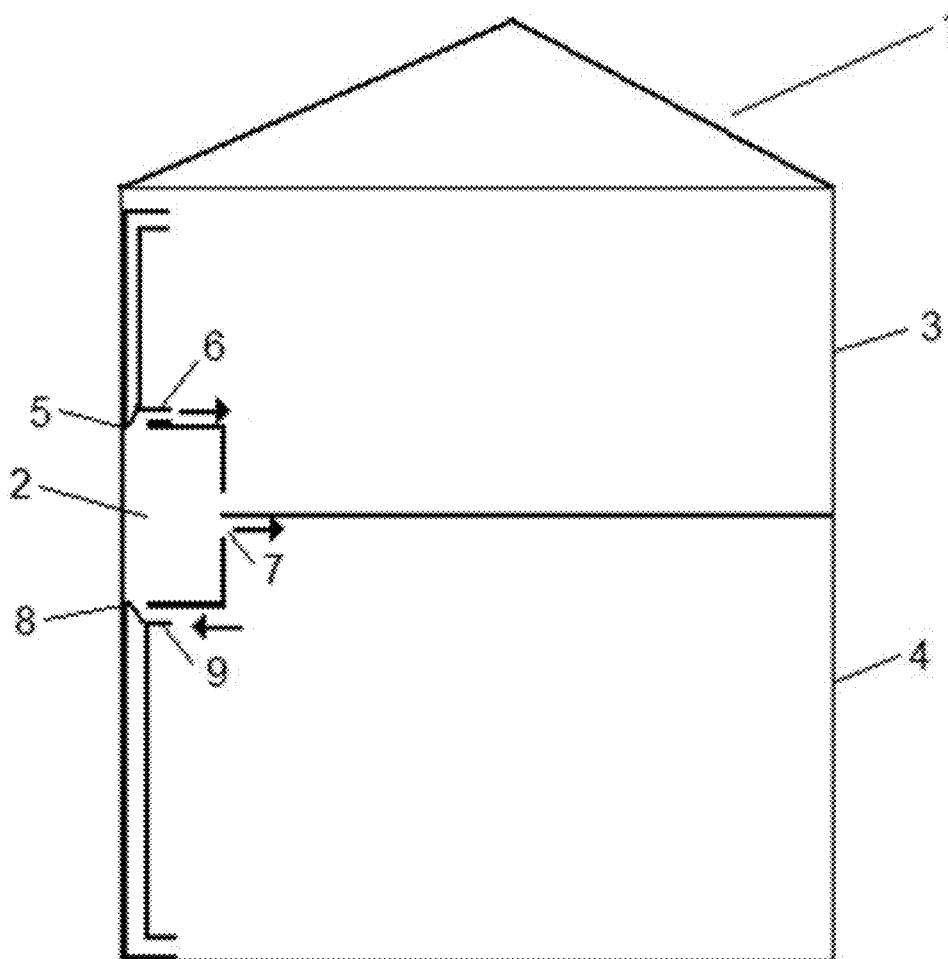




US 20160033145A1

(19) **United States**(12) **Patent Application Publication**
Logan et al.(10) **Pub. No.: US 2016/0033145 A1**(43) **Pub. Date: Feb. 4, 2016**(54) **ROOM-TO-ROOM HEAT PUMP****Related U.S. Application Data**(71) Applicant: **Twin Harbor Labs, LLC**, Plano, TX
(US)(60) Provisional application No. 62/030,320, filed on Jul.
29, 2014, provisional application No. 62/131,436,
filed on Mar. 11, 2015.(72) Inventors: **James D. Logan**, Candia, NH (US);
Erik Hinrichsen, Cambridge, MA (US);
Ralph Draper, Nottingham, NH (US);
Richard A. Baker, JR., West Newbury,
MA (US); **Sean Joseph**, Windham, NH
(US)**Publication Classification**(51) **Int. Cl.**
F24D 10/00 (2006.01)
F24D 15/04 (2006.01)
(52) **U.S. Cl.**
CPC **F24D 10/003** (2013.01); **F24D 15/04**
(2013.01)(73) Assignee: **Twin Harbor Labs, LLC**, Plano, TX
(US)(21) Appl. No.: **14/812,111**(22) Filed: **Jul. 29, 2015**(57) **ABSTRACT**

A system, method, and device for transferring thermal energy between areas of a structure so as to maintain occupant comfort while minimizing the difference between indoor and outdoor temperatures, thereby minimizing thermal losses from the structure. The device operates effectively in the heating season and cooling season, when outdoor temperatures are cold and hot, respectively.



