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2,522,484

METHOD OF AND APPARATUS FOR CONDITIONING AIR

Filed Oct. 4, 1948

3 Sheets-Sheet 1

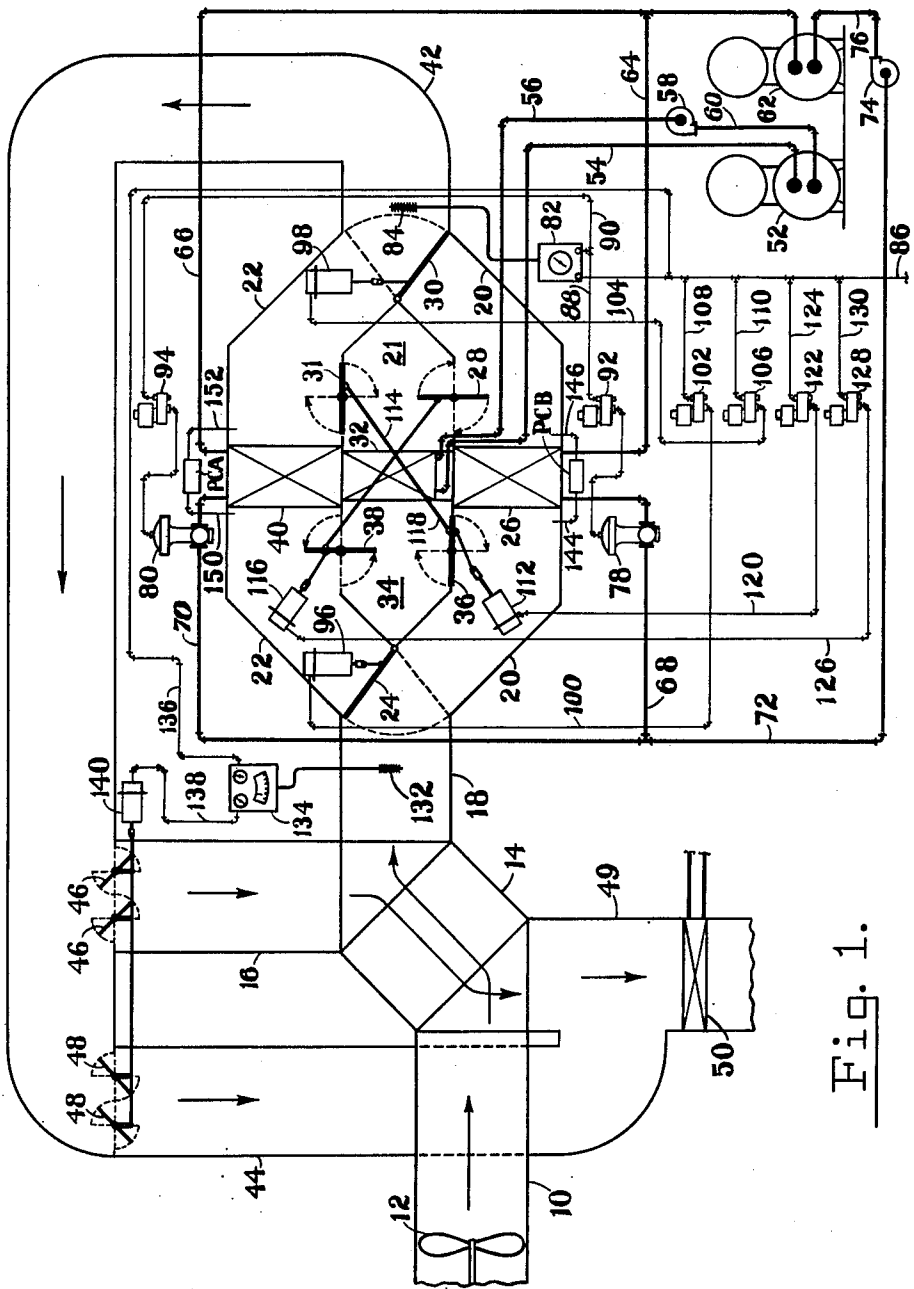


Fig. 1.

