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(54) **Plant for the production of thermo-frigorific energy and method for the optimization of its efficiency**

(57) The plant (1) for the production of thermo-frigorific energy comprises at least one thermo-frigorific unit comprising at least one compressor (2) and one heat exchanger (3) having a circuit of the refrigerant fluid (4)

in thermal exchange with a circuit of hot water (5) for users, in the heat exchanger (3) a cooling circuit of oil (6) of the compressor (2) being integrated, in thermal exchange with the circuit of hot water (5) for users.

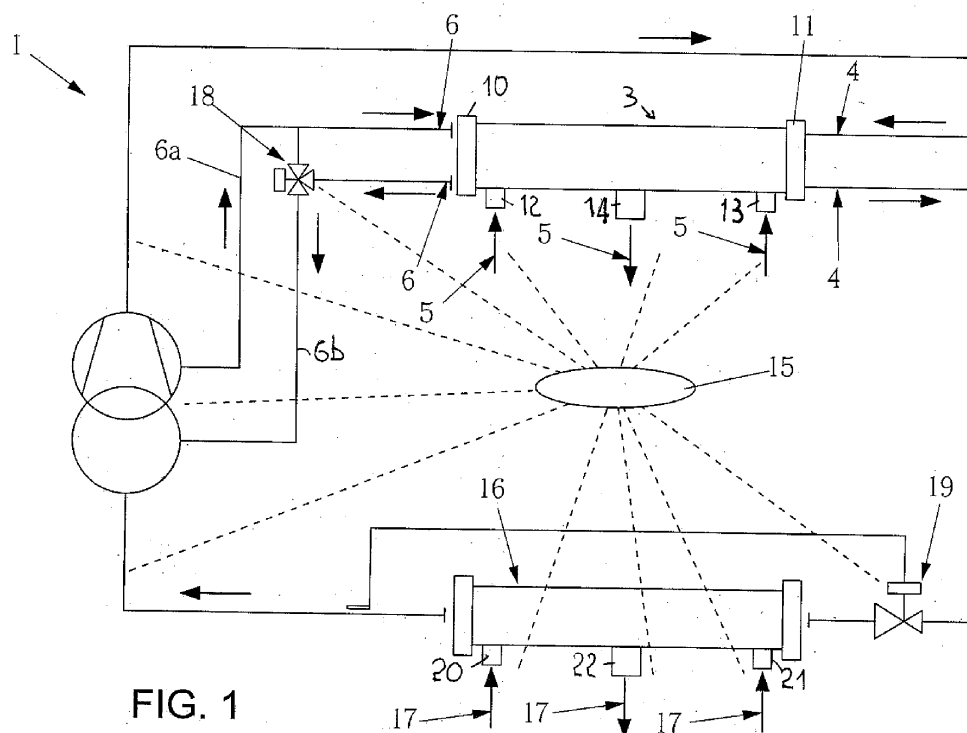


FIG. 1

Description

[0001] The present invention refers to a plant for the production of thermo-frigorific energy and to a method for the optimization of its efficiency and function.

[0002] The invention is applicable to all plants working with both air and water hydronic units, with particular advantages especially in the units providing for a heat recovery (heat pumps, recovery chillers, polyvalent units, etc.)

[0003] A heat pump is for example a thermo-frigorific unit which, through an inverted steam compression cycle, is able in winter operation modes to make available for external use heat taken from a thermal source with lower temperature, i.e. to transfer energy from the evaporator to the condenser.

[0004] The useful effect of a heat pump is to heat a certain quantity of water up to a determined temperature, that is to supply a certain heat power Q_T at a temperature previously set by the user.

[0005] The "Coefficient of Performance" (COP) of a heat pump is defined as the ratio between the useful effect (Thermal Power Q_T) and the electric power necessary for obtaining it (Absorbed Power P_A).

[0006] If having to produce water at high temperature, a heat pump often works with a high compression ratio between intake and exit of the compressor; this determines a decline of the performances of the compressor and of the characteristics of the oil which guarantees the lubrication of the bearings and the tightness of the screws.

