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(54) Title: GEOTHERMAL HEATING, VENTILATING AND COOLING SYSTEM

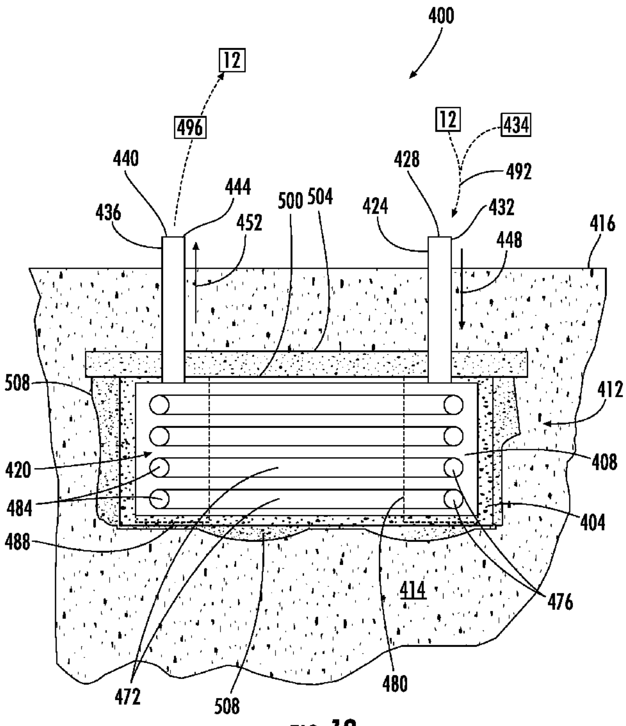

FIG. 13

(57) Abstract: An apparatus for modifying an atmosphere for use in a conditioned zone of a structure. The apparatus typically includes an underground air conduit system to take advantage of geothermal conditions to modify the temperature of air and water vapor flowing through the apparatus. A drain is typically provided for removal of water vapor that condenses to liquid in the air conduit. In some embodiments air from the conditioned zone of the structure may be recycled through the apparatus, together with a source of air that originates outside the conditioned zone of the structure. The apparatus may be integrated into other heating and cooling systems as appropriate to further control the air temperature. The apparatus may be combined with a solar heated water heater or "trombe" wall type structure where the heat generation in the winter provides a complete balance for year round stable and livable air temperatures.

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GEOTHERMAL HEATING, VENTILATING AND COOLING SYSTEM

CROSS REFERENCES TO RELATED APPLICATIONS

[0001] This patent application claims priority from and is related to U.S. Provisional Patent Application Serial No. 61/085,153 filed 31 July 2008, entitled: GEOTHERMAL HEATING, VENTILATING AND COOLING SYSTEM. Provisional Patent Application Serial No. 61/085,153 is incorporated by reference in its entirety herein.

FIELD

[0002] This disclosure relates to the field of heating, ventilating and cooling systems for buildings and structures. More particularly, this disclosure relates to geothermal-assisted heating, ventilating and cooling systems for building and structures.

BACKGROUND

[0003] It is often desirable to control the temperature and/or humidity within buildings and outdoor structures or facilities that may be inhabited or that may store equipment or commodities or be used for other purposes. Various heating and air conditioning systems are commercially available for these purposes. However, the energy costs associated with operating such systems may be excessive. What is needed therefore are better systems and methods for economically and efficiently controlling the temperature and/or humidity within buildings and outdoor structures or facilities.

SUMMARY

[0004] The present disclosure provides an apparatus for modifying an atmosphere for use in a conditioned zone of a structure. One embodiment includes a tank for containing a thermal ballast material for thermal transport in an underground space below a grade level. This embodiment further includes an air conduit system that is disposed within the tank for contacting the thermal ballast material. The air conduit system has an entry passage with an entry port for an air flow connection with the conditioned zone of the structure and an exit passage with an exit port for the air flow connection with the conditioned zone of the structure.

[0005] Also disclosed is a method for forming an apparatus for modifying an atmosphere for use in a conditioned zone of a structure. The method includes the steps of excavating a space underground below a grade level and casting a tank in-situ in the space. In one embodiment the method includes a step of disposing in the tank an air conduit system, where the air conduit system has an entry passage with an entry port and an exit passage with an exit port, and where the entry port and the exit port are above the grade level. The method futher includes a step of disposing a thermal ballast material in the tank and a step of disposing a lid on the tank, where the lid covers the tank and the thermal ballast material. A further step in this embodiment is backfilling to substantially the grade level the space underground that is not occupied by the tank, the lid, the entry passage, and the exit passage, while providing for retention of the entry port and the exit port above the grade level.

[0006] A further method is disclosed for forming an apparatus for modifying an atmosphere for use in a conditioned zone of a structure. This method includes the steps of excavating a space underground below a grade level and disposing a first thermal transfer material portion in the space. This method also includes steps of disposing a tank having a bottom and sides in the space, where the bottom of the tank rests on the thermal transfer material and disposing in the tank an air conduit system having an entry port and an exit passage with an exit port, wherein the entry port and the exit port are above the grade level.

This method further includes steps of disposing a thermal ballast material in the tank and disposing a lid on the tank, where the lid covers the tank and the thermal ballast material. The method includes a step of disposing a second thermal transfer material portion in the space adjacent the sides of the tank, and then a step of backfilling to substantially the grade level the space underground that is not occupied by the tank, the lid, the entry passage, the exit passage, and the thermal transfer material, while providing for retention of the entry port and the exit port above the grade level.

[0007] The present disclosure further provides an apparatus for modifying an atmosphere for use in a conditioned zone of a structure. Typically the apparatus includes an air conduit having a length and being disposed at least partially in a stable temperature environment. The air conduit is typically configured with an entry port that is open to an atmosphere that is external to the conditioned zone of the structure. Other typical configurations allow a combination of air from an entry port external to the structure and recycled air from a second entry port internal to the structure. The air conduit is also generally configured for conveying a flow of air and water vapor from the entry port, through a substantial portion of the air conduit, and out an exit port in the air conduit into the conditioned zone of the structure. Generally the apparatus includes at least one drain that is in fluid communication with the air conduit. The at least one drain is configured to receive and expel through at least one drain outlet a substantial portion of any water vapor that condenses to a liquid water as the air and the water vapor flow through the air conduit. Generally, the apparatus is further configured such that substantially all of the air and water vapor that flows through the apparatus travels a distance that is substantially equal to the length of the air conduit. In some embodiments the at least one drain comprises a drainage pipe that is disposed in a substantially continuously-downward-sloping orientation. In some embodiments the at least one drain comprises a drainage pipe that is disposed in a substantially continuously-downward-sloping orientation and the at least one drain outlet is disposed proximal to the entry point or proximal to the exit point of the air conduit. In some embodiments the air conduit is disposed in a substantially continuously-downward-sloping orientation from the exit port to the entry port and the drain comprises a trough portion of the air conduit and the entry port comprises the at least one drain outlet. In some embodiments the air conduit is disposed in a substantially continuously-downward-sloping orientation and the at least one drain comprises a trough portion of the air conduit and the at least one drain outlet comprises a drain hole in the trough portion.

[0008] A further embodiment provides a system for conditioning air in a conditioned zone of a structure that includes a source of air external to the conditioned zone and a regulator configured to provide a regulated flow rate of external air from the source of external air. This further embodiment also generally includes an air conduit system that is disposed at least partially in a stable temperature environment and that has a first entry port that is in fluid communication with the air in the conditioned zone of the structure, and that has a second entry port that is in fluid communication with the regulated flow rate of external air, and that has an exit port into the conditioned zone of the structure. This further embodiment typically also provides a source of pressure differential that flows air into the air conduit system from the first entry port and from the second entry port of the air conduit system and through a substantial portion of the air conduit system and out of the exit port of the air conduit system into the conditioned zone of the structure.

[0009] Another further embodiment of an apparatus for modifying an atmosphere for use in a conditioned zone of a structure provides a plurality of flow reversion blocks interconnected by hollow air conduit. Each flow reversion block has a plurality of openings in only one face, wherein air enters the block through one or more openings in the face and exits the block through one or more openings the face.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Various advantages are apparent by reference to the detailed description in conjunction with the figures, wherein elements are not to scale so as to more clearly show the details, wherein like reference numbers indicate like elements throughout the several views, and wherein:

[0011] Fig. 1 is a somewhat schematic perspective view of an apparatus for modifying an atmosphere for use in a conditioned zone of a structure.

[0012] Fig. 2 is a somewhat schematic perspective view of an apparatus for modifying an atmosphere for use in a conditioned zone of a structure.

[0013] Fig. 3 is a somewhat schematic top view of an apparatus for modifying an atmosphere for use in a conditioned zone of a structure.

[0014] Fig. 4 is a somewhat schematic cross section of hollow air conduit and a drainage pipe.

[0015] Fig. 5 is a somewhat schematic elevation view of an air conduit system and a drainage pipe.

[0016] Fig. 6 is a somewhat schematic top view of a portion of an apparatus for modifying an atmosphere for use in a conditioned zone of a structure.

[0017] Fig. 7 is a somewhat schematic top view of an apparatus for modifying an atmosphere for use in a conditioned zone of a structure.

[0018] Fig. 8 is a somewhat schematic side elevation view of a system for conditioning air in a conditioned zone of a structure.

[0019] Fig. 9 is a somewhat schematic elevation view of an apparatus for modifying an atmosphere for use in a conditioned zone of a structure combined with a solar heating system.

[0020] Fig. 10 a somewhat schematic elevation view of an apparatus for modifying an atmosphere for use in a conditioned zone of a structure combined with a solar heating system.

[0021] Figs. 11A and 11B are somewhat schematic elevation views of solar collectors.

[0022] Fig. 12 is a somewhat schematic elevation of an apparatus for modifying an atmosphere for use in a conditioned zone of a structure combined with a solar heating system.

[0023] Fig. 13 is a somewhat schematic elevation of an apparatus for modifying an atmosphere for use in a conditioned zone of a structure.

[0024] Fig. 14 is a somewhat schematic top view of the apparatus for modifying an atmosphere for use in a conditioned zone of a structure.

[0025] Fig. 15 is a somewhat schematic elevation view of the apparatus of Fig. 14 for modifying an atmosphere for use in a conditioned zone of a structure.

[0026] Fig. 15 a somewhat schematic elevation view of an apparatus for modifying an atmosphere for use in a conditioned zone of a structure combined with a solar heating system.

[0027] Fig. 17 is a plot of data from an apparatus for modifying an atmosphere for use in a conditioned zone of a structure that was installed for test purposes.

[0028] Fig. 18 is a somewhat schematic elevation view of the test apparatus that generated the data of Fig. 17.

DETAILED DESCRIPTION

[0029] In the following detailed description of the preferred embodiments, reference is made to the accompanying drawings, which form a part hereof, and within which are shown by way of illustration the practice of specific embodiments of an apparatus for conditioning a flow of air and water vapor from an outdoor atmosphere into a structure and embodiments of an apparatus for conditioning air in a structure and embodiments of an underground air conduit system for conditioning air flowing from an outdoor atmosphere into a structure. It is to be understood that other embodiments may be utilized, and that structural changes may be made and processes may vary in other embodiments.

[0030] In most of the inhabited world it is desirable (at least during parts of the year) to establish an air quality within various structures that is "better" than the ambient atmospheric air quality. Desirable air quality parameters include the following:

Appropriate temperature range
Appropriate relative humidity
Minimal inorganic or carbon particulate inclusions
Minimal organismic inclusions, such as pollen, fungicidal spores, etc.
Minimal harmful odors or chemical vapors
Minimal or no radon gas
Proper oxygenation

[0031] Structures for which these interior atmospheric parameters are desirable include residential, commercial and agricultural structures. Residential structures include both normally-occupied buildings (homes or apartments) as well as ancillary structures such as garages, atriums, and various out-buildings such as gazebos, greenhouses, and so forth. Commercial structures include offices, retail facilities, hotels, nursing homes, hospitals, airport terminals, theatres, arenas, factories, warehouses, greenhouses, and so forth. Agricultural structures include animal shelters, grain barns, greenhouses and ancillary farm buildings. In some instances it may be desirable to enhance the air quality in only a portion of a structure. The term "conditioned zone" is used herein to refer to that portion of the interior of a structure (which in some embodiments may be the entire interior of the structure) that is subject to atmospheric modification.

[0032] A device is presented herein where air is brought into a structure (residential, commercial or industrial) through an underground air conduit or equivalent structure, acting as a heat exchanging system with the underground prevailing geothermal temperature, to condition the incoming air to be of similar temperature to the prevailing geothermal temperatures. This device may be utilized as a stand alone device or integrated with conventional heating, ventilating, and air conditioning (HVAC) components such as heat pumps, air conditioners, and furnaces. This device can also be integrated with a solar hot water heating or "trombe" wall type system, engineered to collect heat to provide the remaining energy required to raise the temperature ranging in the winter time from about 55°F to about 70°F. The structure then becomes substantially "temperature balanced" between geo and solar temperature sources. Implication is of a temperature controlled structure without the use of any fossil fuel or externally provided electric power with the exception of a small solar cell system to operate an air fan and a liquid delivery system from the trombe wall.

[0033] Features of various embodiments described herein include the following:

[0034] The geo cooling/heating unit may be utilized on new structures or on existing structures. In the case of new structures, the assembly can be installed under the structure or next to or some distance from the structure.

[0035] One or more geo modules may be utilized on an extended structure. In the case of an extended house, for example, one wing may be shut off when not used. In fact the module approach is desirable to prevent the large ducting of air over a large building structure.

[0036] In the case of "external structures" such as greenhouses, atriums, garages, etc. the use of only this form of heating and cooling will substantially prevent building temperature extremes and keep the internal atmosphere at all times above a range from about 45 °F (about 7.2 °C) to about 55 °F (about 12.8 °C), depending upon structure quality, and below a range from about 75 °F (about 24 °C) to about 85 °F (about 29 °C) in high summer.

[0037] Air may be cycled internally from the building, through one or more "geocoils" and returned to that structure. External "make up air" may be fed from the outside through the geo unit (if it is outside the desired operating temperature range within the structure) so that a slight positive pressure is applied to the building. This keeps air fresh, and makes air leak from the inside to the outside, thereby eliminating unwanted incoming air leaks.

