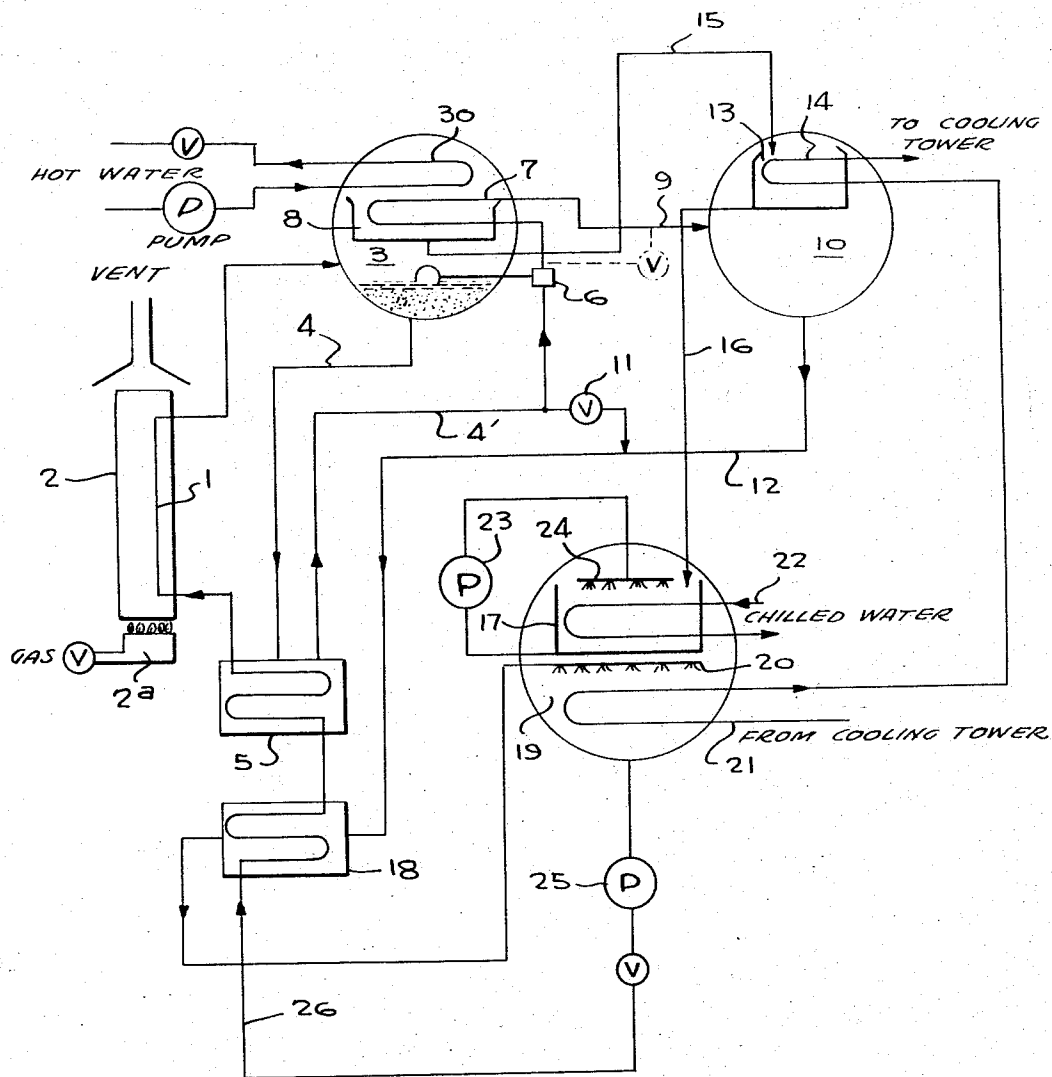


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PROCESS AND APPARATUS FOR SIMULTANEOUS GENERATION
OF HOT AND COLD FLUIDS IN AN ABSORPTION
REFRIGERATION SYSTEM
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PROCESS AND APPARATUS FOR SIMULTANEOUS GENERATION OF HOT AND COLD FLUIDS IN AN ABSORPTION REFRIGERATION SYSTEM

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This invention relates to methods and apparatus for heating water or other fluids simultaneously with the cooling of water or other fluids in multiple separate fluid flow circuits within an absorption refrigeration machine.

