July 1, 1930. R. W. DAVENPORT 1,769,112

PROCESS OF AND APPARATUS FOR TRANSFORMING HEAT

Filed July 21, 1926 2 Sheets-Sheet 1

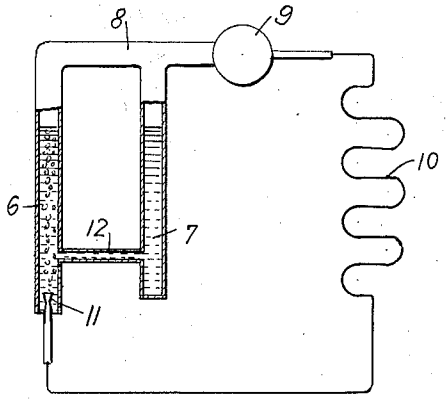

Fig. 1

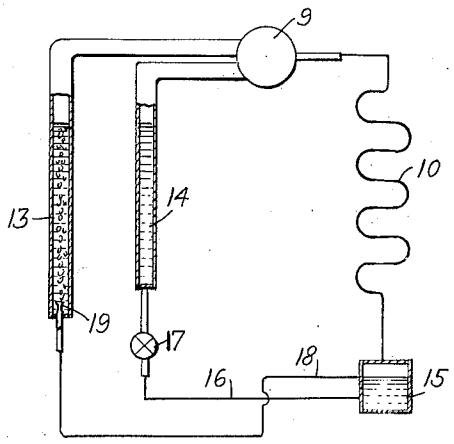

Fig. 2

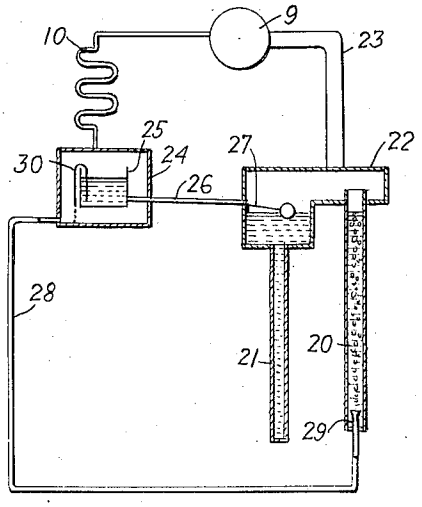

Fig. 3

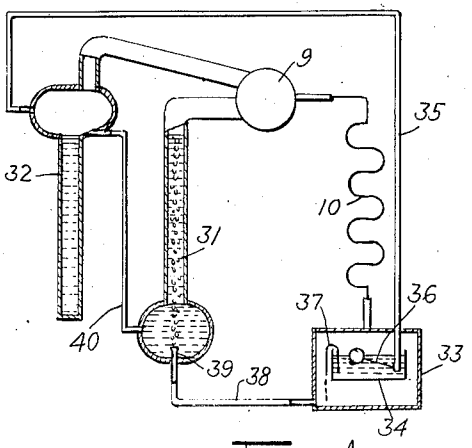

Fig. 4

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PROCESS OF AND APPARATUS FOR TRANSFORMING HEAT

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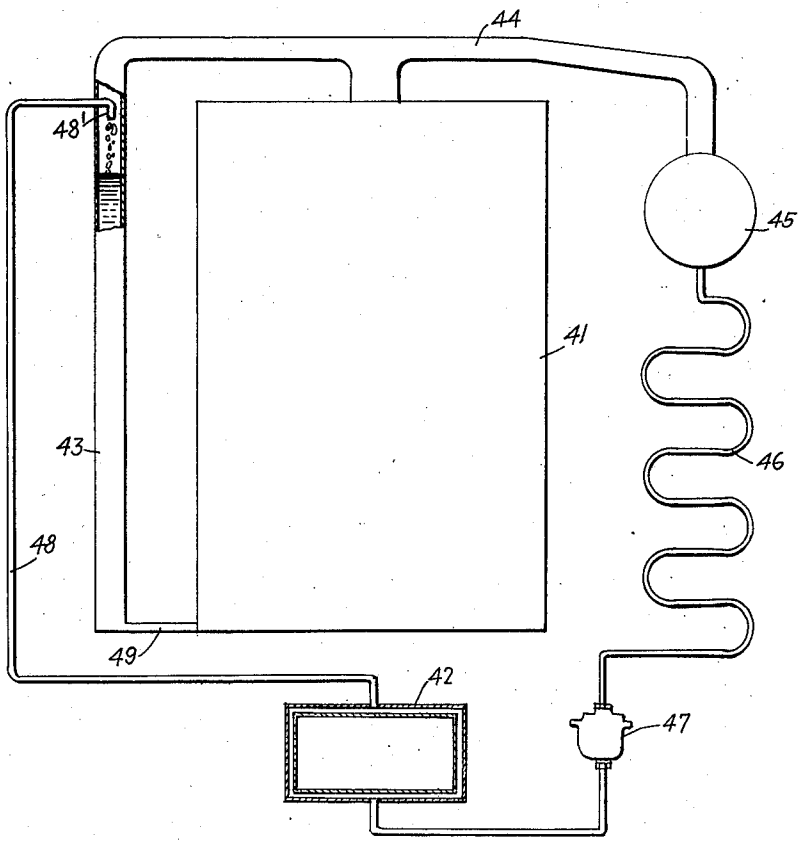

Fig. 5

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PROCESS OF AND APPARATUS FOR TRANSFORMING HEAT

Application filed July 21, 1926. Serial No. 123,912.

This invention relates to the transforming of heat and comprises both a process and apparatus. It particularly concerns the production of refrigeration by artificial means. More particularly it relates to thermodynamic cycles of the type which utilizes a working substance comprising a physical mixture of a volatile liquid and of a gas substantially inert to and insoluble in the liquid and incondensible at ordinary atmospheric temperatures and pressures, as disclosed in my copending application, Serial No. 603,998, filed Nov. 29, 1922, Patent No. 1,619,194 dated March 1, 1927. In one aspect the invention may be considered as an improvement upon and a further development of heat transforming processes of the type disclosed in my copending application, Serial No. 15,172, filed Mar. 12, 1925, Patent No. 1,619,196 dated March 1, 1927.

