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(54) **Cooling System**

(57) The invention relates to a cooling system that has a compressor (1) for conveying a refrigerant from a first line section that has a first pressure level to a second line section that has a second pressure level, higher than the first. The system comprises an expansion device (6) for supplying the refrigerant to a third section that has a third pressure level, lying between the first and second pressure levels, wherein a heater (10) is provided for heating the refrigerant in the second section. As a result, it is advantageously possible to obtain a cooling system operated with solar energy.

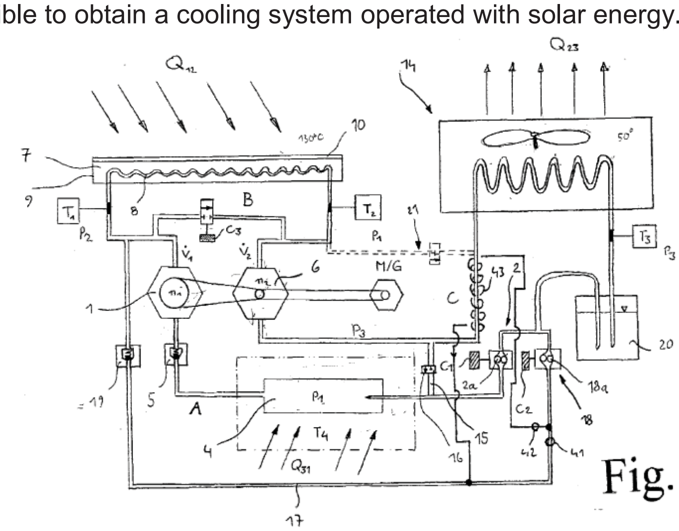

Fig.1

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Description

[0001] The invention relates to a cooling system, in particular for air conditioning.

[0002] Conventional cooling systems for air conditioning normally comprise a compressor driven by a motor for pressurizing a refrigerant, e.g. propane gas, a heat exchanger for cooling and condensing the pressurized refrigerant, and an evaporator for absorbing heat from the environment that is to be air-conditioned.

[0003] Because of the increasing distribution of air conditioners in private residential areas, there is an increase in power consumption. From an ecological perspective as well, the trend toward household and commercial air conditioning is alarming, in particular with regard to the significant power consumption of the air conditioners.

[0004] Based on this, the fundamental object of the invention is to create a cooling system that is distinguished by an improved ecological compatibility.

[0005] This object is achieved according to the invention by a cooling system that has a compressor for conveying a refrigerant from a first section that has a pressure level p1 to a second section that has a higher pressure level p2 than the first pressure level p1, an expansion device for supplying the refrigerant from the second section to a third section that has a third pressure level p3, which lies between the first pressure level p1 and the second pressure level p2, and a solar heater for heating the refrigerant in the second section.

[0006] As a result, it is advantageously possible to operate a refrigerant circuit with a lower power consumption – or with corresponding heating power of the heater with excess energy. With the refrigerant circuit according to the invention it is possible to use the condensed and cooled refrigerant for air conditioning. It is also possible to heat tap water with the heat discharged in the third section. The potential excess energy at the expansion device can be used for mechanical energy, e.g. to operate a generator. The cooling system can also be used for heating purposes.

[0007] An advantageous embodiment according to a special aspect of the present invention is obtained in that the heater is a solar heater. As a result, it is possible in an ecologically advantageous manner to operate an air conditioner off-line and thus entirely autonomously, even in remote areas or in mobile objects, e.g. camping or refrigerated vehicles.

[0008] The expansion device is advantageously formed by a hydrostatic machine. A higher operating efficiency is obtained therewith with relatively small gas flows. In addition to piston systems, impeller systems, axial piston, and propeller or gear systems in particular have proven to be particularly advantageous.

[0009] In particular with large systems that have gas flows of more than 200 l/s, it is advantageously possible to design the expansion device as a preferably multi-step hydrodynamic machine. It is possible to arrange two expansion devices of different volumes parallel to one another, and to operate the two machines individually or collectively at an optimal operating point.

[0010] The conveyor for conveying the refrigerant from the first section of the refrigerant circuit to the second section of the refrigerant circuit is designed as a hydrostatic pump according to a particularly preferred embodiment of the invention. In addition to piston systems, impeller conveyors can also be advantageously used.

