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(54) Title: FLASH DEFROST SYSTEM

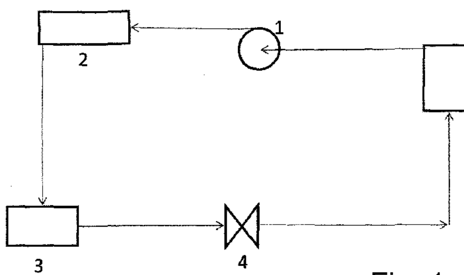

Fig. 1

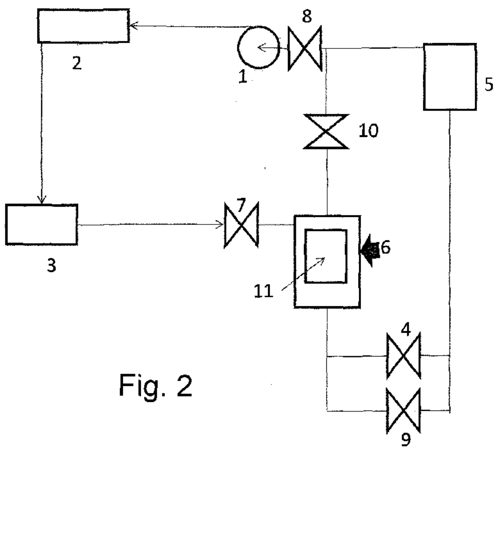

Fig. 2

(57) Abstract: A vapour compression refrigeration system includes a compressor (1) arranged to re-circulate refrigerant through a condenser (2), an expansion device (4) and an evaporator (5). To achieve rapid thermodynamically efficient defrosting of the evaporator, hot refrigerant from the condenser is stored in a defrost receiver (6) before passing through the expansion device (4). In a defrost phase, a valve arrangement (7-10) forms a closed defrost circuit connecting the evaporator (5) to the defrost receiver (6) via defrost valve (10) to allow hot fluid to pass from the defrost receiver to the evaporator and liquid refrigerant in the evaporator flows to the defrost receiver (6) via drain valve (9). In a pre-defrost phase, the valve arrangement closes the fluid input to the evaporator (5) and the compressor operates to partially evacuate the evaporator before the evaporator is connected to the defrost receiver, so that flash flooding of the evaporator with hot vapour occurs. A phase change medium (11) may be included to store heat from the condenser output and return it to the evaporator during defrost. Additional heat may be supplied to the defrost liquid to further increase the defrost speed.

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FLASH DEFROST SYSTEM

TECHNICAL FIELD OF THE INVENTION

This invention relates to a flash defrost system for defrosting evaporators in vapour compression refrigeration systems. As will be explained more fully herein, the invention is applicable to direct expansion, flooded evaporator and liquid overfeed refrigeration systems.

BACKGROUND

In many applications of vapour compression refrigeration systems an evaporator is used to cool air, *inter alia*, in chiller rooms, supermarket chilled display cabinets, domestic freezers and air source heat pumps. In such applications the external surfaces of the evaporator become covered in ice during operation due to condensation and freezing of water vapour in the atmosphere. Ice formation adversely affects the heat transfer performance, and the power consumption of the compressor rises to compensate for loss of evaporator efficiency. All such systems are therefore designed to periodically defrost the evaporator in order to restore performance and minimise running costs.

Common methods of defrost include, in order of defrost speed: discontinuation of the refrigeration process whilst electrical heaters attached to the evaporator are used to melt and release the accumulated ice; discontinuation of the refrigeration effect but, with the compressor still running, diversion of the hot gas output along an extra line to the evaporator for a time sufficient to melt and release the ice; discontinuation of the refrigeration effect and the use of ambient air to melt the ice. To minimise temperature rises in the refrigerated products the time of defrost needs to be short, so that electrical defrost is most commonly used in food applications. However, electrical defrost and hot gas defrost also incur a cost penalty in terms of extra energy used.

WO 2009 034 300 A1 discloses an ice maker which includes a vapour compression refrigeration system having multiple evaporators. Relatively hot refrigerant from a condenser flows through a defrost receiver before passing through the evaporators. Individual evaporators can be defrosted by means of a valve system which connects the evaporator to the defrost receiver to allow hot fluid to pass thermosyphonically from the defrost receiver to the evaporator and liquid refrigerant in the evaporator to return by gravity to the defrost receiver. However, in such a system the length of the defrost period is relatively unimportant since the remaining evaporators will continue to operate.