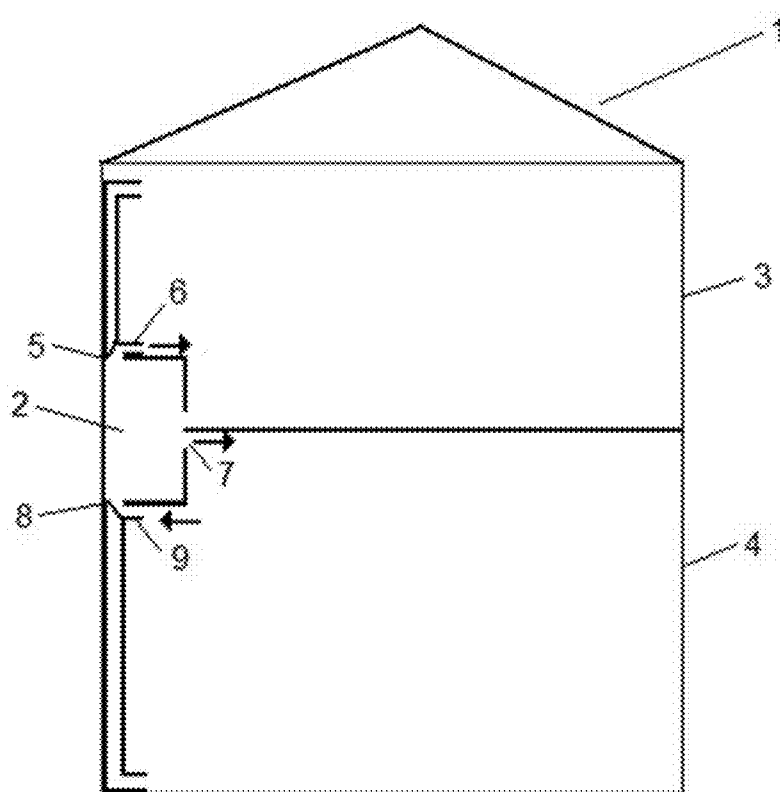


Figure 1

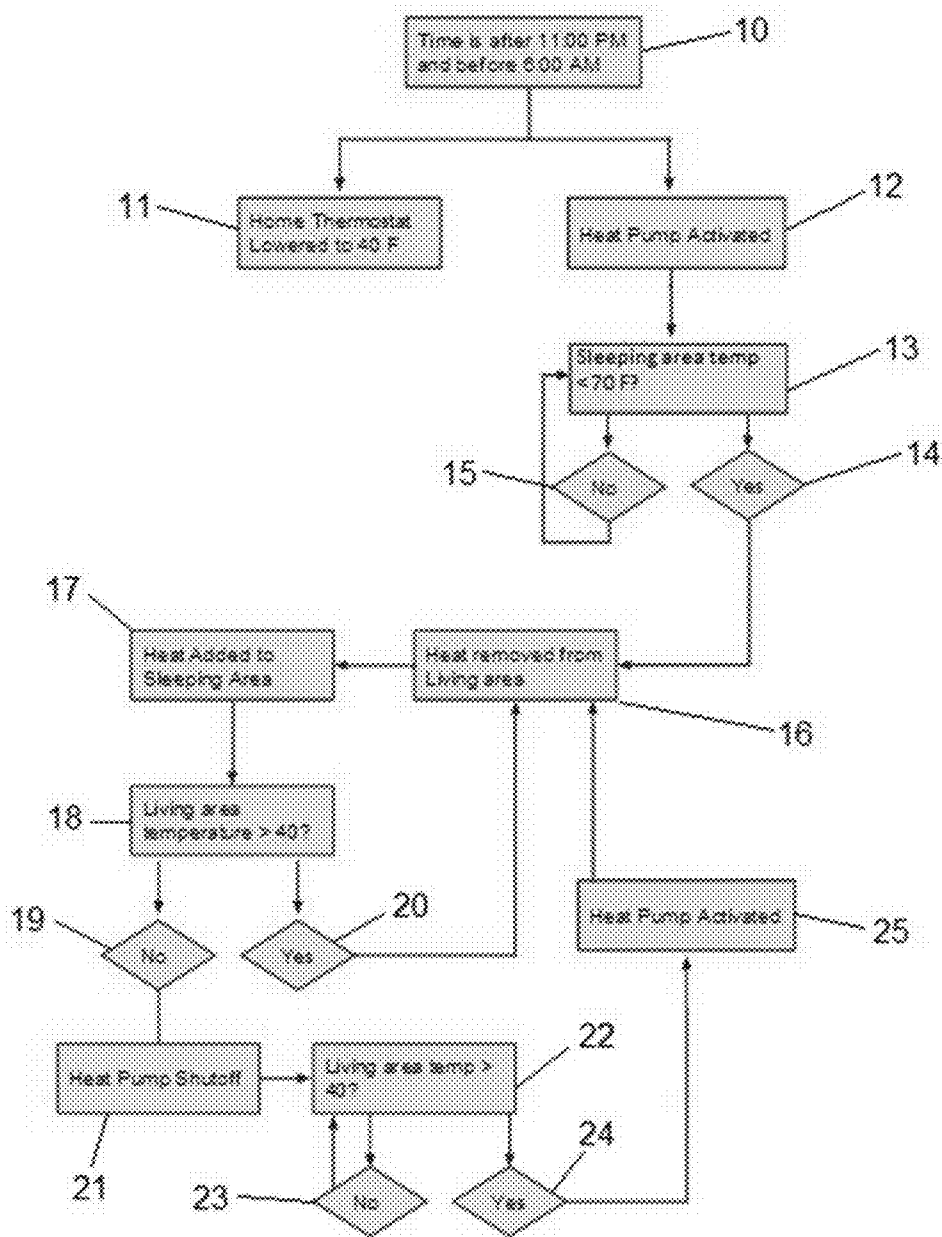


Figure 2

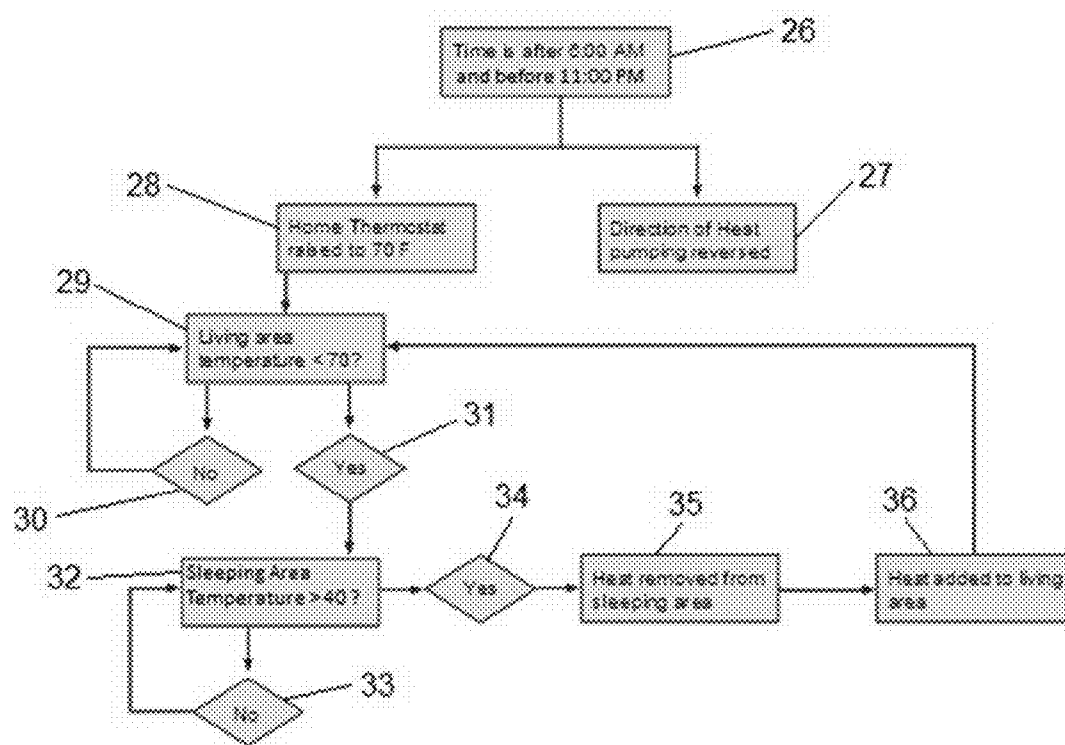


Figure 3

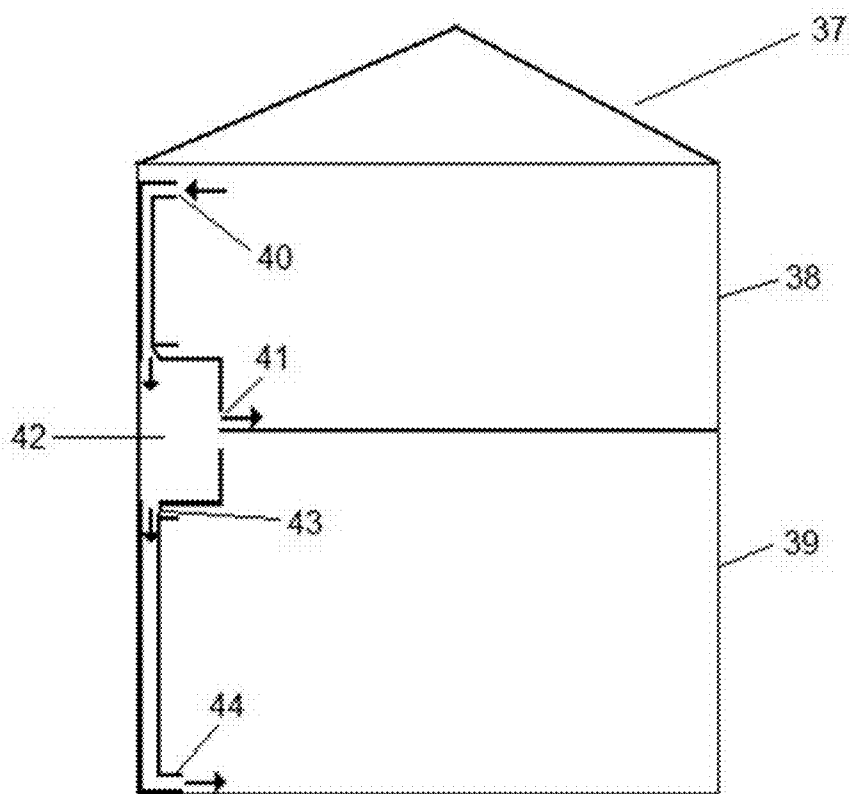


Figure 4

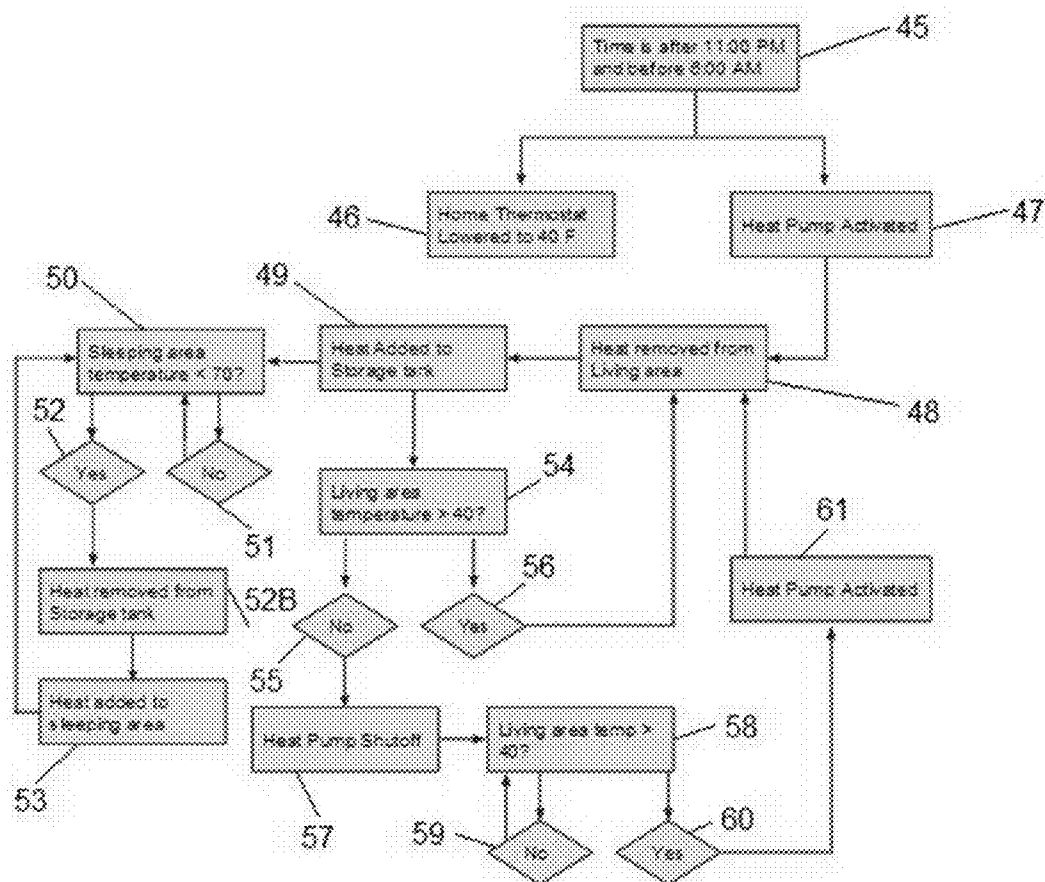


Figure 5

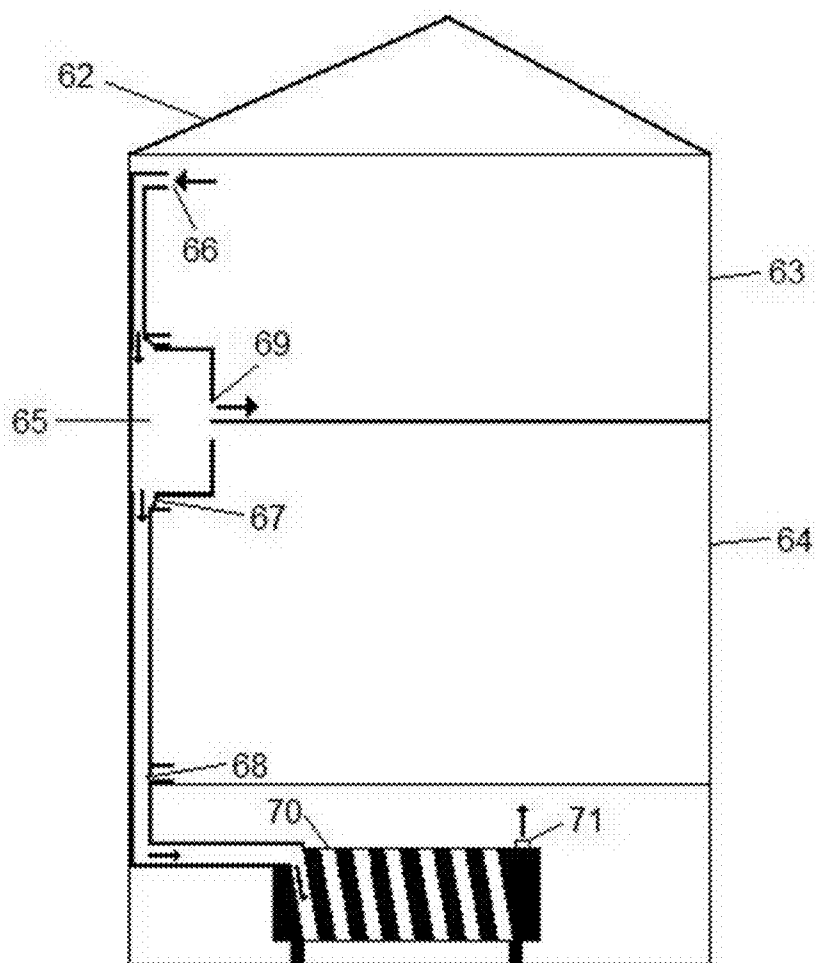


Figure 6

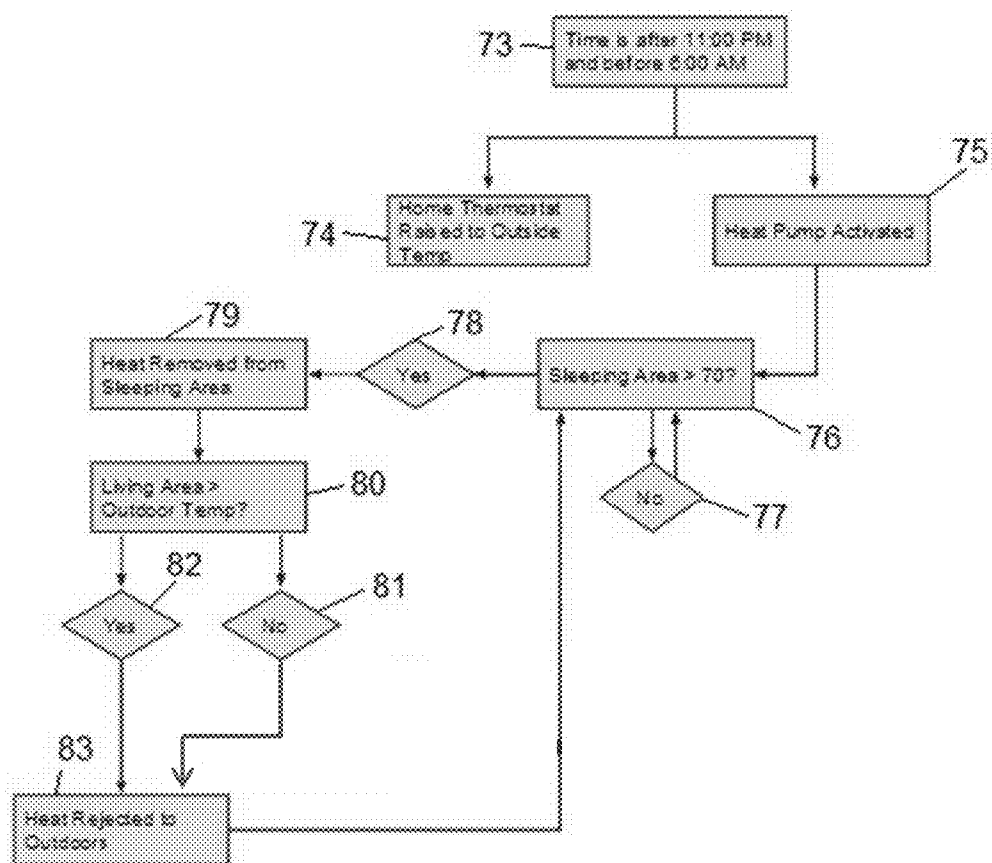


Figure 7

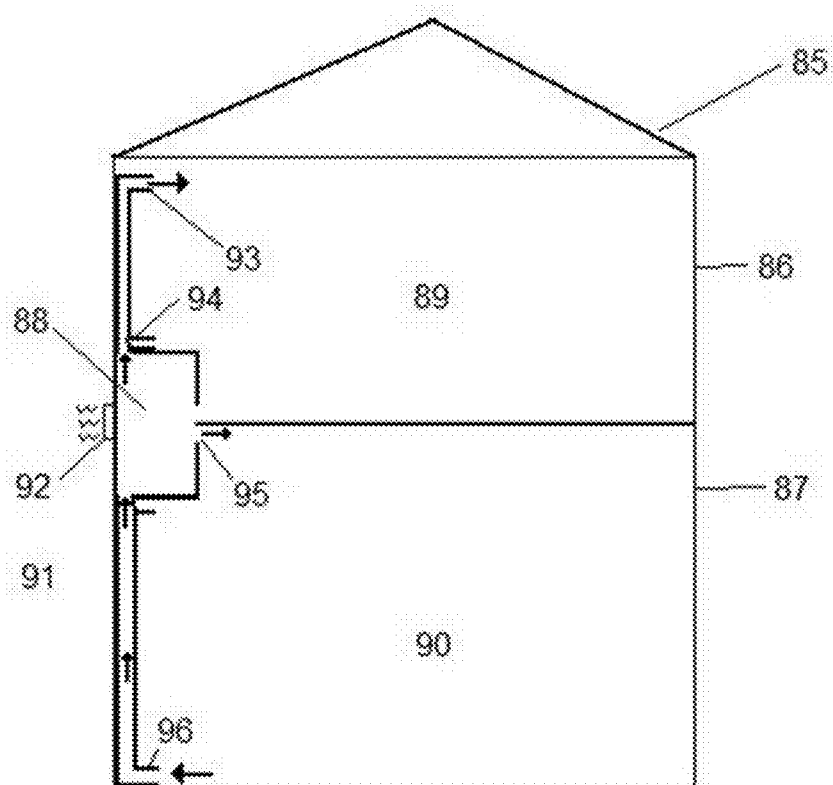


Figure 8

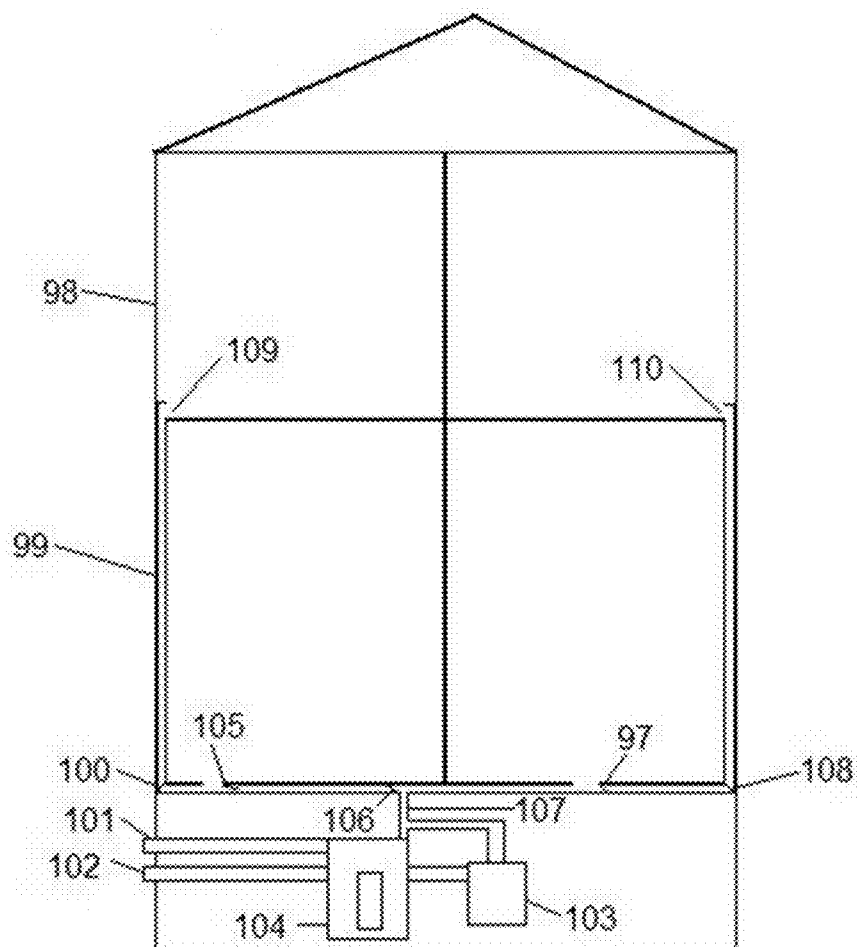


Figure 9A

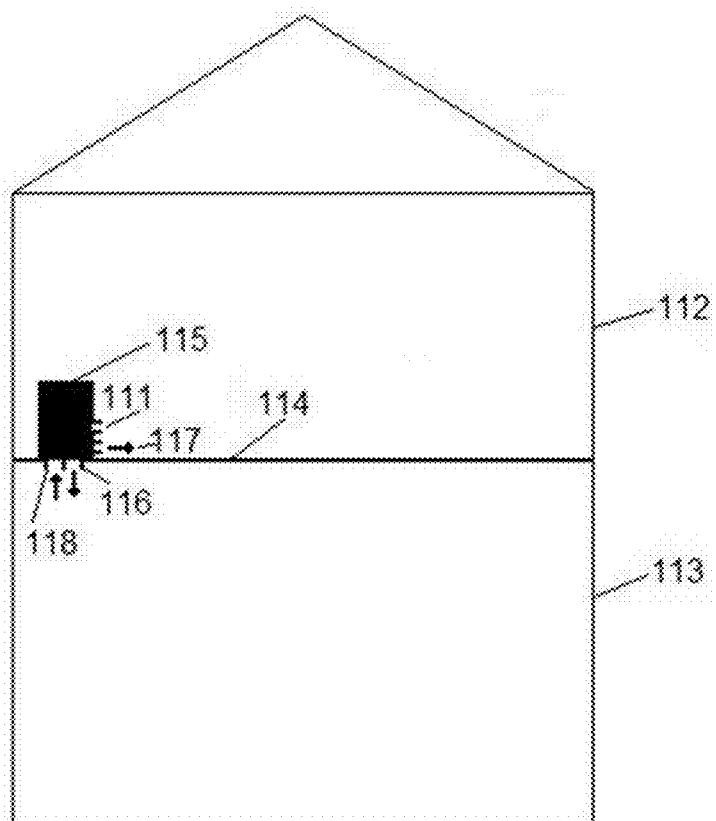


Figure 9B

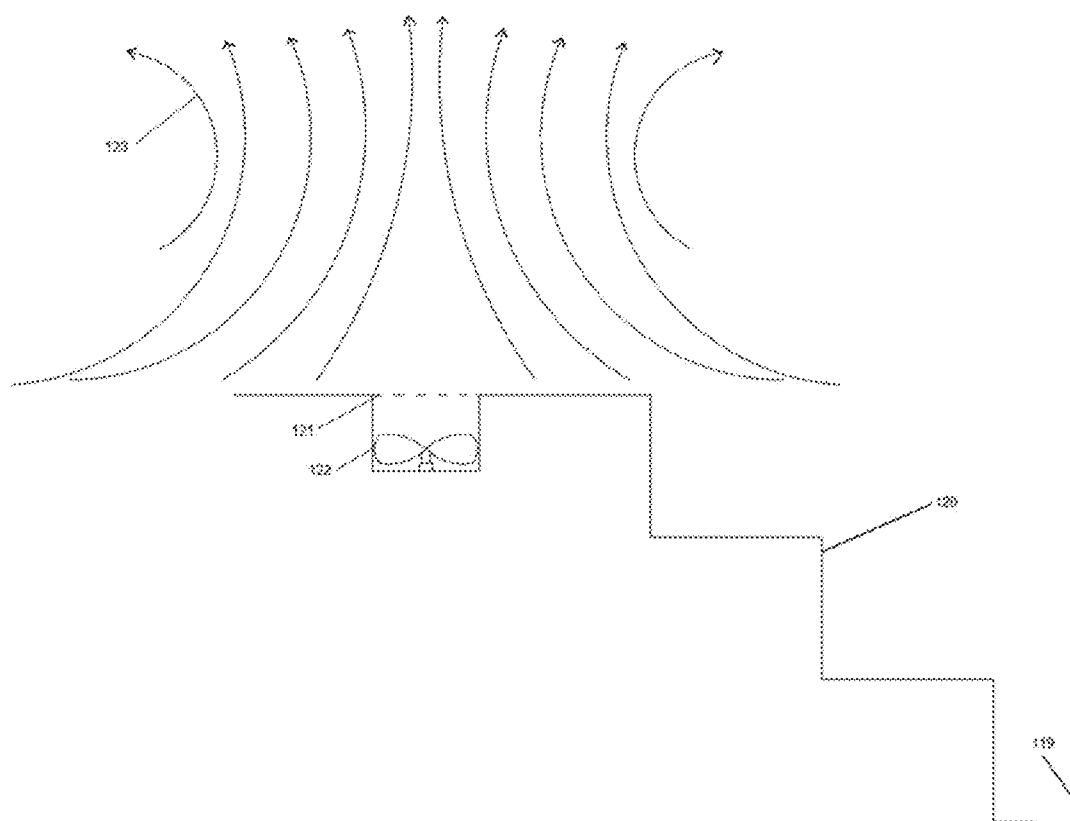


Figure 10

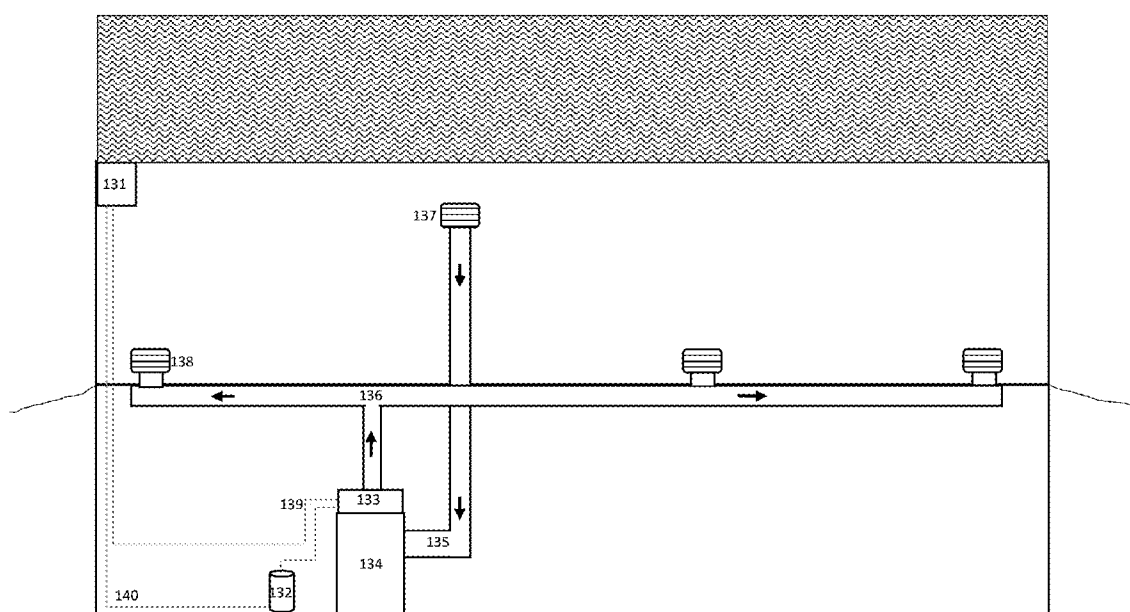


Figure 11

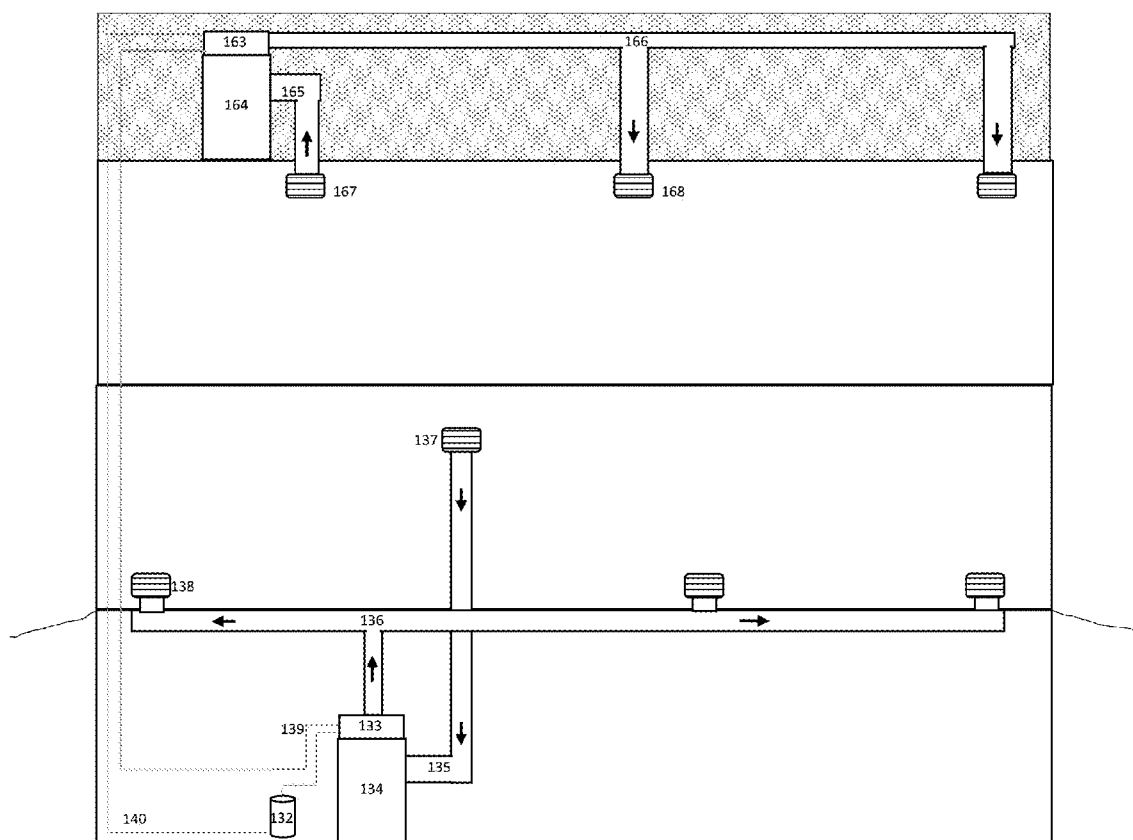


Figure 12

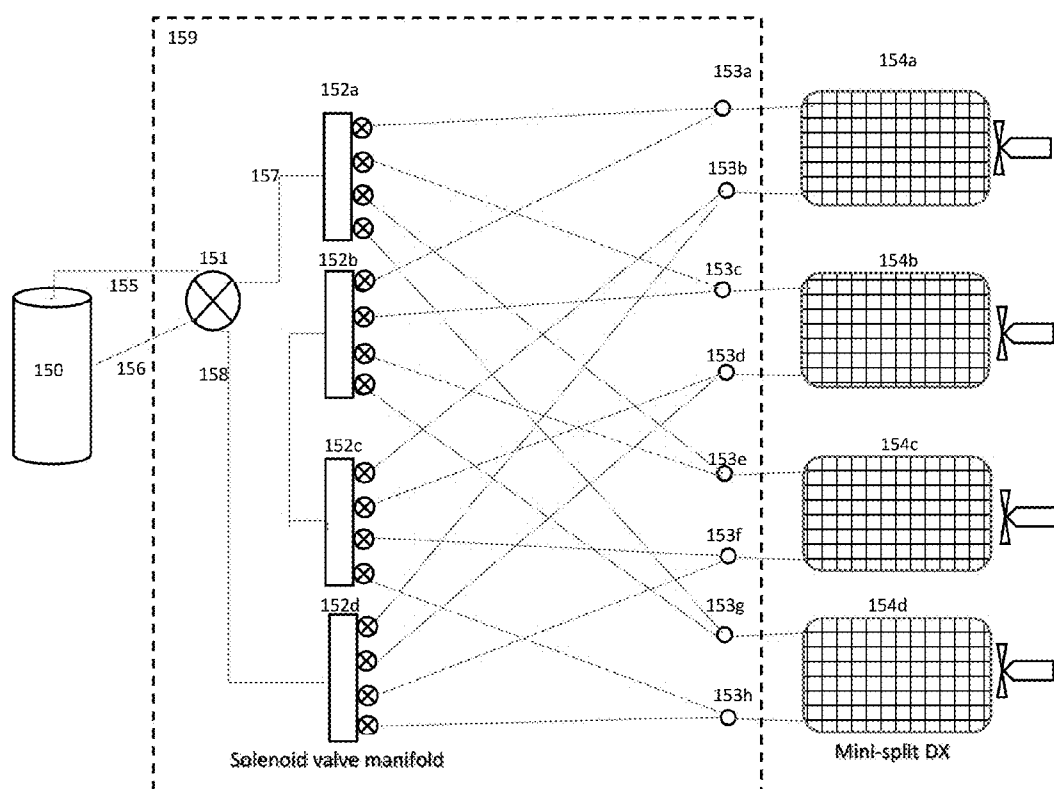


Figure 13

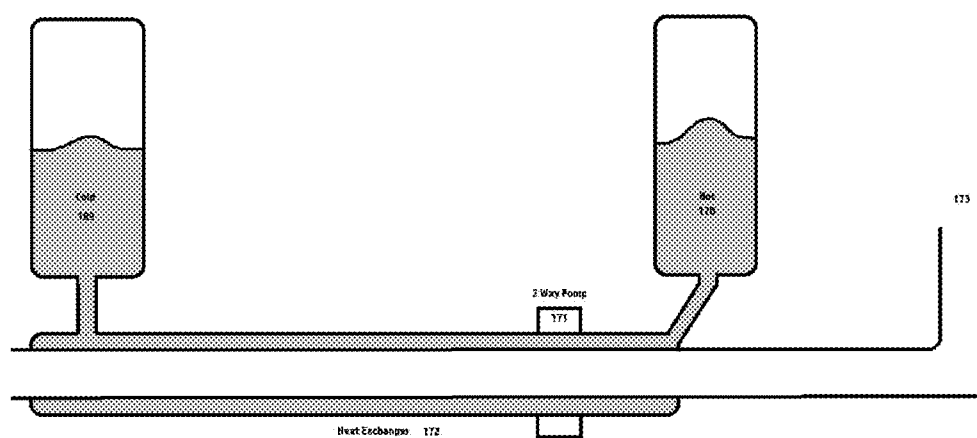


Figure 14

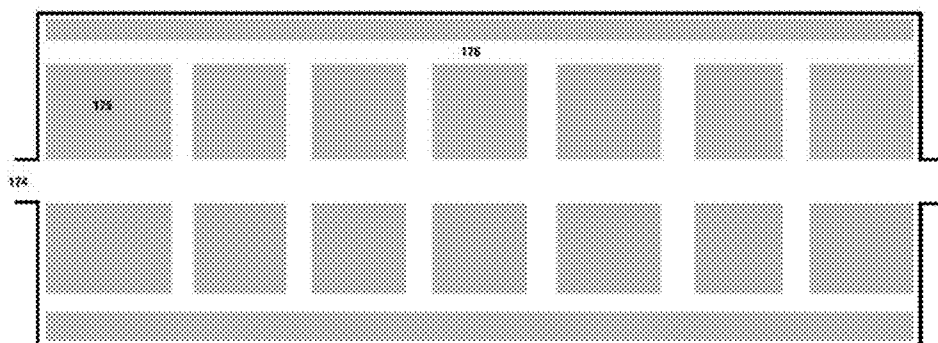


Figure 15

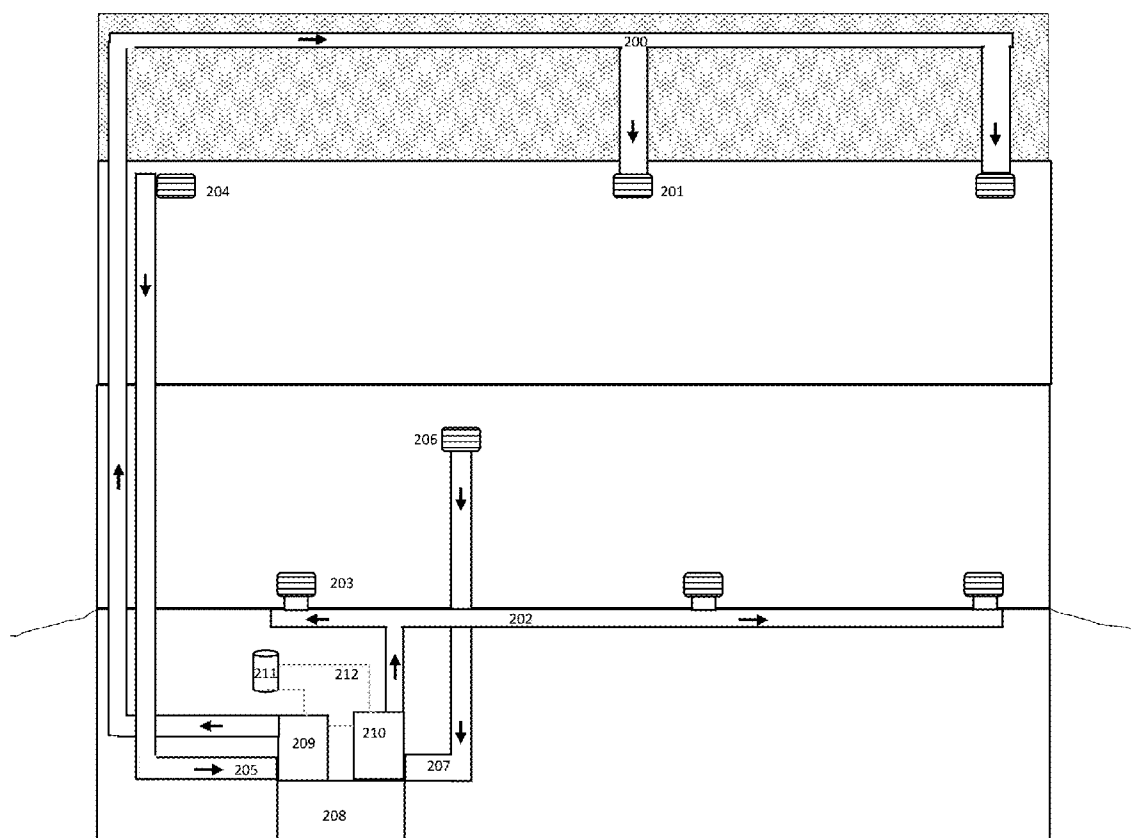


Figure 16

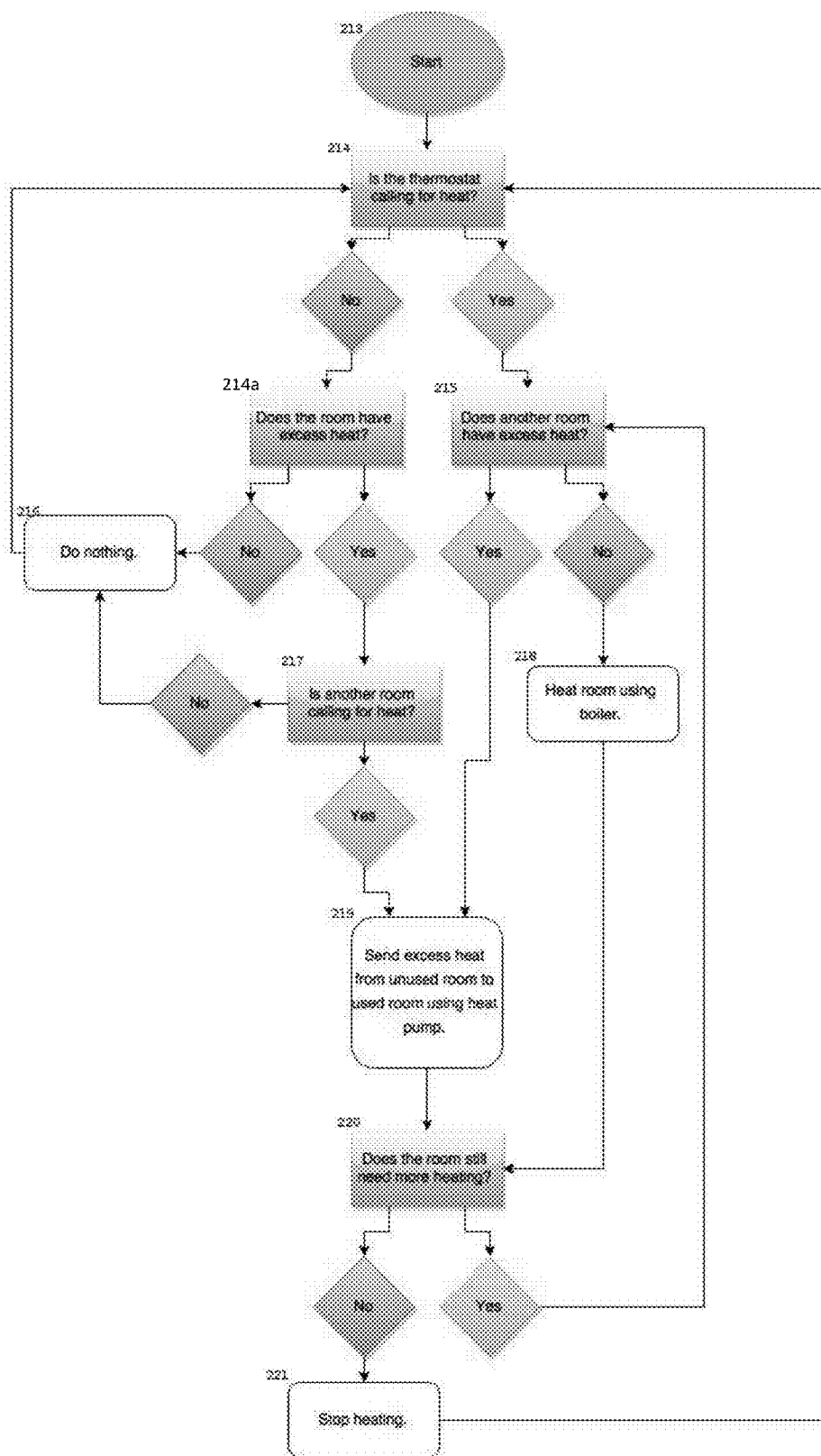


Figure 17

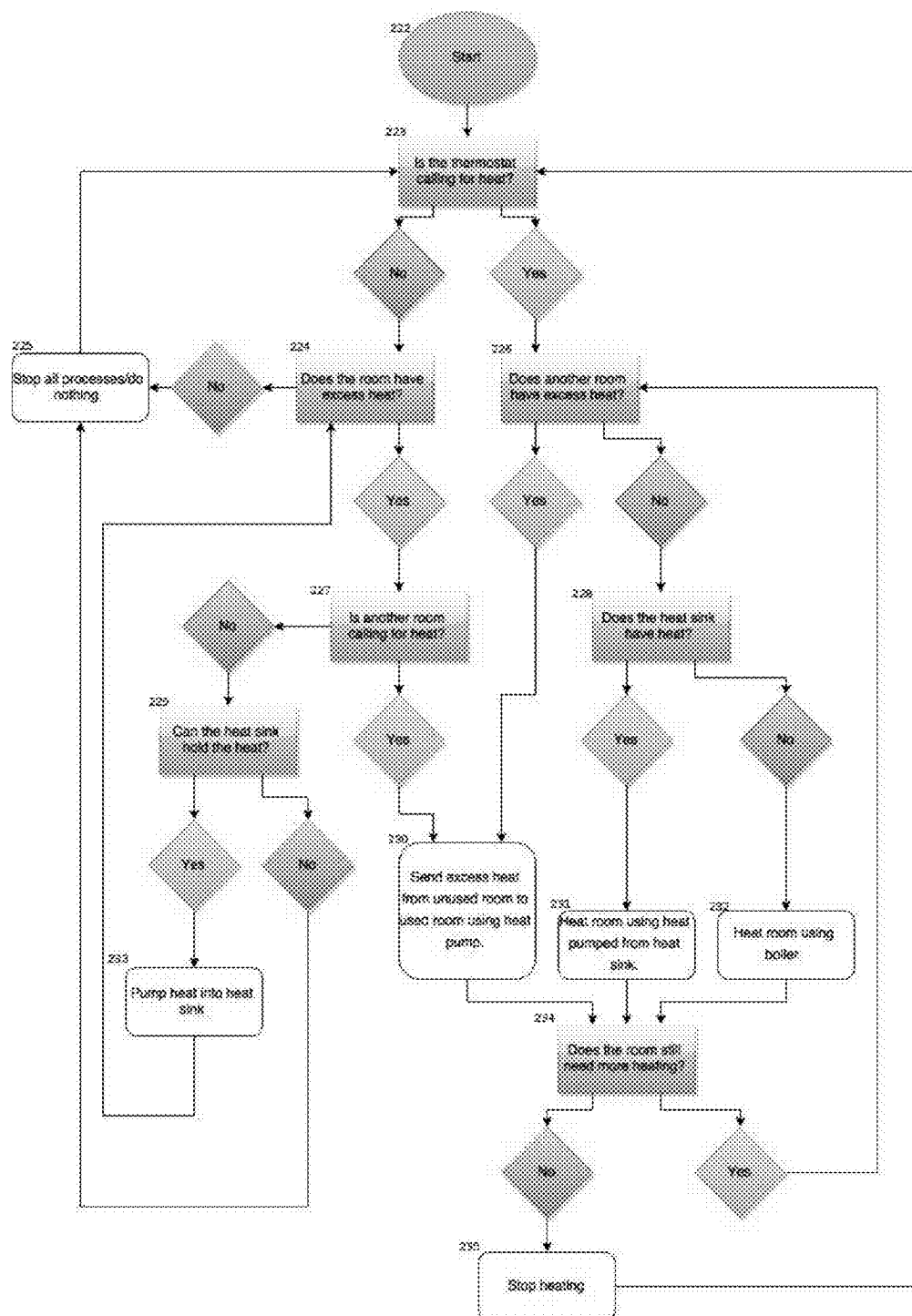


Figure 18

ROOM-TO-ROOM HEAT PUMP

RELATED APPLICATIONS

[0001] This claims the benefit of U.S. Provisional Application Ser. No. 62/030,320, filed Jul. 29, 2014, entitled ROOM-TO-ROOM HEAT PUMP, the entire disclosure of which is herein incorporated by reference and the benefit of U.S. Provisional Application Ser. No. 62/131,436, filed Mar. 11, 2015, entitled ROOM-TO-ROOM HEAT PUMP, the entire disclosure of which is herein incorporated by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to the heating and cooling of individual rooms of a house by means of available heat from other rooms of the house, and manipulating the temperatures of these rooms in order to minimize the heat lost from the house, utilizing a forced hot air type heating system.

BACKGROUND OF THE INVENTION

[0003] The rate of heat loss out of a home is proportional to the difference between the indoor temperature and the outdoor temperature. When this gradient is especially high, such as during winter nights, a typical home can lose over 44,000 Btu per hour (Build it Solar. "Home Heat Loss Calculator". <<http://www.builditsolar.com/References/Calculators/Heat-Loss/HeatLoss.htm>>. Date of Access: 7/25/14.). At current oil prices, this represents \$1.27 per hour in wasted fuel.