[0011] In order to convey and compress the refrigerant from the first section to the second, multi-step hydrodynamic conveyors, in particular radial compressors, can be used, in particular with large volume flows, in the same manner as with the expansion device.

[0012] A particularly high operating efficiency is obtained according to a particularly preferred embodiment of the invention in that the expansion device and the conveyor are mechanically coupled. This mechanical coupling can take place in an advantageous manner at a predetermined gear ratio that takes into account the two pressure levels and the volume expansion caused by heat.

[0013] In order to enable constant operation of the cooling system at an optimal operating point, the gear ratio can preferably be adjusted. The adjustability can be obtained with a gear transmission assembly or preferably with a stepless transmission.

[0014] Leakage of the refrigerant is advantageously prevented in that both the conveyor of the expansion device as well as the coupling device are entirely encapsulated by a collective sealing housing.

[0015] The expansion device and the conveyor can also have an integral design according to a special aspect of the present invention. It is thus possible to use, e.g. a piston assembly with two pistons of different volumes, wherein both pistons are operated with a common eccentric device or crankshaft. Advantageously, a BOXER assembly of the two pistons can be selected for this, by means of which a reduced bearing load and thus a prolonged service life are obtained. With impeller systems, is also possible to either place two different impellers on an axle, or to place the impeller between a compression zone and an expansion zone.

[0016] There is a heat exchanger in the third section of the refrigerant circuit according to a particularly preferred embodiment of the invention, for cooling the refrigerant that was heated in the second section. The heat exchanger can be a heat exchanger cooled by ambient air. Alternatively or additionally, it is possible to use the heat exchanger as a tap water heater. It is possible to use the high portion of energy for heating tap water, and to cool the rest with ambient air. For this, the heat exchanger is preferably in the form of a combination heat exchanger, for heating water and/or ambient air.

[0017] Alternatively to a direct mechanical coupling, it is also possible to couple the conveyor to an electric motor, and to operate it therewith.

[0018] The expansion device can also be coupled to a generator when it is mechanically coupled to the conveyor. In particular with low ambient temperatures and strong sunlight, the cooling system can be operated as a power supply.

[0019] An ideal relationship of the output of the conveyor to the expansion device is obtained advantageously in that the electric motor and the generator are coupled to one another via a control unit.

[0020] The electric motor and the generator advantageously form an integrated module. As a result, it is possible to operate the system by driving the conveyor or expansion device, e.g. if the second circuit section does not supply sufficient heat. When the heating power is higher, the motor functions as a generator.

[0021] Advantageously, there is at least one bypass line for bypassing the heater in the second section. As a result, it is possible to decouple the heater as needed, and to convey the refrigerant directly to the heat exchanger, or the cooler in the second section. Advantageously, there is a valve in the bypass line for opening and closing the bypass line.

[0022] There is advantageously a thermometer for monitoring the temperature of the refrigerant in the second section. Based on the temperatures recorded therewith, it is possible to set an optimal operating state for the cooling system.

[0023] A particularly advantageous embodiment of the invention with regard to the use of the cooling system according to the invention for air-conditioning purposes is obtained in that there is an evaporator in the first section for evaporating the refrigerant conveyed from the third section to the first section. The evaporation heat obtained from the refrigerant can be used for cooling the ambient air in a working, living, or refrigerated space.

[0024] According to a particularly preferred embodiment of the invention, it is possible to use bypass lines to bypass the first section. As a result, it is possible to feed refrigerant to the second section, bypassing the vaporizer, and potentially in the liquid state. The supplying thereof preferably takes place through a hydrostatic pump, preferably a gear-type pump. By supplying liquid refrigerant to the second section, i.e. the heater, the mechanical output of the expansion device is further increased. As a result, it is possible to increase the cooling power or the power generation of the system. It is also possible to conduct a sub-current through the vaporizer, and a sub-current through a parallel pathway.

[0025] There is advantageously a refrigerant reservoir in the system for storing the refrigerant in the liquid state. As a result, it is particularly easy to start up the refrigerant circuit.

[0026] A buffer reservoir is also advantageously provided for supplying a refrigerant. This refrigerant that is heated during a peak operating time, for example, can be cooled at another time, e.g. overnight, when the ambient temperatures are lower.

[0027] An advantageous embodiment of the heater according to another aspect of the present invention is obtained in that it is incorporated in the heat exchanger to form an integral module. This module can be placed in a space-saving manner in the ceiling region in a house, a building, or a vehicle.

