REFRIGERATING PLANT

Original Filed Aug. 18, 1928 2 Sheets-Sheet 1

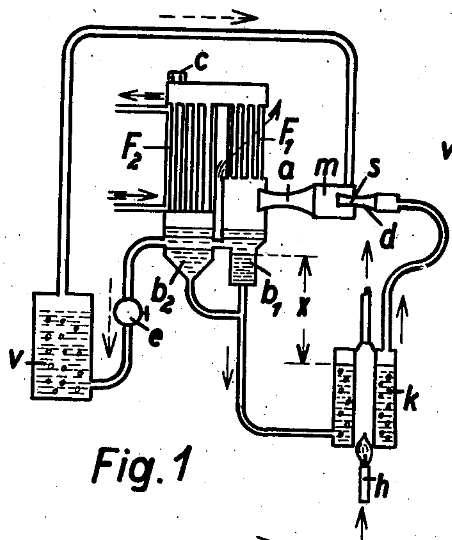

Fig. 1

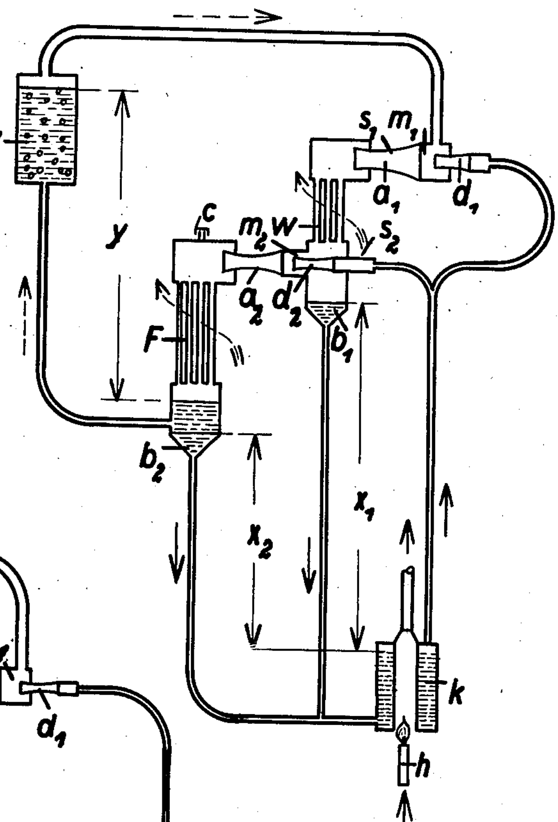

Fig. 2

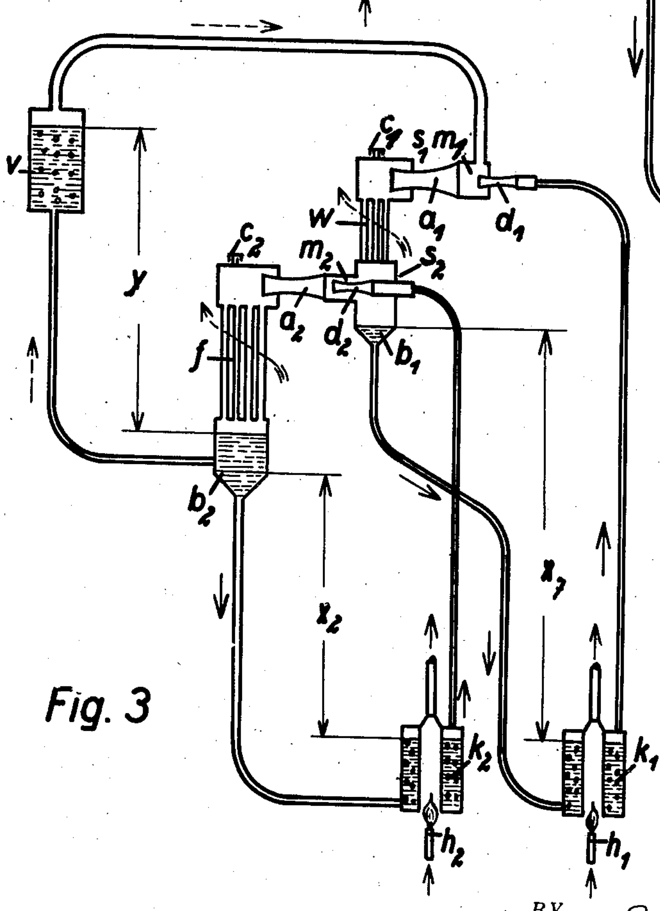

Fig. 3

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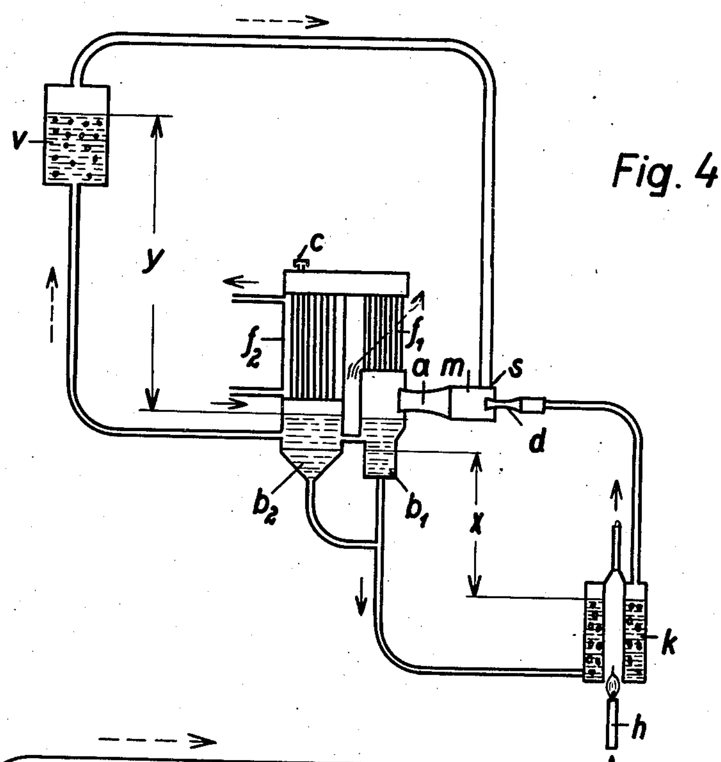

Fig. 4

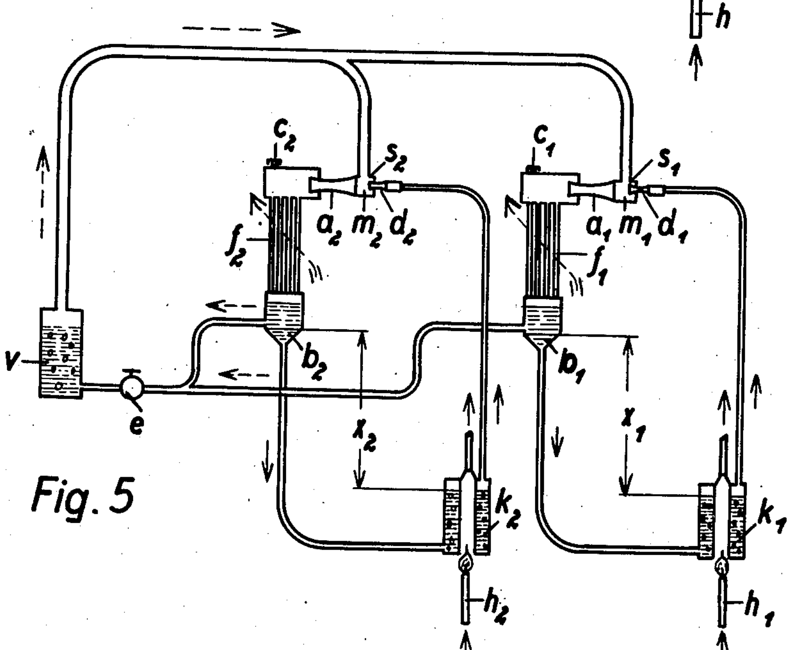

Fig. 5

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UNITED STATES PATENT OFFICE

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REFRIGERATING PLANT

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Original application August 18, 1928, Serial No. 300,505. Divided and this application January 25, 1932, Serial No. 588,548. In Germany August 22, 1927

