

(19)



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(11)

EP 0 887 600 A2

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication: 30.12.1998 Bulletin 1998/53

(51) Int. Cl.<sup>6</sup>: F25B 1/00

(21) Application number: 98111498.6

(22) Date of filing: 23.06.1998

(84) Designated Contracting States: AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE Designated Extension States: AL LT LV MK RO SI

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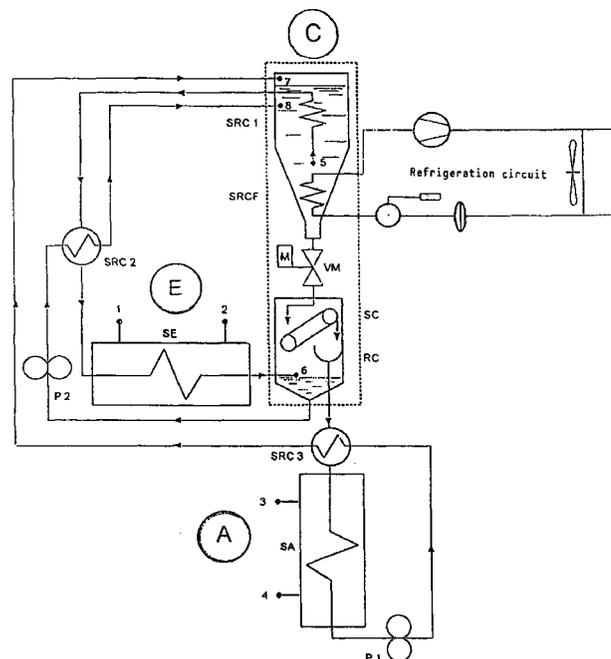
(30) Priority: 24.06.1997 IT MI971493

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(54) Perfected absorption cooling plant and relative working method

(57) Perfected absorption cooling plant, and relative working method, wherein a crystalliser (C) is arranged between an absorption station (A) and an evaporation station (E), wherein a saline solution, consisting advantageously of water and sodium hydroxide, circulates inside the plant and wherein a refrigeration system cooperates with the crystalliser (C) to form the corresponding crystals.



SRC 1..SRC 3 Heat exchangers
P 1 P 2 Pump
SE Exchanger (evaporation station)
SA Exchanger (absorption station)
RC Crystal collector
SC Crystal separator
VM Motorized valve
SRCF Exchanger (refrigeration system)
1-2
3-4

FIG. 1

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## Description

### FIELD OF THE INVENTION

The invention concerns a perfected absorption cooling method and the working method relating thereto.

### BACKGROUND OF THE INVENTION

Various applications in the state of the art need refrigeration or cooling plants to achieve suitable environmental conditions.

Normally, the core of these plants lies in a cooling thermal cycle which can take place in a compression circuit or an absorption circuit. In the first case it is a stable fluid with the appropriate characteristics which makes the cycle, in the second case it is an appropriate solute-solvent solution.

Although these devices in some ways solve the technical problem involved, they also have the following disadvantages.

The yield of such cooling cycles is always rather low, thus causing a considerable waste of energy, particularly in industrial applications.

Compression circuits are extremely complex in construction due to their particular power requirements or the minimum achievable temperature.

Absorption circuits could be more competitive if it were possible to re-use several evaporation stages in series, each one with a lower pressure than the previous one, but this is prevented by the high saline concentration: in fact the vapour pressure is lowered (the boiling temperature is increased) which prevents the application of a high number of evaporations.

### SUMMARY OF THE INVENTION

The purpose of the invention is to overcome the shortcomings of the state of the art.

The object of the invention therefore is a perfected absorption cooling plant and the relative working method, which include simplicity of construction, considerable reliability and an optimum thermal yield.

Briefly, according to the invention, an absorption cooling plant has been perfected comprising a crystalliser, an evaporation station, an absorption station, a plurality of pumps, a plurality of heat exchangers, a refrigeration system and a saline solution which circulates inside and achieves the cooling cycle of the plant.

