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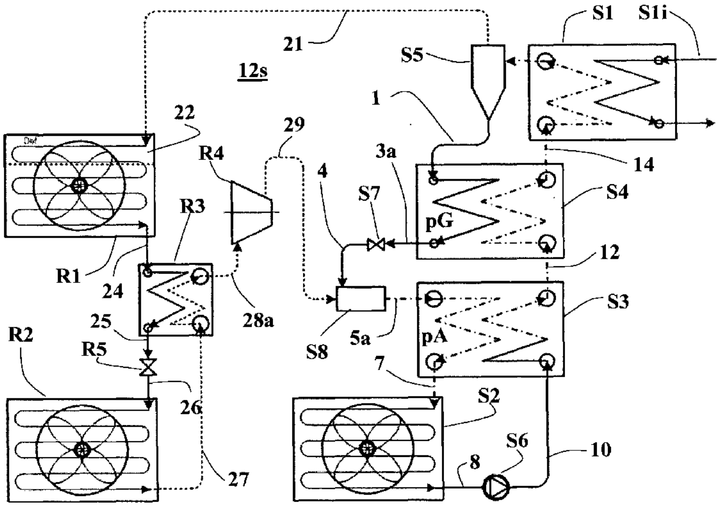

Fig. 3

(57) **Abstract**: The present invention relates to air-cooled absorption refrigerating system and method that can be operated by means of low grade heat source. In general, the refrigeration is performed by mixing a stream of evaporated refrigerant with a stream of weak refrigerant solution, producing a reconstituted solution by absorbing portions of the evaporated refrigerant into the stream of weak refrigerant by means of air-cooled absorber means, pumping the reconstituted solution into heater means being in heat exchange relationship with a stream of hot weak refrigerant solution and conducting the weak refrigerant solution therefrom for use in the mixing, evaporating refrigerant from a stream of reconstituted solution from the heater means by means of generator means being in heat exchange relationship with a stream of heat transfer fluid or gas, separating a stream from the generator means into the (residual) stream of hot weak refrigerant solution and a main refrigerant vapor stream, condensing the main refrigerant vapor stream by means of air-cooled condenser means, reducing the pressure of a stream of condensed refrigerant vapor from the air-cooled condenser means and conducting the same into evaporator means and evaporating the condensed refrigerant to form the stream of evaporated refrigerant and conducting it therefrom for use in the mixing.

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AIR COOLED ABSORPTION COOLING SYSTEM OPERABLE BY LOW GRADE HEAT

Field of the Invention

The present invention generally relates to absorption cooling systems. More particularly, the invention relates to a method and system for air cooled TPL (triple pressure level) absorption cooling that can be operated by low grade heat.

Background of the Invention

The present invention provides an absorption cooling system that can be operated utilizing relatively low grade heat sources e.g., solar energy, low-grade steam source, and industrial processes exhaust heat.

Typical absorption cooling systems utilize a heat source to vaporize under pressure a refrigerant material from a rich solution (generator/desorber). The pressurized desorbed refrigerant is then condensed by rejecting heat from it to the ambient surrounding, and it is then used for cooling by evaporating it under lower pressure conditions, whereby ambient heat is absorbed from the refrigerated space. The evaporated refrigerant is then absorbed back into the weak solution (absorber) to provide a reconstituted (rich) solution as the process is continuously repeated.

US 4,171,619 describers a refrigeration system wherein heat from a solar energy source heats a refrigerant and absorbent solution in a generator to provide a refrigerant vapor to condensing and evaporating means, and wherein a compressor is used to compress vapor passing from the evaporator to the absorber, or between the evaporator and the condenser, and a pump is used for pressurizing the reconstituted solution obtained from the absorber. In this refrigeration system however a cooling tower is required for providing cooling water to the absorber and condenser.

WO 2007/110854 describes a vehicle air conditioning system utilizing an absorption compressor designed to work in parallel with a conventional mechanical compressor, wherein heat energy from the vehicle exhaust gas is used by the air conditioning system as a heat source. The absorption cycle in this international application is very simple providing compression cycle mode or simple absorption sub cycle functioning in place of the compressor, while the rest part of the refrigerant sub cycle remain the same. In addition, nor the absorption system or the compression cycle in this air conditioning system is used for heating the vehicle.

The methods described above have not yet provided satisfactory air cooled absorption cooling systems operated by low grade heat.

It is therefore an object of the present invention to provide systems and methods for absorption cooling that can be efficiently operated employing air as a cooling medium.

It is another object of the present invention to provide systems and methods for absorption cooling that can be efficiently operated utilizing low grade heat sources.

Other objects and advantages of the invention will become apparent as the description proceeds.

Summary of the Invention

A broad aspect of some embodiments of the invention relates to providing air-cooled absorption refrigeration systems which generation process is capable of being operated by means of alternative or renewable heat sources (e.g., solar energy, industrial processes exhaust heat, or the like) at relatively low temperatures (e.g., up to 130°C) for cooling and refrigeration by means of single-stage triple pressure level (TPL) absorption. Elements of the absorption systems of the present invention are preferably cooled by ambient air streams, and the system may be divided into high-pressure, intermediate-pressure and low-pressure, regimes.

The TPL absorption cycle preferably comprises refrigerant and solution sub-cycles, wherein the low-pressure regime resides in the refrigerant sub-cycle, the intermediate-pressure regime resides in the solution sub-cycle, and the high-pressure regime partly resides in both sub-cycles. Separator means may be employed in the solution sub-cycle for separating evaporated refrigerant obtained in the generation process and for introducing the separated refrigerant into the refrigerant sub-cycle.

In some embodiments of the invention low-pressure refrigerant from the refrigerant sub-cycle is introduced into the solution sub-cycle by means of a mixing device, such as for example a mixer ejector, preferably by a type of jet ejector mixer, capable of producing a mixture of the low-pressure refrigerant with a stream of high-pressure weak solution introduced to it. Alternatively or additionally, a compressor may used to compress the low-pressure refrigerant before mixing it with the intermediate-pressure weak solution, and in such embodiments a simple mixer unit may be utilized for mixing the compressed refrigerant and the intermediate-pressure weak solution.

A broad aspect of some embodiments of the present invention relates to improving the refrigerant generation process by a heat exchange process in the high-pressure regime in which heat from the weak solution returned from the generation process is transferred to a stream of air-cooled rich solution pumped from the absorption process. Accordingly, in some exemplary embodiments of the invention a solution heat exchanger is utilized in the high-pressure regime for transferring heat from the weak solution returned from the generation process to an air-cooled stream of rich solution pumped thereinto from an absorption process, prior to it being subject to the generation process.

A broad aspect of some embodiments of the invention relates to improving generation efficiency by means of separator means in the high-pressure sub-cycle for separating evaporated refrigerant from the rich solution streamed from the heat exchange process, and for introducing the separated refrigerant into the refrigerant sub-cycle. The residual rich solution, remaining after the evaporated refrigerant was separated, is preferably flown to the refrigerant generation process for evaporating more refrigerant from it.

A broad aspect of some embodiments of the invention relates to improving generation efficiency by splitting the heat exchange process during which heat is transferred to the air-cooled rich solution pumped from the absorption process such that part of the heat exchange process in carried out in the high-pressure regime, and another part of the heat exchange process is carried out partly in the intermediate-pressure regime. In these preferred embodiments of the invention a first heat exchange stage (e.g., pre-absorber heat exchanger - pA) is employed for transferring heat from the mixture of refrigerant and weak solution obtained by the mixing device in the intermediate-pressure regime to the air-cooled high-pressure rich solution pumped from the absorbing process, and a second heat exchange stage (pre-generator heat exchanger - pG) is employed in the high-pressure regime for transferring heat from the weak solution returned from the generation process to the high-pressure rich solution streamed from the first heat exchange stage, prior to it being introduced to the generation process.

A broad aspect of some embodiments of the invention relates to improving generation efficiency by means of separator means in the solution sub-cycle between the first and second heat exchange stages for separating evaporated refrigerant from the high-pressure rich solution streamed from the first heat exchange stage and for introducing the separated refrigerant into the refrigerant sub-cycle. The residual rich solution, remaining after the evaporated refrigerant was separated, is preferably flown to the second heat exchange stage for evaporating more refrigerant from it.

Accordingly, in some preferred embodiments of the invention the generation process may be split into three stages: i) evaporating refrigerant from the high pressure strong solution pumped from the air-cooled absorber means by means of first heat exchanger means in heat exchange relationship with the mixed stream from the mixer means, separating the evaporated refrigerant solution and merging it into a main evaporated refrigerant stream; ii) evaporating refrigerant from a residual stream of high pressure strong solution obtained from the separating by means of a second heat exchanger means in heat exchange relationship with hot stream of weak refrigerant solution, further separating the evaporated refrigerant solution and merging it into the main evaporated refrigerant stream; and iii) evaporating refrigerant from a residual stream of high pressure strong solution obtained form the further separating by means of third heat exchanger means in heat exchange relationship with a stream of heat transfer fluid or gas (e.g., supplied using a low grade heat source), yet further separating the evaporated refrigerant solution and merging it into the main evaporated refrigerant stream and using the residual solution as the hot stream of weak refrigerant solution supplied to the second heat exchanger means.

A broad aspect of some embodiments of the present invention relates to improving the evaporation efficiency by means of a heat exchange process in the refrigerant sub-cycle in which a stream of condensed high-pressure refrigerant is cooled by a stream of low-pressure evaporated refrigerant obtained in the evaporation process.

The term rich solution used herein refers to a refrigerant solution having relatively high levels of absorbed refrigerant by the absorbent, and the term weak solution used herein refers to a refrigerant solution having relatively low-levels of absorbed refrigerant by the absorbent. The term pressure regime used herein refers to zones or sections in the refrigerant circuit (i.e., in the refrigerant and the solution sub-cycles) having pressure conditions which can be distinctively characterized relative to those in the other zones or sections.

In an exemplary embodiment of the invention an air-cooled absorption refrigerating system is provided which comprises generator means in heat exchange relationship with a stream of heat transfer fluid or gas for generating a refrigerant vapor from a high-pressure rich refrigerant solution stream, separator means to separate said high-pressure refrigerant solution into a weak solution stream and a stream of said refrigerant vapor, air-cooled condenser means to form a condensed refrigerant stream from said stream of refrigerant vapor, cooler means in heat exchange relationship with a low-pressure evaporated refrigerant stream to form a cooled condensed refrigerant stream from said condensed refrigerant stream, an expansion valve to form a cooled low-pressure condensed refrigerant stream, and optionally a small amount of refrigerant vapor stream, from said cooled condensed refrigerant stream, evaporator means to form said low-pressure evaporated refrigerant stream from said cooled low-pressure condensed refrigerant stream and for cooling a surrounding material (e.g., indoor air in a refrigerated space), heater means in heat exchange relationship with said weak solution stream to form said high-pressure rich refrigerant solution stream, pressure reducer means to form an intermediate-pressure weak solution stream from a stream of weak solution obtained from said heat exchanging means, mixer means for producing a mixed stream comprising a mixture of said intermediate-pressure weak solution stream and said intermediate-pressure evaporated refrigerant stream, air-cooled absorber means for receiving said mixed stream and producing an air-cooled rich refrigerant solution, and pump means for producing said air-cooled high-pressure rich solution stream.

According to one aspect the present invention is directed to an air-cooled absorption refrigerating system comprising: generator means in heat exchange relationship with a stream of heat transfer fluid or gas (e.g., type of low grade heat source), separator means adapted to separate a stream from the generator means into a weak refrigerant solution stream and a main refrigerant vapor stream, air-cooled condenser means to condense the main refrigerant vapor stream, an expansion valve to reduce the pressure of a condensed refrigerant stream from the air-cooled compressor means, evaporator means to form a stream of evaporated refrigerant from a stream from the expansion valve and to cool a surrounding material, a main heat exchanger means to exchange heat between the weak refrigerant solution stream and a high-pressure rich refrigerant solution stream, mixer means (e.g., jet ejector mixer) to produce a mixed stream from the stream of evaporated refrigerant from the evaporator means and from a stream of weak solution from the heat exchanger means, air-cooled absorber means to reconstitute the mixed stream, and pump means to produce the high-pressure rich refrigerant solution stream from a stream from the air-cooled absorber means.

