

19



ORGANISATION AFRICAINE DE LA PROPRIETE INTELLECTUELLE

51

Inter. Cl.⁸
F01K 17/02
F01K 23/04
F01K 25/10
F02C 7/143

11

N° 17730

FASCICULE DE BREVET D'INVENTION

21

Numéro de dépôt : 1201600007
 (PCT/NL14/050428)

22

Date de dépôt : 01/07/2014

30

Priorité(s) :

BE n° 2013/0478 du 09/07/2013

73

Titulaire(s) :

P.T.I.,

Ossendrechtseweg 91,
 NL-4631 BB HOOGERHEIDE (NL)

VAN BEVEREN Petrus Carolus,

Ossendrechtseweg 91,
 NL-4631 BB HOOGERHEIDE (NL)

72

Inventeur(s) :

VAN BEVEREN Petrus Carolus (NL)

24

Délivré le : 24/02/2017

45

Publié le : 26.10.2017

74

Mandataire : Cabinet ÉKÉMÉ LYSAGHT SARL,
 B.P. 6370, YAOUNDE (CM).

54

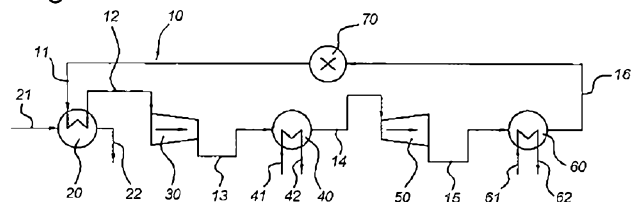
Titre : Heat recovery and upgrading method and compressor for using in said method.

57

Abrégé :

A heat recovery and upgrading method comprises cycles of the subsequent steps of providing a working fluid comprising a liquid phase in a working fluid stream; transferring heat to the working fluid stream such as to partially evaporate working fluid in liquid phase to obtain a two-phase working fluid stream in liquid phase and gas phase; compressing the two-phase working fluid stream so as to increase a temperature and pressure of the working fluid and to evaporate working fluid in liquid phase; and transferring heat from the working fluid stream by means of condensation of working fluid. In the first step the working fluid is preferably in a predominantly single-phase working fluid stream in liquid phase when heat is transferred to the working fluid, in the third step working fluid in liquid phase is preferably evaporated so that a two-phase working fluid stream is maintained, especially a wet gas-phase working fluid.

Fig. 1



DEMANDE DE BREVET D'INVENTION

- 1) P.T.I.
- 2) VAN BEVEREN Petrus Carolus

Heat recovery and upgrading method and
compressor for using in said method

INVENTEUR : VAN BEVEREN Petrus Carolus

- 1) P.T.I
- 2) VAN BEVEREN Petrus Carolus

HEAT RECOVERY AND UPGRADING METHOD AND COMPRESSOR FOR USING IN SAID METHOD

FIELD OF THE INVENTION

5 [01] The invention relates to a heat recovery and upgrading method comprising cycles of the subsequent steps of providing a fluid in a fluid stream; transferring heat to the fluid stream such as to evaporate the fluid; compressing the fluid; and transferring heat from the fluid.

10 BACKGROUND OF THE INVENTION

[02] Such method is known and is applied generally in industrial heat pump processes in which heat at a relatively low temperature is transferred to heat at a higher temperature. This is achieved by transferring heat at the relatively low temperature to a working fluid in liquid phase such that the working medium
15 evaporates into the gas phase. Subsequently, the working fluid in gas phase is compressed, which causes the temperature and pressure of the fluid to rise, after which heat can be transferred by means of condensation from the working fluid to another medium for use of that medium at a relatively higher temperature. Limitations of the existing compression heat pump systems are the relative low condensation
20 temperatures of about maximum 100°C.

SUMMARY OF THE INVENTION

[03] It is an objective of the invention to provide a heat recovery and upgrading method that allows providing heat at a high temperature, especially at a temperature
25 above 80°C or even 100°C.

[04] It is another or alternative objective of the invention to provide a heat recovery and upgrading method that allows providing heat at a temperature in excess of 150°C or even 175 °C.

[05] It is yet another or alternative objective of the invention to provide a heat
30 recovery and upgrading method that allows providing heat at a higher temperature, from a medium having a lower temperature in the range of 60°C to 120°C.

[06] It is yet another or alternative objective of the invention to provide a heat recovery and upgrading method that allows recovery and reuse of industrial waste heat streams in the order of 100°C to a temperature that is in the order of 200°C.

35 [07] It is yet another or alternative objective of the invention to provide an efficient heat recovery and upgrading method in the high temperature range.

