

Aug. 9, 1932.

A. SELIGMANN

1,870,265

REFRIGERATING PROCESS AND THE APPARATUS APPLICABLE THERETO

Filed Aug. 18. 1928

7 Sheets-Sheet 1

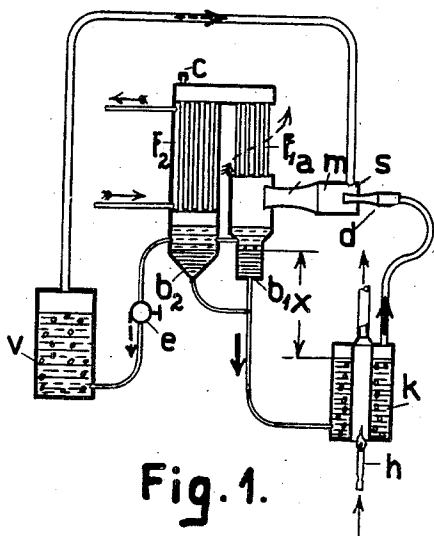


Fig. 1.

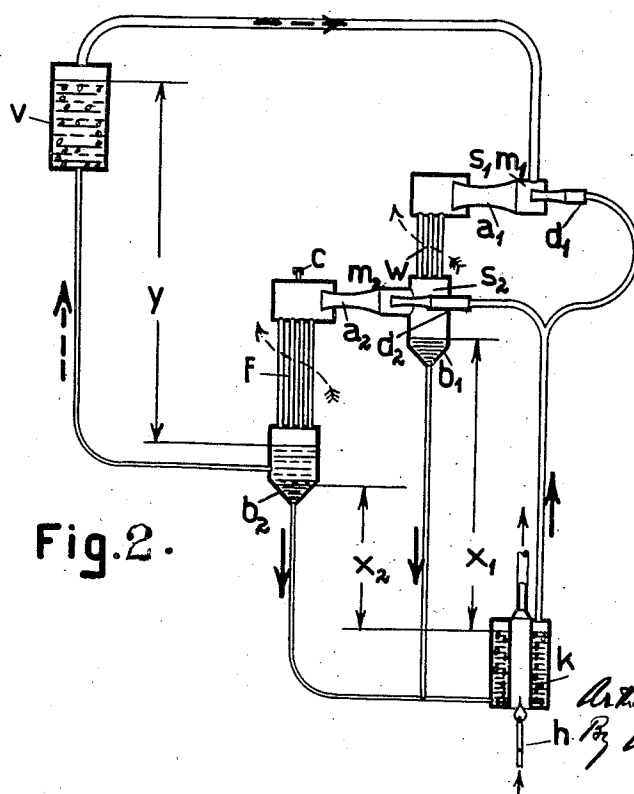


Fig.2.