The usual or conventional method of causing a liquid to evaporate in a closed cycle refrigerating system is simply to pump the vapor from the receptacle containing the liquid. When conditions are such that the density of the vapor in the pump cylinder (or its equivalent) at the end of the suction stroke is approximately that corresponding with the maximum density of the saturated vapor on the liquid in the evaporator, the maximum efficiency attainable in this step of the cycle is reached. But it is well known that the vapor density in the pump does not correspond with the vapor density of the liquid and that the pump operates much below its theoretical efficiency. These conditions may result from the reduction of the area of contact between the liquid and the column of vapor connecting its surface with the pump cylinder or from the elimination or reduction of air or gases from the liquid.

I have noted that these conditions become more and more pronounced and effective in causing this difference in vapor density as the normal vapor density at the liquid surface decreases. In other words the effect is greater with liquids of low vapor tension than with liquids of high vapor tension, and with a given liquid the effect increases as the temperature of the liquid decreases. Thus a liquid such as alcohol may be evaporated with a fair approach to normal efficiency at a temperature of 60° F., for example, even with a limited vapor contact area and in the absence of air, but upon attempting to lower its temperature below 32° F., for example, by pumping in the ordinary manner the vapor density in the pump cylinder falls so low as to produce an insignificant refrigerating effect. Consequently with a substance of this type having a comparatively high boiling point (as working substances go) it is necessary to apply methods and apparatus of the type disclosed in my copending applications above referred to in order to produce results below the freezing point of water.

