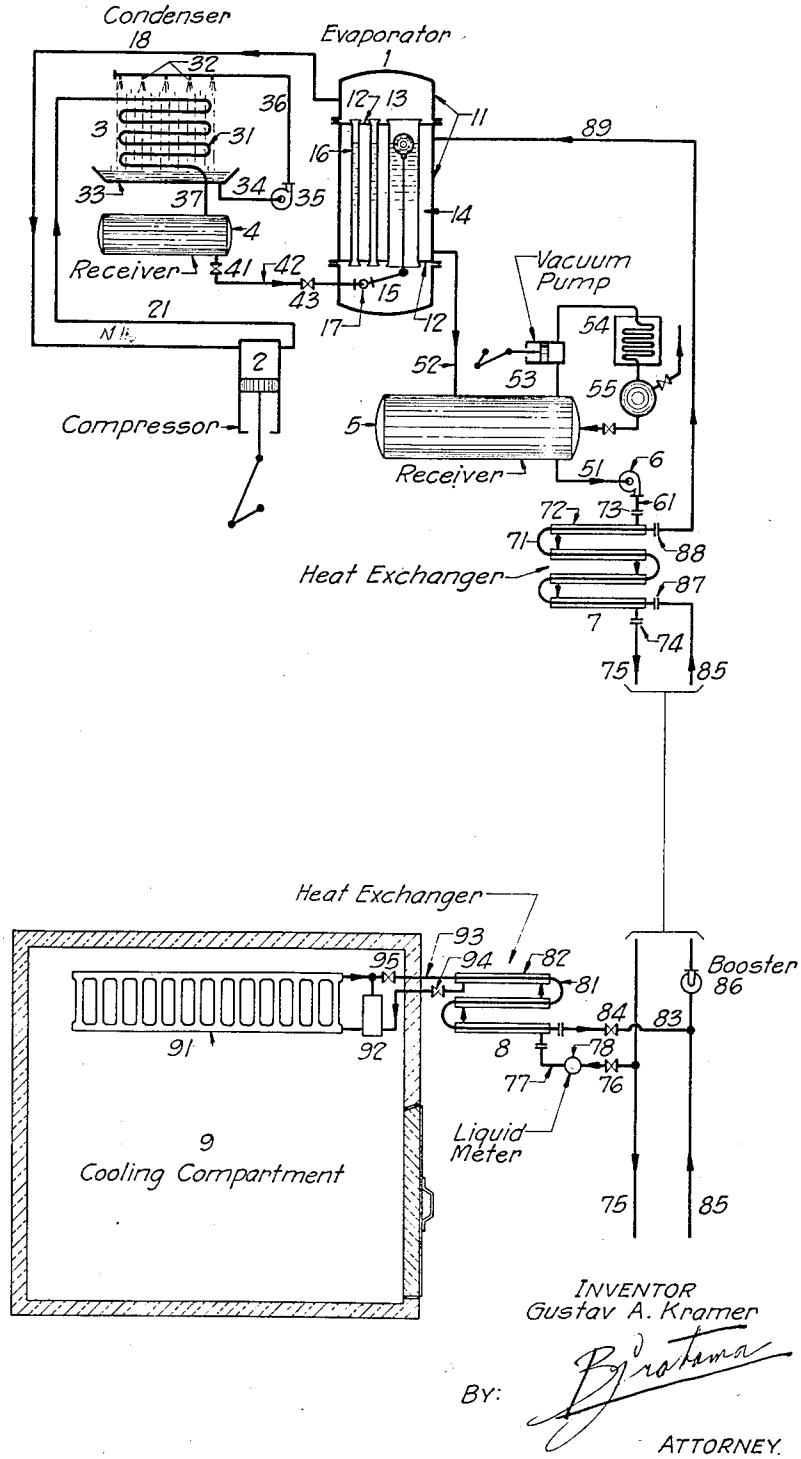
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REFRIGERATING SYSTEM

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REFRIGERATING SYSTEM

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This invention relates to improvements in refrigerating systems in general and more particularly to the kind used for the cooling of various rooms or refrigerators from one central point. Refrigerating systems of this kind are usually known by the name of "district refrigeration". In such systems the refrigeration produced by mechanical means in the refrigerating machinery of the central cooling plants or by means of melting ice is usually distributed to locations more or less distant by means of heat transmission agents such as brine, cooling gases, etc. There are some instances in which the refrigerant itself is carried from the central plant by suitable piping to the place where the cooling effect is desired and is there evaporated in suitable coils, the vapors being returned to the compressor for repeated liquefaction or to the absorber for absorption. The former system in which a second medium in itself not classed as a refrigerant, is being used for the transmission of the refrigeration being produced, is commonly called an indirect refrigeration system the latter, a direct expansion system.

