

Dec. 28, 1965

E. S. STEVENS

3,225,819

APPARATUS AND METHOD FOR AIR TO AIR HEAT EXCHANGE

Filed Aug. 31, 1962

4 Sheets-Sheet 1

FIG. 1

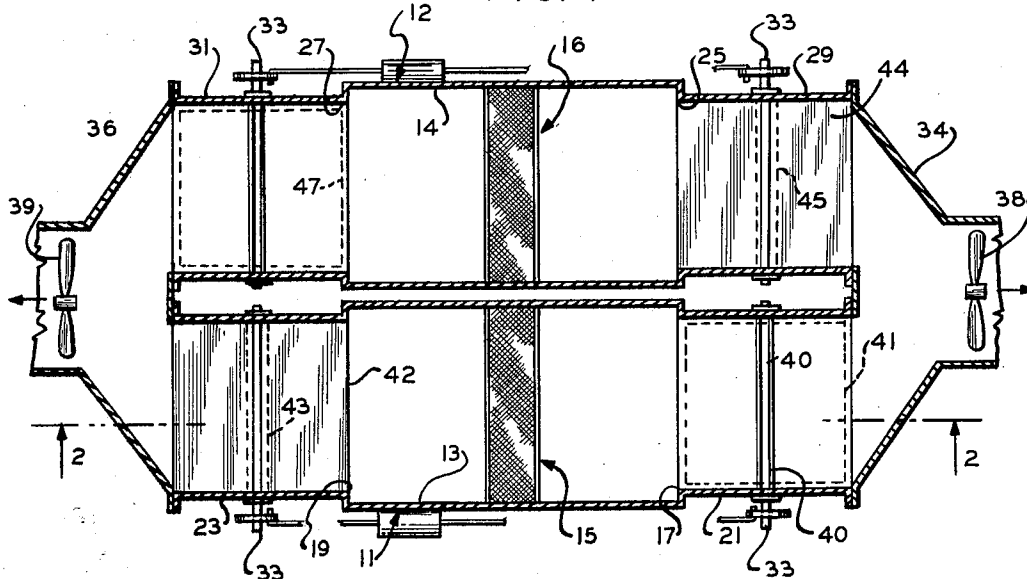
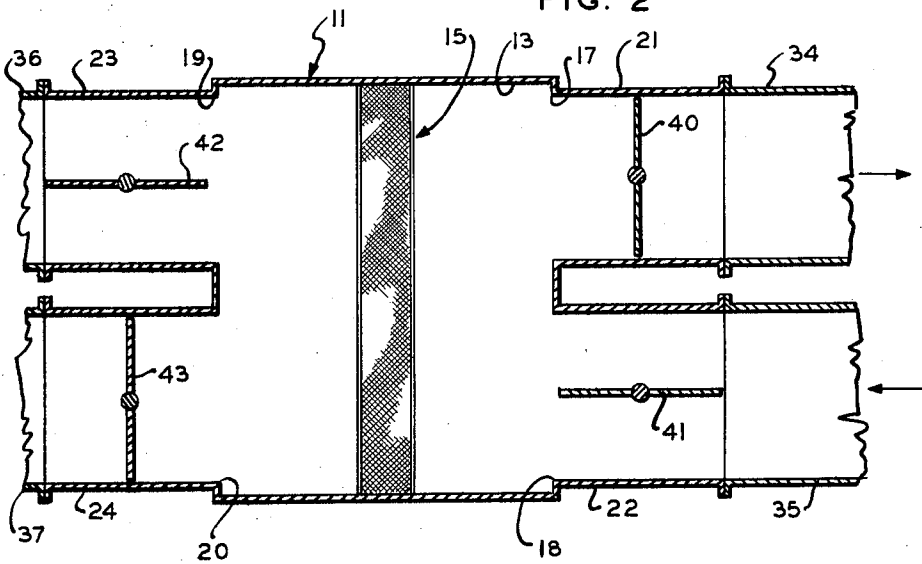


