Aug. 23, 1949. W. E. DODSON 2,479,732

LOW-TEMPERATURE REFRIGERATING SYSTEM

Filed Aug. 5, 1947

Fig. 1.

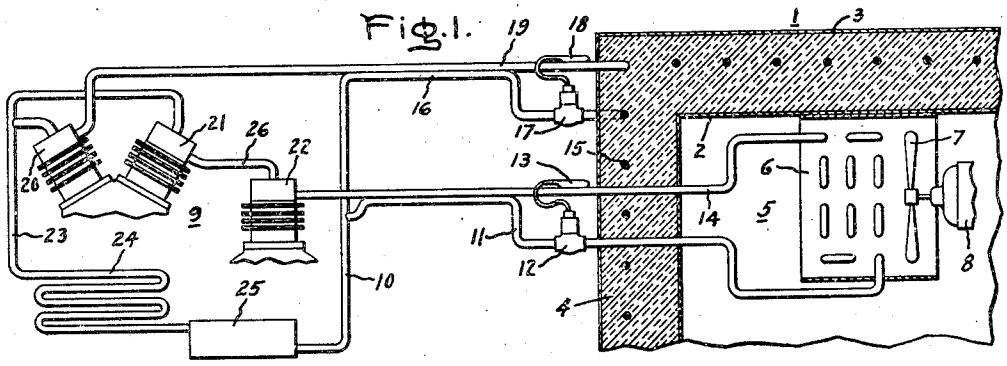


Fig. 2.

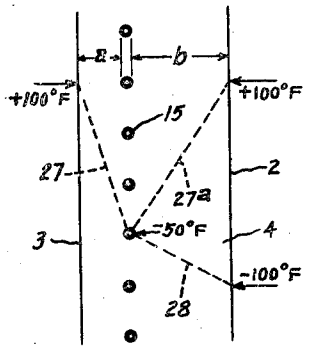


Fig. 3.

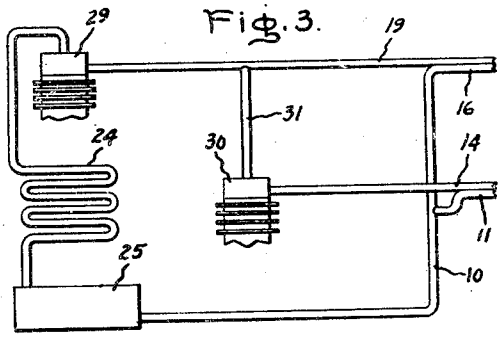
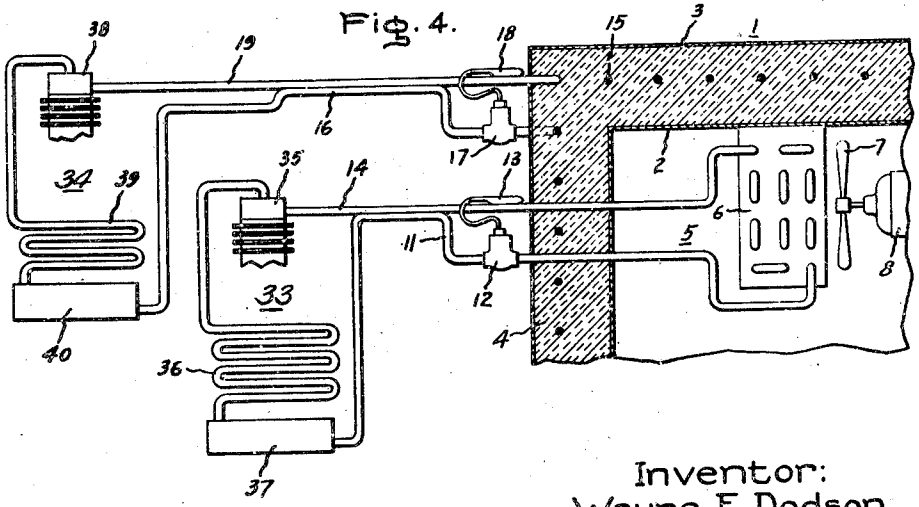


Fig. 4.