The working method relative to the plant according to the invention comprises a plurality of passes of a saline solution through a crystalliser, an evaporation station, an absorption station and a plurality of heat exchangers which, at every pass, modify the concentration of the saline solution thus making feasible the cooling cycle obtained with the plant according to the invention.

The perfected absorption cooling plant according to the invention is characterised by the fact that it includes the characteristics described in Claim 1.

With the perfected absorption cooling plant and with the relative working method according to the invention the following advantages are obtained.

The thermal yield obtained is decidedly greater than that of systems known to the state of the art, both those using compression circuits and those using absorption circuits.

Simplicity of construction is guaranteed by the fact that the plant uses componentry technology of the type which is widely employed in the field of refrigeration machines in general.

A further advantage is that the entire plant is extremely reliable, and safe to manage and control.

### BRIEF DESCRIPTION OF THE DRAWINGS

Further characteristics, advantages and construction details of the perfected absorption cooling plant and the relative working method according to the invention will be better understood by examining the following description, with reference to the attached drawings which show a preferential form of embodiment as a non-restrictive example.

Fig. 1 is a diagram of the perfected absorption cooling plant according to the invention.

Fig. 2 is a diagram of the plant shown in Fig. 1, using a different type of crystalliser.

Fig. 3 is a flow chart of the plant according to the invention applied to a vacuum distiller, which also shows the energy flows inside the plant according to the invention, wherefrom it can be seen that with a thermal power at inlet of 1.5 KCal thermal powers of 28.6 KCal are obtained.

Fig. 4 is another flow chart showing the energy flows inside the plant according to the invention.

Fig. 5 is a flow chart showing the percentage variation of the solute-solvent in a saline solution used inside the plant according to the invention.

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

With particular reference to the numbers and letters in the Figures of the attached drawings, the perfected absorption cooling plant and the relative working method according to the invention are based on the crystallisation of a solution and on the variations in concentration at the different points of the plant. As is well-known, the solubility of a solid in its solvent increases with temperature and the solution is said to be saturated when it reaches the maximum concentration of the solute, as a balance is achieved between the dissolved substance and the substance present as a residue.

The solution in environment C, which serves as a crystalliser, is cooled by a refrigeration or cooling sys-

tem until the temperature of crystallisation is reached; this temperature varies according to the concentration and the solvent-solute pair. The crystals thus obtained by means of the motorised valve VM arrive at the separator SC and are conveyed to the collector RC.

The crystal collector RC communicates with the exchanger SA of an absorption station A and with the exchanger SE belonging to an evaporation station E, which can be of different types.

The vapour generated in the exchanger SE comes into contact with the crystals and is absorbed, thus generating heat which is removed by a fluid circulating in the exchanger SA (points 3 and 4 of Figs. 1 and 2) to give maximum absorption.

The solution thus obtained is sent by means of the pump P1, after passing through the exchanger SCR3, to the crystalliser C in order to repeat the cycle (point 7).

Another current emerging from the crystalliser C (point 5) passes through the heat recuperators SCR1 and SCR2 and then arrives at the exchanger SE, where the diluted solution is heated by the circulating fluid which causes it to evaporate and consequently causes an increase in concentration.

The vapours and the concentrated solution return to the crystalliser C (point 6) where they separate: the vapours are absorbed as previously described in the exchanger SA, while the concentrated solution, collected on the bottom, is sent by means of the pump P2 to the crystalliser C (point 8).

The shape of the crystalliser is subordinated to the type of separator used for the crystals, but there are various types on the market, all suitable for the plant according to the invention. Figs. 1 and 2 show two variants of a crystalliser.

As a non-restrictive example, we shall now describe a practical application of the plant according to the invention in an apparatus for vacuum distillation.

The solvent-solute pair used is water and sodium hydroxide ( $H_2O - NaOH$ ), but it is possible to use different solutions, such as for example water and lithium bromide and other saline solutions with characteristics similar to these.