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7 Sheets-Sheet 2

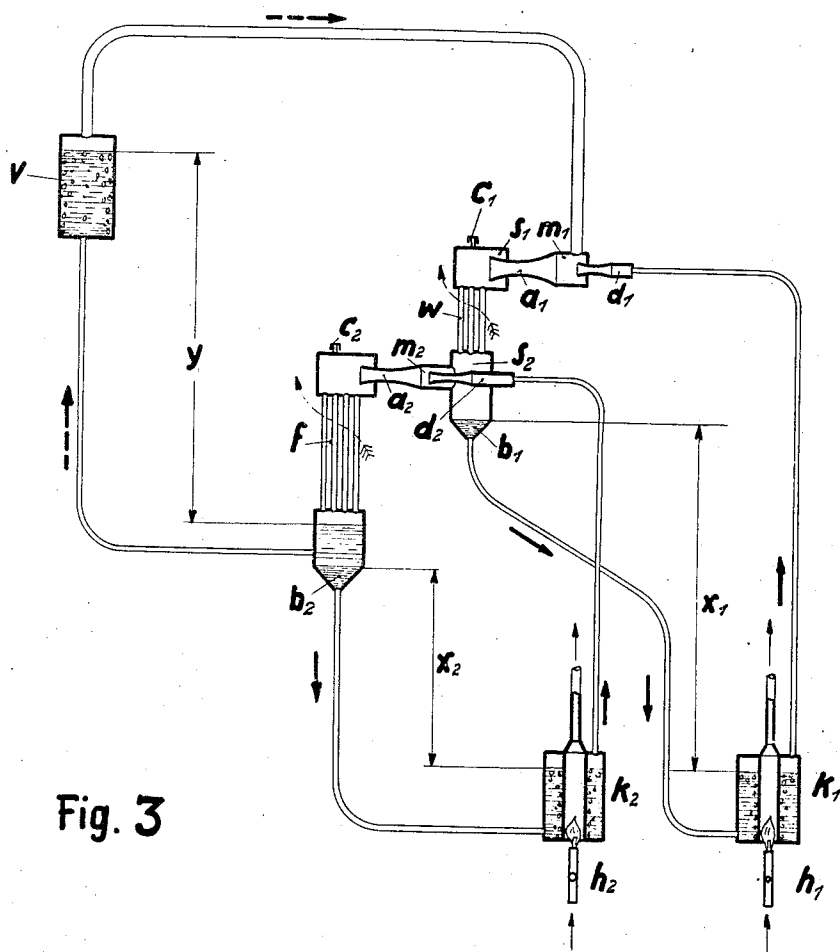


Fig. 3

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7 Sheets-Sheet 3

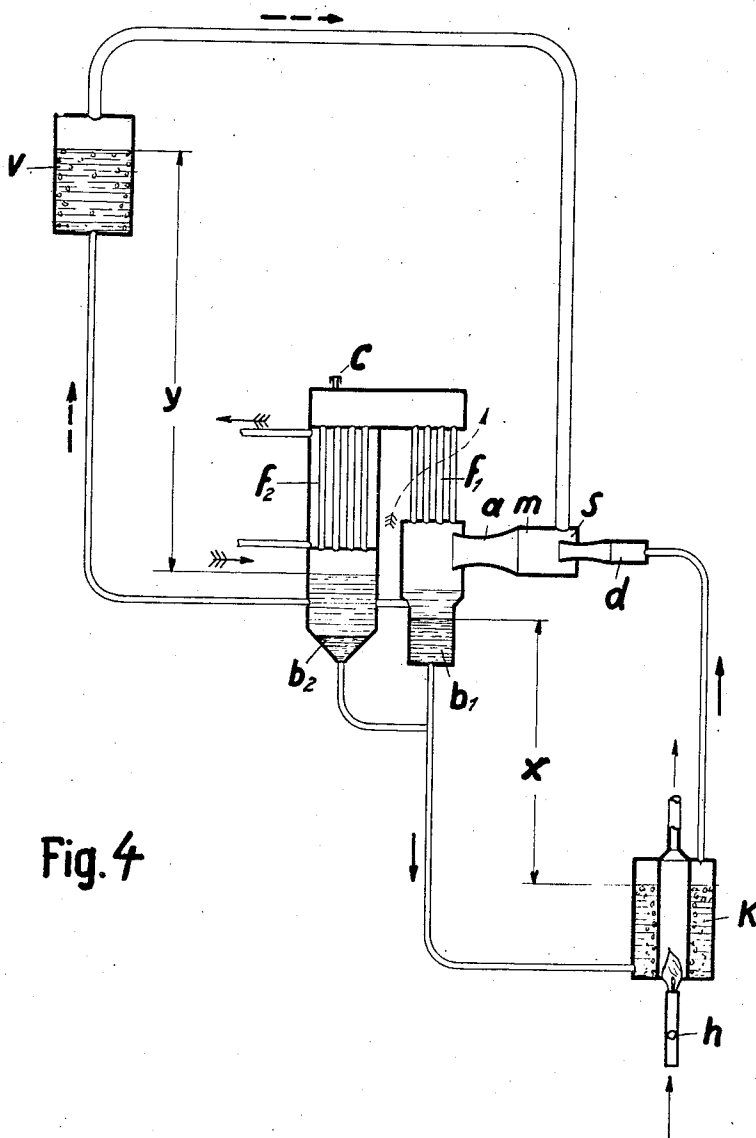


Fig. 4

