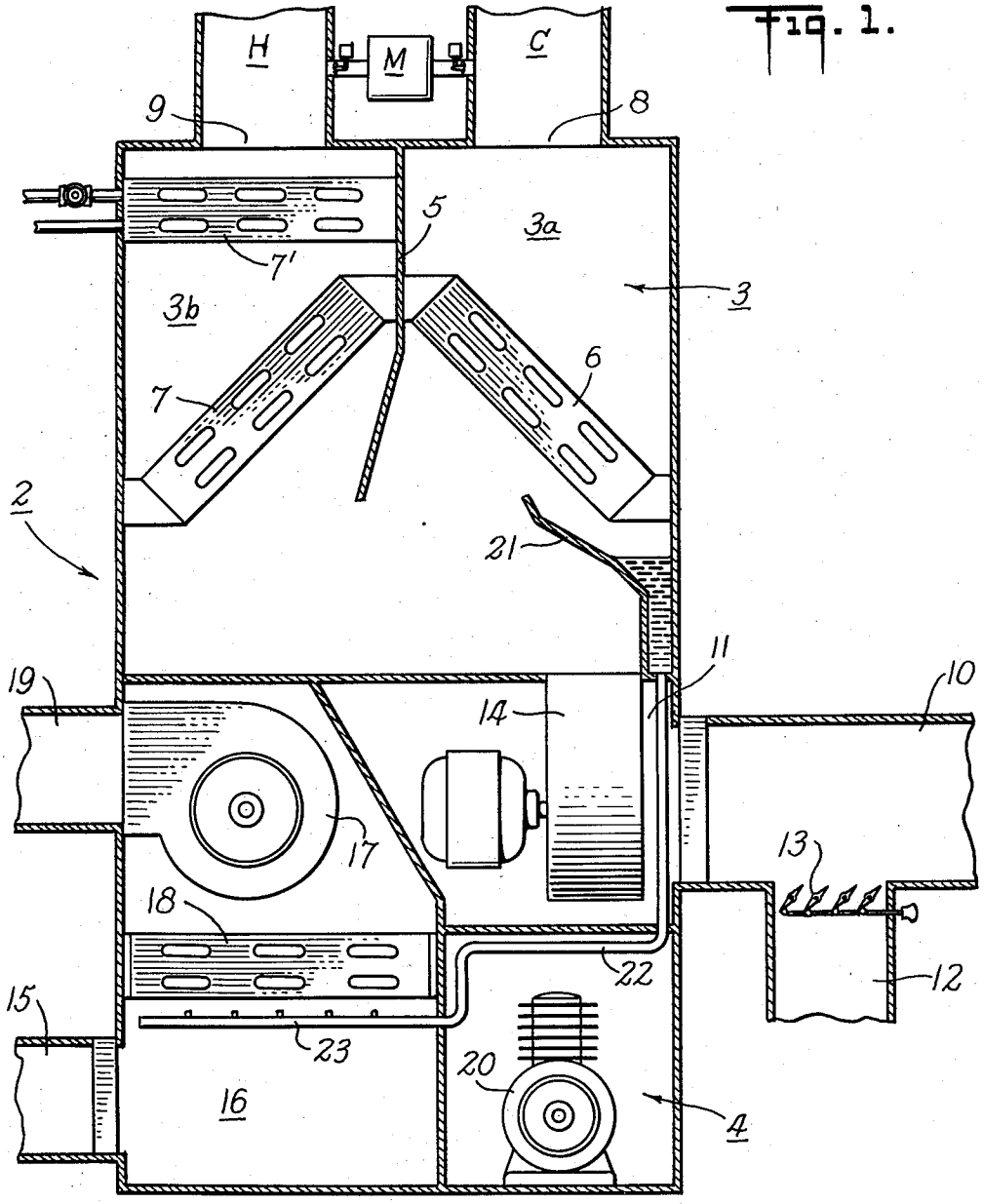
July 14, 1959 R. W. WATERFILL 2,894,375

AIR CONDITIONING AND HEAT PUMP SYSTEM

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Fig. 1.



