductive coil **418** may form a first system with the facesheet **440** and a second system with the septum **442**. The first system and the second system may include two different resonant frequencies and the inductive coil **418** may be configured to operate at either of the resonant frequencies. In certain such examples, a controller may allow for the inductive coil **418** to operate at either of the two resonant frequencies and allow the inductive coil **418** to switch between operating from one resonant frequency to the other resonant frequency.

The septum **442** may also be a porous material and may allow air to flow from one side to the other side of the septum **442**. In certain examples, the septum **442** may be heated to vary the speed of sound of the air or the pressure of the air by, for example, changing the temperature around the vicinity of the septum **442**. The change in the speed of sound may change the volume of the flow of air through the perforations of the septum **442** and thus may aid in the attenuation of sound.

In addition to skin **400**A in Fig. **4**A, skin **400**B in Fig. **4**B may be another skin configuration. Skin **400**B may include the backsheet **438**, the facesheet **440**, the inductive coil **418**, and the support components **444**A-C, all of which may be similar to the backsheet, facesheet, inductive coil, and support components of the skin **400**A in Fig. **4**A. Additionally, the skin **400**B may also include a sound absorber **446**.

The sound absorber **446** may be, for example, a sound absorber that includes a fiber bulk absorber, a foam layer, or a porous mat that may allow air to flow through the mat. The sound absorber **446** may be at least partially made from a ferromagnetic metal and may be made from a material that may aid in absorbing sound (e.g., a material such as a NiCr fiber bulk absorber). In certain examples where the sound absorber **446** is at least partially made from a ferromagnetic metal, the facesheet **440** may not be made from a material that includes a ferromagnetic metal. In such an example, the inductive coil **418** may electromagnetically couple with the sound absorber **446** and the sound absorber **446** may, thus, generate heat. The heat generated by the sound absorber **446** may then be conducted to the facesheet **440**, raising the temperature of the facesheet **440** and melting any ice on the facesheet **440** or preventing the formation of ice on the facesheet **440**.

Skin **400**C of Fig. **4**C may be a further skin configuration. Skin **400**C may include the backsheet **438**, the facesheet **440**, the inductive coil **418**, and the support components **444**A-E, all of which may be similar to the corresponding components of the skin **400**A in Fig. **4**A.

In addition, the skin **400**C may include an inner sheet **448**. The inner sheet **448** may, in certain examples, be a mesh or porous sheet that may allow air to flow through the inner sheet **448**. A further example of such a porous sheet may be a feltmetal™ sheet that has a cross-linked structure. The feltmetal structure may be a matrix of wire and/or mesh, for example a regular or irregular cross-linked structure made of a ferromagnetic metal wire, sponge, or other porous media. In certain examples, the inner sheet **448** may be at least partially constructed from a ferromagnetic metal. In certain such examples where the inner sheet **448** is a feltmetal, the matrix of the feltmetal may be at least partially ferromagnetic metal.

Certain examples of the skin **400**C may not perfectly align the holes or porous portion of the inner sheet **448** with the holes or porous portion of the facesheet **440**. Such misalignment may affect the flow of air through the facesheet **440** and/or the inner sheet **448** and thus, the misalignment may be used to tune such flow and change the noise attenuation characteristics of the skin.

In addition to the configurations described, other skin configurations may also be used with the inductive coil anti-icing and noise absorption system. For example, an additional insulating layer may be installed between the facesheet **440** and the inner sheet **448** of the skin **400**C. The insulating layer may aid in the retention of heat generated by the facesheet **440** and/or the inner sheet **448** and may, accordingly, decrease the number of electromagnetic generation cycles of the inductive coil **418**. Additionally, the facesheet **440** may not be present in certain examples. Instead, the supporting structure may include feltmetal mesh, possibly containing ferromagnetic metal, melted into the supporting structure.

In certain examples that use the skin at multiple locations on the aircraft, the skin may vary in thickness depending on the area of application. In certain such examples, the porous skin may be the thickest near a lip region (i.e., the forward most region) of an aircraft engine nacelle. Certain other such examples may vary the thickness of the skin depending on the noise source of the noise that needs to be attenuated. For example, different noise frequencies may be attenuated with different thicknesses.

One, some, or all of the various skin configurations described herein may be incorporated into an inductive coil anti-icing and noise absorption system. The inductive coil anti-icing and noise absorption system may be mounted on an aircraft and may perform anti-icing and noise absorption functions concurrently. The functions may be performed at least when the aircraft is operational. Fig. **5** illustrates a flowchart detailing an operation of an inductive coil anti-icing and noise absorption system in accordance with the disclosure.

In step **500**, the aircraft may be operational. The engine of the aircraft may be operational and air may flow through the components of the aircraft.

In step **502**, power may be provided to the inductive coil(s). Power may be provided to the inductive coil(s) in any manner described herein. When the inductive coil(s) are powered, the inductive coil(s) may generate an electromagnetic field or multiple electromagnetic fields in step **504**.

The electromagnetic fields generated in step **504** may be captured by a skin in step **506**. The skin may be electromagnetically excited by the electromagnetic field. The skin, when electromagnetically excited, may generate heat in step **510**. In certain examples, at least a portion of the skin may be porous.

In step **512**, air may flow through the porous portion of the skin. Air may flow through, for example, a porous facesheet, a septum, an inner sheet, or other component of the skin. The airflow through the skin may attenuate noise in step **514**. The noise attenuation steps **512** and **514** may occur concurrently with steps **502** to **510**.

The inductive coil anti-icing and noise absorption system may be assembled to the aircraft using certain techniques. An example of such a technique is shown in Fig. **6**. Fig. **6** illustrates a flowchart detailing an assembly process of an aircraft component containing an inductive coil anti-icing and noise absorption system in accordance with the disclosure.

In step **602**, the skin may be manufactured. The skin manufactured may be any version of the skins detailed in Figs. **4**A-C herein. The skin may include a component containing ferromagnetic metal. The component may incorporate ferromagnetic metal through the base material, through at least one coating, through deposition, through structurally or cosmetically linking the ferromagnetic material to another material, or through any other technique. In certain examples, more than one of the techniques described may be used to incorporate the ferromagnetic metal into the component.

In step **604**, the skin may be coupled to the aircraft. The skin may, for example, be installed to an engine (i.e., on the engine nacelle), a wing or other airfoil, or a fuselage of the aircraft.

