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(54) **LOW NOISE INCUBATORS**

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G10K 11/175 (2006.01)

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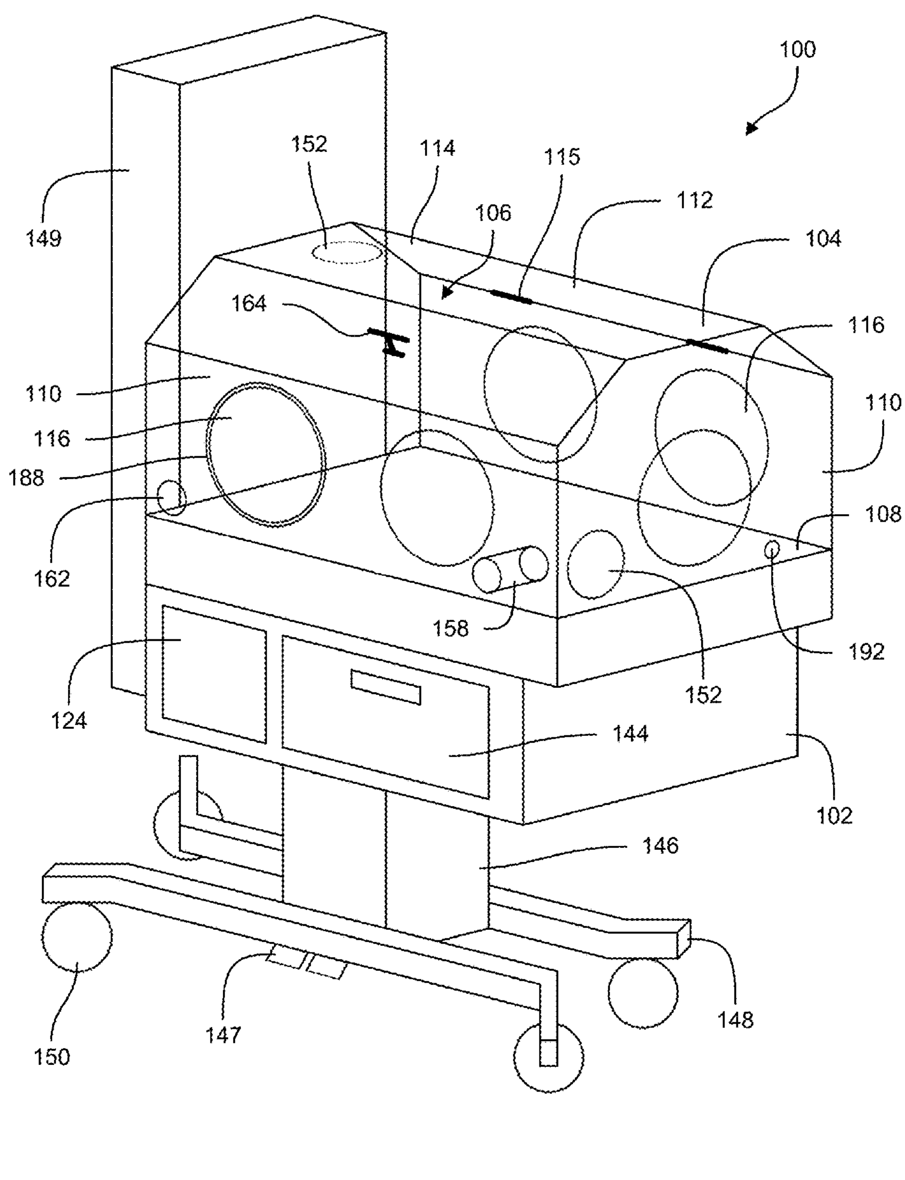
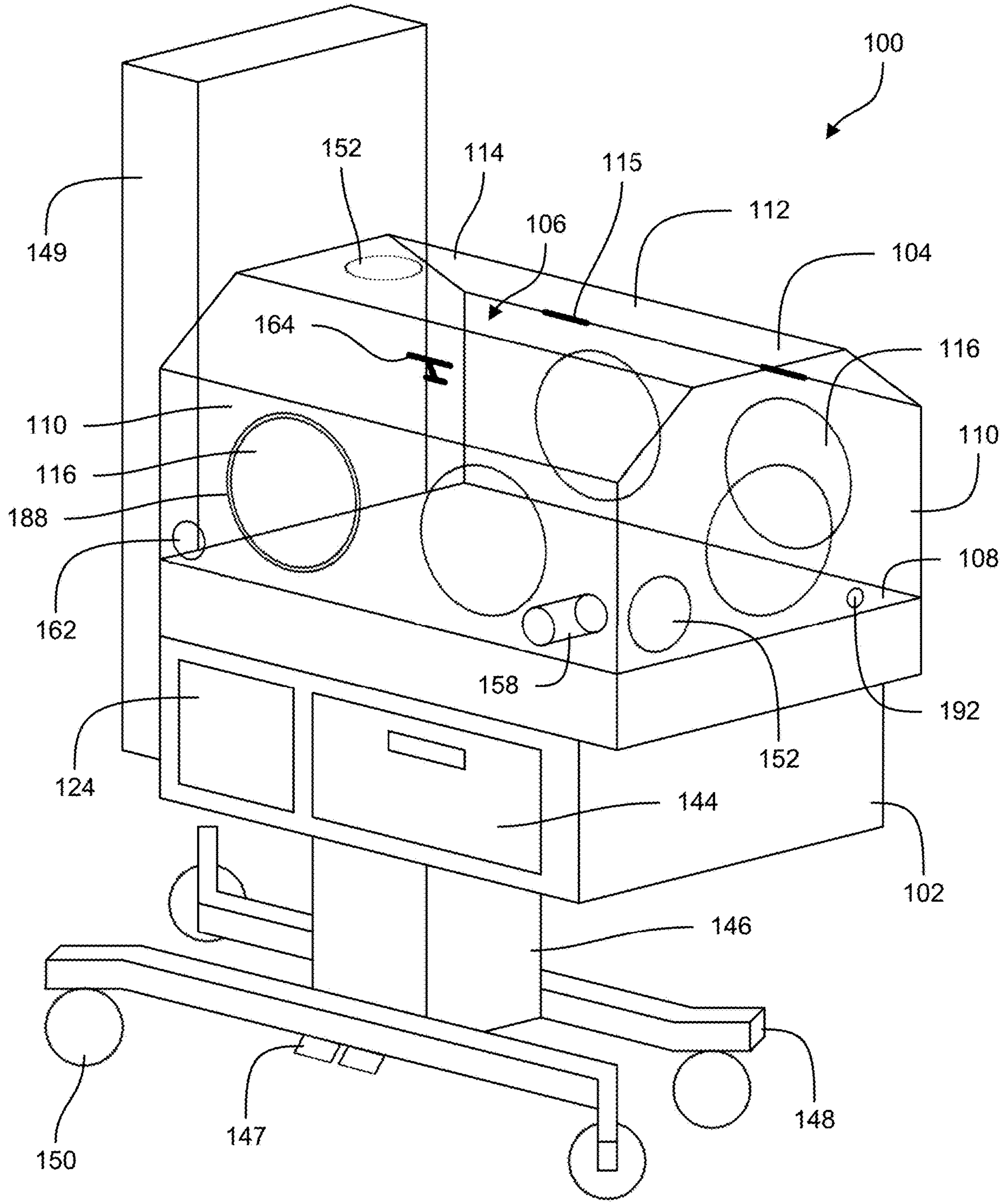
CPC *A61G 11/009* (2013.01); *G10K 11/175* (2013.01)

(57) **ABSTRACT**

An incubator can include a body, a bed supported by the body, and a canopy defining an interior chamber that includes the bed. The incubator can include any combination of various features configured to reduce sound energy inside the incubator. The incubator can include a passive radiator, a Helmholtz resonator, a meta material absorber, an active noise cancelation system, a vented door latch assembly, an acoustically permeable seal, a pressure relief valve, a lift mechanism that uses a belt drive, double paned canopy walls, a bin with insulating compliant elements, a manual pressure release valve, a pressure differential notification system, non-parallel or curved canopy walls, a mattress with reticulated foam, and/or an acoustic filter.

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162
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FIG. 1

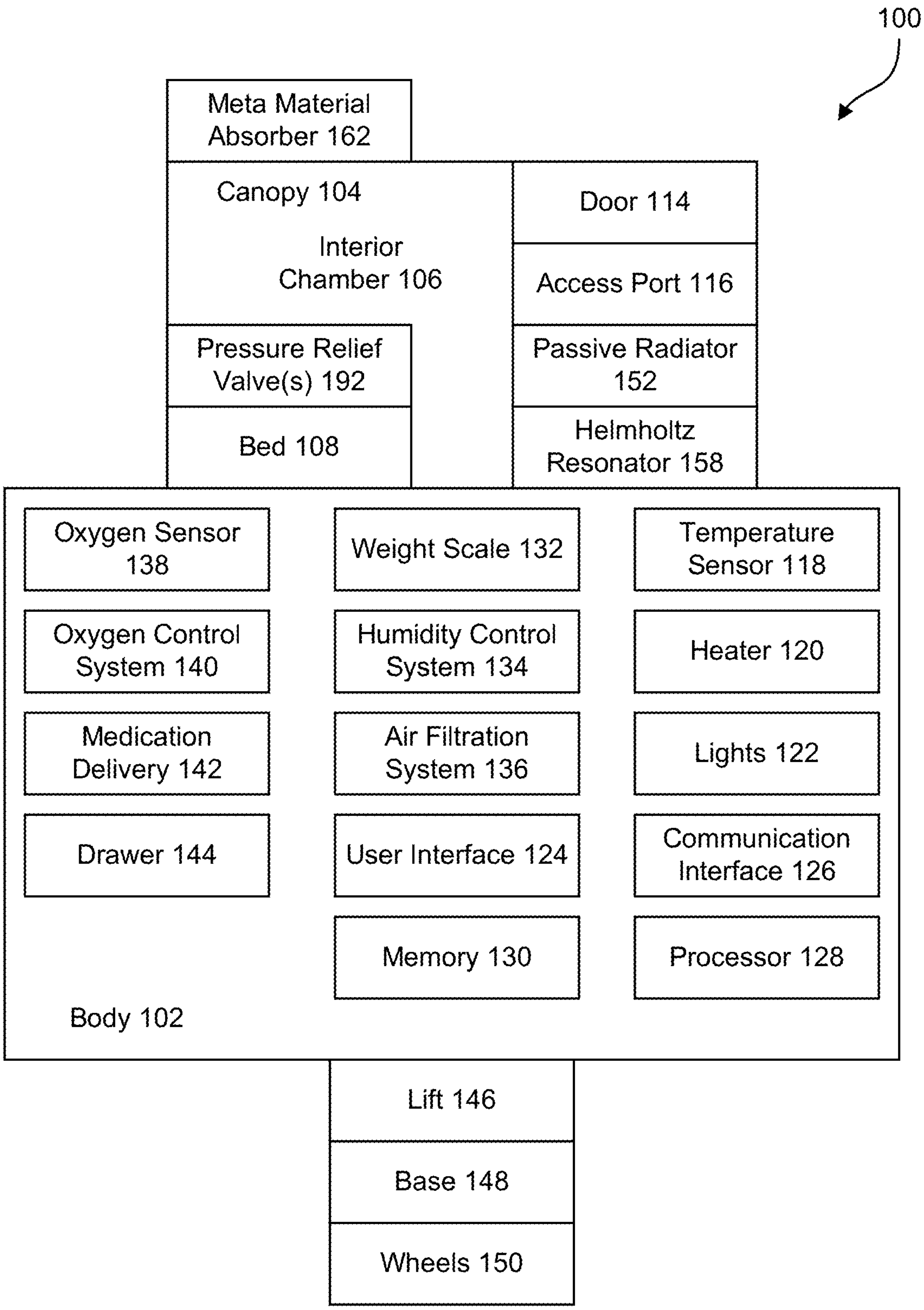
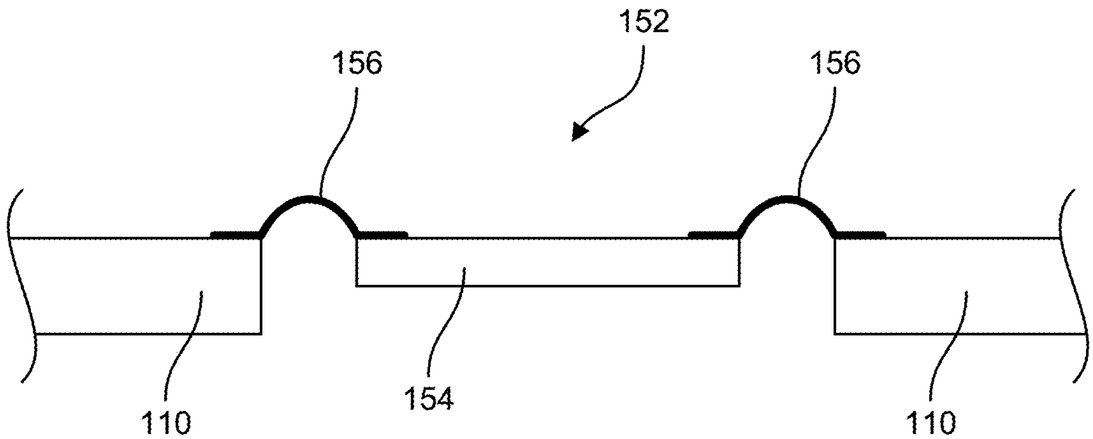

100
Meta Material Absorber 162
Canopy 104
Interior Chamber 106
Door 114
Access Port 116
Pressure Relief Valve(s) 192
Passive Radiator 152
Bed 108
Helmholtz Resonator 158
Oxygen Sensor 138
Weight Scale 132
Temperature Sensor 118
Oxygen Control System 140
Humidity Control System 134
Heater 120
Medication Delivery 142
Air Filtration System 136
Lights 122
Drawer 144
User Interface 124
Communication Interface 126
Memory 130
Processor 128
Body 102
Lift 146
Base 148
Wheels 150

FIG. 2


152
156
156
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154
110

FIG. 3

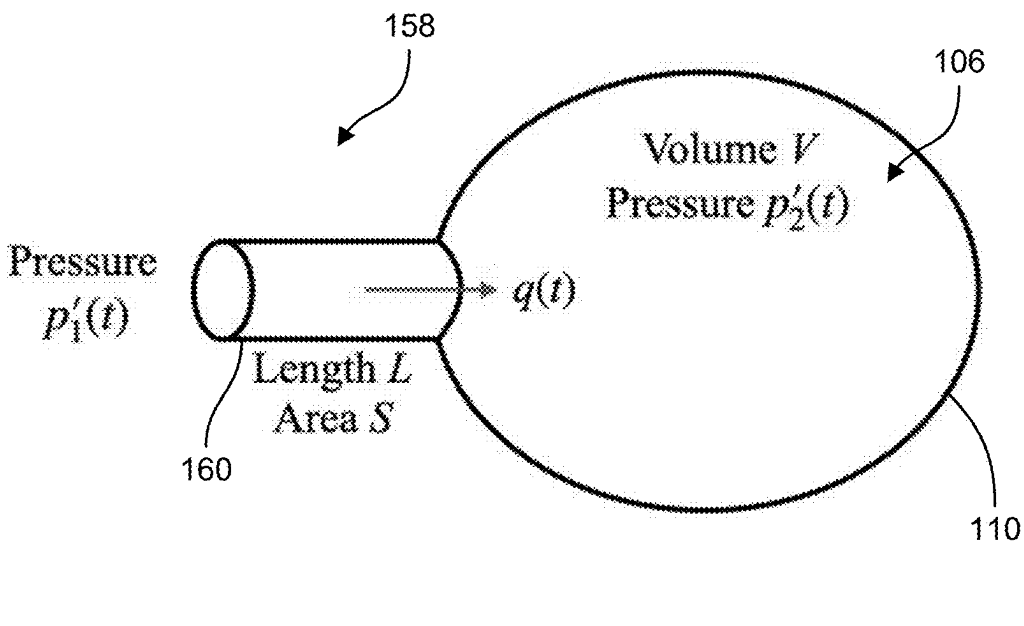

158
106
Volume V
Pressure $p_2'(t)$
Pressure
$p_1'(t)$
$q(t)$
Length L
Area S
160
110

