Feb. 7, 1939. C. H. DOYLE 2,146,058

REFRIGERATING METHOD

Filed Dec. 18, 1936 2 Sheets-Sheet 1

Fig. 1

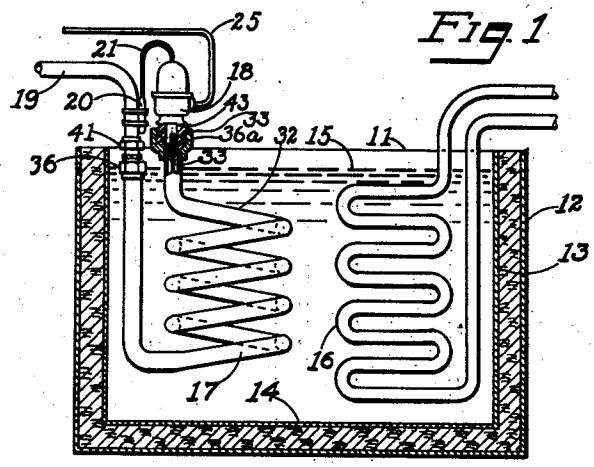


Fig. 2

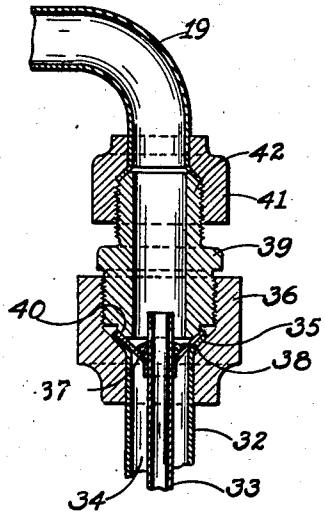


Fig. 6

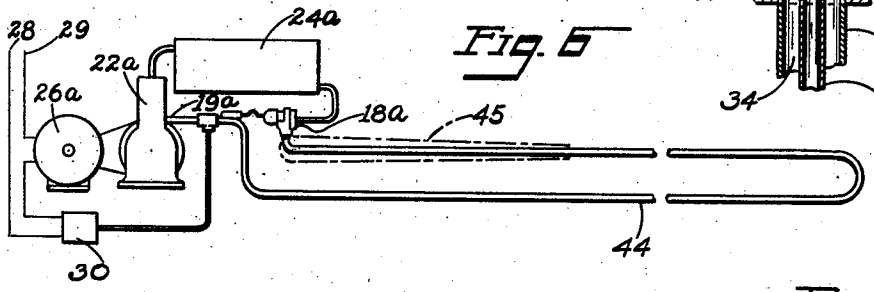


Fig. 3

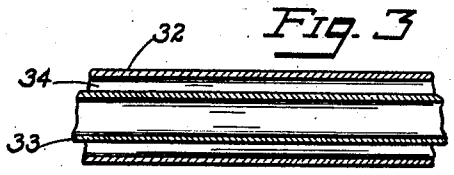


Fig. 7

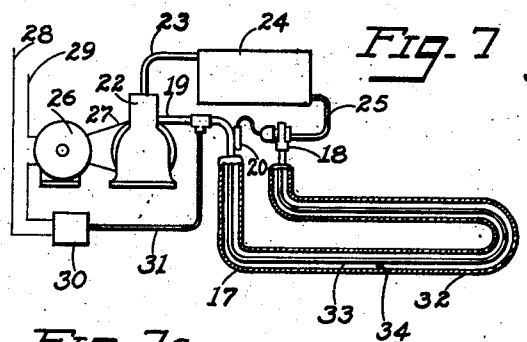


Fig. 4

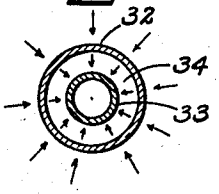


Fig. 5

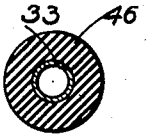
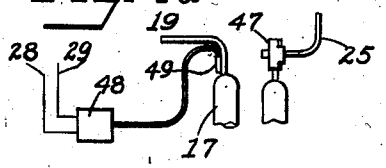


