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(19) **United States**(12) **Patent Application Publication****Narayanamurthy et al.**(10) **Pub. No.: US 2008/0034760 A1**(43) **Pub. Date: Feb. 14, 2008**(54) **THERMAL ENERGY STORAGE AND COOLING SYSTEM WITH ISOLATED EXTERNAL MELT COOLING**(22) Filed: **Aug. 10, 2007****Related U.S. Application Data**

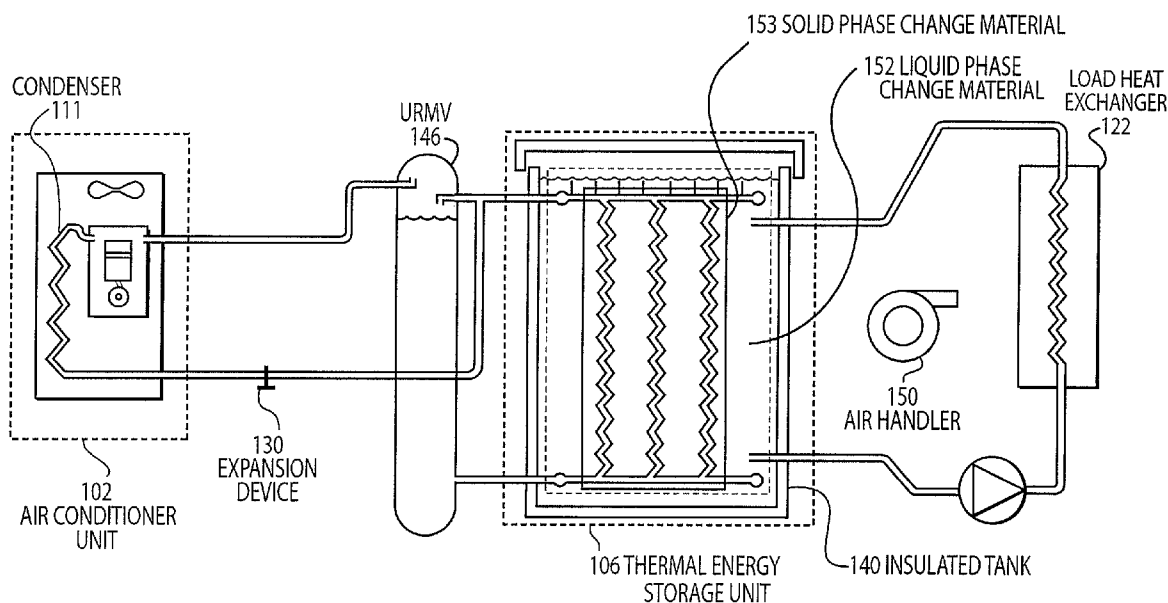
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F25D 17/02 (2006.01)(52) **U.S. Cl.** **62/59; 62/434**(57) **ABSTRACT**

Disclosed are a method and device for a refrigerant-based thermal energy storage and cooling system with isolated external melt cooling. The disclosed embodiments provide a refrigerant-based ice storage system with increased reliability, lower cost components, and reduced power consumption compared to a single phase system such as a glycol system.

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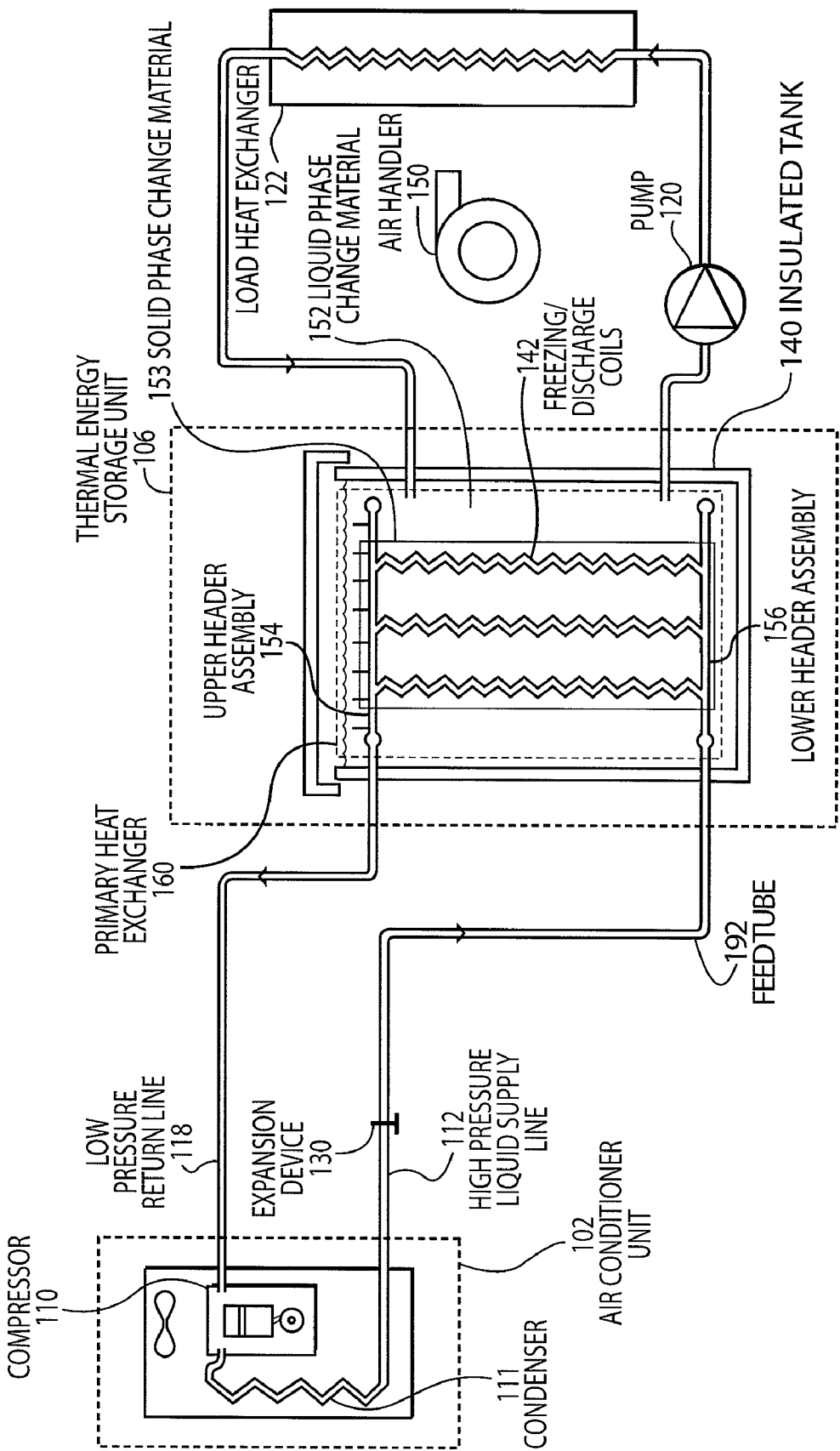


