

July 22, 1969

J. R. DE FRIES
HEAT EXCHANGER

3,456,718

Filed June 21, 1967

4 Sheets-Sheet 1

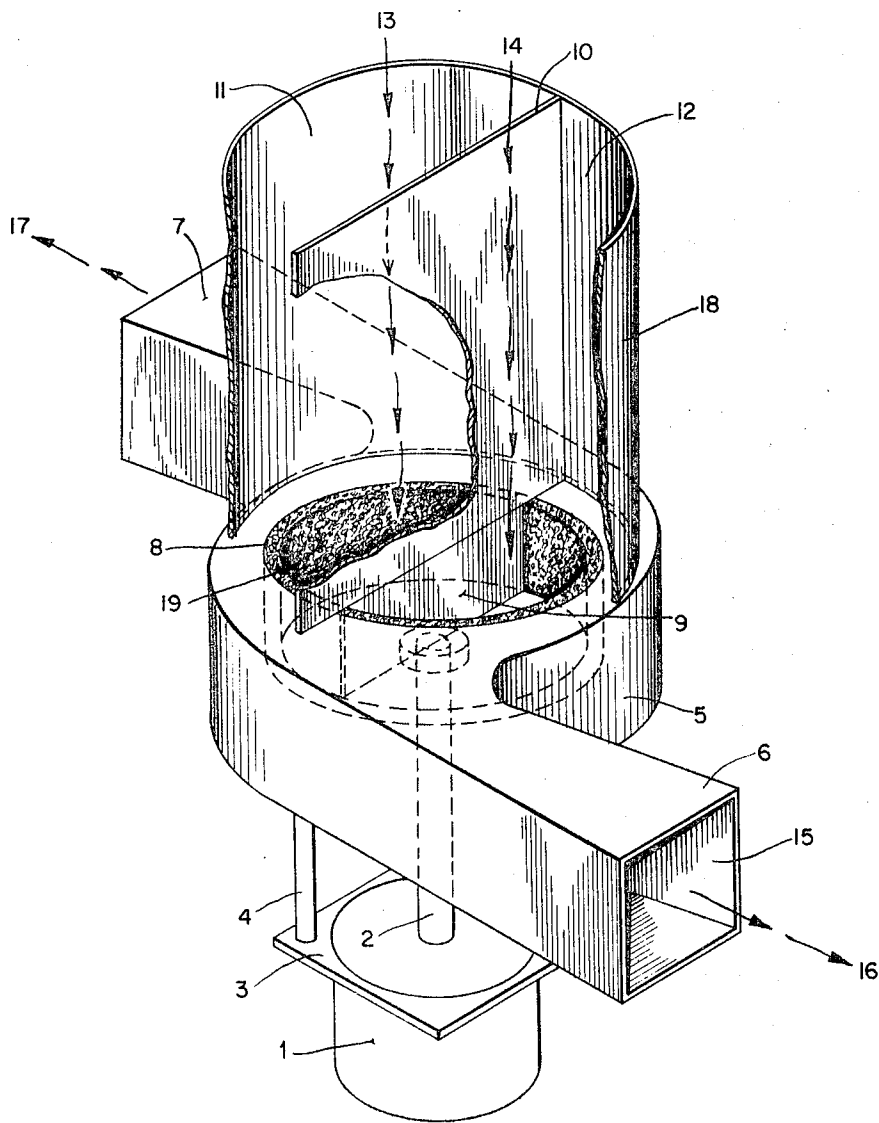


Fig. 1