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REFRIGERATING PROCESS AND THE APPARATUS APPLICABLE THEREOF

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7 Sheets-Sheet 4

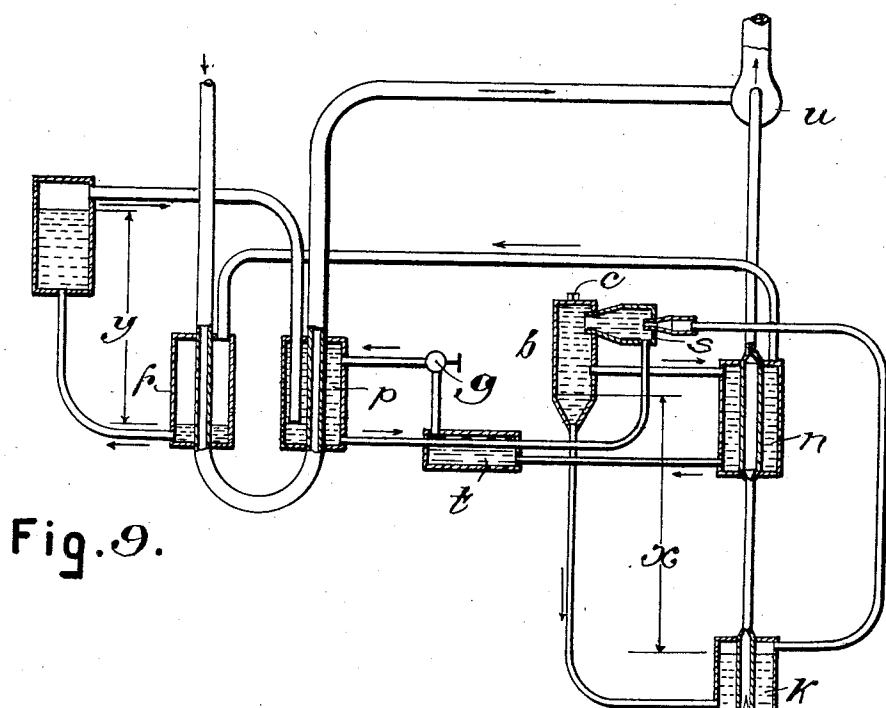


Fig. 9.

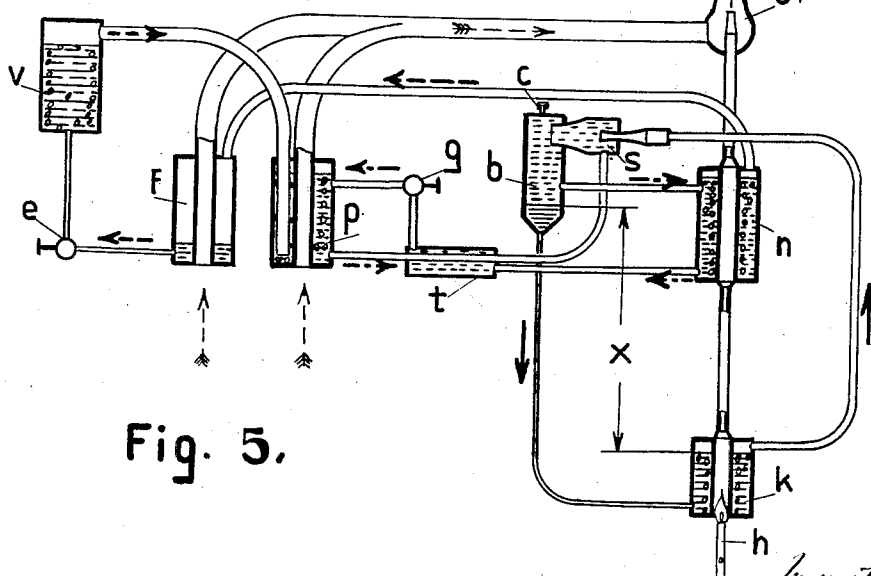


Fig. 5.