[08] It is yet another or alternative objective of the invention to provide a compressor for use in heat recovery and upgrading method that provides heat in an

efficient way at a high temperature.

[09] At least one of the above objectives is achieved by a heat recovery and upgrading method comprising cycles of the subsequent steps of

- a. - providing a working fluid comprising a liquid phase in a working fluid stream;
- 5 b. - transferring heat to the working fluid stream such as to partially evaporate working fluid in liquid phase to obtain a two-phase working fluid stream in liquid phase and gas phase;
- c. - compressing the two-phase working fluid stream so as to increase a temperature and pressure of the working fluid and to evaporate working fluid in liquid phase; and
- 10 d. - transferring heat from the working fluid stream by means of condensation of working fluid.

The method yields a temperature rise of the working medium upon compression, which causes working fluid in liquid phase to evaporate. Evaporation limits the temperature rises, but causes a pressure increase. The working fluid is compressed to

15 yield a condensation regime of the working fluid at a desired temperature, for which a sufficiently high pressure is required. Compression of a gas-phase working fluid only would provide so-called superheating of the gas phase, which drastically lowers the efficiency of the process. The inventive method allows reaching a high temperature in

20 a condensation regime of the gas-phase working fluid, so that heat at a high temperature can be recovered and upgraded to a high temperature and subsequently be transferred from the working fluid for reuse in another or same process.

[10] Preferably, step a comprises providing the working fluid in a predominantly single-phase working fluid stream in liquid phase for a very efficient transfer of heat to the working fluid stream.

25 [11] In further preferred embodiment step c comprises compressing working fluid to evaporate working fluid in liquid phase such that a two-phase working fluid stream is maintained, especially a wet gas-phase working fluid. Having all liquid-phase working fluid evaporated allows most efficient and accurate obtaining of the required condensation regime of temperature and pressure of the working fluid. In case some

30 liquid-phase working fluid is still present after compression, it may evaporate after compression and adversely influence temperature and pressure of the working fluid.

[12] In an advantageous embodiment the working fluid comprises first and second components, a boiling temperature of the second component being lower than a boiling temperature of the first component at a same pressure. Advantageously, a

35 boiling temperature of the working fluid is between boiling temperatures of the first and second components and dependent on the ratio in which the first and second components are present in the working fluid. Such binary working fluid allows setting of characteristics, such as a required boiling and condensation temperature, of the

working fluid, and tuning of the working fluid to the specific heat recovery process in which it is employed.

[13] Preferably, the first and second components are selected such as to provide a non-separating mixture, which is efficiently achieved when the first and second components are alkali ionized components when mixed together. In an embodiment the first component is water and the second component is ammonia.

[14] In embodiments in step b heat is collected from a first medium and transferred to the working fluid stream and/or in step d heat is transferred to a second medium.

10 [15] In a preferred embodiment at least part of the liquid phase of the two-phase working fluid stream is provided as droplets in step c before and/or during compression of the working fluid stream and/or at least part of the liquid phase of the two-phase working fluid stream is separated from the two-phase working fluid stream and provided as droplets in step c before or during compression of the working fluid stream. The droplets provide a large droplet surface area to droplet volume ratio which yields an efficient heating and therefore evaporation of the droplets of liquid-phase working fluid. A larger volume of liquid-phase working volume will evaporate when presented in droplet form during compression of the working fluid.

15 [16] In an advantageous embodiment the droplets are provided at an inlet of and/or in a compression chamber of a compressor for compression of the working fluid. Introducing the droplets just at the inlet of and/or in the compression chamber guarantees that droplets are present during compression of the working fluid in the compression chamber, which otherwise might have merged into a larger volume of liquid-phase working fluid.

20 [17] In a further preferred embodiment the liquid phase of the two-phase working fluid stream is provided as a spray of tiny droplets, which provides an ever larger surface area to volume ratio of the droplets for an even further improved evaporation during compression.

25 [18] In an embodiment the method comprises subsequent to step c the step of expansion of the working fluid steam. This additional step is preferably carried out after heat transfer from the working fluid. Advantageously, power is recovered from expansion of the working fluid. In an embodiment, which can, for instance, be achieved when the working fluid is expanded in a positive displacement expander or turbine.

30 [19] In another aspect the invention provides for a compressor for use in step c of the above method, wherein the compressor is configured for compressing a two-phase working fluid so as to increase a temperature and pressure of the working fluid and to evaporate working fluid in liquid phase.

[20] In embodiments the compressor comprises a distribution arrangement configured for providing at least part of the liquid phase of the two-phase working fluid stream (12) as droplets in the compressor and the compressor may comprise a separation arrangement configured for separating at least part of the liquid phase of the two-phase working fluid stream (12) from the two-phase working fluid stream and a distribution arrangement configured for providing the separated liquid phase as droplets in the compressor.

