



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
04.04.2018 Bulletin 2018/14

(51) Int Cl.:
F01K 19/10^(2006.01) F22G 5/12^(2006.01)

(21) Application number: **16191160.7**

(22) Date of filing: **28.09.2016**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

- **PILI, Roberto**
85748 Garching (DE)
- **EYERER, Sebastian**
80997 München (DE)
- **SPLIETHOFF, Hartmut**
82140 Olching (DE)

(71) Applicant: **Technische Universität München**
80333 München (DE)

(74) Representative: **Hoefer & Partner Patentanwälte mbB**
Pilgersheimer Straße 20
81543 München (DE)

(72) Inventors:
• **WIELAND, Christoph**
80469 München (DE)
• **KOHLHEPP, Andreas**
85051 Ingolstadt (DE)

Remarks:
Amended claims in accordance with Rule 137(2) EPC.

(54) **ENERGY CONVERSION METHOD AND SYSTEM**

(57) The present invention concerns an energy conversion method and system based on a Clausius-Rankine cycle and in particular on an organic Rankine cycle. The method comprises steps of providing a processing medium (2) carrying heat and/or under high pressure and temperature with increased energy content, expanding the processing medium (2) in order to generate and extract work, thereby transferring - at least in part - the processing medium (2) into a vapor state and in particular into a superheated vapor state, condensing - at least in part - the expanded processing medium (2) in said vapor state, thereby cooling and transferring the processing medium (2) into a fluid state, wherein after expanding and before and/or during condensing processing medium (2) in a non-vapor state and/or in a cooled state is continuously introduced into the expanded processing medium (2) in said vapor state to be condensed, thereby desuperheating the expanded processing medium (2) in said vapor state.

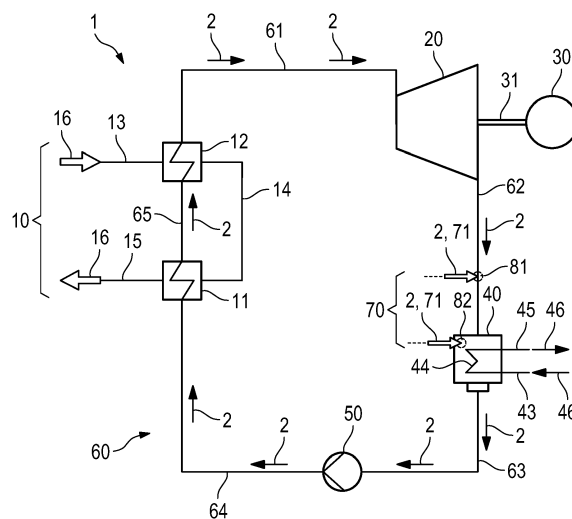


Fig. 1

Description

[0001] The present invention concerns an energy conversion method and system and in particular an energy conversion method and system which are based on a Clausius-Rankine cycle and more particular on an organic Rankine cycle.

[0002] Clausius-Rankine cycle processes and in particular organic Rankine cycle (ORC) processes are inter alia used in connection with heat recovery from low-temperature heat sources and in particular for generating work from such sources.

[0003] Because of its physical nature, conventional ORC processes based on polytropic expansion with extraction of work end up in a superheated vapor state of the underlying processing and/or working medium. Consequently, the process of condensing the expanded and superheated vapor of the processing medium requires for the desuperheating process a comparable large area for cooling the superheated vapor phase of the processing medium. These requirements yield a comparable large design or system size of the underlying condenser.

[0004] It is an object underlying the present invention to provide an energy conversion method and system which are capable of converting energy more effectively and of extracting work with a reduced design size of the underlying means.

[0005] The object is achieved by an energy conversion method according to independent claim 1 and by an energy conversion system according to independent claim 6. Preferred embodiments are defined in the respective dependent claims.

[0006] According to a first aspect of the present invention an energy conversion method is provided which is based on a Clausius-Rankine cycle and in particular on an organic Rankine cycle.

[0007] The energy conversion method proposed by the present invention comprises steps of

(i) providing a processing and/or working medium, in particular a fluid, liquid or vapor, carrying heat and/or under high pressure and temperature with increased energy content,

(ii) expanding the processing and/or working medium in order to generate and extract work, thereby transferring - at least in part - the processing and/or working medium into a vapor state and in particular into a superheated vapor state, and

(iii) condensing - at least in part - the expanded processing and/or working medium in said vapor state, thereby cooling and transferring the processing and/or working medium into a fluid state,

(iv) wherein according to the present invention after expanding and before and/or during condensing processing and/or working medium in a non-vapor

state and/or in a cooled state is continuously introduced into the expanded processing and/or working medium in said vapor state to be condensed, thereby desuperheating the expanded processing and/or working medium in said vapor state.

[0008] It is therefore a key aspect of the present invention to perform desuperheating of the expanded processing and/or working medium in the superheated state by continuously supplying the processing and/or working medium in a non-vapor state and/or in a cooled state. By these measures means for conventional desuperheating can be reduced or even avoided, thereby reducing the size and costs of the heat exchange processes and means.

[0009] In the following, the technical terms processing medium and working medium are used as synonyms in the sense of the present invention.

[0010] According to a preferred embodiment of the energy conversion method said step of continuously introducing said processing medium in said non-vapor state and/or in said cooled state is performed by at least one of spraying and injecting and/or by using said processing medium in said non-vapor state and/or in said cooled state in at least one form of a liquid state, a mist, a state of a dispersed fluid and a state with a temperature below the temperature of the expanded processing medium in said vapor state. By these measures it is possible to achieve the desired increase of efficiency without increasing significantly the complexity of the processes and the equipment.

[0011] The key idea of the present invention and its benefits can be employed with a variety of processing media, including pure media and their mixtures.

[0012] In an advantageous embodiment of the method according to the present invention processing medium is a heat exchange medium, a dry or arid medium, a wet medium, an isentropic medium, pure fluids and/or mixtures thereof and/or comprises an organic compound or a plurality thereof.

[0013] The usage of wet medium as a processing or working medium might be advantageous only in connection with extreme superheating of the processing or working medium.

[0014] A particular simple and reliable processing scheme can be achieved if according to a preferred improvement of the method said processing medium in said non-vapor state and/or in said cooled state is provided by feeding back condensed processing medium from a downstream side of the condensing step, in particular from an exit of the condensing step.

[0015] It is of particular advantage if according to a further development of the inventive method said step of providing the processing medium carrying heat comprises at least one of the steps of preheating the processing medium and - in particular consecutively - evaporating the processing medium in order to form a vapor state thereof, in particular by using an external heat source.

Because of the increased degree of efficiency, this allows the usage and evaluation of waste heat or of heat from the conversion of e.g. biomass, solar energy or any other source of heat from a low temperature source.

[0016] According to a further aspect of the present invention an energy conversion system is provided, which is configured to perform an energy conversion method based on a Clausius-Rankine cycle and in particular on an organic Rankine cycle and/or based on a method according to the present invention.

[0017] The system according to the present invention comprises means configured to provide a processing medium carrying heat and/or under high pressure and temperature with increased energy content, means configured to expand the processing medium in order to generate and extract work, thereby transferring - at least in part - the processing medium into a vapor state and in particular into a superheated vapor state, and means configured to condense - at least in part - the expanded processing medium in said vapor state, thereby cooling and transferring the processing medium into a fluid state.

[0018] According to the present invention means is provided which is configured to continuously introduce after the means for expanding and before and/or within the means for condensing processing medium in a non-vapor state and/or in a cooled state into the expanded processing medium in said vapor state to be condensed, thereby desuperheating the expanded processing medium in said vapor state.

[0019] In order to achieve a reliable and simple configuration for the energy conversion system said means for continuously introducing said processing medium in said non-vapor state and/or in said cooled state preferably is or comprises at least one of an injector and a sprayer.

[0020] A comparable compact structure for the configuration of the system according to the present invention can be achieved if said at least one of an injector and a sprayer is located at or in a junction of a conduit fluidly connecting the means for expanding and the means for condensing and/or at or in a junction of an entry of the means for condensing.

[0021] As a feedback process regarding the processing medium to be continuously introduced before or within the stage of condensing is of high importance, according to an advantageous embodiment of the energy conversion system said means for continuously introducing the processing medium in said non-vapor state and/or in said cooled state comprises a conduit for supplying - in particular in a feedback manner - the processing medium in said non-vapor state and/or in said cooled state, by branching off from a conduit conveying the processing medium exiting from said means for condensing and/or either before or after a pump for driving the processing medium within said conduit.