FIG. 4

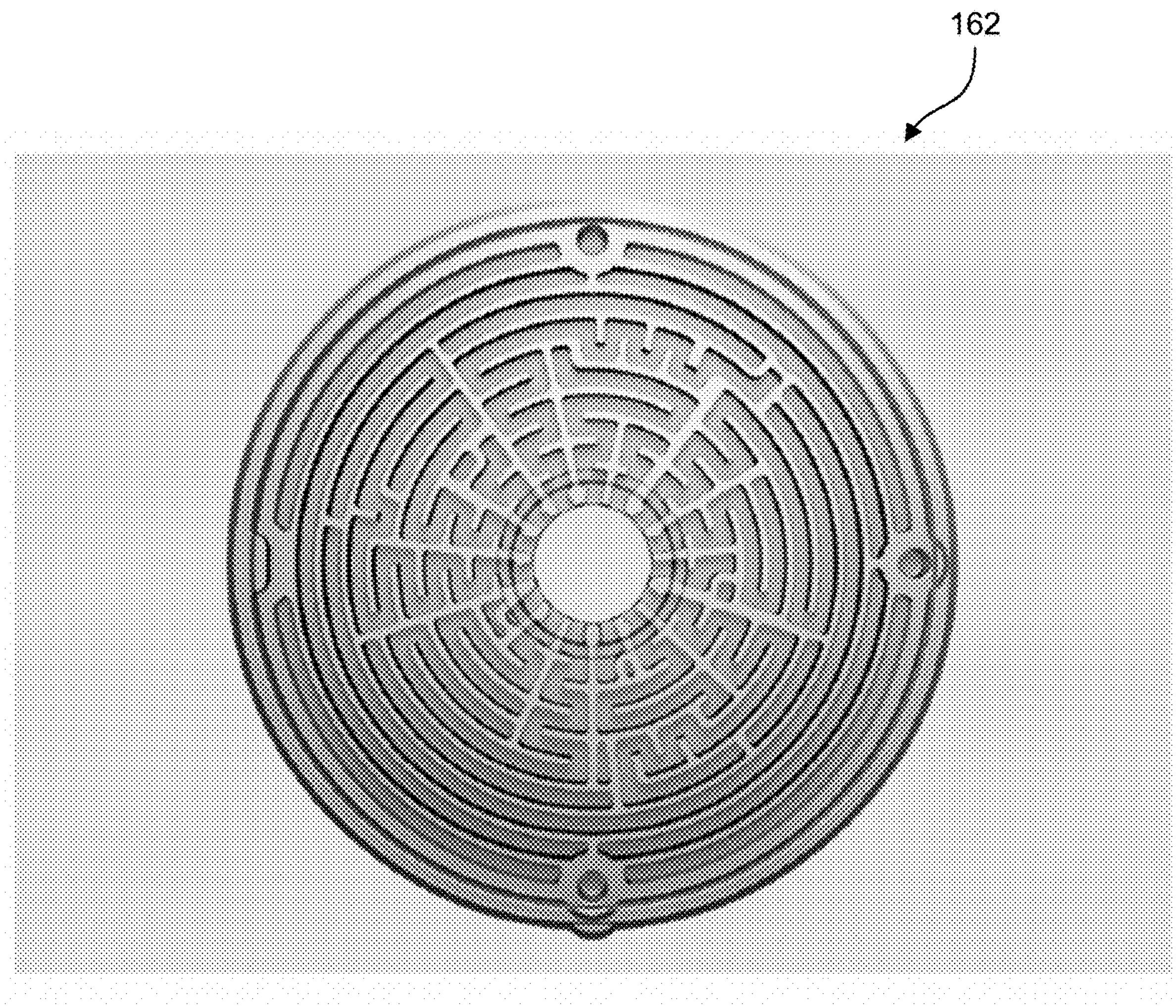
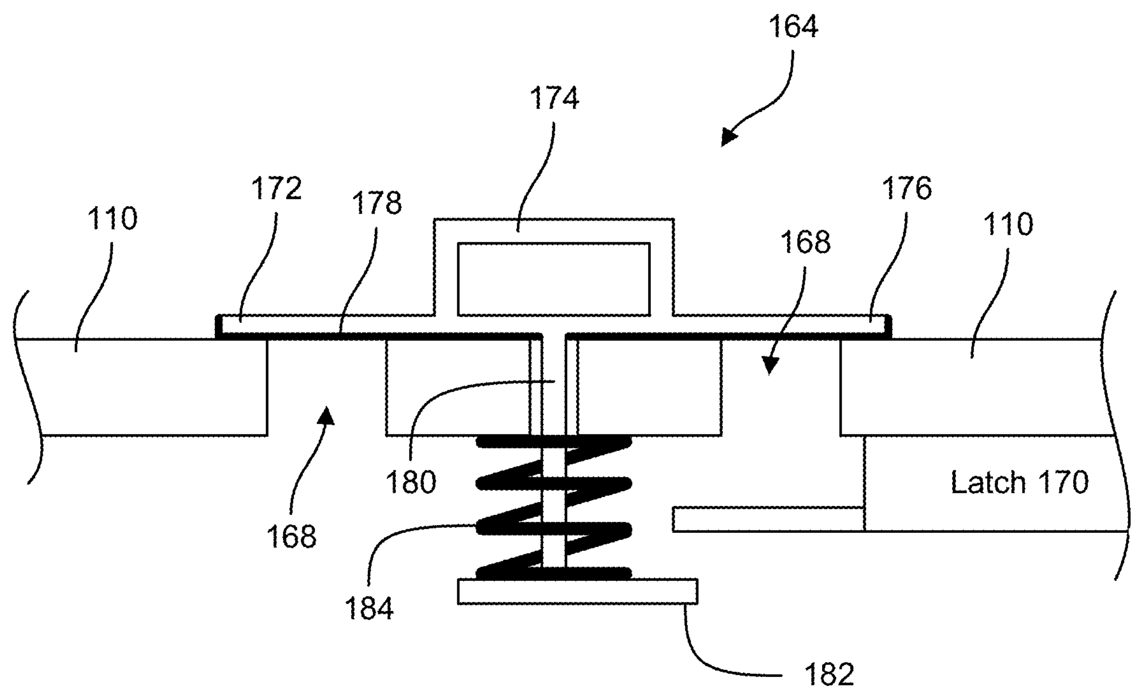


FIG. 5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Latch 170
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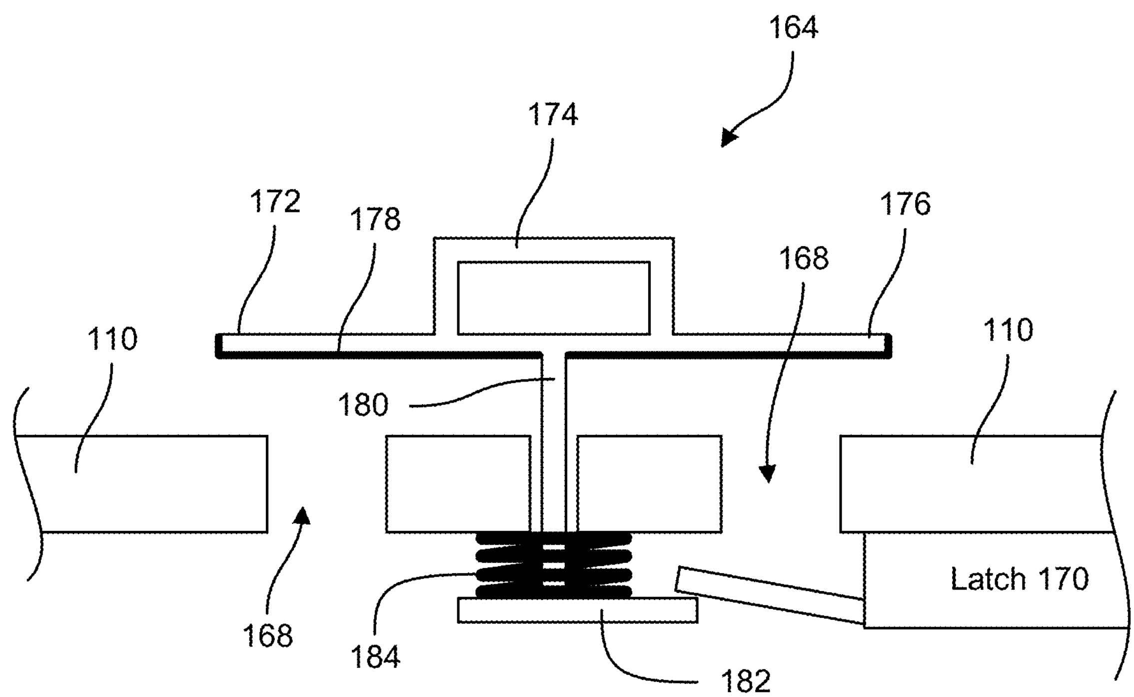
FIG. 6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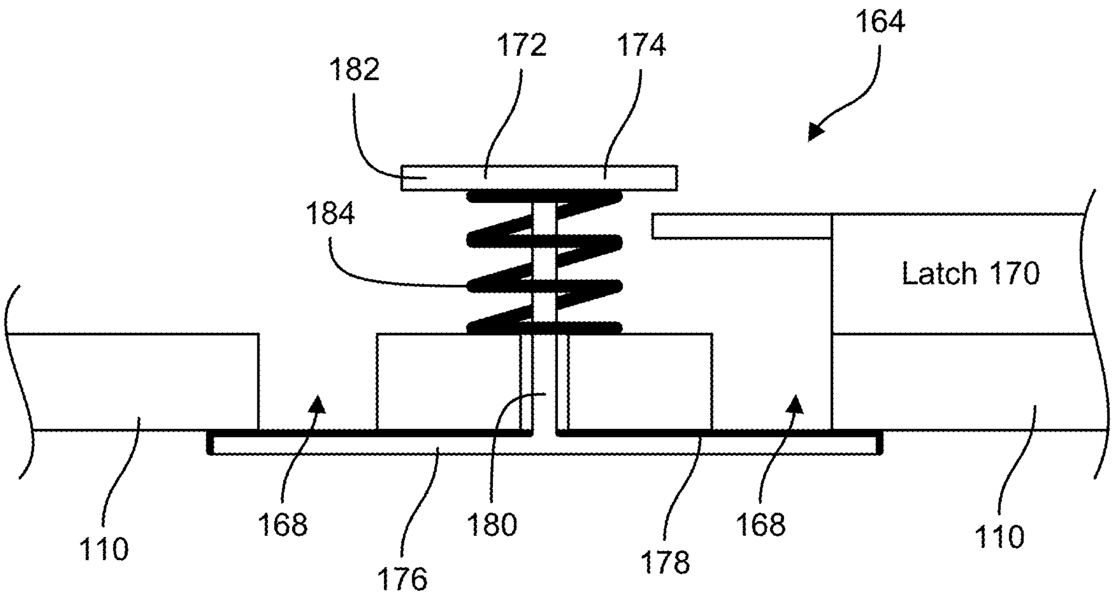
Latch 170
168
184
182

FIG. 7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Latch 170
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168
180
168
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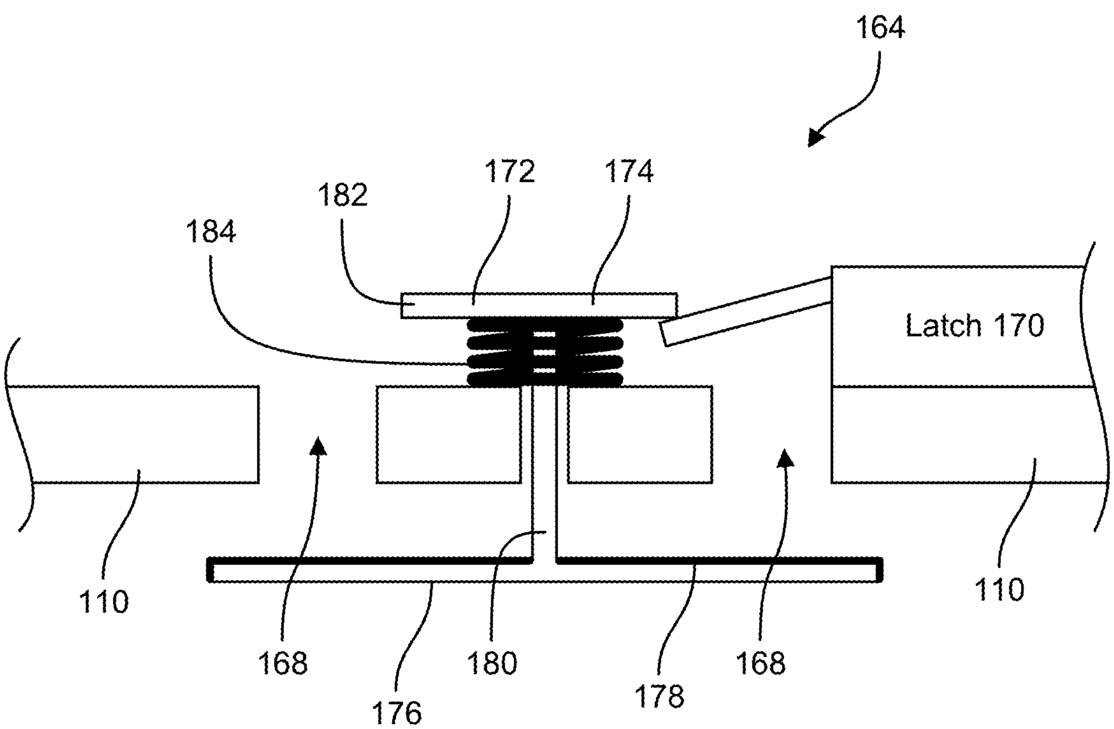
176
178

FIG. 8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184
Latch 170
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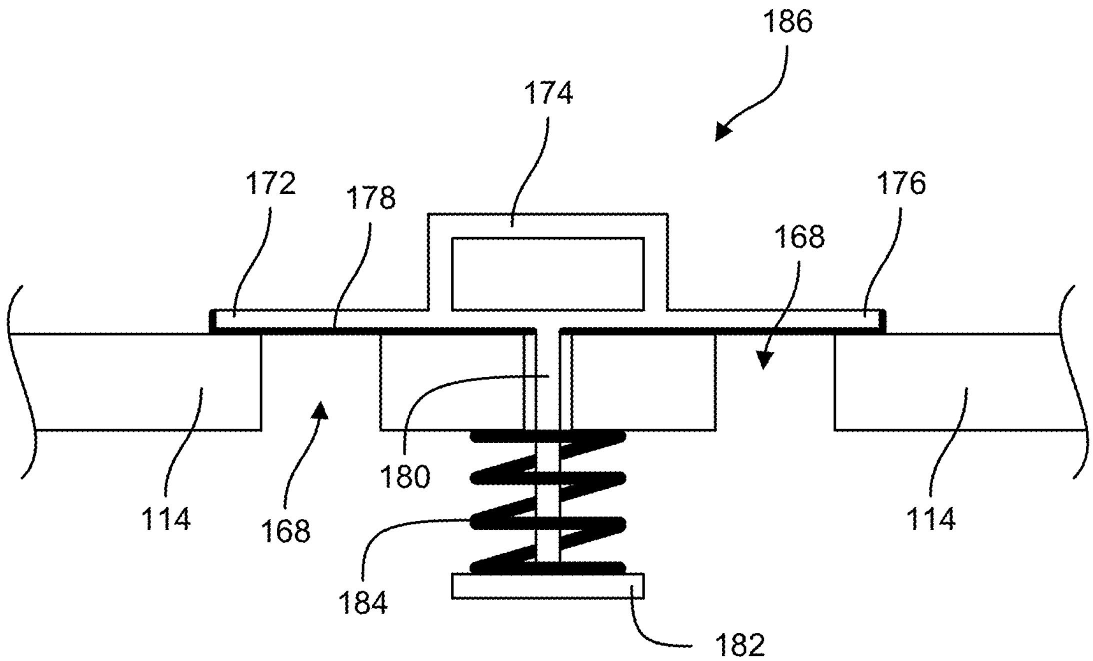
FIG. 9


