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(54) COOLING SYSTEM

(57) A cooling system (1) for cooling water comprises: a refrigeration circuit, for circulating a refrigerant fluid; an evaporator (2); a compressor (3); a condenser (4); an expansion device (5) and an additional evaporator (6), configured to provide a heat exchange between the refrigerant fluid and water to be cooled, wherein the additional evaporator (6) is provided in the refrigeration circuit downstream of the condenser (4) and includes an outlet (62) for feeding the refrigerant fluid back to the condenser (4), so as to bypass the compressor (3).

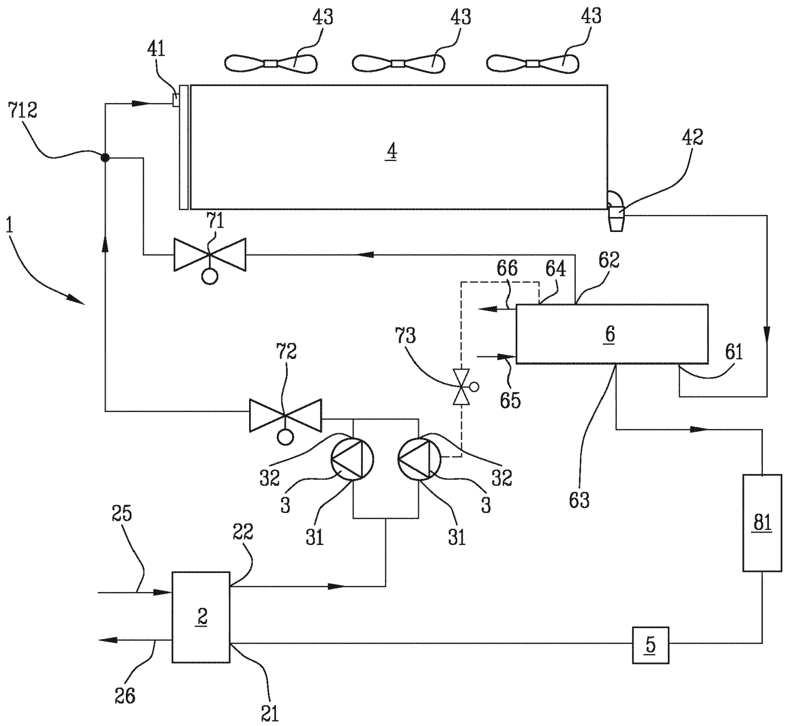

Fig.1

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Description

[0001] This invention relates to a cooling system and a method for cooling. Cooling systems are known e.g. from patent documents GB2233080A and JPH0252959A.

[0002] Cooling systems are commonly used to refrigerate a fluid such as air (in air conditioning systems or in refrigerators) or water (in industrial plants). In the cooling systems field, so called "free cooling systems" are known; such systems have a free-cooling mode and a cooling mode. During typical operation, cooling systems are run in a cooling mode, wherein energy is expended by operating a compressor. However, when the outside temperature is low, the free cooling systems may be run in the free-cooling mode, wherein the outside ambient air itself may be utilized to provide cooling to the working fluid without engaging the compressor. Free cooling systems are disclosed in patent documents WO2008/079118A1, WO2008/079138A1, WO2008/079116A1, WO2009/038552A1. These systems comprise a condenser, a compressor, an evaporator, an expansion device and a pump; in the cooling mode, the compressor works and the pump is bypassed, while in the free-cooling mode the pump works and the compressor is bypassed. However, these systems have the drawback that they may be operated only in the cooling mode or, alternatively, in the free-cooling mode: if the outside temperature is not low enough to activate the free-cooling mode, the free-cooling concept may not be exploited, namely the outside ambient air may not be utilized to provide cooling. Thus, these systems have limited efficiency and flexibility. Moreover, the pump requires an energy expense and further limits the efficiency of the system in the free-cooling mode.

[0003] The evaporator of the free-cooling systems of the above cited documents have no specific requirements. However, special evaporators called "flooded evaporators" are known, for example from patent document CN103925747A. The flooded evaporator of such document includes: a housing, having an inlet on its bottom, for receiving liquid, and an outlet at its top, to release gas; a plurality of heat exchange tubes disposed in a housing; a distributor plate, arranged into the housing at its bottom, to avoid liquid discharge phenomenon; a retaining fluid plate arranged into the housing at its top, to prevent liquid drops to be released together with the gas (in fact, typically downstream of the evaporator a compressor is provided, and a presence of liquid drops in the gas results in cavitation inside the compressor, which is harmful for the compressors components). However, the distributor plate and the retaining fluid plate produce pressure drops in the refrigeration circuit, which limit the performance of the refrigeration cycle.

[0004] Scope of the present invention is to provide an evaporator, a cooling system and a method for cooling which overcomes at least one of the aforementioned drawbacks.

[0005] This scope is achieved by the apparatus and a method according to the appended claims.

[0006] According to one aspect of the present description, it regards a cooling system for cooling water. More generally, it regards a cooling system for cooling a fluid (such as water or air). In the following, we will refer to the fluid that is cooled by the system with the term "water"; however, the description applies, mutatis mutandis, to a system configured for cooling another fluid (such as air).

[0007] In an embodiment, the cooling system comprises a refrigeration circuit. The refrigeration circuit is configured for circulating a refrigerant fluid.

[0008] In an embodiment, the cooling system comprises an evaporator. The evaporator is configured for providing a heat exchange between the refrigerant fluid (flowing in the refrigeration circuit) and the water to be cooled.

[0009] In an embodiment, the cooling system comprises a compressor. The compressor is configured for compressing the refrigerant fluid (flowing in the refrigeration circuit). Preferably, the compressor is positioned in the refrigeration circuit downstream of the evaporator.

[0010] In an embodiment, the cooling system comprises a condenser. The condenser is configured for providing a heat transfer from the refrigerant fluid (flowing in the refrigeration circuit) to ambient air. The condenser, preferably, is positioned in the refrigeration circuit downstream of the compressor.

[0011] In an embodiment, the cooling system comprises an expansion device. The expansion device is configured for expanding the refrigerant fluid. The expansion device, preferably, is positioned in the refrigeration circuit upstream of the evaporator.

[0012] Preferably, the cooling system comprises an additional evaporator (further to the evaporator above disclosed). The additional evaporator is configured to provide a heat exchange between the refrigerant fluid and water to be cooled. Specifically, in the additional evaporator, the heat is transferred from the water to the refrigerant fluid, resulting in an evaporation of the refrigerant fluid and a cooling of the water. Preferably, the additional evaporator is provided in the refrigeration circuit downstream of the condenser. Preferably, the additional evaporator includes an outlet for feeding the refrigerant fluid back to the condenser, so as to bypass the compressor. In fact, the outlet of the additional evaporator is connected to an inlet of the condenser. In this way, the compressor is bypassed. Also, preferably, the expansion device is bypassed. Also, preferably, the evaporator is bypassed.

[0013] Therefore, two pathways for the refrigerant fluid are provided in the refrigeration circuit: in a first pathway (traditional cooling mode), the refrigerant fluid flows (successively) through the evaporator, the compressor, the condenser and the expansion device, from which it is fed again to the evaporator, in a second pathway (free-cooling mode), the refrigerant fluid flows through the additional evaporator, from which it is fed to the condenser, from which it is fed again to the additional evaporator and so on.

[0014] If the ambient air has a sufficiently low temperature, the fluid may entirely be circulated through the second pathway (free-cooling mode), while if the ambient air has not a sufficiently low temperature, the fluid may be circulated partly through the first pathway and partly through the second pathway (in a hybrid mode, partly traditional cooling and partly free-cooling), or entirely through the first pathway (traditional cooling mode).

[0015] In this light, the object solution is aimed at providing a system which can exploit the free cooling concept, even in a situation where the outside temperature is not low enough to completely operate the system in a free-cooling mode; hence, the object solution allows to reduce the energy consumption of the compressor in such a situation.

[0016] In an embodiment, the additional evaporator includes a liquid zone. In an embodiment, the additional evaporator includes a vapor zone. The fluid coming from the condenser, being in a liquid phase, is received in the liquid zone. In fact, the additional evaporator includes an inlet which is provided at the liquid zone.