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7 Sheets-Sheet 5

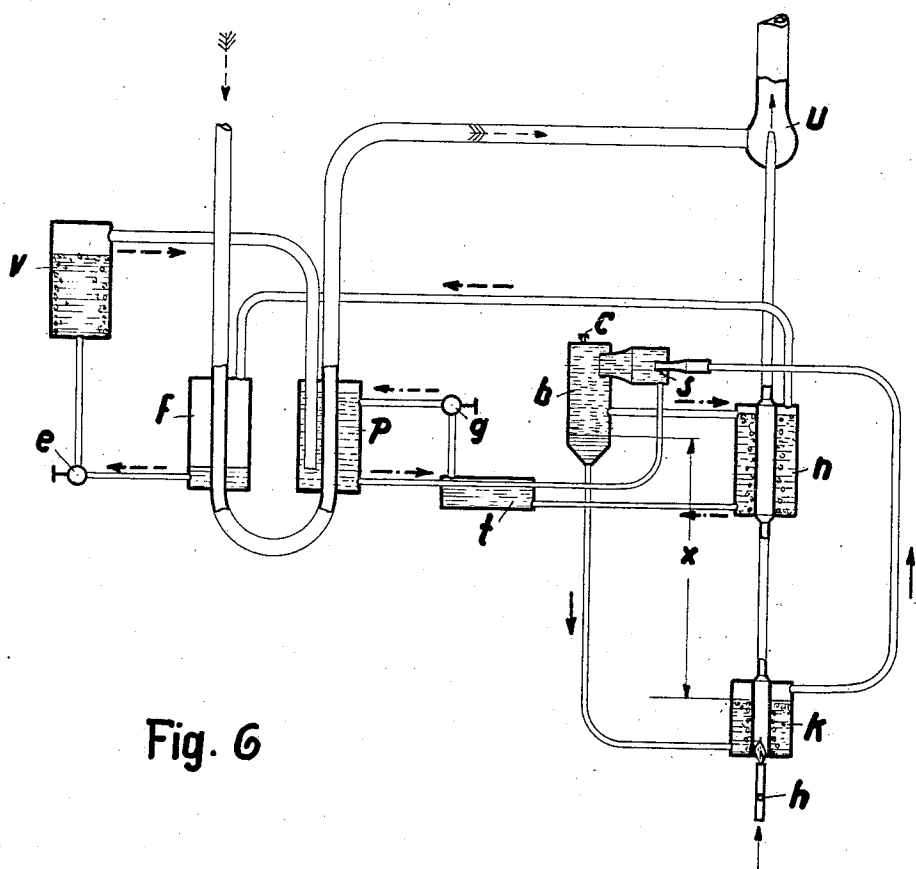


Fig. 6

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7 Sheets-Sheet 6

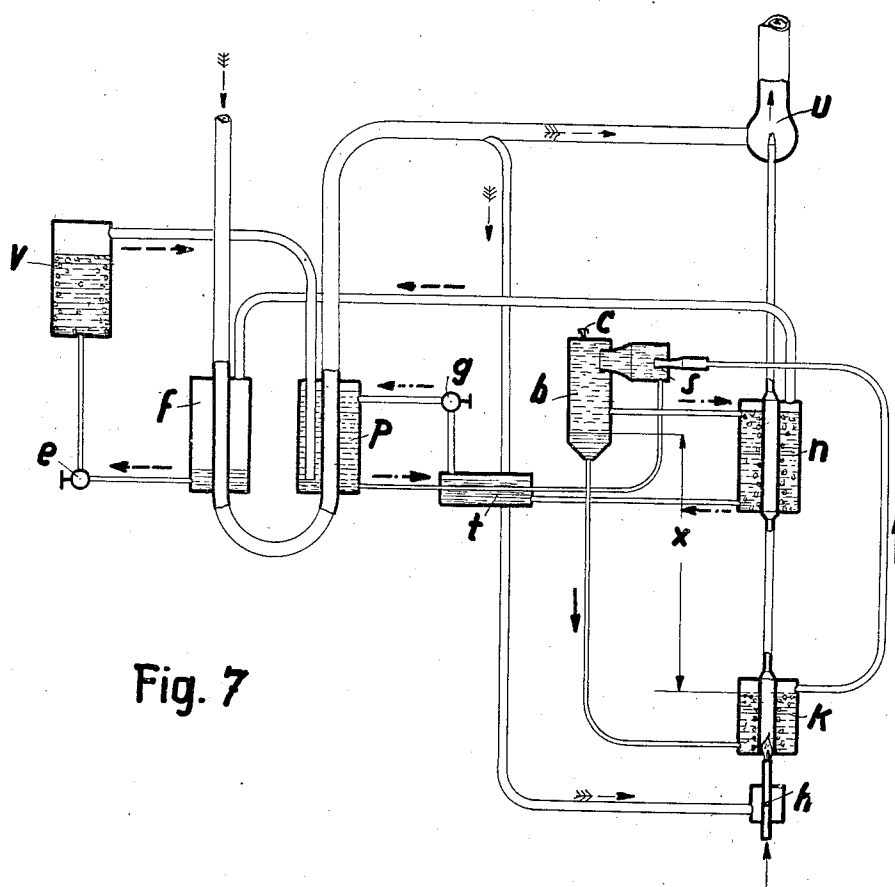


Fig. 7

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7 Sheets-Sheet 7

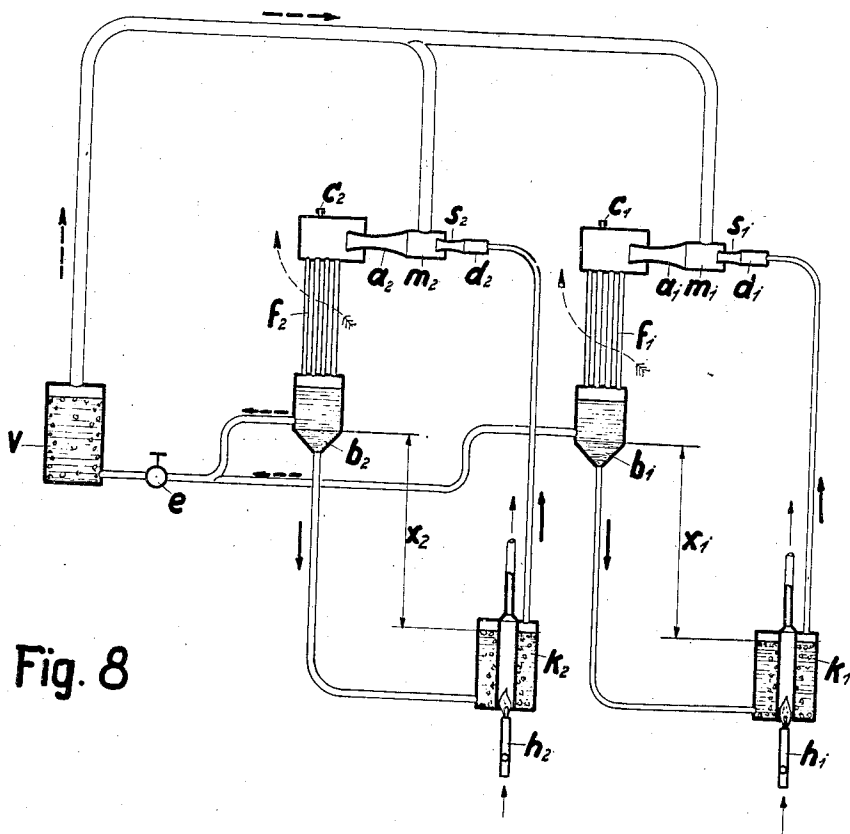


Fig. 8

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UNITED STATES PATENT OFFICE

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REFRIGERATING PROCESS AND THE APPARATUS APPLICABLE THERETO

Application filed August 18, 1928, Serial No. 300,505, and in Germany August 22, 1927.

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 vapour throughout the following description. This vapour, under suitably high temperature and pressure 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 vapourized 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 separated again by heating 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 always necessary raising of a material from lower to higher pressure by a process specially 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 supplied; 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 process requires switch mechanism, which must either be operated 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 failure of the cooling water, no dangerous pressure can be set up.

The invention fulfils 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 condenser" and flows back from there to the boiler, after the power medium and refrigerating medium have separated one from the other. The condensation of the power medium and the refrigerating medium can be effected jointly or in separate places, and the power medium can also be condensed before entering the compressor and the latter arranged as a liquid spray jet compressor. 