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(54) SYSTEM FOR COOLING A CABINET

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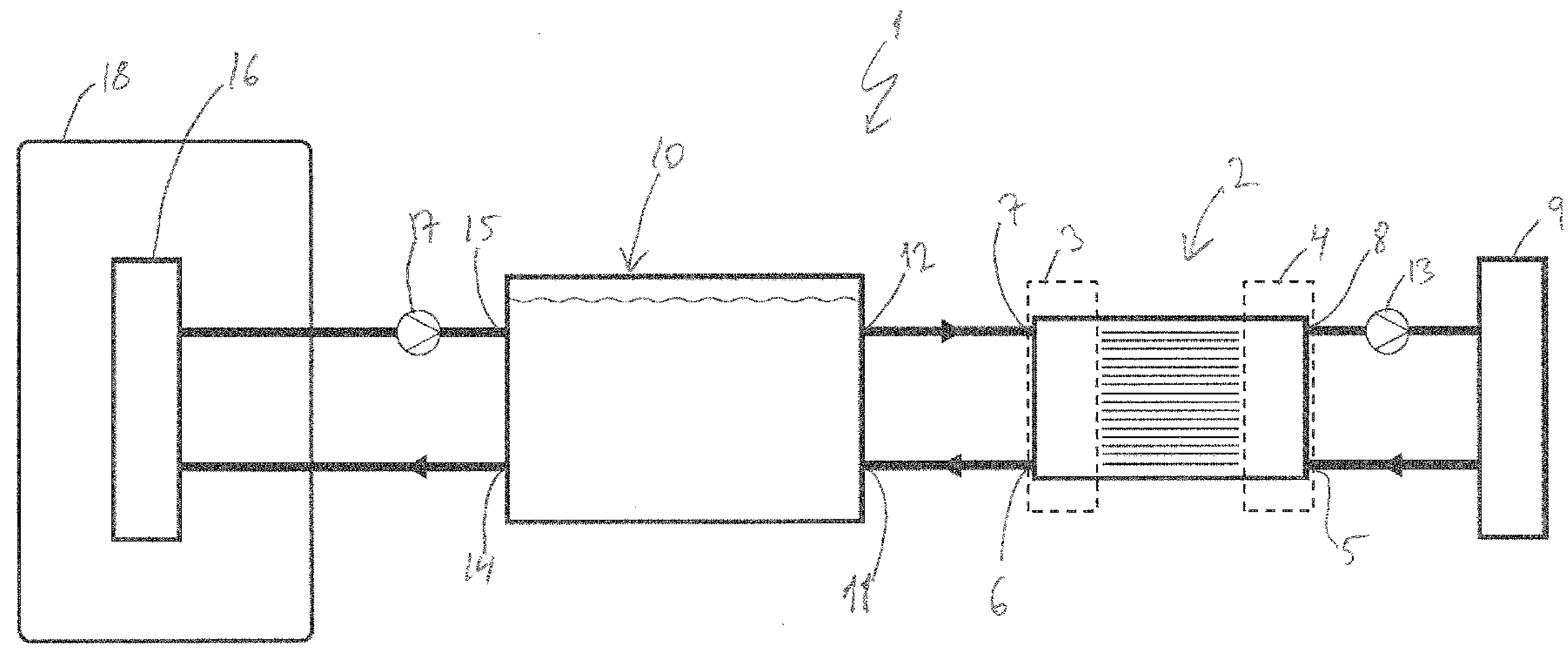
(57) **ABSTRACT**

The present disclosure relates to a cooling system comprising an active magnetic regenerator having a cold side and a hot side, a hot side heat exchanger connected to the hot side of the magnetic regenerator, one or more cold side heat exchangers, and a cold store reservoir comprising a volume of heat transfer fluid and connected between said one or more cold side heat exchangers and the cold side of the magnetic regenerator, wherein the cooling system is configured to provide a first flow cycle of said heat transfer fluid between the cold store reservoir, the magnetic regenerator and the hot side heat exchanger adapted to transfer thermal energy from the cold store reservoir to the hot side heat exchanger, and at least a second flow cycle of said heat transfer fluid between the cold store reservoir and said one or more cold side heat exchangers adapted to transfer thermal energy from said one or more cold side heat exchangers to the cold store reservoir.