[0038] The geo system is typically engineered to control relative humidity by a water removal system in the geocoil or by including a humidification device.

[0039] In the case of residential and commercial office space where air temperatures are to be controlled within a narrow range, say from about 70 °F (about 21 °C) to about 72°F (about 22 °C) then the air intake from the geocoil unit may be fed into the return air or air intake of an additional heat pump or equivalent system, either air cooled or geothermal heat pump, which then has only to heat air from an inlet air temperature ranging from about 55 °F (about 12.8 °C) to about 70°F (about 21 °C) in the winter as opposed to heating outside air, which may range from about -10 °F (about -23 °C) to about 30 °F (about -1 °C) depending on local conditions. In the summer time, it may be that an integrated HVAC system has only to reduce air inlet from a temperature of about 74°F (about 23 °C) to about 70°F (about 21 °C) as opposed to dealing with air entering the building at about 100°F (about 37 °C) from air leaks into the building. (The air leaks into the building may be substantially eliminated by slightly over-pressurizing the interior of the building.)

[0040] From the point above, the geo air intake may be combined with a sun heated hot water system and heat exchanged to be used as a means to raise the inlet air from about 55 °F (about 12.8 °C) to about 70 °F (about 21 °C) in winter times as opposed to utilizing a heat pump system of any type.

[0041] Plastic conduits may be used to provide cleanable surfaces for the reduction of mold, spores etc. This generally provides a thermal insulation between ground temperature and the air inside geo air conduits. The use of carbon nanotube doped plastics for the fabrication of high thermal conductivity piping may enhance the apparatus performance. For example, the use of plastic air conduits with carbon nanotube impregnation (to improve the thermal conductivity of the air conduit walls) may be used to provide a cleanable air conduit system that has greatly enhanced heat transfer from the soil to the air inside the geo air conduit. The use of internal hydrophobic materials as internal coatings, or other coatings may be used to repel water and contaminant collection on internal surfaces of piping and materials in contact with the air brought into a structure

[0042] Air conduits are typically specially sealed to prevent radon or other materials being transferred from the soil to the air inside the air conduit.

[0043] The internal air conduit walls may be plastic, optionally including the nanotube impregnation and/or may be coated with hydrophobic surfactants (designed to prevent adherence of water droplets and contaminants to the internal air conduit walls) to permit enhanced transport of condensed water vapor and other materials to the geo system drain lines.

[0044] The geo air conduit system may be embedded in raw soil, or in sand, or in water, or in other subterranean materials, to allow “conduit shuffling” if temperature shifts occur in the air conduit for any reason. The air conduits may also be embedded in concrete to allow high thermal contact from the air conduit wall to the surrounding soil thermal profile.

[0045] Where systems are embedded in a hillside then water and condensate drainage may be arranged without special needs for the drain sump discussed elsewhere herein. Where the system is built on flat or near flat ground so that the elevation of the desired temperature profile is below grade, then the drain sump as mentioned in this application is typically provided. In addition the system is preferably substantially water and air tight to prevent water build up in the event of flooding or locations where the water line might be below grade but above the elevation of the geo system air conduit.

[0046] Various embodiments of an apparatus for modifying an atmosphere for use in a conditioned zone of a structure may be combined with a solar heating system and consequently provide a source of heat and a source of cooling that may be totally independent of any fuel system. If solar cells are utilized to provide a source of power (when combined with a battery and appropriate controls system) for controllers and for operation of pumping of air and fluid, then the system may be completely free of any external source of energy from conventional sources (electricity, fossil, nuclear, oil). Such systems may also be configured to provide hot water as necessary.

[0047] Various other heating and cooling systems may be used in cooperation with embodiments described herein to modify the atmosphere in the conditioned zone of a structure. Examples are furnaces, air conditioning units, and heat pumps. Some heat pumps may take advantage of a geothermal effect to improve their efficiency. This geothermal effect is a condition where the temperature of the earth underground is different and more stable than the atmospheric temperature at that locale. For example, in the southern United States, the ground temperature at about six feet (approximately 2 meters) below the surface of the earth remains at temperatures between about 50°F to 55°F (about 10°C to 13°C) year around, whereas the atmospheric temperature may range from between about 10°F to 100°F (about 12°C to 38°C). A similar geothermal effect occurs in lakes and streams although currents may modify layers of differing temperature. These geothermal effects may, for example, be used by heat pumps to remove or add heat in order to heat or cool conditioned zones of various structures. The process typically involves pumping water or other thermal ballast material through a conduit that has been configured to establish the temperature of the liquid close to the underground temperature. Typically the heat pump extracts heat from the liquid when the atmospheric temperature is lower than the ground temperature and transfers heat into the liquid when the atmospheric temperature is higher than the ground temperature.

[0048] Disclosed herein are various embodiments of apparatuses for passing air through an underground air conduit system in order to heat or cool the air that flows through the air conduit system. Almost always, such flow includes both air and water vapor. For example, atmospheric air almost never has zero percent humidity; there is almost always some water vapor in atmospheric air. The term “air conduit” as used herein refers to a conduit for conveying air and water vapor. If the air and water vapor enter the air conduit system at a temperature that is higher than the underground temperature a portion of the water vapor may occasionally condense into liquid water. It is desirable to remove the condensate water from the air conduit system so that the water does not plug up the air conduit system or create other problems such as excessively high relative humidity levels.

[0049] Figure 1 illustrates an apparatus 10 for modifying an atmosphere for use in a conditioned zone 12 of a structure. The apparatus 10 includes an air conduit system 14. The air conduit system 14 is an example of a geocoil that was referred to previously herein. The air conduit system 14 includes six segments of conduit material such as piping or conduit, A, B, C, D, E, F, and an optional seventh segment, G. Other embodiments may include more or fewer segments. The air conduit system 14 is configured to flow the atmosphere through a serpentine path, which is beneficial for minimizing the footprint required for such an apparatus. As used herein the term “serpentine path” refers to a path that starts as pointed in a first direction and then bends to a second direction that is substantially reverse to the first direction and then bends to a third direction that is substantially reverse to the second direction and pointed in substantially the same direction as the first direction. This pattern may be repeated multiple times in whole or in part. The air conduit system 14 may be formed from a plastic material such as polyvinylchloride (PVC), or high density polyethylene (HDPE), or polyethylene, or from other plastic materials. The air conduit system 14 may be formed from plumbing pipes or drainage culverts or tubing or similar products. It is desirable that the materials used for construction of the air conduit system

14 have minimal out-gassing characteristics. The air conduit system 14 is disposed at least partially underground, or disposed in another environment having a generally stable temperature. As used herein the term "underground" refers to a location that is in the earth (below grade level). Some embodiments include configurations where the air conduit system 14 is at least partially disposed underwater. "Underwater" refers to a location that is in a body of water such as in a lake or river, or that is underground below the water table. In some embodiments portions of the air conduit system 14 may be underground and portions may be underwater. The air conduit system 14 has an entry port 16 that is in fluid communication with an atmosphere 18 that is external to the conditioned zone 12 of the structure. As used herein the term "in fluid communication" means that a fluid may pass between the recited elements (in this case the source atmosphere 18 and the entry port 16) either directly or may pass between the recited elements through more intervening elements. Typically the source atmosphere 18 is the outdoor ambient atmosphere but in some embodiments the source atmosphere may be another source of air, either natural or man-made. For example, in some embodiments optional segment G may be included and the source atmosphere 18 may be from the conditioned zone 12 of the structure. In configurations that include the optional segment G, the entry port 16 is the opening of the optional segment G.

[0050] The air conduit system 14 also has an exit port 20 that is in fluid communication with the conditioned zone 12 of the structure. The air conduit system 14 is configured for conveying a flow of air and (typically) water vapor from the source atmosphere 18, into and through the entry port 16, through a substantial portion of the air conduit system 14, and out the exit port 20 into the conditioned zone 12 of the structure.

[0051] In the embodiment of Figure 1, the lateral segments B, C, D, E, and F of the air conduit system 14 are disposed substantially parallel to a flat plane 22 that is geologically level. ("Geologically level" refers to being horizontal with respect to the earth.) In such configurations the air conduit system (e.g., air conduit system 14) is referred to as being disposed substantially level. If the air contains water vapor, as the air and water vapor are drawn through the air conduit system 14 and are cooled below the dew point of the air/vapor mixture, a portion of the water vapor may condense. Because the air conduit system 14 is substantially level, any water vapor condensation might remain inside the air conduit system for an extended period of time. Such residual water might provide an environment for undesirable organisms such as mold to live and grow or might develop a foul smell that might be transferred into the conditioned zone 12 of the structure. To reduce this risk, a drainage pipe 30 is provided to remove water vapor condensate from the system 14. The drainage pipe 30 is in fluid communication with the air conduit system 14 through a series of stand pipes 32, and water condensate is expelled through a drain outlet 34. Preferably such water condensate is expelled to the outdoor atmosphere. The term “expelled to the outdoor atmosphere” means that the water condensate is discharged outdoors (as a liquid) at or above ground as referenced to the localized grade level at the location of discharge. While condensation may not be a problem in many installations of the air conduit system 14, it is generally desirable to provide for discharge of any condensation that may develop.

[0052] The drainage pipe 30 is disposed in a substantially-downward sloping orientation from a first standpipe 36 that is proximal to the exit port 20 to a last standpipe 38 that is proximal to the drain outlet 34. Since the air conduit system 14 is substantially level, the stand pipes increase in length from the first standpipe 36 to the last standpipe 38 in order to establish the continuously-downward-sloping orientation of the drainage pipe 30. If the air conduit system 14 is deployed on substantially level ground then the moisture may be routed from the drain outlet 34 to a sump pump for extraction from underground. If the air conduit system 14 is deployed on sloping terrain the layout of the air conduit system 14 may be configured to expose the drain outlet 34 to open air at a location on the sloping terrain, such that the moisture drains gravitationally from the system 14 without any pumping.

[0053] While in the embodiment of Figure 1 the drainage pipe 30 is in a substantially continuously-downward-sloping orientation from the exit port 20 to the entry port 16 of the air conduit system 14, in an alternate embodiment the drainage pipe 30 may be in a substantially continuously-downward-sloping orientation in the opposite direction (i.e., from the entry port 16 to the exit port 20). In such configurations the longest (first) standpipe 36 is proximal to the entry port 16 and the shortest (last) standpipe 38 is proximal to the exit port 20 and the drain outlet 34 is proximal to the exit port 20.

[0054] In embodiments where the drain includes a drainage pipe (such as drainage pipe 30) that is disposed in a substantially continuously-downward-sloping orientation, it is advantageous to dispose the drain outlet 34 either proximal to the entry port 16 (as depicted in Figure 1) or (where the drainage pipe slopes in the other direction) proximal to the exit port (e.g., exit port 20) of the air conduit system 14. This facilitates maintenance and cleaning of the drainage pipe 30.

[0055] The normal flow of air and (typically) water vapor through the air conduit system 14 is through segments G through A. However, the drainage pipe 30 may be a potential alternate flow path. In order to ensure proper cooling or heating of air for the conditioned zone 12 of the structure, is desirable that the apparatus 10 be configured such that substantially all of the air and water vapor that flows through the air conduit system 14 travels a distance that is substantially equal to the length of the air conduit system 14. The apparatus 10 of Figure 1 meets this objective because, if some air and water vapor enters the drain outlet 34, then air and water vapor will flow either up into the air conduit system 14 or will flow on a path through the drainage pipe 30 that is substantially equal to the length of the air conduit system 14. There is no “shortcut” that would allow any significant amount of the air and water vapor flowing through the system 10 to not be exposed to the underground temperature for a distance that is substantially equal to the distance of exposure of the air and water vapor that flows through the air conduit system 14. However, in the previously-described alternate embodiment where the drainage pipe 30 is in a substantially continuously-downward-sloping orientation from the entry port 16 to the exit port 20 and the shortest (last) standpipe 38 is proximal to the exit port 20, outside air may drawn into the drain outlet 34 through the standpipe into section A of the air conduit system 14 without traveling a distance that is substantially equal to the length of the air conduit system 14.

[0056] As previously indicated, in the embodiment of Figure 1 the air conduit system 14 is substantially level. In an alternate embodiment the air conduit system 14 may be disposed in a substantially continuously-downward-sloping orientation that parallels the substantially continuously-downward-sloping orientation of the drainage pipe 30. In such alternate embodiments the stand pipes 32 would all be substantially the same length. In some alternate embodiments the air conduit system 14 may be disposed in a continuously-upward-sloping orientation from the exit port 20 to the entry port 16, and in some alternate embodiments the air conduit system 14 may be disposed with various segments (e.g., B, C, D, E, and F) disposed in generally randomly-sloping orientations. In such alternate embodiments the lengths of the stand pipes 32 are adjusted so that the drainage pipe 30 remains in a substantially continuously-downward-sloping orientation.

[0057] Figure 2 illustrates a further embodiment of an apparatus 40 for modifying an atmosphere for use in a conditioned zone 12 of a structure. The apparatus 40 includes an air conduit system 44 comprising six segments, A′, B′, C′, D′, E′, and F′. An optional segment G′ may also be included. In other embodiments more or fewer segments may be employed. The air conduit system 44 is an example of a geocoil that was referred to previously herein. The air conduit system 44 may be formed from a plastic material such as polyvinylchloride (PVC), or high density polyethylene (HDPE), or polyethylene, or other materials as discussed with respect to the previously-describe air conduit system 14. The air conduit system 44 is disposed at least partially underground or underwater or in another environment having a stable temperature environment. The air conduit system 44 has an entry port 46 that is in fluid communication with a source atmosphere 18. As explained with respect to Figure 1, the optional segment G′ may be included to utilize air from the conditioned zone 12 of the structure as the source atmosphere 18. The air conduit system 44 also has an exit port 50 that is in fluid communication with the conditioned zone 12 of the structure. The air conduit system 44 is configured for conveying a flow of air and (typically) water vapor from the source atmosphere 18, in through the entry port 46 and through a substantial portion of the air conduit system 44, and out the exit port 50 into the conditioned zone 12 of the structure. If the optional segment G′ is used, the entry port 46 is the opening of the optional segment G′.

