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(54) **COOLING SYSTEM WITH ADJUSTABLE INTERNAL HEAT EXCHANGER**

(71) Applicant: **EATON INTELLIGENT POWER LIMITED**, Dublin 4 (IE)

(72) Inventor: **Leonid WALTER**, Baden-Baden (DE)

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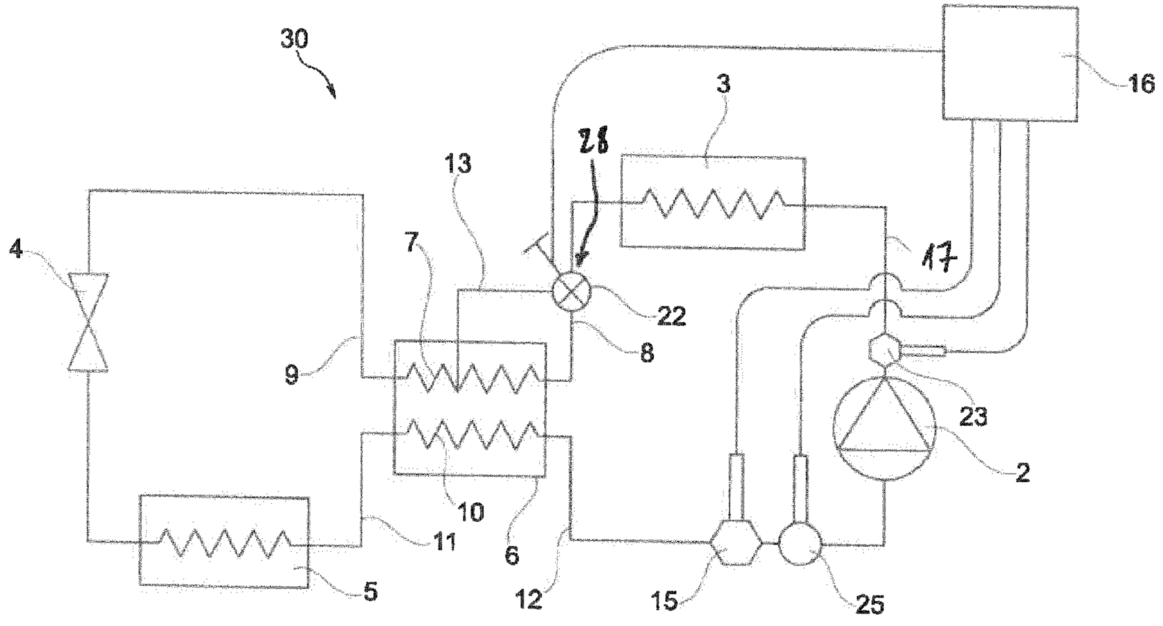
(57) **ABSTRACT**

A cooling system includes: connected in a loop by fluid lines and in succession, a compressor, a condenser, an expansion valve, and an evaporator; and an internal heat exchanger having a first conduit in heat exchanging contact with a second conduit, the first conduit being part of the fluid line between the condenser and the expansion valve and the second conduit being part of the fluid line between the evaporator and the compressor. A bypass fluid line is arranged between two ends of the first conduit of the internal heat exchanger or extends between one of the two ends of the first conduit and a position along a length of the first conduit.