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3 Sheets-Sheet 2

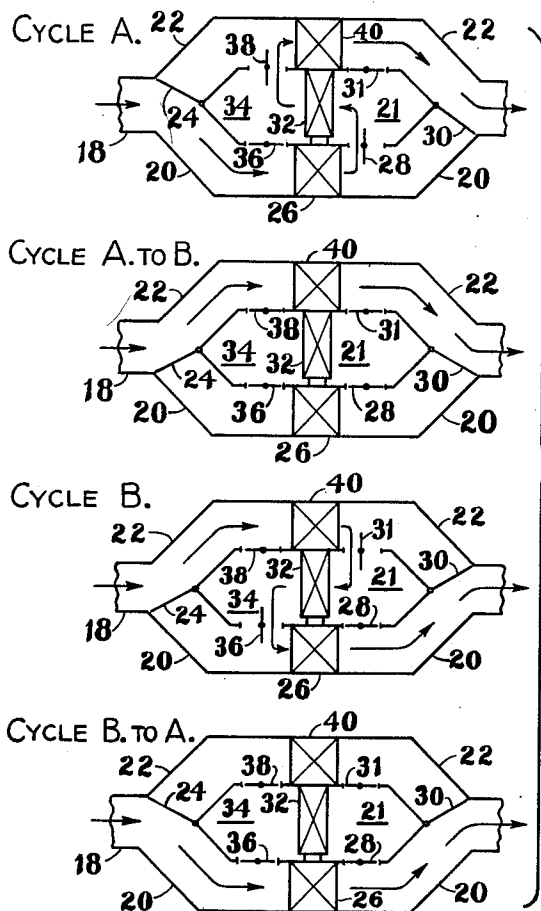


Fig. 2.

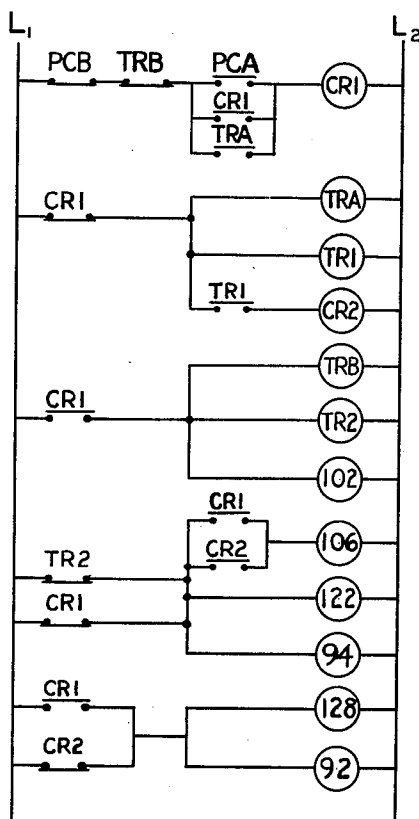


Fig. 3.

CYCLE	PCA	PCB	TRA	TRB	CRI	TRI	CR2	TR2	102	106	94 122	92 128
A	0	X	TIMING	0	0	X	X	0	0	X	X	0
A TO B TRANSITION	X	X	0	TIMING	X	0	0	TIMING	X	X	X	X
B	0	X	0	TIMING	X	0	0	X	X	0	0	X
B TO A TRANSITION	0	0	TIMING	0	0	TIMING	0	0	0	0	X	X

Fig. 4.