[0058] The lateral segments B′, C′, D′, E′, and F′ of the air conduit system 44 of Figure 2 are disposed in a substantially continuously-downward-sloping orientation with respect to the horizontal flat plane 22. In such configurations the air conduit system (e.g., air conduit system 44) is referred to as having a substantially continuously-downward-sloping orientation.

[0059] A trough portion 60 of the air conduit system 44 forms a drain for the apparatus 40. Water 62 may condense into the trough portion 60 and flow out of the air conduit system through the entry port 46, and in such embodiments the entry port 46 comprises the drain outlet. In some embodiments at least one drain hole 64 may be provided in the trough portion 60 of the air conduit system 44 to permit some of the water 62 to be expelled from the air conduit system 44 before the water 62 reaches the entry port 46. If the optional segment G′ is included in the apparatus 40, then a drain hole 64 is typically provided proximal to the intersection of segments F′ and G′. If the air conduit system 44 does not include any drain hole(s) 64 (i.e., all of the condensate water 62 drains out the entry port (46)), then typically the air conduit system 44 is deployed on a sloping terrain and the air conduit system 44 is configured to expose the entry port 46 to open air at a location on the sloping terrain where the moisture may drain.

[0060] If the drain hole 64 is underground and not in fluid communication with the source atmosphere 18 or in fluid communication with any other source of air and water vapor, such an embodiments may be configured such that substantially all of the air and water vapor that flows through the air conduit system 44 travels a distance that is substantially equal to the length of the air conduit system 44. That is, substantially all of the air and water vapor that flows through the air conduit system 44 enters the air conduit system through the entry port 46, and exits through the exit port 50.

[0061] In the embodiment of Figure 2 the air conduit system 44 is in a substantially continuously-downward-sloping orientation from the intersection of segments A′ and B′ to the unconnected end of segment F′ (if the optional segment G′ is not included) or to the intersection of segments F′ and G′ (if the optional segment G′ is included). In an alternate embodiment the air conduit system 44 may be in a substantially continuously-downward-sloping orientation in the opposite direction. That is, the air conduit system may be in substantially continuously-downward-sloping orientations from the unconnected end of segment F′ (if the optional segment G′ is not included) or from the intersection of segments F′ and G′ (if the optional segment G′ is included) to the intersection of segments A′ and B′. In such configurations a drain hole (such as drain hole 64) is typically provided proximal to the intersection of segments A′ and B′. In some embodiments the air conduit system 44 is disposed substantially parallel to the flat plane 22. In such configurations a plurality of drain holes similar to the drain hole 64 are typically employed to drain the condensate water 62 from the air conduit system 44.

[0062] Figure 3 depicts an embodiment of an underground apparatus 100 for modifying an atmosphere for use in a conditioned zone of a structure. The apparatus 100 is an example of a geocoil that was referred to previously herein. The apparatus 100 includes a plurality of flow reversion blocks 102 that are interconnected by hollow air conduit 104. The reversion blocks 102 are used to direct the flow of air and water vapor from a source atmosphere in a serpentine path. The reversion blocks 102 may be constructed of metal, cast concrete, mold-formed plastic or similar construction and materials. Preferably any concrete surfaces are lined with a barrier to prevent incursion by radon or other underground gases. The hollow air conduit 104 may be a plastic material such as polyvinylchloride (PVC) or high density polyethylene (HDPE), or polyethylene, or other materials, as previously described. The hollow air conduit 104 may be formed from plumbing pipes or drainage culverts or tubing or similar products fabricated from other materials. Each of the reversion blocks 102 have a plurality of faces 106, and each of the reversion blocks 102 have a plurality of openings 108 in only one face (e.g., face 110). A plurality of U-channels 112 are provided in each of the reversion blocks 102, and the reversion blocks 102, the air conduit 104, and the U-channels 112 are configured such that air enters the reversion block 102 through one or more openings 108 in the single face (e.g., 110) and exits the reversion block 102 through one or more openings 108 in the single face (e.g., 110). The apparatus 100 has an entry port 114 and an exit port 116. The reversion blocks are typically disposed underground and may be configured so that the hollow air conduit 104 has a substantially continuously-downward-sloping orientation from the exit port 116 to the entry port 114.

[0063] Note that the U-channels 112 may be passages cast into the reversion blocks 102, or the U-channels 112 may comprise plastic tubes wherein the reversion blocks 102 are cast around the plastic tubes. In some embodiments the U-channels 112 comprise plastic tubes with no concrete cast there-around (i.e., no reversion block 102 is employed). In either embodiment one or more drainage pipes 118 may be used to provide moisture drainage. If more than one drainage pipes 118 are employed, drainage may occur through one or more of the drainage pipes 118, depending on how the moisture is routed. If the apparatus 100 is deployed on substantially level ground then the moisture may be routed to a sump pump for extraction from underground. If the apparatus 100 is deployed on sloping terrain the layout of the apparatus 100 may be configured to expose the drain end of the drain pipe(s) 118 to open air at a location on the sloping terrain, wherein the moisture drains gravitationally from the system without any pumping.

[0064] Figure 4 illustrates a cross section of a portion of the apparatus 100 of Figure 3. It is preferable that a diameter 120 of the drain pipe 118 be significantly smaller than a diameter 122 of the hollow air conduit 104 so that very little air flows through the drain pipe 118 compared with the amount of air flowing through the hollow air conduit 104. Even if the length of the drain pipe 118 is less than the length of the hollow air conduit 104, substantially all of the air and water vapor that flows through the apparatus 100 may travel a distance that is substantially equal to the length of the hollow air conduit 104 if the diameter 120 of the drain pipe 118 significantly smaller than the diameter 122 of the hollow air conduit 104, because in that configuration of diameters very little air and water vapor may flow through the drain pipe

118 compared with the amount of air and water vapor that flows through the hollow air conduit 104.

[0065] Figure 5 illustrates an elevation view of a portion of the apparatus 100 of Figure 3. Direction arrow 130 represents the direction of air flow through the hollow air conduit 104 and direction arrow 132 represents the direction of water condensate flow through the hollow air conduit 104 into the drain pipe 118. In deployments of air conduits in geographic areas where flooding may occur or the air conduit is exposed to the underground water table, it is highly desirable that the air conduit system and the drainage pipe (if used) be water tight and configured to drain any flood water or underground water from the system.

[0066] Figure 6 illustrates an alternate embodiment of a reversion block 170. The reversion block 170 includes a hollow block 172. The hollow block 172 has two ports 174 into a hollow interior 176. Conduit tubes 178 are disposed in the ports 174 of the reversion block 170. Caulking or a similar material may be used to seal the conduit tubes 178 in the ports 174. Alternately, since the reversion block 170 is typically disposed underground, dirt or other material such as concrete may be packed around the outside of the interfaces between the ports 174 and the conduit tubes 178 to seal the conduit tubes 178 in the ports 174. A drain hole 180 may be provided in the bottom of the hollow block 172. In some embodiments the reversion block 170 may be constructed with no bottom face, and in such embodiments the entire open bottom is the drain hole.

[0067] Figure 7 depicts a top view of an alternate configuration of an underground apparatus 190 for modifying an atmosphere for use in a conditioned zone of a structure. Apparatus 190 employs a series of air conduits 192 disposed alternately over and under a series of reversion blocks 194.

[0068] Figure 8 depicts an apparatus 200 for conditioning air in a conditioned zone 202 of a structure. The apparatus 200 includes an underground air conduit system 204. A drain 206 is provided for the underground air conduit system 204 to remove a substantial portion of any water vapor condensation that may form in the air conduit system 204. The air conduit system 204 has a first entry port 210 that is in fluid communication with a first source of air 212 that is in the conditioned zone 202. Consequently, in the embodiment of Figure 8 air from the structure may be recycled through the apparatus 200. There is a regulator 216 that is configured to provide a regulated flow 218 of external air 220. The regulator 216 may also be configured to regulate the flow of the first source of air 212. The terms "regulated flow" and "regulate the flow" as used herein refer to configurations where a flow rate is adjusted depending upon the condition of at least one flow control parameter. For example, the regulator 216 may be a back pressure control valve that is set to maintain a flow rate that is adjusted to maintain a slight overpressure between the air pressure in the conditioned zone 202 and the outside air pressure 226. A binary flow rate ("on" or "off") is considered to be an "adjusted" flow rate. Note that in the embodiment of Figure 8 the external air 220 is outdoor ambient air, but in other embodiments the external air 220 may be from a different natural or man-made air source.

[0069] The air conduit system 204 has a second port 224 that is in fluid communication with the regulated flow 218 of external air 220. The air conduit system 204 also has an exit port 230 into the conditioned zone 202. In the embodiment of Figure 8 an air processor 240 is provided to induce a flow of air into the air conduit system 204 from the first entry port 210 and from the second entry port 224 through the air conduit system 204 and out of the exit port 230 into the conditioned zone 202. The air processor 240 may also be configured to shut off air flow from the air conduit system 204 when such air flow would not be beneficial to maintaining a desired temperature inside the conditioned zone 202. The air processor 240 may be suction fan. The air processor 240 is an example of a source of pressure differential. In other embodiments the source of a pressure differential may be a passive thermal convection arrangement or the source of pressure differential may be the fan of a heating furnace. A fan is the preferred source of pressure differential to establish a slight overpressure within the conditioned zone compared to outside air pressure. If the source of pressure differential is the fan of a heating furnace, the furnace may be configured to draw a second source of air 242 from the conditioned zone 202 into the furnace.

[0070] As further illustrated in Figure 8, a first source of air 212 from the conditioned zone 202 may be drawn through the first entry port 210 into the air conduit system 204. This flow is typically induced by the air processor 240, which as previously stated may be a fan or a furnace fan assembly. A manifold portion of the regulator 216 and an air filter may be provided to facilitate mixing and cleaning of air from the first source of air 212 from the conditioned zone 202 and the external air 220. Note – when the outside air temperature 250 is cold (for example below 50°F (10°C), the regulator 216 is typically configured to shut off air from the first source of air 212 and only external air 220 is drawn through the air conduit system 204 where it may be warmed up to 50°F (10°C).

[0071] The air processor 240 preferably includes a valve manifold that can selectively draw air from either the air conduit system 204 or from the second source of air 242 from the conditioned zone 202, or from both of those sources, depending upon the temperature 252 inside the conditioned zone 202 and the outside air temperature 250. One or more appropriately placed thermostats may be used to make a single or collective decision regarding the air sources.

[0072] In some embodiments a thermostat controls a variable speed fan which controls air intake through the air conduit system 204 and out the exit port 230. If the temperature 252 in the conditioned zone 202 increases above a set point, then the fan speed may be increased to introduce more cooling. In some embodiments the apparatus 200 may be configured for optionally stopping the flow of the first source of air 212, and in such configuration, if the temperature 252 in the conditioned zone drops below a set point then the flow of the first source of air 212 may be stopped and external air 220 may be the only flow of air through the air conduit system 204. If necessary, external air 220 (and optionally air from the first source of air 212) and/or the second source of air 242 from the conditioned zone 202 may be heated (such as by a furnace portion of the air processor 240) to reach a target temperature.

[0073] Typically it is desirable to maintain a temperature 252 inside the conditioned zone 202 of about 70°F (about 10°C). As previously indicated, the underground temperature 254 is typically around 50°F (about 10°C). When the outside air temperature 250 is hot, e.g., about 90°F (about 32°C) or at least above about 70°F (about 21°C) the regulator 216 may be continuously turned on and, depending upon the building size and occupancy, a small, e.g., about 20 cubic feet per minute (about 0.56 m^3/min), volume of external air 220 may drawn through the regulator 216. This air is added to the first source of air 212 from the conditioned zone 202. That is, the air processor 240 typically draws air from the external air 220 and air from first source of air 212 that is in the conditioned zone 202 into the air conduit system 204 to be cooled.

[0074] If the outside air temperature 250 is between about 50°F and 70°F (about 10°C - 21°C) then air flow from the air conduit system 204 may be shut off and if the air processor 240 is a furnace, a second source of air 242 from the conditioned zone may be drawn into the furnace as appropriate under (for example) thermostat control.

[0075] When the outside air temperature is cold, e.g., below about 50°F (about 10°C), the air processor 240 is configured to shut off air from the air conduit system 204 and air from the second source 242 in the conditioned zone 202 is preferably drawn through a heater in the air processor 240 to heat the conditioned zone. Alternately, when the outside air temperature 250 is cold, e.g., below about 50°F (about10°C) then the regulator 216 may configured to shut off the first flow of air 212 from the conditioned zone 202 and flow of external air 220 may be continuously turned on and, depending upon the building size and occupancy, a small, e.g., about 20 cubic feet per minute (about 0.56 m^3/min), volume of external air 220 may drawn through the regulator 216. The air processor 240 draws the external air 220 into the air conduit system 204 to be warmed to a temperature approaching 50°F (about 10°C) prior to heating that air in a furnace portion of the air processor 240.

[0076] The underground air conduit system 204 may comprise relatively large diameter pipes – such as about 3 to 4 inches (about 7.6 to 10 cm) in diameter or larger. The specific diameter of the pipes is preferably selected in view of site geothermal conditions, the linear footage of pipe that will be used, and the particular requirements of the structure/building with which it will be used.

[0077] The pipes (e.g., tubes 104 of Figure 3) are preferably constructed of plastic with the following characteristics:

- good thermal conductivity to permit effective heat transfer
- low porosity to prevent infusion of radon or other underground gas transference
- chemical resistance to mold build up
- easy clean-ability
- sloped orientation for drainage, and
- condensate drainage and removal system
- low out-gassing of vapors from the plastic itself

[0078] Various embodiments described herein are designed to utilize comparatively stable sub-surface temperatures to condition air suitable for occupied structures. At approximately 6 ft (about 2m) below ground level the ambient temperature is approximately 50° F to 55° F (about 10 °C to about 13 °C) year round in the southern USA. Such a location where variation in temperature is substantially less than the variation in ambient atmosphere temperature is referred to as a stable temperature environment. If sufficient length and surface area of air conduit is set at that level, then heat transfer through the air conduit structure will cause air passing through the air conduit to substantially adjust to the ambient soil temperature. Further air quality adjustments may include changes in relative humidity and removal of spores and other particulate materials. Additionally, the introduction of unacceptable chemically based vapors may be prevented or controlled to provide good quality air for long term good living conditions.