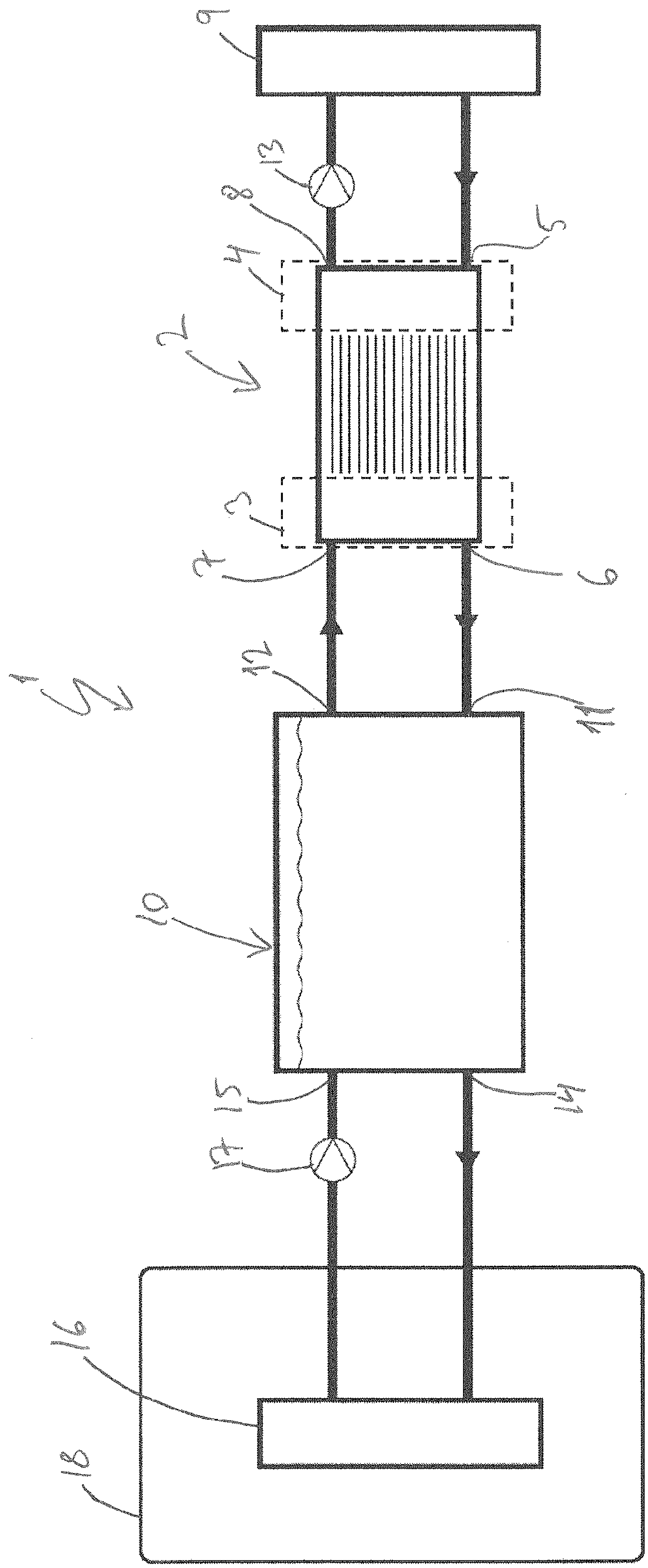



Fig. 1

# SYSTEM FOR COOLING A CABINET

**[0001]** The present disclosure relates to a cooling system employing an active magnetic regenerator, a method for cooling a cabinet employing the system, and an associated refrigerator.

## BACKGROUND OF THE INVENTION

**[0002]** A typical magnetic cooling system is based on an active magnetic regenerator (AMR) cooling cycle comprising a magnetic regenerator formed of a magnetocaloric material, i.e. a material that heats up when placed in a magnetic field. It is known, that magnetocaloric materials can be used for heating and/or cooling purposes. Magnetic refrigerators are known in the art, an example disclosed in US 2011/0308258, wherein a number of magnetocaloric stages forming a magnetic refrigerator, are used to transfer thermal heat from a heat transfer fluid in a cold side heat exchange circuit to a heat transfer fluid in a hot side heat exchange circuit.

**[0003]** A conventional refrigerator, such as a household refrigerator, is based on a refrigeration cycle driven by a compressor and expansion valve in order to deliver the required cooling load. When the refrigerator has obtained the desired temperature, the refrigeration cycle has to deliver a certain steady state load. However, in use, a refrigerator cabinet is frequently opened in order to access the content. The interior of the refrigerator cabinet is consequently heated and in order to ensure that the content of the cabinet is kept cool, the cooling cycle needs to deliver a pull down load higher than the steady state load in order to cool the interior of the cabinet, preferably within a short period. A refrigerator with a certain steady state demand may have a pull down demand which is two to four times higher than the steady state demand. However, the refrigeration cycle of a conventional refrigerator is at least dimensioned for the required pull down demand. Consequently, the refrigeration cycle is running in a start-stop mode during steady state operation.

