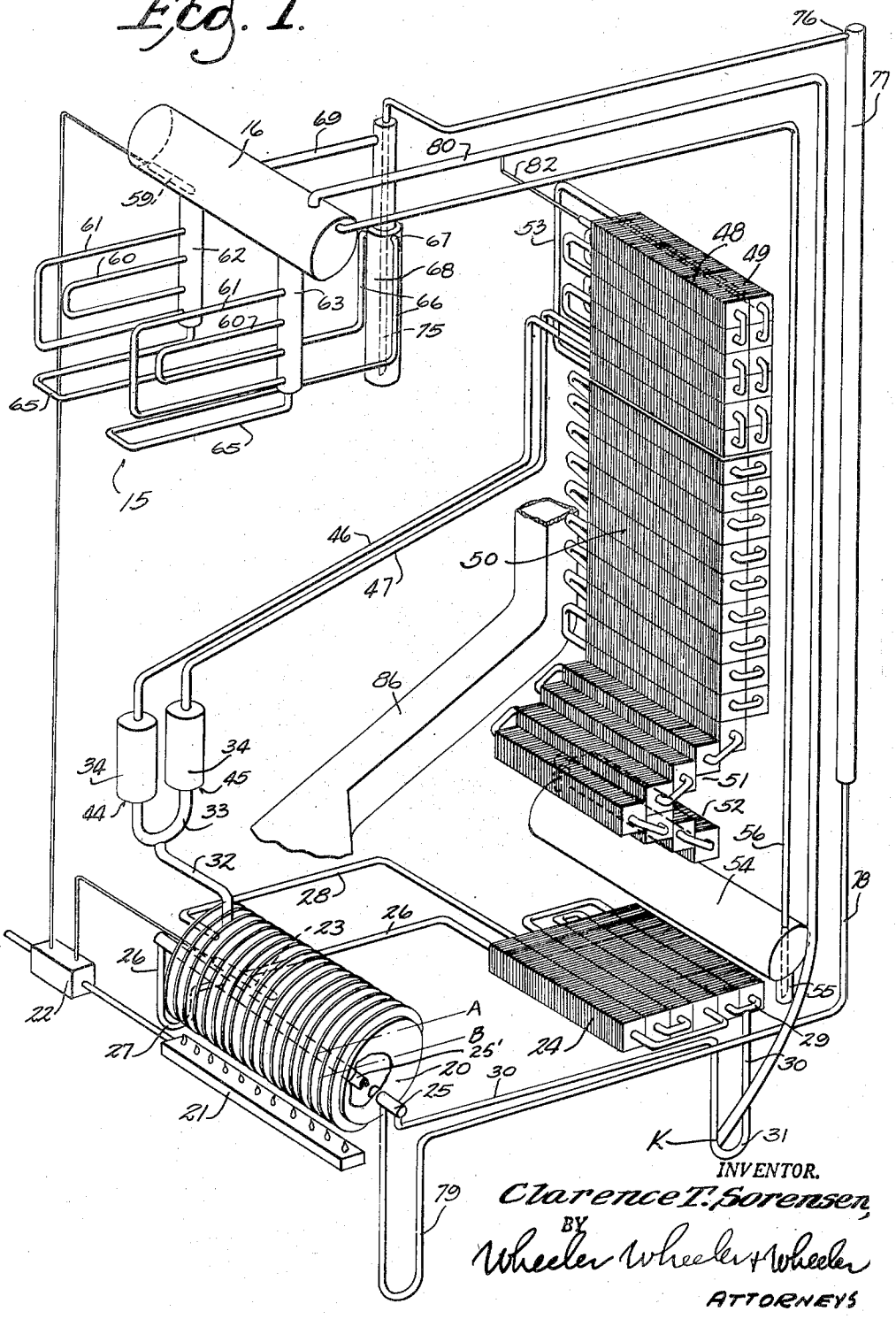
May 31, 1955 C. T. SORENSEN 2,709,575

METHOD AND APPARATUS FOR HEAT EXCHANGE

Original Filed Nov. 13, 1946 2 Sheets-Sheet 1

Fig. 1.