The environment of the crystalliser C comprises two sections: a refrigeration section, where the solution is taken to the temperature of crystallisation, and the other to separate the crystals; the latter communicates with the exchangers SE and SA of the evaporation station E and the absorption station A, and is located above the two exchangers.

The refrigeration section is shaped like a truncated cone so as to allow the crystals to collect on the bottom and to convey them to the separator.

Moreover, although this is not indispensable for the functioning of the plant, around or inside the refrigeration section there is an exchanger to recover the refrigeration units of the solution which has already been treated. In the lower part another exchanger connected with a conventional refrigeration system takes the solu-

tion to a temperature of about  $0^{\circ}C$ .

The solution arriving at the crystalliser C consists of two currents, one arriving from the exchanger SA of the absorption station A with a concentration of 66% of NaOH (equal to 100 parts of  $H_2O$  and 50 parts of NaOH in weight) at a temperature of  $50^{\circ}C$ , the other current from the exchanger SE of the evaporation station E with a concentration of 50% of NaOH (equal to 50 parts of  $H_2O$  and 50 parts of NaOH in weight) at a temperature of  $30^{\circ}C$ .

When the two currents join, they achieve a solution with a concentration of 60% of NaOH (equal to 150 parts of  $H_2O$  and 100 parts of NaOH in weight).

This solution entering the crystalliser C is pre-cooled by the exchanger SCR1 and finally taken to the temperature of  $0^{\circ}C$  by the exchanger SRCF.

At this temperature the solution is over-saturated and a residue (crystals) is formed: the concentration of the solution will fall to 33% NaOH (equal to 50 parts of  $H_2O$  and 100 parts of NaOH in weight) including, in the example in question, 100 parts (or grams) of NaOH crystals as residue.

The solution thus obtained is removed at point 5, which is situated inside the crystalliser and, after passing through the heat exchangers SRC1 and SRC2, due to the effect of gravity reaches the exchanger SE of the evaporation station E.

The latter is enveloped, on the shell side, by saturated, condensing water vapours at a temperature of  $48^{\circ}C$  arriving from the exchanger SA of the absorption station A.

Thus the solution continues to receive heat and can continue to evaporate until it reaches a new concentration of 50% NaOH (equal to 50 parts of  $H_2O$  and 50 parts of NaOH in weight) at a temperature of  $40^{\circ}C$ .

In this transformation, the solution absorbs heat and a pressure of about 47 Pa of residual vacuum will be created.

The solution thus obtained and the vapour which is generated (in this example, 50g) return to the lower part of the crystalliser C (point 6), they separate and the solution is sent back by means of the pump P2, after passing through the exchangers SCR1 and SCR2, to the crystalliser C so as to restart the cycle.

The crystals generated arrive in the collector RC connected to the exchanger SA, and, since they are deliquescent and with a zero vapour pressure compared with that of water, the vapour is absorbed, and consequently heat is generated, so that the crystals return to a state of solution, absorbing the vapour (50g) generated in the exchanger SE.

The absorption heat in the exchanger SA is yielded to the water which begins to boil, generating vapour.

The concentration at outlet of the exchanger is 66% (equal to 100 parts  $H_2O$  and 50 parts of NaOH in weight).

This solution, by means of the pump P1, is sent, after passing through the exchanger SCR1, to the crys-

talliser to repeat the cycle.

Naturally, the shape and size of the various elements comprising the perfected absorption cooling plant according to the invention, the solutions used, the temperatures, the pressures and the concentrations achieved, shall be able to vary according to the different requirements; however, the plant still remains within the field of the invention as described above.

