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(54) IMPROVED OPEN-CYCLE STEAM ENGINE WITH DOUBLE CENTER OF ROTATION PISTON

(57) Steam engine (L) with a piston with double center of rotation comprising a stator (A) and a rotor (B) configured to expand a fluid to generate useful mechanical work, the stator (A) and the rotor (B) defining: an expansion chamber (Ve) configured to expand a pressurized fluid and having an inlet duct for receiving a pressurized fluid and an outlet duct for expelling the expanded fluid from the expansion chamber (Ve) to the external environment and an inactive compression chamber (Vc).

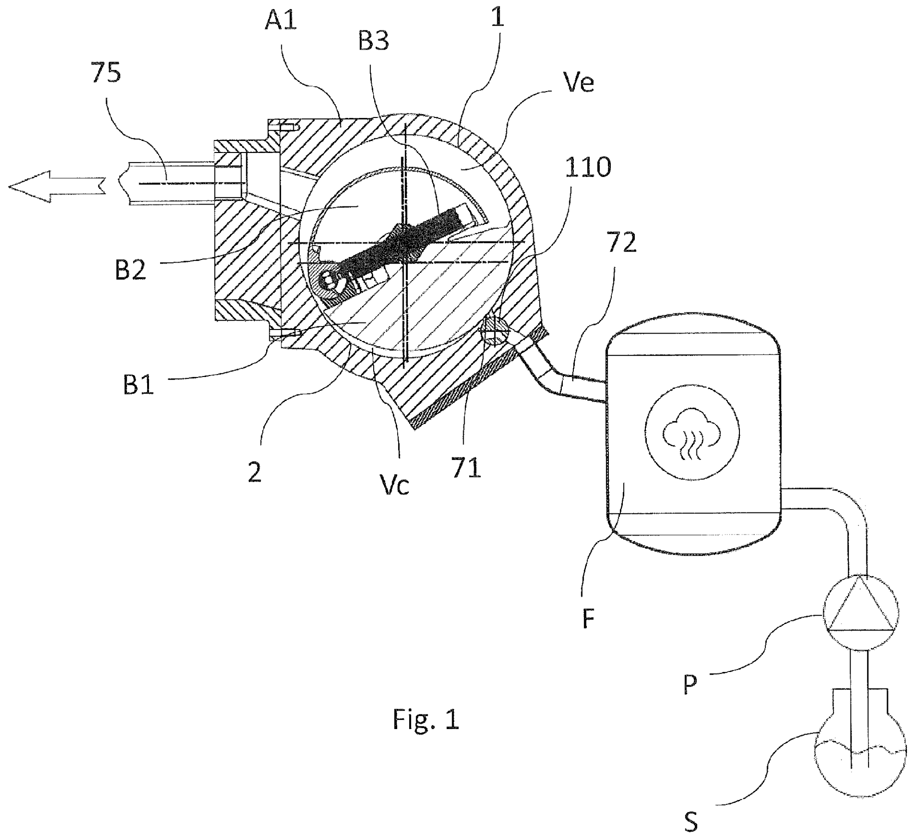

Fig. 1

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Description

Technical Field

[0001] The present invention relates to a steam engine with a piston with double center of rotation configured to perform an open thermodynamic cycle.

Background Art

[0002] A steam engine is known from the state of the art, with a piston with double center of rotation which turns within a substantially cylindrical double cavity compartment, determining a closed thermodynamic cycle exploiting the temperature and pressure of the steam, to obtain useful mechanical work, passing to the different temperatures and pressure in the various steps of the thermodynamic cycle. The steam engine comprises an expansion chamber and a compression chamber in fluid communication with a boiler which supplies pressurized fluid at the inlet of the expansion chamber and receives compressed fluid from the compression chamber. The chambers are also in fluid communication with a condenser. Specifically, the condenser receives the expanded fluid from the expansion chamber at the inlet and, following the condensation of the expanded fluid, supplies the condensed fluid at the inlet of the compression chamber. Such a steam engine is for example disclosed in Italian patent no. 102016000123578. Thereby, the steam engine is capable of performing a thermodynamic cycle having the following steps:

a) heating the fluid in a special heat exchanger/boiler at higher temperatures Tv,
b) a subsequent input into the expansion chamber ideally at the boiler pressure, until the volume Vi (equivalent to Ve in figure 4) or optimal mass for the cycle is reached by means of a valve which regulates the quantity thereof,
c) an ideally adiabatic expansion of the fluid introduced into the expansion chamber until reaching the final expansion volume Vf (equivalent to Ve in figure 5),
d) input of the expanded fluid into the condenser with temperature reduction to the lower level Tc,
e) the condensate exiting by gravity and/or pressure wave enters the compression chamber with volume Vc,
f) the condensate is compressed by the rotor and when the boiler pressure is exceeded, by means of a unidirectional valve, which in practice is a lamellar valve, it is re-input into the heater, closing the cycle.

Problems of the Background Art

[0003] The machine known in the creation of the thermodynamic cycle in collaboration with other elements such as boiler and condenser has showed impulsive operation due to the alternation of the expansion and compression steps. In other words, the thermodynamic cycle performed by the steam machine produces a continuous series of temperature and pressure transients.