[0079] Preferably the air conduit systems are configured so that the internal surfaces are smooth and resist the buildup of moisture, dirt, mold or other contaminants that may be detrimental to the quality of the air in the piping. Preferably the piping is configured so that "duct cleaning" approaches can be utilized to clean and maintain the air conduit system over the long term.

[0080] Various embodiments described herein work best when configured to support a specific structure. Sprawling complexes of buildings may advantageously utilize several of these systems, where sections of buildings that are not in current use may be closed off. However, because the cost of operation of these systems is typically so low that their operation may be maintained to economically maintain an enclosed area in clean and good condition until occupied and then one or more conditioned zones may be easily brought to optimal operating temperature. Supplemental systems may be utilized to provide temperature stabilization of walls and roofing structures to minimize heating/cooling requirements for building envelopes. Primary and supplemental systems may be used independently or together.

[0081] Embodiments described herein may be integrated into new structures, or retrofitted into existing structures. Underground air conduit systems may be placed under the building or in an adjacent area. Systems may be applied to permanent home structures and also mobile home and manufactured structures by placing the structure over a pre buried geothermal system.

[0082] One of the primary benefits of embodiments described herein is that the use of geothermal temperatures minimizes the energy consumption required to keep a home or other structure in comfortable conditions, irrespective of external weather conditions. Systems described herein involve simple elements that minimize system installation and maintenance costs compared with Freon-based air conditioning systems, heat pumps, and similar electromechanical approaches. For example, systems may be designed that, at the most, utilize a fan and typically have no other moving parts. Therefore, the expected lifetime of these systems may be expected to equal or exceed the lifetime of the associated structure. Since no internal heat exchangers or other expansive equipment is required, the equipment “footprint” is minimal, which maximizes available living space.

[0083] Figure 9 depicts a geo cooling system 300 for modifying an atmosphere for use in a conditioned zone 302 of a structure 304. Also depicted is an external system 320 for heating hot water (or a thermal mass) and a system 322 for transferring heat to a heat storage system 330. Further there is a system 332 for transferring heat to a radiator/heat exchanger 334 through which inlet air 336 from the geo cooling system is fed into the conditioned zone 302. Hot water 340 may also be provided from the heat storage system 330.

[0084] Figure 10 depicts an alternate configuration of the elements of Figure 9. For example, in the embodiment of Figure 10 the heat storage system 330 is above ground system 322 for transferring heat to a heat storage system and unlike the embodiment of Figure 9, in the embodiment of Figure 10 there is no provision for hot water 340 Also the embodiment of Figure 10 provides for the admittance of outside air 344 into the conditioned zone 302 of the structure 304.

[0085] Figs. 11A and 11B are somewhat schematic illustrations of solar collectors that may be used as components of the external system 320 for heating hot water (or a thermal mass).

[0086] Figure 12 depicts a geo cooling system 300 for modifying an atmosphere for use in a conditioned zone 302 of a structure 304. Also depicted is an external system 320 for heating hot water (or a thermal mass) and a system 322 for transferring heat to a liquid heat exchanger 370. Further there is a system 374 for transferring heat to a radiator/heat exchanger 378 through which inlet air 336 from the geo cooling system is fed into the conditioned zone 302.

[0087] Figure 13 depicts a further apparatus 400 for modifying an atmosphere for use in a conditioned zone of a structure. The apparatus 400 has a tank 404 for containing a thermal ballast material 408 in an underground space 412 in the ground 414 below a grade level 416. The grade level 416 may generally conform to the topography of the surrounding region, or the grade level 416 may be modified for such purposes as enhancing drainage. The tank 404 may be constructed from concrete, metal, fiberglass, plastic, or other materials. Typically the thermal ballast material 408 comprises water. Other liquids may be used or included with water to improve the thermal conductivity or other properties of the thermal ballast material 408. Gel-like semi-solid materials such as silicone thermal transfer materials, greases, or gummy materials that have relatively high thermal conductivity may also be used as the thermal ballast material 408.

[0088] In the embodiment of Figure 13 there is an air conduit system 420 disposed within the tank 404 for contacting the thermal ballast material 408. The use of a tank 404 with a thermal ballast material 408 may improve thermal connectivity between the ground 414 and the air conduit system 408 compared with placing the air conduit system 408 directly in the ground 414. The thermal ballast material 408 generally enhances heat transfer between the tank 404 and the air conduit system 420. The air conduit system 420 has an entry passage 424 with an entry port 428 for an air flow connection 432 with the conditioned zone of the structure (such as conditioned zone 12 of Figure 1) or with outside air 434, and an exit passage 436 with an exit port 440 for an air flow connection 444 with the conditioned zone of the structure (such as conditioned zone 12 of Figure 1). Air flow into the air conduit system 420 is indicated by a first arrow 448 and air flow out of the air conduit system 420 is indicated by a second arrow452 . The air conduit system 420 includes a series of conduits 472 each of which has one end 476 disposed in a first manifold box 480 and a second opposing end 484 disposed in a second manifold box 488. If only one conduit 472 is used there may be no need for the first manifold box 480 or the second manifold box 488. A single conduit 472 may connect directly to the entry passage 424 and the exit passage 436. The conduits 472 are in contact with the thermal ballast material 408. The first manifold box 480 is in fluid communication with the entry passage 424 and the second manifold box 488 is in fluid communication with exit passage 436, such that input air 492 may flow into the entry port 428, then into the first manifold box 488, then into the conduits 472 then into the second manifold box 488, then into the exit passage 438 and finally out the exit port 440 as output air 496.

[0089] While the input air 492 is flowing through the conduits 472, heat is transferred from the thermal ballast material 408 through the conduits 472 to the input air 492 if there is a falling temperature gradient from the thermal ballast material 408 through the conduits 472 to the input air 492, and heat is transferred from the input air 492 through the conduits 472 to the thermal ballast material 408 if there is a falling temperature gradient from the input air 492 through the conduits 472 to the thermal ballast material 408.

[0090] In the embodiment of Figure 13 there is a lid 500 that covers the tank 408 and there is foam material 504 that is disposed above the lid 408 in the underground space 412 below the grade level 416. The foam material 504 helps maintain the thermal stability of the thermal ballast material 408 in the tank 404. A thermal transfer material 508 is disposed under the tank 404 and around the sides of the tank 404. The thermal transfer material 508 is typically installed as a slurry (such as raw concrete) or a sludge (such as mud), and is provided for the purpose of enhancing the thermal conductivity between the tank 404 and the underground space 412. In time the thermal transfer material 508 may solidify from its initially-installed slurry or sludge consistency, but in doing so it is expected to maintain some measure of enhanced thermal conductivity, particular in comparison with voids (air pockets) that might occur without the installation of the thermal transfer material 508.

[0091] Figure 14 illustrates a top view of an apparatus 600 for modifying an atmosphere for use in a conditioned zone of a structure. The apparatus 600 includes an air conduit system 604 that includes a set of conduits 608 having a serpentine path. In some embodiments the set of conduits 608 is a single conduit, and in some embodiments the set of conduits 608 includes a plurality of conduits that are disposed one atop another. By virtue of the orthographic projection used for this illustration, the top-down view of Figure 14 is the same regardless of whether the set of conduits 608 is one conduit or a plurality of conduits that are disposed one atop another. Each conduit in the set of conduits 608 is preferably formed as an extrusion process that forms a straight segment and then forms a "u-bend" and then forms another straight segment and then forms another "u-bend," and so forth. Alternately the set of conduits 608 may be formed by bending straight tubes into a serpentine path using mechanical tube benders, optionally with heating of the straight tubes. Such forming processes may produce geometries that have a substantially continuously-downward-sloping orientation, which simplifies installation of the set of conduits 608 in the field.

[0092] In the embodiment of Figure 14 the set of conduits 608 is disposed within a tank 612 and a thermal ballast material 616 is disposed in the tank 612. In some embodiments the set of conduits 608 may be disposed underground directly in contact with soil. The set of conduits 608 connects to a first manifold box 620 and a second manifold box 624. The first manifold box 620 includes a primary entry port 628 and a secondary entry port 632. Typically only one of the two entry ports (628 or 632) is employed in a particular installation, with the other port being closed off. Alternative ports (e.g., 628 and 632) may be provided in order to facilitate different installation options. The second manifold box 624 also has a primary exit port 636 and a secondary exit port 640. The tank 612 typically has a length 644 of about 12 feet (about 3.7 meters) and a width 648 of about 8 feet (about 2.4 meters).

[0093] Figure 15 illustrates a side view of the apparatus 600 of Figure 14. For simplicity of illustration, Figure 15 illustrates only one conduit in the conduit set 608. As previously discussed, the conduit set 608 may include multiple conduits set one atop another which, if illustrated, would be visible in Figure 15 in a manner analogous to strands of insulated conductors in a ribbon cable unfurling back and forth across the illustration from side to side and top to bottom, except that the multiple conduits (such as in conduit set 608) are typically spaced apart, whereas the strands of insulated conductors in a ribbon cable adjoin each other. The use of multiple smaller pipes instead of a single larger pipe increases the surface area of pipe that is exposed to the thermal ballast material 408. For example, one six inch diameter conduit has an equivalent cross section of four three inch diameter conduits and twice the surface area of the six inch conduit.

[0094] The tank 612 typically has a height 652 of about 3 feet (about 0.9 meters). Figure 15 further illustrates that the conduit set 608 is disposed in a tilted orientation such that any condensation of water vapor in air flowing through the conduit set 608 that condensed may drain to a sump collection port 656. The sump collection port 656 may drain such condensate into the ground, in which case a plumbing drain "trap" is preferably included to retain a portion of the condensate in a u-shaped segment that at least partially blocks the passage of gasses or living creatures from the ground into the apparatus 600. Alternately the sump collection port 656 may be sealed off from the ground and accumulate the condensate for pump-out through the primary entry port 628 or the secondary entry port 632. When the sump collection port 656 is sealed off from the ground in this fashion the apparatus 600 illustrates a configuration having a drain (i.e., the sump collection port 656) that is in flow communication with an air conduit (i.e., the conduit set 608), where the drain has at least one drain outlet for receiving and expelling (for example, via pumping-out through the primary entry port 628) to the outdoor atmosphere a substantial portion of any water vapor that condenses to a liquid water as the air and the water vapor flow through the air conduit (i.e., the conduit set 608). The conduit set 608 is an example of a drainage pipe that is disposed in a substantially continuously-downward-sloping orientation where at least one drain outlet (e.g., the sump collection port 656) is disposed proximal to an entry point (e.g., primary entry port 628) of an air conduit (e.g., the conduit set 608).

[0095] Figure 15 also illustrates that the tank 612 has a domed bottom 660 formed convex to an underground space. The domed bottom 660 may be shaped in as a cone or a pyramid. The domed bottom 660 may be provided for the purpose of assisting in the flotation of air pockets up and away from the bottom of the tank 612 when it is installed in an underground space. Such air pockets would likely reduce the thermal conductivity between the ground and the tank 612. Typically a tilt angle 666 of between about ten degrees and 20 degrees is adequate for this purpose.

[0096] Figure 16 illustrates how the apparatus 600 of Figure 14 and 15 may be integrated with other devices for the purpose of heating and cooling a conditioned zone of a structure 700. The apparatus 600 is installed in the ground 704 below a grade level 708. In the embodiment of Figure 16 an intake system 712 inducts outside air and water vapor 716 and directs it to a first route 720 or to a second route 724 or to both the first route 720 and the second route 724. Outside air and water vapor 716 that is directed to the first route 720 passes through a transfer conduit 728 to the entry port 628 of the apparatus 600. After flowing through the conduit set 608 (Figures 14 and 15) of the apparatus 600, conditioned air 730 may be discharged through the exit port 636 of the apparatus 600 into an energy recovery and ventilation unit 750. The energy recovery and ventilation unit 750 generally incorporates an air mixing box and may include air conditioning mechanisms such as dehumidifiers. The energy recovery and ventilation unit 750 may draw in outside air and water vapor 716 through the second route 724, or the energy recovery and ventilation unit 750 may draw conditioned air 730 from the apparatus 600, or the energy recovery and ventilation unit 750 may draw in outside air and water vapor 716 through the second route 724 and conditioned air 730 from the apparatus 600. The choice is made by evaluating such factors a the temperature of the outside air and water vapor 716, the temperature of the conditioned zone of the structure 700, and a user's preference for providing regular fresh air. In the embodiment of Figure 16, the energy recovery and ventilation unit 750 is further configured to optionally recirculate a portion of the conditioned air 730 back through the transfer conduit 728 to the apparatus 600.

[0097] Typically the energy recovery and ventilation unit 750 is configured to direct at least a portion of the conditioned air 730 into the conditioned zone of the structure 700. As shown in Figure 16, a hot water radiator 754 may be employed to heat the conditioned air 730 that is directed into the conditioned zone of the structure 700 by the energy recovery and ventilation unit 750. In the embodiment of Figure 16, hot water for the hot water radiator 754 is provided by a trombe (such as a trombe wall unit) that receives hot water circulated from a solar water heater 762. In some embodiments the trombe is a stand-alone unit that is used to heat the conditioned zone of the structure 700 without passing hot water from the solar water heater 762 to a radiator (e.g., hot water radiator 754), and in such stand-alone trombe embodiments the hot water radiator 754 is not used.

[0098] In the embodiment of Figure 16 the conditioned air 730 that is directed into the conditioned zone of the structure 700 by the energy recovery and ventilation unit 750 passes through a conventional HVAC system 766. The conventional HVAC system 766 may either heat or cool the conditioned air 730 that is directed into the conditioned zone of the structure 700 by the energy recovery and ventilation unit 750. After passing through the conventional HVAC system 766 the conditioned air 730 that is directed into the conditioned zone of the structure 700 by the energy recovery and ventilation unit 750 is distributed to the conditioned zone of the structure 700 by an air distribution system 770. One further feature identified in Figure 16 is a cleanout port 790 that is provided in this embodiment to provide access to pump condensed water from the apparatus 600 or to provide access to the apparatus 600 for other maintenance services.