The conventional or "straight-pumping" method of removing vapor as practiced in all ordinary processes, must of course always be performed at a constant temperature-pressure level. With the straight-pumping method, therefore, it is impossible to produce differential refrigerating effects with a single pump except by evaporating the liquid in separate stages, and lowering the vapor pressure, which is the total pressure on the liquid, in each successive stage as the vapor approaches the pump intake. Many varieties of such systems have been suggested and are used, in the art. It is particularly to be noted that one fundamental characteristic of all varieties of the old process is that the total or indicated gauge pressure of the vapor must be different in the separate stages, and further, that vapor must enter the pump at the lowest of all these pressures.

As will be hereinafter set forth, my improved process is basically different in this fundamental. My evaporation is carried on at a constant total indicated gauge pressure but at a variety of temperatures, and the vapor may enter the pump at the highest partial vapor pressure.

One object of my invention is to improve the processes of and apparatus for evaporating liquid for the production of cooling effects. Another object is to provide a single

thermodynamic cycle for the removal of heat from separate compartments at different low temperatures. Another object is to effect economies in operation and to produce new thermodynamic effects by a novel combination of the conventional refrigerating cycle with my vapor-gas cycle. Other objects will be apparent from the detailed description which follows.

In a refrigerating system particularly of the household type, it is usually the case that only a part of the heat need be removed at temperatures below 32° F., as in the freezing compartment. Most of the heat may be removed at temperatures above freezing as in the food storage compartment. Hence my invention consists essentially in processes and apparatus by which a liquid working substance may be evaporated at one point so as to absorb heat at temperatures below freezing and at another point at temperatures above freezing. The invention contemplates the use of a single evaporator or of a plurality of evaporators to accomplish the above purpose but only one pump or compressor is required. The invention is such as to lend itself readily to many forms of expression, certain of which are shown in the accompanying drawings, merely by way of illustration and not in a limiting sense.

In the drawings:

Fig. 1 is a diagrammatic view of one arrangement of elements for practicing my improved process; and

Figs. 2 to 5 inclusive are similar views also largely diagrammatic in character showing modifications.

While the processes and apparatus about to be disclosed are capable of use with any of the known low boiling liquid refrigerants when used in conjunction with a gas substantially inert to and insoluble in the liquid, the resulting temperatures tend to run too low for my purpose. However, the invention is particularly adapted to volatile liquids having relatively high boiling points. Such liquids preferably comprise such compositions of matter as carbon tetrachloride, methylene chloride, the methyl and ethyl chlorides comprising the substances commonly known as the chlorinated methyl and chlorinated ethyl derivaters, alcohols, etc.

In putting the invention into practice many forms and arrangements of apparatus may be used certain of which are shown rather diagrammatically in the accompanying drawings. In Fig. 1 two vessels or evaporators 6 and 7 are provided for containing the liquid working substance, such as methylene chloride for example. These vessels open into a common header 8 leading to a pump or compressor 9 so that both evaporators are subjected to the same suction effect. The stream of vapor and gas withdrawn from evaporators 6 and 7 by pump 9 is discharged at a higher temperature and pressure into a condenser 10 of any suitable or desired type where heat is extracted and the vapor of the liquid is at least partly condensed. The products of condenser 10 in the form of a stream of mixed gas, liquid and the residual vapor are expanded into evaporator 6 through a suitable expansion member, such as Venturi nozzle 11 capable of passing all the condenser products in contiguity. The expansion of the products of the condenser into evaporator 6 in conjunction with the suction effect of pump 9 produces marked cooling and heat absorbing effects in accordance with the process disclosed in my aforementioned copending application, Serial No. 15,172, filed March 12th, 1925. Thus evaporator 6 operates on the gas-vapor principle while evaporator 7 in which no expansion takes place operates on the conventional or straight pumping principle and while the total pressure which would be indicated on a gauge (not shown) connected into header 8 would obtain equally in 6 and 7, the partial vapor pressure may be higher in 7 than in 6 and the partial gas pressure higher in 6 than in 7. Since this arrangement results in a greater heat temperature reducing effect in evaporator 6 as compared with evaporator 7, the former may be utilized for low temperature work such as the freezing of liquids while evaporator 7 may be used in compartments maintained at a higher temperature, such as, food storage chambers. Evaporators 6 and 7 may be interconnected, if desired, by a passage 12, making in effect a single evaporator, but the tendency will still persist for part 6 to run at a lower temperature than part 7 in spite of the circulation of liquid set up through part 12, which circulation, of course, may be controlled or limited to a considerable extent by the size of such connection.