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 pressure 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 unfavourable 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 of the above 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 power and refrigerating media. As the materials applicable as refrigerating media in as far as they admit of small pressure difference 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-cooling; 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 shown in Fig. 1, in which the evaporator is located at a higher level than the condenser; Fig. 5 shows an arrangement operating on the absorption principle; Fig. 6 shows a similar arrangement in which the cooling medium successively passes through the condenser and the absorber. Fig. 7 also shows a similar arrangement, in which the preheated air is used as combustion air for the boiler. Fig. 8 shows a similar arrangement as Fig. 1, in which several jet compressors are connected

in parallel. Figure 9 shows an arrangement similar to Figure 6 in which the throttle valve in the pipe connecting the evaporator with the condenser is eliminated and the evaporator is placed at a higher elevation than the condenser.

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, *g* the throttle valve for the poor solution, *h* the burner for the boiler heater, *k* the boiler, *m* the mixing chamber of the jet compressor, *n* the generator, *p* the absorber, *s* the jet compressor, *t* the heat exchanger, *u* the blower, *v* the evaporator, *w* the condenser for the power medium, *x* the difference in the height between the level of the liquid power medium in the condenser and in the boiler, *y* the difference in height between the levels of the liquid refrigerating medium in the evaporator and in the condenser.

The arrangement 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 vapour 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 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 *f₁*, 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 *f₂* 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 *b₁*, a small residue in the collecting chamber *b₂* 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 liquids 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, a narrow opening or a narrow pipe) where it again expands to the evaporator pressure; in the evaporator *v* it is vapourized 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 naturally cannot be applied as a liquid to be vapourized, as specified above; however, e. g. a solution of salts in water (such as chlorides of potassium, sodium, calcium, magnesium) or other materials (as e. g. sugar) can be fed to the evaporator as it freezes at lower temperatures; only the solvent of the solution vapourizes (as e. g. the water), as the evaporator pressure is correspondingly lower. Even if small quantities of the material in solution are carried 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 vapour 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 power and refrigerating 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 anywhere, 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 vapourize to be applied as refrigerating medium. 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 medium must be chemically neutral one as regards the other, and insoluble one with the other in the liquid state. There are sufficient suitable materials that comply with all these requirements. Also it is not absolutely necessary that the power medium be less volatile than the refrigerating medium. For example besides water materials can be used as a refrigerating medium as carbonic di-sulphide CS_2 , butane C_4H_{10} , pentane C_5H_{12} , hexane C_6H_{14} , various alcohols, e. g. methyl-alcohol CH_3OH , ethyl-alcohol $\text{C}_2\text{H}_5\text{OH}$, and ether $(\text{C}_2\text{H}_5)_2\text{O}$, the chlorine substitution products of the sebaceous order, e. g. methyl-chloride CH_3Cl , carbon-tetrachloride CCl_4 and others or mixtures.

