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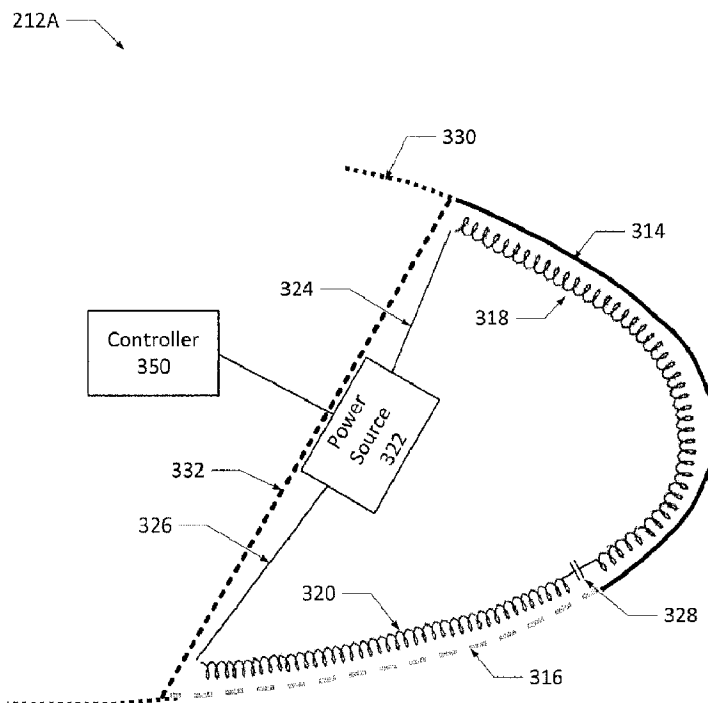
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(54) Title: SYNERGETIC NOISE ABSORPTION AND ANTI-ICING FOR AIRCRAFTS



(57) **Abrégé/Abstract:**

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(57) **Abrégé(suite)/Abstract(continued):**

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
5 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
10 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

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

BACKGROUND

10 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
15 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.

20 SUMMARY

 In one embodiment, there is provided an apparatus. The apparatus includes a first skin of an aircraft. The first skin includes a porous facesheet, a backsheet, a porous septum disposed between the porous facesheet and the backsheet, and a first air volume disposed between the porous facesheet and the porous septum. The first
25 skin further includes a second air volume disposed between the porous septum and the backsheet, wherein the porous septum is configured to attenuate noise by changing a speed of sound and/or an air pressure around a vicinity of the porous septum via increasing a temperature of the porous septum. The apparatus further

includes an inductive coil configured to be electromagnetically coupled to the porous facesheet and the porous septum to increase a temperature of the porous facesheet and the porous septum due to the electromagnetic coupling, wherein the inductive coil is configured to operate at a first frequency to heat the porous facesheet and operate
5 at a second frequency to heat the porous septum. The apparatus further includes a non-porous second skin of the aircraft, wherein: the non-porous second skin comprises a first ferromagnetic metal, and the non-porous second skin at least partly defines a cavity.

The apparatus may include a power supply configured to provide power to the
10 inductive coil, and a capacitor disposed separate from the power supply and electrically coupled to the inductive coil.

The inductive coil may be a first inductive coil and may further include a second inductive coil located at least partly within the cavity and configured to be electromagnetically coupled to the non-porous second skin to increase a temperature
15 of the non-porous second skin due to the electromagnetic coupling.

The first inductive coil and the second inductive coil may be connected in series. The capacitor may be coupled between the first inductive coil and the second inductive coil. The first inductive coil and the first skin may form a first system. The second inductive coil and the non-porous second skin may form a second system.
20 The capacitor may be configured to affect an amount of current flowing from the power supply through the first inductive coil and the second inductive coil such that resonant frequencies of the first system and the second system have values within a preferred resonant frequency range.

The apparatus may include a controller communicatively coupled to the power
25 supply. The controller may be configured to determine a preferred power supply frequency of the power supply, wherein impedance within the first inductive coil and/or the second inductive coil is near a minimum when the power supply is operating at the preferred power supply frequency, and cause the power supply to operate at the preferred power supply frequency.

The capacitor may be a first capacitor and the apparatus may further include a second capacitor. The first inductive coil and the second inductive coil may be connected in parallel. The first capacitor may electrically coupled to the first inductive coil to form a first electrical system. The second capacitor may electrically coupled to
5 the second inductive coil to form a second electrical system. The first electrical system and the second electrical system may be configured to be substantially equal in impedance.

The power supply may be a first power supply configured to provide power to the first inductive coil and further may include a second power supply configured to
10 provide power to the second inductive coil.

