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Description

This invention relates to the generation of energy by means of a working fluid, and to the regeneration of a working fluid. More particularly, this invention relates to a method of and to apparatus for generating energy by means of a working fluid and for regenerating such a working fluid.

In the generation of energy by expansion of a working fluid the energy which can be produced by expansion of the working fluid is limited by the temperatures at which heating and cooling mediums can economically be provided for regeneration of the working fluid. The result is, therefore, that such a working fluid is expanded from a high pressure charged level to a low pressure spent level, with the high pressure charged level being governed by the maximum pressure at which the working fluid can be evaporated with the available heating medium, and with the spent low pressure level being governed by the minimum pressure at which the working fluid can be condensed with the available cooling medium.

GB—A—294,882 discloses a single stage process for the generation of energy by the expansion of a working fluid in which the fluid is expanded from a charged high pressure level to a spent low pressure level to release energy and the spent working fluid is regenerated by condensing it in an absorption stage by dissolving it in a solvent solution while cooling with a cooling medium. The pressure of the solvent solution containing the dissolved working fluid is then increased and the working fluid be regenerated is evaporated by heating, after which it is withdrawn for reexpansion to release energy and the balance of the solvent solution remaining after evaporation of the working fluid is re-cycled to constitute the solvent solution for the absorption stage.

The invention is based on the principle that by using a plurality of regeneration stages rather than a single stage, and by increasing the pressure incrementally in each successive stage, the working fluid can be regenerated from a low pressure to a much higher pressure even though the same temperature cooling medium is used in each stage and the same temperature heating medium is also used in each stage.

Such multi-stage regeneration is achieved, in accordance with the invention, by the steps of:—

(a) in a first regeneration stage condensing the spent working fluid in a first absorption stage by dissolving it in a solvent solution while cooling with a cooling medium, the solvent solution comprising a solvent having an initial working fluid concentration which is sufficiently low provide a solvent solution boiling range suitable for absorption of the working fluid;

(b) increasing the pressure of the solvent solution containing the dissolved working fluid in the first regeneration stage and evaporating the working fluid being regenerated by heating in a first evaporation stage;

(c) re-cycling the balance of the solvent solution remaining after evaporation of the working fluid in the first evaporation stage, to constitute the solvent solution for the first absorption stage of that first regeneration stage;

(d) feeding the evaporated working fluid from the first regeneration stage to a succeeding regeneration stage;

(e) subjecting the evaporated working fluid from each preceding regeneration stage to corresponding regeneration in each succeeding regeneration stage to produce a charged working fluid in each succeeding stage which is at a higher pressure than the working fluid entering that stage; and

(f) withdrawing regenerated charged gaseous working fluid from a final regeneration stage for re-expansion to release energy.

As a consequence, although the concentration of low boiling component is higher in the solvent solution in each successive stage, it can still absorb the unit quantity of working fluid because the pressure of the working fluid is higher in each successive stage. At the same time, although the pressure of the solvent solution containing the unit quantity of working fluid is higher in each successive evaporation stage, the concentration of lower boiling component is higher in each successive evaporation stage. Therefore, the unit quantity of working fluid can again be evaporated in each successive evaporation stage, although heating medium at the same temperature is being used in each stage.

The working fluid may be expanded to a spent low pressure level where the condensation temperature of the gaseous working fluid is below the minimum temperature of the cooling medium in the absorption stage.

Since the solvent solution in each regeneration stage is recycled, the solvent solution constitutes a closed loop in that stage, and is separate from the solvent solution in each other regeneration stage. Furthermore, in each regeneration stage, the quantity of working fluid being regenerated is dissolved in the solvent solution of that stage, and the equivalent quantity of working fluid being regenerated is evaporated from the solvent solution in the evaporation stage of each regeneration stage.

It will be appreciated that the quantity of solvent solution, and the initial concentration of working fluid in the solvent solution in each regeneration stage will be separately adjusted as may be required for specific operating conditions, and as may be required for variations in the minimum temperature level of an available cooling medium.

The solvent of the solvent solution may be any suitable solvent which is a solvent for the working fluid, which has a boiling point above the maximum temperature which will be attained in any evaporation stage, and which will provide a solvent solution when working fluid is dissolved therein, which has a boiling point which decreases as the concentration of working fluid increases.

While the solvent solution is preferably a binary solution, it will be appreciated that it may be a solution of a plurality of liquids.

A number of working fluids which would be suitable, are known to those skilled in the art. Any of such working fluids may be employed in this invention.

In one embodiment of the invention, the working fluid and solvent may be in the form of hydrocarbons having appropriate boiling points. Thus, for example, the solvent may be in the form of butane or pentane while the working fluid may be in the form of propane. In an alternative example, the working fluid may be an appropriate freon compound, with the solvent being an appropriate solvent for that compound.

In a preferred embodiment of the invention, the working fluid is in the form of ammonia and the solvent is in the form of water. In this embodiment of the invention, at a pressure of one atmosphere the boiling point of water is 100°C whereas the boiling point of pure ammonia is −33°C. As the concentration of ammonia in water increases, the boiling point of the aqueous ammonia solution will decrease. From binary phase diagrams of water and ammonia solutions, the appropriate initial concentration of ammonia in the solvent solution for each regeneration stage, can readily be determined for this invention from the pressure and temperature which will prevail in each condensation stage.

In a preferred embodiment of the invention, the initial concentration of working fluid in the solvent solution in each regeneration stage, and the proportion of solvent solution to working fluid to be regenerated will be selected so that after complete absorption of the working fluid being regenerated in the absorption stage of the regeneration stage, the solvent solution will have a boiling point marginally above the minimum temperature attained in that absorption stage during use.

In practice, therefore, the minimum quantity of solvent solution will be employed which will satisfy this requirement thereby reducing cooling medium requirements to the minimum, and thereby further reducing heating medium requirements to the minimum.

It will be appreciated that since the pressure is increased between the absorption stage and evaporation stage of each regeneration stage, there will be a stepwise or incremental increase in pressure between each preceeding regeneration stage and each succeeding regeneration stage. It follows, therefore, that the initial concentration of working fluid in the solvent solution for each successive regeneration stage will be correspondingly higher to provide a boiling range for the solvent solution in each stage which is suitable for dissolving or absorbing the working fluid at the pressure prevailing in that stage.

In a preferred embodiment of the invention, the pressure is increased between the absorption and evaporation stages of each regeneration stage, to the maximum pressure at which the working fluid being regenerated can be evaporated effectively in the evaporation stage by the, or by a heating medium, available for heating the evaporation stage.

The pressure is, therefore, preferably increased in each regeneration stage to the maximum level where the solvent solution in each evaporation stage will, after evaporation of the working fluid in that stage, have a boiling point marginally below the maximum temperature attainable in that evaporation stage.

By appropriate control of the pressure, evaporation of the required quantity of working fluid being regenerated can be readily effected in each evaporation stage. Control valve means may, however, be provided to control the quantity of evaporated working fluid which is fed from each regeneration stage to each succeeding regeneration stage. Thus, if a greater quantity of working fluid than that required for regeneration has been evaporated in an evaporator stage, only the required quantity will pass to the succeeding regeneration stage. The balance will be recycled with the solvent solution.

The method of this invention may preferably include the step of, in each regeneration stage, feeding the solvent solution and evaporated working fluid from the evaporation stage to a separation stage for separating the working fluid being regenerated.

The separator stage may be provided by a separator of any conventional suitable type known to those skilled in the art.