[0017] In the additional evaporator, the refrigerant fluid is evaporated, absorbing heat from the water that is cooled. The evaporating refrigerant fluid migrates from the liquid zone towards the vapor zone. The vapor zone is provided above the liquid zone (along the vertical direction parallel to the weight force). Thus, in the vapor zone, the refrigerant fluid is in a vapor phase (in particular, a saturated vapor phase).

[0018] The outlet of the additional evaporator is provided at the vapor zone. The outlet of the additional evaporator is connected to the inlet of the condenser, for feeding the refrigerant fluid in the vapor phase back to the condenser. Therefore, the refrigerant fluid is condensed in the condenser, passing to the liquid phase, and is fed again to the liquid zone of the additional evaporator.

[0019] In an embodiment, the additional evaporator has an additional outlet in the liquid zone. In an embodiment, the additional outlet is provided in a bottom of the additional evaporator. The additional outlet is connected to the evaporator, for feeding to the evaporator the refrigerant fluid in the liquid phase. In an embodiment, the additional outlet of the additional evaporator is connected to the evaporator through the expansion device.

[0020] Therefore, when the system is operated in the traditional cooling mode, the refrigerant fluid in the liquid phase coming from the condenser is received in the additional evaporator, and exits the additional evaporator (in the liquid phase) through the additional outlet. The additional evaporator may thus work as a liquid receiver.

[0021] In an embodiment, the additional evaporator further includes an economizer outlet. The economizer outlet is provided at the vapor zone. The economizer outlet is connected to an economizer branch that is connected directly to the compressor. The refrigerant fluid from the economizer outlet is fed to the compressor in the vapor phase, in order to cool it down. Specifically, when the system is operated in the traditional cooling mode, the refrigerant fluid that is received into the liquid receiver (namely the additional evaporator) may be in a saturated liquid phase, and may partially evaporate in the liquid receiver, producing a small amount of refrigerant fluid in the vapor phase (saturated gas). This refrigerant fluid in the vapor phase (saturated gas) it extracted from the liquid receiver through the economizer outlet and is fed to the compressor.

[0022] In an embodiment, the additional evaporator includes a shell. The shell delimits an internal volume for containing the refrigerant fluid. The inlet of the additional evaporator is open to the internal volume. The outlet, the additional outlet and the economizer outlet are, also, in communication with the internal volume.

[0023] In an embodiment, the liquid zone is provided at a lower portion of the shell and the vapor zone is provided ad an upper portion of the shell. The upper portion of the shell is at a higher level (along the vertical direction, parallel to the weight force) with respect to the lower portion of the shell (liquid zone).

[0024] In an embodiment, the additional evaporator includes a plurality of pipes.

[0025] The plurality of pipes may form a set of pipes. The plurality of pipes passes through the internal volume. The plurality of pipes may comprise a plurality of sets (that is, sub sets) of pipes. Preferably, the plurality of pipes includes a first sub set of pipes passing through the liquid zone and a second sub set of pipes passing through the vapor zone. The set of pipes is configured for circulating water to be cooled. The set of pipes is configured for cooling down the water flowing there through.

[0026] In an embodiment, the additional evaporator is a flooded evaporator.

[0027] In an embodiment, the system comprises a first controlled valve. In an embodiment, the first controlled valve is a (motorized) ball valve. In an embodiment, the first controlled valve is partialized. The outlet of the additional evaporator is connected to an inlet of the condenser through the first controlled valve, to regulate the flow of refrigerant fluid passing there through. In an embodiment, the first controlled valve is operable in an open position (or configuration) and in a closed position (or configuration). In the following, the open configuration may be referred also as "first open configuration". In the (first) open configuration, the first controlled valve allows the refrigerant fluid to flow from the outlet of the flooded evaporator to the inlet of the condenser.

[0028] In an embodiment, the first controlled valve is also operable in a second open configuration, which allows the refrigerant fluid to flow from the inlet of the condenser to the outlet of the flooded evaporator.

[0029] In an embodiment, the cooling system comprises a second controlled valve. In an embodiment, the second controlled valve is a (motorized) ball valve. The compressor has an outlet which is connected to the inlet of the condenser through the second controlled valve, to control (regulate) the flow of refrigerant fluid passing there through. In an embodiment, the second controlled valve is operable in an open position and in a closed position. In the closed position, the second controlled valve prevents a flow of refrigerant fluid back to the outlet of the compressor.

[0030] In an embodiment, the cooling system comprises a control unit. In an embodiment, the control unit is programed for controlling the first controlled valve. In an embodiment, the control unit is programed for controlling the second controlled valve.

[0031] In an embodiment, the expansion device is an expansion valve. The expansion valve is operable in a closed configuration and in an open configuration. In an embodiment, the control unit is programed for controlling the expansion valve.

[0032] The control unit is programmed to operate the system in a free-cooling mode. In the free-cooling mode the first controlled valve is in the (first) open position and the second controlled valve is in the closed position (to avoid a migration of the refrigerant fluid to the compressor in the free-cooling mode). In an embodiment, the free-cooling mode, the expansion valve is in the closed configuration, to prevent a flow of the refrigerant fluid in the liquid phase from the flooded evaporator towards the evaporator. Therefore, in the free-cooling mode, the refrigerant fluid (which has condensed in the condenser) is fed to the additional evaporator, where it evaporates, and then is fed again to the condenser.

[0033] The control unit is programmed to operate the system in a (traditional) cooling mode. In the (traditional) cooling mode the first controlled valve is in the closed position and the second controlled valve is in the open position. In an embodiment, in the (traditional) cooling mode the expansion valve is in the open configuration. Therefore, in the traditional cooling mode, the additional evaporator works as a mere liquid receiver: the refrigerant fluid in the liquid phase, from the condenser, is fed to the expansion valve (passing through the liquid receiver) and then, from the expansion valve is fed to the evaporator (to cool down the water flowing through the evaporator).

[0034] In an embodiment, the control unit is programmed to operate the system in a hybrid cooling mode. In the hybrid cooling mode, the first controlled valve is in the open position and the second controlled valve is, also, in the open position. In an embodiment, in the hybrid cooling mode the expansion valve is in the open configuration. Therefore, in the hybrid cooling mode, the refrigerant fluid in the liquid phase, from the condenser, is fed to the additional evaporator; in the additional evaporator, part of the refrigerant fluid evaporates and exiting from the outlet of the additional evaporator is fed back to the condenser, while the remaining part of the refrigerant fluid exiting from the additional outlet of the additional evaporator is fed to the expansion valve and then to the evaporator. The partition of the refrigerant fluid between the outlet and the additional outlet is possible thanks to an appropriate dimensioning of the additional evaporator (specifically, of the internal volume and of the pipes) and appropriate partialisation of the first controlled valve and the second controlled valve.

[0035] Hence, preferably, the control unit is configured to control the first and second controlled valve, to operate the system in the free-cooling mode, in the cooling mode and in the hybrid mode. These features allow an automated operation of the cooling system in said free-cooling mode, in cooling mode and hybrid mode.

[0036] In an embodiment, the control unit is programmed to operate the system in a heat recovery mode (by opening both the first controlled valve and the second controlled valve). Preferably, in the heat recovery mode, the first controlled valve is in the second open configuration and the second controlled valve is in the open position. In an embodiment, in the heat recovery mode, the expansion valve is in the open configuration. Therefore, in the heat recovery mode, the refrigerant fluid in the vapor phase (coming from the compressor) is fed to the additional evaporator through the outlet, and the additional evaporator works as a condenser, thus the refrigerant fluid exits the additional evaporator in the liquid phase through the additional outlet. The compressor, in the heat recovery mode, is working. The water flowing through the evaporator is cooled; on the contrary, the water flowing through the pipes of the additional evaporator is warmed. In the heat recovery mode, the condenser may be bypassed or, more in general, may work in parallel to the heat exchanger. This heat recovery mode is useful if there is a request for cooling a flow of water and, in the meantime, a request for warming another flow of water. In this connection, it is observed that the system, in the heat recovery mode, may work in (at least) two (sub)modes: (i) in a first mode, the heat exchanger works in parallel with the condenser; (ii) in a second mode, the condenser is bypassed and only the heat exchanger operates as condenser.

