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C. L. RINGQUIST ET AL

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AIR CONDITIONING APPARATUS WITH DEFROSTING MEANS

Filed Aug. 21, 1946

2 Sheets-Sheet 1

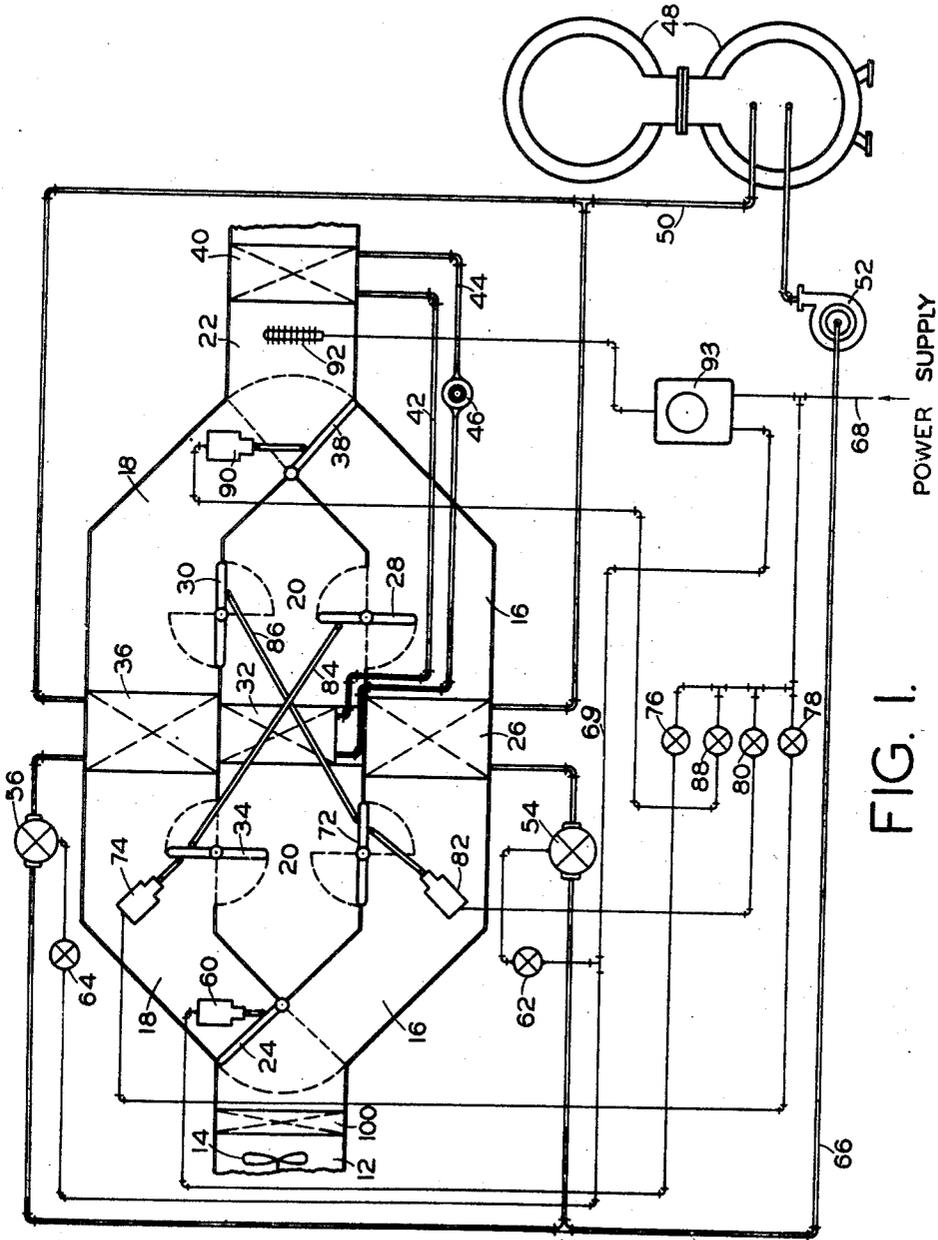


FIG. 1.