In another embodiment, there is provided a method of using the apparatus described above. The method involves powering the first and the second inductive coils, generating electromagnetic fields with the first and the second inductive coils, electromagnetically coupling the first inductive coil to the first skin, electromagnetically
15 coupling the second inductive coil to the non-porous second skin, and increasing, by the electromagnetically couplings, the temperature of the first skin and the non-porous second skin of the aircraft.

The porous facesheet may include a second ferromagnetic metal and the porous septum may include a third ferromagnetic metal.

20 The apparatus may include a power supply configured to provide power to the inductive coil, and a controller configured to provide instructions for the power supply to provide power to the inductive coil to operate at the first frequency and the second frequency.

The controller may be configured to operate the inductive coil at the first
25 frequency to heat the first air volume and operate the inductive coil at the second frequency to heat the first air volume and the second air volume to change the speed of sound and/or the air pressure around the vicinity of the porous septum.

The porous septum may be configured to allow air to flow from one side of the porous septum to another side of the porous septum.

30 The porous facesheet may define a flow surface of a nacelle of the aircraft.

In another embodiment, there is provided an aircraft including the apparatus described above. The aircraft may include a fuselage, a wing coupled to the fuselage, and an engine coupled to the wing, the fuselage, or both, wherein at least one of the fuselage, the wing, or the engine comprises the apparatus.

5 In another embodiment, there is provided a method. The method involves powering, with a power supply, a first inductive coil and a second inductive coil, generating a first electromagnetic field with the first inductive coil and a second electromagnetic field with the second inductive coil, and electromagnetically coupling, with the first electromagnetic field, the first inductive coil to a first skin of an aircraft.
10 The first skin includes a porous facesheet, a backsheet, a porous septum disposed between the porous facesheet and the backsheet, and a first air volume disposed between the porous facesheet and the porous septum. The first skin further includes a second air volume disposed between the porous septum and the backsheet, wherein the porous septum is configured to attenuate noise by changing a speed of
15 sound and/or an air pressure around a vicinity of the porous septum via increasing a temperature of the porous septum. The method further involves increasing, by electromagnetically coupling the first inductive coil to the porous facesheet or the porous septum, a temperature of the porous facesheet or the porous septum, wherein the first inductive coil is configured to operate at a first frequency to heat the porous
20 facesheet and operate at a second frequency to heat the porous septum. The method further involves electromagnetically coupling, with the second electromagnetic field, the second inductive coil to a non-porous second skin of an aircraft, wherein the non-porous second skin comprises a non-porous portion, and increasing, by electromagnetically coupling the second inductive coil to the non-porous second skin
25 of the aircraft, a temperature of the non-porous second skin of the aircraft.

The method may involve one or both of melting, by increasing the temperature of the porous facesheet, ice on the porous facesheet and/or melting, by increasing the temperature of the non-porous second skin of the aircraft, ice on the non-porous second skin of the aircraft, and preventing, by increasing the temperature of the porous facesheet, formation of ice on the porous facesheet and/or preventing, by increasing the temperature of the non-porous second skin of the aircraft, formation of ice on the non-porous second skin of the aircraft.

The first inductive coil and the first skin of the aircraft may be a first heating system and providing power to the first inductive coil may include providing power to the first inductive coil such that the first heating system is operating substantially at a resonant frequency of the porous facesheet or the porous septum.

The second inductive coil and the non-porous second skin of the aircraft may be a second heating system and providing power to the second inductive coil may include providing power to the second inductive coil such that the second heating system is operating substantially at a second resonant frequency of the second heating system.

Power may be periodically provided to the first and/or the second inductive coil according to a power providing schedule and the method may involve determining, before providing power to the first and/or the second inductive coil, ice build-up on the first or non-porous second skin of the aircraft.

The method may involve detecting at least one environmental factor, and determining the power providing schedule, wherein the at least one environmental factor is a factor in determining the power providing schedule.

A more complete understanding of the disclosure will be afforded to those skilled in the art, by a consideration of the following detailed description of one or more implementations. 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.

5 Figs. 3A-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. 4A-C illustrate various example skin configurations in accordance with the disclosure.

10 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.

15 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.

20

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
 5 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
 10 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
 15 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.

20 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
 25 **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.

5 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.

10 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**.

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

20 The examples of the inductive coil anti-icing systems described in Figs. 3A-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
25 abatement.

Note that while Figs. 3A-C illustrate a cutaway of a portion of an engine nacelle, the various components illustrated in Figs. 3A-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. 3A 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 **212A** of Fig. 3A 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, 5 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 10 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, 15 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, packaging, reliability, etc.). The ferromagnetic metal may be a smart susceptor that may be tuned to be heated to specific temperatures when 20 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 25 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 30 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 backsheets. The facesheet and the backsheets 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 backsheets 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. 4A-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. **3A**, 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. 3A, a capacitor **328** may be installed within the electrical connection connecting the first inductive coil **320** and the
5 second inductive coil **318**.