FIGURE 1

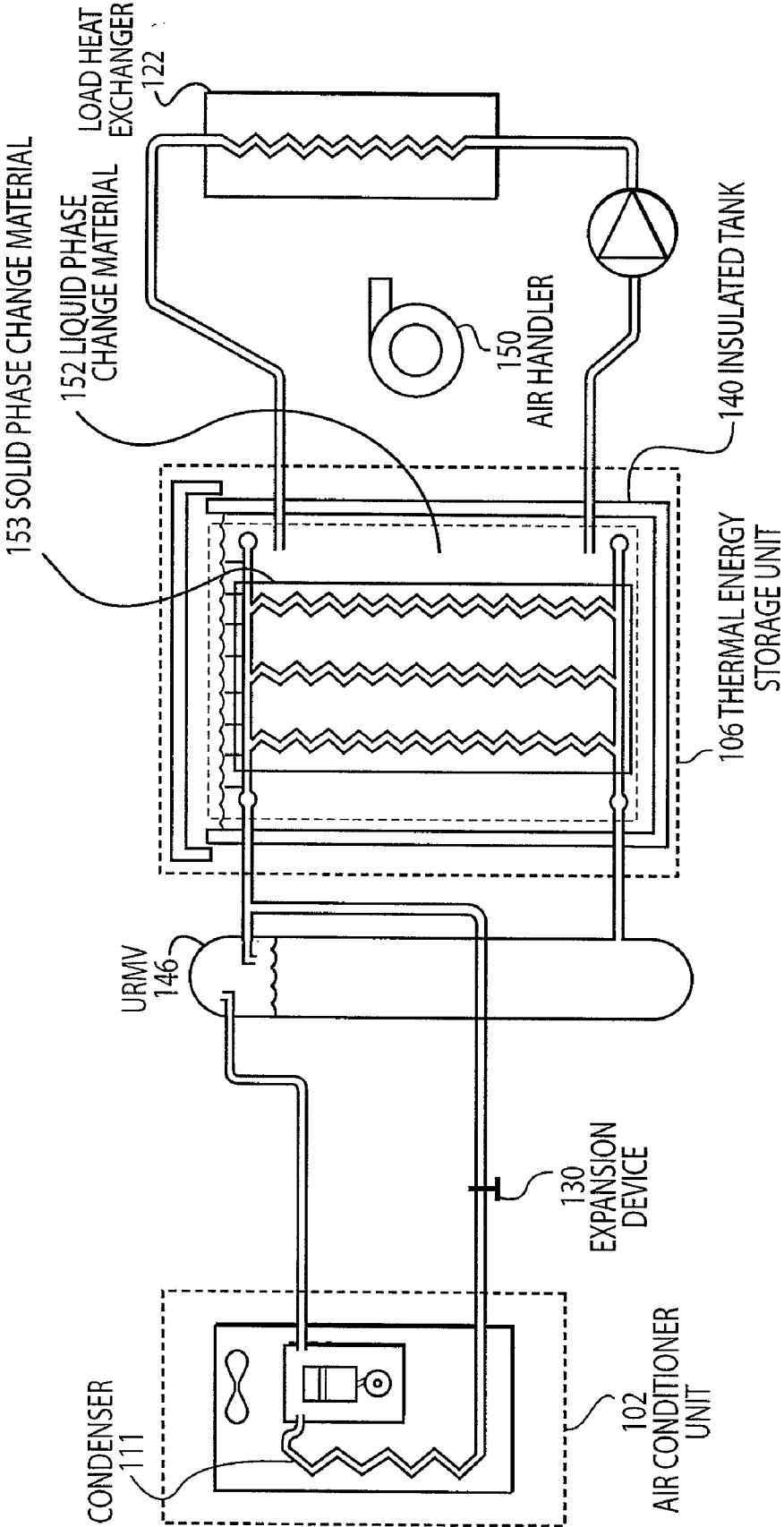


FIGURE 2

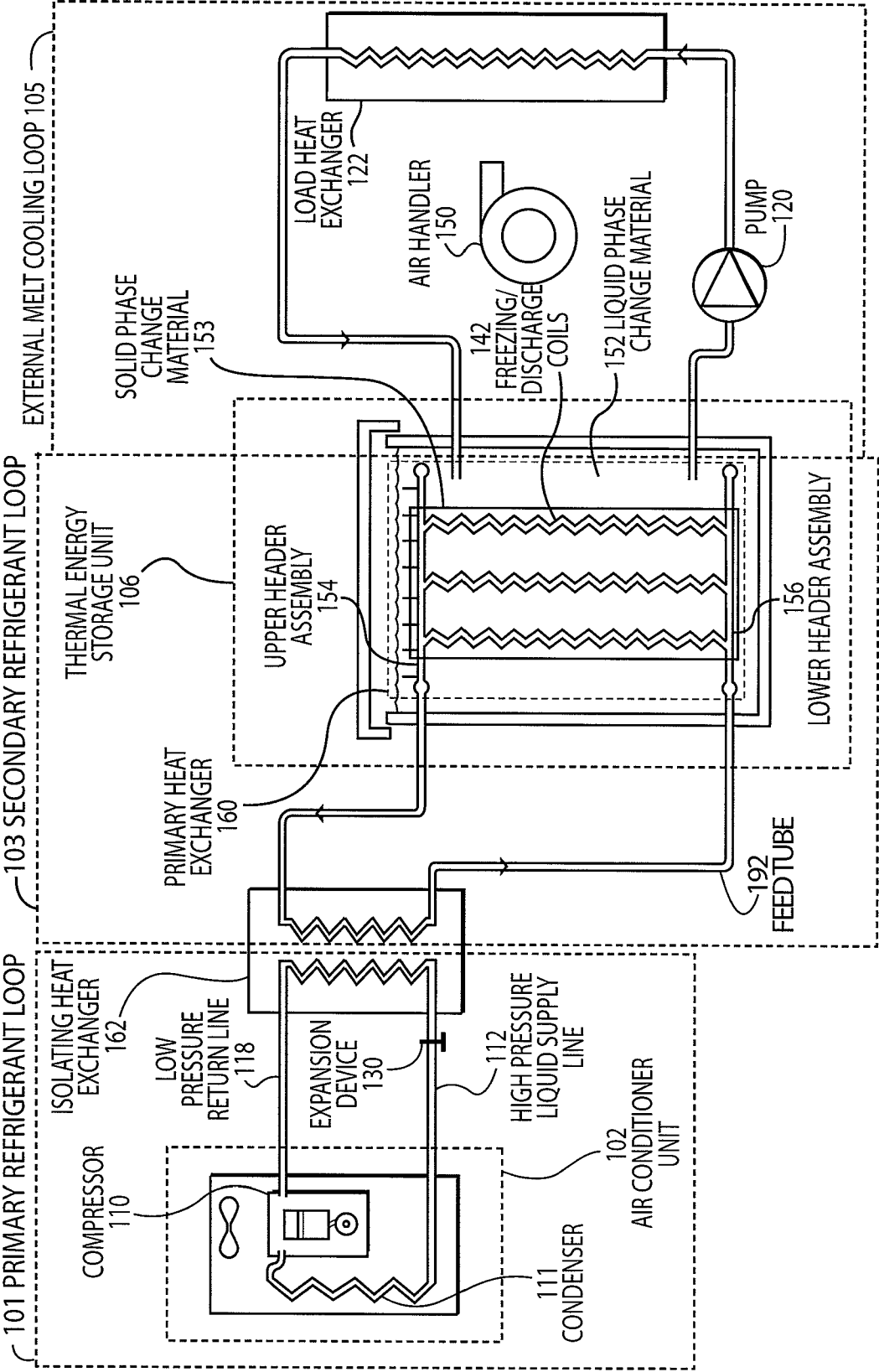


FIGURE 3

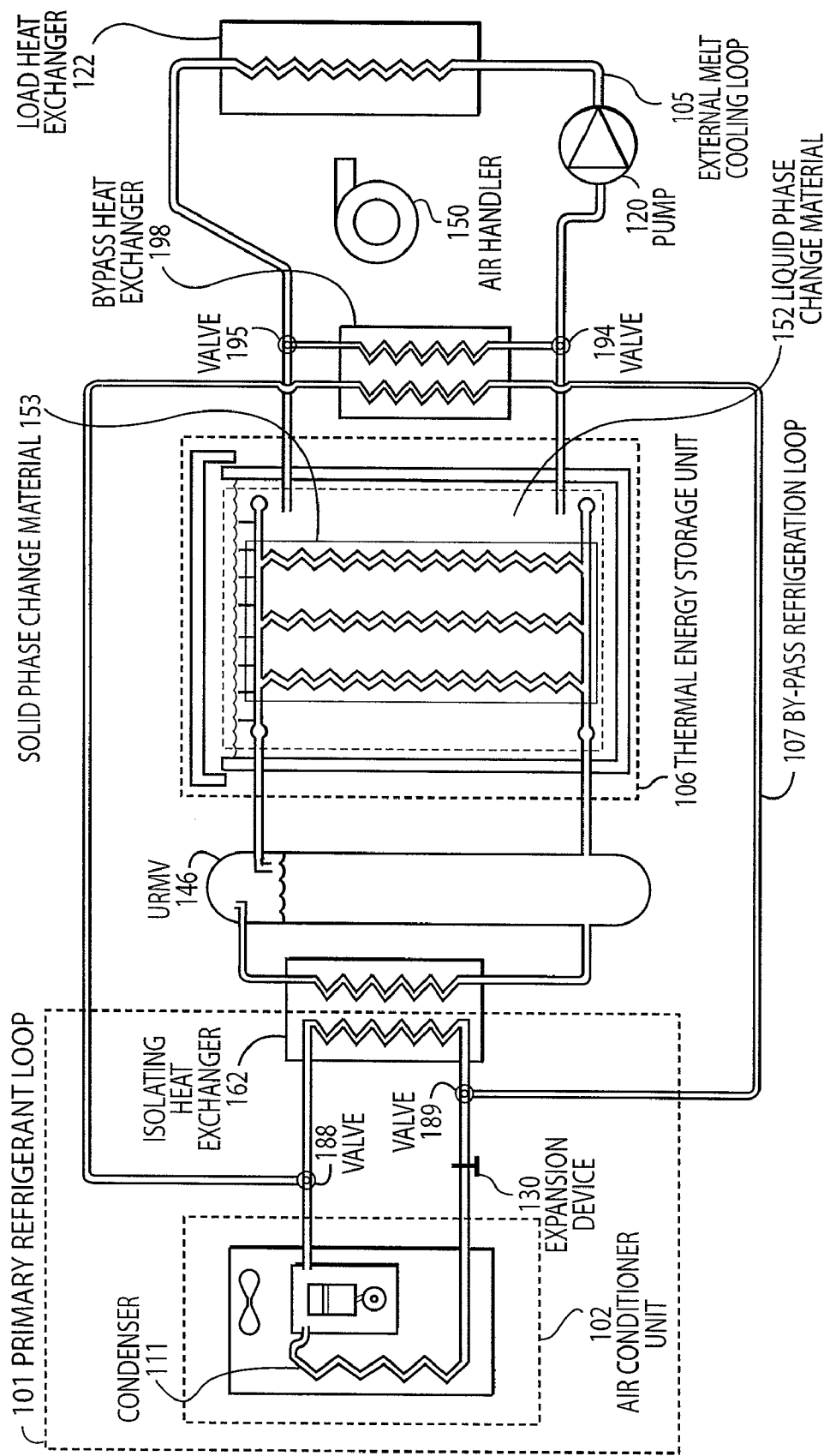


FIGURE 4

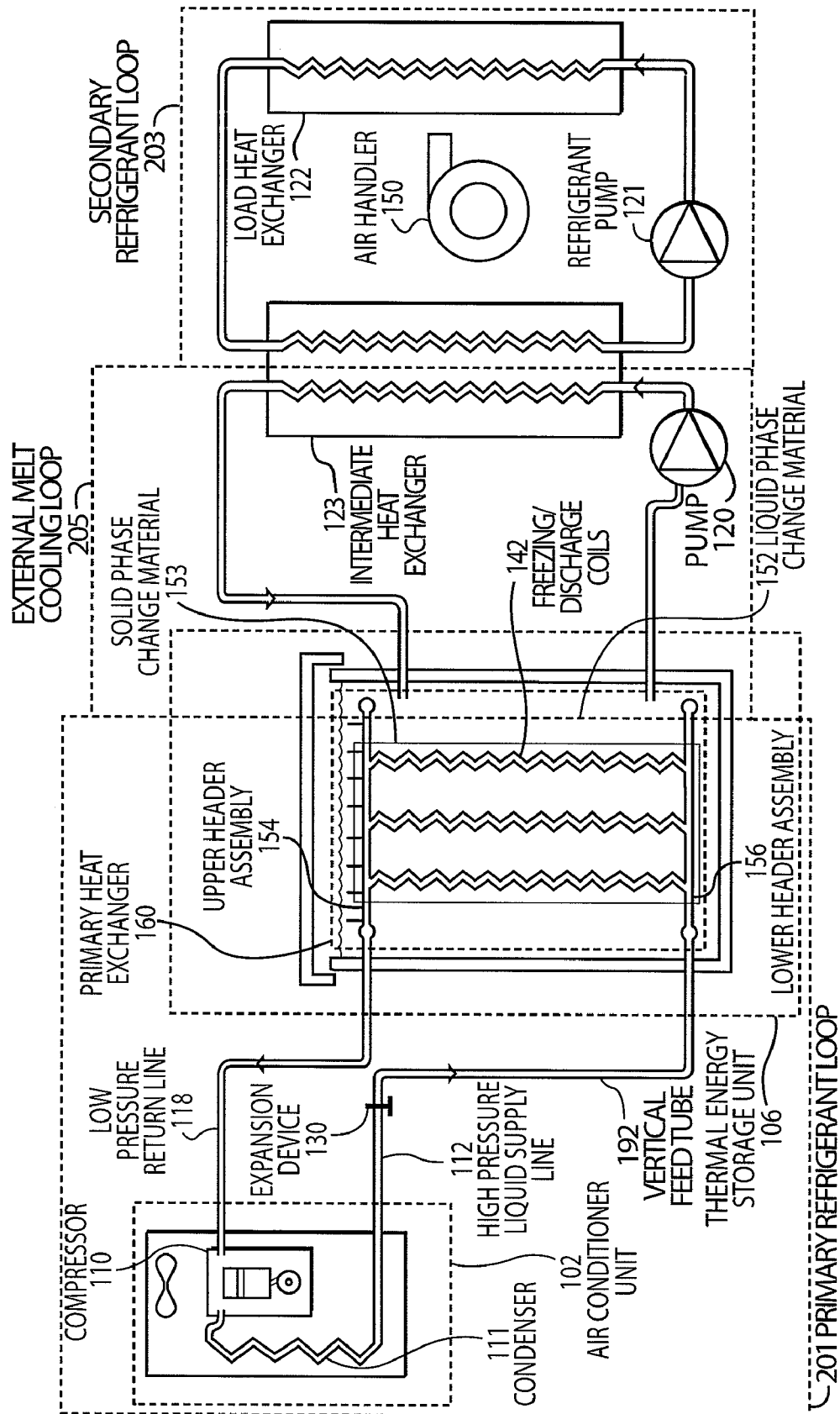


FIGURE 5

THERMAL ENERGY STORAGE AND COOLING SYSTEM WITH ISOLATED EXTERNAL MELT COOLING

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is based upon and claims the benefit of U.S. provisional application No. 60/822,034, entitled "Thermal Energy Storage and Cooling System with Isolated External Melt Cooling", filed Aug. 10, 2006, the entire disclosure of which is hereby specifically incorporated by reference for all that it discloses and teaches.

BACKGROUND OF THE INVENTION

[0002] With the increasing demands on peak demand power consumption, ice storage has been utilized to shift air conditioning power loads to off-peak times and rates. A need exists not only for load shifting from peak to off-peak periods, but also for increases in air conditioning unit capacity and efficiency. Current air conditioning units having energy storage systems have had limited success due to several deficiencies including reliance on water chillers that are practical only in large commercial buildings and have difficulty achieving high-efficiency. In order to commercialize advantages of thermal energy storage in large and small commercial buildings, thermal energy storage systems must have minimal manufacturing costs, maintain maximum efficiency under varying operating conditions, emanate simplicity in the refrigerant management design, and maintain flexibility in multiple refrigeration or air conditioning applications.

[0003] Systems for providing thermal stored energy have been previously contemplated in U.S. Pat. No. 4,735,064, U.S. Pat. No. 5,225,526, both issued to Harry Fischer, U.S. Pat. No. 5,647,225 issued to Fischer et al., U.S. Pat. No. 7,162,878 issued Jan. 16, 2007 by Narayanamurthy et al., U.S. patent application Ser. No. 11/112,861 filed Apr. 22, 2005 by Narayanamurthy et al., U.S. patent application Ser. No. 11/138,762 filed May 25, 2005 by Narayanamurthy et al., U.S. patent application Ser. No. 11/208,074 filed Aug. 18, 2005 by Narayanamurthy et al. and U.S. patent application Ser. No. 11/284,533 filed Nov. 21, 2005 by Narayanamurthy et al. All of these patents utilize ice storage to shift air conditioning loads from peak to off-peak electric rates to provide economic justification, and are hereby specifically incorporated by reference herein for all they teach and disclose.

