May 2, 1933. B. F. RANDEL 1,906,414

METHOD OF REFRIGERATION

Filed Jan. 22, 1930 3 Sheets-Sheet 1

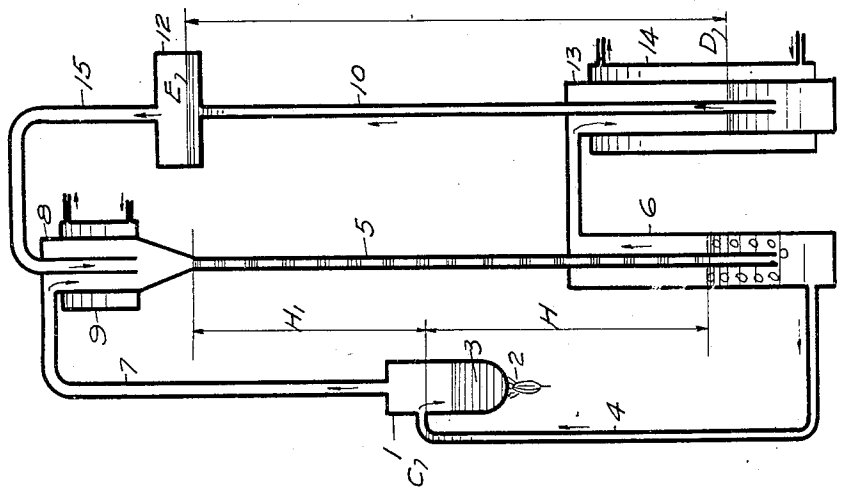


FIG. 3.

