

[72] Inventor Neil E. Hopkins
York, Pa.
[21] Appl. No. 60
[22] Filed Jan. 2, 1970
[45] Patented July 20, 1971
[73] Assignee Borg-Warner Corporation
Chicago, Ill.

3,283,533 11/1966 Aronson..... 62/494
3,304,742 2/1967 Eisberg..... 62/476
3,316,735 5/1967 Edberg..... 62/476

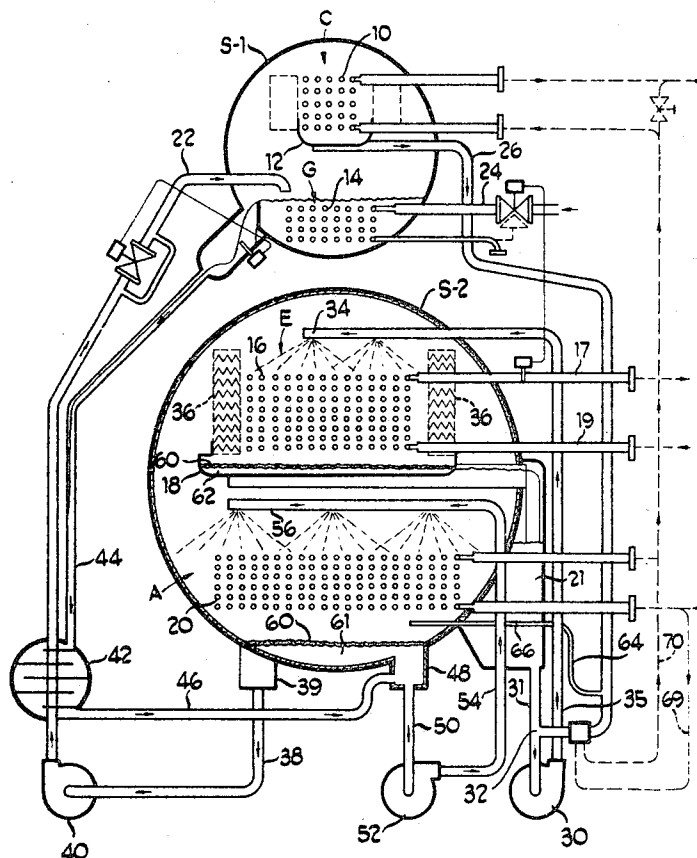
Primary Examiner—William F. O'Dea
Assistant Examiner—P. D. Ferguson
Attorneys—Donald W. Banner, William S. McCurry and John W. Butcher

