Jan. 19, 1937. J. G. BERGDOLL 2,068,478

METHOD OF AND APPARATUS FOR CONDENSING REFRIGERANT IN REFRIGERATIVE CIRCUITS

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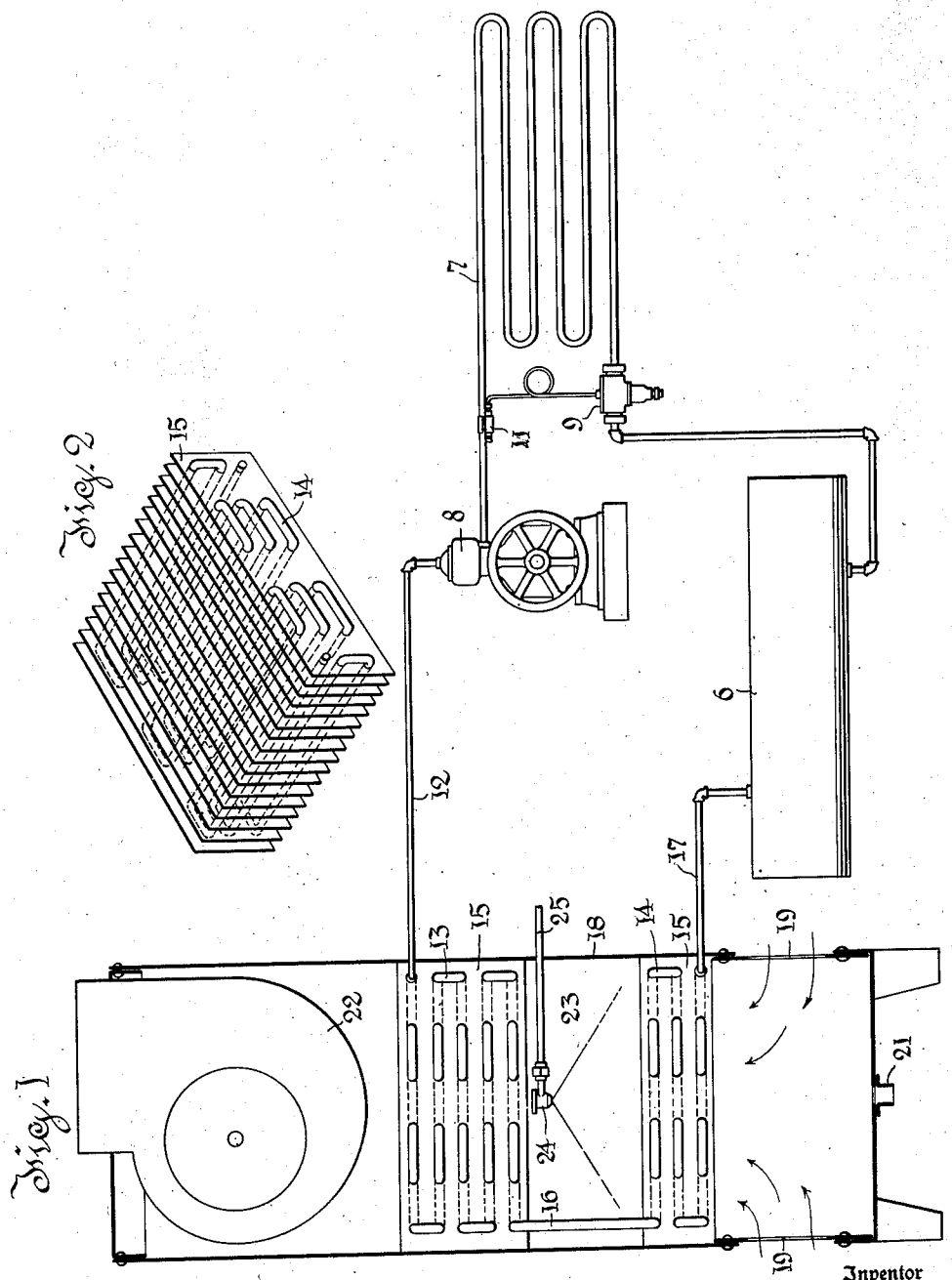