[0037] In an embodiment, the additional evaporator is arranged, with respect to the condenser, at a lower level, in such a way as to allow the refrigerant fluid to move from the condenser to the additional evaporator by piezometric lift. Therefore, in the free-cooling mode, no pump is required to circulate the refrigerant fluid. In fact, the refrigerant fluid in the liquid phase moves from the condenser to the additional (flooded) evaporator by effect of the piezometric lift, and the refrigerant fluid in the vapor phase naturally migrates from the additional (flooded) evaporator to the condenser (in fact, a gas naturally moves from a warmer zone to a cooler zone, and the evaporator is warmer than the condenser). This circulation is possible because of the bypass branch (that connects the outlet of the additional evaporator directly to the inlet of the condenser), which, bypassing the compressor, the evaporator and the expansion device, minimizes the pressure drops.

[0038] However, in a possible embodiment, the circulation is not achieved by means of the piezometric lift, but the system includes a liquid pump (arranged downstream of the condenser and upstream of the additional evaporator) to circulate the refrigerant fluid from the outlet of the condenser to the inlet of the additional evaporator.

[0039] In an embodiment, the cooling system includes a water circuit for circulating the water to be cooled. The water circuit passes through the evaporator. In an embodiment, the water circuit also passes through the additional evaporator. In an embodiment, water is circulated through the additional evaporator and, then, through the evaporator. In an embodiment, a water outlet of the additional evaporator, for releasing the water out of the additional evaporator, is connected to a water inlet of the evaporator, for guiding said water to the evaporator. So, water may be subjected to a first cooling step in the free-cooling mode (until a temperature compatible with the outside air temperature) and, then to a second cooling step in the (traditional) cooling mode (until the temperature desired, thanks to the energy supplied to the compressor).

[0040] The present description also relates to a method for cooling water.

[0041] In an embodiment, the method comprises a step of circulating a refrigerant fluid in a refrigeration circuit.

[0042] In an embodiment, the method comprises a step of evaporating the refrigerant fluid by transferring heat from water to be cooled to the refrigerant fluid, in an evaporator.

[0043] In an embodiment, the method comprises a step of compressing the (evaporated) refrigerant fluid, through a compressor.

[0044] In an embodiment, the method comprises a step of condensing the refrigerant fluid, through transferring heat from the refrigerant fluid to ambient air, in a condenser. The condenser is provided downstream of the compressor.

[0045] In an embodiment, the method comprises a step of expanding the (condensed) refrigerant fluid, through an expansion device.

[0046] In an embodiment, the method comprises an additional step of evaporating the refrigerant fluid, by transferring heat from water to be cooled to the refrigerant fluid, through an additional evaporator. In an embodiment, the additional evaporator receives the refrigerant fluid from the condenser. The method also includes a step of feeding the refrigerant fluid from the condenser (directly) to the additional evaporator.

[0047] In an embodiment, the method comprises a step of feeding the refrigerant fluid coming out of the additional evaporator back to the condenser, so as to bypass the compressor.

[0048] In an embodiment, the additional step of evaporating comprises generating a vapor phase of the refrigerant fluid (by transferring heat from the water to the refrigerant fluid, in the additional evaporator). In an embodiment, the additional step of evaporating comprises separating the vapor phase of the refrigerant fluid and a liquid phase of the refrigerant fluid. In an embodiment, in the feeding step the refrigerant fluid being in the vapor phase is fed from the additional evaporator to the condenser.

[0049] In an embodiment, the method comprises a step of supplying the refrigerant fluid being in the additional evaporator in the liquid phase to the evaporator (through the expansion device).

[0050] The present description also regards a flooded evaporator. In an embodiment, the flooded evaporator comprises a shell, delimiting an internal volume, and a plurality (or set) of pipes passing through the internal volume. In an embodiment, the flooded evaporator includes an inlet and an outlet. The inlet is provided at a lower portion of the shell, to receive a refrigerant fluid in a liquid phase. The outlet is provided at an upper portion of the shell, to release the refrigerant fluid in a vapor phase. The flooded evaporator is configured to provide a heat transfer from the fluid circulating in the plurality (or set) of pipes (preferably, water) to the refrigerant fluid flowing from the inlet to the outlet of the flooded evaporator. In an embodiment, the flooded evaporator comprises an additional outlet, provided at the lower portion of the shell, to release the refrigerant fluid in the liquid phase.

[0051] In an embodiment, the internal volume of the shell includes an upper volume delimited by the upper portion of the shell and by the plurality of pipes. The outlet is open to the upper volume. Therefore, no plate (upper cap) for collecting drops is arranged between the plurality of pipes and the upper portion of the shell (such as in traditional flooded evaporators). This feature allows a reduction of the pressure drops, resulting in a higher performance.

[0052] In an embodiment, the internal volume of the shell includes a lower volume delimited by the lower portion of the shell and by the plurality of pipes. The inlet is open to the lower volume. The additional outlet is open to the lower volume. Therefore, no distributor is provided between the lower portion of the shell and the plurality of pipes (such as in traditional flooded evaporators). This feature allows a reduction of the pressure drops.

[0053] In an embodiment, the inlet has a size which is equal to a size of the additional outlet. Thus, the flooded evaporator may efficiently work as a liquid receiver because the flow rate of the liquid that enters into the additional evaporator (through the inlet) may be equal to the flow rate of the liquid that exits the additional evaporator (through the additional outlet).

[0054] In an embodiment, the flooded evaporator comprises an economizer outlet. The economizer outlet is provided at the upper portion of the shell, to release the refrigerant fluid in the vapor phase.

[0055] The system may also be different from the one of the preferred embodiments above described. For example, the cooling system may include a single evaporator (which may be a flooded evaporator or a plate type evaporator or another type of evaporator), having an inlet for the liquid refrigerant fluid coming from the condenser at the liquid zone, and an outlet at the vapor zone. In the traditional cooling mode, the fluid coming from the condenser passes through the expansion device, then through the evaporator, then through the compressor and finally is fed back to the condenser. In the free cooling mode, the fluid coming from the condenser is directly fed to the evaporator (preferably through a branch that bypasses the expansion device, in order to reduce the pressure drops), and then is directly fed back to the condenser (through a branch that bypasses the compressor). In this embodiment, provided that the evaporator is located at a sufficiently lower level with respect to the condenser and the pressure drops are sufficiently low (thanks to the bypasses), the fluid may circulate in the free-cooling mode without the provision of a pump, thanks to the piezometric lift. However, in this embodiment, the traditional cooling mode and the free-cooling mode are alternative.

[0056] In another embodiment, the system may comprise the condenser and a single evaporator (which may be a flooded evaporator), without any compressor neither expansion valve. Preferably, the condenser is at a higher level with respect to the evaporator. In this embodiment the system is only operable in the free-cooling mode (if the outside temperature is low enough). With respect to a single heat exchanger that directly exchanges heat between the water to be cooled and ambient air, this system (having a refrigeration circuit with an evaporator, in which water is cooled, and a condenser, in which the refrigerant fluid is condensed releasing heat to ambient air), has the benefit that it is glycol-free (since glycol is necessary to prevent icing of the water in the single heat exchanger).

[0057] These and other features of the invention will become more apparent from the following detailed description of a preferred, non-limiting example embodiment of it, with reference to the accompanying drawings, in which:

- Figure 1 schematically illustrates a cooling system according to the present description, in a hybrid cooling mode;
- Figure 2 illustrates the cooling system of figure 1 in a free-cooling mode;
- Figure 3 illustrates the cooling system of figure 1 in a traditional cooling mode;
- Figure 4 illustrates the cooling system of figure 1 in a heat recovery mode;
- Figures 5A e 5B schematically illustrates a flooded evaporator of the cooling system of figure 1, in a longitudinal section view and in a cross-section view, respectively;
- Figure 6 shows the flooded evaporator of figures 5A e 5B, in a perspective view;
- Figure 7 shows a plurality (a set) of pipes of the flooded evaporator of figures 5A e 5B.

[0058] With reference to the accompanying drawings, the numeral 1 denotes a cooling system.

[0059] The cooling system 1 comprises a refrigeration circuit.

[0060] The cooling system 1 comprises an evaporator 2. The evaporator 2, in a possible embodiment, is a plate-type heat exchanger. The evaporator 2 has an inlet 21 for receiving refrigerant fluid (in the liquid phase). The evaporator 2 has an outlet 22 for releasing the refrigerant fluid (in the vapor phase). The evaporator 2 has a water inlet 25 for receiving water to be cooled. The evaporator 2 has a water outlet 26 for releasing the water that has been cooled by releasing heat to the refrigerant fluid.