In step **606**, the inductive coil may be installed on the aircraft. In certain examples, the inductive coil may be positioned within a cavity that is at least partly defined by the skin installed on the aircraft. At least a part of the inductive coil may be positioned within **1-2** inches of at least a part of a skin. While the example described in Fig. **6** may perform step **604** before **606**, certain other examples may perform step **606** before step **604**, or may perform portions of or the entirety of step **604** and portions of or the entirety of step **606** concurrently.

In step **608**, the inductive coil may be connected to the power source. The power source may additionally be connected to a controller. The controller may have previously been connected to the power source, may be connected to the power source when the inductive coil is connected to the power source, or may be connected to the power source after the inductive coil has been connected to the power source. After step **608**, certain examples may then perform further assembly steps. For example, where the skin and inductive coil are components of an aircraft engine, the aircraft engine may then be further installed onto a fuselage, wing, or other engine mounting point of the aircraft.

While specific embodiments have been described and illustrated, such embodiments should be considered illustrative of the subject matter described herein and not as limiting the claims as construed in accordance with the relevant jurisprudence.

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

1. An apparatus comprising:

a portion of a nacelle comprising a skin, wherein:

the skin comprises a ferromagnetic porous facesheet configured to electromagnetically couple with an electromagnetic field to generate heat, a ferromagnetic porous inner sheet disposed apart from and behind the porous facesheet, and a non-ferromagnetic backsheet coupled to the porous facesheet and the porous inner sheet, wherein the porous facesheet is made of a first smart susceptor configured to couple with an inductive coil at a first resonant frequency to be heated to a first temperature, and wherein the porous inner sheet is made of a second smart susceptor configured to couple with the inductive coil at a second resonant frequency to be heated to a second temperature different from the first temperature;

at least a portion of the skin forms a flow surface of the nacelle; and

the skin at least partly defines a cavity.

2. The apparatus of claim **1**, wherein an opening of the porous facesheet is misaligned with an opening of the porous inner sheet.

3. The apparatus of claim **1** or **2**, wherein the inner sheet comprises a cross-linked structure.

4. The apparatus of any one of claims **1** to **3**, wherein the porous facesheet is one of comprised of and coated with a ferromagnetic metal and at least a portion of the skin is located on a leading edge of the nacelle.

5. The apparatus of any one of claims **1** to **4**, wherein the skin further comprises a support component between the porous facesheet and the backsheet, and wherein the support component comprises a honeycomb.

CA 2932990 2020-01-17

6. The apparatus of any one of claims **1** to **5**, wherein the inner sheet comprises at least one of a plurality of perforations, a mesh, a porous mat, a regular cross-linked structure and an irregular cross-linked structure, wherein the cross-linked structure is made of one of a ferromagnetic metal wire, sponge, and other porous media.

7. The apparatus of any one of claims **1** to **6**, wherein the porous facesheet is configured to attenuate noise.

8. The apparatus of any one of claims **1** to **7**, further comprising the inductive coil, wherein the inductive coil is located at least partly within the cavity and configured to electromagnetically couple to the porous facesheet and the porous inner sheet, wherein the porous facesheet and the porous inner sheet are configured to increase in temperature when electromagnetically coupled to the inductive coil, and wherein the inductive coil is configured to operate at the first resonant frequency and the second resonant frequency.

9. The apparatus of claim **8**, wherein the inductive coil is a first inductive coil, the skin is a first skin, the ferromagnetic porous facesheet comprises a first ferromagnetic metal, and further comprising a second skin and a second inductive coil such that:

the second skin at least partly defines the cavity;

the second skin is comprised of at least one of the first ferromagnetic metal and a second ferromagnetic metal;

the first inductive coil is configured to be electromagnetically coupled to the first skin; and

the second inductive coil is configured to be electromagnetically coupled to the second skin.

10. The apparatus of claim **9**, wherein the second skin is non-porous.

11. The apparatus of any one of claims **1** to **5** , wherein the inner sheet comprises a sound absorber comprising at least one of a fiber bulk absorber, a foam layer, and a porous mat.

12. The apparatus of any one of claims **1** to **11**, wherein the inner sheet is disposed adjacent to the facesheet.

13. The apparatus of claim **12**, wherein the inner sheet is disposed adjacent to the facesheet, wherein the facesheet comprises first openings, wherein the inner sheet comprises second openings, and wherein the first openings and the second openings are misaligned such that at least a portion of the second openings is obscured by a portion of the facesheet.

14. An aircraft comprising the apparatus of any one of claims **1** to **13** and:
a fuselage;
a wing coupled to the fuselage;
an engine coupled to at least one of the wing and the fuselage wherein at least one of the fuselage, the wing, and the engine includes the apparatus.

15. A method comprising:
receiving a skin comprising at least a ferromagnetic porous facesheet, a ferromagnetic porous inner sheet disposed apart from and behind the porous facesheet, and a non-ferromagnetic backsheet, wherein the porous facesheet is made of a first smart susceptor configured to electromagnetically couple with an electromagnetic field at a first resonant frequency to be heated to a first temperature, and wherein the porous inner sheet is made of a second smart susceptor configured to electromagnetically couple with the electromagnetic field at a second resonant frequency to be heated to a second temperature; and
coupling the skin to an engine to form at least a portion of an engine nacelle, wherein at least a portion of the skin forms a flow surface of the engine nacelle.

CA 2932990 2020-01-17

16. The method of claim **15**, further comprising:
installing an inductive coil within a cavity of the engine nacelle;
electrically connecting the inductive coil to a power supply; and
positioning at least a portion of the skin within **1-2** inches of at least a portion of the inductive coil.

17. The method of claim **16**, wherein the skin is a first skin, the inductive coil is a first inductive coil, the ferromagnetic porous facesheet comprises a first ferromagnetic metal, and the method further comprises:
coupling a second skin to the engine, wherein a portion of the second skin is comprised of at least one of the first ferromagnetic metal and a second ferromagnetic metal;
installing a second inductive coil within the cavity of the engine nacelle, wherein at least a portion of the second skin is within **1** foot of at least a portion of the second inductive coil; and
electrically connecting the second inductive coil to one of the power supply and a second power supply.

18. The method of claim **17**, wherein the power supply is a first power supply and the method further comprises connecting the second inductive coil to the second power supply.

19. The method of any one of claims **15** to **18**, wherein the inner sheet is disposed adjacent to the facesheet, wherein the facesheet comprises first openings, wherein the inner sheet comprises second openings, and wherein the first openings and the second openings are misaligned such that at least a portion of the second openings is obscured by a portion of the facesheet.