[0004] To improve this situation, many homeowners currently employ a method called night setback. In night setback mode, the homeowner lowers the thermostat several degrees during the night. As the difference between the indoor and outdoor temperature decreases due to heat loss, the rate of heat loss out of the house decreases as well. Since most of the home isn't occupied during this time, the temperature may drop below comfortable levels. Energy usage studies have found savings of around 6% for typical homes using night setback (Manning, M. M., M. C. Swinton, F. Szadkowski, J. Gusdorf, and K. Ruest. "The Effects of Thermostat Set-back in winter and Set-up during summer on Seasonal Energy Consumption, Surface Temperatures and Recovery Times at the CCHT Twin House Facility." *ASHRAE Transactions* 113: 1-12). Furthermore, heating bills are reduced by approximately 1% per degree of nightly indoor temperature reduction.

[0005] Although night setback saves on heating costs, it has some limitations. First, the number of degrees setback is limited by the rate of heat loss from the home. That is, the degrees of setback cannot exceed the degrees normally lost throughout the night, as setback is a passive method. The typical recommended night setback is only 8° F. This means that the energy savings are limited to a fairly modest percentage of the overall bill on the order of 5%-8%.

[0006] The second major limitation of night setback is that the home may become too cold for comfort in the morning. To address this, the furnace or boiler may be turned on some time before the homeowner wakes up using a programmable thermostat. However, turning the furnace or boiler on earlier markedly reduces energy savings. In fact, it is for this reason that programmable thermostats, which purport to reduce heating costs by facilitating setback, lost their Energy Star rating (Jim Gunshinan. "Energy Star Changes Approach to Programmable Thermostats". Home Energy Magazine. March/April 2007 issue. <<http://www.waptac.org/data/files/>

website/docs/technical tools/energy star/energy star changes approach to programmable thermostate.pdf>.).