[0061] The cooling system 1 comprises a compressor 3. In an embodiment, the cooling system 1 comprises a couple of compressors 3. The compressor 3 has an inlet 31 for receiving the refrigerant fluid coming from the outlet 22 of the evaporator. The compressor 3 has an outlet 32 for releasing the compressed refrigerant fluid.

[0062] The cooling system 1 comprises a condenser 4. The condenser 4 has an inlet 41 for receiving refrigerant fluid. The inlet 41 of the condenser 4 receives the refrigerant fluid (being in the vapor phase) from the outlet 32 of the compressor 3. The condenser 4 is configured to condense the refrigerant fluid by releasing heat to ambient air. The condenser 4, in an embodiment, includes a plurality of air fans 43 configured for forcing ambient air. The condenser 4 has an outlet 42 for releasing the refrigerant fluid in the liquid phase.

[0063] In an embodiment, the cooling system 1 comprises a second controlled valve 72, between the outlet 32 of the compressor 3 and the inlet 41 of the condenser 4. The second controlled valve 72, preferably, is an on/off valve (which has only two possible operating positions: closed and open). Operatively, the second controlled valve 72 is open when the compressor 3 is ON, and is closed when the compressor 3 is OFF.

[0064] The cooling system includes an additional evaporator 6. The additional evaporator 6 is formed as a flooded evaporator 6. The additional evaporator 6 has an inlet 61 for receiving the refrigerant fluid from the outlet 42 of the condenser 4 (in the liquid phase). The additional evaporator has an outlet 62 for releasing the refrigerant fluid.

[0065] The additional evaporator 6 includes a shell 60. The shell 60 delimits an internal volume.

[0066] The shell 60 includes an upper portion 601 and a lower portion 602. The upper portion 601 is located above the lower portion 602, along a vertical direction V (parallel to the weight force). In an embodiment, the shell 60 has a cylindrical shape elongated along a longitudinal direction L. The longitudinal direction L is perpendicular to the vertical direction V. In an embodiment, the upper portion 601 and the lower portion 602 has a semicircular cross section.

[0067] The inlet 61 is located at a lower portion 602 of the shell 60. The outlet 62 is located at an upper portion 601 of the shell 60.

[0068] The additional evaporator 6 includes a plurality (or set) of pipes 67, that traverse the internal volume.

The pipes 67 are elongated along the longitudinal direction L. The pipes 67 are configured to circulate warm water that has to be cooled.

[0069] The internal volume includes a lower volume which is delimited by the lower portion 602 of the shell 60 and by the plurality (or set) of pipes 67 (or by a part of the pipes 67). The lower volume defines a liquid zone 68. The inlet 61 is open to the lower volume, to fill the liquid zone 68 with liquid refrigerant fluid.

[0070] The internal volume includes an upper volume which is delimited by the upper portion 601 of the shell 60 and by the plurality (or set) of pipes 67 (or by a part of the pipes 67). The upper volume defines a vapor zone 69. The outlet 62 is open to the upper volume, to collect the vapor refrigerant fluid from the vapor zone 69.

[0071] The additional evaporator 6 has a water inlet 65, for receiving water to be cooled.

[0072] In the additional evaporator 6, the water releases heat to the refrigerant fluid, resulting in an evaporation of the refrigerant fluid and a cooling of the water. The vapor, naturally, migrates above the liquid; thus, the refrigerant fluid naturally migrates from the liquid zone 68 to the vapor zone 69.

[0073] The additional evaporator 6 has a water outlet 66 for releasing the water that has been cooled.

[0074] In an embodiment, the water outlet 66 of the additional evaporator 6 is connected to the water inlet 25 of the evaporator 2. In this case, the water flows subsequently through the additional evaporator (for a first cooling) and then through the evaporator 2 (for a second cooling). In another embodiment, two distinct flows of water flow through the evaporator 2 and the additional evaporator 6.

[0075] The outlet 62 of the additional evaporator 6 is connected to the inlet 41 of the condenser 4, through a bypass branch that bypasses the compressor 3.

[0076] In an embodiment, the cooling system 1 comprises a first controlled valve 71 which is arranged in the bypass branch between the outlet 62 of the additional evaporator 6 and the inlet 41 of the condenser 4. The first controlled valve 71 may be an on/off valve (which has only two possible operating positions: closed and open) or may be a modulating valve (which is capable of a plurality of operating position, for modulating the flow of fluid passing there through).

[0077] A second conduit connects the second controlled valve 72 to the inlet 41 of the condenser 4. A first conduit connects the first controlled valve 71 to the inlet 41 of the condenser 4. In an embodiment, the first and the second conduit intersect at a junction 712.

[0078] In an embodiment, the additional evaporator includes an additional outlet 63. The additional outlet 63 is provided at the liquid zone 68 (for collecting refrigerant fluid in the liquid phase).

[0079] The cooling system 1 comprises an expansion device 5. The expansion device 5, in an embodiment, is an expansion valve. The expansion valve is operable in an open position and in a closed position.

[0080] The additional outlet 63 of the additional evaporator 6 is connected to the expansion device 5. The expansion device 5 receives the liquid refrigerant fluid from the additional evaporator 6, expands it and supplies it to the evaporator 2.

[0081] In an embodiment, the cooling system 1 comprises a filter 81. The filter 81 is arranged between the outlet 63 of the additional evaporator and the expansion device 5. Thus, the additional evaporator 6, having the outlet 62 connected to the inlet 41 of the condenser 4, provides a bypass for the expansion device 5, the evaporator 2 as well as for the filter 81.

[0082] In an embodiment, the cooling system 1 comprises an economizer outlet 64. The economizer outlet 64 is provided at the vapor zone 69 of the additional evaporator 6. The economizer outlet 64 is connected to an economizer branch, which ends into the compressor 3.

[0083] In an embodiment, the cooling system 1 comprises a third controlled valve 73. The third controlled valve is arranged in the economizer branch, between the economizer outlet 64 and the compressor 3.

[0084] The cooling system 1 comprises a control unit. The control unit controls the first controlled valve 71, the second controlled valve 72, the third controlled valve 73 and the expansion valve 5.

[0085] The control unit is configured to operate the cooling system 1 in a traditional cooling mode. In the traditional cooling mode, the control unit opens (or keeps open) the expansion valve 5 and the second controlled valve 72, and closes (or keeps closed) the first controlled valve 71. Preferably, the control unit in the traditional cooling mode also opens the third controlled valve 73.

[0086] The control unit is configured to operate the cooling system 1 in a free-cooling mode. In the free-cooling mode, the control unit opens (or keeps open) the first controlled valve 71 (in a first open configuration: to let the fluid flow from the outlet 62 of the additional evaporator 6 to the inlet 41 of the condenser 4) and closes (or keeps closed) the second controlled valve 72, the third controlled valve 73 and the expansion valve 5.

[0087] The control unit is configured to operate the system in a hybrid-cooling mode. In the hybrid-cooling mode, the control unit opens (or keeps open) the first controlled valve 71 (in the first open configuration), the second controlled valve 72 and the expansion valve 5. Preferably, in the hybrid-cooling mode, the control unit closes (or keeps closed) the third controlled valve 73.

[0088] The control unit is configured to operate the system in a heat recovery mode. In the heat recovery mode, the control unit opens (or keeps open) the expansion valve 5 and the second controlled valve 72 (such as in the traditional cooling mode); furthermore, the control unit opens (and keeps open) the first controlled valve 71, in a second open configuration, in which the refrigerant fluid (in the vapor phase) flows from the compressor 3 to the outlet 62 of the additional evaporator, entering the additional evaporator in the vapor phase (through the outlet 62); in this embodiment, the additional evaporator 6 works as a condenser, heating up the water that flows from the inlet 65 to the outlet 66 of the additional evaporator 6. The fact that the first controlled valve 71 operates in the first open configuration (in which the refrigerant fluid flows from the outlet 62 of the additional evaporator 6 to the compressor 3), or in the second open configuration (in which the refrigerant fluid flows from the compressor 3 to the outlet 62 of the additional evaporator 6) depends essentially on the external temperature; if the external temperature is lower than the temperature of the water in the additional evaporator 6, the first controlled valve 71 operates in the first open configuration (wherein the system may operate in the hybrid mode or in the free cooling mode); conversely, if the external temperature is higher than the temperature of the water in the additional evaporator 6, the first controlled valve 71 operates in the second open configuration (wherein the system may operate in the heat recovery mode).