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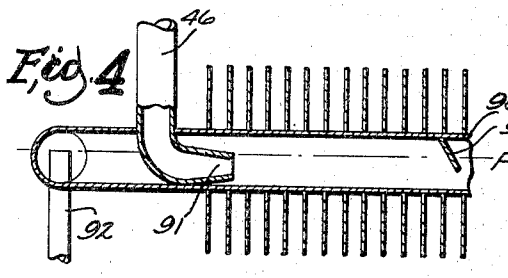

Fig. 4

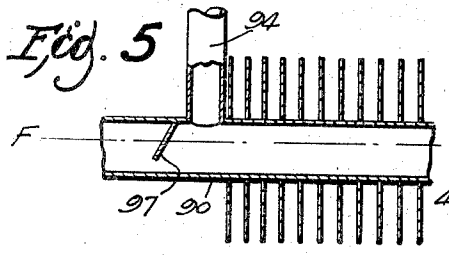

Fig. 5

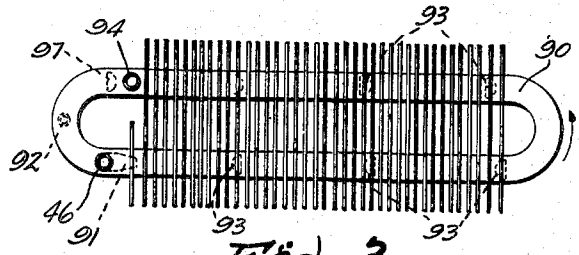

Fig. 3

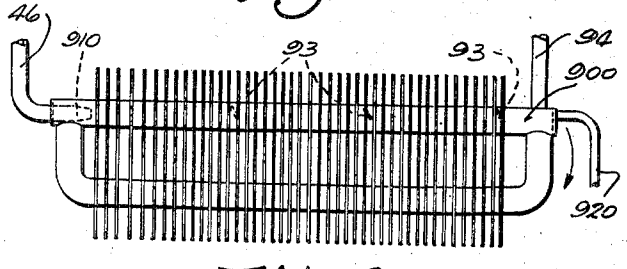

Fig. 6

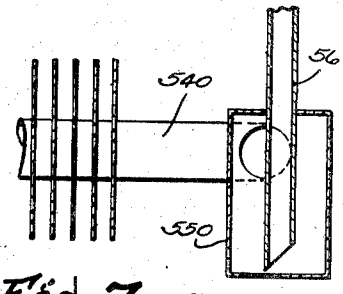

Fig. 7

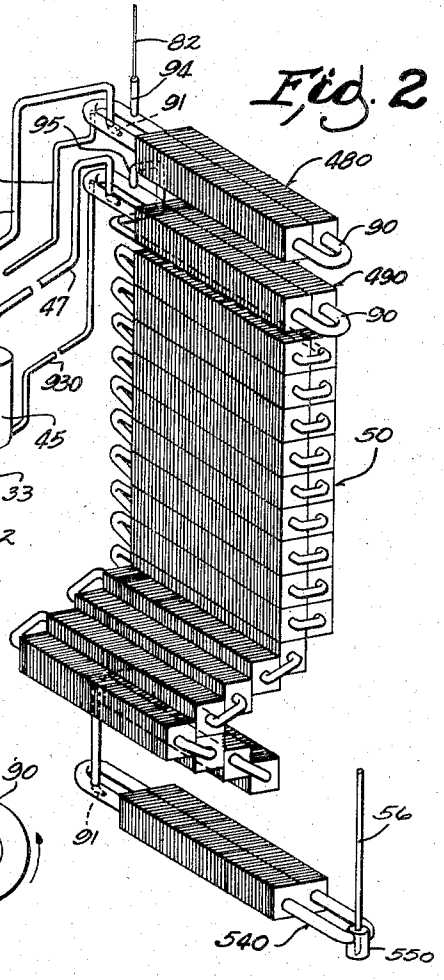

Fig. 2

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United States Patent Office 2,709,575
Patented May 31, 1955

2,709,575

METHOD AND APPARATUS FOR HEAT EXCHANGE

Clarence T. Sorensen, Lakewood, Ohio, assignor of twelve and one-half per cent to L. S. McLeod, Evanston, Ill., ten per cent to W. H. Kendall, Cleveland, Ohio, five per cent to P. W. Lewis, and five per cent to W. W. Lorch, both of St. Louis, Mo.