[0007] A related technology to the Room-to-Room Heat Pump invention is the air-to-air heat pump, which has been adopted by some homeowners as a home heating system. Air sourced heat pumps extract heat from the outdoor air and move it inside. They are quite efficient, with a typical coefficient of performance ("COP" which is a ratio of heating or cooling provided to electrical energy consumed) of 3, but suffer from performance decrease in cold weather. When the outdoor temperature falls below about 40° F., the coils on the heat pump's compressor begin to frost over. As this happens, the heat pump must use energy to defrost the coils, which decreases efficiency. In addition, there is less available energy in the air at colder temperatures, which causes heat pumps to work harder to warm the homes. Below a certain temperature, heat pumps must call on a backup heating system, typically electric resistive heating. Electric resistive heating has a COP of 1, so relying on the backup heating system also decreases efficiency.

DESCRIPTION OF THE INVENTION

[0008] The Room-to-Room Heat Pump reduces heating costs by reducing heat loss to the outside at night by decreasing the difference between the unoccupied indoor rooms' temperature and the outdoor temperature. Rather than passively allowing the temperature of the home to drop as in the setback case, the heat pump actively lowers the temperature in some rooms or parts of the house, typically those unoccupied during certain hours or days, by pumping heat from those portions of the house that are unoccupied to portions of the house that are occupied. This subsequently decreases the rate at which heat escapes from the unoccupied portions of the home. The aim of the Room-to-Room Heat Pump invention is to bring the temperature of the unoccupied areas of the home as close to the outdoor temperature as is safely possible, thereby limiting the rate of heat loss from the home.

[0009] This process is achieved by means of an indoor-air sourced heat pump compactly installed within the house. The heat pump transfers thermal energy between rooms or portions in the house, rather than with the outdoors, and may be reversed such that heat can flow in either direction between such portions. The ability of the heat pump to reverse direction enables it to operate in both the summer and winter and allows the movement to and from certain rooms of the house.