[0099] Various methods may be use to install an apparatus for modifying an atmosphere for use in a conditioned zone of a structure. Most methods begin with a step of excavating a space underground below a grade level. The excavation site may be linked with either existing or new construction, and may, for example, be undertaken below a planned floor in a new construction or may be undertaken adjacent existing construction. The bottom surface of the excavation may be sloped to help provide a substantially continuously-downward-sloping orientation of conduits in the apparatus. One embodiment proceeds with a step of casting a tank in-situ in the space. In this embodiment the tank is typically cast of concrete. The term "casting a tank" as used herein refers to a step where at least the bottom of the tank is cast, but the sides of the tank may be formed from blocks or other prefabricated elements while still encompassing the intent of the term "casting a tank." The benefit of casting at least the bottom of the tank is that good thermal conductivity will be established between the ground and the tank if the concrete is poured directly onto (cast onto) the bottom of the excavated space. In this method, once the tank is cast in-situ, an air conduit system having an entry passage with an entry port and an exit passage with an exit port is disposed in the cast tank, such that the entry port and the exit port are above the grade level. A thermal ballast material is then disposed in the tank. A further step is disposing a lid on the tank, where the lid covers the tank and the thermal ballast material. The method generally concludes by backfilling to substantially the grade level the space underground that is not occupied by the tank, the lid, the entry passage, and the exit passage, while providing for retention of the entry port and the exit port above the grade level.

[00100] Another method for forming an apparatus for modifying an atmosphere for use in a conditioned zone of a structure also begins by excavating a space underground below a grade level. This method then proceeds with a step of disposing a first thermal transfer material portion in the space. The thermal transfer material is typically installed as a slurry or a sludge (such as concrete or mud), and it is provided for the purpose of enhancing the thermal conductivity between a tank that will subsequently be installed and the underground space. Once the thermal transfer material is installed a tank having a bottom and sides is installed in the space, where the bottom of the tank rests on the thermal transfer material. The method further includes a step of disposing in the tank an air conduit system having an entry passage with an entry port and an exit passage with an exit port, where the entry port and the exit port are above the grade level. The method also includes a step of disposing a thermal ballast material in the tank. The thermal ballast material adds weight to sink the tank into the slurry or sludge and provide good thermal contact between the tank and the thermal transfer material. A lid is disposed on the tank, where the lid covers the tank and the thermal ballast material. In this method a second portion of thermal transfer material is disposed in the space adjacent the sides of the tank. The method generally concludes with backfilling to substantially the grade level the space underground that is not occupied by the tank, the lid, the entry passage, the exit passage, and the thermal transfer material, while providing for retention of the entry port and the exit port above the grade level.

[00101] Various methods may be used to modify an atmosphere for use in a conditioned zone of a structure. For example, a method may involve establishing a cycle of transitions between on and off phases of flow of outside air through an underground air conduit to reformulate the outside air as conditioned air for use in the conditioned zone of the structure. The off phase may be monitored for a likelihood of an undesirable characteristic of the conditioned air in the air conduit. Monitoring may include sensor measurements or time duration measurements. The undesirable condition may be excessively high temperature, or the undesirable condition may be stale air that has been substantially dormant for an extended period of time, and may have picked up off-gasses from the underground air conduit. Prior to the transition from an off phase of flow to an on phase of flow, the conditioned air in the air conduit may be discharged to an outside atmosphere if the likelihood of the undesirable characteristic exceeds a threshold value. The term "outside atmosphere" refers to the ambient air atmosphere outside the conditioned zone of the structure. For example, the time duration of the off phase may be monitored and if the time duration exceeds a limit value (perhaps exceeding about five minutes) the air in the air conduit may be discharged to the outside atmosphere before starting the cycle for flowing outside air through the underground air conduit to the conditioned zone of the structure. . Alternately or in addition, the temperature of the conditioned air in the underground air conduit may be monitored and if it exceeds a threshold value (such as about 80 °F (about) the conditioned air in the underground air conduit may be discharged to the outside atmosphere before starting the cycle for flowing outside air through the underground air conduit to the conditioned zone of the structure.

EXAMPLE

[00102] Figure 17 illustrates experimental results from an apparatus for modifying an atmosphere for use in a conditioned zone of a structure that was installed for test and evaluation purposes. The system was built and situated under a driveway in preparation for a future building. Figure 18 shows its basic construction. This system was constructed as two layers of piping as shown and is arranged based upon 4.0” diameter inlet and outlet pipes. The primary heat exchange pipes are 3.0 inch diameter. To ensure good ground contact, the piping system was buried in low grade concrete, which also serves to physically protect the system. Expanded polystyrene geofoam provided an additional thermal barrier over the concrete to minimize thermal transport to and from the surface. Testing of the system is accomplished utilizing an air fan assembly to draw air through the piping assembly. A temperature sensor was placed at the air inlet. A similar sensor was placed at the air outlet. Both temperatures were plotted continuously, one example of which is shown in Figure 17. Air flow through the system was approximately 200 cubic feet per minute (about 5,670 liters per minute). Testing of the system did not require a building placed on the system. Having a building might actually be a complicating factor because the building construction parameters might then influence performance measurements. In the two day period illustrated in Figure 17, the temperature of outdoor air admitted to the test system through its inlet (entry port) varied from just above 55 °F (about 12.8 °C) to almost 100 °F (about 37.8°C). However the apparatus for modifying an atmosphere for use in a conditioned zone of a structure provided air at an outlet (exit port) temperature that varied only between about 67 °F (about 19.4 °C) and 73 °F (about 22.8 °C). Unexpectedly little condensation of water vapor occurred in the test system over several months of operation.

[00103] The foregoing descriptions of embodiments have been presented for purposes of illustration and exposition. They are not intended to be exhaustive or to limit the embodiments to the precise forms disclosed. Obvious modifications or variations are possible in light of the above teachings. The embodiments are chosen and described in an effort to provide the best illustrations of principles and practical applications, and to thereby enable one of ordinary skill in the art to utilize the various embodiments as described and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the appended claims when interpreted in accordance with the breadth to which they are fairly, legally, and equitably entitled.

CLAIMS

What is claimed is:

1. An apparatus for modifying an atmosphere for use in a conditioned zone of a structure, comprising:

   a tank for containing a thermal ballast material in an underground space below a grade level; and

   an air conduit system disposed within the tank for contacting the thermal ballast material, the air conduit system having an entry passage with an entry port for an air flow connection with the conditioned zone of the structure and an exit passage with an exit port for the air flow connection with the conditioned zone of the structure.

2. The apparatus of Claim 1 wherein the air conduit system comprises a conduit having a serpentine path.

3. The apparatus of Claim 1 wherein the air conduit system comprises a plurality of conduits following substantially parallel serpentine paths.

4. The apparatus of Claim 1 wherein the tank has a lid and the apparatus further comprises insulative foam disposed above the lid and below the grade level.

5. The apparatus of Claim 1 wherein the tank has a domed bottom formed convex toward the underground space.

6. A method for forming an apparatus for modifying an atmosphere for use in a conditioned zone of a structure, comprising:

   (a) excavating a space underground below a grade level;

   (b) casting a tank in-situ in the space;

   (c) disposing in the tank an air conduit system having an entry passage with an entry port and an exit passage with an exit port, wherein the entry port and the exit port are above the grade level;

(d) disposing a thermal ballast material in the tank;

(e) disposing a lid on the tank, the lid covering the tank and the thermal ballast material

(f) backfilling to substantially the grade level the space underground that is not occupied by the tank, the lid, the entry passage, and the exit passage, while providing for retention of the entry port and the exit port above the grade level.

7. The method of Claim 6 wherein step (e) further comprises disposing a foam insulation above the lid on the tank below the grade level, and wherein step (f) comprises backfilling to substantially the grade level the space underground that is not occupied by the tank, the lid, the foam insulation, the entry passage, and the exit passage, while providing for retention of the entry port and the exit port above the grade level.

8. A method for forming an apparatus for modifying an atmosphere for use in a conditioned zone of a structure, comprising:

(a) excavating a space underground below a grade level;

(b) disposing a first thermal transfer material portion in the space;

(c) disposing a tank having a bottom and sides in the space, where the bottom of the tank rests on the thermal transfer material;

(g) disposing in the tank an air conduit system having an entry passage with an entry port and an exit passage with an exit port, wherein the entry port and the exit port are above the grade level;

(h) disposing a thermal ballast material in the tank;

(i) disposing a lid on the tank, the lid covering the tank and the thermal ballast material;

(j) disposing a second thermal transfer material portion in the space adjacent the sides of the tank;

(k) backfilling to substantially the grade level the space underground that is not occupied by the tank, the lid, the entry passage, the exit passage, and the thermal transfer material, while providing for retention of the entry port and the exit port above the grade level.

9. The method of Claim 8 wherein step (i) further comprises disposing a foam insulation above the lid on the tank below the grade level, and wherein step (k) comprises backfilling to substantially the grade level the space underground that is not occupied by the tank, the lid, the foam insulation, the entry passage, the exit passage, and the thermal transfer material, while providing for retention of the entry port and the exit port above the grade level.

10. A method for modifying an atmosphere for use in a conditioned zone of a structure, comprising:

(a) establishing a cycle of transitions between on and off phases of flow outside air through an underground air conduit to reformulate the outside air as conditioned air for use in the conditioned zone of the structure;

(b) monitoring the off phase for a likelihood of an undesirable characteristic of the conditioned air in the air conduit;

(c) prior to the transition from an off phase of flow to an on phase of flow, discharging the conditioned air in the air conduit to an outside atmosphere if the likelihood of the undesirable characteristic exceeds a threshold value.

11. The method of Claim 10 wherein step (b) comprises monitoring a time duration of the off phase and wherein the threshold value of step (c) comprises an elapsed time interval.

12. The method of Claim 10 wherein step (b) comprises monitoring a temperature of the conditioned air in the air conduit and wherein the threshold value of step (c) comprises a maximum temperature.

13. An apparatus for modifying an atmosphere for use in a conditioned zone of a structure, comprising:

    an air conduit having a length and being disposed at least partially in a stable temperature environment, wherein the air conduit has an entry port that is open to an outdoor atmosphere that is external to the conditioned zone of the structure;

    an air movement system for conveying a flow of air and water vapor from the entry port through the air conduit and out an exit port in the air conduit into the conditioned zone of the structure; and

    at least one drain that is in flow communication with the air conduit, the drain having at least one drain outlet for receiving and expelling to the outdoor atmosphere that is external to conditioned zone of the structure a substantial portion of any water vapor that condenses to a liquid water as the air and the water vapor flow through the air conduit;

    wherein the apparatus is further configured such that substantially all of the air and water vapor that flows through the apparatus travels a distance that is substantially equal to the length of the air conduit.

14. The apparatus of Claim 10 wherein the at least one drain comprises a drainage pipe that has a length that is substantially the same length as the length of the air conduit and that is disposed in a substantially continuously-downward-sloping orientation.

15. The apparatus of Claim 10 wherein the at least one drain comprises a drainage pipe that is disposed in a substantially continuously-downward-sloping orientation and the at least one drain outlet is disposed proximal to the entry point or proximal to the entry port of the air conduit.

16. The apparatus of Claim 10 wherein the air conduit is disposed in a substantially continuously-downward-sloping orientation from the exit port to the entry port and the drain comprises a trough portion of the air conduit and the entry port comprises the at least one drain outlet.

17. The apparatus of Claim 10 wherein the air conduit is disposed in a substantially continuously-downward-sloping orientation and the at least one drain comprises a trough portion of the air conduit and the at least one drain outlet comprises a drain hole in the trough portion.

18. A system for conditioning air in a conditioned zone of a structure, comprising:

a source of air external to the conditioned zone;

a regulator configured to provide a regulated flow rate of external air from the source of external air;

an air conduit system disposed at least partially in a stable temperature environment and having a first entry port that is in fluid communication with the air in the conditioned zone of the structure, and having a second entry port that is in fluid communication with the regulated flow rate of external air, and having an exit port into the conditioned zone of the structure; and

a source of pressure differential that flows air into the air conduit system from the first entry port and from the second entry port of the air conduit system and through a substantial portion of the air conduit system and out of the exit port of the air conduit system into the conditioned zone of the structure.

19. An apparatus for modifying an atmosphere for use in a conditioned zone of a structure, comprising a plurality of flow reversion blocks interconnected by air conduit, each block having a plurality of openings in only one face, wherein air enters the block through one or more openings in the face and exits the block through one or more openings the face.