[0007] The lubricating oil commonly used in screw compressors for the conditioning at temperatures greater than 110/120°C loses its peculiar properties in terms of viscosity. For such reason, compressor producers impose, in order to be able to work with certain boundary conditions in terms of evaporation/condensation temperature, the use of a liquid gas injection system in the circuit of the refrigerant fluid at the intake of the compressor of an oil cooling system. Such systems generally work only and in function of the discharge temperature of the compressor

[0008] The liquid gas injection system has many drawbacks, among which a limited extension of the working range, a general inefficiency caused by the fact, that the gas which was compressed does not laminate itself and feed the evaporator, but is directly injected in the compressor in order to lower its discharge temperature, a cyclic and discontinuous temperature trend, and a localized cooling with consequent thermal stress in the points interested by the injection.

[0009] The traditional oil cooling system is generally made by using a further water or air exchanger dedicated for this purpose.

[0010] The traditional oil cooling system, if a suitable forced-air exchanger is provided, laments a low efficiency concerning the heat exchange, a yield influenced by boundary conditions outside its own control as the exter-

nal temperature (which can much vary during the day and according to the seasons of year) and the fouling of the finned battery, a low reliability bound to the use of a further fan, a certain noise, and the impossibility to recover the heat which instead is dispersed to the atmosphere.

[0011] The traditional oil cooling system, if a suitable water exchanger is provided, laments the drawback of having to provide for a water circuit dedicated for this purpose, with the complications bound to the presence of such further water circuit which has to be suitably insulated and discharged in order to prevent frost during the plant stops. Any heat recovery for the main users can furthermore be complex, uncontrollable and inefficient due to the fact that two water flows at a different temperature are mixing. Also the regulation of the plant, and particularly the control of the water temperature produced by the users, can be inaccurate and discontinuous.

[0012] Technical task of the present invention is therefore to realize a plant for the production of thermo-frigorific energy and a method for optimizing its efficiency, such to permit to eliminate the drawbacks lamented of the known art.

[0013] Within this technical task an aim of the invention is to realize a plant for the production of thermo-frigorific energy which has a broad working range by guaranteeing the greatest reliability, efficiency and structural simplification.

[0014] The technical task, and these and other aims according to the present invention are reached by realizing a plant for the production of thermo-frigorific energy of the type comprising at least one thermo-frigorific unit having at least one compressor and one heat exchanger having a circuit of the refrigerant fluid in thermal exchange with a circuit of hot water for users, characterized in that in said heat exchanger a cooling circuit of the oil of the compressor is integrated, in thermal exchange with the circuit of hot water for users.

[0015] In a first preferred embodiment of the invention, the heat exchanger comprises a tube nest.

[0016] Preferably the circuit of hot water for users is within the volume of the tube nest heat exchanger on the shell side, whereas the circuit of the refrigerant fluid and the cooling circuit of oil are within the volume of the tube nest heat exchanger on the tube side.

[0017] Preferably in said tube nest heat exchanger each cooling circuit of the refrigerant fluid is of the asymmetric type with two passages (that is, with a different and optimized number of tubes between the first and second passage in function of the variation of the thermo-fluid-dynamic properties of the fluid during the heat exchange process in the exchanger).

[0018] Preferably in the tube nest heat exchanger each oil cooling circuit is of the type with two asymmetric passages (that is, with a different and optimized number of tubes between the first and the second passage, in function of the variation of the thermo-fluid-dynamic properties of the fluid during the heat exchange process in the

exchanger).

[0019] Preferably the hot water circuit for users has two inlets and only one outlet from the tube nest heat exchanger.

[0020] Preferably the outlet is centrally positioned and the two inlet ways are positioned at the opposite ends of the tube nest heat exchanger.

[0021] In a second preferred embodiment of the invention the heat exchanger is of a plate type with a dual circuit.

[0022] Preferably the plant has an integrated control logic which modulates the flow in the cooling circuit of oil according to the boundary conditions of the plant itself.

[0023] The invention reveals a plant for the production of thermo-frigorific energy of the type comprising at least one thermo-frigorific unit comprising at least one compressor and one heat exchanger having a circuit of the refrigerant fluid in thermal exchange with a circuit of hot water for users, characterized in that said circuit of hot water for users has two inlets and only one outlet from the heat exchanger.

[0024] The present invention also reveals a method for the optimization of the efficiency of a plant for the production of thermo-frigorific energy comprising at least one thermo-frigorific unit having at least one compressor and one heat exchanger having a circuit of the refrigerant fluid in thermal exchange with a circuit of hot water for users, characterized in that in said heat exchanger a thermal exchange is created between a cooling circuit of oil of the compressor and said circuit of hot water for users, so that by virtue of the transmission of thermal energy from the cooling circuit of oil to the circuit of hot water for users, the cooling circuit of oil of the compressor cools itself and at the same time the circuit of hot water for users is subjected to a further heating with respect to that due to the thermal exchange with the circuit of the refrigerant fluid.