2 Claims. (Cl. 62—115)

My invention relates to a compression refrigerating apparatus of the type wherein the raising of the refrigerating medium from a lower evaporator pressure to the higher condenser pressure is effected by a jet compressor and is particularly applicable to small refrigerating plants for household use. This application is a division of my earlier application for Refrigerating process and the apparatus applicable thereto, Serial Number 300,505 which was filed on August 18, 1928 and which became Patent No. 1,870,265, dated August 9, 1932.

My invention makes use of the compression and reexpansion of a gas, called the "refrigerating medium", to effect refrigeration. It may be possible to utilize a "permanent gas" as a refrigerating medium but still in practice an alternating condensation and re-vaporization will be employed almost exclusively; for the sake of simplicity, therefore, let the refrigerating medium be assumed to be a vapor throughout the following description. This vapor under suitably high pressure and temperature conditions in the "condenser" radiates heat into its surroundings (cooling water or air) by which means it is totally or partially condensed, and owing to its expansion on account of lowered temperature, extracts heat from the goods to be refrigerated directly or indirectly in the evaporator and is thereby totally or partially vaporized again; in this cycle, the refrigerating medium must be raised again from a lower to a higher pressure between evaporator and condenser. The refrigerating medium can also be absorbed after leaving the condenser in a so-called "absorber" by a "solvent", heat being released; and then being separated again by heating it in the "generator"; in this case, the "strong solution" has to be raised from the lower absorber pressure to the higher generator pressure.

The above invention accomplishes the almost necessary raising of a material from lower to higher pressure by a process especially safe in its operation. Its application as said above is particularly suitable for small plants, i. e. for households or for the smaller industrial undertakings in which case it is more a question of absolute safety in operation and reliability in spite of any sort of unsuitable handling than the utmost utilization of the power applied: that, however, does not preclude its application under special conditions also for larger plants. For the achievement of this invention is great safety in operation in that all packing glands and similar constructional details where the refrigerating medium might be able to escape or the air to enter are eliminated, and likewise all revolving or reciprocating machine parts which are subject to wear and tear; further, the process continues evenly without intermission while an interrupted pressure requires switch mechanism which must be operated either by hand—and may be either wrongly operated or forgotten—or by automatic switch control gear which from experience is notably lacking in safety of operation and is also costly. Moreover, in a case of the failure of the cooling water, no dangerous pressure can be set up.

The invention fulfills these requirements in that it provides for the change of pressure between evaporator and condenser by means of a jet compressor. The "power vapor" necessary for operating the compressor is generated in the "power medium evaporator" (hereinafter called briefly the "boiler"); after it has passed through the jet compressor giving off energy to the refrigerating medium, it is precipitated in the "power medium compressor" and flows back from there to the boiler, after the power medium and the refrigerating medium have separated one from the other. The power medium, or at least its greatest portion is then condensed in a separate place, only a relatively small portion being condensed with the refrigerating medium. It is however always essential for the invention that the power medium and also the refrigerating medium must be totally enclosed throughout their working cycle, that the power medium condenser should be placed higher than the boiler, so that the power medium can flow by gravity from the former to the latter, and that two kinds of material differing one from the other are utilized for power medium and refrigerating medium.