The example shown in Fig. 3A 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
10 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
15 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.

20 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
25 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. 3B 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. 3A to the engine nacelle leading edge **212A**, engine nacelle leading edge **212B** of Fig.

3B 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. **3A**, the first inductive coil **320** and the second inductive **318** may be coupled in parallel to the power source **322**. Electrical connector **334A** may be coupled to the power source **322** and the second inductive coil **318**. Electrical connector **334B** may be coupled to the power source **322** and the first inductive coil **320**. The electrical connector **334A** may include a capacitor **336A** and an electrical connector **334B** may include the capacitor **336B**. The first inductive coil **320** and the capacitor **336B** may form a first system. The second inductive coil **318** and the capacitor **336A** may form a second system. The capacitors **336A** and **336B** 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. **3C** 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 **212C** of Fig. **3C** may also be similar to the engine nacelle leading edge **212A** of Fig. **3A**. However, where Fig. **3A** includes one power source, the example of the inductive coil anti-icing and noise absorption system in Fig. **3C** includes two power sources; power sources **338A** and **338B**. The power source **338A** may be coupled to the first inductive coil **320** via the electrical connector **334B** while the power source **338B** may be coupled to the second inductive coil **318** via the electrical connector **334A**.

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
5 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. **3A-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.
10 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. **3A-C** as an example, one inductive coil may be electromagnetically coupled to both the first skin **316** and the second skin **314**).

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

Skin **400A** in Fig. **4A** is such a skin configuration. The skin **400A** includes a backsheet **438**, a facesheet **440**, a septum **442**, and support components **444A-E**.
20 Additionally, Fig. **4A** also includes an inductive coil **418** to illustrate a possible position of an inductive coil if the skin **400A** 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
25 **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 **444A-E** may additionally aid in supporting the facesheet **440**. In various

examples, the support components **444A-E** may be structural materials such as walls and/or honeycombs that may lend additional stiffness to the skin **400A**.

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
5 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**.

10 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.

15 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
20 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).

25 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.

- 5 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. **4A** 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
10 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
15 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
20 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
25 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 **400A** in Fig. **4A**, skin **400B** in Fig. **4B** may be another skin configuration. Skin **400B** may include the backsheet **438**, the facesheet **440**, the inductive coil **418**, and the support components **444A-C**, all of which may be similar to

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

In addition, the skin **400C** 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 **400C** 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
5 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 **400C**. The insulating layer may aid in the retention of heat
10 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.

15 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
20 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
25 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
5 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
10 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
15 **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
20 the disclosure.

In step **602**, the skin may be manufactured. The skin manufactured may be any version of the skins detailed in Figs. **4A-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
25 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:

5

a first skin of an aircraft, wherein the first skin comprises:

a porous facesheet;

10

a backsheet;

a porous septum disposed between the porous facesheet and the backsheet;

15

a first air volume disposed between the porous facesheet and the porous septum; and

20

a second air volume disposed between the porous septum and the backsheet, wherein the porous septum is configured to attenuate noise by changing a speed of sound and/or an air pressure around a vicinity of the porous septum via increasing a temperature of the porous septum;

25

an inductive coil configured to be electromagnetically coupled to the porous facesheet and the porous septum to increase a temperature of the porous facesheet and the porous septum due to the electromagnetic coupling, wherein the inductive coil is configured to operate at a first frequency to heat the porous facesheet and operate at a second frequency to heat the porous septum; and

30

a non-porous second skin of the aircraft, wherein:

the non-porous second skin comprises a first ferromagnetic metal;
and

5

the non-porous second skin at least partly defines a cavity.

2. The apparatus of claim 1, further comprising:

10

a power supply configured to provide power to the inductive coil; and

a capacitor disposed separate from the power supply and electrically
coupled to the inductive coil.

15

3. The apparatus of claim 2, wherein the inductive coil is a first inductive coil and
further comprising a second inductive coil located at least partly within the cavity
and configured to be electromagnetically coupled to the non-porous second skin
to increase a temperature of the non-porous second skin due to the
electromagnetic coupling.

20

4. The apparatus of claim 3, wherein:

the first inductive coil and the second inductive coil are connected in series;

25

the capacitor is coupled between the first inductive coil and the second
inductive coil;

the first inductive coil and the first skin form a first system;

the second inductive coil and the non-porous second skin form a second system; and

5 the capacitor is configured to affect an amount of current flowing from the power supply through the first inductive coil and the second inductive coil such that resonant frequencies of the first system and the second system have values within a preferred resonant frequency range.

10 5. The apparatus of claim 4, further comprising a controller communicatively coupled to the power supply, wherein the controller is configured to:

15 determine a preferred power supply frequency of the power supply, wherein impedance within the first inductive coil and/or the second inductive coil is near a minimum when the power supply is operating at the preferred power supply frequency; and

cause the power supply to operate at the preferred power supply frequency.