[0025] In the method for the optimization of the efficiency of a plant for the production of thermo-frigorific energy preferably the oil flow in the cooling circuit is modulated according to the boundary conditions of the plant.

[0026] The boundary conditions comprise the evaporation and condensation temperature of the refrigerant fluid, the inlet and outlet temperature of the water heat exchanger of the circuit of hot water for users, the degree of division of the compressor.

[0027] Preferably in order to obtain the thermal load and the outlet temperature of the hot water exchanger for users, the flow of the cooling circuit, the division and the intrinsic compression ratio of the compressor are controlled at the same time.

[0028] Preferably, in order to obtain the outlet temperature from the oil exchanger of the cooling circuit, the flow of the cooling circuit, the division and the intrinsic compression ratio of the compressor are controlled at the same time.

[0029] The present invention teaches how to cool down the compressor oil and to control its return temper-

ature through a circuit inserted inside the hot heat exchanger (condenser) by recovering the relative energy for heating water directed to users. This permits to extend the operational range of the plant, to guarantee its function, to maximize its efficiency, and to simplify its embodiment with respect to other known technical solutions.

[0030] Further characteristics and advantages will be more evident from the description of a preferred but non exclusive embodiment of the plant for the production of thermo-frigorific energy according to the finding, illustrated in an indicative and non limitative way in the annexed drawings, in which:

figure 1 schematically shows the plant; and figure 2 shows a perspective view of the integrated heat exchanger.

[0031] With reference to cited figures, a plant is shown for the production of thermo-frigorific energy globally indicated with the reference character 1.

[0032] The plant 1 comprises a thermo-frigorific unit in turn comprising a compressor 2 and a heat exchanger 3 (condenser) having a circuit of the refrigerant fluid 4 in thermal exchange with a hot water circuit 5 for users.

[0033] Advantageously, in the heat exchanger 3 a cooling circuit of the oil 6 of the compressor 2 is integrated, in thermal exchange with the hot water circuit 5 for users.

[0034] The cooling circuit of oil 6 has, between the line 6a connecting the delivery of the compressor 2 at the intake of the heat exchanger 3 and the line 6b connecting the exit of the heat exchanger 3 with the intake of the compressor 2, a three-way bypass valve 18 of the heat exchanger 3.

[0035] The heat exchanger 3 is of the type with a tube nest, and comprises a tubular shell 7, first tubes 8, second tubes 9, and at the opposite base ends of the shell 7 has a blind tube plate 10 and a tube plate with support couplings 11 of the first tubes 8 and of the second tubes 9.

[0036] The hot water circuit 5 for users is inside the volume of the heat exchanger 3 on the shell side 7, whereas the circuit of the refrigerant fluid 4 is inside the volume of the heat exchanger 3 on the tube side 8 and the cooling circuit of oil 6 is inside the volume of the heat exchanger 3 on the tube side 9.

[0037] Each of the two circuits of the refrigerant fluid 4 is of the asymmetric type with two passages, so like each of the two cooling circuits of the oil 6 is of the asymmetric type with two passages.

[0038] The circuit of hot water 5 for users instead has two radial inlets 12, 13 in the shell 7, at the opposite ends of it, and only one radial outlet 14 centrally formed in the shell 7.

[0039] The two inlets 12, 13 and the outlet 14 are aligned along a cylindrical generating line of the shell 7.

[0040] Although the described heat exchanger 3 is of the type with a tube nest, any other type of heat exchanger is conceivable, for example one of a plate type with

dual circuit.

[0041] The thermo-frigorific unit also comprises a heat exchanger 16 having the circuit of the refrigerant fluid 4 in thermal exchange with a circuit of cold water 17 (evaporator).

[0042] Along the circuit of refrigerant fluid 4 a lamination valve 19 is present.

[0043] The plant 1 also has a logic controller 15 communicating with the compressor 2, with the heat exchanger 3, with the exchanger 16 and with the valves 18 and 19.

[0044] The logic controller 15 has an integrated control logic which modulates the flow in the cooling circuit of oil 6 according to the boundary conditions of the plant 1 itself.