In Fig. 2, the two evaporators disclosed, namely 13 and 14 are quite distinct from each other and connect with pump 9 through separate conduits, while still forming parts of the same closed circuit. Pump 9 withdraws vapor only from evaporator 14 and both vapor and gas from evaporator 13. The gas and vapor thus withdrawn from both is discharged into a suitable condenser 10 which discharges the condensed and the non-condensed components of the working substance into a chamber 15 where liquid gathers at the bottom and the gas and residual vapor at the top. The connection 16 for liquid only extends from the lower part of chamber 15 to evaporator 14 supplying the latter through the conventional form of a liquid feeding device or so-called expansion valve 17. From the upper portion of chamber 15 extends a conduit 18, the inlet of which is so disposed relative to the liquid

level in chamber 15 as to pass the gas and the uncondensed vapor with or without a limited amount of liquid to expand through the nozzle member 19 into evaporator 13. In this form of the invention there is no connection between the two evaporators, which, accordingly, operate at widely differing temperatures dependent upon the particular volatile liquid which is used as the major component of the working substance.

In Fig. 3, the evaporators 20 and 21 have a common header 22 with a conduit 23 leading to pump 9, which discharges the vapor and gas into condenser 10, which in turn discharges into a chamber 24 containing a receptacle 25 for the condensed vapor or liquid refrigerant. A conduit 26 leads from the lower part of receptacle 25 so that liquid only is fed to evaporator 21 under control of an automatic float device 27. A conduit 28 leads from the bottom of chamber 24 to a feeding device 29 adapted to pass in contiguity both the gaseous and liquid components of the working substance. To insure the feeding of the proper amount of liquid through conduit 28, suitable means are provided for passing liquid in measured quantity from receptacle 25 to the bottom of chamber 24. One means for this purpose may comprise a wick 30 hung over the edge of receptacle 25 with one end dipping into the liquid.

Fig. 4 shows a slightly different arrangement from that shown in Fig. 3. Evaporators 31 and 32 have separate connections leading to pump 9 which discharges as usual into condenser 10 from which the products pass to a chamber 33 containing liquid receptacle 34. From the bottom of receptacle 34 extends a conduit 35 to the upper part of evaporator 32, the flow of liquid therethrough being controlled by a float valve arrangement 36, in this instance mounted in the receptacle 34 itself. A wick 37 conducts liquid in limited amount from receptacle 34 to the bottom of chamber 33 whence leads a conduit 38 for the stream of gas, vapor and liquid to expand through nozzle 39 into evaporator 31. Overflow conduit 40 leads from the upper portion of evaporator 32 to the lower part of evaporator 31 so that liquid refrigerant is permitted to pass to the vapor-gas evaporator 31 after being precooled in the straight pumping evaporator 32. This distinguishes from the apparatus shown in Fig. 1 where liquid fed to and precooled in the vapor-gas evaporator 6 is enabled to pass through connection 12 to the straight pumping evaporator 7.