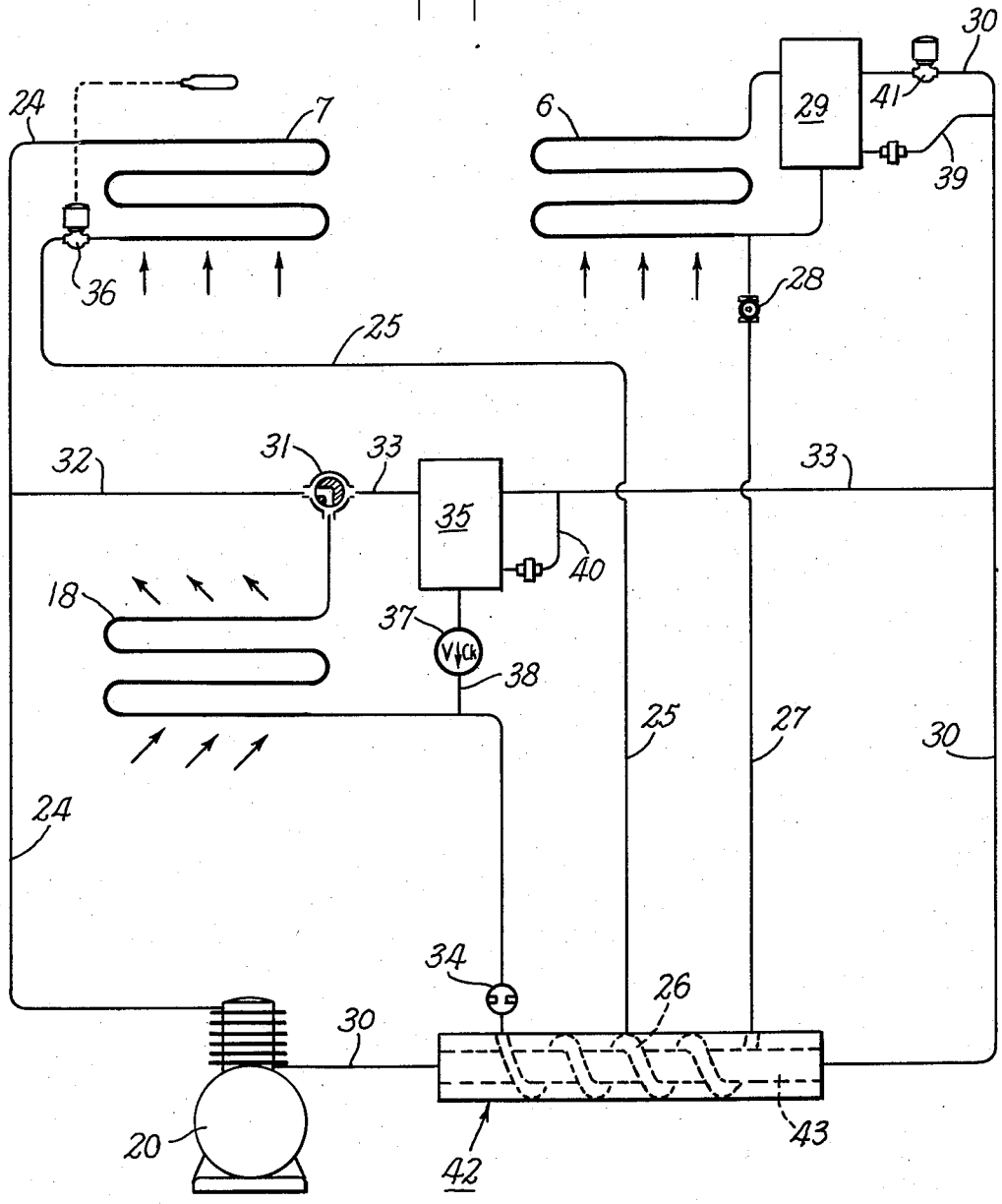
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Fig. 2.



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AIR CONDITIONING AND HEAT PUMP SYSTEM

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7 Claims. (Cl. 62—196)

This invention relates to air conditioning systems, and more in particular to such systems which are adapted for heat pump operation, that is, for heating the conditioned space during cool weather, as well as for cooling the conditioned space during hot weather.