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LOW-TEMPERATURE REFRIGERATING SYSTEM

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Application August 5, 1947, Serial No. 766,386

7 Claims. (Cl. 62—116)

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My invention relates to refrigerating systems for operation at low temperatures and particularly to such systems for cooling air in cold storage compartments, test rooms, and the like.

Cold storage rooms are commonly cooled by mechanical refrigerating machines comprising condensing units for liquefying gaseous refrigerant and evaporators wherein the liquid refrigerant is vaporized by the absorption of heat, the vaporized refrigerant being returned to the condensing unit. The coefficient of performance of a refrigerating machine varies widely depending upon the temperature which must be maintained by the evaporator. When, for example, evaporator temperatures below, say zero degrees Fahrenheit, are employed, the capacity of the refrigerating machine is materially reduced over its capacity at the higher temperatures employed, for example, in the temporary preservation of foods. Accordingly, its is an object of my invention to provide a low temperature refrigerating system wherein the major portion of the heat load may be removed at relatively high coefficients of performance of the refrigerating machine.

It is another object of my invention to provide a low temperature refrigerating machine including an improved and more efficient arrangement for maintaining low temperatures within a compartment to be cooled.

It is a further object of my invention to provide an improved refrigerating system for operation at low temperatures and which shall make possible the application of a smaller refrigerating machine for carrying a predetermined heat load.

Further objects and advantages of my invention will become apparent as the following description proceeds, and the features of novelty which characterized my invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

For a better understanding of my invention, reference may be had to the accompanying drawing in which Fig. 1 represents diagrammatically a low temperature refrigerating system embodying my invention; Fig. 2 is a diagrammatic view of a wall of the system of Fig. 1 with a graph illustrating a characteristic of operation of the system; Fig. 3 represents a modified form of the invention; and Fig. 4 represents a further modification of the invention.

Referring now to the drawing, the refrigerating system illustrated in Fig. 1 comprises a thermally insulated cabinet or room 1, a portion only of which has been illustrated, and which is provided with inner and outer retaining walls

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2 and 3 which are spaced apart and accommodate a body of insulation 4 therebetween. Within the cabinet there is provided a compartment 5 which is cooled by an evaporator 6, the air in the compartment being circulated over the evaporator by operation of a fan 7 driven by an electric motor 8. The use of motor 8 and fan 7 is optional as it will be understood that circulation by gravity may be used. Liquid refrigerant is supplied to the evaporator 6 from a condensing unit 9, the refrigerant flowing from a liquid line 10 through a branch liquid line 11 to the evaporator under control of a thermostatic expansion valve 12. The valve is provided with a feeler bulb or temperature control element 13 connected in heat exchange relation with a suction line 14 through which vaporized refrigerant is withdrawn from the evaporator and returned to the condensing unit. The condensing unit may be controlled in any suitable manner in accordance with well-known practice to maintain the air in the compartment 5 within a suitable predetermined range of temperatures, for example a temperature in the neighborhood of sixty degrees below zero Fahrenheit. When a refrigerated compartment is operated at such low temperatures, there is a very substantial load due to the leakage of heat from the air outside the cabinet through the insulation to the evaporator; and, if the evaporator within the compartment is required to remove this heat at the low temperature of the compartment, the refrigerating machine must operate at a relatively low coefficient of performance. In order to reduce the load due to leakage through the cabinet walls, a second evaporator is arranged within the insulation 4. This evaporator comprises a refrigerant conduit having a plurality of turns or runs 15 extending back and forth through the insulation in planes substantially parallel to the walls 2 and 3 and distributed over a major portion of the thermally insulated walls of the compartment. It will be understood that the location and thickness of the insulated walls are determined by the arrangement of the refrigerated compartment 5 with respect to other adjacent refrigerated areas, and that the amount of insulation required will vary depending upon the normal ambient temperatures to be encountered at various portions of the outer wall 3. The evaporator 15 is connected to receive liquid refrigerant from the liquid line 10 through a branch line 16 under control of a thermostatic expansion valve 17. The valve 17 is provided with a temperature responsive element 18 in heat exchange relation with the dis-

charge or suction line of the evaporator 15 as indicated at 19. By arranging the evaporator 15 in this manner it is possible to abstract a large quantity of heat from the insulated wall so that a major portion of the temperature drop between the outside air and the air in the cabinet takes place between the outside wall 3 and the evaporator 15. Since the heat thus removed is removed at a relatively high temperature, the coefficient of performance of the refrigerating machine is relatively high. Obviously, the heat removed by evaporator 15 reduces the amount to be removed through the evaporator 6 at the necessarily lower coefficient of performance.