Fig. 7a



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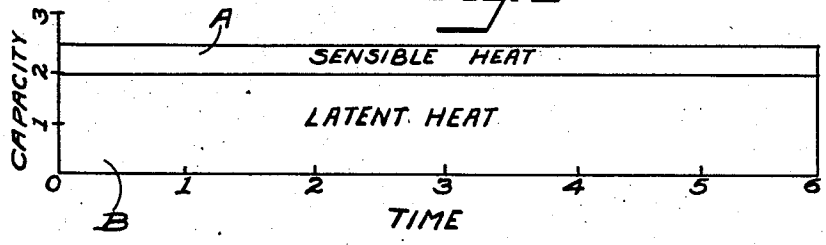
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Fig. 8



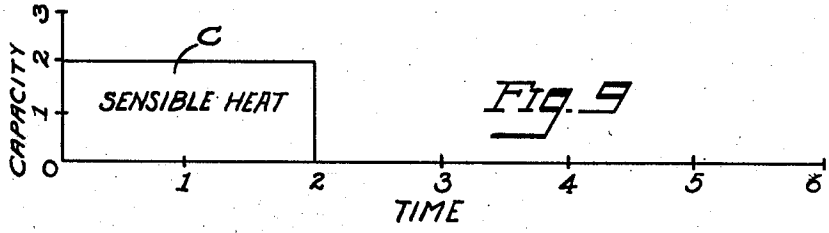


Fig. 9

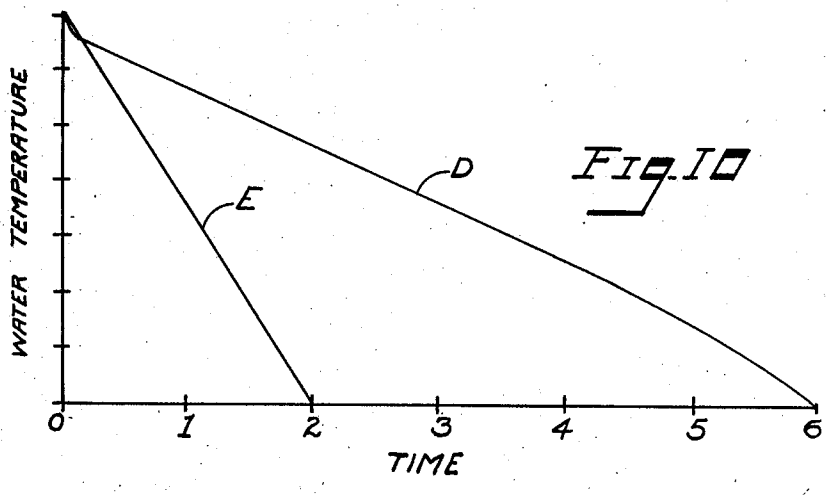


Fig. 10

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REFRIGERATING METHOD

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Application December 18, 1936, Serial No. 116,571

3 Claims. (Cl. 62—177)

This invention relates to improvements in refrigerating methods and apparatus.

An object of the invention is to provide an improved method of refrigerating fluid media.

A further object is to provide an improved method of rapidly withdrawing heat from a fluid to be refrigerated while maintaining the fluid above a predetermined temperature.

Another object is to provide a method of the above type wherein the sensible heat is transferred from the fluid to be refrigerated to an intermediate medium, uniformly concentrated through the intermediate medium, and uniformly removed from the intermediate medium through a small area at high concentration, whereby the apparatus may be small in proportion to the speed of removal of sensible heat.

Another object is to provide suitable apparatus for carrying out the above methods.

Still another object is to provide apparatus of the above type which is compact, simple and low in cost.

A still further object is to provide apparatus of the above type applicable to water coolers, beer coolers and the like.