An object of this invention is to provide a highly efficient and dependable air conditioning system, which is adapted to maintain desired temperature and humidity conditions within a zone or space. A further object is to provide such a system which utilizes a medium such as water or air from outside the conditioned space for the dissipation of excess heat and for acquiring heat when heating is required. A further object is to provide a system of the above character which constitutes a dependable and constant source of cold and hot air in separate streams for use as required as, for example, in a dual duct air conditioning system. A further object is to provide a system of the above character which has a heat exchange element which may be connected to operate as a condenser when rejection of heat from the system is required and to operate as an evaporator when the absorption of heat is required. A further object is to provide for the above with apparatus which is relatively simple in its operation, and which requires minimum changes in the mode of operation as the heating and cooling loads vary and particularly when the major load changes from heating to cooling, and vice versa. A further object is to provide for the above with air handling arrangements which are of simplified construction and operation. These and other objects are in part obvious, and in part pointed out below. In the drawings:

Fig. 1 is a sectional side elevational view of an air-conditioning apparatus constituting one embodiment of the present invention; and

Fig. 2 is a diagrammatic view of the heat exchange system used in the apparatus illustrated in Figure 1, and showing the valve means for connecting a heat exchange element for operation either as a second condenser or as a second evaporator.

The present invention relates generally to an air conditioning system which may have other applications, but is particularly adapted for and shown applied to a dual duct air conditioning system in the illustrated embodiment. Such a dual duct air conditioning system delivers separate streams of cold and hot air for selective use as required in a single compartment or a plurality of different compartments or zones of the enclosure to be conditioned. The separate streams of air are heated and cooled, respectively, by a single heat exchange system containing a working medium or refrigerant such as Freon. The heat exchange system comprises a condenser arranged in heat exchange relation with the stream of air to be heated, an evaporator arranged in heat exchange relation with the stream of air to be cooled and a conduit liquid refrigerant line connecting the condenser and evaporator. Suitable means such as a compressor withdraws vapor from the evaporator at low pressure and temperature and delivers it to the condenser at

a high pressure and temperature. In accordance with the present invention, an additional heat exchange element is provided which is adapted to act either as an auxiliary condenser to dissipate heat or as an auxiliary evaporator to absorb heat. This heat exchange element is arranged in heat exchange relation with a stream of a heat exchange medium from outside the enclosure to be conditioned, and is connected at one end to the conduit or liquid refrigerant line which extends between the condenser and evaporator to deliver liquid to the heat exchange element or to receive liquid therefrom. In the illustrated embodiment the heat exchange medium from outside the enclosure is a stream of ambient air, but it is to be understood that the medium may be water from a well or other source which constitutes either a source of heat or a heat sink to which heat is dissipated. A two-way valve is provided for connecting the opposite end of the heat exchange element to either the high pressure outlet from the compressor or to the low pressure inlet to the compressor. When the valve is positioned to connect the heat exchange element to the high pressure side of the compressor, the element operates as a condenser for rejecting heat to the stream of outside ambient air. When the valve is positioned to connect the heat exchange element to the low pressure side of the compressor, the element operates as an evaporator for acquiring heat from the stream of outside ambient air. Restricting means also are provided in the conduit means between the condenser, evaporator and heat exchanger to adapt the latter to operate either as a condenser or as an evaporator.

Referring to Fig. 1 of the drawings, a dual duct air conditioning apparatus is illustrated comprising a casing **2** divided horizontally to provide an upper air conditioning section **3** and a lower air handling and equipment section **4**. A vertically arranged septum **5** divides the upper portion of the conditioning section **3** into separate paths **3***a* and **3***b* for the flow of air to be conditioned. A cooling element or evaporator **6** is mounted in the path **3***a* for cooling the stream of air flowing therethrough and a heating element or condenser **7** is mounted in the path **3***b* for heating the air flowing through this other path. Separate outlet ports **8** and **9** lead from the separate cooling and heating paths **3***a* and **3***b* above the heating and cooling elements **6** and **7**, respectively, to deliver separate streams of cool and warm air through ducts C and H for use as required in one or a plurality of the different compartments or zones to be conditioned. A return air duct **10** is connected to the side of the casing **2** which opens into a suction chamber **11** in the lower equipment and air handling section **4** of the casing. A fresh air duct **12** may be connected to the return air duct **10** for mixing fresh air with the return air before it enters chamber **11**. The amount of fresh air supplied for mixture with return air is controlled by adjustable louvers **13** operated either manually or automatically by any suitable means. A fan **14** in chamber **11** delivers the mixed air into section **3** of the casing **2** for flow through paths **3***a* and **3***b*.