[0022] In order to reliably control the process of continuously introducing the processing medium in said non-vapor state and/or in said cooled state said conduit of

said means for continuously introducing the processing medium in said non-vapor state and/or in said cooled state comprises a pump and/or a control valve for controlling the supply of the processing medium in said non-vapor state and/or in said cooled state.

[0023] Said means for expanding the processing medium may be or comprise a turbine or other expansion device, in particular operatively connected to a generator.

[0024] In addition or alternatively, said means for providing the processing medium may be a consecutive arrangement of a preheater and an evaporator, in particular connected to an external heat source and/or in separated or integrated form.

[0025] According to a further alternative or additional embodiment, said means for condensing the processing medium may be or comprise a condenser, in particular with a heat exchanger connected to an external heat sink.

[0026] These and further details, advantages and features of the present invention will be described based on embodiments of the invention and by taking reference to the accompanying figures.

Figure 1 is a schematic view describing general aspects of an embodiment of the energy conversion system according to the present invention.

Figures 2 and 3 describe in a similar manner preferred embodiments of the energy conversion system according to the present invention.

Figures 4 to 6 are diagrams describing the temperature-entropy relationship of wet, dry and isentropic processing media, in particular within ORC processes.

Figures 7 to 9 schematically depict aspects of desuperheating processes in a conventional condenser tube, in a condenser tube formed according to the present invention, and in a conventional condenser tube retrofit with inventive means for desuperheating by continuously introducing processing medium in a non-vapor and/or cooled state.

Figure 10 schematically describes a conventional energy conversion system.

In the following, embodiments and the technical background of the present invention are presented in detail by taking reference to accompanying figures 1 to 10. Identical or equivalent elements and elements which act identically or equivalently are denoted with the same reference signs. Not in each case of their occurrence a detailed description of the elements and components is repeated.

[0027] The depicted and described features and further properties of the invention's embodiments can arbitrarily be isolated and recombined without leaving the gist of the present invention.

[0028] Figure 1 is a schematic view describing general aspects of an embodiment of the energy conversion system 1 according to the present invention.

[0029] The energy conversion system 1 according to the present invention as depicted in figure 1 majorly comprises means 10 for providing a processing medium 2 for instance in form of a liquid, a vapor, a gas or a combination thereof, followed by means 20 for expanding the processing medium 2 and coupled to a generator 30 by coupling means 31, followed by means 40 for condensing the processing medium 2.

[0030] All the means 10, 20, and 40 are consecutively interconnected by a conduit or pipe arrangement 60 having conduit or pipe sections 61, 62, 63, 64 and 65.

[0031] The first pipe section 61 defines a fluidic connection between the means 10 for providing the processing medium 2 and the means 20 for expanding the processing medium 2. The second pipe section 62 gives a fluidic connection between the means 20 for expanding the processing medium 2 and the means 40 for condensing the processing medium 2. The third and fourth pipe sections 63 and 64 establish a fluidic connection between the means 40 for expanding the processing medium 2 and the means 10 for providing the processing medium 2 - with a pump 50 connected therebetween - and thereby closing the processing cycle.

[0032] The pump 50 between the pipe sections 63 and 64 is configured to drive the processing medium 2 within the conduit arrangement 60.

[0033] The means 10 for providing the processing medium 2 may comprise at an upstream side a preheater 11 connected by a fifth pipe section 65 to an evaporator 12 which forms also a part of the means 10 for providing the processing medium 2.

[0034] The preheater 11 and the evaporator 12 may be formed as a single and integrated component.

[0035] Via conduits 13, 14 and 15 the evaporator 12 and the preheater 11 are coupled to an external heat source 16, which can be formed by an external heat exchange medium.

[0036] As described so far, this particular arrangement in general coincides with the setup of a conventional energy conversion system 1' as shown in figure 10.

[0037] In addition to the conventional design as shown in figure 10, the energy conversion system 1 according to the present invention shown in figure 1 additionally comprises means 70 for continuously introducing processing medium 2 in a non-vapor state and/or in a cooled state which comprises at least one injector 71 or sprayer 71 in the embodiment shown in figure 1.

[0038] However, the provision of an injector 71 or a sprayer 71 is just an option which is mandatory. In some embodiments a simple junction may be sufficient without any spray dispersion functionality or the like.

[0039] The injector 71 or sprayer 71 can be arranged such that introduction of the processing medium 2 in said non-vapor state and/or in said cooled state is achieved either at a first junction 81 at a downstream side of the means 20 for expanding the processing medium 2 and at an upstream side of the means 40 for condensing the processing medium 2. Therefore, in figure 1 the first junction 81 is situated within the second pipe section 62.

[0040] Additionally or alternatively, a second junction 82 might be used for continuously introducing the processing medium 2 in said non-vapor state and/or in said cooled state which is situated within a neighborhood of an entry or in the entry of the means 40 for condensing the processing medium 2, i.e. the condenser 40.

[0041] The condenser 40 as such is equipped with pipe sections 43, 44, and 45 for being connected to an external heat sink 46, for instance to a further and external heat exchange medium.

[0042] By these measures, the energy conversion system 1 according to the present invention as shown in figure 1 is capable of continuously introducing the processing medium 2 in a non-vapor state and/or in a cooled state into the expanded processing medium 2 in said vapor state to be condensed in order to achieve desuperheating of the expanded processing medium 2 without the burden of conventional desuperheating processes and means to thereby achieve a higher degree of efficiency with reduced size and costs of the underlying processes and means.

[0043] Figures 2 and 3 describe in a similar manner preferred embodiments of the energy conversion system 1 according to the present invention and exemplify in a more concrete manner how the continuous introduction of the processing medium 2 in said non-vapor state and/or in said cooled state may be achieved by means of a feedback process and structure.

[0044] Both embodiments are based on a configuration where the means 70 for continuously introducing the processing medium 2 in said non-vapor state and/or in said cooled state with its injector 71 or sprayer 71 is connected to the downstream sides of the means 20 for expanding the processing medium 2 in the second pipe section 62. However, this is not mandatory.

[0045] In figure 2 a conduit 73 of the means 70 for continuously introducing the processing medium 2 in said non-vapor state and/or in said cooled state derives from the fourth pipe section 64 after the pump 50 at branch 74. Right before junction 81 and the injector 71 or sprayer 71 a control valve 76 is provided for controlling the operation of continuously introducing the processing medium 2 in said non-vapor state and/or in said cooled state.

[0046] In the embodiment shown in figure 3, said conduit 73 derives from the third pipe section 63 before the pump 50 at branch 75. As the branch 75 is situated before the pump 50, an optional pump 77 may be provided in the conduit 73 before the valve 76 under such circumstances.

[0047] As described in more detail below with respect

to particular thermodynamic properties, figures 4 to 6 show diagrams 90 describing the temperature-entropy relationship of wet, dry and isentropic processing media 2, respectively, within particular ORC processes.

[0048] In each diagram 90, to each abscissa 91 the entropy S and to each ordinate 92 the temperature T of the underlying processing medium 2 are applied thereby explaining the phase relationship by means of a temperature-entropy diagram.

[0049] For each of the examples of the wet, dry or arid, and isentropic processing media 2 - respectively corresponding to figures 4 to 6 - the liquid-vapor or two-phase region borderline 93 divides the entire thermodynamic region into a two-phase region 101 of the liquid-vapor coexistence region below the bell shaped curve 93 and the single-phase regions 102 and 103 of the liquid phase and of the vapor phase, respectively.

[0050] The hatched area 94 with its boundary represents schematically the region for the ORC process.

[0051] The circle area 95 corresponds to an exemplary region of states of the processing medium 2 at the end of the expansion process.

[0052] Figures 7 to 9 schematically depict aspects of desuperheating processes in a conventional condenser tube 41' of a conventional means 40' for condensing a processing medium 2, in a condenser tube 41 formed according to the present invention, and in a conventional condenser tube 41' modified according to the present invention by retrofit with inventive means for desuperheating by continuously introducing processing medium 2 in a non-vapor and/or in a cooled state, respectively.

[0053] Aligned with each of the condenser tubes 41', 41 is a diagram describing the temperature T applied at its respective ordinate within the respective condenser tube 41', 41 as a function of position x along its entire elongation 99', 99 applied at its respective abscissa.

[0054] The respective traces p' , p represent the course of the respective pressure within the condenser tubes 41', 41 along the cubes' elongations 99', 99.