The evaporator 6 is operated at a relatively low pressure in order to abstract heat at a low temperature from the air in the compartment 5, and the evaporator 15 is operated at a substantially higher pressure for operation at the higher temperature. In order to maintain the two different temperatures in the evaporators 6 and 15, the condensing unit 9 is constructed as a two-stage or multi-stage compressor. As illustrated, the condensing unit includes two high pressure cylinders 20 and 21 and a low pressure cylinder 22 all provided with suitable pistons (not shown). Refrigerant compressed in the high pressure cylinders is delivered through a discharge line 23 to a condenser 24 where it is cooled and liquefied and then flows to a liquid receiver 25 to which the liquid line 10 is connected. In order to operate the evaporator 6 at a low pressure, the cylinders 21 and 22 are connected in tandem as a two-stage unit, refrigerant from the evaporator 6 being delivered to the cylinder 22 from the line 14 and compressed and then discharged through an interstage connection 26 to the intake of the cylinder 21. The evaporator 15 is connected through the suction line 19 to the high pressure cylinder 20. The pistons of the high pressure cylinders and of the low pressure cylinder may be actuated by the same motor (not shown) or by separate motors.

The operation of the refrigerating system shown in Fig. 1 maintains the required temperature gradient or drop between the ambient air outside the wall 3 and the air within the compartment 5. By way of example, Fig. 2 illustrates diagrammatically the manner in which the temperature gradient is maintained. Assuming by way of illustration that it is desired to maintain a temperature within the compartment 5 of one hundred degrees below zero Fahrenheit and that the temperature of the outside air is one hundred degrees above zero Fahrenheit, then the total temperature drop is two hundred degrees. In a wall having a thickness of the order of six inches and with suitable thermal insulation, the evaporator 15 may be arranged in a plane about two inches from the wall 3 and about four inches from the wall 2, these distances being indicated by the letters *a* and *b* respectively. If the refrigerating system is operated so that the evaporator 15 maintains a temperature of fifty degrees below zero Fahrenheit, then about three-fourths of the temperature gradient will occur between the wall 3 and the evaporator, as indicated at 27, and the remaining one-fourth between the evaporator and the wall 2, as indicated at 28. Under these conditions of operation, assuming that the insulation has a coefficient of conductivity of 0.3 B. t. u./hr./sq. ft. of surface/degree Fahrenheit, then for a one hundred square foot area of the wall a total of 2250 B. t. u./hr. will enter the wall 3, 1875 B. t. u./hr. will be absorbed

by the evaporator 15, and 375 B. t. u./hr. by the evaporator 6. On the other hand, should the evaporator 15 be cut out of operation, then the evaporator 6 would be required to carry a load of approximately 1000 B. t. u./hr., this being the total leakage in a 100 sq. ft. area when a temperature of one hundred degrees below zero Fahrenheit is maintained in the compartment 5 with an ambient temperature of one hundred degrees Fahrenheit. Although in this latter case only 1000 B. t. u./hr. need be removed by the refrigerating machine, this heat must be removed at a low coefficient of performance and a relatively large refrigerating machine will be required. By employing the evaporator 15 the total required capacity of the refrigerating machine is substantially less.