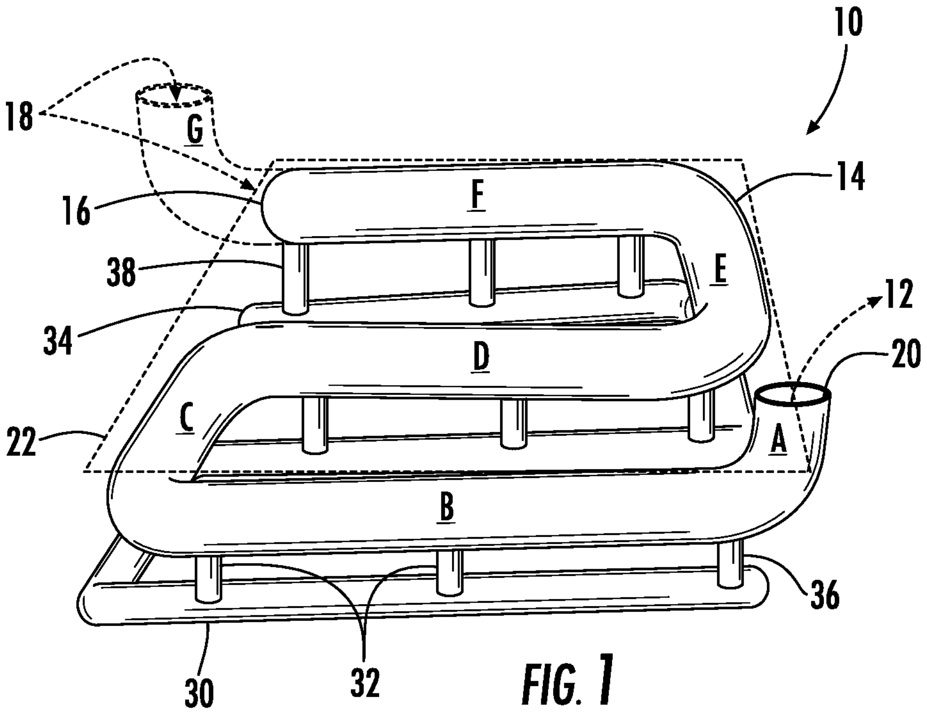

10
18
G
16
F
14
38
E
34
D
12
20
22
C
A
B
36
30
32

FIG. 1

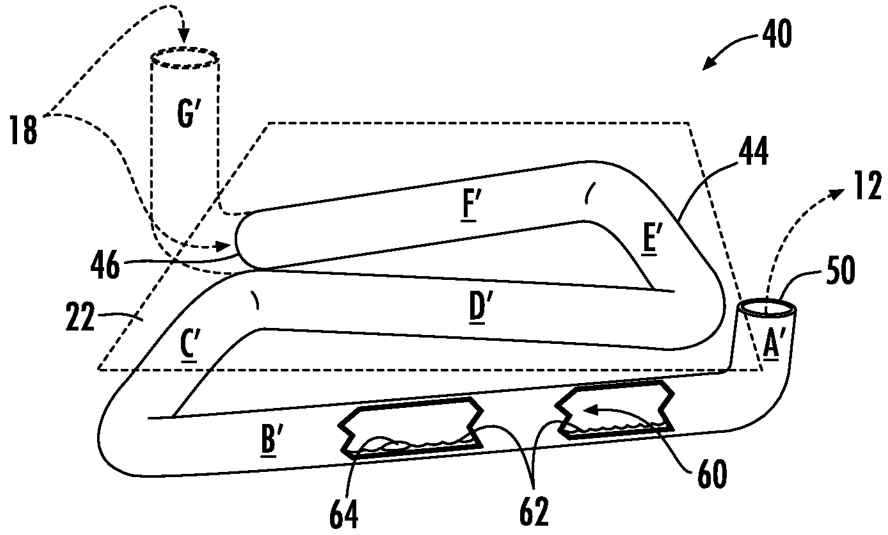

40
18
G′
44
F′
12
E′
46
D′
50
22
C′
A′
B′
60
64
62

FIG. 2

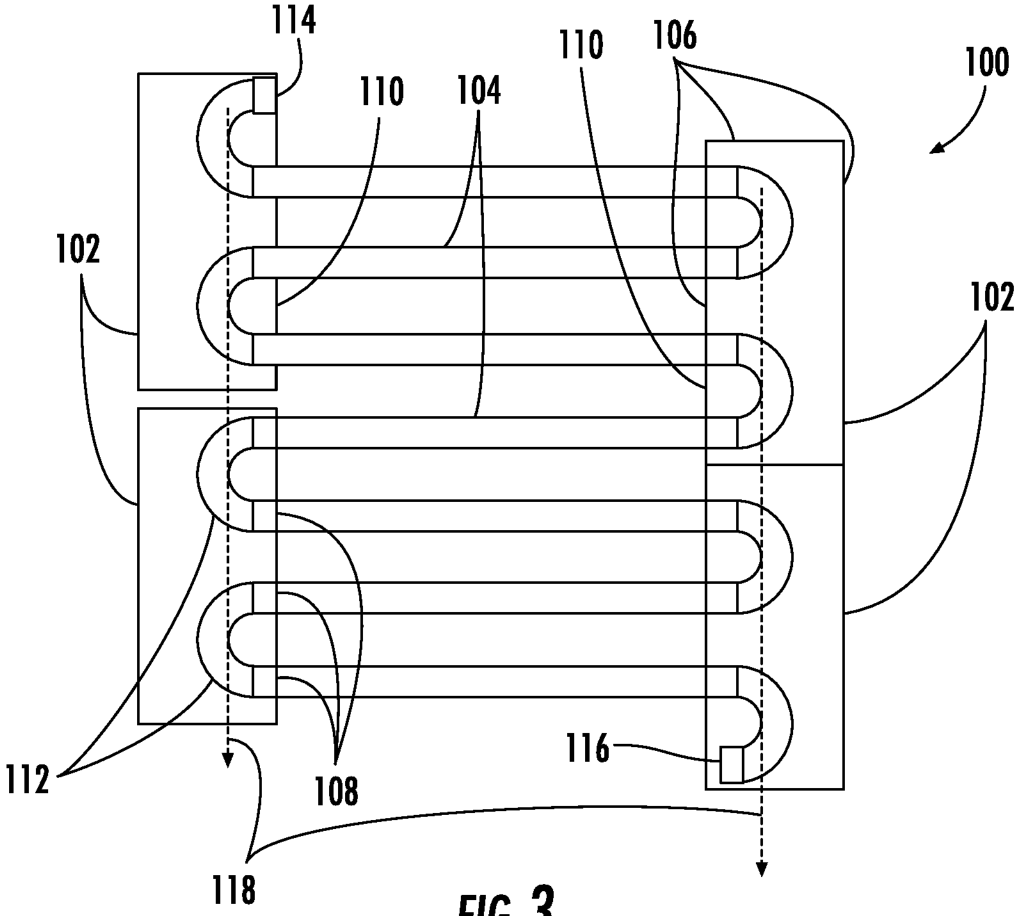


FIG. 3

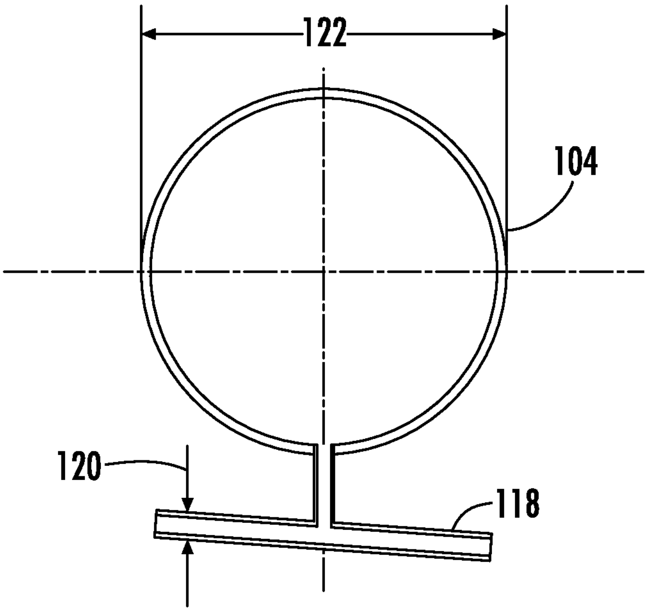


FIG. 4

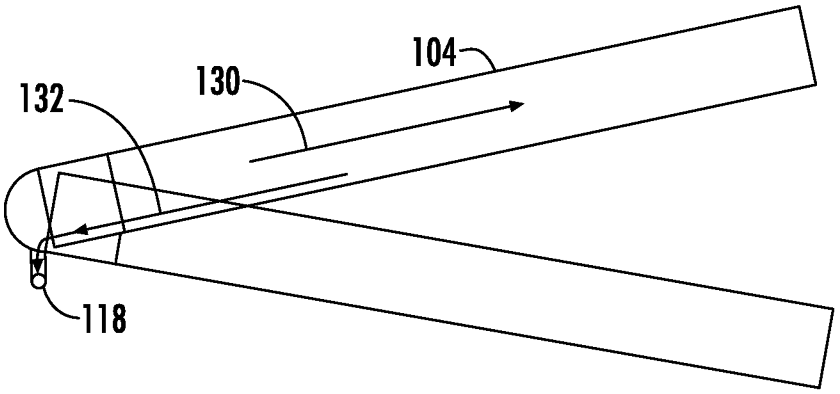


FIG. 5

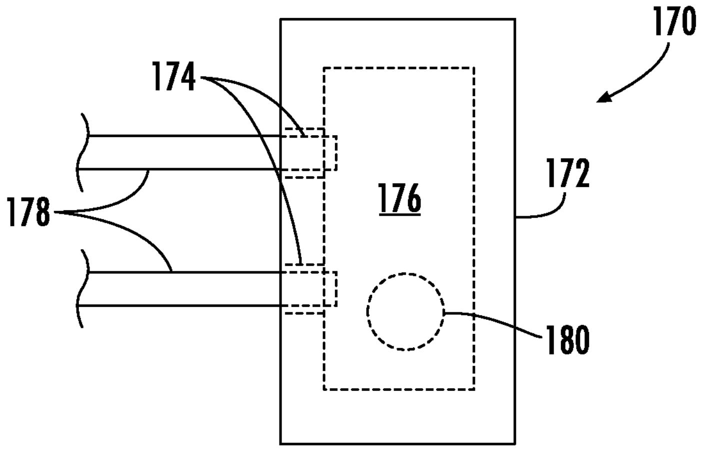


FIG. 6

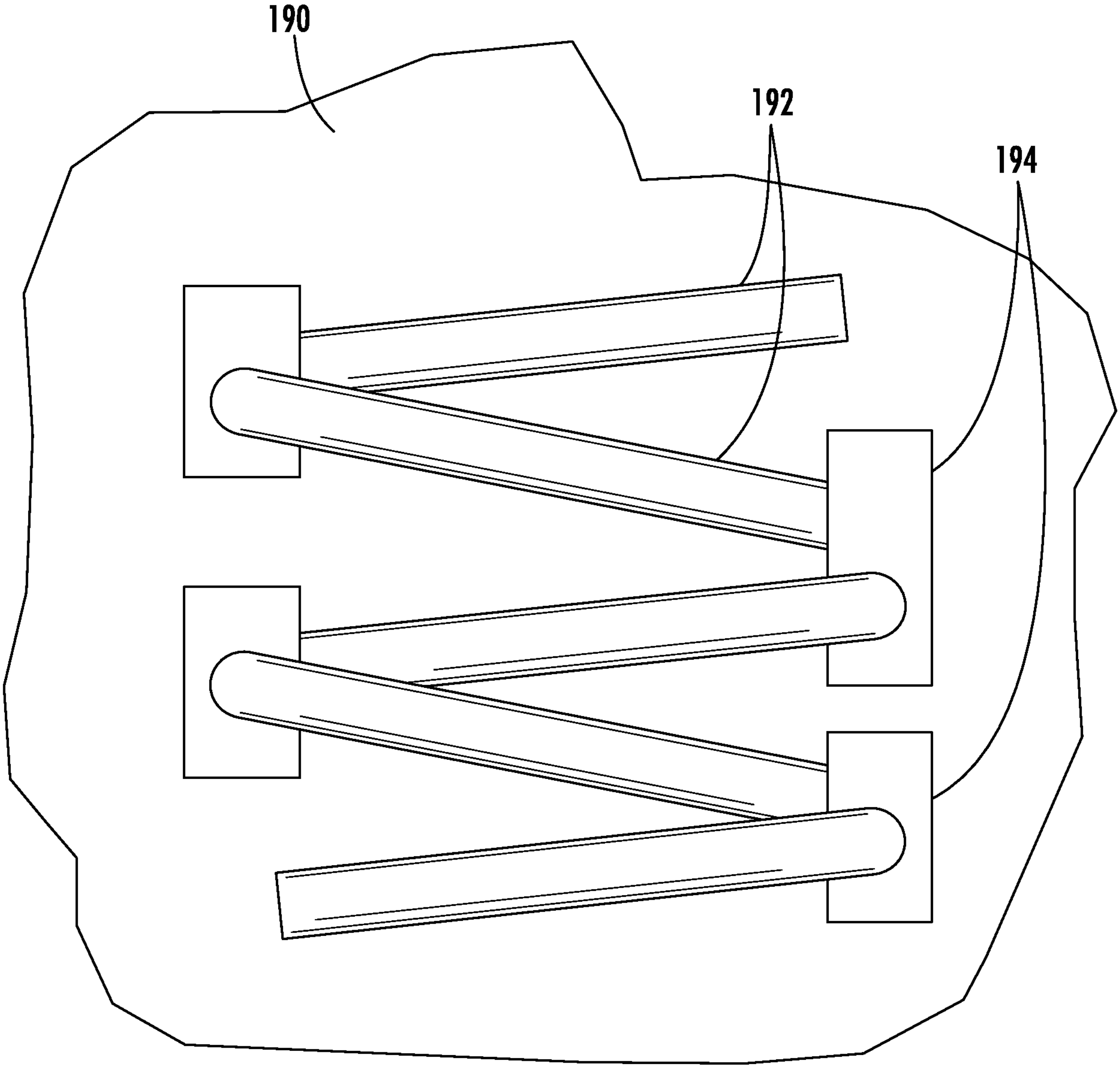


FIG. 7

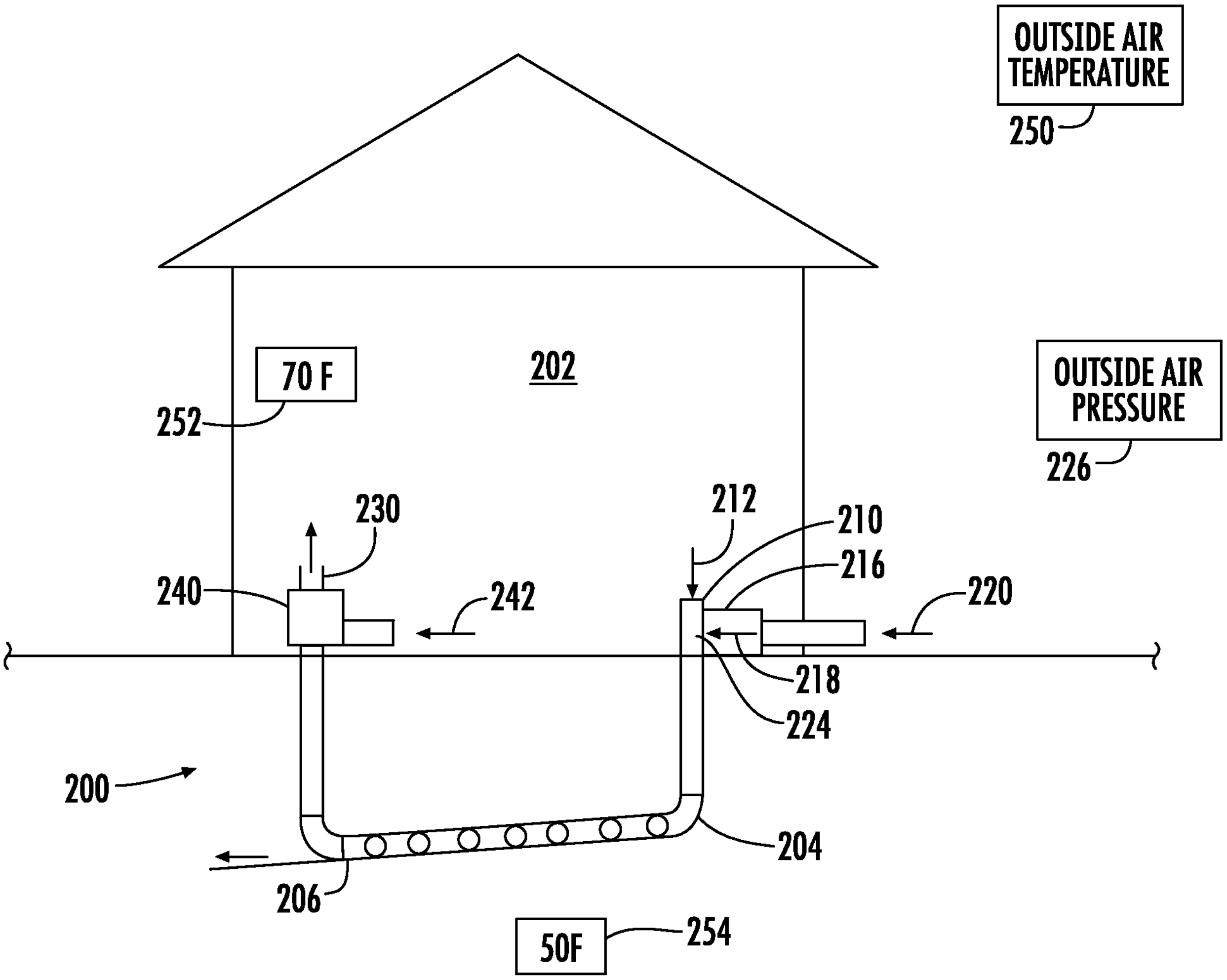

OUTSIDE AIR TEMPERATURE
250
202
70 F
252
OUTSIDE AIR PRESSURE
226
230
212
210
216
240
242
220
218
224
200
204
206
50F
254

FIG. 8

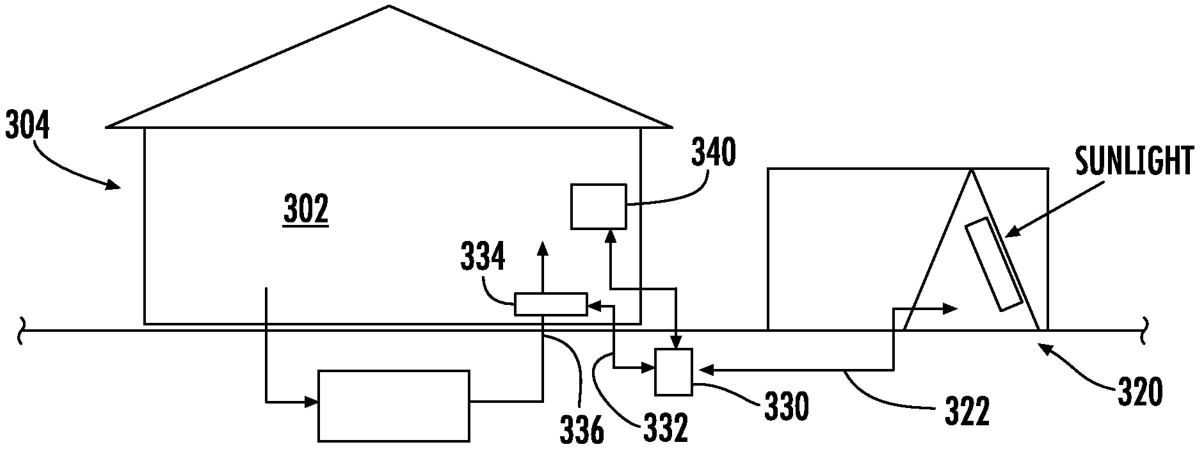