FIG. 2



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E. S. STEVENS

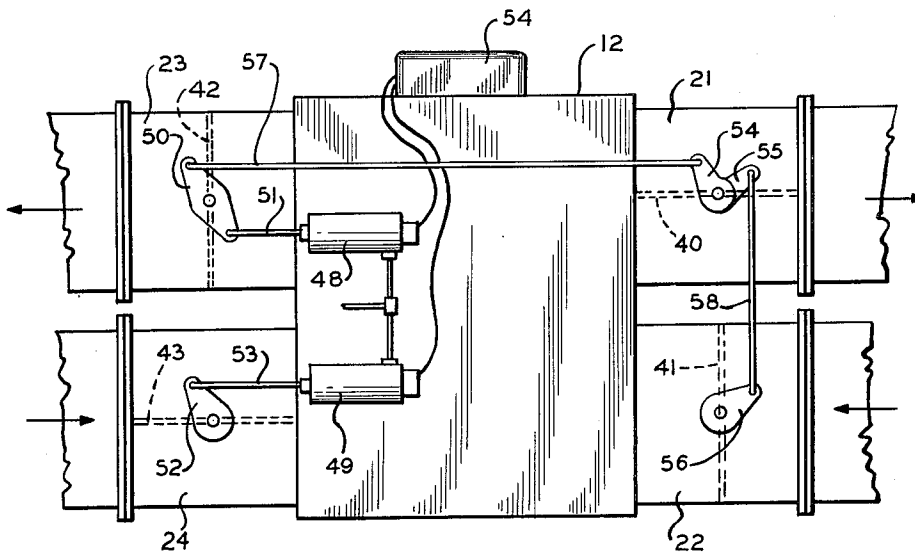
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4 Sheets-Sheet 2