20 6. The apparatus of claim 3, wherein the capacitor is a first capacitor and further comprising a second capacitor, wherein:

25 the first inductive coil and the second inductive coil are connected in parallel;

the first capacitor is electrically coupled to the first inductive coil to form a first electrical system;

30 the second capacitor is electrically coupled to the second inductive coil to form a second electrical system; and

the first electrical system and the second electrical system are configured to be substantially equal in impedance.

5 7. The apparatus of claim 3, wherein the power supply is a first power supply configured to provide power to the first inductive coil and further comprising a second power supply configured to provide power to the second inductive coil.

8. A method of using the apparatus of claim 3, the method comprising:

10

powering the first and the second inductive coils;

generating electromagnetic fields with the first and the second inductive coils;

15

electromagnetically coupling the first inductive coil to the first skin;

electromagnetically coupling the second inductive coil to the non-porous second skin; and

20

increasing, by the electromagnetically couplings, the temperature of the first skin and the non-porous second skin of the aircraft.

25 9. The apparatus of claim 1, wherein the porous facesheet comprises a second ferromagnetic metal and the porous septum comprises a third ferromagnetic metal.

10. The apparatus of claim 1, further comprising:

30

a power supply configured to provide power to the inductive coil; and

a controller configured to provide instructions for the power supply to provide power to the inductive coil to operate at the first frequency and the second frequency.

5 **11.** The apparatus of claim **10**, wherein the controller is configured to operate the inductive coil at the first frequency to heat the first air volume and operate the inductive coil at the second frequency to heat the first air volume and the second air volume to change the speed of sound and/or the air pressure around the vicinity of the porous septum.

10

12. The apparatus of claim **1**, wherein the porous septum is configured to allow air to flow from one side of the porous septum to another side of the porous septum.

15 **13.** The apparatus of claim **1**, wherein the porous facesheet defines a flow surface of a nacelle of the aircraft.

14. An aircraft comprising the apparatus of claim **1**, the aircraft further comprising:

a fuselage;

20

a wing coupled to the fuselage; and

an engine coupled to the wing, the fuselage, or both, wherein at least one of the fuselage, the wing, or the engine comprises the apparatus.

25

15. A method comprising:

powering, with a power supply, a first inductive coil and a second inductive coil;

30

generating a first electromagnetic field with the first inductive coil and a second electromagnetic field with the second inductive coil;

5 electromagnetically coupling, with the first electromagnetic field, the first inductive coil to a first skin of an aircraft, wherein the first skin comprises:

a porous facesheet;

10 a backsheet;

a porous septum disposed between the porous facesheet and the backsheet;

15 a first air volume disposed between the porous facesheet and the porous septum; and

20 a second air volume disposed between the porous septum and the backsheet, wherein the porous septum is configured to attenuate noise by changing a speed of sound and/or an air pressure around a vicinity of the porous septum via increasing a temperature of the porous septum;

25 increasing, by electromagnetically coupling the first inductive coil to the porous facesheet or the porous septum, a temperature of the porous facesheet or the porous septum, wherein the first inductive coil is configured to operate at a first frequency to heat the porous facesheet and operate at a second frequency to heat the porous septum;

electromagnetically coupling, with the second electromagnetic field, the second inductive coil to a non-porous second skin of an aircraft, wherein the non-porous second skin comprises a non-porous portion; and

5 increasing, by electromagnetically coupling the second inductive coil to the non-porous second skin of the aircraft, a temperature of the non-porous second skin of the aircraft.

16. The method of claim 15, further comprising one or both of:

10

melting, by increasing the temperature of the porous facesheet, ice on the porous facesheet and/or melting, by increasing the temperature of the non-porous second skin of the aircraft, ice on the non-porous second skin of the aircraft; and

15

preventing, by increasing the temperature of the porous facesheet, formation of ice on the porous facesheet and/or preventing, by increasing the temperature of the non-porous second skin of the aircraft, formation of ice on the non-porous second skin of the aircraft.

20

17. The method of claim 15, wherein the first inductive coil and the first skin of the aircraft is a first heating system and providing power to the first inductive coil comprises providing power to the first inductive coil such that the first heating system is operating substantially at a resonant frequency of the porous facesheet or the porous septum.

25

18. The method of claim 17, wherein the second inductive coil and the non-porous second skin of the aircraft is a second heating system and providing power to the second inductive coil comprises providing power to the second inductive coil

such that the second heating system is operating substantially at a second resonant frequency of the second heating system.

5 **19.** The method of claim **15**, wherein power is periodically provided to the first and/or the second inductive coil according to a power providing schedule and the method further comprises determining, before providing power to the first and/or the second inductive coil, ice build-up on the first or non-porous second skin of the aircraft.