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Fig. 2

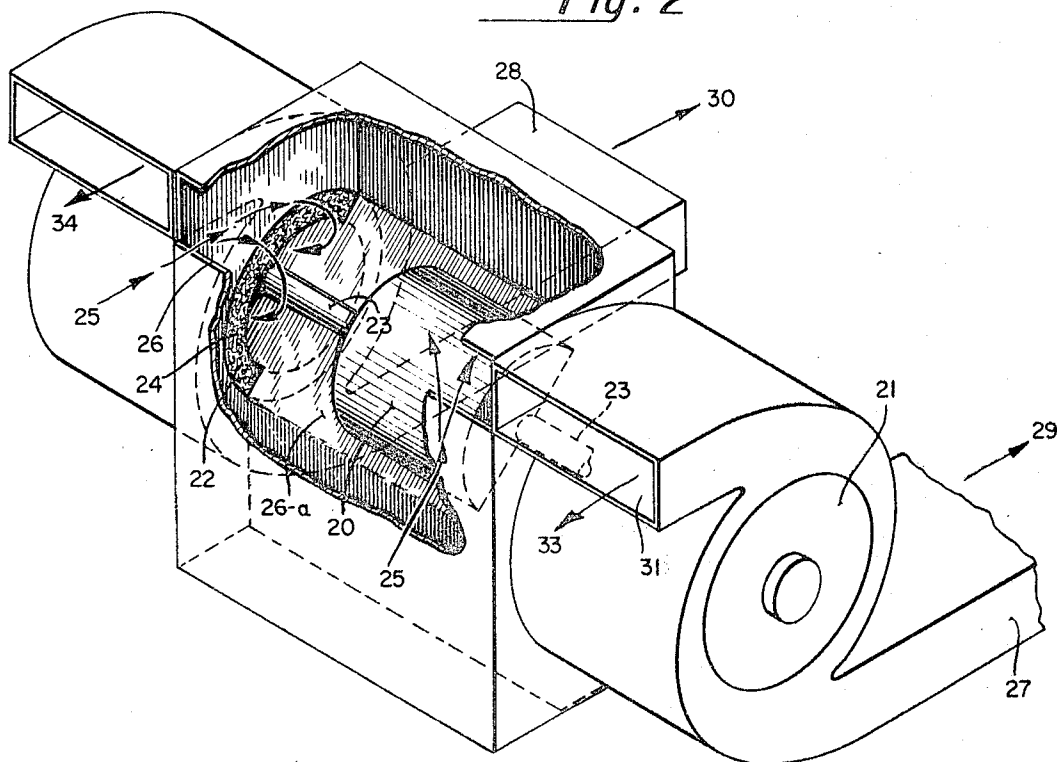
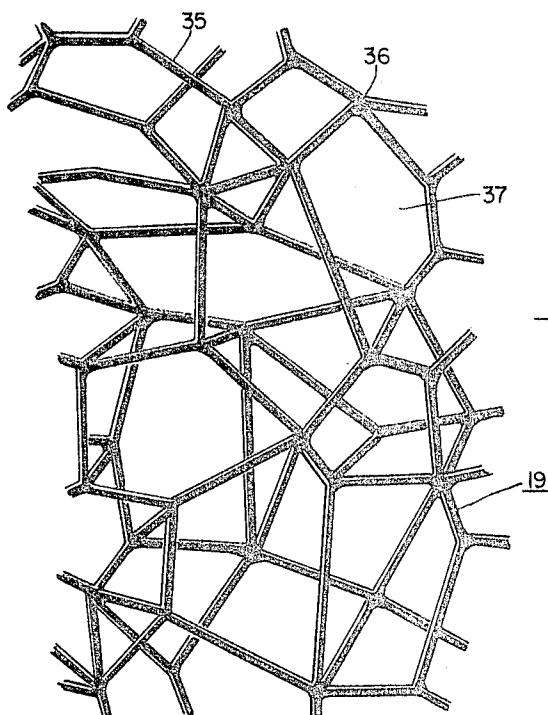