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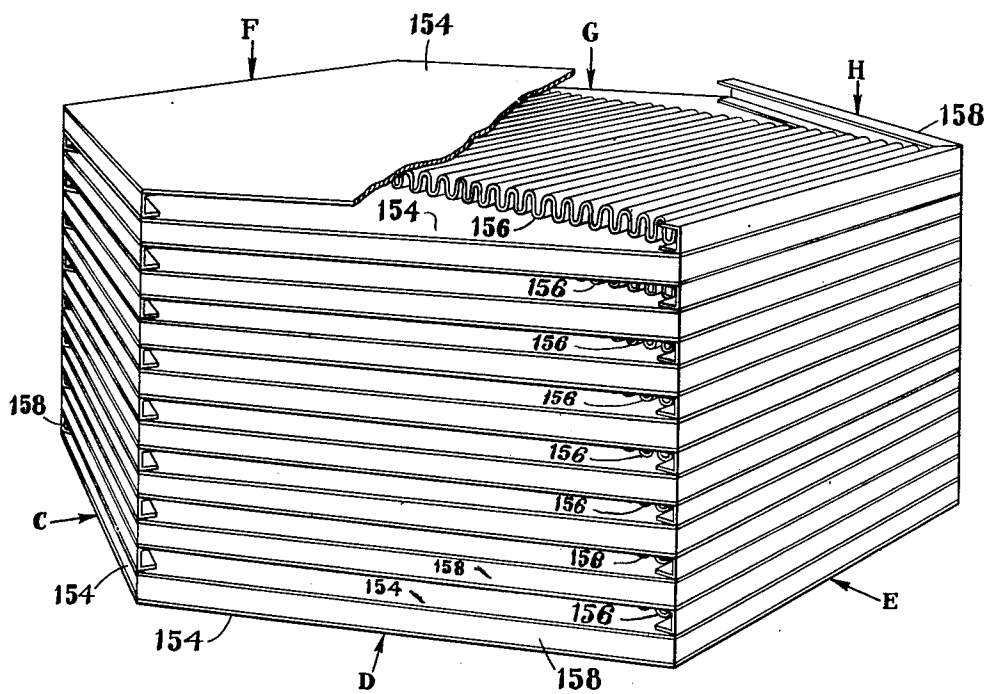


Fig. 5.

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METHOD OF AND APPARATUS FOR
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10 Claims. (Cl. 62—6)

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This invention relates to apparatus for conditioning air by cooling it to a temperature below its dew point in order to remove moisture.

More particularly the apparatus of this invention provides a continuous supply of air which has been dehumidified to a predetermined dew point temperature which is below freezing. Defrosting is accomplished by using the heat from the air being conditioned so that no outside heat source is required for defrosting the coil. The coil being defrosted also removes heat from the air being conditioned, and in this way reduces the total refrigerating load of the system.

An air to air heat exchanger passes the entering air in counterflow heat exchange relationship with the cooled dehumidified air thereby precooling the entering air and reheating the leaving air. Precooling the entering air in this manner reduces considerably the refrigerating load. The dehumidified air is also reheated without supplying heat from an outside source.

One object of the invention is to provide an apparatus which will deliver a continuous supply of air which has been dehumidified to a predetermined dew point below freezing.

Another object of the invention is to provide apparatus which uses heat from the air being conditioned to defrost the refrigerating coils.

Another object of the invention is to provide heat exchange between the air in different stages of the conditioning process to economically precool and reheat the air.

Still another object of the invention is to provide apparatus automatically controlled to deliver air having a substantially constant predetermined absolute humidity.

Further objects of the invention will become apparent from the following specification taken in connection with the drawings which form a part of this application, and in which

Fig. 1 is a diagrammatic view of a preferred and practical embodiment of the improved air conditioning apparatus.

Fig. 2 is a simplified diagrammatic view of the cycles of operation of the improved air conditioning apparatus.

Fig. 3 is a wiring diagram of the control apparatus.

Fig. 4 is a table showing the operation of the control elements during each cycle.

Fig. 5 is a perspective view of the improved counterflow air to air heat exchanger.

Referring to Fig. 1 and cycle A of Fig. 2, numeral 10 indicates generally an inlet duct through which air or gas to be conditioned is moved by a