The present invention seeks to provide a new and inventive form of defrost system which is capable of providing more rapid and energy-efficient defrosting of the evaporator than has hitherto been possible.

SUMMARY OF THE INVENTION

The present invention proposes a vapour compression refrigeration system including a compressor arranged to re-circulate refrigerant through a condenser, an expansion device and an evaporator, in which relatively hot refrigerant from the condenser flows through a defrost receiver before passing through the expansion device, and, in a defrost phase, a valve arrangement connects the evaporator to the defrost receiver to create a defrost circuit which allows hot fluid to pass from the defrost receiver to the evaporator and liquid refrigerant in the evaporator to flow to the defrost receiver,

characterised in that the refrigeration system is constructed and operated such that, in a pre-defrost phase, the valve arrangement closes the fluid input to the evaporator and the compressor operates to partially evacuate the evaporator before the evaporator is connected to the defrost receiver.

By isolating the input to the evaporator prior to commencement of the defrost phase and allowing the compressor to remove refrigerant from the evaporator, the commencement of the defrost phase causes the hot refrigerant to boil and results in immediate flash flooding of the evaporator with hot refrigerant vapour. The invention therefore provides a means of defrosting the evaporator which uses a minimum amount of net energy from the system and which also enables a significant reduction in the defrost period. In food applications therefore, the invention minimises excursions from the ideal storage temperature of the product.

BRIEF DESCRIPTION OF THE DRAWINGS

The following description and the accompanying drawings referred to therein are included by way of non-limiting example in order to illustrate how the invention may be put into practice. In the drawings:

Figure 1 is a diagram of a known form of vapour compression refrigeration circuit upon which the present invention is based;

Figure 2 is a diagram of a first such refrigeration circuit incorporating a defrost system in accordance with the invention;

Figure 3 is a diagram of a second such refrigeration circuit incorporating a defrost system in accordance with the invention;

Figure 4 is a modified form of the refrigeration circuit shown in Fig. 3;

Figure 5 is a modified form of the refrigeration circuit shown in Fig. 2 which can be used with multiple evaporators; and

Figure 6 shows a further modification as applied to the refrigeration circuit of Fig.5.

DETAILED DESCRIPTION OF THE DRAWINGS

Fig. 1, shows a widely used direct expansion arrangement to which the present invention may be applied, comprising a closed refrigerant circuit in which a compressor 1 pressurises vapour phase refrigerant. The hot superheated gas leaving the compressor passes to a condenser 2 in which desuperheating and subcooling occurs. The warm high pressure liquid refrigerant then passes to a liquid receiver vessel 3 acting as a refrigerant reservoir. Liquid from the reservoir supplies an expansion device 4 where a rapid drop in pressure produces a two phase stream of cold vapour and liquid which then enters the bottom of evaporator 5. Evaporation of the liquid phase is completed in the evaporator so that the required cooling effect is achieved. Cold sub-cooled vapour from a top exit of the evaporator 5 then returns to the inlet of the compressor 1 via the suction line of the compressor and the cycle is repeated.

Various embodiments of the invention will now be described which achieve rapid energy-efficient defrosting of the evaporator in such a refrigeration system. In the following description and drawings the reference numbers used in **Fig. 1** are applied to corresponding items within the refrigeration system.

In the first embodiment which is shown in **Fig. 2** a defrost receiver 6 is inserted into the liquid stream between the main liquid reservoir 3 and the expansion device 4, which may be an expansion valve. A shut-off valve 7 is inserted into the flow path between the receiver 3 and the defrost receiver 6, and an isolation valve 8 is inserted between the exit of the evaporator 5 and the inlet of the compressor 1. A drain valve 9 is connected in parallel with the expansion valve 4, and a defrost valve 10 is connected between the top of the defrost receiver 6 and the exit of the evaporator 5. During normal operation the expansion valve 4 and valves 7 and 8 are open and valves 9 and 10 are closed resulting in a refrigerant flow circuit which is essentially the same as that shown in **Fig. 1**. As previously explained however, normal operation of the circuit will result in ice formation on the outside of the evaporator due to condensation of atmospheric water vapour.