FIG. 3



INVENTOR
EDDIE S. STEVENS
BY *John H. Davis*
ATTORNEY

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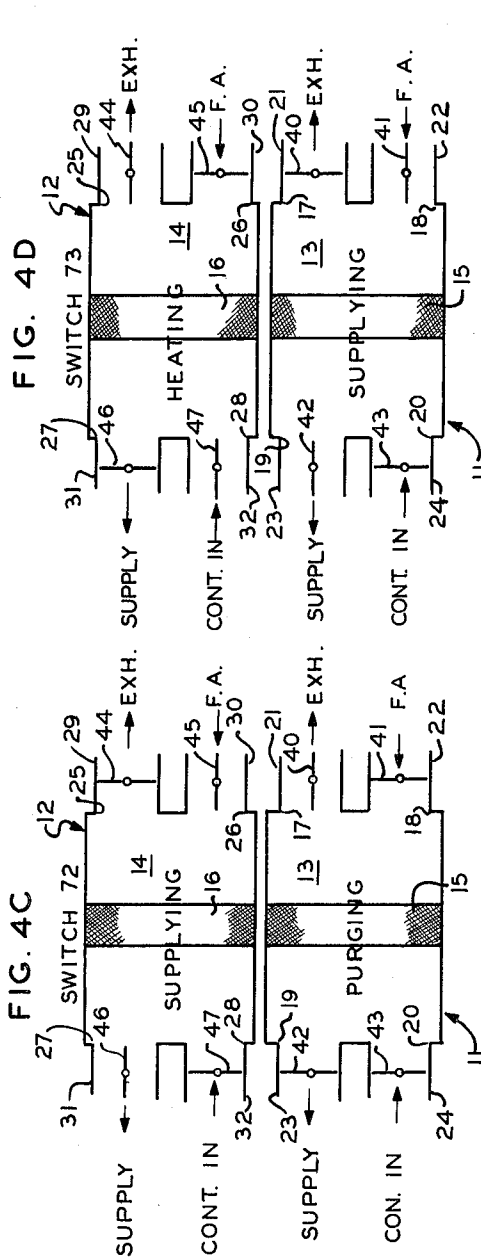
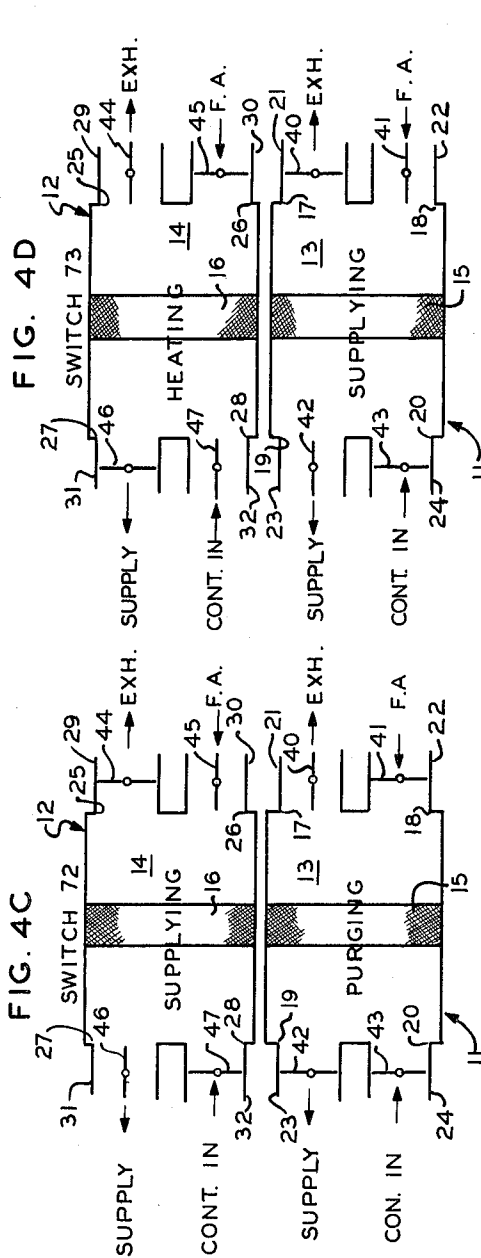
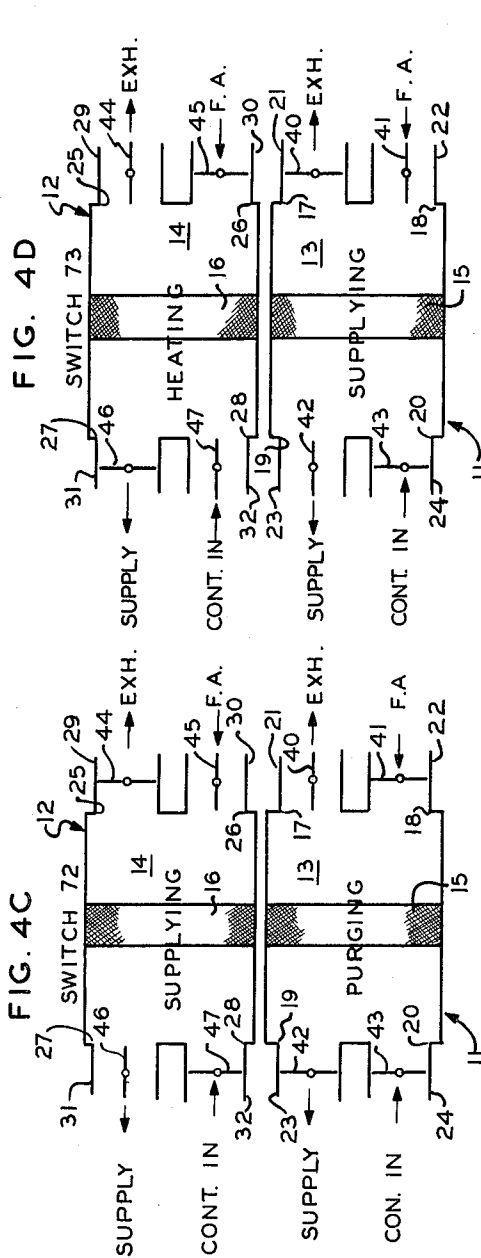
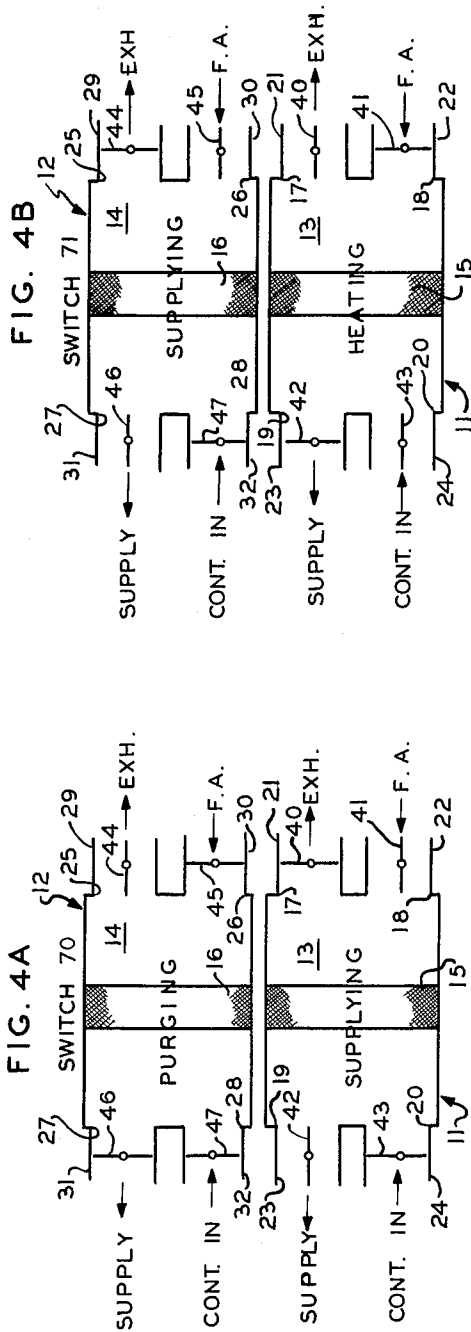
E. S. STEVENS