SUMMARY OF THE INVENTION

[0004] An embodiment of the present invention may therefore comprise a refrigerant-based thermal energy storage and cooling system comprising: a refrigerant loop containing a refrigerant comprising: a condensing unit, the condensing unit comprising a compressor and a condenser; an expansion device connected downstream of the condensing unit; and, a primary heat exchanger that acts as an evaporator and is located within a tank filled with a fluid capable of a phase change between liquid and solid, the primary heat exchanger that facilitates heat transfer from the refrigerant from the condenser to cool the fluid and to freeze at least a portion of the fluid within the tank; a cooling loop containing the fluid from the tank comprising: a load heat exchanger connected to the tank that transfers cooling

capacity of the fluid to a heat load; and, a pump that distributes the fluid from the tank to the load heat exchanger and returns the fluid to the tank.

[0005] An embodiment of the present invention may also comprise a refrigerant-based thermal energy storage and cooling system comprising: a first refrigerant loop containing a first refrigerant comprising: a condensing unit, the condensing unit comprising a compressor and a first condenser; an expansion device connected downstream of the condensing unit; and, a first evaporator on a primary side of an isolating heat exchanger located downstream of the expansion device; a second refrigerant loop containing a second refrigerant comprising: a second condenser on a secondary side of the isolating heat exchanger; a tank filled with a fluid capable of a phase change between liquid and solid and containing a primary heat exchanger therein, the primary heat exchanger in fluid communication with the second condenser and that utilizes the second refrigerant from the second condenser to cool the fluid and to freeze at least a portion of the fluid within the tank; a load heat exchanger connected in fluid communication with the fluid in the tank that transfers cooling capacity of the fluid to a heat load; and, a pump for distributing the fluid from the tank to the to the load heat exchanger.