10 **20.** The method of claim **19**, further comprising:

detecting at least one environmental factor; and

15 determining the power providing schedule, wherein the at least one environmental factor is a factor in determining the power providing schedule.

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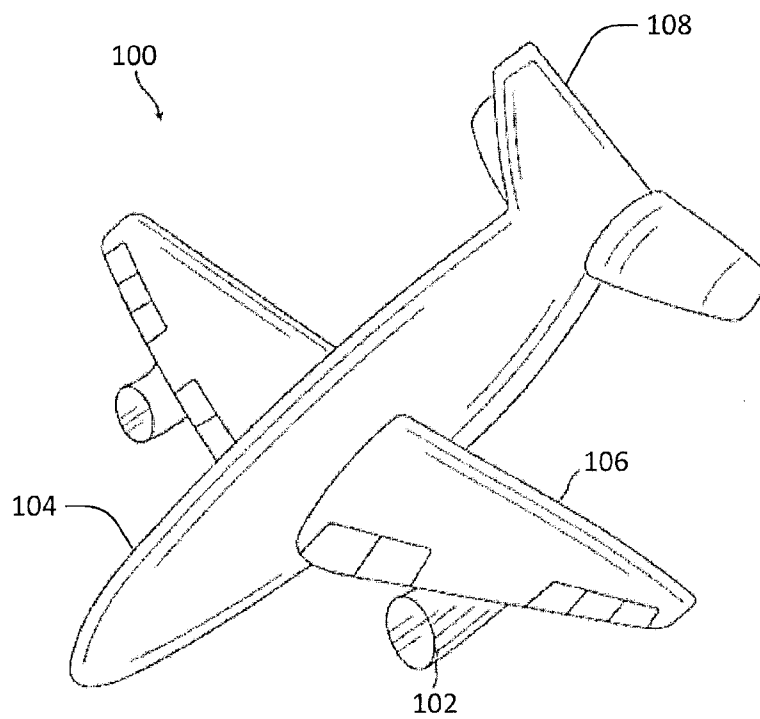


FIG. 1

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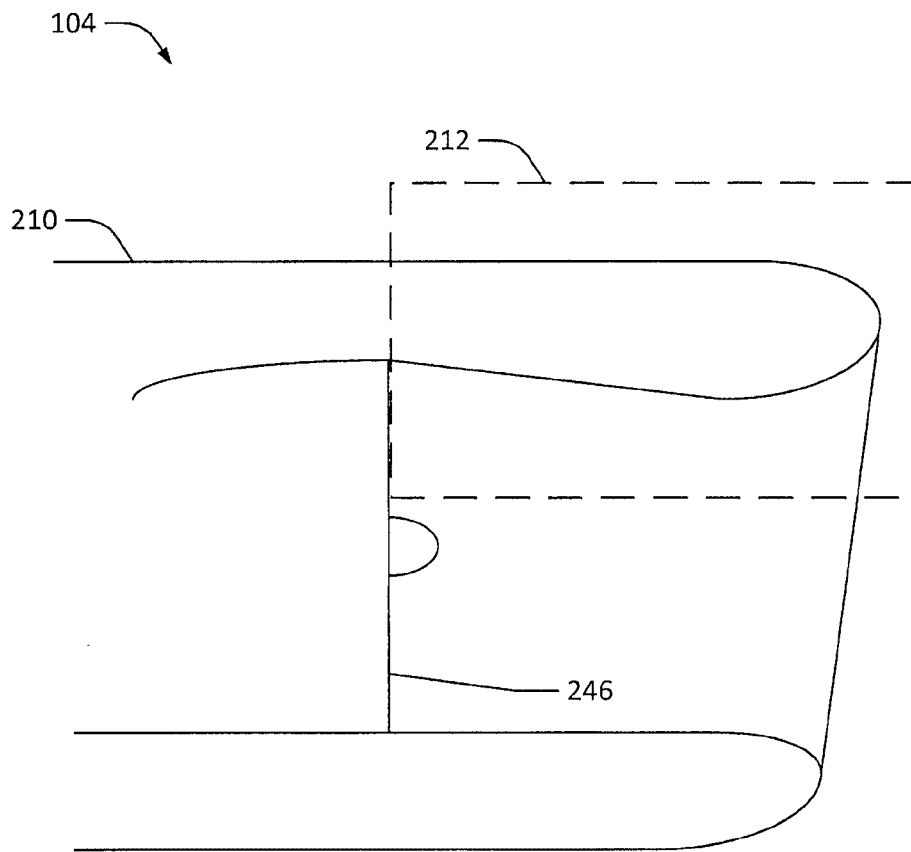