The solvent solution which is recycled to the absorption stage in each regeneration stage, is conveniently expanded to reduce its pressure to a pressure corresponding with or approaching that of the pressure of the working fluid being regenerated in that absorption stage.

In a preferred embodiment of the invention, in each regeneration stage, the solvent solution which is recycled, is recycled in heat exchange relationship with the evaporation stage to thereby reduce the heating medium requirements for the evaporation stage.

The solvent solution which is recycled in each regeneration stage, may be recycled at least partially in heat exchange relationship with the absorption stage.

Where the recycled solvent solution is recycled in heat exchange relationship with an absorption stage, the cooling medium requirement will decrease because the quantity of heat to be removed will remain constant, but the capacity of the absorption stage will have to be increased. Conversely, if the recycled solvent solution is not recycled in heat exchanger relationship with the absorption stage, the capacity of the absorption stage will decrease while the requirement of cooling medium will increase.

In practice, therefore, depending upon the source and availability of the cooling medium, on the basis of economic considerations, the reduced cost of supplying lesser quantities of cooling medium can be balanced against the capital costs of increasing the capacity of the absorption stages to determine whether the recycled solvent solution should be recycled in heat exchange relationship, or at least partially in heat exchange relationship with the absorption stages, or not at all.

In an embodiment of the invention, all of the absorption stages of the regeneration stages may be carried out separately in a single composite absorption stage which is cooled by means of cooling medium from a common source. Furthermore, all of the evaporation stages may be carried out separately in a single composite evaporation stage which is heated by means of a heating medium from a common source.

While this invention may have various applications, and while various types of cooling and heating means known to those skilled in the art, may be employed, this invention can have particular application in regard to the utilization of readily and economically available cooling and heating mediums for the generation of energy.

The invention can, therefore, have specific application where low temperature differential heating and cooling mediums are employed.

A preferred application of the invention would, therefore, be in the field of thermal energy conversion using cool water withdrawn from a body of water as the cooling medium, and using, as heating medium, hot water from a body of water, water heated by solar heating, hot water heated additionally by solar heating means, or water or heating fluid in the form of waste heat fluids from industrial plants.

A preferred application of the invention would, therefore, be in the field of ocean thermal energy conversion [OTEC] where ocean surface water is used as the heating medium and ocean water withdrawn from a sufficient depth from an ocean is used as the cooling medium, thereby resulting in a low temperature differential between the heating and cooling mediums.

Normally ocean water would be withdrawn from a depth of about 200 feet (61 m) to provide the most economical cooling medium at the lowest temperature. The temperature does not tend to decrease significantly beyond a depth of about 200 feet (61 m).

A further preferred application of the invention would be in regard to solar ponds for supplying the heating medium, and also the cooling medium if desired.

The expansion of the working fluid from a charged high pressure level to a spent low pressure level to release energy may be effected by any suitable conventional means known to those skilled in the art, and the energy so released may be stored or utilized in accordance with any of a number of conventional methods known to those skilled in the art.

In a preferred embodiment of the invention, the working fluid may be expanded to drive a turbine of conventional type.

In an embodiment of the invention, where the mass ratio between the solvent solution being recycled through an absorption stage and the working fluid being regenerated is sufficient, the pressure of the solvent solution leaving the evaporation stage may be utilized to increase the pressure of the working fluid being regenerated which is introduced into the absorption stage with the recycled solvent solution.

In this embodiment of the invention, instead of expanding the solvent solution which is recycled to reduce its pressure to a pressure corresponding with or approaching that of the pressure of the working fluid being regenerated in an absorption stage, the solvent solution may be injected into the absorption stage in such a manner as to entrain the working fluid and draw the working fluid into the absorption stage.

Various injection systems are known to those skilled in the art which could be used for this purpose. As an example, an injection system such as an injection nozzle having a restricted zone to create a zone of low pressure may be used. With such an injection nozzle, the working fluid will be introduced into the proximity of the restricted zone so that the reduced pressure created will permit the working fluid to be introduced into the absorption stage.

It will be appreciated that, depending upon relative flow rates and pressures, it may still be necessary to control the pressure of the recycled solvent solution by expanding it to provide an appropriate pressure.

By utilizing the pressure, or at least part of the pressure, of the solvent solution which is recycled, this will contribute to an increase in pressure in the absorption stage. This can provide the advantage of improving absorption in the absorption stage, or can be utilized to permit expansion of the working fluid to an even lower spent level. In this event, the initial increase in pressure provided by the solvent solution may be utilized to increase the pressure in the absorption stage, to a level where absorption can be effectively achieved in accordance with this invention.

Applicant believes that this application of the pressure of the solvent solution will tend to be valuable in the first stage, and probably the first and second stages of a multi-stage regeneration system while, in a system employing only two stages it will tend to be less valuable. This will primarily be due to the fact that the mass ratio between the recycled solvent solution and the working fluid will not be sufficient.

Preferred embodiments of the invention are now described by way of example with reference to the accompanying drawings.

In the drawings:—

Figure 1 shows a schematic representation of one embodiment of the method of this invention;

Figure 2 shows a fragmentary schematic representation of the method of Figure 1 incorporating a modification to the expansion stage; and

Figure 3 shows a fragmentary schematic representation of a further embodiment of the invention in which injection means is utilized to inject the working fluid being regenerated.

With reference to Figure 1 of the drawings, numeral 50 refers generally to apparatus for use in generating energy by the expansion of a gaseous working fluid from a charged high pressure level to a spent low pressure level to release energy, and for regenerating the spent working fluid.

The apparatus 50 includes expansion means in the form of a turbine 52 in which a gaseous working fluid is expanded from a charged high pressure level to a spent low pressure level to released energy to drive the turbine 52. The gaseous working fluid at the high pressure level is fed to the turbine 52 along charged line 54 and is discharged from the turbine 52 along spent line 56.

The apparatus 50 further includes regeneration means for regenerating the spent gaseous fluid. The regeneration means comprises four successive incremental regeneration stages.

For ease of reference the components of each regeneration stage have been identified by a letter followed by a suffix in arabic numerals indicating the particular regeneration stage. In addition, the flow lines for each regeneration stage have been identified by reference numerals having a prefix corresponding to that of the particular regeneration stage.

The first regeneration stage comprises an absorber A1 for condensing the gaseous working fluid by dissolving it in a solvent solution, a pump P1 for pumping the solvent solution containing the dissolved working fluid to increase the pressure, evaporator E1 for evaporating the working fluid, and a separator S1 for separating the evaporated working fluid from the solvent solution.

The first regeneration stage includes an influent line 1—1 into which the spent gaseous working fluid from the spent line 56 and solvent solution from a solvent solution recycle line 1—13 are fed into the first stage and through the absorber A1.

The resultant solvent solution from the absorber A1 is fed along line 1—2 to the inlet of pump P1. The solution is discharged from the pump P1 at an increased pressure along line 1—3 and through the evaporator E1. The solvent solution and evaporated working fluid are fed from the evaporator E1 along line 1—4 to the separator S1. The separator evaporated working fluid is fed from the separator S1 along line 1—5 to the influent line 2—1 of the second stage. The solvent solution from the separator S1 is recycled along solvent solution recycle line 1—13 to the influent line 1—1.

The second, third and fourth regeneration stages correspond exactly with the first regeneration stage except that the evaporated, separated working fluid from the separator S4 is withdrawn along line 4—5 and fed into the charged line 54 to repeat the cycle.

In the preferred embodiment of the invention, the gaseous working fluid is ammonia, whereas the solvent is water. In addition, in the preferred embodiment of the invention, the apparatus 50 is an apparatus for use in producing energy by ocean thermal energy conversion.