[0006] An embodiment of the present invention may also comprise a method of providing cooling with a refrigerant-based thermal energy storage and cooling system comprising the steps of: providing cooling to a primary heat exchanger by evaporating a high-pressure refrigerant in the primary heat exchanger that is constrained within a tank containing a fluid capable of a phase change between liquid and solid; freezing a portion of the fluid and form ice within the tank; delivering a liquid portion of the fluid to a load heat exchanger; transferring cooling from the liquid portion of the fluid to the load heat exchanger to provide load cooling; returning the liquid portion of the fluid to the tank; cooling the liquid portion of the fluid with the ice within the tank.

[0007] An embodiment of the present invention may also comprise a method of providing cooling with a refrigerant-based thermal energy storage and cooling system comprising the steps of: providing cooling to a primary heat exchanger by evaporating a high-pressure refrigerant in the primary heat exchanger that is constrained within a tank containing a fluid capable of a phase change between liquid and solid; freezing a portion of the fluid and form ice within the tank; delivering a liquid portion of the fluid to a primary side of an intermediate heat exchanger; transferring cooling from the primary side of the intermediate heat exchanger to a second refrigerant loop containing a second refrigerant through a secondary side of the intermediate heat exchanger; returning the liquid portion of the fluid to the tank; cooling the liquid portion of the fluid with the ice within the tank; delivering the second refrigerant to a load heat exchanger; transferring cooling from the second refrigerant to a load heat exchanger to provide load cooling; returning the second refrigerant to the secondary side of the intermediate heat exchanger; cooling the second refrigerant with the primary side of the intermediate heat exchanger.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] In the drawings,

[0009] FIG. 1 illustrates an embodiment of a refrigerant-based thermal energy storage and cooling system with isolated external melt cooling.

