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REFRIGERATION DISTRIBUTION APPARATUS AND SYSTEM

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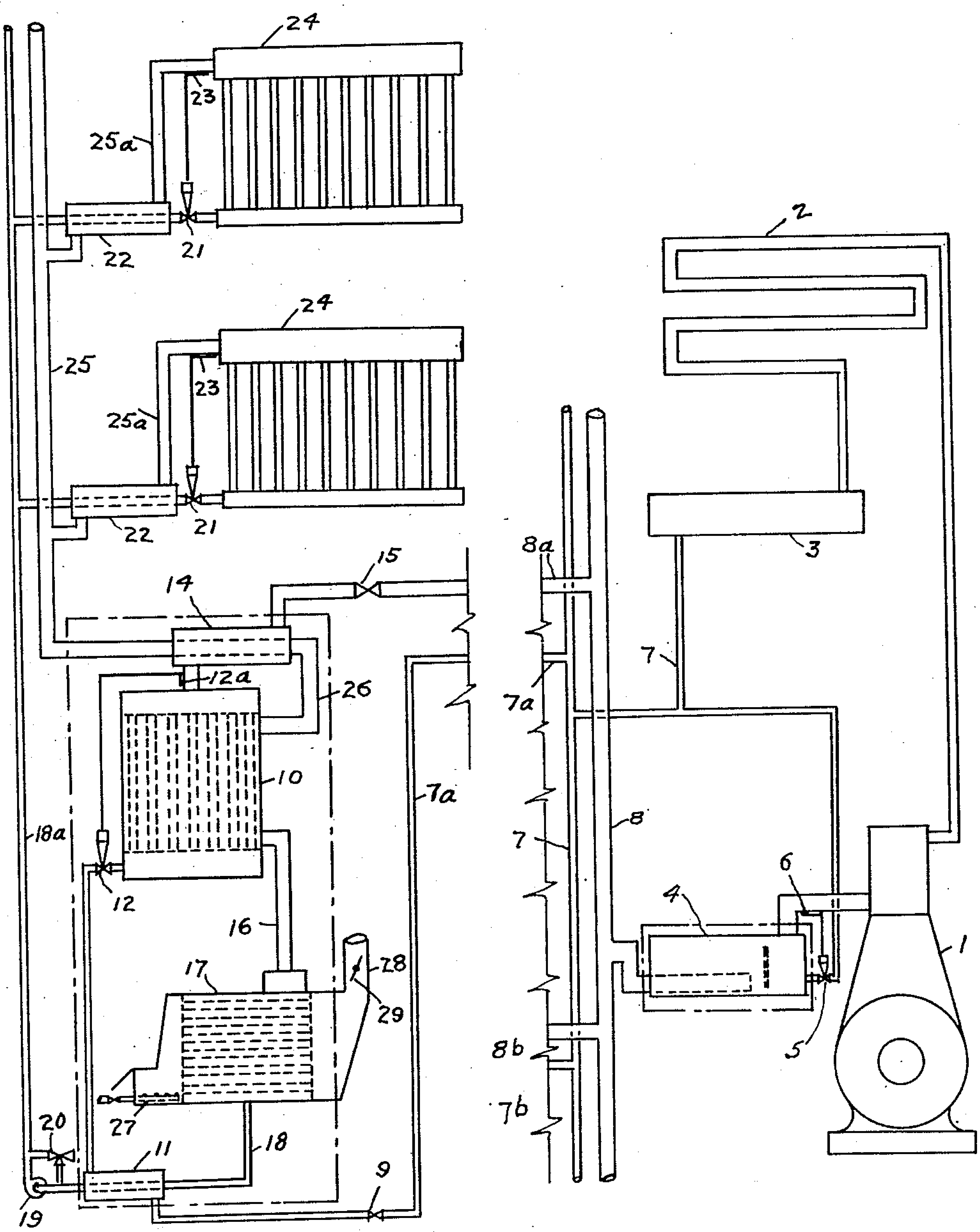

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REFRIGERATION DISTRIBUTION APPARATUS AND SYSTEM

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This invention relates to the distribution of refrigeration to various separate locations from a central source, to the increase of efficiency of such distribution, and to the alternate distribution of heat to the same locations from a central source by means of the same distribution system in both cases.