Fig. 3

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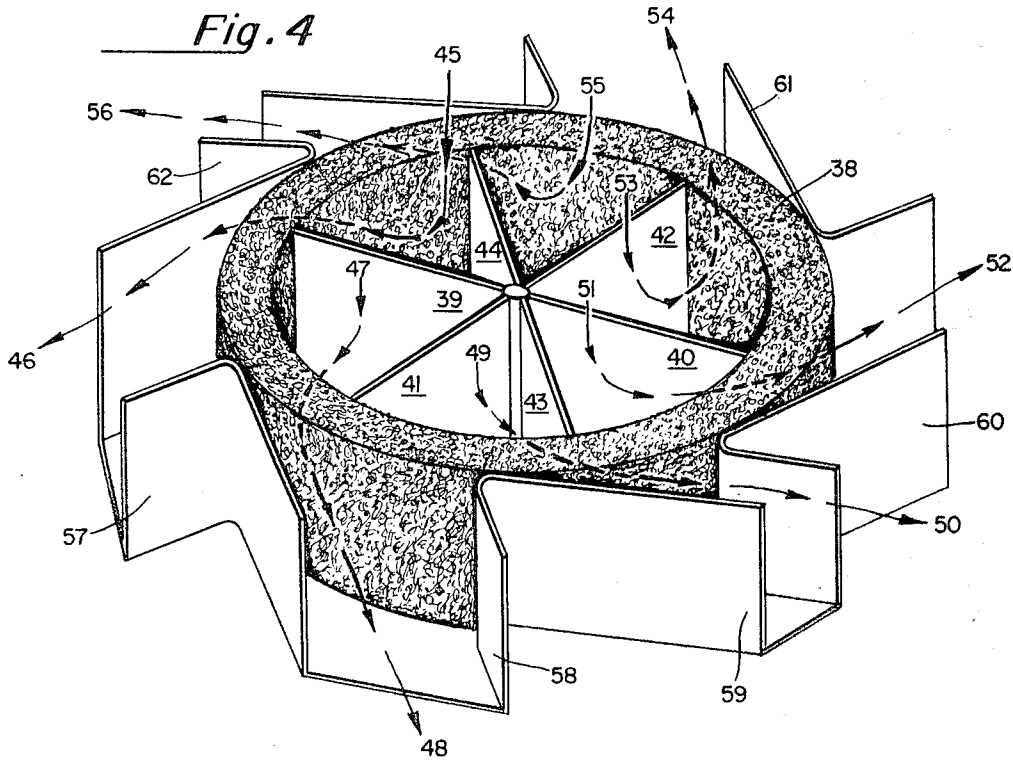
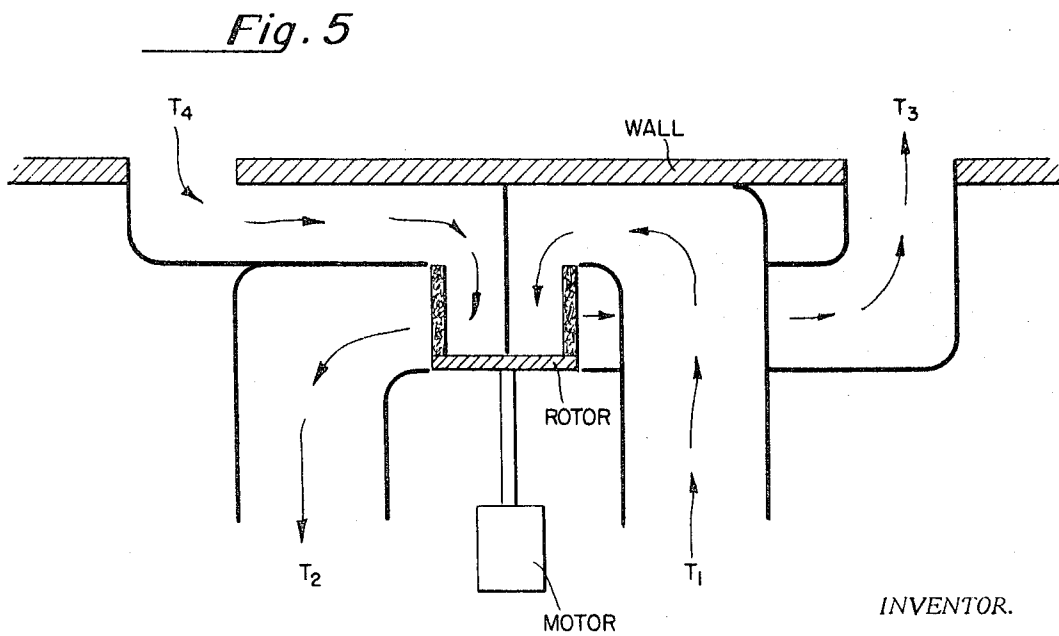
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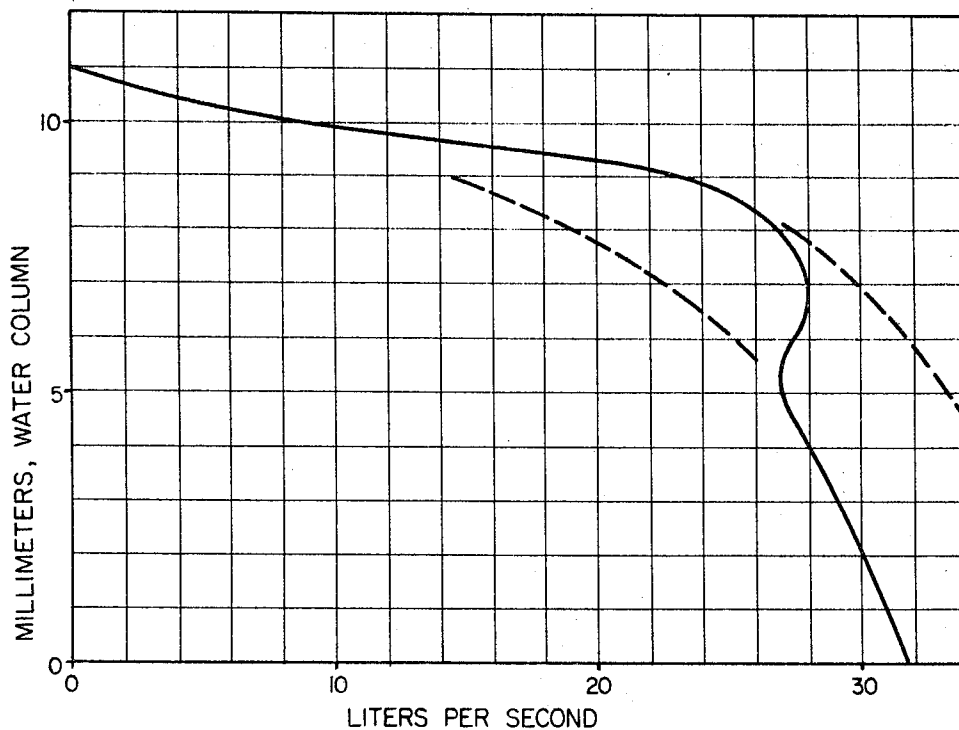