Advantageously, the system may further comprise an additional heat exchanger means to exchange heat between the stream of condensed refrigerant from the air-cooled condenser means and the stream of evaporated refrigerant from the evaporator means, which the conducted therefrom to the mixer means for mixing with the weak solution.

The system may further comprise separator means to separate a stream of rich refrigerant solution from the main heat exchanger means into an additional refrigerant vapor stream, introduced into the main refrigerant vapor stream, and a residual solution, introduced into the generator means.

Preferably, the main heat exchanger means is split into first and second heat exchange stages: i) a first heat exchange stage to exchange heat between the weak refrigerant solution stream and a stream of high-pressure rich solution from the second heat exchange stage; and ii) a second heat exchange stage to exchange heat between a mixed stream from the mixer means and the high-pressure rich solution stream, wherein the air-cooled absorber means is adapted to reconstitute a mixed stream obtained from the second stage heat exchange means.

The system may further comprise separator means to separate the stream of rich refrigerant solution from the second stage heat exchange means into a further refrigerant vapor stream, introduced into the main refrigerant vapor stream, and a residual solution introduced into the first stage heat exchange means.

The system may further comprise pre-cooler means to cool the main refrigerant vapor stream provided to the air-cooled condenser means to a temperature near its saturation temperature.

The system may further comprise pressure reducer means adapted to reduce the pressure of the stream of weak refrigerant solution provided to the mixer device from the first heat exchange stage.

The system may further comprise main compressor means to compress a stream of evaporated refrigerant obtained from the additional heat exchanger means and introduce the same into the mixer means. Optionally, the system may comprise additional compressor means, or multistage compressor means, adapted to compress a stream of compressed refrigerant from the main compressor means and introduce the same into the air-cooled condenser means. Advantageously, the system may further comprise two three-way valves and ductwork adapted to change the system between two operating states: i) wherein a stream of compressed evaporator from the main compressor means is directed into the mixer means and the main stream of refrigerant vapor is directed into the air-cooled condenser means; and ii) wherein a stream of compressed vapor from the main compressor means is directed into the additional compressor means, a stream of compressed refrigerant from the additional compressor means is directed into the air-cooled condenser means, and the main stream of refrigerant vapor is precluded from reaching the air-cooled condenser means.

Optionally, the system may further comprise additional valves and conduits adapted to changes the mode of operation of the system between two states: a heating mode wherein the compressed refrigerant stream from the additional compressor means, or multistage compressor means, is conducted into the evaporator means, a stream of evaporated refrigerant from the evaporator means is conducted into a first inlet of the additional heat exchange means, a stream of condensed refrigerant from the air-cooled condenser means is conducted into a second inlet of the additional heat exchange means which is then conducted therefrom into the main compressor means; and a cooling mode wherein the compressed refrigerant stream from the additional compressor means, or multistage compressor means, is conducted into the air-cooled condenser means, a stream of condensed refrigerant from the air-cooled condenser means is conducted into the first inlet of the additional heat exchange means, a stream of evaporated refrigerant from the evaporator means is conducted into the second inlet of the additional heat exchange means which is then conducted therefrom into the main compressor means.

Control means (e.g., PLC) may used to change the states of the three-way valves and/or of the additional valves to change the state of the system between the operating states and/or between the modes of operations, and to operate the compressing means as needed.

According to another aspect the present invention is directed to a method for cooling a refrigerated space comprising: mixing a stream of evaporated refrigerant with a stream of weak refrigerant solution; producing a reconstituted solution by absorbing portions of the evaporated refrigerant into the stream of weak refrigerant by means of air-cooled absorber means; pumping the reconstituted solution into heater means being in heat exchange relationship with the stream of weak refrigerant solution and conducting the weak refrigerant solution therefrom for use in the mixing; evaporating refrigerant from a stream of reconstituted solution from the heater means by means of generator means being in heat exchange relationship with a stream of heat transfer fluid or gas; separating a stream from the generator means into the (residual) stream of hot weak refrigerant solution and a main refrigerant vapor stream; condensing the main refrigerant vapor stream by means of air-cooled condenser means; conducting the condensed refrigerant vapor stream from the air-cooled condenser means into cooler means being in heat exchange relationship with a stream of cold evaporated refrigerant and conducting the stream of evaporated refrigerant therefrom for use in the mixing; reducing the pressure of a stream of condensed refrigerant from the cooler means and conducting the same into evaporator means; and evaporating the condensed refrigerant in the evaporator means to form the stream of evaporated refrigerant and to cool the refrigerated space.

The method may further comprise separating a stream of reconstituted solution from the heater means into an additional refrigerant vapor stream and conducting it into the main refrigerant vapor stream, and conducting a remaining (residual) stream of reconstituted solution into the generator means.

The heater means may be split into first and second heat exchange stages: i) a first heat exchange stage used for exchanging heat between the weak refrigerant solution stream and a stream of reconstituted solution from the second heat exchange stage; and ii) a second heat exchange stage to exchange heat between a mixed stream obtained in the mixing and the reconstituted solution stream, wherein the absorbing in the air-cooled absorber means comprise reconstituting a mixed stream obtained from the second stage heat exchange means.

The method may further comprise separating a stream of reconstituted solution from the second heat exchange stage into a further refrigerant vapor stream and conducting it into the main refrigerant vapor stream, and conducting a remaining (residual) stream of reconstituted solution into the first heat exchange stage.

The method may further comprise cooling the main refrigerant vapor stream provided to the air-cooled condenser means to a temperature near its saturation temperature.

The method may further comprise reducing the pressure of the stream of weak refrigerant solution provided to the mixing from the first heat exchange stage.

Optionally, the method may further comprise compressing a stream of evaporated refrigerant obtained from the cooler means and using it in the mixing. Optionally, the stream of compressed refrigerant may be conducted into the air-cooled condenser means for condensing.

Alternatively, the stream of compressed refrigerant may be arbitrated between two operation states: i) wherein the stream of compressed refrigerant is used in the mixing; or ii) wherein the stream of compressed refrigerant is used for the condensing. The method may further comprise changing the mode of operation between two states: a heating mode comprising conducting the stream of compressed refrigerant stream into the evaporator means, conducting a stream of evaporated refrigerant from the evaporator means into a first inlet of the cooler means, conducting a stream of condensed refrigerant from the air-cooled condenser means into a second inlet of the cooler means and conducting it therefrom for the compressing; and a cooling mode comprising conducting the compressed refrigerant stream into the air-cooled condenser means, conducting a stream of condensed refrigerant from the air-cooled condenser means into the first inlet of the cooler means, conducting a stream of evaporated refrigerant from the evaporator means into the second inlet of the cooler means and conducting it therefrom for the compressing.

The refrigerant solution may comprise an absorbent material based on one or more of the following phosphates: trimethylphosphate $C_3H_9PO_4$; triethylphosphate $C_6H_{15}PO_4$; tri n-butylphosphate $C_{12}H_{27}PO_4$, on a phosphonate material: Dimethylmethylphosphonate $C_3H_9PO_3$, on one or more of the following Ethylene glycol materials: Ethylene glycol $C_2H_96O_2$; Dimethylether of tetraethyleneglycol $C_{10}H_{22}O_5$; 1,3-propanediol (trimethylene glycol) $C_3H_8O_2$, and/or based on one or more N-C=O bonds selected forms: N,N dimethylacetamid C_4H_9NO; N-methyl,2-pyrrolidinone(methyl-2-pyrrolidone,M-pyrrol) C_5H_9NO; N-methyl; e-caprolactam (hexahydro,1-methyl,2H-azepin 2-one) $C_7H_{13}NO$; 1,3-dimethyl,2-imidazolidinone (dimethylethyleneurea) $C_5H_{10}N_2O$; 1,3-dimethyl,3,4,5,6-tetrahydro-2-pyrimidinone (dimethylpropyleneurea) $C_6H_{12}N_2O$).

The refrigerant material used may be a type of HFC, HFC refrigerants (R32 - difluoromethane CH_2F_2, R152a - 1,1 difluoroethane CH_3CHF_2, R134a - 1,1,1,2 tetrafluoroethane CH_2FCF_3, R125 - pentafluoroethane CF_3CHF_2, R226ea - 1,1,1,2,3,3 hexafluoropropane $CF_3CHFCHF_2$, R226fa - 1,1,1,3,3,3 heptafluoropropane $CF_3CH_2CF_3$, R227ea - 1,1,1,2,3,3,3 heptafluoropropane CF_3CHFCF_3), R600a (iso-butane $(CH_3)_3CH$), or R630 (monomethylamine CH_3NH_2, - dimethylamine$(CH_3)_2NH$), for example.

Brief Description of the Drawings

The present invention is illustrated by way of example in the accompanying drawings, in which similar references consistently indicate similar elements and in which:

- Fig. 1 schematically illustrates a TPL single-stage cycle air cooled system according to one preferred embodiment of the invention utilizing a jet ejector mixer and a solution heat exchanger economizer (HS) at the high-pressure regime of the system;
- Fig. 2 schematically illustrates a TPL single-stage cycle air cooled system according to another preferred embodiment of the invention utilizing a jet ejector

mixer, and a split solution heat exchanger economizer having a pre-generator heat exchanger (pG) in the high-pressure regime and a pre-absorber heat exchanger (pA) in the intermediate-pressure regime;

- Fig. 3 schematically illustrates a TPL single-stage cycle air cooled system according to yet another preferred embodiment of the invention utilizing a compressor, a mixer, a split solution heat exchanger economizer having a pre-generator heat exchanger (pG) in the high-pressure regime and a pre-absorber heat exchanger (pA) in the intermediate-pressure regime;
- Fig. 4 schematically illustrates a TPL single-stage cycle air cooled system according to yet another preferred embodiment of the invention utilizing a split solution heat exchanger economizer as in Fig. 3 and an optional secondary compressor;
- Fig. 5 schematically illustrates a TPL single-stage cycle air cooled system according to yet another preferred embodiment of the invention utilizing a split solution heat exchanger economizer as in Fig. 3, a compressor, and two additional separator ,means;
- Fig. 6 schematically illustrates a TPL single-stage cycle air cooled system according to yet another preferred embodiment of the invention utilizing a split solution heat exchanger economizer as in Fig. 5, and a secondary compressor;
- Fig. 7A schematically illustrates a TPL single-stage cycle air cooled system according to yet another preferred embodiment of the invention utilizing a split solution heat exchanger economizer, additional separators and secondary compressor as in Fig. 6, with further means enabling it to operate as a heat pump (cooling and heating); and

- Figs. 7B and 7C schematically illustrates the refrigerant sub cycle in the TPL single-stage cycle air cooled system shown in Fig. 7A when operated in "cooling mode" (Fig. 7B) and in "heating mode" (Fig. 7C).

Detailed Description of Preferred Embodiments

It is noted that the preferred embodiments of the invention described hereinbelow with reference to the figures illustrate by way of example, and not by way of limitation, the principles of the invention. The figures, which are not necessarily in scale, exemplify preferred embodiments of the invention, and by no means limit the invention to the particular elements described.

An aim of the present invention is to facilitate exploitation of alternative or renewable heat sources at relatively low temperatures, preferably up to 130°C for cooling and refrigeration by means of single-stage triple pressure level (TPL) absorption, which may be operated without a cooling tower. The TPL absorption unit of the invention may be adapted to operate an air conditioning system employing a heat source such as solar energy.

Among various heat sources, the range of low grade temperature sources (e.g., providing temperatures in the range of 80 to 130 °C) such as solar energy, waste heat energy, and the like, is an important and difficult range for utilization and recovery. The utilization of such low grade heat sources is particularly desirous since it leads to elimination of greenhouse and air polluted gases and utilization of environmentally safe energy sources.