## SUMMARY OF THE INVENTION

**[0004]** The conventional compressor based refrigeration cycle is efficient in terms of production costs but relatively inefficient in terms of energy consumption. In contrast hereto the AMR is relatively expensive in terms of production costs but very efficient in terms of energy consumption. The high cost of manufacturing creates a significant barrier for the commercial success of AMR based cooling systems. One purpose of the present invention is therefore to reduce this barrier to utilize the energy efficiency of AMR based cooling.

**[0005]** A first aspect of the present disclosure therefore relates to a cooling system comprising an active magnetic regenerator having a cold side and a hot side, a hot side heat exchanger connected to the hot side of the magnetic regenerator, one or more cold side heat exchangers, and a cold store reservoir comprising a volume of heat transfer fluid and connected between said one or more cold side heat exchangers and the cold side of the magnetic regenerator, wherein the cooling system is configured to provide a first flow cycle of said heat transfer fluid between the cold store reservoir, the magnetic regenerator and the hot side heat exchanger adapted to transfer thermal energy from the cold store reservoir to the hot side heat exchanger, and at least a second flow cycle of said heat transfer fluid, between the cold store reservoir and said one or more cold side heat exchangers adapted to transfer thermal energy from said one or more cold side heat exchangers to the cold store reservoir.

**[0006]** Compressor based cooling systems are dimensioned to the peak load requirements. However, the present inventors have realized that an AMR based cooling system can be dimensioned to approximate the steady state load requirements if a cold store reservoir is provided between the cold side heat exchanger and the AMR. The cold store reservoir comprises a volume of heat transfer fluid thereby significantly increasing the amount of heat transfer fluid in the cooling system and thereby significantly increasing the pull down cooling capacity of the system. The cold store reservoir has the function of a thermal buffer in the refrigeration cycle.

**[0007]** A further aspect of the present disclosure relates to a method for cooling a cabinet from a first higher temperature to a second lower temperature, the cabinet incorporating a cold side heat exchanger of the presently disclosed cooling system, the method comprising the steps of operating the first flow cycle at a first steady state flow rate, operating the second flow cycle at a second flow rate higher than the first steady state flow rate, and monitoring the temperature in the cabinet and the temperature difference across the active magnetic regenerator. This method for cooling a cabinet may be applied by means of the herein disclosed cooling system.

**[0008]** A further aspect of the present disclosure relates to a refrigerator comprising and/or incorporating the herein disclosed cooling system.

**[0009]** Yet a further aspect relates to refrigeration plant comprising a plurality of refrigeration cabinets and the cooling system according to any of the preceding claims (comprising a plurality of second flow cycles) configured for cooling the plurality of refrigeration cabinets, wherein each refrigeration cabinet is connected to the cold store reservoir of the cooling system by means of one of said second flow cycles.

**[0010]** Thus, with the presently disclosed cooling system it is possible to reduce the load requirements for a refrigerator based on AMR which will reduce the production costs significantly. This is primarily due to the cold store reservoir which acts as a thermal buffer for the cooling system allowing the AMR to be dimensioned significantly below the corresponding pull down load. An AMR typically performs best when the output and input temperatures on the cold side are relatively constant and are within a few degrees of each other. The output temperature from the heat transfer fluid exiting the cabinet may in contrast vary significantly during pull down. As an example it may be as hot as 5° C. when initiating a pull down cycle, while in steady state it may be −5° C. The cold store reservoir buffers this temperature variation and ensures that the AMR sees a much smaller variation in temperature.

## DESCRIPTION OF THE DRAWINGS

**[0011]** The invention will in the following be described in greater detail with reference to the accompanying drawing wherein FIG. **1** is a schematic view of one embodiment of the presently disclosed cooling system.

## DETAILED DESCRIPTION OF THE INVENTION

**[0012]** Active magnetic regenerators are known in the art, see e.g. WO 2006/074790, WO 2010/086399, Bahl et al., "Design concepts for a continuously rotating active magnetic regenerator", International journal of refrigeration, 34

(2011), 1792-1796, and Engelbrecht et al., "Experimental results for a novel rotary active magnetic regenerator", International journal of refrigeration, 35 (2012), 1498-1505. Further details of the AMR of the presently disclosed cooling system will therefore not be described herein.