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APPARATUS AND METHOD FOR AIR TO AIR HEAT EXCHANGE

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4 Sheets-Sheet 3



INVENTOR
EDDIE S. STEVENS

BY *John H. Bain*
ATTORNEY

Dec. 28, 1965

E. S. STEVENS

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4 Sheets-Sheet 4

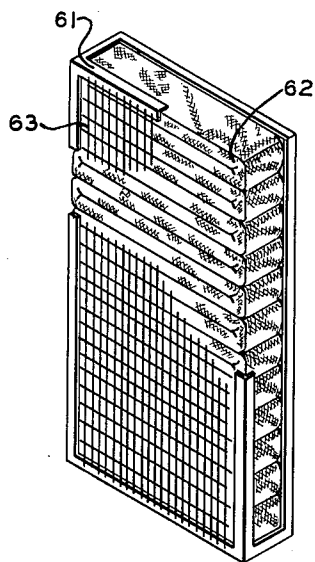
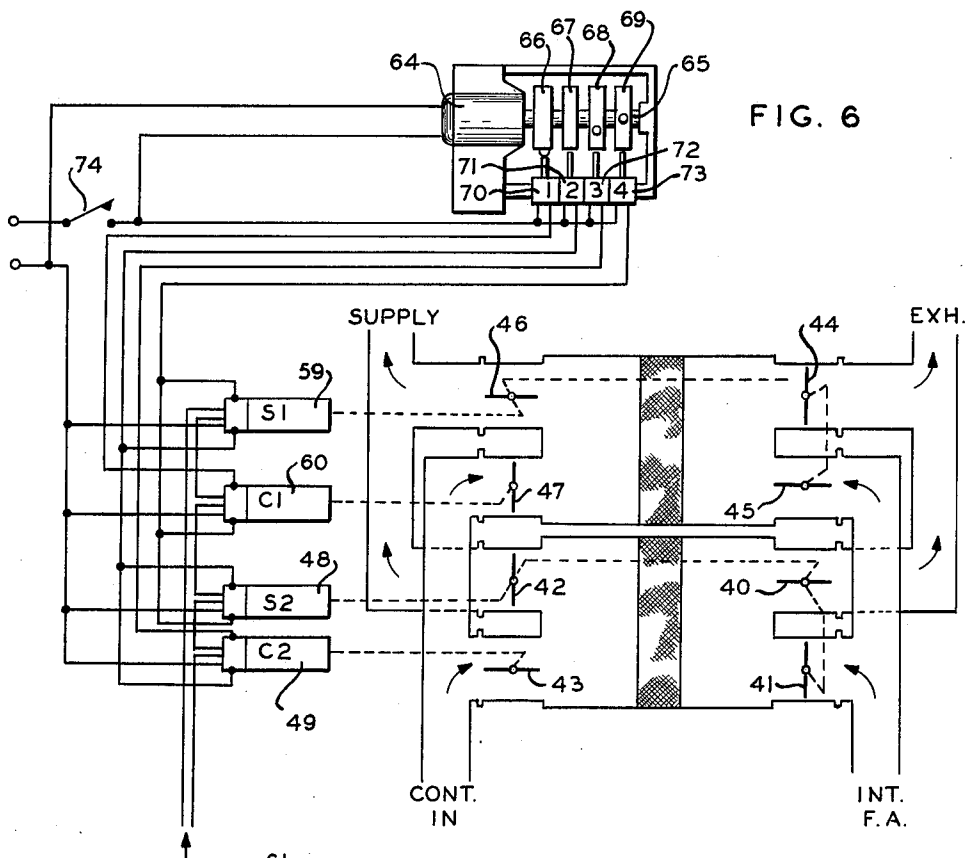


FIG. 5

INVENTOR
EDDIE S. STEVENS
BY *John N. Bain*
ATTORNEY

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3,225,819

APPARATUS AND METHOD FOR AIR TO AIR HEAT EXCHANGE

Eddie S. Stevens, Orange, N.J., assignor to

Daniel Moretti, East Orange, N.J.

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2 Claims. (Cl. 165-2)

My invention relates generally to air to air counterflow heat exchangers and to methods for effecting air to air counterflow heat exchange and specifically to an air to air counterflow heat exchanger and a method for operating such a heat exchanger, employing two separate and distinct heat exchange chambers having stationary but removable heat exchange media mounted therein in which each chamber communicates on one side with a plenum adapted to supply cold, fresh air to the chamber and a separate plenum adapted to receive cooled contaminated exhaust air from the chamber; and the opposite side of each chamber communicates with a plenum adapted to supply hot contaminated air to the chamber and a separate plenum adapted to receive pre-heated fresh air from the chamber.