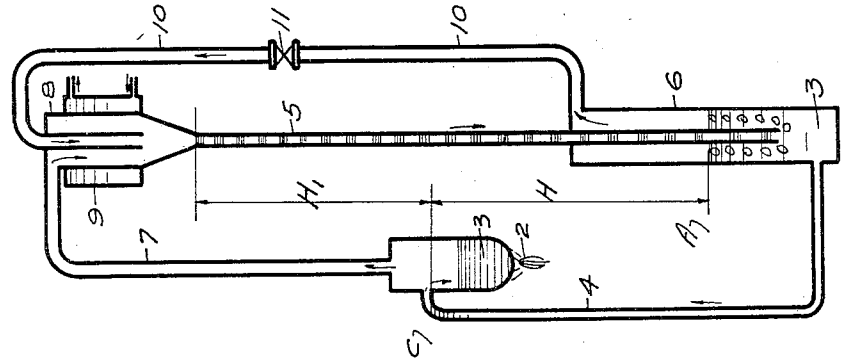


FIG. 2

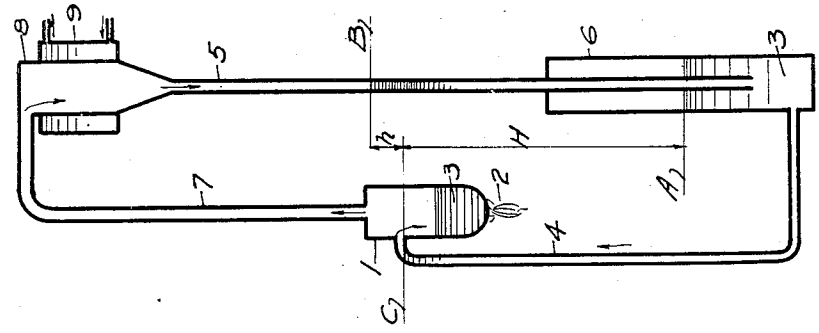


FIG. 1

INVENTOR

Bo Focke Randel

May 2, 1933. B. F. RANDEL 1,906,414

METHOD OF REFRIGERATION

Filed Jan. 22, 1930 3 Sheets-Sheet 2

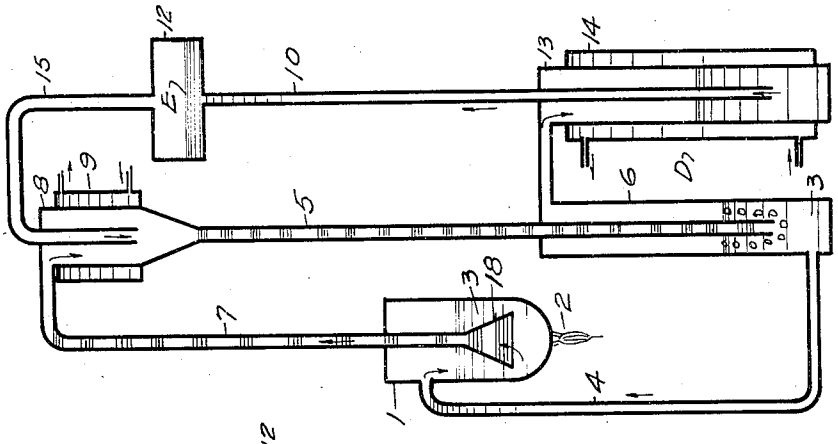


FIG. 6

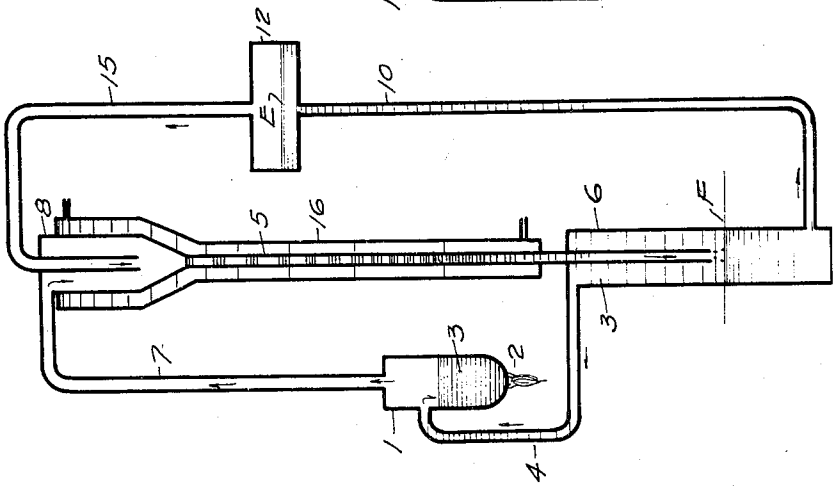


FIG. 5

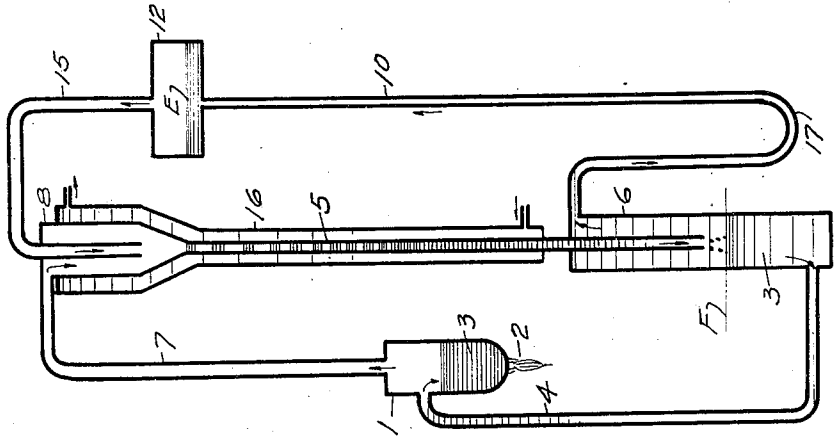


FIG. 4

INVENTOR

Bo Folke Randel

May 2, 1933. B. F. RANDEL 1,906,414

METHOD OF REFRIGERATION

Filed Jan. 22, 1930 3 Sheets-Sheet 3

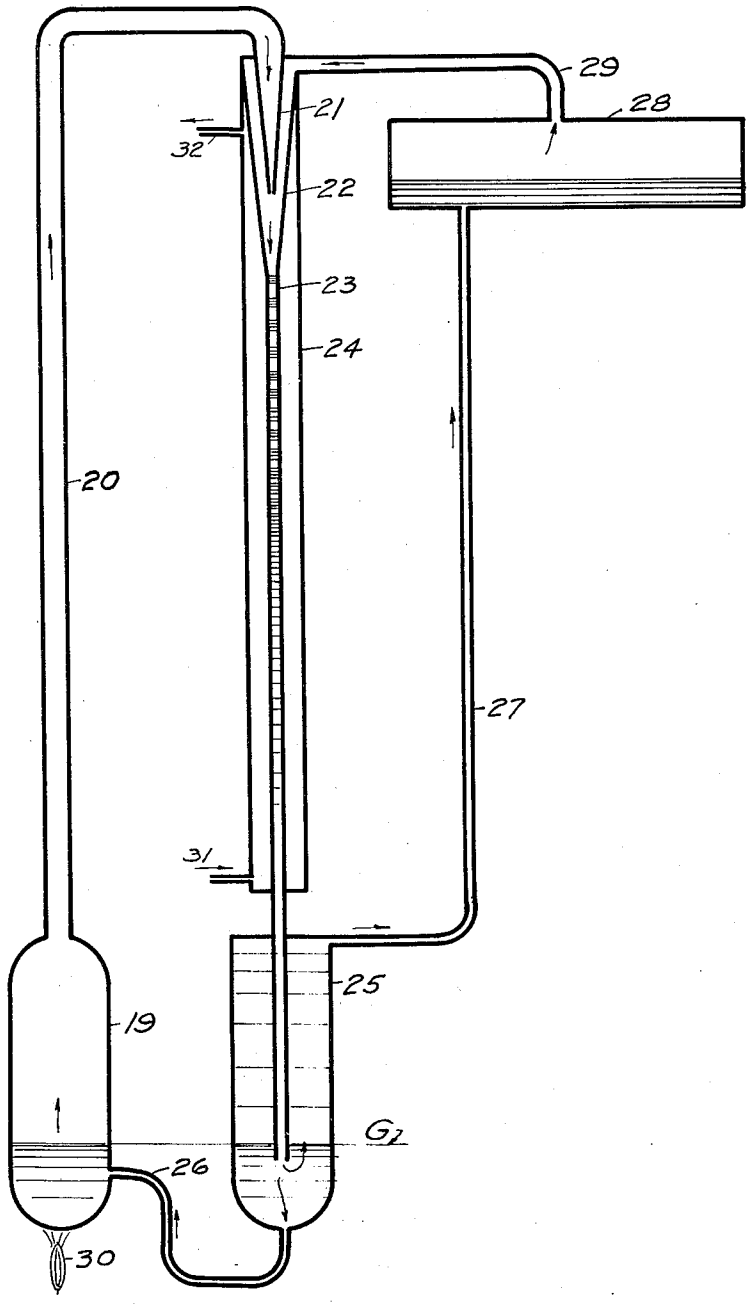


FIG. 7

INVENTOR
Bo Folke Randel

Patented May 2, 1933

1,906,414

UNITED STATES PATENT OFFICE

BO FOLKE RANDEL, OF SAN DIEGO, CALIFORNIA

METHOD OF REFRIGERATION

Application filed January 22, 1930. Serial No. 422,579.

My invention relates to method of refrigeration and the objects thereof are: First, to cause circulation in an apparatus by vaporizing a liquid motive medium in one side of the apparatus then condensing said vapors in another side of the apparatus, the two sides being connected in such a manner as to form a continuous circuit; Second, before the condensation of the motive medium, cause diffusion of vapor of a refrigerant in a vapor of the motive medium, thus creating a lowered partial pressure on said refrigerant. Third, by condensing said motive medium increase the partial pressure on said refrigerant vapor. Fourth, by a descending column of said liquefied motive medium still further increase the pressure on said motive medium sufficient to condense same. Fifth, to devise a method of refrigeration requiring very simple and inexpensive apparatus.

With these and other objects in view as will appear hereinafter, my invention consists of a certain novel method to produce refrigeration and certain novel arrangements of parts in an apparatus to accomplish this method of refrigeration as will hereinafter be described in detail and particularly set forth in the appended claims, reference being had to the accompanying drawings and to the character of reference thereon which form a part of this specification.