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fan 12. One or more additional fans may be used at other points in the system if desired. The air then passes through a counterflow air to air heat exchanger 14 in which heat is transferred to the leaving cold air flowing in the opposite direction through the heat exchanger from duct 16. The air which is now precooled enters duct 18. Assuming that the apparatus is operating on cycle A of Fig. 2, the dampers are in the positions shown in Fig. 1, and the air flows through duct 20, the duct 22 being closed by damper 24. The air then passes over coil 26. The flow of refrigerant through coil 26 has been shut off, and the coil is therefore being defrosted by the air passing through it. The air then passes out of duct 20 into chamber 21, because damper 28 is open and damper 30 is in closed position with respect to duct 20. Since damper 31 is also closed the air passes through cooling coil 32 and into chamber 34. A refrigerant having an entering temperature of about 34° circulates through coil 32 so that the air leaving the coil is reduced in temperature to about 36°. Damper 36 is closed and damper 38 is open. The air therefore enters duct 22 and flows through cooling coil 40 which reduces its temperature to some predetermined point below freezing as 14° F. for example. Damper 30 being in open position with respect to duct 22, the air flows into duct 42. From duct 42 the air flows either through duct 16 or through duct 44 or in some proportion through duct 16 and duct 44 under the control of dampers 46 and 48, the operation of which will be described later. The air flowing through duct 16 passes through heat exchanger 14 and into duct 49. The air passing from duct 16 through heat exchanger 14 to duct 49 is raised in temperature and the air flowing in duct 10 through heat exchanger 14 to duct 18 is lowered in temperature. A heat exchanger 50 is interposed in the duct 49 for heating the air to still a higher temperature if desired.

After the apparatus has been operating on this cycle A for some time the coil 40 becomes frosted to an extent that the frost interferes with the flow of air through the coil and it also interferes with the heat transfer. Automatic means which will be fully described later responds to indications that the coil has become frosted to such an extent that defrosting is desirable, and said automatic means shifts the dampers 24, 28, and 34 to the positions shown in cycle B of Fig. 2 so that the air flows through duct 18, duct 22 and coil 40 to duct 42. During this cycle refrigerant is flowing through coil 26 to cool this coil from its defrosting temperature to its operating tem-

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perature. This cycle A to B has a duration of only a few minutes, and the automatic means then shifts dampers 30, 31, and 36 to the positions shown in cycle B of Fig. 2 so that the air flows from duct 18 through duct 22, coil 40, chamber 21, coil 32, chamber 34, duct 28, coil 26, and to duct 42. Refrigerant flow through coil 40 has been cut off, and the coil is being defrosted by the warm air passing through it. During cycle B defrigerant flows through coil 26 reducing its temperature to the aforementioned predetermined temperature of 14° F. When coil 26 has become frosted to a certain extent, automatic means shifts dampers 24, 31 and 36 to the positions shown in cycle B to A and refrigerant flow is started in coil 40 to bring it down to operating temperature. Cycle B to A has a duration of only a few minutes and dampers 28, 38, and 30 are then shifted to reestablish cycle A already described.

The refrigerant circuits will now be described. Referring to Fig. 1, a refrigeration machine 52 supplies a refrigerant such as chilled water, brine or other anti-freeze to coil 32 through supply pipe 54. A return pipe 56 connects the coil 32 with a circulating pump 58 and a pipe 60 connects the pump 58 to the machine. The refrigeration machine 52 is controlled to supply refrigerant having a temperature of about 34° and therefore coil 32 will not have any frost deposited thereon.

Coils 26 and 40 receive refrigerant such as brine or other anti-freeze from refrigerating machine 62 through pipes 64 and 66 respectively. Pipes 68 and 70 conduct the fluid from coils 26 and 40 respectively to a main return pipe 72 which is connected to circulating pump 74 which in turn is connected by pipe 76 to machine 62. Pneumatically operated valves 78 and 80 are interposed in pipe lines 68 and 70 respectively and control the flow of heat exchange fluid through coils 26 and 40 respectively. Valves 78 and 80 have been shown at the outlet side of coils 26 and 40, but it should be understood that these valves could be mounted at the inlet side if desired, and when a volatile refrigerant is used this location would be preferred. A pneumatic temperature controller 82 is connected to a thermally sensitive element 84 positioned in the air stream at the entrance to duct 42. The pneumatic temperature controller is connected to a pneumatic pressure source 86 and sends out a pressure signal to pneumatic valves 78 and 80 through pipes 88 and 90 respectively. Solenoid operated valves 92 and 94 are interposed in pipes 88 and 90. When valves 92 and 94 are energized they are in open position and allow the pressure signal from pressure controller 82 to reach the pressure chambers of valves 78 and 80 to control the amount of opening of valves 78 and 80. In closed position valves 92 and 94 close pipes 88 and 90 respectively and vent to the atmosphere and pressure chambers of valves 78 and 80 respectively allowing valves 78 and 80 to close.