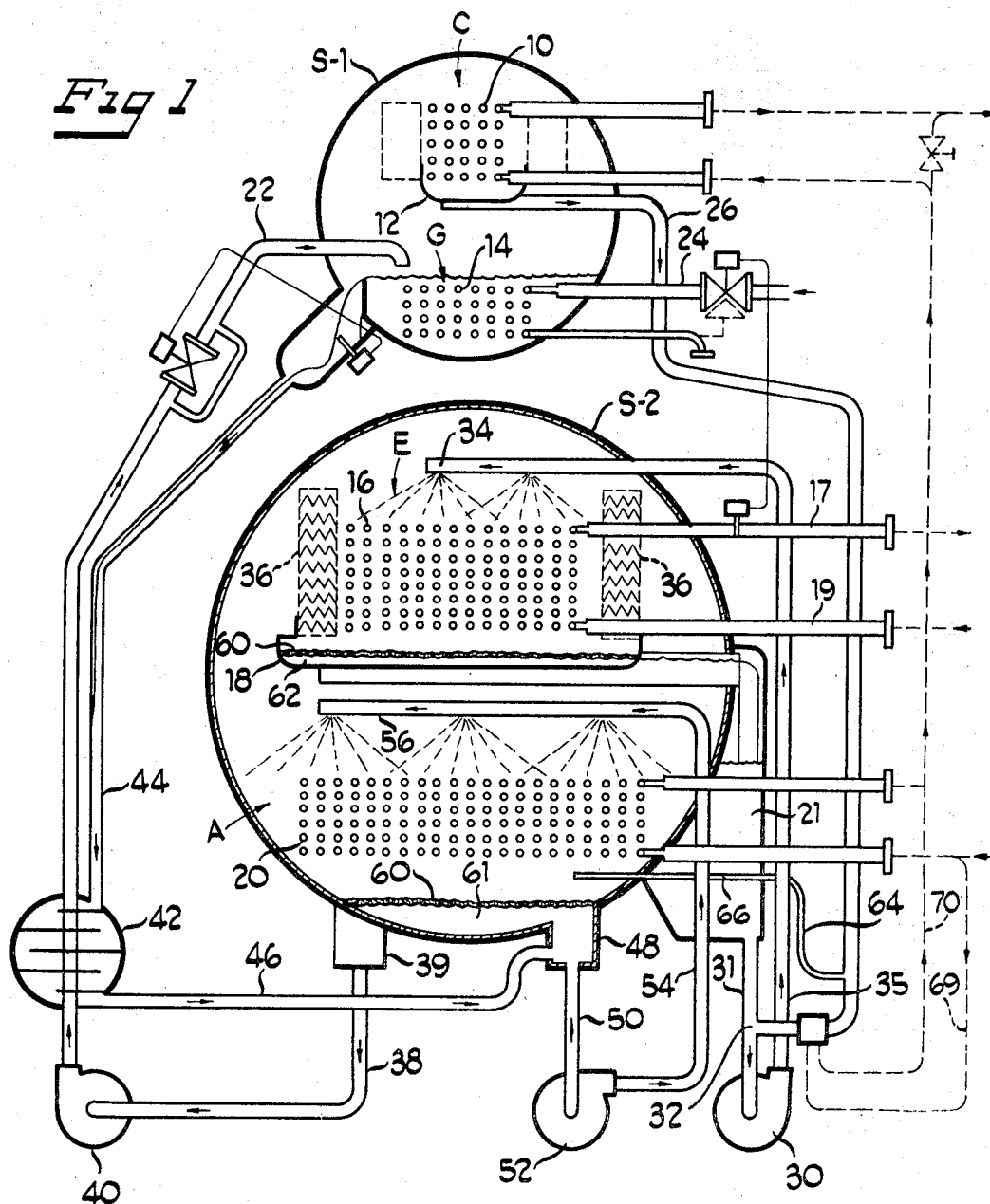
[54] **ABSORPTION REFRIGERATION SYSTEM USING A HEAT TRANSFER ADDITIVE**
3 Claims, 3 Drawing Figs.

[52] U.S. Cl..... 62/476,
62/486
[51] Int. Cl..... F25b 15/06
[50] Field of Search..... 62/141,
476, 485, 486, 494

[56] **References Cited**
UNITED STATES PATENTS
2,679,733 6/1954 Ashley..... 62/494 UX
3,276,217 10/1966 Bourne et al. 62/112 X