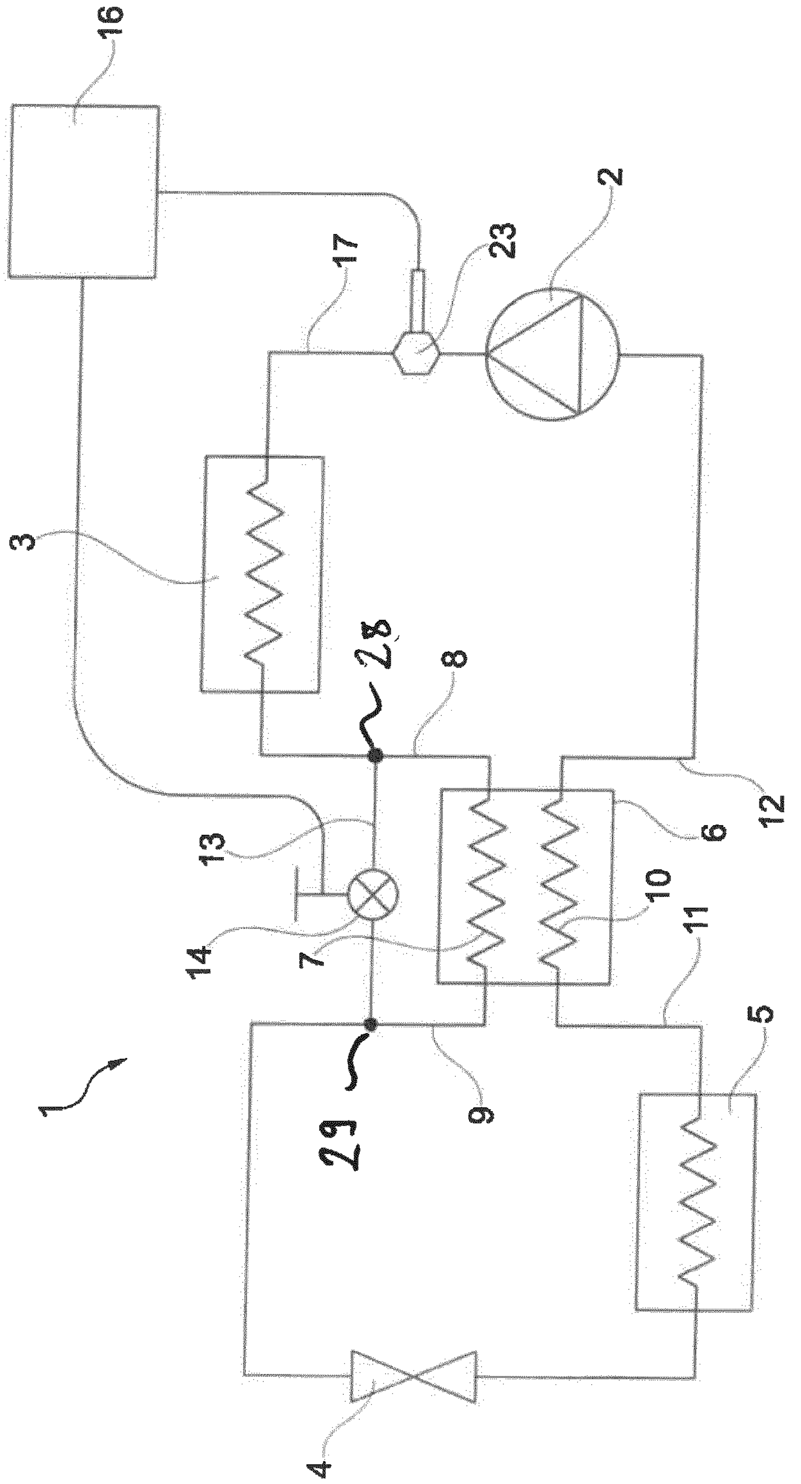


Fig. 1

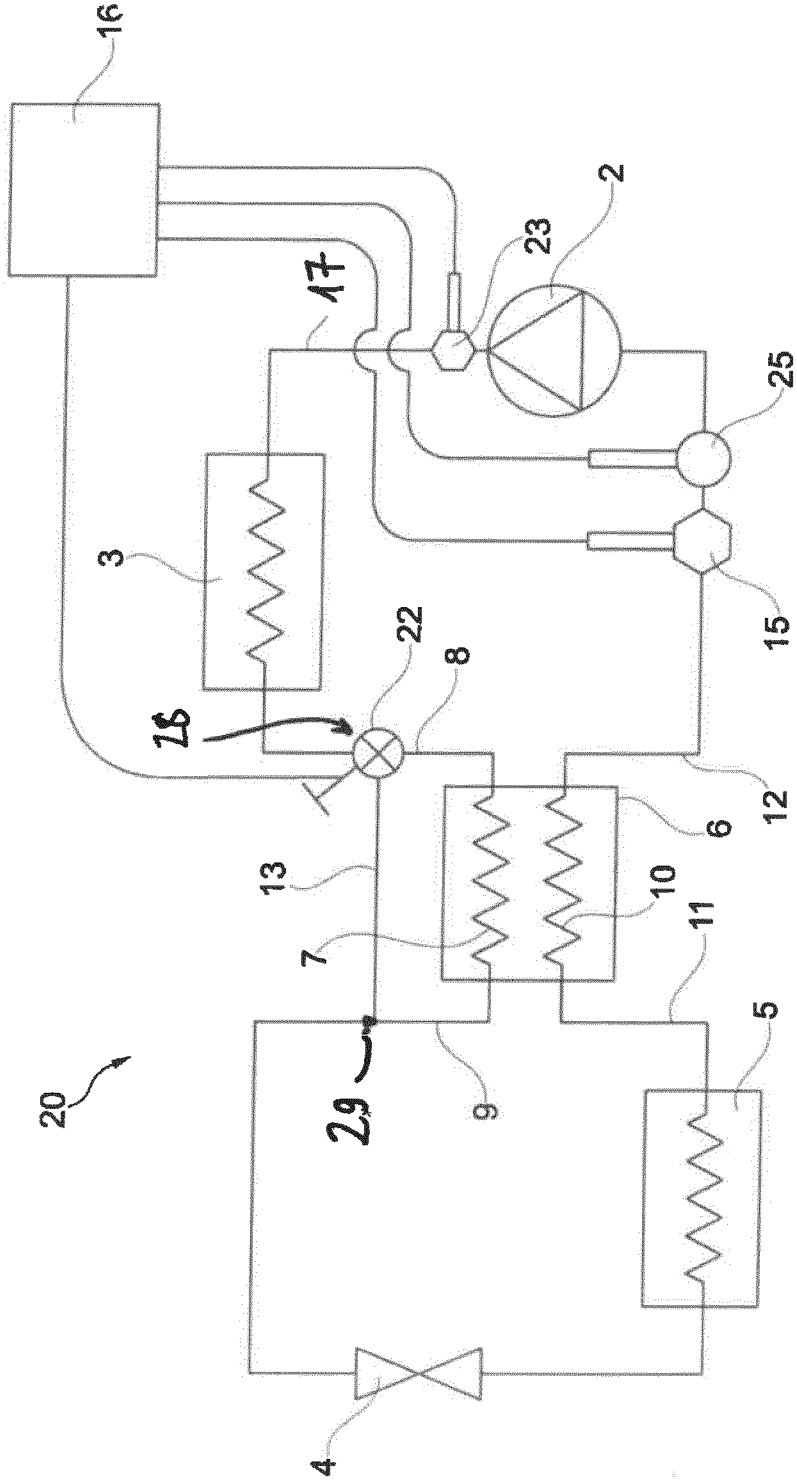


Fig. 2

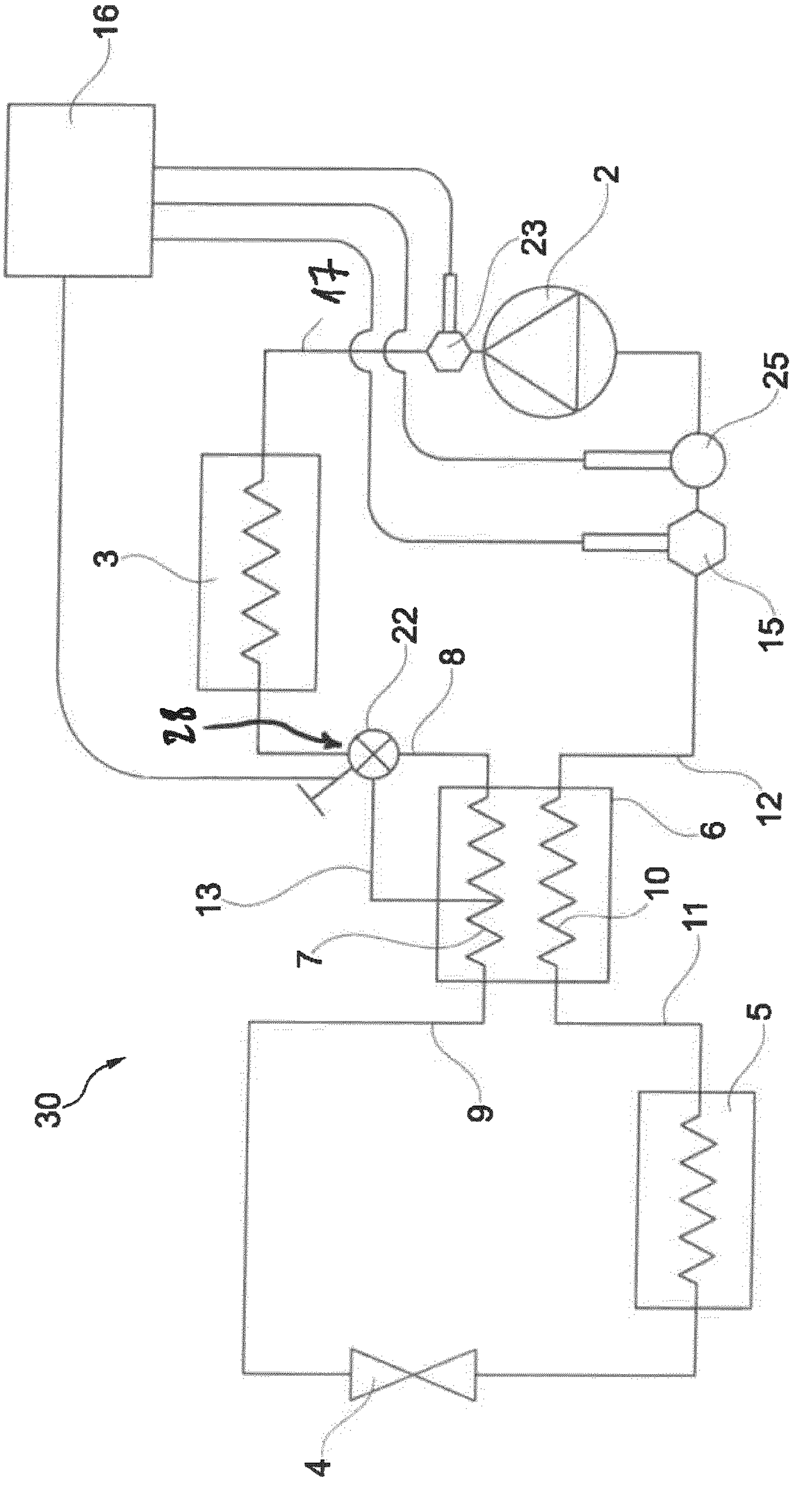


Fig. 3

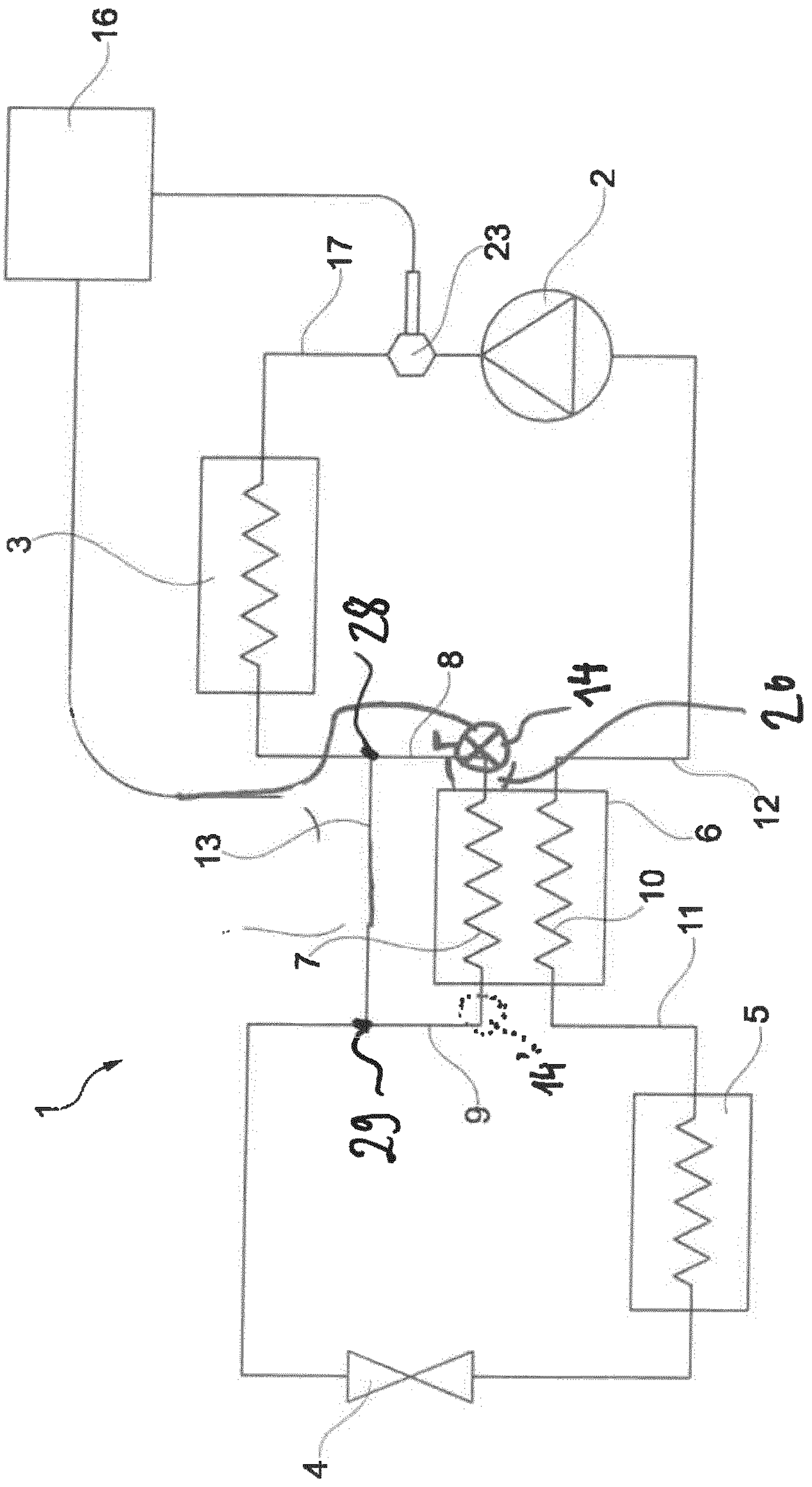