In the indirect system of refrigeration the cooling effect is produced in a location containing the refrigerator in its evaporating coil and this latter in turn is surrounded by the indirect cooling medium, usually a brine solution, which is then pumped to the various refrigerating rooms or cooling compartments where it absorbs heat through the walls of suitably exposed pipe coils or radiators. In systems of this kind the brine reaches its lowest temperature in contact with the evaporating coil and has to be handled through the system at these low temperatures. This necessitates heavy insulation, against the entrance of external heat, of all piping used for the transportation of the brine and any imperfection in the insulation causes the rapid deterioration of the insulating material and of the pipe itself through corrosion caused by the accumulation of moisture. When the system of piping carrying the brine is used over a long distance, large frictional losses in pumping are incurred, which in turn are converted into heat units and result in loss of refrigeration. Most brine solutions are also highly corrosive to material normally available for the construction of the pipe lines and the upkeep and depreciation of these brine circulating systems is correspondingly high.

In systems using direct expansion of the refrigerant in the cooling compartments, the liquefied refrigerant must be piped to the point of utilization. For the purpose of making possible the use of small compressor equipment, so-called high pressure refrigerants are more desirable than those which operate at low pressures and correspondingly large vapor volumes. For this reason plants of the larger size, such as may be commonly considered for district refrigeration, usually employ high pressure refrigerants such as ammonia, carbon dioxide, etc. The piping for the transfer of the condensed high pressure refrigerant from the condensing coil to the cooling compartment must be sufficiently strong to stand up under the highest pressure likely to occur in the system, which makes such piping expensive. The refrigerant itself being usually costly, its loss must be avoided and special care must be taken that all joints, valves, etc., be substantially tight against the leakage of refrigerant. This is still more the case with fluids, like ammonia, whose effect even in large dilution in the air is highly poisonous and corrosive.

There are several other disadvantages in the two systems just described, well known to all versed in the art which will not be elaborated upon.

It is the purpose of this invention to make possible the very desirable system of district refrigeration from one central station without the use of brine or without the use of the direct expansion of a high pressure refrigerant.

It is a further object of the invention to eliminate entirely, or to a large extent, the necessity for insulating the piping used for the transmission of the refrigeration.

It is another object of the invention to enable district refrigeration without the cost of expensive piping, made to resist high pres-

sure or corrosive action or both, and to eliminate danger of explosion and asphyxiation frequently connected with high pressure direct expansion refrigerating systems.

Further objects of this invention will appear from the following description in which I have set forth a preferred application of my invention. It is to be understood that the appended claims are to be accorded the scope and range of equivalents, consistent with the state of prior art.

An apparatus designed for carrying this process into effect is illustrated by way of example in the accompanying drawing which shows more or less diagrammatically a refrigerating unit, consisting of evaporator 1, compressor 2, condenser 3, refrigerant receiver 4, and a heat transmission system, consisting mainly of refrigerant receiver 5, pump 6, heat exchangers 7 and 8, and cooling compartment 9.

Describing the refrigerant unit first, evaporator 1 may be of any conventional type consisting of a series or a multiplicity of coils or vessels in which a refrigerant of the usual type employed, e. g. ammonia, is being evaporated. In the design shown it consists of shell 11 divided by two tube sheets 12 into three compartments 13, 14 and 15. Tubes 16 are expanded or otherwise fastened in tube sheet 12 in the usual manner and a constant level of refrigerant may be maintained in compartment 15 and in tubes 16 by liquid level regulator 17.

From evaporator 1 pipe 18 leads to the intake side of compressor 2. This latter is being driven by some prime mover not shown in the drawing and discharges through pipe 21 into condenser 3. This latter is shown as a pipe coil 31 receiving a spray of cooling water through nozzle 32, the evaporation of the water on the surface of the pipes effecting the necessary cooling. The surplus water dripping from the coils collects in trough 33, from which pipe 34 leads to circulating pump 35 which in turn discharges through discharge pipe 36, connected by nozzles 32.

Condenser 3, through pipe 37, empties into refrigerant receiver 4 which may be a suitable pressure vessel of any type. Valve 41 connects receiver 4 through pipe 42 and shut-off valve 43 with liquid level regulator 17 and so permits the returning of the condensed refrigerant to evaporator 1.