Outside air is supplied to a passageway **16** in the lower section **4** of casing **2** from a duct **15** and the air is continuously circulated through the passageway by a fan **17**. A heat exchange element **18** is mounted in the passageway **16** in heat exchange relation to the air circulating therethrough and the air is discharged from the passageway through duct **19**. Although not shown, it will be understood that the ducts **12**, **15** and **19** communicate with the ambient outside the enclosure to be conditioned. A compressor **20** is mounted in the base of the casing **2** is for supplying a working medium, i.e., refrigerant, to the cooling and heating elements **6** and **7** and heat exchange element **18**. An auxiliary heating element

7' may be mounted in the path 3*b* for supplying heat from any suitable source such as a steam boiler when additional heat is required for the particular climate where the air conditioning unit is installed. Underlying the cooling element 6 is a condensate disposal means 21 which is connected through a line 22 to a liquid distributor 23 for delivering the condensate onto the heat exchange element 18.

The heat exchange system for supplying a working medium, refrigerant, to the heat exchange elements 6, 7 and 18 is illustrated in Fig. 2 as comprising a line 24 from the compressor 20 for delivering refrigerant in vapor phase at high pressure and temperature to the condenser 7. Condenser 7 constitutes a heat rejecting element of the system through which the latent heat of vaporization flows from the relatively hot vapor therein to the stream of air flowing in the path 3*b* to simultaneously heat the air and condense the vapor to a liquid. The condensed refrigerant in liquid phase flows from condenser 7 through a line 25 to one passage 26 of a heat exchanger 42, later to be described in detail, which offers some resistance to flow and constitutes a restricting means.

Refrigerant in liquid phase flows through passage 26 of the heat exchanger 42 and line 27 to expansion valve 28 which restricts and regulates flow to the cooling element or evaporator 6, constituting a heat absorbing element of the heat exchange system. Thus, line 25, passage 26 of heat exchanger 42 and line 27, constitute a liquid refrigerant line for delivering liquid refrigerant from condenser 7 to evaporator 6. Heat flows from the stream of air circulated in path 3*a* to the working medium in the evaporator 6 which evaporates the liquid at a low pressure and temperature and cools the circulating air. An accumulator or surge vessel 29 is provided between the inlet to and outlet from evaporator 6 for separating liquid from vapor and storing surplus refrigerant in the system. Working medium in vapor phase is drawn from the separating or surge vessel 29 through a line 30 to the suction side of compressor 20. As indicated diagrammatically in Figure 1, air from the separate streams of warm and cool air in ducts H and C, respectively, are delivered to one or a plurality of mixing chambers M by any suitable control means for delivery to individual compartments to be conditioned. Each of the mixing chambers M has delivered to it the volume of hot and cool air to maintain its compartment or zone at the desired temperature. Hence, the total load on the system changes with changes in atmospheric conditions from day to day and from season to season. During the summer the load is predominantly a cooling load so that the heat from the condenser exceeds requirements and during the winter the load is predominantly a heating load so that the cooling from the evaporator exceeds requirements. However, with the dual duct air conditioning system as illustrated, a source of either warm or cool air is always available for delivery through the mixing chamber M to the various zones to be conditioned.

In accordance with the present invention, the heat exchange element 18 is arranged to be connected in the heat exchange system to operate as a second condenser when the load is predominantly a cooling load, or to be connected to operate as a second evaporator when the load is predominantly a heating load. Heat exchange element 18 may take any suitable form, but preferably is a coil connected at one end to the passage 26 of the heat exchanger 42, which constitutes a portion of the liquid refrigerant line through which liquid refrigerant flows from condenser 7 to evaporator 6. The opposite end of the heat exchange element 18 is connected to a two-way valve 31 which, in turn, is connected by a line 32 to the high-pressure line 24 from the compressor 20 and by a line 33 to the low-pressure return line 30 to the compressor.

Valve 31 may be of any suitable type and adapted for either manual or automatic operation. In the drawings, a plug type valve is illustrated which is adapted to be turned 90° from one to the other of its two positions. Thus, when valve 31 is in the position illustrated in Fig. 2, line 32 is connected to heat exchange element 18 to deliver working medium thereto in vapor phase at high pressure and temperature. The vapor is condensed in heat exchange element 18 and the liquid is delivered through a restricting device 34 in the form of an orifice to the passage 26 of the heat exchanger 42. By turning the valve 31 to its other position, line 33 connects the heat exchange element 18 to the low pressure of suction return line 30, to the compressor 20. Heat exchange element 18 then operates as an evaporator at low pressure to absorb heat at low temperature from the outside ambient and the heat is converted by the compressor 20 to a high temperature and delivered from the condenser 7 to the stream of air circulating in path 3*b*. An accumulator or surge vessel 35, similar to vessel 29, is connected in line 33 for separating liquid from vapor. Thus, when the heat exchange element is acting as an evaporator, the liquid refrigerant returns to the heat exchange element 18 through a line 38 having a check valve 37 therein, and the vapor flows to the compressor through line 33.