[21] In a preferred embodiment the distribution arrangement is configured for providing droplets at an inlet of and/or in a compression chamber of the compressor.

10 [22] In a further preferred embodiment the distribution arrangement is configured to provide the liquid phase of the two-phase working fluid stream as a spray of tiny droplets.

BRIEF DESCRIPTION OF THE DRAWINGS

15 [23] Further features and advantages of the invention will become apparent from the description of the invention by way of non-limiting and non-exclusive embodiments. These embodiments are not to be construed as limiting the scope of protection. Various other embodiments can be envisioned within the scope of the invention. Embodiments of the invention will be described with reference to the accompanying drawings, in which like or same reference symbols denote like, same or corresponding parts, and in which

[24] Figure 1 shows a flow chart of an embodiment of the invention;

[25] Figure 2 shows a flow chart of a modification of the embodiment of figure 1; and

25 [26] Figure 3 shows a flow chart another embodiment of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

[27] An embodiment in which the heat recovery and upgrading method of the invention is implemented is shown in figure 1. Figure 1 shows a flow chart of a process cycle in which a working fluid is circulated in a main circuit 10. The circuit 10 comprises a first heat exchanger 20, a compressor 30, a second heat exchanger 40, an expander 50 and a third heat exchanger 60. A pump 70 may be incorporated as well in the circuit 10 to provide working fluid stream within the circuit. In some processes a working fluid stream is induced by the process itself, so a pump 70 can in such occasions be dispensed with.

[28] A stream 21 of a first medium comprising hot gases, including vapor, at a temperature of about 120°C and originating from a process is passed through the heat exchanger 20. The stream 21 in the present embodiment a stream of hot gases and

vapor coming from a frying oven, in which potato chips are produced. The gases and vapor are evacuated from the oven using one or more fans (not shown in the figures). The stream 21 of hot gases and vapor is fed into the first heat exchanger 20, in which heat is transferred from the hot gases and vapors in stream 21 to working fluid of the working fluid stream in circuit 10. The working fluid stream in circuit 10 may generally also be referred to as a working fluid stream 10, which flows in a direction as indicated by the arrows in figure 1. The invention is not limited to heat transfer from a stream 21 of a first medium coming from a frying oven, but can be employed in a wide range of other applications as well. A first medium stream 22 that has released heat exits the first heat exchanger 20 and can be further used to release additional heat as will be described further below with respect to the embodiment of figure 2.

[29] The working fluid comprises first and second components, being water as the first component and ammonia as the second component in the embodiment described. The fraction of ammonia in the water ammonia working fluid can be in the range of 0.1% to about 50%. The first and second components of the working fluid are selected such as to provide a non-separating mixture of, preferably, alkali ionized first and second components when mixed together. A boiling temperature of the second component, being ammonia in the embodiment described, is lower than a boiling temperature of the first component, being water in the embodiment described, of the working fluid. A boiling temperature of the working fluid is in between boiling temperatures of the separate first and second components and dependent on the ratio in which the first and second components are present in the working fluid.

[30] The working fluid is provided in a predominantly liquid phase at a pressure of about 1 bar and a temperature of in the order of 30°C to 70°C in the working fluid stream 10 in circuit part 11 just before the first heat exchanger 20. Actual temperatures and pressures disclosed may be dependent on the implementation of the process. Upon transfer of heat to the working fluid stream 10 working fluid in the liquid phase is partially evaporated. The process is embodied such that not all working fluid is evaporated into the gas phase. The amount of heat transferred in relation to the amount and flow rate of liquid phase working fluid provided in the first heat exchanger 20 should be such that some of the working fluid is still in liquid phase in circuit part 12 when having past the first heat exchanger 20. A two-phase working fluid stream, comprising working fluid in liquid phase and gas phase, is therefore present in circuit part 12 after the first heat exchanger 20 at a pressure of about 1 bar and a temperature of about 97°C.

[31] It is noted that gas and vapor as used herein are identical in that both can be condensed from gas/vapor phase into liquid phase and the liquid phase can be evaporated into gas/vapor phase. The term vapor tends to be used for water vapor.

[32] The two-phase working fluid stream 12 is subsequently passed into compressor 30 to be compressed to a pressure with a predetermined condensation temperature of the gas-phase working fluid after compression. During compression the temperature of the working fluid will increase and at least part of the working fluid in liquid phase is evaporated into the gas phase. This is an important step to limit the temperature of the working fluid after compression. Preferably, only part of the liquid-phase working fluid evaporates at compression by compressor 30 to yield a wet gas-phase (two-phase) working fluid stream so as to avoid superheating of the working fluid. Having not all liquid-phase evaporate provides a working fluid stream in which gas phase and liquid phase are in equilibrium. After compression the temperature of the working fluid is about 185°C and its pressure about 12 bar.