Dampers 24 and 30 are moved by pneumatic damper motors 96 and 98 respectively. Motor 96 is connected by pipe 100 to solenoid operated valve 102 and motor 98 is connected by pipe 104 to solenoid operated valve 106. Valves 102 and 106 are similar in construction to valves 92 and 94 previously described and are connected to the pneumatic pressure source 86 by pipes 108 and 110 respectively. Pneumatic damper motor 112 operates dampers 36 and 31 which are connected

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together for simultaneous operation by link 114. Pneumatic damper motor 116 operates dampers 38 and 28 which are connected together for simultaneous operation by link 118. Motors 112 and 116 are connected by pipes 120 and 126 respectively, to solenoid operated valves 122 and 128 which are connected by pipes 124 and 130 respectively to pneumatic pressure source 86. Valves 122 and 128 are similar in construction to valves 92 and 94 previously described.

When the temperature of the outside air entering duct 18 drops below a certain figure there would be danger of frost accumulating in the heat exchanger 14. We therefore provide in the duct 14 a thermally sensitive element 132 connected to a pneumatic temperature controller 134 which is connected by pipe 136 to the pneumatic pressure source 86. The controller 134 sends out a signal through pipe 138 to pneumatic damper motor 140 which controls the positions of dampers 46 and 48. The dampers 48 are normally closed and the dampers 46 are normally open so that all of the air flowing in duct 42 flows through duct 18 and through heat exchanger 14 to duct 49. Temperature controller 134 prevents the temperature of the air in duct 18 from dropping below a predetermined temperature by adjusting the dampers 48 and 46 to by pass the necessary amount of the cooled air from duct 42 through duct 44. A heat exchanger 50 may be interposed in the duct 49 to heat the air flowing in duct 49. Condenser water from refrigerating machine 52 or 62 may be circulated in heat exchanger 50 if desired, or heat exchanger 50 may be connected to an independent source of heat exchange fluid. The air leaving the heat exchanger has therefore been conditioned to the desired temperature and relative humidity.

The mechanism for effecting the complete cycle of operation will now be described. A pressure switch PCB is mounted with pressure sensitive elements 144 and 146 mounted in duct 20, one at each side of the coil. A pressure switch PCA is mounted with pressure sensitive elements 150 and 152 mounted in duct 22. Pressure switch PCB is a normally closed switch which opens when the pressure drop through the coil 26 exceeds a predetermined amount indicating that the frost has accumulated to such an extent that the coil should be defrosted by changing the cycle. Pressure switch PCA is a normally open switch which closes when the pressure drop through coil 40 exceeds a predetermined amount.

Referring now to Fig. 4 which is a table of the cycles of operation and Fig. 3 which is a wiring diagram of the electrical controls, the letters CR are used to designate a control relay and letters TR are used to designate a time delay relay. In Fig. 4 an X indicates that the relay or solenoid is energized, and an O indicates that the relay or solenoid is de-energized. Time relays TRA and TRB are provided to change the cycle after a predetermined length of time, and the controls will operate on a time cycle in the event that the pressure switches PCA and PCB should fail to operate for any reason.

Assume now that cycle A has been operating for some time and coil 40 has become frosted to the extent that a change in cycle is desirable. Switch PCA will close responsive to the pressure drop through the coil and switch system to the A to B cycle. CR1 will be energized because PCB and TRB are normally closed. When winding CR1 is energized, it is maintained energized even

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though contact PCA may open, because contact CR1 bridges contact PCA. Windings TRB, TR2 and 102 are energized through contact CR1. Winding 106 is energized through normally closed contact TR2 and normally open contact CR1 which is closed. Windings 122 and 94 are energized by normally closed contact TR2. Windings 128 and 92 are energized through normally open contact CR1 which is closed. Damper controlling solenoid valves 102, 106, 122 and 128 are energized and damper motors are all under pressure as required for cycle A to B. Solenoid valves 92 and 94 are energized allowing pressure to reach refrigerant valves 80 to 78 which in turn allow refrigerant to flow in coils 40 and 26 as required for cycle A to B.