[0045] In order to optimize the efficiency of the plant 1 in the heat exchanger 3 a thermal exchange is created between the cooling circuit of oil 6 of the compressor 2 and the circuit of hot water 5 for users, so that due to the thermal energy transmission from the cooling circuit of oil 6 to the circuit of hot water 5 for users, the cooling circuit of oil 6 of the compressor 2 cools down and at the same time the circuit of hot water 5 for users is subjected to a further heating with respect to that due to the thermal exchange with the circuit of the refrigerant fluid 4.

[0046] As said it is expected to modulate the oil flow in the cooling circuit 6 according to the boundary conditions of the plant.

[0047] The boundary conditions considered comprise the evaporation and condensation temperature of the refrigerant fluid, the intake and exit temperature of the heat exchanger 3 of the water of the circuit of hot water 5 for users, the degree of division of the compressor 2.

[0048] In order to obtain the thermal load and the exit temperature from the water heat exchanger 3 of the circuit of hot water 5 for users, the flow of the cooling circuit 6, the division and the intrinsic compression ratio of the compressor 2 are controlled at the same time.

[0049] In a similar way, even for obtaining the exit temperature of the oil exchanger 3 of the cooling circuit 6 the flow of the cooling circuit 6, the division and the intrinsic compression ratio of the compressor 2 are controlled at the same time.

[0050] By recovering the energy of hot oil and bringing it at a more suitable temperature to the compressor, a double effect is created in terms of COP for increasing the thermal power delivered to the user and for reducing the absorbed power tank to the better isentropic efficiency of the compressor 2 and to the lower losses due to leakages into the same.

[0051] With the present invention to the heat exchanger 3 the double task is associated, that is to heat water for the users and control the oil temperature to the compressor 2. The integrated control logic then maximizes both effects.

[0052] The working range of the plant is extended without shifting to costly solutions with dual-stage compressors or cycles: it is possible for example to guarantee the water production at high temperature even in particularly

rigid conditions.

[0053] The oil cooling heat is totally recovered in order to heat water for users.

[0054] Further external pumps and complications on the water side are not necessary.

[0055] The load losses of the hydronic circuit are reduced, and so the load of the hydronic circuit and the corresponding global pumping expenses.

[0056] By providing an integrated heat exchanger 3, with respect to two separate heat exchangers, the construction is simplified and the hydraulic and frigorific connections of the plant 1 are reduced, so the plant becomes more silent just due to the fact that it has only one exchanger instead of two.

[0057] The return of oil at the best possible temperature compatibly with the boundary conditions improves the lubrication of the bearings, the tightness of the screws, the efficiency of the compressor 2, and limits its maintenance increasing its useful life.

[0058] It is furthermore more easy and effective to insulate the exchanger 3, whereas minor are the problems due to the discharge of the refrigerant fluid 4 and the eventual icing in it.

[0059] The stand-by absorptions are advantageously reduced, as a certain oil quantity is maintained inside the exchanger 3 contacting the hot water and this permits to avoid supplying, when oil has a suitable temperature, the resistances of the oil cup so eliminating such stand-by absorption.

[0060] The provision in the tube nest exchanger 3 of circuits 8, 9 with two asymmetrical passages permits to balance the number of deliveries in function of the change of thermo-fluid-dynamic characteristics of the refrigerant and oil fluids during such exchange.

[0061] The further provision in the tube nest exchanger 3 of two inlets 12, 13 and only one outlet 14 at the water side permits to divide the flow in two flows so permitting to make a heat exchanger 3 with a smaller diameter, so limiting in the exchanger 3 the constraint of the load losses at the water side and of the maximum flow rate.

[0062] The further provision in the tube nest exchanger 16 of two inlets 20,21 and only one outlet 22 at the water side permits to divide the flow in two flows so permitting to make an exchanger 16 with a smaller diameter and limiting in the exchanger 16 the constraint of the load losses at the water side and of the maximum flow rate.

[0063] By optimizing the distribution at the water side the de-overheating phase of the refrigerant fluid is facilitated (when it works like a condenser 3) and also the overheating (when it works like an evaporator 16) so reaching a more favorable temperature profile in the exchangers 3 and 16.

[0064] By making the exchangers 3 and 16 longer, with the same exchange area it is possible to reduce the number of deliveries and so to balance in a suitable way the ratio between concentrated and distributed load losses, in favor of the distributed load losses which facilitate the heat exchange.