Fig. 5 indicates somewhat diagrammatically a preferred hook-up for household refrigerating apparatus of the type disclosed in my copending application Serial No. 105,372, filed April 29th, 1926, Patent No. 1,726,344 dated August 27, 1929. This hook-up has been found to be particularly useful when the evaporator in the food storage compartment is of such size as to produce an excessive cooling of the compartment when operated on the vapor-gas principle so that the pump is shut down for such long periods as to interfere with the freezing of liquids in the cold box or ice compartment. 41 is the evaporator in the food compartment, 42 the cold box or ice making member and 43 an additional evaporator for a purpose presently to be described. A header 44 connects with the upper portions of evaporators 41 and 43 and leads to a pump 45 which discharges into a condenser 46. The feeding of the liquid and gaseous products of condenser 46 may be controlled by a suitable float device 47, such as that disclosed in the copending application of myself and Harry S. Estler, Serial No. 114,900, filed June 10th, 1926, Patent No. 1,731,710 dated October 15, 1929. The condenser products expanding through device 47 into evaporator or cold box 42 produce violent agitation and rapid vaporizing of the liquid refrigerant in evaporator 42 and the expanded gas, vapor and entrained liquid are drawn into conduit 48 by the action of a pump 45. Conduit 48 opens into evaporator 43 above the liquid level and preferably has a downwardly directed outlet 48'. Thus, vessel 43 functions both as an evaporator operating on the straight pumping principle and also as a separator for the gaseous and liquid components discharging from conduit 48, the liquid falling by gravity into the liquid body in member 43 and the gaseous components passing off through header 44 to the pump. Evaporator or separator 43 is connected beneath the liquid level to evaporator 41, as by conduit 49 so that the liquid refrigerant discharged in a precooled condition from evaporator 42 passes to evaporator 43 and to evaporator 41.

From the above it will be apparent that the present invention provides processes and apparatus by which one or a plurality of evaporators connected into the same closed circuit produce differential cooling or heat absorbing effects, that such effects may result from operating certain of the evaporators upon the vapor-gas principle while others are operated on the conventional straight pumping principle, that condensate only is fed to the straight pumping evaporators while the gaseous products of the condensing step are expanded into the vapor-gas evaporators, and that the systems may be arranged to permit the passage of the liquid component of the refrigerant in a precooled condition from either type of evaporator in a given system to the other type.

I claim as my invention:

1. In a heat transforming system involving the absorption of heat by the vaporizing of a volatile liquid, the process of effecting heat removal at more than one temperature which comprises subjecting a portion of the liquid to vaporization by straight pumping and subjecting another portion of the liquid to the combined effects of pumping and of expansion of a gaseous medium within said liquid.

2. That step in the process of refrigeration which comprises the removing of vapor from two separate bodies of liquid while expanding a mixture of gas and the liquid's own vapor in contact with but one of said bodies.

3. In a heat transforming system of the closed cycle type using as a working substance a volatile liquid and a gas substantially inert to and insoluble in the liquid and its vapor, that step in the refrigerating process which comprises reducing the total pressure on a plurality of bodies of the liquid to induce vaporization and lowering the partial vapor pressure of one of said bodies so as to increase the heat absorbing characteristics thereof by expanding into it a stream of said gas and of the vapor of the liquid.

4. In a heat transforming system of the closed cycle type using as a working substance a volatile liquid and a gas substantially inert to and insoluble in the liquid and its vapor, the thermodynamic process which comprises withdrawing the vapor and the gas from above two bodies of the liquid, extracting heat from the mixture of vapor and gas so withdrawn in order to condense the vapor, feeding the condensate to one of said liquid bodies, and expanding the residual gas and vapor into the other of said bodies.

5. In a heat transforming system of the closed cycle type using as a working substance a volatile liquid and a gas substantially inert to and insoluble in the liquid and its vapor, the thermodynamic process which comprises withdrawing the vapor and the gas from above a plurality of bodies of the liquid, extracting heat from the mixture of vapor and gas so withdrawn in order to condense the vapor, feeding condensate only to one of said bodies, and feeding the residual gas and vapor together with a limited amount of condensate into another of said liquid bodies.

6. In a heat transforming system of the closed cycle type using as a working substance a volatile liquid and a gas substantially inert to and insoluble in the liquid and its vapor, the thermodynamic process which comprises withdrawing the vapor and the gas from above a plurality of bodies of the liquid, extracting heat from the mixture of vapor and gas so withdrawn in order to condense the vapor, feeding condensate only to one of said liquid bodies, feeding the residual gas and vapor together with a limited amount of condensate into another of said liquid bodies, and moving liquid from one of said bodies to the other.