Increasing demands for refrigeration, especially for air cooling, require extensive use of condenser cooling water at the point of demand, which in many cases is available only from the water systems of cities. So serious is this demand that it threatens to incapacitate such water systems for their primary purpose. In any event the cost of water from this source for condenser use will become prohibitive where not already so. Large central water side stations can provide refrigeration much more efficiently and cheaply than scattered isolated plants. If such refrigeration can be economically transmitted to points of use the demand on city water systems will be wholly obviated.

My invention has for one of its objects the method and means for so transmitting refrigeration without the necessity for insulating the pipe lines and substantially without heat losses, and is an extension of and an improvement on my Patents No. 1,885,017 and No. 1,940,734. It has for another of its objects method and means for delivering refrigeration into buildings or other places of use by a secondary, unobjectionable, refrigerant without admitting a noxious, but otherwise desirable, primary refrigerant into such place of use, also without the necessity for insulating the refrigerant lines and substantially without heat losses. It has for a third of its objects the use of the same distribution system to deliver heat as well as refrigeration to the points of use. Other objects will appear from the specification following.

The figure is a schematic diagram of a complete refrigerating and distributing system utilizing my invention. The various devices shown in illustrating the invention are indicative only, as other devices producing similar results might be substituted for them without in any way changing the substance of my invention. Only those valves or apparatus essential to the invention are illustrated, but it will be evident to anyone skilled in the art that an actual installation would include other valves, devices, etc. normal to such installation. The diagram indicates a conventional refrigerating plant comprising a compressor, condenser, receiver and liquid and gas lines to supply distant points of use. Broken lines indicate this distance. At this point of use, only one of which is illustrated, the primary refrigerant from a central plant is used to condense a secondary refrigerant, such as water for instance, or other non-objectionable fluid, which is then distributed as liquid to the various evaporators by a pump or other means. After evaporation in these evaporators the vaporized secondary refrigerant is returned to the secondary condenser to repeat the cycle. By the use of heat exchangers between the incoming liquid and outgoing gas at each evaporator, the gas is raised in temperature to approximately the temperature of such liquid and therefore to that of the contiguous atmosphere. Hence it cannot absorb more heat from its surroundings.

Adjacent to the secondary condenser the heat thus put into the secondary gas is transferred in a heat exchanger to the primary refrigerant suction gas and thus raises the latter's temperature. This superheated primary refrigerant gas can then absorb very little if any heat from its surroundings on its passage back to the primary refrigerating plant. Similarly heat of the primary refrigerant liquid before reduction in pressure into the secondary condenser is transferred by a heat exchanger to the secondary refrigerant liquid leaving the secondary condenser, thus raising the latter's temperature so that it can absorb little, if any, heat from its surroundings on its passage to the various evaporators.

The primary refrigerant gas on its arrival at the central refrigerating plant has its superheat removed by saturation before admission to the compressor. Thus insulation on all the refrigerating lines can be eliminated as well as substantially all heat losses. Hence inexpensive refrigerating pipe lines over long distances can be installed in streets and buildings not substantially different or more expensive than ordinary water or gas pipes, and large amounts of refrigeration can be transmitted through relatively small pipes especially by the use of a high pressure refrigerant of high latent heat such as ammonia or carbon dioxide without the necessity of taking such refrigerants into buildings occupied by human beings.

Describing the schematic diagram of the figure in detail **1** is a typical compressor or absorption machine, **2** a condenser with cooling water circuits omitted, **3** a receiver. **4** is a saturating chamber adapted to contain a supply of primary refrigerant liquid through which the primary suction refrigerant gas passes, and which is supplied by a thermostatic expansion valve, **5**, controlled by a thermo bulb, 6, in contact with the outlet pipe from such saturating chamber. Liquid line, 7, and suction gas line, 8, extend as street mains or other lines to points where it is desired to utilize refrigeration. At such points a secondary condenser, 10, may be installed in a street chamber or in an isolated room of a building, whence objectionable primary refrigerant could not penetrate into such building. A primary refrigerant liquid line or branch, *7a*, equipped with a stop valve, 9, connects to the primary side of a heat exchanger, 11, and thence through a pressure reduction valve, 12, illustrated here as a thermostatic expansion valve, to the primary side of the secondary condenser, 10. A low side float valve could also be used for this function here as well as in the other applications of thermo valves. This secondary condenser is illustrated as a shell and tube type, the primary refrigerant being contained in the head ends and the tubes. The expansion valve, 12, is controlled by the thermo bulb, *12a*, in contact with the outlet pipe of the primary refrigerant from this condenser. The primary refrigerant gas passes from this condenser to and through the primary side of heat exchanger 14, and stop valve, 15, and then thence to the branch primary suction line, *8a*, and main suction line, 8, and back to the central refrigerating plant.