Condenser 7 operates as an air heating element so that it tends to maintain a stream of hot air in the heating path 3*b*. However, when the heating requirements are decreased, the flow of heated air is decreased correspondingly, and there is a corresponding decrease in the amount of heat delivered to the air stream by the condenser. A valve 36 is provided in the liquid line 25 leading from condenser 7, and the control bulb for this valve is positioned in the heated air stream flowing from the condenser. When maximum heating is required, the valve is fully open but, as the heating requirements decrease, the valve tends to close so as to accumulate liquid refrigerant in the coil, and thereby reduce the heat transfer to the air stream.

When valve 31 is positioned as shown, so that heat exchange element 18 acts as a condenser, it receives hot compressed gas from the compressor, and acts in parallel with condenser 7. The cooling of element 18 is maintained at such a level as to insure that condenser 7 will receive sufficient hot compressed gas to maintain the desired air heating effect. Element 18 is never cooled sufficiently to prevent condenser 7 from receiving the amount of hot compressed gas which is needed to produce the desired heating effect at that time. But element 18 is cooled sufficiently at all times to condense all of the refrigerant which is not required in condenser 7. With the arrangement shown, there is a tendency for the system to automatically take care of rather wide variations in the heating load without changing the cooling effect on element 18. In this embodiment, element 18 is cooled by ambient air circulated by fan 17. Hence, the cooling effect is reduced by reducing the fan speed or by even stopping the fan and, if desired, damper means may be provided. However, for most conditions of operation where there is a tendency for element 18 to be cooled excessively, the system will be switched over so that element 18 acts as an auxiliary evaporator in the manner now to be discussed.

When element 18 acts as an evaporator, valve 31 is positioned to connect element 18 to line 33 and thence to the low pressure return line 30 to the compressor 20, and the restricting device 34 operates as an expansion valve for liquid refrigerant flowing from passage 26 to element 18. The evaporator 6 and element 18 then operate in parallel between the heat exchanger 42 and the suction side of compressor 20. As indicated above, check valve 37 in line 38 connects the bottom of vessel 35 to the element 18, and permits the flow of liquid from the vessel to the element, but prevents flow in the opposite direction. Thus, liquid regrigerant cannot bypass the

heat exchange element during the time that the heat exchange element is acting as an evaporator.

The accumulator vessels **29** and **35** have bleed-off connections **39** and **40**, respectively, for returning oil to the compressor **20** and each bleed-off connection has a restrictor therein for limiting the flow of refrigerant therethrough to negligible quantities. A low pressure limiting valve **41** is preferably provided in line **30** from evaporator **6** for the purpose of maintaining the pressure of the refrigerant therein above a freezing temperature to prevent the accumulation of frost thereon. Valve **41** is preferably operated by the pressure in evaporator **6** to gradually close the valve when the pressure falls below a predetermined value and completely close the valve when the pressure approaches a value producing an evaporator temperature close to freezing.

Passage **26** of the heat exchanger **42** is illustrated in Fig. 2 in the form of a coil arranged adjacent to and in counter-current flow relation with the return line **30** from evaporator **6** to compressor **20**. The two passages **26** and **30** are embedded in a block **43** of heat conducting material such as a metal casting to provide a good heat exchange relation between the passages. Line **25** from condenser **7** is connected to the center of passage **26** of heat exchanger **42**, the heat exchange element **18** is connected to one end of the passage adjacent compressor **20** and line **27** is connected to the opposite end of the passage remote from the compressor. When heat exchange element **18** is operated as a condenser, hot liquid from both the element **18** and condenser **7** flows toward the right to the evaporator **6**, while cold vapor from the evaporator flows toward the left through return conduit **30** toward the compressor **20**. One form of the invention having now been described in detail, the mode of operation is explained as follows.