[0055] In the conventional embodiment of the means 40' for condensing the processing medium 2 and its condenser tube 41' as shown in figure 7, the diagram shows conventional phases 96', 97', and 98' for achieving desuperheating, condensation, and subcooling or supercooling, respectively.

[0056] As can be seen from figure 7, the part of the elongation 99' necessary for desuperheating conventionally takes up to 40% of the entire elongation 99' of the conventional condenser pipe 41'.

[0057] In contrast thereto and as shown in figure 8, the means 40 for condensing the processing medium 2 according to the present invention and its condenser pipe 41 show a phase 96 for desuperheating which corresponds to a fraction of the entire elongation 99 of the condenser pipe 41 which is below 10% thereof. Consequently, the entire elongation 99 of the condenser pipe 41 according to the present invention can be reduced when compared to the elongation 99' of the conventional

condenser pipe 41'.

[0058] It has to be noticed, that the representations according to figures 7 to 9 are not true to scale.

[0059] In figure 9, a conventional means 40' for condensing the processing medium 2 is shown which has been modified by adopting means 70 with an injector 71 or sprayer 71 for continuously introducing processing medium 2 in said non-vapor state and/or in said cooled state. This can be seen as a retrofit measure for an existing conventional condenser pipe 41'. Although it maintains its conventional elongation 99', the fraction of the entire elongation 99' necessary for desuperheating and thus corresponding to the phase fraction 96 shown in figure 9 are remarkably reduced when compared to the situation shown in figure 7 and also indicated in figure 9 by a dotted line. As a consequence of the inventive concept, the condensation pressure is reduced from the pressure p' to p leading to an increasing power output of the expander.

[0060] Although the conventional elongation 99' is maintained, the degree of efficiency is increased due to the provided means of the present invention enabling a continuous introduction of the processing medium 2 in a non-vapor and/or in a cooled state for enhancing the desuperheating process.

[0061] The present invention concerns the technical field of power engineering and energy management. In particular aspects of increasing the effectiveness and decreasing the costs in regard to ORC systems are concerned.

[0062] Due to the improvements suggested by the present invention the efficiency of the cycle process underlying the ORC arrangement and a reduction of the investment costs can be achieved. The improvements are not strictly related to a turbine or the provision of any other expansion machine. In addition the improvements are also independent from the processing medium involved, being a dry or arid medium or an isentropic medium, and also from the underlying concept of the power plant in question.

[0063] The means and methods for injection or spray desuperheating at an upstream side or at the entry of a condensing process or means yields and improved heat transfer. In already existing apparatuses lowering the condensation pressure is a benefit, thereby increasing efficiency and performance of the underlying expansion process and machine. In new apparatuses the proposed technology according to the present invention may reduce the amount of heat transfer surfaces of the involved condensers, thereby reducing the overall costs of the apparatus.

[0064] In the following, the technical background of the present invention will be described to some extent:

The organic Rankine cycle is employed in a decentralized manner and in apparatuses and plants of small and middle power classes e.g. of up to 10 MW. The fields of application comprise - but are not limited

to - the decentralized usage of biomass, geothermal power generation, solar energy driven desalination of seawater, waste heat usage of bio gas apparatuses, the latter under the paradigm of a bottoming cycle and micro power plants.

These applications have their advantages in particular in the range of low to medium temperature heat sources in regard to conventional Rankine processes, which are operated by water vapor and/or at temperatures in the range of e.g. 100 °C to 400 °C.

[0065] The following advantages are given:

- (1) good degrees of efficiency at moderate pressures,
- (2) high specific mass flows (low leakage in the turbine or expansion machine),
- (3) possible application in known equipment for cooling and climate regulation, and
- (4) single stage turbine or single stage expansion machine because of a low expansion ratio.

[0066] In principle, the standard ORC process is a Rankine process in its simplest form and comprises as shown in figure 10 a pre-heater 11, an evaporator 12, and a condenser 40 as heat exchanging means, a turbine 20 or a general expansion machine, and a pump 50. These aspects have a high degree of similarity to former times' steam power plants.

[0067] Working or processing media 2 for the ORC technology can be characterized according to their entropy-temperature diagrams as shown in connection with figures 4 to 6.

[0068] Such processing media 2 can be classified as being (i) dry or arid media, for instance R22, (ii) wet media, for instance water or isopentane, and (iii) and isentropic media, for instance R245fa.

[0069] In figures 4 to 6 the two-phase region 101 is situated below the bell shaped curve 93 and in this region the steam or vapor phase and the liquid phase coexist.

[0070] In the left half space outside the bell-shaped curve 93 the liquid/fluid phase region 102 is located. In the right half space the steam or vapor phase region 103 is located. The hatched area 94 schematically indicates the ORC cycle process performed by the apparatus 1' as shown in figure 10. The state after the expansion is indicated by the circle 95.

[0071] When using dry or arid media of fluids as a processing medium 2 the expansion after the turbine or general expansion machine 20 ends with superheated vapor in the region indicated by the circle 95. When using a wet working or processing medium 2 the endpoint of the expansion process may be located directly within the wet vapor or wet steam region, i.e. within the two-phase region 101. In the case of isentropic processing media 2

the saturated vapor or steam curve 93 is isentropic, thereby corresponding to a constant entropy. Ideally, the expansion ends directly on the saturated vapor or steam curve 93.

[0072] Under real circumstances, however, an expansion process is always connected with an increase of entropy. Therefore, the end point of the expansion process - even when using isentropic media - is located in the phase region 103 of superheated vapor or steam, however, at moderate vapor pressures.

[0073] The problem with these superheated states after the expansion process is connected with the comparable poor heat transfer capabilities of the vapor phase. Indeed, the heat transfer capability is reduced by several orders of magnitude when compared to condensation in the two-phase region 101. Consequently, large heat exchange surfaces are necessary for performing a desuperheating process until the curve of saturated vapor is reached. This effect is due to the poor heat transfer under these conditions making necessary condensers 40 of large volume with the consequence of increased investment costs.

[0074] In addition, the above-mentioned problem in particular occurs when using dry processing media 2. But also for isentropic working media 2 the drawbacks have to be observed, as under real changes of state the expansion process ends in the superheated vapor phase, too.

[0075] According to the present invention an efficient means and process for desuperheating are proposed. This is achieved by using - in a continuous manner and after the expansion process and before or at the beginning of or within/during condensation - the introduction of the processing medium 2 in a non-vapor and/or in a cooled state, for instance by injecting, spraying or the like and/or by using the processing medium 2 in form of a liquid, a mist, a state of a dispersed fluid or the like. The inventive method for desuperheating will be referred to in the following as injection cooling.

[0076] The proposed means and method according to the present invention use desuperheating by continuously introducing the processing medium 2 in a non-vapor state and/or in a cooled state in order to improve the ORC process.

[0077] Condensation in the conventional ORC process is schematically shown in figure 7.

[0078] In the process underlying figure 7, a conventional horizontal condenser pipe 41' underlying the conventional condenser 40' is used. The superheated vapor 2 first of all is desuperheated before it can condense in the two-phase region at constant temperature. The liquid 2 as such may also be used in a subcooled or supercooled state. This takes place majorly at the end of the condenser 40', i.e. in the neighborhood of its exit and in the region of the liquid phase.

[0079] As a consequence of the inventive injection cooling, it is possible to reduce the conventional extension or elongation 99' of the entire condenser pipe 41'

and in particular of the desuperheating part of the condenser 40, 40'. This reduces the overall volume of the condenser 40 as can be seen from the embodiment shown in figure 8. In addition, the investment costs at least for the condenser 40 are thereby reduced. For some cases, simulations have shown that the portion of the area which is conventionally necessary for desuperheating is about 25% of the condenser 40.

[0080] In addition, injection cooling according to the present invention may also be used in apparatuses and plants which already exist, i.e. in the sense of a retrofitting measure. By increasing the efficiency of the heat transfer along the entire condenser 40, the condensation pressure can be lowered as indicated in figure 9.

[0081] Figures 2 and 3 more explicitly show embodiments of the present invention being integrated in the ORC process.

[0082] The increase of the degree of efficiency of the inventive injection cooling is effective in all possible variants or embodiments of the underlying ORC process, as long as the processing medium 2 enters the condenser 40 in a superheated state. Such circumstances occur with almost every working or process medium 2, partly also in connection with wet media, namely based on the lossy expansion means and process of the underlying expansion means 20.