**[0013]** The cold store reservoir significantly increases the amount of heat transfer fluid in the cooling system. This additional volume of heat transfer fluid increases the heat capacity (and thereby the cooling capacity) of the presently disclosed cooling system. In the steady state during operation of the present cooling system the heat transfer fluid is cooled to a certain minimum temperature, i.e. the volume of heat transfer fluid present in the cold store reservoir is cold. This volume of cold heat transfer fluid can then act as a buffer in the cooling circuit. By increasing the flow from the cold store reservoir through the cold side heat exchanger, i.e. the second flow cycle, it is possible to increase the cooling load of the system for a limited period of time, i.e. a pull down can be provided without increasing the first flow cycle, i.e. without increasing the power load of the AMR. I.e. in one embodiment the presently disclosed cooling system is configured such that the first flow cycle is operated independently of the second flow cycle(s). I.e. the flow rates of the first cycle and said at least second flow cycle can preferably be controlled independently of each other.

**[0014]** The presently disclosed cooling system is provided with a certain volume of heat transfer fluid. The amount of heat transfer fluid depends on the specific cooling demand of the cooling system, e.g. required steady state load and pull-down load. A certain fraction of this volume is inside the cold store reservoir, this fraction typically depends on the required pull-down load as will be explained below. In one embodiment at least 50% of the total volume of heat transfer fluid in the cooling system is located in the cold store reservoir, or at least 60%, or at least 70%, or at least 75%, or at least 80%, or at least 85%, or at least 90%, or at least 92%, or at least 94%, or at least 95%, or at least 96%, or at least 97%, or at least 98%, or at least 99% of the total volume of heat transfer fluid in the cooling system is located in the cold store reservoir.

**[0015]** In one embodiment, the presently disclosed system comprises at least a first pump adapted to circulate heat transfer fluid between the cold store reservoir, the AMR and the hot side heat exchanger, i.e. at least a first pump to operate/drive the first flow cycle. The AMR is preferably configured to be in continuous operation, i.e. constant cooling the heat transfer fluid flowing through the AMR and thereby constantly cooling the heat transfer fluid in the cold store reservoir. This is advantageous as it enables the construction of a highly optimised AMR. An AMR cooling circuit performs best when the temperature of the heat transfer fluid that enters the AMR is close to the specified temperature of the heat transfer fluid that exists the AMR, preferably this temperature difference is only a few degrees. By mixing the fluid exiting from the cold side heat exchanger into the reservoir it is ensured that the temperature of the heat transfer fluid that enters the hot side of the AMR is lower than the heat transfer fluid exiting the cold side heat exchanger, thereby reducing the temperature difference between the hot side and the cold side of the AMR, thereby optimizing the AMR performance. Further, the wear of the components of the AMR is reduced by minimizing the number of starts and stops. Thus, the first pump may be configured to uphold approximate steady state conditions of the first flow cycle in order to optimize the operation of the AMR.

**[0016]** In one embodiment, the presently disclosed cooling system further comprises at least a second pump adapted to circulate the heat transfer fluid between the cold side heat exchanger(s) and the cold store reservoir, i.e. at least a second pump to operate the second flow cycle(s). The temperature of the cold side heat exchanger may thereby be controlled with higher precision. It is thus possible to control the temperature of the cabinet with a higher precision. The flow rate of the first flow cycle may be controlled based on the temperature inside the cabinet that needs cooling. The cooling delivered to this cabinet can then be regulated in order to cope with the demand, i.e. this at least second pump may be configured to (at least indirectly) provide the pull-down load of the cooling system.

**[0017]** A further advantage of the presently disclosed system is that it is the same heat transfer fluid that flows through the entire cooling system, i.e. the components of present cooling system are preferably fluidly interconnected. This eliminates the need for additional heat exchangers between the cold store reservoir and the cold side heat exchanger and/or most importantly between the cold store reservoir and the AMR. This simplifies the presently disclosed cooling system greatly compared to prior art compressor based thermal reservoir systems that must use a first heat transfer fluid at the hot end and a second fluid transfer fluid at the cold end. Avoiding the use of additional heat exchangers also reduces the energy consumption and the increases the energy efficiency of the cooling system.