The counterflow principle is well-known in the air to air heat exchanger art to result in high levels of efficiency. This principle of counterflow is employed in the so-called Lungstrom wheel or rotary heat exchanger. In the rotary heat exchanger, a rotatable wheel is provided with a plurality of radial spokes dividing the wheel into separate, wedge-shaped sectors. Each sector is provided with some suitable heat exchange media which is adapted to pass air therethrough. The wheel is mounted with its face generally perpendicular to the direction of flow of hot contaminated exhaust gases from some industrial process and cold fresh air flowing in the opposite direction. The two air streams are separate and distinct and counterflow with respect to each other, the hot contaminated gas passing through one-half of the wheel while the cold, fresh air simultaneously passes in the opposite direction through the other half of the wheel. As the wheel rotates, the heat exchange material first passes through the hot, contaminated, exhaust gas stream absorbing heat therefrom and then through the cold, fresh air stream releasing its heat thereto. All rotary air to air heat exchangers have several important disadvantages. They are extremely costly to manufacture and require expensive and inordinately large installations. In addition, such installations require bushings, bearings, motors, gears and pulleys which are subject to wear, particularly if high temperatures are employed thereby resulting in high maintenance costs. As a functional consideration, the rotary heat exchanger inevitably permits a substantial amount of contaminated air carry over from the contaminated air stream into the fresh air stream. Still further, the rotating wheel is subject to thermal distortion which is accentuated by high temperatures for which the rotary exchanger is allegedly most adaptable. The wheel thus becomes generally concave or dish-shaped along a plane perpendicular to its axis causing a considerable amount of air leakage which substantially reduces the overall efficiency of the installation. Thus, there is at present great need for a less costly, more compact and more efficient heat exchanger which is adapted to operate over wide temperature ranges including extremely high temperatures.

Therefore, it is among the objects and advantages of my invention to provide apparatus and methods for air to air heat exchange in which there is an alternate counterflow of hot, contaminated exhaust air with respect to cold, fresh air through a heat exchange media.

Another object of my invention is to provide apparatus and methods for air to air heat exchange employing two

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separate and distinct heat exchange chambers having stationary but removable heat exchange media mounted therein.

A further object of my invention is to provide apparatus and methods for air to air heat exchange employing two separate and distinct heat exchange chambers in which one chamber supplies preheated fresh air for use while the other chamber simultaneously recovers heat from a stream of hot contaminated exhaust air, the chambers periodically alternating their respective functions.

Still another object of my invention is to provide apparatus and methods for air to air heat exchange employing two separate and distinct heat exchange chambers in which each chamber communicates on one side with a plenum adapted to supply cold, fresh air to the chamber and a separate plenum adapted to exhaust cooled, contaminated air therefrom, and the opposite side of each chamber communicates with a plenum adapted to introduce hot contaminated air to the chamber and a separate plenum adapted to exhaust preheated fresh air therefrom.

Yet another object of my invention is to provide apparatus and methods for air to air heat exchange in which each duct either supplying or receiving air from each chamber is provided with a rotatable damper which is adapted to automatically open and close in timed relationship to each of the other dampers on each chamber.

Still a further object of my invention is to provide apparatus and methods for air to air heat exchange in which the plenums on the respective sides of each chamber are each provided with means adapted to generate negative pressure within each of the chambers.

A still further object of my invention is to provide apparatus and methods for air to air heat exchange in which the counterflow principle may be employed with stationary heat exchange media.

Yet another object of my invention is to provide apparatus and methods for air to air heat exchange employing the counterflow principle in which there is no carry-over of contaminated gases from the contaminated stream to the fresh air stream.

Another object of my invention is to provide apparatus and methods employing the counterflow principle in which each of two separate heat exchange chambers may be purged of contaminated air before fresh air is admitted thereto.

Still another object of my invention is to provide apparatus and methods for air to air heat exchange wherein thermal expansion of parts of the apparatus will not produce warping or cause air leakage or contaminated air carry-over into the fresh air stream.

A further object of my invention is to provide apparatus and methods for air to air heat exchange in which the heat exchange media and the heat exchange chambers are both stationary and the entire apparatus employs no large or heavy moving parts requiring bearings, seals or other friction reducing means.

Yet a further object of my invention is to provide apparatus and methods for air to air heat exchange employing two separate heat exchange chambers which may be mounted immediately adjacent to each other or at distant locations, each chamber being connected to a plurality of ducts and plenums which may become integral parts of the apparatus.

Still a further object of my invention is to provide apparatus and methods for air to air heat exchange in which the normal expansion of portions of the apparatus and connective equipment will not result in air leakage or contaminant carry-over.

Another object of my invention is to provide apparatus and methods for air to air heat exchange in which the

apparatus has a relatively low cost of production and installation with minimal maintenance.

These objects and advantages as well as other objects and advantages may be achieved by my invention, one embodiment of which is illustrated in the drawings in which:

FIGURE 1 is a top plan cross-sectional view of two separate heat exchange chambers showing conduits communicating therewith with dampers mounted therein.

FIGURE 2 is a side elevational cross-sectional view taken along line 2—2 in FIGURE 1 looking in the direction of the arrows.

FIGURE 3 is a side elevational view of my heat exchangers showing the damper control system on one side thereof.