When defrosting of the evaporator is required the expansion valve 4 is firstly closed to close off the fluid inlet of the evaporator while the compressor 1 continues to run. The suction line to the compressor continues to draw refrigerant vapour from the evaporator 5, causing partial evacuation of the evaporator. After a sufficient period of time, valves 7 and 8 are closed and valve 10 is opened allowing high pressure liquid refrigerant in the defrost receiver 6 to flash over into the evaporator 5, which is at a very low pressure. (The compressor may be turned off during this phase.) Refrigerant vapour condenses in the evaporator releasing latent heat and transferring it at high heat transfer efficiency until the pressures in the evaporator 5 and the defrost receiver 6 equalise, at which point drain valve 9 is opened to allow liquid refrigerant in the evaporator to drain back into the receiver 6 under the action of gravity. When the temperature of the liquid in the receiver 6 falls to a predetermined level indicating that defrost is complete, valves 9 and 10 are closed and valves 4, 7 and 8 are opened and the normal operation of the refrigeration circuit resumes.

In a further improvement of the defrost system in accordance with the invention the heat energy extracted from the hot liquid refrigerant and made available for defrost may be augmented by means of a phase-change unit 11 contained within the defrost receiver 6. A suitable phase-change medium is encapsulated within the phase-change unit 11 so that during normal operation the hot liquid refrigerant flows in contact with the phase-change unit melting the phase-change material and storing enthalpy from the liquid refrigerant stream as latent heat. During the defrost stage the stored heat energy is released into the refrigerant stream circulating in the closed loop thereby accelerating the defrost process. The result of such extraction of heat from the hot liquid refrigerant stream is to increase the thermodynamic efficiency of the overall refrigeration circuit through a more effective expansion process, which largely compensates for the extra energy needed to re-cool the evaporator after a defrost. The energy cost of the defrost process is thereby minimised.

In a second embodiment of the invention which is shown in **Fig. 3** the liquid reservoir 3 is arranged to act as a defrost receiver. The evaporator is at a higher level than the receiver, and the expansion device 4 is of a type which can be fully opened to remove the restriction, for example an expansion valve driven by a stepper motor. An isolation valve 12 in the compressor suction line is open when the compressor is running and closed at other times. A defrost valve 13 connects the exit of the evaporator to the top of the receiver 3 and is shut in normal operation. When defrost is initiated the expansion valve 4 is fully closed for a period to allow the evaporator to empty via the suction line. The compressor 1 is then switched off and valve 12 is shut. The expansion valve 4 is fully opened allowing hot liquid to drain back to the liquid receiver, and valve 13 opens allowing vapour from the top of the receiver 3 to flash over into the partially evacuated evaporator. As the evaporator is above the receiver and the line from the receiver 3 through the expansion valve 4 is full of liquid a flow will be established from the evaporator through the expansion valve back to the receiver 3. Vapour will continue to flow from the receiver 3 through the defrost valve 13 to the evaporator 5 where it will condense, and the condensed liquid will then flow back to the receiver 3 via the expansion valve 4.

In a variation of this embodiment a heat exchanger 14 containing a phase change medium may be added between the receiver 3 and the expansion valve 4. This increases the energy storage capacity while minimising the refrigerant charge. Alternatively, as shown in Fig. 4, a heat exchanger 15 of the fluid-to-fluid type can be used. The secondary of the heat exchanger is connected to a pump 16 which circulates an antifreeze fluid from a separate tank 17 in a closed circuit, thus acting to increase the thermal storage capacity of the defrost system.

In refrigeration installations with multiple evaporators fed from common liquid supply and suction manifolds, such as those used in supermarket display cabinets or cold storage facilities, the embodiment of the invention shown in **Fig. 5** may be used. The individual evaporators 5 and associated defrost circuitry constructed and operated as previously described in relation to Fig. 2 are each connected to the common liquid manifold 18 and suction manifold 19. It will be noted that in this case each evaporator 5 is associated with its own defrost receiver 6 so that flash defrosting of the individual evaporators may again take place as described.

In the embodiments described above the evaporator 5 should be higher than the heat store module formed by the defrost receiver 6 and the phase-change unit 11 (if provided) so that liquid refrigerant can return to the receiver 6 under the action of gravity. **Fig. 6** shows how this requirement can be obviated by adding a pump 20 in series with the valve 9 between the liquid outlet from the evaporator 5 and the defrost receiver 6. The pump 20 will return cold liquid refrigerant from the evaporator 5 to the heat store 6, 11 where it can evaporate and return to the evaporator as vapour. It should also be noted that with such an arrangement the valve 9 could be replaced with a non-return valve, removing the requirement for actuation by the refrigeration control system.