Other objects and advantages of the invention will become evident during the course of the following description in connection with the accompanying drawings, in which:

Figure 1 is a view partly in section illustrating a form of the invention applied to a liquid cooler;

Figure 2 is a detail view of a suitable suction tube connection to the cooling coil;

Figure 3 is a fragmental longitudinal section of the cooling coil;

Figure 4 is a cross sectional view of the same;

Figure 5 is a cross sectional view of an alternative form of cooling device;

Figure 6 is a diagrammatic view of a standard refrigerating system;

Figure 7 is a similar diagrammatic view of a system including the present invention;

Figure 7*a* illustrates an alternative expansion valve and switch arrangement;

Figure 8 is a co-ordinate diagram illustrating the removal of heat from water in a cooler by standard refrigerating apparatus;

Figure 9 is a similar diagram illustrating heat removal by means of the present invention; and

Figure 10 is a graphical representation of comparative speeds of lowering fluid temperatures by means of a standard system and by means of the present invention.

Referring to Figure 1, the numeral 11 indicates a reservoir having an outer shell 12, an insulating sheath 13 and an inner shell 14. The device, as illustrated, represents a beer cooler, the inner shell 14 containing a water bath 15 in which may be suspended one or more beer coils 16. Also suspended or otherwise supported in the bath 15 is a cooling coil 17 of a construction hereinafter described, connected at one end to an expansion valve or equivalent device 18 and at the other end to a suction line 19. The valve 18 may be of the well known thermostatic type having a control bulb 20 preferably attached to the suction line 19 adjacent the latter's connection to the coil 17 and connected to the valve 18 by means of the usual capillary tube 21.

Referring to the diagrammatic Figure 7, the suction line 19 is connected to a compressor 22 having a discharge pipe 23 leading to a condenser 24. From the condenser 24 (which may include in combination the usual receiver) a liquid line 25 is adapted to deliver liquified refrigerant to the expansion valve 18. The compressor 22 is operable by a motor 26 through a belt 27, the motor being adapted to receive current from current supply lines 28 and 29 through a suitable pressure or thermostatic control device herein illustrated as a pressure switch 30 having the usual tubular connection 31 to the suction line 19.

The construction of the cooling coil 17 is as follows, referring to Figures 1, 2, 3 and 4:

The coil proper consists of an outer tube 32 surrounding and spaced from an inner tube 33, the space between the tube walls being filled in the present embodiment with a brine solution 34 or the like. The inner tube 33 is the expansion element, and a suitable means of connecting tube 33 to the suction line 17 and of sealing the brine 34 between the inner and outer tube walls is shown in Figure 2. The outer tube 32 has formed thereon a conical flare 35 and is provided with the usual flared union nut 36. The inner tube 33 carries a conical ferrule 37 adapted to overlie the flare 35, the ferrule 37 being soldered or otherwise sealed at 38 to the tube 33 a short space from the end of the latter.

In making the joint, a reducing union 39 is inserted in the nut 36 and screwed into the latter until the conical end 40 of the union engages the ferrule 37. When the nut and the union are screwed tightly together, the ferrule 37 and flare 35 are compressed together between the conical surfaces of the nut and union. It will thus be seen that by means of the structure shown tight seals are provided both for the refrigerant in the inner tube 33 and the brine 34 between the tubes

by use of a single standard nut and union. The suction line 19, which is preferably of smaller diameter than the outer coil tube 32, may be secured with the usual flared type of joint by means of a flared union nut 41 of proper size screwed to the upper end 42 of the reducing union 39.

The joint at the expansion valve end of the coil 17 may be made in the same manner as described except that instead of the union 39 a shank 43 is provided on the expansion valve itself, the shank being shaped in the same manner as the lower end of the union 39 and adapted to cooperate with the flared union nut 36a on the outer tube 32 as shown in Figure 1.