During the summer, when the load is predominantly a cooling load, but with some heating being required, the valve **31** is turned either manually or automatically to the position illustrated in Figure 2 to connect the heat exchange element **18** to the high pressure side of the compressor **20**. Working medium in vapor phase at high temperature and pressure then flows to the condenser **7** and the heat exchange element **18** connected in parallel. Condensed refrigerant from the condenser **7** flows to the right in passage **26**, joining condensed refrigerant from the heat exchange element **18** to form the stream of liquid refrigerant flowing to the evaporator. As indicated above, passage **26** provides a connection between heat exchange element **18** and both the condenser and the evaporator and, during the time when element **18** is acting as an evaporator, the main flow from line **25** is to the left. However, with the predominant cooling load, as now being discussed, the entire flow in passage **26** is to the right, and thence through line **27** and expansion valve **28** to the evaporator **6** at a reduced pressure. The refrigerant evaporates at a low pressure and temperature to cool the stream of air flowing through path *3a*.

The vapor from the evaporator **6** flows through the vessel **29** and low pressure return line **30** to the suction side of compressor **20** in heat exchange relation and counter-current to the liquefied working medium flowing through the passage **26** of heat exchanger **42** to the evaporator **6**.

Return air in duct **10** and fresh air in duct **12** are mixed in the desired proportion under the control of the adjustable louvers **13**. The air is delivered by the fan **14** into the conditioning section of casing **2** under pressure. A portion of the air flows through path *3a* in heat exchange relation with the evaporator **6** where it is cooled and a portion flows through path *3b* in heat exchange relation with condenser **7** where it is heated.

The warm and cool air streams flow through ducts H and C to one or a plurality of mixing boxes M as controlled by a humidistat or thermostat in the enclosures to be conditioned. The warm air may be used to heat certain compartments such as sub-basements or may be mixed with cold dehumidified air to temper the air before it is delivered to the enclosure.

When the heating by condenser **7** exceeds requirements, valve **36** restricts the flow of condensate therefrom in accordance with the temperature of the warm air stream. This causes condensate to back up into the condenser and reduce its heat transfer surface and increase the pressure therein. As the pressure in condenser **7** increases above the pressure drop through the heat exchange element **18**, resulting from the restricting device **34**, the proportion of vapor flowing to and condensed in the element increases with a corresponding decrease in the vapor flowing to and condensed in the condenser. In other words, less heat is rejected from the refrigerant through condenser **7** to heat the air in path *3b*, and more heat is rejected through the heat exchange element **18** to the outside ambient. Thus, the condenser **7** and the heat exchange element **18** cooperate to automatically adjust the proportion of heat dissipated to the air stream to be conditioned and the outside ambient, respectively, in accordance with requirements for any operating condition.

During the winter, when the load is predominantly a heating load with some cooling required, the valve **31** is turned through an angle of 90° either manually or automatically to connect the heat exchange element **18** to the low pressure return line **30**. Working medium supplied to the condenser **7** condenses therein and the liquid is delivered to passage **26** of heat exchanger **42**. The liquid working medium then flows to both the evaporator **6** and heat exchange element **18**. The outside air supplies heat at low temperature to the working medium in heat exchange element **18** as it is circulated and evaporated. The vapor then flows through the three-way valve **31** and lines **33** and **30** to the compressor **20**. Heat also is supplied to the working medium in the evaporator **6** to evaporate the working medium therein, and the vapor therefrom flows from the evaporator to the compressor **20**. In the compressor **20** the working medium is compressed to a high pressure and temperature and delivered through the line **24** to the condenser **7** where its latent heat of vaporization is transferred to the stream of air flowing in heat exchange relation thereto. When required, additional heat is supplied to the stream of air from the auxiliary heating coil **7'**. The hot air then flows through the outlet **9** to the hot-air duct H where it is delivered to the mixing boxes M for the various compartments to be conditioned. Simultaneously, air from the stream cooled by evaporator **6** is supplied to those enclosures that require cooling. Valve **41** maintains the desired low temperature in evaporator **6**, and prevents accumulation of ice. When there is no cooling load, there may be only a small seepage of liquid refrigerant through the circuit of evaporator **6**, but the system is conditioned for immediate cooling operation at all times. It has been indicated above that, when the system is operating with a maximum cooling load, valve **36** may be completely closed, and condenser **7** may be completely filled with liquid refrigerant. However, at any time that there is a demand for heating, the condenser immediately performs its heating function.