20. The method of any one of claims **15** to **19**, wherein the inner sheet comprises a sound absorber and is disposed adjacent to the facesheet, and wherein the sound absorber comprises at least one of a fiber bulk absorber, a foam layer, and a porous mat.

21. A method comprising:

moving a vehicle with an engine, wherein the engine includes a nacelle and at least a portion of the nacelle comprises a skin comprising a ferromagnetic porous facesheet, a ferromagnetic porous inner sheet disposed apart from and behind the porous facesheet, and a non-ferromagnetic backsheet, wherein the porous facesheet is made of a first smart susceptor configured to electromagnetically couple with an electromagnetic field at a first resonant frequency to be heated to a first temperature, and wherein the porous inner sheet is made of a second smart susceptor configured to electromagnetically couple with the electromagnetic field at a second resonant frequency to be heated to a second temperature;

flowing air through the porous facesheet; and

attenuating noise by, at least, the flowing of air through the porous facesheet.

22. The method of claim **21**, wherein an opening of the porous facesheet is misaligned with an opening of the porous inner sheet, and wherein the method further comprises flowing air through the porous inner sheet.

23. The method of claim **22**, wherein the inner sheet is ferromagnetic and the method further comprises:

generating the electromagnetic field with an inductive coil;

electromagnetically coupling, with the electromagnetic field, the inductive coil to at least one of the ferromagnetic facesheet and the inner sheet; and

increasing, by electromagnetically coupling the electromagnetic field to at least one of the facesheet and the inner sheet, temperatures of at least one of the facesheet and the inner sheet.

24. The method of any one of claims **21** to **23**, wherein the attenuating noise by the flowing of air through the facesheet comprises attenuating noise generated by the engine.

25. The method of any one of claims **21** to **24**, wherein inner sheet comprises a cross-linked structure.

26. The method of claim **23**, wherein the inner sheet separates the skin into a first compartment and a second compartment and the method further comprises varying the temperature between the first compartment and the second compartment by heating the first smart susceptor to the first temperature and the second smart susceptor to the second temperature.

27. An apparatus comprising:

a portion of a nacelle comprising a skin, wherein:

at least a portion of the skin is porous, wherein the portion of the skin that is porous is configured to attenuate noise;

at least a portion of the skin forms a flow surface of the nacelle;

the skin at least partly defines a cavity;

the portion of the skin that is porous comprises a porous facesheet and the skin further comprises a backsheet coupled to the porous facesheet; and

the apparatus further comprises an inductive coil located at least partly within the cavity and configured to be electromagnetically coupled to the skin, wherein the skin is configured to increase in temperature when electromagnetically coupled to the inductive coil,

characterized in that the skin is comprised of a ferromagnetic metal, wherein the skin further comprises a ferromagnetic metal component, at least partly comprised of the ferromagnetic metal, disposed between the facesheet and the backsheet.

28. The apparatus of claim **27**, wherein the ferromagnetic metal component is a septum.

29. The apparatus of claim **28**, wherein the porous facesheet is one of comprised of and coated with the ferromagnetic metal and at least a portion of the skin is located on a leading edge of the nacelle.

30. The apparatus of claim **28** or **29**, wherein the skin further comprises a support component between the porous facesheet and the backsheet, wherein the support component comprises a honeycomb.

31. The apparatus of any one of claims **27** to **30**, wherein the portion of the skin that is porous comprises at least one of a plurality of perforations, a mesh, a porous mat, and one of a regular cross-linked structure and an irregular cross-linked structure, wherein the cross-linked structure is made of one of a ferromagnetic metal wire, sponge, and other porous media.

32. The apparatus of any one of claims **27** to **31**, wherein the inductive coil is a first inductive coil and the apparatus further comprises a second inductive coil located at least partly within the cavity.

33. The apparatus of claim **32**, wherein the skin is a first skin, the ferromagnetic metal is a first ferromagnetic metal, and further comprising a second skin such that:

the second skin at least partly defines the cavity;

the second skin is comprised of at least one of the first ferromagnetic metal and a second ferromagnetic metal;

the first inductive coil is configured to be electromagnetically coupled to the first skin; and

the second inductive coil is configured to be electromagnetically coupled to the second skin, wherein the second skin is non-porous.

Date Reçue/Date Received 2020-04-30

34. The apparatus of any one of claims **27** to **33**, further comprising a support structure within the nacelle, wherein the support structure partly defines the cavity and the skin is located forward of the support structure.

35. An aircraft comprising the apparatus of any one of claims **27** to **34**.

36. A method comprising:
receiving a skin comprising at least a porous facesheet and a backsheet, wherein at least a portion of the skin is comprised of a ferromagnetic metal; and coupling the skin to an engine to form at least a portion of an engine nacelle, wherein at least a portion of the skin forms a flow surface of the engine nacelle;
installing an inductive coil within a cavity of the engine nacelle; and
electrically connecting the inductive coil to a power supply,
wherein the skin further comprises a ferromagnetic metal component, at least partly comprised of the ferromagnetic metal, disposed between the facesheet and the backsheet.

37. The method of claim **36**, further comprising positioning at least a portion of the skin within **1** to **2** inches of at least a portion of the inductive coil.

38. The method of claim **37**, wherein the skin is a first skin, the inductive coil is a first inductive coil, the ferromagnetic metal is a first ferromagnetic metal, and the method further comprises:
coupling a second skin to the engine, wherein a portion of the second skin is comprised of at least one of the first ferromagnetic metal and a second ferromagnetic metal;
installing a second inductive coil within the cavity of the engine nacelle, wherein at least a portion of the second skin is within **1** foot of at least a portion of the second inductive coil; and
electrically connecting the second inductive coil to one of the power supply and a second power supply.

39. The method of claim **38**, wherein the power supply is a first power supply and the method further comprises connecting the second inductive coil to the second power supply.

40. A method comprising:
moving a vehicle with an engine, wherein the engine includes a nacelle and at least a portion of the nacelle comprises a skin;
flowing air through a porous portion of the skin, wherein the skin is comprised of a ferromagnetic metal; and
attenuating noise by, at least, the flowing of air through the porous portion of the skin,
wherein the skin further comprises a porous facesheet and a backsheet and flowing air through the porous portion of the skin comprises flowing air through the porous facesheet, and
wherein the skin further comprises a ferromagnetic metal component, at least partly comprised of the ferromagnetic metal, disposed between the facesheet and the backsheet and the method further comprises:
generating an electromagnetic field with an inductive coil;
electromagnetically coupling, with the electromagnetic field, the inductive coil to the ferromagnetic metal component; and
increasing, by electromagnetically coupling the inductive coil to the ferromagnetic metal component, a temperature of the ferromagnetic metal component.