[0004] The thermodynamic cycle is performed in the steps in which the exhausted steam at the end of the expansion enters the condenser, from which the condensate exits (two-phase water/steam) which the machine compresses in the boiler where it is heated again to the steam state to be re-input, through a regulating valve, into the expansion chamber of the machine to restart the cycle. This results in the creation of pressure waves in the "low pressure/temperature" zone in the condenser area shown in figure 9. Such pressure waves are due to the reduction of the volume of fluid exiting the expansion chamber Ve (with impulsive trend) which, when entering the condenser undergoes a volume reduction, causes a suction effect from the ducts 75 and 76 and from the motion of the rotor itself which varies the distribution of the internal volumes during the rotation of the machine L, accentuating the phenomenon.

[0005] Figures 4-9 depict the steam engine of the prior art, where the pressure waves and/or undesirable pressure changes are depicted with a wavy arrow, while the desired flow is depicted with straight arrows. The generation of the pressure waves is due to two main phenomena:

i) the first phenomenon preventing a continuous flow of condensate exiting the condenser towards the compression chamber of the machine is due to the "puff or pulse of steam exiting the expansion chamber which enters the condenser. Specifically, the steam pulse reached in the condenser in contact with the cold surfaces undergoes a drastic decrease in volume. This causes a pressure drop, drawing some of the fluid from the previous cycle into the condenser from the connection ducts between the expansion chamber and the compression chamber. Such a drawing effect is accentuated by the fluid accumulated in the connection duct with the compression chamber where it has accumulated;
ii) the second disturbance phenomenon is due to the variation of the subdivision, during rotation, of the volumes inside the machine. The rotor behaves like a bellows, sucking and expelling during the arc of rotation. The total internal volume of the stator chamber is kept constant at all times. During a rotation step, the expansion volume increases, the remaining volume decreases by the same amount. The fluid at the center of the machine with the decrease in volume thereof increases the pressure. The consequence is a fluid puff or impulse from the machine towards the condenser along the connection duct between the condenser and the compression chamber in the opposite direction to that desired to compress the condensate in the boiler (figures 5 and 6). In a second rotation step, the same phenomenon

occurs but in the opposite direction where the central part of the rotor, with the decrease of the compression volume, has a sucked effect from the connection duct between the inlet of the condenser and the outlet of the expansion chamber.

[0006] The set of such phenomena causes pressure pulses (or pressure waves) contrary to the desired flow. These pressure changes in the "cold zone" of the cycle create a strong disturbance to the path of the condensate towards the compression chamber which must re-compress it in the boiler. This creates a rejection of condensate exiting the condenser, which has difficulty entering the machine by gravity and consequently the compression which brings it back to the boiler is penalized, creating an accumulation in the pipes and in the center of the rotor. This set of phenomena leads, after a transition step in which the accumulation of condensed fluid increases more and more, to the blockage of the rotation of the machine.

Object of the Invention

[0007] The object of the invention in question is to obtain a steam engine with a piston with double center of rotation able to overcome the drawbacks of the prior art mentioned above.

[0008] In particular, it is an object of the present invention to provide an open-cycle steam engine with a piston with double center of rotation capable of avoiding the effects of pressure waves generated during the thermodynamic cycle and simultaneously improving the efficiency of the engine itself.

Advantages of the Invention

[0009] Advantageously, the steam engine allows the desired thermodynamic cycle to be achieved by radically eliminating the problem associated with the condensed fluid.

[0010] Advantageously, the steam engine allows the improvement and practical performance of a thermodynamic cycle with fluid, water or other fluid, adapted to create an open cycle to generate mechanical energy.

[0011] Advantageously, the steam engine allows to eliminate the connection valves of the closed cycle, allowing to solve the wear problems of the valves themselves.

SHORT DESCRIPTION OF THE FIGURES

[0012] Further features and advantages of the present invention will become more apparent from the description of an exemplary, but not exclusive, and therefore non-limiting preferred embodiment of an open-cycle steam engine with a piston with double center of rotation as illustrated in the appended figures, in which:

- figure 1 shows a schematic, sectional view of the steam engine in accordance with an embodiment of the present invention;
- figure 2 shows an exploded view of the stator casing of the steam engine in accordance with the embodiment of figure 1;
- figure 3 shows an exploded view of the rotor in accordance with the embodiment of figure 1;
- figure 4 shows a schematic sectional view of a steam engine in accordance with the state of the art in a first angular position of the rotor in which the introduction step of the fluid to be expanded has ended;
- figure 5 shows a schematic sectional view of a steam engine in accordance with the state of the art in a second angular position of the rotor in which the expansion step was completed shortly before the discharge step;
- figure 6 shows a schematic sectional view of a steam engine in accordance with the state of the art in a third angular position of the rotor, the present figure illustrates the condensation step in which a suction is created (indicated by the wavy arrows) towards the condenser in the ducts 75 and 76 due to the decrease in the volume of the steam in the condenser;
- figure 7 shows a schematic sectional view of a steam engine in accordance with the state of the art in a fourth angular position of the rotor and a relative enlargement of the circled zone, the angular position illustrates the step prior to compression where it is highlighted how the condensate enters by gravity into the compression chamber through the slit between rotor and casing (shown in the relative enlargement);
- figure 8 shows a schematic sectional view of a steam engine in accordance with the state of the art in a fifth angular position of the rotor in which the initial condensate compression step is illustrated;
- figure 9 shows a schematic sectional view of a steam engine in accordance with the state of the art in a sixth angular position of the rotor and a relative enlargement of the circled zone, the angular position illustrates the end of the compression step where the condensate, with the boiler pressure reached and exceeded, opens the lamellar or unidirectional valve and is re-input in the boiler itself.