[0065] The plant for the production of thermo-frigorific energy so conceived is subject to many changes and variations, all within the range of the inventive concept; furthermore all details can be substituted with technically equivalent elements.

[0066] In practice the used materials, and also the dimensions, can be of any kind according to the needs and the state of the art.

Claims

1. A plant (1) for the production of thermo-frigorific energy of the type comprising a thermo-frigorific unit comprising at least a compressor (2) and a heat exchanger (3) having a circuit of the frigorigenous fluid (4) in thermal exchange with a circuit of the hot water (5) for users, **characterised in that** in said heat exchanger (3) a cooling circuit of the oil (6) of the compressor (2) is integrated, in thermal exchange with the circuit of the hot water (5) for users.
2. The plant (1) for the production of thermo-frigorific energy according to one or more preceding claims, **characterised in that** said heat exchanger (3) comprises a tube nest.
3. The plant (1) for the production of thermo-frigorific energy according to preceding claim, **characterised in that** the circuit of the hot water (5) for users is within the volume of the heat exchanger (3) on the shell side (7), whereas the circuit of the frigorigenous fluid (4) and the cooling circuit of the oil (6) are within the volume of the heat exchanger (3) on the tube side (8, 9) .
4. The plant (1) for the production of thermo-frigorific energy according to one or more claims 2 and 3, **characterised in that** in said heat exchanger (3) each circuit of the frigorigenous fluid (4) is of the asymmetric type with two passages.
5. The plant (1) for the production of thermo-frigorific energy according to one or more claims 2 to 4, **characterised in that** in said heat exchanger (3) each cooling circuit of the oil (6) is of the asymmetric type with two passages.
6. The plant (1) for the production of thermo-frigorific energy according to one or more claims 2 to 5, **characterised in that** said circuit of the hot water (5) for users has two inlets (12, 13) and only one outlet (14) from said heat exchanger (3).
7. The plant (1) for the production of thermo-frigorific energy according to preceding claim, **characterised in that** said one outlet (14) is centrally positioned and said two inlet ways (12, 13) are positioned at the opposite ends of said heat exchanger (3).
8. The plant (1) for the production of thermo-frigorific energy according to one or more preceding claims, **characterised in that** said heat exchanger (3) is of a plate type with a dual circuit.
9. The plant (1) for the production of thermo-frigorific energy according to one or more preceding claims, **characterised in that** it has an integrated control logic (15) which modulates the flow in the cooling circuit of the oil (6) according to the conditions at the contour of the plant (1)
10. A method for the optimization of the efficiency of a plant (1) for the production of thermo-frigorific energy of the type comprising at least a thermo-frigorific unit comprising at least a compressor (2) and a heat exchanger (3) having a circuit of the frigorigenous fluid (4) in thermal exchange with a circuit of the hot water (5) for users, **characterised in that** in said heat exchanger (3) a thermal exchange is so created between a cooling circuit of the oil (6) of the compressor (2) and said circuit of the hot water (5) for users, that by virtue of the transmission of thermal energy from the cooling circuit of the oil (6) to the circuit of the hot water (5) for users, the cooling circuit of the oil (6) of the compressor (2) cools itself and at the same time the circuit of the hot water (5) for users is subjected to a further warming with respect to that caused by the thermal exchange with the circuit of the frigorigenous fluid (4).
11. The method for the optimization of the efficiency of a plant (1) for the production of thermo-frigorific energy according to preceding claim, **characterised in that** it modulates the oil flow in the cooling circuit (6) according to the conditions at the contour of the plant (1).
12. The method for the optimization of the efficiency of a plant for the production of thermo-frigorific energy according to preceding claim, **characterised in that** said conditions at the contour comprise the vaporization and condensation temperature of the frigorigenous fluid, the discharge temperature, the inlet and outlet temperature of the heat exchanger (3) of the water of the circuit of the hot water (5) for users, the degree of division of the compressor (2).
13. The method for the optimization of the efficiency of a plant for the production of thermo-frigorific energy according to one or more claims 10 to 12, **characterised in that** in order to obtain the thermal load and the outlet temperature of the exchanger (3) of the water of the circuit of the hot water (5) for users, the flow of the cooling circuit (6) the division and the intrinsic compression ratio of the compressor (2) are

controlled at the same time.