### Claims

1. Perfected absorption cooling plant, characterised in that it comprises a crystalliser (C), an evaporation station (E), an absorption station (A), at least a pump (P1, P2), at least a heat exchanger (SRC2, SRC3), a refrigeration system and a saline solution which, circulating inside, achieves the cooling cycle of the said plant. 15
2. Plant as in Claim 1, characterised in that the saline solution consists of water and sodium hydroxide. 20
3. Plant as in any claim hereinbefore, characterised in that the saline solution consists of water and lithium bromide. 25
4. Plant as in any claim hereinbefore, characterised in that the evaporation station (E) and the absorption station (A) each include at least a heat exchanger (SE, SA). 30
5. Plant as in Claim 4, characterised in that the crystalliser (C) cooperates with the refrigeration system which is suitable to make the saline solution reach the temperature of crystallisation inside the crystalliser (C) and that the crystalliser (C) comprises a section to separate the crystals, said section communicating with the evaporation station (E) and the absorption station (A), by means of the heat exchangers (SE, SA) of said stations. 35 40
6. Plant as in Claim 5, characterised in that the refrigeration system comprises a part inside the crystalliser (C), shaped like a truncated cone, at least a heat exchanger being included to recover the refrigeration units of the already treated solution, and at least an exchanger being connected to the refrigeration system. 45
7. Plant as in any claim from 4 to 6 inclusive, characterised in that the saline solution entering the crystalliser (C) is composed of two currents, one coming from the exchanger (SA) of the absorption station (A), and the other coming from the exchanger (SE) of the evaporation station (E), the current arriving from the exchanger (SA) of the absorption station (A) having a concentration and a temperature greater than that found in the current arriving from the exchanger (SE) of the evaporation station (E). 50
8. Plant as in any claim hereinbefore, characterised in that the saline solution entering the crystalliser (C) is pre-cooled by a first heat exchanger (SRC1) and taken to a super-saturated condition by a second heat exchanger (SRCF), achieving the formation of crystals as a residue and a lowering of the concentration of the solution. 55
9. Plant as in Claims 4 and 8, characterised in that the saline solution remaining at the end of the formation of the crystals as a residue is removed at a point (5) inside the crystalliser (C) and passes through the first heat exchanger (SRC1) and a further heat exchanger (SRC2) to then reach the heat exchanger (SE) inside the evaporation station (E), the last heat exchanger (SE) being enveloped on the shell side by saturated vapours arriving from the exchanger (SA) of the absorption station (A), so as to allow the solution to receive heat, increasing its temperature and its concentration.
10. Plant as in Claim 9, characterised in that the saline solution and the vapour which is generated during the passage through the evaporation station (E) are sent, at the outlet thereof, to the lower part of the crystalliser (C) where, after separation, the saline solution is returned by means of a pump (P2) to the last heat exchanger (SRC2) and from the latter back to the first heat exchanger (SRC1) of the crystalliser (C) so as to restart the cycle.
11. Plant as in Claim 4, characterised in that the crystals generated as a residue arrive at a collector (RC) which is connected with the heat exchanger (SA) of the absorption station (A) and wherein the crystals return to a state of solution absorbing the vapour generated in the exchanger (SE) of the evaporation station (E) while the absorption heat in the heat exchanger (SA) of the absorption station (A) is yielded to the water which begins to boil and generates vapour thus restoring the concentration of the saline solution as at the start-of-cycle, which is then sent by means of a pump (P1) to a heat exchanger (SCR1) of the crystalliser (C) so as to repeat the cycle.
12. Absorption cooling method, characterised in that it comprises a plurality of passes of a saline solution through a crystalliser (C), an evaporation station (E), an absorption station (A) and a plurality of heat exchangers (SCR2, SCR3) suitable to modify at every pass the concentration of the solution.
13. Method as in Claim 12, characterised in that the passing of the saline solution through the crystal-

liser (C) comprises the passage of the solution through a refrigeration system in order to reach the temperature of crystallisation and the passage through a section to separate the crystals, which section communicates with the evaporation station (E) and the absorption station (A). 5

14. Method as in Claims 12 or 13, characterised in that the passing of the saline solution through the evaporation station (E) and the absorption station (A) 10 comprises the passage through the heat exchangers (SE, SA) of the said stations.