186
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184
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FIG. 10

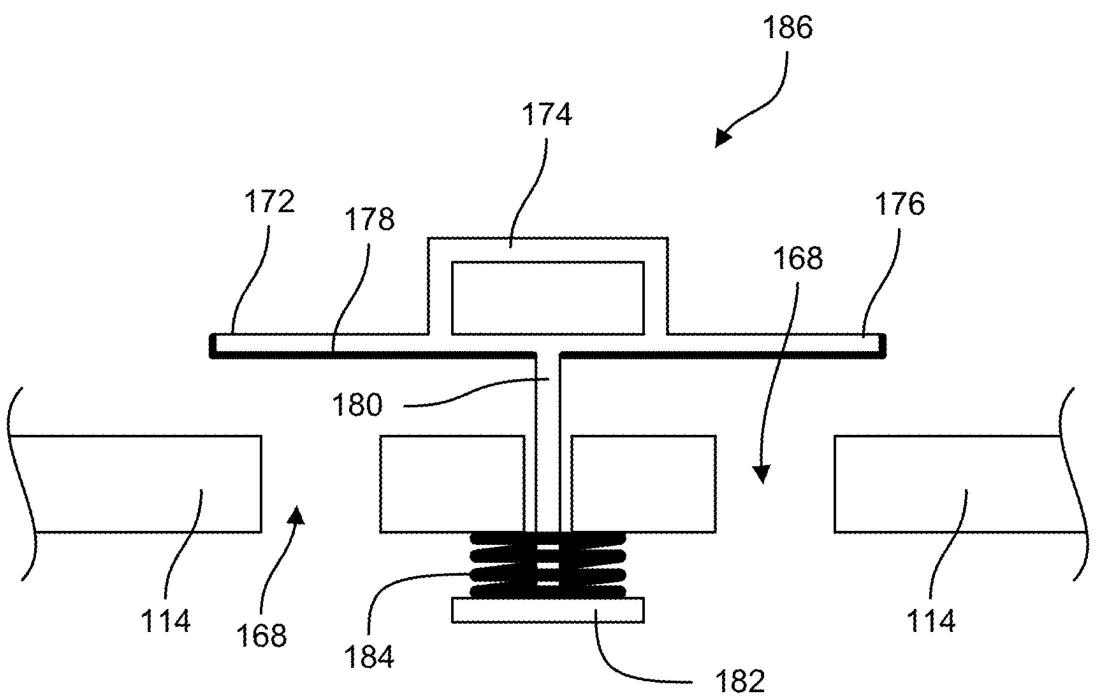
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FIG. 11