DETAILED DESCRIPTION

[0013] Even if not explicitly highlighted, the individual features described with reference to the specific embodiments shall be understood as accessory and/or interchangeable with other features, described with reference to other embodiments.

[0014] The present invention relates to an open-cycle steam engine L with a piston with double center of rotation illustrated in figures 1-3, the general features of which are reported in Italian patent No. 102016000123578.

[0015] It should be noted that with respect to patent no. 102016000123578, the solution illustrated in figure 1 includes an open cycle which, as better described in the following, allows to solve the problems of the steam engine of patent no. 102016000123578 illustrated in figures 4-9 and in the previous paragraphs.

[0016] The steam engine L with a piston with double center of rotation comprises a stator A and a rotor B and preferably a flywheel W configured to overcome the dead spots during the cycle. Specifically, the engine L comprises a first and a second element A2, A3 defining the stator body A1. In other words, the first and the second element A2, A3 define the sides of the stator body A1 defining in turn the stator A. With regard to the rotor B, this comprises a first semicylindrical element B1 on which the pressure of the fluid which creates the rotation or driving torque acts, provided with a shaft for power take-off, a second semicylindrical element B2 which acts as a compression element and a third element B3 configured to couple the first and the second semicylindrical element B1, B2. It should be noted that the stator A and the rotor B and any flywheel W substantially have the structural features of steam engine with a piston with double center of rotation described in international patent applications WO 2004/020791 A1, WO 2010/031585 A1, and WO 2014/083204 A1.

[0017] The stator A and the rotor B define an expansion chamber Ve and a compression chamber Vc. Specifically, inside the stator body A1 an expansion compartment 1 is defined within which the expansion chamber Ve is formed and a compression compartment 2 within which the compression chamber Vc is formed.

[0018] It should be noted that the expansion chamber Ve is configured to receive a pressurized fluid, for example steam, and expand it by rotating the rotor B, preferably up to ambient pressure.

[0019] The expansion chamber Ve comprises an inlet opening 71 and an outlet opening. The inlet opening 71 is configured to receive the pressurized fluid through a regulating valve 110 and the outlet opening is configured to expel the expanded fluid into the external environment. Preferably, the expansion chamber Ve comprises an outlet duct connected to the relative outlet opening and is configured to receive the expanded fluid from the expansion chamber Ve, directing it towards the external environment, as will be explained below. The expansion chamber Ve comprises an inlet duct connected to the relative inlet opening 71 and configured to convey the pressurized fluid inside the expansion chamber Ve, for example, from a boiler or heating element F.

[0020] In accordance with the open-circuit embodiment, illustrated in figures 1 and 2, the condenser and the relative fluid connections with the casing A1, the fluid connections between the casing A1 and the boiler F and the relative valves interposed in the fluid connections which characterized the closed-cycle steam engine have been eliminated.

[0021] Specifically, the compression chamber Vc is inactive. In other words, the compression chamber Vc remains dead. Specifically, the compression chamber Vc has no connection ducts with the external environment with respect to the stator body A1. In detail, the compression chamber Vc is blind, avoiding the compression of the fluid.

[0022] In accordance with a preferred embodiment of the present invention, the compression chamber Vc is smaller in size than the expansion chamber Ve. Preferably, the expansion chamber Ve has an expansion volume and the compression chamber Vc has a compression volume, so that the compression volume is negligible with respect to the expansion volume. Specifically, the compression volume of the compression chamber Vc is an inactive volume.

[0023] Advantageously, having a limited number of components, the steam engine L is easy to manufacture and constructively economical.

[0024] According to a preferred embodiment, the steam engine L comprises a heating element or boiler F configured to produce the pressurized fluid and in fluid communication with the inlet channel of the expansion chamber Ve. Specifically, the heating element F comprises at least one outlet, configured to supply the steam engine L with the pressurized fluid. The heating element or boiler F also has an inlet configured to receive a fluid to be heated. As illustrated in figure 2, the inlet of the heating element or boiler F is in fluid communication with a fluid source S which can be a water tank or the water mains, which allows to supply the fluid to be heated which is equal to the same mass of the fluid introduced into the external environment in accordance with the known art. Specifically, the steam engine L comprises a duct connecting the heating element F and the fluid source S which puts the heating element F in fluid communication with the fluid source S. According to the embodiment illustrated in figures 1 and 2, a hydraulic pump P, known to the person skilled in the art, is associated with the duct connecting the heating element F and the fluid source S and is configured to withdraw the fluid from the fluid source S and send it to the heating element F.

[0025] In accordance with the embodiment of figures 1 and 2, the engine further comprises an inlet connection duct 72 configured to put the outlet of the heating element F in fluid communication with the inlet duct of the expansion chamber Ve.

[0026] In accordance with a preferred embodiment, the inlet connection duct 72 and the inlet duct of the expansion chamber Ve define an inlet duct 72 configured to put the outlet of the heating element F and the inlet opening 71 of the expansion chamber Ve in fluid communication.

[0027] In accordance with a preferred embodiment, the stator body A1 comprises a longitudinally formed housing configured to house the input valve 110. To optimize the efficiency of the steam engine, the input valve 110 is adapted to regulate the amount of fluid introduced into the expansion chamber such that at the end of expansion the fluid is at ambient pressure. Specifically, the input valve 110 is placed at the inlet opening 71 and configured to regulate the inlet of the pressurized fluid into the expansion chamber Ve and to make the pressure of the expanded fluid exiting the expansion chamber Ve equal to the ambient pressure. In detail, the input valve 110 is interposed between the inlet opening 71 and the inlet duct of the expansion chamber Ve to regulate the passage of the pressurized fluid from the heating element F to the expansion chamber Ve.