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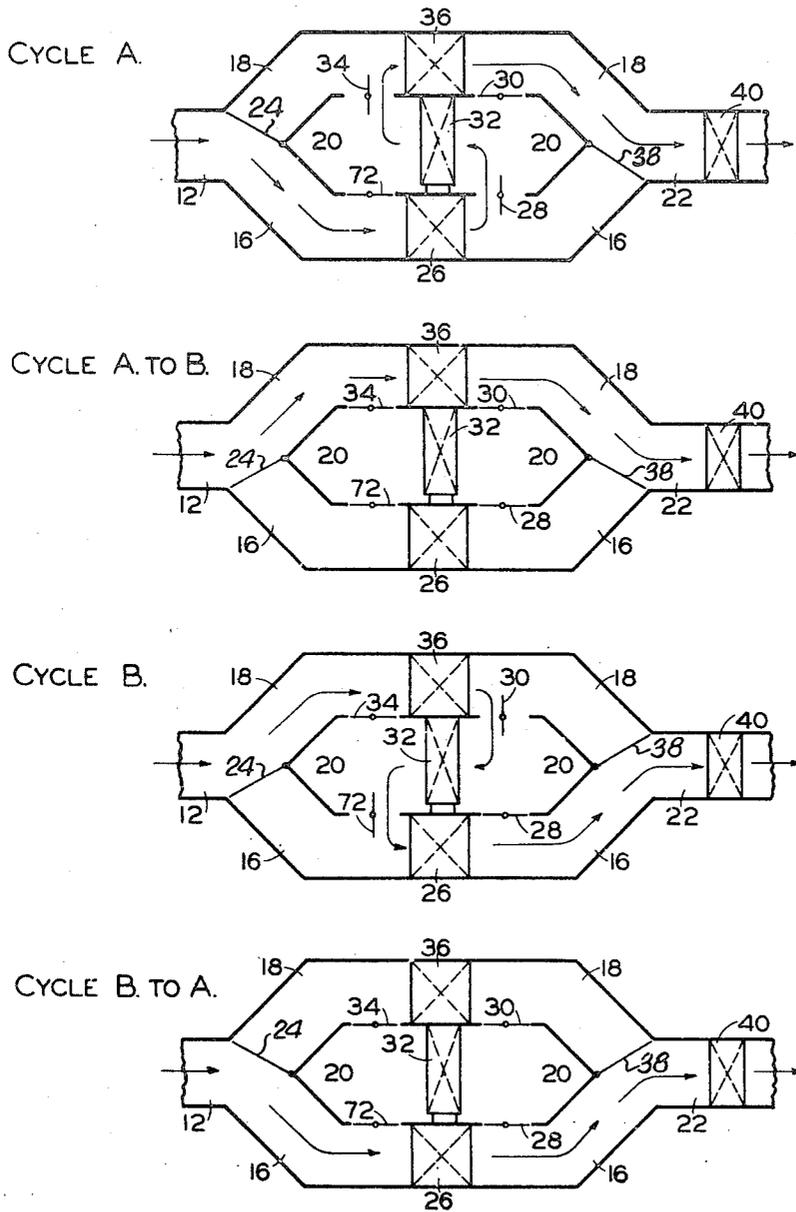


FIG. 2.

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2,481,348

AIR-CONDITIONING APPARATUS WITH DEFROSTING MEANS

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13 Claims. (Cl. 62-6)

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This invention relates to the art of air conditioning, and is more particularly concerned with providing conditioned air or gas on a continuous basis without the necessity of shutting down the apparatus.

It is well known that where air or gas must be dehumidified to a condition at or below the frost point, a duplication of equipment is required so that the air or gas can be delivered on a continuous basis without shutting down the equipment for removal of ice or frost accumulations. The present invention permits a considerable saving in refrigeration since the total amount of refrigeration is available for the purpose of conditioning this air or gas, and at the same time the necessity of duplicating certain of the equipment is eliminated.

One object of the present invention, then, is to provide an apparatus for conditioning air or gas, particularly when the air or gas must be conditioned to a temperature at or below the frost point.

Another object of this invention is to provide an apparatus which will allow air or gas that has been conditioned below the frost point to be delivered on a continuous basis without the necessity of using more than one system or apparatus for this purpose.

Still another object of the present invention is to provide an apparatus which will deliver on a continuous basis, in one direction, air or gas that has been conditioned below the frost point without the necessity of shutting down the apparatus for defrosting.