[0083] Means and processes for injection cooling as such are already known in the prior art. However, they are used for temperature regulation and reduction of specific enthalpy after adiabatic restriction or throttling or in a temporary manner only.

[0084] In contrast to that, the present invention suggests a continuous injection cooling, i.e. a continuous introduction of the processing medium 2 in a non-vapor state and/or in a cooled state, and in particular after a polytropic expansion with extraction of work, wherein in contrast to the conventional case the saturation region cannot be reached due to pure physical reasons despite the polytropic reduction of pressure. Therefore, negative properties of the still superheated processing fluid or medium 2 regarding the heat transfer capabilities within the condenser 40 can be avoided according to the present invention yielding remarkably improved properties with the saturated fluid or processing medium 2.

[0085] In addition to the foregoing description of the present invention, for an additional disclosure explicit reference is taken to the graphic representation of figures 1 to 10.

[0086] List of reference signs

1	Energy conversion system
1'	conventional energy conversion system
2	processing medium
10	means for providing the processing medium 2
11	preheater
12	evaporator
13	conduit
14	conduit

15	conduit
16	external heat source, heat exchange medium
20	means for expanding the processing medium 2, turbine
5	30 generator
31	coupling means
40	means for condensing the processing medium 2, condenser
40'	conventional means for condensing the processing medium 2, condenser
10	41 condenser pipe/tube
41'	conventional condenser pipe/tube
43	conduit
44	conduit
15	45 conduit
46	external heat source, heat exchange medium
50	pump
60	conduit/pipe arrangement/system
20	61 conduit/pipe
62	conduit/pipe
63	conduit/pipe
64	conduit/pipe
70	means for continuously introducing the processing medium 2
25	71 injector/sprayer
73	conduit
74	branch after pump 50
75	branch before pump 50
30	76 valve
77	pump
81	junction into conduit 62
82	junction into condenser 40
90	graph, temperature-entropy diagram
35	91 abscissa, entropy S
92	ordinate, temperature T
93	liquid-vapor/two-phase region borderline
94	ORC region
95	state region after expansion
40	96 desuperheating phase
96'	conventional desuperheating phase
97	condensation phase
97'	conventional condensation phase
98	supercooling phase
45	98' conventional supercooling phase
99	elongation
99'	conventional elongation
101	liquid-vapor two-phase region
102	liquid phase region
50	103 vapor phase region
p	pressure
p'	pressure
S	entropy
T	temperature
55	x position along elongation of condenser tube/pipe 41, 41'

Claims

1. Energy conversion method based on a Clausius-Rankine cycle and in particular on an organic Rankine cycle, comprising steps of:
 - providing a processing medium (2) carrying heat and/or under high pressure and temperature with increased energy content,
 - expanding the processing medium (2) in order to generate and extract work, thereby transferring - at least in part - the processing medium (2) into a vapor state and in particular into a superheated vapor state,
 - condensing - at least in part - the expanded processing medium (2) in said vapor state, thereby cooling and transferring the processing medium (2) into a fluid state, wherein after expanding and before and/or during condensing processing medium (2) in a non-vapor state and/or in a cooled state is continuously introduced into the expanded processing medium (2) in said vapor state to be condensed, thereby desuperheating the expanded processing medium (2) in said vapor state.
2. Method according to claim 1, wherein said step of continuously introducing said processing medium (2) in said non-vapor state and/or in said cooled state is performed
 - by at least one of spraying and injecting and/or
 - by using said processing medium (2) in said non-vapor state and/or in said cooled state in at least one form of a liquid state, a mist, a state of a dispersed fluid and a state with a temperature lower than the temperature of the expanded processing medium (2) in said vapor state.
3. Method according to any one of the preceding claims, wherein said processing medium (2) is a heat exchange medium, a dry or arid medium, a wet medium, an isentropic medium, pure fluids and/or mixtures thereof and/or comprises an organic compound or a plurality thereof.
4. Method according to any one of the preceding claims, wherein said processing medium (2) in said non-vapor and/or in said cooled state is provided by feeding back condensed processing medium (2) from a downstream side of the condensing step, in particular from an exit of the condensing step.
5. Method according to any one of the preceding claims, wherein said step of providing the processing medium (2) carrying heat comprises at least one of the steps of preheating the processing medium (2) and - in particular consecutively - evaporating the processing medium (2) in order to form a vapor state thereof, in particular by using an external heat source (16).
6. Energy conversion system (1), configured to perform an energy conversion method based on a Clausius-Rankine cycle and in particular on an organic Rankine cycle and/or on a method according to any one of claims 1 to 5, comprising:
 - means (10) configured to provide a processing medium (2) carrying heat and/or under high pressure and temperature with increased energy content,
 - means (20) configured to expand the processing medium (2) in order to generate and extract work, thereby transferring - at least in part - the processing medium (2) into a vapor state and in particular into a superheated vapor state,
 - means (40) configured to condense - at least in part - the expanded processing medium (2) in said vapor state, thereby cooling and transferring the expanded processing medium (2) into a fluid state,
 wherein means (70) is provided which is configured to continuously introduce after the means (20) for expanding and before and/or within the means (40) for condensing processing medium (2) in a non-vapor state and/or in a cooled state into the expanded processing medium (2) in said vapor state to be condensed, thereby desuperheating the expanded processing medium (2) in said vapor state.
7. System (1) according to claim 6, wherein said means (70) for continuously introducing said processing medium (2) in said non-vapor state and/or in said cooled state is or comprises at least one of an injector (71) and a sprayer (71).
8. System (1) according to claim 7, wherein said at least one of an injector (71) and sprayer (71) is located at or in a junction (81) of a conduit (62) fluidly connecting the means (20) for expanding and the means (40) for condensing and/or at or in a junction (82) at or in an entry of the means (40) for condensing.
9. System (1) according to any one of claims 6 to 8, wherein said means (70) for continuously introducing the processing medium (2) in said non-vapor state and/or in said cooled state comprises a conduit (73) for supplying
 - in particular in a feedback manner - the

processing medium (2) in said non-vapor state and/or in said cooled state, by branching (74, 75) off from a conduit (63, 64) conveying the processing medium (2) exiting from said means (40) for condensing and/or either before or after a pump (50) for driving the processing medium (2) within said conduit (63, 64).

10. System (1) according to claim 9, wherein within said conduit (73) of said means (70) for continuously introducing the processing medium (2) in said non-vapor state and/or in said cooled state comprises e.g. a pump (77) and/or a control valve (76) for controlling the supply of the processing medium (2) in said non-vapor state and/or in said cooled state.
11. System (1) according to any one of claims 6 to 10, wherein said means (20) for expanding the processing medium (2) is or comprises a turbine or other expansion devices, in particular operatively connected to a generator (30).
12. System (1) according to any one of claims 6 to 11, wherein said means (10) for providing the processing medium (2) is a consecutive arrangement of a preheater (11) and an evaporator (12), in particular connected to an external heat source (16) and/or in separated or integrated form.
13. System (1) according to any one of claims 6 to 12, wherein said means (40) for condensing the processing medium (2) is or comprises a condenser, in particular with a heat exchanger connected to an external heat sink (46).

Amended claims in accordance with Rule 137(2) EPC.

1. Energy conversion method based on a Clausius-Rankine cycle and in particular on an organic Rankine cycle, comprising steps of:
 - providing a processing medium (2) carrying heat,
 - expanding the processing medium (2) in order to generate and extract work, thereby transferring - at least in part - the processing medium (2) into a vapor state and in particular into a superheated vapor state,
 - condensing - at least in part - the expanded processing medium (2) in said vapor state, thereby cooling and transferring the processing medium (2) into a fluid state,

characterized in

that after expanding and during condensing

processing medium (2) in a non-vapor state and/or in a cooled state is continuously introduced into the expanded processing medium (2) to be condensed and being in said vapor state, thereby desuperheating the expanded processing medium (2) in said vapor state.