Fig. 6

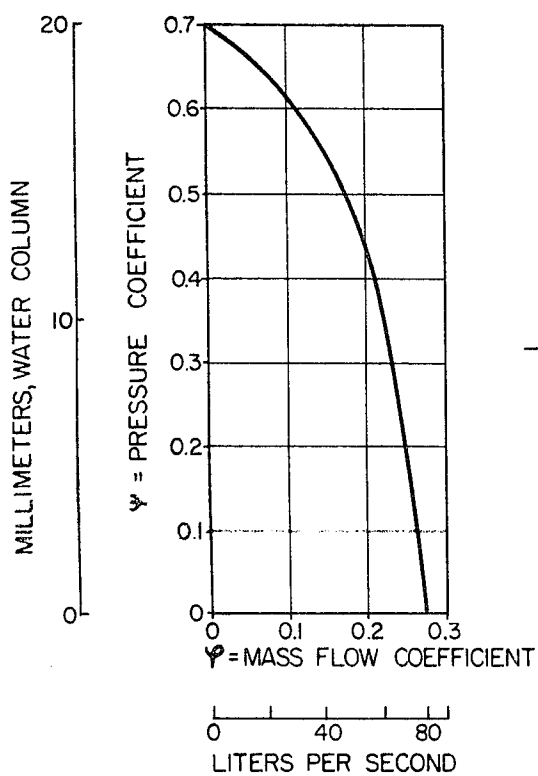


Fig. 7

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HEAT EXCHANGER

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Filed June 21, 1967, Ser. No. 647,846

Int. Cl. F28d 17/00; A23c 3/02

U.S. Cl. 165—10

22 Claims

ABSTRACT OF THE DISCLOSURE

Heat exchanger comprising a blower with two discrete outlet ports and two discrete inlet ports, solid partition dividing rotor interior into two separate sections, rotor comprising a material having a multiplicity of spaced strands which act as turbulence generators such as reticulated polyurethane foam.

This invention relates to heat-transfer apparatus and to apparatus such as fans for the movement of gaseous material. It thus relates to apparatus for combining heat-transfer and air movement, such as air-conditioners, humidifiers and ventilators. It particularly relates to a special impeller which transfers heat from one air stream to another while moving both streams of air.

Heat exchangers with moving heat transmitter have been known for some time, as for example in Ljungstrom power plants and Dow Corning ceramic cell system of gas turbines. However, in such cases two separate chambers are used leading to a moving, usually rotating element which contacts gases in one stream and then moves on to the other stream of gas to which the heat is transferred. These heat exchangers have a higher efficiency per unit of volume than stationary exchangers but as a rule they are also more expensive.

Transmission of heat from discharged waste air to incoming fresh air considerably reduces the calories required to heat a given quantity of fresh air. For many applications, such as air-conditioning and automobile heating such gas to gas heat exchangers have not been used to date for economic reasons. The problem therefore consists in designing a simple, light, heat exchanger and air-mover which will operate satisfactorily even at small differences in temperature, and which can be produced at moderate cost.