The apparatus 50 is, therefore, conveniently installed on the seashore or on a floating platform. In addition, the apparatus 50 includes pump means [not shown] for pumping surface water from the surface of an ocean to the evaporators of the apparatus to constitute the heating medium for the apparatus, and includes pump means [not shown] for pumping cold water from a sufficient depth of such an ocean for constituting the cooling medium for cooling the absorbers of the apparatus 50.

Thus, the absorber A1 includes circulation means having an inlet 1—9 and an outlet 1—10 for circulating deep ocean water through the absorber A1. Similarly, the evaporator E1 includes an inlet 1—11 and an outlet 1—12 for circulating ocean surface water through the evaporator for heating the evaporator E1.

Further, in each regeneration stage, the recycle line 1—13, 2—13, 3—13 and 4—13 has an evaporator heat exchanger line 1—15, 2—15, 3—15 and 4—15, respectively, passing in heat exchange relationship through the evaporator E.

In addition, in each of the regeneration stages, the solvent solution recycle line —13 may have a condenser heat exchange line 1—16, 2—16, 3—16 and 4—16, respectively, extending in heat exchange relationship through the absorber A or, alternatively, may completely bypass the absorber A as indicated by chain-dotted lines 1—18, 2—18, 3—18 and 4—18.

Where the recycled solvent solution passes in heat exchange relationship through the absorber of each regeneration stage, it will assist in cooling the absorber and will thus reduce the quantity of cooling water required to effect the required cooling in that absorber since the quantity of heat to be transferred will remain constant. It will, however, necessitate an increase in the absorber capacity and thus, in the absorber size.

In practice, therefore, the capital cost of an increase in absorber size can be balanced against the cost of the additional quantity of cooling medium to decide, on the basis of pure economics, as to whether the recycle line should pass through the absorbers, should completely bypass the absorbers, or should pass partially through the absorbers.

In the preferred embodiment of the invention, the recycle lines will bypass the absorbers.

In the preferred embodiment of the invention, the gaseous working fluid is ammonia, whereas the solvent solution is a solution of ammonia in water.

The use of the apparatus 50, and thus the process of this invention, is now described with reference to a preferred ocean thermal energy conversion system typically employing, as heating medium, surface water at a temperature of 27°C, and employing as cooling medium, deep ocean water [typically at a depth of not less than about 200 feet (61 m)] having a temperature of about 4°C.

Since the boiling point of pure ammonia is −33°C at a pressure of one atmosphere (0.0986 bar), and since the minimum temperature of the cold water cooling medium is 4°C, it would normally not be possible to regenerate ammonia at a pressure of one atmosphere (0.986 bar) by using such a cooling medium. In other words, regeneration would only be possible if the ammonia working fluid were at a pressure where the boiling point of ammonia is above 4°C.

In other words, regeneration of the gaseous working fluid would only be possible if the working fluid is expanded across the turbine 52 to a pressure at which it is capable of regeneration with the available cooling medium. This imposes a direct and severe limitation on the energy which can be generated since the maximum pressure to which the ammonia working fluid can be regenerated is also limited by the evaporation capacity of the hot water heating medium at 27°C.

In practice, utilizing surface water at a temperature of about 27°C, evaporation of ammonia in the final evaporator E4 can only be achieved in an effective manner at a maximum pressure of about nine atmospheres (8.882 bar).

It will be appreciated, therefore, that if the working fluid can be expanded from a charged level of nine atmospheres (8.882 bar) to a spent level pressure of one atmosphere (0.986 bar), as opposed to a spent level pressure of say only four atmospheres (3.947 bar), the quantity of energy released will be increased substantially.

In the preferred process as illustrated in Figure 1, the gaseous ammonia working fluid is indeed allowed to expand across the turbine 52 from a pressure of about nine atmospheres (8.882 bar) to a pressure of about one atmosphere (0.986 bar).

A specific quantity of gaseous working fluid to be regenerated, at a spent pressure level of one atmosphere (0.986 bar) is, therefore fed to the first stage alone influent line 1—1.

This quantity of gaseous working fluid is condensed in the absorber A1 by dissolving it in a solvent solution which is fed along solvent solution recycle line 1—13 into the influent line 1—1 at the same pressure of one atmosphere (0.986 bar).

In the preferred embodiment of the invention, the solvent solutions will not be passed in heat exchange relationship through the absorbers. Thus, the spent gaseous ammonia, which may contain about 10% by weight of liquid ammonia, will be at a temperature of about −33°C, whereas the corresponding solvent solution will be at a temperature of about 8°C.

The solvent solution comprises water having an initial ammonia concentration which is sufficient to provide a binary solution which at the pressure of one atmosphere (0.986 bar), has a boiling point within the temperature range which will prevail in the absorber A1. Further, the proportion of solvent solution to the quantity of working fluid to be regenerated is such that after the solvent solution has dissolved the quantity of working fluid to be regenerated in the absorber A1, the resultant binary solution will have a concentration which will provide, at the pressure of one atmosphere (0.986 bar), a boiling point marginally above the minimum temperature of the cooling medium. The boiling point of the solvent solution will thus be in the region of about 6°C where the minimum temperature of the cold water is about 4°C.

In this way it will be insured that the total quantity of working fluid to be regenerated will dissolve in the solvent solution, and that the minimum quantity of solvent solution to dissolve that quantity of gaseous ammonia will be employed thereby reducing the cold water requirements and the capacity of the absorber A1 to the practical minimum.

The solvent solution containing the dissolved working fluid being regenerated, will leave the absorber A1 at a temperature of about 6°C and at a pressure of one atmosphere (0.986 bar), and is pumped by the pump P1 to the evaporator E1.

The pump P1 is controlled to increase the pressure of the solvent solution to the maximum pressure at which the dissolved ammonia working fluid can be effectively evaporated in the evaporator E1 by means of the surface water heating medium at a maximum temperature of 27°C.

Preferably, the pressure increase is controlled so that after evaporation of the quantity of working fluid being regenerated, the solvent solution in the evaporator E1 will have a boiling point marginally below 27°C, such as about 25°C.

This pressure can readily be determined from a binary water/ammonia phase diagram in relation to the prevailing ammonia concentration and temperature range in the evaporator E1.

It will naturally be appreciated that the initial concentration of ammonia in water for the solvent solution, as also the required quantity of solvent solution; which is fed to the absorber A1, can also readily be determined from such a phase diagram on the basis of the known pressure and temperature range.

The evaporated working fluid and solvent solution are fed along line 1—4 to the separator S1, where they are allowed to separate.

From the separator S1, the solvent solution, at a temperature of about 25°C will be recycled along the solvent solution recycle line 1—13 to constitute the solvent solution for the first stage. The separated, evaporated ammonia working fluid at about 25°C is fed from the separator S1 to the second regeneration stage along influent line 2—1. As in the case of the first regeneration stage, the quantity of working fluid being regenerated, is mixed with a solvent solution recycled from a separator S2 of the second regeneration stage along the solvent solution recycle line 2—13 for dissolving the working fluid in the absorber A2.

Since the pressure in the absorber A2 will be greater than the pressure in the absorber A1, it follows that the initial concentration of ammonia in the solvent solution for the second stage will be correspondingly higher to insure that an appropriate boiling point is again provided for effectively dissolving or absorbing the working fluid being regenerated in the absorber A2.

It will be appreciated that the solvent solution which is recycled from the separator S to the absorber A in each stage leaves the separator S at a higher pressure than the pressure of the influent working fluid. Each solvent solution recycle line 1—13, 2—13, 3—13 and 4—13, therefore, includes a pressure-reducing valve V1, V2, V3 and V4, respectively, for reducing the pressure of the recycled solvent solution to the same pressure as that of the influent working fluid being regenerated.