In the accompanying drawings, Figures 1, 2 and 3 show successive steps illustrating the principle upon which my method is based and Figures 4, 5, 6 and 7 show possible modifications of the apparatus wherein my method is carried out.

The figures are diagrammatic. The apparatus wherein my method is carried out may be built in several different ways and the parts thereof are conventional and well known in the arts.

I employ in general two mediums in my method of refrigeration. One, a motive medium and the other a refrigerating or cooling medium. Both mediums are chemically inert towards each other and immiscible in liquid form. Both mediums shall be capable of being vaporized and again condensed back to liquid form.

Referring to Fig. 1, assume a boiler 1 heated by a flame 2. The boiler contains a liquid 3, which liquid also fills tube 4 up to level C where said tube enters boiler 1, tube 5 to level B and part of high pressure chamber 6 to level A. If no heat was applied to boiler 1 the level of the liquid in tube 5 would be the same as level C in tube 4, but with apparatus in operation, as will be described, the level in tube 5 will be slightly raised a distance h from C to B.

It is assumed that the apparatus is sealed, and that the space above liquid level in boiler 1, tube 7, low pressure chamber 8 and tube 5 is filled with vapor of the liquid used. Also that space above level A in high pressure chamber 6 is filled with a noncondensable gas, for instance, air.

Surrounding low pressure chamber 8 is a cooling jacket 9 allowing water or other medium to cool the vapors in said chamber.

With flame 2 in operation, the liquid in boiler 1 will boil and form vapors, these vapors rising in tube 7 to low pressure chamber 8. In this chamber the vapors are cooled and condensed to liquid form, the condensate so formed passing down tube 5, raising the level of the liquid in this tube a small distance h from level C to B. With the raising of liquid level in tube 5 a flow will occur down this tube up tube 4 and with liquid discharging into boiler 1. A general circulation of vapors and liquid will be set up as indicated by arrows. The system as shown may be likened to a gravity return steam heating system with a boiler 1, a radiator 8 and condensate return pipe 5.

It is seen that a differential of pressures will be established between chambers 8 and 6. With a pressure of P pounds in chamber 8, the pressure on the entrapped air in chamber 6 will be P pounds plus pressure due to weight of liquid column H.

Referring to Fig. 2, I have an identical arrangement as shown in Fig. 1 with the addition of a tube 10 with regulating valve 11, connecting the vapor space of lower chamber 6 and upper chamber 8. The operating of

the apparatus is similar to the operation of the apparatus shown in Fig. 1 until valve 11 is opened. With the opening of this valve there will be a circulation of the air from high pressure chamber 6 through tube 10 up to low pressure chamber 8. In this chamber, the air will mix with the condensed liquid and will be drawn down through tube 5, the liquid forming pistons enclosing bubbles of air during the descent. The requirement to do this is that the weight of the combined liquid and air column H plus H1 shall be greater than the liquid column H.

The arrangement is similar to a conventional barometric condenser where the exhaust steam is condensed, and the vacuum is created by the descending column of condensate drawing non-condensable gases along in a delivery pipe. It is seen, that if the liquid used is water, it will be possible to create a near vacuum by a column approx. 32 feet high. If mercury is the liquid used, the height to produce vacuum in the upper chamber and discharging against atmospheric pressure or 14.7 lbs. abs. will be approx. 30 inches. A pressure difference of 14.7 lbs. may therefore be established between upper low pressure chamber and lower high pressure chamber. These values are very approximate, and an additional height of liquid column will be required to offset lowering of the weight due to mixing of the air with the liquid.

In Fig. 2 I have therefore illustrated the fundamental elements of my invention, which includes an expander, expanding a gas from a high pressure to a lower pressure and a compressor, compressing the expanded gas to the original high pressure, and by making the liquid column sufficiently high or using a liquid of high specific gravity, I may obtain a pressure difference sufficiently large to cause a heat exchange which may be employed in a practical refrigerating apparatus.