FIGURE 4a, 4b, 4c, and 4d are schematic views of my heat exchanger showing the relative positions of the respective dampers during four cycles in the operation of the exchanger;

FIGURE 5 is a partially cut away view in perspective of a heat exchange unit adapted for mounting within one of the chambers;

FIGURE 6 is a circuit diagram of the control mechanism for the dampers.

Referring now to the drawings in detail, my heat exchanger comprises a pair of generally rectangular housings 11 and 12 defining, respectively, generally rectangular heat exchange chambers 13 and 14. A generally rectangular heat exchange unit, respectively 15 and 16, is mounted transversely across each of the respective chambers 13 and 14. Each end of housing 11 is provided with a pair of vertically aligned, generally rectangular openings, respectively 17, 18 and 19, 20. A generally rectangular conduit, respectively 21, 22, 23 and 24, is mounted on the end of the housing 11 communicating respectively with the openings 17, 18, 19 and 20. The conduits 21, 22, 23 and 24 are generally parallel to each other and generally perpendicular to the heat exchange unit 15, on opposite sides thereof.

In like manner, housing 12 is provided with a pair of vertically aligned, generally rectangular openings in each of its opposed ends, respectively 25, 26, 27 and 28. Generally rectangular conduits, respectively 29, 30, 31, and 32 are mounted on opposite ends of the chamber 12 communicating respectively with the openings 25, 26, 27 and 28.

Transverse shafts 33 are rotatably mounted across each of the conduits 21, 22, 23, 24, 29, 30, 31 and 32.

Conduits 21 and 29, communicating respectively with chambers 13 and 14, are connected to, and communicate with a common plenum 34. In like manner, conduits 22 and 30, also communicating respectively with chambers 13 and 14 and located beneath conduits 21 and 29, are connected to, and communicate with common plenum 35. Conduits 23 and 31 are connected to and communicate with a common plenum 36. Similarly, conduits 24 and 32, located beneath conduits 23 and 31 and communicating respectively with chambers 13 and 14 are connected to and communicate with a common plenum 37.

Air pump or exhaust means 38 are mounted in the common plenum 34 and is adapted to generate a vacuum in either of chambers 13 or 14. Similarly, an air pump or exhaust means 39 is mounted within the plenum 36 and is adapted to generate a vacuum in either of chambers 13 and 14.

Butterfly type dampers 40, 41, 42, 43, 44, 45, 46 and 47 are mounted for rotation on shafts 33 in, respectively, conduits 21, 22, 23, 24, 29, 30, 31 and 32. When rotated to a position generally perpendicular to the end of each housing, 11 and 12, the respective dampers will close the respective conduits.

The butterfly dampers are adapted to periodically rotate with shafts 33 in timed relationship with each other. The dampers are controlled by an electro-mechanical sys-

tem shown in FIGURE 3 and illustrated in the schematic wiring diagram of FIGURE 6. Referring to FIGURE 3, there is shown an electro-mechanical system which controls the dampers in the conduits communicating with chamber 13. There is an identical system controlling the dampers in the conduits communicating with chamber 14. A pair of electrically operated solenoids 48 and 49 are mounted on the side of housing 11. A transverse cross arm 50 is mounted for rotation with shaft 33 extending transversely through conduit 23, on the outside thereof. An operating rod 51 connected to the armature of solenoid 48 is pivotally connected to one side of the cross member 50. The shaft 33 mounted transversely across the conduit 24 is provided with an offset arm 52 adapted to rotate therewith. An operating rod 53 connected at one end to the armature of solenoid 49 is pivotally connected at its opposite end to offset arm 52. A pair of offset arms 54 and 55 are mounted for rotation with shaft 33 extending transversely across conduit 21; the arms 54 and 55 being mounted at approximately right angles to each other. A single offset arm 56 is mounted for rotation on the end of shaft 33 extending transversely through conduit 22. A connecting rod 57 is pivotally mounted at one end to the end of cross arm 50 opposite rod 51 and at its opposite end to offset arm 54. Similarly, a connecting rod 58 is pivotally mounted at one end to offset arm 55 and at its opposite end to offset arm 56. Thus, movement of operating rod 51 connected to the armature of solenoid 48 will actuate dampers 42, 40 and 41. Operating arm 53 connected to the armature of solenoid 49 operates only damper 43.

In an identical manner on the opposite side of the heat exchanger, solenoids 59 and 60 operate the dampers in the conduits communicating with chamber 14. In this regard, solenoid 59, shown schematically in FIGURE 6, operates dampers 46, 44 and 45 mounted respectively, transversely through conduits 31, 29 and 30. Solenoid 60 operates only damper 47 in conduit 32. The dotted lines in FIGURE 6 represent operating rods and connecting arms as shown in FIGURE 3.