For each successive regeneration stage, therefore, the initial concentration of ammonia in the solvent solution will increase step-wise in correspondence with the step-wise increase in pressure provided by the pump means in each stage.

It will be appreciated that the apparatus will include an appropriate number of regeneration stages until the quantity of working fluid being regenerated, has been regenerated to the appropriate charged high pressure level in a final regeneration stage such as the fourth regeneration stage shown in the drawing. It will further be appreciated that the spent pressure level to which the working fluid is expanded, will likewise determine the number of regeneration stages required. Thus if the working fluid is expanded to only say 3 atmospheres (2.649 bar), only two or three regeneration stages may be required.

In the embodiment illustrated in the drawing, the pump means P4 will increase the pressure of the solvent solution to about nine atmospheres (8.882 bar) thereby yielding a charged regenerated working fluid at a pressure of about nine atmospheres (8.882 bar) which is withdrawn from the separator S4 and fed along the charged line 54 to the turbine 52.

It will be appreciated that in the preferred embodiment of the invention, the process will be carried out as a continuous process in which a constant quantity of working fluid by unit time is continuously being expanded across the turbine 52 and is then continuously being regenerated in the regeneration means.

To further illustrate the use of the invention in the preferred embodiment as illustrated in Figure 1, typical parameters of the process are now indicated with reference to specific theoretical calculations performed on the basis of 1 kilogram of gaseous ammonia working fluid, and on the basis of deep ocean water at a minimum temperature of 4°C as cooling medium, and surface ocean water at a maximum temperature of 27°C as heating medium.

These parameters as calculated are set out in Tables I, II, III and IV below for the first, second, third and fourth regeneration stages, respectively.

In each table, the particular point at which the parameter has been calculated, is indicated by the appropriate reference numeral in the drawing. These points are listed in the first column of each table.

The colums in the tables are as follows:

(a) First column—reference numerals (RN);
(b) Second column—temperature (t) in °C;
(c) Third column—pressure (p) in atmospheres;
(d) Fourth column—ratio by weight of total ammonia (dissolved and undissolved) to water plus total ammonia (RATIO);
(e) Fifth column—weight (w) in kilograms; and
(f) Sixth column—Enthalpy (E) in kcal/g.

TABLE I

RN	t	p (bar)	RATIO	w	E
1—0	−32.0	1.0 (0.986)	.9920	1.0000	354.45
1—1	+9.0	1.0 (0.986)	.4266	22.2556	−642
1—2	+6.0	1.0 (0.986)	.4266	22.2556	−20.0
1—3	+6	1.8 (1.776)	.4266	22.2556	−20.0
1—4	+25.0	1.8 (1.776)	.4266	22.2556	17.9730
1—5	+25.0	1.8 (1.776)	.9920	1.0000	400.0
1—6	+25.0	1.8 (1.776)	.4000	21.2556	0.0
1—7	+8.0	1.8 (1.776)	.4000	21.2556	−23.4
1—8	+8.0	1.0 (0.986)	.4000	21.2556	−23.4

TABLE II

RN	t	p (bar)	RATIO	w	E
2—1	+10.0	1.8 (1.776)	.5160	17.2457	9.4125
2—2	+6.0	1.8 (1.776)	.5160	17.2457	−10.80
2—3	+6.0	3.0 (2.649)	.5160	17.2457	−10.80
2—4	+25.0	3.0 (2.649)	.5160	17.2457	28.6905
2—5	+25.0	3.0 (2.649)	.9920	1.0000	403.0
2—6	+25.0	3.0 (2.649)	.4867	16.2457	5.65
2—7	+8.0	3.0 (2.649)	.4867	16.2457	−14.63
2—8	+8.0	1.8 (1.776)	.4867	16.2457	−14.63

TABLE III

RN	t	p (bar)	RATIO	w	E
3—1	+10.0	3.0 (2.649)	.6490	8.0000	48.625
3—2	+6.0	3.0 (2.649)	.6490	8.0000	10.00
3—3	+6.0	5.0 (4.934)	.6490	8.0000	10.00
3—4	+25.0	5.0 (4.934)	.6490	8.0000	68.688
3—5	+25.0	5.0 (4.934)	.9920	1.0000	409.5
3—6	+25.0	5.0 (4.934)	.6000	7.0000	20.00
3—7	+8.0	5.0 (4.934)	.6000	7.0000	−2.00
3—8	+8.0	3.0 (2.649)	.6000	7.0000	−2.00

TABLE IV

RN	t	p (bar)	RATIO	w	E
4—1	+10.0	5.0 (4.934)	0.9000	5.4231	124.45
4—2	+6.0	5.0 (4.934)	0.9000	5.4231	80.0
4—3	+6.0	9.0 (8.882)	.9000	5.4231	80.0
4—4	+25.0	9.0 (8.882)	.9000	5.4231	139.59
4—5	+25.0	9.0 (8.882)	.9920	1.0000	412.0
4—6	+25.0	9.0 (8.882)	.8792	4.4231	78.0
4—7	+8.0	9.0 (8.882)	.8792	4.4231	60.0
4—8	+8.0	9.0 (8.882)	.8792	4.4231	60.0
4.9	+8.0	5.0 (4.934)	.8792	4.4231	60.0

From the above theoretical calculations, the total heat supplied to the four evaporator stages amounted to 1258.35 kcals, while the total heat removed from the four absorption stages amount to 1200.8 kcals.

The difference of 57.55 is the work put in per kilogram of working fluid regenerated and thus the theoretical amount of work which is available.

The energy required to operate the pumps was calculated to be 2.08 kkals/kg of working fluid regenerated.

The theoretical amounts of work available is therefore 55.47 kcal/kg of working fluid.

If it is assumed that the efficiency of the turbine is 85%, the theoretical thermal efficiency will be 4.408%.

The theoretical thermal efficiency of an ideal Carnot cycle system operating with a cooling medium at a constant temperature of 4°C and with a heating medium at a constant temperature of 27°C, would be 7.04%. However, considering that the temperature of the heating and cooling mediums must change in such a process, the efficiency of the theoretical ideal thermodynamical cycle will be only about 4.9%.

Therefore, the ratio of the efficiency of a system in accordance with this invention on the basis of the theoretical calculations, would be:

(a) 62.55% in relation to an ideal Carnot cycle system;

(b) about 82% in relation to an ideal thermodynamical cycle under corresponding conditions.

It is an advantage of the embodiment of the invention as illustrated with reference to the drawing, that an effective system can be provided for generating energy by using the relatively low temperature differential between surface ocean water as heating medium and deep ocean water as cooling medium.

It is a further advantage of this embodiment that a system can be provided for regeneration of spent gaseous ammonia at a relatively low level of about one atmosphere (0.986 bar) or less.

It is a further advantage of the embodiment of the invention as illustrated, that because the regeneration range of the gaseous working fluid has been increased, the gaseous working fluid can be expanded from a high pressure level of about nine atmospheres (8.882 bar), to a low pressure level of about one atmosphere (0.986 bar) or less. Thus, the quantity of energy available for release is substantially greater than would be the case if the working fluid were expanded from a pressure of about nine atmospheres (8.882 bar) to a pressure of only about four or five atmospheres (3.9476 or 4.934 bar).

