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COOLING APPARATUS

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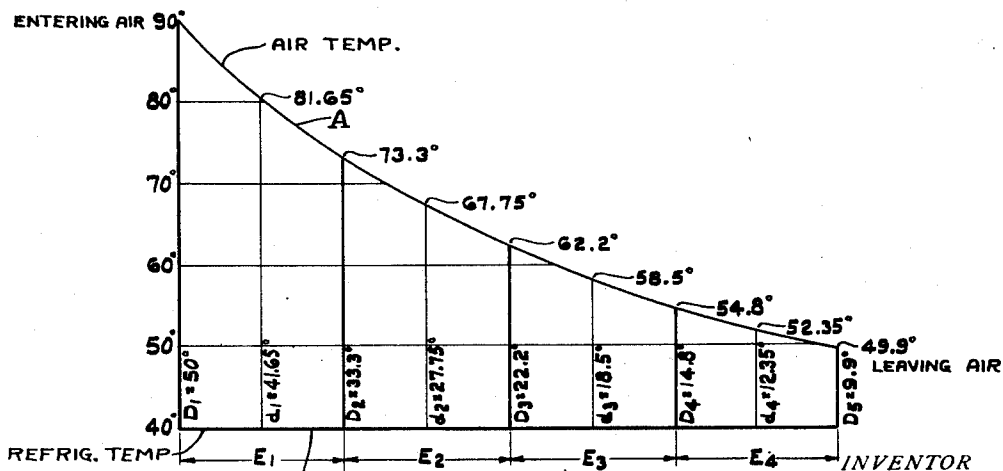
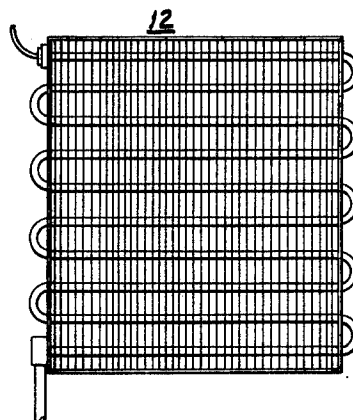
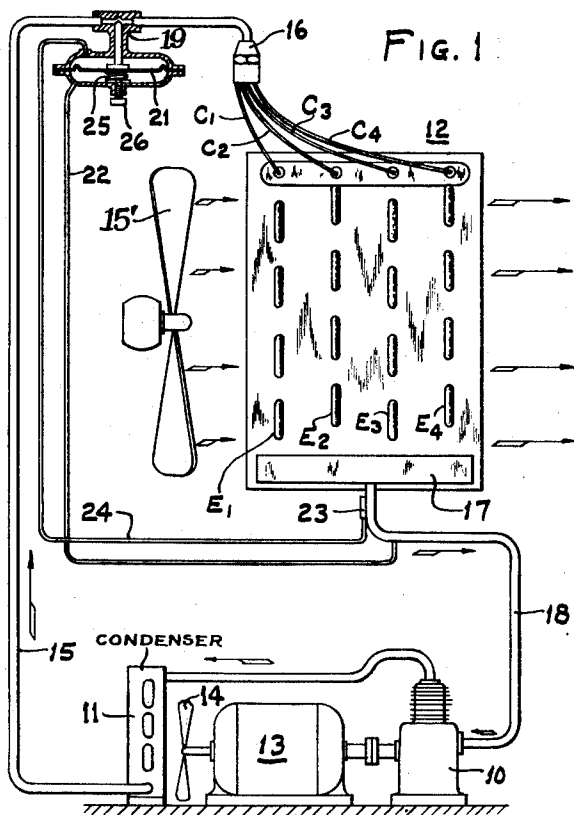


FIG. 3.

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COOLING APPARATUS

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17 Claims. (Cl. 62—129)

My invention relates to refrigerating apparatus, more particularly to an evaporator comprising a plurality of evaporator elements or coils of the dry expansion type for cooling air or other fluid, said elements being arranged in series with respect to flow of air to be cooled and in parallel with respect to flow of refrigerant, and it has for an object to increase the cooling action obtained from a given size evaporator of this type.

More particularly, it is an object of my invention to utilize the full heat-exchanging capacity, or at least a greater portion thereof, of each element of an evaporator of the character set forth.

As heretofore constructed, in evaporators of this type, equal quantities of refrigerant are supplied to the several elements. Inasmuch as all the refrigerant admitted to each element must be evaporated, each element received only the quantity which could be evaporated by the element which is last in series in the order of flow of the air or other fluid to be cooled; whereas the other elements are capable of evaporating greater quantities, due to the fact that there is a greater difference between temperature of the air to be cooled and the temperature of the refrigerant.