14. The method for the optimization of the efficiency of a plant for the production of thermo-frigorific energy according to one or more claims 10 to 13, **characterised in that** in order to obtain the outlet temperature from the exchanger (3) of the oil of the cooling circuit (6), the flow of the cooling circuit (6) the division and the intrinsic compression ratio of the compressor (2) are controlled at the same time. 5 10
15. A plant (1) for the production of thermo-frigorific energy of the type comprising at least a thermo-frigorific unit comprising at least a compressor (2) and a heat exchanger (16) having a circuit of the frigorigenous fluid (4) in thermal exchange with a circuit of the cold water (17) for users, **characterised in that** said circuit of the cold water (17) for users has due inlets (20, 21) and just one outlet (22) from the heat exchanger (17). 15 20

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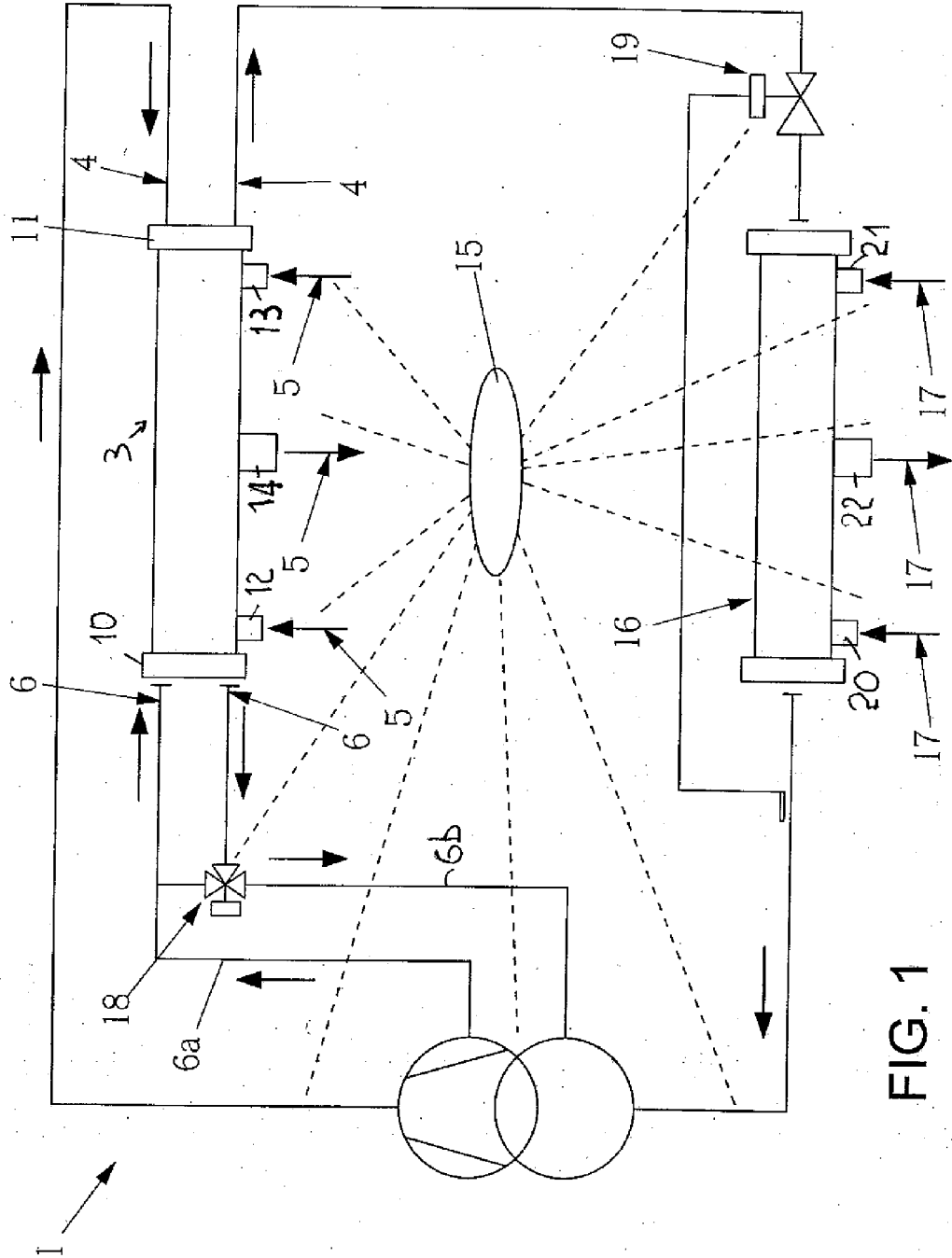