7. In a refrigerating system of the closed cycle type comprising spaced bodies of a volatile liquid and the remainder of the system filled with a gas substantially inert to and insoluble in the liquid, the refrigerating process which comprises vaporizing, compressing and condensing the said liquid, effecting vaporization of one liquid body by straight pumping and of the other liquid body by pumping combined with the expansion of gas and vapor into the body, and passing liquid from one body to the other during the pumping operation.

8. In apparatus for producing a cooling effect by the vaporization of a volatile liquid, a plurality of evaporators for containing liquid to be evaporated, means for removing gas and vapor from the upper portions of said evaporators, means for condensing at least a part of the vapor so removed, and means utilizing at least a part of the gas and vapor to induce an increased vaporization of liquid in certain of said evaporators.

9. In apparatus for producing a cooling effect by the vaporization of a volatile liquid, a plurality of evaporators for containing liquid to be evaporated, means for removing gas and vapor from the upper portions of said evaporators, means for condensing at least a part of the vapor so removed, and means for expanding said gas and a part of the vapor into certain of said evaporators to induce greater vaporization and an increased cooling effect.

10. In a refrigerating system of the closed type utilizing as a working substance a volatile liquid and a gas substantially inert to and insoluble in the liquid, a plurality of evaporators, each arranged to contain a body of the liquid, means withdrawing the gas and the vapor of the liquid from said evaporators, means for condensing said vapor, and means for feeding condensate only to one evaporator and the remaining products of the condensing means to another evaporator.

11. In a refrigerating system utilizing as a working substance a volatile liquid and a gas substantially inert to and insoluble in the liquid, two evaporators, a pump, and a condenser connected together to form a closed cycle system, each evaporator arranged to contain a body of said liquid, and means utilizing the partial pressures of the components of the working substance for producing a differential heat absorbing effect in said evaporators.

12. In a refrigerating system utilizing as

a working substance a volatile liquid and a gas substantially inert to and insoluble in the liquid, two evaporators, a pump, and a condenser connected together to form a closed cycle system, each evaporator arranged to contain a body of said liquid, and means for feeding condensed liquid only to one of said evaporators and the remaining products of the condenser to the other evaporator.

13. In a refrigerating system utilizing as a working substance a volatile liquid and a gas substantially inert to and insoluble in the liquid, two evaporators, a pump, and a condenser connected together to form a closed cycle system, each evaporator arranged to contain a body of said liquid, means for feeding condensate only to one of said evaporators, and means for expanding the gas and the residual vapor from the condenser into the body of liquid in the other evaporator.

14. In a refrigerating system utilizing as a working substance a volatile liquid and a gas substantially inert to and insoluble in the liquid, two evaporators, a pump, and a condenser connected together to form a closed cycle system, each evaporator arranged to contain a body of said liquid, and means for feeding liquid from said condenser intermittently to one of said evaporators, and means continuously passing a stream of gas, vapor and liquid from the condenser to the other evaporator.

15. In a refrigerating system utilizing as a working substance a volatile liquid and a gas substantially inert to and insoluble in the liquid, two evaporators, a pump, and a condenser connected together to form a closed cycle system, each evaporator arranged to contain a body of said liquid, means for feeding liquid only from said condenser to one evaporator, and means for feeding the gas and residual vapor from said condenser along with a limited amount of liquid to the other evaporator.

16. In a refrigerating system utilizing as a working substance a volatile liquid and a gas substantially inert to and insoluble in the liquid, two evaporators, a pump, and a condenser connected together to form a closed cycle system, each evaporator for containing a body of said liquid, means for maintaining a substantially constant total pressure while producing a differential heat absorbing effect in said evaporators, and means permitting movement of liquid from one evaporator to the other.

17. In a refrigerating system utilizing as a working substance a volatile liquid and a gas substantially inert to and insoluble in the liquid, two evaporators, a pump, and a condenser connected together to form a closed cycle system, each evaporator for containing a body of said liquid, means for feeding condensed liquid only to one of said evaporators and the remaining products of the condenser to the other evaporator, and means permitting movement of liquid from one evaporator to the other.

Signed by me at Detroit, Wayne County, Michigan, this 16th day of July, 1926.

RANSOM W. DAVENPORT.