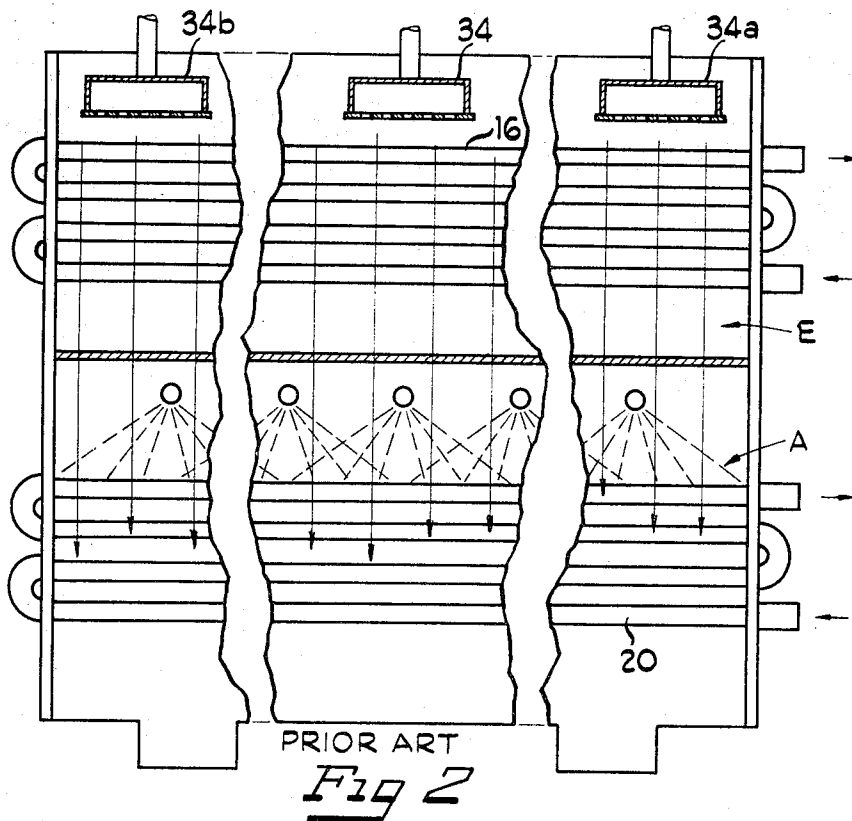
ABSTRACT: An apparatus and method for increasing the effectiveness of a heat transfer additive, such as, for example, 2-ethyl, *n*-hexanol, in an absorption refrigeration machine by introducing the refrigerant containing the additive directly from the condenser into a circulating stream of refrigerant being withdrawn from the evaporator, and being pumped to the evaporator refrigerant distribution system, thus distributing the additive flow from the condenser uniformly throughout the evaporator surface. Any noncondensables from the condenser are vented back to the absorber, where they are removed by a conventional purge device. Increased capacity can also be achieved by cooling the refrigerant with condensing water.





INVENTOR
NEIL E. HOPKINS

BY *Thomas B. Hunter*
ATTORNEY



ABSORPTION REFRIGERATION SYSTEM USING A HEAT TRANSFER ADDITIVE

BACKGROUND AND SUMMARY OF THE INVENTION

This invention relates generally to improvements in absorption refrigeration systems and more particularly to an apparatus and method of increasing the effectiveness of an additive which is normally used in the solution to augment the heat transfer, particularly in the absorber and condenser.

It is well known to those skilled in the art that certain additives, such as, for example, 2-ethyl, *n*-hexanol, can produce a substantial increase in the overall capacity of an absorption refrigeration machine of the type employing water as a refrigerant and a hygroscopic saline solution, such as lithium bromide, as an absorbent.

Additives of this type create a turbulent film on the exterior of the heat exchange tubes which results in better heat transfer than a laminar film. In any event, a significant increase in capacity occurs when 2-ethyl, *n*-hexanol and similar compounds are added to the lithium bromide absorbent solution and/or the refrigerant (water).

One of the problems encountered in the use of such additives is that their relatively low solubility in the absorbent saline solution or refrigerant causes them to separate and become trapped in certain parts of the system. When this occurs, the additive is, for all practical purposes, removed from the solution; and the heat transfer efficiency of the system drops off rapidly. In U.S. Pat. No. 3,276,217, issued to J. R. Bourne et al. on Oct. 4, 1966, there is described a technique whereby the additive is kept in solution by means of heat applied to the solution at predetermined points to boil it out of the solution and induce its transfer to a point where it may be reincorporated into the solution to maintain its effectiveness. In the present invention, the additive is more uniformly distributed throughout the system by mixing a stream of refrigerant from the condenser with a circulating stream of refrigerant withdrawn from the evaporator and reintroducing it into the evaporator by sprays. In contrast, the conventional system withdraws liquid refrigerant, i.e., water, from the condenser and permits it to expand directly into the evaporator by means of a distributor such as that described in U.S. Pat. No. 3,316,735, issued to Per Edberg on May 2, 1967. The invention also contemplates the subcooling of the refrigerant by condensing water, before it is introduced into the recirculating stream.