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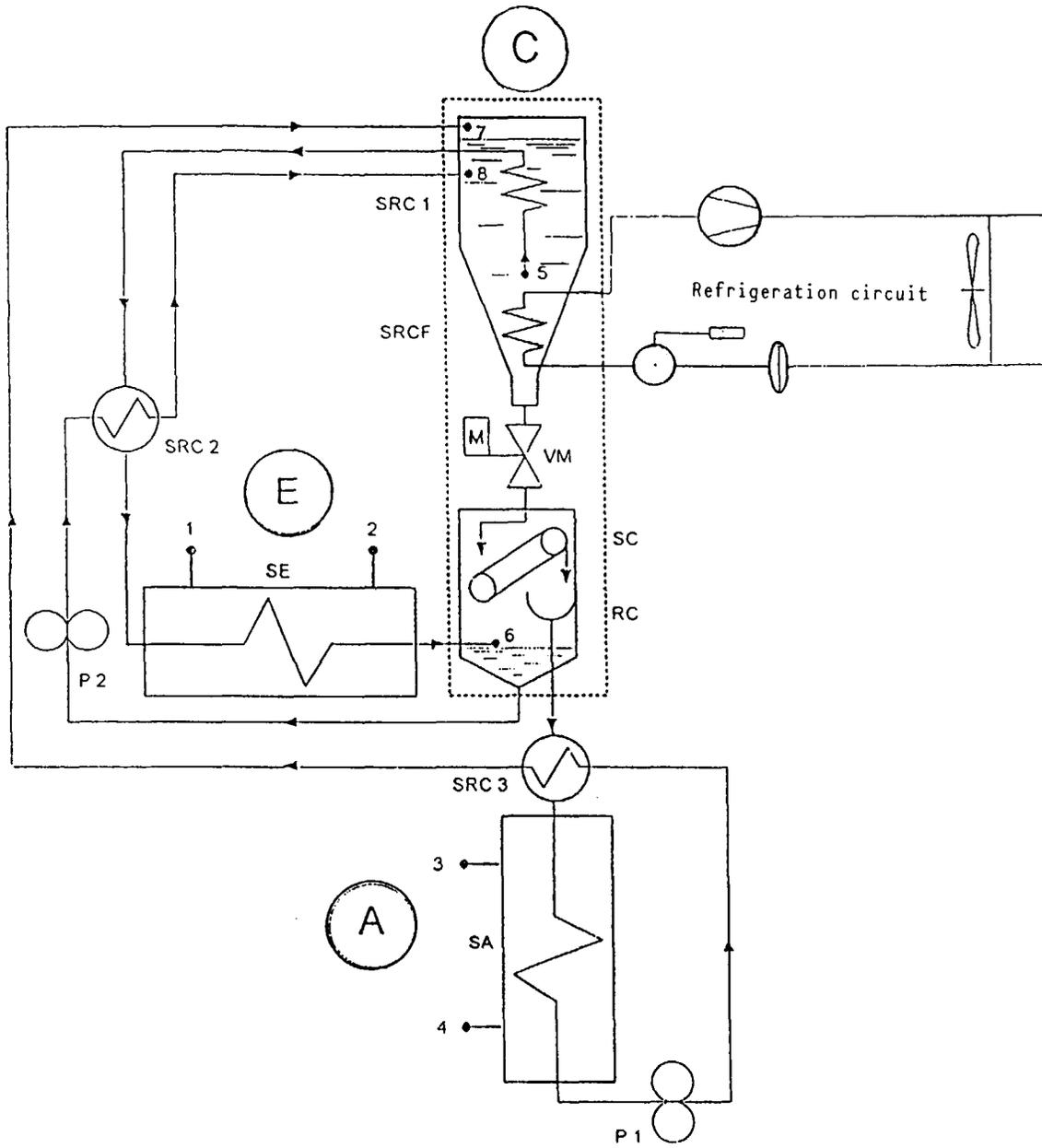
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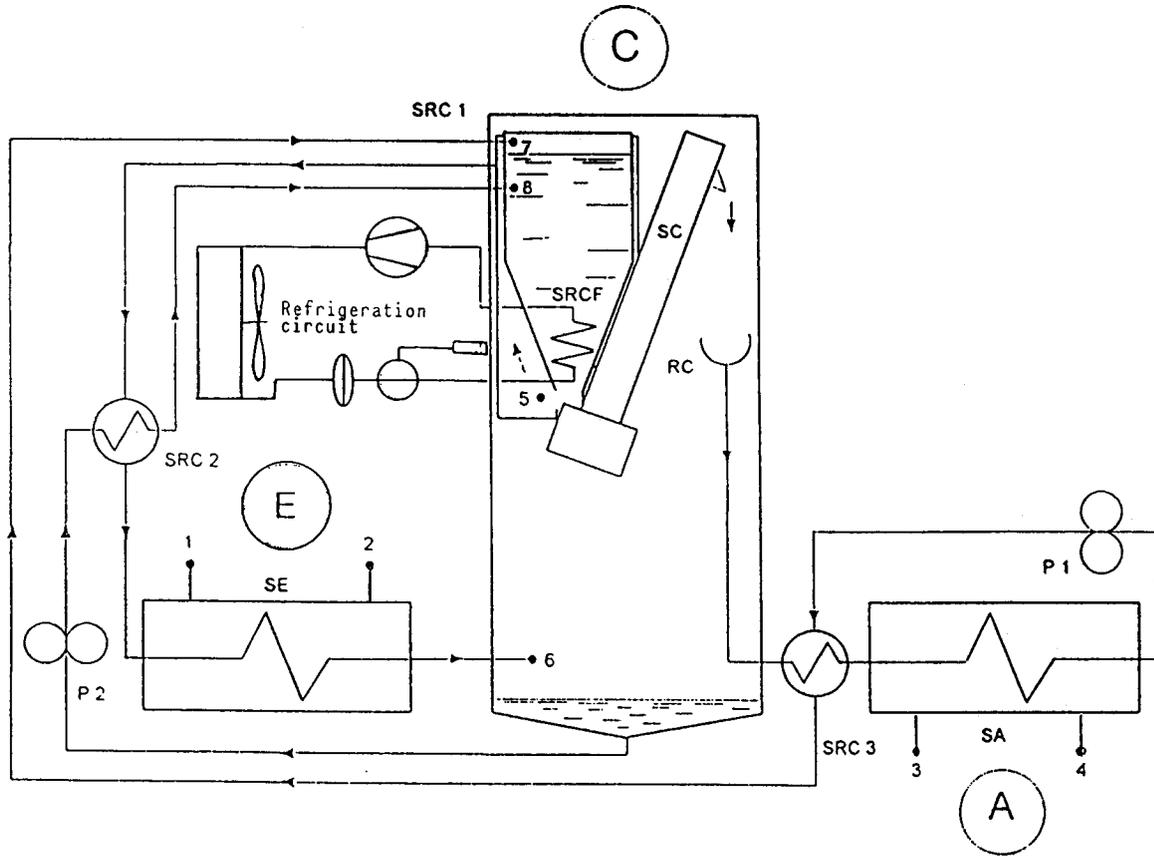