Fig. 1

Inventor
John G. Bergdoll

By Dodge and Dodge

Attorneys

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Fig. 3

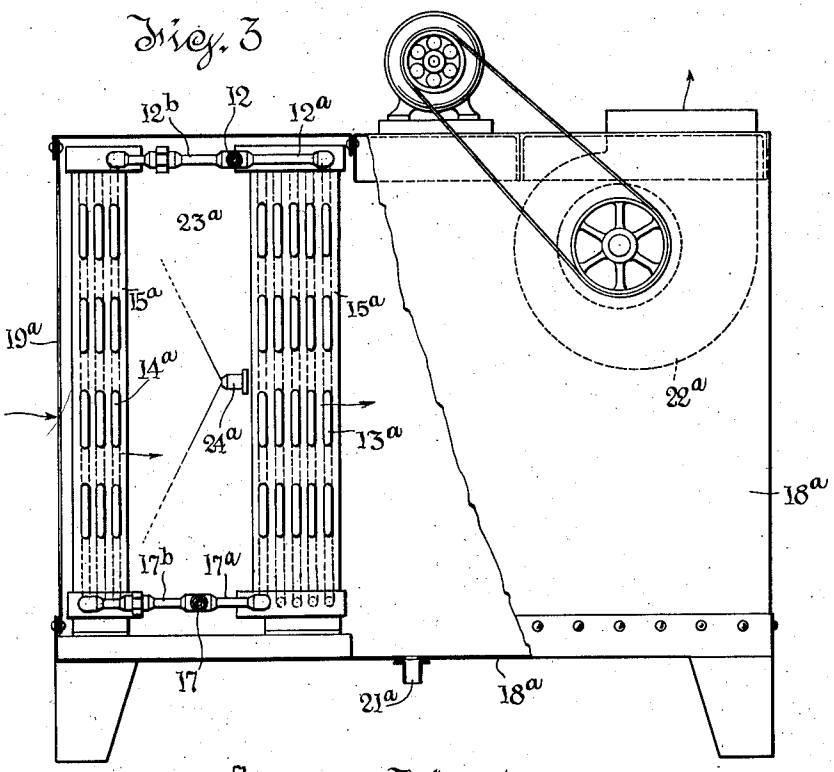
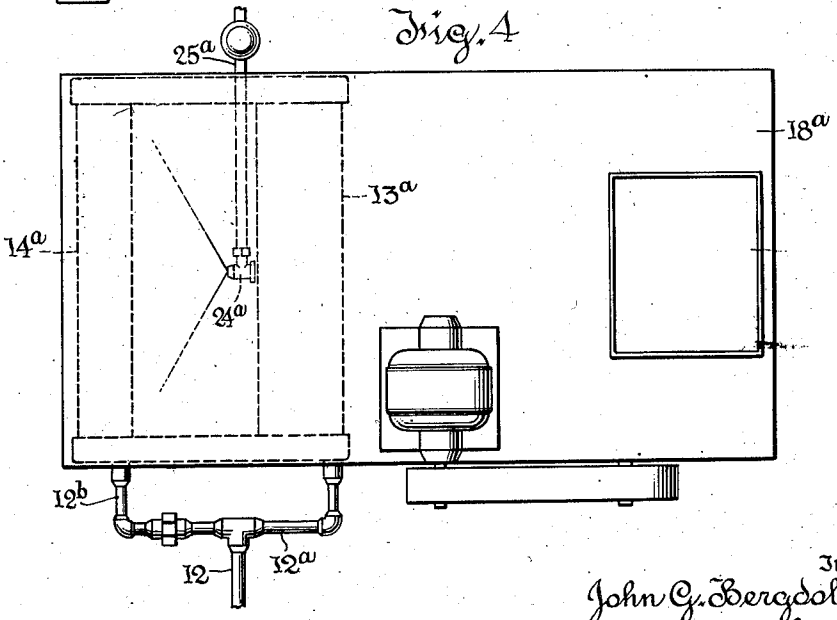


Fig. 4



Inventor

John G. Bergdoll

By Dodge Allen & Sons

Attorneys

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METHOD OF AND APPARATUS FOR CONDENSING REFRIGERANT IN REFRIGERATIVE CIRCUITS

John G. Bergdoll, York, Pa., assignor to York Ice Machinery Corporation, York, Pa., a corporation of Delaware

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5 Claims. (Cl. 257—37)

This invention relates to refrigeration and particularly to the condensing phase of the refrigerating cycle.

In the larger cities the use of city water for condenser cooling is meeting with serious objection because of the heavy drain on the water supply. Recourse to cooling towers is commonly impracticable because of space requirements and because a circulating pump is required, while air cooling not only requires a large circulating fan but results in high head pressures and consequent loss of efficiency. Often it is difficult to find in stores, railway cars, and the like, space suitable for a cooling tower or large circulating fan.

To compare the three condensing systems, consider that a "ton" of refrigeration involves rejecting 250 B. t. u. per minute from the condenser. In terms of city water this means two gallons per minute with 15° temperature rise, the water being wasted. A cooling tower must circulate about five gallons of water per minute, the temperature rise being 6°, the water being recirculated and evaporation made up. In conventional air cooling it is necessary to circulate 730 cubic feet of air per minute, the temperature rise being 20°, and the head pressure being undesirably high.