The embodiment of the invention as illustrated in the drawing can provide a further advantage arising from the fact that the cold water requirements need only be sufficient to provide a final temperature in each absorber of about 6°C. The temperature of the cold water cooling medium can thus increase across each absorber as indicated in the above tables. Thus, the cooling medium requirements will be substantially less than would be the case if it were necessary to supply a sufficient quantity of cooling water at a sufficient rate to approach the Carnot cycle ideal where the cooling medium would remain at the constant minimum temperature. The same considerations apply to the heating medium, where the hot water is allowed to cool from about 27°C to the temperature indicated in the above tables across each evaporator stage thereby again providing a substantially reduced heating water requirement over that required by the ideal Carnot cycle operation.

It will be appreciated that since, in each absorber, the cooling range for the solvent solution and working fluid is substantially the same, and the temperature range for the cooling medium is substantially the same, the absorbers of the four regeneration stages can conveniently be combined into a single composite absorber through which the lines 1—1, 2—1, 3—1 and 4—1 pass separately for cooling by means of a single circulating supply of cold water. In the same way, all the evaporators can be combined in a single composite evaporator heated by means of the circulating hot water from a single source.

It will further be appreciated that, theoretically the quantity of solvent solution in each regeneration stage should remain constant, and that the initial concentration of ammonia in water to constitute the solvent solution, should also remain constant for constant minimum cooling water temperatures and constant maximum heating water temperatures.

In practice, however, the quantity of solvent solution will have to be adjusted during use to compensate for varying conditions and for losses. In addition, the concentration of ammonia in water in each regeneration stage, will have to be adjusted periodically in relation to seasonal variations in the minimum temperature of cold water and maximum temperature of hot water.

It will also be appreciated that where heating of the hot water can economically be achieved, such as by solar heating or the like, the effectiveness of the process of this invention can be improved. Such supplemental heating will, therefore, be employed under appropriate conditions if dictated by economic considerations.

With reference to Figure 2 of the drawings, numeral 150 refers generally to an alternative embodiment of the method and apparatus of this invention to the embodiment illustrated in Figure 1.

The apparatus 150 corresponds substantially with the apparatus 50 and corresponding parts are indicated by corresponding reference numerals.

In the apparatus 150, in place of the single turbine 52 of the apparatus 50, a two-stage turbine system is employed comprising a first turbine 152 and a second turbine 53.

The charged working fluid is partially expanded across the first turbine 152 into a vessel 170.

From the vessel 170 the partially expanded working fluid is led along separate conduits 171 and 172 through the absorber A2 and through the absorber A1 respectively in heat exchange relationship with the cooling water. This is done to reduce the temperature of the cooling water which can be useful in certain circumstances, at the expense of raising the temperature of the partially expanded working fluid before it is expanded fully through the second turbine 53.

Thereafter the partially spent working fluid is further expanded across the second turbine 53 to its final spent level. It is then fed as before, along the spent line 56 to the influent line 1—1.

Applicant believes that by utilizing a two-stage turbine system with heat exchange of the partially expanded working fluid, the effectiveness of the system can be improved particularly where the system includes a number of regeneration stages. Applicant believes that it will tend to be less significant where fewer stages are employed.

With reference to Figure 3 of the drawings, the drawing shows, to an enlarged scale, the apparatus of Figure 1 which has been adapted in the first and second regeneration stages for the pressure of the recycled solvent solution to be utilized in increasing the pressure of the influent spent working fluid into the absorption stage A1 and the absorption stage A2 respectively.

As indicated in Figure 3, the absorption stage A1 incorporates an injection system for injecting the recycled solvent solution at a pressure substantially higher than the pressure of the spent working fluid into the absorber A1.

The injection system is in the form of an injection nozzle 180 having an intermediate restricted zone to generate a zone of low pressure.

The spent line 56 joins the nozzle 180 at the restricted zone and, as is known those skilled in the art, in an attitude where the reduced pressure generated at the restricted zone by the solvent solution being injected through the nozzle 180 into the absorber A1, will draw the spent working fluid into the nozzle 180 and thus into the absorber A1.

It will be appreciated that the effectiveness of this system will depend upon the mass ratio between the solvent solution being recycled and the working fluid being regenerated.

If the ratio is to low, it will not be possible to introduce the total quantity of working fluid being regenerated by means of the flow of the solvent solution being recycled.

In practice therefore, depending upon conditions, it may be necessary to partially reduce the pressure of the solvent solution being recycled before entry into the nozzle 180, or it may be necessary to introduce some of the working fluid being regenerated through the nozzle 180, and the remainder directly into the absorber A1.

While the absorber A2 has not been illustrated in Figure 3, it will be appreciated that the working fluid being regenerated in the second regeneration stage will be introduced into the absorber A2 by means of an injection system corresponding to that of the absorber A1.

The embodiment of the invention as illustrated in Figure 3 of the drawings, can provide the advantage that the pressure of the solvent solution being recycled in the first and second stages respectively can be at least partially utilized to introduce the working fluid being regenerated, and to increase the pressure in the first and second absorbers A1 and A2.

This affect can be utilized to improve the effectiveness of absorption in the first and second absorbers A1 and A2. Alternatively, or in addition, this feature can be utilized to permit expansion of the charged working fluid to a yet lower pressure across the turbine 52, with reliance being placed on the pressure contribution of the solvent solution being recycled to raise the pressure in the absorber A1 to a level where effective absorption of the working fluid being regenerated can be effected. Similarly, if employed in relation to the second regeneration stage, the same considerations wil apply where the working fluid introduced into the absorber A2 can be at a lower pressure, and reliance is placed on the pressure of the solvent solution being recycled into the absorber A2, to increase the pressure to a level for effective absorption in the absorber A2.

Applicant believes that the injection system can be advantageous in the apparatus 50 particularly in the first and second stages, but would tend to have lesser value in subsequent stages.

Claims

1. A method of generating energy, which comprises expanding a gaseous working fluid from a charged high pressure level to a spent low pressure level to release energy, and regenerating the spent working fluid by condensing the working fluid in an absorption stage by dissolving it in a solvent solution while cooling with a cooling medium, increasing the pressure of the solvent solution containing the dissolved working fluid and evaporating the working fluid being regenerated by heating in an evaporation stage, withdrawing the evaporated working fluid for re-expansion to release energy, and recycling the balance of the solvent solution remaining after evaporation of the working fluid to constitute the solvent solution for the absorption stage, characterized in that the spent working fluid is regenerated in a plurality of successive regeneration stages by the steps of:—

(a) in a first regeneration stage condensing the spent working fluid in a first absorption stage by dissolving it in a solvent solution while cooling with a cooling medium, the solvent solution comprising a solvent having an initial working fluid concentration which is sufficiently low to provide a solvent solution boiling range suitable for absorption of the working fluid;

(b) increasing the pressure of the solvent solution containing the dissolved working fluid in the first regeneration stage and evaporating the working fluid being regenerated by heating in a first evaporation stage;

(c) recycling the balance of the solvent solution remaining after evaporation of the working fluid in the first evaporation stage, to constitute the solvent solution for the first absorption stage of that first regeneration stage;

(d) feeding the evaporated working fluid from the first regeneration stage to a succeeding regeneration stage;

(e) subjecting the evaporated working fluid from each preceding regeneration stage to corresponding regeneration in each succeeding regeneration stage to produce a charged working fluid in each succeeding stage which is at a higher pressure than the working fluid entering that stage; and

(f) withdrawing regenerated charged gaseous working fluid from a final regeneration stage for re-expansion to release energy.

2. A method according to claim 1, characterized in that the spent working fluid is regenerated in between two and four successive regeneration stages.