[0010] In the preferred embodiment of the invention, the heat pump removes heat from an unoccupied room and transfers it to an occupied room at a pre-determined time. This decreases the temperature gradient for the portion of the house giving up heat while maintaining the occupied rooms at a comfortable temperature. The activation time may be set manually by the homeowner. Alternatively, a programmable smart thermostat may automatically learn the homeowner's behavior and adjust the room temperatures accordingly. The heat pump in this invention has an assumed Coefficient of Performance (COP) of 3, which is standard performance for an air-to-air heat pump. This means that for every unit of energy put into the device, it moves 3 units of energy in the form of heat. The fact that the heat pump is located inside the heating envelope of the house allows the waste heat produced by the machine to itself to be used as a heat source for the house itself thus reducing the cost of moving heat from room to room during the heating season. Given this energy recapture, the largest cost to run the system is therefore the differ-

ence in cost per BTU between the electricity used to run the heat pump and the cost of a BTU provided by the house's normal heat source, which could be oil, propane, etc. Problems with icing on compressor coils are avoided by maintaining the home temperature above the icing temperature.

[0011] This level of efficiency enables the invention to rapidly move heat from one area of the home to another and to do so at a low cost. The cost of operating the heat pump must be lower than the savings in order to justify the installation of the invention. As is proved in a later section, the savings are greater than the cost of operation.

BRIEF DESCRIPTION OF THE FIGURES

[0012] The invention description below refers to the accompanying drawings, of which:

[0013] FIG. 1 is an overview block diagram for the invention in heating season mode during night operation;

[0014] FIG. 2 is a diagram of the invention in a house in heating season mode during night operation;

[0015] FIG. 3 is an overview block diagram for the invention in heating season mode during morning operation;

[0016] FIG. 4 is a diagram of the invention in a house in heating season mode during morning operation;

[0017] FIG. 5 is an overview block diagram for an embodiment of the invention with thermal storage in heating season mode during night operation;

[0018] FIG. 6 is a diagram of an embodiment of the invention with thermal storage in a house in heating season mode during morning operation;

[0019] FIG. 7 is an overview block diagram for the invention in cooling season mode during night operation;

[0020] FIG. 8 is a diagram of the invention with heat rejection capability;

[0021] FIG. 9A is a diagram of the HVAC integration method of invention installation;

[0022] FIG. 9B is a diagram of mobile small-footprint method of invention installation;

[0023] FIG. 10 is a diagram showing the air curtain embodiment of the invention.

[0024] FIG. 11 is a diagram of a house using a forced hot air system using a heat pump to transfer heat between rooms.

[0025] FIG. 12 is a diagram of a two story house with two furnaces using a heat pump to transfer heat between the rooms.

[0026] FIG. 13 is a diagram of a multi-evaporator, multi-condenser heat exchange system.

[0027] FIG. 14 is a diagram of a water tank heat sink system

[0028] FIG. 15 is a diagram of a concrete heat sink system

[0029] FIG. 16 is a diagram of a two story house with a multi-zone furnace using a heat pump system to move heat between rooms.

[0030] FIG. 17 is a thermostat logic diagram for the simplest iteration of the product.

[0031] FIG. 18 is a thermostat logic diagram for the iteration which includes the heat sink component.

DETAILED DESCRIPTION OF FIGURES

[0032] FIG. 1 shows Room-to-Room Heat Pump nighttime operation in heating season mode. A room-to-room heat pump 2 is installed between two floors of a two floor home 1. The Room-to-Room heat pump 2 operates between an occupied area 3 and an unoccupied area 4. Due to cold weather, heated air is required in the occupied area 3. The Room-to-

Room heat pump 2 draws air from the unoccupied area 4 into an intake vent 9. A damper 8 is automatically positioned so that air from the top of the unoccupied area 4, which is warmer than air from the bottom of the area due to warm air's tendency to rise, is drawn into heat pump 2. A second damper 5 is automatically positioned so that air exits the heat pump 2 at a lower vent 6. Cool air is exhausted back into the unoccupied area 4 from an exhaust vent 7.

[0033] FIG. 2 describes the home heating pump process flow for heating season mode during nighttime use. Exemplary sleep and wake times and temperatures are used herein for purpose of clarity. If the time is after 11:00 PM and before 6:00 AM (step 10), the living area thermostat for the first floor, the unoccupied space, is lowered to 40° F. (step 11). At the same time, the heat pump is activated (step 12). The heat pump monitors the temperature of the sleeping area until the sleeping area temperature drops below 70° F. (step 13). (Note that throughout this document we use 70° F. as the desired temperature of a room and 40° F. for the coldest point that a room should be allowed to get. In practice, both of these numbers would be configurable by a user or an installer.) If the sleeping area temperature is not below 70° F., the heat pump continues to monitor the room temperature (step 15). If the sleeping area temperature is below 70° F. (step 14), the heat pump removes heat from the living area (step 16). It adds this heat to the sleeping area (step 17). The cold air is exhausted back into the living area. The device also monitors the temperature of the living area (step 18). If the living area temperature drops below 40° F. (step 19), the heat pump shuts off (step 21). The heat pump then continues to monitor the living area temperature (step 22 and 23) until the living area temperature is above 40° F. (step 24). If the living area temperature is above 40° F., the heat pump continues to remove heat from the living area (step 25) and transfers it to the occupied areas when the temperature of such occupied areas falls below 70 degrees.

[0034] FIG. 3 shows the process for morning operation in heating season mode. The morning is a transition time, when both the sleeping and living areas may be occupied, so both are kept at comfortable temperatures. When the time is after 6:00 AM and before 11:00 PM (step 26), the Room-to-Room Heat Pump enters morning mode. A solenoid valve in the heat pump switches, causing the direction of heat pumping to reverse (step 27). At the same time, the living area thermostat is raised to 70° F. (step 28). The Room-to-Room Heat Pump evaluates whether the living area temperature is below 70° F. (step 29). If it is not (step 30), the process returns to step 29. If it is (step 31), the Room-to-Room Heat Pump then evaluates whether the sleeping area temperature is above 40° F. (step 32). If it is (step 34), heat is removed from the sleeping area (step 35) and added to the living area (step 36). The device proceeds to step 29 and continues to monitor the room temperatures and continues through the previously described process until the morning period ends.

[0035] FIG. 4 describes Room-to-Room Heat Pump operation in morning heating season mode within a two floor home 37. Air from the sleeping area 38 enters the top sleeping area vent 40. The vent carries the air to the heat pump 42, which extracts heat from air in the sleeping area 38. The resulting cooled air is exhausted back into the sleeping area 39 at the lower sleeping area vent 44. The warmed air exits the Room-to-Room Heat Pump at the exhaust vent 41. Dampers 43 are automatically positioned as shown to facilitate the described movement of air. The result of the morning heating season

mode operation is that the sleeping area temperature is decreased while the living area temperature is raised.

[0036] FIG. 5 describes Room-to-Room Heat Pump operation in heating season mode in the nighttime for an alternate conception with thermal storage capabilities. If the time is after 11:00 PM and before 6:00 AM (step 45), the living area thermostat is lowered to 40° F. (step 46). At the same time, the heat pump is activated (step 47). The heat pump removes heat from the living area (step 48) and adds it to the storage tank (step 49). The device evaluates whether the sleeping area temperature is below 70° F. (step 50). If not, it continues to monitor the temperature (step 51). If the temperature of the sleeping area is below 70° F. (step 52), heat is removed from the storage tank (step 52B) and added to the sleeping area (step 53). The device then continues to monitor the sleeping area temperature (step 50).

[0037] The device also monitors the living area temperature (step 54). If the living area temperature is not above 40° F. (step 55), the heat pump ceases to remove heat from the living area (step 57) until such time as the living area temperature rises above 40° F. (steps 58 and 60). If the living area is above 40° F. (step 60), the heat pump is reactivated (step 61) and the device proceeds to step 48.

[0038] FIG. 6 diagrams Room-to-Room Heat Pump operation in morning heating season mode with thermal storage capability in an exemplary two floor home 62. Thermal energy is removed from the unoccupied area 63 and stored in the thermal storage tank 70. Thermal storage tank 70 is a large vessel composed of and/or filled with a material with a high specific heat capacity. In one embodiment, the thermal storage tank 70 is made out of a metal such as aluminum and filled with water. The thermal storage tank 70 is heavily insulated to prevent heat loss.

[0039] Air from the unoccupied area 63 is drawn into the heat pump 65 at upper intake 66. The heat pump 65 extracts hot air and exhausts cool air back into the unoccupied area 63 via 69. The valves 67 are automatically turned so as to facilitate the movement of the air in the prescribed path to take it to the thermal storage tank. The ducts 71 are wrapped around the thermal storage tank 70 in the manner of a heat exchanger to facilitate the exchange of heat from the ducts 71 to the thermal storage tank 70. Alternatively, the warm air can go through an air-to-water heat exchanger to transfer the heat to the tank. Following this exchange, the resultant cool air is exhausted at the end of duct 71 into the basement.

[0040] When warm air is required, the direction of action may be reversed so as to draw cool air from the basement over the heat exchanger on the thermal storage tank 70 and move it to either room as required.

[0041] This method is an advantageous addition to the Room-to-Room heat pump invention because it enables the device to drive down the thermal gradient in unoccupied rooms without subsequently increasing the gradient in occupied rooms. Alternatively, it enables efficient storage of thermal energy during times when the entire home is unlikely to be occupied, such as while the occupants are at work or away on a trip. Although occupants might turn down their thermostats in order to achieve the same lowering of the thermal gradient, the time to achieve such a reduction via the slow emission of heat from the house will be much longer than if such heat loss (and subsequent storage in a heat tank) is done actively with a heat pump.

[0042] FIG. 7 shows the process flow for the Room-to-Room Heat Pump in nighttime cooling season operation.

During the warm season of the year, the method of operation of the Room-to-Room Heat Pump may be switched to provide cold air to the sleeping area without altering the method of operation.

[0043] When the time is within the pre-set nighttime hours (step 73), the living space thermostat is raised to the ambient outdoor temperature (step 74). Alternatively, the home air conditioning system may be deactivated. In the event that the home has no air conditioning system, this step is omitted. At the same time, the heat pump is activated (step 75). The device monitors the occupied area, that is, the sleeping area, temperature (step 76). If the sleeping area temperature is below the preset maximum threshold, no action is performed (step 77) and the device continues to monitor the occupied area temperature (step 76). If the occupied area temperature is above the preset maximum threshold (step 78), the heat pump removes heat from the occupied area (step 79). Next, it evaluates whether the unoccupied area temperature is above a threshold temperature (step 80). This threshold may be the ambient outdoor temperature or a pre-set temperature of the user's choice. If the unoccupied area is above or below the temperature setting (step 82), heat is rejected to the outdoors (step 83). The device always radiates heat to the outdoors. Following step 83, the device continues monitoring the occupied area temperature (step 76).

[0044] FIG. 8A diagrams a method of operation of the Room-to-Room Heat Pump with heat rejection capability, an advantageous feature for cooling season mode.

[0045] The ambient outdoor temperature 91 is warmer than the user finds comfortable, so he would like the occupied area 86 to have a lower temperature. The heat pump 88 maintains the occupied room temperature 89 at a preset temperature. The Room-to-Room Heat Pump uses air from unoccupied areas of the home 87. This air is likely to be cooler to begin with, which increases the efficiency of the heat pump 88.

[0046] Air is drawn into the lower intake vent 96 and passed through the heat pump 88. Excess heat is rejected to the atmosphere at the heat sink 92, which may passively reject heat with heat fins or actively with a fan. The air is then exhausted back into the unoccupied area 87 at the lower exhaust vent 95, while the occupied room 86 is cooled by air from upper vent 93. Automatic valves 94 are adjusted as shown to facilitate this movement.

[0047] FIG. 9A diagrams the heating, ventilation, and air conditioning (HVAC) system integration method of installation of the Room-to-Room Heat Pump 103. The Room-to-Room Heat Pump 103 is integrated into the home HVAC system and ductwork, said system comprising a heat provider such as a furnace or boiler 104 and ductwork 99, 101, 102, 107. 101 and 102 are direct access with outdoor air, which would be useful in certain situations and would remain unused in other situations. In the diagrammed installation, the home has multiple heating and cooling zones 98, 99. The HVAC system controls heating and cooling zones 98, 99 with automatic valves 100, 106, 108 that selectively targets zones with vents and louvers 97, 105, 109, 110, and its method of operation is to be understood by a person skilled in the art. This diagram is for illustration only and is not intended to limit the embodiment to a particular design.

[0048] The air supplying duct 101 takes fresh air through an intake pipe for the furnace or boiler 104, while the exhaust duct 102 allows the furnace or boiler 104 and heat pump 103 to exhaust air. Air is drawn into the heat pump 103 from any

of the selected rooms and ventilated into any of the selected rooms as previously described operations require.

[0049] FIG. 9B illustrates a simple retrofit method of home installation in a two floor house. This method introduces a low cost option for installation which does not require professional assistance.

[0050] The Room-to-Room heat pump **118** is positioned so as to interface between both the upper level **112** and the lower level **113**. In this embodiment, the user could drill a hole through the floor **114** to accommodate the ducts **118** and **116** and forms a connection between the home levels. Alternatively, smaller holes could be drilled through the floor to pass tubing of refrigerant that run between a condenser on one floor and an evaporator on the other floor. The compressor to force the movement of the refrigerant could be located on either floor.

[0051] To warm the upper level **112**, the device draws air from the lower level **113** through vent **118** into the heat pump **115**. The upper level **112** is warmed with air from vent **117**, while cool air is exhausted into lower level **113** through exhaust **116**.

[0052] The same device installed as depicted may also be used to warm the lower level **113** or provide cool air to either level **112** or **113**. To cool upper level **112**, air is drawn into the heat pump **115** through vent **118**. Cool air is ventilated into area **112** through vent **117**, while warm air is exhausted outside.

[0053] FIG. 10 diagrams the operation of the air curtain embodiment of the Room-to-Room Heat Pump invention. As illustrated, the invention is in the cooling season mode while the upper floor is occupied. The air curtain is an advantageous feature because areas of the home are to be maintained at different temperatures, which may cause air to rise or sink along the stairs according to which area is warmest. As this is counter to the operational goals of the Room-to-Room Heat Pump, the air curtain prevents such motion.

[0054] A fan **122** is installed in the floor at the top of the stairs **120**. A grate **121** is installed above the fan **122** so that occupants may walk above it safely. The operation of the fan **122** causes the air above it to form eddies as shown in **123**, thus preventing the free flow of air to or from the lower level **119**.

[0055] In a forced hot air heating system, as seen in FIG. 11, the ductwork is already in place to return the heated air in the room through the heating system's hot-air ductwork **136**. There is already a fan in the furnace **134** for moving the air to the room that is calling for heat. A condenser **133** can then be added to the furnace **134** after the fan so that the fan can take the heat from the condenser **133** and send that heat to the rooms. Additional logic in the furnace control circuit runs the fan but does not fire the furnace **134** so that the heating can be done solely with the condenser **133**. Should additional heat be required beyond the capabilities of the condenser **133**, then the furnace **134** itself can supplement the heat from the condenser **133**. The compressor **132** is located near the furnace **134**. In the summer, this condenser **133** can be run in reverse, becoming an evaporator, thus supplying cooling to the rooms via the ductwork **136**.