[33] At the compression stage part of the working fluid stream enters the compressor 30 in liquid phase. Evaporation of the liquid-phase working fluid upon compression will limit the temperature rise of the working fluid in the gas phase after compression to a desired and predetermined temperature or temperature range. The compression ratio of compressor 30 is set such as to achieve a desired and predetermined pressure or pressure range of the gas-phase working fluid in circuit part 13. The amount of liquid-phase working fluid present before compression is such that pressure and temperature of the working fluid stream 13 after compression is at or within desired and predetermined levels or ranges. To achieve an efficient evaporation of the liquid-phase working fluid upon compression the liquid-phase working fluid is provided as droplets in the working fluid stream 12 just before and/or during compression by compressor 30. An efficient evaporation of liquid-phase working fluid prevents superheating of gas-phase working fluid to a temperature that is not in equilibrium with the liquid-phase. The liquid-phase working fluid is preferably provided as a spray comprising very small droplets of liquid-phase working fluid to achieve a high droplet surface to droplet volume ratio so that a very efficient heat transfer to the droplet and therefore evaporation of a droplet is achieved. In the present embodiment the compression ratio of compressor is set to achieve a pressure of the gas-phase working fluid with a corresponding condensation temperature of about 180°C in circuit part 13.

[34] The compressed wet gas-phase working fluid subsequently enters a second heat exchanger 40, in which the gas-phase working fluid is condensed to release its heat. Condensation is efficiently achieved when gas-phase working fluid is in equilibrium with the liquid-phase working fluid in the working fluid stream. The heat is released to a stream 41 of a second medium, being frying oil coming from the frying oven in the embodiment disclosed. The frying oil should have a temperature of about 180°C in the frying oven, but is cooled to about 153°C due to the frying process of

potato chips. Stream 41 of frying oil from the frying oven has about this temperature of 153°C and is heated to about 180°C in frying oil stream 42 by heat exchanger 40 through heat release from the condensed working fluid. Frying oil stream 42 is passed to the frying oven (not shown in the figures) for reuse in the frying process.

5 [35] After heat release in the second heat exchanger 40 the compressed working fluid has a temperature of about 173°C and is passed to an expander 50 to reduce the pressure of the working fluid from about 12 bar to about 1 bar. The expanding working fluid releases power to the expander 50, which is used for power recovery. After expansion in expander 50 a two-phase working fluid continues as a
10 working fluid stream having a liquid phase and a gas phase in circuit part 15. The compressor 30 and the expander 50 are preferably of the positive displacement type, such as a Lysholm rotor or vane-type rotor. The expander may comprise a turbine.

[36] The power recovered by expander 50 is used to assist in driving compressor 30. An electromotor (not shown) for driving compressor 30, expander 50
15 and compressor 30 can be mounted in a common drive train (on a common axis). Alternatively, the expander can generate electrical power, for instance, when configured as an expander-generator. The electromotor drives the compressor assisted by (electrical) power from the expander 50. Power released from the working fluid in expander 50 is thus recovered and reused in compressing working fluid by
20 compressor 30.

[37] A pressure sensor (not shown in the figures) is mounted in circuit part 13 to monitor a pressure of the compressed gas-phase working fluid, which is to be compressed to a predetermined pressure yielding a desired condensation temperature of the compressed gas-phase working fluid. The pressure measured by the pressure
25 sensor is passed in a control loop (not shown in the figures) to the electromotor driving the compressor 30 to control a rotational speed of the electromotor and compressor 30 so as to set a compression ratio of the compressor 30 which yields the predetermined pressure of the compressed gas-phase working fluid in circuit part 13.

[38] The expanded two-phase working fluid stream 15 is passed to a third heat exchanger 60, in the embodiment shown, in which the working fluid is condensed to yield a substantially single-phase working fluid stream in circuit part 16. In the third heat exchanger 60 heat is released from the two-phase working fluid stream 15 to another second medium, which is production water in the embodiment disclosed. A production water stream 61 enters heat exchanger 60 at a temperature of about 25°C,
35 which is well below the boiling temperatures of both the first and second components, being water and ammonia, of the working fluid so as to allow condensation of the working fluid. A production water stream 62 having a temperature of about 60°C leaves third heat exchanger 60. Actual temperature of the production water stream 62

leaving heat exchanger 60 is governed by the design of the third heat exchanger and by flow conditions of working fluid stream and production water stream. The production water can be used for washing, cleaning and heating. The temperature of the working fluid after the heat exchanger is also in the order of about 60 °C.