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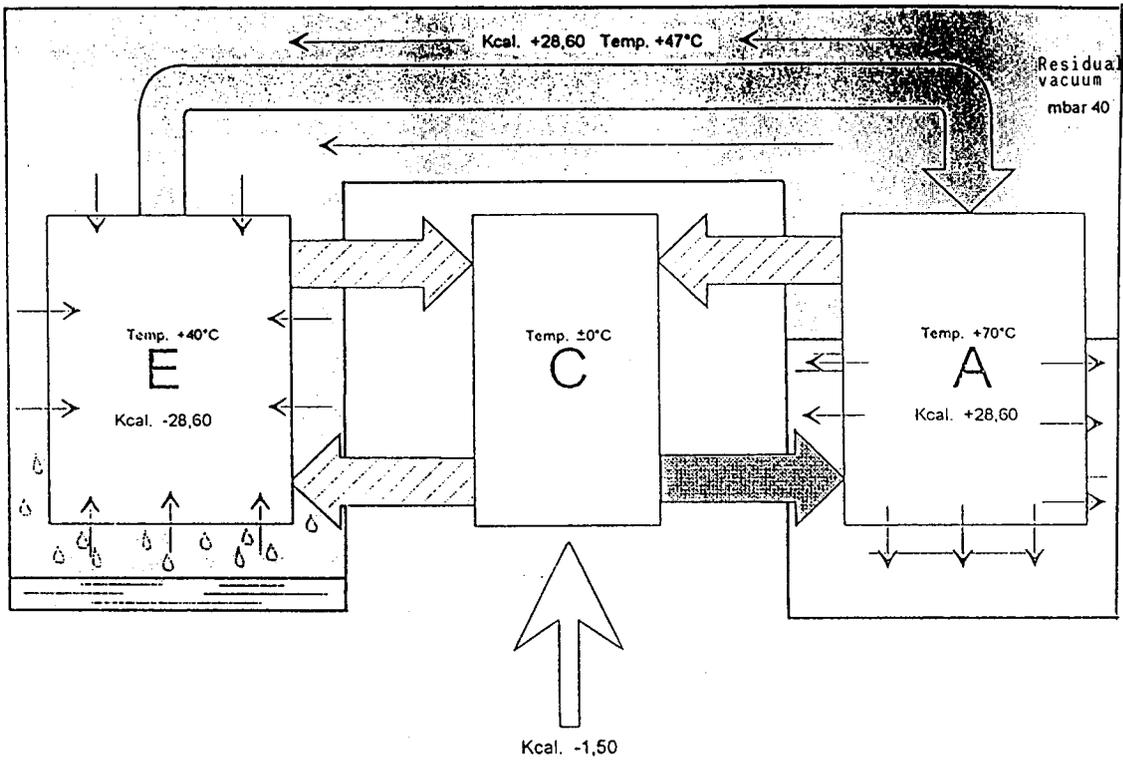
- SRC 1, SRC 2, SRC 3 Heat exchangers
- P 1, P 2 Pump
- SE Exchanger (evaporation station)
- SA Exchanger (absorption station)
- RC Crystal collector
- SC Crystal separator
- VM Motorized valve
- SRCF Exchanger (refrigeration system)
- 1-2
- 3-4