41. The method of claim **40**, wherein the ferromagnetic metal component is porous and the method further comprises flowing air through the ferromagnetic metal component,
wherein the ferromagnetic metal component is located between the facesheet and the backsheet and separates the skin into a first compartment and a second

compartment, and the method further comprises varying the temperature between the first compartment and the second compartment.

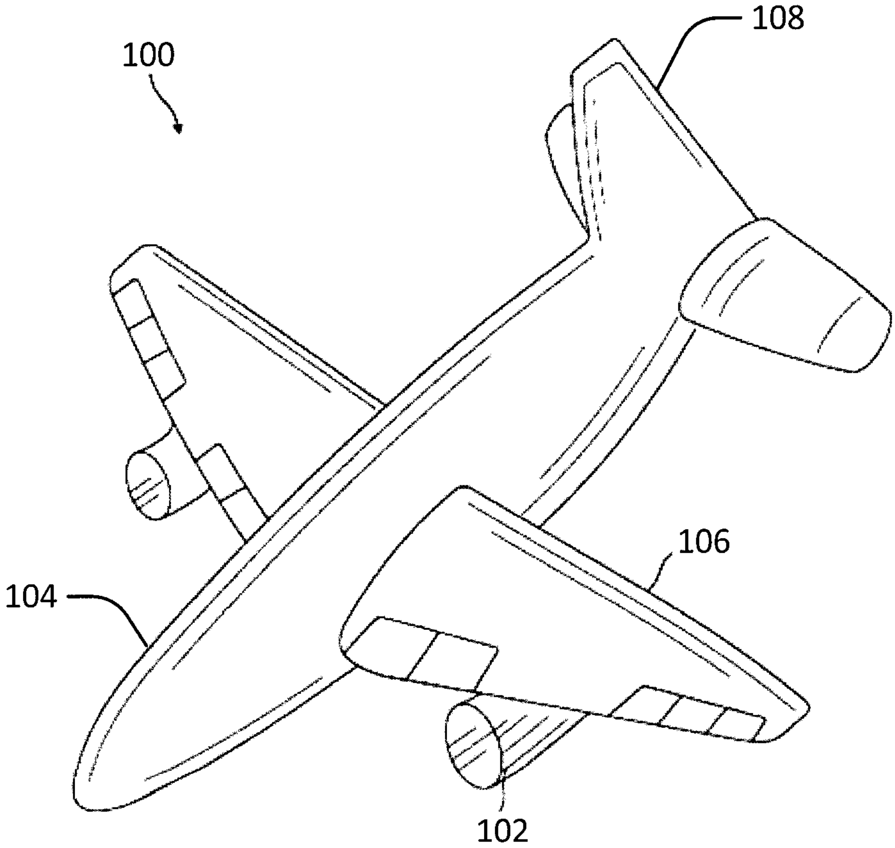


FIG. 1

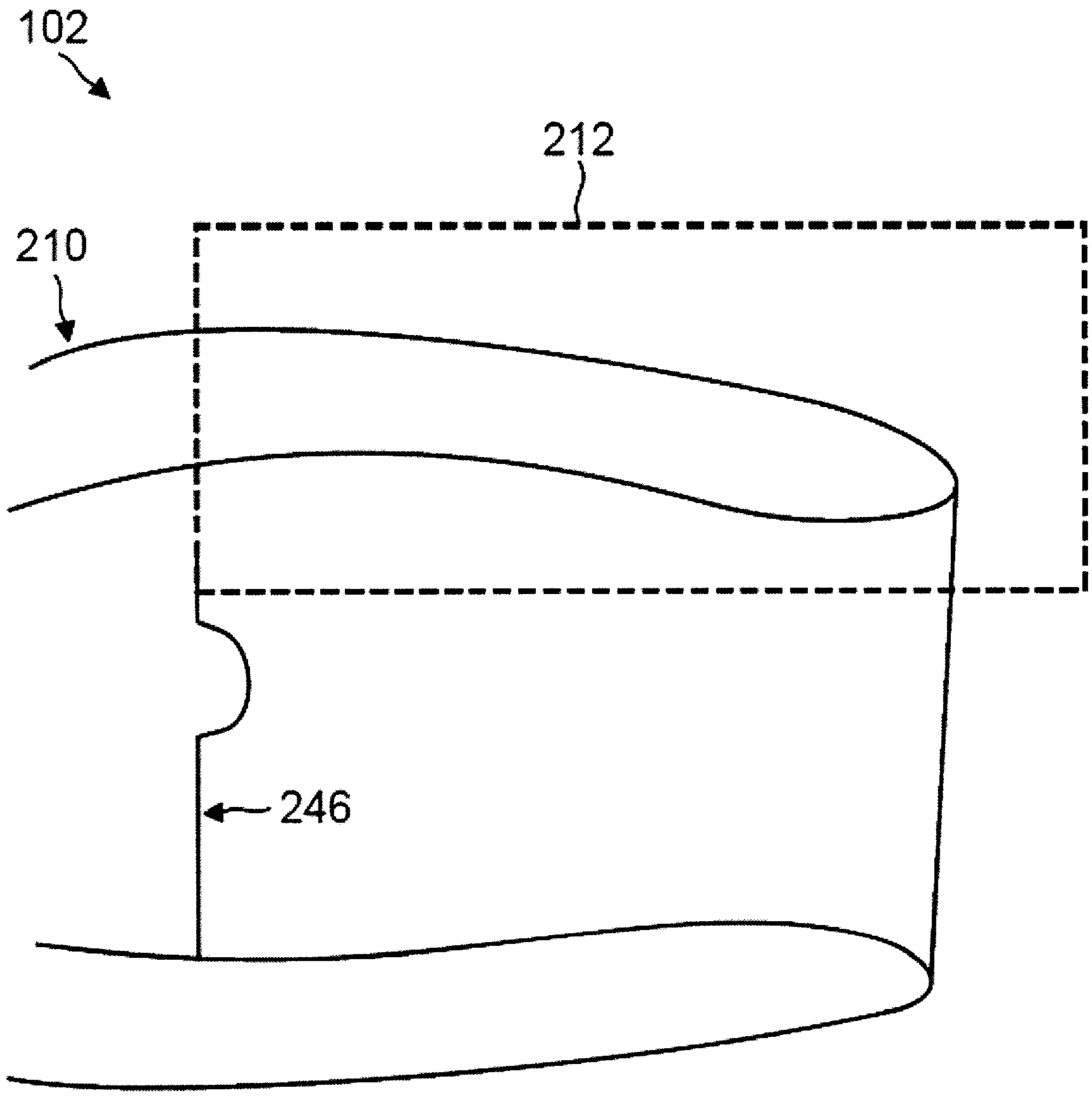
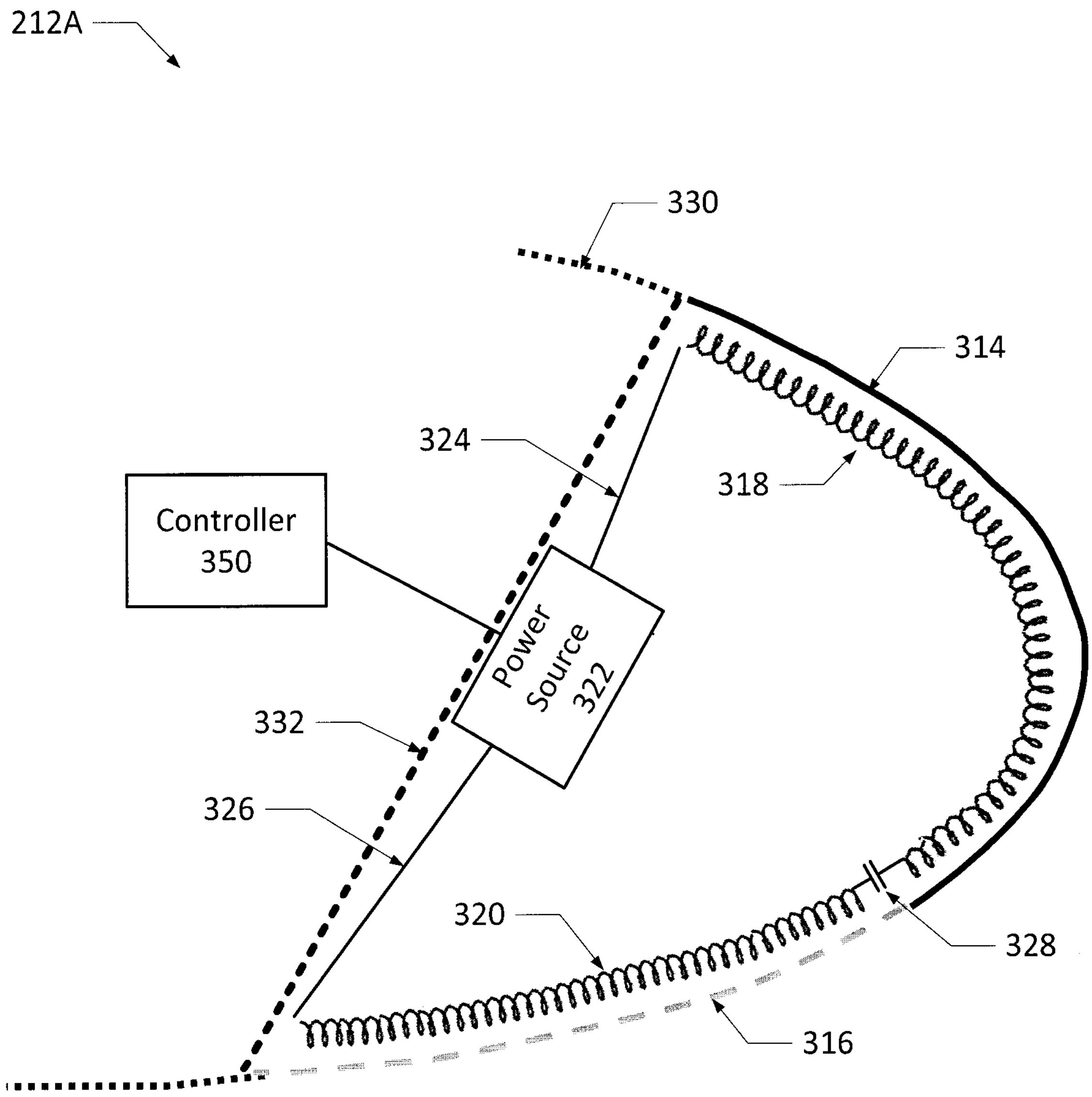