My invention is particularly useful with direct fired absorption refrigeration machines where the energy for distilling the liquid refrigerant from the absorbing fluid is provided by hot gases generated by combustion of a fuel. The absorption refrigeration process wherein liquids are cooled by the evaporation of a volatile refrigerant is well known. Machines which will produce, as desired, either hot water or chilled water are also well known. My apparatus differs from other heating and cooling machines in that it will simultaneously produce either or both effects, in any desired proportion, up to the full capacity of the machine.

My invention is an improvement of the double effect absorption cycle for example, of the type occurring in the system disclosed in United States Patents Numbers 3,146,602 and 3,146,604, granted September 1, 1964; Number 3,167,928 granted February 2, 1965; and Number 3,187,515 granted June 8, 1965, all to Judson S. Swearingen, wherein a portion of the refrigerant is condensed through heat exchange causing boiling of the more concentrated absorbent solution in a closed heat exchanger at pressures substantially lower than the pressure at which it was caused to boil by heat transferred from hot products of combustion.

An object of the present invention, therefore, is the provision of a novel method and apparatus for simultaneously producing heating and cooling of water in any desired proportion, in an absorption refrigeration system.

Another object of the present invention is the provision of a novel method and apparatus for simultaneously producing hot water and chilled water in an absorption refrigeration system of the double effect or multiple effect types, wherein vaporization occurs in two or more stages or "effects" at two or more different pressures, the hot water being produced in any desired proportion at the first effect stage.

Another object of the present invention is the provision of a novel method and apparatus as described in immediately preceding paragraph, wherein the heating of water is readily controlled by the temperature and rate of flow of water to be heated.

Other objects, advantages and capabilities of the present invention will become apparent from the ensuing detailed description.

This invention is particularly directed, in its preferred form, to a process wherein the refrigerant is water and the absorbing liquid is a salt solution. In a preferred form, the concentration of the salt solution is by a staged vaporization procedure in a multiple-effect vaporizing process. In such process, the vaporization occurs in two or more stages called "effects," at two or more different pressures. In each effect the liquid is heated and partially vaporized. The vapor is separated from the liquid in a separation zone, for example, in a two-effect vaporizing step. Liquid passing to the first-effect separation zone is heated and partially vaporized in a heater, which may be termed the first-effect generator. The unvaporized liquid is separated from the generated vapor and liberated

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gases in the first effect separation zone at the aforesaid higher pressure. The partially concentrated salt solution is cooled and passed to the lower pressure second-effect separating zone through coils located in what may be termed a first effect condenser and second-effect generator. Vapor from the first-effect separating zone is condensed by heat exchange through these coils, thus transferring heat to the circulating, partially concentrated salt solution, to supply heat to vaporize additional water from this partially concentrated salt solution at the second effect generator during the passage of the salt solution to the lower pressure second-effect separation zone.

The vapor separated in the second-effect separation zone is condensed in a second-effect condensation zone by a cooling liquid passing in heat exchange with the vapor in the second-effect condensation zone. Condensate from the first-effect condensation zone enters the second-effect condensation zone, where it is combined with condensate of vapor separated in the second-effect separator. The combined condensate stream is introduced into an evaporation zone at a still lower pressure and evaporated at such lower pressure by heat exchange with the fluid to be refrigerated. The low pressure in the last-mentioned evaporation-zone is maintained by absorbing the resultant vapor in the concentrated salt solution in the absorption zone.