In preliminary studies carried out by the inventors, thermophysical and transport properties of various environmentally acceptable refrigerants (HFC) with different organic absorbents were examined and a thorough performance analysis of TPL cycles has been performed, in order to evaluate the potential performance of the cycle with these working fluids (possible refrigerant and absorbent materials indicated hereinbelow).

An important objective of the present invention, *inter alia*, is utilizing renewable energy for cooling without utilizing a cooling tower. The significance of this work lies in the potential to provide air conditioning (heating and cooling) and refrigeration by utilizing low grade heat sources, mainly solar radiation and waste heat energy.

Triple pressure level single stage absorption cycle

In Fig. 1 there is shown a basic TPL system **10s** according to one preferred embodiment of the invention, utilizing jet ejector mixer **JM** and a solution heat exchanger **S0** (**HS**) mounted between generator **S1** and air-cooled absorber **S2**. Heat exchanger unit **S0** functions as an economizer by transferring heat from the hot weak solution leaving generator **S1** through separator **S5** (passed via pipelines **1** and **3**) to the cold reconstituted solution pumped by pump **S6** (via pipelines **8, 10** and **14**) towards generator unit **S1**. The rich solution is heated in the generator unit **S1** by means of a heat transfer gas or fluid conducted thereinto via inlet **S1i** or any other form of heat supplied, and having temperatures generally in the range of 90 to 140 °C, preferably about 120 °C.

The rich solution is separated in separator unit **S5** into: i) a stream of refrigerant conducted through pipeline **21** to air-cooled condenser unit **R1**; and ii) a weak solution stream conducted through pipeline **1** to heat exchanger **S0**. The weak solution leaving heat exchanger **S0** is conducted through pipeline **3** into jet ejector mixer **JM** wherein it is mixed with the refrigerant conducted into jet ejector mixer **JM** through pipeline **28**. The mixed solution and refrigerant vapor are conducted through pipeline **5** into air-cooled absorber unit **S2** wherein it is cooled (e.g., to about 30 - 50 °C) to produce the rich (reconstructed) solution conducted to pump **S6** through pipeline **8**.

The stream of refrigerant is condensed in air-cooled condenser unit **R1** (e.g., to about 30 - 50 °C) from which it is conducted thorough pipeline **24** into refrigerant heat exchanger **R3** and therefrom through pipeline **25** and expansion valve **R5** into evaporator **R2**. The evaporated refrigerant is conducted through pipeline **27** into refrigerant heat exchanger **R3** and therefrom through pipeline **28** into jet ejector mixer **JM**.

The pressure regimes in system **10s** may be defined as follows: High-pressure regime in the strong solution path from pump **S6** through pipeline **10**, economizer heat exchanger **S0**, pipeline **14** and generator **S1** as it passed into separator unit **S5**, and therefrom in the weak solution path exiting separator unit **S5**, passing through pipeline **1** into economizer heat exchanger **S0** and therefrom through pipeline **3** to jet ejector mixer **JM** and in the refrigerant path from separator unit **S5** through pipeline **21**, air cooled condenser **R1**, pipeline **24**, refrigerant heat exchanger **R3** and pipeline **25** to expansion valve **R5**; intermediate-pressure regime in the mixed solution and refrigerant vapor path exiting jet ejector mixer **JM** outlet through pipeline **5**, air cooled absorber **S2**, and pipeline **8** into pump **S6**; and low-pressure regime in the refrigerant path from expansion valve **R5** through pipeline **26**, evaporator unit **R2**, pipeline **27**, refrigerant heat exchanger **R3** and pipeline **28** into jet ejector mixer **JM**.

A pre-cooler unit **22** may be provided in air-cooled condenser **R1** for cooling the hot refrigerant gas supplied through pipeline **21** to a temperature near to its saturation temperature. Pre-cooler unit **22** may be integrated into air-cooled condenser unit **R1**, or alternatively, it may be provided as a separate unit adapted to receive and cool the hot refrigerant gas supplied through pipeline **21**, and conduct it therefrom into air-cooled condenser unit **R1**.

Fig. 2 exemplifies an embodiment of another TPL system **11s** according to another preferred embodiment of the invention wherein the economizer heat exchanger (**S0** in Fig. 1) is split into two separate heat exchange stages (also referred to herein as split economizer): pre-generator heat exchanger **S4** (**pG**) at the high-pressure side receiving weak solution leaving separator **S5** through pipeline **1** wherefrom it is passed through pipeline **3a** to jet ejector mixer **JM**; and pre-absorber heat exchanger **S3** (**pA**) in the intermediate-pressure side receiving mixed solution leaving jet ejector mixer **JM** through pipeline **5a** toward air cooled absorber **S2** through pipeline **7**.

The pressurized strong solution produced by pump **S6** is conducted through pipeline **10** into pre-absorber heat exchanger **S3**, and through pipeline **12** into pre-generator heat exchanger **S4**, wherefrom it is conducted through pipeline **14** into generator **S1**. Splitting the economizer heat exchanger (**S0** in Fig. 1) in this way allows conveying heat from the hot solution leaving jet ejector mixer **JM** in the intermediate-pressure path of system **11s** to the reconstituted solution pumped by pump **S6** from absorber **S2** and through pipeline **8** into the high-pressure part of system **11s**.

The pressure recovery by jet ejector mixer **JM** is typically limited by the flow conditions and can be substantially improved by replacing jet ejector mixer **JM** with a common compressor (**R4**) and/or pressure reducer means (**S7**) and a mixer unit (**S8**) as exemplified in TPL system **12s** shown in Fig. 3. In this preferred embodiment the evaporated refrigerant passed through refrigerant heat exchanger **R3** is conducted through pipeline **28a** to compressor **R4**, wherein it is compressed and flown through pipeline **29** to mixer unit **S8**. Replacing jet ejector mixer **JM** with compressor **R4**, pressure reducer means (**S7**) and mixer unit **S8** in such way enables increasing the pressure in the intermediate-pressure regime (defined by pipelines **29**, **4**, **5a**, **7** and **8**) to a higher controlled pressure, and thereby to improve the cycle performances, namely, increasing the COP (coefficient of performance) and decreasing the circulation ratio (mass flow rates of the strong solution to the refrigerant).

In the TPL systems **11s** and **12s** using a split economizer configuration, shown in Fig. 2 and Fig. 3, the release of refrigerant vapor from the strong solution flown through generator **S1** is commenced in the pre-absorber heat exchanger **S3** (**pA**) continuing in pre-generator heat exchanger **S4** (**pG**) and completed in generator **S1**. During this process the released refrigerant vapor is also heated as it is passed through pre-generator heat exchanger **S4** (**pG**) and generator **S1**. Thereafter, the separated refrigerant is cooled at condenser unit **R1**, preferably at the entrance of condenser unit **R1** by means pre-cooler unit **22**. As explained hereinabove, system **12s** in Fig. 3 is similar to system **11s** in Fig. 2, and utilizes similar elements but employs compressor unit **R4**, pressure reducer **S7**, and a simpler mixer unit **S8** instead of jet ejector mixer (**JM**), and thus it will not be described herein in details for the sake of brevity.

Another preferred embodiment of the invention utilizing the split economizer configuration is exemplified in Fig. 4, showing a TPL single-stage absorption system **13s** similar to system **12s** shown in Fig. 3, but which employs an (optional) additional compressor unit **R6**. TPL system **13s** comprises the following parts: in the solution sub cycle (**S**); generator **S1**, air cooled absorber **S2**, pre-absorber heat exchanger **S3**, pre-generator heat exchanger **S4**, separator **S5**, solution pump **S6**, solution pressure reducer **S7** (e.g., throttling valve) and mixer unit **S8**, in the refrigerant sub cycle (**R**); air cooled condenser **R1**, evaporator **R2**, optional refrigerant heat exchanger **R3**, main compressor **R4**, expansion valve **R5**, optional secondary compressor **R6**, and two separation valves, **V21** and **V29**.

In this preferred embodiment shown in Fig. 4 rich solution flown through the air cooled absorber outlet **8** is pumped from air-cooled absorber **S2** into the high-pressure part (defined by pipelines **10**, **12** and **14**) toward the generator **S1** by pump **S6** (thorough pipelines **8** and **10**) and preheated in the pre-absorber solution heat exchanger **S3** by the hot mixed stream coming from the mixer **S8** toward absorber **S2** (through pipelines **5a** and **7**), and in the pre-generator heat exchanger **S4** by the hot weak solution flown from generator **S1** toward mixer **S8** (through pipelines **1**, **3a** and **4**). At generator **S1** heat is added from available heat source (e.g., solar-heated water, geothermal-heated water, power plant exhaust heat, or any other form of available heat supply) introduced thereinto via heat source inlet **S1i**, releasing at separator **S5** part of the refrigerant that is flown through pipeline **21** to the refrigerant sub-cycle. The weak solution leaves the pre-generator heat exchanger **S4** through pipeline **3a** and therefrom flown through a pressure reducing device **S7** and pipeline **4** into mixer **S8**, wherein it is mixed with the refrigerant vapors flown from the evaporator **R2** through pipeline **27**, refrigerant heat exchanger **R3** and compressor **R4** which increases the pressure of the evaporated refrigerant flown through pipeline

29. The mixed solution and refrigerant vapor flown from mixer unit **S8** enters the pre-absorber heat exchanger **S3** through pipeline **5a**, wherein part of the refrigerant is absorbed by the weak solution which is then passed through pipeline **7** into absorber **S2**, wherein the rest of the refrigerant is absorbed during the cooling process, which completes the solution sub-cycle **S**.

From separator **S5** the released refrigerant vapor passed through pipeline **21** flows into the air cooled condenser **R1**, wherein it condenses. The liquefied refrigerant leaving condenser **R1** through pipeline **24** flows through the refrigerant heat exchanger **R3**, wherein it is cooled by the cold refrigerant vapor leaving evaporator **R2** through pipeline **27**, and therefrom it is passed through pipeline **25** to expansion valve **R5** and therefrom through pipeline **26** into evaporator **R2**. The refrigerant vapors obtained in evaporator **R2** are flown through pipeline **27** to refrigerant heat exchanger **R3**, and therefrom through pipeline **28a** to compressor **R4** which increases the pressure of the evaporated refrigerant to the intermediate elevated pressure. The compressed evaporated refrigerant produced by compressor **R4** is flown through pipeline **29** toward mixer **S8**, which completes the refrigerant sub-cycle **R**.

Generator **S1**, pre-absorber heat exchanger **S3**, pre-generator heat exchanger **S4**, and optional refrigerant heat exchanger **R3**, may be implemented by means of conventional heat exchangers, such as but not limited to shell and tube types. Absorber **S2**, condenser **R1**, and evaporator **R2** are preferably implemented by means of air-cooled units, such as but not limited to the types of air-cooled units used in standard air-conditioning heat exchangers.

Separator **S5** may be implemented by a type of cyclone, or any other such separator means. Solution pump **S6** may be implemented by a type of multistage centrifugal, positive displacement, for example, or by another type of pump. Solution pressure reducer **S7** may be implemented by a type of pressure regulator, orifice, for example, or by another suitable type of pressure regulation means. Mixer **S8** may be implemented by a type of spray nozzle, for example. Compressors **R4** and **R6** are preferably a type of screw, reciprocate, for example, or another suitable type of compressing means. Expansion valve **R5** may be implemented by a type of thermostatic expansion valve, capillary tubes or other type. Separation valves, **V21** and **V29** are preferably implemented by a type of controllable three-way valve or by any other suitable controllable valve type. Pre-cooler unit **22** is preferably, but not necessarily, a part of the entrance of condenser **R1**.