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 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 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 stages 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 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. 8. With this arrangement of several boilers, either with simultaneous or consecutive control, there is the advantage, that each nozzle can be operated separately from the others without any 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 advantage 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 unfavourable 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 effects work 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 vapourizing 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 1:11 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.

Figs. 5, 6 and 7 show arrangements based on the absorption principle. The refrigerating vapour coming from the evaporator v is dissolved by a solvent in the absorber p . The strong solution after passing through the so-called heat exchanger t , is raised by the jet pump s to the generator n , while the power medium flows back to the boiler, as in the other arrangements. The power medium is condensed in this case by mixing with the solution. By this means not only is the decrease in heat content which can be converted into kinetic energy very great, but also the solution on its way to the generator is preheated. In the generator, the refrigerating medium is expelled from the solution by the application of heat, is then precipitated in the condenser f and flows back to the evaporator v after throttling in e , while the poor solution flows back through the heat exchanger t after throttling at g to the absorber. It follows, that in the absorption process multistage compressors can also be applied.

In all types of construction care must be taken to employ the heating gas and cooling water to the best advantage. In this way, for example the heat radiated from the boiler can be applied to a certain extent for heating the generator, or vice versa, according to whether a more or less volatile power medium is applied (Fig. 5). The cooling medium (water or air) which primarily cools the condenser can flow from there to the absorber. Where running water is not available, air cooling can also be provided, as shown in Figs. 6 and 7. The cooling air can be employed in a similar way; the well heated cooling air can then serve partly as combustion air for the heating flame of the boiler, as shown in Fig. 7.

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, as shown in Figs. 5, 6 and 7, will carry the cooling air with it and ensure its proper circulation. (Blower u .)

What I claim is:—

1. The process of refrigerating, which consists in raising by jet compression a refrigerating medium dissolved in a solvent from the lower absorbing pressure to the higher generating pressure, evaporating the power medium different from the refrigerating medium prior to its work in the jet compression, then condensing the same by mixing it with the solution, separating the power medium and the solution by the agency of their different specific gravities, and permitting the power medium to flow back to be again evaporated.

2. The process of refrigerating, which consists in raising by jet compression a refrigerating medium dissolved in a solvent from the lower absorbing pressure to the higher generating pressure, evaporating the power medium used in the jet compression and different from the refrigerating medium prior to its work in the jet compression, condensing the power medium by mixing it with the solution, then separating the power medium and solution by the agency of their different specific gravities, and permitting the power medium to flow back by its specific weight to be again evaporated, while supplying heat by the same heating medium to the evaporating and generating elements.

3. The process of refrigerating, which consists in raising by jet compression a refrigerating medium dissolved in a solvent from the lower absorbing pressure to the higher generating pressure, vaporizing the power medium used in the jet compression and different from the refrigerating medium prior to its work in the jet compression, condensing the power medium by mixing it with the solution, then separating the power medium and the solution by the agency of their different specific gravities, and finally permitting the power medium to flow back by its specific weight to be again evaporated, while cooling by the same cooling medium the condensing and absorbing elements.

4. The process of refrigerating, which consists in raising by jet compression a refrigerating medium dissolved in a solvent from the lower absorbing pressure to the higher generating pressure, alternately vaporizing and condensing the power medium used in the jet compression and different from the refrigerating medium in a completely closed cycle, permitting the power medium to flow back by its specific weight to be again evaporated, while utilizing a portion only the cooling air after having been preheated in the condensing operation as combustion air in the evaporating operation.