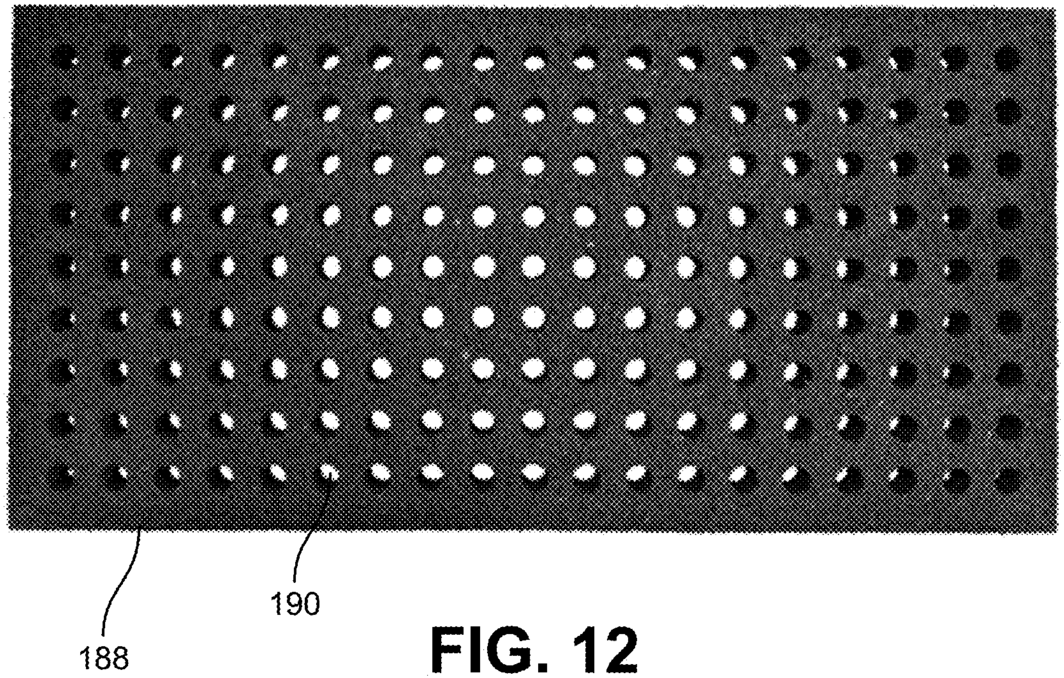

FIG. 12

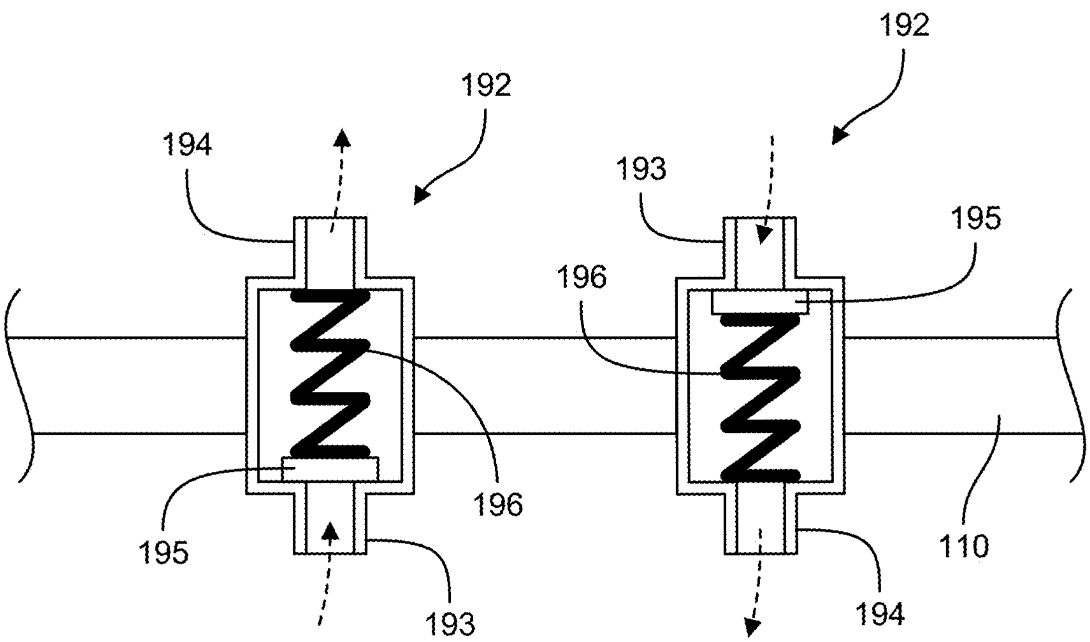

FIG. 13

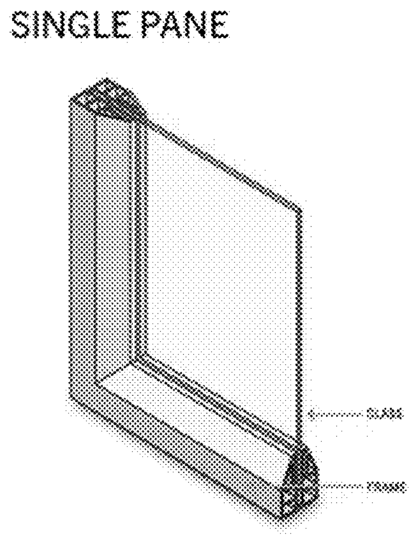

FIG. 14A

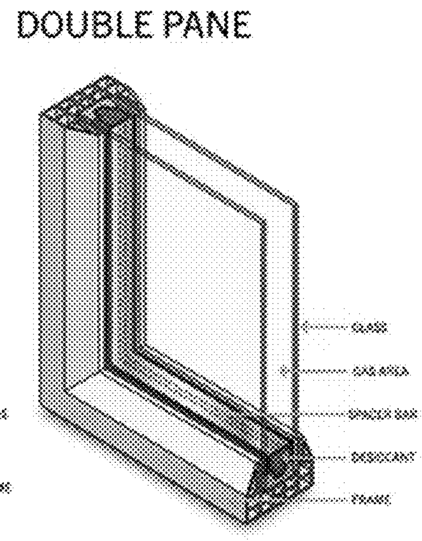

FIG. 14B

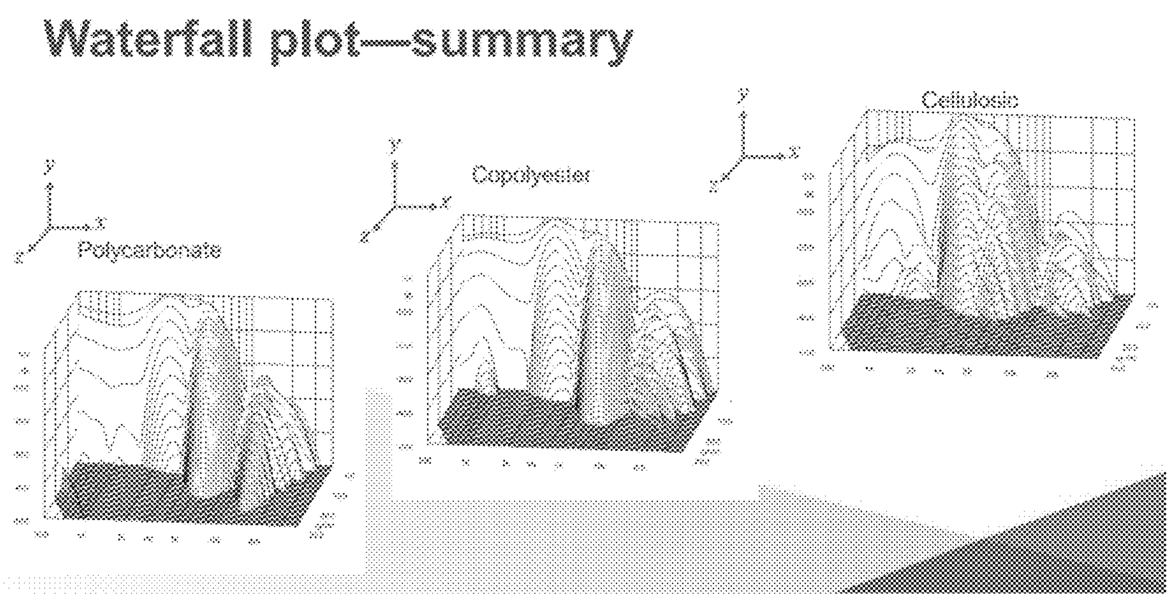

FIG. 14C

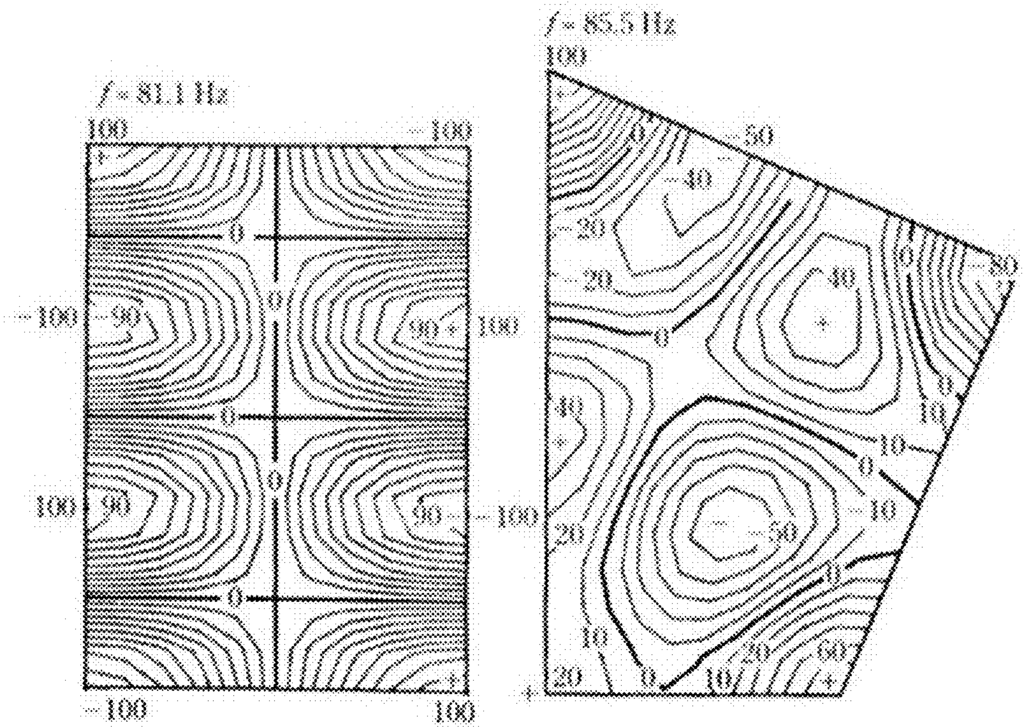

FIG. 15

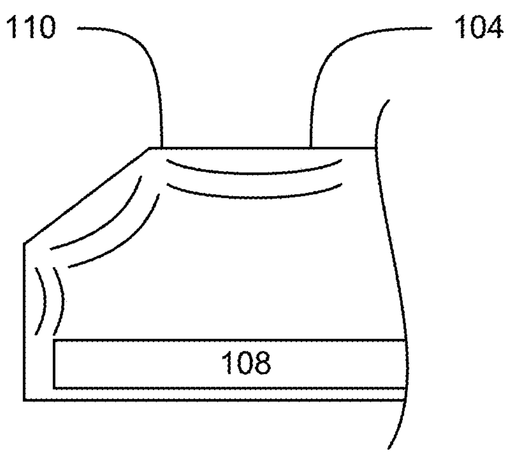

FIG. 16A

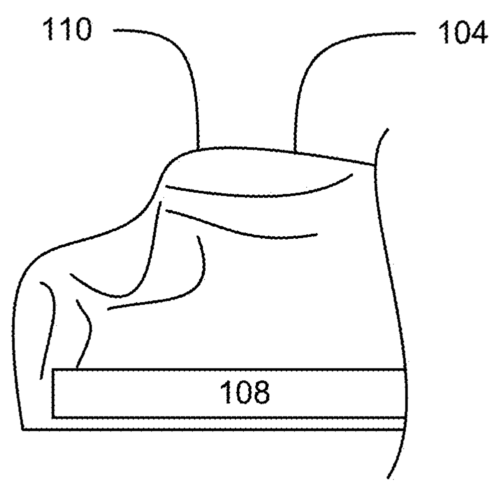

FIG. 16B

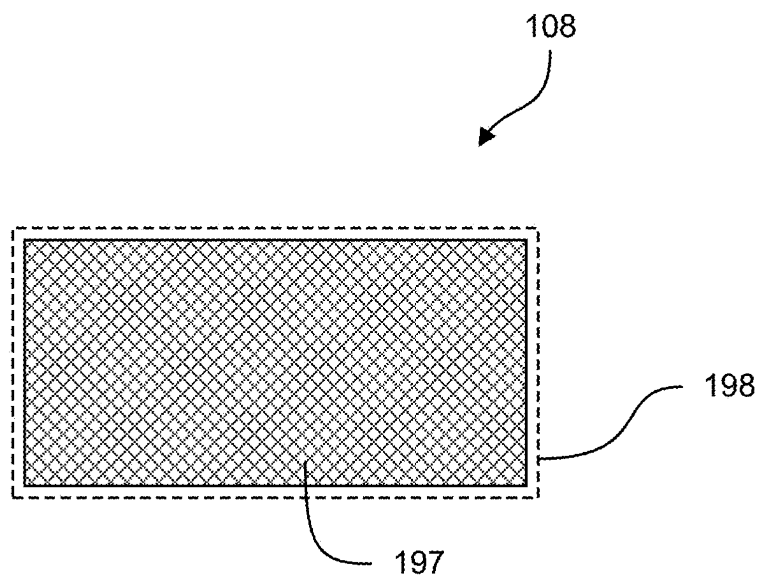
108
198
197

FIG. 17

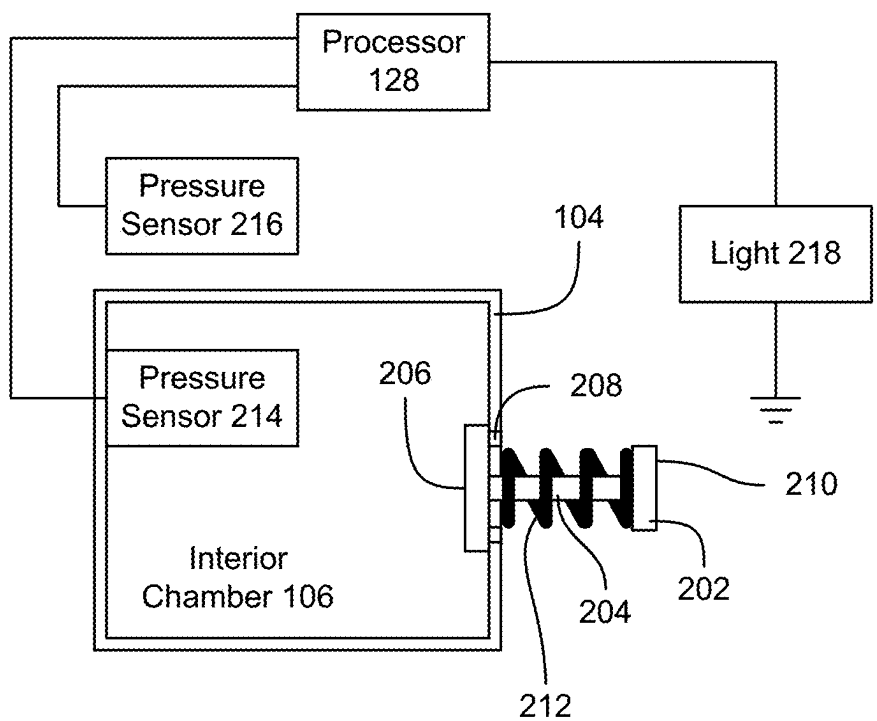
Processor 128
Pressure Sensor 216
104
Light 218
Pressure Sensor 214
206
208
210
Interior Chamber 106
202
204
212

FIG. 18

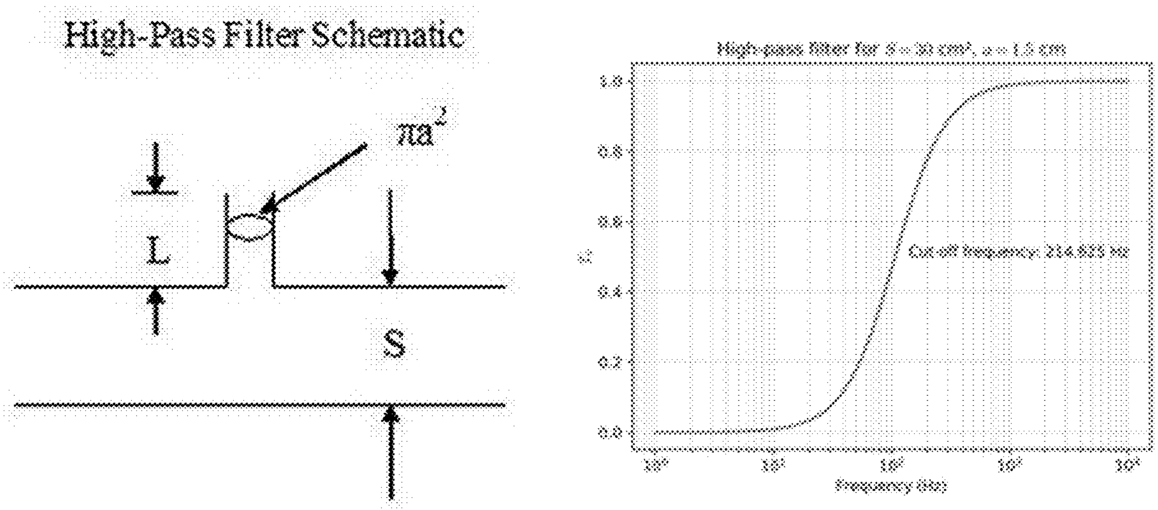
High-Pass Filter Schematic
πa^2
L
S
Frequency (Hz)

FIG. 19

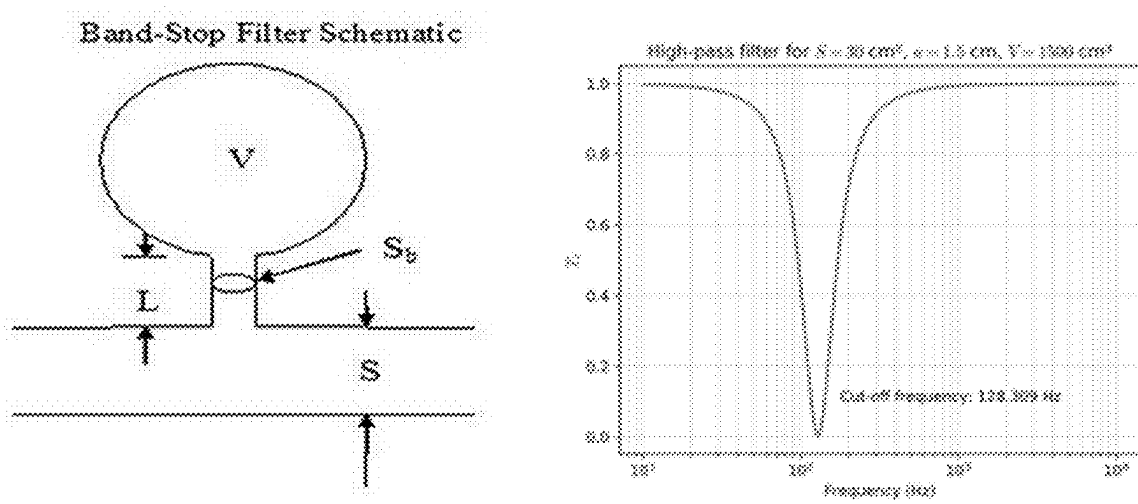
Band-Stop Filter Schematic
V
S_b
L
S
Frequency (Hz)