Turning to the heat transmission system, there too a refrigerant is used, which is evaporated in the cooling compartment and condensed by means of the refrigeration produced in the refrigerating unit. This refrigerant, hereafter called the secondary refrigerant, is usually different in chemical and physical properties from the primary refrigerant used in the refrigerating unit. Vessel 5 is a receiver for this secondary refrigerant after its condensation in the condensing compartment of evaporator 1; this receiver is connected with a small vacuum pump 53 which removes permanent gases, and maintains the desired vacuum. A small condenser 54 may be employed to recover from these gases the vapors of the refrigerant which are collected in receiver 55 from which they may be returned to the main refrigerant receiver 5.

The secondary refrigerant is delivered from refrigerant receiver 5 through pipe 51 to pump 6 which forces it through pipe 61 into heat exchanger 7. This latter may be of any of the well known types of equipment available for this purpose but is shown here as consisting of pipe coil 71 surrounded by jacket 72. The refrigerant enters through nozzle 73 and leaves it through nozzle 74, where it enters pipe main 75. This latter is of a suitable size to carry the amount of liquid refrigerant necessary for the total refrigeration of the cooling compartments located in its particular district and is provided with outlet valves conveniently located for service to the various cooling compartments. From main 75 the liquid refrigerant enters service connection 77 through valve 76 and passes through liquid meter 78 to heat exchanger 8 consisting of coils 81 provided with jackets 82. The liquid enters cooling coil 91, suitably arranged in cooling compartment 9, through shut-off valve 94.

Cooling coil 91 may be a unit of multiple parallel tubes held between two manifolds, frequently employed for such purposes and may be provided with liquid level regulator 92 so adjusted as to maintain the normally required level of liquid refrigerant in coil 91. Valve 94 serves as a shut-off for the liquid refrigerant, valve 95 as a regulator or shut-off of refrigerant vapors. The temperature of coil 91 may be regulated by adjustment of valve 95, which may be operated automatically by means of a thermostat, not shown.

The vapors generated through the evaporation of the refrigerant in coil 91 pass through pipe 93 into heat exchanger 8 and from here are conveyed through pipe 83 and service valve 84 into main 85. This is constructed of pipes of suitable dimensions to carry the amount of vapors evolved by the evaporation of the refrigerant, in the cooling compartment back towards the refrigerating unit. The vapor pipe 85 may be provided with one or more boosters 86, merely for the purpose of accelerating the travel of vapors whereby the necessary size of the main 85 is reduced. The vapors collecting in main 85 travel through heat exchanger 7, entering the same through nozzle 87 and leaving it through nozzle 88. They are then passed through pipe 89 into compartment 14 of evaporator 1 where the cooling effect produced in pipes 16 by the evaporation of the refrigerant contained in them,

causes their condensation. The condensed refrigerant is returned through pipe 52 to refrigerant receiver.

I have only illustrated one form of apparatus suitable to carry out the process of the present invention, but other designs may be used to obtain the results of this invention and I do not limit myself to the particular form of apparatus shown.

While the foregoing is a general description of the main pieces of equipment necessary to carry out the operation of the system in its simplest form, in actual practice there are more parts required which for the simplicity of the description are not included here. While these parts, which may comprise devices for purging the system of permanent gases, pressure and temperature regulators, thermometers, automatic starting and stopping equipment for prime movers, etc., or any such devices which are commonly employed in refrigerating plants of various descriptions for more efficient or safer operation, may be added as convenience or necessity requires, their addition does not alter the principle of operation of the system hereinafter to be described.

In operating my system the compressor number 2 is kept in motion by its prime mover in the usual manner, drawing vapors through pipe 14 from chamber 13, thereby reducing the pressure in the latter and promoting the evaporation of the primary refrigerant in chamber 12 and pipes 16. The vapors of the primary refrigerant drawn from compartment 13 through pipe 18 are compressed by compressor 2 through pipe 21 into condenser 3 where they are condensed by the cooling action of the latter caused partly by the evaporation of water spray from the surface of the coils and partly by conduction of heat to the atmosphere. The condensed liquid is returned into receiver 4 which acts as a storage tank for the surplus refrigerant and from which the liquid is forced back into evaporator 1 by the higher pressure in receiver 4 whenever the automatic liquid level regulator 17 opens its valve.