[0089] In the heat recovery mode, the flow of fluid flowing through the second controlled valve 72 is divided (at the junction 712) into a first fluid portion, flowing through the condenser 4, and a second fluid portion, flowing through the first controlled valve 71 towards the (outlet of) the additional evaporator 6 (which acts as a condenser).

[0090] If the fans 43 of the condenser 3 are OFF and the first controlled valve 71 is full open, the first fluid portion is significantly lower than the second fluid portion; in this case, the first fluid portion is substantially negligible and the condenser is substantially bypassed.

[0091] According to an aspect of the present disclosure, it is possible to regulate the first fluid portion with respect to the second fluid portion. In order to achieve such a regulation, the following is observed.

[0092] The fans 43 of the condenser 4 may be turned on (and their speed may be controlled) by the control unit; the action of the fans 43 increases the first fluid portion with respect to the second fluid portion.

[0093] Alternatively, or in combination, the first controlled valve 71 may be a modulating valve, controlled by the control unit to regulate (to set) the relative amount of the second fluid portion.

[0094] It is also envisaged to add a further (fourth) control valve upstream the inlet of the condenser (downstream the junction 712); through this valve, it would be possible to force the whole amount of fluid to flow through the first controlled valve 71.

Claims

1. A cooling system (1) for cooling water, comprising:

- a refrigeration circuit, for circulating a refrigerant fluid;
- an evaporator (2), for providing a heat exchange between the refrigerant fluid and water to be cooled;
- a compressor (3), for compressing the refrigerant fluid downstream of the evaporator (2);
- a condenser (4), for providing a heat transfer from the refrigerant fluid to ambient air, downstream of the compressor (3);
- an expansion device (5), for expanding the refrigerant fluid downstream of the condenser (4),

characterized in that it further comprises an additional evaporator (6), configured to provide a heat exchange between the refrigerant fluid and water to be cooled, wherein the additional evaporator (6) is provided in the refrigeration circuit downstream of the condenser (4) and includes an outlet (62) for feeding the refrigerant fluid back to the condenser (4), so as to bypass the compressor (3).

2. The cooling system (1) of claim 1, wherein the additional evaporator (6) includes:

- a liquid zone (68), in which the refrigerant fluid is received from the condenser (4) in a liquid phase;
- a vapor zone (69), in which the refrigerant fluid is in a vapor phase;

wherein the outlet (62) is provided at the vapor zone (69) and is connected to an inlet (41) of the condenser, for feeding the refrigerant fluid in the vapor phase back to the condenser (4).

3. The cooling system (1) of claim 2, wherein the additional evaporator (6) has an additional outlet (63) in the liquid zone (68), for feeding to the evaporator (2) the refrigerant fluid in the liquid phase.

4. The cooling system (1) of claim 3, wherein the additional outlet (63) of the additional evaporator (6) is connected to the evaporator (2) through the expansion device (5).

5. The cooling system (1) of any of the previous claims from 2 to 4, wherein the additional evaporator (6) has an inlet (61) for receiving the refrigerant fluid from the condenser (4), wherein said inlet (61) is at the liquid zone (68).

6. The cooling system (1) of any of the previous claims from 2 to 5, wherein the additional evaporator (6) includes an economizer outlet (64), provided at the vapor zone (69) for feeding the refrigerant fluid in the vapor phase to the compressor (3).

7. The cooling system (1) of any of the previous claims from 2 to 6, wherein the additional evaporator (6) includes a shell (60) delimiting an internal volume for containing the refrigerant fluid and a plurality of pipes (67) passing through the internal volume and configured for circulating water to be cooled, wherein the liquid zone (68) is provided at a lower portion (602) of the shell (60) and the vapor zone (69) is provided at an upper portion (601) of the shell (60), which is at a higher level with respect to the liquid zone.

8. The cooling system (1) of any of the previous claims, wherein the additional evaporator (6) is a flooded evaporator.

9. The cooling system (1) of any of the previous claims, wherein one or both of the following conditions are verified:

i) the cooling system (1) comprises a first controlled valve (71), wherein the outlet (62) of the additional evaporator (6) is connected to an inlet (41) of the condenser (4) through the first controlled valve (71), to control the flow of refrigerant fluid passing there through;
ii) the cooling system (1) comprises a second controlled valve (72), wherein the compressor (3) has an outlet (32) which is connected to the inlet (41) of the condenser (4) through the second controlled valve (72).

10. The cooling system (1) of claim 9, comprising a control unit programed for controlling the first controlled valve (71) and the second controlled valve (72), to operate the system (1) in one or more of the following operating modes:

- in a free-cooling mode, by opening the first controlled valve (71) and by closing the second controlled valve (72);
- in a cooling mode, by opening the second controlled valve (72) and by closing the first controlled valve (71);
- in a hybrid mode or in a heat recovery mode, responsive to the external temperature being lower or higher than the water temperature in the additional evaporator (6), respectively, by opening both the first controlled valve (71) and the second controlled valve (72).

11. The cooling system (1) of claim 10, wherein one or both of the following conditions are verified:

i) the first controlled valve (71) is a modulating valve and the control unit is configured to control the controlled valve (71) to at least one intermediate operative configuration, further to an open configuration and a closed configuration;
ii) the condenser (4) includes a plurality of fans (43) and the control unit is configured to control said fans (43), in a heat recovery mode wherein both the first controlled valve (71) and the second controlled valve (72) are set in open configuration.

12. The cooling system (1) of any of the previous claims, wherein the additional evaporator (6) is arranged, with respect to the condenser (4), at a lower level, in such a way as to allow the refrigerant fluid to move from the condenser (4) to the additional evaporator (6) by piezometric lift.

13. The cooling system (1) of any of the previous claims, including a water circuit for circulating the water to be cooled through the evaporator (2) and through the additional evaporator (6), wherein a water outlet (66) of the additional evaporator (6), for releasing the water out of the additional evaporator (6), is connected to a water inlet (25) of the evaporator (2), for guiding said water to the evaporator (2).

14. A method for cooling water, comprising the following steps:

- evaporating a refrigerant fluid circulating in a refrigeration circuit, by transferring heat from water to be cooled to the refrigerant fluid, in an evaporator (2);
- compressing the evaporated refrigerant fluid, through a compressor (3);
- condensing the refrigerant fluid, through transferring heat from the refrigerant fluid to ambient air, in a condenser (4) which is provided downstream of the compressor (3);
- expanding the condensed refrigerant fluid, through an expansion device (5);

characterized in that the method further comprises:

- an additional step of evaporating the refrigerant fluid, by transferring heat from water to be cooled to the refrigerant fluid through an additional evaporator (6), which receives the refrigerant fluid from the condenser (4);
- a step of feeding the refrigerant fluid coming out of the additional evaporator (6) back to the condenser (4), so as to bypass the compressor (3).

15. The method of claim 14, wherein the additional step of evaporating comprises generating a vapor phase of the refrigerant fluid and separating said vapor phase from a liquid phase of the refrigerant fluid, wherein in the feeding step the refrigerant fluid being in the vapor phase is fed from the additional evaporator (6) to the condenser (4).