FIG. 20

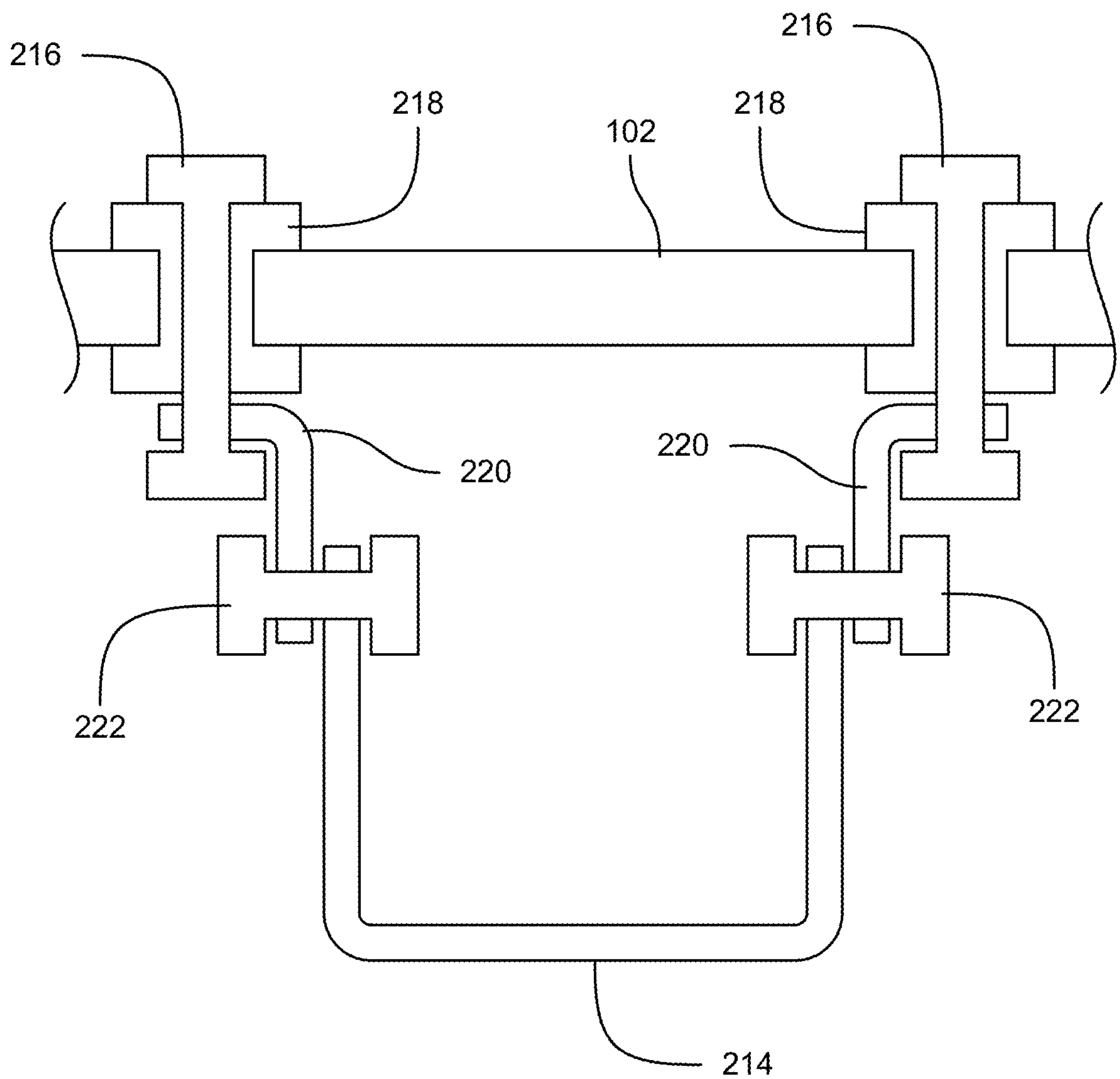

FIG. 21A

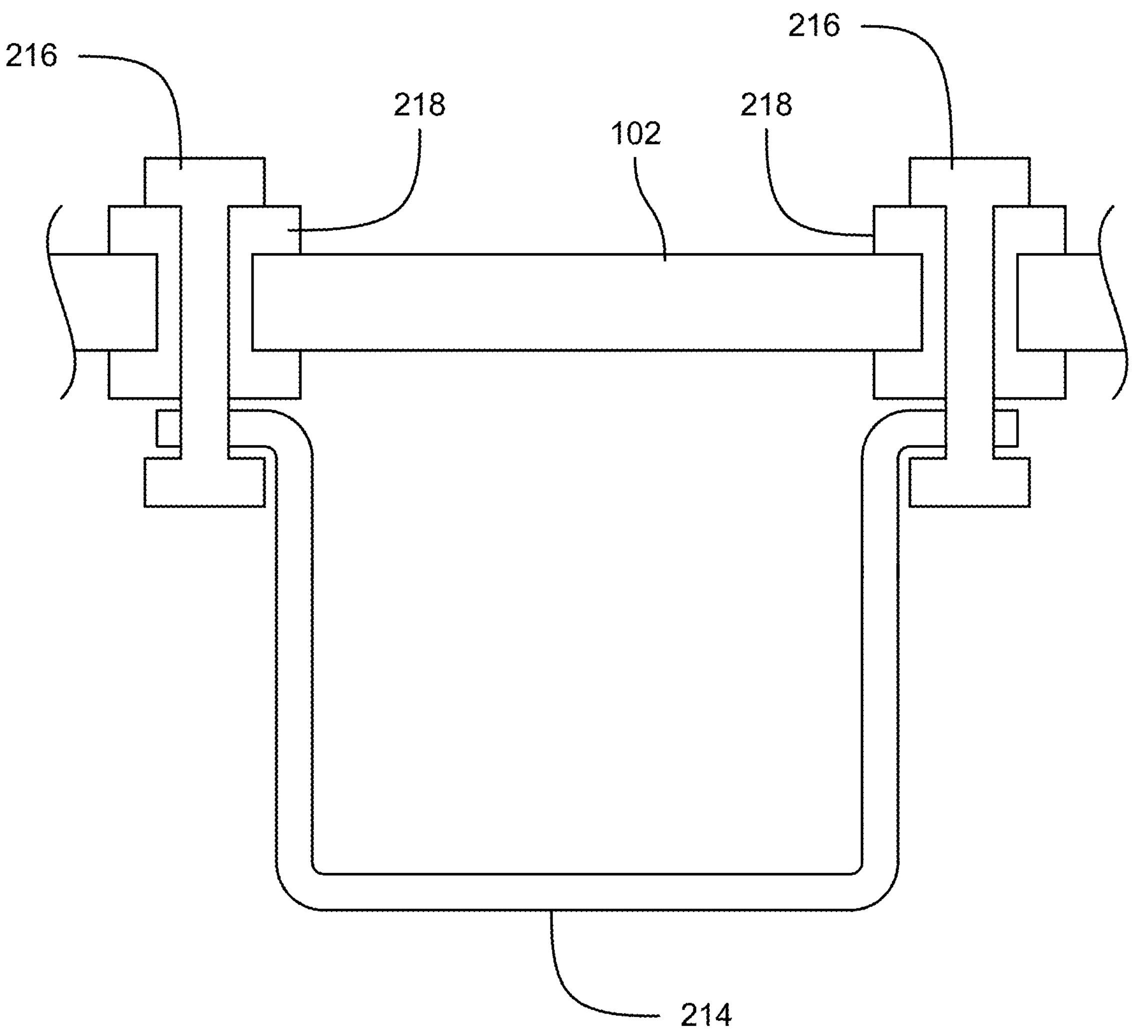

FIG. 21B

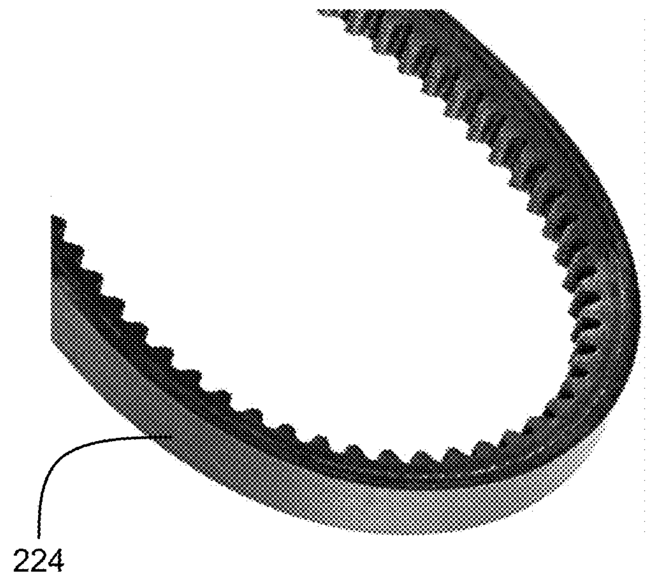

FIG. 22

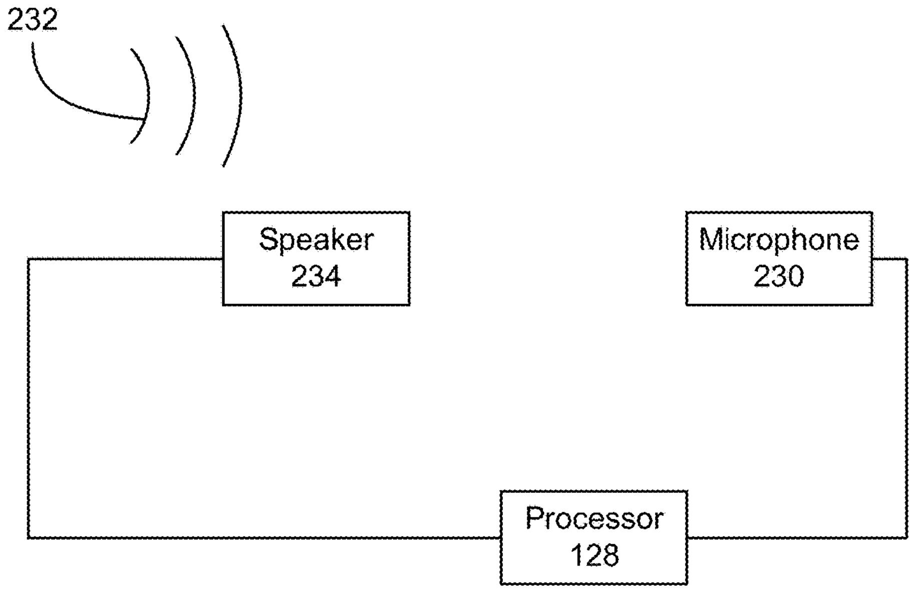

FIG. 23

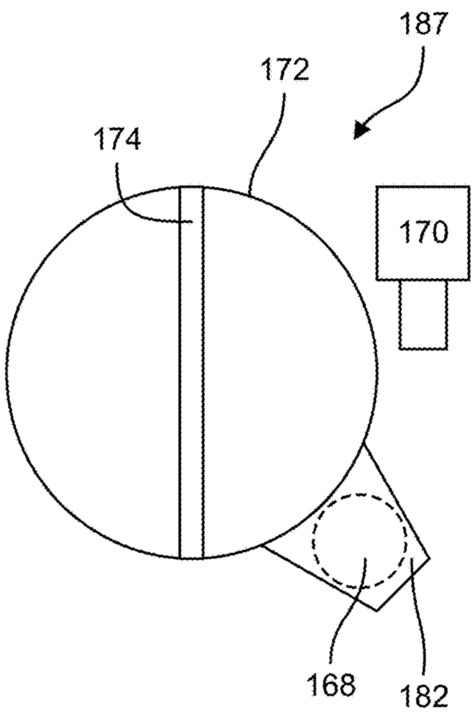

FIG. 24A

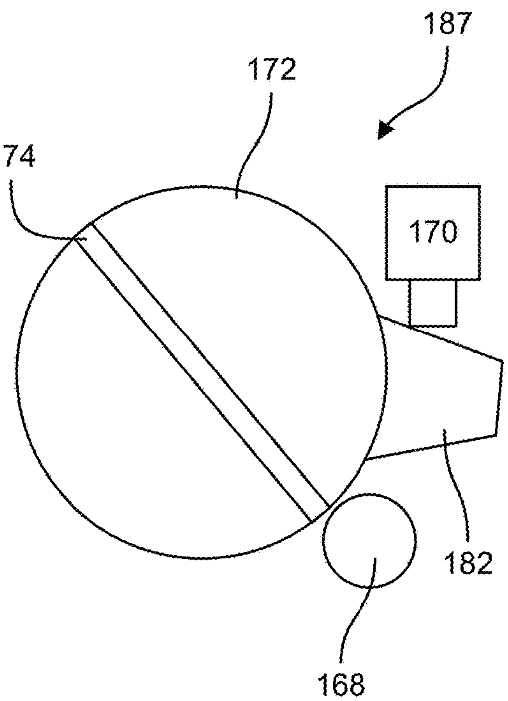

FIG. 24B

LOW NOISE INCUBATORS

INCORPORATION BY REFERENCE TO ANY PRIORITY APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 63/553,089, filed Feb. 13, 2024, which is hereby incorporated by reference in its entirety. Any and all applications for which a foreign or domestic priority claim is identified in the Application Data Sheet as filed with the present application are hereby incorporated by reference under 37 CFR 1.57 for all purposes and for all that they contain.

BACKGROUND

Field of the Disclosure

[0002] Some embodiments disclosed herein relate to incubators, such as incubators with noise reduction features.

Description of the Related Art

[0003] Brain development is correlated to quantity and quality of sleep, such as for infants, including premature infants. Disturbing the rest of a premature infant can slow cognitive development and can cause learning disabilities. Premature infants are often placed in an incubator, such as an isolette chamber, and some incubators can produce high noise environments that can disturb the rest of the infant. A need exists for incubators with low noise or with noise-reduction features.

SUMMARY

[0004] Some embodiments disclosed herein can relate to an incubator, which can include a body, a bed supported by the body, a canopy defining an interior chamber that includes the bed, and at least one passive radiator.

[0005] Some embodiments disclosed herein can relate to an incubator, which can include a body, a bed supported by the body, a canopy defining an interior chamber that includes the bed, and at least one Helmholtz resonator.

[0006] Some embodiments disclosed herein can relate to an incubator, which can include a body, a bed supported by the body, a canopy defining an interior chamber that includes the bed, and at least one meta material absorber.

[0007] Some embodiments disclosed herein can relate to an incubator, which can include a body, a bed supported by the body, a canopy defining an interior chamber that includes the bed, and an active noise cancelation system. The active noise cancelation system can include a microphone positioned in the interior chamber of the incubator, and a processor configured to receive signals representative of noise recorded by the microphone. The processor can be configured to produce cancelation sound based at least in part on the signals received from the microphone. The active noise cancellation system can include a speaker configured to play the cancelation sounds.

[0008] Some embodiments disclosed herein can relate to an incubator, which can include a body, a bed supported by the body, a canopy defining an interior chamber that includes the bed, a door having a closed configuration and an open configuration that provides access to the interior chamber, and a latch assembly that includes one or more vent openings, and an actuator that is movable between a closed configuration that closes the one or more vent openings and an open configuration that opens the one or more vent openings so that air can flow between the interior chamber and an ambient area around the incubator. The latch assembly including a mechanism configured to interface with the actuator when the actuator moves beyond the open configuration so that movement of the actuator activates the latch assembly mechanism to release the door from the closed configuration. The vent openings can be open to permit air flow between the interior chamber and the ambient area before the door is released. The actuator can be a pull actuator. The actuator can be a push actuator. The actuator can be biased to the closed configuration.

[0009] Some embodiments disclosed herein can relate to an incubator, which can include a body, a bed supported by the body, a canopy defining an interior chamber that includes the bed, and a door having a closed configuration and an open configuration that provides access to the interior chamber. The door can have a vent handle that is configured to open a vent to permit air flow between the interior chamber and an ambient area outside the incubator before the door opens.

[0010] Some embodiments disclosed herein can relate to an incubator, which can include a body, a bed supported by the body, a canopy defining an interior chamber that includes the bed, and a door having a closed configuration and an open configuration that provides access to the interior chamber. The door can include one or more vent openings and a handle that is movable between a closed configuration that impedes air flow through the one or more vent opening and an open configuration that permits air flow through the one or more vent openings. A biasing member can be configured to bias the handle to the closed configuration. The force to move the handle to the open configuration can be less than the force to move the door to the open configuration, such that the handle is configured to open the vents to permit air flow between the interior chamber and the ambient area before the door opens.

[0011] Some embodiments disclosed herein can relate to an incubator, which can include a body, a bed supported by the body, a canopy defining an interior chamber that includes the bed, a door having a closed configuration and an open configuration that provides access to the interior chamber, and a seal configured to acoustically seal between the door and the canopy when the door is closed. The seal material can be configured to acoustically open when the door is open. The seal material can include a series of holes that acoustically close when the door is closed and that open as the door transitions from the closed position to the open position, so that air can flow through the seal.

[0012] Some embodiments disclosed herein can relate to an incubator, which can include a body, a bed supported by the body, a canopy defining an interior chamber that includes the bed, and one or more pressure relief valves.

[0013] Some embodiments disclosed herein can relate to an incubator, which can include a body, a bed supported by the body, a canopy defining an interior chamber that includes the bed, and a lift mechanism configured to raise or lower the bed and canopy. The lift mechanism can use a belt drive system.

[0014] Some embodiments disclosed herein can relate to an incubator, which can include a body, a bed supported by the body, and a canopy defining an interior chamber that includes the bed. The canopy can include at least one of polycarbonate, copolyester, and cellulosic.

[0015] Some embodiments disclosed herein can relate to an incubator, which can include a body, a bed supported by the body, and a canopy defining an interior chamber that includes the bed. One or more of the walls of the canopy can be double paned.

[0016] Some embodiments disclosed herein can relate to an incubator, which can include a body, a bed supported by the body, a canopy defining an interior chamber that includes the bed, a bin suspended from the body, one or more compliant elements disposed between the bin and the body to at least partially insulate the body from vibrations of the bin.

[0017] Some embodiments disclosed herein can relate to an incubator, which can include a body, a bed supported by the body, a canopy defining an interior chamber that includes the bed, and a manual pressure release valve. The incubator can include a first pressure sensor inside the incubator interior chamber, a second pressure sensor outside the interior chamber, and a processor configured to receive signal from the first pressure sensor and the second pressure sensor and to determine a pressure differential between inside the interior chamber and outside the interior chamber. The processor can be configured to provide a notification when a pressure differential is determined. The processor can be configured to provide a notification when a pressure differential above a threshold is determined.

[0018] Some embodiments disclosed herein can relate to an incubator, which can include a body, a bed supported by the body, and a canopy defining an interior chamber that includes the bed. The walls of the canopy can be non-parallel.

[0019] Some embodiments disclosed herein can relate to an incubator, which can include a body, a bed supported by the body, and a canopy defining an interior chamber that includes the bed. The walls of the canopy can be curved.

[0020] Some embodiments disclosed herein can relate to an incubator, which can include a body, and a bed supported by the body. Therein the bed can include a mattress that includes reticulated foam. The incubator can include a canopy that defines an interior chamber that includes the bed. The mattress can include a cover that is substantially acoustically transparent.

[0021] Some embodiments disclosed herein can relate to an incubator, which can include a body, a bed supported by the body, a canopy defining an interior chamber that includes the bed, and an acoustic filter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Certain embodiments will be discussed with reference to the following figures, wherein like reference numerals can refer to similar features throughout. The figures are provided for illustrative purposes and the innovations are not limited to the specific implementations illustrated in the figures.

[0023] FIG. **1** shows a perspective view of an example incubator.

[0024] FIG. **2** shows a schematic diagram of the example incubator.

[0025] FIG. **3** shows an example embodiments of a passive radiator.

[0026] FIG. **4** shows an example embodiment of a Helmholtz resonator.

[0027] FIG. **5** shows an example embodiment of a meta material absorber.

[0028] FIG. **6** shows an example of a latch mechanism in a closed configuration.

[0029] FIG. **7** shows the example latch mechanism in an open configuration.

[0030] FIG. **8** shows another example of a latch mechanism in a closed configuration.

[0031] FIG. **9** shows an example of a latch mechanism in a closed configuration.

[0032] FIG. **10** shows an example embodiment of a vent handle in a closed state.

[0033] FIG. **11** shows the vent handle in an open state.

[0034] FIG. **12** shows an example of an acoustically leaky seal.

[0035] FIG. **13** shows an example of pressure relieve valves on the incubator.

[0036] FIG. **14**A shows a single pane wall.

[0037] FIG. **14**B shows a dual pane wall.

[0038] FIG. **14**C shows acoustic waterfall plots for polycarbonate, copolyester, and cellulosic.

[0039] FIG. **15** shows a comparison of two shapes with the same area and different shapes.

[0040] FIG. **16**A shows an example incubator with flat walls.

[0041] FIG. **16**B shows an example incubator with curved walls.

[0042] FIG. **17** shows an example embodiment of a mattress for the incubator.

[0043] FIG. **18** shows an example embodiment of an incubator with a pushbutton pressure release valve.

[0044] FIG. **19** shows an example of a high-pass acoustic filter.

[0045] FIG. **20** shows an example of a band-stop acoustic filter.

[0046] FIG. **21**A shows an example of a structure for coupling a bin to an example incubator.

[0047] FIG. **21**B shows another example of a structure for coupling a bin to example incubator.

[0048] FIG. **22** shows a belt for use with an incubator lift system.

[0049] FIG. **23** shows an active noise cancelation system for an incubator.

[0050] FIG. **24**A shows an example embodiment of a handle mechanism for an incubator in a closed configuration.

[0051] FIG. **24**B shows the example handle mechanism for an incubator in an open configuration.

DETAILED DESCRIPTION OF CERTAIN EMBODIMENTS

[0052] The various features and advantages of the systems, devices, and methods of the technology described herein will become more fully apparent from the following description of the examples illustrated in the figures. These examples are intended to illustrate the principles of this disclosure, and this disclosure should not be limited to merely the illustrated examples. The features of the illustrated examples can be modified, combined, removed, and/or substituted as will be apparent to those of ordinary skill in the art upon consideration of the principles disclosed herein.

[0053] Infants, especially premature infants, are often placed in an incubator, such as an isolette chamber, such as when in a Neonatal Intensive Care Unit (NICU). The incubator can provide a controlled environment for the infant, such as by controlling the temperature, oxygen content, air filtration, humidity, and/or light, etc. of the area inside the incubator. The incubator can be an isolette, which can isolate the infant from germs, for example. The incubator can include one or more sensors or other monitoring features for monitoring the patient. In some cases, the incubator can produce a relatively high-noise environment inside the incubator, which can disturb the rest of the patient. Poor sleep quality is correlated with impeded development in infants and can lead to delayed mental development and physical issues later in life, for example. Quality sleep can be beneficial to healing and development in various contexts. Although some embodiments are discussed in connection with incubators for use with infants, the principles and features disclosed herein can be applied to incubators, isolette, or other chambers for use with various other types of patients including children, adults, and elderly patients.

[0054] In some cases, the goal for sound levels inside a Neonatal Intensive Care Unit (NICU) can be about 40 to 45 dB sound pressure level (SPL), although higher noise levels can occur. An incubator can transmit ambient sounds and vibrations into the interior of the incubator, and in some cases, the incubator can actually amplify ambient noise so that the patient experience higher noise levels. Measurements of noise levels inside and outside some incubators showed that over a wide range of frequencies the incubators actually amplifies the sound, resulting in levels inside the incubator of up to about 18 dB higher than the sound outside the incubator. Accordingly, in some cases, rather than isolating the infant, the isolette tended to increase exposure to sound. The incubator (e.g., an isolette) can include one or more walls or partitions (e.g., on all four sides and a cover in some cases), such as to protect the infant. In some cases the partitions, walls, covers, and/or lids can be made of clear plastics (e.g., polycarbonate or acrylic). The infant can be placed inside the incubator, such as on a pad or cloth. Access to the infant (e.g., for performing medical care) can be achieved by opening the incubator, such as by opening one or more ports on the side(s), opening an entire side, or lifting a lid of the incubator. Measurements were taken showing that opening and/or closing of some incubators can produce noise spikes of over 100 dB SPL (e.g., 110 dB SPL). In some cases, use of the incubator can produce sounds that can disturb the patient. For example, raising and lowering the isolette chamber, accessing storage bins below the chamber, and/or rolling the isolette to new locations within the premises (e.g., NICU), can produce undesired noise levels (e.g., in excess of 85 dB SPL in some instances). Even if the sounds are transient, they can disrupt the rest of the patient in the incubator.