[0028] Preferably, the input valve 110 is for example a rotary valve 110 made synchronous by the gears R1, R2, R3, where the gear R1 is fixed on the drive shaft 80, the gear R3 is fixed on the rotary valve 110 and the gear R2 is fixed on the stator body and coupled to the gears R1, R3, as described in detail in the aforementioned patent applications.

[0029] As illustrated in the embodiment of figures 1 and 2, the engine further comprises an outlet connection duct 75 configured to put the outlet duct of the expansion chamber Ve in fluid communication with the external environment to obtain the open cycle.

[0030] In accordance with a preferred embodiment, the outlet connection duct 75 and the outlet duct of the expansion chamber Ve define an outlet duct 75 configured to put the outlet opening of the expansion chamber Ve in fluid communication with the external environment.

[0031] Thereby, in accordance with the described embodiment the steam engine performs an open thermodynamic cycle, performed between the temperature Tv and the temperature Tc equal to the ambient temperature:

a) heating the fluid by means of the heating element or boiler F to the higher temperature Tv,
b) subsequent input into the expansion chamber Ve ideally at the boiler pressure, until the optimal volume Vi or mass for the cycle is reached by the valve 110 which regulates the quantity thereof;
c) ideally adiabatic expansion of the fluid input into the expansion chamber Ve until reaching the final expansion volume Vf, preferably at ambient pressure;
d) expulsion of the expanded fluid into the external environment

[0032] Advantageously, the engine according to the present invention allows to maintain high efficiency.

[0033] In accordance with a preferred embodiment and known techniques, it is possible by means of a heat exchanger to preheat the fluid to input into the boiler F, exploiting the residual heat of the fluid expelled from the expansion chamber Ve.

[0034] It should be noted that the open-cycle steam engine prevents the occurrence of the first phenomenon i) linked to the pressure contraction in the condenser which draws the fluid present in the inlet duct of the compression chamber Vc and/or in the duct 76 in the form of a condensate, preferably two-phase, of the previous cycle. In fact, the expanded fluid is ejected directly into the external environment avoiding any drawing for the aforementioned volumetric contractions. In other words, the removal of the condenser D and the duct 76 prevents the condensate fluid present in the inlet duct from migrating towards the condenser D.

[0035] Furthermore, the inactive compression chamber Vc prevents the generation of pressure waves or puffs, due to the reduction of the compression volume and the increase of the expansion volume when the rotor closes like a bellows, which have an effect on the thermodynamic cycle.

[0036] It should be noted that the combination of the open cycle and the inactive compression chamber Vc also allows the second phenomenon ii) to be overcome.

[0037] Advantageously, the open cycle performed by the steam engine according to the present invention allows to simplify the engine itself by also eliminating the typical connection valves of the closed cycle, solving the problems of wear of the valves themselves and of pressure loss.

Claims

1. Steam engine (L) with a piston with double center of rotation, **characterized in that it comprises:**

   - a stator (A) and a rotor (B) configured to expand a fluid to generate useful mechanical work, the stator (A) and the rotor (B) defining:

     - an expansion chamber (Ve) configured to expand a pressurized fluid and having an inlet duct for receiving a pressurized fluid and an outlet duct for expelling the expanded fluid from the expansion chamber (Ve) towards the external environment, and
     - an inactive compression chamber (Vc).

2. Steam engine (L) according to claim 1, wherein the expansion chamber (Ve) has an expansion volume and the compression chamber (Vc) has a compression volume, the compression volume being negligible with respect to the expansion volume.

3. Steam engine (L) according to claims 1 or 2, wherein the engine comprises a heating element (F) configured to produce by heating the pressurized fluid to be sent to the expansion chamber (Ve), the heating element (F) having an outlet in fluid communication with the inlet channel of the expansion chamber (Ve) to send the pressurized fluid to the expansion chamber (Ve).

4. Steam engine (L) according to claim 3, wherein the heating element (F) has an inlet configured to receive fluid to be heated.

5. Steam engine (L) according to claim 3 or 4, wherein the engine comprises an inlet connection duct (72) configured to put the inlet duct of the expansion chamber (Ve) in fluid communication with the outlet of the heating element (F).

6. Steam engine (L) according to any one of claims 1 to 5, wherein the engine comprises an outlet connection duct (75) configured to put the outlet duct of the expansion chamber (Ve) in fluid communication with the external environment.

7. Steam engine (L) according to any one of claims 1-6, the engine comprising an input valve (110) placed at the inlet opening (71) and configured to regulate the inlet of the pressurized fluid into the expansion chamber (Ve) and to make the pressure of the expanded fluid exiting the expansion chamber (Ve) equal to the ambient pressure.