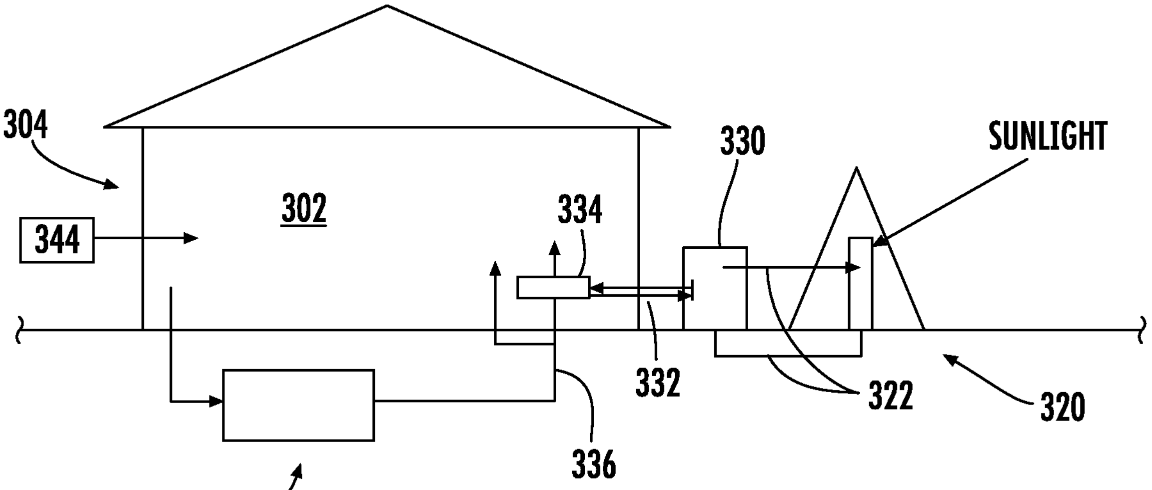

304
302
340
SUNLIGHT
334
336
332
330
322
320
300

FIG. 9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302
344
330
SUNLIGHT
334
332
322
320
336
300

FIG. 10

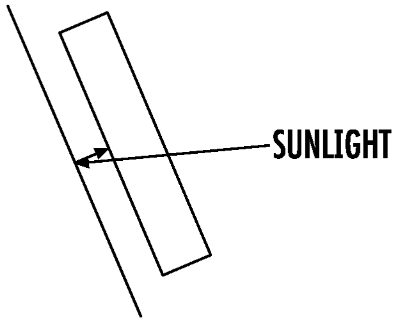


FIG. 11A

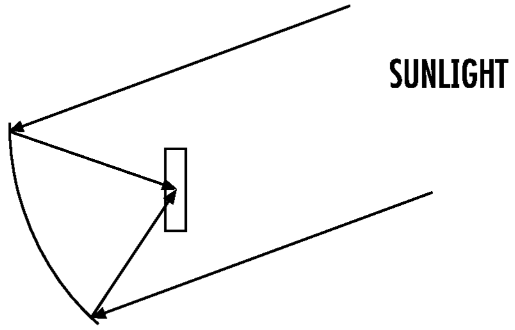


FIG. 11B

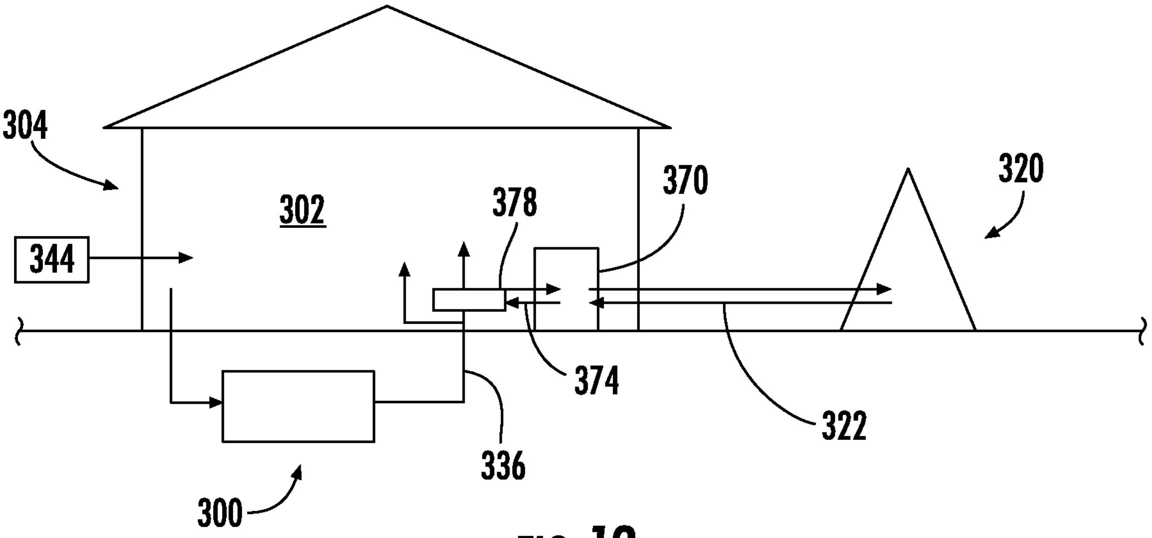
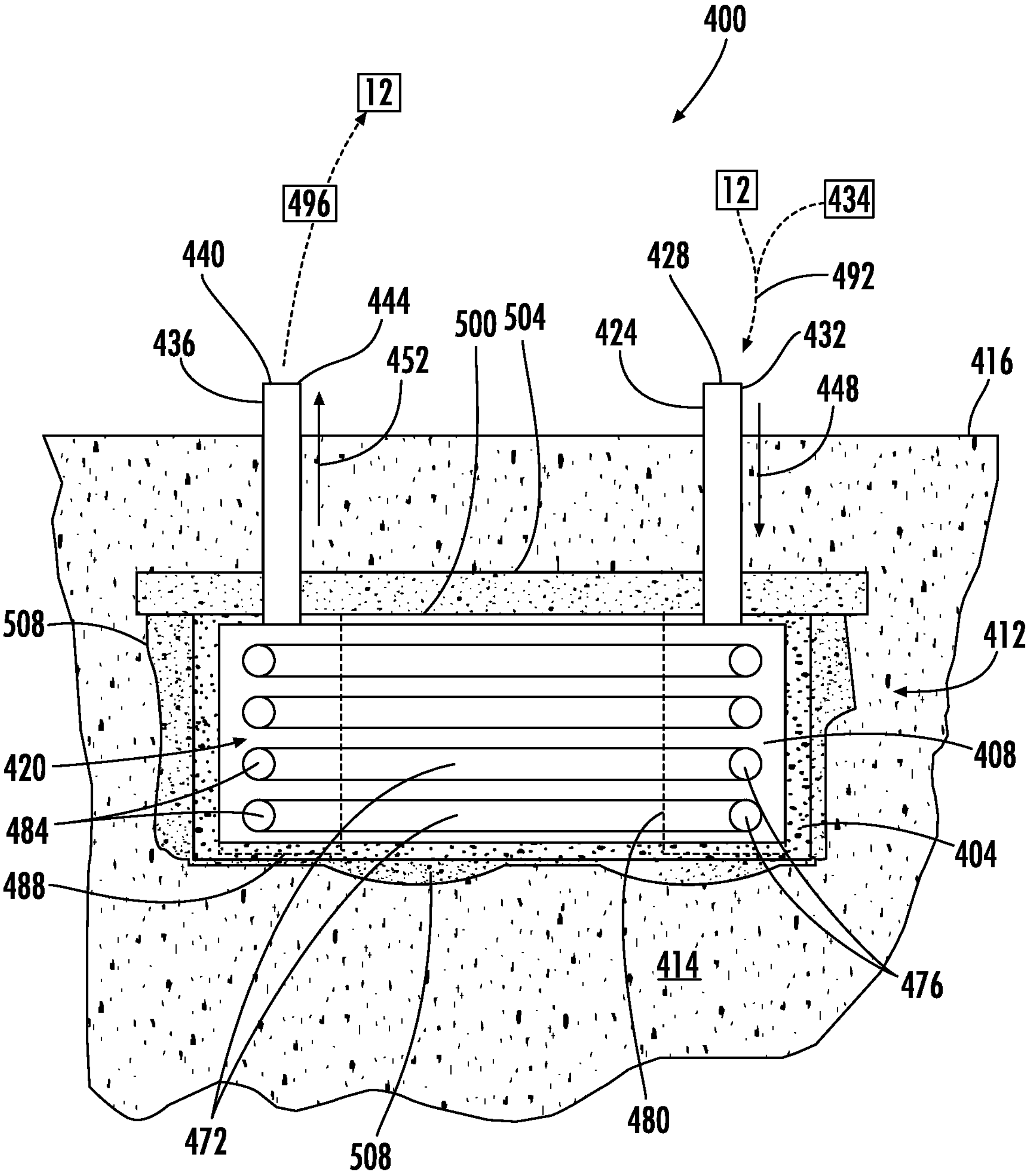


FIG. 12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12
496
12
434
440
444
428
492
436
500
504
424
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452
448
416
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412
420
408
484
404
488
414
476
472
508
480