[0028] An advantageous embodiment of the invention with respect to a particularly high return temperature of the refrigerant from the heater is obtained in that the heater comprises a focusing lens assembly for focusing the heat radiation and irradiating the heating lines for conducting the refrigerant. The heating lines are preferably made of metal, in particular a heat-resistant ferrous alloy, or a copper alloy. The heating lines are preferably designed to function at an operating pressure of 80 bar with sufficient safety.

[0029] The lens assembly is formed by a Fresnel lens assembly according to a particularly preferred embodiment of the invention. It is also possible to use other optical principles for focusing the sunlight onto the heating lines. In addition to refraction effects, reflection or refraction/reflection effects can also be used for focusing the light onto the heating lines.

[0030] There is preferably an insulator, at least in the region of the heater, for insulating the refrigerant heating lines. As a result, it is possible to heat the refrigerant, substantially independently of the ambient temperature, to a temperature that corresponds to the solar power. In particular in the embodiment combining the heat exchanger and the heater, a disadvantageous heat transference to the refrigerant condenser is avoided. The insulator is advantageously formed by a foam glass material.

[0031] A glass plate is joined in a sealing manner to the insulator made of foam glass, such that a weather-resistant exterior is obtained. The Fresnel lens assembly can be formed directly in the cover glass plate. Sections of the heating lines are advantageously embedded in a sealing manner in the foam glass.

[0032] The object specified in the introduction is also achieved with a method for transforming solar heat, in which a refrigerant is conveyed by a conveyor from a first section that has a first pressure level to a second section that has a second pressure level, heated in the second section by solar heat, and the heated refrigerant is expanded in a third section by an expansion device, and cooled in the third section, wherein the pressure in the third section is set such that the refrigerant is condensed, after which the refrigerant is returned from the third section to the first section.

[0033] As a result, it is possible to operate an air conditioner with reduced, or even without, outside power consumption. With warmer solar radiation, it is possible to release mechanical energy.

[0034] The refrigerant is preferably vaporized in the first section. The system pressure is preferably in the range of 1.5 to 8 bar.

[0035] The mechanical energy released by the expansion device is advantageously used for driving the conveyor and/or a generator. The power coupling ratio between the conveyor and the expansion device is preferably set based on the thermal energy in the second section. This results in a higher efficiency of the system.

[0036] A refrigerant in the present case is understood to be a medium that assumes a gaseous or liquid state at the pressures and temperatures present in the system. Refrigerants such as toluene, flurinol 100, propane, isobutene, ammonia (R717), dichloro-tetra-ethane (R114), difluoride-chloromethane (R12), trichloro-fluoromethane (R11), trichloro-trifluoro-ethane (R113).

[0037] When operating only the generator, it is possible to use a working medium that is exclusively liquid or gaseous at the pressures and temperatures in the system.

[0038] Advantageously, the optimal operating point for the refrigerant circuit is determined by a computer with regard to the heat supplied thereto in the second section. The pressures in the individual sections of the refrigerant circuit are set with respect to a circuit optimization determined by the computer, such that a maximum system efficiency is obtained. It is possible to operate the system such that a specific portion of the energy is used for air conditioning, and if there is excess power, this is supplied to the electric grid, or stored in a battery.

[0039] The heater is preferably a solar heater. The expansion device is preferably a hydrostatic machine, e.g. a piston machine, an impeller machine, or a gear-type or propeller machine.

[0040] It is also possible to design the expansion device as a hydrodynamic machine. This embodiment is particularly suitable for large-scale gas flows.

[0041] With systems of up to ca. 40 kW, the conveyor is preferably a hydrostatic pump, e.g. a piston or diaphragm pump. With large inputs, the conveyor is preferably a multi-step hydrodynamic pump.

[0042] The expansion device and the conveyor are preferably mechanically coupled to one another such that they can be switched on and off. The expansion device and the conveyor are preferably accommodated in a collective housing in a sealed manner.

[0043] There is preferably a heat exchanger in the third section for cooling the refrigerant that has been heated in the second section. This heat exchanger is preferably an ambient air cooler.

[0044] Alternatively, or in combination with this measure, it is also possible to use the heat exchanger to heat tap water.

[0045] The heat exchanger is preferably a combination heat exchanger for heating water and/or ambient air.