Referring to Fig. 3 I have shown an apparatus, where the principles illustrated in Figures 1 and 2 are applied in a practical way. The motive liquid is assumed to be mercury and the refrigerating medium is assumed to be hexane. Hexane liquid will vaporize at a temperature of 10 degrees F. under 0.393 lbs. abs. pressure and will liquefy at 90 degrees condensing temperature under 3.88 lbs. abs. pressure. The high and low pressure difference is therefore only 3.487 pounds and a mercury column less than 8 inches high will be sufficient to perform the work of compression. In a practical apparatus, this column will be made considerably higher.

Mercury is vaporized in boiler 1, and due to the very low pressure in this boiler, the required temperature will not be excessive. Also, the heat input is small, as the spec. heat and latent heat of mercury is very low. Mercury vapor will rise in tube 7 to diffusion chamber 8.

Liquid hexane is contained in evaporator 12, which evaporator connects with high pressure chamber 6 by tube 10 and diffusion chamber 8 by tube 15. In this chamber, hexane vapor will diffuse into the mercury vapor causing a flow of said vapor from evaporator 12 through the lowering of its partial pressure and thus further evaporation in said evaporator. The mixture of vapors is then cooled sufficiently to liquefy the mercury vapor, thus increasing the partial vapor pressure on the refrigerant. The liquid mercury will then form slugs in pipe 5, enclosing spaces of refrigerant vapor and still further compress same during the descent into 6. The vapor will separate from the liquid and will pass over to condenser 13, where it is cooled by water or other medium in jacket 14 and liquefied, the liquid being driven upwards into the evaporator by the differential of pressures, there to be re-evaporated.

Instead of hexane, many other mediums may be used. The necessary requirements being small pressure difference between high and low pressures, low condensing pressure and low vaporizing pressure. Also that the mediums shall be immiscible in liquid form. Water may be used as refrigerating medium, or pentane, heptane, ethers, alcohols and other hydrocarbons. Water may be the motive medium with many other mediums as refrigerating agents.

Referring to Fig. 4, a modication of the apparatus is illustrated. In this modification the condenser liquefying the refrigerating medium and the cooling arrangement provided for condensing the motive medium are combined in one. The entire length of tube 5 is here enclosed in cooling jacket 16.

The object is to condense and liquefy the refrigerating medium in this tube 5 during the descent into high pressure chamber 6, the pressure on the refrigerating medium gradually increasing during the path downwards. The liquefied refrigerating medium being lighter than the liquid motive medium will separate into chamber 6 and will float on top of the motive medium, forming a definite line F of separation between the two mediums. From this chamber 6, the liquefied refrigerating medium flows up into evaporator 12. The operation in other respects is similar to the operation in apparatus shown in Fig. 3.

Referring to Fig. 5, another modification of the apparatus is illustrated. This modification is similar to modification illustrated in Fig. 4, except the apparatus is suitable in cases where the liquefied refrigerating medium is heavier than the liquefied motive medium.

In this modification I may use water as motive medium and trichlorethylene as refrig-

erating medium. This medium has a spec. gravity of 1.47 in liquid form and will therefore sink to lower part of chamber 6, while the water will separate and float on top. Trichlorethylene will vaporize at 5 degrees temperature and 0.16 lbs. abs. pressure and will liquefy at 86 degrees and 1.72 lbs. pressure. A water column to accomplish the compression will therefore not be excessively high. In other respects the operation is similar to operation of apparatus illustrated in Fig. 4.

Referring to Fig. 6 another modification of the apparatus is illustrated. The apparatus illustrated in Fig. 6 is similar to apparatus as illustrated in Fig. 3 except construction in boiler 1.

The tube 7 is constructed at its lower end in the shape of a funnel, similar to a percolator. It is seen that by this arrangement not only vapors will rise in tube 7, but liquid also will accompany this vapor up to upper chamber 8. The provision required to cause such motion is that the weight of the combined vapor and liquid in columns 7 and 4 shall be less than the weight of liquid and vapor in tube 5. This may be accomplished by adjusting the relative elevations of the different parts of the apparatus.