The absorbent used may be based on phosphate (trimethylphosphate $C_3H_9PO_4$, triethylphosphate $C_6H_{15}PO_4$, tri n-butylphosphate $C_{12}H_{27}PO_4$, and others), on phosphonate (Dimethylmethylphosphonate $C_3H_9PO_3$, and others), on Ethylene glycol (Ethylene glycol $C_2H_96O_2$, Dimethylether of tetraethyleneglycol $C_{10}H_{22}O_5$, 1,3-propanediol (trimethylene glycol) $C_3H_8O_2$, and others), or on N-C=O bonds (N,N dimethylacetamid C_4H_9NO, N-methyl,2-pyrrolidinone(methyl-2-pyrrolidone,M-pyrrol) C_5H_9NO, N-methyl, e-caprolactam (hexahydro,1-methyl,2H-azepin 2-one) $C_7H_{13}NO$, 1,3-dimethyl,2-imidazolidinone (dimethylethyleneurea) $C_5H_{10}N_2O$, 1,3-dimethyl,3,4,5,6-tetrahydro-2-pyrimidinone (dimethylpropyleneurea) $C_6H_{12}N_2O$), for example, though other suitable absorbents may be similarly employed.

The refrigerant used may be a type of HFC, HFC refrigerants (R32 - difluoromethane CH_2F_2, R152a - 1,1 difluoroethane CH_3CHF_2, R134a - 1,1,1,2 tetrafluoroethane CH_2FCF_3, R125 - pentafluoroethane CF_3CHF_2, R226ea - 1,1,1,2,3,3 hexafluoropropane $CF_3CHFCHF_2$, R226fa - 1,1,1,3,3,3 heptafluoropropane $CF_3CH_2CF_3$, R227ea - 1,1,1,2,3,3,3 heptafluoropropane CF_3CHFCF_3), R600a (iso-butane $(CH_3)_3CH$), or R630 (monomethylamine CH_3NH_2, - dimethylamine$(CH_3)_2NH$), for example, though other suitable refrigerants may be similarly employed.

All of the abovementioned parameters are given by way of example only, and may be changed in accordance with the differing requirements of the various embodiments of the present invention. Thus, the abovementioned parameters should not be construed as limiting the scope of the present invention in any way.

It is noted that in case the heat is not capable of supplying (via inlet **S1i** or any other form of heat supplied) the amount of heat required for the operation of generator **S1**, the preferred embodiments of the invention may be modified for introducing an auxiliary heat source supply by heaters (not shown), such as for example, electrical heater, gas heater, heat storage, or any other such heat source.

Whenever the low energy heat source provided via heat input **S1i** (or any other form of heat supplied) is not available (e.g., if implemented by an intermittent heat source such as solar heat), a vapor compression cycle with similar cooling capacity can be operated by activating the secondary compressor **R6** that is utilized for increasing the refrigerant pressure from the intermediate-pressure to the condenser pressure (in pipeline **30**). In this case, the solution sub cycle **S** is separated from the refrigerant sub cycle **R** by valves **V21** and **V29** by changing them into state **'2'**. It is noted that this separated refrigerant cycle can also be operated as a heat pump.

The serially connected compressors, **R4** and **R6**, can be replaced by any suitable compressor (or set of compressors) which output pressure can be controlled (i.e. frequency control means).

As exemplified in system **14s** shown in Fig. 5, illustrating a yet another preferred embodiment of the invention, similar to system **12s** in Fig. 3, in which separator **S12** is added at the outlet of pre-absorber heat exchanger **S3**, and another separator **S14** is added at the outlet of pre-generator heat exchanger **S4**, in order to partially overcome the heating of the refrigerant vapors in the high-pressure part.

In this preferred embodiment the reconstituted solution flown from pre-absorber heat exchanger **S3** through pipeline **12t** is supplied to pre-generator heat exchanger **S4** through pipeline **12a** after passing through separator **S12** which streams portions of the refrigerant vapor separated by it to pipeline **21** through pipeline **12g**. Similarly, the reconstituted solution flown from pre-generator heat exchanger **S4** through pipeline **14t** is supplied to generator **S1** through pipeline **14s** after passing through separator **S14**, which streams portions of the refrigerant vapors separated by it to pipeline **21** through pipeline **14g**. As in the previously described embodiments, the reconstituted solution flown from generator **S1** is provided to separator **S5** via pipeline **1**, and the separated refrigerant vapor is flown to pipeline **21** through pipeline **1g**. In this way the pre-generator heat exchanger **S4** (**pG**) and the generator **S1** are receiving mainly liquid solution at their inlets and consequently less heat has to be supplied to these units. As a consequence, the required components sizes are reduced, less heat has to be supplied to the generator and the COP is increased. The refrigerant vapors from separators **S12** and **S14** are mixed with the refrigerant vapor from the generator separator **S5** and flow toward condenser **R1** through pipeline **21**.

The main driving force of the absorption systems of the invention is the heat supplied to generator **S1** (via inlet **S1i**). If this heat energy is obtained from a solar energy source the functionality of the system depends on the availability of the heat source. That dependency can be resolved by adding a heat storage unit (not shown) or by utilizing the semi-compression cycle in the system between pipelines **21** and **29**, by adding a second compressor **R6** and two valves, **V21** and **V29**, installed in pipelines **21** and **29** respectively, in order to complete a compression cycle, as shown in the preferred embodiments of Figs. 4 and 6.

With reference to Fig. 6, in this preferred embodiment at normal operating conditions valves **V21** and **V29** are in state **'1'** in order to enable the refrigerant vapor from the separators **S5**, **S12** and **S14** flown through pipeline **21** to flow toward condenser **R1** and from compressor **R4** through pipeline **29** toward mixer **S8**. When the solar energy cannot supply sufficient heat, valves **V21** and **V29** are turned to state **'2'**, disconnecting the absorption sub cycle (**S**) and connecting secondary compressor **R6** to the compressor **R4** in series in order to complete a compression cycle with the same evaporator capacity. This is an on-off arrangement.

For example, when the solar energy source can supply only part of the necessary heat to generator **S1**, the heat source temperature can be kept stable by lowering the flow rate; as a result there will be a reduction in the amount of refrigerant vapor released in generator **S1**. To keep the amount of refrigerant vapor streamed toward condenser **R1** stable, replacing valves **V21** and **V29** to controllable valves is advantageous. By that replacement, continuous operation of the secondary compressor **R6** is employed in order to add the completion amount of refrigerant vapor to be mixed with the refrigerant vapor coming from generator **S1**. In this way the two sub cycles (**S** and **R**) can operate continuously to maintain constant evaporator capacity. Whenever the solar energy is not sufficient, valves **V21** and **V29** will be turned to state '**2**' and the cycle will operate as a compression cycle.

When the heat supply is not available and the cycle turned to operate as a compression cycle (state '**2**' - the absorption sub cycle **S** is disconnected), and yet there is heating demands, the cycle described with reference to Fig. 6 can be modified to operate as a heat pump, as exemplified in Figs. 7A-7C, by adding valves **V24**, **V26** and **V27** to the compression sub cycle (**R**) and additional ductwork to enable the cycle to operate in two modes: i) cooling, also illustrated in Fig. 7B; or ii) heating, also illustrated in Fig. 7C.

Valve **V26** is installed in both pipelines **21** and **26** and adapted to arbitrate the flow through these pipelines between two states: '**1**' (illustrated in Fig. 7B) - refrigerant flown through pipeline **21** is conducted through pipeline **21a** to air-cooled condenser unit **R1**, and the refrigerant flown through pipeline **26** is conducted through pipeline **26a** to evaporator **R2**; and '**2**' (illustrated in Fig. 7C) - wherein refrigerant flow through pipeline **21** is conducted through pipeline **26a** to evaporator **R2**, and the refrigerant flown through pipeline **26** is conducted through pipeline **21a** to air-cooled condenser unit **R1**.

Valves **V24** and **V27** are installed in both pipelines **24** and **27** and adapted to arbitrate the flow through these pipelines between two states: **'1'** (illustrated in Fig. 7B) - refrigerant flown through pipeline **24** is conducted through pipeline **24a** to first inlet **i1** of refrigerant heat exchanger **R3**, and the refrigerant flown through pipeline **27** is conducted through pipeline **27a** to second inlet **i2** of refrigerant heat exchanger **R3**; and **'2'** (illustrated in Fig. 7C) - wherein refrigerant flow through pipeline **24** is conducted through pipelines **24b** and **27a** to second inlet **i2** of refrigerant heat exchanger **R3**, and the refrigerant flown through pipeline **27** is conducted through pipelines **27b** and **24a** to first inlet **i1** of refrigerant heat exchanger **R3**.

In this way, whenever valves **V24**, **V26** and **V27** are set into state **'1'** (i.e., compressed refrigerant is flown from compressors **R4** and **R6** to air-cooled condenser unit **R1** and therefrom through refrigerant heat exchanger **R3** to evaporator **R2**) the compression sub cycle **R** is operated in the cooling mode (Fig. 7B), and whenever valves **V24**, **V26** and **V27** are set into state **'2'** (i.e., compressed refrigerant is flown from compressors **R4** and **R6** to evaporator **R2** and therefrom through refrigerant heat exchanger **R3** to air-cooled condenser unit **R1**) the compression sub cycle **R** is operated in the heating mode (Fig. 7C).

Valves **V24**, **V26** and **V27**, may be implemented by means of any suitable types of electronically controllable valves, or by means of an arrangement of controllable two-way and three-way valves. Control means (not shown - e.g., control logic, programmable logic controller - PLC, microcontroller, MCU, or the like) may be used to change the states of the controllable valves in the preferred embodiments of the invention described hereinabove, arbitrate the refrigerant streams and operate the compressor means as needed, which is within the skills of those versed in the art. As exemplified in Fig. 7C, when system **14s** is operated in the heating mode, functionality of condenser **R1** is performed by evaporator **R2** and therefore pre-cooler unit **22'** may optionally be used separately, or as a part of, evaporator **R2** unit.

Advantageously, the present invention provides triple pressure absorption systems designs that use environmentally acceptable working refrigerants and absorbents fluids and utilize low energy heat sources. The expected COP (coefficient of performance) in preferred embodiments of the invention is about 0.7-1.3 (depends on operating conditions and the working fluids). By advanced control system the COP can be as high as the COP of compression cycle at the same condenser and evaporator conditions. As can be seen in example 2 the COP of the compression cycle alone is about 4.1.

EXAMPLE 1

Table 1 provides expected temperature and pressure ranges in various components of the TPL single-stage cycle air-cooled system operating with R134a of the invention illustrated in Fig. 7A, as obtained in a computerized simulation. It is noted that features of the components in the system depend on the working fluids. In this example the presented data are for the R134a-DMETEG solution.

Table 1

Component*	**Flow pattern**	**Temperature range [°C]**	**Pressure range [bar]****
Generator	Liquid Heat source	< 140	
	solution	< 130	< 13.5
Pre-Generator	Weak solution	70 to 90	< 13.5
	Mixed flow of strong solution and Refrigerant vapor	70 to 90	< 13.5
Mixer	Mixed flow of Weak solution and Refrigerant vapor	70 to 90	5 to 10
Pre-Absorber	Mixed flow of Weak solution and Refrigerant vapor	60 to 90	5 to 10
	Mixed flow of strong solution and Refrigerant vapor	50 to 80	< 13.5
Absorber	Mixed flow of Weak solution and Refrigerant vapor	< 50	5 to 10
	air	< 45	~1
Condenser	Refrigerant vapor to liquid	< 50	< 13.5
	air	< 45	~1
Refrigerant heat exchanger	Refrigerant liquid	20 to 50	< 13.5
	Refrigerant vapor	0 to 40	2.5 to 3.5
Evaporator	Refrigerant liquid to vapor	-5 to +5	2.5 to 3.5
	Air or liquid	0 to 10	~1
Compressor 1	Refrigerant vapor	50 to 80	2.5 to 10
Compressor 2	Refrigerant vapor	70 to 100	5 to 13.5

* Construction material: Brass, steel, stainless steel, etc. Sealing materials: depends on the working fluids properties,

** The pressure ranges which presented in this table are functions of the refrigerant. In this table the presented values are for the refrigerant R134a.