[0046] The expansion device is preferably coupled to a generator. The electric motor and the generator are preferably coupled to a power source via a control unit. The electric motor and generator can preferably be operated as such in an alternating manner.

[0047] There is preferably at least one bypass line for bypassing the heater in the second section. There is preferably a valve in the bypass line for opening or closing the bypass line.

[0048] There is preferably a thermometer for measuring the temperature of the refrigerant heated in the second section.

[0049] There is preferably a vaporizer in the first section for vaporizing the refrigerant conveyed from the third section to the first section.

[0050] There is preferably a bypass line for bypassing the first section.

[0051] A hydrostatic conveyor is preferably used in the bypass line. There is preferably a refrigerant reservoir in the system for storing refrigerant in the liquid state.

[0052] There is preferably also a buffer reservoir for supplying a refrigerant , wherein the heated refrigerant is cooled overnight.

[0053] The heat exchanger and the heater are preferably integrated to form a module.

[0054] The heater preferably comprises a focusing lens assembly that is preferably a Fresnel lens assembly.

[0055] There is advantageously an insulator for insulating the refrigerant heating line. The insulator is preferably formed by foam glass. The foam glass insulator is preferably joined to a glass plate in a sealing manner.

[0056] The Fresnel lens assembly is preferably formed in the glass plate. The heating of the refrigerant preferably takes place through heating lines, wherein sections of the heating lines are embedded in a sealing manner in the foam glass.

[0057] The object specified in the introduction is also achieved by a method for transforming solar energy in which a refrigerant is conveyed from a first section at a first pressure level to a second section at a second pressure level, heated in the second section through solar heat, and the heated refrigerant is expanded in a third section by means of the an expansion device, and cooled in the third section, wherein the pressure in the third section is set such that the refrigerant is condensed, and the refrigerant is then returned from the third section to the first section.

[0058] The refrigerant is preferably vaporized in the first section. The mechanical energy released by the expansion device is preferably used for driving the conveyor and/or a generator.

[0059] The power ratio between the conveyor and the expansion device is preferably coordinated to the heating power in the second section.

[0060] Further details and features of the invention can be derived from the following description in conjunction with the drawings. Therein:

Fig. 1 shows a simplified schematic drawing illustrating the structure of a first preferred embodiment of the cooling system according to the invention;

Fig. 2 shows a drawing illustrating a combination module with an integrated solar panel and ambient air heat exchanger;

Fig. 3 shows a drawing illustrating a preferred embodiment of a high-temperature panel for heating a preferably organic refrigerant.

[0061] The cooling system shown in Fig. 1 will be broken down into three sections, “A,” “B,” and “C” below for the following explanation.

First section A:

[0062] The first section A extends here between a dosing device 2 and a conveyor 1 for conveying a refrigerant, e.g. propane gas, from a first section A.

[0063] The conveyor 1 is in the form of a hydrostatic compressor, and conveys a volume flow v1 at a rotational rate n1. The hydrostatic compressor is a piston compressor or an impeller compressor.

[0064] The dosing device 2 is formed here by a geared conveyor 2a. The conveyed amount is set by a dosing actuator c1. The control of the dosing actuator c1 takes place via a programmed computer, not shown in detail here. Alternatively, it is possible to form the dosing device with a different type of conveyor, or a choke.

[0065] There is also an evaporator in the first section A, by means of which a heat flow Q_{31} can be discharged from the environment of the evaporator at a temperature T4 and a pressure p1 in the evaporator.

[0066] There is also a check valve 5, through which a return flow of refrigerant into the evaporator 4 can be prevented.

[0067] The first section A can be bypassed by a parallel line 17. There is a dosing device 18 for setting the amount of refrigerant conveyed through the parallel line 17, which can be adjusted here by a geared conveyor 18 controlled by a dosing drive c2. There is a check valve for preventing flow in the other direction.

[0068] In order to provide a sufficient amount of refrigerant, there is a reservoir 20. The refrigerant level in the reservoir is preferably taken into account by the central control unit.

Second section B:

[0069] A second section B adjoins the conveyor 1, which extends to an expansion device 6. The expansion device 6 is formed by a hydrostatic machine here.

[0070] There is a heater 7 in the second section B. The heater is formed here by a high-temperature solar panel, and comprises a heating line 8, an insulator 9, and a cover plate 10.