During cycle A to B, TR2 has been timing, and normally closed contact TR2 opens to initiate cycle B after the coil 26 has had time to be defrosted. Windings 106, 122, and 94 are thereby de-energized and dampers 30, 36 and 31 are shifted to the positions shown in cycle B. Solenoid valve 94 being de-energized valve 80 is closed and coil 40 receives no refrigerant and is therefore defrosted by the air flowing over it. Cycle B continues until pressure switch PCB opens indicating that coil 26 has become frosted to the extent that the B to A cycle should be initiated. In the event that PCB should fail to operate, time relay TRB which has been timing will open normally closed contacts TRB. In either event winding CR1 will be de-energized. Windings TRA and TR1 will therefore be energized by normally closed contact CR1. Windings TRB, TR2, and 102 will be de-energized because of normally open contact CR1. Winding 106 is de-energized because of normally open contacts CR1 and CR2. Windings 122 and 94 will be energized through normally closed contact CR1. Windings 128 and 92 will be energized through normally closed contact CR2. Since solenoid valves 122 and 128 are energized and solenoid valves 102 and 106 are de-energized the dampers will assume the positions shown in Fig. 2 cycle B to A. Since solenoid valves 92 and 94 are both energized coil 26 will be receiving refrigerant because it is carrying the refrigerating load and coil 40 will be receiving refrigerant in order that it may be precooled before receiving the refrigerating load.

Cycle B to A extends for a time interval long enough for coil 40 to be precooled and relay TR1 which has been timing then closes normally open contact TR1 to initiate cycle A. During cycle A, winding TRA remains energized through normally closed contact CR1. Winding CR2 is energized through normally open contact TR1 and normally closed contact CR1. Windings TRB, TR2, and 102 are de-energized because of normally open contact CR1. Winding 106 is energized through normally closed contact CR1 and normally open contact CR2. Windings 94 and 122 are energized through normally closed contact CR1. Windings 92 and 108 are de-energized because normally open contact CR1 and normally closed contact CR2 are both open. Since solenoid valves 102 and 128 are de-energized and solenoid valves 106 and 122 are energized the dampers will assume the positions shown in Fig. 1, and cycle A of Fig. 2. Since solenoid valve 92 is de-energized the flow of refrigerant to coil 26 will be shut off and coil 26 will be defrosting. Solenoid valve 94 being energized refrigerant will be flowing through coil 40 to carry the refrigerating load.

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The counterflow air to air heat exchanger 14 will now be described with reference to Fig. 5, which is a perspective view of the same with the top plate broken away to show the heat exchange fin. The body portion of the heat exchanger has generally the shape of a right rectangular parallelepiped, and each end has generally the shape of a right triangular prism. We prefer that each end of the exchanger should have sides which have an included angle equal to the included angle of the sides of the other end. It should be understood however that each end could have a different included angle if desired. A heat exchanger having ends having equal included angles is constructed by welding together into an integral whole a plurality of each of three different elements. These elements are plates 154, corrugated fins 156 and channels 158. The plates 154 are flat hexagonal sheets, and in the case of a heat exchanger having similar ends the opposite sides of the hexagon are parallel.

For purposes of description, the vertical sides of the exchanger are assigned designating letters C, D, E, F, G, and H as shown in Fig. 5 of the drawings. Sides E and F are completely closed by channel members 158. Sides C, D, G and H have alternate portions open and alternate portions closed by channels 158 to provide alternate passageways from sides D to G and C to H. The construction of the exchanger may best be described by reciting the steps of assembling the elements. One of the hexagonal plates 154 is first placed in the assembling jig. The channels 158 have two longitudinal portions making an angle with each other equal to the angle between the sides E and D, E and H, F and C, and F and G. A channel 158 is placed on the plate 154 with one portion extending along the side D and the other portion extending along the side E. Another channel 158 is placed on the plate 154 with one portion extending along the side F and the other portion extending along the side G. A corrugated rectangular fin is placed on the plate 154 so that it extends generally from side E to side F. A second plate 154 is added to the assembly so that it rests upon the fin 156 and the channels 158 previously assembled. The parts thus far assembled form a passageway between sides C and H. Two more channels are now placed on the second plate 154 with one channel extending along the sides E and H and another channel extending along the sides C and F. A second fin 156 and a third plate 154 are placed upon the assembly in the manner previously described. A second passageway has now been formed between the second and third plates; said passageway extends between sides D and G. The above procedure is continued until a heat exchanger of the desired size has been assembled. I prefer to make the heat exchanger of aluminum, but any suitable metal may be used if desired. The surfaces of the elements which contact the surface of another element are provided with a relatively thin coating of lower melting brazing alloy. The assembled heat exchanger is put into a salt bath to weld or "brazed" the elements into an integral unit. It should be understood that the welding can be accomplished provided at least one of any two contacting surfaces have welding material thereon. It should also be understood that the top and bottom plate 154 may be of heavier material than the intermediate plates 154 to reduce the danger of damaging the unit in handling. If desired the heat