Another object of the present invention is to provide an apparatus for conditioning air or gas which may use warm, unconditioned air or gas to defrost the cooling coils in this apparatus.

Yet another object of the present invention is to provide a sequence of cooling and reheating stages for conditioning air or gas, whereby the air or gas may be economically dehumidified and reheated in a comparatively small space.

Another object of this invention is to provide an apparatus which will condition air or gas by dehumidifying it and subsequently reheating it so that the conditioned air or gas will have a continuous uniform moisture content and dry bulb temperature.

Still another object of the present invention is to provide a means of control whereby the conditioned air or gas will be uniform as to moisture content and dry bulb temperature.

With the foregoing and other advantages in view, this invention consists in the apparatus and

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system hereinafter described and claimed and illustrated in the accompanying drawings wherein:

Fig. 1 is a diagrammatic view of a preferred and practical embodiment of the new and improved air or gas conditioning system, and

Fig. 2 is a simplified diagrammatic view of the cycles of operation of the new and improved air or gas conditioning system.

It is to be understood that these drawings are illustrative of the present invention, and are not to be considered as limitations thereof, since various changes and modifications may be made without departing from the spirit of the invention or the scope of the appended claims.

Referring to the drawings in which the same reference numerals have been used to indicate the same or like parts, and first adverting to Fig. 1, the reference numeral 12 indicates generally an inlet duct or pipe through which air or gas is moved by the fan 14 through either the duct 16 or 18, then through the duct space 20, and then through either duct 16 or 18 to the outlet duct 22. The system may be arranged in either horizontal or vertical position as desired.

As a typical illustration to aid in the understanding of the operation of this new and novel apparatus, assume the following conditions:

Gas at 70° F. saturated is to be conditioned to 25° F. saturated when leaving coil 36 in duct 18 or when leaving coil 26 in duct 16. This 70° gas enters the apparatus through the inlet duct 12 into the duct 16—the duct 18 being closed by the damper 24. The gas then passes over the coil 26, defrosting that coil, provided a previous cycle has occurred. The gas then passes out of the duct 16 and into the duct space 20—the damper 28 being in an open position. The damper 30 meanwhile is in closed position, thus forcing the gas to pass over the coil 32 where it is reduced to 57.5° F. saturated. The gas then flows into the duct 18—the damper 34 being in open position. The gas then passes over coil 36 and is reduced to 25° F. saturated. The gas then leaves the duct 18 through the open damper 38 and into outlet duct 22. In this illustration the purpose of reducing the gas temperature to 25° F. saturated was the elimination of moisture. It is to be understood, of course, that other temperatures and conditions may be used with equally good results. Any sensible heat pickup after reducing the gas 25° F. saturated is a gain. Therefore, the gas may now travel through the heating coil, which has been designated by the reference numeral 40, and which is interposed in the outlet

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duct 22. Coil 40 is connected by pipe circuits 42 and 44 to cooling coil 32 to form a heat reclamation cycle. A pump 46 is interposed in the pipe circuits 42 and 44 to circulate the heat exchange medium from cooling coil 32 to heating coil 40 and back again.

The heating coil 40 restores to the gas, as sensible heat, both the latent and sensible heat which the cooling coil 32 abstracted. Thus the gas has been dehumidified to the equivalent of 25° F. saturated, but leaves the apparatus with part of the sensible heat restored, which had to be removed for dehumidification. Conversely, this heat reclamation causes the heat exchange medium to be reduced in temperature by the passage of 25° F. gas over the heating coil 40. The heat exchange medium, thus reduced in temperature, is returned to the cooling coil 32 at a lower temperature than at which it left the same coil, thus causing a direct saving in the amount of refrigeration required to reduce the gas temperature to 25° F. The coil 40 might be omitted entirely, and it need only be used when it is desired to raise the outlet temperature of gas emitting either from the coils 26 or 36. If desired, the coil 32 may also be omitted from the apparatus. In this illustration given above, the gas now leaves the apparatus through the outlet duct 22 at a dew point temperature of 25° F., but a dry bulb temperature of 60° F.