The present invention involving air cooling using humidified air, will do the work with 400 cubic feet of air per minute and ½ pound of water per minute, the water being sprayed by an atomizing nozzle into the cooling air, and being completely evaporated in the air before the air contacts the coil. The water is preferably sprayed into the air after the air has exchanged heat with a part of the condenser. The water is furnished by the city mains, and is wasted, passing off as vapor. The head pressure is substantially lower than that secured with ordinary air cooling.

It is important to recognize the distinction from evaporative condensers in which water is sprayed or flowed directly over the condenser coils. Such condensers are objectionable because of the accumulation of scale and rust, and for use on railway cars are further objectionable because of the accumulation of cinders and dirt, and the danger of freezing up where a car so equipped is carried on long runs through widely varying temperatures.

Preferred embodiments of the invention will now be described by reference to the accompanying drawings, in which:—

Fig. 1 shows chiefly in vertical section, a vertical condensing device according to the invention and comprising two condensing coils connected in series. In this view a related refrigerating circuit is shown in diagrammatic elevation.

Fig. 2 is a perspective of the lower condensing coil.

Fig. 3 is an elevation, partly in section, of a condenser similar to that shown in Fig. 1 except that the unit is horizontal instead of vertical and the two coils are connected in parallel instead of in series.

Fig. 4 is a plan of the condenser shown in Fig. 3.

Referring first to Fig. 1, the receiver is indicated at 6, the evaporator at 7, and the compressor at 8. 9 indicates an expansion valve which is illustrated as of the thermally controlled type, the valve being actuated by pressures developed in a thermostatic bulb 11 which responds to the temperature of the refrigerant leaving the evaporator 7. The parts so far described are intended to be typical of any refrigerating circuit with which the condenser now to be described might be used.

The discharge line from the compressor 8 is indicated at 12 and leads to the upper one of two condensing coils or units 13 and 14. The construction of these two coils is illustrated in Fig. 2, which is a perspective view of the coil 14. As clearly shown in that figure, each condensing unit comprises a sinuous coil whose effective heat transfer surface is increased by the use of a plurality of fins or radiating plates 15. The coils 13 and 14 are essentially identical except that the coil 13 is slightly longer and has correspondingly larger heat transfer surface. The larger coil is the second coil in the path of air flow. The coil 13 is connected in series with the coil 14 by means of the connecting line 16, and the coil 14 discharges liquefied refrigerant into the receiver by means of the liquid line 17.

The units 13 and 14 are spaced apart and are mounted one above the other in a vertical casing 18 having air inlet ports 19 near its lower end. There is a drain connection 21 to carry off any water which might accumulate, but it must be expressly understood that in the normal operation of the device no water will accumulate. Air is drawn upward through the casing 18 and discharged from the upper end of the casing to any suitable point, by means of a motor-driven fan diagrammatically illustrated at 22.

Mounted in the space or chamber 23 between the two condenser units 13 and 14 is a spray

nozzle 24 supplied with water under pressure through a pipe 25 which is connected to any suitable source, preferably the city mains. The nozzle 24 directs an atomized spray downward, i. e., in opposition to the upward flow of air through the casing 18, and at a rate such that all or substantially all of the sprayed water is evaporated while in suspension in the air stream. In other words, it is not the function of the spray head 24 to shower water on the lower condenser unit 14, nor is it contemplated that any substantial quantity of water in the liquid state will be carried into contact with the condenser unit 13 by the upward flowing air current.

In practice account is taken of the fact that the amount of moisture carried by air entering at 19 will vary, and the rate of supply of moisture through the nozzle 24 is so limited that under extreme conditions the moisture supplied will be not more than sufficient, and preferably somewhat less than sufficient, to saturate the air stream.

Assuming that the compressor 8 and the fan 22 are both in operation, the system functions as follows:

The liquid refrigerant from the receiver 6 is supplied to the evaporator coil 7 under control of the automatic expansion valve 9 and refrigerant vaporized in the coil 7 is drawn off by the compressor 8, compressed, and delivered to the upper end of the condenser unit 13, through which it passes downward, then downward through the connection 16 to the unit 14, through which it passes downward to the liquid line 17 and receiver 6. From this it follows that the passage of refrigerant through the condenser has a counter-flow relation to the air flowing upward through the casing 18.

The operative characteristics of the condenser can be more clearly understood if a concrete example taken from actual practice is given. Assume that the air entering the casing 18 through the inlets 19 has a dry bulb temperature of 80° F. and a wet bulb temperature of 65° F. Under these conditions the air after passing in contact with the first condenser unit 14 will enter the spray chamber 23 with a dry bulb temperature of approximately 100° F. This dry bulb temperature will be reduced to approximately 75° F. by the action of the spray in the chamber 23. After passage in contact with the second condenser unit 13 the dry bulb temperature of the air will be approximately 95° F. It is not strictly necessary but it is believed to be desirable, that the unit 13 have a slightly greater heat exchange surface, as shown.