[0055] FIG. **1** shows an example embodiment of an incubator **100**, which can include low-noise or reduced-noise features. FIG. **2** shows a schematic diagram of an example embodiments of the incubator **100**. The incubator **100** can be configured to avoid or impede amplification of ambient sounds. In some embodiments, the incubator **100** can be configured to attenuate ambient sounds, for example so that the patient inside the incubator **100** experiences less noise than the ambient environment outside the incubator **100**. The incubator **100** can include access features (e.g., one or more doors, covers, or ports) that can provide access to the patient inside the incubator **100** without producing loud sounds (e.g., below about 70 dB, about 65 dB, about 60 dB, about 55 dB, about 50 dB, about 45 dB, about 40 dB, about 35 dB, or about 30 dB SPL, or less, or any values or ranges between any of these values, although other configurations are possible). In some embodiments, the incubator 100 can be configured to be raised and/or lowered without producing loud sounds (e.g., below about 70 dB, about 65 dB, about 60 dB, about 55 dB, about 50 dB, about 45 dB, about 40 dB, about 35 dB, or about 30 dB SPL, or less, or any values or ranges between any of these values, although other configurations are possible). In some cases, the incubator **100** can include a storage compartment (e.g., a drawer), which can be opened and/or closed without producing loud sounds (e.g., below about 70 dB, about 65 dB, about 60 dB, about 55 dB, about 50 dB, about 45 dB, about 40 dB, about 35 dB, or about 30 dB SPL, or less, or any values or ranges between any of these values, although other configurations are possible). Additional features and aspects of the incubator **100** are discussed herein.

[0056] The incubator **100** can include a body portion **102** and canopy **104**. The body portion **102** can support the canopy **104**. The canopy **104** define an interior chamber **106**. A bed **108** can be positioned inside the interior chamber **106**. The bed **108** can include a cushion, a pad, a blanket, etc. The bed **108** can be configured to position the infant, or other patient, inside the interior chamber **106**. The bed **108** and/or the body **102** can define a bottom of the interior chamber **106**. The canopy **104** can include one or more side walls **110** (e.g., four walls), which can define the sides of the interior chamber **106**, and a top wall **112** or cover, which can define the top of the interior chamber **106**. The canopy **104** can include a door **114**. For example, in some cases, the top **112**, a side wall **110**, or a portion thereof, can open to expose the interior chamber **106**. In some cases, the canopy can include one or more access ports **116**, which can enable a user to reach into the interior chamber without opening the full door **114**. In some cases, the access port(s) **116** can be covered with door(s) that can be opened to provide access to the interior chamber **106** through the port(s) **116**. In some cases, the port(s) **116** can include one or more glove ports or other membrane ports, which can enable a user to manipulate the interior chamber **106** while glove or other membrane separates the user from the interior chamber **106**. Accordingly, the user can access the infant without exposing the infant to contact with the ambient area outside the incubator **100**. In the embodiments illustrated in FIG. **1**, the top of the canopy **104** can include hinges **115** so that the top **112** of the enclosure can lift as a door **114**. The door **114** could be on a side panel **110** or any other suitable location. In some cases, multiple doors **114** can be used. The canopy **104** can have any suitable shape, such as a having 3, 4, 5, 6, 8 or more sides, having curved walls, having a single, bubble-shaped wall, etc.

[0057] The incubator **100** can include a temperature senor **118**, which can measure the temperature of the interior chamber **106**. Any suitable type of temperature sensor **118** can be used. The incubator **100** can include a heater **120**, which can be used to heat the interior chamber **106**, such as based on information from the temperature sensor **118** (e.g., with a feedback loop or any other suitable control technique). In some embodiments, a thermoelectric controller can be used. In some cases, the incubator **100** can have a temperature controller that can both heat and cool the incubator, which can facilitate control of the temperature. In some cases, the incubator can include one or more lights **122**. The lights **122** can be used to heat the interior chamber

106 (e.g., using an infrared lamp or other suitable light). In some cases, the light(s) **122** can be used for phototherapy or for illumination.

[0058] The incubator **100** can include a controller that is configured to operate the incubator **100**, such as to perform various functions and features described herein. The controller can include a processor **128**, which can be a hardware processor, a computer processor, an integrated circuit, an application specific integrated circuit (ASIC), a general purpose processor, or the like. In some cases multiple processors **128** can be used, such as different processors for different functionality, or for load sharing or multi-threaded processing. The incubator **100** can include memory **130**, which can store information. The memory **130** can be non-transitory computer-readable medium. The memory **130** can be non-volatile memory, or volatile memory, random access memory (RAM), or a hard drive, a solid state drive, flash memory, or any other suitable type of storage device. The memory **130** can include instructions, such as computer-readable instructions, which can be executed by the processor **128**, such as to perform the functions and features discussed herein.

[0059] The incubator **100** can include a user interface **124**, which can include one or more user input elements configured to receive input from a user, such as one or more buttons, keys, dials, switches, knobs, a keyboard, a mouse, a touch sensitive surface, etc. The user interface **124** can include one or more user output elements configured to output information to a user, such as a display (e.g., a touch screen display), a speaker, a printer, etc. The incubator can include a communication interface **126**, which can send or receive information from an external device, such as over a network (e.g., a hospital network, the internet, etc.). The user interface can be wired or wireless, such as Ethernet, WiFi, Bluetooth, etc. The incubator **100** can receive input via the user interface **124** and/or the communication interface **126**, and the incubator can perform operations based at least in part on the input. For example, the incubator can control the heater **120** to heat the interior chamber **106** based at least in part on a target temperature set by input, which can be received via the user interface **124** and/or from an external device via the communication interface **126**. In some cases, the incubator **100** can output information (e.g., sensor data, patient information, incubator settings, alerts, error messages, etc.) via the user interface **124** and/or to an external device (e.g., a monitoring station) via the communication interface **126**.

[0060] In some implementations, the incubator **100** can include a weight scale **132**, which can be configured to measure the weight of the patient, of the bed **108**, or of other components. The incubator **100** can include a humidity control system **134**, which can include a humidity sensor and a humidity controller, which can access a water reservoir (or water source) and/or fan, or other features, to control the humidity in the interior chamber. The incubator **100** can include an air filtration system **136**, which can include a fan to circulate air and one or more filters. Any suitable filters or filtering systems can be used. The incubator **100** can include an oxygen sensor **138**, which can be configured to measure the oxygen level or content in the interior chamber **106**. The incubator **100** can include an oxygen control system **140**, which can access an oxygen reservoir or source and can control the oxygen in the interior chamber **106**, such as at least in part based on the oxygen sensor **138**. In some embodiments, the incubator **100** can include a medication delivery system **142**, which can deliver medication to the patient. The incubator **100** can include one or more drawers **144**, which can be opened and/or closed, such as to access one or more storage compartments. The incubator **100** can include a drawer or door that can be opened to provide access to a water reservoir, or an oxygen reservoir, or a medication reservoir, or any other portion or region of the incubator **100**.

[0061] The incubator **100** can include a base **148**, which can support the body **102**. In some cases, the incubator **100** can include a lift **146** for adjusting the height of the body **102**, the canopy **104**, the interior chamber **106**, the bed **108**, and/or various other components. The incubator **100** can include lift controls **147**, such as pedals or foot-operated switches, such as one to raise the incubator **100** and one to lower the incubator **100**, however the user interface **124** could also be used. The incubator can include wheels **150** for moving the incubator **100**, such as caster wheels. In some cases, the wheels can lock to impede movement of the incubator **100**.

[0062] Some components that are shown in FIG. **2** as part of the body **102** of the incubator **100** can be partially or completely inside the interior chamber **106**, such as the weight scale **132**, the temperature sensor **118**, the heater **120**, the lights **122**, the humidity sensor, the oxygen sensor **138**, etc. Additional sensors or other components can be included with the incubator **100**. In some embodiments, the incubator **100** (e.g., the body **102** thereof) can include a tower **149** or raised portion, which can include various components described or shown as part of the body **102**, such as the user interface **124** (e.g., touch screen), the drug delivery system **142** (e.g., medication bag holder), lights **122**, heater **120**, etc. In some cases, some of the features of the incubator **100** can be omitted. For example, an some incubators **100** can omit the lift **146**, the drawer **144**, the lights **122**, the medical delivery system **142**, or various other components disclosed herein. The incubator **100** can include other features that are not shown or described as would be understood by a person of skill in this field.

[0063] In some embodiments, the incubator **100** can include one or more passive radiators **152**. The passive radiator **152** can be placed on the top **112** of the enclosure or canopy **104** and/or on one or more of the sides **110** of the enclosure or canopy **104**. In some embodiments, the door **114** can include one or more passive radiators **114**. Any suitable number of passive radiators **152** can be used, such as 1, 2, 3, 4, 6, 8, 12, or more passive radiators **152**. The passive radiator(s) **152** can be tuned to resonate 180 degrees out-of-phase with pressure waves inside the interior chamber **106** of the incubator **100**. The passive radiator(s) **152** can be tuned to resonate out-of-phase (e.g., about 180 degrees out-of-phase) with specific frequencies or frequency ranges that are targeted for attenuation inside the incubator **100**. For example, the opening and/or closing of the door **114** can produce sound of a frequency or frequency range. One or more passive radiators **152** can be configured to resonate out-of-phase (e.g., by about 180 degrees) with that frequency, or range of frequencies, or a frequency within the range. In some cases, peak frequency can be targeted, such as the frequency with the highest intensity. The passive radiator **152** can be configured to resonate out-of-phase (e.g., by about 180 degrees) with the frequency with the highest intensity during the event (e.g., opening and/or closing the door **114**). Multiple passive radiators **152** could be used. The passive radiator(s) **152** can be tuned to different frequencies or ranges, such as by adjusting the mass of the moving portion and/or the stiffness of the suspension element.

[0064] FIG. **3** shows an example embodiment of a passive radiator **152**. The wall **100** of the enclosure or canopy **104** can have an opening. At least a portion of the diaphragm **154** or radiator mass can be positioned in the opening, or in front of the opening on one side or the other. A suspension **156** can couple the diaphragm **154** to the wall **110**, and the suspension **156** can be configured to enable the diaphragm **152** to move (e.g., along a direction that is axial to the opening, which would be up and down in the orientation of FIG. **3**). Movement of the diaphragm **154** can increase or decrease the volume of the interior chamber **106** depending on the direction of movement. That expansion or contraction can counter pressure waves in the incubator. Accordingly, the passive radiator(s) **152** can reduce the spikes of sound inside the interior chamber **106**. The diaphragm **154** can be a cone, or a plate, or any suitable structure. The opening and/or diaphragm **154** can have a substantially circular shape in some cases, although any suitable shapes could be used. In some cases, the passive radiator **152** can be substantially optically clear, for example so as to not obstruct the view of the patient.

[0065] In some embodiments, the incubator **100** can include one or more Helmholtz resonators **158**. The Helmholtz resonator(s) **158** can be placed on the top **112** of the enclosure or canopy **104** and/or on one or more of the sides **110** of the enclosure or canopy **104** and/or on the bottom of the chamber **108**. In some embodiments, the door **114** can include one or more Helmholtz resonators **158**. In some cases, the Helmholtz resonator **158** can be under or outside the enclosure and a pipe can direct the acoustical energy from the interior chamber **106** to the Helmholtz resonator **158**. Any suitable number of Helmholtz resonators **158** can be used, such as **1**, **2**, **3**, **4**, **6**, **8**, **12**, or more Helmholtz resonators **158**. The Helmholtz resonator(s) **158** can be tuned to resonate 180 degrees out-of-phase with pressure waves inside the interior chamber **106** of the incubator **100**. The Helmholtz resonator(s) **158** can be tuned to resonate out-of-phase (e.g., about 180 degrees out-of-phase) with specific frequencies or frequency ranges that are targeted for attenuation inside the incubator **100**. For example, the opening and/or closing of the door **114** can produce sound of a frequency or frequency range. One or more Helmholtz resonator(s) **158** can be configured to resonate out-of-phase (e.g., by about 180 degrees) with that frequency, or range of frequencies, or a frequency within the range. In some cases, peak frequency can be targeted, such as the frequency with the highest intensity. The Helmholtz resonator(s) **158** can be configured to resonate out-of-phase (e.g., by about 180 degrees) with the frequency with the highest intensity during the event (e.g., opening and/or closing the door **114**), by way of example. Multiple Helmholtz resonators **158** could be used. The Helmholtz resonator(s) **158** can be tuned to different frequencies or ranges, such as by adjusting the length, depth, cross sectional area and/or total volume of components of the Helmholtz resonator.

[0066] FIG. **4** shows an example embodiment of a Helmholtz resonator(s) **158**. The wall **100** of the enclosure or canopy **104**, or other portion of the incubator **100** can have an opening. A pipe **160** or tube can be coupled to the opening. The pipe **160** can be open at both ends, so that air can flow through the pipe **160**. The opening and/or the pipe **160** can have substantially circular cross-sectional shapes in some cases, although any suitable shapes could be used. The pipe **160** can have a length L and an area S, which can be tuned to absorb or cancel energy of the target noise frequency or range. In some cases, multiple Helmholtz resonators **158** can be used, such as tuned to absorb different frequencies or ranges.

[0067] In some embodiments, the incubator **100** can include one or more meta material absorbers **162**. Meta materials are a class of physical structures that have small features built into them that act as acoustical absorbers, such as over a wide range of frequencies. Sound can be trapped in the various paths of different sizes and shapes and can result in out-of-phase reflections The meta material absorber (s) **162** can be molded materials that can be mounted on the surfaces of the incubator **100** (e.g., on flat surfaces). The Meta material absorber(s) **162** can be mounted on an inside surface of the canopy **104**, or other portion of the incubator **100**. In some cases, the meta material absorber(s) **162** could be mounted on an outside of the canopy **104**, or other portion of the incubator **100**, such as to absorb ambient noise. The meta material absorber(s) **162** can be placed on the top **112** of the enclosure or canopy **104** and/or on one or more of the sides **110** of the enclosure or canopy **104**. In some embodiments, the door **114** can include one or more meta material absorber(s) **162**. Any suitable number of meta material absorber(s) **162** can be used, such as 1, 2, 3, 4, 6, 8, 12, or more. The meta material absorber(s) **162** can be tuned to absorb specific frequencies or frequency ranges that are targeted for attenuation inside the incubator **100**. For example, the opening and/or closing of the door **114** can produce sound of a frequency or frequency range. One or more meta material absorber(s) **162** can be configured to absorb that frequency, or range of frequencies, or a frequency within the range. In some cases, a peak frequency can be targeted, such as the frequency with the highest intensity. The meta material absorber(s) **162** can be configured to absorb the frequency with the highest intensity during the event (e.g., opening and/or closing the door **114**), by way of example. Multiple meta material absorbers **162** could be used. The meta material absorber(s) **162** can be tuned to different frequencies or ranges, such as by varying the cross sectional area and/or length of any given feature such that sound is reflected back out-of-phase, such as for a given frequency or range of frequencies. FIG. **5** shows an example embodiment of a meta material absorber **162**.

[0068] In some embodiments, the incubator **100** can include a latch assembly **164** that breaks a seal or leaks before opening a door **114** or access port **116** (e.g., which can have doors). In some instances, much of the noise is due to opening and/or closing the door **114** or access ports **116** of the incubator **100**. For some incubators, as the door starts to open, the movement of the door can cause the volume inside the incubator to change significantly, especially due to the relatively small volume of the interior chamber of the incubator, which can produce a significant pressure differential and resulting pressure wave. The incubator **100** can have a latch assembly **164** for opening a door **114** (e.g., of a main access opening or of an access port **116**), where the latch assembly **164** is configured to open a vent path (e.g., an air pathway between the interior chamber **106** and the ambient area outside the incubator **100**), such as before the door **114** is released or before the door **114** moves toward the open position. Then when the door **114** is released or starts moving, the pressure differential can be at least partially released through the open vent path, at least partially reducing the pressure wave. The latch **164** can "gradually" open a large, low restriction pathway for air to flow prior to opening the actual access port, which can result in a much lowered velocity of air into the incubator **100**, thereby reducing noise.