5. The process of refrigerating, which consists in raising by jet compression a refrigerating medium dissolved in a solvent from the lower absorbing pressure to the higher generating pressure, alternately vaporizing and condensing the power medium used in the jet compression and different from the refrigerating medium in a completely closed cycle and permitting it to flow back by its specific weight to be again evaporated, causing a circulation of condensing cooling air, and utilizing a portion only of such air as combustion air in the vaporizing operation.

6. A refrigerating apparatus, comprising an evaporator, a jet compressor, a boiler having a vapor space connected with the power medium inlet nozzle of said compressor, a condenser connected with the pressure nozzle of said compressor, a separator connected

with said condenser and the liquid space of said boiler, and pipe conduits connecting said condenser with said evaporator, said condenser being disposed at a height above said boiler to enable the power medium to flow back by its specific weight to said boiler, said evaporator being disposed at a higher level than said separator to thereby cause the refrigerating medium to overcome the static pressure of a column of liquid on its way between said condenser and said evaporator.

7. A refrigerating apparatus comprising an evaporator, a jet compressor, an absorber connected therewith, a counter-current heat exchanger having one chamber connected with said absorber and with the suction nozzle of said jet compressor, a separator connected with the pressure nozzle of said compressor, a boiler having a vapor space connected with the power medium inlet nozzle of said compressor, the liquid space of said boiler being connected with said separator, a generator connected with said separator and with the other chamber of said counter-current heat exchanger, a throttling device connected with said heat exchanger and said absorber, connecting conduits between said generator and said condenser and between the latter and said throttling device, and pipe conduits connecting said throttling device with said evaporator, said separator being disposed at a height to enable the power medium collecting therein to flow back by its specific weight to said boiler.

8. The process of refrigerating, which consists in raising by jet compression a refrigerating medium dissolved in a solvent from the lower pressure to the higher generating pressure, evaporating the power medium different from the refrigerating medium prior to its work in the jet compression, then condensing the same by mixing it with the solution then separating the power medium and solution by the agency of their different specific gravities, and permitting the power medium to flow back to be again evaporated while utilizing a portion only of the cooling air after having been preheated in the condensing and absorbing operation as combustion air in the evaporating operation.

9. The process of refrigerating, which consists in raising by jet compression a refrigerating medium dissolved in a solvent from the lower pressure to the higher generating pressure, evaporating the power medium different from the refrigerating medium prior to its work in the jet compression, then condensing the same by mixing it with the solution then separating the power medium and solution by the agency of their different specific gravities and permitting the power medium to flow back to be again evaporated while causing a circulation of the cooling air through a draft from the exhaust gases of the heating medium.

10. A refrigerating apparatus comprising an evaporator, a jet compression, an absorber connected therewith, a counter-current heat exchanger having one chamber connected with said absorber and with the suction nozzle of said jet compressor, a separator connected with the pressure nozzle of said compressor, a boiler having a vapor space connected with the power medium inlet nozzle of said compressor, the liquid space of said boiler being connected with said separator, a generator connected with said separator and with the other chamber of said counter-current heat exchanger, connecting conduits between said generator and said condenser and between the latter and said evaporator, said separator being disposed at a height to enable the power medium collecting therein to flow back by its specific weight to said boiler, said evaporator being disposed at a higher level than said condenser thereby to cause the refrigerating medium to overcome the static pressure of a column of liquid on its way between said condenser and said evaporator.
11. The process of refrigerating which consists in raising by jet compression a refrigerating medium dissolved in a solvent from the lower absorbing pressure to the higher generating pressure, evaporating a power medium different from the refrigerating medium prior to its work in the jet compression, condensing the same by mixing it with the solution separating the power medium and the solution by the agency of their different specific gravities and permitting the power medium to flow back by its specific weight to be again vaporized, the evaporation of the refrigerating medium occurring at a higher level than the condensation.

In testimony whereof I affix my signature.
ARTHUR SELIGMANN.