Original application November 13, 1946, Serial No. 709,519, now Patent No. 2,525,431, dated October 10, 1950. Divided and this application November 18, 1949, Serial No. 131,643

9 Claims. (Cl. 257—1)

This invention relates to improvements in absorption refrigeration systems and processes. The present application is a division of my application 709,519 filed November 13, 1946, now Patent 2,525,431, granted October 10, 1950, as a continuation in part of my application 417,107 entitled Absorption Refrigeration Systems and Processes and filed October 30, 1941, now abandoned.

It is an object of the invention to facilitate the action of a heat exchanger such as a condensing radiator and to make it more efficient and enable heat exchange to proceed more rapidly with less radiating surface in a device of the present character by circulating a heat exchange fluid, using arriving fluids to maintain the heat exchange fluid in circulation, and forcing the arriving fluids into and through the heat exchange fluid whereby, in the present device, the liquid absorbs heat from the gases during the heat rejecting cycle and delivers off such heat by radiation during intervals when no gases are being supplied to the condenser.

In the drawings:

Fig. 1 is a diagrammatic perspective showing the circuit connections between the component units of a refrigerating mechanism embodying my invention.

Figs. 2 is a view on a reduced scale fragmentarily illustrated in diagrammatic perspective circuit connections similar to those of Fig. 1 but employing modified condensing radiator arrangements.

Fig. 3 is a view in plan of a modified condenser arrangement such as is illustrated in Fig. 2.

Fig. 4 is an enlarged detail view in vertical section through a portion of the condenser shown in Fig. 3.

Fig. 5 is a view similar to Fig. 4 taken on a different section through the device of Fig. 3.

Fig. 6 is a view in side elevation through a different embodiment of the type of condenser radiator shown in Fig. 3.

Fig. 7 is a fragmentary detail view taken in section on an enlarged scale through a portion of the condenser receiver shown in Fig. 2.

Like parts are identified by the same reference characters throughout the several views.

The boiler or generator 20 of the refrigeration system disclosed in my patent above identified may comprise a substantially cylindrical tank lying on its side and peripherally flanged to facilitate heat exchange. Any desired heat may be provided, as exemplified by a burner 21 turned on and off by an automatic valve diagrammatically illustrated at 22, the control for which may be as disclosed in Dillman Patent 2,224,099. Any other controls, manual or automatic, may be substituted so far as the present invention is concerned.

The strong liquid or saturated absorbent may fill the generator substantially to the level indicated at A, at which level the thermostat 23 forming a part of the control system will be covered. The lowest level which the weak liquid absorbent will reach in the generator is

represented by the line at B in Fig. 1, at which level the thermostat 23 will be exposed above the level of the liquid.

Between the level of the bottom of the generator and the level represented by the line B, I provide a single or multiple cooling radiator at 24 in an absorbent cooling loop which provides a closed circuit between the radiator and the absorbent liquid in the generator. The hot liquid outlet from the generator is provided from the high end of an inclined pipe 25 which projects from both ends of the generator, as best shown in Fig. 1. Pipe 26 provides a trap at 27 and extends thence to the radiator 24. If a duplex cooling radiator is provided as specifically illustrated in Fig. 1, a separate pipe 28 may issue from approximately the same level in the generator to flow in parallel through the cooling radiator 24. From the discharge portion 29 of the single or duplex cooling radiator coils issues a return pipe 30 provided at 31 with a trap and returning in an upward direction into pipe 25 at its lower end.

Approximately the lower one half of pipe 25 is cut away within the generator or boiler 20, leaving at 25' within the boiler an inverted semi-tubular trough upwardly inclined but maintained at all times below the level of absorbent in the generator. Except for the traps 27 and 31, all portions of the circulatory loop, including cooling radiator 24, are higher than the bottom of the generator and lower than the minimum level of absorbent therein.

Generator 20 is provided with an outlet at 32 for gaseous refrigerant driven from the absorbent during the heating portion of the cycle. The outlet pipe 32 leads to a U-tube 33, the ends of which enter separate float chambers 34.