3. A method according to claim 1 or claim 2, characterized in that the working fluid is expanded to a spent low pressure level at which the condensation temperature of the working fluid is below the minimum temperature of the cooling medium.

4. A method according to any one of claims 1 to 3, characterized in that, in each regeneration stage, the initial concentration of working fluid in the solvent solution is sufficient, and the proportion of solvent solution to working fluid to be regenerated is such that after absorption of the working fluid being regenerated in that absorption stage, the solvent solution will have a boiling point marginally above the minimum temperature attained in that absorption stage.

5. A method according to any one of claims 1 to 4, characterized in that the pressure is increased between the absorption and evaporation stages of each regeneration stage to about the maximum pressure at which the working fluid being regenerated in that stage can be evaporated from the solvent solution in the evaporation stage by a heating medium available for heating the evaporation stage.

6. A method according to any one of claims 1 to 5, characterized in that, in each regeneration stage, the solvent solution and evaporated working fluid are fed from the evaporation stage to a separation stage for separating the working fluid being regenerated, and in that, in each regeneration stage, the solvent solution which is recycled to the absorption stage is expanded to reduce its pressure to the pressure of the working fluid being regenerated in that absorption stage.

7. A method according to any one of claims 1 to 6, characterized in that, in each regeneration stage, the solvent solution which is recycled is recycled at least partially in heat exchange relationship with the solvent solution containing the dissolved working fluid between the absorption and evaporation stages.

8. A method according to any one of claims 1 to 7, characterized in that all of the absorption stages of the successive regeneration stages are carried out separately in a single composite absorption stage which is cooled by means of the cooling medium, and in that all of the evaporation stages of the successive regeneration stages are carried out separately in a single composite evaporation stage.

9. A method according to any one of claims 1 to 8, characterized in that the cooling medium is provided by cool water withdrawn from a body of water, and in that each evaporation stage is heated by means of hot water withdrawn from the same body of water.

10. A method according to any one of claims 1 to 9, characterized in that the working fluid being regenerated is introduced into each absorption stage at a pressure where the condensation temperature of the working fluid is below the minimum temperature of the cooling medium.

11. A method according to claim 4, characterized in that, in each regeneration stage, the proportion of solvent solution to working fluid being regenerated is approximately the minimum quantity which will, after absorption of the working fluid being regenerated in that absorption stage, provide a boiling point which is marginally above the minimum temperature attained in that absorption stage.

Patentansprüche

1. Verfahren zur Energie-Erzeugung unter Expansion eines gasförmigen Arbeitsfluids von einem hohen Ladungsdruckniveau zu einem niedrigen Auslaufdruckniveau zur Energie-Freigabe und zur Regeneration des verbrauchten Arbeitsfluids durch Kondensation des Arbeitsfluids in einer Absorptionsstufe mittels seiner Auflösung in einer Lösungsmittellösung, während es mit einem Abkühlungsmittel abgekühlt wird, Erhöhung des Druckes der Lösungmittellösung, die das aufgelöste Arbeitsfluid enthält, und Verdampfung des regenerierenden Arbeitsfluids durch Erwärmung in einer Verdampfungsstufe, Abziehen des verdampften Arbeitsfluids zur Re-Expansion unter Energie-Freigabe, sowie Recycling bzw. Zurückführung des Ausgleichs der Lösungsmittellösung, das nach der Verdampfung des Arbeitsfluids übrigbleibt, und die Lösungmittellösung für die Absorptionsstufe darstellt, dadurch gekennzeichnet, daß das verbrauchte Arbeitsfluid in einer Vielzahl von aufeinanderfolgenden Regenerationsstufen durch folgende Schritte gekennzeichnet wird:

(a) in einer ersten Regenerationsstufe wird das verbrauchte Arbeitsfluid in einer ersten Absorptionsstufe kondensiert, indem es in einer Lösungsmittellösung aufgelöst wird, während mit einem Kühlungsmittel gekühlt wird, wobei die Lösungsmittellösung ein Lösungsmittel umfaßt, das eine Anfangsarbeitsfluidkonzentration besitzt, die ausreichend niedrig ist, um einen

Lösungsmittellösungssiedebereich vorzusehen, der zur Absorption des Arbeitsfluids geeignet ist;

(b) Erhöhung des Druckes der Lösungsmittellösung, die das aufgelöste Arbeitsfluid in der ersten Regenerationsstufe enthält, und Verdampfung des regenerierenden Arbeitsfluids durch Erwärmung in einer ersten Verdampfungsstufe;

(c) Recycling des Ausgleiches der nach der Verdampfung des Arbeitsfluids in der ersten Verdampfungsstufe verbleibenden Lösungsmittellösung unter Ausbildung der Lösungsmittellösung zur ersten Absorptionsstufe der ersten Regenerationsstufe;

(d) Zuführung des verdampften Arbeitsfluids an einer ersten Regenerationsstufe zu einer anschließenden Regenerationsstufe;

(e) Unterwerfen des verdampften Arbeitsfluids einer jeden vorhergehenden Regenerationsstufe einer entsprechenden Regeneration in jeder nachfolgenden Regenerationsstufe unter Erzeugung eines Ladungsarbeitsfluids in jeder nachfolgenden Stufe, die einen höheren Druck besitzt, als das in dieser Stufe eintretende Arbeitsfluid; und

(f) Abziehen des regenerierten gasförmigen Ladungsarbeitsfluids aus einer Endregenerationsstufe zur Re-Expansion unter Energiefreigabe.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß das verbrauchte Arbeitsfluid zwischen zwei und vier aufeinanderfolgenden Regenerationsstufen regeneriert wird.

3. Verfahren nach Anspruch 1 oder Anspruch 2, dadurch gekennzeichnet, daß das Arbeitsfluid zu einem niedrigen Verbrauchs- bzw. Auslaufdruckniveau expandiert wird, bei dem die Kondensationstemperatur des Arbeitsfluids unter der Minimaltemperatur des Kühlmittels liegt.

4. Verfahren nach irgendeinem der Ansprüche 1 bis 3, dadurch gekennzeichnet, daß die Anfangskonzentration des Arbeitsfluids in jeder Regenerationsstufe in der Lösungsmittellösung ausreichend ist, und daß das Verhältnis von Lösungsmittellösung und zu regenerierendem Arbeitsfluid derart ist, daß nach der Absorption des sich regenerierenden Arbeitsfluids in der Absorptionsstufe die Lösungsmittellösung einen Kochpunkt besitzt, der nur geringfügig über der Minimaltemperatur liegt, die in dieser Absorptionsstufe erreicht wird.

5. Verfahren nach irgendeinem der Ansprüche 1 bis 4, dadurch gekennzeichnet, daß der Druck zwischen den Absorptions- und Verdampfungsstufen jeder Regenerationsstufe bis etwas zum höchsten Druck erhöht wird, bei dem das zu regenerierende Arbeitsfluid in der Stufe aus der Lösungsmittellösung in der Verfampfungsstufe durch ein Heizmedium verdampft werden kann, das zur Erwärmung in der Verdampfungsstufe zur Verfügung steht.

6. Verfahren nach irgendeinem der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß in jeder Regenerationsstufe die Lösungsmittellösung und das verdampfte Arbeitsfluid von der Verdampfungsstufe zu einer Trennungsstufe geführt werden, um das sich regenerierende Arbeitsfluid abzutrennen, und daß in jeder Regenerationsstufe die Lösungsmittellösung, die zur absorptionsstufe recyclisiert wird, expandiert wird, um ihren Druck auf den Druck des Arbeitsfluids zu reduzieren, das in dieser Absorptionsstufe regeneriert wird.