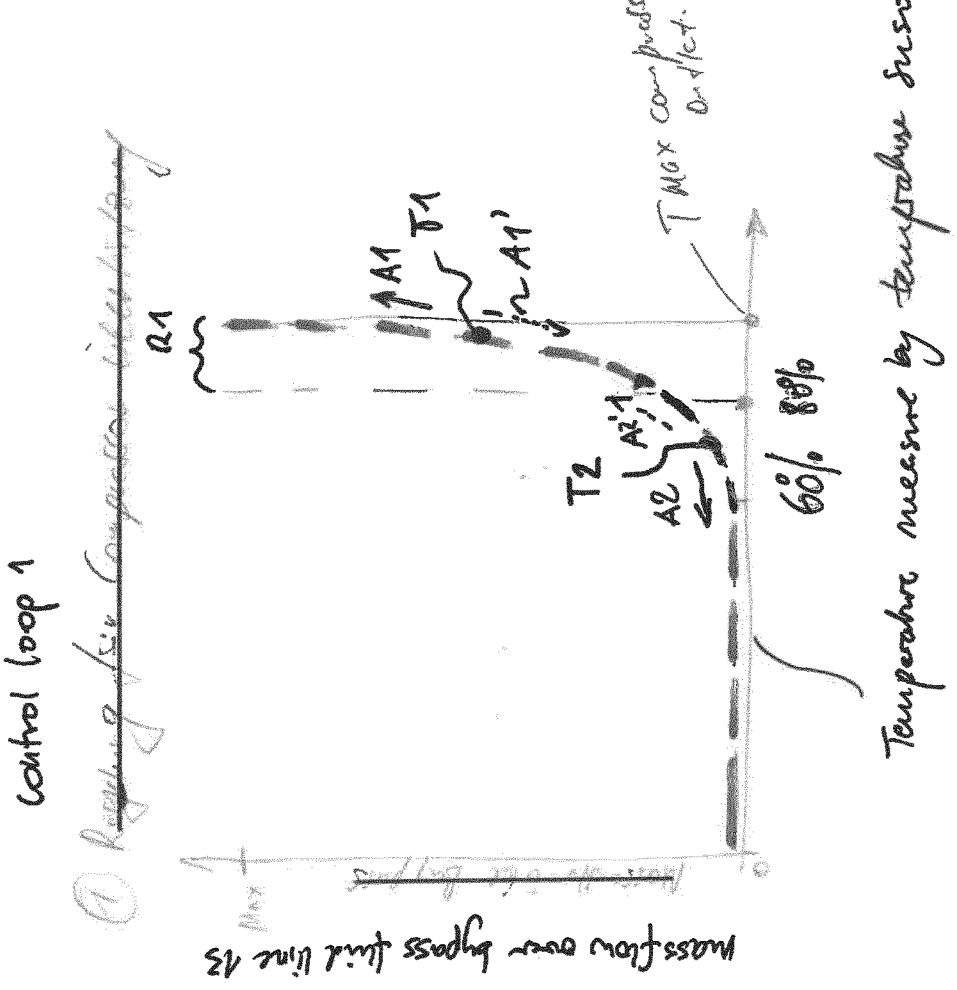


Fig.4

Fig. 5a


Control loop 1
massflow over bypass fluid line 13
max
0
Temperature measure by temperature sensor 23 (fig.2)
TMax compressor outlet
60%
80%
R1
A1
T1
A1'
A2
A2'
T2