The mechanism of the so-called steam refrigerator is well known; in this, the working cycle is open and therefore refrigerating medium as well as power medium must pass out into the open air and their loss compensated elsewhere, for which purpose mechanically actuated parts and packing glands are necessary. Refrigerating plants with vapor injection and a closed working cycle in which the condenser pressure is equal to the boiler pressures are also well known; even if it is possible to arrange the injection in such a way that the power medium regains its initial pressure by virtue of its condensation, this class of apparatus always consumes a very great quantity of driving vapor, i. e. it is of low efficiency, and, moreover, the condensation has to take place at a higher pressure than is requisite, in other words, the refrigerating process must be carried on under unfavorable conditions. With another well-known device, a second injector is used for returning the power medium to the boiler, but, apart from the fact that this means complication and increased cost of the plant, it has a very low degree of efficiency, while the return by gravity in accordance with this invention has an efficiency of practically 100%, since the velocity of the returning liquid can be regulated so slow that friction loss can be entirely neglected. Yet again in another well known appliance, gravity is utilized for return flow, but the same material is applied for refrigerating and power media. As the materials applicable as refrigerating media in as far as they admit of small pressure differences between evaporator and condenser are comparatively light liquids and since to obtain a reasonably favorable degree of efficiency, the boiler pressure ought to exceed the condenser pressure as much as possible, it follows that, with this appliance, a very great construction height is required, which generally is not available, certainly not in small plants and long pipe lines are also necessary which result in a disproportionately high refrigerating loss.

The working process in accordance with the present invention eliminates all these disadvantages.

In the annexed drawings, in which I have shown, by way of illustration, in a diagrammatic manner, various embodiments of my invention, Fig. 1 shows an arrangement operating according to compression principle with single-stage compression and partly air, partly water-cooled; Fig. 2 likewise shows an arrangement based on the compression principle but with two-stage compression and a common boiler for both stages; Fig. 3 shows a similar arrangement as Fig. 2, except that for each pressure stage a separate boiler is provided. Fig. 4 shows an arrangement similar to that in Fig. 1, in which the evaporator is located at a higher level than the condenser. Finally, Fig. 5 shows a similar arrangement as Fig. 1, in which several jet compressors are connected in parallel.

In all the views, *a* indicates the pressure nozzle of the jet compressor, *b* the separator, *c* the filling tube, *d* the inlet nozzle, *e* the throttle valve for the refrigerating medium, *f* the condenser, *h* the burner for the boiler heater, *k* the boiler, *m* the mixing chamber of the jet compressor, *s* the jet compressor, *v* the evaporator, *w* the condenser for the power medium, *x* the difference in height between the level of the liquid power medium in the boiler and in the condenser.

The arrangment shown in Fig. 1 operates as follows: in the boiler *k*, the power medium, e. g. mercury, is evaporated (e. g. at a temperature of 675° F.) by the application of heat (e. g. by heating with a Bunsen burner *h*); the vapor rises under the boiler pressure P_k (e. g. 14.6 lbs/sq. in. absolute) and flows with great velocity through the inlet nozzle *d* of the jet compressor *s* into the mixing chamber *m*; cooling naturally takes place in converting pressure into velocity which is very opportune here. The pressure in the mixing chamber P_m is somewhat lower than the evaporator pressure P_v, so that the refrigerating medium (e. g. water) is sucked up out of the evaporator *v*. Refrigerating medium and the power medium enter the "delivery" or "outlet nozzle" *a* together; here the velocity is converted back largely into pressure and both materials enter the first "collecting chamber" or "separator" *b* under a pressure P_b, which is still lower than the boiler pressure P_k, but a fraction higher than the condenser pressure P_f of the refrigerating medium (e. g. 1 lb/sq. in.abs.); under these circumstances, partial condensation may occur in the delivery nozzle, which is completed in the condenser *f*. In the construction chosen as an example this consists of two parts, an upward air-cooled pipe coil f_1 in which a great portion of the power medium precipitates at a relatively higher temperature (e. g. between 500 and 300° F.) and a downward water-cooled pipe coil f_2 in which the refrigerating medium is condensed (e. g. under a pressure of 0.96 lbs/sq. in. and a temperature of 100° F.). The power medium collects for the most part in the collecting chamber b_1, a small residue in the collecting chamber b_2 in a fluid state on the bottom of the chamber, and flows from them back to the boiler *k* by gravity. In the example chosen, the difference in height between the levels of the liquid in chamber *b* and in boiler *k* would have to be $x=2'6''$. The refrigerating medium flows from the second collecting chamber through the throttle or "regulating device" *e* (which may be a valve, narrow opening or a narrow pipe) where it again expands to the evaporator pressure; in the evaporator *v* it is vaporized by extracting heat from the goods to be refrigerated and is then sucked up again to the compressor. It is, as said above, not absolutely necessary to condense the power medium and the refrigerating medium separately as both can be condensed together, but in practice the power medium should not be cooled off more than is necessary. The plug marked *c* serves for filling up with power and refrigerating media and for removing air or other permanent gases and is kept tightly closed during normal operation.