In accordance with the above, it is a principal object of the invention to provide an improved method for more uniformly distributing a heat transfer additive in the refrigerant of an absorption refrigeration machine.

Another object of the invention is to provide a suitable apparatus to carry out the above method.

Additional objects and advantages will be apparent from reading the following detailed description taken in conjunction with the drawings.

THE DRAWINGS

FIG. 1 is a cross-sectional view, partly schematic, of an absorption refrigeration machine constructed in accordance with the principles of the present invention;

FIG. 2 is a broken, cross-sectional view through the evaporator and absorber in a more simplified shell construction of the prior art; and

FIG. 3 is a detailed partial cross-sectional view, partly schematic, of the refrigerant recirculation system shown in FIG. 1.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings and particularly to FIG. 1, there is shown an absorption refrigeration machine providing the environment for the present invention. The upper shell S-1 includes a tube bundle 10 which cooperates with a pan 12 to provide a condenser C; and a second tube bundle 14

cooperates with the lower portion of shell S-1 to provide a generator G. In the lower shell S-2, tube bundle 16 is arranged above a pan 18, both of which cooperate to provide an evaporator E; and a fourth tube bundle 20, located underneath pan 18, provides the absorber A.

The operation of an absorption refrigeration machine depends on a refrigerant that boils at a temperature below that of a liquid being chilled and an absorbent possessing great affinity for the refrigerant. In the particular system to be described, the refrigerant is water and the absorbent is an aqueous solution of a hygroscopic salt, such as lithium bromide. While some absorption machines actually circulate the refrigerant directly to a load, the apparatus illustrated herein uses a secondary heat exchange medium (usually water) which is chilled in the evaporator by indirect contact with the refrigerant and then circulated to and from the load.

The generator G, the condenser C, the evaporator E, and the absorber A are all connected to provide a closed circuit, continuous cycle refrigeration system. Relatively dilute (about 59 percent LiBr by weight) absorbent solution is circulated to the generator G through conduit 22 where it comes in contact with tube bundle 14, to which a heating medium, such as steam or hot water, is supplied through line 24. Under the pressure and temperature conditions existing in the upper shell (about one-tenth atmosphere) the solution boils, releasing water vapor and concentrating the solution. The water vapor boiled off in the generator flows upwardly to the condenser C where the vapor is brought into contact with tube bundle 10 through which cooling water (from a cooling water tower or the like) is circulated. The refrigerant condensing on tube bundle 10 collects in pan 12 and is carried by a conduit 26 to mix with refrigerant being delivered to the inlet side of the refrigerant pump 30. This intersection of the refrigerant line 26 with pump inlet line 31 is indicated by reference numeral 32. Refrigerant pump 30 carries the combined stream to a spray header 34 through line 35 where it is distributed over the chilled water coil 16. This refrigerant flows downwardly in contact with evaporator tube bundle 16, or chilled water coil, where it abstracts heat from water circulating to and from the load through lines 17 and 19, dropping the temperature of the chilled water from approximately 54° F., (as it is normally returned to the load, at full capacity), to approximately 44° F. Unevaporated refrigerant collects in pan 18 and flows to reservoir 21 attached to the lower shell conduit 31 to the inlet side of refrigerant pump 30, and then back to distributor 34.

The water vapor formed in the evaporator by contact with the chilled water coil passes through eliminators 36, which are employed to reduce the amount of liquid refrigerant carried into the absorber, and sweeps downwardly into the absorber section A where it is absorbed in the absorbent solution, the heat of solution being removed by contact with the absorber tube bundle 20, also supplied with cooling water and usually connected in series with condenser coil 10.