Fig.1

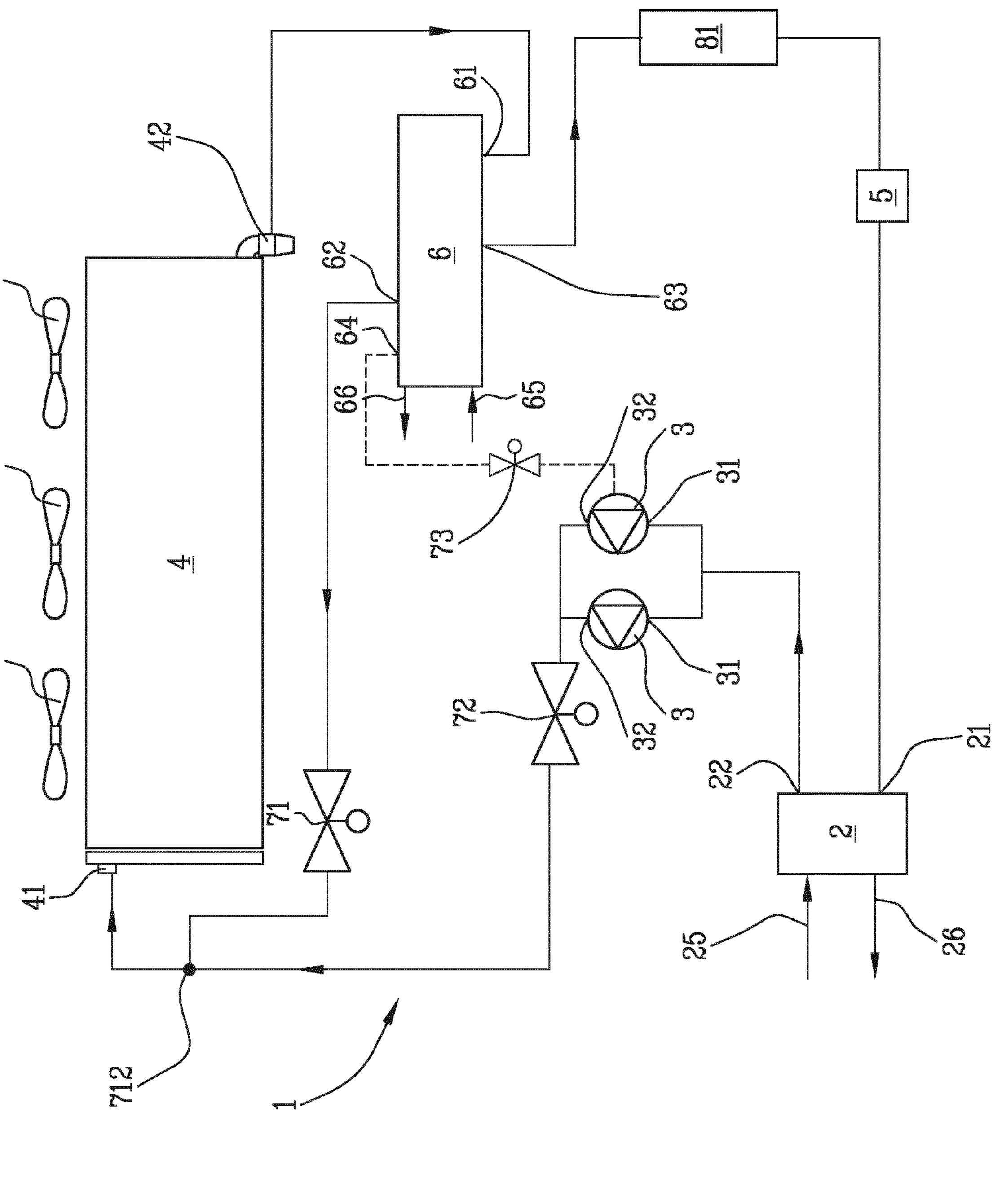


Fig.2

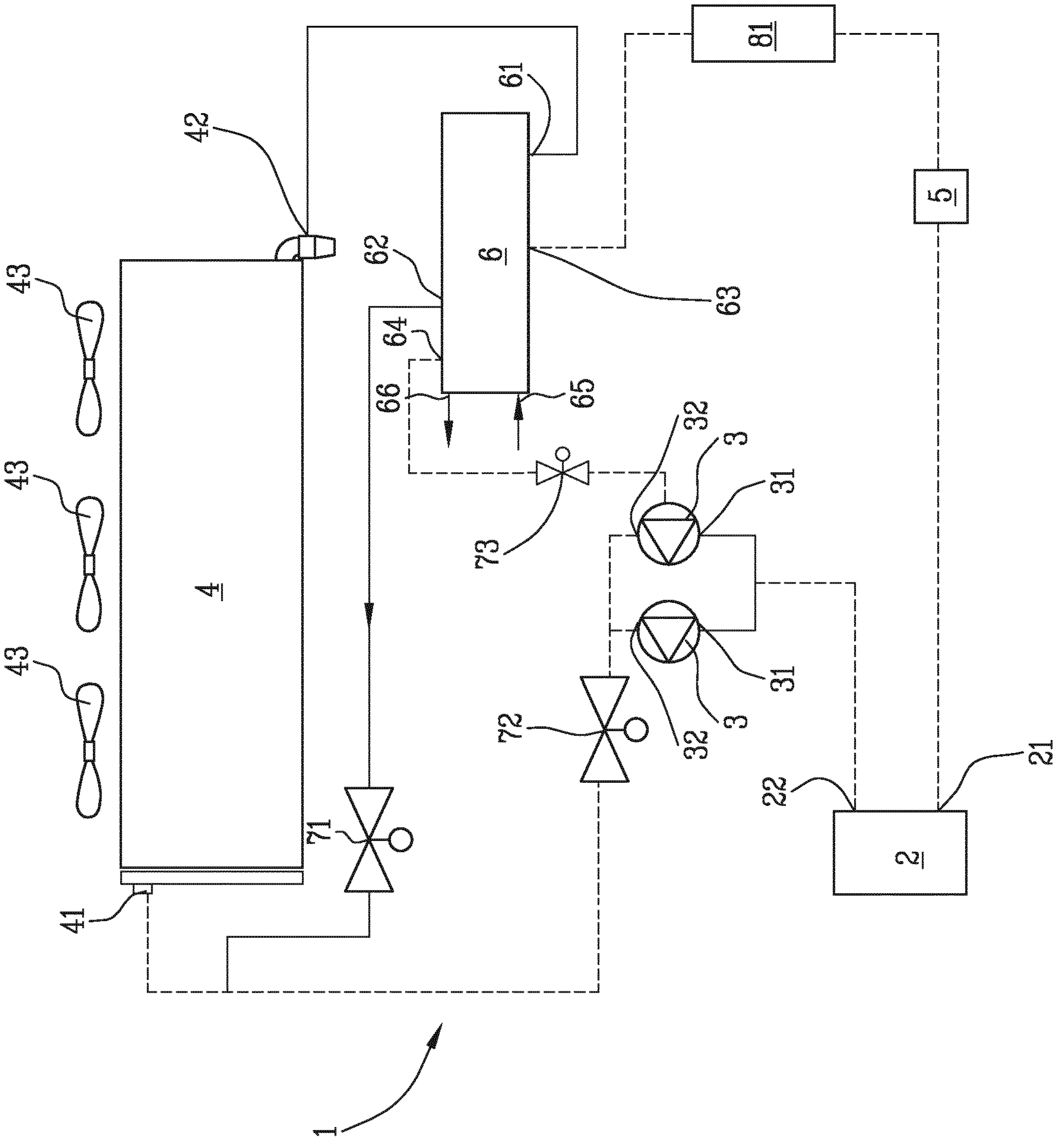


Fig.3

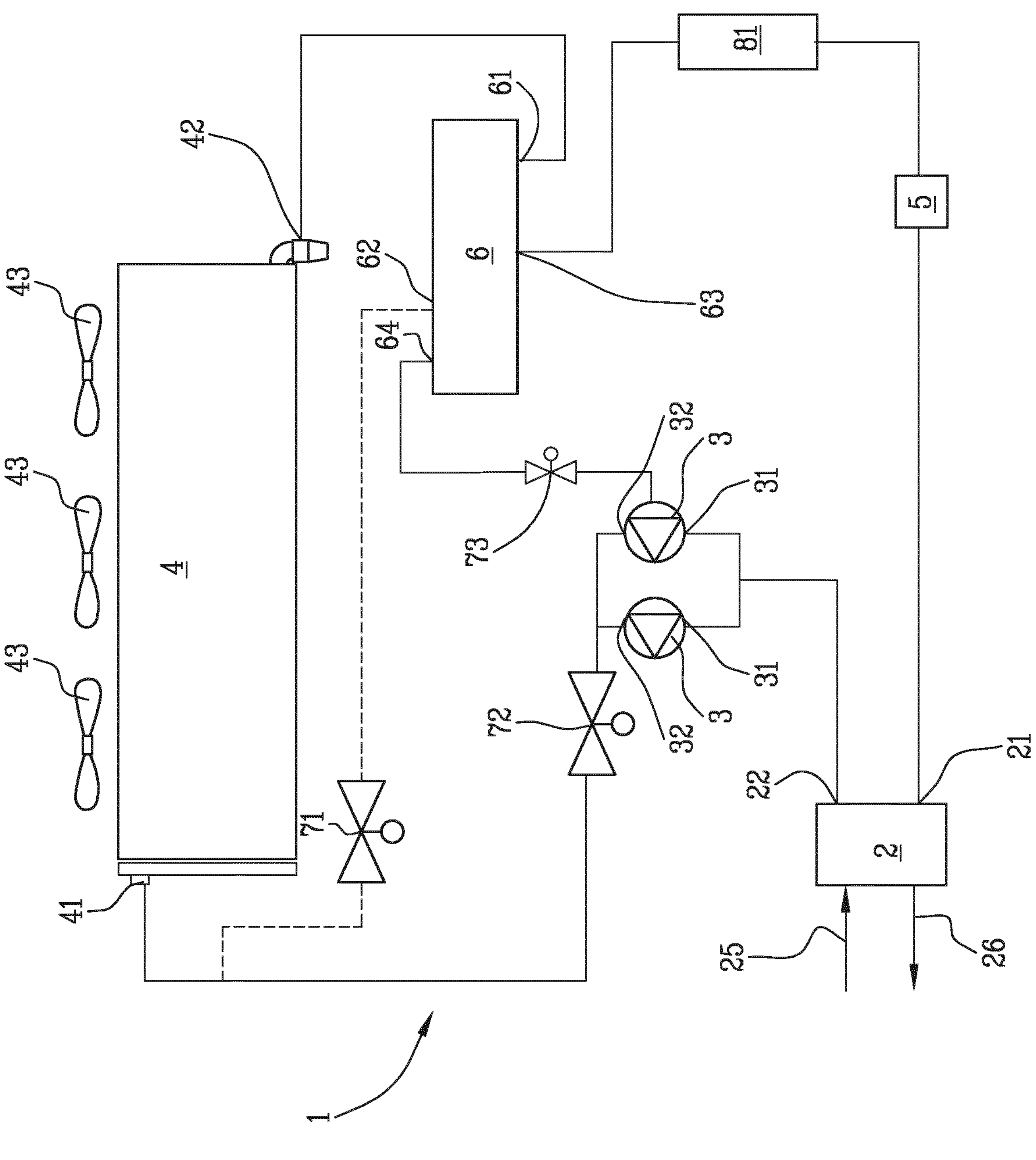