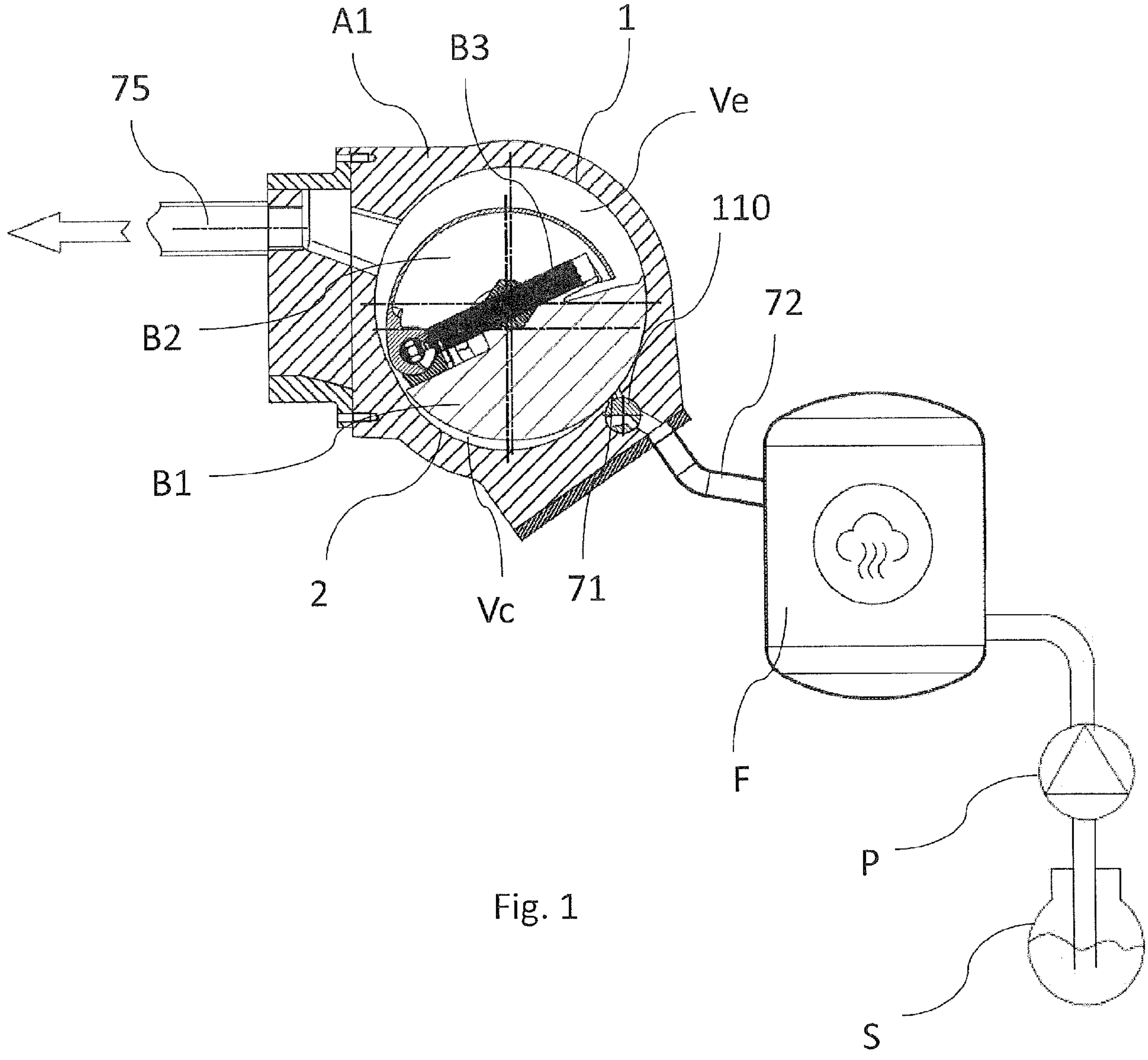

Fig. 1

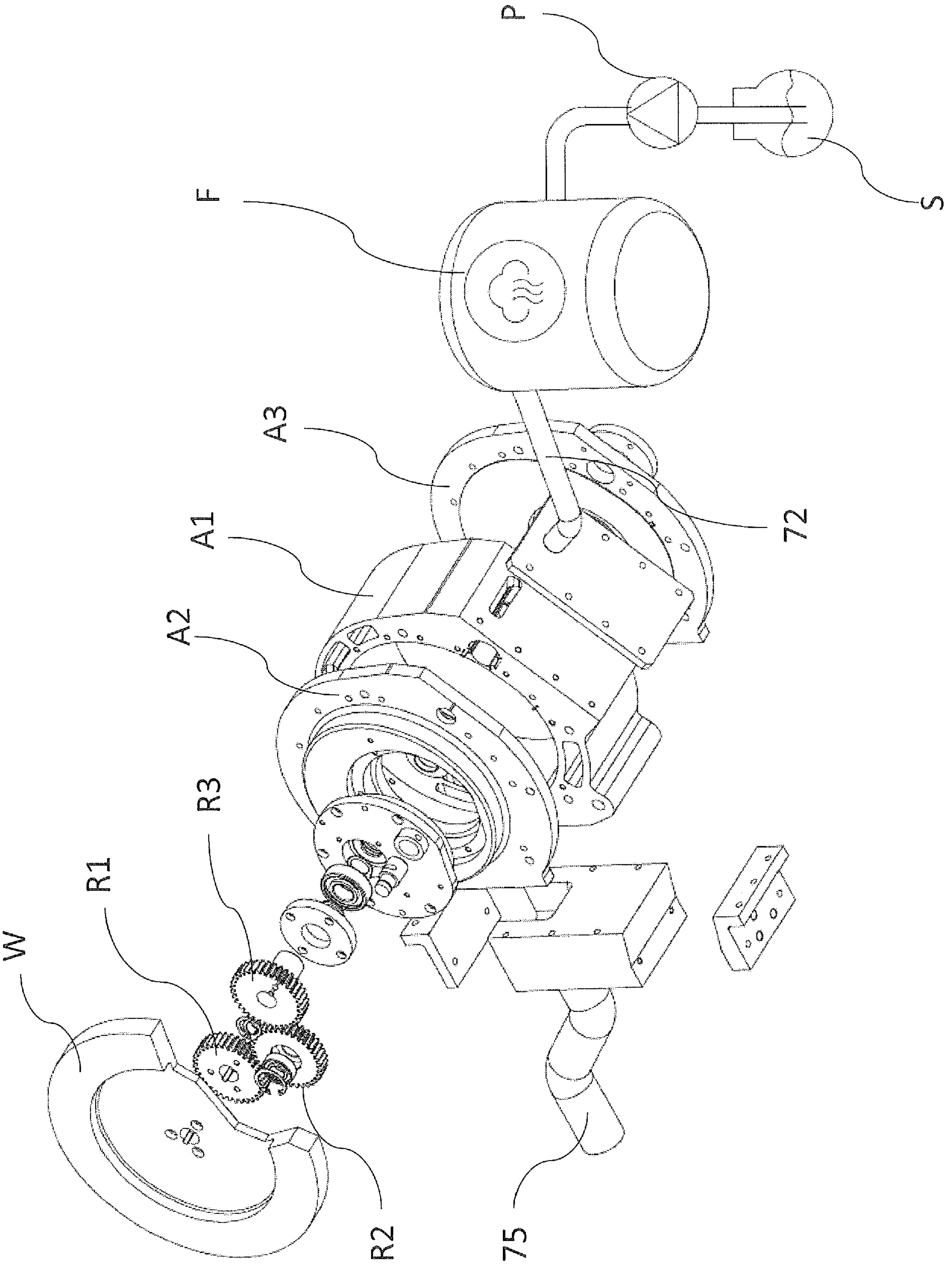

Fig. 2

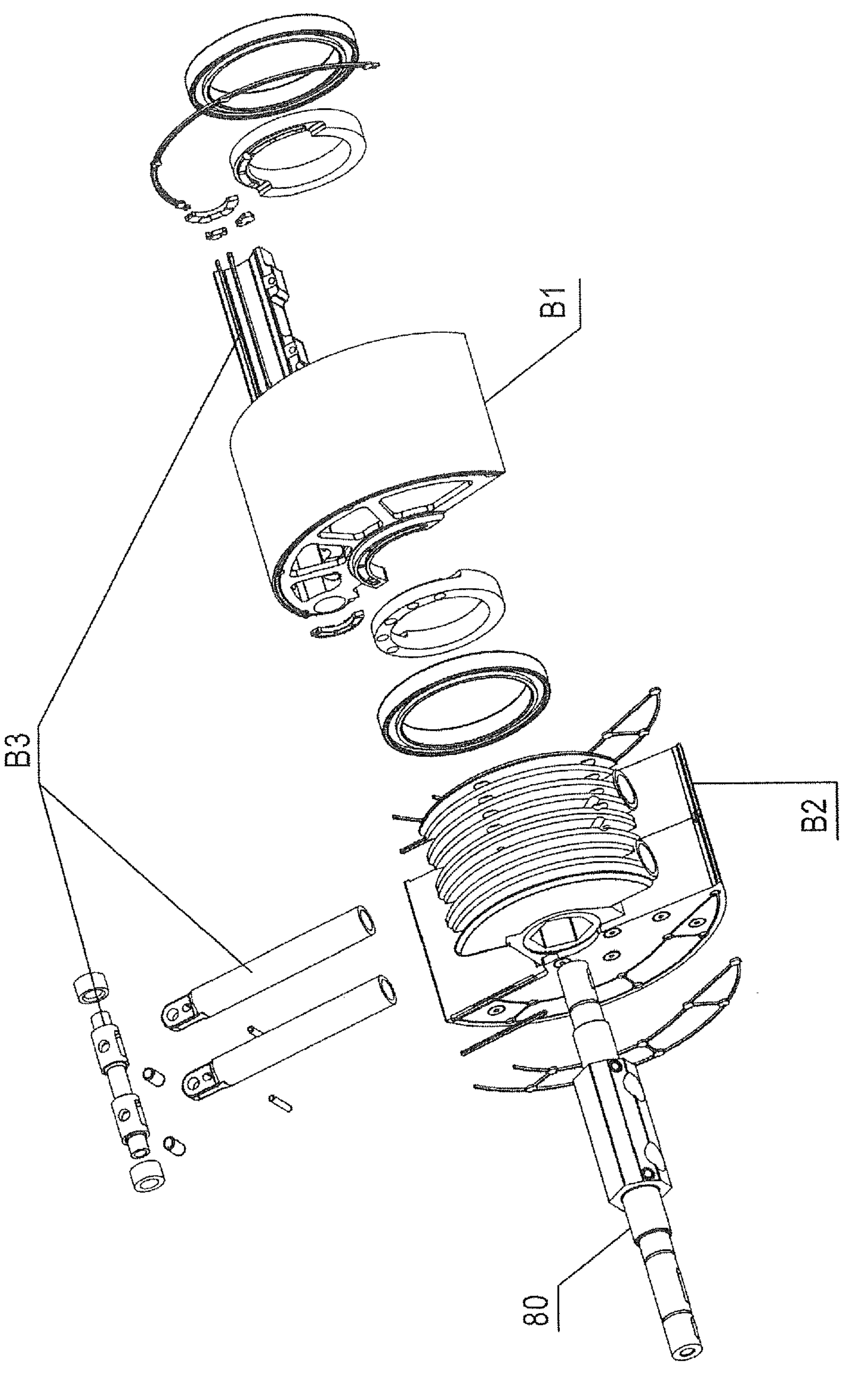

Fig. 3

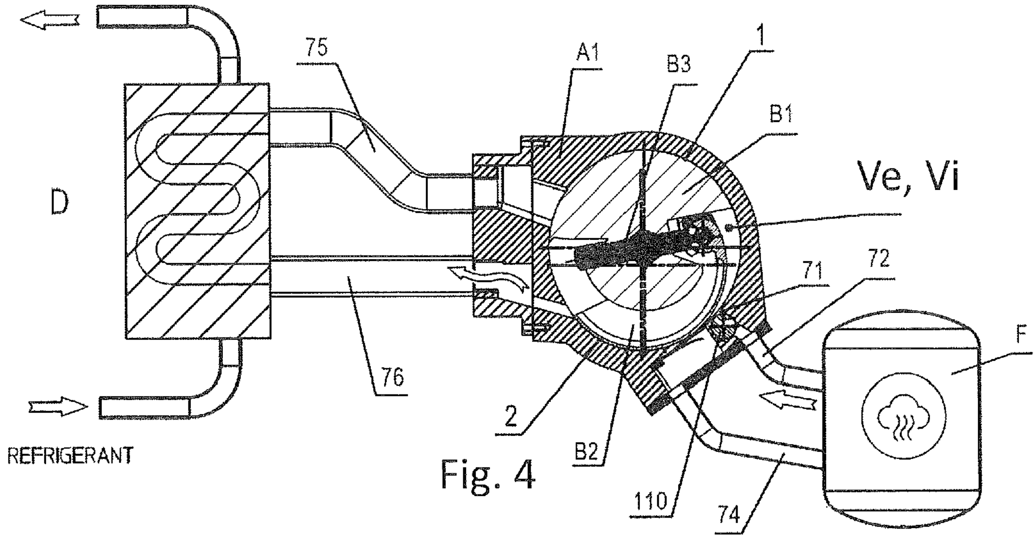