FIG. 2



212A
330
314
324
318
Controller
350
Power
Source
322
332
326
320
328
316

FIG. 3A

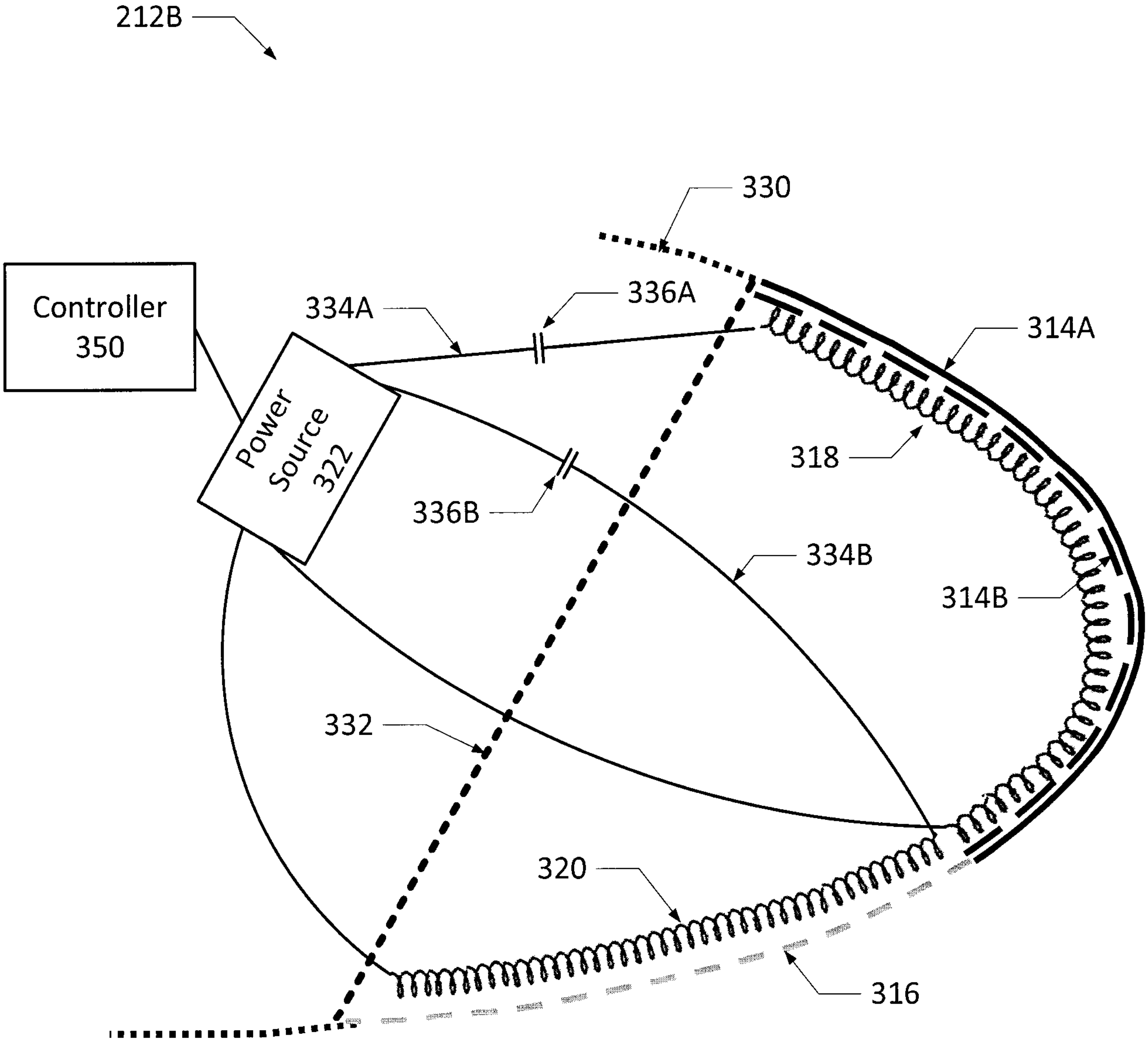

212B
330
Controller
350
334A
336A
314A
Power
Source
322
318
336B
334B
314B
332
320
316

FIG. 3B

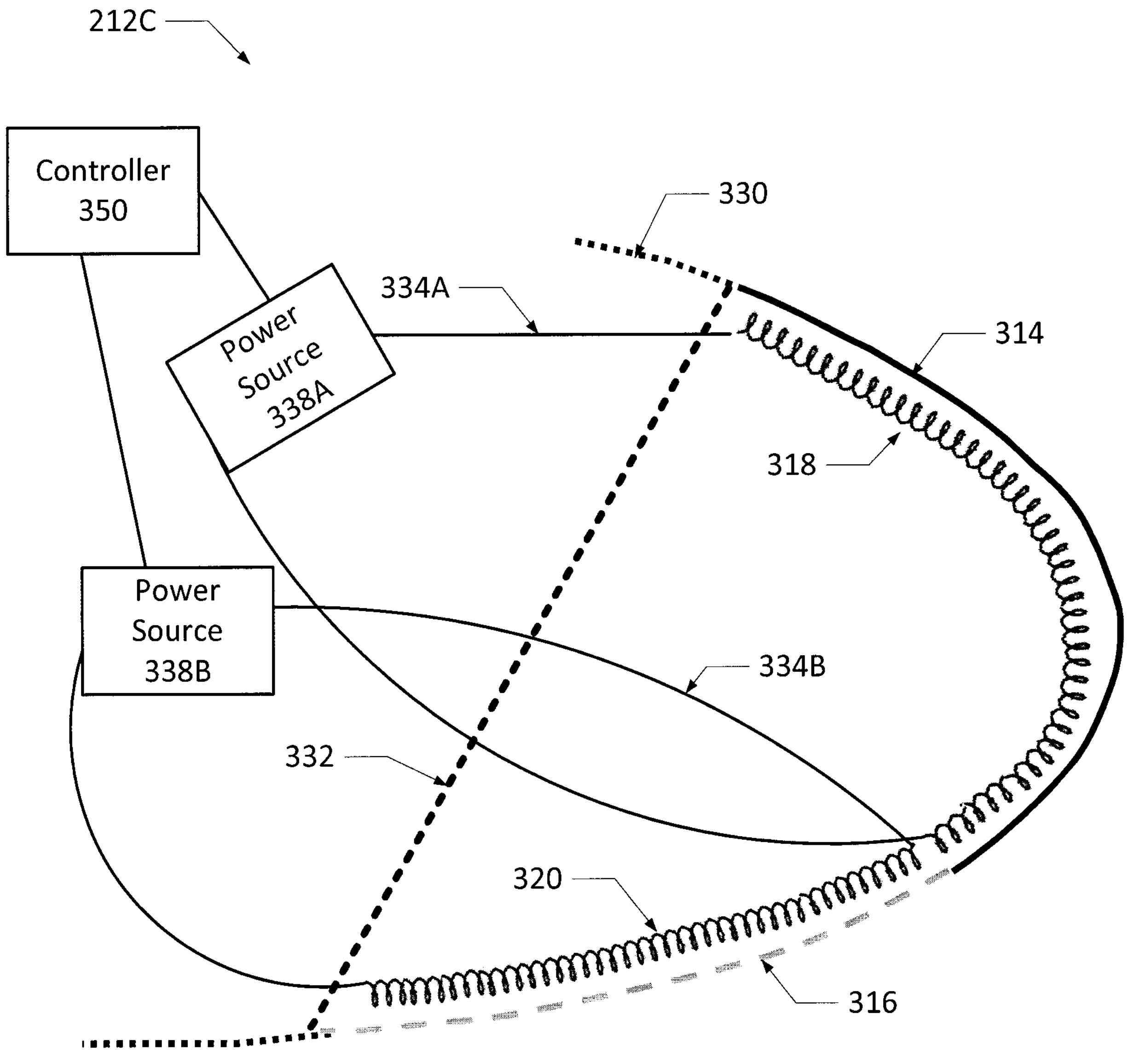

212C
Controller
350
Power
Source
338A
Power
Source
338B
330
334A
314
318
334B
332
320
316