In accordance with my invention, I distribute the refrigerant to the several elements in successively decreasing proportions in the order in which the fluid to be cooled comes into heat-exchanging relation therewith. More particularly the refrigerant is distributed in proportion to the differences in temperature between the air at the respective elements and the refrigerant. Where the several elements have equal cooling surfaces, as assumed in this case, the proportions of refrigerant decrease in geometrical progression.

Where the air reaches the dew point while passing through the evaporator, the evaporator elements in contact with the air after reaching the dew point receive increased quantities of refrigerant in accordance with their inherently increased capacities. The distribution of refrigerant to the latter group of evaporator elements is however, in the same relation as pointed out above.

The above and other objects are effected by my invention as will be apparent from the following description and claims taken in accordance with the attached drawing forming a part of this application in which:

Fig. 1 is a diagrammatic view of refrigerating apparatus embodying my invention;

Fig. 2 is a side elevation of the evaporator; and,

Fig. 3 is a curve showing the successive temperatures of the air passing through the evaporator.

Referring now to the drawing more in detail, I show, in Fig. 1, a refrigerating system comprising a compressor 10, a condenser 11, and an evaporator 12. The compressor 10 is driven by a motor 13 and air for cooling the condenser 11 is circulated therethrough by a fan 14, which may also be driven by the motor 13.

The evaporator 12 comprises a plurality of evaporator elements, in this case, four cross-finned coils E₁ to E₄. The evaporator coils are preferably, and as shown, identical and have equal cooling surfaces. Air or other fluid to be cooled, is circulated through the evaporator by a fan 15, the air passing into heat exchanging relation successively with the evaporator coils E₁ to E₄.

Condensed refrigerant is supplied from the condenser 11 through a conduit 15. It is distributed to the evaporator coils E₁ to E₄ in parallel by means of capillary tubes C₁ to C₄, respectively, the latter being connected through a distributor 16 with the conduit 15. The coils discharge vaporized refrigerant into a header 17, which is connected to the compressor 10 by a suction conduit 18.

I have found that the degree to which an evaporator element is able to cool the air passing in heat exchanging relation therewith is substantially proportional to the difference in temperature of such air and the refrigerant flowing through the evaporator element. The evaporator coil E₁, therefore, is able to effect a greater amount of cooling and to evaporate a greater quantity of refrigerant than the other evaporator elements, the evaporating and cooling capacity of the others being successively smaller. I, therefore, make the capillary tubes of unequal lengths, so as to supply successively smaller quantities of liquid refrigerant to the several coils.

In explaining the distribution of liquid refrigerant to the several tubes, an example will first be given in which it is assumed that the dew point of the air is below the temperature to which the air is cooled. It is assumed also that the air enters the evaporator at 90° F., that the temperature of the refrigerant is 40° F., that each evaporator coil has the capacity to effect a reduction in temperature equal to one-third of the temperature difference between the entering air and the refrigerant and that there are four coils. The first coil E₁, then, will reduce the temperature of the air one-third of the 50° temperature difference, to 73.3° F.

In the second coil E₂, the temperature reduction is one-third of the 33.3° difference between the temperatures of the incoming air and the refrigerant, bringing the leaving air temperature to 62.2° F. Similarly, the succeeding evaporators E₃ and E₄ reduce the air temperature to 54.8° and 49.9° F., respectively.

The above values are plotted in Fig. 3, in which the curve A represents the decreasing temperature of the air and the straight line B represents the constant temperature of the liquid refrigerant. The differences between the temperature of the air entering the several coils E₁ to E₄ and the temperature of the refrigerant are designated D₁ to D₄, respectively; while the temperature differences of the leaving air and refrigerant are represented by D₂ to D₅, respectively, D₂, for example, being the temperature of the air leaving the coil E₁ and entering the coil E₂. The designations d₁ to d₄ represent the difference between the refrigerant temperature and the average air temperature, which, for practical purposes, may be taken as the arithmetical mean between the entering and leaving air temperatures.

The capillary tubes in this case are designed, as by suitably varying their relative lengths, to apportion liquid refrigerant to the evaporator elements or coils E₁ to E₄ in the ratio of the values d₁ to d₄, which values decrease in geometrical progression.

A thermal valve 19 is preferably provided in the conduit 15 for controlling the total quantity of refrigerant supplied to the evaporator, so as to maintain a substantially constant degree of superheat of the refrigerant vapor discharged from the evaporator. The supply of refrigerant is thereby limited to the quantity that can be completely evaporated.

The valve is controlled by a diaphragm 21. The pressure in the evaporator is conveyed through a tube 22 and imposed on the diaphragm 21 in closing direction. A thermostatic bulb 23, responsive to the temperature of the discharged refrigerant, provides a pressure which is a function of said temperature, said pressure being communicated through a tube 24 and imposed on the other side of the diaphragm. The difference in the pressures on the diaphragm is a measure of the superheat of the discharged refrigerant, as is well known in the art. A spring 25 biases the diaphragm against the pressure difference and is provided with a screw threaded adjustment 26 to provide for adjustment of the degree of superheat maintained by the valve 19.