7. Verfahren nach irgendeinem der Ansprüche 1 bis 6, dadurch gekennzeichnet, daß in jeder Regenerationsstufe die Lösungsmittellösung, die recyclisiert wird, mindestens teilweise in Wärmeaustauschbeziehung zur Lösungsmittellösung recyclisiert wird, die das aufgelöste Arbeitsfluid zwischen den Absorptions- und Verdampfungsstufen enthält.

8. Verfahren nach irgendeinem der Ansprüche 1 bis 7, dadurch gekennzeichnet, daß sämtliche Absorptionsstufen der aufeinanderfolgenden Regenerationsstufen getrennt in einer einzigen Verbundabsorptionsstufe durchgeführt werden, die mittels des Kühlmediums gekühlt wird, und daß sämtliche Verdampfungsstufen der aufeinanderfolgenden Regenerationsstufen getrennt in einzer einzigen Verbundverdampfungsstufe ausgeführt werden.

9. Verfahren nach irgendeinem der Ansprüche 1 bis 8, dadurch gekennzeichnet, daß das Kühlmittel durch Kühlwasser gebilder wird, das aus einem Kühlbehälter abgezogen wird, und daß jede Verdampfungsstufe mittels Heißwasser erwärmt wird, das von dem gleichen Wasserbehälter abgezogen wird.

10. Verfahren nach irgendeinem der Ansprüche 1 bis 9, dadurch gekennzeichnet, daß das zu regenerierende Arbeitsfluid in jede Absorptionsstufe mit einem Druck eingeführt wird, bei dem die Kondensationstemperatur des Arbeitsfluids unterhalb der Minimaltemperatur des Kühlmediums liegt.

11. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß in jeder Regenerationsstufe der Anteil der Lösungsmittellösung zum zu regenerierenden Arbeitsfluid annähernd die minimale Menge beträgt, die nach Absorption des zu regenerierenden Arbeitsfluids in der Absorptionsstufe einen Kockpunkt liefert, der nur geringfügig über der Minimaltemperatur liegt, die in dieser Absorptionsstufe erreicht wird.

Revendications

1. Procédé de génération d'énergie, qui consiste à détendre un fluide gazeux de travail d'un niveau de pression élevé chargé à un niveau de pression bas usé pour libérer de l'énergie, et à régénérer le fluide de travail usé en condensant le fluide de travail dans un étage d'absorption par dissolution de ce fluide dans une solution de solvant, en même temps qu'il est refroidi à l'aide d'un milieu de refroidissement, à élever la pression de la solution de solvant contenant le fluide de travail dissous et à évaporer le fluide de travail en cours de régénération par chauffage dans un étage d'évaporation, à soutirer le fluide de travail évaporé pour le détendre de nouveau

afin de libérer de l'énergie et à recycler la partie restante de la solution de solvant subsistant après l'évaporation du fluide de travail afin de constituer la solution de solvant pour l'étage d'absorption, caractérisé en ce que le fluide de travail usé est régénéré dans plusieurs étages successifs de régénération par les étapes qui consistent:

(a) dans un premier étage de régénération, à condenser le fluide de travail usé dans un premier étage d'absorption en le dissolvant dans une solution de solvant en même temps qu'il est refroidi à l'aide d'un milieu de refroidissement, la solution de solvant comprenant un solvant ayant une conventration initiale en fluide de travail qui est suffisamment basse pour établir une plage d'ébullition de la solution de solvant convenant à l'absorption de fluide de travail;

(b) à élever la pression de la solution de solvant contenant le fluide de travail dissous dans le premier étage de régénération et évaporer le fluide de travail en cours de régénération par chauffage de ce fluide dans un premier étage d'évaporation;

(c) à recycler la partie restante de la solution de solvant subsistant après l'évaporation du fluide de travail dans le premier étage d'évaporation, afin de constituer la solution de solvant pour le premier étage d'absorption de ce premier étage de régéneration;

(d) à charger le fluide de travail évaporé du premier étage de régénération vers un étage suivant de régénération;

(e) à soumettre le fluide de travail évaporé provenant de chaque étage précédent de régénération à une régénération correspondante dans chaque étage suivant de régénération afin de produire, dans chaque étage suivant, un fluide de travail chargé qui est à une pression plus élevée que celle du fluide de travail entrant dans cet étage; et

(f) à retirer le fluide de travail gazeux chargé régénéré d'un étage final de régénération pour une nouvelle détente pour la libération d'énergie.

2. Procédé selon la revendication 1, caractérisé en ce que le fluide de travail usé est régénéré dans deux à quatre étages successifs de régénération.

3. Procédé selon la revendication 1, ou la revendication 2, caractérisé en ce que le fluide de travail est détendu à un niveau de pression bas usé auquel la température de condensation du fluide de travail est inférieure à la température minimale du milieu de refroidissement.

4. Procédé selon l'une quelconque des revendications 1 à 3, caractérisé en ce que, dans chaque étage de régénération, la concentration initiale de fluide de travail dans la solution de solvant est suffisante, et la proportion de solution de solvant au fluide de travail à régénérer est telle qu'après l'absorption du fluide de travail en cours de régénération dans cet étage d'absorption, la solution de solvant présente un point d'ébullition marginalement supérieur à la température minimale atteinte dans cet étage d'absorption.

5. Procédé selon l'une quelconque des revendications 1 à 4, caractérisé en ce que la pression est élevée entre les étages d'absorption et d'évaporation de chaque étage de régénération à environ la pression maximale à laquelle le fluide de travail en cours de régénération dans cet étage peut être évaporé à partir de la solution de solvant dans l'étage d'évaporation par un milieu chauffant disponible pour le chauffage de l'étage d'évaporation.

6. Procédé selon l'une quelconque des revendications 1 à 5, caractérisé en ce que, dans chaque étage de régénération, la solution de solvant et le fluide de travail évaporé sont chargés de l'étage d'évaporation vers un étage de séparation destiné à séparer le fluide de travail en cours de régénération, et en ce que, dans chaque étage de régénération, la solution de solvant qui est recyclée vers l'étage d'absorption, est détendue afin que sa pression soit réduite à la pression du fluide de travail en cours de régénération dans cet étage d'absorption.