[0056] The compressor **132** is located in the basement so that the heat from the compressor can be used in the heating of the house in the winter. In the summer, large duct with a fan could be used to expel the excess heat from the house. The compressor **132** should be in an insulated enclosure in the basement so that the heat can be controlled.

[0057] Existing ductwork **136** in the forced hot air system is used so as to maximize comfort in the occupied rooms.

[0058] The evaporator **131** is supplied by tubing **140** containing a Chlorofluorocarbon (such as Freon), a Hydrochlorofluorocarbon, a Hydrofluorocarbon or similar refrigerant. This refrigerant cycles through the tubing **140**, **139** to an evaporator **131**. The evaporator **131** could be located in the portion of the house where the heat is being recovered. Alternatively, ductwork could take the heat from the rooms where the heat is being recovered to a central evaporator, perhaps located near the furnace **134**, and then the cooled air is returned through separate ductwork. The evaporator **131** is also known in the industry as a mini-split direct expansion (or mini-split DX) unit.

[0059] The separate ductwork for the heat pump does not need to be of the same size as the normal ductwork, as there is no need to maintain comfort in the unoccupied rooms (although the quicker it is extracted, the less loss occurs through the walls).

[0060] Placement of the ductwork for heat extraction, or alternatively the location of the evaporator **131**, should be in a room or an area of the house with maximum exposure to the external weather. This could be an area with 2 or 3 outside walls and perhaps a roof exposure. Or it could be an area with a large number of windows, or that is poorly insulated. The goal is to extract the heat from this area before it is lost through the walls. In the summer, this may be a room with a southern exposure with many windows that will be quickly heated by the sun.

[0061] In an alternative embodiment, the heat extracted could be stored in a big heat sink in the basement, as described above and in FIG. 6. This heat sink would need to be heavily insulated to minimize heat loss.

[0062] FIG. 12 shows a two story house with two heating units, one in the attic **164** and the other in the basement **134**. The reference numbers in the basement units are the same as used in FIG. 11 as the devices are the same. The difference between FIG. 11 and FIG. 12 involve the equipment in the attic.

[0063] In FIG. 12, the coolant from the compressor **132** moves through the tubes **140** to an evaporator/condenser unit **163** in the attic. When in heat pump mode, the heat is moved between evaporator/condenser units **163** in the attic and the evaporator/condenser unit **133** in the basement. The air arrives at the furnace **164** from the return vent **167** through the return ducts **165**. The furnace **164** may also include an air conditioning unit. When heating the second floor, the furnace **164** may run the burner to supplement the heat from the condenser **163**.

[0064] In an alternative embodiment, ductwork is used to move air between the units in the attic and in the basement instead of coolant. This embodiment can be seen in FIG. 16.

[0065] FIG. 16 shows the heating system utilizing one embodiment of the current invention on a two story, two zone home with a single heating plant **208**. In this figure, the air enters the heating system through the returns, **206** for the first floor and **204** on the second floor. The air flows through the ductwork **207** and **205** to the heating plant. The return air from the second floor flows from the ductwork **205** into the heat exchanger **209** and then into the supply ductwork **200** and to the supply vents **201**. The return air from the first floor flows from the return ductwork **207** into the heat exchanger **210** and then into the supply ductwork **202** and to the supply vents **203**.

[0066] The heat exchangers 209 and 210 perform multiple functions, which are described in further detail below. The heat exchangers 209 and 210 have blowers to move the air through the ductwork and have coolant coils for performing the function of a condenser or an evaporator, transferring heat either from or to the coolant in the coolant tubes 212. The coolant is moved through the system with a compressor 211. The coolant tubes 212 include valves that permit the flow of coolant to be reversed, so that heat can be transferred from either the second floor heat exchanger 209 to the first floor heat exchanger 210 or in the other direction. This allows heat to be extracted from one floor and transferred to the other floor. In addition, the heat exchangers 209 and 210 allow the air to be heated or cooled by the heating plant 208.

[0067] The compressor 211 in FIG. 16 (and possibly in the compressors 132 in FIGS. 11 and 12) could be located in the basement of the house, conserving the heat from the compressor 211 in the building. Ductwork may be necessary in the summer to vent this heat outside of the house through the use of louvers and valves. In certain situations there are advantages to maintaining thermal isolation between some of the various components of the system. Alternately, a water cooled compressor could be used, and the heat exchanged into a heat exchanger 209 and 210 in the winter or to a cooling tower in the summer.

[0068] There are many combinations of heating and cooling the first and second floors in the summer and winter to add or subtract heat from an area of the house, each of these combinations are easily understood by one of ordinary skill in the art given the figures and specification of the present invention.

[0069] To achieve maximum flexibility in the transfer of heat between any two rooms, a multi-condenser, multi-evaporator system is shown in FIG. 13. Multiple condensers 154a-d and evaporator 154a-d units (also known as mini-split DX) are installed throughout the house, including one outside in some embodiments. Since this system is flexible and can be run in either direction, each unit 154a-d can function as either a condenser or an evaporator, depending on which direction the refrigerant is flowing. The condenser/evaporator units 154a-d also include a fan to move the air across the coils. The compressor 150 pushes high pressure refrigerant into a dual-input, dual-output solenoid valve 151 that can send the high pressure refrigerant from the tube 155 to either the tube for manifold 152a (tube 157) or manifold 152d (tube 158). A control system determines the state of the solenoid and thus which direction the refrigerant flows. If it goes to tube 157, then the refrigerant will go to manifold 152a (these manifolds are known in the industry as solenoid valve manifold units). This manifold 152a has four ports, although one of ordinary skill in the art could envision using any number of ports for the manifolds 152a-d depending on the size of the system. Manifold 152a has the four ports controlled by the control system so that only one port is open at a time (however, a more sophisticated control system may allow multiple ports to be opened simultaneously to allow for the removal or insertion of heat to multiple rooms simultaneously). Say that it is desired that the room containing evaporator/condenser 154a be used to remove heat. Then the first port on manifold 152a is opened to allow the refrigerant from 157 to flow through port 1 on manifold 152a through junction 153a and then through tubing through the walls of the house to evaporator 154a which is performing the evaporation function in this example. The refrigerant then flows out of evaporator 154a

back through the tubes in the walls into junction 153b. Port 1 on manifold 152c is opened by the control system to receive the refrigerant (port 1 on manifold 152d must be closed to prevent the refrigerant from going straight back to the compressor 150). The refrigerant is then piped to manifold 152b for distribution to a condenser 154a-d. Say that it is desired to add heat to the room containing condenser 154d, then the control system will open port 4 on manifold 152b, allowing the refrigerant to flow to junction 153g and through the walls of the house to condenser 154d. The refrigerant then flows out of the condenser 154d, through the walls of the house to junction 153h, and into manifold 152d, port 4. From manifold 153h, the refrigerant flows through tube 158, through the dual-input, dual-output solenoid valve 151 and then through tube 156 and back into the compressor 150. One of ordinary skill in the art can determine other combinations to move heat in or out of any room with a condenser/evaporator 154a-d. A control system for the heating/cooling system coordinates a series of valves on the refrigerant tubing between each of these units, allowing heat to be extracted or placed at any one of the condenser or evaporator units at any point in time.

[0070] While the tubing connecting the compressor 150 with the evaporator/condensers 154a-d seem complicated, in one embodiment it is envisioned that this could be a single manufactured part 159 covering the dual-input, dual-output solenoid valve 151, the manifolds 152a-d, the junctions 153a-h and all of the interconnecting tubing and solenoid controls. While FIG. 13 shows a 4 evaporator/condenser 154a-d system, one of skill in the art could understand how to build a similar system with any number of evaporator/condenser units 154a-d. The installer would then need to connect tubing 155 and 156 to the compressor 150 and run pairs of tubing from the part 159 to each evaporator/compressor 154a-d located in various rooms in the house.

[0071] A control system operates the system in FIG. 13, controlling the direction of the refrigerant so that one compressor/evaporator 154a-d operates as an evaporator, taking heat out of a room, and another operates as condenser adding heat to a room. In a more complicated system, it is envisioned that the control system could control all multiple compressors or evaporators in the system.

[0072] With this system, heat can be transferred in or out of a number of rooms. Additional movement of heat can be facilitated if one of the condenser/evaporators 154a-d is located outside.

[0073] Note that this system could be simplified if the condenser/evaporator is coupled to a typical heating system and the heat (or cooling) is distributed through the normal ductwork, as see in FIG. 10.

Description of Room-To-Room Operation

Night Operation—Heating Season Mode

[0074] At a certain time determined either by the user or automatically, the Room-to-Room Heat Pump activates. For instance, in manual setup mode the user might turn on the Room-to-Room Heat Pump and adjust the thermostat down to 40° F. at 10:00 PM.

[0075] The heat pump acts upon two locations. The first is referred to as the “Living Area”. This area is made up of rooms that are unoccupied in the night, such as the living room, kitchen, and dining room. In night time operation, the heat pump rapidly cools down the air in the Living Area to the predetermined Cold Temperature, which is either controlled

by a thermostat on the heat pump or by a central household thermostat. The second area is referred to as the “Sleeping Area”. This area is made up of the bedroom and other areas likely to be occupied during the night, such as the bathroom. At the same time the device is cooling down the living area, it begins to warm the sleeping area. Warm air is brought into the sleeping area to bring it up to a comfortable temperature and maintain that temperature as heat is lost throughout the night. This keeps the homeowner comfortable without wastefully heating unoccupied rooms.

[0076] The effect of the Room-to-Room Heat Pump is that the average temperature of the house may be substantially lowered without negatively impacting the homeowner’s comfort. For example, the home may be maintained at an average temperature of 55° F., which would ordinarily be uncomfortably cold. The action of the Room-to-Room Heat Pump maintains the occupied areas of the home at 70° F. by drawing heat from the unoccupied areas, whose temperatures subsequently drop. As the temperature of these unoccupied areas decreases, the difference between their temperatures and the outdoor temperature is diminished. This decreases the rate of heat lost out of the home. The net effect is the same as if the home were maintained at the average temperature.

[0077] According to the United States Department of Energy, every degree of setback over an eight hour period equates to an annual heating bill savings of approximately 1% when used consistently (U.S. Department of Energy. “Thermostats”, Nov. 26, 2013. Date of Access: Jun. 20, 2014. <<http://energy.gov/energysaver/articles/thermostats>>.) Maintaining the average temperature at 55° instead of 70° F. would save 15% annually on heating. Moreover, the savings are actually greater than 1% per degree, as the heat pump can act during the daytime as well as night.

[0078] In the course of its use, the operation of the Room-to-Room Heat Pump itself warms the house to some extent. Due to the laws of thermodynamics, this thermal energy will be approximately equal to electrical energy drawn from the grid. Any heat lost from the home net of the heat pump’s waste heat must eventually be replaced by the furnace or boiler. Because the occupied areas of the home are maintained at a high temperature, heat loss from the house works to decrease the temperature of the unoccupied areas. With each cycle of day-night, the unoccupied area is becoming progressively colder. Finally, the unoccupied area will fall below the minimum set point, thus triggering the furnace or boiler to activate.

[0079] As part of their normal operation, heat pumps remove humidity from the air. This may be problematic in the wintertime, when humidity levels are already quite low. In one embodiment of the invention, the water removed from the air is collected and added back into the air at a later stage. By adding a humidifying step to the process, the dehumidification effects inherent to heat pumps are counterbalanced.

Daytime Operation—Reversing

[0080] The heat pump’s operation throughout the night keeps the occupied areas of the house warm at the expense of the unoccupied areas. While this saves a substantial amount of energy, it leaves those unoccupied areas too cold for user comfort. To address this situation, the Room-to-Room Heat Pump invention may be reversed. The reversibility means that it can operate in both directions: removing or adding heat to each room.

[0081] The reversing mode is enabled by means of a solenoid valve built into the device. Solenoid valves are operated electronically, so that the device can send a signal when it is entering reverse mode. This causes the solenoid valve to flip, reversing the direction of flow of the coolant fluid in the heat pump. Persons skilled in the art will be familiar with the operation and purpose of a solenoid valve.

[0082] When the refrigerant fluid flows in reverse, the device operates in the opposite way as in heating season mode. It removes heat from the sleeping area and adds it to the living area. The time required to complete the reversal in the morning depends on factors such as the size of the device and the size of the unoccupied areas. Industry studies show that it takes approximately one hour to bring the air back to the set point following night time setback, so the device will need to reverse about an hour before the user gets out of bed. It should not completely reverse the area temperatures, but rather bring them into equality. If the device were to completely reverse the temperatures, the sleeping area would be excessively cold when the user awoke.

[0083] If the user finds the average home temperature to be too cold in the morning, the user may program the thermostat to increase to a more comfortable level during the morning hours, then decrease again after the user leaves for the day.

[0084] In one embodiment, the schedule of the user is known by the system and the system moves the heat to the area that the user is going to before he arrives. For instance, if the user typically awakes at 7 AM, the user could program a calendar based thermostat so that the system will start at 6:30 AM to move the heat from the bedroom to the kitchen so that the kitchen is warm when the user arrives. Additional heat from the traditional heating system may also be used to heat the kitchen to supplement the heat movement.

[0085] Alternatively, if the user finds that he desires both the bedroom and the kitchen to be warm at 7 AM, the traditional heating system could be used to heat the kitchen from 6:30 AM until 7:30 AM, and then utilize the present invention to move the heat from the bedrooms back to the kitchen.

[0086] The calendar based thermostat could be as simple as a set-back thermostat or as complicated as a device that interfaces with the user’s calendar app on a smart phone or personal computer. Furthermore, the app or the thermostat could review the user’s history of sleep and wake times and predict when the heat should be transferred.

[0087] If this cold temperature is unacceptable to the user, he may choose to engage the home furnace or boiler in addition to the heat pump. This would then bring the cold rooms’ temperatures up to an acceptable level by the time the user is inhabiting them. Leaky or poorly insulated homes, too, may need to activate the furnace or boiler in the morning. This is necessary when too much heat has escaped the home. As the home loses heat, its average temperature continues to drop. If one room’s temperature is kept at room temperature while the furnace or boiler is not engaged for a significant period of time, the unoccupied room’s temperature will drop at twice the rate as usual. This may become an issue over repeated reversals. As a general rule, the unoccupied room’s temperature should not drop below 40° F., as temperatures lower than this may result in icing of the heat pump’s coils. This decreases efficiency, because the heat pump thaws its coils with electricity. Therefore, the home thermostat is set no lower than the icing temperature of the realized device.

Method of Installation

[0088] There are two methods of installation and integration conceptualized for the Room-to-Room Heat Pump. The method chosen will be a function of cost and the home's infrastructure. The total integration method may be ideal for new home construction, while the retrofit method accommodates existing homes.

A. Retrofit Method

[0089] The first method of installation is a retrofit method. The Room-to-Room Heat Pump is installed in such a way that it can interface with each home level, which may require a hole be cut through the upper level floor. The heat pump may intake air directly at the pump body, or it may use extended ducts strategically located for ideal unit operation.