From the chambers 34, pipes 46 and 47 lead with a substantial upward pitch to the lower flights of rectifying radiators 48 and 49 respectively. The radiators are preferably identical; the runs of pipe at 46 and 47 are substantially identical, it being desired that pipe 46 and radiator 48 be in balance from a heat exchange standpoint with pipe 47 and radiator 49. Referigerant evaporated in the generator or boiler 20 passing upwardly through the respective valve sets 44 and 45, is accompanied by a certain amount of absorbent liquid which is unavoidably entrained therewith. The heat exchange capacity of the rectifying radiators 48 and 49 is so determined with reference to normal conditions to which the device is exposed in use, that no appreciable quantities of refrigerant will be condensed in rectifying radiators 48 and 49 but substantially all of the absorbent will be condensed therein and will flow backwardly through the radiators and the pipes 46 and 47 to the still or generator at 20.

Immediately beneath the pair of rectifying radiators 48 and 49 (in the preferred physical disposition of the parts), I provide a condenser radiator 50 of much larger capacity which may have added sections at 51 and 52 which are so disposed as to facilitate the flow through them of the coldest air circulating in the flue in which the radiator assembly is located. The pipe 53 discharging from the top of rectifying radiator 49, enters the top of condenser radiator 50, such radiator comprising a finned tube which is continuous in a series of convolutions downwardly to its lower end. At its lower end the tube which comprises condenser radiator 50 may communicate with a radiator receiver 54, the use of which is optional since the refrigerant condensed in radiator 50 may, if desired, be discharged directly from the condenser radiator without first being accumulated in the receiving tank 54.

The cooling radiator 24 and the condenser radiators 50, 51, 52, alternate in giving off heat at different periods of

the cycle so that the heat given off by one in no way affects the heat radiating capacity of the other. Together they are practically continuously rejecting heat, thereby maintaining a substantially continuous air current up the flue.

Whether the condensed refrigerant is taken from accumulator 54 or directly from the condensing radiator section 52, there will in either case be a well provided at 55 from which conduit 56 leads upwardly to an upper portion of the evaporator receiver. The bulb 59 of the control thermostat may be located in receiver 16 if desired.

From the bottom of the evaporator tank 16 open the headers 62 and 63 of the evaporator 15. U-shaped tubes 60, 61 extend in communication with each of the headers 62 and 63. Each header, however, is extended downwardly below the bottom of tube 61 and provided with a tube 65 which follows a U-shaped pattern but extends rearwardly and upwardly at 66 and thence horizontally at 67 into a standpipe 68 at an intermediate point. The top of the standpipe is placed in comunication by means of tube 69 with the top of the receiver 16.

From the bottom of the well which is provided by the closed lower end of stand-pipe 68, leads a conduit 75 which may conveniently be spaced from the extreme lower end of the chamber by beveling its end as shown in Fig. 1. This conduit issues from the top of the chamber and thence extends at 76 into an enlarged duct 77, the lower end of which is drained by pipe 78 leading through trap 79 into the lower end of pipe 25, whereby a return connection is provided for liquid absorbent.

Gaseous refrigerant evaporating in the evaporator tubes 60, 61, headers 62 and 63, pipes 60 and 61, and in the receiver 16, is returned from the top of the receiver 16 through pipe 80 down to one of the lowermost portions of the circuit near the bottom of the trap 31 in the portion of the absorbent circulating loop through which the cooled absorbent is returned from cooling radiator 24 to the generator or still 20. The point of connection is designated at K in Fig. 1. The pressure balancing connection from conduit 46 through rectifying radiator 48 to the evaporator is made by means of tube 82 which leads from the top of radiator 48 into the refrigerant return pipe 80, although any other connection at a high level to the upper end of the evaporator or adjusting portions of the system, would serve equally well.

The various traps should desirably be proportioned as follows:

The column of liquid in the tube 75 in the well 68 of the evaporator, as measured from the lower end of the tube 75 to the level of liquid in the evaporator, should at all times be less than the distance between the bottom of trap 79 vertically to the level A (the maximum level of liquid in the boiler generator 20). In practice, I prefer that the extent of trap 79 below the maximum liquid level in the generator be approximately 1½ inches greater than the distance from the bottom of tube 75 to the maximum level of refrigerant in the evaporator.