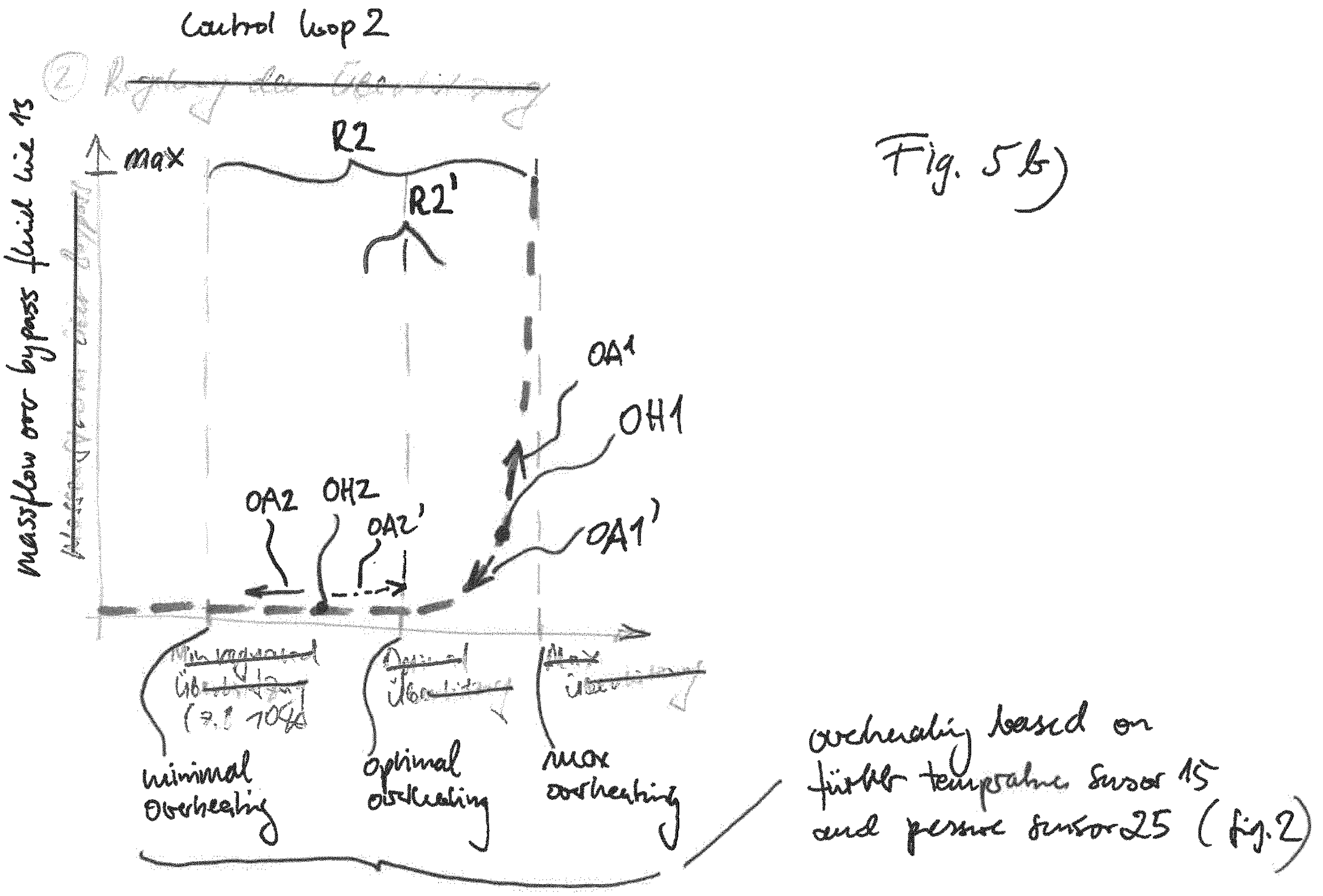

Control loop 2
~~② Regelung der Überhitzung~~
massflow over bypass fluid line 13
max
R2
R2'
OA1
OH1
OA1'
OA2
OH2
OA2'
~~Min. Überhitzung (z.B. 10K)~~
~~Optimal Überhitzung~~
~~Max Überhitzung~~
minimal Overheating
optimal overheating
max overheating
overheating based on further temperature sensor 15 and pressure sensor 25 (fig. 2)

Fig. 5b)

COOLING SYSTEM WITH ADJUSTABLE INTERNAL HEAT EXCHANGER

CROSS-REFERENCE TO PRIOR APPLICATIONS

[0001] This application is a U.S. National Phase application under 35 U.S.C. § 371 of International Application No. PCT/EP2017/064200, filed on Jun. 9, 2017, and claims benefit to British Patent Application No. GB 1610120.6, filed on Jun. 10, 2016. The International Application was published in English on Dec. 14, 2017 as WO 2017/212058 under PCT Article 21(2).

FIELD

[0002] The invention relates to a cooling system comprising, connected in a loop by fluid lines and in succession, a compressor, a condenser, an expansion valve and an evaporator, further comprising an internal heat exchanger having a first conduit in heat exchanging contact with a second conduit, wherein the first conduit is part of the fluid line between the condenser and the expansion valve and wherein the second conduit is part of the fluid line between the evaporator and the compressor.

BACKGROUND

[0003] Such a cooling system is for example known from EP 1043550. This publication describes a cooling system in which a fluid, in particular CO2 is used, which is made super-critical in the high pressure line between the compressor and the expansion valve. Due to the cooling effect of the condenser, the pressure in the high pressure line could vary. Especially, dependent on the ambient temperature. In cold weather, the fluid in the high pressure line would be cooled down to a far lower temperature, than in hot weather. This results in a different pressure in the high pressure line depending on the ambient temperature. This change in pressure has an adverse effect on the COP (coefficient of performance) of the cooling cycle.

[0004] EP 1043550 proposes to provide a bypass channel around the low-pressure line of the internal heat exchanger, i.e. between the evaporator and the compressor. The bypass channel is provided with a controllable valve, which is controlled based on the pressure in the high pressure line to ensure, that the fluid, in particular CO2, is kept at the optimal pressure. So, if the pressure rises in the high pressure line, the bypass channel is closed, such that the fluid in the high pressure line can be cooled down with the internal heat exchanger and accordingly lower the pressure in the high pressure line. On the other hand, if the pressure falls, the bypass channel is opened, such that the fluid in the high pressure line is not cooled further by the internal heat exchanger resulting in a higher pressure.

[0005] An internal heat exchanger (IHX) exchanges heat between the warm high pressure side and the cold suction side. Generally, the usage of an internal heat exchanger in a refrigeration cycle has a positive effect on mainly two physical values, the cooling capacity and the system efficiency (COP). The cooling capacity is mainly influenced by two factors, the refrigerant mass flow and the enthalpy difference in the evaporator.

[0006] The enthalpy difference is influenced by the cool down of the refrigerant on the high pressure side of the internal heat exchanger. The lower the temperature of the refrigerant at the high pressure side outlet of the IHX the bigger is the enthalpy difference in the evaporator, leading to increasing cooling capacity. At the suction side of IHX the refrigerant is heated up and dries out (drop lets of liquid refrigerant are evaporated in the IHX). This dry out has a positive effect on the compressor since the power consumption goes down. This additionally leads to a better COP value.

[0007] An additional potential positive effect is that the overheating of the evaporator could be partly moved into the IHX which enables the use of a larger portion of the evaporator surface for air cooling instead of overheating the refrigerant. In summary: The higher the available IHX heat transfer capacity would be the better the above mentioned positive effects could be exploited. This would help to provide better cooling capacity and a higher COP of the entire AC system.

[0008] However, increasing the IHX performance is limited by the maximum allowable gas temperature on the suction side of the compressor. The reason is that a higher suction side temperature increases the operating temperature in the compressor and as a consequence also the discharge temperature. The maximum allowable operating temperature is specified by compressor manufacturers and is the limiting factor. Therefore, the maximum compressor temperature is also limiting the maximum possible IHX performance.

[0009] Also the IHX performance of the base system is not flexible, IHX length, geometry and material are factors which determine the heat exchange capacity. These factors are fixed, but to provide optimal AC system performance in all changeable environments and drive conditions and also for different refrigerants used in one system (R134a/HFO1234yf) adaptable performance of the IHX is required.

SUMMARY

[0010] In an embodiment, the present invention provides a cooling system, comprising: connected in a loop by fluid lines and in succession, a compressor, a condenser, an expansion valve, and an evaporator; and an internal heat exchanger having a first conduit in heat exchanging contact with a second conduit, the first conduit being part of the fluid line between the condenser and the expansion valve and the second conduit being part of the fluid line between the evaporator and the compressor, wherein a bypass fluid line is arranged between two ends of the first conduit of the internal heat exchanger or extends between one of the two ends of the first conduit and a position along a length of the first conduit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The present invention will be described in even greater detail below based on the exemplary figures. The invention is not limited to the exemplary embodiments. Other features and advantages of various embodiments of the present invention will become apparent by reading the following detailed description with reference to the attached drawings which illustrate the following:

[0012] FIG. **1** shows a schematic view of a first embodiment of a cooling system according to the invention.

[0013] FIG. **2** shows a schematic view of a second embodiment of a cooling system according to the invention.

[0014] FIG. **3** shows a schematic view of a third embodiment of a cooling system according to the invention.

[0015] FIG. **4** shows a schematic view of a fourth embodiment of a cooling system according to the invention.

[0016] FIGS. **5***a* and **5***b* show a schematic view of a two diagrams governing a preferred embodiment of the method for controlling a cooling system according to the invention.

DETAILED DESCRIPTION

[0017] In an embodiment, the present invention reduces the above mentioned disadvantages.