FIG. 3C

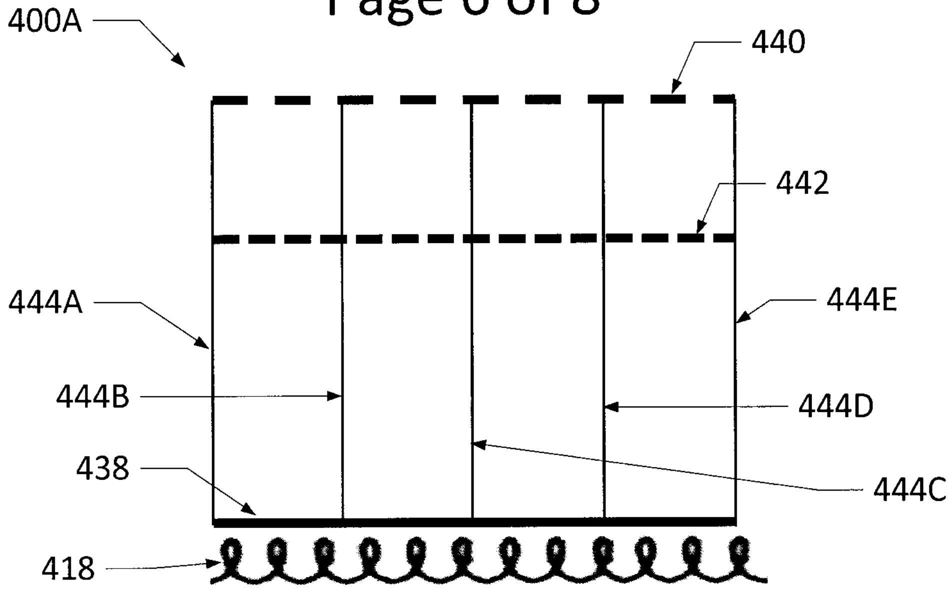


FIG. 4A

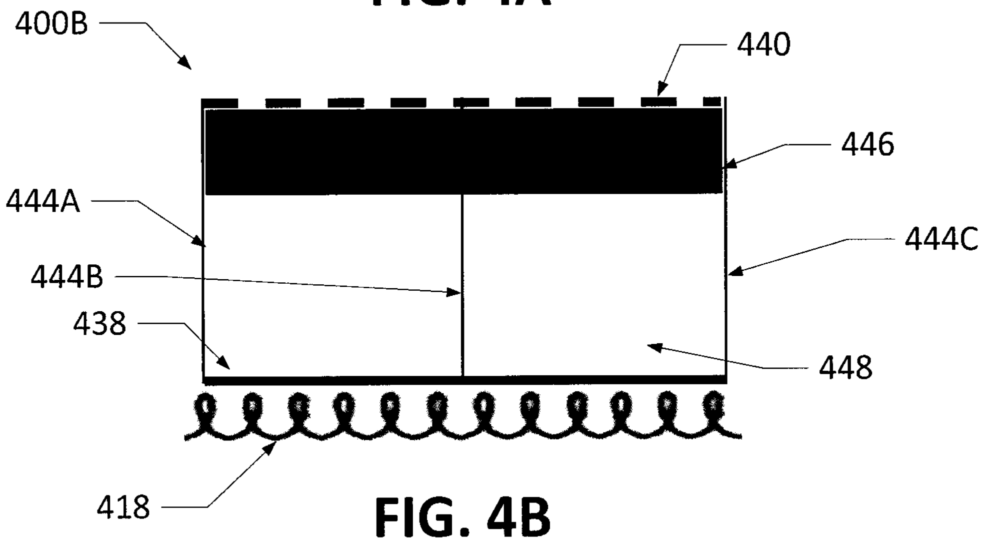


FIG. 4B

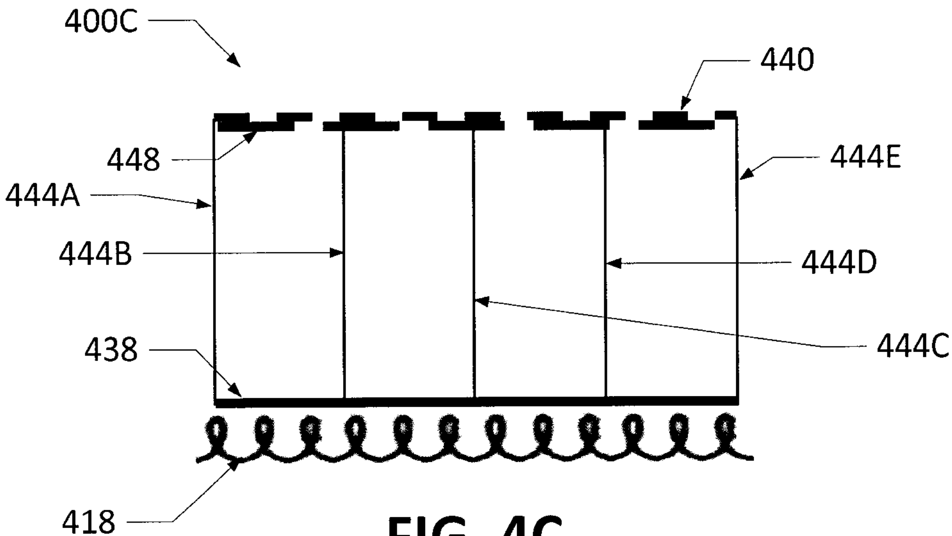


FIG. 4C

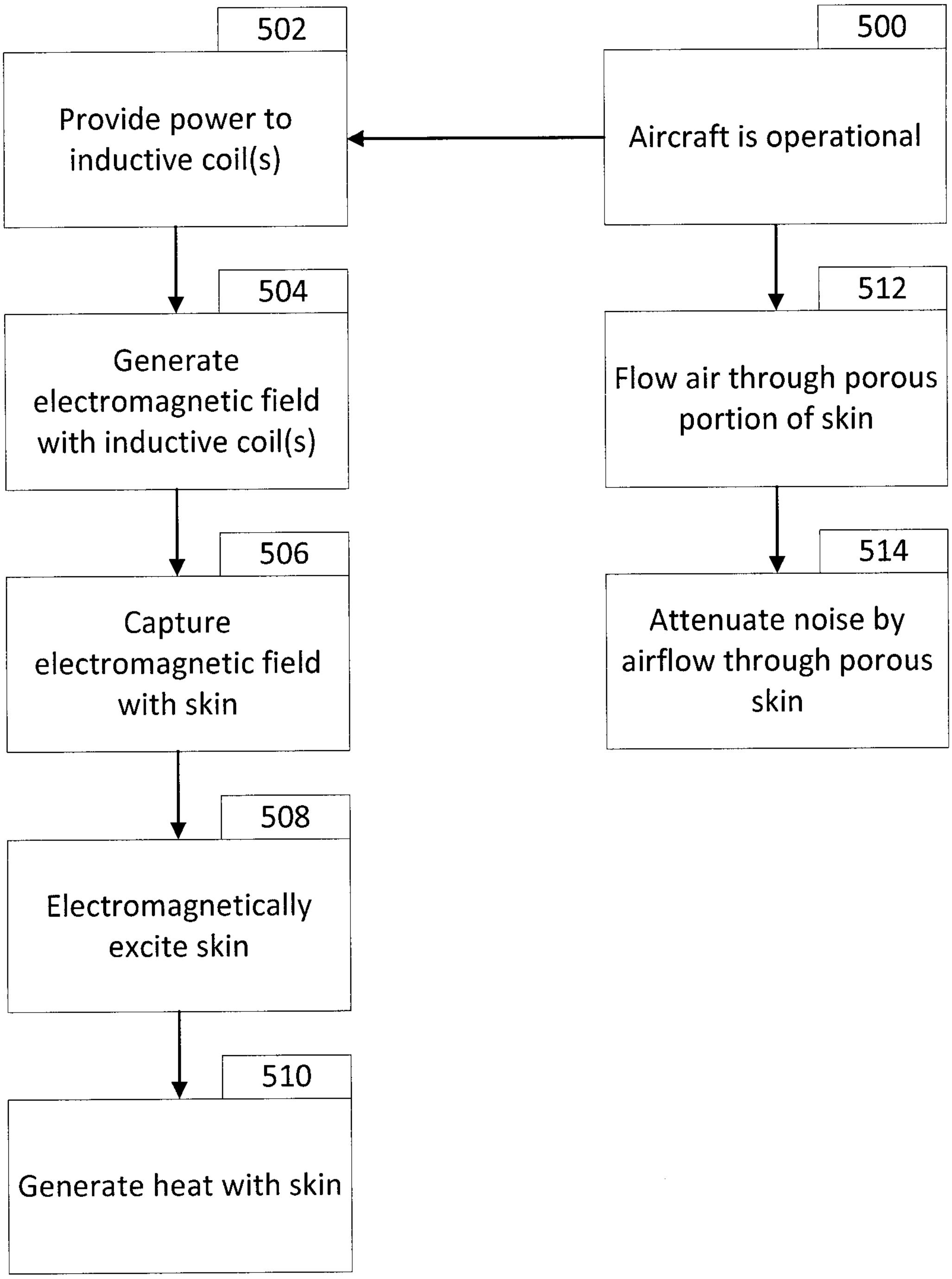

502
Provide power to inductive coil(s)
500
Aircraft is operational
504
Generate electromagnetic field with inductive coil(s)
512
Flow air through porous portion of skin
506
Capture electromagnetic field with skin