Heat exchange between movable media and fixed bodies takes place by transmission of the thermal stimulation condition of the molecule on the fixed body. If high heat transfer coefficients are desired, as many as possible of the medium's molecules must come into contact with the fixed body. At the present state of technology this is possible in hypercritical flow according to Reynolds' definition, i.e. at full turbulence. The marginal layers which are to be expected in the laminar area have only weak exchange functions, because essentially only the molecules of the marginal layers reach the surface. There was therefore no reason for exploring laminar turbulence with heat exchanging elements.

A micro-turbulence generator is a body around which, basically, air is laminarily whirled and in which the laminary disturbance is released. In such a body a vortex (Karman path) forms in the direction of the air stream. This vortex decreases by viscous damping, more rapidly as the deviation from the critical Reynolds' factor increases. In the case of fine fibers in an air stream of 30 feet per second the area of influence of such a turbulence generator is small. The vortices are, at most, equivalent to twice the fiber diameter. The disturbance is limited to a small space only, so that the designation "micro-turbulence generator" herein used, appears to be appropriate.

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The heat exchanger of the present invention may be considered, from a physical standpoint as a number of such microturbulence generators connected in series in the direction of the air stream. They are elements of a three-dimensional member, positioned, partly at least, in the area of the disturbance caused by the micro-turbulence generator, and preceding it in the direction of the air stream. Under these conditions the heat transfer reaches very high values if the elements of the member are used as heat carriers. Compared with the calculations for laminar conditions, the measured values are higher by the tenth power. Obviously, the thermal capacity of such a delicate member with little air resistance is very small. The heat exchanger must rotate rapidly or be operated as a belt and in the tests the travel time of half of a cylindrical fiber ring through a radial air stream was 12 milliseconds.

A number of secondary effects are produced. Thus, a strong air flow on the fibers in tangential direction is created by the circulatory friction of the media. The heat exchanger acts as a ventilator and in many cases special air moving installations become superfluous.

The delicate structure of the member traps foreign matters and acts as a coarse filter. In air-conditioning units and automobile equipment, this represents a welcome supplementary effect. Moreover, the strong viscous damping of air vibrations in such a system acts as a sound-absorber which is a great advantage for many applications, such as room ventilating.

Another secondary effect becomes apparent when the media passing through the heat exchanger absorbs humidity which has reached the exchanger by spraying or condensation. In view of the large surface, an intensive evaporation results, which is strongly assisted by the micro-turbulence. By means of a separate cycle and making use of the heat exchanger, this intensive evaporation can be developed into an extensive evaporative cooling system.

The member also has the effect of an explosion protector; thus a chemical reaction of two media mixed in the runner cannot take place inside of the basket at normal speed.

Thus, one object of this present invention is to provide a novel, inexpensive, efficient combined heat transfer and air moving device.

Another object is to provide a new and novel impeller for a centrifugal fan, which impeller also acts as a heat exchanger.

Another object of this invention is to provide an improvement in the operation of room ventilating equipment whereby to combine the movement of air and the exchange of heat between the air moved into the room and the air moved out of the room.

These and other objects and advantages of the invention will be apparent from the following description, in which reference is made to the accompanying drawings, forming a part hereof, and wherein:

FIGURE 1 is a perspective view of a push-pull heat-exchanger blower of the present invention.

FIGURE 2 is the perspective view of a simplified form of a dual-fan blower of the present invention.

FIGURE 3 is a greatly enlarged perspective view of the material of which the impeller is constructed, in a preferred form.

FIGURE 4 is a perspective view of a modified form of the present invention wherein the impeller cage is modified to improve the heat-exchange efficiency of the fan of the present invention.

FIGURE 5 is a schematic diagram of the push-pull, heat exchanger of the present invention.

FIGURE 6 is a curve illustrating the efficiency of an impeller of the present invention made of reticulated polyurethane foam.

FIGURE 7 is a curve showing the characteristics of a push-pull fan having a capillary impeller made of reticulated polyurethane foam.

For the purpose of describing the invention the following description is directed to preferred means of forming a heat-exchanger-blower, but it is to be understood that the various instrumentalities of which the invention consists can be variously arranged and organized and that the invention is not limited to the structure of a blower or heat-exchanger having the precise arrangements and organizations of the instrumentalities as herein shown and described.