[0018] In an embodiment, the present invention provides a cooling system, which cooling system is characterized in that a bypass fluid line arranged between the two ends of the first conduit of the internal heat exchanger.

[0019] Providing the bypass fluid line between the two ends of the first conduit and therefore in the high pressure or liquid line of the cooling system, allows for a direct control of the heat exchange in the IHX.

[0020] It also provides for the advantage that the pressure drop is limited. There is no significant pressure drop because of low flow speed of refrigerant in its liquid phase. With a bypass on the suction side, as known in the prior art, there is a risk of pressure drop due to bypass components and a corresponding negative impact on whole system.

[0021] The hose diameters on the liquid side of the system are smaller than on the suction side, therefore allowing for a more compact (smaller, hose, valve and more compact connectors) arrangement of the invention, for example in the engine compartment of a vehicle. This also results in lower production costs.

[0022] The invention has further the advantage, that it has no negative impact on noise, vibration, and harshness (NVH) behavior. Compared to a bypass solution on the suction side, the flow noise in a system according to the invention will not increase. The NVH behavior is already critical in conventional AC systems, because the evaporator often acts as a loud speaker.

[0023] With the invention, there is also no risk of oil accumulation. The oil transport through the cooling system is ensured by avoiding to create so called oil pockets since the oil is dissolved in the liquid. In the prior art, this is way more critical on the suction side where the refrigerant is in vapor phase. In such a case, the oil is typically swept along with the gas-phase refrigerant—a sufficient flow speed needs to be ensured, which would be at risk with a suction-side bypass solution.

[0024] Furthermore, a liquid phase bypass, as provided by the invention, offers improved flow control compared to a gas-phase (faster and turbulent flow) bypass, as known in the prior art, due to the lower flow speed (of the liquid) and more constant conditions.

[0025] In case an internal heat exchanger is used, a bypass can more easily be arranged and with a limited number of modifications, because the liquid side in the internal heat exchanger is typically the outside tube. This allows for example for connection of the by-pass channel along the length of the liquid line of the internal heat exchanger to provide a partial by-pass. Thus a bypass can easily be added where needed.

[0026] EP 1043550 discloses a method by controlling the heat transfer of the IHX by providing a bypass channel in the low pressure or suction line. With the bypass channel, the heat transfer of the IHX can be managed to control the pressure in the high pressure line.

[0027] As EP 1043550 requires that the pressure in the high pressure or liquid line is kept constant, a bypass channel cannot be provided in the high pressure line, as this would influence the pressure, when the bypass channel is opened or closed.

[0028] Therefore, EP 1043550 provides a bypass channel in the low pressure line, such that the heat exchange of the IHX is influenced, while the pressure in the high pressure line is not influenced directly by opening or closing the bypass channel. This is also the result of the state of the fluid in the low pressure line, which fluid has the gaseous state. The gaseous can easily be compressed, such that any influences of opening or closing the bypass channel has no substantial effect on the pressure in the low pressure line, let alone the pressure in the high pressure line.

[0029] With the invention, the bypass channel is arranged in the high pressure line, in which the fluid is liquid and provides easy control of the amount of liquid flowing through the IHX and through the bypass. So, although the pressure in the high pressure line may fluctuate, the control of the IHX is more direct with the bypass channel in the high pressure line, resulting in a better control of the temperature on the suction side of the compressor and according results in a longer lifespan of the compressor, while optimizing the COP.

[0030] A preferred embodiment of the cooling system according to the invention further comprises a controllable valve arranged in the bypass fluid line for controlling the amount of fluid flowing through the bypass fluid line. This amount of fluid flowing through the bypass fluid line and therefore not flowing through the IHX depends on the necessary amount of heat exchange needed for an optimal cooling system performance. In a preferred embodiment the controllable valve is a two way valve. In a further embodiment the controllable valve is a proportional valve. In a further embodiment the controllable valve is a proportional three way valve.

[0031] In a further embodiment of the cooling system according to the invention the controllable valve is a three way valve and is arranged either at the junction of the bypass fluid line and the fluid line between the condenser and the internal heat exchanger (inlet junction) or at the junction of the bypass fluid line and the fluid line between the internal heat exchanger and the expansion valve (outlet junction).

[0032] With the three way valve there is direct control possible of the amount of refrigerant flowing through the bypass line and the heat exchanger. If a two way valve is used in the bypass fluid line, then changing resistance in the internal heat exchanger will influence the ratio of the amount flowing through the bypass line and the internal heat exchanger.

[0033] A preferred embodiment of the cooling system according to the invention, further comprises a temperature sensor arranged in the fluid line between the compressor and the first conduit of the internal heat exchanger for controlling the controllable valve based on the temperature measured by the temperature sensor.

[0034] By continuously measuring the refrigerant temperature on the discharge line, i.e. the fluid line between the compressor and condenser, and corresponding control of the by-pass valve, it is possible to provide optimal IHX performance in all changeable environments and drive conditions, wherein the compressor is protected against overheating.

[0035] The coupling between the temperature sensor and the controllable valve could be a direct connection, using a thermostatically control. This is a mechanical connection, wherein typically a gas, expanding in the temperature sensor part is used to mechanically control a valve. However, it is preferred to have an electronic controller coupling the controllable valve and the temperature sensor, as this provides for more flexibility in the control strategy.

[0036] In a further preferred embodiment the temperature sensor arranged in the fluid line between the compressor and the first conduit of the internal heat exchanger is arranged between the compressor and the condenser, preferably directly after the compressor.

[0037] A further preferred embodiment of the cooling system according to the invention further comprises a temperature sensor arranged in the fluid line between the second conduit of the internal heat exchanger and the compressor and a control device connected to the temperature sensor and the controllable valve, for controlling the controllable valve based on the temperature measured by the temperature sensor.

[0038] Preferably, the cooling system further comprises a pressure sensor arranged in the fluid line between the second conduit of the internal heat exchanger and the compressor.

[0039] By both measuring the temperature and the pressure on the suction side of the compressor, it is possible to ensure that only gaseous refrigerant enters the compressor. This in turn allows for the superheating of the refrigerant, which typically is done in the evaporator, to be done in the internal heat exchanger. This enables the full capacity of the evaporator to be used for cooling air, while the internal heat exchanger will ensure the superheating of the refrigerant and accordingly ensure that only gaseous refrigerant enters the compressor.

[0040] In yet another embodiment also the expansion valve is controllable, such that all aspects of the cooling system can be controlled and optimal settings can be chosen depending on the circumstances.

[0041] In a preferred embodiment the cooling system filled with R134a or HFO1234yf as refrigerant. In a further preferred embodiment the cooling system is free of CO2.

[0042] In a further embodiment the fluid line between the condenser and the first conduit of the internal heat exchanger is permanently open.

[0043] In a further embodiment the bypass fluid line contains only a single controllable valve and/or the amount of fluid flowing through the bypass fluid line is controlled via a single controllable valve.

[0044] In a preferred embodiment the smallest diameter of the fluid line between the inlet junction and the first conduit of the internal heat exchanger can be larger than the largest diameter of the bypass fluid line. This has the advantage that the bypass fluid line can be dimensioned smaller, which saves cost.

[0045] In an alternative embodiment the smallest diameter of the bypass fluid line is larger than the largest diameter of the fluid line between the inlet junction and the first conduit of the internal heat exchanger.

[0046] In a further preferred embodiment the condenser is free of a branch-off. Preferably, the condenser comprises exactly one inlet and exactly one outlet. In a further preferred embodiment the first conduit of the internal heat exchanger and the expansion valve are connected solely via a single fluid line.

[0047] In a further preferred embodiment the controllable valve is integrated in a connecting flange of the internal heat exchanger.

[0048] In a further preferred embodiment the cooling system is free of any sensor in a fluid line between the condenser and the internal heat exchanger.