[0069] FIG. **6** shows an example latch assembly **164** in a closed configuration. FIG. **7** shows the example latch assembly **164** in an open configuration. The latch assembly **164** can include one or more openings **168** in the wall **110** or **112** of incubator **100**. The latch assembly **164** can include an actuator **172**, which can be manipulated by the user to trigger a latch **170** which can release or open the door **114**. The actuator **172** can include a grip or handle **174** configured to be gripped or manipulated by the user to move the actuator **172**. For example, the user can pull on the grip **174** to move the actuator **172**, although a push actuator could be used in some implementations. The actuator **172** can include a cover **176**, which can cover the one or more openings **168** when the actuator **172** is in a closed configuration. The cover **176** can include a seal **178**, such as a flexible or elastomeric material (e.g., silicone or rubber), on the underside or on the side that faces the wall **110**. The seal **178** can substantially seal against the wall **110** to close the one or more openings. When moved to the open configuration (e.g., in FIG. **7**), the seal **178** can unseal from the wall **110** and air can pass through the one or more openings **168**.

[0070] The actuator **172** can be biased to the closed configuration, such as by a spring **184**, although any suitable biasing structure can be used (e.g., a resilient band, flexible arms, etc.). The actuator **172** can include a shaft **180** that extends from the cover **176**, through an opening in the wall **110**, and to a flange **182**. The spring **184** can be positioned between the flange **182** and the wall **110**. When the actuator **176** is moved to the open configuration (e.g., FIG. **7**), the spring **184** can be compressed. When the force is released, the spring **184** can push the actuator **172** toward the closed position (e.g., FIG. **6**).

[0071] The actuator **172** can trigger the latch **170**, such as when it moves from the closed configuration to the open configuration. The latch **170** can have lever or other actuation member, which can extend into the path of the flange **182** as it moves from the closed configuration to the closed configuration. The flange **182** can include a protrusion or other structure configured to actuate the level, or other actuation member, of the latch **170**, to thereby release the latch **170** and enable the door **114** to be opened.

[0072] Many variations are possible. In some cases, the seal **178** can be omitted. In some cases, the latch **170** can use a different mechanism to be triggered as the one or more openings. For example, the lever or latch mechanism can be coupled to the actuator **175**, so that the lever moves as the user pulls, or pushes, the actuator **176**, and the latch **170** can be configured to not release until after the actuator has moved sufficiently to open the one or more openings **168**. In some cases, the lever or other latch mechanism can be tethered to the actuator **176** with some slack, so that the actuator **176** can move by a distance to open the one or more openings before the slack is removed. Then once the vent through the opening(s) **168** is open and the slack on the tether is removed, further movement of the actuator can cause the latch **170** to release or open the door **114**.

[0073] In some embodiments, the door **114** can include a vent mechanism integrated into the handle **174** for opening the incubator **100**. FIG. **10** shows the vent handle **186** in a closed configuration. FIG. **11** shows the vent handle **186** in an open configuration. The vent handle **186** can include some features similar to the latch assembly **164** of FIGS. **6** to **9**. However, the vent handle **186** can omit the latch **170**. The user can pull on the handle **174** to open the door **114** of the incubator. The spring **184** and/or the door **114** can be configured so that the spring **184** at least partially compresses before the door **114** opens. For example, the force to compress the spring **184** can be less than the force to move the door **114**. The spring **184** can be selected with a relatively low spring force, which can be sufficiently high to bias the actuator **172** to the closed configuration (e.g., FIG. **10**), but can be sufficiently low that the spring compress to transition the actuator **172** to the open state (e.g., FIG. **11**) before the door **114** opens. The door **114** (e.g., the hinges **115** thereof) can be configured to require a threshold amount of force before the door opens, and that threshold force can be higher than the amount of force to compress the spring **184** to open the vent handle (e.g., FIG. **11**). When the user pulls the handle **174**, the actuator **172** can move from the closed configuration of FIG. **10** to the open configuration of FIG. **11**, for example without opening the door. In the open configuration the one or more openings **168** can be open to permit air to flow between interior chamber **106** of the incubator **100** and the ambient environment. By continuing to pull on the handle **174**, such as with additional force, the user can open the door **114**. Because the vent through the one or more openings **168** is open before the door moves significantly, the pressure differential caused by moving the door can be at least partially dissipated by venting air through the one or more openings **168**. When closing the door, in some cases gravity can pull the door downward toward the closed position, which can compress the biasing member or spring **184** and open the openings **168** to vent air as the door is closed. Once the door is closed, the user can release the handle **174** or lower the handle **174** so that the cover **172** closes the openings **168**. In some cases, the door **114** can be biased towards the closed position, such as by a spring, or other biasing member, or with one or more magnets. The force to move the cover **172** (e.g., and compress the spring or biasing member **184**) can be less than the force to move the door **114**. Thus the cover **172** can move to open the vents of openings **168** before the door **114** opens and/or the vent openings **168** can remain open until after the door **114** is closed. In some examples, the door **114** can be biased close by magnets so that pulling or pushing on the latch releases pressure by opening the vent but also provides a force to overcome the attraction of the magnets to open the door. The doors for the access ports **116** and/or one or more main access doors **114** can include the latch assembly **164** or the vent handle **186** embodiments.

[0074] In some embodiments, the incubator **100** can have acoustically leaky seals **188**, such as around the door **114** and/or around the access port(s) **116**. In FIG. **1**, one of the access ports **116** is shown surrounded by the seal **188**. Although only one access port **116** is shown with the seal **188**, for illustration, any number of openings, ports, doors, etc. can include the seal **188**. FIG. **12** shows an example embodiment of the acoustically leaky seal material. The seal can include a soft compliant material with a series of holes **190** therethrough (e.g., arranged in a grid, although other arrangements of the holes could be used). When compressed, the seal material **188** can mostly or entirely close the holes **190**. When the seal **188** is uncompressed, the holes **190** can open. The holes **190** can permit air to pass through the seal **188**. The seal **188** can be sufficiently soft that the acoustic leak can be accelerated by a pressure differential. The doors for the access ports **116** and/or one or more main access doors **114** can include the acoustically leaky seal **188**. In some embodiments, the seal **188** can have a relatively dense but porous material, such that air can flow through the seal **188**, but only at a certain or restricted speed. As a pressure differential builds, the size of the pores can naturally increase so that the pressure releases. One example of the acoustically leaky seal **188** is reticulated foam with relatively small pore sizes.

[0075] The access port **116** can have an access door that can be opened or closed. When closed, the seal **188** can substantially seal the interface between the door and the access port **116**. As the door for the access port **116** is opened, the seal **188** can expand to become acoustically leaky, such as to permit air to flow through the seal, such as to at least partially relieve a pressure differential produced by opening the door. When closing the door of the port **116**, the seal **188** can permit air to flow through the seal as the door is closed, and can then seal acoustically when the door of the port **166** actually closes.

[0076] In some embodiments, the incubator **100** can include one or more pressure relief valves **192**. The pressure relief valve(s) **192** can be placed on the top **112** of the enclosure or canopy **104** and/or on one or more of the sides **110** of the enclosure or canopy **104**. In some embodiments, the door **114** can include one or more pressure relief valve(s) **192**. Any suitable number of pressure relief valve(s) **192** can be used, such as 1, 2, 3, 4, 6, 8, 12, or more pressure relief valve(s) **192**. FIG. **1** shows a single pressure relief valve **192** for illustration. The pressure relief valves can include check valves or one-way valves that are configured to permit air to flow in one direction through the valve, while substantially impeding flow of air in the other direction. The pressure relief valve(s) **192** can be tuned to open when a pressure differential between the internal chamber **106** of the incubator **100** and the ambient area outside the incubator is above a threshold amount. If a pressure differential above that threshold exists, the pressure relief valve **192** can open to permit air flow that reduces the pressure differential.

[0077] FIG. **13** shows an example embodiment that includes two pressure relief valves **192**. A first press relief valve (e.g., on the left in FIG. **13**) can permit fluid (e.g., air) to flow from the incubator to the ambient area outside the incubator. The second relief valve (e.g., on the right in FIG. **13**) can permit fluid (e.g., air) to flow from the ambient area outside the incubator to the internal chamber **106** inside the incubator **100**. The wall **100** of the enclosure or canopy **104** or door **114** can have an opening. The pressure relief valve **192** can include a housing with an inlet **193** and an outlet **194**. Inside the housing the valve **192** can have a stopper **195**, which can be biased to a closed position by a spring **196**. The spring **196** can press the stopper **195** against the housing to close the inlet **193**, for example. If a pressure differential is strong enough to compress the spring **106**, the stopper **105** can retract from the housing to open the pressure relief valve **192**. Air can pass through the pressure relief valve **192** when open. Once enough air has passed to reduce the pressure differential below the threshold the spring **196** can reseal the stopper **105** against the housing to close the valve **192**. The pressure relief valve **192** on the left in FIG. **13** can open in response to a pressure differential where the internal incubator pressure is higher than an ambient pressure. The pressure relief valve **192** on the right in FIG. **13** can open in response to a pressure differential where the ambient pressure is higher the than internal incubator pressure. The incubator **100** can have two pressure relief valves **192** (e.g., as shown in FIG. **13**), e.g., with opposite orientations, such as for bi-directional operation. Other types of pressure relief valves, check valves, or one-way valves can be used, such as a duck-bill check valve, etc.

[0078] In some implementation, the incubator **100** can include dual wall construction, such as for the side walls **110**, the top wall **112**, the door **114**, and/or for the covers of the access ports **116**. FIG. **14**. Any portion of the incubator **100** (e.g., isolette) cover can use dual wall or dual pane construction. FIG. **14**A shows an example of single pane construction. FIG. **14**B shows an example of dual pane construction. A first pane or sheet can be spaced apart from a second pane or sheet. The frame or housing can support the panes in the spaced-apart configuration. A gas or vacuum can be disposed between the panes. A spacer bar can be positioned between the panes, such as along the periphery or where the panes engage the frame or housing. The spacer bar can keep the panes spaced apart. A desiccant material can be used between the panes, in some cases. In some cases, the panes can be made of glass. In some embodiments, the panes can be made of plastic.

[0079] In some embodiments, the incubator can use plastics with relatively high internal loss to acoustic energy, which can increase the loss of noise transmitting through the plastics. For example, the plastic materials can reduce self-ringing and resonance of the plastic viewing parts of the incubator **100**. For example, the side walls **110**, the top wall **112**, the door **114**, and/or for the covers of the access ports **116** can be made of a plastic material, such as polycarbonate, copolyester, or cellulosic. In some cases, acrylonitrile butadiene styrene (ABS) plastic can be used. In some cases, Tritan copolyester can be used. FIG. **14**C shows acoustic waterfall plots for polycarbonate, copolyester, or cellulosic. In some cases, these materials could be used for other components of the incubator **100**, such as the body **102**, the base **148**, etc. In some cases, other materials could be used. In the waterfall plots, the X-axis (along the left-right direction on the bottom of the plots) is frequency in Hertz, the Y-axis (along the front-back direction on the right of the plots) is time in milliseconds, and the Z-axis (along the up-down direction on the left of the plots) is intensity in dB. In the plots, superior performance can be indicated by a lower amount of energy in time, thus minimizing the Y and Z axis components.

[0080] In some embodiments, the incubator **100** can be made of flat facets, such as with parallel sides. In FIG. **1**, the incubator has a rectangular profile. In some cases, other shapes can be used, which can reduce or eliminate standing waves. By way of example, in some cases, the side walls **110** and/or the top wall **112** can be curved. In some cases, the side walls **110** can be arranged in a non-parallel configuration. FIG. **15** shows a comparison of two shapes with the same area. The shape on the left is rectangular, whereas the shape on the right is four-sided but nonrectangular, for example, the sides are non-parallel. FIG. **15** shows the 1,3 mode for the rectangular area and for the nonrectangular area. The sound field in the nonrectangular area is distorted as compared to the rectangular area. In some cases, the irregular shape does not necessarily reduce the overall energy internally, but it can distributes the energy in a manner that reduces the level over more areas.

[0081] In some embodiments, the incubator **100** can have an internal chamber **106** that does not have any corners or hard edges and/or flat surfaces. In some cases, the shape of the canopy **104** can direct energy away from the patient. The shape of the canopy **104** can dissipate energy away. In some cases, the curved surfaces are not parabolic in shape (e.g., which could focus the acoustic energy). The curved or angled surfaces can reduce or disrupt reflections, in some cases. FIG. **16**A shows an example embodiment where the walls **110** of the incubator are flat, with corners. FIG. **16**B shows an example embodiments where the walls are curved. The curved walls can disrupt reflections more than the flat walls.

[0082] With reference to FIG. **17**, in some embodiments, the incubator **100** can include a bed **108** with a mattress **197** that includes reticulated foam (e.g., highly reticulated foam). The mattress **197** can be placed inside a cover **198**, which can be a fabric cover, which can be substantially acoustically transparent. In some cases, the cover can be hydrophobic. The cover **198** can permit sound to pass through to the mattress **197**, and the mattress **197** can absorb sounds. In effect, the patient can sleep on a sound absorbing panel inside the incubator **100**. Other types of beds can be used. In some cases, the bed **108** can include a mattress that includes polyurethane foam on the inside and a cover (e.g., a vinyl cover) on the outside.

[0083] In some embodiments, the incubator **100** can include a manual pressure release feature, such as a push-button pressure release valve **202**. The pressure release valve **202** can include a shaft **204** that extends through an opening through the canopy **104** (e.g., through a wall **110**). The end of the shaft **204** inside the interior chamber **106** can be coupled to a cover, which can cover and seal the shaft opening and/or one or more openings **208** through the canopy **204** (e.g., through the wall **110**) when in the closed position, which is shown in FIG. **18**. The side of the shaft **204** outside the internal chamber **106** can be coupled to a head **210**. A spring **212** can be positioned between the head **210** and the wall **110**, and the spring **212** can bias the pressure release valve to the closed position shown in FIG. **18**. The user can press the head **210** to move the head **210**, shaft **204**, and cover **206** inward, so that the cover **206** unseals the one or more openings **308** through the canopy **204** (e.g., through the wall **110**), so that air can flow between the interior chamber **106** and the ambient area outside the incubator **100**, such as to equalize a pressure differential. The spring **212** can bias the valve **202** to the closed position.

[0084] In some embodiments, the incubator **100** can include a first pressure sensor **214** inside the interior chamber **106** and a second pressure sensor **216** outside the interior chamber **106**. The processor **128** can analyze signals or data from the first pressure sensor **214** and the second pressure sensor **216**, such as to determine a pressure differential between the interior chamber and the ambient environment. If the processor **128** determines that a pressure differential is present, or that a determined pressure differential is above a threshold pressure value (e.g., which can be stored in memory **130**), the processor **128** can provide an alert or notification, such as via the user interface **124**, the communication interface **126**, and/or a light **218**. For example the light **218** can illuminate when a pressure differential (e.g., above a threshold in some cases) is identified.

[0085] In some embodiments, the incubator **100** can include one or more acoustical filters. In some cases, the acoustical filter(s) can include an open pathway to the outside. Various types of filters can be used. For example, a high-pass filter can be used, as illustrated in FIG. **19**. In some instances, a NICU has relatively low amounts of mid-to-high frequency noise content. Accordingly, a high pass filter can permit the higher frequencies to pass while attenuating the lower frequencies. The high-pass filter can be tuned to have a cut-off frequency according to the needs and goals of the particular circumstances. In some implementations, a band-stop filter can be used, as illustrated in FIG. **20**. When a noise in a particular range of frequencies is the concern, a band-stop filter can attenuate that range of frequencies, while letting other frequencies pass through. The band of frequencies to be stopped can be tuned based on the particular circumstances. The filter can be built in mechanical structures, such as be hidden in floor or walls of the incubator **100**. The filter(s) can include pathways with expansion chambers, side chambers, and openings that produce high pass, low pass, band stop, and/or band bass filter functions.