**[0018]** The cold store reservoir is provided with at least four inlets/outlets of heat transfer fluid of possibly significantly different temperatures. Thus, there may be a temperature gradient of the heat transfer fluid inside the cold store. In a further embodiment of the cooling system at least one mixing element is located in the cold store reservoir and configured to control the mixing of hot and cold heat transfer fluid inside the cold store reservoir. This may help to reduce and/or control this temperature gradient.

**[0019]** In a further embodiment the cold store reservoir is stratified to provide for layers of heat transfer fluid. This stratification may be vertical and/or horizontal and may be one way of controlling, maintaining or reducing the temperature gradient of the heat transfer fluid.

**[0020]** Another way to control the mixing of the heat transfer fluid in the cold store reservoir is the location of the various inlets and outlets, utilizing the fact that the hot heat transfer fluid will tend to stay or flow towards the top of the cold store reservoir. During pull-down it may therefore be an advantage that the inlet to the cold store reservoir from the cold side heat exchanger is located at a higher level than the corresponding outlet. Correspondingly it may be an advantage that the inlet to the cold store reservoir from the active magnetic regenerator is located at a lower level than the corresponding outlet. During steady state operation it may be an advantage that there is a forced mixing of the heat transfer fluid inside the cold store reservoir.

**[0021]** The selection of the heat transfer fluid depends on the specific application of the cooling system, e.g. refrigerator or a freezer. In one embodiment the heat transfer fluid comprises water and/or brine. Furthermore the heat transfer fluid may comprise a corrosion inhibitor. Water or brine or mixtures thereof are relatively harmless to the environment and has a high heat capacity. An example of a suitable brine is Zitrec S with a density of $\rho$=1200 kg/$m^3$ and a specific heat of c=3.1 kJ/kg*K. If water is used, corrosion inhibitors and/or anti-freeze substance(s) may advantageously be added.

**[0022]** In order to estimate the load requirements of the presently disclosed cooling system, i.e. to estimate the volume of the cold store reservoir vs. the required pull-down load, it can be assumed that the AMR is operated at constant cooling load $dQ_{SS}/dt$ (SS=steady state). The steady state load $dQ_{SS}/dt$ is the load required to keep a cabinet that needs cooling at a constant temperature and this load is typically dependent on the desired cabinet temperature, the ambient temperature and the insulation properties of the cabinet. During pull-down (PD) the cooling load is increased to $dQ_{PD}/dt>dQ_{SS}/dt$ to cool down the cabinet. This will cause the temperature of the heat transfer fluid in the cold store reservoir to increase. As long as the heat transfer fluid in the cold store reservoir is colder than the cabinet that needs cooling (i.e. the cold cabinet), a cooling load can be extracted from the cold store reservoir. However, in practice it may be necessary to keep a sufficient temperature drop across the cold side heat exchanger to maintain an adequate efficiency. It can be assumed that the cold side heat exchanger is dimensioned such that the steady state flow rate $v_{SS}$ is sufficient to extract the constant cooling load $dQ_{SS}/dt$ from the cold cabinet with the cold store reservoir at a temperature equal to the exit temperature of the AMR. In this case the cold store reservoir can be "bypassed" at steady state, i.e. the AMR is operated with the designed temperature span and cooling load. Thus, the AMR span is not larger than otherwise; however, the steady state cooling load will be slightly higher due to heat losses from the cold store reservoir, since a larger part of the insulated volume is now colder. An added benefit of the cooling system is that the entire temperature drop does not need to be heat exchanged away when the cold store reservoir is recirculated.

**[0023]** The volume V of additional heat transfer fluid in the cooling system, i.e. the volume of heat transfer fluid in the cold store reservoir, must be selected to allow for a certain temperature rise $\Delta T$ of the heat transfer fluid in the cold store reservoir to a temperature of $T_{SS}+\Delta T$, where $\Delta T$ typically is in the order of the temperature difference between the cold side inlet and outlet of the AMR. Then the pull-down load of the cooling system can be sustained for the time $t_{PD}$ given by:

$$t_{PD} = \frac{1}{\dot{Q}_{PD} - \dot{Q}_{SS}} \rho V c \Delta T$$

where ρ and c are the density and heat capacity, respectively, of the heat transfer fluid. The flow through the cold side heat exchanger must typically be adjusted such that $dQ_{PD}/dt$ can actually be absorbed, i.e. $v_{PD}>v_{SS}=v_{AMR}$. For a small cooling appliance where $\Delta T$=2 K and V=40 liter we have that $t_{PD}$=90 min, i.e. the pull-down load can be sustained for 90 minutes if a temperature rise of the heat transfer fluid in the cold store reservoir of 2 degrees can be accepted, and where the volume of heat transfer fluid in the reservoir is 40 liter. The selection of V and $\Delta T$ is thus a balance between the cost of the AMR and the practical limitations of size of the cold store reservoir. In order to minimize the cost of the AMR, $\Delta T$ is typically on the order of 2 degrees. In a state of the art energy efficient household refrigerator, exemplary values for the loads are, $dQ_{SS}/dt$=25 W and $dQ_{PD}/dt$=80 W for a small appliance. If this household refrigerator should be cooled by the presently disclosed cooling system the steady state load requirements of the AMR should approximate these 25 W, preferably the AMR should be dimensioned to a steady state load slightly above the steady state load requirements, i.e. slightly more than 25 W in this case. Exemplary values for a large household appliance are $dQ_{SS}/dt$=77 W and $dQ_{PD}/dt$=160 W. In the case of cooling a household refrigerator the present cooling system can be incorporated in the cabinet of the refrigerator.

**[0024]** Thus, in general the AMR of the presently disclosed cooling system may be configured to approximate the steady state cooling load requirements of the cabinet (or cabinets) that need cooling. E.g. preferably 0-20% more than a predefined $dQ_{SS}/dt$, or less than 20%, 18%, 16%, 15%, 14%, 13%, 12%, 11%, 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than 1% more than the predefined $dQ_{SS}/dt$.

**[0025]** The cold store reservoir may further comprise an expansion volume, preferably filled with a gas such as air. E.g. the inside volume of the cold store reservoir is not completely filled with heat transfer fluid by leaving an open volume above the heat transfer fluid. The expansion volume may be an advantage when the cooling system is not in use, for example during transportation, where thermal expansion or contraction of the heat transfer fluid may vary significantly. Thus, the cooling system may further comprise a release valve configured to pressure-equalize the cold store reservoir. E.g. the thermal expansion of e.g. brine during transport to very cold places can be compensated.

**[0026]** As stated previously a further aspect of the present disclosure relates to a refrigeration plant comprising a plurality of refrigeration cabinets and with the presently disclosed cooling system configured for cooling the plurality of cooling cabinets, wherein each refrigeration cabinet is connected to the cold store reservoir of the cooling system by means of one of said second flow cycles. I.e. the AMR and the cold store reservoir may be located centrally and be fluidly (e.g. pipelined) connected to a plurality of cold side heat exchangers, where each of said cold side heat exchangers may be cooling a cabinet. In this case the cooling system typically does not need to be incorporated in a cabinet and the cold store reservoir may consequently be dimensioned to be very large. As apparent from above this may significantly increase the time the pull-down load can be sustained, even when the AMR is dimensioned to a temperature difference of merely 2 degrees.

Further Aspect of the Invention

**[0027]** One of the advantages of the presently disclosed cooling system is that the same heat transfer fluid can flow in the entire system, i.e. it is the same heat transfer fluid in the first and second flow cycle(s) and in the cold store reservoir, thereby optimizing the heat transfer efficiency of the system. However, a cooling system employing a cold store reservoir can also function with the first flow cycle using a first heat transfer fluid and the second flow cycle(s) using a second heat transfer fluid and without a fluid connection between the cold store reservoir and the cold side of the AMR. A further/second aspect of the present disclosure therefore relates to a cooling system comprising

- **[0028]** an active magnetic regenerator having a cold side and a hot side,
- **[0029]** a hot side heat exchanger connected to the hot side of the magnetic regenerator,

**[0030]** one or more cold side heat exchangers, and

**[0031]** a cold store reservoir comprising a volume of a second heat transfer fluid and connected to said one or more cold side heat exchangers,

**[0032]** a cold store heat exchanger located between the cold store reservoir and the cold side of the magnetic regenerator,

**[0033]** wherein the cooling system is configured to provide:

**[0034]** a first flow cycle of a first heat transfer fluid between the magnetic regenerator and the hot side heat exchanger adapted to transfer thermal energy from the cold side of the magnetic regenerator to the hot side heat exchanger, and

**[0035]** at least a second flow cycle of said second heat transfer fluid between the cold store reservoir and said one or more cold side heat exchangers adapted to transfer thermal energy from said one or more cold side heat exchangers to the cold store reservoir.