[0071] The refrigerant is further heated in the heater 7 by supplying a heat flow Q_{12}. A thermal sensor T2 is used for detecting the temperature of the heated refrigerant.

[0072] The initial temperature of the refrigerant before entering the heater is detected by a thermal sensor T1. Based on the difference in temperature, T1-T2, the heating power, or the amount of added heat can be calculated in conjunction with the conveyor 1 and the expansion device 6, e.g. via the rotational rates thereof.

[0073] There is a bypass 11 for bypassing the second section B, through which the refrigerant can bypass the heater in the circuit. The bypass 11 is controlled via a valve 12 for opening it. The actuation of the valve 12 takes place via an actuator c3.

Third Section C:

[0074] A third section C extends between the expansion device 6 and the dosing device 2. The third section C comprises a heat exchanger 14. In the embodiment shown here, the heat exchanger 14 is in the form of a water/ambient air combination heat exchanger. The heat flow Q_s can be discharged from the refrigerant via the heat exchanger 14.

[0075] There is a thermometer T3 for monitoring the temperature at the output of the heat exchanger 14. There is a pressure p3 at the output of the heat exchanger 14, which can be detected via a pressure sensor, not shown herein.

[0076] The third section can be bypassed by a bypass line 15. The bypass can be adjusted via a choke 16 in a range of 0 to 70%. The actuation likewise takes place via the central control unit.

Buildup of Pressure in the Second Section B:

[0077] The pressure in the second section B is determined by the amount of refrigerant that is supplied, the amount of heat, and the amount of refrigerant discharged via the expansion device 6.

[0078] The pressure level is obtained in particular by a reciprocal tensioning of the conveyor 1 and the expansion device 6. This tensioning can take place mechanically through corresponding gear ratios or through corresponding actuation.

[0079] The expansion device 6 is connected here to a motor/generator device M/G. The conveyor 1 can also be driven via this device in the embodiment shown here.

[0080] The expansion device 6 can be bypassed via a bypass device 21.

[0081] A preferred embodiment of a solar air-conditioner module 23 is shown in Fig. 2, that comprises a high temperature solar panel 7 and an ambient air heat exchanger 14. The heat exchanger 14 is located on a shaded side of the solar panel 7. There is an insulator 22 between the heat exchanger and the solar panel. The angle of the solar air-conditioner module 23 can be adjusted to the position of the sun. An actuator 24 is provided for this. The adjustment preferably likewise takes place according to the specifications of the central control unit.

[0082] The lines for the heat exchanger are formed by an extrusion profile, and arranged in a fan-like manner. The dimension of the lines are such that they can withstand a refrigerant pressure of up to 200 bar. The configuration thereof is such that a chimney effect is obtained. Optionally, a ventilator can also be provided to improve the cooling effect.

[0083] The conveyor, expansion device, and motor/generator M/G are advantageously also integrated in the solar module 23. The solar module thus also be used for producing energy without being integrated in an air-conditioning system.

[0084] A detail of a preferred embodiment of a heater 7 is shown in a very simplified illustration in Fig. 3. The heating line 8 is formed by a tube 25 here. The tube 25 forms a cavern 26, which has a matte black surface here.

[0085] The tube 25 is substantially insulated from the exterior by means of a foam glass insulation 27. Numerous units of this type, composed of insulating elements and tubes 25 are arranged, adjacent to one another, in a plane or cylindrical surface, and coupled to the refrigerant circuit.

[0086] There is a cover plate 28 in front of the tube 25, seen from the direction where the light enters. The cover plate 28 is provided with optical elements 29, which deflect the incident light into the corresponding caverns. In the embodiment shown here, the optical elements are formed by Fresnel lens contours. In the proximal lens contours, the deflection of the light is based on a refraction effect. The deflection at the contours further away from the respective heating lines is based on total internal reflection effects.

[0087] The optical elements can also be formed on the outer surface of the cover plate and/or in an intermediate layer. The cover plate can be supported by the insulator.

Function:

[0088] There are different pressure levels, p1, p2, and p3, in sections A, B, and C. Pressure p1 is 1.5 bar, for example. Refrigerant is conveyed to the second section by the conveyor 1, and compressed to the pressure p2, e.g. 60 bar. The refrigerant heats up to a temperature T2 in doing so, and is subsequently heated further in the heater 7.