exchanger 14 may be provided with corrugated triangular shaped fins between the plates 154 in the triangularly prismatic end portions. These triangular fins support the plates 154 during the welding operation and strengthen the completed unit. The spacing of the corrugations may be considerably greater than the spacings of the corrugations of the fin 156 to prevent substantial heat exchange in this cross flow region.

It is to be understood that various modifications and changes can be made in this invention without departing from the spirit and scope thereof as set forth in the claims.

We claim:

1. An air conditioning apparatus comprising an air to air heat exchanger having a first series of air passageways and a second series of air passageways in heat exchange relationship with each other, a casing having an inlet, an outlet, and two branch ducts connecting said inlet and said outlet, said inlet being connected to said first series of air passageways and said outlet being connected to said second series of air passageways, a chamber extending between said branch ducts, a cooling coil positioned in one of said ducts, a second cooling coil positioned in the other of said ducts, means for moving air through said first series of air passageways, then through said casing and then through said second series of air passageways, movable dampers for opening and closing each branch duct at each end, movable dampers for opening and closing each duct to the chamber at each side of each of the coils, means for controlling said dampers to provide for the flow of air through either of said ducts first as desired, and means for supplying refrigerant to the coil which is last in the path of air, a thermostat in the path of air leaving the casing, both of said last two mentioned means being responsive to said thermostat.

2. An air conditioning apparatus comprising an air to air heat exchanger having a first series of passageways for air entering the apparatus and a second series of passageways for air leaving the apparatus, a casing having an air inlet and an air outlet, said air inlet being connected to said first series of passageways, said casing having two branch ducts, a cooling coil positioned in one of said ducts, a second cooling coil positioned in the other of said ducts, a chamber extending between said branch ducts, means providing for the passage of air through said casing first through one duct and the cooling coil therein, then through the chamber and through the second duct and said cooling coil therein, means to selectively send the air through one or the other of said ducts first as desired, and means to supply refrigerant to which ever cooling coil is last in the path of air and to cut off the supply of refrigerant to the cooling coil in the other duct, a third duct connecting the outlet of said casing with said second series of passageways, and means for moving air through said first passageways, then through said casing, then through said third duct and then through said second series of passageways.

3. A method of conditioning air to a dew point below the freezing point of water comprising passing said air through an air to air heat exchanger, then passing said air through another heat exchanger reducing its temperature to some point above the freezing point of water, then passing said air through still another heat exchanger reducing its temperature to a point be-

low the freezing point of water, and then passing at least some of said air again through said air to air heat exchanger to heat said air.

4. An air conditioning apparatus comprising an air to air heat exchanger having a first series of air passageways and a second series of air passageways in heat exchange relationship with each other, a casing having an inlet connected to the first series of air passageways and an outlet connected to the second series of air passageways, a second heat exchanger mounted in said casing between said inlet and said outlet, means for moving air through said first series of air passageways then through said casing and the second heat exchanger mounted therein, and then through said second series of air passageways, and means for by-passing at least part of the air around said second series of air passageways.