The operation of the device is as follows, assuming the bath 15 to be initially at or about room temperature:

Current being turned into the supply lines 28 and 29 by closing of a master switch or the like (not shown) the motor 26 drives the compressor 22, tending to exhaust the interior of the inside tube 33 through the suction line 17. Due to the small size and comparative shortness of the tube 33, the pressure therein is reduced very rapidly until the automatic expansion valve 18 is opened, admitting liquid refrigerant to the interior of tube 33. The diameter and length of tube 33 being small, as noted above, the refrigerant travels rapidly through it, lowering its temperature and refrigerating the surrounding brine sheath 34. Exit of liquid refrigerant from the coil proper is arrested in the usual manner by the action of the thermostatic bulb 20 and connected apparatus which respond to the lowering in temperature of the suction tube 17 to reduce the opening of the expansion valve 18 and cause a further lowering of temperature throughout the tube 33.

As the temperature of the tube 33 is lowered, the entire brine sheath 34 is refrigerated and in turn absorbs heat from the water bath 15 through the wall of the outer tube 32, thereby refrigerating the water and setting up convection currents within the bath to cause substantially uniform lowering of the latter's temperature. Due to the constriction and confinement of the brine sheath 34, heat from the water passes through the outer tube 32 and brine 34 to the inner tube 33 largely by conduction in a radial manner as illustrated by the arrows in Figure 4, and without appreciable convection within the brine, the latter thus comprising a static sheath.

Thus the heat entering through the comparatively large area of the outer tube 32 is concentrated radially in its passage through the brine sheath 34 and passes to the refrigerant through the small area of the inner tube. Due to the small area of tube 33, a comparatively large temperature difference exists between the brine and refrigerant in order to effect passage of the heat. On the other hand, the larger area of the outer tube 32 causes the heat to pass from the water 15 to the brine with a comparatively small temperature difference. As the heat is concentrated radially in the brine, as noted above, a temperature gradient is maintained radially throughout the brine between the large inner area of outer tube 32 and the small outer area of inner tube 33. The result of the action described is that the temperature within the tube 33 may be kept well below the freezing point of water while the temperature of the outer tube 32 remains slightly above the freezing point and therefore remains free from ice formations. Thus, while the outer tube rapidly absorbs heat from the water, the heat absorbed is all sensible heat tending to lower the water's temperature, no latent heat being absorbed as occurs with ordinary cooling coils upon which ice formation takes place. All extraction of heat by the refrigerating system being utilized solely to lower the temperature of the water, the bath temperature falls steadily and rapidly, the temperature and corresponding pressure in the inner cooling coil 33 also being lowered by action of the thermostatic valve 18 until by action of the pressure switch 30 the circuit of the motor 26 is broken to stop the motor and compressor 22. Heat continues to be absorbed from the water 15 into the brine 34, thus gradually reducing the temperature gradient in the latter and allowing the temperature and pressure of the inner coil 33 to rise until the pressure switch 30 recloses to restore the motor and compressor to operation, and quickly refrigerate the entire tube 33 at low temperature. The temperature of the water continues to fall steadily until it reaches the required temperature for properly refrigerating the beer coils 16.

The areas of the outer and inner tubes 32 and 33 and the size of the brine sheath 34 are so proportioned that while the running temperature in tube 33 is maintained at a low value, such as —4 degrees Fahrenheit, the outer surface of the tube 32 does not fall entirely to the freezing point, being normally maintained at slightly above freezing. It is evident, therefore, that no ice can form on the cooling coil 17, so that its entire surface is effective at all times for the removal of sensible heat from the water.

To fully bring out the advantages of the present invention, it is pertinent to set forth the normal operation of a typical system not employing the present method and apparatus, such a system being illustrated diagrammatically in Figure 6, in which a direct expansion coil 44 is operatively connected between an expansion valve 18a and a suitable compressor 22a operable by a motor 26a in the usual manner. To attempt to refrigerate water in a cooler of the type illustrated by means of a direct expansion coil having an outside area equivalent to or greater than that of applicant's tube 32 while maintaining the coil above the freezing point of water would require large compressor capacity to operate successfully with the high back pressure which would be necessary. The large compressor capacity entails large initial cost. Furthermore, if the direct expansion coil, which has practically no heat storage capacity such as is supplied in the present invention by the brine sheath 34, is to be maintained at nearly constant temperature slightly above the freezing point of water, the necessarily close setting of the pressure switch 30 and expansion valve 18a and the large capacity of the compressor would cause "short cycling", that is objectionably frequent starts and stops of the compressor.