From the secondary side of the secondary condenser, 10, in which a secondary refrigerant, such as water, is caused to condense by the evaporation of the primary refrigerant in the primary side thereof, a connection, 16, drains the condensed secondary refrigerant into a receiver, 17, illustrated as a shell and tube container and adapted to act as boiler when supplied with heat. Such heat may be supplied in any convenient manner, such as here illustrated by a gas burner, 27. From the bottom of this shell and tube receiver a line, 18, conducts the condensed secondary liquid to secondary side of heat exchanger, 11, in heat exchange relationship to the primary refrigerant liquid in the primary side thereof, and thence to a pump, 19, shown as a centrifugal but not necessarily or even preferably such. This pump may be by-passed by a relief and stop valve, 20. This pump delivers refrigerant liquid through liquid line, *18a*, to the various evaporators, 24, which may be at any desired levels, of which only two are illustrated.

From this liquid line, secondary liquid refrigerant is supplied by the admission valves, 21, shown as thermostatically controlled by thermo bulbs, 23, through heat exchangers, 22, to evaporators, 24. The vaporized secondary refrigerant passes through outlet pipes, *25a*, and heat exchangers, 22, in heat exchange relation with the incoming liquid to the same evaporator, to return line, 25, and thence to heat exchanger, 14, in heat erchange relation to the primary refrigerant gas from the secondary condenser, 10, and thence by pipe connection, 26, back to the secondary side of said secondary condenser, thus completing its cycle.

When the secondary side of such a system as described is thoroughly evacuated and correctly charged with the desired secondary refrigerant so that the secondary receiver contains sufficient liquid, and the primary side is similarly evacuated and connected to an operating suitable primary refrigerating system, the opening of valves, 9 and 15, will admit primary liquid refrigerant to the secondary condenser, 10, and cause condensation therein of secondary refrigerant vapor from the evaporators, 24. The operation of pump, 19, will lift secondary liquid refrigerant to the said evaporators from the receiver, 17. The liquid leaving this receiver, 17, is at substantially the temperature of condensation of the condenser, 10, which in turn is near the temperature of the evaporating primary refrigerant therein. This secondary liquid in passing through heat exchanger, 11, extracts heat from the primary liquid passing through the same exchanger, correspondingly heating itself and cooling the primary liquid. Hence the primary liquid will have more net cooling capacity available when admitted to the secondary condenser, 10, than if it had not been thus sub-cooled. In other words less primary refrigerant liquid will need to be circulated to produce a given refrigerant effect. Conversely, the secondary liquid heated in the exchanger, 11, can absorb little, if any, heat on its passage to the various evaporators, 24, and hence not sweat or frost, and not require any insulation.

The warmed secondary refrigerant liquid on arriving at the various evaporators is again cooled in the heat exchangers, 22, by giving up heat to the outgoing vaporized secondary refrigerant leaving these evaporators thus raising the temperature of such refrigerant vapor substantially to the temperature of the incoming liquid so that it can absorb little, if any, heat on its passage back to the heat exchanger, 14, and hence not frost or sweat, or require insulation.

In heat exchanger, 14, the returning secondary vapor from all of the evaporators of one installation will be cooled by the outgoing vaporized primary refrigerant utilized in that installation, and therefore enter the condenser, 10, at but little above the temperature of condensation, while the outgoing primary refrigerant vapor will be heated substantially to the temperature of the secondary vapor, thus involving little heat loss, if any, and requiring no insulation on its passage back to the primary refrigerating plant.

It has already been pointed out above that just previous to entering the compressor this primary refrigerant gas is saturated to the temperature corresponding to its pressure, thus restoring its condition substantially to that it had on evaporation.

In this manner all necessity for insulation on refrigerating lines is eliminated. All such lines are kept at substantially constant temperatures and therefore not subject to widely varying temperatures and consequently not requiring expensive expansion joints. Experience has shown that metal structures such as rails or pipes so maintained and simply buried in the earth without other provision against movement cannot develop sufficient strain to cause movement through the earth and so cannot accumulate concentrated strains at joints. Hence by using this system refrigerating lines may be laid as inexpensively as ordinary illuminating gas or water lines.