On the other hand, the distance from the bottom of trap 79 to the minimum level B of liquid in the boiler-generator shall be less than the distance from the bottom of tube 75 to the maximum level of liquid in the evaporator receiver 16.

The vertical distance of point K below the level A which represents the maximum level of liquid in the boiler-generator is also less (preferably by about 1½ inches) than the length of pipe 75 from the bottom thereof to the maximum level of liquid in the evaporator receiver 16.

The device operates as follows:

As generally described in Dillman Patent 2,224,099, the heating cycle is initiated by heating the thermostat bulb 59 after such bulb is exposed by the receding level of liquid in the evaporator receiver 16 as the refrigerant therein becomes evaporated for cooling purposes. This opens the automatic valve at 22 supplying fuel to burner 21 and the flame ignited by a suitable pilot (not shown) heats the boiler generator or still 20.

Due to the re-absorption of refrigerant by the absorbent in the still 20, the height of liquid in the still at the commencement of the cycle will be represented approximately by the line A (Fig. 1). While it is broadly immaterial what refrigerant and what absorbent are used, it may for the purposes of this disclosure, be assumed that the absorbent is ordinary water and the refrigerant is ammonia gas.

The heat will expel ammonia gas from the strong liquor in the generator 20, and the ammonia gas, together with such water vapor as is unavoidably entrained therewith, will issue from the generator through pipe 32 and enter the U-tube 33, escaping therefrom through valves 36 into the chambers 34 to the valve sets 44 and 45.

As above noted, the heat rejecting capacity of rectifying radiators 48 and 49 is so chosen as to condense most of the water vapor without condensing the ammonia vapor. The condensate will flow back through pipe 46 and pipe 47 to chambers 34, raising the floats 35 in such chambers and thereby lifting the check valves 36 from their seats to permit the return of the condensate to the generator. Meantime the principal delivery of refrigerant vapor is occurring through the condensing radiator 50, 51, 52, and the condensed refrigerant is being received and stored in the receiver 54 (or in the bottom of the condenser section 52, or both). Some substantial portion of the condensed refrigerant would be delivered directly to the evaporator at this point but for the equalization of pressures throughout the system achieved through pipe 46 and balancing radiator 48 and capillary connection 82 to the top of the system.

The amount of refrigerant delivered to the top of the system will be negligible because the refrigerant so delivered tends to remain gaseous whereas the refrigerant delivered through pipe 47 and rectifying radiator 49 is condensed in radiator condenser section 50, 51, 52, and, occupying considerably less volume in its condensed state, it makes room for the constant accession of further supplies of gaseous refrigerant through this portion of the system. Condensation is, of course, achieved by a combination of high pressure and heat rejection in the condenser radiator sections.

The direct communication of pressure through the balancing pipe 46, rectifying radiator 49, and communicating pipe 82, likewise prevents the absorbent from being forced backwardly up from the generator through either of the return ducts 79 or 80.

So far as the absorption liquid is concerned, it will be apparent that no convection currents will be established between the generator 20 and the loop cooling radiator 24 for the reason that the absorbent is substantially at the same level throughout the circuit comprising the generator, the loops, and radiator 24. Consequently the absorbent will remain substantially non-circulatory in the loop system during the heating phase of the cycle.

When the evaporation has progressed to the point where the absorbent in generator 20 has dropped to the level indicated at B, thereby partially or wholly exposing the thermostatic bulb 23 above the liquid level, the controls will function to cut off the supply of fuel to the burner 21, thus initiating the cooling phase. Air will continue to rise through the heated flue 86 about the fins of the generator 20, rapidly cooling the generator and thereby decreasing the pressures existing in the generator. Pressures will remain high in the rectifying and condensing radiators 48, 49, 50, 51, 52, because the check valve chambers 34, prevent the maximum pressure achieved during the heating phase from becoming relieved back to the generator. However, the low pressures now existing in the generator will eventually result in at least partial reduction of pressures at the evaporator, the pipes 76—77—78 and 80 affording free com-

munication between the generator and the refrigerator save only for the seals provided at 31 and 79.