FIG. 1

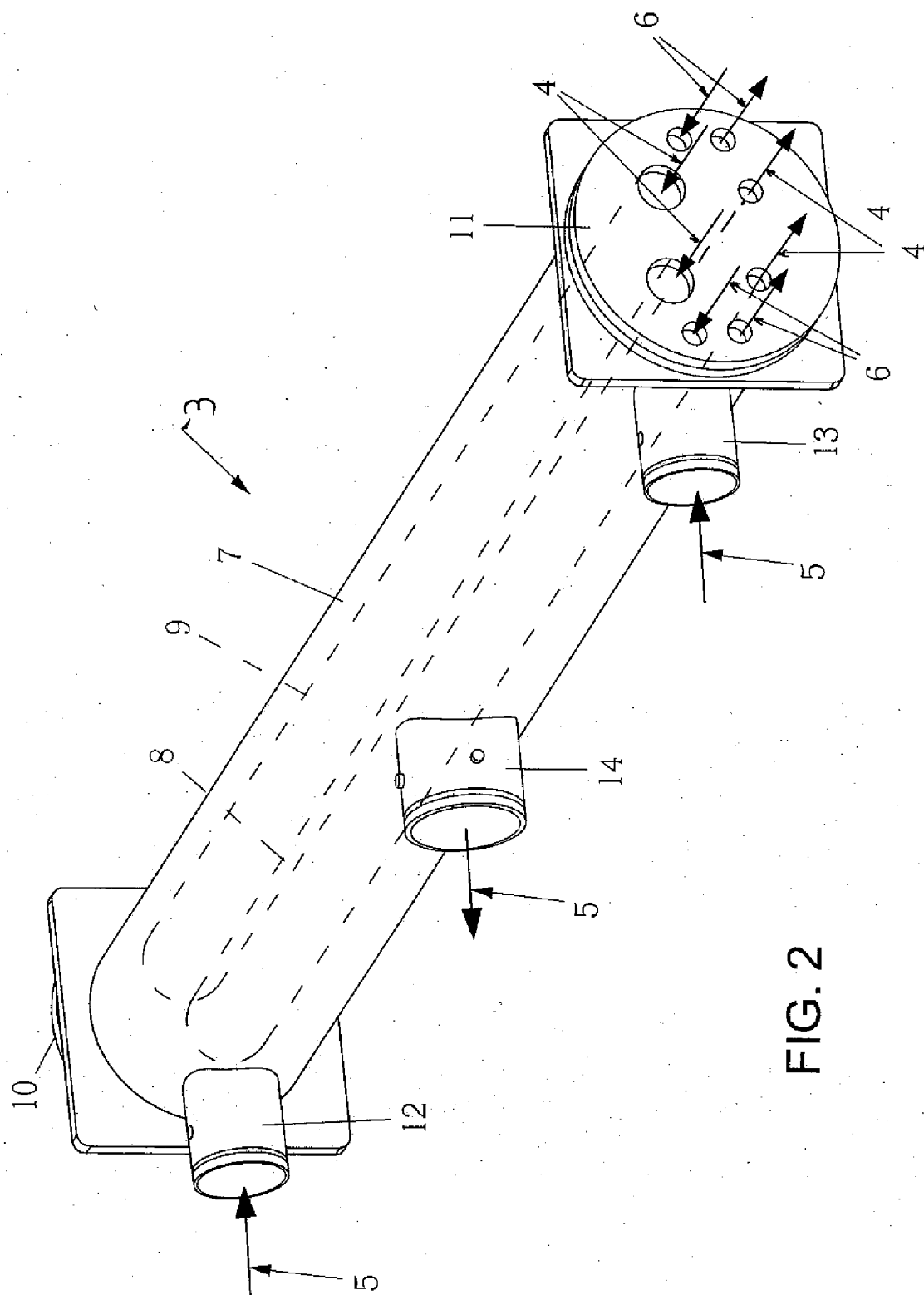


FIG. 2



EUROPEAN SEARCH REPORT

Application Number
EP 11 15 7425

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 12 August 2011	Examiner de Graaf, Jan Douwe
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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EPO FORM 1503 03/82 (P04C01)



EUROPEAN SEARCH REPORT

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

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