The vapor pressure of the salt solution in the absorption stage is maintained sufficiently low to establish the desired pressure in the absorbing zone, and therefore in the condensate-evaporation zone. This establishes the temperature of the water being evaporated at the desired refrigeration temperature.

By adding a heat exchanger in proximity to the condensing side of the second effect generator, the heat of condensation, normally passed to the relatively cooler and more concentrated absorbent solution to cause boiling at the lower second effect pressure, is instead transferred in the new heat exchanger to the water or other fluid causing it to be heated.

All or any part of the vapor boiled from the absorbent solution in the first effect generator might be condensed either by heat transferred to the second effect generator or to the water heating exchanger or to both simultaneously, in any proportion, as the temperature on the transferred side of the heat exchangers may dictate; thus the heat of condensation of the first effect vapor is used to raise the temperature of the heating fluid or to produce additional refrigerant vapor at a lower temperature and pressure in the second effect generator.

I have found the lithium bromide-water cycle to be particularly suitable for my invention. At essentially atmospheric pressure, the boiling refrigerant solution leaving the first effect generator is generally in the temperature range of 250° F. to 300° F. These temperatures permit economical use of small exchangers to heat water to the generally desirable temperatures ranging from 150° F. to 200° F.

My cycle is self-regulating and easily controlled by the temperature and rate of flow of water to be heated. If there is no demand for water heating, the entire capacity of the apparatus is available for cooling. When there is maximum demand for heating, the entire output is available for heating. Any ratio of heating and cooling between these extremes is automatically provided to meet the use demand.

The present invention will now be described in greater detail by reference to the figure of the accompanying drawing, illustrating a schematic flow of diagram of an absorption refrigeration system embodying the present invention.

Referring to the accompanying drawing, the absorption liquid, which may be termed a dilute solution, and is for

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example a salt solution, preferably a solution of lithium bromide in water, passes through conduit system 1, in a heater 2, which I term a first-effect generator. Here, the dilute solution is heated to the vaporization point, by application of heat directly from a gas burner 2a, to boil off some of the water vapor from the dilute solution. This water vapor and the solution, which may now be termed an intermediate solution, signifying a medium concentration of lithium bromide and water, are passed to a separator or separator zone 3 where the water vapor and intermediate solution are separated by suitable known means, such for example, as baffle plates provided in the separator.

The intermediate solution which collects in the separator 3 is passed by conduit 4 through a heat exchanger 5, in indirect heat exchange relation with relatively cooler dilute solution passing to the conduit system 1 in the first-effect generator 2. The cooled intermediate solution then passes from the heat exchanger 5 through conduit 4' and float valve 6 to coils 7 in a first-effect condenser 8 into indirect heat exchange relation with the water vapor separated from the intermediate solution in the separator 3. The water vapor separated from the intermediate solution in the separator 3 passes to the condenser zone 8, which serves simultaneously as a first-effect condenser and a second-effect generator, as the water vapor from the separator 3, originally heated to about, for example, 300° F., condenses for example into about 205° F. refrigerant through thermal interchange with the intermediate solution flowing in the coils 7. The heat given up by this condensing water vapor boils off additional water vapor from the intermediate solution in the coils 7 forming a concentrated solution, which concentrated solution and water vapor are conveyed through conduit 9 into separator 10. The solution in the coils 7 in the second effect generator or first effect condenser 8 is preferably at a low pressure, for example on the order of about 60 mm. Hg.

A portion of the flow through line 4' may, if desired, be by-passed by valve 11 directly into line 12, to be later described, or such a valved by-pass line may be positioned as indicated in broken lines, whereby a portion of the intermediate solution may be by-passed around coils 7 and introduced directly into separator 10.