The structure of the heat exchange units, 15 and 16, is shown in detail in FIGURE 5. Each unit comprises a generally rectangular frame 61 which is adapted for mounting within chambers 13 and 14 to extend transversely thereacross generally parallel to the ends thereof, perpendicular to the sides thereof and perpendicular to the direction of movement of air through the respective chambers. The frame 61 is packed with some suitable heat exchange media 62. In FIGURE 5, the media is shown to be a continuous strip of knitted or woven filamentous material mounted in the frame with its edges extending transversely across each of the chambers, generally perpendicular to the path of air movement therethrough and folded over itself in a series of layers extending from the bottom of each chamber to the top thereof. A plurality of wires 63 are mounted across the frame 61 from top to bottom to retain the heat exchange media 62 therein against accidental displacement. The media 62 may be woven from any suitable metal such as stainless steel, copper, aluminum, nickel or any other metal which has a high heat capacity and is chemically resistant to substances which may be entrained in the air passing therethrough. In addition, a non-metal such as fiber glass may be employed instead of a metal. Fiber glass is particularly useful in highly acid atmospheres. Still further, combinations of woven or knitted fiber glass and some metal such as stainless steel may be employed. In this regard, the stainless steel provides the fiber glass with mechanical body support. It is also proper to employ a filamentous wool material having its filaments lying in random directions. For instance, the frame may be filled with steel wool, aluminum wool or copper wool. The packing density of the heat exchange media 62 is a function of the permissible limits of pressure drop across the unit. Obviously, the less dense the packing media, the

less severe will be the pressure drop. It should also be born in mind that the heat exchange media would extend in sheets lying in planes generally perpendicular to the direction of air movement through the chambers 13 and 14. The diameter of the filaments employed is not critical excepting that the filaments should be mechanically strong enough to withstand the movement of air therethrough and to be resistant to crushing under its own weight. In addition, the diameter of the filaments should not be too great since the thinner the filament, the greater the heat exchange area per unit and weight. This is the finning effect which is derived from use of filamentous material. Although it is preferred to use a filamentous material, a heat exchange plate having many configurations either perforated or unperforated could be employed so long as air is able to move therethrough or therebetween.

The rotation of the respective dampers is controlled by the electro-mechanical system shown schematically in FIGURE 6. A motor 64 having a constant predetermined r.p.m. is provided. The output shaft 65 of the motor 64 is provided with four cams 66, 67, 68 and 69. The respective cams are adapted to operatively engage micro-switches 70, 71, 72 and 73. The switches 70, 71, 72 and 73 are electrically connected to and adapted to operate the solenoids 48, 49, 59 and 60. The main power switch 74 is adapted to energize the motor 64 and the respective solenoids.

The operation of my heat exchanger is illustrated in FIGURES 4a and 4d. In FIGURE 4a, cold, fresh air is being admitted to chamber 13 through conduit 22 communicating therewith, to absorb heat from the previously heated heat exchange unit 15 and to pass thence through conduit 23 communicating with the opposite side of chamber 13 to some industrial process as preheated, fresh air. Of course, this is predicated upon the fact that in a previous cycle, the heat exchange unit 15 has been heated by contaminated, hot exhaust gas from some industrial process.

In FIGURE 4a, chamber 14 is being purged of contaminated air previously admitted thereto to heat exchange unit 16. In this regard, the exhaust means 38 in plenum 34 is energized with damper 44 in conduit 29 in an open position. The other dampers are all closed thereby creating a vacuum in chamber 14 which substantially withdraws the contaminated air therefrom.

In order to set the respective dampers for the cycle shown in FIGURE 4a, micro-switch 70 is closed by cam 66, de-energizing solenoid 60. Thus, damper 47 in conduit 32 is closed to cut off the intake of contaminated hot air. Previously, damper 46 in conduit 31 and damper 45 in conduit 30 were closed and damper 44 in conduit 29 open. These dampers remain in their respective positions. The dampers in the conduits communicating with chamber 13 remain in the positions shown in FIGURE 4a.

In FIGURE 4b, micro-switch 71 is closed energizing solenoids 59 and 49 and de-energizing solenoid 48 thereby: (a) opening damper 46 in conduit 31 communicating with chamber 14; (b) closing damper 44 in conduit 29 communicating with chamber 14; (c) opening damper 45 in conduit 30 communicating with chamber 14; (d) closing damper 42 in conduit 23 communicating with chamber 13; (e) opening damper 40 in conduit 21 communicating with chamber 13; (f) closing damper 41 in conduit 22 communicating with chamber 13; (g) opening damper 43 in conduit 24 communicating with chamber 13.