As in all refrigeration dehumidifying apparatus where it is necessary to use a cooling medium at or below the frost point, ice or frost will form on the coil or other apparatus used for heat transfer purposes. In the illustration given above ice has gradually accumulated on the coil 36 until its effectiveness as a transfer medium is about to be impaired. The defrosting of the coil 36 and the simultaneous transfer of the function of dehumidifying and cooling from the coil 36 to the coil 26 may be accomplished as follows:

The cooling coils 26 and 36 are supplied with a cold heat exchange medium, for example, brine from a refrigeration unit 48 through a pipe circuit 50 having a circulating pump 52 therein to circulate the heat exchange medium. The brine circuit is formed by the supply pipe 50 from the refrigeration unit 48 to the valves 54 and 56, which selectively allow the flow of cooling medium either to the cooling coil 26 or the cooling coil 36. A pump 52 is interposed in the return conduit 66 to pull the cooling medium from the coils back to the refrigerating unit 48. The valves 54 and 56 are connected to and rendered operative by the valves 62 and 64, respectively, these latter valves 62 and 64 being connected to a pneumatic temperature controller 93 by line 69. The temperature controller 93 is connected to a power supply 68, either air (as shown) or electric or other suitable power means, and is responsive to a thermally sensitive element, generally designated by the reference numeral 92 to regulate the amount of flow of the brine.

If desired, a precooling unit 100 may be interposed in the inlet air duct 12. This precooling unit 100 may use cold water or any other suitable cooling medium. This precooling coil 100 then operates to cool the warm, unconditioned air or gas entering the apparatus thus removing a portion of the moisture from the air or gas in liquid form. The removal of this moisture lengthens the time that it takes for the cooling coils 26 and 36 to frost up. The cooling coils 26 and 36 are thus kept operating for longer periods of time without the necessity of changing the air flow to defrost the coil. It has also been found that

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the apparatus operates more efficiently when a portion of the moisture is removed by said precooling, for the efficiency of the cooling coils is impaired by the deposition of frost on the coils, and the longer this can be prevented the more efficient the apparatus. As an alternative method of construction, if desired, the cooling coil which has been designated by the reference numeral 32 may be moved from its position between the cooling coils 26 and 36 as is shown most clearly in Fig. 1, and positioned in the air or gas inlet 12 to occupy the position of the precooling coil 100 as shown in Fig. 1. If the coil 32 is positioned in the air or gas inlet 12, then the warm entering air or gas may be cooled and a portion of the moisture may be removed from said air or gas as liquid. Removal of any moisture from the incoming air or gas lengthens the time that it takes for the cooling coils 26 and 36 to frost up. It has also been found that positioning the coil 32 in the air inlet 12 rather than between the coils 26 and 36, as shown in Fig. 1, results in a higher exit temperature of the air from the outlet 22 since the reheating coil 40, which is connected to the coil 32 by suitable conduits which contain heat exchange medium, operates at a higher temperature since the heat exchange medium in these conduits is not cooled as much as when the cooling coil 32 is positioned between the cooling coils 26 and 36. When the coil 32 is positioned in the air inlet 12, or when a precooling coil 100 is used in the air inlet 12, the incoming air or gas is cooled so that it takes somewhat longer to defrost the coils 26 or 36 when they have become frosted up than when the warm entering air or gas is allowed to flow directly over the frosted coils 26 or 36.

In the sequence of operations described above the cold heat exchange medium is only supplied to coil 36, the flow of this medium being shut off to coil 26 by valve 54. As accumulations of ice and frost on the coil 36 develop, it is necessary to shift to cooling coil 26 if the efficiency of the apparatus is to be maintained. This shift is accomplished as is shown most clearly in Fig. 2. The arrows indicate the direction of gas flow. In Fig. 2 the top drawing labeled "Cycle A" shows the flow of gas as described in the illustration just given. In this cycle the gas enters the inlet duct 14 and flows into the duct 16, since the damper 24 is in a closed position and shuts off the duct 18. The gas then flows through coil 26, defrosting said coil, and then enters the duct 20 through the open damper 28 and passes through the coil 32 and out into duct 18 through open damper 34. Here the gas flows through cooling coil 36, which is operating, and then out through the outlet duct 22 and through the reheating coil 40. The second drawing of Fig. 2, which is labeled "Cycle A to B," shows a transition period between the shift from operating cooling coil 36 to operating cooling coil 26. As the cooling coil 36 begins to lose efficiency due to accumulations of ice and frost, the damper 24 is shifted by means of driving motor 60 actuated by valve 76, so that duct 16 is shut off. Simultaneously driving motor 74 actuated by valve 78 closes the dampers 34 and 28, to which it is connected by means of a suitable linkage designated generally by the reference numeral 84, and valve 54 opens to admit refrigerant flow to coil 26 to precool this coil. The gas entering through inlet duct 12 now passes into duct 18, and then passes directly through cooling coil 36 and out the outlet duct 22 and through reheating coil 40. During this cycle, which con-