By controlling the total amount of liquid refrigerant supplied to the evaporator in accordance with the amount that can be evaporated by the evaporator as a whole, and apportioning the quantities to the several coils in accordance with the respective temperature differences, each coil receives substantially the quantity of liquid refrigerant which it has the capacity to evaporate.

The above example is based on the assumption that the air to be cooled has a dew point not higher than the temperature to which the air is cooled. In actual practice, however, the air usually has a higher dew point, and the coils which the air contacts after it has reached the dew point should receive increased quantities of refrigerant, since the capacity of a coil is inherently higher when moisture in the air is being condensed. In designing an evaporator for practical conditions, therefore, the quantities of refrigerant to the coils contacting the air before it reaches the dew point are in accordance with their capacities to cool

dry air, as in the example of Fig. 3. The quantities of refrigerant supplied to the remaining coils are increased in accordance with the increased capacities providing the additional refrigerant required for effective condensation of the moisture. Said last-mentioned quantities decrease in substantially geometrical progression similarly to the variation in quantities supplied to the first coils.

While I have shown my invention in but one form, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various changes and modifications without departing from the spirit thereof, and I desire, therefore, that only such limitations shall be placed thereupon as are imposed by the prior art or as are specifically set forth in the appended claims.

I claim:

1. In apparatus for cooling a fluid, a plurality of cooling elements arranged in series with respect to the flow of the fluid to be cooled and in parallel with respect to flow of the cooling fluid, means for supplying cooling fluid to the cooling elements in successively decreasing quantities in the order in which the fluid to be cooled is brought into heat-exchanging relation therewith, and a common exhaust conduit connected to said cooling elements for discharging cooling fluid therefrom.

2. In apparatus for cooling a fluid, the combination of a plurality of cooling elements with which the fluid to be cooled comes into heat-exchanging relation successively, means for supplying liquid refrigerant to said cooling elements in parallel, means for apportioning the supply of refrigerant to the cooling elements in successively decreasing quantities in the order in which the fluid to be cooled comes into heat-exchanging relation therewith, and a common exhaust conduit connected to said cooling elements for withdrawing the liquid refrigerant therefrom.

3. In apparatus for cooling a fluid, a plurality of evaporator elements of the dry expansion type, means for circulating fluid to be cooled in heat-exchanging relation with the evaporator elements in series, means for supplying liquid refrigerant to said evaporator elements in parallel in quantities decreasing successively in the order in which the fluid to be cooled is brought into heat-exchanging relation with the evaporator elements, and means for withdrawing vaporized refrigerant from said evaporator elements at substantially the same pressure.

4. In apparatus for cooling a fluid, the combination of a plurality of evaporator elements of the dry expansion type with which the fluid to be cooled comes into heat-exchanging relation successively, means for supplying liquid refrigerant to the evaporator elements in parallel, means for apportioning the liquid refrigerant to the evaporator elements substantially in accordance with their respective capacities to evaporate the liquid refrigerant, and means for effecting vaporization of liquid refrigerant in, and withdrawing vaporized refrigerant from, said evaporator elements at substantially the same pressure.

5. In apparatus for cooling fluid, the combination of a plurality of evaporator elements of the dry expansion type, means for circulating fluid to be cooled successively in heat-exchanging relation with the evaporator elements, means for supplying and distributing liquid refrigerant in parallel to the evaporator elements substantially in proportion to the capacities of the several elements to evaporate refrigerant in cooling

said fluid, and means for withdrawing vaporized refrigerant from said evaporator elements at substantially the same pressure.

6. In apparatus for cooling a fluid, the combination of a plurality of evaporator elements of the dry expansion type, means for conveying fluid to be cooled in heat-exchanging relation with said elements in series, means for distributing refrigerant to the several elements substantially in proportion to the respective differences between the average temperature of the fluid in heat-exchanging relation with the element and the temperature of the refrigerant, and means for effecting vaporization of liquid refrigerant in, and withdrawing vaporized refrigerant from, said evaporator elements at substantially the same pressure.

7. In apparatus for cooling a fluid, the combination of a plurality of evaporator elements of the dry expansion type, means for conveying fluid to be cooled in heat-exchanging relation with said elements in series, means for apportioning refrigerant to the several elements substantially in proportion to the respective differences between the average temperature of the fluid being cooled by the element and the temperature of the refrigerant in the element, and means for withdrawing vaporized refrigerant from said evaporator elements at substantially the same pressure.