**[0036]** In this second aspect the first and second heat transfer fluids are not fluidly connected and the transfer of heat between the cold store reservoir and the active magnetic regenerator is provided by means of the cold store heat exchanger, i.e. the cold side of the AMR is cooling the cold store via the cold store heat exchanger. The first and second heat transfer fluids may be the same type or different types of heat transfer fluid. AMR based cooling systems employing a cold store reservoir and a traditional heat exchanger between the cold store reservoir and the AMR have not been disclosed in the prior art. This solution also solves the problem of reducing the peak load requirements of the AMR thereby significantly reducing the manufacturing costs.

**[0037]** As stated previously an AMR is most efficient when the output and input temperatures on the cold side are relatively constant, e.g. within a few degrees of each other. The configuration of the cold store heat exchanger, i.e. in terms of size, is advantageously optimized to ensure an adequate temperature difference between the outlet and the inlet of the cold side of the AMR to provide for an efficient operation of the AMR. This second aspect of the present disclosure may incorporate any of the features disclosed herein.

## Examples

**[0038]** FIG. **1** shows an embodiment 1 of the presently disclosed cooling system. The cooling system **1** comprises an active magnetic regenerator **2**. As previously stated AMR's are known in the art and design thereof will not be described in detail herein.

**[0039]** The AMR **2** is provided with four inlets/outlets: A hot side inlet **5**, a cold side outlet **6**, a cold side inlet **7** and a hot side outlet **8**. The hot side outlet **8** is connected to the inlet of a hot side heat exchanger **9**, where through heat transfer fluid flows and returns to the AMR **2** through the hot side inlet **5**. The cold side outlet **6** is connected to a cold store reservoir **10** via the inlet **11** so that the cooled heat transfer fluid exiting the AMR **2** enters the cold store reservoir **10**. The cold side inlet **7** is connected to the cold store reservoir **10** via the outlet **12**.

**[0040]** The hot side heat exchanger **9** is positioned so the heat transfer fluid can be cooled when flowing through it. In a traditional compressor based household refrigerator the hot side heat exchanger is positioned on the rear of the cabinet so that it can transfer heat to the surroundings.

**[0041]** A first flow cycle of heat transfer fluid is constituted by the flow of heat transfer fluid between the cold store reservoir **10**, the AMR **2** and the hot side heat exchanger **9**. This first flow cycle is controlled by a first pump **13**.

**[0042]** A cold side heat exchanger **16** is provided in a cabinet **18** that needs cooling. The cabinet **18** is insulated and can be a cabinet for a conventional household or industrial refrigerator. The cold side heat exchanger **16** is connected to the cold store reservoir **10** by means of outlet and inlets **14** and **15** so that heat transfer fluid can flow through the cold side heat exchanger **16** and return to the cold store reservoir **10**. A second flow cycle of heat transfer fluid is constituted by the flow of heat transfer fluid between the cold store reservoir **10** and the cold side heat exchanger **16**. This second flow cycle is controlled by a second pump **17**.

**[0043]** By the use of the system shown in FIG. **1** the flow rate through the cold side heat exchanger **16** can then be controlled independently from the flow rate through the magnetic refrigerator **2** and hot side heat exchanger **9**.

**[0044]** The inlet **11** is preferably positioned at a higher level than the outlet **12** in order to create a temperature gradient inside the cold store reservoir **10**. Correspondingly the outlet **14** from the cold store reservoir is positioned at a lower level than the inlet **15**.

**[0045]** For example the present cooling system may be designed such that the heat transfer fluid entering the AMR **2** at inlet **7** is approx. −5° C. and the temperature of the heat transfer fluid exiting the AMR at outlet **6** is approximately −7° C. The temperature entering the cold side heat exchanger **16** from the cold store reservoir **10** will then have the temperature of approx. −7° C. (or a little higher such as −5° C.). The temperature returning from the cold side heat exchanger **16** can in a steady state be as low as approximately −3° C., whereas it is higher during pull-down, where the temperature of the heat transfer fluid entering the cold store reservoir at inlet **15** can be as high as 5° C.

**[0046]** In the cold store reservoir **10** shown on FIG. **1** there is an open volume above the heat transfer fluid. This open volume can be used to compensate for the volume changes of the heat transfer fluid, e.g. during transportation where the temperature can vary significantly thereby functioning as expansion volume. The cold store reservoir **10** can also be equipped with a safety valve that opens if the pressure inside the cold store reservoir **10** gets too high and/or too low. Such a safety valve will hinder damages to the cooling system in case it is subjected to critically high or low temperatures.