The separator 10 includes suitable known means such as baffle plates, for separating the concentrated solution and added water vapor conveyed through conduit 9, and includes a second effect condenser indicated generally at 13, which is at a slightly lower pressure, for example on the order of 55 mm. Hg. Cooling water, for example from a suitable cooling tower, is conducted through coils 14 in the second effect condenser 13. The water vapor separated in the separator 10 is condensed by the cooling water in the coils 14 of second effect condenser 13, and is mixed with condensed water collected at the first effect condenser 8, and conveyed through conduit 15 to second effect condenser 13, which commingled condensed water is then passed through line 16 into evaporator 17 operating at a still lower pressure of, for example, about 5 mm. Hg. The concentrated solution separated at the second effect condenser 13 and separator 10 is fed through conduit 12 and heat exchanger 18 to absorber 19, where it is discharged by sprays 20 over cooling coils 21 connected, for example, in series with cooling coil 14 and supplied with water from the cooling tower.

The concentrated solution fed to the absorber 19, which is in communication with the evaporator 17, has a very high affinity for water vapor and its rate of absorption increases with decreasing temperature. This concentrated solution, which is cooled somewhat at the heat exchanger 18 and cooled further by dripping over the cooling coils 21, is surrounded by water vapor from the evaporator, absorbing this water vapor very rapidly to maintain the desired low pressure in the absorber-evaporator. The commingled condensed water fed to the evaporator 17 through conduit 16, in part flashes at the reduced pressure, reduc-

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ing the temperature to a selected low value for example about 38° F., the remainder passing in heat exchange relation with fluid to be cooled, for example water in coils 22, cooling the fluid in the coils 22 and vaporizing the condensed water falling over the coils 22 which is absorbed by the concentrated solution and collected in the bottom of the absorber evaporator as dilute solution for return to the first effect generator 2. The unvaporized water in evaporator 17 is recirculated by pump 23 and spray system 24. The dilute solution collected at the bottom of the evaporator-absorber is delivered by pump 25 and conduit 26 through heat exchangers 18 and 5 to the first effect generator 2.

In order to provide for simultaneous production of hot water with this absorption refrigeration system while the chilling of water is being produced in the coils 22, additional heat exchanger coils 30 are provided in proximity to the condensing side of the second effect generator formed by the coils 7, in thermal interchange with the superheated water vapor from the separator 3. The water heating exchanger formed by the coils 30 is connected externally of the second effect generator and separator 3 to a suitable water or other fluid conduit system having, if desired, a pump and conventional valve means incorporated therein for regulating the flow of water or other fluid therethrough. The heat of condensation of the superheated vapor in the first effect condenser-second effect generator zone, which is normally passed to the relatively cooler and more concentrated intermediate solution in the coils 7 to cause boiling of the same at the lower second effect pressure is instead or in part transferred in the new heat exchanger coils 30 to the water or other fluid solution therein causing it to be heated. All or part of the water vapor boiled from the dilute solution in the first effect generator 2 might be condensed either by heat transferred to the second effect generator coils 7 or to the water heating exchanger coils 30 or to both simultaneously, in any proportion, as the temperatures on the transferred side of these heat exchangers may dictate. By this arrangement, the heat of condensation of the first effect vapor from the generator 2 is used to raise the temperature of the heating fluid in the water heating exchanger coils 30 or to produce additional refrigerant water vapor at a lower temperature and pressure in the second effect generator coils 7.

It will be apparent that because of this arrangement of the water heating exchanger coil 30 in proximity to the second effect generator coils 7, the entire capacity of the apparatus is available for cooling if there is no demand for water heating, or is available for heating if there is maximum demand for heating, and that any ratio of heating and cooling between these extremes required to meet the heat demands of the water in the water heating coil 30 is automatically determined by the flow rate of water entering and leaving the coil 30 and the temperature of the water entering the coil 30. It will be appreciated that the amount of heat absorbed in the water heating coil 30 is determined by (a) the temperature of the water entering coil 30, (b) the flow rate of water in coil 30, and (c) the temperature of the vapor or fluid in contact with the coil 30. Since the latter temperature is more or less constant, the amount of heat transferred to the water in coil 30 is effectively controlled by varying the flow rate of the water entering and leaving the coil 30. Actually, the amount of heating enjoys preference over the available amount of cooling. The amount of heat delivered by the system is regulated by the temperature and flow rate of the water through coil 30, and the amount of cooling is regulated by the temperature and flow rate of the chilled water in coil 22, but the cooling is of necessity limited by what is left over after the heat desired in coil 30 is extracted.