[0089] A substantially adiabatic expansion to the pressure p3 takes place in the expansion device 6. The energy released thereby is used in part for driving the conveyor 1 and the rest is used for driving the generator G/M. The refrigerant is condensed in the heat exchanger 14 at the pressure p3. The condensed refrigerant is delivered to the reservoir 20. A refrigerant flow from the reservoir 20, dosed via a dosing device 2, is delivered to the evaporator 4. Heat Q_{31} can be discharged from a space or medium that is to be cooled via the evaporator 4. The refrigerant that has been vaporized and heated in the evaporator is returned to the heater via the conveyor 1. A sub-flow of the refrigerant diverted from the reservoir 20 is delivered directly to the heater 7 using a dosing gear pump 18 via the check valve 19. This increases the efficiency of the expansion device 6. It is also possible to pre-heat the refrigerant. This can take place through a heat exchange with the refrigerant between the expansion device 6 and the actual heat exchanger 14. It is also possible to obtain an internal heat exchange (internal heat exchanger 43) between the liquid refrigerant conveyed by the pump 18a and the refrigerant that has not been cooled, downstream of the expansion device 6. The lines necessary for this internal heat exchange can preferably be actuated via valves 41, 42.

Claims

1. A cooling system that has a compressor for conveying a refrigerant from a first section with a pressure level p1 to a second section with a higher pressure level p2 than the first pressure level p2, an expansion device for delivering the refrigerant from the second section to a third section that has a third pressure level p3 lying between the first pressure level p1 and the second pressure level p2, and a heater for heating the refrigerant in the second section.

2. The cooling system according to claim 1, characterized in that the heater is a solar panel heater, and/or in that the expansion device is a hydrostatic machine, and/or in that the expansion device is a hydrodynamic machine, and/or in that the conveyor is a hydrostatic pump.

3. The cooling system according to claim 1 or 2, characterized in that the expansion device and the conveyor are mechanically coupled.

4. The cooling system according to at least one of the claims 1 to 3, characterized in that there is a heat exchanger in the third section for cooling the refrigerant heated in the second section.

5. The cooling system according to at least one of the claims 1 to 4, characterized in that the heat exchanger is an ambient air cooler and/or a tap water heater, and/or a combination heat exchanger for heating water and/or ambient air.

6. The cooling system according to at least one of the claims 1 to 5, characterized in that the expansion device is coupled to a generator.

7. The cooling system according to at least one of the claims 1 to 6, characterized in that an electric motor and a generator are coupled to one another via a control unit.

8. The cooling system according to at least one of the claims 1 to 7, characterized in that there is at least one bypass line for bypassing the heater in the second section, and/or in that there is a valve in the bypass line for opening or closing the bypass line, and/or in that there is a thermometer for monitoring the temperature of the refrigerant in the second section, and/or in that there is an evaporator in the first section for vaporizing the refrigerant conveyed from the third section to the first section, and/or in that there is a bypass line for bypassing the first section, and/or in that a hydrostatic conveyor is placed in the bypass line, and/or in that there is a refrigerant reservoir in the system for storing the refrigerant in the liquid state, and/or in that there is a buffer reservoir for providing a refrigerant, wherein the heated refrigerant is cooled overnight, and/or in that the heat exchanger and the heater form an integral module.

9. The cooling system according to at least one of the claims 1 to 8, characterized in that the heater comprises a focusing lens assembly, and/or in that the lens assembly is a Fresnel lens assembly, and/or in that there is an insulator for insulating the refrigerant heating lines, and/or in that the insulator is formed by foam glass, and/or in that the insulated formed by foam glass is joined to a glass plate in a sealing manner, and/or in that the Fresnel lens assembly is formed in the glass plate, and/or in that the heating of the refrigerant takes place through heating lines, and in that sections of the heating lines are embedded in the foam glass in a sealing manner.

10. A method for transforming solar energy in which a refrigerant is conveyed by means of a conveyor from a first section that has a first pressure level to a second section that has a second pressure level, heated in the second section by solar heat, and the heated refrigerant is expanded by means of an expansion device in a third section, and cooled in the section, wherein the pressure in the third section is set such that the refrigerant condenses, and the refrigerant is then returned from the third section to the first section.

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Certification

This is to certify that the foregoing translation of the patent entitled **Cooling System** was made from German to English from the source document by a competent translator well acquainted with both languages, and that, to the best of our knowledge and belief, it is a true and complete rendering into English of the selected text.

Date: July 19, 2019

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