5. An air conditioning apparatus comprising an air to air heat exchanger having a first series of air passageways and a second series of air passageways in heat exchange relationship, a casing having an inlet connected to said first series of air passageways and an outlet connected to said second series of air passageways, a second heat exchanger mounted in said casing between said inlet and said outlet, means for moving air through said first series of air passageways then through said casing and the second heat exchanger mounted therein, and then through said second series of air passageways, adjustable means for by-passing varying portions of the air around one of said series of air passageways, power means for adjusting said adjustable means, and thermostatic means upstream with respect to said second heat exchanger for controlling said power means to adjust said adjustable means to vary the amount of air which is by passed.

6. An air conditioning apparatus comprising an air to air heat exchanger having a first series of air passageways and a second series of air passageways in heat exchange relationship with each other, a casing having an inlet connected to said first series of air passageways and an outlet connected to said second series of air passageways, a second heat exchanger mounted in said casing between said inlet and said outlet, means for moving air through said first series of air passageways then through said casing and the second heat exchanger mounted therein and then through said second series of air passageways, a by-pass duct connected to said casing between said second heat exchanger and said outlet for by-passing air around said second series of air passageways, adjustable damper means for varying the proportion of air flowing through said by-pass duct and said second series of air passageways, power means for adjusting said adjustable damper means and thermostatic means upstream with respect to said second heat exchanger, said power means being responsive to said thermostatic means to adjust said adjustable damper means to vary the quantity of air which is by-passed.

7. A method of conditioning air to a dew point below the freezing temperature of water comprising passing said air through an air to air heat exchanger to cool said air to a temperature above the freezing point of water, then passing said air through one of two air to refrigerant heat exchangers to cool the air and raise the temperature of said one air to refrigerant heat exchanger, then passing said air through the

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other of said two air to refrigerant heat exchangers to cool said air to a temperature below the freezing point of water, then passing at least some of said air again through said air to air heat exchanger, then changing the path of air flow so that the air flows first through said other of said two air to refrigerant heat exchangers and then through said one air to refrigerant heat exchanger.

8. An air conditioning apparatus comprising an air to air heat exchanger having a first series of air passageways and a second series of air passageways in heat exchange relationship with each other, a casing having an inlet connected to the first series of air passageways and an outlet connected to the second series of air passageways, said casing having two branch ducts and a chamber extending between said branch ducts, a first cooling coil in the first branch duct, a second cooling coil in the second branch duct, a third cooling coil in said chamber. valve means providing for the passage of air through said casing, first through said first duct and the first cooling coil therein, then through the chamber and the third cooling coil therein and then through the second duct and the second cooling coil therein, means to selectively provide for the passage of air through one or the other of said ducts first as desired, means to supply refrigerant to whichever cooling coil is last in the path of air and to cut off the supply of refrigerant to the cooling coil in the other duct and means for moving air through said first series of air passageways, then through said casing and then through said second series of air passageways.

9. An air conditioning apparatus comprising an air to air heat exchanger having a first series of air passageways and a second series of air passageways in heat exchange relationship with each other, a casing having an inlet connected to the first series of air passageways and an outlet connected to the second series of air passageways, said casing having two branch ducts and a chamber extending between said branch ducts, a first cooling coil in the first branch duct, a

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second cooling coil in the second branch duct, a third cooling coil in said chamber, valve means providing for the passage of air through said casing first through said first duct and the first cooling coil therein, then through the chamber and the third cooling coil therein, and then through the second duct and the second cooling coil therein, means to selectively provide for the passage of air through one or the other of said ducts first as desired, means to supply refrigerant to whichever cooling coil is last in the path of air and to cut off the supply of refrigerant to the cooling coil in the other duct, means to supply refrigerant having a temperature not substantially less than 32° to said third cooling coil and means for moving air through said first series of air passageways then through said casing and then through said second series of air passageways.

10. A method of conditioning air to a dew point below the freezing point of water comprising passing said air through an air to air heat exchanger in one direction then passing said air through another heat exchanger reducing its temperature to some point above the freezing point of water, then passing said air through still another heat exchanger reducing its temperature to a point below the freezing point of water and then passing at least some of said air again through said air to air heat exchanger in a direction substantially parallel and opposite to said one direction.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,019,351	Lathrop	Oct. 29, 1935
2,093,968	Kettering	Sept. 21, 1937
2,159,570	Sewell	May 23, 1939