FIG. 2

212A

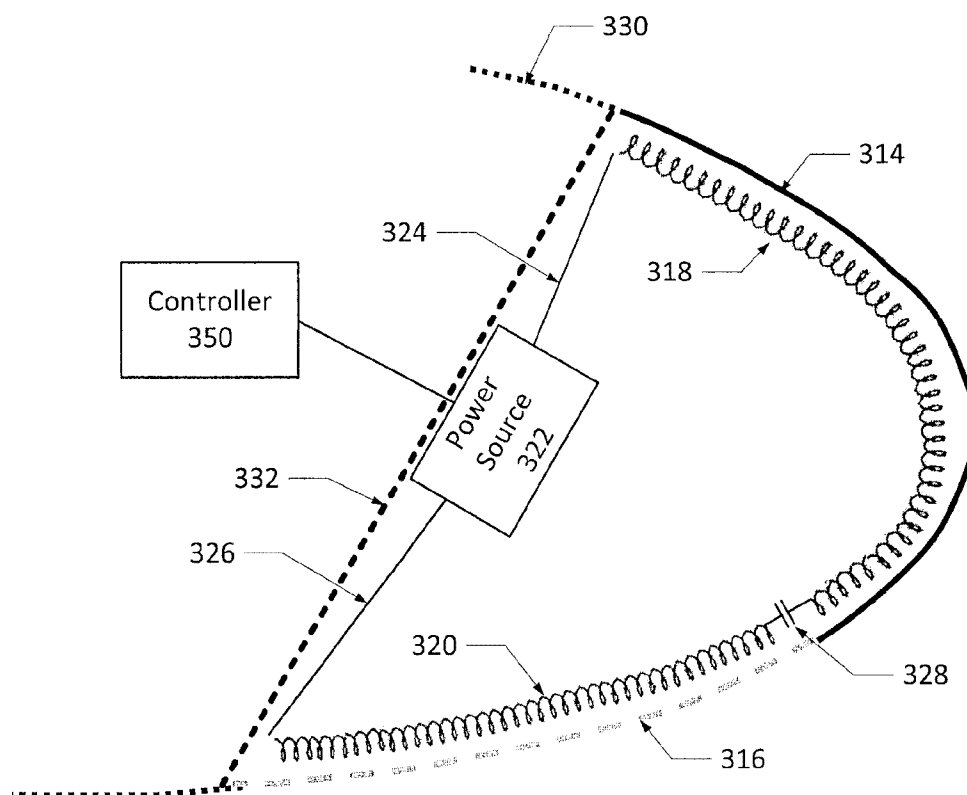


FIG. 3A



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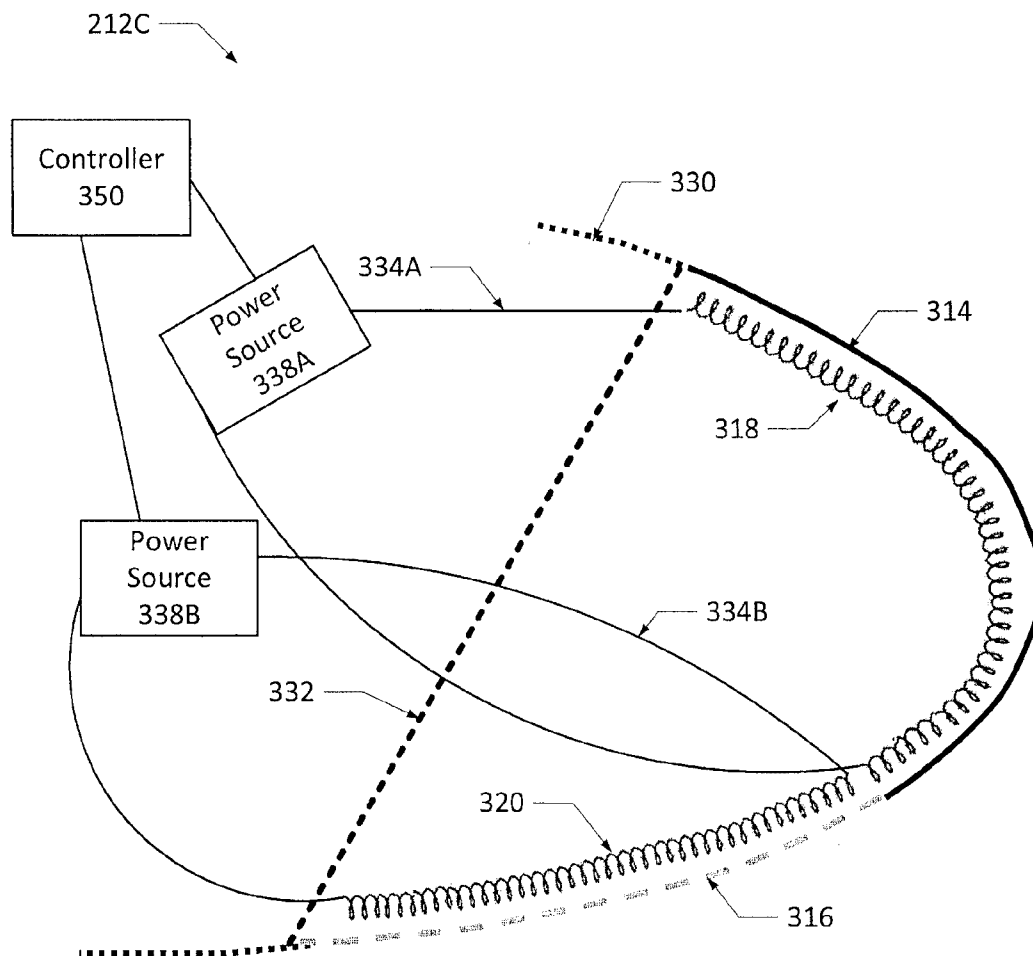