Under some conditions of operation, particularly during pull-down when the temperature within the compartment 5 is high, it may be desirable to operate the evaporator 15 first in order to remove the stored heat from the walls before the temperature of the compartment 5 is reduced materially. After the stored heat has been removed in this manner to an extent sufficient to bring the temperature at the evaporator 15 down to the required value, the evaporator 6 may be operated to lower the temperature within the compartment 5 quickly to its required value. This type of operation is indicated in Fig. 2 by the dotted line 27*a*, which represents the gradient between the high temperature within the compartment 5 and the low temperature of the evaporator 15 at the time when the evaporator 6 is to be started. A control arrangement for effecting this type of operation is disclosed and claimed in my copending application Serial No. 766,387, filed concurrently herewith and assigned to the same assignee as the present invention.

In the system of Fig. 3, only the arrangement of the condensing unit has been illustrated, as the remaining portions are identical with that of Fig. 1. Corresponding elements of Fig. 3 have been designated by the same numerals as in Fig. 1. The condensing unit of Fig. 3 is a two-stage compressor having a high pressure cylinder 29 and a low pressure cylinder 30. These cylinders are provided with pistons (not shown) driven by the same motor (not shown) or by separate motors as desired. Refrigerant withdrawn from the evaporator 6 through the suction line 14 is compressed in the cylinder 30 and is delivered through a discharge connection 31 to the suction line 19 of the evaporator 15 and is thus delivered to the intake of the cylinder 29. The discharge connection 31 and the end portion of the conduit 19 thus provide an interstage connection between the cylinders 29 and 30. The refrigerant withdrawn from the evaporator 15 and that delivered from the compressor 30 are compressed in the cylinder 29 and delivered through a discharge line 32 to the condenser 24 where the refrigerant is liquefied and flows to the liquid receiver 25 and thence through the liquid line 10 back to the evaporator. The operation of the system of Fig. 3 to maintain the required temperatures and to secure the desired relatively high overall coefficient of performance is essentially the same as that of Fig. 1, the evaporator 15, however, being operated at interstage pressure instead of at a pressure determined by operation of a separate compressor, as in Fig. 1.

The modification of Fig. 4 is similar to that of Fig. 1 and corresponding parts have been designated by the same numerals. The system

of Fig. 4 differs from that of Fig. 1 in that the compressing apparatus comprises two separate refrigerating machines 33 and 34 connected to the evaporators 6 and 15, respectively. The refrigerating machine 33 comprises a compressor 35, a condenser 36 and a liquid receiver 37. Vaporized refrigerant withdrawn from the evaporator 6 through the suction line 14 is delivered to the compressor 35 where it is compressed and discharged to the condenser 36 to be liquefied, the liquid refrigerant collecting in the receiver 37 and flowing directly to the liquid line 11 of the evaporator. The compressor 35 is operated to maintain a predetermined low pressure and may be controlled in accordance with the temperature of the air in the compartment 5 in the usual manner. Refrigerant vaporized in the evaporator 15 is delivered through the suction line 19 to a compressor 38 of the unit 34 and is liquefied in a condenser 39 from which it flows to a liquid receiver 40 and returns to the evaporator through the liquid line 16. The compressor 38 operates at a higher pressure than the compressor 35 and maintains the evaporator 15 at the desired higher temperature. The compressor 38 may be controlled in any suitable manner, for example, in accordance with suction line pressure or the temperature of the evaporator 15. The condensing unit 34 thus operates at a higher coefficient of performance than the condensing unit 33 and, as indicated by the sample characteristics of Fig. 2 which are applicable to all three illustrated embodiments of the invention. The machine 34 may be arranged to carry the major portion of the heat load so that the over-all coefficient of performance of the refrigerating apparatus of Fig. 4 is thereby raised substantially over that of the coefficient of performance of the condensing unit 33 alone.

While I have illustrated my invention in connection with particular types of refrigerating machines, other applications will readily occur to those skilled in the art. For example, although the system illustrated employ evaporators directly for cooling the walls and interior of the storage compartment, it is obvious that the evaporators may be employed to cool brine or other suitable secondary refrigerant which is then circulated through cooling units arranged in the walls and in the storage compartment. I do not, therefore, desire my invention to be limited to the specific details illustrated and described, and I intend by the appended claims to cover all modifications within the spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a low temperature refrigerating system, means including a thermally insulated wall for providing a chamber to be cooled, a first cooling element arranged to abstract heat from the medium within said chamber, a second cooling element arranged within said wall, means including a refrigerant compressing apparatus having a high pressure compressor and a low pressure compressor for supplying cooling fluid to said elements, and means for operating said low pressure compressor to abstract heat from said first element at a predetermined low temperature and said second compressor to abstract heat from said second element at a predetermined higher temperature.