tinues only for a relatively short period of time, coil 36 is operating, and coil 26 has refrigerant flowing therethrough and is therefore being pre-cooled.

The third drawing of Fig. 2, labeled "Cycle B" shows subsequent operation. Valve 80 actuates driving motor 82, which opens dampers 72 and 30—said dampers being connected to the driving motor 82 by means of a suitable linkage 86. At the same time the valve 88 actuates driving motor 90 to shift the damper 38 so as to close duct 18. Gas entering the duct 12 now passes into duct 18 and over coil 36, defrosting said coil. The gas then passes through the open damper 30 and over coil 32, then through open damper 72, over cooling coil 26, then passes out the outlet duct 22, and through reheat coil 40. In this cycle, coil 36 is being defrosted, and coil 26 is cooling the gas.

The last drawing of Figure 2, which has been labeled "Cycle B to A" shows the transition as the cooling coil 26 loses efficiency due to accumulations of ice and frost. Driving motor 60 is actuated by valve 76, and shifts damper 24 to close off duct 18, and at the same time valve 80 actuates driving motor 82 to close dampers 72 and 30 and valve 56 opens to admit refrigerant to coil 36 to precool this coil. The gas entering through inlet duct 12 now passes through duct 16 and directly through coil 26, and then out the outlet duct 22 and through the reheat coil 40. In this cycle coil 26 is operating, and coil 36 has refrigerant flowing therethrough and is therefore being pre-cooled. Like cycle "A to B" this cycle is of relatively short duration, after which the operations are repeated—the drawing labeled "Cycle A" showing the positions of the dampers and the flow of gas just described. These cycles, above described, may be repeated as often as desired with either manual control or an automatic device, such as a cycle timer, or other suitable automatic apparatus, to make entirely automatic the functioning of the apparatus. While we have shown our apparatus with numerous motors and controls, it is to be understood that the apparatus may be greatly simplified, for example, a single motor with suitable linkage and cams may be used to operate the dampers 24, 34, 38, 72, and 38.

It is apparent from the above description that the method of operation used in the present invention is a continuously operating system for the delivery of gas or air at dew points as low as the frost point, or lower, without the necessity of shutting down the apparatus for defrosting or deicing. It will also be readily apparent that the present invention does away with the necessity of duplicating apparatus.

In order to demonstrate further advantages of the apparatus of the present invention described herein, reference may be made to a technical problem of cooling 10,000 C. F. M. of free air or gas, which on entering the apparatus at 70° F. saturated, leaves at a final condition of 60° F. dry bulb and 25° F. dew point. The conditioning of the air or gas, as set forth in the above example, might be obtained by the use of a single cooling coil such as the cooling coil 26 or 36, and then reheated, but a refrigeration requirement of 90 tons would be necessary. However, by the use of the new and improved apparatus of the present invention, utilizing the herein described method of dehumidifying and reheating, it is possible to reduce the refrigeration

load from 90 tons to 56 tons, and at the same time deliver this gas or air at the same dew point.

A thermally sensitive element 92 is responsive to the temperature of the outgoing air in the outlet 22 and is connected to pneumatic temperature controller 93 to control the operation of valves 56 and 56 and to regulate the amount of refrigerant which is supplied to these cooling coils. In this manner the temperature and/or the humidity of the outgoing air may be accurately controlled.

The thermally sensitive element 92 and pneumatic temperature controller 93 by proper controls and apparatus, may also be used to selectively direct the flow of cooling medium either to the cooling coil 26 or the cooling coil 36 and may also be used to control the operation of the driving motors 60, 74, 82 and 90, which in turn control the operation of the dampers 24, 34 and 28, 72 and 30, and 38, respectively so as to direct the flow of air initially either through the duct 16 or the duct 18 as previously described.