Although the specific embodiments described above are applied to refrigeration systems of the direct expansion type which maintain a constant superheat at the evaporator exit, the invention can also be applied to flooded evaporator and liquid overfeed refrigeration systems. In such systems the evaporator is fed with liquid refrigerant and filled with boiling refrigerant so that a mixture of liquid refrigerant and refrigerant vapour exits from the evaporator. This requires the addition of a low pressure accumulator in the suction line so that the liquid can be separated from the vapour which is returned to the compressor. Provided the return to the accumulator is above the fluid level in the evaporator all of the liquid in the evaporator should evaporate when the liquid feed to the evaporator is turned off during the pre-defrost phase. The valve arrangement may need to be modified, but the basic principle of partial evacuation of the evaporator followed by flash flooding with hot refrigerant from the liquid supply line would still apply.

In each embodiment of the invention the heat energy extracted from the hot liquid refrigerant can be augmented by means of electrical power supplied by a resistance heater located in or around the defrost receiver with the purpose of accelerating the defrost process.

The timing and sequencing of the valve operation, the sizing and positioning of the defrost receiver relative to the evaporator, and the use of thermal capacity enhancement by means of phase change materials, secondary fluid circuit or electrical power can be optimised for maximum overall system efficiency.

The type of valves which may be employed in the refrigeration units described above include, *inter alia*, check valves, solenoid valves, expansion valves and three-way valves.

The control system employed to manage the operation of the refrigeration systems described above will initiate and terminate the defrost process based on information supplied by temperature and pressure sensors fitted at strategic points around the refrigerant circuits.

Whilst the above description places emphasis on the areas which are believed to be new and addresses specific problems which have been identified, it is intended that the features disclosed herein may be used in any combination which is capable of providing a new and useful advance in the art.

CLAIMS

1. A vapour compression refrigeration system including a compressor (1) arranged to re-circulate refrigerant through a condenser (2), an expansion device (4) and an evaporator (5), in which relatively hot refrigerant from the condenser flows through a defrost receiver (6/3) before passing through the expansion device, and, in a defrost phase, a valve arrangement (10/13, 9, 4) connects the evaporator to the defrost receiver to create a defrost circuit which allows hot fluid to pass from the defrost receiver (6/3) to the evaporator (5) and liquid refrigerant in the evaporator to flow to the defrost receiver,

characterised in that the refrigeration system is constructed and operated such that, in a pre-defrost phase, the valve arrangement (9, 4) closes the fluid input to the evaporator (5) and the compressor (1) operates to partially evacuate the evaporator (5) before the evaporator is connected to the defrost receiver (6/3).

2. A vapour compression refrigeration system according to Claim 1 in which the hot refrigerant from the condenser (2) is stored in the defrost receiver (6/3) before passing through the expansion device (4) and, at the commencement of the defrost phase, the stored refrigerant is admitted to the evaporator through a defrost valve (10/13).

3. A vapour compression refrigeration system according to Claim 1 in which energy from the hot liquid refrigerant obtained

from the condenser (2) is stored in a phase-change medium (11/14) which is in heat-exchange contact with the hot liquid, and the stored energy is released into the defrost fluid flowing through the evaporator (5) during the defrost phase.

4. A vapour compression refrigeration system according to Claim 3 in which the phase-change medium (11) is contained within the defrost receiver (6).

5. A vapour compression refrigeration system according to Claim 3 in which the phase-change medium (14) is included between the defrost receiver (3) and the expansion device (4).

6. A vapour compression refrigeration system according to Claim 1 in which a fluid-to-fluid heat exchanger (15) is included between the defrost receiver (3) and the expansion device (4) and a heat storage fluid is circulated through the secondary of the heat exchanger to a storage reservoir (17).

7. A vapour compression refrigeration system according to Claim 1 in which heating means is arranged to provide additional heat input to the hot refrigerant flowing from the condenser (2).

8. A vapour compression refrigeration system according to Claim 1 which includes a plurality of evaporators (5) and in which each evaporator is associated with a respective defrost receiver (6).

9. A vapour compression refrigeration system according to Claim 1 in which a pump (20) is arranged to return liquid refrigerant from the evaporator (5) to the defrost receiver (6) during the defrost phase.