FIG. 3C

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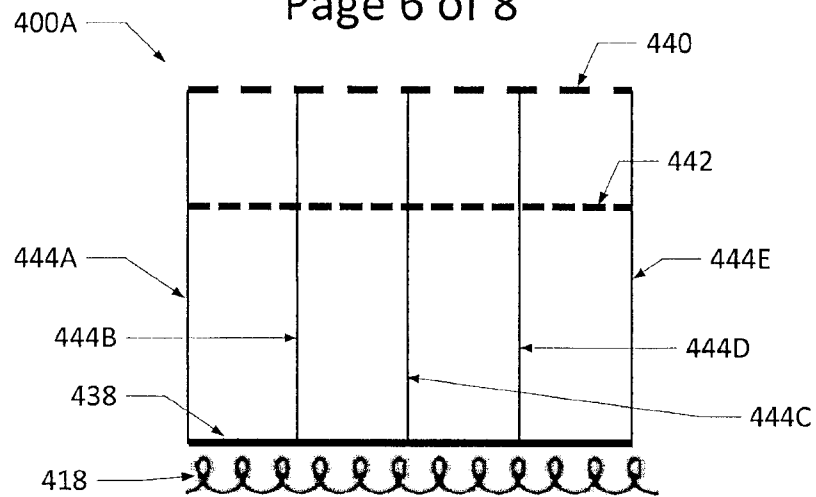