Especially in the case of air conditioning jobs, it is evident that such a system offers material advantages and economies over any other arrangement. Objectionable refrigerants can be excluded from quarters occupied by human beings, large circulating air ducts are avoided, refrigeration is developed directly at the final point of use without moving appliances, no insulation or excessive loss is involved as with all other systems of transmitting refrigeration, refrigeration may be primarily developed in large central stations at economies far greater than in small isolated units, much cheaper distributing lines can be used, and cheap condensing water can be secured from flowing streams or from large spray ponds not possible in congested centers.

In some installation codes now under discussion it is proposed to prohibit the use of toxic refrigerants in connection with unobjectionable secondary refrigerant transfer fluids, such as brine or water, unless such secondary fluids are vented to atmosphere before being admitted to inhabited buildings. It is evident that my invention herein is easily adaptable to such code requirements by simply interposing an intermediate refrigeration transfer medium, such as brine or water, vented where required, between the surfaces in contact with the primary refrigerant and the surfaces in contact with the secondary refrigerant in the secondary condenser, 10. In this manner toxic primary refrigerant could never by any possibility be admitted into my secondary refrigerating system. In this modified arrangement the secondary condenser would comprise two steps instead of one, namely, the first transferring refrigeration from the primary system to the intermediate fluid and the second from the intermediate fluid to the secondary system, instead of directly from the primary to the secondary system. Such a modification is contemplated in my invention.

This same arrangement is adaptable for heating as well as cooling. When heating may be desired, as in winter, valve, 9, in the primary liquid refrigerant line should be closed, and the primary system operated until the liquid refrigerant beyond that valve and in the condenser, 10, is vaporized and evacuated. Then the valve, 15, in the primary refrigerant gas line should be closed, thus eliminating the primary refrigerant from the secondary apparatus altogether. The furnace, shown as a gas burner, 27, should be lighted and, if required, the by-pass valve, 20, around the pump, 19, should be opened thus providing a free passage for condensate from the evaporators, 24, to the receiver, 17, now to be used as a heating boiler. The hot gases from the burner, 27, pass through the tubes of the receiver-boiler, 17, and thence to stack, 28. A damper, 29, should be provided to prevent air from passing when the apparatus is used for refrigeration.

Fluid vaporized in receiver-boiler, 17, will pass through secondary condenser, 10, and heat exchanger, 14, without effect as there is no co-operating fluid to receive heat exchange therein. Such vapor will therefore pass to the various evaporators, 24, now acting as condensers and on condensation therein will deliver up its latent heat to the spaces to be heated. The thermo valves, 21, will be open due to the temperature of their control bulbs, and hence all condensate will pass by gravity down the liquid line, 18*a*, back to the receiver-boiler, thus completing its cycle. Hence, especially in the case of water as a refrigerant, the same system of pipes, evaporators, condensers and apparatus may be used as either a heating or cooling system and not constitute a menace from any cause.

The space enclosed within the dot and dash lines of Fig. 1, embracing certain of the secondary apparatus at one place and the saturator adjacent the compressor at another place, should of course be insulated, as at these points considerable differences of temperature may exist between the refrigerating fluids and the surrounding air. The amount of such insulation is relatively very small compared to that saved on the various pipes and distributing lines involved.

Similar applications of refrigeration can be taken from the distributing mains, 7 and 8, at any number of points indicated as 7*b* and 8*b*. It is evident that only one transfer arrangement from primary to secondary system will be required for each installation, and only one saturating apparatus for a complete refrigerating system unless a plurality of such units, one for each compressor, might prove more desirable. These are engineering considerations and do not affect the scope of my invention, for which I make the following claims:

1. In the operation of a refrigerating system comprising the generation of refrigeration at one location and its delivery for use at another location, the method of distribution by a primary and a secondary system comprising the condensation of a primary volatile refrigerant of relatively high pressure and small volume in the primary system at location of generation, the evaporation of this primary refrigerant in thermal relation with another and secondary volatile refrigerant of relatively lower pressure and larger volume in the secondary system at location of use, the condensation of said secondary refrigerant thereby, the return of the vaporized primary refrigerant to its initial location and its recondensation thereat in continuing cycles, the increase of the pressure of the condensed secondary refrigerant above its pressure of condensation, the use of said pressure to effect delivery of this liquefied secondary refrigerant to desired evaporators, the evaporation of said secondary refrigerant therein, and the return of the vaporized secondary refrigerant again to thermal relation with the liquid primary refrigerant in continuing cycles at location of use.