To overcome the foregoing objections it is customary to supply a comparatively long coil 44 and set the expansion valve 18a to give a normal coil temperature considerably below freezing. Due to the long coil of comparatively large tubing, the initial or starting back pressure must be kept fairly low if very large compressor capacity is to be avoided. As a result, when the system is started, the end portion of the coil 44 next the expansion valve 18a is quickly brought to low temperature and ice forms thereon as illustrated at 45, Figure 6, while little or no evaporation occurs in the remainder of the coil which instead operates as a super-heater for the gas passing through

it. The ice formation on the forward portion of the tube throws an insulating blanket around that portion and the area of evaporation moves ahead through the coil, building an ice blanket as it advances, until the entire coil is coated with an increasingly thick mass of ice which prevents any direct absorption of heat from the water. Removal of heat from the water must thereafter occur through the ice sheet, and as it is a practical impossibility to provide exactly sufficient compressor capacity and regulation to maintain a constant thickness of ice under the varying loads imposed by operation of the cooling device in service, the usual result is that the thickness of ice continues to grow, thus further increasing the insulating effect about the coil and decreasing the amount of water available for circulation around the beer or other liquid coils, as well as interfering with circulation about both liquid coils and cooling coil by bridging the space between adjacent turns of the latter and gradual building up of an obstructing ice dam. This frequently leads to the fracturing of the coils.

It is obvious that uniform cooling of the liquid coils in a bath cannot be maintained by a system operating as described above, and the interference with proper convection currents is cumulative, as the greater the obstructing ice mass becomes and the less water remaining liquid, the greater the tendency to further ice formation. Unless the system is periodicaly shut down to allow the ice to melt it becomes practically inoperative as a proper liquid cooler, and it is a common occurrence with drinking water coolers in soda fountains and the like for the ice to bridge entirely to the liquid coils and cause the water therein to freeze.

It is thus evident that uniform and continuously proper operation of liquid coolers and the like of the type described can not be accomplished by the use of coils upon which ice formation takes place, and it has not been found practical with direct expansion coils as described to maintain water temperatures below approximately 39 degrees Fahrenheit without the formation of ice.

With the present invention, due to the fact that the gradient between water temperature and the low refrigerant temperature occurs in the brine sheath **34** rather than in a film of water surrounding the refrigerant pipe, it is possible to maintain the water bath **15** as low as 33 degrees Fahrenheit without any appreciable ice formation.

The difference in operation of a cooler system by the method and apparatus of the present invention and by the usual system is set forth graphicaly in Figures 9 and 8 in which the ordinates represent refrigerating capacity of the system and abscissas represent time of operation.

In Figure 8, referring to the usual system, the total rectangular area, that is A+B, represents the total heat removed in bringing the water bath temperature down from any given value such as room temperature to normal operating temperature. Due to the progressive formation of ice **45**, Figure 6, on the coil **44** a large proportion of the heat removed, that is area B, is latent heat of freezing, so that only area A, a fraction of the total removed, is sensible heat extracted in cooling the water.

The latent heat B is impounded and can only be recovered by shutting down the system to melt the ice, at which time refrigeration of the water bath is not sufficiently rapid or steady for proper cooling of the liquid coils.

In Figure 9, referring to the present invention, there is no removal of latent heat, and the entire area C, which is equivalent to area A, is sensible heat removed from the water. Thus it will be seen that while the capacity ordinate of Figure 9 may be substantially smaller than that of Figure 8, the time abscissa of area C is also much smaller than that of Figure 8 due to the absence of latent heat in Figure 9. The effect of the foregoing is shown comparatively in graphical Figure 10, in which ordinates represent water temperatures and abscissas time units. With operation of the usual system as shown in Figure 8, the water temperature follows curve D, requiring 6 time units to reach the base temperature. With the present invention wherein all heat removed is sensible heat, the temperature follows curve E, reaching the base temperature in two time units. In other words, the present invention is adapted to lower the water temperature much more rapidly than prior systems having greater refrigerating capacity.