While only one form of the present invention has been particularly shown and described, it will be ap-

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parent that various modifications may be made within the spirit and scope of the invention, and it is desired, therefore, that only such limitations be placed on the invention as are imposed by the prior art and set forth in the appended claims.

What is claimed is:

1. A process for simultaneously producing heating of a selected fluid to be heated and cooling of a selected fluid to be cooled in a multiple effect absorption refrigeration system comprising the steps of heating an aqueous salt solution to its vaporization point to produce a partially concentrated salt solution and water vapor at a first selected pressure, separating said water vapor from said partially concentrated salt solution in a separating zone, withdrawing and cooling said partially concentrated salt solution, condensing water vapor in a condensing zone in vapor communication with said separating zone by indirect heat exchange with said cooled, partially concentrated salt solution passing from said separating zone causing partial vaporization of said partially concentrated salt solution at said condensing zone producing further concentrated salt solution and additional water vapor at a lower pressure than in said separating zone, passing fluid to be heated in indirect heat exchange relation to said partially concentrated salt solution and condensing water vapor at said condensing zone to effect heating of said fluid to be heated, separating water vapor from said further concentrated salt solution at a second separating zone, condensing said last named water vapor to form a condensate in a condensing zone at a lower pressure than said first-mentioned separating zone, and passing said condensate into an evaporating zone maintained at a lower pressure than said second separating zone and vaporizing said condensate in heat exchange relation with fluid to be cooled.

2. A process for simultaneously producing heating of a selected fluid to be heated and cooling of a selected fluid to be cooled in a multiple effect absorption refrigeration system comprising the steps of heating an aqueous salt solution to its vaporization point to produce a partially concentrated salt solution and water vapor at a first selected pressure, separating said water vapor from said partially concentrated salt solution in a separating zone, withdrawing and cooling said partially concentrated salt solution, condensing water vapor in a condensing zone in vapor communication with said separating zone by indirect heat exchange with said cooled, partially concentrated salt solution passing from said separating zone causing partial vaporization of said partially concentrated salt solution at said condensing zone producing further concentrated salt solution and additional water vapor at a lower pressure than in said separating zone, passing fluid to be heated in indirect heat exchange relation to said partially concentrated salt solution and condensing water vapor at said condensing zone to effect heating of said fluid to be heated, separating water vapor from said further concentrated salt solution at a second separating zone, condensing said last named water vapor to form a condensate in a condensing zone at a lower pressure than said first-mentioned separating zone, passing said condensate into an evaporating zone maintained at a lower pressure than said second separating zone, and vaporizing said condensate in heat exchange relation with fluid to be cooled, passing said last mentioned water vapor to an absorption zone into contact with cooled concentrated salt solution in said absorption zone to establish the low pressure at said evaporating zone, and withdrawing the salt solution from said absorption zone as an aqueous salt solution for recycling through the above-recited steps.

3. The process defined in claim 1, wherein said fluid to be heated is heated by heat exchange with the partially concentrated salt solution passing through said condensing zone and by condensation of said water vapor condensing at said condensing zone.

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4. The process defined in claim 1, wherein said fluid to be heated is heated by heat exchange with the partially concentrated salt solution passing through said condensing zone.

5. The process defined in claim 1, wherein said fluid to be heated is heated and by condensation of said water vapor condensing at said condensing zone.