Referring to FIGURE 1, a motor 1 rotates shaft 2 in a counterclockwise direction. The flange plate 3 and columns 4 connect the motor housing to the housing 5. The shaft 2 is connected to a cup-shaped rotor or cage 8. At the periphery of the rotor 8 is a fine air-permeable member 19 which may be made of reticulated foam or felt or similar material. The inner portion of the cup-shaped rotor 8 is divided by the non-rotating partition 9.

A stream of air 13 is admitted through the conduit 11 (here formed by one-half of pipe 18 separated by divider 10) to the space at the left of the rotor partition 9. It flows through the rotor 8 and member 9 and is discharged in the direction of arrow 16 through the duct 15.

Another air stream 14 enters through channel 12, in a similar manner, and reaches the space to the right of partition 9. It also flows through rotor 8 and member 9 and is discharged through duct 7 in the direction of arrow 17.

The face of the rotor 8 and the member 19 are thus continually moving from one air stream to the other. Only a small amount (approx. 5%) of air is transferred from one stream to the other. If a difference exists between the temperatures of the two streams, the temperature of the rotor member 19 adapts itself to the temperature of the stream it is then contacting because of the small size and the high heat transfer coefficient. It thus transfers heat from one stream to the other.

FIGURE 2 shows a similar device which is specially designed for ventilating rooms: The motor 20 rotates the baskets 21 and 22 by means of the shaft 23, which projects on both sides of the motor. Rotation in FIGURE 2 is counterclockwise when viewed from the right. The baskets 21 and 22 each contain on their periphery a fine permeable member 24 which has the heat exchanging and air conveying characteristics, as previously described.

When an air stream 25 enters through the top slot 26, it flows through that half of the baskets 21 and 22 above the partition 26-a, and out the discharge ducts 27 and 28 in the direction of the arrows 29 and 30, to the room to be ventilated.

An air stream which enters the central section through a lower slot (not shown but similar to slot 26) to the underside of the partition 26-a flows through the lower semi-circular areas of baskets 21 and 22 and through the discharge ducts 31 and 32 and in the direction of arrows 33 and 34, generally into the open air.

The members 24 of the baskets 21 and 22 absorb part of the heat of the exhaust air stream, transferring it by rotation to the incoming fresh air which is generally cooler. In air-cooled rooms, when operated in summer, for example, the inverse effect is automatically obtained; i.e. the exhaust air cools the incoming warm fresh air through the rotating baskets. With this simple system an intermediate temperature (according to the limit of the heat exchanging capacity) can be achieved.

Secondary advantages, such as sound absorption by the baskets, the filtering effects, and air movement, permit a very simple and compact construction of this apparatus, notwithstanding its manifold functions. In addition, it represents a considerable progress over other systems which require a number of units to accomplish the same purpose.

FIGURE 3 shows the construction of the heat exchanger member 19. The strands 35, connected at junctions 36 form a reticulated three-dimensional member which, compared to the open space 37, is very delicate. The strands 35 act as microturbulence generators. They generate a disturbance in the air stream which reaches the next strands and produces excellent heat transfer, as has been shown by actual tests. These results are achieved despite the fact that the strands 35, according to the Reynolds' factor, are below the usual range of the critical measurements for fully developed turbulence at normal air velocity.

In a preferred form, the air-permeable member 19 is made from reticulated polyurethane foam like that described in U.S. Patent to Volz, No. 3,171,820.

A basket 8 was fitted with a member 19 of cylindrical shape, weighing 24 grams and having a diameter of 150 millimeters and a height of 45 millimeters. The rotor turned at 2500 r.p.m. and the temperature difference between the two streams was 20° C. A difference of 8% or 0.8° C. was measured on the discharge temperature at the discharge ducts 7 and 15. The air conveying capacity reached 84 liters/sec. at the free outlet of both streams.

FIGURE 4 shows another embodiment of the heat exchanger. For the sake of better illustration the motor and cover are not drawn. The basket 38 rotates in counterclockwise direction when viewed from the top. The interior of the basket contains the non-rotating partitions 39-40, 41, 42 and 43-44. They form six segmental inlet channels, corresponding with six diffusers aligned on the perimeter of the basket: inlet 45 with diffuser 46, inlet 47 with diffuser 48, inlet 49 with diffuser 50, inlet 51 with diffuser 52, inlet 53 with diffuser 54 and inlet 55 with diffuser 56. The diffusers are formed by the ducts 57, 58, 59, 60, 61 and 62.