2. Method according to claim 1, wherein said step of continuously introducing said processing medium (2) in said non-vapor state and/or in said cooled state is performed
 - by at least one of spraying and injecting and/or
 - by using said processing medium (2) in said non-vapor state and/or in said cooled state in at least one form of a liquid state, a mist, a state of a dispersed fluid and a state with a temperature lower than the temperature of the expanded processing medium (2) in said vapor state.
3. Method according to any one of the preceding claims, wherein said processing medium (2) is a heat exchange medium, a dry or arid medium, a wet medium, an isentropic medium, pure fluids and/or mixtures thereof and/or comprises an organic compound or a plurality thereof.
4. Method according to any one of the preceding claims, wherein said processing medium (2) in said non-vapor and/or in said cooled state is provided by feeding back condensed processing medium (2) from a downstream side of the condensing step, in particular from an exit of the condensing step.
5. Method according to any one of the preceding claims, wherein said step of providing the processing medium (2) carrying heat comprises at least one of the steps of preheating the processing medium (2) and - in particular consecutively - evaporating the processing medium (2) in order to form a vapor state thereof, in particular by using an external heat source (16).
6. Energy conversion system (1), configured to perform an energy conversion method based on a Clausius-Rankine cycle and in particular on an organic Rankine cycle and/or on a method according to any one of claims 1 to 5, comprising:
 - means (10) configured to provide a processing medium (2) carrying heat,
 - means (20) configured to expand the processing medium (2) in order to generate and extract work, thereby transferring - at least in part - the processing medium (2) into a vapor state and in

particular into a superheated vapor state,
 - means (40) configured to condense - at least
 in part - the expanded processing medium (2)
 in said vapor state, thereby cooling and trans-
 ferring the expanded processing medium (2) in-
 to a fluid state,

characterized in

that means (70) is provided which is configured to
 continuously introduce after the means (20) for ex-
 panding and within the means (40) for condensing
 processing medium (2) in a non-vapor state and/or
 in a cooled state into the expanded processing me-
 dium (2) to be condensed and being in said vapor
 state, thereby desuperheating the expanded
 processing medium (2) in said vapor state.

7. System (1) according to claim 6,
 wherein said means (70) for continuously introduc-
 ing said processing medium (2) in said non-vapor
 state and/or in said cooled state is or comprises at
 least one of an injector (71) and a sprayer (71).
8. System (1) according to claim 7,
 wherein said at least one of an injector (71) and
 sprayer (71) is located at or in a junction (81) of a
 conduit (62) fluidly connecting the means (20) for
 expanding and the means (40) for condensing and/or
 at or in a junction (82) at or in an entry of the means
 (40) for condensing.
9. System (1) according to any one of claims 6 to 8,
 wherein said means (70) for continuously introduc-
 ing the processing medium (2) in said non-vapor
 state and/or in said cooled state comprises a conduit
 (73) for supplying - in particular in a feedback manner
 - the processing medium (2) in said non-vapor state
 and/or in said cooled state, by branching (74, 75) off
 from a conduit (63, 64) conveying the processing
 medium (2) exiting from said means (40) for con-
 densing and/or either before or after a pump (50) for
 driving the processing medium (2) within said conduit
 (63, 64).
10. System (1) according to claim 9,
 wherein said conduit (73) of said means (70) for con-
 tinuously introducing the processing medium (2) in
 said non-vapor state and/or in said cooled state com-
 prises a pump (77) and/or a control valve (76) for
 controlling the supply of the processing medium (2)
 in said non-vapor state and/or in said cooled state.
11. System (1) according to any one of claims 6 to 10,
 wherein said means (20) for expanding the process-
 ing medium (2) is or comprises a turbine or other
 expansion devices, in particular operatively connect-
 ed to a generator (30).

12. System (1) according to any one of claims 6 to 11,
 wherein said means (10) for providing the processing
 medium (2) is a consecutive arrangement of a pre-
 heater (11) and an evaporator (12), in particular con-
 nected to an external heat source (16) and/or in sep-
 arated or integrated form.

13. System (1) according to any one of claims 6 to 12,
 wherein said means (40) for condensing the
 processing medium (2) is or comprises a condenser,
 in particular with a heat exchanger connected to an
 external heat sink (46).