2. In the operation of a refrigerating system, the method of distributing refrigeration by a primary system and a secondary system, comprising the condensation of a primary volatile refrigerant in the primary system, the evaporation of this primary refrigerant in thermal contact with another, secondary, volatile refrigerant in the secondary system, the condensation of said secondary refrigerant thereby, the return of the vaporized primary refrigerant to its initial place of condensation and its re-condensation thereat, increase of the pressure of the liquid secondary refrigerant after condensation thereof, delivery of this liquified secondary refrigerant to desired locations of use and its evaporation thereat, return of the vaporized secondary refrigerant resulting therefrom to thermal contact again with the liquid primary refrigerant, and the exchange of heat between the primary and secondary refrigerant liquids and between the secondary and primary refrigerant vapors respectively.

3. In the operation of a refrigerating system, the method of distributing refrigeration by a primary system and a secondary system, comprising the condensation of a primary volatile refrigerant in the primary system, the evaporation of this primary refrigerant in thermal contact with another, secondary, volatile refrigerant in the secondary system, the condensation of said secondary refrigerant thereby, the return of the vaporized primary refrigerant to its initial place of condensation and its re-condensation thereat, increase of the pressure of the liquid secondary refrigerant after condensation thereof, delivery of this liquified secondary refrigerant to desired locations of use and its evaporation thereat, return of the vaporized secondary refrigerant resulting therefrom to thermal contact again with the liquid primary refrigerant, and the exchange

of heat between the primary and secondary refrigerant liquids and between the secondary and primary refrigerant vapors respectively and between the liquid secondary refrigerant flowing to and the vaporized secondary refrigerant flowing from said locations of evaporation.

4. In the operation of a refrigerating system, the method of distributing refrigeration by a primary system and a secondary system as set forth in claim 3 and the saturation of the primary refrigerant vapor on its return to its initial place of condensation and before re-condensation thereat.

5. The method of distributing refrigeration comprising the transmission of a voltatile primary refrigerant of relatively high pressure and small volume between the location of its condensation and various locations of use, evaporation of this primary refrigerant at such locations of use in heat exchange relationship with, and thereby condensing, a volatile secondary refrigerant of relatively lower pressure and larger volume than said primary refrigerant, and the evaporation of said secondary refrigerant in heat exchange relationship with material to be cooled at the said various locations of use.

6. The method of distributing refrigeration as set forth in claim 5, and the exchange of heat between the primary and secondary refrigerant liquids and between the secondary and primary refrigerant vapors respectively.

7. The method of distributing refrigeration as set forth in claim 5, and the exchange of heat between the liquid and vapor phases of the secondary refrigerant adjacent to the location of its evaporation.

8. For the purpose of distributing refrigeration at spatially separated locations, the combination of a secondary refrigerating system comprising a plurality of evaporators similarly separated, a secondary condensing apparatus of a colder temperature than said evaporators, liquid flow and vapor return conduits connected between said condensing apparatus and said evaporators, a supply of secondary volatile refrigerant fluid in said secondary system, means for increasing the pressure of the liquefied secondary fluid after condensation thereof, and means for reducing the said pressure of the liquid refrigerant various amounts as may be required by the several locations of the evaporators, with a primary refrigerating system comprising primary evaporating apparatus in thermal relation with the said secondary condensing apparatus, primary condensing apparatus, primary refrigerant liquid flow and primary refrigerant vapor return conduits connected between said primary evaporating apparatus and primary condensing apparatus, a supply of primary volatile refrigerant fluid in said primary system, means for regulating the flow of said refrigerant fluids in their respective systems, and means for exchanging heat between the primary and secondary liquefied refrigerants and between the secondary and primary vaporized refrigerants respectively.