EXAMPLE 2

The calculated results of a triple pressure level cycle system (TCa-S-C, shown in Fig. 7A) with R134a-DMETEG solution operating under the following conditions: Generator 110°C, air cooled condenser and absorber 50°C and evaporator 0°C, are summarized in the table 2.

It is noted that inline the pressure drops are negligible. In this example:

Pressures [bar] - high = 13.17 , intermediate = 9.43 , low= 2.93

COP=1.055 , circulation ratio=2.072

kW/TR of the absorption cycle = 0.658 and for the compression cycle = 0.860

Table 2

```
* TCa-S-C *  Absorptin/Compression Cycle with R134a - DMETEG
----------------------------------------------------------------------------
  1     2        3        4       5      6          7      8       9       10     11
 Solution->    t °C    P bar     z      i       Refrigerant->    t °C   P bar    j
============================================================================
 .10.   Pump    50.16  13.17 0.5977 119.06
 .12s   pAs     69.47  13.17 0.5160 129.86  =>.12r  pAs     67.36  13.17 158.79
 .14s   pGs     81.26  13.17 0.3868 138.06 <=>.14r  pGs     74.43  13.17 160.56
 .1s.   Gen    110.00  13.17 0.2224 157.23 <=>. 1g  Gen     91.68  13.17 164.92
 .3..   pGp     74.47  13.17 0.2224 136.44    .21.  vap     76.96  13.17 161.19
 .3e.   EQp     90.45   9.43 0.2224 145.67    .22.  Def     50.00  13.17 154.41
                                              .23.  Con     50.00  13.17 117.71
                                              .25.  HR1     30.95  13.17 110.49
                                              .26. Evpi      0.00   2.93 110.49
                                              .27. Evpo      0.00   2.93 147.72
                                              .28.  HRg     35.00   2.93 154.93
 .4..   BP.     74.47   9.43 0.2224 136.44 <= .29. Comp     74.36   9.43 161.79
 .5s.   Mix     78.93   9.43 0.2827 138.11 <=>.5r.  Mix     75.93   9.43 162.17
 .7s.   pAp     58.75   9.43 0.4631 124.61 <=>.7r.  pAp     58.75   9.43 158.06
 .8..   Abs     50.00   9.43 0.5977 118.98
----------------------------------------------------------------------------
** Heat input/output in Kcal/hr for 1 kg/hr refrigerant **
Qgen = 28.265 , QpG   = 22.278 , QpA =  32.498 , Qabs= 29.028
Qdef =  6.781 , Qcon = 36.698 , Qhr =   7.219 , Qevp= 37.221
              , Wcomp=  6.853 , Wp  =   0.170 , Xevp=  0.220
----------------------------------------------------------------------------
                         Sol.  [kg/hr]  Ref.
Flow rates     Abs:     2.0716          0.0000 (  0.00% generated)]
               pAs:     1.7217          0.3500 ( 35.00% generated)]
               pGs:     1.3590          0.3627 ( 36.27% generated)]
               Gen:     1.0716          0.2874 ( 28.74% generated)]
               Mix:     1.1618          0.9098 (  9.02% absorbed)]
              pA1p:     1.5521          0.5195 ( 48.05% absorbed)]
----------------------------------------------------------------------------
COP-absorption = 1.055 , dPcomp1 = 6.50, kW/TR =0.658
Comp-2 , T30=88.5C, Wcomp2= 2.319kcal/hr
COP(comp1+comp2)=4.1   , dPcomp2 = 3.74, kWC/TR=0.860
                                              % =0.766
----------------------------------------------------------------------------
```

Each point along the cycle is defined by the temperature [°C], pressure [bars], weight fraction (for the solution) and enthalpies i, j [kcal/kg].
Each component is defined by the heat transfer [kcal/hr] and the mass flow rate [kg/hr].

The above examples and description have of course been provided only for the purpose of illustration, and are not intended to limit the invention in any way. As will be appreciated by the skilled person, the invention can be carried out in a great variety of ways, employing more than one technique from those described above, all without exceeding the scope of the invention.

CLAIMS

1. An air-cooled absorption refrigerating system comprising: generator means in heat exchange relationship with a stream of heat transfer fluid or gas, separator means adapted to separate a stream from said generator means into a weak refrigerant solution stream and a main refrigerant vapor stream, air-cooled condenser means to condense said refrigerant vapor stream, an expansion valve to reduce the pressure of a condensed refrigerant stream from said air-cooled condenser means, evaporator means to form said evaporated refrigerant stream from a stream from said expansion valve and to cool a surrounding material, a heat exchanger means to exchange heat between said weak refrigerant solution stream and a high-pressure rich refrigerant solution stream, mixer means to produce a mixed stream from a stream of evaporated refrigerant from said evaporator means and from a stream of weak solution from said heat exchanger means, air-cooled absorber means to reconstitute said mixed stream, and pump means to produce said high-pressure rich refrigerant solution stream from a stream from said air-cooled absorber means.

2. A system according to claim 1 further comprising an additional heat exchanger means adapted to exchange heat between a stream from the air-cooled condenser means and an evaporated refrigerant stream from the evaporator means.

3. A system according to claim 1 or 2 wherein stream of heat transfer fluid or gas is supplied from a type of low grade heat source.

4. A system according to claim 1, 2 or 3, further comprising separator means to separate a stream of rich refrigerant solution from the heat exchanger means into an additional refrigerant vapor stream, introduced into the main

refrigerant vapor stream, and a solution, introduced into the generator means.

5. A system according to claim 1, 2, 3 or 4, wherein the heat exchanger means is split into first and second heat exchange stages: i) a first heat exchange stage to exchange heat between the weak refrigerant solution stream and a stream of high-pressure rich solution from said second heat exchange stage; and ii) a second heat exchange stage to exchange heat between a mixed stream from the mixer means and the high-pressure rich solution stream, wherein the air-cooled absorber means is adapted to reconstitute a mixed stream obtained from said second stage heat exchange means.

6. A system according to claim 5 further comprising separator means to separate a stream of rich refrigerant solution from the second stage heat exchange means into a further refrigerant vapor stream, introduced into the main refrigerant vapor stream, and a refrigerant solution, introduced into the first stage heat exchange means.

7. A system according to claim 1, 2, 3, 4 or 5 further comprising pre-cooler means to cool the main refrigerant vapor stream provided to the air-cooled condenser means to a temperature near its saturation temperature.

8. A system according to claim 6 wherein the mixer means is a type of jet ejector mixer.

9. A system according to claim 6 further comprising pressure reducer means adapted to reduce the pressure of the stream of weak refrigerant solution provided to the mixer device from the first heat exchange stage.

10. A system according to claim 9, further comprising main compressor means to compress a stream of evaporated refrigerant obtained from the additional heat exchanger means and introduce the same into the mixer means.

11. A system according to claim 10, further comprising additional compressor means, or multistage compressor means, adapted to compress a stream of compressed refrigerant from the main compressor means and introduce the same into the air-cooled condenser means.

12. A system according to claim 11, further comprising two three-way valves adapted to change said system between two operating states: i) wherein a stream of compressed vapors from the main compressor means is directed into the mixer means and the main stream of refrigerant vapor is directed into the air-cooled condenser means; and ii) wherein a stream of compressed evaporator from the main compressor means is directed into the additional compressor means, a stream of compressed refrigerant from said additional compressor means is directed into the air-cooled condenser means, and the main stream of refrigerant vapor is precluded from reaching the air-cooled condenser means.

13. A system according to claim 11 or 12, further comprising additional valves and conduits adapted to change the mode of operation of said system between two states: a heating mode wherein the compressed refrigerant stream from the additional compressor means, or multistage compressor means, is conducted into the evaporator means, a stream of evaporated refrigerant from said evaporator means is conducted into a first inlet of the additional heat exchange means receives, a stream of condensed refrigerant from the air-cooled condenser means is conducted into a second inlet of said additional heat exchange means which is then conducted therefrom into the main compressor means; and a cooling mode wherein the compressed refrigerant stream from the additional compressor means, or multistage compressor means, is conducted into the air-cooled condenser means, a stream of condensed refrigerant from the air-cooled condenser means is conducted

into said first inlet of said additional heat exchange means, a stream of evaporated refrigerant from said evaporator means is conducted into said second inlet of the additional heat exchange means which is then conducted therefrom into the main compressor means.

14. A system according to claim 12 or 13, further comprising control means adapted to change the states of the three-way valves and/or of the additional valves to, and operate the compressor means to change the state of said system between the operating states and/or the modes of operations.

15. A system according to any one of claims 1 to 14 wherein the refrigerant solution comprises an absorbent material based on one or more of the following phosphates: trimethylphosphate $C_3H_9PO_4$; triethylphosphate $C_6H_{15}PO_4$; tri n-butylphosphate $C_{12}H_{27}PO_4$, on a phosphonate Dimethylmethylphosphonate $C_3H_9PO_3$, based on one or more of the following Ethylene glycol materials: Ethylene glycol $C_2H_96O_2$; Dimethylether of tetraethyleneglycol $C_{10}H_{22}O_5$; 1,3-propanediol (trimethylene glycol) $C_3H_8O_2$, and/or based on one or more N-C=O bonds selected forms: N,N dimethylacetamid C_4H_9NO; N-methyl,2-pyrrolidinone(methyl-2-pyrrolidone,M-pyrrol) C_5H_9NO; N-methyl; e-caprolactam (hexahydro,1-methyl,2H-azepin 2-one) $C_7H_{13}NO$; 1,3-dimethyl,2-imidazolidinone (dimethylethyleneurea) $C_5H_{10}N_2O$; 1,3-dimethyl,3,4,5,6-tetrahydro-2-pyrimidinone (dimethylpropyleneurea) $C_6H_{12}N_2O$).

16. A system according to any one of claims 1 to 15 wherein the refrigerant material is selected from the group comprising: HFC, HFC refrigerants (R32 - difluoromethane CH_2F_2, R152a - 1,1 difluoroethane CH_3CHF_2, R134a - 1,1,1,2 tetrafluoroethane CH_2FCF_3, R125 - pentafluoroethane CF_3CHF_2, R226ea - 1,1,1,2,3,3 hexafluoropropane $CF_3CHFCHF_2$, R226fa - 1,1,1,3,3,3 heptafluoropropane $CF_3CH_2CF_3$, R227ea -

1,1,1,2,3,3,3 heptafluoropropane CF_3CHFCF_3), R600a (iso-butane $(CH_3)_3CH$), or R630 (monomethylamine CH_3NH_2, -dimethylamine$(CH_3)_2NH$).

17. A method for cooling a refrigerated space comprising:

mixing a stream of evaporated refrigerant with a stream of weak refrigerant solution;

producing a reconstituted solution by absorbing portions of said evaporated refrigerant into said stream of weak refrigerant by means of air-cooled absorber means;

pumping said reconstituted solution into heater means being in heat exchange relationship with a stream of hot weak refrigerant solution and conducting said weak refrigerant solution therefrom for use in said mixing;

evaporating refrigerant from a stream of reconstituted solution from said heater means by means of generator means being in heat exchange relationship with a stream of heat transfer fluid or gas;

separating a stream from said generator means into said stream of hot weak refrigerant solution and a main refrigerant vapor stream;

condensing said main refrigerant vapor stream by means of air-cooled condenser means;

reducing the pressure of a stream of condensed refrigerant vapor from said air-cooled condenser means and conducting the same into evaporator means; and

evaporating said condensed refrigerant in said evaporator means to form said stream of evaporated refrigerant and conducting said stream of evaporated refrigerant therefrom for use in said mixing.

18. A method according to claim 17 further comprising cooling the condensed refrigerant vapor stream from the air-cooled condenser means by means of cooler means being in heat exchange relationship with the stream of evaporated

refrigerant, and conducting said stream of evaporated refrigerant therefrom for use in said mixing;

19. A method according to claim 17 or 18 wherein the stream of heat transfer fluid or gas is supplied from a type of low grade heat source.

20. A method according to claim 17, 18 or 19 further comprising separating a stream of reconstituted solution obtained from the heater means into an additional refrigerant vapor stream and conducting it into the main refrigerant vapor stream, and conducting a remaining stream of reconstituted solution into the generator means.