6. In a multiple effect absorption refrigeration apparatus including a first effect generator, a first effect separator, a first effect condenser including first heat exchanger coil means located in a vapor zone having vapor communication with said first effect separator, said first coil means also forming a second effect generator, a second effect condenser, an evaporator, an absorber in vapor communication with said evaporator, means to pass liquid from said absorber to said first effect generator and from said first effect generator to said first effect separator, means to pass liquid from said first effect separator through said first heat exchanger coil means to said absorber to effect condensation of vapor at said first effect condenser, means to pass condensate from said condensers into said evaporator, and means to pass fluid to be cooled in heat exchange with condensate in said evaporator; the improvement comprising the addition of second heat exchanger coil means to said vapor zone in heat exchange relation with said first heat exchanger coil means and with vapor undergoing condensation at said first effect condenser for heating a fluid circulated through said second heat exchanger coil means.

7. In a multiple effect absorption refrigeration apparatus including a first effect generator, a first effect separator, a first effect condenser including first heat exchanger coil means located in a vapor zone having vapor communication with said first effect separator, said first coil means also forming a second effect generator, a second effect condenser, an evaporator, an absorber in vapor communication with said evaporator, means to pass liquid from said absorber to said first effect generator and from said first effect generator to said first effect separator, means to pass liquid from said first effect separator through said first heat exchanger coil means to said absorber to effect condensation of vapor at said first effect condenser, means to pass condensate from said condensers into said evaporator and means to pass fluid to be cooled in heat exchange with condensate in said evaporator; the improvement comprising the addition of second heat exchanger coil means to said vapor zone in heat exchange relation with said first heat exchanger coil means for heating a fluid circulated through said second heat exchanger coil means by thermal exchange with the liquid circulating through said first heat exchanger coil means.

8. In a multiple effect absorption refrigeration apparatus including a first effect generator, a first effect separator, a first effect condenser including a first heat exchanger coil means located in a vapor zone having vapor communication with said first effect separator, said first coil means also forming a second effect generator, a second effect condenser, an evaporator, an absorber in vapor communication with said evaporator, means to pass liquid from said absorber to said first effect generator and from said first effect generator to said first effect separator, means to pass liquid from said first effect separator through said first heat exchanger coil means to said absorber to effect condensation of vapor at said first effect condenser, means to pass condensate from said condensers into said evaporator, and means to pass fluid to be cooled in heat exchange with condensate in said evaporator; the improvement comprising the addition of a second heat exchanger coil means to said vapor zone in heat exchange relation with vapor undergoing condensation at said first effect condenser for heating a fluid circulated through said second heat exchanger coil means by heat of condensation of vapor undergoing condensation in said vapor zone at said first effect condenser.

9. In a multiple effect absorption refrigeration apparatus including a first effect generator for heating a circulation solution to produce vapor therefrom, a first effect separator, a first effect condenser including first heat exchanger coil means located in a vapor zone having vapor communication with said first effect separator, said first coil means also forming a second effect generator, a second effect separator, a second effect condenser in vapor communication with said second effect separator, an evaporator, an absorber in vapor communication with said evaporator, means to pass circulation solution from said absorber to said first effect generator, means to pass circulation solution and vapor from said first effect generator to said first effect separator, means to pass circulation solution from said first effect separator through said first heat exchanger coil means to effect condensation of vapor in said vapor zone at said first effect condenser and production of additional vapor from the circulation solution in said coil means, means for passing the circulation solution and additional vapor in said coil means to said second effect separator, means for passing circulation solution from said second effect separator to said absorber, means to pass condensate from said first

effect condenser and said second effect condenser to said evaporator, and means to pass liquid to be cooled in heat exchange with condensate in said evaporator; the improvement comprising the addition of second heat exchanger coil means to said vapor zone in heat exchange relation with said first heat exchanger coil means and with vapor undergoing condensation at said first effect condenser for heating a liquid to be heated circulated through said second heat exchanger coil means through thermal exchange with the circulation solution in said first heat exchanger coil means and condensation of vapor in said vapor zone.

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LLOYD L. KING, *Primary Examiner.*