[0010] FIG. 2 illustrates an embodiment of a refrigerant-based thermal energy storage and cooling system with isolated external melt cooling that utilizes a universal refrigerant management vessel.

[0011] FIG. 3 illustrates a configuration of an embodiment of a refrigerant-based thermal energy storage and cooling system with secondary refrigerant isolation and isolated external melt cooling.

[0012] FIG. 4 illustrates a configuration of an embodiment of a refrigerant-based thermal energy storage and cooling system with secondary refrigerant isolation and direct cooling (bypass) capability.

[0013] FIG. 5 illustrates a configuration of an embodiment of a refrigerant-based thermal energy storage and cooling system with secondary refrigerant isolation and a secondary refrigerant loop.

DETAILED DESCRIPTION OF THE INVENTION

[0014] While this invention is susceptible to embodiment in many different forms, there is shown in the drawings and will be described herein in detail specific embodiments thereof with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and is not to be limited to the specific embodiments described.

[0015] FIG. 1 illustrates an embodiment of a refrigerant-based thermal energy storage and cooling system with isolated external melt cooling. This embodiment may function with or without an accumulator vessel or URMV (universal refrigerant management vessel), and is depicted in FIG. 1 without the vessel. FIG. 2 depicts the system with a URMV. This embodiment incorporates an air conditioner unit 102 utilizing a compressor 110 to compress cold, low pressure refrigerant gas to hot, high-pressure gas. Next, a condenser 111 removes much of the heat in the gas and discharges the heat to the atmosphere. The refrigerant comes out of the condenser as a warm, high-pressure liquid refrigerant delivered through a high-pressure liquid supply line 112 to an expansion device 130 and to a thermal energy storage unit 106 via feed tube 192. This expansion device 130 may be a conventional or non-conventional thermal expansion valve, a mixed-phase regulator and surge vessel (reservoir) or the like. Cooling is transferred to the thermal energy storage unit 106 by the primary heat exchanger 160 as expanding refrigerant is fed from a lower header assembly 156 through the freezing/discharge coils 142, to the upper header assembly 154. Low-pressure vapor phase and liquid refrigerant is then returned to compressor 110 via low pressure return line 118 completing the refrigeration loop.

[0016] The thermal energy storage unit 106 comprises an insulated tank 140 that houses the primary heat exchanger 160 surrounded by a thermal reservoir such as a phase change material (typically fluid/ice depending on the current system mode). The primary heat exchanger 160 further comprises a lower header assembly 156 connected to an upper header assembly 154 with a series of freezing and discharge coils 142 to make a fluid/vapor loop within the insulated tank 140. The upper and lower header assemblies 154 and 156 communicate externally of the thermal energy storage unit 106 with inlet and outlet connections.

[0017] The embodiment illustrated in FIG. 1 utilizes at least one conventional air conditioner unit 102 as the principal cooling source. Multiple air conditioner units may be

utilized without departing from the spirit of the invention. The thermal energy storage unit 106 operates using an independent refrigerant loop that transfers the cooling between the air conditioner unit 102 and the thermal energy storage unit 106. The disclosed embodiment functions in two principal modes of operation, charging (ice-make) and cooling (ice-melt) mode.

[0018] In charging mode, compressed high-pressure refrigerant leaves the air conditioner unit 102 through high-pressure liquid supply line 112 and is fed through an expansion device 130 to cool the thermal energy storage unit 106 where it enters the primary heat exchanger 160 through the lower header assembly 156 and is then distributed through the freezing coils 142 which act as an evaporator. Cooling is transmitted from the freezing coils 142 to the surrounding liquid phase change material 152 that is confined within the insulated tank 140 and freezes at least a portion of the phase change material 153 (ice) surrounding the freezing coils 142 and storing thermal energy in the process. Warm liquid and vapor phase refrigerant leaves the freezing coils 142 through the upper header assembly 154 and exits the thermal energy storage unit 106 returning to the air conditioner unit 102 through the low pressure return line 118 and is fed to the compressor 110 and re-condensed into liquid.

[0019] In cooling mode, cool liquid phase change material leaves the lower portion of the insulated tank 140 and is propelled by a pump 120 to a load heat exchanger 122 where cooling is transferred to a load with the aid of an air handler 150. This load heat exchanger 122 may be a single or multiple evaporators such as might be used to provide multi-zone cooling, mini-split evaporators or the like. Warm liquid leaves load heat exchanger 122 where the liquid is returned to header 154 of the thermal energy storage unit 106 and draws cooling from the solid phase change material 153 surrounding the coils.

[0020] Because the system isolates the primary refrigerant from a secondary phase change material loop, the system additionally allows the use of a variety of refrigerants to be used within the device. For example, one type of highly efficient refrigerant that may have properties that would discourage use within a dwelling (such as propane) may be utilized within the primary refrigerant loop, while a more suitable material (such as water, ammonia, slurry ice, brine, ethylene glycol, propylene glycol, various alcohols (Isobutyl, ethanol), sugar, other eutectic materials or the like) can be used for the secondary loop that may enter the dwelling. This allows greater versatility and efficiency of the system while maintaining safety, environmental and application issues to be addressed.

[0021] The embodiment illustrated in FIG. 2 shows the system of FIG. 1 further utilizing an accumulator vessel or URMV. As described in the previous embodiment, the thermal energy storage unit 106 operates using an independent refrigerant loop that transfers the cooling between the air conditioner unit 102 and the thermal energy storage unit 106. In this example, acting as a collector and phase separator of multi-phase refrigerant, the accumulator or universal refrigerant management vessel (URMV) 146 is in fluid communication with both the thermal energy storage unit 106 and the air conditioner unit 102.

[0022] The disclosed embodiment also functions in two principal modes of operation, charging (ice-make) and cooling (ice-melt) mode. Cooling mode is identical to that of

FIG. 1 and ice-make includes the additional function of the URMV. In charging mode, the URMV 146 accumulates liquid refrigerant leaving the expansion device 130 and separates vapor phase refrigerant from the liquid phase refrigerant. Condensed refrigerant leaves the lower portion of the URMV 146 through a first outlet and is expanded in the coils of the thermal energy storage unit 106 where cooling is transferred to the phase change material within the insulated tank 140. Expanded refrigerant leaves the thermal energy storage unit 106 and returns to the upper portion of the URMV where remaining liquid phase refrigerant is accumulated in the URMV and vapor phase refrigerant is returned to the air conditioner unit through a second outlet for compression, condensation and heat extraction.