21. A method according to any one of claims 17 to 20 wherein the heater means is split into first and second heat exchange stages: i) a first heat exchange stage used for exchanging heat between the hot weak refrigerant solution stream and a stream of reconstituted solution from said second heat exchange stage; and ii) a second heat exchange stage to exchange heat between a mixed stream obtained in the mixing and the reconstituted solution stream, wherein the absorbing in the air-cooled absorber means comprise reconstituting a mixed stream obtained from said second stage heat exchange means.

22. A method according to claim 21 further comprising separating a stream of reconstituted solution from the second heat exchange stage into a further refrigerant vapor stream and conducting it into the main refrigerant vapor stream, and conducting a remaining stream of reconstituted solution into the first heat exchange stage.

23. A method according to claim to any one of claims 17 to 22, further comprising cooling the main refrigerant vapor stream provided to the air-cooled condenser means to a temperature near its saturation temperature.

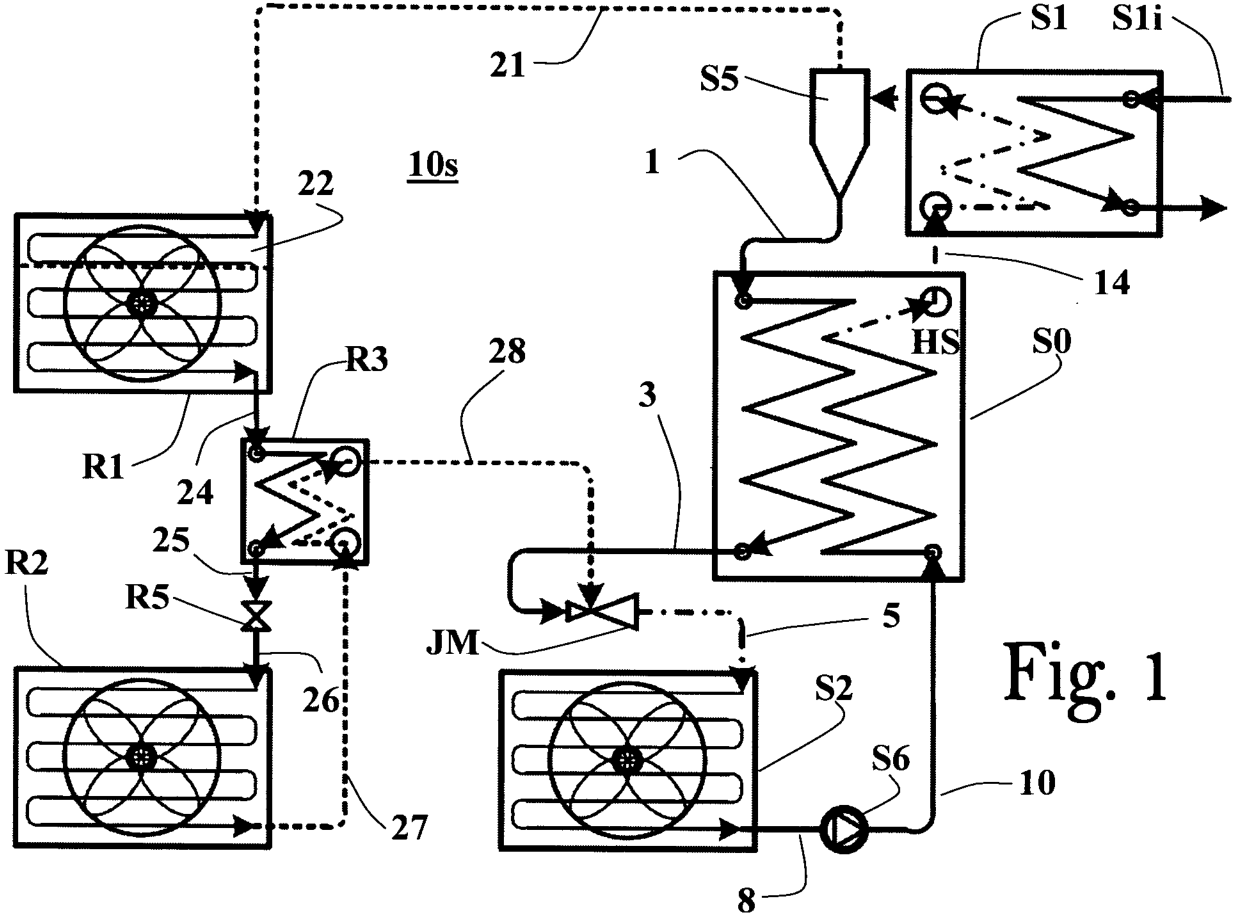
24. A method according to claim 21 further comprising reducing the pressure of the stream of weak refrigerant solution provided to the mixing from the first heat exchange stage.

25. A method according to claim 24 further comprising compressing a stream of evaporated refrigerant obtained from the first heat exchanger stage and using it in the mixing.

26. A method according to claim 25 further comprising conducting the stream of compressed refrigerant into the air-cooled condenser means for condensing.

27. A method for cooling a refrigerated space having a stream of compressed refrigerant comprising arbitrating said stream of compressed refrigerant between two operation states: i) wherein said stream of compressed refrigerant is used in the mixing according to claim 25; or ii) wherein said stream of compressed refrigerant is used for the condensing according to claim 26.

28. A method according to claim 27 further comprising changing the mode of operation between two states: a heating mode comprising conducting the stream of compressed refrigerant stream into the evaporator means, conducting a stream of evaporated refrigerant from said evaporator means into a first inlet of the cooler means, conducting a stream of condensed refrigerant from the air-cooled condenser means into a second inlet of said cooler means and conducting it therefrom for the compressing; and a cooling mode comprising conducting the compressed refrigerant stream into the air-cooled condenser means, conducting a stream of condensed refrigerant from the air-cooled condenser means into said first inlet of said cooler means, conducting a stream of evaporated refrigerant from said evaporator means into said second inlet of the cooler means and conducting it therefrom for the compressing.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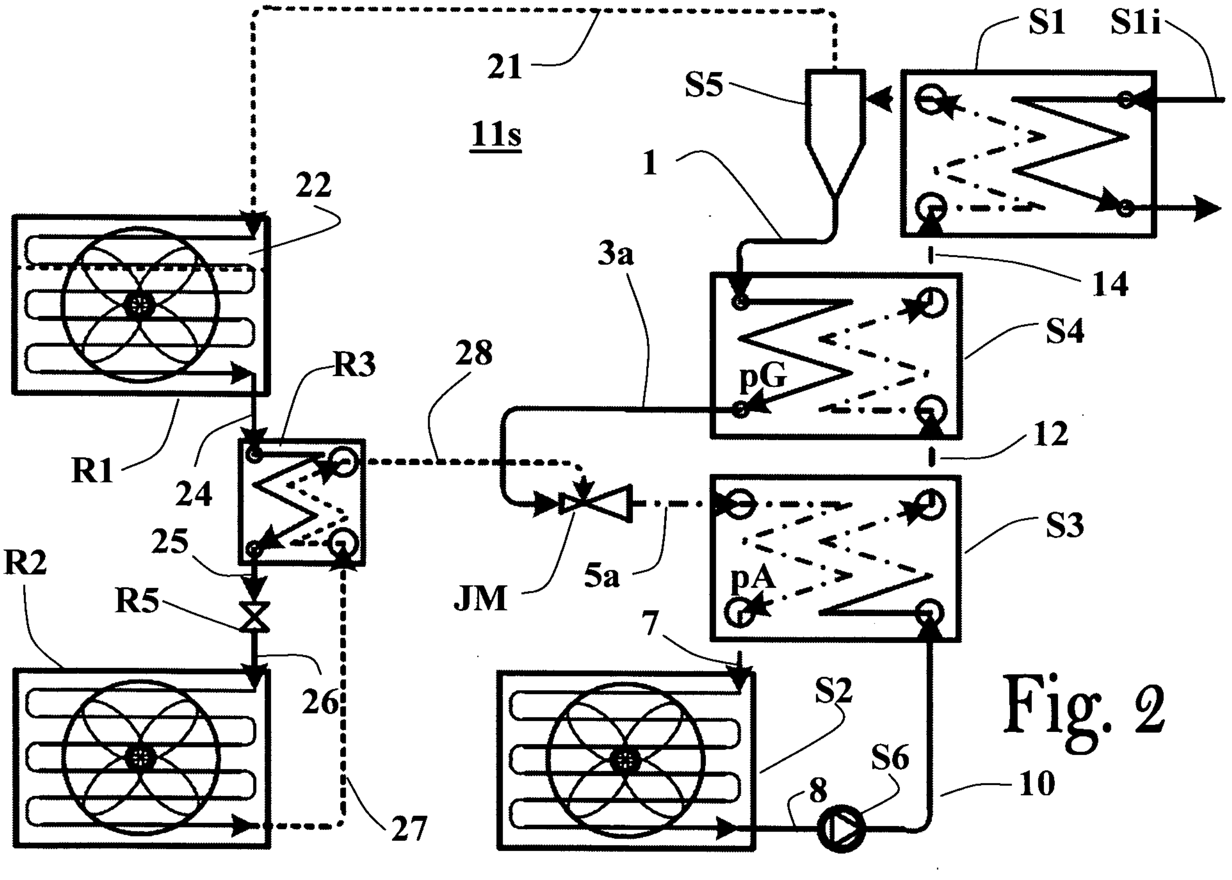
S1
S1i
S5
10s
1
22
14
HS
S0
28
R3
3
R1
24
25
R2
R5
JM
5
26
S2
S6
10
27
8

Fig. 1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S4
pG
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R3
12
R1
24
JM
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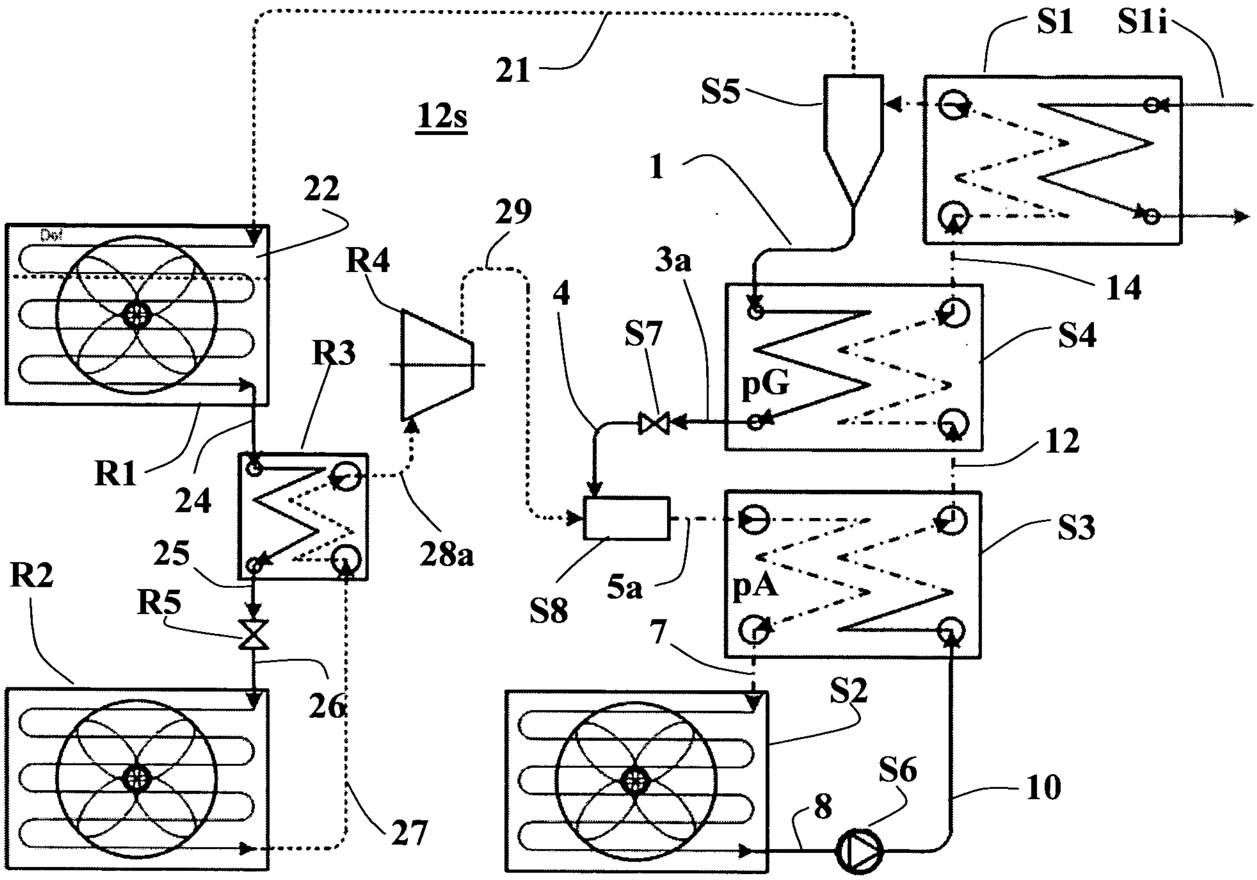
S3
25
pA
R2
R5
7
26
S2
S6
8
10
27