[0086] In some cases, the movement of storage compartments on the incubator can produce noise that can disturb the patient. For example, in some incubators, bins can be coupled to the frame or main body of the incubator with bolts or other hard couplings that can transfer vibrations from the bin to the frame of the incubator, and from there to the patient. For example, as a storage container slides (e.g., as a drawer or removable bin), that movement can produce vibrations and/or noise that can disrupt the patient. In some embodiments, the incubator **100** can include storage bins that are hung from lossy components to reduce or minimize transmission of noise and/or vibrations from the bin(s) to the body of the incubator **100**. With reference to FIG. **21**A, the bin can be suspended from the body **102** or frame of the incubator **100**. The body **102** or frame can include two openings through which fasteners **216** can extend. Bushings **218** can be used between the fasteners **216** and the body **102**. The bushings **218** can have a lower durometer than the fasteners **216**. Polymer pieces **220** can be coupled to the fasteners **216** and can extend downward from the fasteners **216**. Additional fasteners **222** can be coupled to the ends of the polymer pieces **220**. A support **214** can be coupled to the additional fasteners **222**. The support **214** can support a bin or a drawer or a storage container. In some cases, the support **214** can be a slide, along which a portion of the bin can slide as the bin moves (e.g., between a closed configuration and an open configuration). Various types of supports **214** can be used. In some cases, the bin can be removable and the support **214** can be a hook or other receiver for removably receiving the bin. The support **214** can be insulated from the frame or body **102** of the incubator by one or more compliant parts such that transmission of the drawer (e.g., which can slide in and out in the "U" of part the support **214** of FIG. **21**A). Thus, vibration from the bin moving in and out can be attenuated or isolated from the main frame or body **102** of the incubator **100**. One or more of the materials that couple the support **214** or the bin to the frame or body **102** (e.g., the bushing(s) **218**, the fastener(s) **216**, the coupling piece(s) **220**, and/or the additional fasteners **222**) can have a hardness of about 40, about 45, about 50, about 55, about 60, about 65, about 70 durometers, or more. FIG. **21**B shows another example embodiment where the support **214** is coupled to the fasteners **216**. The additional fasteners **222** and pieces **220** can be omitted, in some cases. In some cases, the pieces **220** can be absorbers configured to absorb vibrations. For example, in some implementations, the bushing(s) **218** and fasteners **216** can be tuned to reduce transmission of noise and/or vibration over a first range of frequencies, and the coupling piece(s) **220** and the additional fastener(s) **222** can be tuned to reduce transmission of noise and/or vibration over a second range of frequencies, which can be different from the first range of frequencies. The incubator can have one or more compliantly suspended bins. In some embodiments, double-compliance suspension can be used to couple the bin to the frame or body **102** of the incubator.

[0087] In some embodiments, the incubator can be raised and/or lowered using the lift **146**. In some embodiments, the lift **146** does not use a chain driver or jack screws, since both of those can be mechanically noisy. Jack screws have several hard metal interfaces that generate noise and transmit vibration. The lift can use a pair of toothed wheels and a belt, which can be relatively quiet. FIG. **22** shows an example embodiment of a belt **224** that can be used with the lift **146**. The belt **224** can have teeth on the inside, which can interface with teeth on a gear or wheel.

[0088] In some embodiments, the incubator **100** can use active noise cancellation. With reference to FIG. **22**, the incubator **100** can include a microphone **230**, which can be positioned hear the head of the patient when in the incubator **100**. Noise **232** can be measured by the microphone **230**, and corresponding signals can be sent to a processor **128**, which can be a digital signal processor. The processor **128** can determine cancelation sounds based at least in part on the signals received from the microphone **230**. For example, the cancelations sounds can be inverted versions of the sounds picked up by the microphone **230**. The cancelation sounds can be played by a speaker **234**. The cancelation sounds can attenuate the sounds **232**, such as by destructive interference. In some cases, the active noise cancelling features can work best for canceling relatively low frequencies. The microphone **230** can be near the patient for a feedback approach. In some cases, the microphone **230** can be outside the incubator **100** or otherwise positioned so that the noise **232** reaches the microphone before reaching the patient, so that the system has time to prepare and play the cancelation sounds before the sound arrives at the patient. The noise cancelation system can use a feed forward approach, or a hybrid of feedback and feed-forward. In some cases, multiple microphones **230** can be used, such as at different locations (e.g., one near the patient inside the incubator **100** and one outside the incubator **100**).

[0089] FIG. **24**A shows an example embodiment of a rotating vented handle mechanism **187** in a closed configuration, and FIG. **24**B shows the handle mechanism **187** in an open configuration. The handle mechanism **187** can include a handle or grip **174** that can be manipulated by a user, such as to rotate the handle mechanism. A cover **172** can rotate with the handle **174**. The cover **172** can cover or close one or more openings **168** in a wall or door of the incubator when in the closed configuration. In FIG. **24**A, the opening **168** is shown in a dashed line because it is covered. As the handle **174** is rotated, the cover **172** can move to an open position where the opening **168** is uncovered so that air can flow through the opening **168**. The assembly can include a latch **170**, which can be actuated to open a door **114**. The handle mechanism **187** can include a protrusion or other actuation feature **182**, which can trigger the latch **170** when the handle **174** is rotated further than the open position that opens the vent through the opening **168**. Accordingly, when the door **114** is released to open, the vent can already be open so that a pressure differential from opening the door can be reduced.

Additional Information

[0090] In some embodiments, the methods, techniques, microprocessors, and/or controllers described herein are implemented by one or more special-purpose computing devices. The special-purpose computing devices may be hard-wired to perform the techniques, or may include digital electronic devices such as one or more application-specific integrated circuits (ASICs) or field programmable gate arrays (FPGAs) that are persistently programmed to perform the techniques, or may include one or more general purpose hardware processors programmed to perform the techniques pursuant to program instructions in firmware, memory, other storage, or a combination thereof. The instructions can reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of a non-transitory computer-readable storage medium. Such special-purpose computing devices may also combine custom hard-wired logic, ASICs, or FPGAs with custom programming to accomplish the techniques. The special-purpose computing devices may be desktop computer systems, server computer systems, portable computer systems, handheld devices, networking devices or any other device or combination of devices that incorporate hard-wired and/or program logic to implement the techniques.

[0091] The microprocessors or controllers described herein can be coordinated by operating system software, such as IOS, Android, Chrome OS, Windows XP, Windows Vista, Windows 7, Windows 8, Windows 10, Windows Server, Windows CE, Unix, Linux, SunOS, Solaris, iOS, Blackberry OS, VxWorks, or other compatible operating systems. In other embodiments, the computing device may be controlled by a proprietary operating system. Conventional operating systems control and schedule computer processes for execution, perform memory management, provide file system, networking, I/O services, and provide a user interface functionality, such as a graphical user interface ("GUI"), among other things.

[0092] The microprocessors and/or controllers described herein may implement the techniques described herein using customized hard-wired logic, one or more ASICs or FPGAS, firmware and/or program logic which causes microprocessors and/or controllers to be a special-purpose machine. According to one embodiment, parts of the techniques disclosed herein are performed a controller in response to executing one or more sequences instructions contained in a memory. Such instructions may be read into the memory from another storage medium, such as storage device. Execution of the sequences of instructions contained in the memory causes the processor or controller to perform the process steps described herein. In alternative embodiments, hard-wired circuitry may be used in place of or in combination with software instructions.

[0093] Moreover, the various illustrative logical blocks and modules described in connection with the embodiments disclosed herein can be implemented or performed by a machine, such as a processor device, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A processor device can be a microprocessor, but in the alternative, the processor device can be a controller, microcontroller, or state machine, combinations of the same, or the like. A processor device can include electrical circuitry configured to process computer-executable instructions. In another embodiment, a processor device includes an FPGA or other programmable device that performs logic operations without processing computer-executable instructions. A processor device can also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. Although described herein primarily with respect to digital technology, a processor device may also include primarily analog components. For example, some or all of the techniques described herein may be implemented in analog circuitry or mixed analog and digital circuitry.

[0094] Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise," "comprising," "include," "including," and the like are to be construed in an inclusive sense, as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to." The words "coupled" or connected," as generally used herein, refer to two or more elements that can be either directly connected, or connected by way of one or more intermediate elements. Additionally, the words "herein," "above," "below," and words of similar import, when used in this application, shall refer to this application as a whole and not to any particular portions of this application. Where the context permits, words in the Detailed Description using the singular or plural number can also include the plural or singular number, respectively. The words "or" in reference to a list of two or more items, is intended to cover all of the following interpretations of the word: any of the items in the list, all of the items in the list, and any combination of the items in the list. All numerical values provided herein are intended to include similar values within a range of measurement error.

[0095] Although this disclosure contains certain embodiments and examples, it will be understood by those skilled in the art that the scope extends beyond the specifically disclosed embodiments to other alternative embodiments and/or uses and obvious modifications and equivalents thereof. In addition, while several variations of the embodiments have been shown and described in detail, other modifications will be readily apparent to those of skill in the art based upon this disclosure. It is also contemplated that various combinations or sub-combinations of the specific features and aspects of the embodiments may be made and still fall within the scope of this disclosure. It should be understood that various features and aspects of the disclosed embodiments can be combined with, or substituted for, one another in order to form varying modes of the embodiments. Any methods disclosed herein need not be performed in the order recited. Thus, it is intended that the scope should not be limited by the particular embodiments described above.

[0096] Conditional language, such as, among others, "can," "could," "might," or "may," unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include, while other embodiments do not include, certain features, elements and/or steps. Thus, such conditional language is not generally intended to imply that features, elements and/or steps are in any way required for one or more embodiments or that one or more embodiments necessarily include logic for deciding, with or without user input or prompting, whether these features, elements and/or steps are included or are to be performed in any particular embodiment. Any headings used herein are for the convenience of the reader only and are not meant to limit the scope.

[0097] Further, while the devices, systems, and methods described herein may be susceptible to various modifications and alternative forms, specific examples thereof have been shown in the drawings and are herein described in detail. It should be understood, however, that the disclosure is not to be limited to the particular forms or methods disclosed, but, to the contrary, this disclosure covers all modifications, equivalents, and alternatives falling within the spirit and scope of the various implementations described. Further, the disclosure herein of any particular feature, aspect, method, property, characteristic, quality, attribute, element, or the like in connection with an implementation or embodiment can be used in all other implementations or embodiments set forth herein. Any methods disclosed herein need not be performed in the order recited. The methods disclosed herein may include certain actions taken by a practitioner; however, the methods can also include any third-party instruction of those actions, either expressly or by implication.

[0098] The ranges disclosed herein also encompass any and all overlap, sub-ranges, and combinations thereof. Language such as "up to," "at least," "greater than," "less than," "between," and the like includes the number recited. Numbers preceded by a term such as "about" or "approximately" include the recited numbers and should be interpreted based on the circumstances (e.g., as accurate as reasonably possible under the circumstances, for example ±5%, ±10%, ±15%, etc.). For example, "about 3.5 mm" includes "3.5 mm." Phrases preceded by a term such as "substantially" include the recited phrase and should be interpreted based on the circumstances (e.g., as much as reasonably possible under the circumstances). For example, "substantially constant" includes "constant." Unless stated otherwise, all measurements are at standard conditions including ambient temperature and pressure.

1. An incubator comprising:

a body;

a bed supported by the body;

a canopy defining an interior chamber that includes the bed; and

one or more of:

at least one passive radiator;

at least one Helmholtz resonator;

at least one meta material absorber;

an active noise cancelation system;

a door having a closed configuration and an open configuration that provides access to the interior chamber, wherein the door has a vent handle that is configured to open a vent to permit air flow between the interior chamber and an ambient area outside the incubator before the door opens;

a door having a closed configuration and an open configuration that provides access to the interior chamber, and a seal configured to acoustically seal between the door and the canopy when the door is closed, and wherein the seal material is configured to acoustically open when the door is open;

one or more pressure relief valves;

a manual pressure release valve;

a lift mechanism configured to raise or lower the bed and canopy, wherein the lift mechanism uses a belt drive system;

a bin suspended from the body, and one or more compliant elements disposed between the bin and the body to at least partially insulate the body from vibrations of the bin; and

an acoustic filter.

2. The incubator of claim **1** comprising:

the at least one Helmholtz resonator.

3. The incubator of claim **1** comprising:

the at least one meta material absorber.

4. The incubator of claim **1** comprising:

the active noise cancelation system.

5. The incubator of claim **4**, wherein the active noise cancelation system includes:

a microphone positioned in the interior chamber of the incubator;

a processor configured to receive signals representative of noise recorded by the microphone, wherein the processor is configured to produce cancelation sound based at least in part on the signals received from the microphone; and

a speaker configured to play the cancelation sounds.

6. An incubator comprising:

a body;

a bed supported by the body;

a canopy defining an interior chamber that includes the bed;

a door having a closed configuration and an open configuration that provides access to the interior chamber; and

a latch assembly comprising:

one or more vent openings;

an actuator that is movable between a closed configuration that closes the one or more vent openings and an open configuration that opens the one or more vent openings so that air can flow between the interior chamber and an ambient area around the incubator; and

a mechanism configured to interface with the actuator when the actuator moves beyond the open configuration so that movement of the actuator activates the latch assembly mechanism to release the door from the closed configuration;

wherein the vent openings are open to permit air flow between the interior chamber and the ambient area before the door is released.

7. The incubator of claim **6**, wherein the actuator is a pull actuator.

8. The incubator of claim **6**, wherein the actuator is a push actuator.

9. The incubator of claim **6**, wherein the actuator is biased to the closed configuration.

10. The incubator of claim **1** comprising:

the door having a closed configuration and an open configuration that provides access to the interior chamber, wherein the door has the vent handle that is configured to open the vent to permit air flow between the interior chamber and an ambient area outside the incubator before the door opens.

11. An incubator comprising:

a body;

a bed supported by the body;

a canopy defining an interior chamber that includes the bed; and

a door having a closed configuration and an open configuration that provides access to the interior chamber, wherein the door includes:

one or more vent openings;

a handle that is movable between a closed configuration that impedes air flow through the one or more vent opening and an open configuration that permits air flow through the one or more vent openings;

a biasing member configured to bias the handle to the closed configuration, wherein the force to move the handle to the open configuration is less than the force to move the door to the open configuration, such that the handle is configured to open the vents to permit air flow between the interior chamber and the ambient area before the door opens.

12. The incubator of claim **1** comprising:

the door having a closed configuration and an open configuration that provides access to the interior chamber; and

the seal configured to acoustically seal between the door and the canopy when the door is closed, and wherein the seal material is configured to acoustically open when the door is open.

13. The incubator of claim **12**, wherein the seal material includes a series of holes that acoustically close when the door is closed and that open as the door transitions from the closed position to the open position, so that air can flow through the seal.

14. The incubator of claim **1** comprising:

the one or more pressure relief valves.

15. The incubator of claim **1** comprising:

the lift mechanism configured to raise or lower the bed and canopy, wherein the lift mechanism uses the belt drive system.

16. The incubator of claim **1** wherein the canopy includes at least one of polycarbonate, copolyester, and cellulosic.

17. The incubator of claim **1** wherein one or more of the walls of the canopy is double paned.

18. The incubator of claim **1** comprising:

the bin suspended from the body;

the one or more compliant elements disposed between the bin and the body to at least partially insulate the body from vibrations of the bin.

19. The incubator of claim **1** comprising:

the manual pressure release valve.

20. The incubator of claim **19**, comprising:

a first pressure sensor inside the incubator interior chamber;

a second pressure sensor outside the interior chamber; and

a processor configured to receive signal from the first pressure sensor and the second pressure sensor and to determine a pressure differential between inside the interior chamber and outside the interior chamber.

21. The incubator of claim **20**, wherein the processor is configured to provide a notification when a pressure differential is determined.

22. The incubator of claim **1** wherein the walls of the canopy are non-parallel.

23. The incubator of claim **1** wherein the walls of the canopy are curved.

24. The incubator of claim **1** wherein the bed includes a mattress that includes reticulated foam.

25. The incubator of claim **24**, wherein the mattress includes a cover that is substantially acoustically transparent.

26. The incubator of claim **1** comprising:

acoustic filter.

* * * * *