[0023] FIG. 3 illustrates an embodiment of a refrigerant-based thermal energy storage and cooling system with secondary refrigerant isolation and isolated external melt cooling. As with the embodiment of FIG. 1, the disclosed system functions with or without an accumulator vessel or URMV. FIG. 3 depicts the system without the vessel and FIG. 4 depicts the system with a URMV. The present embodiment utilizes a primary refrigeration loop 101 that includes at least one air conditioner unit 102 with a compressor 110 and condenser 111 creating high-pressure liquid refrigerant that is delivered through a high-pressure liquid supply line 112 to an isolating heat exchanger 162 through an expansion device 130. Low-pressure refrigerant is returned to compressor 110 via low pressure return line 118. An additional benefit of incorporating a URMV within the system is that it allows additional application flexibility with the geometry of the refrigerant lines. This additional refrigerant reservoir facilitates longer line lengths of the refrigerant lines, and thus, greater distance tolerances for locating components.

[0024] Cooling is transferred through the isolating heat exchanger 162 to a thermal energy storage unit 106 within a secondary refrigeration loop 103. This thermal energy storage unit 106 is comparable to that depicted in FIG. 1, and acts as an evaporator during an ice-make cycle. A load heat exchanger 122 in conjunction with an air handler 150 is connected within an external melt cooling loop 105 to transmit cooling from thermal energy storage unit 106 and provide isolated cooling in one mode.

[0025] Valves may be placed in various places within the secondary refrigerant loop 103 and external melt cooling loop 105 to allow multi-mode conditions with minimal complexity and plumbing. A pump 120 is placed in the external melt cooling loop 105 to pump cold liquid phase change material from the insulated tank 140 to the load heat exchanger 122 and back to the thermal energy storage unit 106 in cooling mode. This load heat exchanger 122 may be a single or multiple evaporators such as might be used to provide multi-zone cooling, mini-split evaporators or the like.

[0026] The present embodiment may function in two principal modes of operation, ice-make and ice-melt. In ice-make or charge mode, the primary refrigerant loop 102 is used to cool the primary side of the isolating heat exchanger 162 that transfers heat to the secondary refrigerant loop 103. The secondary refrigerant loop 103 can be either pump driven by adding a refrigerant pump within the loop, typically between the isolating heat exchanger 162 and the lower header assembly 156 (not shown), or gravity feed (as shown and described). The gravity feed system of FIG.

3 is self equalizing when in charging mode with respect to the effectiveness of the freezing/discharge coils 142.

[0027] This self equalization that occurs during the ice build mode can be beneficial. Large stresses can be applied to the ice storage heat exchanger during uneven ice builds which can ultimately result in mechanical failure or rupture of the heat exchanger. Pump feed systems cannot self equalize because refrigerant is forced into each coil regardless of the amount of ice already surrounding the coil. Another advantage to a gravity feed system is the absence of a pump which requires a power source and also adds additional potential failure modes to the system.

[0028] In either gravity or pump fed systems, the secondary refrigerant loop 103 carries cooled condensed refrigerant to the thermal energy storage unit 106 where it enters the primary heat exchanger 160 through the lower header assembly 156 and is then distributed through the freezing coils 142 which act as an evaporator. Cooling is transmitted from the freezing coils 142 to the surrounding liquid phase change material 152 that is confined within the insulated tank 140 and freezes at least a portion of the phase change material 153 (ice) surrounding the freezing coils 142 and storing thermal energy in the process. Within the insulated tank 140, a portion of the phase change material remains liquid and typically will surround the solid material (although a slurry may also be used). This cold liquid phase change material 152 is drawn from the lower portion of the insulated tank 140 within the thermal energy storage unit 106 with a pump 120 and circulated through the load heat exchanger 122 and used to cool a heat load utilizing an air handler 150. Warm liquid phase change material 152 leaves the load heat exchanger 122 and is returned to the insulated tank 140 where it is cooled by melting the solid phase change material 153 (ice) surrounding the freezing coils 142.

[0029] In charging mode, the thermal energy storage unit 106 acts as an evaporator and cooling is transmitted to fluid that is confined within the thermal energy storage unit 106 thus storing thermal energy. Warm liquid and vapor phase refrigerant leaves the freezing coils 142 through the upper header assembly 154 and exits the thermal energy storage unit 106 returning to the isolating heat exchanger 162 and re-condensed into liquid.

[0030] In ice-melt or cooling mode, the primary refrigerant loop 102 can continue to cool, can be shut down, or can be disengaged. Cool liquid refrigerant is drawn from the thermal energy storage unit 106 and is pumped by a pump 120 to the load heat exchanger 122 where cooling is transferred to a load with the aid of an air handler 150. The warm mixture of liquid and vapor phase refrigerant leaves the load heat exchanger 122 where the mixture is returned to the thermal energy storage unit 106 now acting as a condenser. Vapor phase refrigerant is cooled and condensed by drawing cooling from the cold fluid or ice. As with the embodiment of FIG. 1, the principal modes of operation, ice-make, ice-melt and direct cooling can be performed with the use of a series of valves (not shown) that control the flow of refrigerant.

[0031] FIG. 4 illustrates an embodiment of a refrigerant-based thermal energy storage and cooling system with secondary refrigerant isolation and isolated external melt cooling. As described in the previous embodiment, the primary refrigerant loop transfers cooling between the air conditioner unit 102 and the isolating heat exchanger 162. The thermal energy storage unit 106 operates using the

secondary refrigerant loop **103** by receiving cooled refrigerant from the isolating heat exchanger **162** via the URMV **146** that acts as a collector and phase separator of the multi-phase refrigerant. An additional benefit of incorporating a URMV within the system is that it allows additional application flexibility with the geometry of the refrigerant lines. This additional refrigerant reservoir facilitates longer line lengths of the refrigerant lines, and thus, greater distance tolerances for locating components.

[0032] The disclosed embodiment also functions in the two modes of operation, charging and cooling with the addition of a direct cooling mode. Cooling mode is identical to that of FIG. 3 and ice-make includes the additional function of the URMV. In charging mode, the URMV **146** accumulates liquid refrigerant and separates any vapor phase refrigerant leaving the isolating heat exchanger **162**. Condensed refrigerant leaves the lower portion of the URMV **146** and is expanded in the primary heat exchanger **160**, and cooling is transferred to the phase change material within the insulated tank **140**. Expanded refrigerant leaves the thermal energy storage unit **106** and returns to the upper portion of the URMV where remaining liquid phase refrigerant is accumulated in the URMV and vapor phase refrigerant is returned to the isolating heat exchanger **162** for cooling.