[0090] The ducts have different intake points which are activated sequentially depending on the method of usage and time of day. In heating season mode, the intake point closest to the unoccupied room's ceiling would be activated at night. The point closest to the floor of the occupied room would be used for output. During the daytime, the intake point closest to the ceiling of the sleeping area would be activated, while the point closest to the floor of the living area would be used for output. This method allows the device to preferentially select the specific locations in rooms that are likely to have the highest concentration of heat. The rationale for point selection is based on the principle that hot air tends to rise.

[0091] This method of installation may require the drilling of a hole in the floor of the upper room(s) and ceiling of the lower room(s) to enable the device to interface between levels of the house. The holes are sealed to eliminate air leaks, which carry significant heat transfer along with them.

B. Integration with Existing System

[0092] The Room-to-Room Heat Pump can be integrated or built into the home's HVAC system. When the home has multiple heating and cooling zones, the device can then selectively target rooms to heat or cool through the heating vents in the respective rooms through the use of controllable ductwork. The controllable ductwork would consist of louvers and valves used to create thermal isolation between various components of the system when it is advantageous. The heat pump can be integrated into the HVAC ductwork in such a way that it does not interfere with the operation of the furnace. In one embodiment, it is built into the ductwork of the existing furnace or boiler system.

[0093] Another option would be a unique method of using an air-source heat pump. Some homes currently use heat pumps as the sole source of heating for the home. These heat pumps extract heat from the outside air to warm the house. The heating systems using these outdoor heat pumps can be designed in such a way that the heat pump can also move heat from room to room. This method requires multiple heating and cooling zones, which gives the device excellent control over the temperature of rooms within the house.

[0094] In another embodiment, multiple condenser and evaporator units are installed throughout the house, including one outside. A control system for the heating/cooling system coordinates a series of valves on the refrigerant tubing between each of these units, allowing heat to be extracted or inserted at any one of the condenser or evaporator units at any point in time. In this embodiment, a central compressor has manifold (a distribution device attached that splits the tubing of refrigerant into multiple tubes, each tube equipped with a

solenoid to control where the refrigerant goes). A control system allows one solenoid to open, allowing the refrigerant to flow through tubing to an evaporator in the room where heat is to be removed. The tubing on the other side of the evaporator returns to a location near the compressor. Here, a second manifold (or set of solenoids and distribution device allow the refrigerant to flow back into a common tube) collects the tubes from each of the evaporators and then sends the refrigerant into a manifold that manages the distribution to the various condensers where heat is rejected. On the other side of the evaporators, a fourth manifold collects the low pressure refrigerant from the evaporators. The design also allows for the system to be run in both directions, so that each condenser and evaporator could function with the other functionality. Each condenser/evaporator includes a directional fan to move the air in the room across the coils. The fan will take warmer air from the ceiling through the coils and direct the conditioned air towards the floor. With this system, heat can be transferred in or out of a number of rooms. Additional movement of heat can be facilitated if one of the condenser/evaporators is located outside to collect or disperse heat.

[0095] Heat pumps used to heat homes typically have backup electrical resistance heating. These come online when the heat pump is for some reason unable to supply the necessary heat to the house, such as when the outdoor temperature is too low. Electrical heating has a COP of 1, a third the value of a typical heat pump, so using the backup rapidly increases costs. Therefore, integrating the Room-to-Room Heat Pump method into an air-source heat pump system can decrease energy costs by cutting reliance on backup heating. The heat pump is controlled by an algorithm that for instance moves heat from unoccupied areas to sleeping areas rather than calling on the backup heater.

[0096] The home integration installation method has advantages over the retrofit method. Improved integration into the ductwork decreases the visible footprint of the device. The device is also installed away from the sleeping area, so users cannot hear it. In addition, the system integration method of installation eliminates the need to drill holes into existing walls and/or flooring, which must be done carefully to avoid creating thermal leaks. However, this method is likely more expensive than the retrofit method, requiring professional installation. It would therefore be a good candidate for new construction or remodeling, when it can be designed into the system.

[0097] In contrast, the retrofit method is an affordable alternative for homeowners looking to reduce their heating bills. Well-positioned installation will minimize the visual and auditory footprint of the device.

Thermostat Control

[0098] The Room-to-Room Heat Pump device makes use of no less than two thermometer readings to operate successfully. A thermometer located in each of the control zones is required, as the device needs to be aware of when either of the unoccupied or occupied rooms is too cold or too warm. The temperature readings could come from existing thermostats, as in the case of total system integration installation method. Alternatively, small digital thermometers may be located on the ducts in the controlled rooms. These thermometers may be wirelessly connected to the central device, or connected with a communication circuit.

[0099] In one embodiment, an outdoor temperature reading is also used for the cooling season mode. This may be derived

by placing a digital thermometer outside of the house, or alternatively by making use of an internet connection to find local weather conditions. In another embodiment of the cooling season mode, the home heating pump does not interface with the outdoor air at all, and instead expels warm air directly into the unoccupied area. In this case, only two thermometers are needed.

[0100] In one embodiment, the Room-to-Room Heat Pump is controlled with a manual thermostat. The thermostat has temperature settings for the occupied and unoccupied zones. For each additional controlled zone, an additional thermostat setting is needed. As the room temperatures fall above or below the desired temperature, the heat pump activates or shuts off depending on the mode of operation.

[0101] Another embodiment of the invention has a programmable thermostat controller, which would enable the user to change the temperatures at a predetermined time. This allows the user to choose when the heat pump activates and at what time it reverses according to his preferences.

[0102] In another embodiment, the Room-to-Room Heat Pump can interface with the central thermostat. The thermostat can call upon the Room-to-Room Heat Pump based on user programming. It can also coordinate use of the Room-to-Room Heat Pump and the furnace or boiler in order to minimize energy usage.

[0103] In another embodiment, the heating system as a whole can be controlled by a “smart” programmable thermostat. If the thermostat has wireless connectivity, a mobile app enables the user to activate the device remotely. As the thermostat learns the homeowner’s habits, it selectively calls upon the Room-to-Room Heat Pump to guide heat from room to room without being called upon to do so. In addition, the heat pump may detect room occupancy automatically. In one embodiment, it does this by means of motion detectors placed in the controlled rooms. In an alternate embodiment, remote sensing devices tethered to a user-held device such as a smartphone to determine the user’s location. By determining the user’s location, the Room-to-Room Heat Pump may direct heat where it is needed in response to a user’s movements.

[0104] FIG. 17 shows the logic for the systems operation during the winter months. This logic diagram does not go to the level of specificity involving a few degree hysteresis, but someone sufficiently skilled of the art could easily apply hysteresis concepts to avoid heat pump cycling. Element **213** denotes the initiation of the system along with the boot up of all sensors. Once the system is initialized **213**, the thermostat for the space in question compares the actual temperature of the space with that of the setting on the thermostat **214**. If the thermostat determines that the actual temperature is significantly (a couple degree hysteresis is used to avoid cycling) below the temperature setting on the thermostat it moves on to element **215**. If the thermostat determines that the actual temperature is not significantly (a couple degree hysteresis is used to avoid cycling) below the temperature setting on the thermostat it moves on to element **214a**. **214a** causes the thermostat to check to see if the space is significantly above the temperature setting on the thermostat. If the temperature is not significantly above the setting, element **216** is called and no actions are taken, leading the system back to **214**. Alternatively, if **214a** returns that the space is hotter than desired, **217** is called and a search is run to see if one of the other spaces in the home is calling for heat. If element **217** comes back negative, **216** is called. However, if element **217**

comes back affirmative, the excess heat in the space is pushed by the heat pump to the space calling for heat **219**.

[0105] Returning to element **215**, when **215** is called, a check is made to see if any other zones have passed element **214a**. If this is the case, element **219** is once again called. In this instance however, the space in question is the space being heated, not the space supplying the heat. In the event no other zones have passed **214a**, element **218** is called, supplying heat to the zone in question using a traditional boiler system. Both element **218** and element **219** proceed directly to element **220** upon being called. Element **220** causes the thermostat to run an additional check to see if the space being heated still requires additional heat to reach the desired temperature. As long as it does, element **215** is once again called. When it does not, heating processes are stopped **221**, and the process begins again at **214**.

[0106] FIG. 18 describes a similar system to FIG. 17 but includes the added component of the heat sink discussed in the Method of Installation Section. This logic diagram does not go to the level of specificity involving a few degree hysteresis, but someone sufficiently skilled of the art could easily apply hysteresis concepts to avoid the known issue of heat pump cycling. Element **222** denotes the initiation of the system along with the boot up of all sensors. Once the system is initialized **222**, the thermostat for the space in question compares the actual temperature of the space with that of the setting on the thermostat **223**. If the thermostat determines that the actual temperature is significantly (a couple degree hysteresis is used to avoid cycling) below the temperature setting on the thermostat it moves on to element **226**. If the thermostat determines that the actual temperature is not significantly (a couple degree hysteresis is used to avoid cycling) below the temperature setting on the thermostat it moves on to element **224**. Element **224** causes the thermostat to check to see if the space is significantly above the temperature setting on the thermostat. If it is not above the set value, **225** is called and all heating processes are stopped, and **223** is called again. If element **224** yields positive results, **227** is called, looking to see if another space is calling for heat. If element **227** finds that no other spaces are calling for heating, **229** is called (otherwise **230** is called). **229** checks to see if the heat sink component is able to store the excess heat present in the space. The heat sink is considered able to store the excess heat if it is currently below a maximum temperature determined to be most efficient for heat storage. If it can store the excess heat, element **233** is called and the heat is pumped to the sink and then the system returns to **224** to see if another room needs heat. If the heat sink cannot store the excess heat, element **225** is once again called. Returning to element **226**, a request is made by the thermostat to see if any other spaces have excess heat. If another room does have excess heat **230** is called. When element **230** is called heat is pumped directly from the unused room to the room that requires heating. If element **226** comes back negative, an additional check is run to see if there is heat that can be used currently residing in the heat sink **228**. The heat sink will be considered to have heat if it is above a minimum temperature determined to be the most efficient for heat storage. If the heat sink has heat that can be used by the space, element **231** is called, pumping the heat from the heat sink into the room. If the heat sink does not have excess heat, element **232** is called, which sends a request to the boiler to heat the room in question. When elements **230**, **231**, and **232** are called, the system begins to check the thermostat to see if the space requires additional heating **234**. If the space does

require additional heating, the program returns to **226** and rechecks to see which heat source to use to continue heating. On the other hand, when the space no longer needs additional heating, a stop command is issued **235** and the program returns to **223**.

Thermal Storage

[0107] An alternate conception of the Room-to-Room Heat Pump includes the ability to store heat. This can maximize energy savings in situations where, for instance, only a small amount of heat is required in the sleeping area. Rather than allowing the unoccupied areas to lose thermal energy to the ambient atmosphere, the device stores thermal energy in a storage tank. Thermal energy from indoor air is stored in a thermal tank by means of a heat exchanger wrapped around for instance a water-filled tank. If the tank or refrigerant loop is well insulated, it can store large amounts of heat with a minimal loss rate.

[0108] The device separates the task of removing heat from the unoccupied room from adding heat to the occupied room. If heat is continually removed from a large room and added to a smaller room, it may cause the room to become uncomfortably hot, thus triggering heat pump shut down. However, this allows the unoccupied room temperature to decline more slowly, which cuts into energy savings. Decoupling the cooling of the unoccupied rooms from the warming of the occupied room or vice versa eliminates the previously described problem. The same method may be used in cooling season mode, with a thermal storage tank being cooled rather than warmed.

[0109] FIG. **14** denotes a system of two tanks and a heat exchanger used as a heat sink to aid the heat pump. The system relies on a hot tank **170** and a cold tank **169**. Both of the two tanks would be as thermally isolated from the surroundings as is feasible. The advantage of the two separated tanks is the ability to manipulate the temperature delta in the heat exchanger and the heat pump in order to optimize the required resources for the various heating processes the tanks take part in. The size of the two tanks varies with the requirements of the home they are installed in, some calculations related to this can be found in the "water heat sink size calculations". In addition to the tanks, a heat exchanger **172** operates to exchange heat from the tank system to the heat pump coolant filled tubes, (or in a separate iteration, directly with the air). In a heating operation the two way pump **171** would suck water from the cold tank **170**, run it through the heat exchanger **172** and into the hot tank **169**. In this operation, most commonly occurring during winter months, the system would be acting as an condenser. Conversely, in a cooling process, water would be pulled in the opposing direction by the two way pump **171**, in this situation it would be operating as a evaporator. Worth noting is that the heat exchanger **172** utilizes high surface area and conductive materials to aid in the efficient transfer of the heat. When running through the system, steps must be taken to avoid freezing in the water tanks. There are multiple options to avoid freezing, one of which is adding salt to the water, another is adding antifreeze to the water. Additionally, the pump will help to avoid freezing because the water is moving.

[0110] The hot tank **170** will lose heat over time if not replenished. In this situation, eventually the water in the hot tank **170** will become cold. Once the temperature in the hot

tank **170** falls below a set point, all of the water in the hot tank is pumped back to the cold tank **169**. In the cooling season this is reversed.

[0111] FIG. **15** shows a concrete heat sink used to store excess heat pulled from unused rooms in the home. Note that concrete is just an example; any combination of solid materials with high heat capacity would be suitable. The system relies on concrete structures **175** embedded in a pipe **174** that acts as a heat exchanger. Because of the nature of the heat sink, one side of the concrete will be warmer than the other, in a heating process air will be drawn from the cold end of the concrete towards the hot end, and then in a cooling process the opposite will occur. Specific attention should be paid to the concrete in this iteration, steps must be taken to avoid cracking, or damage due to the thermal expansion of the concrete. The main advantage of the concrete iteration of the thermal storage tank is the potential for it to take up less volume in the home, it also has a major disadvantage of being difficult to disassemble in the event of maintenance issues.

[0112] One of the advantages of utilizing a thermal storage unit is the ability for a user to engage in off-peak heating. Currently, energy prices are not dependent on the time of day, but in certain markets the idea has been brought up before. In a situation where using electricity at night is cheaper for a homeowner than during the day, off-peak heating would significantly reduce energy costs. The process of off-peak heating would have two steps; the first of these is during off-peak hours the heat pump would work to heat the thermal storage tank to prepare for required heating during the day. Then, later during on-peak hours the hot reservoir would run through the heat exchanger, helping to heat the house when energy costs are higher.

[0113] An important factor for both the concrete and the water iteration of the heat storage unit concept is the relationship between the size of the storage unit and the required size of the heat pump. The nature of the process heat pumps utilize in order to facilitate heating or cooling results in decreased efficiency of the heat pump as the temperature delta between the inlet and the outlet of the heat pump increase. As the size of the storage unit decreases, it takes a larger temperature delta to store the same amount of heat (due to conservation of energy), this in turn requires a more powerful heat pump to be able to complete the process. In the opposite case, as the heat sink size increases, the required temperature delta to store the same amount of energy decreases, also allowing for a smaller heat pump. Striking the balance between heat sink size and heat pump size will vary with the thermal footprint of the home.