**FIG. 1**



- SRC 1..SRC 3 Heat exchangers
- P 1 P 2 Pump
- SE Exchanger (evaporation station)
- SA Exchanger (absorption station)
- RC Crystal collector
- SC Crystal separator
- VM Motorized valve
- SRCF Exchanger (refrigeration system)
- 1 - 2
- 3 - 4

FIG. 2



-  Solution
-  Vapour
-  Crystals
- E Evaporation
- A Absorption
- C Crystallisation

FIG. 3

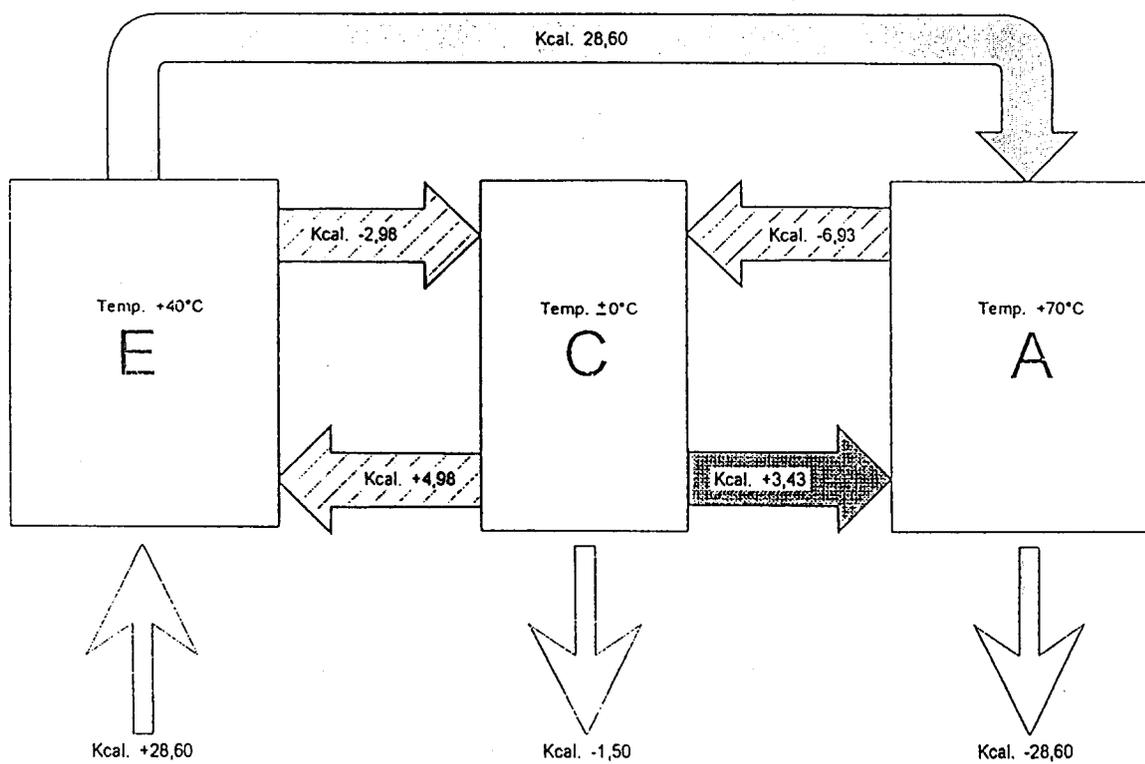
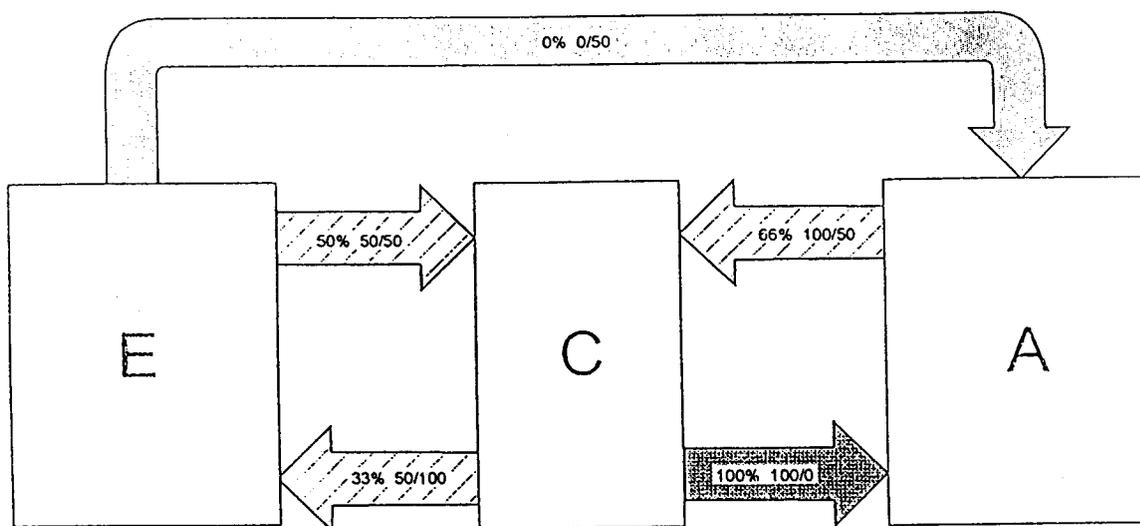


FIG. 4



-  Solution
-  Vapour
-  Crystals
- E Evaporation
- A Absorption
- C Crystallisation

FIG. 5