A heat exchange now takes place between all six streams and allows an number of special circuit arrangements.

Thus, a stream of incoming air can be conveyed to the inlet 45 and out the diffuser 46. Then it is fed to inlet 49 through an appropriate channel, and returned from outlet 50 to inlet 53; finally leaving the system at 54. Another stream is fed in at 55, its discharge 56 is directed to inlet 51; the discharge at 52 is directed to inlet 47, eventually leaving the system at 48. Both streams are in a counter-current connection; the already cooled air in 53 will be further cooled at 55 by one stage only. The already heated air from 56 will meet a warmer basket at 51 and will eventually be further heated in the last stage at 47.

The circuit arrangement of FIGURE 4 demonstrates that the heat exchanger according to the present invention is capable of performing the operations of known stationary heat exchangers, including very elaborate systems, as for instance the counter-current arrangement.

As previously mentioned, the multiple-stage cooling by evaporation is a special additional advantage of the heat exchanger.

If air is introduced at 45 and a spray of water is added, an intensive evaporation takes place in the basket and the heat of evaporation is withdrawn from the air stream and the basket. At this point, the discharge air at 46 is almost saturated. If dry air, without addition of water now enters at 47, it will be cooled by the basket and escape cooled but unsaturated at 48. This air is then again fed at 49, with addition of water spray. Once more, the heat of evaporation is withdrawn, but through the first stage, in view of the temperature of the fresh air which already has a lower temperature level. Discharge air at 50 again is almost saturated and is removed in the same way as the air at 46. Dry air which enters at 51 will now be strongly cooled; it is then withdrawn at 52 and re-introduced at 53 with the addition of water. The saturated cold air leaves the system at 54. In a last stage, dry and highly humidified fresh air can then

be introduced at 55. By means of the basket, which has become very cold in the meantime, this air is brought to a low temperature level and discharged at 56. This process represents a regenerative circle with evaporative cooling, used in the technique of air liquefaction. By the use of the heat exchanger of the present invention, this process can be performed easily and simply.

Referring now to FIGURE 5 there is shown a schematic presentation of the push-pull air-mover of the present invention, mounted in the wall of a room. The temperature of air in the room is indicated by T₁, and the temperature of the outside air is indicated by T₄. Incoming air T₄ passes through the reticulated foam member of the impeller basket and is discharged into the room at a temperature of T₂. The exhaust air, also passing through the impeller, is discharged into the outside atmosphere at a temperature T₃.

Actual tests conducted under the given condition produced measured inside temperatures (T₁) of 19.4° C. and outside temperatures (T₄) of 5.5° C. Thus a difference in temperature of 13.9° C. existed between the inside and outside air.

Measuring the temperature of the air at T₂ showed that the cool air was heated up to 13.6° C. and the discharge exhaust air T₃ cooled down to 14.1° C. The difference in temperature of the two air streams after passing through the unit was only 0.5° C.

This unit was drawing into the room 48 liters of air per second and had effectively heated the outside air from 5.5° C. up to 13.6° C. This differential of 8.1° C. indicates approximately 400 watts per second of heat was delivered to the air. The same quantity of air was evacuated at the same time. The motor was consuming about 40 watts per second and hence the net gain was 360 watts of heat per second.

Refer now to FIGURE 6 which is a curve of data illustrating the efficiency of an impeller of the present invention when made from reticulated polyurethane foam, manufactured by the process described in the Volz U.S. Patent No. 3,171,820. It had a pore size (number of holes per linear inch) of 25 per inch. The rotating member had an outside diameter of 127 mm. and a height of 28 mm. It was rotated at speeds between 2,550 and 2,700 revolutions per minute. Note that in the usable range of pressure (i.e. between 3 mm. and 9 mm. water column) there is substantially no change in the volume of air being moved. This shows the inherent stability of the system.

Note also that the dotted line extensions at the break in the curve shows that this curve is effectively a composite of two separate curves. The effect, in the single impeller made of reticulated polyurethane foam, is easily achieved in the apparatus of the present invention but is not achievable when other materials are used as the air-permeable member in the rotating basket.