[0033] In direct cooling mode the thermal energy storage unit **106** is bypassed and a by-pass refrigeration loop **107** delivers condensed refrigerant leaving the air conditioner unit **102** directly to a primary side of a bypass heat exchanger **198** and is then returned to the air conditioner unit **102**. The secondary side of the bypass heat exchanger **198** is in communication with the load heat exchanger **122** with the external melt cooling loop **105**. Valves **194** and **196** can be used isolate this loop from the thermal energy storage unit **106**, while additional valves **188** and **189** can be used to remove the isolating heat exchanger **162** from the primary refrigerant loop **101** and facilitate the by-pass refrigeration loop **107**. As with previous embodiments, a pump **120** is placed in the external melt cooling loop **105** to pump cold liquid phase change material that from secondary side of the bypass heat exchanger **198** to the load heat exchanger **122** and back. An air handler **150** is utilized in conjunction with the load heat exchanger **122** to provide cooling to a heat load. This load heat exchanger **122** may be a single or multiple evaporators such as might be used to provide multi-zone cooling, mini-split evaporators or the like.

[0034] Whereas FIGS. 1-3 depict bimodal systems (ice-make and ice-melt), it is within the scope of the present disclosure that any of the described embodiments are also adaptable for use of a direct cooling loop such as described in FIG. 4 with simple geometric and valve modifications.

[0035] FIG. 5 illustrates a configuration of a refrigerant-based thermal energy storage and cooling system with secondary refrigerant isolation and a secondary refrigerant loop **203**. As described in the embodiment of FIG. 1, the primary refrigerant loop **201** transfers cooling between the air conditioner unit **102** and the thermal energy storage unit **106**. During ice-make phase, the thermal energy storage unit **106** containing the primary heat exchanger **160** acts as an expansion device where expanding refrigerant is fed from a lower header assembly **156** through the freezing/discharge coils **142**, to the upper header assembly **154**. Cooling is transmitted from the freezing coils **142** to the surrounding liquid phase change material **152** that is confined within the insulated tank **140** and freezes at least a portion of the phase

change material **153** (ice) surrounding the freezing coils **142** and storing thermal energy in the process. Warm liquid and vapor phase refrigerant leaves the freezing coils **142** through the upper header assembly **154** and exits the thermal energy storage unit **106** returning to the air conditioner unit **102** through the low pressure return line **118** and is fed to the compressor **110** and re-condensed into liquid.

[0036] In cooling mode, cool liquid phase change material leaves the lower portion of the insulated tank **140** and is propelled by a pump **120** to a primary side of an intermediate heat exchanger **123** where cooling is transferred from the external melt cooling loop **205** to a secondary refrigerant loop **203**. Warm liquid leaves the intermediate heat exchanger **123** and is returned to the upper portion of the thermal energy storage unit **106** and the warm liquid draws cooling from the solid phase change material **153** surrounding the coils. The secondary refrigerant loop **203** flows through the secondary side of the intermediate heat exchanger **123** drawing cooling from the fluid on the primary side and warming the liquid phase change material. This cools and condenses the refrigerant which is either propelled by a refrigerant pump **121** (as shown) or driven by a gravity fed thermosiphon (not shown) to a load heat exchanger **122** where the refrigerant is expanded and cooling is delivered to a heat load with the aid of an air handler **150**. The warm mixed or vapor phase refrigerant is then returned to the intermediate heat exchanger **123** to complete the secondary refrigerant loop **203**.

[0037] As with the embodiment of FIG. 2, the embodiment of FIG. 5 may include a URMV, as well as an isolating heat exchanger (as demonstrated in FIG. 3), a by-pass refrigeration loop and bypass heat exchanger or any combination thereof as exemplified in FIG. 4.

[0038] By utilizing such an embodiment current dwellings that use standard air conditioning systems may be readily adapted or retrofit to a thermal storage system by the addition of a thermal energy storage unit **106**, expansion device **130**, Intermediate heat exchanger **123**, pump **120** and refrigerant pump **121**. Because the system isolates the primary refrigerant from a secondary phase change material loop and a secondary refrigerant, the system additionally allows the use of a variety of refrigerants to be used within the device. The disclosed embodiments therefore provide a refrigerant-based thermal storage system method and device wherein an isolated external melt cooling loop is utilized to transfer cooling to a heat load utilizing a phase change material.

[0039] It is also possible to utilize the secondary refrigerant loop **203** of the embodiment of FIG. 5 as a cooling loop where the secondary refrigerant is kept in liquid phase throughout its cycle. This would allow a wide variety of materials to be used to accomplish the heat transfer between the intermediate heat exchanger **123** and the load heat exchanger **122**. These materials may include, but are not limited to: water, ammonia, slurry ice, brine, ethylene glycol, propylene glycol, various alcohols (Isobutyl, ethanol), sugar, other eutectic materials or the like.

[0040] The foregoing description of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and other modifications and variations may be possible in light of the above teachings. The embodiment was chosen and described in order to best explain the principles of the invention and its practical

application to thereby enable others skilled in the art to best utilize the invention in various embodiments and various modifications as are suited to the particular use contemplated. It is intended that the appended claims be construed to include other alternative embodiments of the invention except insofar as limited by the prior art.

1. A refrigerant-based thermal energy storage and cooling system comprising:

- a refrigerant loop containing a refrigerant comprising:
 - a condensing unit, said condensing unit comprising a compressor and a condenser;
 - an expansion device connected downstream of said condensing unit; and,
 - a primary heat exchanger that acts as an evaporator and is located within a tank filled with a fluid capable of a phase change between liquid and solid, said primary heat exchanger that facilitates heat transfer from said refrigerant from said condenser to cool said fluid and to freeze at least a portion of said fluid within said tank; a cooling loop containing said fluid from said tank comprising:
 - a load heat exchanger connected to said tank that transfers cooling capacity of said fluid to a heat load; and,
 - a pump that distributes said fluid from said tank to said load heat exchanger and returns said fluid to said tank.

2. The system of claim 1 further comprising:

- a refrigerant management vessel in fluid communication with, and located between said condensing unit and said primary heat exchanger comprising:
 - an inlet connection that receives refrigerant from said condensing unit and said primary heat exchanger;
 - a first outlet connection that supplies refrigerant to said primary heat exchanger; and,
 - a second outlet connection that supplies refrigerant to said condensing unit.

3. The system of claim 1 wherein said expansion device is a thermal expansion valve.

4. The system of claim 1 wherein said expansion device is a mixed-phase regulator.

5. The system of claim 1 wherein said fluid is a eutectic material.

6. The system of claim 1 wherein said fluid is water.

7. The system of claim 1 wherein said first refrigerant is a different material from said second refrigerant.

8. The system of claim 1 wherein said load heat exchanger is at least one mini-split evaporator.

9. A refrigerant-based thermal energy storage and cooling system comprising:

- a first refrigerant loop containing a first refrigerant comprising:
 - a condensing unit, said condensing unit comprising a compressor and a first condenser;
 - an expansion device connected downstream of said condensing unit; and,
 - a first evaporator on a primary side of an isolating heat exchanger located downstream of said expansion device;
- a second refrigerant loop containing a second refrigerant comprising:
 - a second condenser on a secondary side of said isolating heat exchanger;

- a tank filled with a fluid capable of a phase change between liquid and solid and containing a primary heat exchanger therein, said primary heat exchanger in fluid communication with said second condenser and that utilizes said second refrigerant from said second condenser to cool said fluid and to freeze at least a portion of said fluid within said tank;

- a load heat exchanger connected in fluid communication with said fluid in said tank that transfers cooling capacity of said fluid to a heat load; and,

- a pump for distributing said fluid from said tank to said load heat exchanger.