8. In apparatus for cooling fluid, the combination of a plurality of evaporator elements of the dry expansion type, means for circulating fluid to be cooled successively in heat-exchanging relation with the evaporator elements, means for supplying and distributing liquid refrigerant in parallel to the evaporator elements in quantities which vary as a function of the respective differences between temperature of the fluid being cooled and temperature of the refrigerant, and means for effecting vaporization of liquid refrigerant in, and withdrawing vaporized refrigerant from, said evaporator elements at substantially the same pressure.

9. In apparatus for cooling a fluid, the combination of a plurality of evaporator elements of the dry expansion type arranged in series with respect to flow of the fluid to be cooled, means for supplying liquid refrigerant, means for admitting said liquid refrigerant to the evaporator elements in quantities which decrease in geometrical progression in the order of flow of fluid being cooled, and means for effecting vaporization of liquid refrigerant in, and withdrawing vaporized refrigerant from, said evaporator elements at substantially the same pressure.

10. In an air cooler, the combination of a plurality of evaporator elements arranged in series with respect to air flow, refrigerant supply means, capillary tubes for distributing refrigerant to said evaporator elements in parallel, said capillary tubes being dimensioned to supply refrigerant at successively diminishing rates in the direction of air flow, and a common suction line connected to the several evaporator elements.

11. In apparatus for cooling a fluid, the combination of a plurality of evaporator elements with which the fluid to be cooled comes into heat-exchanging relation successively, means for supplying liquid refrigerant to the evaporator elements in parallel, flow-controlling means for apportioning the liquid refrigerant to the evaporator elements substantially in accordance with their respective capacities to evaporate the liquid

refrigerant, and a common suction line connected to the several evaporator elements.

12. In apparatus for cooling a fluid, the combination of a plurality of evaporator elements with which the fluid to be cooled comes into heat-exchanging relation successively, means for supplying liquid refrigerant to the evaporator elements in parallel, flow-controlling means for apportioning the liquid refrigerant to the evaporator elements in successively decreasing quantities in the order in which the fluid to be cooled is brought into heat exchanging relation therewith, and means for withdrawing vaporized refrigerant from said evaporator elements at substantially the same pressure.

13. In apparatus for cooling a fluid, the combination of a plurality of evaporator elements with which the fluid to be cooled comes into heat exchanging relation successively, means for supplying liquid refrigerant to the evaporator elements in parallel, an automatic expansion valve for controlling the common supply, and flow resistance passages between said valve and said evaporator elements of such dimensions as to apportion the liquid refrigerant to the evaporator elements in successively decreasing quantities in the order in which the fluid to be cooled is brought into heat exchanging relation therewith.

14. In apparatus for cooling a fluid, the combination of a plurality of evaporator elements with which the fluid to be cooled comes into heat exchanging relation successively, liquid refrigerant supply means, an automatic expansion valve for controlling flow of refrigerant from said supply means, and a plurality of distributor tubes of varying lengths connected between said valves and the respective evaporator elements for distributing the liquid refrigerant to the latter in parallel, said tubes being of such dimensions as to apportion the liquid refrigerant to the evaporator elements in successively decreasing quantities in the order in which the fluid to be cooled is brought into heat exchanging relation therewith.

15. In apparatus for cooling a fluid, the combination of a plurality of evaporator elements with which the fluid to be cooled comes into heat exchanging relation successively, liquid refrigerant supply means, passages of fixed flow resistance connected between said supply means and the respective evaporator elements for distributing liquid refrigerant to the latter in parallel, said passages being of such dimensions as to apportion liquid refrigerant to the evaporator elements in successively decreasing quantities in the order in which the fluid to be cooled is brought into heat exchanging relation therewith, and means for withdrawing vaporized refrigerant from said evaporator elements at substantially the same pressure.

16. In apparatus for cooling a fluid, the combination of a plurality of evaporator elements with which the fluid to be cooled comes into heat exchanging relation successively, liquid refrigerant supply means, a plurality of fixed flow resistance tubes of varying lengths connected between said supply means and the respective evaporator elements for distributing liquid refrigerant to the latter in parallel, said tubes being of such dimensions as to apportion the liquid refrigerant to the evaporator elements in successively decreasing quantities in the order in which the fluid to be cooled is brought into heat exchanging relation therewith, and means for

withdrawing vaporized refrigerant from said evaporator elements at substantially the same pressure.

5 17. In air cooling apparatus, the combination of first and second evaporator elements, means for conveying a stream of air in contact with said evaporator elements to be cooled thereby, means for supplying liquid refrigerant to said evaporator elements in parallel, first and second

means for controlling the flow of liquid refrigerant to said first and second evaporator elements, respectively, and adapted to supply different quantities of liquid refrigerant to said first and second evaporator elements, and means 5 including a passage common to said evaporator elements for withdrawing vaporized refrigerant therefrom at substantially the same pressure.

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