If a temperature lower than about 35° F. must be obtained in the evaporator, then water cannot naturally be applied as a liquid to be vaporized as specified above; however, a solution of salts in water (such as chlorides of potassium, sodium, calcium, magnesium) or other materials (e. g. sugar) can be fed to the evaporator as it freezes at lower temperatures; only the solvent of the solution vaporizes (as e. g. the water) as the evaporator pressure is correspondingly lower. Even if small quantities of the material in solution are taken along this will do no harm whatever, on the contrary their presence in the condenser is quite advantageous because of the reduction of the pressure. Besides such an addition of material in solution to the refrigerating liquid has a certain effect of regulation on its action; if for instance the supply output of the compressor is greater than the quantity flowing through the throttling device, the solution in the evaporator will become more concentrated, the vapor pressure will drop and with it very quickly the supply output of the compressor.

Other materials besides water and mercury can obviously be applied as refrigerating and power media. But as, with the application of mercury as a power medium, a variation of pressure of about 60 lbs./sq. in. can be obtained with a difference of height of only 10', which is available nearly everywhere, there is no reason why such materials as are usually applied as refrigerating media and which work with a greater pressure variation should not also be employed. The compression can also be effected in two or more stages as shown in Figs. 2 and 3 and the compressor's mode of operation can be converted as to its first stage from jet injection to gap action

(Gaede's diffusion system), so that an exceptionally low pressure can be maintained properly in the evaporator, enabling materials which are difficult to vaporize to be applied as refrigerating media. In principle, there is consequently, hardly any restriction in the choice of refrigerating media. In practice, for the sake of safety, in all cases where such appliances are to be installed for household use, those materials will always be chosen for preference whose condensation pressure is not considerably above atmospheric pressure. An exceptionally high vacuum will also be avoided as a general rule because certain difficulties occur in maintaining it properly, and penetration of air drastically lowers the efficiency of the device. Further those materials will generally be avoided that are in any way poisonous or contain elements of danger by decomposition, explosion or combustion, or which attack metals strongly, and, of course, power and refrigerating media must be chemically neutral as regards each other and insoluble, one with the other in the liquid state.

As power media carbon tetrachloride CCl_4 or water may, for instance, be employed; with these, the necessary difference in height is indeed greater than that for mercury, but even so, this remains within manageable limits as long as the refrigerating medium is chosen to correspond.

Even if there is a failure of the cooling water or a choking of the throttling section, no inadmissible height of pressure can occur because the jet compressor does not force in a continually sustained quantity of refrigerating medium like a piston compressor but on the contrary, its output decreases rapidly in proportion to increasing recoil pressure until it finally drops to zero.