10. The system of claim of claim 9 further comprising:

- a refrigerant management vessel connected to receive said second refrigerant from said isolating heat exchanger and supply said second refrigerant to said primary heat exchanger, and to receive said second refrigerant from said primary heat exchanger and supply said second refrigerant to said isolating heat exchanger.

11. The system of claim 9 wherein said expansion device is a thermal expansion valve.

12. The system of claim 9 wherein said expansion device is a mixed-phase regulator.

13. The system of claim 9 wherein said fluid is a eutectic material.

14. The system of claim 9 wherein said fluid is water.

15. The system of claim 9 wherein said first refrigerant is a different material from said second refrigerant.

16. The system of claim 9 wherein said load heat exchanger is at least one mini-split evaporator.

17. The system of claim 9 further comprising:

- a by-pass refrigerant loop that allows said first refrigerant to by-pass said primary heat exchanger and provide cooling directly to said fluid downstream of said tank and transfer cooling to said heat load.

18. A refrigerant-based thermal energy storage and cooling system comprising:

- a first refrigerant loop containing a first refrigerant comprising:

- a condensing unit, said condensing unit comprising a compressor and a condenser;

- an expansion device connected downstream of said condensing unit; and,

- a primary heat exchanger that acts as an evaporator and is located within a tank filled with a fluid capable of a phase change between liquid and solid, said primary heat exchanger that facilitates heat transfer from said first refrigerant from said condenser to cool said fluid and to freeze at least a portion of said fluid within said tank;

- a cooling loop containing said fluid from said tank comprising:

- an intermediate heat exchanger connected to said tank that transfers cooling capacity of said fluid to a primary side of said intermediate heat exchanger;

- a pump that distributes said fluid from said tank to said intermediate (load) heat exchanger and returns said fluid to said tank;

- a second refrigerant loop containing a second refrigerant comprising:

- a load heat exchanger connected in fluid communication with a secondary side of said intermediate heat exchanger that transfers cooling capacity of said second refrigerant to a heat load; and,

a refrigerant pump for distributing said second refrigerant from said intermediate heat exchanger to said load heat exchanger and back to said intermediate heat exchanger.

19. The system of claim **18** wherein said expansion device is a thermal expansion valve.

20. The system of claim **18** wherein said expansion device is a mixed-phase regulator.

21. The system of claim **18** wherein said fluid is a eutectic material.

22. The system of claim **18** wherein said fluid is water.

23. The system of claim **18** wherein said first refrigerant is a different material from said second refrigerant.

24. The system of claim **18** wherein said load heat exchanger is at least one mini-split evaporator.

25. The system of claim **18** wherein said second refrigerant remains liquid.

26. The system of claim **18** further comprising:

a refrigerant management vessel connected to receive said second refrigerant from said isolating heat exchanger and supply said second refrigerant to said primary heat exchanger, and to receive said second refrigerant from said primary heat exchanger and supply said second refrigerant to said isolating heat exchanger;

27. The system of claim **18** further comprising:

a by-pass refrigerant loop that allows said first refrigerant to by-pass said primary heat exchanger and provide cooling directly to said fluid downstream of said tank and transfer cooling to said intermediate heat exchanger.

28. A method of providing cooling with a refrigerant-based thermal energy storage and cooling system comprising the steps of:

providing cooling to a primary heat exchanger by evaporating a high-pressure refrigerant in said primary heat exchanger that is constrained within a tank containing a fluid capable of a phase change between liquid and solid;

freezing a portion of said fluid and form ice within said tank;

delivering a liquid portion of said fluid to a load heat exchanger;

transferring cooling from said liquid portion of said fluid to said load heat exchanger to provide load cooling; returning said liquid portion of said fluid to said tank; and, cooling said liquid portion of said fluid with said ice within said tank.

29. The method of claim **28** further comprising the step of: managing volumes and phase of said first refrigerant with a refrigerant management vessel, said refrigerant management vessel in fluid communication with said primary heat exchanger and said condenser.

30. A method of providing cooling with a refrigerant-based thermal energy storage and cooling system comprising the steps of:

providing cooling to a first evaporator on a primary side of an isolating heat exchanger by evaporating a high-pressure refrigerant in said first evaporator;

transferring cooling from said primary side of said isolating heat exchanger to a second refrigerant loop containing a second refrigerant through a secondary side of said isolating heat exchanger;

providing cooling with said second refrigerant loop to a primary heat exchanger that is constrained within a tank containing a fluid capable of a phase change between liquid and solid;

freezing a portion of said fluid and form ice within said tank;

delivering a liquid portion of said fluid to a load heat exchanger;

transferring cooling from said liquid portion of said fluid to said load heat exchanger to provide load cooling; returning said liquid portion of said fluid to said tank; and, cooling said liquid portion of said fluid with said ice within said tank.

31. The method of claim **30** further comprising the step of: managing volumes and phase of said second refrigerant with a refrigerant management vessel, said refrigerant management vessel in fluid communication with said isolating heat exchanger and said primary heat exchanger.

32. The method of claim **30** further comprising the step of: by-passing said primary heat exchanger with said primary refrigerant; delivering said primary refrigerant to said to said fluid downstream of said tank; and, transferring cooling to said intermediate heat exchanger.

33. A method of providing cooling with a refrigerant-based thermal energy storage and cooling system comprising the steps of:

providing cooling to a primary heat exchanger by evaporating a high-pressure refrigerant in said primary heat exchanger that is constrained within a tank containing a fluid capable of a phase change between liquid and solid;

freezing a portion of said fluid and form ice within said tank;

delivering a liquid portion of said fluid to a primary side of an intermediate heat exchanger;

transferring cooling from said primary side of said intermediate heat exchanger to a second refrigerant loop containing a second refrigerant through a secondary side of said intermediate heat exchanger;

returning said liquid portion of said fluid to said tank;

cooling said liquid portion of said fluid with said ice within said tank;

delivering said second refrigerant to a load heat exchanger;

transferring cooling from said second refrigerant to a load heat exchanger to provide load cooling;

returning said second refrigerant to said secondary side of said intermediate heat exchanger; and,

cooling said second refrigerant with said primary side of said intermediate heat exchanger.

34. The method of claim **33** further comprising the step of: managing volumes and phase of said first refrigerant with a refrigerant management vessel, said refrigerant management vessel in fluid communication with said primary heat exchanger and said condenser.

35. The method of claim **33** further comprising the step of: isolating said primary heat exchanger from said condensing unit with an isolating heat exchanger that transfers heat to and from said primary heat exchanger and said condensing unit.

36. The method of claim **33** further comprising the step of: maintaining said second refrigerant in liquid phase throughout said second refrigerant loop.