514
Attenuate noise by airflow through porous skin
508
Electromagnetically excite skin
510
Generate heat with skin

FIG. 5

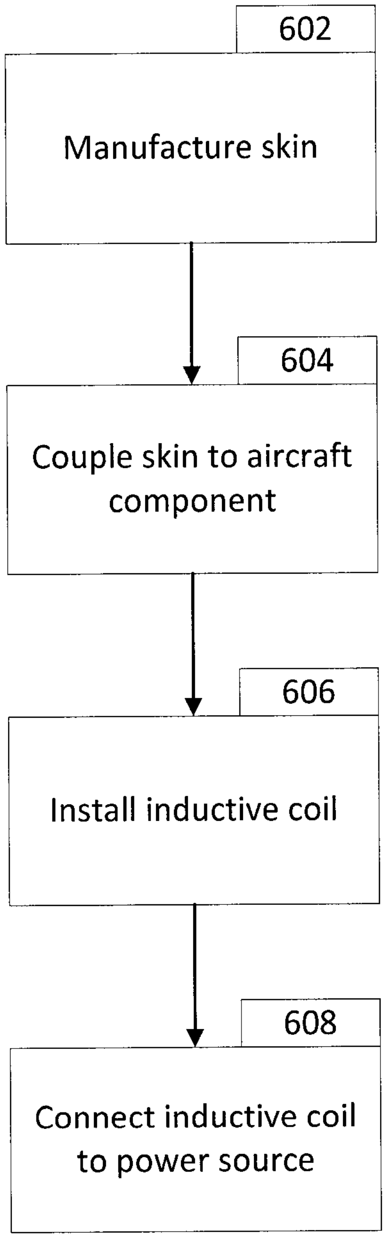
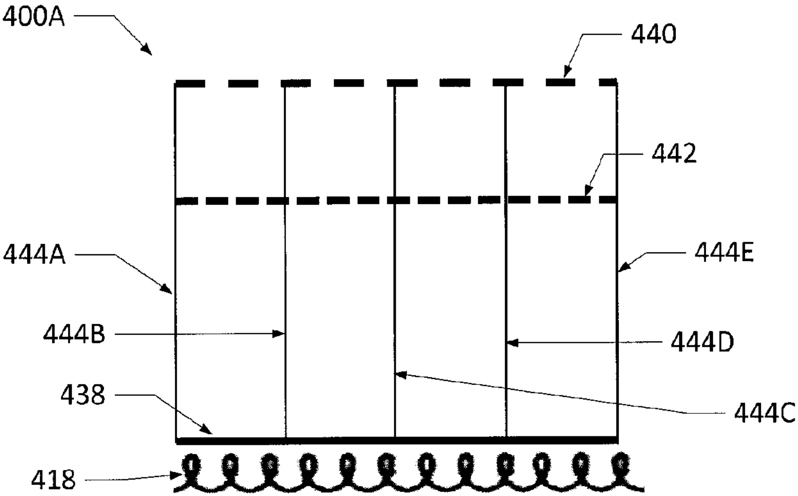

602
Manufacture skin
604
Couple skin to aircraft component
606
Install inductive coil
608
Connect inductive coil to power source

FIG. 6


400A
440
442
444A
444E
444B
444D
444C
438
418