It will now be observed that the present invention provides a heat exchange system which is particularly adapted for use in a dual-duct air conditioning apparatus and operates to regulate the relative proportions of heat rejected to and absorbed from the ambient and the air supplied to the enclosures to be conditioned. It will further be observed that a heat exchange element is provided which may be connected in the system to operate either as a second condenser or as a second evaporator for cooling or heating. It will further be observed that the heat exchange system provides for an exchange of heat between the vapor flowing to the compressor and the liquid flowing from the condenser to the evaporator. The present invention provides a novel heat exchange

system in a dual-duct type air conditioning apparatus which is of simple and compact construction and adapted for economical manufacture and use.

While a single embodiment of the invention is herein illustrated and described, it will be understood that changes may be made in the construction and arrangement of elements without departing from the spirit or scope of the invention. For example, for some systems, the restricting means between the heat exchange element and heat exchanger 42 is in the form of a valve which restricts flow in one direction and permits unrestricted flow in the opposite direction or may comprise valves arranged in parallel paths of flow with one constructed and arranged to permit restricted flow in one direction and prevent flow in the other direction and the other of which prevents flow in said one direction and permits unrestricted flow in the other of said directions. Therefore, without limitation, the invention is defined by the following claims.

I claim:

1. In an air conditioning system for an enclosure, means forming a dual-duct air supply system formed by a hot air duct and a cold air duct and means to direct a stream of air from a common source to said ducts thereby to maintain constant supplies of air in both of said ducts, a refrigeration system having a condenser in said hot air duct and an evaporator in said cold air duct and also having an auxiliary unit which is adapted to act alternately as an auxiliary condenser and evaporator, means to pass a heat interchange medium into heat interchange relationship with refrigerant in said auxiliary unit thereby to dissipate heat from the refrigerant when said auxiliary unit is acting as a condenser and to deliver heat to the refrigerant when said auxiliary unit is acting as an evaporator, said refrigeration system including refrigerant lines and valve means to connect said auxiliary unit alternately in parallel refrigerant flow relationship with said condenser or with said evaporator, restrictor means which acts an an expansion valve when said auxiliary unit is acting as an evaporator and which restricts the flow of liquid refrigerant from said auxiliary unit when said auxiliary unit is acting as a condenser, and said restrictor means comprising a fixed restrictor and a temperature responsive restrictor on the liquid outlet from said condenser responsive to the temperature of the air in said hot air duct.

2. Apparatus as described in claim 1, which includes a bypass line having a check valve therein and connected in parallel relationship with said auxiliary unit when said auxiliary unit is acting as an evaporator.

3. Apparatus as described in claim 2, which includes a heat interchange unit having a refrigerant passageway through which gas refrigerant flows to said compressor and having a liquid refrigerant passageway the central portion of which is connected to said condenser and the ends of which are connected respectively to said auxiliary unit and to said evaporator.

4. Apparatus as described in claim 3, which is in the form of a unitary construction and which includes a vertical casing construction which is divided into compartments forming passageways for the flow of air and which includes an auxiliary heating coil downstream from said condenser and said hot air duct.

5. Apparatus as described in claim 4, which includes a single fan that circulates air through said ducts and wherein said heat transfer medium is air and said apparatus includes an air circulating fan for circulating air through said auxiliary unit.

6. Apparatus as described in claim 5, which includes means to collect condensate from said evaporator and to deliver the condensate in the stream of air flowing through said auxiliary unit.

7. In an air conditioning system for an enclosure, means forming a dual-duct air supply system formed by a hot air duct and a cold air duct and means to direct a stream of air from a common source to said ducts thereby to maintain constant supplies of air in both of said ducts, a refrigeration system having a condenser in said hot air duct and an evaporator in said cold air duct and also having an auxiliary unit which is adapted to act alternately as an auxiliary condenser and evaporator, means to pass a separate heat interchange medium into heat interchange relationship with refrigerant in said auxiliary unit thereby to dissipate heat from the refrigerant when said auxiliary unit is acting as a condenser and to deliver heat to the refrigerant when said auxiliary unit is acting as an evaporator, said refrigeration system including refrigerant lines and valve means to connect said auxiliary unit alternately in parallel refrigerant flow relationship with said condenser or with said evaporator, said refrigerant lines comprising a common connection between the condenser, evaporator and auxiliary unit, and restrictor means in the common connection including an expansion valve adjacent the evaporator and restricting orifice adjacent the auxiliary unit which acts as an expansion valve when said auxiliary unit is connected by the valve means to operate as an evaporator and which restricts the flow of refrigerant from said auxiliary unit when the latter is connected by the valve means to operate as a condenser.

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