Air Curtains

[0114] In the process of maintaining two areas of a home at different temperatures, a large thermal gradient is created. Thermal gradients cause heat to move from area of high temperature to low temperature. In areas of a home where volumes of air at different temperatures interface, the previously described thermal gradient can cause a rapid transfer of heat between the two areas. To prevent this transfer of heat, an embodiment of the invention creates curtains of air at thermal loss points such as staircases. This curtain creates vortices in the air which impedes its flow, thereby arresting the transfer of heat. For example, in cooling season mode the occupied area may be the upper floor. Because the upper floor is kept at a lower temperature than the lower floor, the air from the upper floor will tend to flow down the staircase. The air

curtain pushes back the air, preventing it from flowing freely. In this case, heat is still exchanged at the warm-to-cold interface, but at a much slower rate than if the air could flow unimpeded.

[0115] In one embodiment, the curtains are created by positioning the air vents of the invention in such a way that the normal operation of the device creates vortices in the air which prevent the free air flow between occupied and unoccupied areas.

[0116] In another embodiment, fans placed in the floor at the designated thermal interface points create the previously mentioned thermal curtain effect. The fans or vents are integrated into the floor such that they do not create a tripping hazard.

Mechanical Distinctions

[0117] One embodiment of the Room to Room Heat Pump system contains four major mechanical distinctions from a traditional two zone heat pump system. These mechanical distinctions taken together describe an entirely new and distinct piece of hardware. A traditional two zone heat pump uses a simple fan to direct airflow in the home, allowing only one direction of airflow. Additionally, a normal heat pump contains only one large refrigerant coil, which is sufficient to fulfill simplistic heating or cooling processes. A traditional two zone heat pump system also contains simplistic ducting, with only one inlet and outlet to the heat pump to draw air from/too. Lastly, simplistic valving is present in a traditional heat pump system, with no need for reversible refrigerant flow there is no need for advanced valving.

[0118] This embodiment of the Room to Room Heat Pump differs from the traditional heat pump system regarding fan use. This room to room heat pump may use two axial flow fans, in contrast with the simple one directional single fan design of a traditional heat pump. The simple one fan design uses a fan positioned at the outlet of the heat pump to direct flow throughout the house. An axial flow fan can be operated in both the forward or backwards direction effectively, allowing for it to be effectively reversible. The use of multiple fans with reversible flow may be useful in the implementation of the room to room heat pump in this embodiment due to its need for reversible airflow in multiple zones. Note that each fan would correspond to a different and independent zone, so as not to interfere with one another.

[0119] The use of a single, long refrigerant coil is one of the defining features of a normal heat pump. This embodiment of the Room to Room Heat Pump uses two smaller refrigerant coils, instead of the traditional one coil system. The two separate refrigerant coils allow for multiple independent thermal processes to be occurring at one time. Having multiple independent thermal processes occurring at one time allows for the simultaneous cooling of one space while also heating another.

[0120] In a multi-zone system for home heating/cooling, one single inlet and outlet duct is used to connect to the heat pump. The two ducts separate, and allow for one zone to be

subjected to a thermal process while another is left be, or allows for both zones to be subjected to the same thermal process at once. In this embodiment of the heat pump system, two completely separated duct systems may be used. Two separate inlets and two separate outlets are used for maintaining the distinction between the two zones. This is to allow independent airflow for multiple concurrent operations of the heat pump.

[0121] Normal heat pumps use simplistic valving in order to control refrigerant flow in the compressor for thermal processes. Because of the complexity of the new system, more complex valving is used in this embodiment in order to fit the needs of the system. This valving of increased complexity is used because the new system uses a reversible refrigerant flow from the compressor. Reversible refrigerant flow allows for the completion of multiple independent operations.

[0122] One additional mechanical component to the room to room heat pump is a housing for the heat pump and compressor that can be thermally isolated from the house or the outside when it is useful. In the winter months, thermal isolation from the house would not be useful, but thermal isolation from the outdoors would be. In the summer months, conversely, the system would be thermally isolated from the home and thermally linked with the outdoors. Note that in the summer months indoor air will be recirculated by the heat pump for cooling processes, and heat generated by the heat pump would be pumped out of the house

Calculations

[0123] There are several technical issues which were addressed to validate the feasibility of this invention. The first technical issue is whether there is enough heat available within the house to maintain the temperature of the occupied area. Air itself has a low thermal capacity, meaning it doesn't store much heat energy. However, a number of other household materials contain significant amounts of heat. The following section evaluates the heat available for transfer in a representative house.

[0124] The second task is to evaluate the savings when the home heating pump is installed. This value is likely to vary substantially based on a number of factors, such as home size and fluctuating energy costs, so a representative home is used. The economics of specific homes will be evaluated by the installer.

Thermal Capacitance Calculations

Summary of Findings

[0125] There is sufficient heat available for the heat pump to deliver 6270 Btu/hr. With a typical heat pump COP (Coefficient of Performance) of 3, this draws 613 W. It removes 4180 Btu/hr from the source room in the same time period. This is substantial enough to heat the sleeping area and lower the living area temperature to 40° F.

[0126] Task: Estimate the thermal storage in a living room, accounting for walls, floor, ceiling, and furnishings.

Assumptions

1. Weight of furnishings= 200 lb_m wood
2. $c_{p,wood} = 0.48 \text{ Btu/lb}_m \cdot \text{F}$.
3. Room Size $20' W \times 20' L \times 9' H$
4. Drywall, 68 lb_m for $4' \times 8' \times 1/2''$
5. $\textcircled{2} = 0.26 \text{ Btu/lb}_m \cdot \text{F}$.
6. $\rho_{wood} = 45 \frac{\text{lb}_m}{\text{ft}^3}$
7. Neglect exterior wall
8. Initial T of interior, walls, floor, ceiling, floor = 70° F .
9. Final T of above = 40° F .
10. Floor is $1''$ thick, under floor + hardwood

Solution Steps

1. Calculate interior wall area, ft²
2. Calculate floor and ceiling area, ft²
3. Calculate weight of 3 interior walls, lb_m
4. Calculate weight of ceiling, lb_m
5. Calculate weight of floor, lb_m
6. Calculate energy released by walls, floor, ceilings, and furnishings to the room between 70° F and 40° F .

Solution

Step 1: Calculate interior wall area

$$A(\text{ft}^2)_{\text{wall}} = (20 \text{ ft} \cdot 9 \text{ ft}) \cdot 3 = 540 \text{ ft}^2$$

Step 2: Calculate wall and ceiling areas

$$A(\text{ft}^2)_{\text{floor}} = A(\text{ft}^2)_{\text{ceiling}} = 20 \text{ ft} \cdot 20 \text{ ft} = 400 \text{ ft}^2$$

Step 3: Calculate the mass of the 3 walls

Mass = Area * Density [Drywall density is available in lb/ft²]

$$M_{\text{walls}} = A_{\text{wall}} \cdot \rho_{\text{dry wall}}$$

$$M_{\text{walls}} = 540 \text{ ft}^2 \cdot \frac{68 \text{ lb}_m}{32 \text{ ft}^2} = 1148 \text{ lb}_m$$

Step 4: Calculate the mass of the ceiling

$$M_{\text{ceiling}} = 400(\text{ft}^2) \cdot \frac{68 \text{ lb}_m}{32 \text{ ft}^2} = 850 \text{ lb}_m$$

Step 5: Calculate the mass of the floor

$$M_{\text{floor}} = A_{\text{floor}} \cdot \frac{1}{2} \text{ in. thickness} \cdot A_{\text{floor}}$$

$$M_{\text{floor}} = 400 \text{ ft}^2 \cdot \left[\frac{1}{2} \text{ in} \cdot \frac{1 \text{ ft}}{12 \text{ in}} \right] \cdot \frac{45 \text{ lb}_m}{\text{ft}^3} = 750 \text{ lb}_m$$

Step 6: Calculate the energy released by walls, floor, and

furnishings between 70° F .(init. T) and 40° F .(final T)

Heat Transfer:

$$Q(\text{Btu}) = \sum (M \cdot c_p) \cdot \Delta T = \Delta(E_{\text{floor}} + E_{\text{ceiling}} + E_{\text{walls}} + E_{\text{furn.}})$$

$$\cdot \text{Floor: } 750 \text{ lb}_m \cdot 0.48 \frac{\text{Btu}}{\text{lb}_m \cdot \text{F}} \cdot (70 - 40) = 10800 \text{ Btu}$$

$$\circ Q_{\text{fl}} = 10800 \text{ Btu}$$

$$\cdot \text{Ceiling: } 850 \text{ lb}_m \cdot 0.26 \frac{\text{Btu}}{\text{lb}_m \cdot \text{F}} \cdot (70 - 40) = 6630 \text{ Btu}$$

$$\circ Q_{\text{cl}} = 6630 \text{ Btu}$$

$$\cdot \text{Walls: } 1148 \text{ lb}_m \cdot 0.26 \frac{\text{Btu}}{\text{lb}_m \cdot \text{F}} \cdot (70 - 40) = 8950 \text{ Btu}$$

$$\circ Q_{\text{wall}} = 8950 \text{ Btu}$$

-continued

$$\cdot \text{Furniture: } 200 \text{ lb}_m \cdot 0.48 \frac{\text{Btu}}{\text{lb}_m \cdot \text{F}} \cdot (70 - 40) = 2880 \text{ Btu}$$

$$\circ Q_{\text{fur}} = 2880 \text{ Btu}$$

$$Q_{\text{tot}} = Q_{\text{fl}} + Q_{\text{cl}} + Q_{\text{wall}} + Q_{\text{fur}} = 10800 + 6630 + 8950 + 2880$$

$$Q_{\text{tot}} = 29260 \text{ Btu}$$

Time elapsed – 11:00 PM to 6:00 AM = 7 hours

$$q\left(\frac{\text{Btu}}{\text{hr}}\right) = \frac{29260 \text{ Btu}}{1 \text{ hr}} = 4180 \frac{\text{Btu}}{\text{hr}}$$

Heat to Occupied Room

Estimate the energy delivered to the bedroom

if 29260 Btu are extracted from the room below.

$\textcircled{2}$ indicates text missing or illegible when filed

Required Water Heat Storage Unit Size Calculation

[0127] Heat energy extracted from a room=Q=29260 [BTU]

[0128] Constant pressure specific heat capacity of water= $C_{p,w}=1.000 \text{ [BTU/lb}_m\text{F]}$

[0129] Temperature delta= $\Delta T=50 \text{ [F]}$

[0130] Mass of water= $m_w \text{ [lb}_m\text{]}$

$$Q[\text{BTU}] = m_w[\text{lb}_m] \cdot C_{p,w} \left[\frac{\text{BTU}}{\text{lb}_m \text{F}} \right] \cdot \Delta T[\text{F}]$$

$$29260 = m_w \cdot 1.000 \cdot 50$$

[0131] $m_w=585 \text{ lb}_m$

[0132] Density of water= $\rho_w=8.338 \text{ [lb}_m\text{/gal]}$

[0133] Volume of water= $V_w \text{ [gal]}$

$$\rho_w[\text{lb}_m\text{/gal}] = m_w[\text{lb}_m] / V_w[\text{gal}]$$

$$8.338 = 585 / V_w$$

[0134] $V_w=70.2$ gallons of water

Required Concrete Heat Storage Unit Size Calculation

[0135] Heat energy extracted from a room=Q=29260 [BTU]

[0136] Constant pressure specific heat capacity of concrete= $C_{p,c}=0.210 \text{ [BTU/lb}_m\text{F]}$

[0137] Temperature delta= $\Delta T=50 \text{ [F]}$

[0138] Mass of concrete= $m_c \text{ [lb}_m\text{]}$

$$Q[\text{BTU}] = m_c[\text{lb}_m] \cdot C_{p,c} \left[\frac{\text{BTU}}{\text{lb}_m \text{F}} \right] \cdot \Delta T[\text{F}]$$

$$29260 = m_c \cdot 0.210 \cdot 50$$

[0139] $M_c=2790 \text{ lb}_m$

[0140] Density of concrete= $\rho_c=150 \text{ [lb}_m\text{/ft}^3\text{]}$

[0141] Volume of concrete= $V_c \text{ [ft}^3\text{]}$

$$\rho_c[\text{lb}_m\text{/ft}^3] = m_c[\text{lb}_m] / V_c[\text{ft}^3]$$

$$150 = 2790 / V_c$$

[0142] $V_c=19 \text{ ft}^3$ of concrete

1. An apparatus for moving heat from a first room of a building to a second room within said building for a first

period of time and at a second period of time moving heat from said second room to said first room, said apparatus comprising:

- A cooling air intake vent located inside of said first room,
 - An evaporator fan for drawing cooling air from said cooling air intake vent across an evaporator and expelling said cooling air back into said first room,
 - A compressor for circulating coolant through said evaporator to a condenser through coolant tubing,
 - A condenser fan drawing warming air from the second room across the condenser and expelling said warming air back into the second room, wherein heat is transferred from said first room to said second room during the first period of time, and
 - A valve coupled to said coolant tubing that allows the coolant to reverse direction, thus transferring heat from said second room to said first room at the second period of time.
2. The apparatus of claim 1 wherein the first room is an unoccupied room during the first period of time.
 3. The apparatus of claim 1 wherein the second room is an occupied room during the first period of time.
 4. The apparatus of claim 1 further comprising a second evaporator in a third room connected via the coolant tubing, wherein the tubing incorporates values for directing said coolant to either the evaporator or the second evaporator.
 5. The apparatus of claim 1 further comprising a second condenser in a third room connected via the coolant tubing,

wherein the tubing incorporates values for directing said coolant to either the condenser or the second condenser.

6. The method of claim 1 further comprising directing said coolant through valves to a heat exchanger at a thermal storage unit connected via the coolant tubing.
7. A method for moving heat from a first room of a building to a second room within said building for a first period of time and at a second period of time moving heat from said second room to said first room, said method comprising:
 - Drawing cooling air in from a cooling air intake vent located inside of said first room,
 - Moving the cooling air with an evaporator fan from the cooling air intake vent across an evaporator,
 - Expelling the cooling air back into said first room,
 - Circulating coolant with a compressor through coolant tubing from said evaporator to a condenser,
 - Drawing warming air with a condenser fan from the second room across the condenser,
 - Expelling said warming air back into the second room,
 - Wherein heat is transferred from said first room to said second room during the first period of time, and
 - Transferring heat from said second room to said first room at the second period of time, the transfer utilizing a valve coupled to said coolant tubing that allows the coolant to reverse direction.
8. The method of claim 7 wherein the first room is an unoccupied room during the first period of time.

* * * * *