Figs. 2 and 3 show a two-stage arrangement of the jet compressor. After the first stage, which produces an intermediate pressure, the power medium is precipitated and flows back to the boiler, the refrigerating medium is further compressed in the second stage with some freshly introduced power medium. This kind of arranging the steps in series is more economical than the arrangement whereby the evaporator of the higher stage constitutes the condenser of the lower stage. Naturally either one or both stages can work with a liquid jet or along with the diffusion system, and yet more than two stages can be provided if the amount of pressure required demands this. A special boiler can be provided to drive each stage, and according to circumstances, different power media as shown in Fig. 3. Also, if the quantity of power medium required is too great, several nozzles can be provided side by side as shown in Fig. 5. This arrangement of several boilers, with the nozzles either arranged in parallel or in series, involves the advantage that each nozzle can be operated separately from the others without any special control members being provided in the pipes. This is a very desirable feature for regulation when, for example, the required refrigerating effect varies within wide limits, or when the condenser temperature or the evaporator temperature required is subject to great change as for instance sometimes only a cooling operation, sometimes the actual manufacture of ice is desired.

Figs. 2, 3 and 4 show yet another variation. The expansion of the refrigerating medium from condenser to evaporator is not obtained here by means of throttling, but by arranging the evaporator higher so that the liquid must be forced upwards against gravity. This has the following advantages over the throttling method; the varying of the throttling section by the handling of a valve as it is usual in large plants shall be avoided here; or a narrow opening of fixed adjustment—quite apart from the fact that it is liable to be stopped up by dirt—allows only an absolutely fixed quantity to pass through with a certain pressure difference, and if the refrigerating effect and with it, the supply output of the compressor, and consequently also the quantity of the liquid passing through the throttling device be increased, all this is only possible with a fixed throttle aperture, if at the same time the condenser pressure is increased, i. e. the process is carried out under unfavorable conditions; with the arrangement above described, on the other hand, the difference of pressure between condenser and evaporator is practically independent of the quantity forwarded. Moreover, the refrigerating liquid effectively operates to overcome gravity in rising from the condenser to the evaporator; the compression is effected not by throttling, but adiabatically, and it is well known that by this means the degree of efficiency of the whole process is improved. For example with the application of carbon tetrachloride as refrigerating medium, a vaporizing temperature of 15° F. and a condensing temperature of 100° F., the evaporator pressure would be 9.37 lbs./sq. in., the condenser pressure 4 lbs./sq. in., consequently the pressure ratio 1 to 11 and the pressure difference 3.6 lbs./sq. in. In this case a two-stage compressor will be applied and the difference in height between evaporator and condenser must be about $y=5'9''$, because the specific gravity of the refrigerating medium is about 97 lbs./cub. ft.

In all types of construction, naturally care must be taken to employ the heating gas and the cooling water to the best advantages. The well heated cooling air can serve partly as combustion air for the heating flame of the boiler.

As the heating gas even with the most efficient usage always carries off a relatively high temperature in the exhaust pipe, it can be utilized by means of a suitable appliance (chimney) for producing a powerful draught, and this will carry the cooling air with it and ensure its proper circulation.

I claim:

1. The process of refrigerating which consists in raising by jet compression a refrigerating medium from the lower evaporating pressure to the higher condensing pressure in a plurality of pressure stages, evaporating the power medium different from the refrigerating medium in each stage prior to its work in the jet compression, condensing the power medium, separating the power medium and the refrigerating medium by the agency of their different specific gravities, permitting the power medium to flow back to be evaporated again while separately evaporating a fresh power medium and sucking the refrigerating medium into the next higher compression stage by said fresh power medium, separating the last mentioned power medium and the refrigerating medium by the agency of their different specific gravities, permitting the last mentioned power medium to flow back by its specific weight, and condensing the refrigerating medium in the last pressure stage.

2. A multi-stage refrigerating apparatus, comprising an evaporator, a plurality of jet compressors, the suction nozzles of the first jet compressor being connected with the evaporator,

a plurality of boilers, each having a vapor space connected with the power medium inlet nozzle of a corresponding jet compressor, a condenser connected with the pressure nozzle of each compressor, a separator connected with each condenser, the separator of a lower stage being connected with the suction nozzle of the jet compressor of the higher stage, a single expansion device connected with the last separator and said evaporator, each separator being connected with the liquid space of that boiler which is connected with the immediately previous jet compressor, each condenser being disposed at a height above the respective boiler so as to enable the power medium to flow back by its specific weight to its boiler.

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