[0049] In an embodiment, the invention provides a method for controlling a cooling system according embodiments described above, comprising the steps:

[0050] measuring, preferably continuously, a fluid temperature of a refrigerant of the cooling system using a temperature sensor comprised by a fluid line between the compressor and the condenser, wherein the temperature sensor is preferably located close to or directly at the outlet side of the compressor,

[0051] controlling, proportionally to the fluid temperature measured by the temperature sensor, a mass flow of fluid passing through the internal heat exchanger by automatically actuating a controllable valve that is arranged to control the amount of fluid flowing through the bypass fluid line.

[0052] In a preferred embodiment the method includes the step:

[0053] beginning to proportionally reduce the mass flow of fluid passing through the internal heat exchanger by automatically actuating the controllable valve that is arranged to control the amount of fluid flowing through the bypass fluid line and corresponding, if the measured temperature after the compressor is shortly before exceeding a predefined temperature threshold or range and thereby reducing the heat exchange in the internal heat exchanger.

[0054] Preferably the control is designed such that no unsteady change in heat exchange occurs.

[0055] In a In an even further preferred embodiment the method includes the step:

[0056] beginning to proportionally increase the mass flow of fluid passing through the internal heat exchanger by automatically actuating the controllable valve that is arranged to control the amount of fluid flowing through the bypass fluid line and corresponding, if the measured temperature after the compressor starts to fall below the predefined temperature threshold or range and thereby increasing the heat exchange in the internal heat exchanger.

[0057] In a further preferred embodiment the method includes the steps:

[0058] measuring, preferably continuously, the fluid temperature and the pressure of the refrigerant of the cooling system using a further temperature sensor and a pressure sensor both of which are comprised by a fluid line between the second conduit of the internal heat exchanger and the compressor, wherein the further temperature sensor and the pressure sensor are preferably located close to or directly at the inlet side of the compressor;

[0059] continuously determining or calculating, based on the measurements of the further temperature sensor and a pressure sensor and using a controller, an overheating of the fluid;

[0060] In a further preferred embodiment the method includes the step:

- **[0061]** proportionally increasing the fluid mass flow through the bypass fluid line if the overheating of the fluid exceeds or is about to exceed a predefined overheating max overheating threshold or overheating range

[0062] In a further preferred embodiment the method includes the step:

- **[0063]** proportionally reducing the fluid mass flow through the bypass fluid line if the overheating of the fluid falls or is about to fall below the predefined max overheating threshold or overheating range.

[0064] In a further preferred embodiment the method includes the step:

- **[0065]** keeping the mass flow through the bypass fluid line steady close or equal to zero, if the continuously determined or calculated overheating remains on the predefined optimal overheating threshold or within the predefined overheating range.

[0066] FIG. **1** shows schematically a cooling system **1** comprising, connected in a loop by fluid lines and in succession, a compressor **2**, a condenser **3**, an expansion valve **4** and an evaporator **5**.

[0067] To further improve the cooling system **1**, an internal heat exchanger **6** is provided with a first conduit **7** arranged in the line **8**, **9** between the condenser **3** and the expansion valve **4**, and a second conduit **10** arranged in the line **11**, **12** between the evaporator **5** and the compressor **2**.

[0068] Furthermore, a bypass fluid line **13** with a controllable valve **14** is arranged between the line **8** and line **9**, i.e. between the two ends of the first conduit **7** of the internal heat exchanger **6**. The bypass fluid line **13** is arranged between an inlet junction **28** and an outlet junction **29**.

[0069] The fluid line **8** between the condenser **3** and the first conduit **7** of the internal heat exchanger **6** is permanently open. The first conduit **7** of the internal heat exchanger **6** and the expansion valve **4** are connected solely via the single fluid line **9**.

[0070] A temperature sensor **23** is arranged in the fluid line **17** between the compressor **2** and the condenser **3** to measure the discharge temperature of the refrigerant exiting the compressor **2**. The temperature sensor **23** is arranged between the compressor **2** and the condenser **3** close to the compressor **2**.

[0071] Both the controllable valve **14** and the temperature sensor **23** are connected to a controller **16**, such that the controllable valve **14** can be controlled based on the measured temperature in the fluid line **17**.

[0072] As can be seen from FIG. **1**, the bypass fluid line **13** contains only a single valve, that is the controllable valve **14**. The amount of fluid flowing through the bypass fluid line **13** is controlled only via this single controllable valve **14**.

[0073] The controllable valve **14** is a two way proportional valve. If the controllable valve **14** is closed (0% position) no fluid passes through the bypass fluid line **13**. The smallest diameter of the bypass fluid line **13** is larger than the largest diameter of the fluid line **8**, **9** between the inlet junction **28** and the outlet junction via the first conduit **7** ok

[0074] The fluid line **8** between the condenser **3** and the inlet junction **28** as well the fluid line **9** between the outlet junction **29** and the expansion valve is sufficiently large in diameter to transport the combined mass of fluid through the bypass fluid line **13** and the first conduit.

[0075] Therefore, if the controllable valve **14** is maximum open (100% position), the largest share of the fluid exiting the condenser **3** passes through the bypass fluid line.

[0076] Alternatively or additionally to designing the fluid line **8**, **9** between the inlet junction **28** and the outlet junction via the first conduit **7** comparatively smaller in diameter, a slight pressure drop via the first conduit **7** can be achieved by placing a throttle on the inlet or outlet side of the first conduit **7**, e.g. in a connecting flange **26** of the internal heat exchanger (see FIG. **6**).

[0077] In the exemplary embodiment shown in FIG. **1** the bypass fluid line **13** is embodied by a pipe with about (for example) 10 mm diameter, while fluid line **8** is embodied by a pipe with about (for example) 8 mm diameter. Other diameters are possible.

[0078] With the temperature sensor arranged in the high pressure line **17** directly after the compressor **2**, the discharge temperature can be controlled and accordingly allows for protecting the compressor **2** against overheating. The discharge temperature is influenced by the suction temperature, the compressor rpm and the power consumed by the compressor. So, also with this temperature sensor **23** being arranged after the compressor **2**, the compressor can be protected and the heat exchange capacity can be maximized and optimized.

[0079] FIG. **2** shows a second embodiment **20** of a cooling system according to the invention. The cooling system **20** is similar to the cooling system **1** of FIG. **1** and the same parts are referenced by the same reference signs.

[0080] In the embodiment **20**, the bypass fluid line **13** is provided at the junction of the fluid line **8** and the bypass line **13** with a controllable valve **22**. This provides for a better fluid control and allows for a direct control of the amount of refrigerant flowing through the bypass line **13** and the first fluid line **7** of the heat exchanger **6**.

[0081] Furthermore, the embodiment **20** comprises a second temperature sensor **15** arranged in the line **12** between the internal heat exchanger **6** and the compressor **2**. Also a pressure sensor **25** is arranged in the line **12** between the internal heat exchanger **6** and the compressor **2**. The second temperature sensor **15** and the pressure sensor **25** are arranged directly or close at/to the inlet side of the compressor **2**.

[0082] These additional sensors **15** and **25** provide for an improved control in comparison to the embodiment of FIG. **1** allowing for maximal optimization of the cooling system performance.

[0083] The pressure value measured by the sensor **25**, in combination with the temperature, measured by the temperature sensor **15**, in this line **12**, can be used to control the ideal refrigerant overheating before the compressor **2**. This provides for a higher COP and compressor protection, while making the partial outsourcing of refrigerant overheating from the evaporator **5** into the IHX **6** possible.

[0084] The use of a temperature sensor **15**, a temperature sensor just after the compressor **2** and a pressure sensor in the line **12**, can be combined in any configuration desired to provide optimal controllability and maximal possible optimization of the cooling system performance.

[0085] FIG. **3** shows a schematic view of a third embodiment of a cooling system according to the invention. This embodiment **30** is almost identical to the embodiment **20** as shown in FIG. **2**.