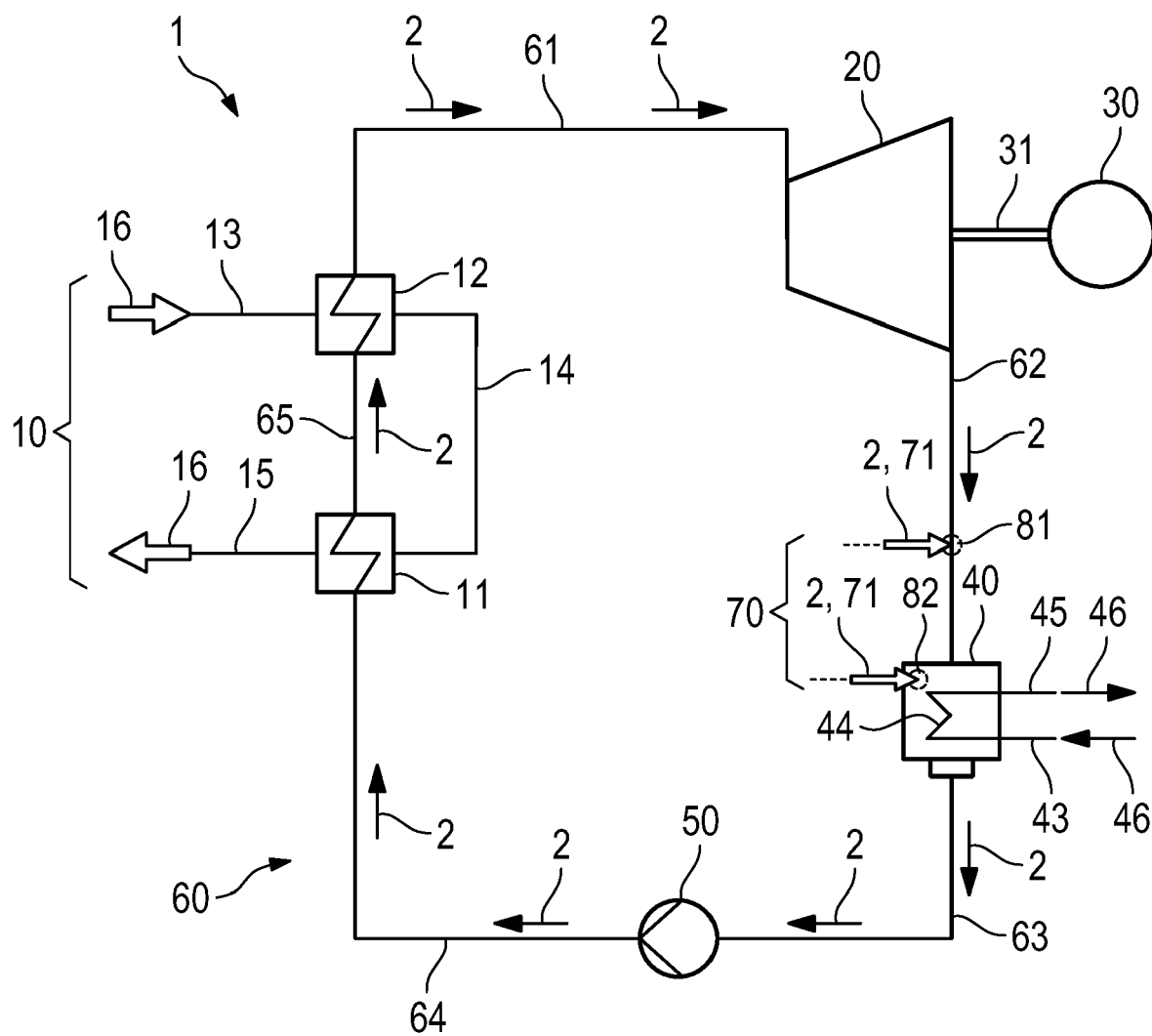


Fig. 1

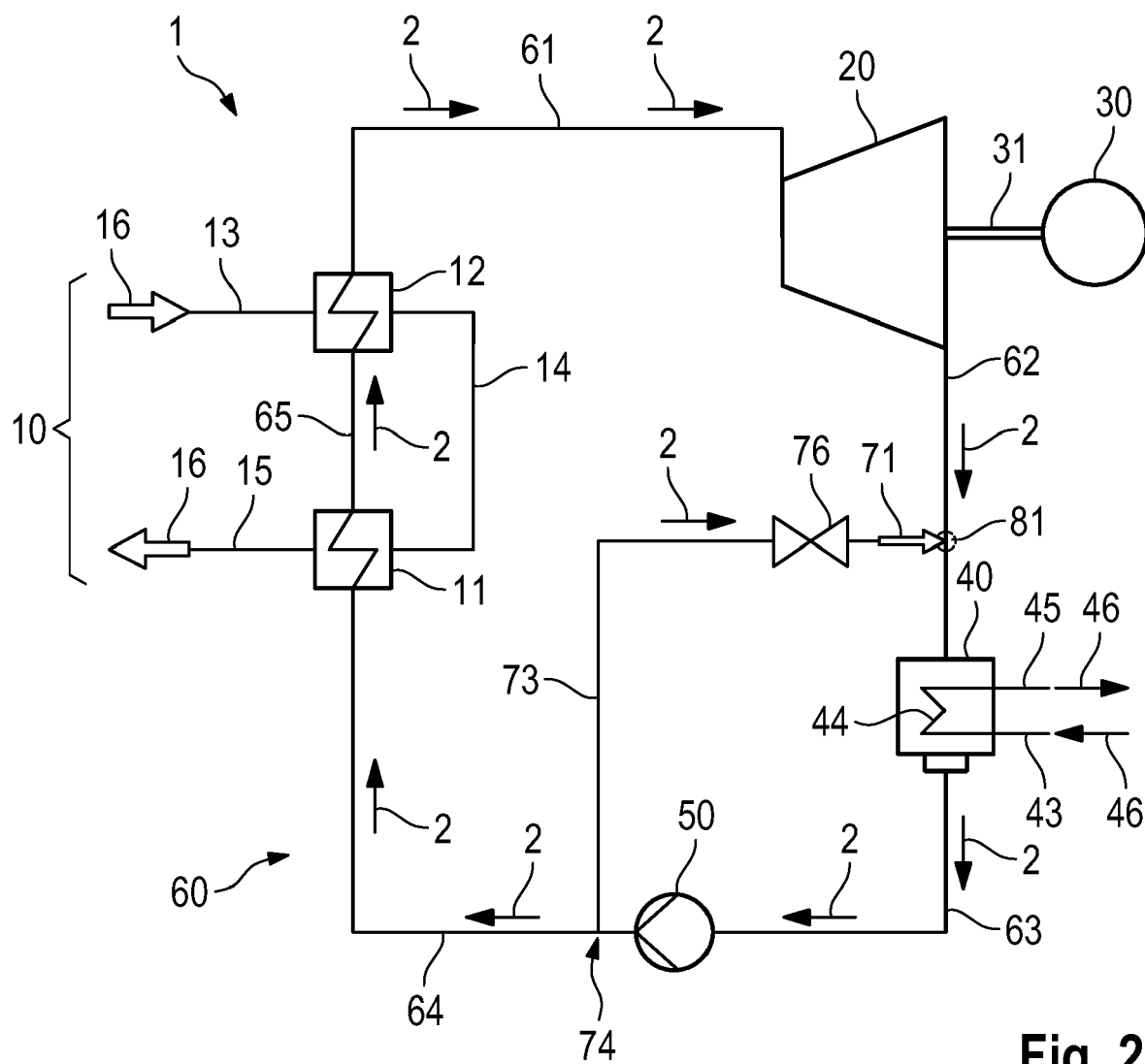


Fig. 2

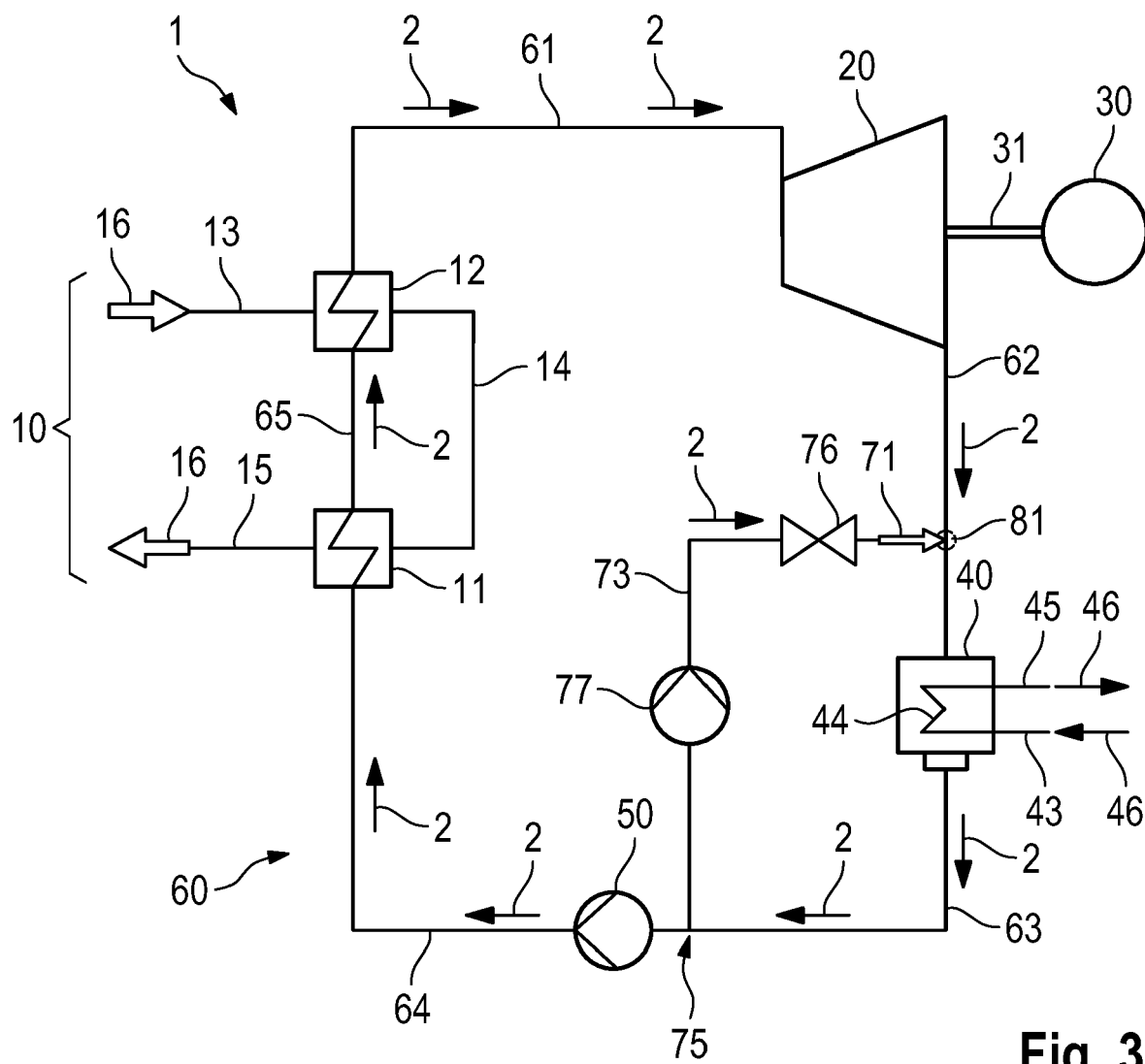


Fig. 3

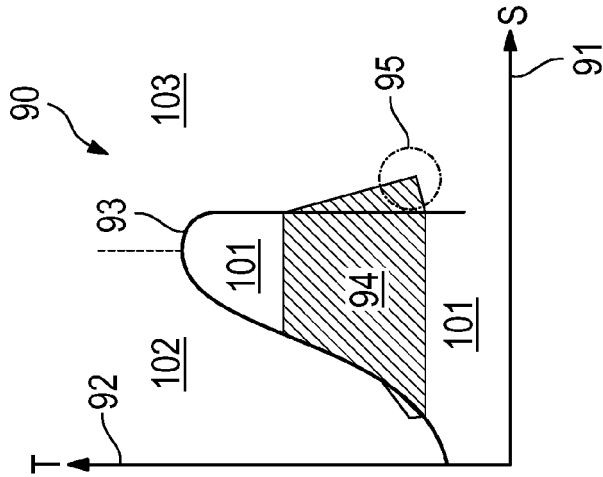


Fig. 4

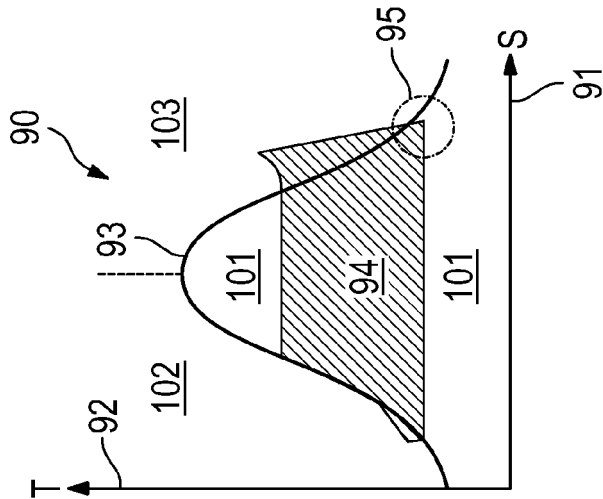


Fig. 5