The cycle would be changed in the following manner. Assume that the system is operating on cycle A as shown in Fig. 1. As coil 36 becomes frosted the temperature in duct 22 tends to rise, but element 92 and temperature controller 93 cause the valve 56 to increase the flow of brine to maintain the control temperature. However, a point is reached when the maximum possible flow of brine is going through the coil, and because of the frost on the coil the temperature in duct 22 continues to rise. Element 92 and temperature controller 93 respond to this abnormal temperature rise and the temperature controller 93 sends out a pressure above normal control pressure. This abnormal pressure, by proper controls such as a program device, is then used to actuate the valves 62, 64, 76, 78, 80, and 88 in the proper sequence to produce changes in the cycle as described above. Such controls are well known in the art and it is not considered necessary to show them in detail.

If it is desired to control the operation of the said valves, motors and dampers responsive to an interval of time, then a device (not shown) designed to operate a valve upon the lapse of a predetermined interval of time may be used either in conjunction with or substituted for the pneumatic temperature controller or, an instrument (not shown) responsive to the accumulation of frost on the cooling coils 26 and 36 may be either used in conjunction with or substituted for the thermostat 92.

Although the term "air" has been used in the specification and the claims, it is to be understood that we are using the word "air" in its generic sense to mean atmospheric air or any other gas, for the apparatus of this invention is suitable for heating any type of air or gas and we do not wish to limit our applications to atmospheric air alone. It is also to be understood that the illustrations and examples given have been by way of illustration and not limitation since various changes and modifications may be made without departing from the spirit of the invention or the scope of the appended claims.

Having thus described our invention what we claim is:

1. In an air conditioning apparatus comprising a casing with air inlet and outlet and two ducts, means to move the air through said casing and through a first coil positioned in one of said ducts and then through a second coil positioned in the other of said ducts, means to selectively send the air through one or the other of said

ducts first as desired, and means to supply refrigerant to whichever of said coils is last in the path of said air, and to cut off the supply of refrigerant to the coil first in the path of said air, both of said last two means being responsive to conditions indicating that one of the coils in the ducts has become frosted.

2. In an air conditioning apparatus comprising a casing with air inlet and outlet and two ducts, means to move air through said casing and through a first coil positioned in one of said ducts and then through a second coil positioned in the other of said ducts, means to selectively send the air through one or the other of said ducts first as desired, and means to supply refrigerant to whichever of said coils is last in the path of said air and to cut off the supply of refrigerant to the coil first in the path of the air.

3. In an air conditioning apparatus comprising a casing with air inlet and outlet and two ducts, means to move air through said casing and through a first coil positioned in one of said ducts, and then through a second coil positioned in the duct space between the said two ducts and then through a third coil positioned in the other of said ducts, means to selectively send the air through one or the other of said ducts first as desired, and means to supply refrigerant to whichever of said coils is last in the path of said air and to cut off the supply of refrigerant to the coil first in the path of the air.

4. In an air conditioning apparatus comprising a casing with air inlet and outlet and two ducts, means to move air through said casing and through a first coil positioned in one of said ducts, then through a second coil positioned in the duct space between the said two ducts and then through a third coil positioned in the other of said ducts, means to selectively send air through one or the other of said ducts first as desired, and means to alternately supply refrigerants to one and then the other of the said first and third cooling coils in said ducts, and a reheating coil positioned in the path of air emitting from said outlet and operatively connected by conduits containing heat exchange medium with the afore-said second cooling coil.

5. In an air conditioning apparatus comprising a casing with an air inlet and outlet and two ducts, means to move air through said casing and through a first cooling coil positioned in one of said ducts and then through a second cooling coil positioned in the other of said ducts, means to selectively send air through one or the other of said ducts first as desired, means to alternately supply refrigerant to first one and then the other of said cooling coils, both of said last two means being responsive to conditions indicating that one of said coils has become frosted.

6. An apparatus of the type described comprising a casing with air inlet and outlet and two ducts, a cooling coil positioned in one of said ducts, a second cooling coil positioned in the other of said ducts, means to move air through said casing and alternately through either of said ducts and cooling coils first as desired, and means to alternately supply refrigerant to first one and then the other of said cooling coils, both of said last two means being responsive to conditions indicating that one of said cooling coils has become frosted.