As the water vapor is absorbed by the absorbent solution, the solution naturally becomes more dilute and is withdrawn through conduit 38 to the inlet side of generator pump 40. The relatively cool, dilute solution to be forwarded to the generator passes through a solution heat exchanger 42 where it is brought into direct heat exchange relation with the hot, concentrated solution passing from the generator through conduit 44. The relatively concentrated solution is cooled through an appreciable range, withdrawn from solution heat exchanger through conduit 46, and introduced into a stream of relatively dilute solution in a suction connection 48 (located at a point remote from the suction connection 39 for the dilute solution line 38). The concentrated solution is mixed with said dilute solution to form an intermediate (62-63 percent LiBr) strength solution which is taken off through line 50 and pumped by solution pump 52 via line 54 to the absorber spray header 56. This intermediate strength solution of lithium bromide is continuously distributed through nozzles over the absorber tube bundle 20. In a conventional system, refrigerant distribution box 34 would be arranged as shown in the sim-

plified shell of FIG. 2, close to the longitudinal center of the unit. Alternately, distribution boxes are sometimes arranged in two sections, associated with the ends of the unit as indicated by distributors 34'a and 34'b. In any event, the dimensions of the distribution boxes of the type described in U.S. Pat. No. 3,316,735 are somewhat limited, and it is impractical to arrange them along the length of the entire unit for uniform distribution. As best shown in FIG. 1, the vapor from the evaporator E flows out through eliminators 36 and then downwardly around pan 18 into the absorber A. Looking at a longitudinal view, such as in FIG. 2, the path of vapor flow, indicated by the arrows, should be uniformly distributed over the length of the unit. However, with the distribution box (FIG. 2) arranged in the longitudinal midsection of the unit at 34', then refrigerant from the condenser being expanded to the distribution box would tend to distribute the additive from the condenser, not uniformly over the length of the unit, but the vapor flow directly below the distribution box would tend to be favored in the amount of heat transfer additive present. Alternatively, if the distribution boxes are located at the ends of the unit, as at 34'a and 34'b, then the vapor flow from the evaporator to the absorber at the ends of the unit would be favored and the vapor flow from the middle of the unit would be proportionally lacking in this additive.

The situation would be improved if the distribution box were arranged to be active over the entire length of the unit, so that all parts of the evaporator would have equal participation in the additive-rich refrigerant from the condenser.

While it is possible to construct a distribution box in this manner, this solution would add somewhat to the expense and space requirements. This invention solves this problem by a unique design, which design has other advantages about to be described.

First of all, by applying the refrigerant flow from the condenser directly into the refrigerant pump suction, this refrigerant, with additive, passes through the refrigerant pump, where the additive is mixed in the refrigerant stream, and then this stream is sent to be uniformly distributed over the evaporator surface. This permits the entire evaporator surface to obtain a proportional share of the additive, with the result that the refrigerant vapor stream passing from the evaporator to the absorber is uniformly proportioned with additive vapor flow. Thus, all parts of the absorber solution are absorbing refrigerant, which contains additive, and thus all parts of the absorber are permitted to work at their maximum heat transfer capability.

Also, the perforated distribution chamber used in conventional design is eliminated altogether for a cost saving; and since the liquid refrigerant from the condenser is not flash cooled in going to the evaporator circuit, but is introduced into the refrigerant circulating line at condenser pressure. Consequently, a means is provided whereby refrigerant subcooling can be achieved, using a condensing water-cooled heat exchanger, for approximately a 2 percent benefit in system capacity and 2 percent reduction in steam consumption per ton.

Referring to FIG. 3, which shows the detail of the refrigerant flow from the condenser to the connecting point 32, in the refrigerant recirculating line, this novel arrangement will now be described.