10. A method of defrosting a vapour compression refrigeration system including a compressor (1) arranged to re-circulate refrigerant through a condenser (2), an expansion device (4) and an evaporator (5), in which relatively hot refrigerant from the condenser flows through a defrost receiver (6/3) before passing through the expansion device, and, in a defrost phase, a valve arrangement (10/13, 9, 4) connects the evaporator to the defrost receiver to allow hot fluid to pass from the defrost receiver (6/3) to the evaporator (5) and liquid refrigerant in the evaporator to flow to the defrost receiver,

characterised in that the refrigeration system is constructed and operated such that, in a pre-defrost phase, the valve arrangement (9, 4) closes the fluid input to the evaporator (5) and the compressor (1) operates to partially evacuate the evaporator (5) before the evaporator is connected to the defrost receiver (6/3).

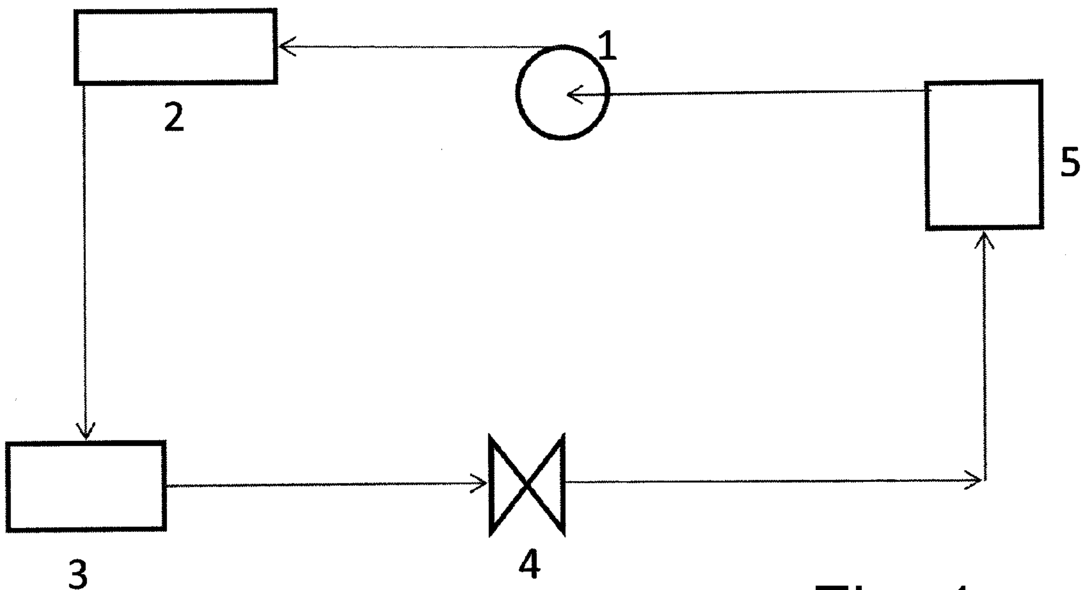

Fig. 1

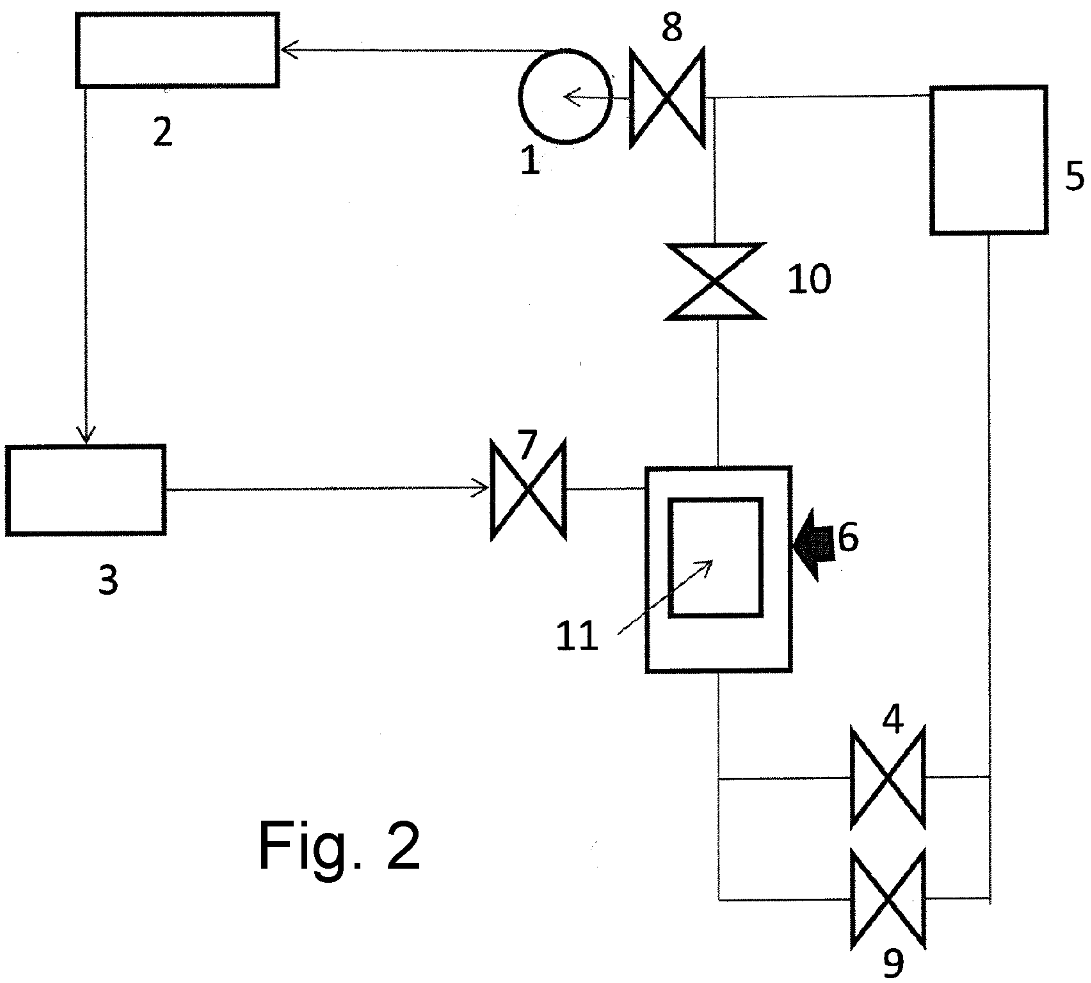

Fig. 2

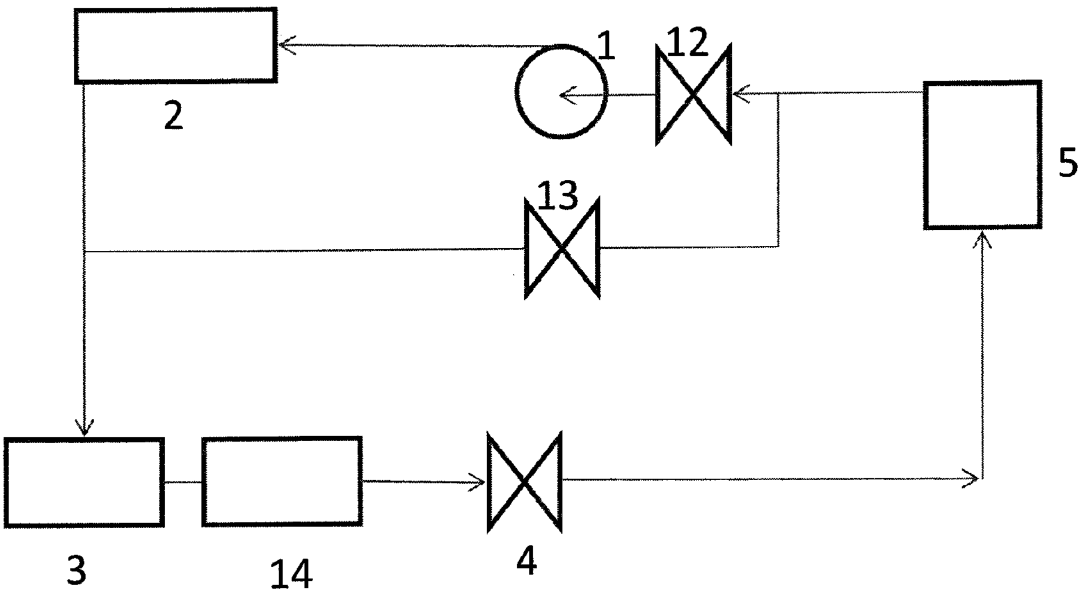

Fig. 3

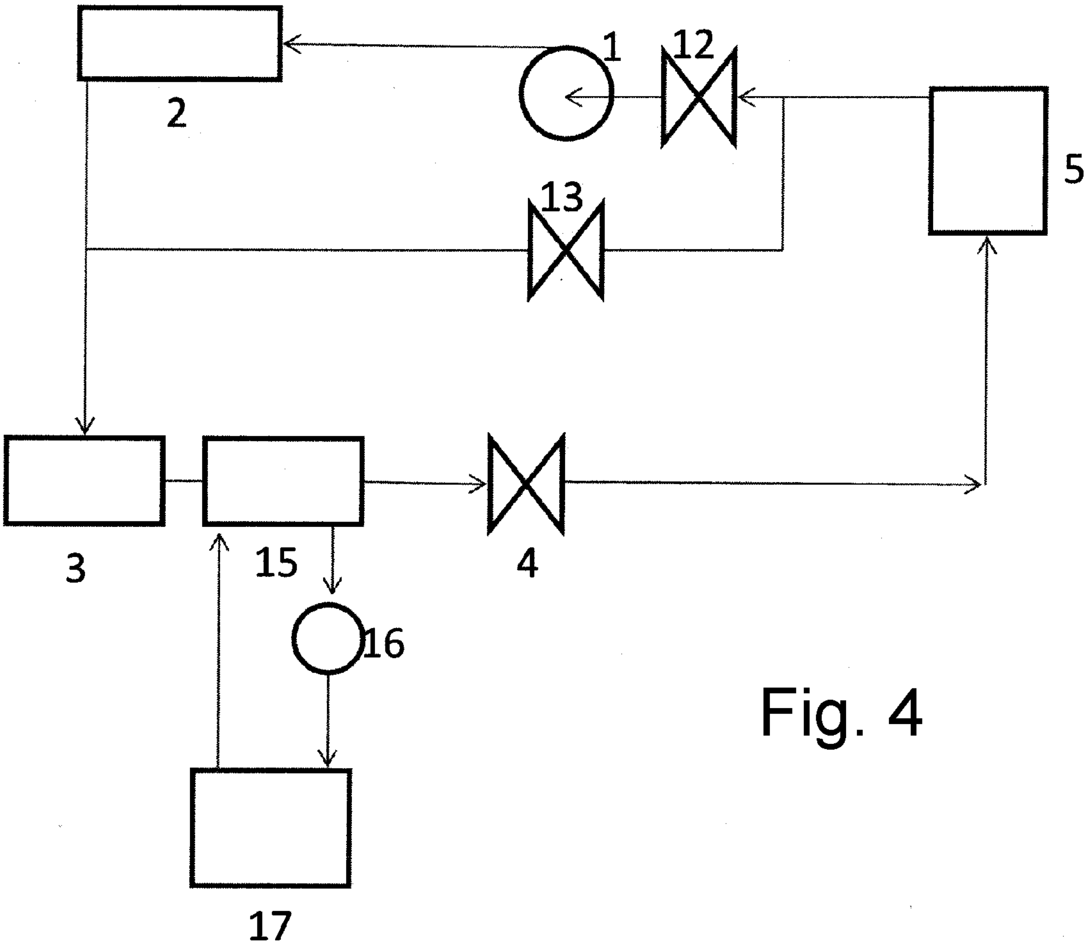

Fig. 4

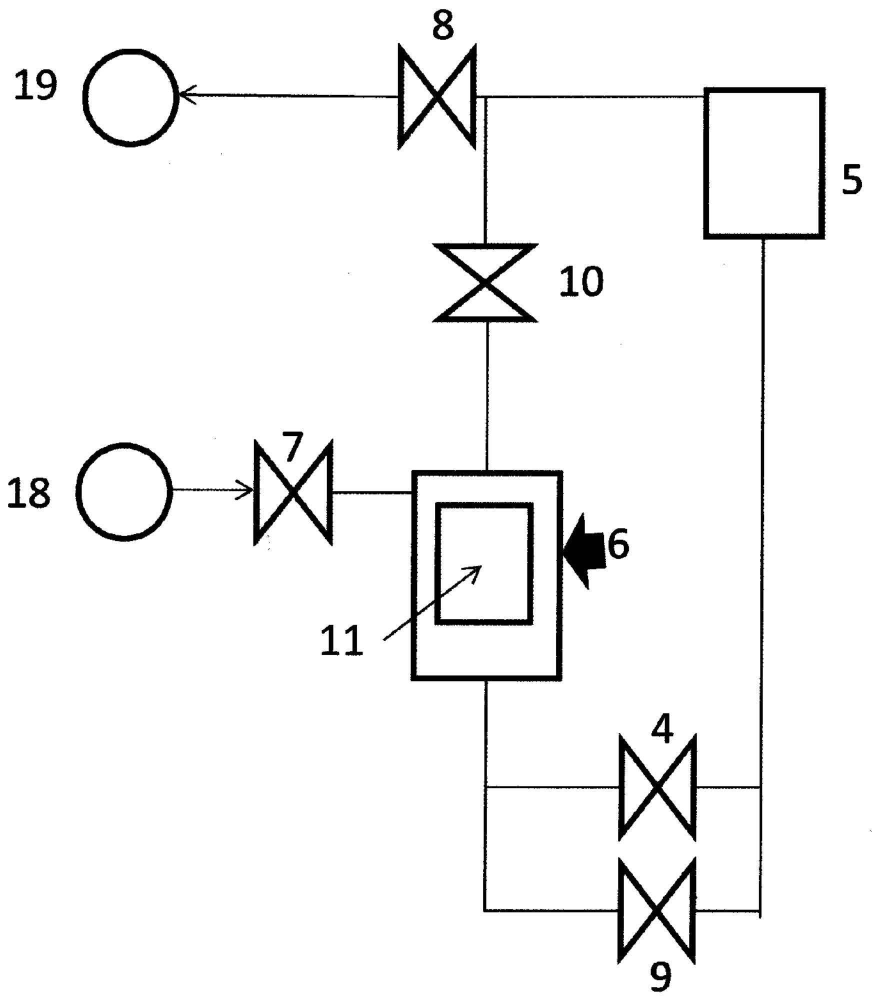

Fig. 5

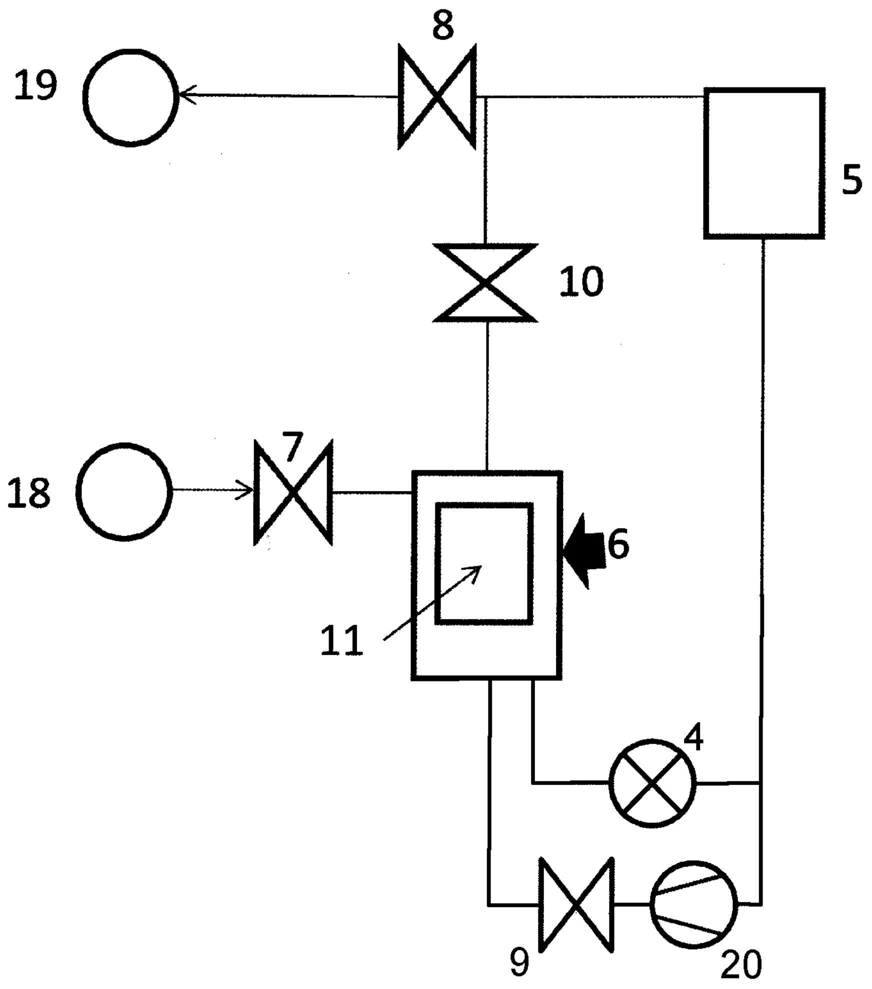

Fig. 6