Fig. 2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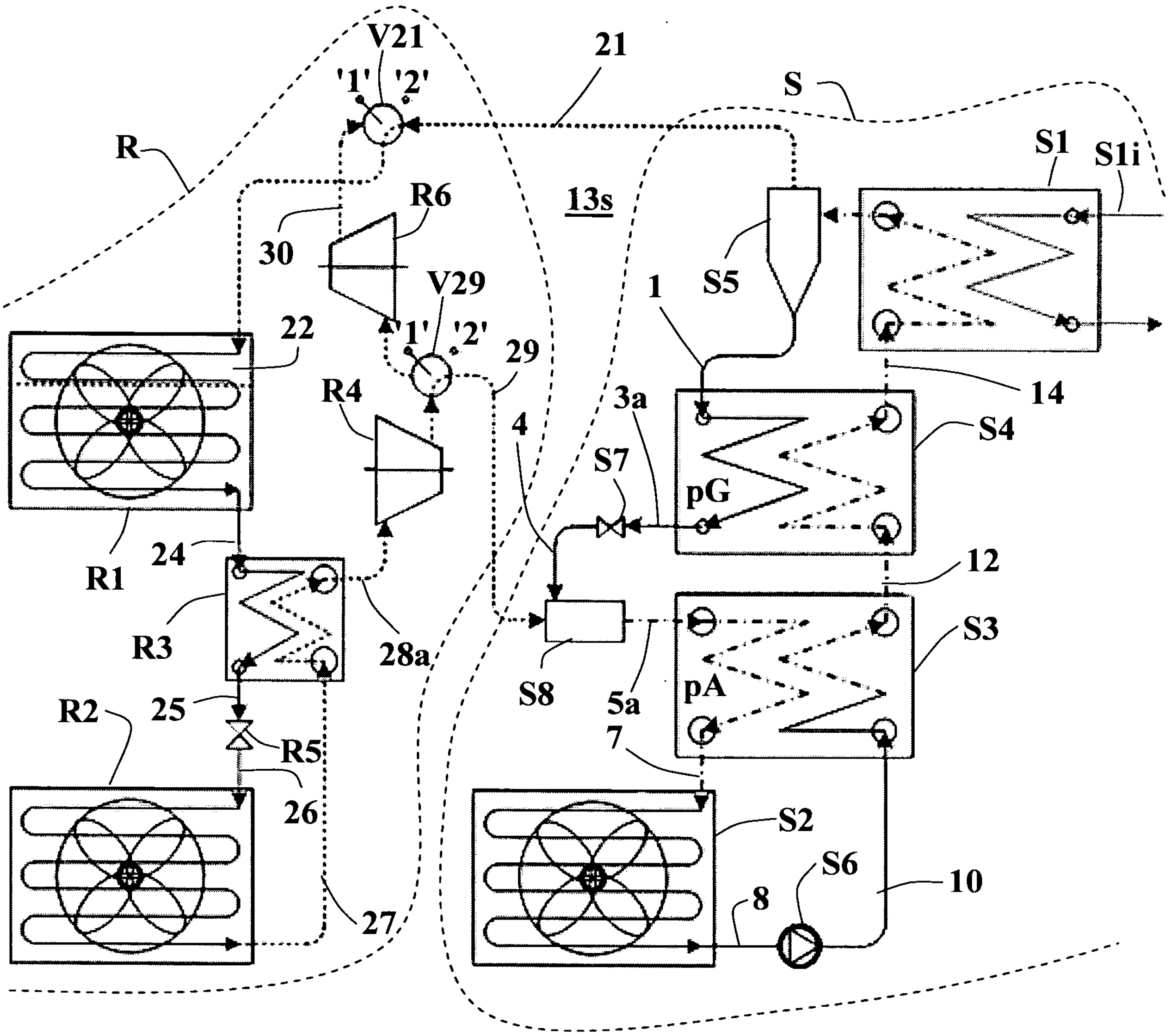
22
Def
29
R4
3a
4
14
S4
S7
R3
pG
R1
24
12
28a
S8
S3
25
5a
pA
R2
R5
7
26
S2
S6
10
8
27

Fig. 3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'2'
22
29
14
R4
3a
S4
4
S7
pG
R1
24
12
R3
S8
S3
28a
pA
5a
R2
25
R5
7
26
S2
S6
10
8
27

Fig. 4

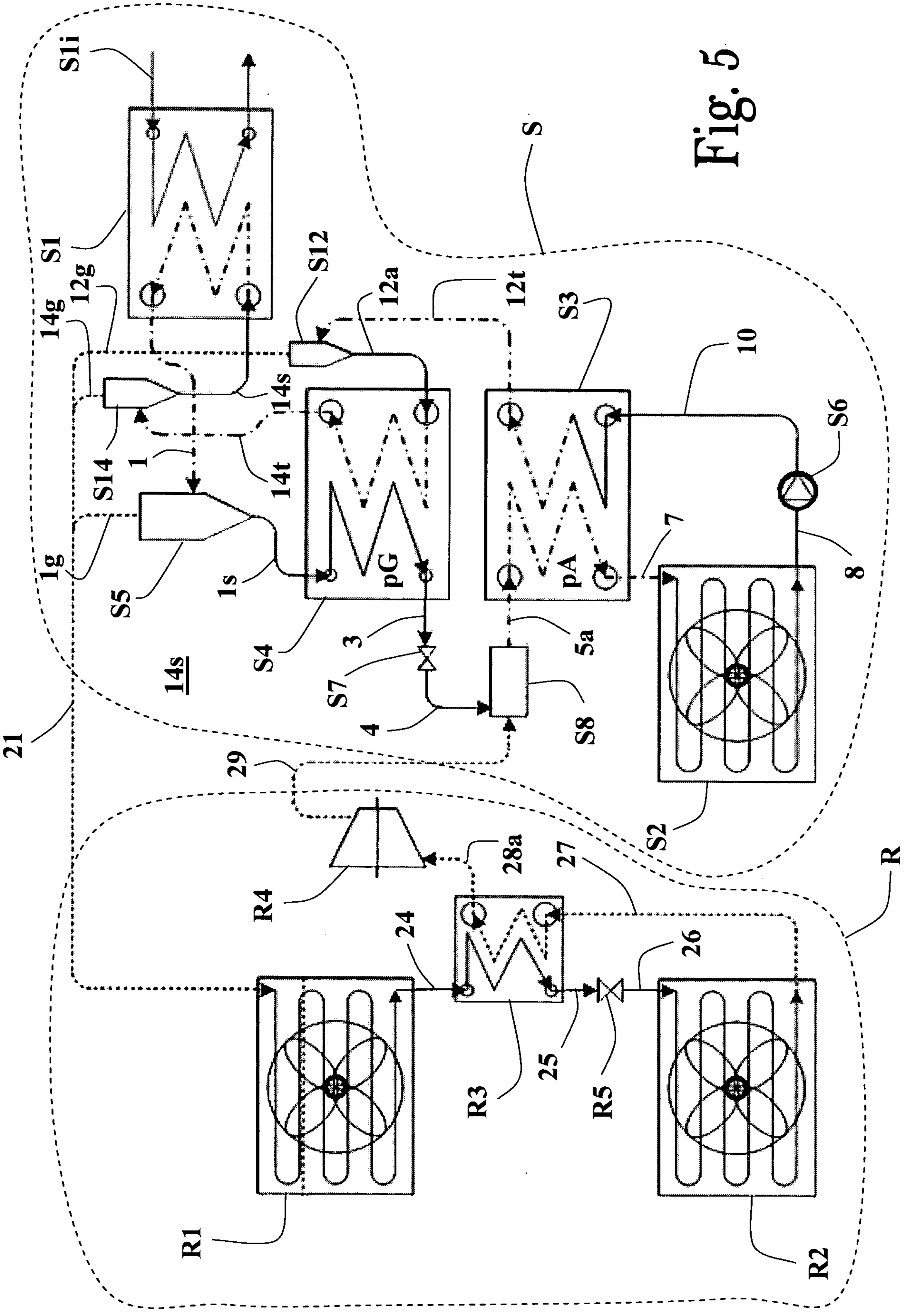
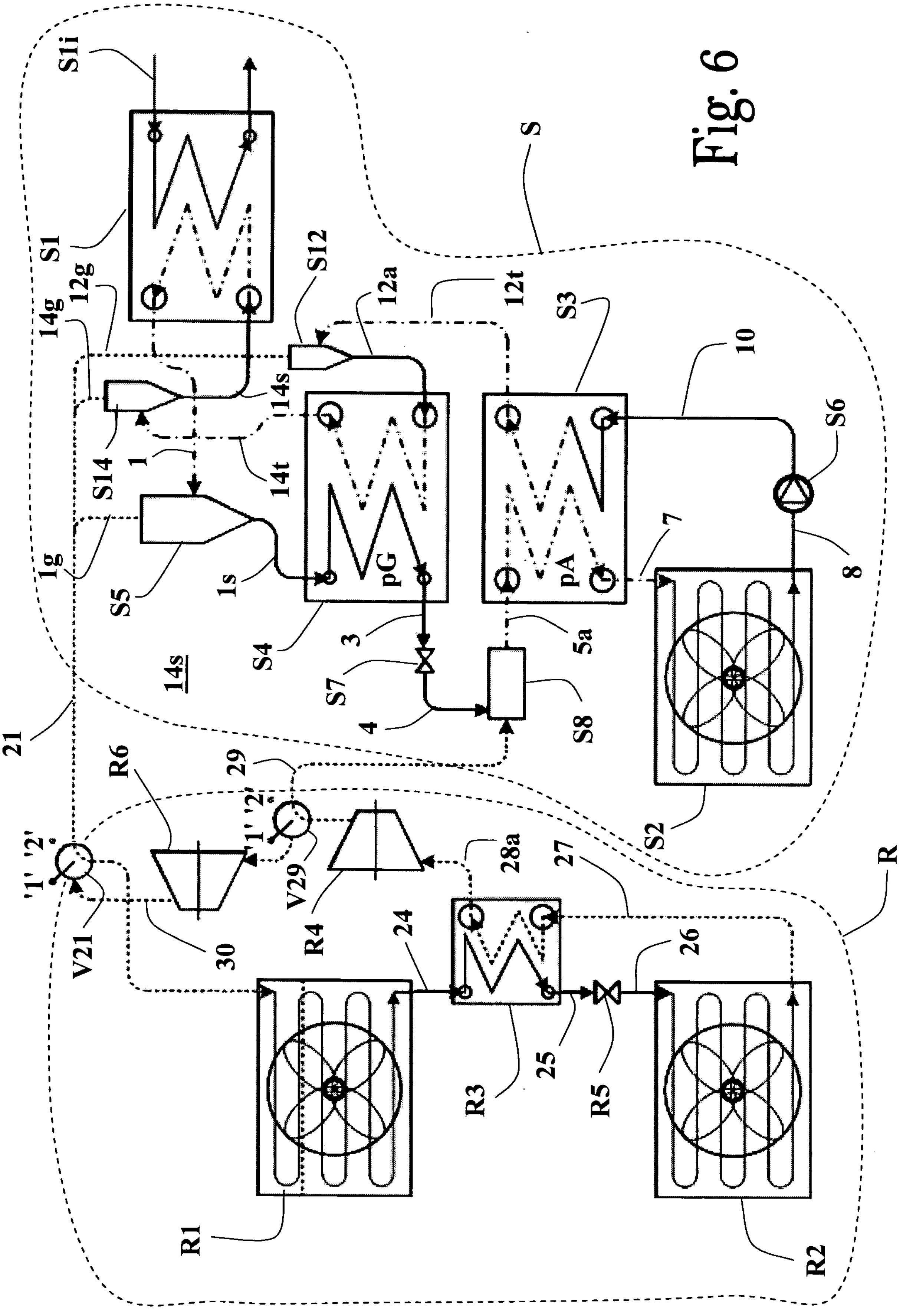