9. For the purpose of distributing refrigeration at spatially separated locations, the combination of a secondary refrigerating system comprising a plurality of evaporators similarly separated, a secondary condensing apparatus of a colder temperature than said evaporators, liquid flow and vapor return conduits connected between said condensing apparatus and said evaporators, a supply of secondary volatile refrigerant fluid in said secondary system, means for increasing the pressure of the liquefied secondary fluid after condensation thereof, and means for reducing the said pressure of the liquid refrigerant various amounts as may be required by the several locations of the evaporators, with a primary refrigerating system comprising primary evaporating apparatus in thermal relation with the said secondary condensing apparatus, primary condensing apparatus, primary refrigerant liquid flow and primary refrigerant vapor return conduits connected between said primary evaporating apparatus and primary condensing apparatus, a supply of primary volatile refrigerant fluid in said primary system, means for regulating the flow of said refrigerant fluids in their respective systems, means for exchanging heat between the primary and secondary liquefied refrigerants and between the secondary and primary vaporized refrigerants respectively, and means for exchanging heat between the liquefied secondary refrigerant flowing to the secondary evaporators and the vaporized secondary refrigerant flowing from the secondary evaporators respectively.

10. For the purpose of distributing refrigeration at spatially separated locations, the combination of a secondary refrigerating system comprising a plurality of evaporators similarly separated, a secondary condensing apparatus of a colder temperature than said evaporators, liquid flow and vapor return conduits connected between said condensing apparatus and said evaporators, a supply of secondary volatile refrigerant fluid in said secondary system, means for increasing the pressure of the liquefied secondary fluid after condensation thereof, means for reducing the said pressure of the liquid refrigerant various amounts as may be required by the several locations of the evaporators, with a primary refrigerating system comprising primary evaporating apparatus in thermal relation with the said secondary condensing apparatus, primary condensing apparatus, primary refrigerant liquid flow and primary refrigerant vapor return conduits connected between said primary evaporating apparatus and primary condensing apparatus, a supply of primary volatile refrigerant fluid in said primary system, means for regulating the flow of said refrigerant fluids in their respective systems, means for exchanging heat between the primary and secondary liquefied refrigerants and between the secondary and primary vaporized refrigerants respectively, means for exchanging heat between the liquefied secondary refrigerant flowing to the secondary evaporators and the vaporized secondary refrigerant flowing from the secondary evaporators respectively, and means for saturating the vaporized primary refrigerant before its admission to the primary condensing apparatus.

11. The method of distributing refrigeration comprising the transmission of a volatile primary refrigerant at relatively high pressure and small volume between the location of its condensation and various locations of use, evaporation of this primary refrigerant at such locations of use in heat exchange relationship with, and thereby condensing, a volatile secondary refrigerant of relatively lower pressure and larger volume than said primary refrigerant, and the evaporation of said secondary refrigerant in heat exchange relationship with material to be cooled at the said various locations of use, exchanging heat between the primary and secondary refrigerant liquids and between the secondary and primary

refrigerant vapors respectively, and exchanging heat between the liquid and vapor phases of the secondary refrigerant adjacent to the location of its evaporation.

12. The method of distributing refrigeration as set forth in claim 11, and the saturation of the primary refrigerant adjacent to the location of its condensation.

13. In an arrangement for merchandising refrigeration to the members of a community, the combination, with a primary refrigeration system arranged to deliver liquid refrigerant at high pressure to and withdraw the same at lower pressure from the points where the refrigeration is to be distributed, of a secondary refrigeration system at each of such points and arranged to be operated by the primary system; said primary system including a central plant having mechanism for converting refrigerant vapor into a liquid, an expansion device at each point of distribution and a network of pipes extending from said plant and each located underground for a substantial portion of its length and connected to one of said devices; the capacity of said mechanism to produce liquid refrigerant and the normal carrying capacity of the pipes conveying liquid refrigerant being so correlated as to supply the refrigerant at an elevated pressure to each expansion device; each of said secondary systems being arranged to use a non-toxic refrigerant and operate throughout at a low over-all pressure and including a condenser in heat exchange relation with the respective expansion device of the primary system a plurality of evaporators and means for circulating refrigerant from the condenser to said evaporators and returning the refrigerant therefrom to said condenser.

14. An arrangement of the type set forth in claim 13 in which water is used as the refrigerant in each secondary system and such system is operated throughout at sub-atmospheric pressure and includes an expansion valve associated with each evaporator and a compressor for pumping water vapor from the evaporators and discharging it into the condenser of said system.

15. An arrangement of the type set forth in claim 13 in which the primary system is provided with a shut off valve at each of said expansion devices and the steam heating system of a customer is provided with a pump and constitutes one of the secondary systems, the radiators of such system for providing comfort heating being provided each with an expansion valve, the boiler for normally supplying steam to the radiators being formed to serve as a condenser in heat exchange relation with the respective expansion device of the primary system and the pump being arranged to circulate water to said expansion valves.

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