Several other modifications may be devised, all suitable to perform the work in my method of refrigeration and I do not limit myself to any one type of apparatus nor to any one combination of mediums, but include all arrangements and all mediums suitable to carry out my method. In one modification the apparatus may for instance be constructed along conventional injector lines, allowing for compression of the cooling agent by utilizing the kinetic energy of the vaporized motive medium flowing from a higher pressure into a condensing space under lower pressure. This modification is shown in diagramatic form in Fig. 7.

In this Fig. 7, boiler 19 containing mercury liquid is heated by flame 30. Mercury vapor will ascend tube 20 to injector nozzle 21 in low pressure chamber 22. This chamber is surrounded by cooling jacket 24 allowing for water or air cooling.

As mercury vapor enters the low pressure chamber 22, the flow being restricted so as to maintain the high pressure in boiler 19 and tube 20, condensation and reduction of pressure will occur in this chamber 22. The velocity of the mercury vapor issuing from a higher pressure to a lower pressure or near vacuum will force any other vapors present in chamber 22 down through delivery tube 23 to high pressure chamber 25.

The evaporator 28 contains a suitable cooling agent, which will be vaporized under the low pressure produced in chamber 22, being in communication with same through tube 29. The descending column of mercury in delivery tube 23 will compress the vapor of the cooling agent and liquefy same by the removal of heat, jacket 24 allowing for water or air as cooling medium. In other respects the apparatus operates similar to apparatus illustrated in Fig. 4.

Having thus described my invention, what I claim is:

1. A method of refrigeration comprising elevating water by thermodynamic force to a higher position, allowing said water to descend and form slugs enclosing vapor of trichlorethylene compressing same, removing the heat of vaporization during said compression and then vaporizing said resultant liquid trichlorethylene under the lowered pressure produced by the descending column of said water.

2. A method of refrigeration employing a motive medium and a refrigerant in a closed and sealed system which comprises vaporizing the motive medium by heat application, vaporizing the refrigerant with the object of heat absorption and under conditions so as to maintain substantially equal pressures on refrigerant vapor and vapor of the motive medium, diffusing said vapors into each other, thus causing a reduction of partial pressure on each vapor, cooling the mixture of vapors to liquefy the vapor of the motive medium, but not the refrigerant vapor, thus increasing the partial pressure on refrigerant vapor, allowing the liquefied motive medium and the refrigerant vapor to fall under the influence of gravity to a lower point, increasing the pressure on said refrigerant vapor due to the liquid column thus formed, separating the refrigerant vapor from the liquefied motive medium, cooling and liquefying the refrigerant vapor and returning each respective liquid to points of vaporization.

3. A method of refrigeration employing a motive medium and a refrigerant which comprises generating force by thermodynamic action to cause circulation of said mediums, vaporizing the motive medium, vaporizing the refrigerant, causing diffusion of said vapors into each other, then condensing the vapor of said motive medium, adding its partial pressure to the partial pressure on refrigerant vapor, causing bodies of the condensate to descend, said bodies enclosing quantities of vapor of said refrigerant; cooling the mixture of condensed motive medium and refrigerant vapor so as to liquefy said refrigerant vapor, separating the resultant liquid mixture and returning the respective liquids to points of vaporization.

4. A method of refrigeration employing a motive medium and a refrigerant in a closed system which comprises vaporizing the motive medium by heat application, vaporizing the refrigerant with the object of heat absorption and under conditions so as to maintain substantially equal pressures on refrigerant

vapor and vapor of the motive medium, diffusing said vapors into each other thus causing a reduction of the partial pressures on each vapor and a mixture of vapors, cooling said mixture of vapor sufficient to liquefy said vapor of said motive medium and reducing its partial vapor pressures, thus increasing the vapor pressure on the refrigerant, removing the liquefied motive medium and the refrigerant vapor from point of diffusion by enclosing the said vapor between descending slugs of said liquid, increasing the pressure on said refrigerant vapor sufficient to liquefy same by cooling, separating the two liquids and returning each to its respective points of vaporization.

In testimony whereof, I have hereunto set my hand at San Diego, California, this 30th day of December, 1929.

BO FOLKE RANDEL.