In the structure just described the refrigerant and the cooling air have a counter-flow relation and the refrigerant is cooled in two successive stages, in the first of which heat is exchanged with the humidified air and in the second of which heat is exchanged with atmospheric air. This characteristic, however, is not strictly necessary. In Figs. 3 and 4 an arrangement is shown in which the two condenser units are connected in parallel instead of series. In these views the opportunity has been taken to illustrate a horizontal as contradistinguished from a vertical unit.

In these figures the two condensing units 13ª and 14ª are similar in construction to the units 13 and 14 already described, but there is no series interconnection such as the connection 16 of Fig. 1. Instead, the high pressure line 12 has two branches 12ª and 12ᵇ leading respectively to the units 13ª and 14ª. Similarly, there are branches 17ª and 17ᵇ leading from the units 13ª and 14ª respectively to the liquid line 17. The casing 18ª is designed for horizontal flow, has a single air inlet port 19ª and a drain connection 21ª. The motor-driven fan is indicated at 22ª. The chamber 23ª between the two units 13ª and 14ª is similar in form and function to the chamber 23 and contains a spray nozzle 24ª which in this case directs its spray horizontally in opposition to the air stream.

The operation of the structure shown in Figs. 3 and 4 is generally similar to that shown in Fig. 1 but there is no counter-flow relation between the refrigerant flow and the air flow, and the refrigerant is not cooled in two stages though there are two phases of condensation. Part of the refrigerant is cooled in the unit 14ª by heat exchange with untreated atmospheric air. Another part of the refrigerant is cooled in the unit 13ª by heat exchange with humidified air. This action is entirely practicable in view of the fact that humidification approximately restores the original dry bulb temperature of the air. While the arrangement shown in Fig. 1 is believed to be preferable, the arrangement shown in Figs. 3 and 4 is within the scope of the invention.

There are obvious advantages in raising the temperature of the air by heat exchange with one unit before introducing the humidifying water.

Because of the temperature limits customarily encountered in condensing refrigerants, and because of requirements characteristic of condenser installations in small stores and on railroad cars, the invention offers decided practical advantages. It permits the use of slightly more than half the air necessary in conventional air-cooled systems, and approximately 1/32 of the water necessary in conventional water-cooled systems using city water, and results in head pressures which are decidedly lower than can be secured with conventional air cooling. Consequently, the operative characteristics are well within practical limits, so that the invention solves what has hitherto been a difficult problem in the particular classes of service above specified.

I claim:

1. The method of liquefying compressed refrigerant in a refrigerating circuit, which comprises heat exchange with air in two phases, in one of which the exchange is with untreated atmospheric air, and in the other of which the exchange is with the same air after heating by the first exchange and treatment with a substantially uniform quantity of atomized water sufficient to ensure approach to saturation of the air.

2. The method of liquefying compressed refrigerant in a refrigerating circuit, which comprises heat exchange by the same refrigerant with air in two successive stages, in the second of which stages the exchange is with untreated atmospheric air and in the first of which stages the exchange is with the same air after heating by the second stage exchange and treatment with a substantially uniform quantity of atomized water sufficient to ensure approach to saturation of the air.

3. A condenser adapted for insertion in a refrigerating circuit, said condenser comprising two heat exchanging units of the surface type spaced apart; means for connecting both said

units in series with each other in said refrigerating circuit; means for forcing air in heat exchanging contact with said units successively; and means for supplying water in a finely divided state to said air as it passes through the space between the units and at a rate which will insure substantially complete evaporation of the water before passage through the second unit.

4. A condenser adapted for insertion in a refrigerating circuit, said condenser comprising two heat exchanging units of the surface type spaced apart; means for connecting both said units in series with each other in said refrigerating circuit; means for forcing air in heat exchanging contact with said units successively and in counterflow relation to the flow of refrigerant; and means for supplying water in a finely divided state to said air as it passes through the space between the units and at a rate which will insure substantially complete evaporation of the water before passage through the second unit.

5. A condenser adapted for insertion in a refrigerating circuit and comprising, in combination, two heat exchanging units of the surface type spaced apart; means for connecting both said units in such refrigerating circuit; means for passing air in heat exchanging contact with said units successively; means for supplying water in a finely divided state to said air as it passes through the space between the units at a rate so limited that substantially complete evaporation of the water in the air and approach to saturation of the air will be ensured before the air passes through the second unit; and flow directing means so arranged that substantially all the air passes serially in heat exchanging contact with the two units.

JOHN G. BERGDOLL.