7. An apparatus of the type described comprising a casing with air inlet and outlet and two ducts, a cooling coil positioned in one of said ducts, a second cooling coil positioned in the other

of said ducts, means to move air through said casing and alternately through either of said ducts and cooling coils first as desired, and means to alternately supply refrigerant to first one and then the other of said cooling coils, a third cooling coil positioned in the space between said ducts and operatively connected by ducts containing heat exchange medium with a reheating coil positioned in the path of air emitting from said outlet.

8. An apparatus of the type described comprising a casing with air inlet and outlet and two ducts, a cooling coil positioned in said inlet to pre-cool air flowing through the apparatus, means to move air through said casing and through a second cooling coil positioned in one of said ducts and then through a third cooling coil positioned in the other of said ducts, means to selectively send the air through one or the other of said ducts first as desired, and means to supply refrigerant to whichever cooling coil is last in the path of said air and to cut off the supply of refrigerant to the cooling coil in the other duct.

9. An apparatus of the type described comprising a casing with air inlet and outlet and two ducts, a cooling coil positioned in said inlet to pre-cool air flowing through the apparatus, means to move air through said casing and through a second cooling coil positioned in one of said ducts and then through a third cooling coil positioned in the other of said ducts, means to selectively send the air through one or the other of said ducts first as desired, and means to supply refrigerant to whichever cooling coil is last in the path of said air, and to cut off the supply of refrigerant to the cooling coil in the other duct, both of said last two means being responsive to conditions indicating that one of the cooling coils in the ducts has become frosted.

10. In an air conditioning apparatus comprising an air inlet and outlet and two ducts, a cooling coil positioned in said air inlet, and a reheating coil positioned in said air outlet and connected to said cooling coil in said inlet by conduits containing heat exchange medium, means to move air through said air inlet and cooling coil and then successively through a second cooling coil positioned in one of said ducts and then through a third cooling coil positioned in the other of said ducts and then through said reheating coil and out the said air outlet, and means to selectively send the air through one or the other of said ducts first as desired, and means to supply refrigerant to whichever cooling coil is last in the path of said air and to cut off the supply of refrigerant to the cooling coil in the other duct.

11. In an air conditioning apparatus comprising an air inlet and outlet and two ducts, a cooling coil positioned in said air inlet and a reheating coil positioned in said air outlet and connected to said cooling coil in said inlet by conduits containing heat exchange medium, means to move air through said air inlet and cooling coil and then successively through a second cooling coil positioned in one of said ducts and then through a third cooling coil positioned in the other of said ducts and then through said reheating coil and out the said air outlet, and means to selectively send the air through one or the other of said ducts first as desired, and means to supply refrigerant to whichever cooling coil is last in the path of said air and to cut off the supply of refrigerant to the cooling coil in the other duct, both of said last two

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means being responsive to conditions indicating that one of the cooling coils in the ducts has become frosted.

12. A fluid conditioning apparatus comprising a casing having an inlet duct, an outlet duct, and two branch ducts connecting said inlet duct and said outlet duct, a heat exchanger in each of said branch ducts, means for moving fluid from said inlet duct to said outlet duct, movable means in said casing for directing said fluid from said inlet duct to said outlet duct first through one of said heat exchangers and then through the other of said heat exchangers, means for moving said movable means to direct said fluid from said inlet duct first through said other of said heat exchangers and then through said one of said heat exchangers, and means to supply refrigerant to whichever of said heat exchangers is last in the path of said fluid.

13. A fluid conditioning apparatus comprising an inlet duct and an outlet duct, a first duct connecting said inlet duct and said outlet duct, a second duct connecting said inlet duct and said outlet duct, a first heat exchanger in said

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first duct, a second heat exchanger in said second duct, a third duct connecting said first and second ducts at points upstream and downstream of each of said heat exchangers, means for moving a fluid from said inlet duct to said outlet duct, movable valve means in said ducts for directing said fluid from said inlet duct to said outlet duct first through said first coil and then through said second coil, and means for moving said valve means to direct said fluid from said inlet duct to said outlet duct first through said second coil and then through said first coil.

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