[0086] The difference is the arrangement of the bypass fluid line **13**, which not fully extends between the line **8** and line **9**, i.e. between the two ends of the first conduit **7** of the internal heat exchanger **6**. In this embodiment **30**, however, the bypass fluid line extends from the line **8** to a position along the length of the first conduit **7** of the internal heat exchanger **6**. This provides a partial bypass fluid line **13**.

[0087] As can be seen from FIGS. **2** and **3**, the amount of fluid flowing through the bypass fluid line **13** is controlled only via a single controllable valve **22**, which is a three way proportional valve defining the inlet junction **28**.

[0088] FIG. **4** shows schematically a cooling system **1** comprising, connected in a loop by fluid lines and in succession, a compressor **2**, a condenser **3**, an expansion valve **4** and an evaporator **5**.

[0089] To further improve the cooling system **1**, an internal heat exchanger **6** is provided with a first conduit **7** arranged in the line **8**, **9** between the condenser **3** and the expansion valve **4**, and a second conduit **10** arranged in the line **11**, **12** between the evaporator **5** and the compressor **2**.

[0090] Furthermore, a bypass fluid line **13** is arranged between the line **8** and line **9**, i.e. between the two ends of the first conduit **7** of the internal heat exchanger **6**. The first conduit **7** of the internal heat exchanger **6** and the expansion valve **4** are connected solely via the single fluid line **9**.

[0091] The controllable valve **14** in form of a proportional two way valve is placed, preferably directly, at the input side of the first conduit **7** of the internal heat exchanger **6**. Alternatively (shown dotted) a controllable valve **14'** can be placed, preferably directly, at the output side of the first conduit **7** of the internal heat exchanger **6**.

[0092] A temperature sensor **23** is arranged in the fluid line **17** between the compressor **2** and the condenser **3** to measure the discharge temperature of the refrigerant exiting the compressor **2**. The temperature sensor **23** is arranged between the compressor **2** and the condenser **3** directly after (and close to the outlet of) the compressor **2**.

[0093] Both the controllable valve **14** and the temperature sensor **23** are connected to a controller **16**, such that the controllable valve **14** can be controlled based on the measured temperature in the fluid line **17**.

[0094] As can be seen from FIG. **4** the amount of fluid flowing through the IHX line **7** is controlled only via this single controllable valve **14**.

[0095] The controllable valve **14** is a two way proportional valve. If the controllable valve **14** is closed (0% position) all fluid from the condenser **3** passes through the bypass fluid line **13**.

[0096] In the embodiment of FIG. **4**, the diameter of the bypass fluid line **13**, i.e. between inlet junction **28** and outlet junction **29** is smaller than the diameter of fluid lines **8**, **9** between the inlet junction **28** and the outlet junction **29** via the first conduit **7**.

[0097] Therefore, if the controllable valve **14** is maximum open (100% position), the largest share (almost 100%) of the fluid exiting the condenser **3** passes through the first conduit **7** of the internal heat exchanger **6**.

[0098] In the embodiment of FIG. **4** the controllable valve **14** is, by way of example, integrated in a connecting flange **26** on the inlet side of the internal heat exchanger **6**. Alternatively the controllable valve **14** can be placed in the fluid line **8** between the inlet junction **28** and the first conduit **7**, or (shown dotted) controllable valve **14** can be placed in in the fluid line **9** between the outlet junction **29** and the first conduit **7**.

[0099] In the embodiment shown in FIG. **4** the bypass fluid line **13** is embodied by a pipe with about (for example) 6 mm diameter, while fluid line **8** is embodied by a pipe with about 8 mm diameter. Other diameters are possible.

[0100] FIG. **5** shows a schematic view of a two diagrams governing a preferred embodiment of the method for controlling a cooling system cooling system according to the invention. By way of example FIG. **5** refers to the cooling system **20** of FIG. **2**.

[0101] The vertical axis of diagram a) denotes the mass flow of fluid through bypass fluid line **13**, while the horizontal axis of diagram a) denotes the temperature measures by temperature sensor **23** on the outlet side of compressor **2**. Thus, diagram a) refers to a first control loop.

[0102] The vertical axis of diagram b) denotes the mass flow of fluid through bypass fluid line **13**, while the horizontal axis of diagram b) denotes the overheating determined based on the measurements of the further temperature sensor **25** and the pressure sensor **15** on the inlet side of compressor **2**. Thus, diagram a) refers to a second control loop.

[0103] Diagram a)

[0104] A fluid temperature of a refrigerant of the cooling system **20** is measured continuously using the temperature sensor **23** comprised by a fluid line **17** between the compressor **2** and the condenser **3**. The temperature sensor **23** is located close to the outlet side of the compressor **2**.

[0105] Proportionally to the fluid temperature measured by the temperature sensor **25**, a mass flow of fluid passing through the internal heat **6** exchanger is controlled by automatically and proportionally actuating the controllable valve **22** that is arranged to control the amount of fluid flowing through the bypass fluid line **13**.

[0106] In diagram **5** a) the measured temperature T**1** after the compressor is, for example, shortly before exceeding a predefined range R**1** (indicated by solid arrow A**1**). Therefore the mass flow of fluid passing through the internal heat exchanger **6** is reduced by automatically actuating the controllable valve **22**. Thus, the mass flow through bypass fluid line **13** increases as can be seen from the diagram.

[0107] Thereby the heat exchange in the internal heat exchanger **6** is decreased, which keeps T**1** in the desired range R**1** (indicated by dotted arrow A**1'**).

[0108] The desired range R**1** extends in the example from 80% Tmax (maximum temperature at the outlet side of compressor **2**) to Tmax. Alternatively, for example, the desired range R**1** could extend from 60% Tmax to Tmax. Of course, the range R**1** can be adapted to a specific cooling system. Tmax can be, for example, 100° C. or 150° C. or in between.

[0109] Even though it is generally desirable to keep temperature at the outlet side of compressor **2** as low as possible, the first control loop allows for a maximum thermal utilization of the internal heat exchanger **6** in the sense that it allows to operate it safely in a region close to Tmax. In other operating points of the cooling system measured temperature T**2** after the compressor **2** may be below 50% Tmax. In this case the flow through the bypass fluid line **13** can be zero. Thus, it becomes apparent that the first control loop acts as a first safety loop.

[0110] If, however, a measured temperature T**2** after the compressor is, for example, shortly before falling below the predefined range R**1** (indicated by solid arrow A**2**), the mass flow of fluid passing through the internal heat exchanger **6** is increased by automatically actuating the controllable valve **22**. Thus, the mass flow through bypass fluid line **13** decreases as can be seen from the diagram.

[0111] Thereby the heat exchange in the internal heat exchanger **6** is increased, which steers T**2** back to the desired range R**1** (indicated by dotted arrow A**2**').

[0112] In both cases the mass flow is controlled proportionally so that no unsteady change in heat exchange occurs.

[0113] The mass flow through the bypass fluid **13** line is kept steady, if the temperature measured by temperature sensor **23** remains c within the predefined range R**1**.

[0114] Diagram b)

[0115] The fluid temperature and the pressure of the refrigerant of the cooling system are continuously measured the using a further temperature sensor **15** and a pressure sensor **25** both of which are comprised by a fluid line **12** between the second conduit **10** of the internal heat exchanger **6** and the compressor **2**. The further temperature sensor **15** and the pressure sensor **25** are located close to the inlet side of the compressor **2**.

[0116] Based on the measurements of the further temperature sensor **15** and the pressure **25** an overheating of the fluid is continuously determining using controller **16**. Controller **16** also controls the proportional three way valve **22**.

[0117] In diagram **5** b) the determined overheating OH**1** on the inlet side of the compressor **2** is, for example, shortly before exceeding a predefined overheating range R**2** (indicated by solid arrow OA**1**). By way of example the overheating range can be 5 Kelvin to 15 Kelvin, with an optimal overheating of 10 Kelvin in the middle.

[0118] Thus, the fluid mass flow through bypass fluid line **13** is increased by proportionally opening, controlled by controller **16**, the controllable valve **23** towards the bypass fluid line **13**. Thereby the heat exchange in the internal heat exchanger **6** is decreased, which steers OH**1** back to the desired range R**2** (indicated by dotted arrow OA**1**').