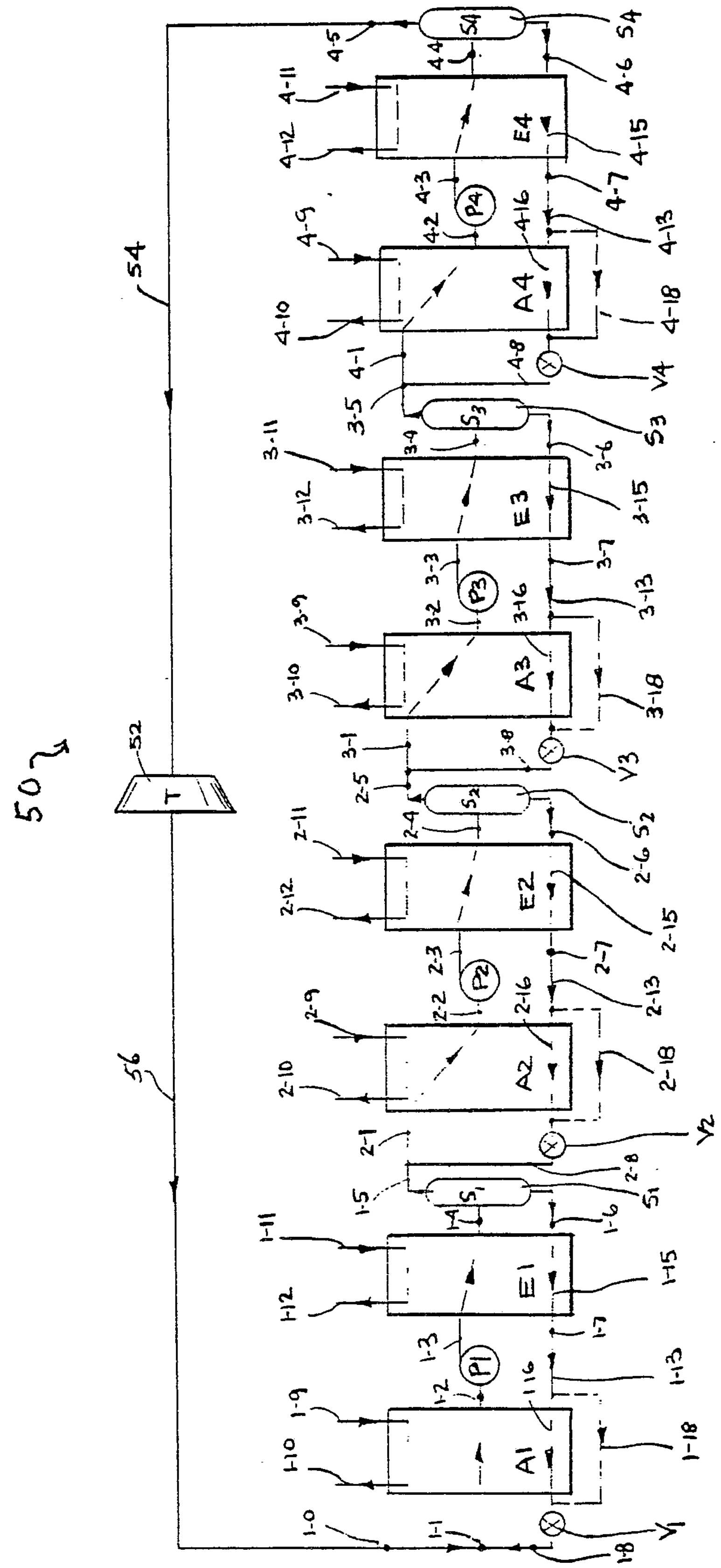
7. Procédé selon l'une quelconque des revendications 1 à 6, caractérisé en ce que, dans chaque étage de régénération, la solution de solvant qui est recyclée est recyclée au moins partiellement en relation d'échange de chaleur avec la solution de solvant contenant le fluide de travail dissous entre les étages d'absorption et d'évaporation.

8. Procédé selon l'une quelconque des revendications 1 à 7, caractérisé en ce que tous les étages d'absorption des étages de régénération successifs sont mis en oeuvre séparément dans un seul étage composé d'absorption qui est refroidi au moyen du milieu de refroidissement, et en ce que tous les étages d'évaporation des étages successifs de régénération sont mis en oeuvre séparément dans un seul étage composé d'évaporation.

9. Procédé selon l'une quelconque des revendications 1 à 8, caractérisé en ce que le milieu de refroidissement est fourni par de l'eau froide soutirée d'une masse d'eau, et en ce que chaque étage d'évaporation est chauffé au moyen d'eau chaude soutirée de la masse d'eau.

10. Procédé selon l'une quelconque des revendications 1 à 9, caractérisé en ce que le fluide de travail en cours de régénération est introduit dans chaque étage d'absorption à une pression à laquelle la température de condensation du fluide de travail est inférieure à la température minimale du milieu de refroidissement.

11. Procédé selon la revendication 4, caractérisé en ce que, dans chaque étage de régénération la proportion de solution de solvant au fluide de travail en cours de régénération est approximativement égale à la quantité minimale qui, après absorption du fluide de travail en cours de régénération dans cet étage d'absorption, établit un point d'ébullition qui est marginalement supérieur à la température minimale atteinte dans cet étage d'absorption.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52
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A2
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P3
P4
S1
S2
S3
S4
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V3
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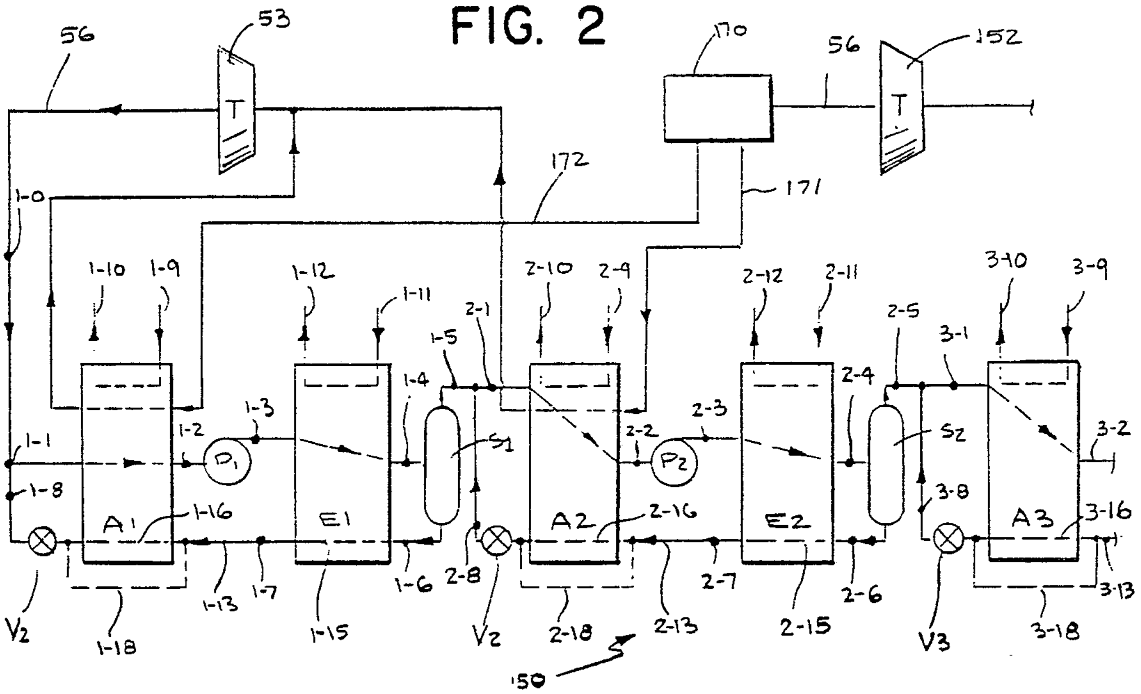
4-18

FIG. 1

FIG. 2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A2
2-16
E2
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A3
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V2
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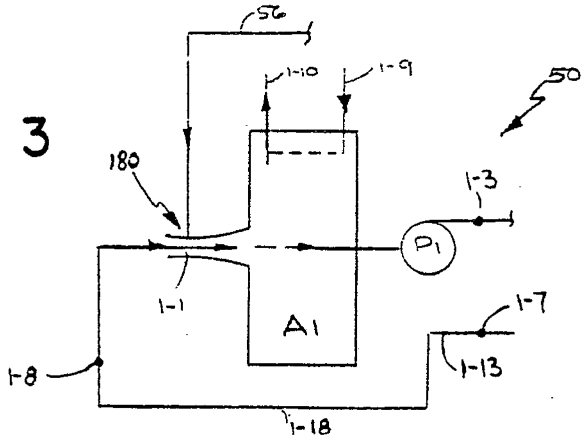
V3
3-18
3-13
150

FIG. 3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