As soon as the evaporator pressure drops below the pressure in the condenser radiators, the entire supply of liquid refrigerant accumulated in the condenser radiators and the radiator receiver 54, will be delivered by the existing pressure differential from the well 55 through the pipe 56 to the evaporator receiver 16 which will be substantially filled by the liquid refrigerant thus transferred. Once the transfer of liquid refrigerant commences, it will be accelerated by heat rejected from the radiator 24 as hereinafter described, tending to raise the temperature of the refrigrant in the accumulator 54, thereby increasing the pressure at this point in the system.

As soon as the liquid refrigerator is delivered to the evaporator it will normally commence to evaporate therein. The resulting refrigerant vapor passing through the return pipe 80 to the point K in the trap 31, will bubble into the weak liquor standing in trap 31 and will rise in the return side of trap 31 toward the generator. This will exert a very substantial pumping action initiating the rapid circulation of absorbent through the loop system, including loop cooling radiator 24. Since the weak liquor into which the returning vapor is delivered at K is already cool, re-absorption will immediately commence, and this absorption will continue as the refrigerant bubbles move with the weak liquor in the returning side of the loop toward the generator. If the capacity of radiator 24 is approximately equal to the capacity of the generator at this point in the cycle, this circulation will ultimately completely replace the hot weak liquor in the generator with cool weak liquor from the cooling radiator, leaving the generator filled with cool liquor and leaving substantially all of the warmer weak liquor in the radiator where it may speedily give off its heat.

This heat will be delivered to convection currents of air rising in the flue and these currents will tend to reheat, to a material degree, the accumulator 54, thereby raising the pressure of the refrigerant trapped in this accumulator and accelerating the delivery of the remainder of such refrigerant toward the evaporator receiver 16 as above described.

In the meantime such bubbles as are still entrained unabsorbed in the weak liquor entering pipe 25 at its lower end from loop duct 30, are not released in the generator to bubble noisely to the surface. The weak liquor itself is freely discharged into the generator by reason of the fact that the whole lower half of pipe 25 is cut away. The remaining upper half 25' of pipe 25 serves, however, as an inclined and inverted trough which retains the bubbles in full contact with the weak liquid in the generator and in constantly shifting communication therewith as the bubbles slowly rise by reason of the inclination of the inverted trough. Ordinarily all such gases will be completely absorbed in traversing the length of the inverted trough section 25' of pipe 25, but should any such bubbles fail to be absorbed they are still held against release and returned through pipe 26 to the cooling radiator 24. There are important advantages in delivering the gaseous refrigerant at K into the return side of the loop circuit where it will act upon weak liquor which has already been cooled.

The absorbent, in liquid form, is materially heavier than the refrigerant, and insofar as any absorbent is condensed or passed in liquid form into the evaporator, it will tend to settle to the lowest point in the evaporator system and will therefore be collected in tubes 65 which leads from the lower ends of headers 62, 63. The problem of returning such liquid absorbent from the evaporator to the generator without completely emptying the evaporator of liquid refrigerant is solved by the system disclosed in the following manner.

At that portion of the cycle when the initial cooling of the generator results in delivery of liquid refrigerant from the condenser to the evaporator receiver, the pressure differential created by the influx of liquid refrigerant into the top of the receiver forces out of pipes 65 of the evaporator a substantial part of their entire liquid contents, these being discharged into the stand-pipe 68 midway of the height thereof through duct 67. This operation, therefore, results in delivering into the stand-pipe 68 all of the liquid absorbent which has collected in the evaporator. The proportions of the parts are so determined as to make such of thus delivering to the standpipe all of the liquid absorbent even though some liquid refrigerant may also be similarly delivered to the stand-pipe.