In the conventional system, the refrigerant is expanded from condensing pressure to evaporator pressure by an orifice normally located in the refrigerant line 26 from the condenser. In this invention, there is no expansion of the refrigerant through an orifice or any other expansion device, and the pressure difference existing between the condenser and the evaporator is taken care of by a difference in elevation Y-Y between the refrigerant in the refrigerant reservoir suction sump 21, and the level X-X of refrigerant in line 26. Since operating conditions vary, depending upon capacity and other variables of an operating system, the difference between condensing pressure and evaporating pressure will vary and, consequently, the levels of refrigerant at Y-Y and X-X will vary somewhat. This

variation is indicated by showing the level in the evaporator sump as Y-Y or Y'-Y' and level in the refrigerant line 26 as X-X or X'-X'. The difference in level between Y-Y and X-X would vary in a normal operating system between the minimum of 1.3 feet and the maximum of about 2.7 feet.

In the conventional system, the orifice feeding the refrigerant to the evaporator is normally oversized so that some vapor passes through with the liquid. Thus, any noncondensables which may accumulate in the condenser are able to pass to the lower shell where the purge system removes them from the system. In the present invention, since there is no passage of vapor from the condenser, inasmuch as a liquid level is established, at X-X for example, any noncondensables in the top shell would not be able to pass to the lower shell. A vent line, 64, is therefore used for a restricted vapor flow of vapor to bleed off any noncondensables which may tend to collect.

The vent line, 64, should properly have an orifice, or other restriction 66. The entrance end of the vent tube 67, should have relatively low velocity so that water droplets are not forced into the vent tube, and the vent tube should properly project downward in pipe 26, as shown.

With a liquid level established at X-X or X'-X', the level is always below the entrance 67, of vent tubes 64, for proper venting of noncondensables. Also, the liquid level is always above the level of junction 32 into the pump suction line, so that vapor is not blown through from the condenser. The fact that entrance connection 32 is always below the surface of the liquid, permits the use of a heat exchanger 68 for subcooling of the refrigerant flowing from the condenser. Cooling water line 69 takes 85° condensing water from the cooling water entrance connection to the absorber, and line 70 returns cooling water to absorber connection 95, which permits a small stream of cooling water to bypass the absorber, being used for refrigerant subcooling. In this manner, refrigerant at 110° before the heat exchanger can be cooled to 90°, which amounts to a 2 percent benefit in capacity and a 2 percent reduction in steam consumption per ton.

There is normally sufficient elevation in the evaporator pan above pump suction so that the differences in vapor pressure between the top shell and the lower shell can be compensated for by the difference in liquid level in the evaporator pan compared to the drop leg carrying the condensed refrigerant. There would be no flashing of this refrigerant and the level could be established approximately a foot above the level of the pump. Accordingly, a liquid subcooling coil 68 may be used in line 26 using 85° F. cooling water such as that being supplied to the condenser and absorber heat exchangers. This could result in 2 percent savings in steam consumption and nearly a 2 percent capacity increase of the unit.

While this invention has been described in connection with a certain specific embodiment thereof, it is to be understood that this is by way of illustration and not by way of limitation; and the scope of the appended claims should be construed as broadly as the prior art will permit.

What I claim is:

1. An absorption refrigeration machine comprising a generator, a condenser, an absorber and an evaporator connected to provide a closed-circuit, continuous cycle refrigeration system; means for circulating a refrigerant and an absorbent solution through said refrigeration machine, said absorbent solution and said refrigerant containing a heat transfer additive; a chilled liquid coil in said evaporator; first conduit means for withdrawing liquid refrigerant from said condenser and delivering it into contact with said chilled liquid coil; second conduit means for withdrawing liquid refrigerant from said evaporator and recirculating it back to said chilled liquid coil; said conduit means for withdrawing refrigerant from said condenser including means for introducing it into the stream of recirculating refrigerant being directed to said evaporator, whereby said refrigerant is not introduced into said evaporator until it has mixed with said recirculating refrigerant.

5

6

2. An absorption refrigeration machine as defined in claim 1 including heat exchange means for subcooling the refrigerant flowing from said condenser.

3. An absorption refrigeration machine as defined in claim 1

including a vent line interconnecting said first conduit means with said absorber, whereby vapor contained in said refrigerant stream may be transferred into said absorber.

5

10

15

20

25

30

35

40

45

50

55

60

65

70

75