2. In a low temperature refrigerating system, means including a thermally insulated wall for providing a chamber to be cooled, a first cooling element arranged within said chamber to cool the air therein, a second cooling element comprising a plurality of runs of tubing distributed throughout a major area of said wall and arranged substantially in a plane parallel to the surfaces of said wall, means including a refrigerant compressing apparatus having a high pressure compressor and a low pressure compressor for supplying cooling fluid to said elements, and means for operating said low pressure compressor to abstract heat from said first element at a predetermined low temperature and said second compressor to abstract heat from said second element at a predetermined higher temperature.

3. In a low temperature refrigerating system, means including a thermally insulated wall for providing a chamber to be cooled, a first cooling element arranged within said chamber to cool the air therein, a second cooling element comprising a plurality of runs of tubing distributed throughout a major area of said wall and arranged substantially in a plane parallel to the surfaces of said wall, means including a refrigerant compressing apparatus having a high pressure compressor and a low pressure compressor for supplying cooling fluid to said elements, and means for operating said low pressure compressor to abstract heat from said first element at a predetermined low temperature and said high pressure compressor to abstract heat from said second element at a predetermined higher temperature, said plane in which said second element is arranged being located within the thermal insulation between said inner and outer walls in a position such that the major portion of the temperature drop at normal room temperatures from the outer wall to the inner wall occurs between the outer wall and said plane.

4. In a low temperature refrigerating system, means including a thermally insulated wall for providing a chamber to be cooled, a first cooling element arranged to abstract heat from the medium within said chamber, a second cooling element arranged within said wall, means including a two-stage refrigerant compressing apparatus for supplying cooling fluid to said elements, and means for operating the low pressure stage of said apparatus to abstract heat from said first element at a predetermined low temperature and the high pressure stage of said apparatus to abstract heat from said second element at a predetermined higher temperature.

5. In a low temperature refrigerating system, means including a thermally insulated wall for providing a chamber to be cooled, a first cooling element arranged to abstract heat from the medium wtihin said chamber, a second cooling element arranged within said wall, means including a two-stage refrigerant compressor comprising a high pressure cylinder and a low pressure cylinder for supplying cooling fluid to said elements, means for utilizing said low pressure cylinder to abstract heat from said first element at a predetermined low temperature, and means including an interstage connection between said cylinders for utilizing said high pressure cylinder to abstract heat from said second element at a predtermined higher temperature.

6. In a low temperature refrigerating system, means including a thermally insulated wall for providing a chamber to be cooled, a first cooling element arranged to abstract heat from the medium within said chamber. a second cooling element arranged within said wall, means comprising a compressing apparatus including two

high pressure cylinders having a common discharge connection and a low pressure cylinder for supplying cooling fluid to said elements, means including a connection placing one of said high pressure cylinders and said low pressure cylinder in tandem for abstracting heat from said first element at a predetermined low temperature, and means including a connection between the other of said high pressure cylinders and said second element for abstracting heat from said second element at a predetermined higher temperature.

7. In a low temperature refrigerating system, means including a thermally insulated wall for providing a chamber to be cooled, a first evaporator arranged in said chamber for cooling the air therein, a second refrigerant evaporator arranged within the insulation in said wall and

extending throughout a major area of said wall, a two-stage refrigerant compressor having a low pressure cylinder and a high pressure cylinder, means including a condenser connected to receive refrigerant from said compressor for liquefying refrigerant and supplying liquid refrigerant to said evaporators, means including a connection between said first evaporator and said low pressure cylinder for operating said first evaporator at a predetermined low temperature, and means including a connection between said second evaporator and said high pressure cylinder for operating said second evaporator at a higher predetermined temperature.

WAYNE E. DODSON.

No references cited.