Fig. 4

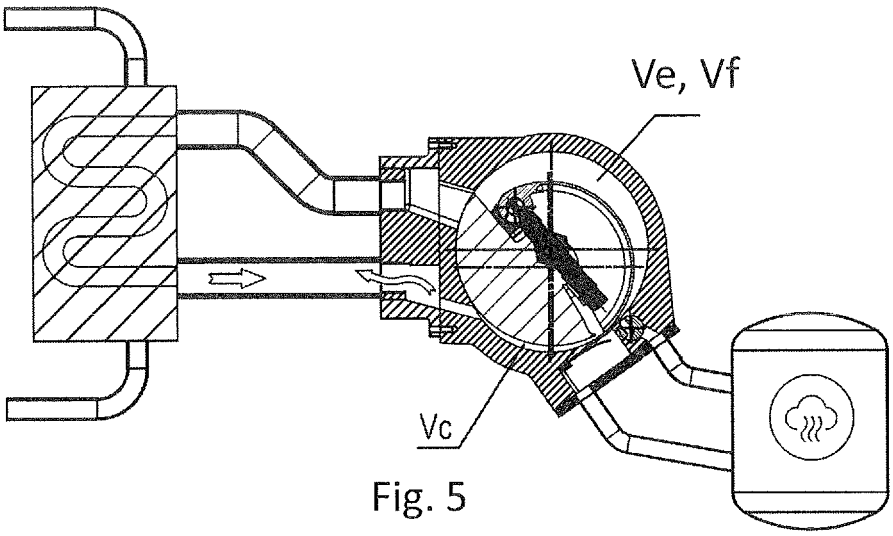

Fig. 5

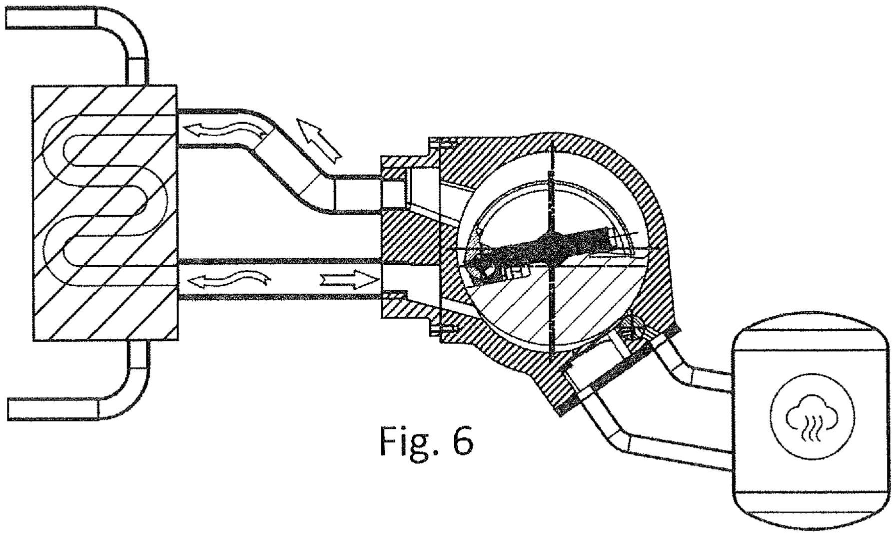

Fig. 6

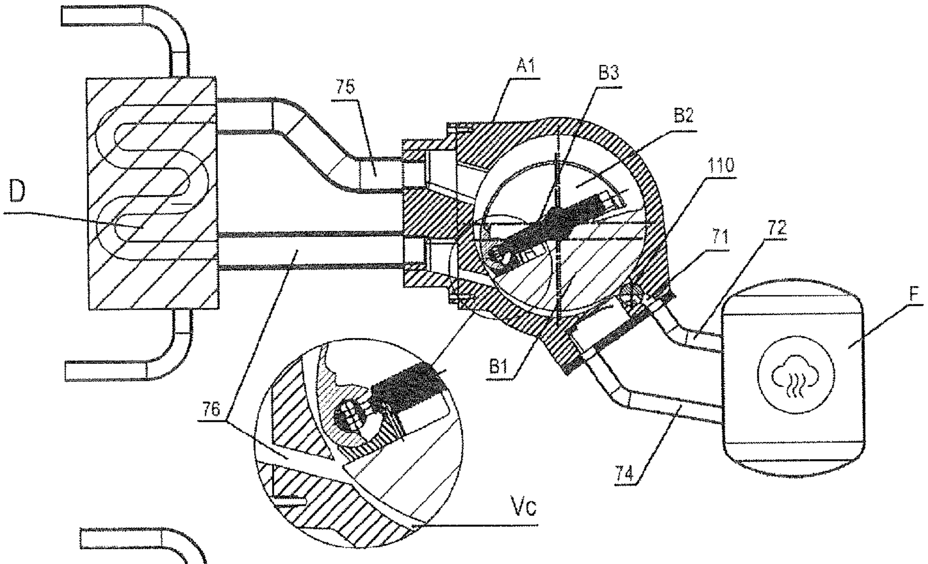

Fig. 7