[0119] If an overheating OH**2** of the fluid falls or is about to fall below the predefined overheating range R**2**, which is indicated by solid arrow AO**2**, second control loops provides for proportionally reducing the fluid mass flow through the bypass fluid line **13**, which can be seen in diagram **5** b). In other words, the controllable valve **22** is proportionally steered towards its closing position.

[0120] Thereby the heat exchange in the internal heat exchanger **6** is increased, which steers OH**2** back to the desired range R**2** (indicated by dotted arrow OA**2**').

[0121] The mass flow through the bypass fluid **13** line can be kept steady, if the continuously determined or calculated overheating OH**1**, OH**2** remains, for example, within the an (smaller) overheating range R**2**' around the optimal overheating point.

[0122] Thus, it becomes apparent that the second control loop acts as a second safety loop, which prevents fluid drops to enter the compressor **2** and thereby avoids a liquid hammer.

[0123] The first control loop represented in diagram a) generally overrules the second control loop represented in diagram b) the first control loop dominates.

[0124] While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive. It will be understood that changes and modifications may be made by those of ordinary skill within the scope of the following claims. In particular, the present invention covers further embodiments with any combination of features from different embodiments described above and below. Additionally, statements made herein characterizing the invention refer to an embodiment of the invention and not necessarily all embodiments.

[0125] The terms used in the claims should be construed to have the broadest reasonable interpretation consistent with the foregoing description. For example, the use of the article "a" or "the" in introducing an element should not be interpreted as being exclusive of a plurality of elements. Likewise, the recitation of "or" should be interpreted as being inclusive, such that the recitation of "A or B" is not exclusive of "A and B," unless it is clear from the context or the foregoing description that only one of A and B is intended. Further, the recitation of "at least one of A, B and C" should be interpreted as one or more of a group of elements consisting of A, B and C, and should not be interpreted as requiring at least one of each of the listed elements A, B and C, regardless of whether A, B and C are related as categories or otherwise. Moreover, the recitation of "A, B and/or C" or "at least one of A, B or C" should be interpreted as including any singular entity from the listed elements, e.g., A, any subset from the listed elements, e.g., A and B, or the entire list of elements A, B and C.

LIST OF REFERENCE SIGNS

[0126] **1**, **20**, **30** cooling system
[0127] **2** compressor
[0128] **3** condenser
[0129] **4** expansion valve
[0130] **5** evaporator
[0131] **6** internal heat exchanger
[0132] **7** first conduit
[0133] **8**, **9** line between condenser and expansion valve
[0134] **10** second conduit
[0135] **11**, **12** line between evaporator and compressor
[0136] **13** bypass fluid line
[0137] **14** controllable valve
[0138] **15** second temperature sensor
[0139] **16** controller
[0140] **17** fluid line between compressor and condenser
[0141] **22** controllable valve
[0142] **23** temperature sensor
[0143] **25** pressure sensor
[0144] **26** connecting flange
[0145] **28** inlet junction
[0146] **29** outlet junction
[0147] T**1**, T**2** temperatures measured by temperature sensor **23**
[0148] OH**1**, OH**2** determined overheating

1. A cooling system, comprising:

connected in a loop by fluid lines and in succession, a compressor, a condenser, an expansion valve and an evaporator; and

an internal heat exchanger having a first conduit in heat exchanging contact with a second conduit, the first conduit being part of the fluid line between the condenser and the expansion valve and the second conduit being part of the fluid line between the evaporator and the compressor,

wherein a bypass fluid line is arranged between two ends of the first conduit of the internal heat exchanger or extends between one of the two ends of the first conduit and a position along a length of the first conduit.

2. The cooling system according to claim **1**, further comprising a controllable valve arranged in the bypass fluid line and being configured to control an amount of fluid flowing through the bypass fluid line.

3. The cooling system according to claim **2**, wherein the controllable valve comprises a three way valve and is arranged either at a junction of the bypass fluid line and the fluid line between the condenser and the internal heat exchanger or at a junction of the bypass fluid line and the fluid line between the internal heat exchanger and the expansion valve.

4. The cooling system according to claim **2**, further comprising a temperature sensor arranged in the fluid line between the compressor and the first conduit of the internal heat exchanger and being configured to control the controllable valve based on a temperature measured by the temperature sensor.

5. The cooling system according to claim **2**, further comprising a temperature sensor arranged in the fluid line between the second conduit of the internal heat exchanger and the compressor, and a control device connected to the temperature sensor and the controllable valve, the control device being configured to control the controllable valve based on a temperature measured by the temperature sensor.

6. The cooling system according to claim **2**, further comprising a pressure sensor arranged in the fluid line between the second conduit of the internal heat exchanger and the compressor.

7. The cooling system according to claim **4**, wherein the temperature sensor arranged in the fluid line between the compressor and the first conduit of the internal heat exchanger is arranged between the compressor and the condenser.

8. The cooling system according to claim **1**, wherein the bypass fluid line contains only a single controllable valve and/or wherein an amount of fluid flowing through the bypass fluid line is controlled only via a single controllable valve.

9. The cooling system according to claim **2**, wherein the controllable valve comprises a proportional valve.

10. The cooling system according to claim **1**, wherein a smallest diameter of the bypass fluid line is larger than a largest diameter of the fluid line, including the first conduit, between an inlet junction and an outlet junction, or

wherein the smallest diameter of the fluid line, including the first conduit, between the inlet junction and the outlet junction is larger than a largest diameter of the bypass fluid line.

11. The cooling system according to claim **1**, wherein the condenser is free of a branch-off,

wherein the first conduit of the internal heat exchanger and the expansion valve are connected solely via the single fluid line, and

wherein the fluid line between the condenser and the first conduit of the internal heat exchanger is permanently open.

12. The cooling system according to claim **2**, wherein the controllable valve is integrated in a connecting flange of the internal heat exchanger.

13. The cooling system according to claim **1**, wherein the cooling system is filled with R134a or HFO1234yf as refrigerant.

14. A method for controlling the cooling system according to claim **1**, comprising the steps of:

measuring, a fluid temperature of a refrigerant of the cooling system using a temperature sensor comprising a fluid line between the compressor and the condenser; and

controlling, proportionally to the fluid temperature measured by the temperature sensor, a mass flow of fluid passing through the internal heat exchanger by automatically actuating a controllable valve that is arranged to control an amount of fluid flowing through the bypass fluid line.

15. The method according to claim **14**, further comprising the steps of:

measuring, the fluid temperature and a pressure of the refrigerant of the cooling system using a further temperature sensor and a pressure sensor,. both of which comprise a fluid line between the second conduit of the internal heat exchanger and the compressor, the further temperature sensor and the pressure sensor being located close to or directly at an inlet side of the compressor;

continuously determining or calculating, based on measurements of the further temperature sensor and a pressure sensor and using a controller, an overheating of the fluid;

proportionally increasing the fluid mass flow through the bypass fluid line if the overheating of the fluid exceeds or is about to exceed a predefined max overheating threshold or overheating range; and/or

proportionally reducing the fluid mass flow through the bypass fluid line close or equal to zero if the overheating of the fluid falls or is about to fall below the predefined max overheating threshold or overheating range; and/or

keeping the mass flow through the bypass fluid line steady, close or equal to zero if the continuously determined or calculated overheating remains on the predefined overheating threshold or within the predefined overheating range.

16. The cooling system according to claim **7**, wherein the temperature sensor arranged in the fluid line between the compressor and the first conduit of the internal heat exchanger is arranged between the compressor and the condenser directly after or close to the compressor.

17. The cooling system according to claim **9**, wherein the proportional valve comprises a proportional two-way valve.

18. The method according to claim **14**, wherein the measuring is continuous.

19. The method according to claim **14**, wherein the temperature sensor is located close to or directly at an outlet side of the compressor.

20. The method according to claim **15**, wherein the measuring is continuous.

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