5 [39] The (substantially) single phase working fluid stream 16 is pumped by feed pump 70 towards circuit part 11, where it is presented as a (substantially) single-phase working fluid stream 11 to the first heat exchanger 20. Pump 70 hardly increases the pressure of the working fluid in the embodiment shown. At this point the cycle is repeated and continues as has been described. In the cycle heat is recovered and
10 transferred from a first medium stream 21 resulting from a production process in first heat exchanger 20 to a liquid phase of a working fluid stream 11 so as to partly evaporate the liquid phase into the gas phase. The resulting two-phase working fluid stream 12 is upgraded by a considerable compression in compressor 30 to yield a working fluid stream 13 at a pressure having a high condensation temperature. Heat
15 contained in the high-temperature working fluid stream 13 can be very efficiently employed in production processes, of which an example is given in the embodiments disclosed.

[40] Figure 2 shows a modification of the embodiment shown in figure 1. Actually two modifications are implemented in the figure 2 embodiment. In a first
20 modification a bypass cycle 110 is provided. A bypass working fluid stream 111 from working fluid stream 16 is passed to a separator 120 to separate the gas-phase working fluid from the liquid-phase working fluid. Liquid-phase working fluid continues to circuit part 11 and a gas-phase working fluid stream 112 passes the separator 120 to an air-cooled condenser 130, in which the working fluid releases heat to the
25 atmosphere. A condensed liquid-phase working fluid stream 113 is merged again with working fluid stream 16 as shown in figure 2. The bypass cycle 110 may be required when not enough production water is available to provide condensation of working fluid in third heat exchanger 60. The need for hot production water may be discontinuous, requiring an alternative to have the working fluid condense into a
30 (substantially) single-phase working fluid stream 11.

[41] In a second modification an auxiliary circuit 210 is connected to main circuit 10 through heat exchanger 220. The first medium stream 22 of partly condensed frying gases and vapor from first heat exchanger 20 is led to auxiliary heat exchanger 220, in which heat is further released to an auxiliary working fluid in
35 auxiliary circuit 210. The auxiliary working fluid is a refrigerant, which is pressurized in auxiliary circuit part 211. Heat release in auxiliary heat exchanger 220 saturates the pressurized refrigerant. The pressurized refrigerant stream 212 is passed to an auxiliary expander 230 to reduce the pressure of the refrigerant stream and to release

power to the auxiliary compressor 230. A resulting two-phase refrigerant stream 213 is led to a separator 240, separating the refrigerant stream into a liquid-phase refrigerant stream in auxiliary circuit part 214.1 and a gas-phase refrigerant stream 214.2. The gas-phase refrigerant stream 214.2 is passed to air-cooled condenser 250 to
5 condense the gas-phase refrigerant stream to a liquid-phase refrigerant stream 214.3. Liquid-phase refrigerant stream 214 is pumped up by auxiliary mediate pump 270 to a required saturation pressure and to close the refrigerant loop towards auxiliary heat exchanger 220.

[42] Power recovered by auxiliary expander 230 is also used to assist in driving
10 compressor 30 in main circuit 10 by connecting auxiliary expander 230 to the drive train of compressor 30. Power recovered by expanders 50 and 230 and used to assist in driving compressor 30 and heat recovery in heat exchangers 20, 40, 60 and 220 dramatically improves the energy efficiency of the whole process.

[43] First medium stream 21, containing water vapor and predominantly air, is
15 in two subsequent heat exchangers 20 and 220 condensed into a two-phase stream 23 that is passed to a separator 280 to yield an air stream 26 and a water stream 25. Water stream 25 can be made available as production water after additional filtration (not shown in the figures), which further reduces a demand on resources.

[44] Figure 3 shows another embodiment of which main circuit 10 is largely
20 identical to the embodiment of figure 1. Main circuit 10 of the figure 3 embodiment does not have an expander in the main circuit. An auxiliary circuit 310 is connected to main circuit 10 through heat exchanger 60. Auxiliary circuit 310 comprises a working fluid that is a mixture of ammonia and water having a lower boiling and condensation
25 temperature than the working fluid in main circuit 10. In the embodiments of figure 3 the working fluid of auxiliary circuit 310 comprises about 50% ammonia and 50% water. However, dependent on the application both components may be mixed in any ratio.