During the entire evaporation phase of the cycle in which the liquid refrigerant is evaporating in the evaporator and the gas is returning to the generator as above described, such liquid absorbent will remain in the well at the bottom of stand-pipe 68. At the initiation of the next heating phase when the burner 21 is again lighted and gas is again expelled from the absorbent in the generator, the initial pressure differential developed in the generator will be communicated immediately through the balancing leg of U-tube 33 and through the valve set 44, pipe 46, rectifying radiator 48 and duct 82 to the top of the evaporator where it will subject to pressure the upper surface of the liquid trapped in the well at the bottom of stand-pipe 68. This pressure will exceed the pressure in the tube 75 which extends downwardly to the bottom of the well for the reason that any back pressure tending to be communicated to tube 75 through trap 79 and pipe 78 is resisted by the head of liquid raised in pipe 78 from trap 79. The result is to establish a pressure differential between the stand-pipe 68 and the tube 75 therein contained, which results in forcing the accumulated liquid from the bottom of the stand-pipe upwardly through tube 75 into tube 76 and thence downwardly through the enlarged pipe 77. The cross section of pipe 77 is sufficiently large with respect to the cross section of tube 76 and tube 75 so that the liquid descending through pipe 77 cannot siphon all of the liquid from the evaporator but can only draw from the stand-pipe 68 such liquid as stands therein below the level of tube 67. It will be noted in Fig. 1 that the well 68 is enlarged from this point downwardly, this being one of several possible means of breaking any siphon action at that point, whereby to prevent any vacuum from being pulled on the upper end of the stand-pipe. As a result, such liquid absorbent as is in the well at the bottom of the stand-pipe is returned, with perhaps a small quantity of liquid refrigerant likewise standing below the level of tube 67 in the stand-pipe. Such remaining body of liquid refrigerant as may have been left in the evaporator tubes 60, 61, 62, 63, 65 at the commencement of the cycle remains undisturbed, as tube 69 balances pressure between tube 68 and receiver 16 to prevent liquid refrigerant from being siphoned back to the generator with purged absorbent.

Thus, by a series of pressure differentials successively established at different intervals in the cycle, I am able progressively to segregate and return absorbent which reaches the evaporator, without inefficiently returning for re-absorption and re-evaporation any substantial quantities of refrigerant which may exist in liquid form in the evaporator.

By reason of its intermittent cycling as above described, my improved refrigeration system develops pressure differentials which are entirely adequate for the alternate evaporation or condensation of refrigerant without requiring the excessively high pressures which are necessary in the continuous type absorption refrigerators. The resulting action is very positive as compared to the action of other absorption systems of the intermittent type. The means of returning liquid absorbent as above described avoids the delivery of any appreciable quantity of hot gases into the evaporator and at the same time so successfully purges the system with a minimum of refrigerant

waste that the hold-over capacity of the brine tank 72 is adequate to prevent defrosting of the quick freezing shelves and ice trays during the heating phase of the cycle.

I have found that the condensing radiators may be made more efficient to require less material and less space and to operate on a new principle if they embody the heat exchange feature which is the specific subject of this application. Each of the rectifying radiators 480, 490, which serve as modified embodiments of the previously described rectifying radiators 48 and 49, is preferably made in the manner clearly shown in Fig. 2 and Fig. 3 to comprise a closed circulatory loop 90 provided with the usual radiating fins and into which the mixed gases delivered from the check and float valve sets are delivered through circulatory flow-inducing nozzles 91 (Fig. 3). Drain pipes 92, 930 connected with the respective circulatory loops maintain normal liquid levels as indicated at F in Fig. 4, below which the nozzle 91 is disposed. Thus the gas issuing from the nozzle 91 engages and entrains the liquid in the circulatory loop 90 to effect circulatory movement thereof around the loop whereby fresh liquid is constantly being presented to the gas issuing from the nozzle. At intervals about the loop, I may provide baffles 93 which extend downwardly below liquid level to force any gas which has separated in the upper part of the loop to re-enter the liquid in order to pass the baffle. I provide outlets 94, 95 from the respective loops 90, communicating with the capillary pressure balancing tube at 82 and outlet 95 communicating with the more conventional condensing radiator 50. Just beyond each of these outlet pipes 94, 95, I provide a much deeper baffle 97 which provides a trap to keep the gases from short circuiting the loop between the inlet and the gas outlet therefrom.

The drain pipes 92 and 930 carry back to the respective valve sets 44, 45 the absorbent liquid condensing in the rectifying loop condensers 480, 490. These are made desirable for the reason that the nozzles 91 preferably enter from above, as shown, whereby separate draining means for returning the weak liquor is appropriate.