Fig.4

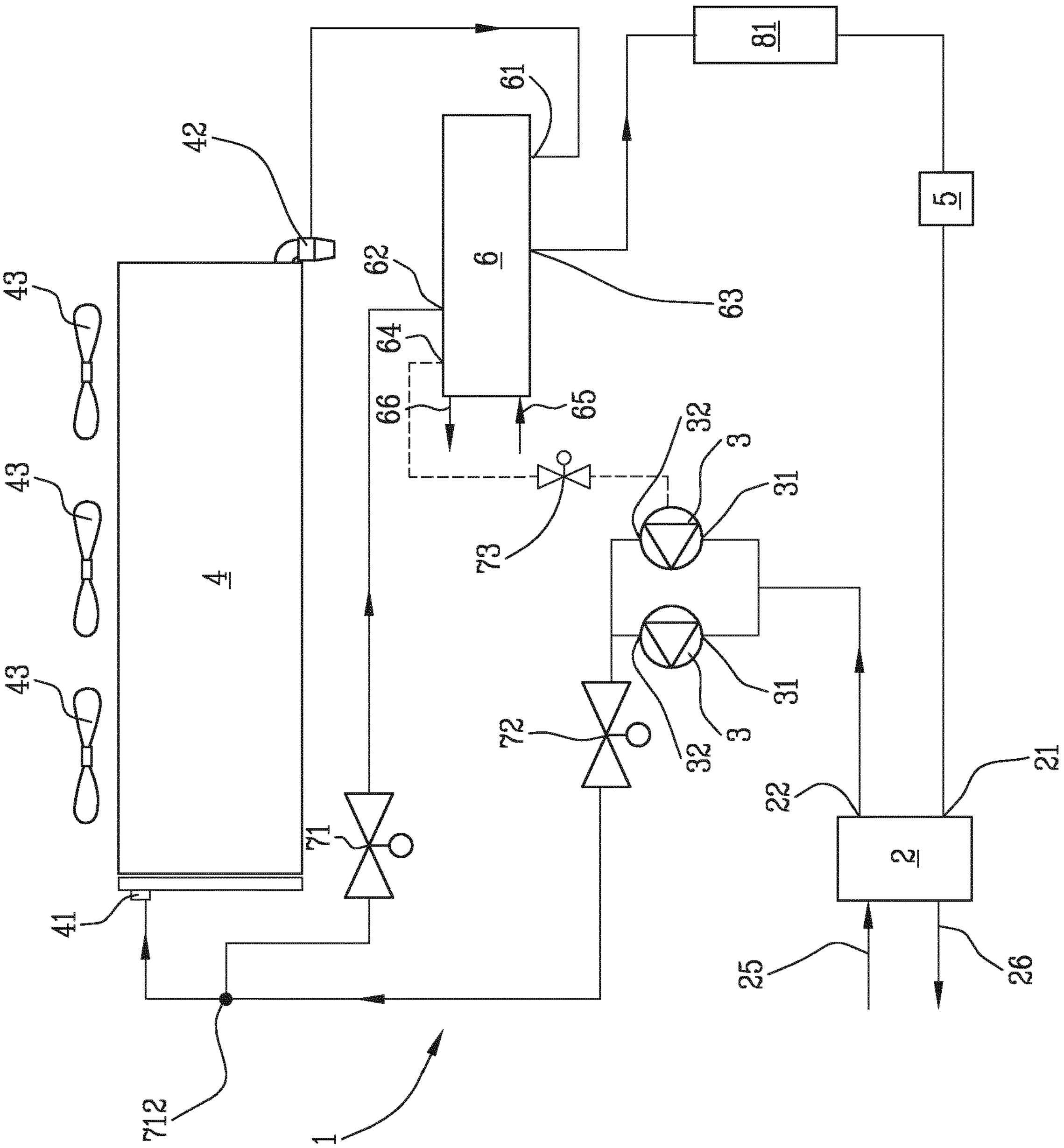


Fig.5B

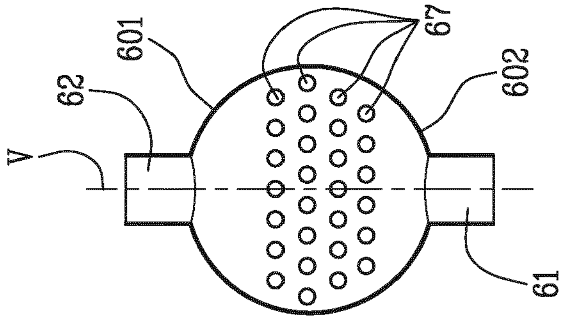
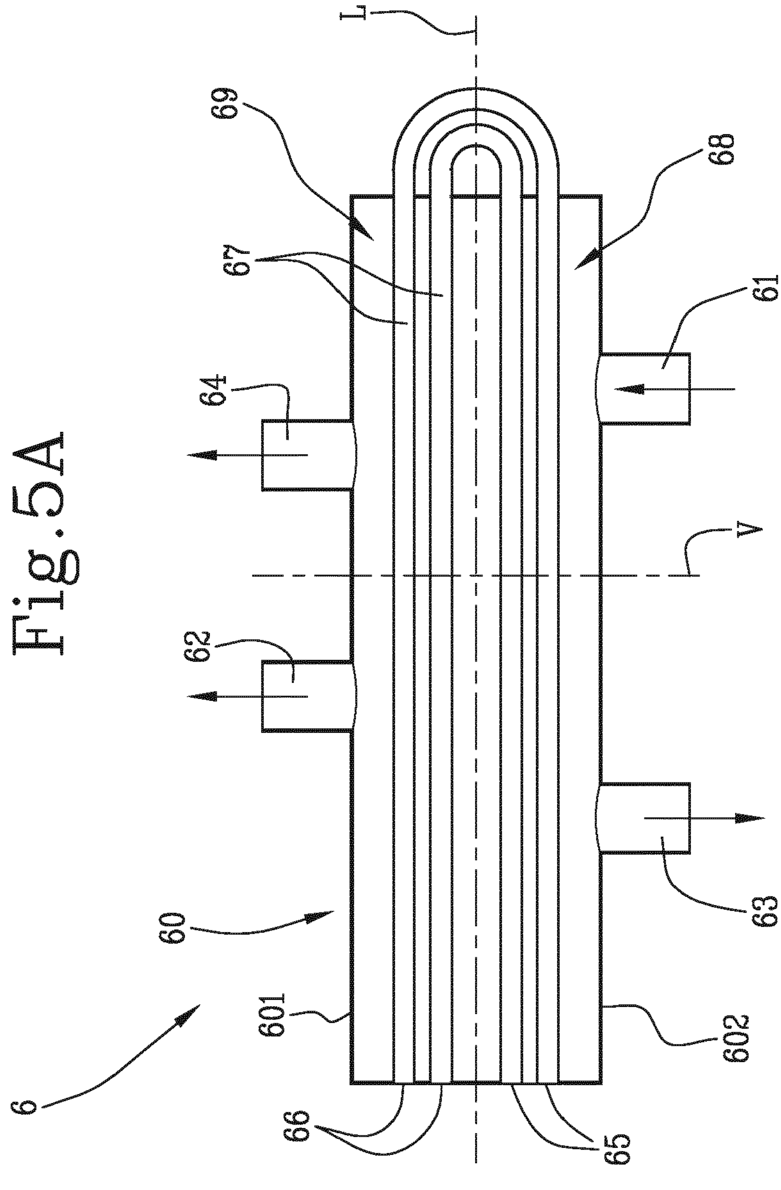