[45] In third heat exchanger 60 heat is transferred from the working fluid of
30 main circuit 10 to the auxiliary working fluid of auxiliary circuit 310. The auxiliary working fluid is at a pressure of about 71 bar at heat exchanger 60 and after the heat exchanger the temperature of the auxiliary working fluid is about 170°C. Subsequently, the auxiliary working fluid is passed to expander 320 to reduce pressure and temperature of the auxiliary working fluid to about 3.5 bar and 67°C, respectively, and
35 to recover power from expansion of the auxiliary working fluid. After expansion the working fluid is passed to an air-cooled condenser to further reduce the temperature to about 30°C. Pump 340 then increases the pressure of the working fluid to about 71 bar at a slight temperature increase to about 31°C, after which the cycle of auxiliary

circuit 310 is repeated again. In the figure 3 embodiment power recovery in auxiliary circuit 310 is more efficient than power recovery in the figure 1 embodiment.

[46] The working fluid in main circuit 10 after heat exchanger 60 in the figure 3 embodiment has a temperature of about 34°C and a pressure of about 12 bar. The
5 pressure is further reduced by expansion valve 80 to about 1 bar to pass working fluid at a temperature and pressure of about 34°C and 1 bar, respectively, to heat exchanger 20, after which the cycle of the main circuit is repeated again.

CLAIMS

1. A heat recovery and upgrading method comprising cycles of the subsequent steps of
 - 5 a. - providing a working fluid comprising a liquid phase in a working fluid stream (11);
 - b. - transferring heat (20) to the working fluid stream (11) such as to partially evaporate working fluid in liquid phase to obtain a two-phase working fluid stream (12) in liquid phase and gas phase;
 - 10 c. - compressing (30) the two-phase working fluid stream (12) so as to increase a temperature and pressure of the working fluid and to evaporate working fluid in liquid phase; and
 - d. - transferring heat (40, 60) from the working fluid stream (13, 14, 15) by means of condensation of working fluid.
- 15 2. The method according to the preceding claim, wherein step a comprises providing the working fluid in a predominantly single-phase working fluid stream (11) in liquid phase.
- 20 3. The method according to any one of the preceding claims, wherein step c comprises compressing working fluid to evaporate working fluid in liquid phase such that a two-phase working fluid stream (13) is maintained, especially a wet gas-phase working fluid.
- 25 4. The method according to any one of the preceding claims, wherein the working fluid comprises first and second components, a boiling temperature of the second component being lower than a boiling temperature of the first component at a same pressure.
- 30 5. The method according to the preceding claim, wherein a boiling temperature of the working fluid is between boiling temperatures of the first and second components and dependent on the ratio in which the first and second components are present in the working fluid.
- 35 6. The method according to any one of the preceding two claim, wherein the first and second components are selected such as to provide a non-separating mixture.

7. The method according to any one of the preceding three claims, wherein the first and second components are alkali ionized components when mixed together.

5 8. The method according to any one of the preceding four claims, wherein the first component is water and the second component is ammonia.

9. The method according to any one of the preceding claims, wherein in step b heat is collected from a first medium and transferred (20) to the working fluid stream (11).

10 10. The method according to any one of the preceding claims, wherein in step d heat is transferred (40, 60) to a second medium.

15 11. The method according to any one of the preceding claims, wherein at least part of the liquid phase of the two-phase working fluid stream (12) is provided as droplets in step c before and/or during compression (30) of the working fluid stream.

20 12. The method according to any one of the preceding claims, wherein at least part of the liquid phase of the two-phase working fluid stream (12) is separated from the two-phase working fluid stream and provided as droplets in step c before or during compression (30) of the working fluid stream.

25 13. The method according to any one of the preceding two claims, wherein the droplets are provided at an inlet of and/or in a compression chamber of a compressor (30) for compression of the working fluid.

30 14. The method according to any one the preceding three claims, wherein the liquid phase of the two-phase working fluid stream (12) is provided as a spray of tiny droplets.

15. The method according to any one of the preceding claims, wherein the method comprises subsequent to step c the step of
- expansion (50) of the working fluid steam (13, 14).

35

16. The method according to the preceding claim, wherein power is recovered from expansion (50) of the working fluid.

17. The method according to any one of the preceding two claims, wherein the working fluid is expanded in a positive displacement expander or turbine (50).

5 18. A compressor for use in step c of the method according to any one of the preceding claims, wherein the compressor is configured for compressing a two-phase working fluid so as to increase a temperature and pressure of the working fluid and to evaporate working fluid in liquid phase.