Fig. 6 simply shows an alternative arrangement using a loop 900 which is arranged vertically instead of horizontally. The nozzle 910 enters axially of the top leg of the loop. The return pipe 920 opens from the upper part of the top leg of the loop and the several baffles 93 are all located in the top leg of the loop. The bottom leg of the loop replaces the special baffle 97 used in the previously described embodiment to prevent gases from bypassing the several baffles 93 en route to the gas discharge pipe 94.

The accumulator 54 need not necessarily comprise a tank as shown in Fig. 1, but may comprise a loop identical with those shown in Figs. 2 or 5 except that the baffles are omitted. Fig. 7 shows a detail of the manner in which the sump 550 connects to the circulatory loop 540.

In these various circulatory loop type condensers, I take advantage of the fact that the gas to be condensed is arriving intermittently. During the interval when no gas is being delivered to the condensers, the fins with which the loop tubes are provided continue to reject heat from the liquid trapped in the loop. Thus, by the time gas is again admitted, the trapped liquid is thoroughly cooled and, as the gas entrains the liquid at the nozzle, thorough admixture is effected and a large and constantly changing liquid surface is presented to the gases to assist in the cooling and condensation thereof. The liquid gives sufficient additional surface to compensate for a greatly decreased length of condenser tube and, at the same time, causes the newly arrived gaseous refrigerant to condense very expeditiously.

Otherwise the modified apparatus embodying any one or more of the several alternative embodiments illustrated operates substantially as above described.

The apparatus and method disclosed in connection with Figs. 2 to 7 are adaptable for heating or cooling a variety of fluids (either gaseous or liquid) through direct contact with an intermediary fluid which is immiscible with the fluid to be heated or cooled and deriving motion from said last mentioned fluid for heat exchange by conduction and convection. Obviously, I do not mean that the two fluids involved must be wholly immiscible, for, in the present case, a certain amount of the gaseous refrigerant will either condense to a liquid and mix with the liquid which is in circulation, or will be dissolved in the circulating liquid. However, it suffices that the fluid to be cooled may be separated by gravity or otherwise from the heat exchange fluid, allowing the heat exchange fluid to give up its heat while circulating to another part of its circuitous path.

I claim:

1. A method of heat exchange with a first fluid confined for circulation in a predetermined closed path which comprises introducing and commingling with the first fluid, a second fluid with which it is materially immiscible, circulating both fluids together along a portion of said closed path, separating said fluids after heat exchange has occurred between them, moving the said second fluid in a closed circuit upon which it is returned to said path for further commingling with the first fluid, and restoring the first fluid toward its original temperature by subjecting it to additional heat exchange after said separation and during movement in said closed circuit.

2. The method of claim 1 in which the second fluid is injected intermittently into the first fluid.

3. The method of claim 2 in which the first fluid is subjected substantially constantly to heat exchange with a third fluid about the tube irrespective of injection of the second fluid.

4. A method of heat exchange which comprises circulating two substantially immiscible fluids in closed circuits having a common branch in which said fluids circulate in the same direction in contact for direct heat exchange, separating said fluids after they have traversed said common branch, and raising the temperature of one fluid and lowering the temperature of the other during their circulation in other portions of their respective circuits.

5. A heat exchange device comprising a closed loop tube, a heat exchange fluid confined for circulation in said tube, means for introducing a second fluid into the tube and effecting circulation thereof in the same direction as the heat exchange fluid for direct heat exchange with the heat exchange fluid as well as with the tube, said heat exchange fluid being at least materially immiscible with said second fluid, and means for the segregated delivery of the second fluid from the tube, leaving the heat exchange fluid therein.

6. The device of claim 5 in which the means for introducing the second fluid comprises an injection nozzle directed along the path of circulation of the heat exchange fluid in the tube and through which nozzle the second fluid is introduced into said tube, whereby to entrain the heat exchange fluid and induce circulation in said tube.

7. The device of claim 5 in which the closed loop tube is horizontally disposed and the circulatory movement of the liquid is generally horizontal.

8. The device of claim 5 in which the closed loop tube is vertically disposed and the circulatory movement of the liquid is in a generally vertical plane.

9. The device of claim 5 in which the closed loop tube is provided with baffle means between the introducing means and the delivery means for precluding fluid separation from said liquid during said heat exchange.

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