The pipes comprising the major surface of evaporator 1 are surrounded by chamber 14 into which are fed the vapors of the secondary refrigerant. Due to the refrigeration produced by pipes 16 the vapors condense and collect in the form of a liquid on tube sheet 12 from where they are emptied through pipe 52 into tank 5, which contains the liquid supply of secondary refrigerant ready for distribution through the heat transmission system. Because of the low temperature of the secondary refrigerant in tank 5 it is advisable to surround this tank with a suitable heat insulation to prevent the loss of refrigerating effect through its walls. The same applies to pump 6 and to all parts of the equipment which are below the temperature of the surrounding atmosphere. The liquid refrigerant is fed through pipe 51 into pump 6, which applies pressure to it as explained below. The liquid refrigerant, now under pressure, passes into the jackets 72 surrounding the pipe coil of heat exchanger 7. Here it is heated up by the sensible heat of the vapors returning towards the central refrigerating unit through main 85 so that when the liquid leaves heat exchanger 7, it has taken up as much of the sensible heat of these vapors as the temperature conditions and the efficiency of the heat exchanger permit and it enters main 75 at a correspondingly higher temperature. Under normal operating conditions one pound of liquid must be passed through main 75 to the cooling compartment for every pound of vapor evaporated there and returning through main 85. If in the heat transmission system a secondary refrigerant be employed whose vapors have approximately the same specific heat as its liquid, the liquid refrigerant leaving heat exchanger 7 through nozzle 74 will have reached about the same temperature at which the vapors enter the heat exchanger from main 85 at nozzle 89. As this temperature generally follows closely that of the atmosphere, it will be seen that no heat insulation is required on main 75, as the refrigerant, after leaving heat exchanger 7, is in main 75 at practically atmospheric temperature.

It is of course essential that no vaporization of the liquid refrigerant takes place in main 75, and pump 6, as mentioned above, is employed to apply sufficient pressure to the liquid to prevent its vaporization during the heating in heat exchanger 7 or at the temperature prevailing in main 75.

As the liquid leaves main 75 through pipe 77 it enters heat exchanger 8 in which it once more is subjected to a counter current heat exchange with the vapors coming from cooling coil 91 and traveling through pipe coil 81 of the heat exchanger. Due to this arrangement it is possible, by suitable dimensions of the heat exchanger surface, to cool the refrigerant by the incoming vapors to a degree where its temperature is nearly equal to that of the refrigerant being evaporated in cooling coil 91. Liquid level regulator 92 maintains a steady supply of refrigerant in this coil and provides against the possibility of the coil filling up with liquid and the liquid flowing back as such through the vapor outlet 93.

The vapor leaving at 93 is cold, having about the temperature of the liquid in the cooling coil. By passing through heat exchanger 8, it is warmed up to about atmospheric temperature and in this condition is returned through pipe 83 to main 85 and finally to heat exchanger 7. Main 85, therefore, does not have to be insulated against loss of refrigeration. In this latter the

vapor meets again the cold liquid coming from storage tank 5 and gradually cools to nearly the temperature of the latter, which is only slightly higher than that prevailing in space 14 of the evaporator 1. From heat exchanger the vapor passes to evaporator 1 where its condensation is effected.

It will be seen that a system of this pipe may operate with any two refrigerants whose physical and chemical properties make their use the most desirable. A high pressure refrigerant as for example, ammonia may be used in the refrigerating unit which is constantly under the care of experienced engineers and which is sufficiently small in size and compact in space to permit the efficient installation of high pressure equipment.

The heat transfer in evaporator 1 occurs from boiling liquid to condensing vapor; therefore the specific heat transfer rate is very high and the active surface of evaporator 1 may be very much smaller than if it were used for cooling of brine. Brines also cause surface corrosion of the evaporating piping, reducing heat transfer rate through the walls and necessitating frequent cleaning. In an evaporator as described in this system, the refrigeration produced being used merely to remove the heat of condensation of another vapor, the surfaces remain clean and thus continuous high efficiency of the system is assured.

The secondary refrigerant, for the heat transmission system, may be selected from many points of view; usually a refrigerant of considerably lower vapor pressure than the primary refrigerant will be most suitable. As has been pointed out before, it is also advantageous to have a secondary refrigerant whose vapor and liquid have nearly equal specific heats so that the heat exchange previously described can be carried out under the most favorable conditions, and a minimum of loss of refrigeration is assured. Its price may be important, especially when large systems are under consideration. Further it may be advantageous to have a secondary refrigerant whose vapor pressure at the temperature obtained in the cooling coil 91 is near one atmosphere, so that there is practically no positive pressure in main 85. For example, and without restricting myself, I may employ ethyl ether. The vapor pressures of this refrigerant are low and under normal conditions most of the apparatus comprising the heat transmission system is under a partial vacuum. To establish and maintain this it may be necessary to employ the small vacuum pump 53, with condenser etc. which removes from the system any permanent gases entering it through imperfection of joints.