FIG. 4A

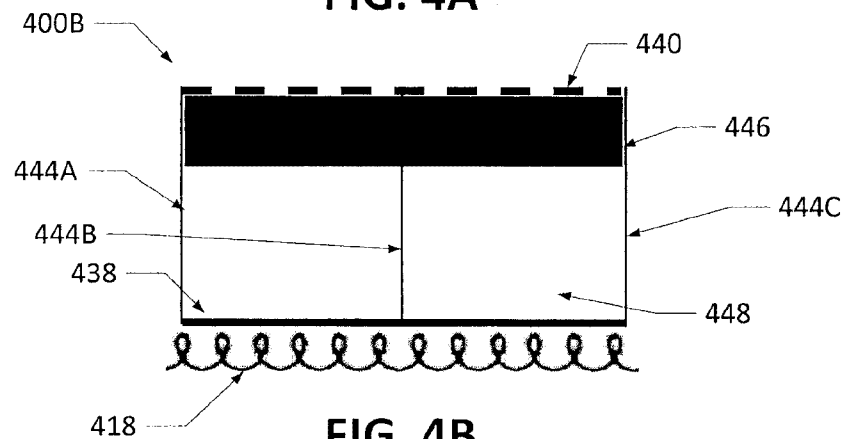


FIG. 4B

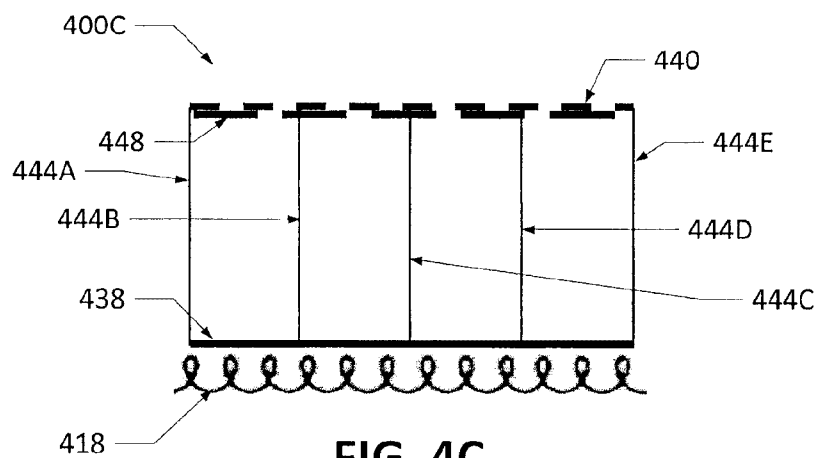


FIG. 4C

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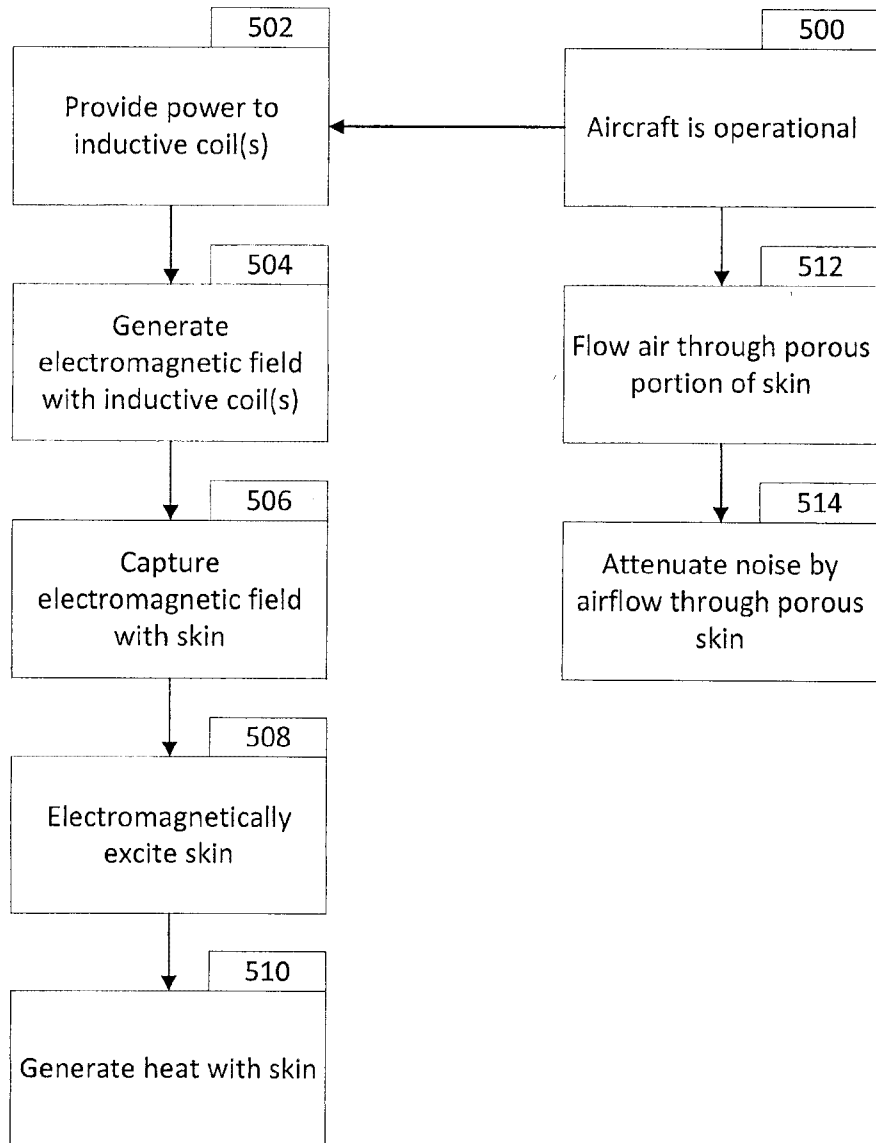


FIG. 5

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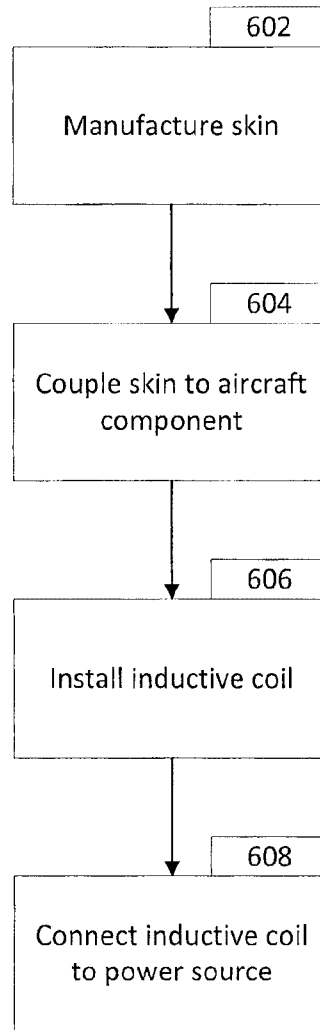


FIG. 6

212A — 