## LIST OF REFERENCES IN DRAWINGS

**[0047]** **1** cooling system

**[0048]** **2** AMR—active magnetic regenerator

**[0049]** **3** cold side of AMR

**[0050]** **4** hot side of AMR

**[0051]** **5** hot side inlet to AMR

**[0052]** **6** cold side outlet of AMR

**[0053]** **7** cold side inlet to AMR

**[0054]** **8** hot side outlet of AMR

**[0055]** **9** hot side heat exchanger

**[0056]** **10** cold store reservoir

**[0057]** **11** inlet to cold store reservoir from cold side of AMR

**[0058]** **12** outlet from cold store reservoir to hot side of AMR

**[0059]** **13** pump operating the first flow cycle

**[0060]** **14** outlet from cold store reservoir to cold side heat exchanger

**[0061]** **15** inlet to cold store reservoir from cold side heat exchanger

**[0062]** **16** cold side heat exchanger

**[0063]** **17** pump operating the second flow cycle

**[0064]** **18** cabinet that needs cooling

**1**. A cooling system comprising

an active magnetic regenerator having a cold side and a hot side,

a hot side heat exchanger connected to the hot side of the magnetic regenerator,

one or more cold side heat exchangers, and

a cold store reservoir comprising a volume of heat transfer fluid and connected between said one or more cold side heat exchangers and the cold side of the magnetic regenerator,

wherein the cooling system is configured to provide:

a first flow cycle of said heat transfer fluid between the cold store reservoir, the magnetic regenerator and the hot side heat exchanger adapted to transfer thermal energy from the cold store reservoir to the hot side heat exchanger, and

at least a second flow cycle of said heat transfer fluid between the cold store reservoir and said one or more cold side heat exchangers adapted to transfer thermal energy from said one or more cold side heat exchangers to the cold store reservoir.

**2**. The cooling system according to any of the preceding claims, wherein the system is configured such that the first flow cycle is operated independently of the second flow cycle (s).

**3**. The cooling system according to any of the preceding claims, wherein the system is configured such that the flow rate of the first flow cycle is operated independently of the flow rate of the second flow cycle(s).

**4**. The cooling system according to any of the preceding claims, further comprising one or more pumps configured to operate the first and/or the second flow cycle.

**5**. The cooling system according to any of the preceding claims, further comprising a mixing element located in the cold store reservoir and configured to control the mixing of hot and cold heat transfer fluid inside the cold store reservoir.

**6**. The cooling system according to any of the preceding claims, wherein the cold store reservoir is stratified to provide for layers of heat transfer fluid.

**7**. The cooling system according to any of the preceding claims, wherein the inlet to the cold store reservoir from the cold side heat exchanger is located at a higher level than the corresponding outlet.

**8**. The cooling system according to any of the preceding claims, wherein the inlet to the cold store reservoir from the active magnetic regenerator is located at a lower level than the corresponding outlet.

**9**. The cooling system according to any of the preceding claims, wherein the heat transfer fluid comprises water and/or brine.

**10**. The cooling system according to any of the preceding claims, wherein the heat transfer fluid comprises a corrosion inhibitor.

**11**. The cooling system according to any of the preceding claims, wherein the cold store reservoir further comprises an expansion volume, preferably filled with a gas such as air.

**12**. The cooling system according to any of the preceding claims, wherein at least 80% of the total volume of heat transfer fluid in the cooling system is located in the cold store reservoir, or at least 85%, or at least 90%, or at least 92%, or at least 94%, or at least 95%, or at least 96%, or at least 97%, or at least 98%, or at least 99% of the total volume of heat transfer fluid in the cooling system is located in the cold store reservoir.

**13**. The cooling system according to any of the preceding claims, further comprising a release valve configured to pressure-equalize the cold store reservoir.

**14**. A method for cooling a cabinet from a first higher temperature to a second lower temperature, the cabinet incorporating a cold side heat exchanger of the cooling system according to any of the preceding claims, the method comprising the steps of:

operating the first flow cycle at a first steady state flow rate,

operating the second flow cycle at a second flow rate higher than the first steady state flow rate, and

monitoring the temperature in the cabinet and the temperature difference across the active magnetic regenerator.

**15**. A refrigerator comprising and/or incorporating the cooling system according to any of the preceding claims **1-13**.

**16**. A refrigeration plant comprising a plurality of refrigeration cabinets and the cooling system according to any of the preceding claims **1-13** configured for cooling the plurality of refrigeration cabinets, wherein each refrigeration cabinet is connected to the cold store reservoir of the cooling system by means of one of said second flow cycles.

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