Damper 47 in conduit 32 communicating with chamber 13 remains closed. Thus, energizing solenoids 49, 59 and 60 have switched chamber 13 from supplying pre-heated fresh air to the industrial process to receiving contaminated hot air from the process and rejecting it on the opposite side of heat exchange unit 15 to common plenum 34. The air is moved through chamber 13 by means of the exhaust pump 38 in plenum 34. Thus, heat exchange

unit 15 which had been supplying hot air to the process and thereby dropping in temperature now receives and absorbs hot air from the contaminated side to become hot again. Similarly, chamber 14 has alternated from the purging cycle to the supplying cycle wherein cold fresh air entering through conduit 30 passes through heat exchange unit 16, previously heated, absorbs heat therefrom and passes thereafter through conduit 31 to supply the industrial process with hot, fresh air.

FIGURE 4c shows the orientation of the dampers when micro-switch 72 is actuated by cam 68, to de-energize solenoid 49 only, thereby closing damper 43 in conduit 24.

The remaining dampers on both sides of the exchanger remain in the position of the previous cycle. Thus, chamber 14 continues to supply pre-heated fresh air to the industrial process. However, chamber 13 has now alternated from a heating cycle to a purging cycle wherein the exhaust fan 38 in plenum 34 draws cooled contaminated air from the chamber 13 while the opposite side of chamber is closed, thereby purging chamber 13.

FIGURE 4d discloses the cycle wherein micro-switch 73 is actuated energizing solenoid 48 and 60 and thereby de-energizing solenoid 59, thereby: (a) closing damper 46 in conduit 31 communicating with chamber 14; (b) opening damper 44 in conduit 29 communicating with chamber 14; (c) closing damper 45 in conduit 30 communicating with chamber 14; (d) opening damper 42 in conduit 23 communicating with chamber 13; (e) closing damper 40 in conduit 21 communicating with chamber 13; (f) opening damper 41 in conduit 22 communicating with chamber 13; (g) opening damper 47 in conduit 32 communicating with chamber 14.

Damper 43 in conduit 24 remains closed. Thus, chamber 13 alternates from a purging cycle to a supplying cycle wherein cold fresh air is admitted through conduit 22, passes through the preheated heat exchange unit 15 absorbing heat therefrom and from thence passes outwardly through conduit 23 to the industrial process. The pump 39 in plenum 36 provides the moving means for the air.

Similarly, chamber 14 has now alternated from a supplying cycle to a heating cycle wherein conduit 30 previously admitting fresh air is now closed and conduit 31 previously rejecting fresh air is now closed, conduit 32 previously closed is now open to admit contaminated hot air to chamber 13 and conduit 29 previously closed is now open to reject contaminated hot air.

Thereafter, the cycle repeats itself beginning with FIGURE 4a and continuing through 4d.

The precise timing of the operation of the dampers must be determined in a somewhat empirical manner depending upon many factors including the temperatures involved and the rate of air transfer. However, the relative timing of the cycles is approximately as follows: (a) supplying phase, one half of a cycle; (b) heating phase, $\frac{7}{16}$ of a cycle; (c) purging phase $\frac{1}{16}$ of a cycle.

In such a relative cycling system, the exhaust means 38 and 39 may operate continuously and there is no cross contamination or carry over of contaminated air into the fresh air stream.

The foregoing description is merely intended to illustrate an embodiment of the invention. The component parts have been shown and described. They each may have substitutes which may perform a substantially similar function; such substitutes may be known as proper substitutes for the said components and may have actually been known or invented before the present invention; these substitutes are contemplated as being within the scope of the appended claims, although they are not specifically catalogued herein.

I claim:

1. An air to air heat exchanger comprising,

(a) a plurality of separate housings, each housing having at least two openings on each of two opposing sides thereof,

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- (b) a mass of filamentous heat exchange material mounted in each housing communicating with the respective openings,
 - (c) separate conduits mounted on each housing communicating with the respective openings, 5
 - (d) dampers in each conduit adapted to periodically open and close the conduits in timed relationship to each other,
 - (e) a pair of plenums on each of said opposed sides of the housings, each plenum connecting at least one conduit on one side of each housing with at least one conduit on the same side of the other housing, each plenum having an additional opening, and 10
 - (f) means in at least one plenum on each opposing side of the housings for generating negative pressure in each housing. 15
2. A method for air to air heat exchange comprising,
- (a) continuously generating negative pressure at each of two opposing ends of a plurality of housings,
 - (b) passing a first stream of gas through heat exchange media in at least one housing by means of said negative pressure generating means, the said first stream initially having a temperature higher than the temperature of the media in the housing through which it is passing, 20

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- (c) simultaneously passing a second stream of gas through heat exchange media in at least one of the other housings by means of said negative pressure generating means, the second said stream initially having a temperature lower than the temperature of the media in the housing through which it is passing,
- (d) periodically alternating the housings through which the said first and second streams of gas pass, and,
- (e) purging each housing by means of said negative pressure each time the hotter stream is terminated and before the colder stream is commenced.

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ROBERT A. O'LEARY, *Primary Examiner.*CHARLES SUKALO, *Examiner.*R. E. BACKUS, *Assistant Examiner.* 25