It will be understood from this description that the lowest temperature in the system is that obtained by the high pressure refrigerant on its evaporation in evaporator 1, and that the temperature of the secondary refrigerant, condensing in compartment 14 of evaporator 1 will be only slightly higher, and the lowest temperature occurring in the heat transmission system. In this way a heat gradient exists between cooling compartment 9 and evaporator 1, which has the great advantage that the vapors flowing from the cooling compartment 9 to evaporator 1 need not be compressed to cause their condensation; in main 85 no compressor is needed, only to reduce the size of the main needed, as mentioned before, it may be advisable to insert one or more boosters merely for accelerating the flow of the vapors.

Space 14 of evaporator 1 is also the point of lowest pressure in the heat transmission system, because of the reduction of vapor volume due to the condensation, another reason why no compressors are needed in main 85, the pressure gradient will maintain a natural flow of vapors from the evaporating coil in the cooling compartment to the point of condensation in evaporator 1.

The highest pressure occurring in the heat transmission system is determined by the vapor pressure of the secondary refrigerant at nearly atmospheric temperature, the temperature of main 75, as it will be understood that the pressure in this main has to be only just so much higher that vaporization is prevented. This pressure in main 75 applied by pump 6, will naturally be higher than the pressure of the returning vapors in main 85, but as the volume of liquid refrigerant fed to the cooling compartments is comparatively small, and the refrigerant itself is a low pressure refrigerant, the piping will never be expensive, and no heat insulation needed.

While in the description of the system the name "district refrigeration" is used, it is evident that the same process of refrigeration may be applied to other systems not falling directly under the classification of district refrigeration. Thus for instance, various refrigerator systems in apartment houses, hotels, industrial plants, cold storage warehouses, ships, etc., may be refrigerated by this method. The advantages enumerated will hold good, although in some cases to a lesser degree.

When the system is being used for distribution of refrigeration from one central station, and the amount of refrigeration consumed at each individual location is of interest from the point of view of accounting or otherwise, the installation of liquid meters as indicated in the sketch at 78 gives a good measure of the refrigeration consumed by the individual cooling coils.

The system lends itself exceptionally well to the maintenance of different temperatures in various cooling compartments, as a simple

throttling of the vapor outlet 95 either by hand or by automatic means governs the amount of evaporation permitted in the individual cooling coil and thereby the amount of heat which it can absorb.

I claim as my invention:

1. In a refrigerating system in which a fluid is alternately evaporated and condensed in a heat transmission cycle, the steps of heating the condensate leaving the condenser by heat exchange with the vapors before these reach the condenser, and heating the cold vapors leaving the evaporator by heat exchange with the liquid before it reaches the evaporator, so that the flow of said condensate and vapors between the points of heat exchange will be effected with the least loss of refrigerating effect.

2. In a refrigerating system in which a fluid is alternately evaporated and condensed in a heat transmission cycle the steps of heating respectively the condensate leaving the condenser and the vapors leaving the evaporator by heat exchange respectively with the incoming vapors and liquid, and subjecting said condensate to pressure to prevent its ebullition due to said heating.

3. In a refrigerating system in which a fluid is alternately evaporated and condensed in a heat transmission cycle: maintaining the flow of vapors in the heat transmission cycle by the reduction of vapor volume due to condensation, and substantially without compression, and heating the condensate and the vapors when leaving respectively the condenser and evaporator by heat exchange respectively with the incoming vapors and liquid.

4. In an apparatus for the transmission of refrigeration the combination of: an evaporator, a condenser and vapor and liquid conveying means connecting said evaporator and condenser, comprising surfaces adapted to exchange heat between said vapor and liquid conveying means, disposed respectively near the condenser and near the evaporator.

5. In an apparatus for the transmission of refrigeration the combination of: an evaporator, a condenser, vapor and liquid conveying means connecting said evaporator and condenser, comprising surfaces adapted to exchange heat between said vapor and liquid conveying means, disposed respectively near the condenser and near the evaporator, means to increase the pressure in said liquid conveying means, and refrigerating means to maintain said condenser at a lower temperature than said evaporator.

In testimony whereof, I have hereunto set my hand.

GUSTAV A. KRAMER.