Fig. 5

S1i
S1
12g
14g
S12
12a
12t
S3
10
S6
S
14s
14t
S14
1
S5
1g
1s
pG
pA
S4
3
S7
4
5a
S8
7
8
S2
14s
21
29
R4
28a
27
R
24
R3
25
R5
26
R1
R2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12t
S3
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10
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S14
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14t
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S4
pG
pA
3
5a
S7
S8
4
7
8
S6
S2
14s
21
R6
29
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V29
R4
28a
27
R
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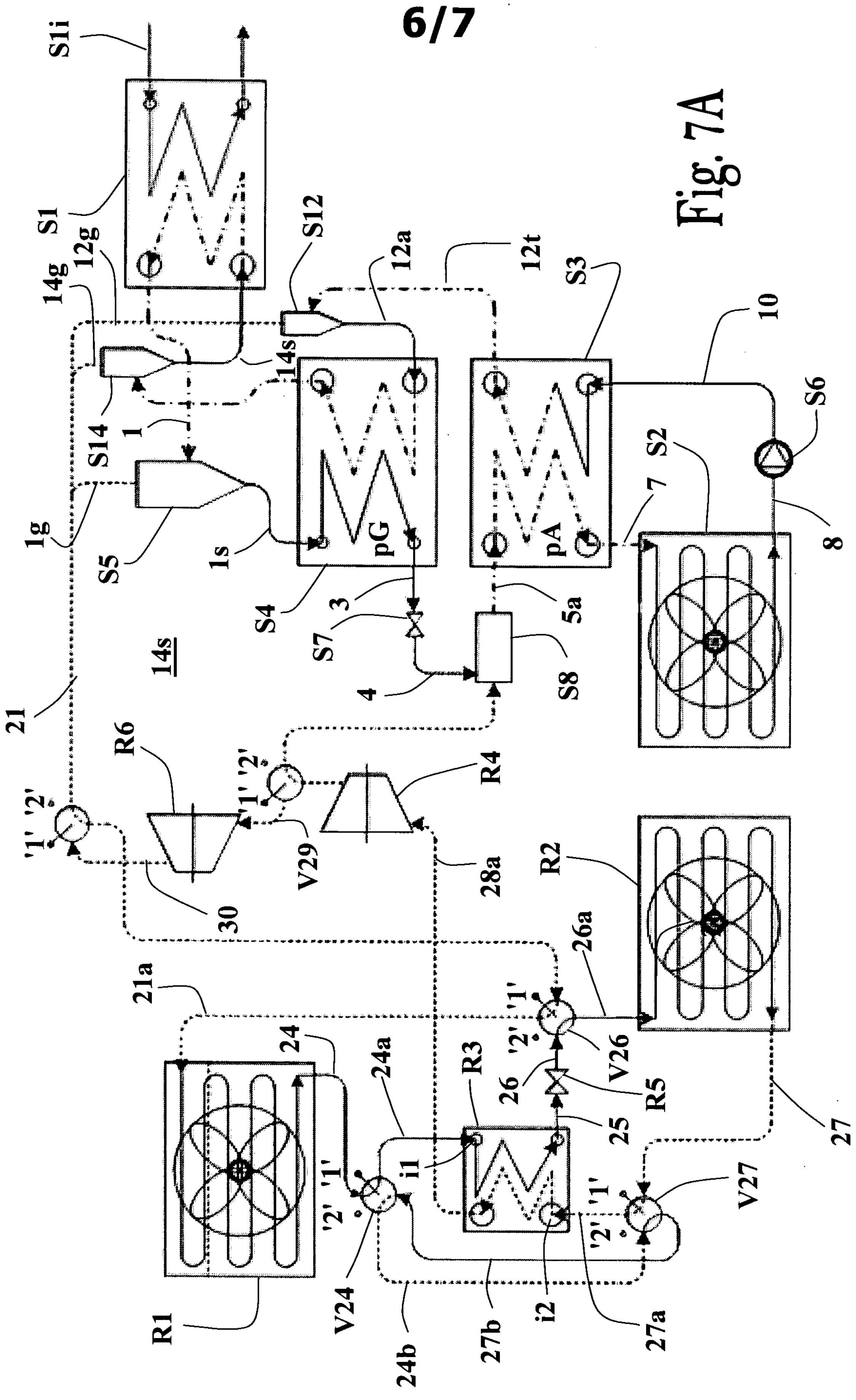
V21
30
24
R3
25
R5
26
R1
R2

Fig. 6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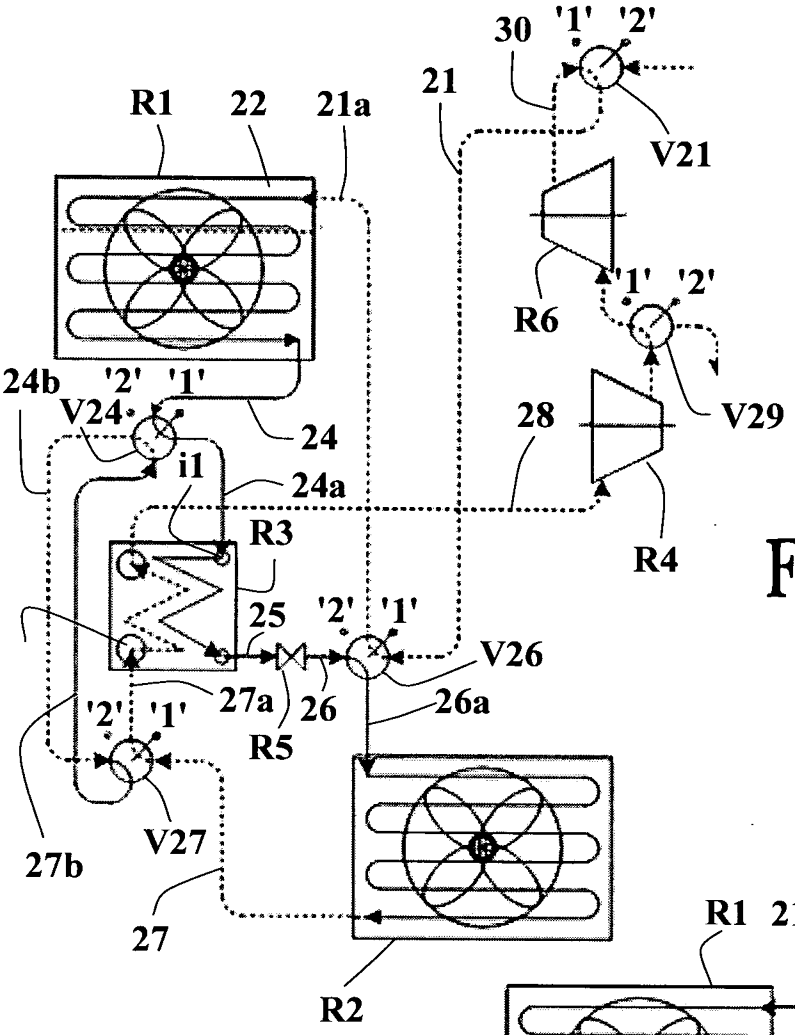
12g
14g
S12
12a
12t
S3
10
S6
S2
8
7
pA
pG
14s
S14
1
S5
1s
1g
S4
3
S7
5a
S8
4
14s
21
R6
'1' '2'
V29
'1' '2'
R4
28a
30
'1' '2'
R2
26a
21a
24
24a
R3
'2' '1'
V26
26
R5
25
27
i1
V24
'2' '1'
V27
'2' '1'
i2
27b
27a
24b
R1

Fig. 7A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'2'
21
V21
R1
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21a
R6
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'2'
24b
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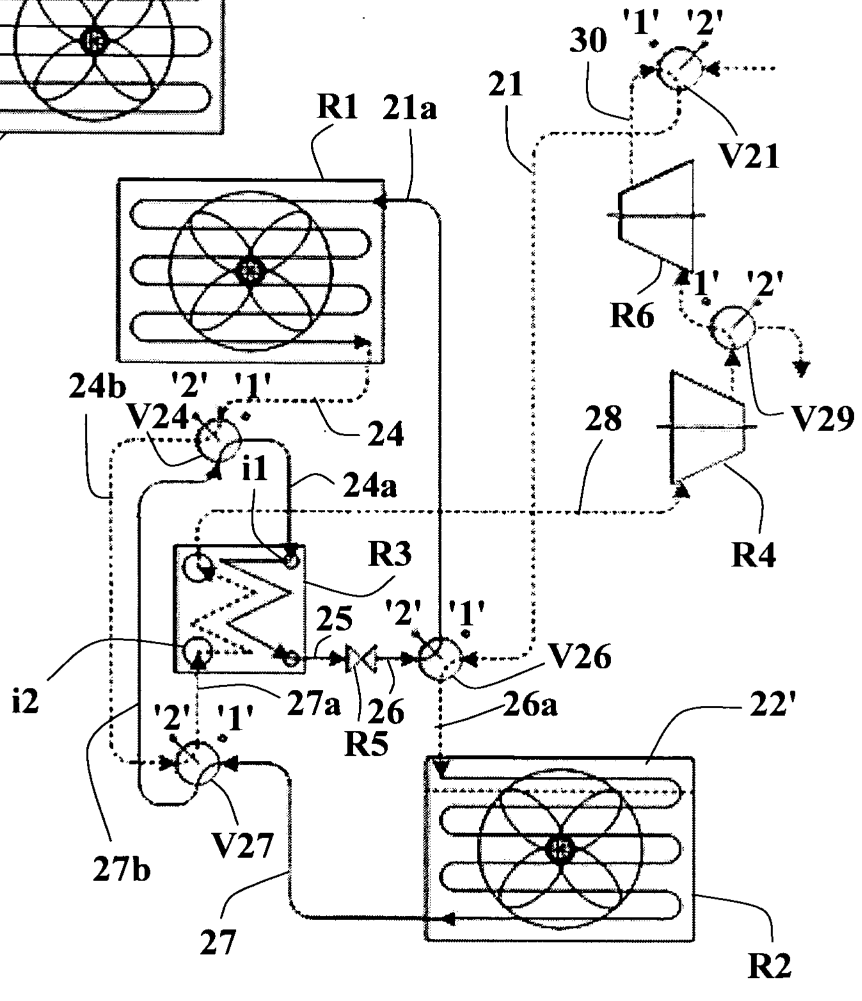
'1'
V24
24
V29
28
i1
24a
R3
R4
25
'2'
'1'
V26
27a
26
26a
'2'
'1'
R5
27b
V27
27
R2

Fig. 7B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V21
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24a
R4
R3
25
'2'
'1'
V26
i2
27a
26
26a
22'
'2'
'1'
R5
V27
27b
27
R2

Fig. 7C