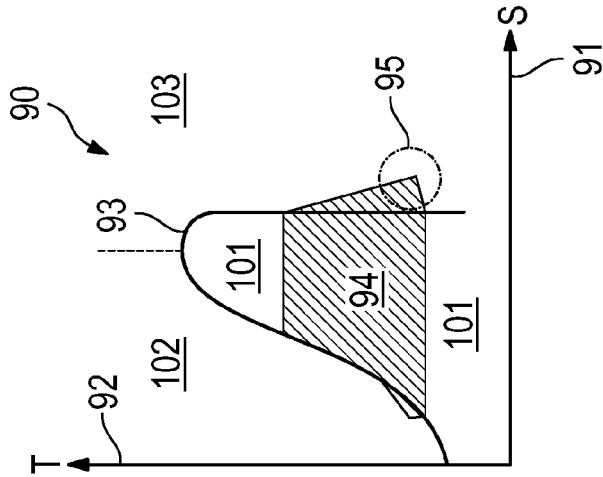


Fig. 6

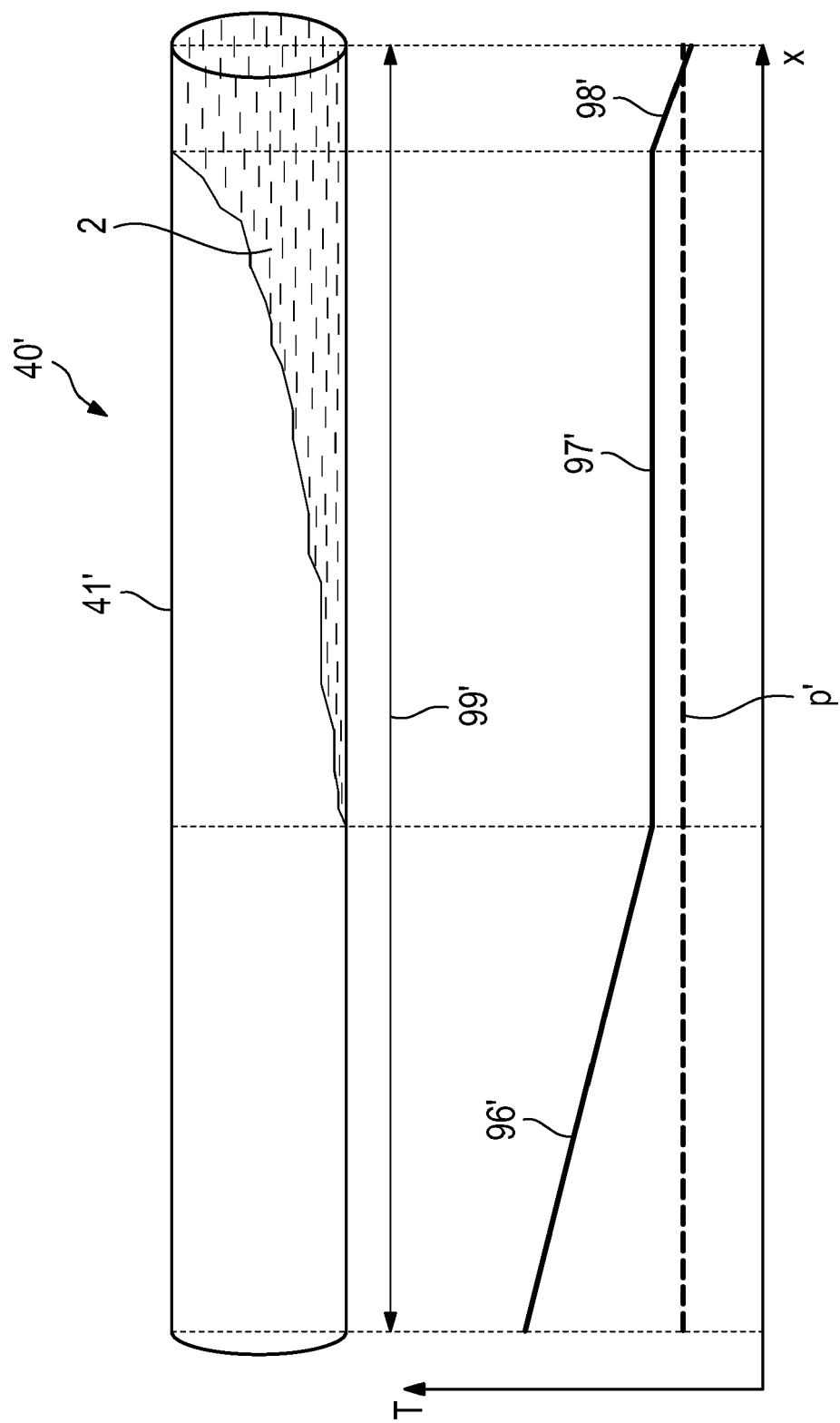


Fig. 7

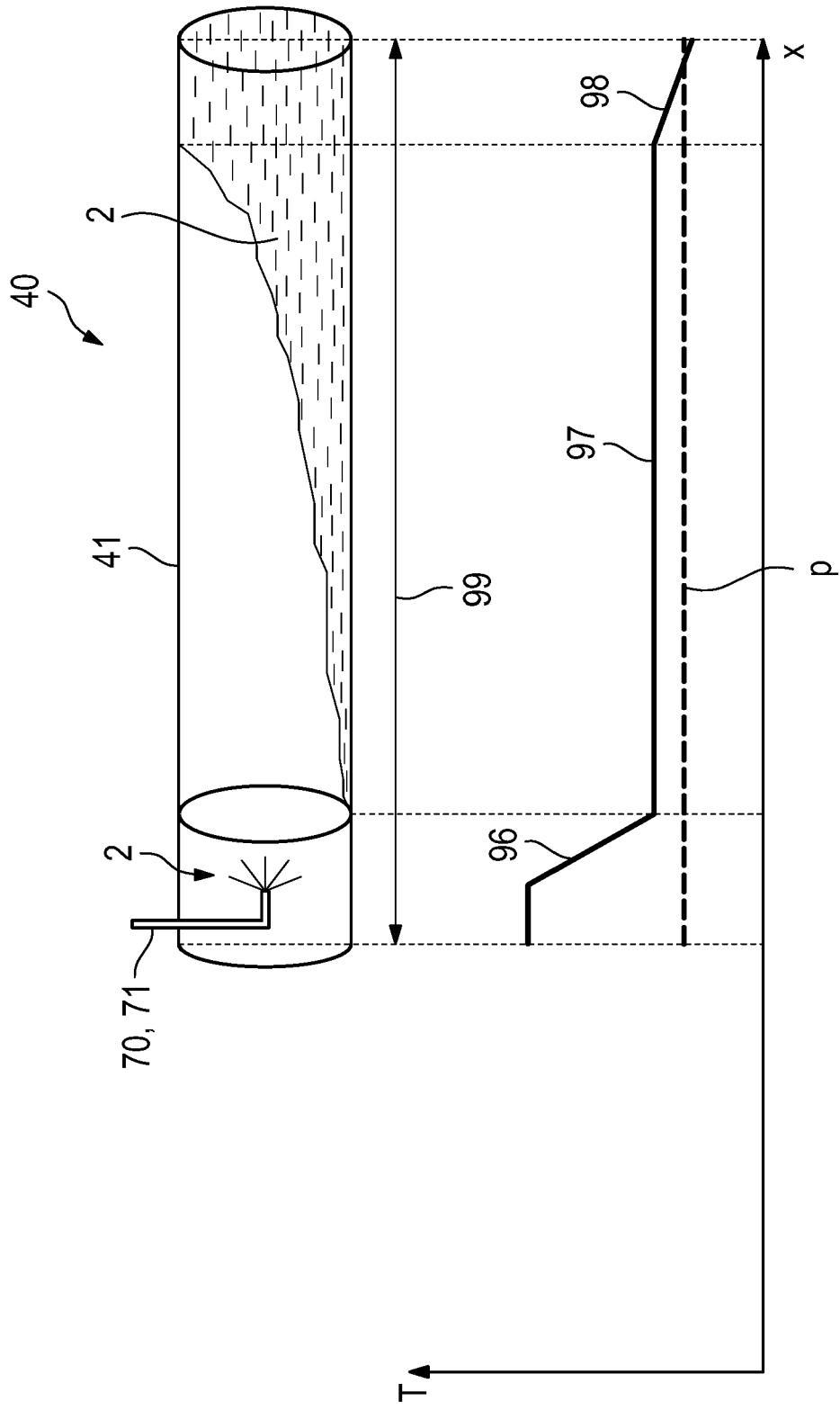


Fig. 8

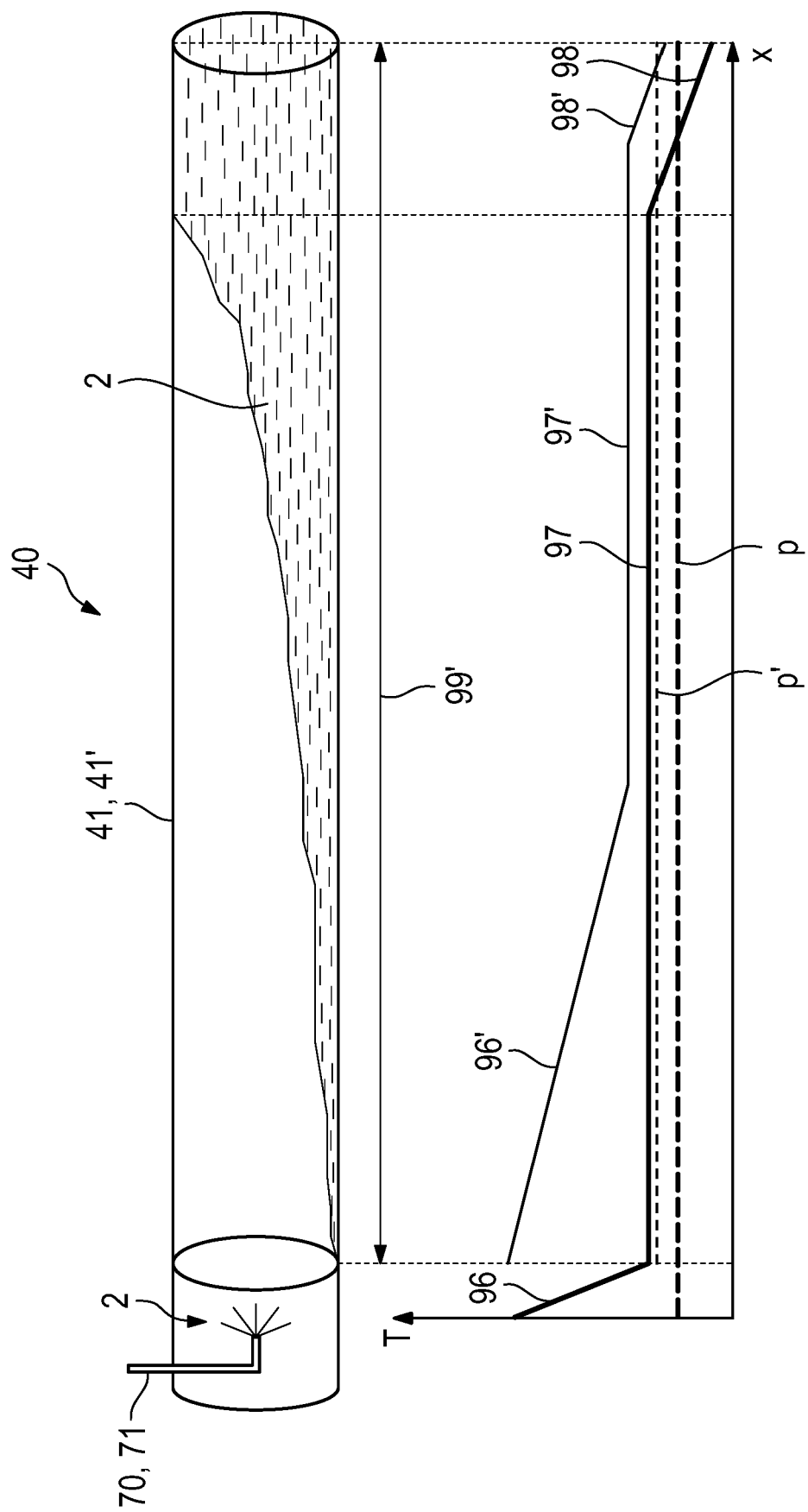


Fig. 9

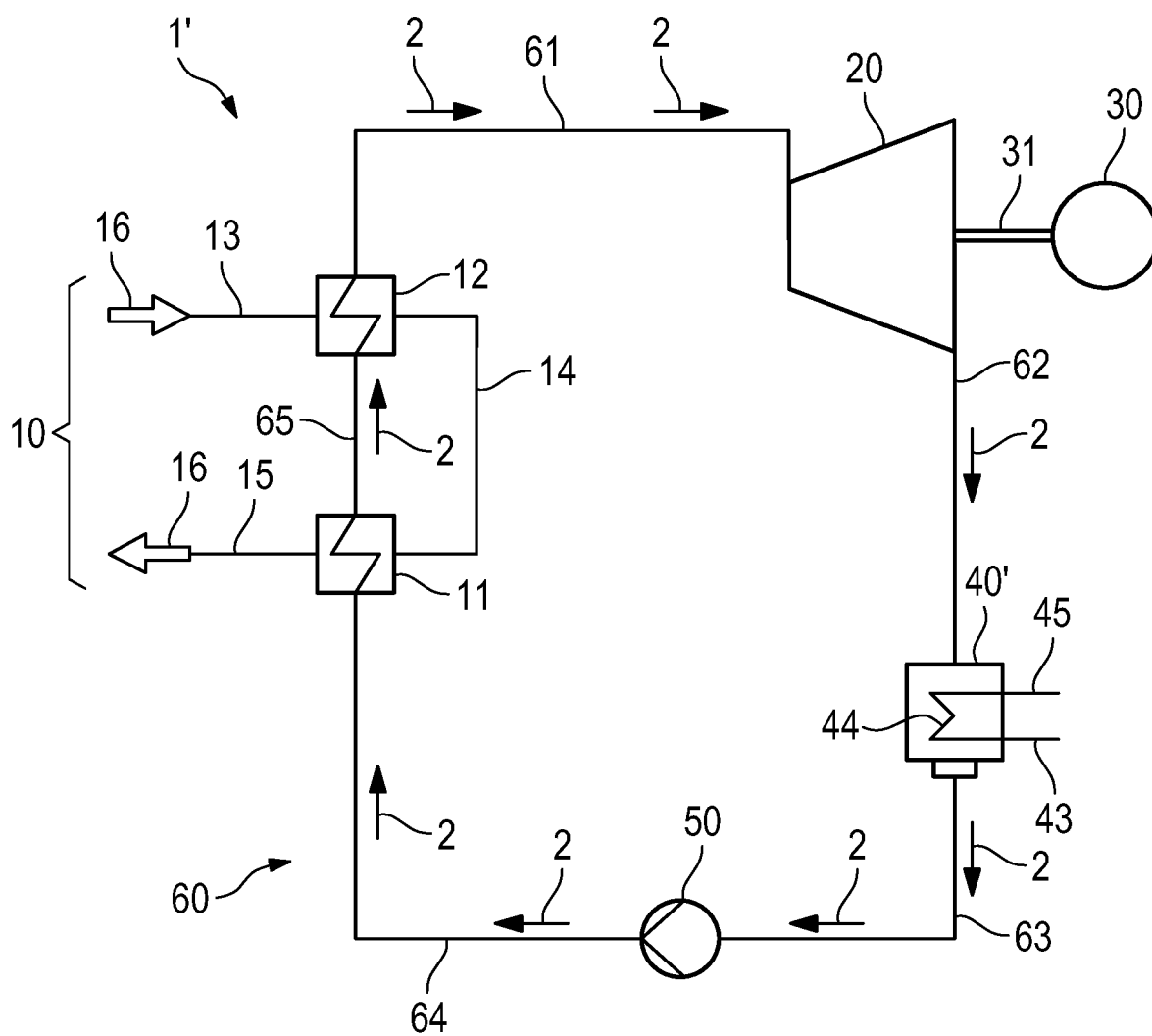


Fig. 10



EUROPEAN SEARCH REPORT

Application Number
EP 16 19 1160

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 2 March 2017	Examiner Röberg, Andreas
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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