An evident practical and commercial advantage of the present invention as made clear by the foregoing description is the fact that it permits the use of a smaller compressor and shorter coil than the prior systems, resulting in lower cost of apparatus and maintenance, saving in space both outside and in the cooling bath, while operation is improved due to the fact that the smaller amount of apparatus is operated at all times to the best advantage, without shut-downs, losses and irregularity in action resulting from the formation of ice.

The improvements and advantages set forth, as well as others which will become evident to those skilled in the art, are accomplished by the method of absorbing heat from the medium to be cooled through a pre-determined area at comparatively high temperature, uniformly concentrating the heat in a second medium, and transferring it to a third medium, that is the refrigerating fluid, at comparatively low temperature. In the preferred form, as previously stated, the sheath **34** consists of a brine solution lying practically dead between the inner and outer tube walls, brine being advantageous because of its high specific heat together with sufficiently low conductivity to prevent too rapid heat transfer and consequent lack of sufficiently wide temperature gradient such as occurs with finned tubing or thick metal piping. In certain cases, wherein it may be desired to slightly increase the storage or hold-over capacity of the sheath **34** the latter may consist of an eutectic fluid which allows an additional storage due to extraction of a small amount of latent heat adjacent the inner tube **33**. In certain other cases the concentration of heat may be accomplished through a sheath of semi-insulating material such as rubber, as shown at **46**, Figure 5, the outer area and thickness of the sheath **46** being so proportioned as to maintain the desired gradient in combination with proper setting of the expansion valve and cut-off control.

Figure 7*a* illustrates the fact that the device instead of operating with a thermostatic valve and pressure switch, may be equipped with a constant-pressure automatic expansion valve **47** and a thermostatic switch **48**, the latter's bulb **49** being attached to the suction line **19** adjacent the outlet coil **17** as previously described. The operation with this arrangement is substantially

the same as described, the thermostatic switch stopping the motor when the suction tube temperature falls to a pre-determined point. In all forms of the device the use of the small expansion tube within its concentrating sheath allows almost instantaneous utilization of the entire expansion surface with high internal velocity and comparatively small compressor capacity, and without formation of liquid slugs or "cold spots".

The method and apparatus have been illustrated as applied to a liquid cooler having a water bath, but it is obvious that it may be applied to many other purposes for cooling other media, whether gaseous, liquid or of other character, the cooling coil 17 being made in any desired shape. In other words, while the invention has been described in preferred form as illustrating the method, it is not limited to the precise structure shown, as various modifications may be made without departing from the scope of the appended claims.

What is claimed is:

1. The method of extracting sensible heat from water which comprises the step of refrigerating an element at a temperature below the freezing point of water, radially transferring heat to said element from a static heat transferring substance in heat exchange relation with said water and element, and maintaining a uniform temperature gradient in said substance therebetween whereby heat exchange between said water and substance occurs above the freezing point of water.

2. The method of extracting sensible heat from a fluid which comprises the step of absorbing heat from said fluid into a static medium by conduction at a temperature above the freezing point of said fluid, the second step of uniformly concentrating said heat through said medium, and the third step of transferring said concentrated heat from said medium to a refrigerating element at a temperature below the freezing point of said fluid.

3. A method of extracting sensible heat from a fluid which comprises the step of intaking the sensible heat from said fluid to an intermediate static medium of predetermined length and cross section, uniformly concentrating the heat in said intermediate medium throughout the length and cross section thereof, uniformly removing said heat from said intermediate medium throughout a small area at approximately the center of the cross section thereof, said removal or outtake of heat being effected at a relatively high concentration per unit of area as compared with a like intake area of the intermediate medium.

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