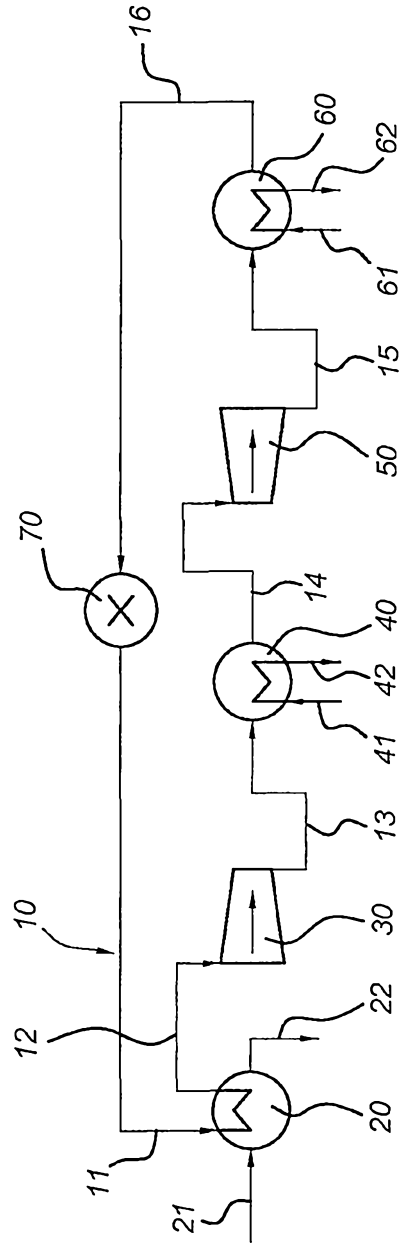
10 19. The compressor according the preceding claim, wherein the compressor comprises a distribution arrangement configured for providing at least part of the liquid phase of the two-phase working fluid stream (12) as droplets in the compressor.

15 20. The compressor according to any one of the preceding two claims, wherein the compressor comprises a separation arrangement configured for separating at least part of the liquid phase of the two-phase working fluid stream (12) from the two-phase working fluid stream and a distribution arrangement configured for providing the separated liquid phase as droplets in the compressor.

20 21. The compressor according to any one of the preceding two claims, wherein the distribution arrangement is configured for providing droplets at an inlet of and/or in a compression chamber of the compressor (30).

25 22. The compressor according to any one of the preceding three claims, wherein the distribution arrangement is configured to provide the liquid phase of the two-phase working fluid stream (12) as a spray of tiny droplets.