Fig.5A



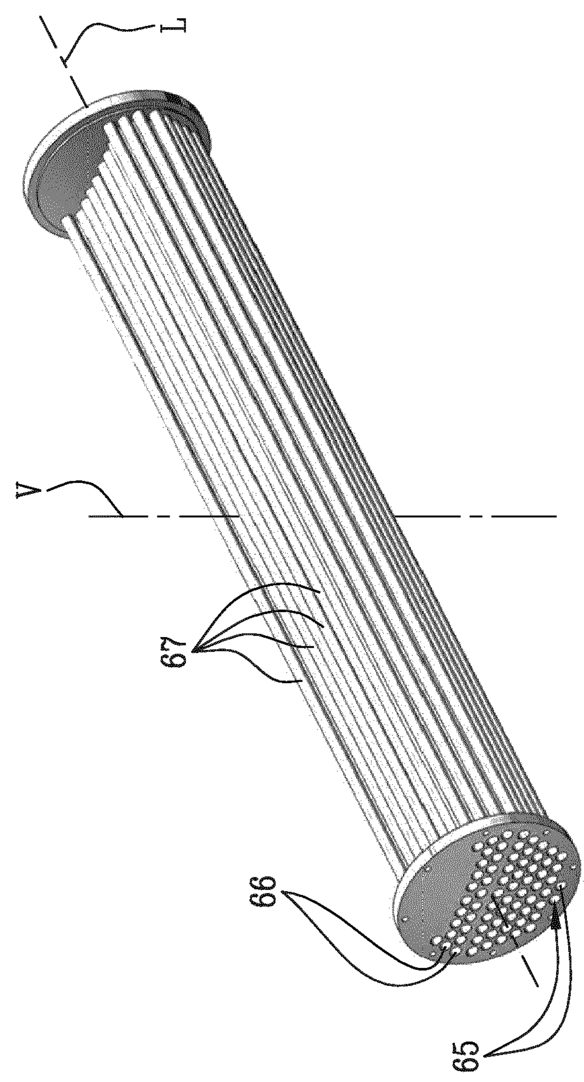


Fig.7

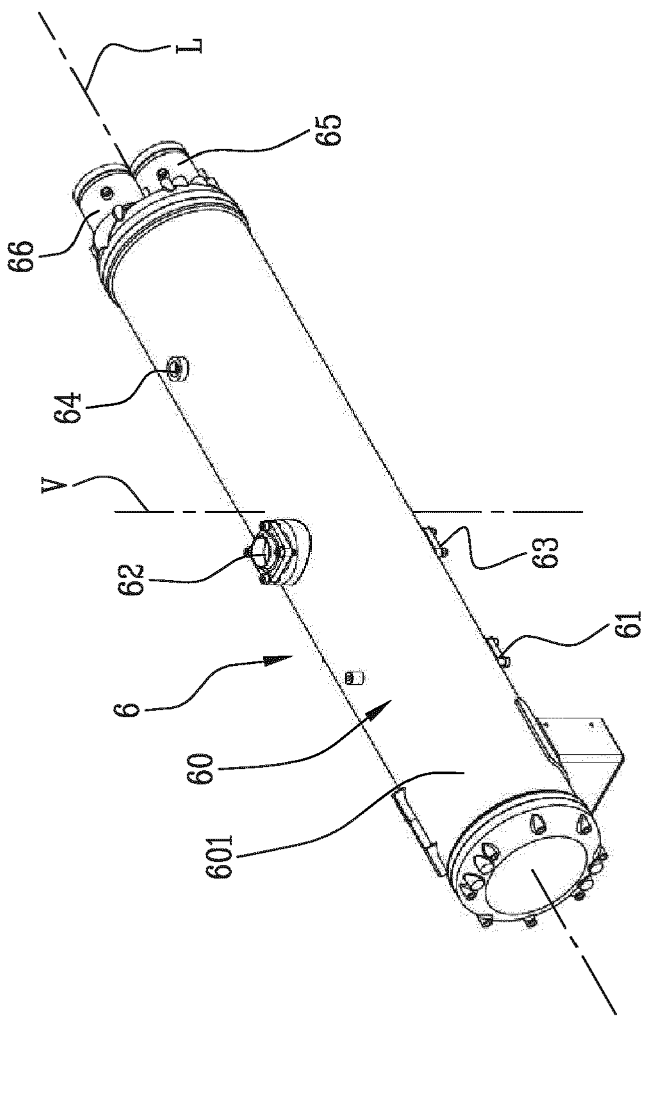


Fig.6

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EUROPEAN SEARCH REPORT

Application Number
EP 19 18 9380

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y A	GB 2 233 080 A (STAR REFRIGERATION [GB]) 2 January 1991 (1991-01-02) * page 6, line 10 - page 7, line 19; figure 2 * * page 2, line 12 - page 3, line 3 *	1-5,7-9, 12-15 6,10,11	INV. F25B25/00 F25B41/00 F25B5/04
Y A	JP H02 52959 A (EBARA CORP) 22 February 1990 (1990-02-22) * abstract; figure 1 *	1-5,7-9, 12-15 6,10,11	
A,D	CN 103 925 747 B (ZHUHAI GREE ELEC APPLIANCES) 24 August 2016 (2016-08-24) * the whole document *	1-15	
A	CN 106 440 437 A (NANJING CANATAL ENV TECH CO LTD) 22 February 2017 (2017-02-22) * abstract; figures *	1-15	
A	US 3 744 273 A (WARE C) 10 July 1973 (1973-07-10) * the whole document *	1-15	TECHNICAL FIELDS SEARCHED (IPC)
A	EP 1 505 357 A1 (MAEKAWA SEISAKUSHO KK [JP]) 9 February 2005 (2005-02-09) * paragraphs [0031] - [0040]; figure 1 *	1-15	F25B
A	US 2011/056664 A1 (DE LARMINAT PAUL [FR] ET AL) 10 March 2011 (2011-03-10) * the whole document *	1-15	

1

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	5 February 2020	Ritter, Christoph

CATEGORY OF CITED DOCUMENTS

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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05-02-2020

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 2233080 A	02-01-1991	NONE	
JP H0252959 A	22-02-1990	JP H0252959 A	22-02-1990
		JP H07122524 B2	25-12-1995
CN 103925747 B	24-08-2016	NONE	
CN 106440437 A	22-02-2017	NONE	
US 3744273 A	10-07-1973	CA 971764 A	29-07-1975
		US 3744273 A	10-07-1973
EP 1505357 A1	09-02-2005	CA 2485757 A1	20-11-2003
		DK 1505357 T3	12-01-2009
		EP 1505357 A1	09-02-2005
		JP 4018443 B2	05-12-2007
		JP 2003329317 A	19-11-2003
		US 2005284169 A1	29-12-2005
		WO 03095906 A1	20-11-2003
US 2011056664 A1	10-03-2011	CN 103069244 A	24-04-2013
		TW 201211479 A	16-03-2012
		US 2011056664 A1	10-03-2011
		WO 2012030359 A1	08-03-2012

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- GB 2233080 A **[0001]**
- JP H0252959 A **[0001]**
- WO 2008079118 A1 **[0002]**
- WO 2008079138 A1 **[0002]**
- WO 2008079116 A1 **[0002]**
- WO 2009038552 A1 **[0002]**
- CN 103925747 A **[0003]**