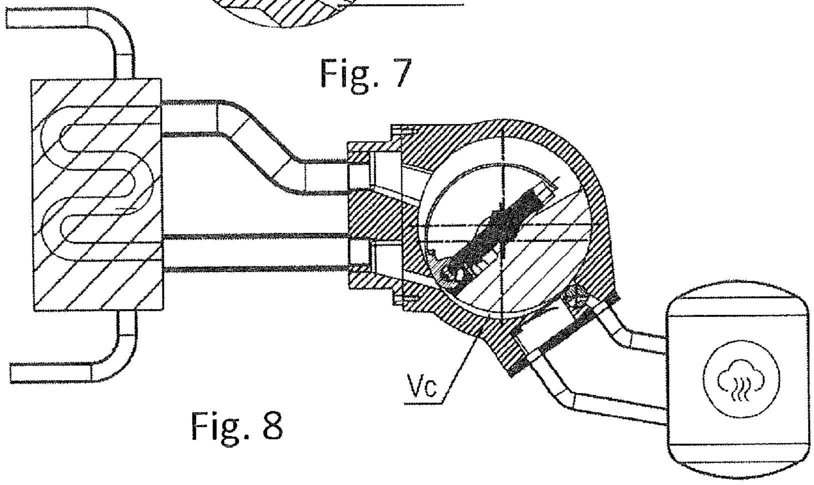

Fig. 8

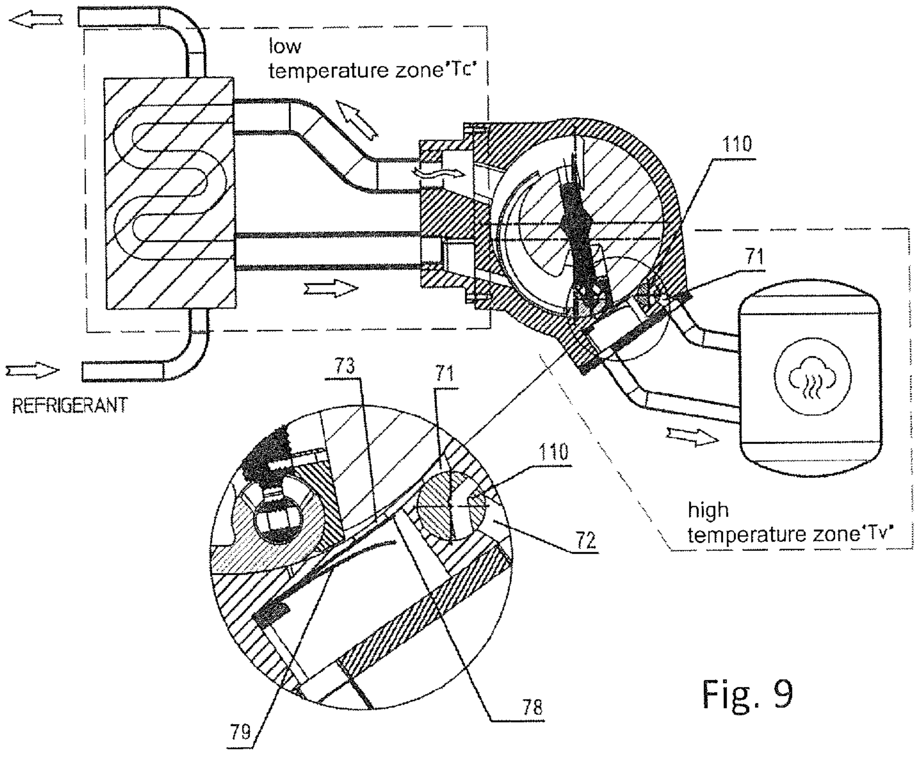

Fig. 9

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EUROPEAN SEARCH REPORT

Application Number
EP 21 17 7832

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	14 October 2021	Durante, Andrea

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