Fig. 1



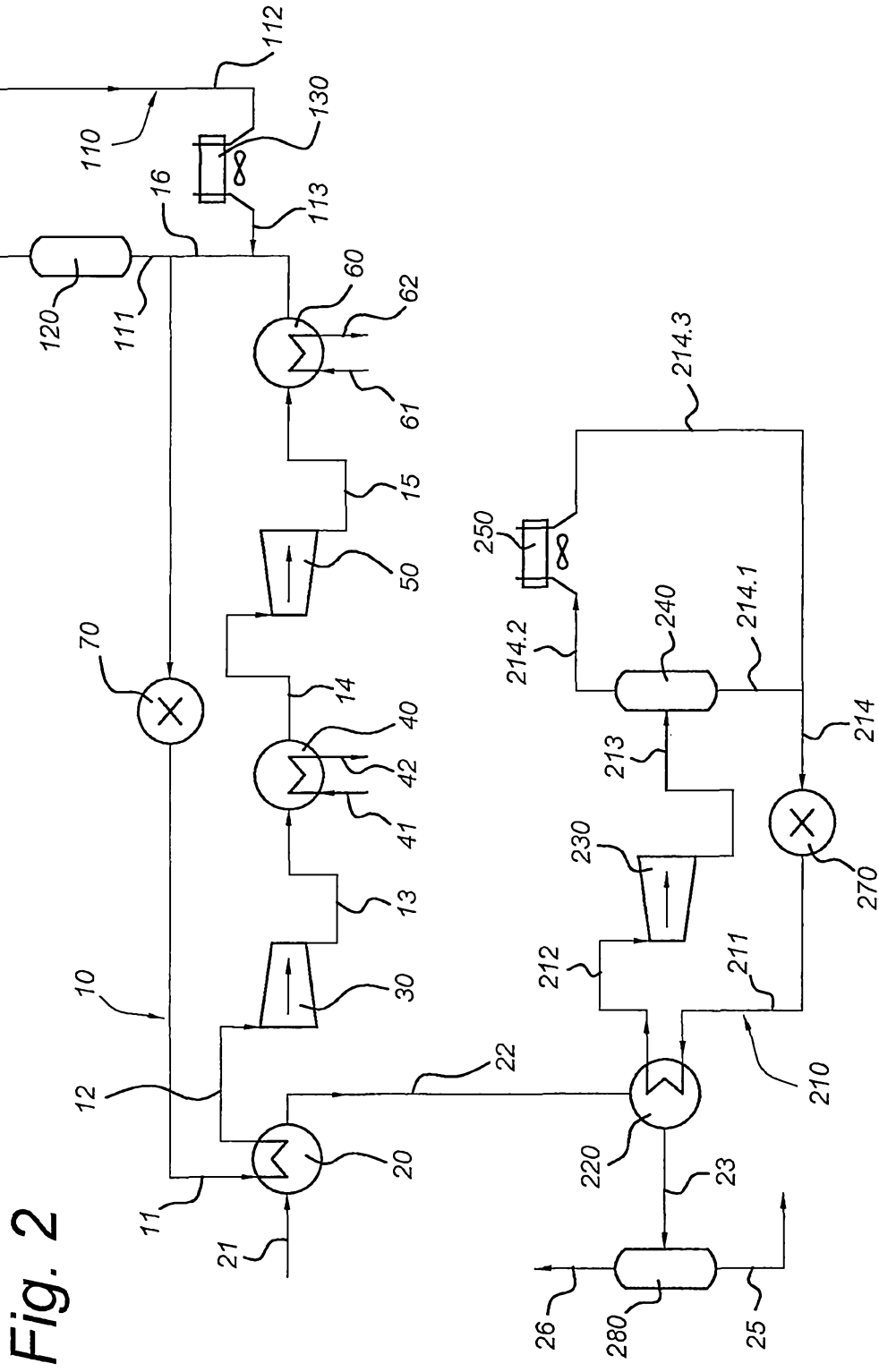
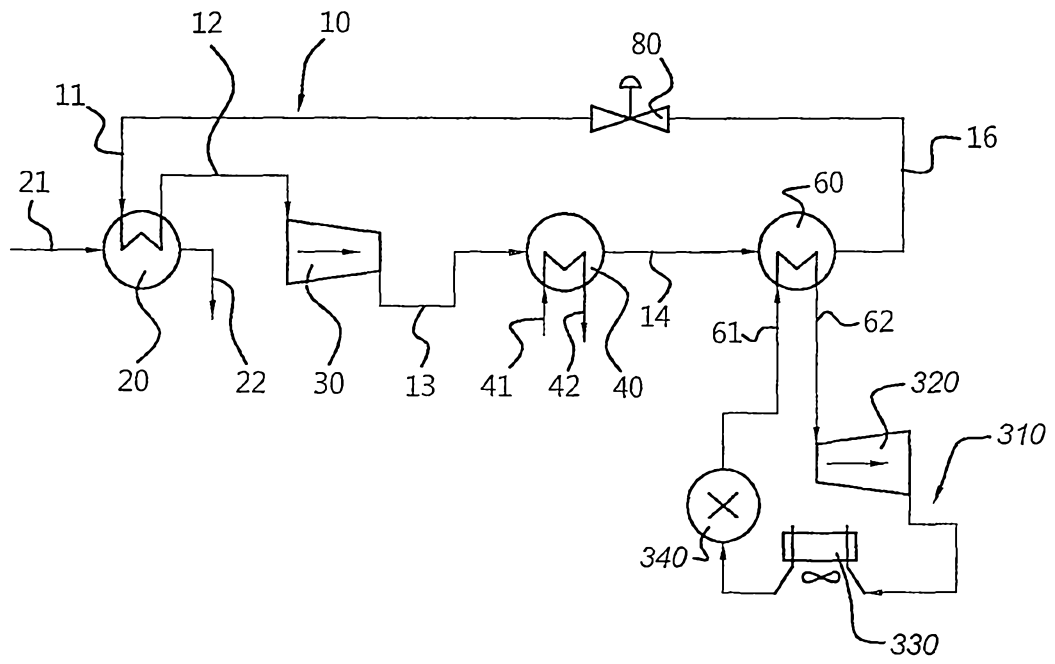


Fig. 2

Fig. 3



ABSTRACT

A heat recovery and upgrading method comprises cycles of the subsequent steps of providing a working fluid comprising a liquid phase in a working fluid stream;

5 transferring heat to the working fluid stream such as to partially evaporate working fluid in liquid phase to obtain a two-phase working fluid stream in liquid phase and gas phase; compressing the two-phase working fluid stream so as to increase a temperature and pressure of the working fluid and to evaporate working fluid in liquid phase; and transferring heat from the working fluid stream by means of condensation

10 of working fluid. In the first step the working fluid is preferably in a predominantly single-phase working fluid stream in liquid phase when heat is transferred to the working fluid. In the third step working fluid in liquid phase is preferably evaporated so that a two-phase working fluid stream is maintained, especially a wet gas-phase working fluid.

15

Planche de l'abrégé

Fig. 1