FIG. 13

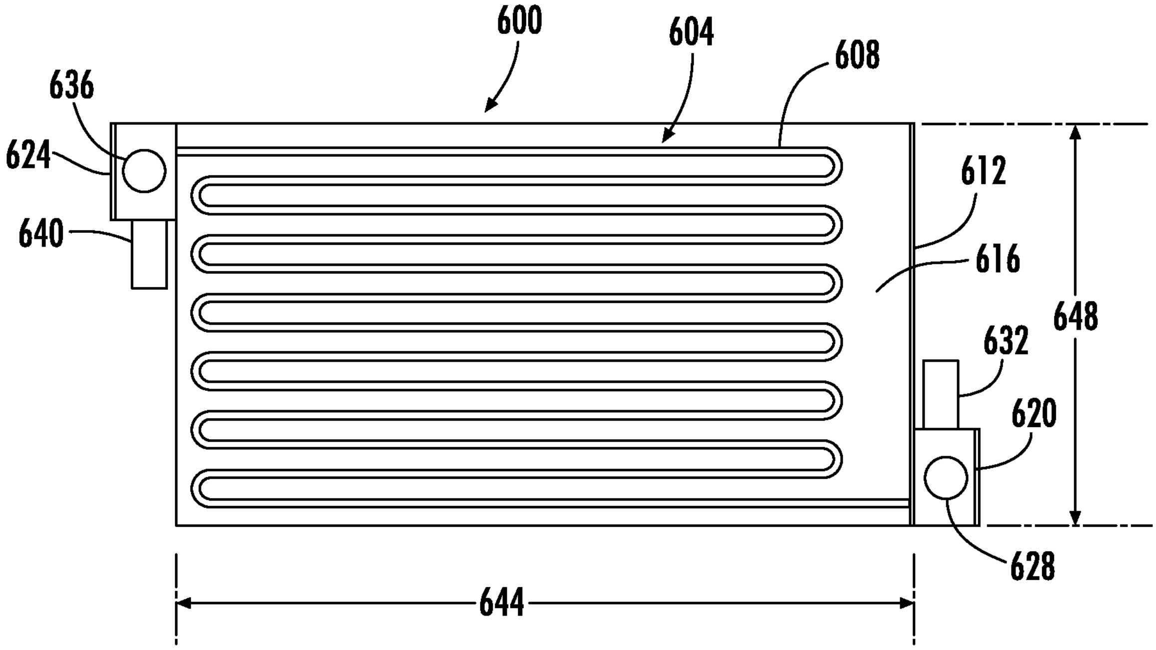
600
604
608
636
624
640
612
616
648
632
620
628
644

FIG. 14

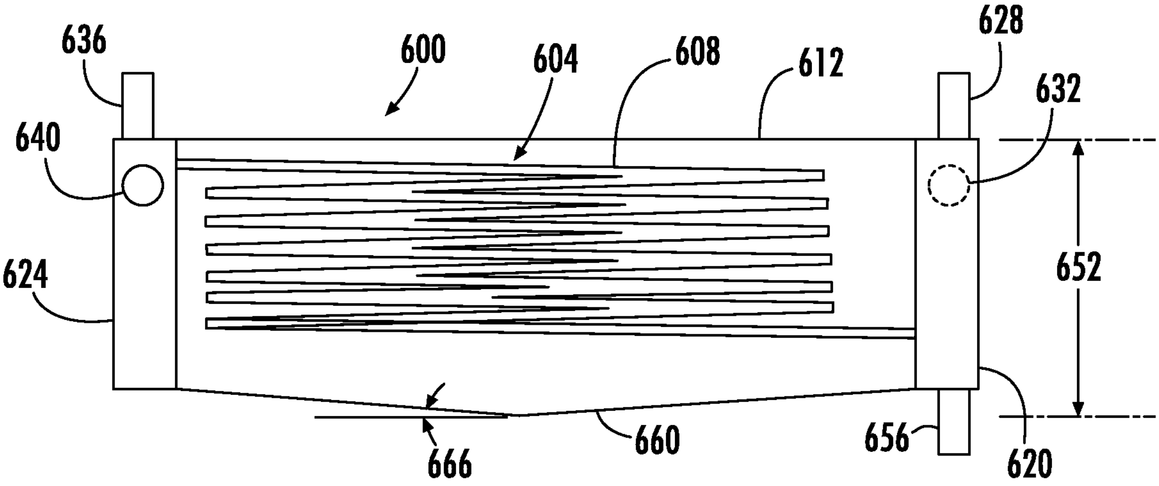
636
600
604
608
612
628
632
640
624
652
666
660
656
620

FIG. 15

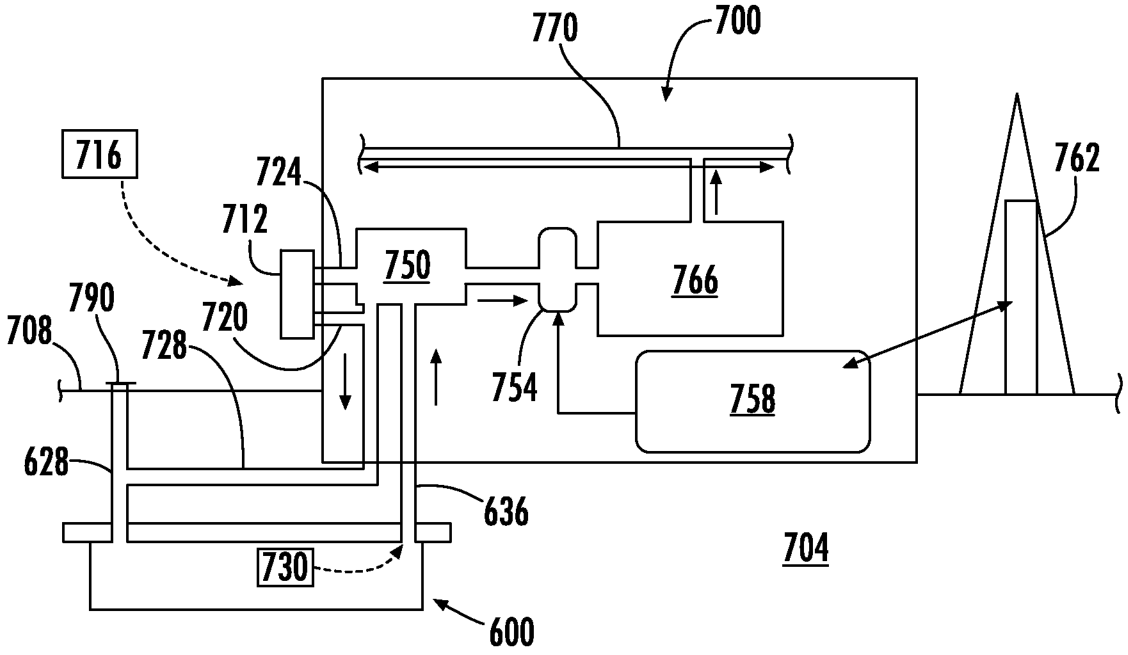
770
700
716
724
712
750
766
762
790
708
720
728
754
758
628
636
704
730
600

FIG. 16

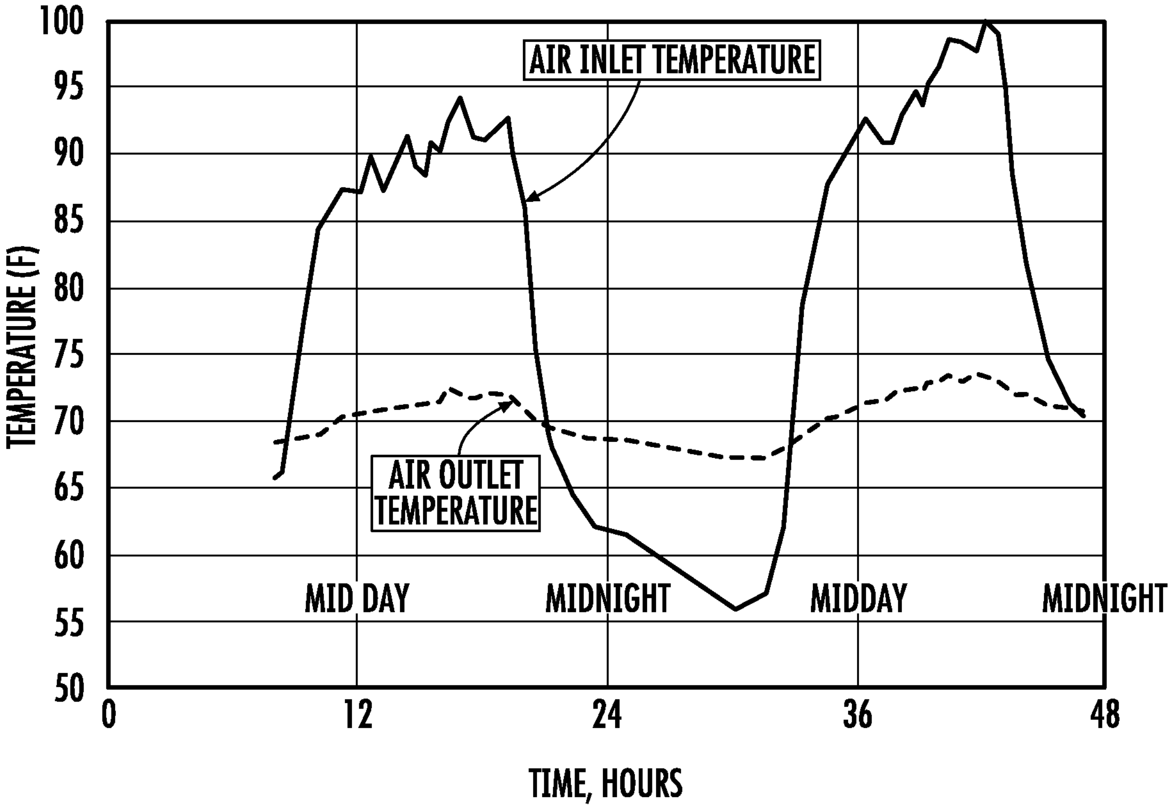
100
95
90
85
80
75
70
65
60
55
50
TEMPERATURE (F)
AIR INLET TEMPERATURE
AIR OUTLET TEMPERATURE
MID DAY
MIDNIGHT
MIDDAY
MIDNIGHT
0
12
24
36
48
TIME, HOURS

FIG. 17

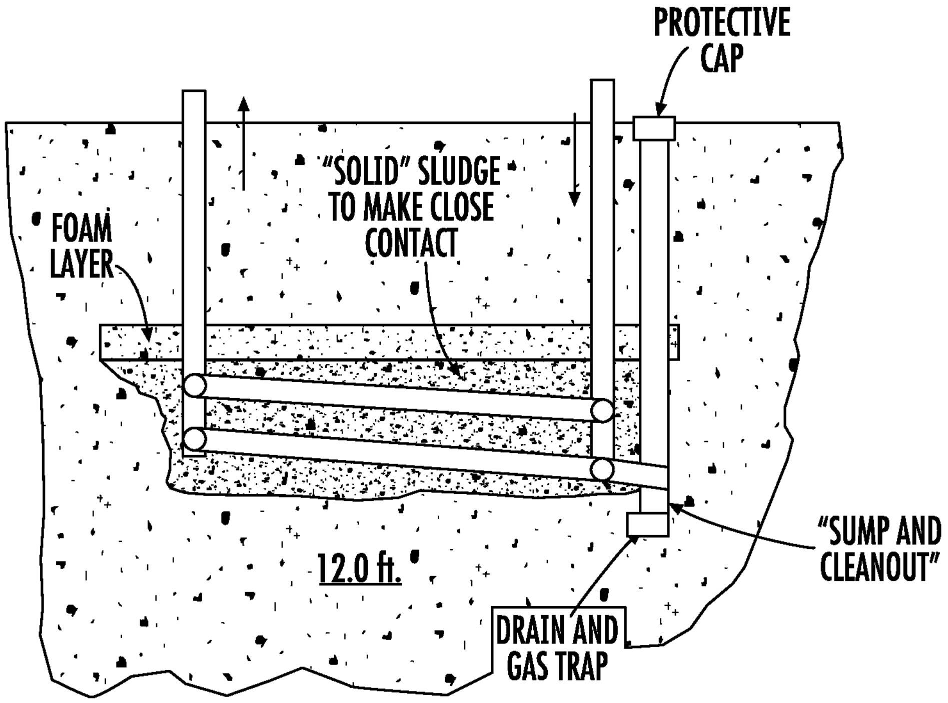
PROTECTIVE CAP
"SOLID" SLUDGE TO MAKE CLOSE CONTACT
FOAM LAYER
"SUMP AND CLEANOUT"
12.0 ft.
DRAIN AND GAS TRAP

FIG. 18

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2009/052418

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F28D 20/00 (2009.01)
USPC - 62/260
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - F28D 20/00; F24J 3/00 (2009.01)
USPC - 62/260; 165/45,10; 126/400,609,610,611,612,613,620; 60/641.2,641,640,643

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
USPTO EAST System (US, USPG-PUB, EPO, DERWENT), PatBase, IP.com, DialogPro

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- Y	US 4,169,461 A (HAUG et al) 02 October 1979 (02.10.1979) entire document	1, 2 ---------- 3-9, 19
X -- Y	US 4,842,048 A (HIGAKI) 27 June 1989 (27.06.1989) entire document	13-18 -------- 10, 12
Y	US 3,996,919 A (HEPP) 14 December 1976 (14.12.1976) entire document	10, 12
Y	US 5,224,357 A (GALIYANO et al) 06 July 1993 (06.07.1993) entire document	3, 6-9
Y	US 4,011,736 A (HARRISON) 15 March 1977 (15.03.1977) entire document	4, 7-9
Y	US 2006/0288724 A1 (AMBS et al) 28 December 2006 (28.12.2006) entire document	19
Y	US 4,286,574 A (VROLYK et al) 01 September 1981 (01.09.1981) entire document	5
A	US 5,941,238 A (TRACY) 24 August 1999 (24.08.1999) entire document	1-19
A	US 2,007,406 A (MILLER) 09 July 1935 (09.07.1935) entire document	1-19
A	US 4,674,561 A (KELLEY) 23 June 1987 (23.06.1987) entire document	1-19

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 09 September 2009	Date of mailing of the international search report 23 SEP 2009
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774