With reference to FIGURE 7, this graph shows the characteristics of a capillary fan using an impeller made of reticulated polyurethane foam of 20 pores per inch. The diameter of the rotating unit was 150 mm. and moved 276 cubic meters per hour with a motor power consumption of only 70 watts, discharging the air into a room of 80 cubic meters. With a rotor of 100 mm. diameter, the air flow was 92 cubic meters per hour at a power consumption of only 28 watts. The chart shows the relationship between mass flow coefficient and pressure coefficient, as well as the pressure in millimeters water column related to the air flow in liters per second.

The following table shows data taken for a twin motor capillary blower utilizing 30 pore per inch reticulated polyurethane foam. In the formulas beneath the table, v represents the peripheral velocity in meters per second, t is the specific weight of the gas, g is the force of gravity, F is the area of the intake opening of the rotor in square meters, and Q is the total flow in cubic meters per second.

Rotor diameter, mm.	Air-flow Q m. ³ /h.		Back-pressure at 0.3Q 6 mm. water column	Motor shaft rating at 220 v.-watt
	Against 2.5 mm. water column	Against 6 mm. water		
75-----	35	0	1.0	1.8
100-----	110	90	8.1	3.0
125-----	240	225	11.7	4.2
150-----	500	460	17	14.0

¹ PkI°=5 mm. water column.

$$P\psi = \frac{v^2 \cdot t}{2g} \text{ (where } \psi = 1 \text{)}$$

$$\frac{P_{eff}}{P\psi = 1} = \psi_{eff}$$

$$Q\psi = F \cdot v \text{ (where } \psi = 1 \text{)}$$

$$\frac{Q_{eff}}{Q\psi = 1} = \psi_{eff}$$

As an illustration of the use of the heat exchanger of the present invention, one can consider the case of conserving fruit in cold storage. In the conservation of bananas, for example, poisonous gases emerge from the bananas and must be kept at a low level of concentration to avoid harm. The storage usually is done at a temperature as low as minus 18° C. So the change of air in the storage space would involve considerable losses of cool air which in term of energy is a considerable amount of the total energy necessary to preserve the bananas. Very often one must use a heat-exchanger to transfer at least a part of the latent heat of the cold air to the incoming new air, but in this special case there are a number of difficulties coming from corrosion, sea water action, fruit acids, etc. making it very expensive to use heat-exchangers. For this specific problem the heat-exchanger of this invention can be used by placing a basket containing polyurethane foam in reticulated form between exhaust and incoming air to condition the bananas storage space. With a temperature of 20° C. on the outside air and a storage temperature of minus 18° C. there would be an average temperature of the incoming air of about 1 to 2° C. The energy to cool the air down to minus 18° C. would thus be reduced by about 60%. This economy of energy is important because bananas storage is usually done in the banana ship and extra cooling apparatus means additional to turbine energies, space requirements, etc., increasing the price of transport to a considerable sum.

Latent heat of aerosols trapped in the air can be used to improve heat exchange by a process which traps the aerosols by the filter effect of the basket. The aerosols can be removed by making the basket and foam in the shape of a frusto-cone, then transporting the aerosols back to the air-intake line.

The present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof, and it is therefore desired that the present embodiment be considered in all respects as illustrative and not restrictive, reference being had to the appended claims rather than the foregoing description and to indicate the scope of the invention.

Having described my invention, what I claim as new and desire to protect by Letters Patent is the following:

1. A heat exchanger having a heat-transmitting three-dimensional structure through which a gaseous media passes, said structure comprising a plurality of strands interconnected at junctions to form a reticulated network, at least some of said strands being spaced-apart from other strands not directly joined thereto at a junction by a distance of at least as great as the thickness of the strands, whereby at least some of said strands operate as microturbulence generators, and are arranged with at least some of the strands lying in the reciprocal turbulent radius of action of at least some preceding strands.

2. A heat exchanger according to claim 1, wherein said strands occupy less than 10% of the volume of the body of the heat-transmitting three-dimensional structure.

3. A heat exchanger according to claim 1 wherein said three-dimensional structure is an organic foam, the membrane surfaces of which have been removed by a suitable after-treatment.

4. A heat exchanger according to claim 1 wherein said three-dimensional structure is a porous material comprised of a multiplicity of single strands inter-connected at individual contact points between the strands to form an open porous network.

5. A heat exchanger according to claim 1 wherein the frictional effect of said three-dimensional structure is used simultaneously for the transmission of heat and in the movement of the heat exchange medium.

6. A heat exchanger according to claim 1 wherein said three-dimensional structure is capable of retaining aerosols out of a transferred medium.

7. A heat exchanger according to claim 1, wherein said structure is capable of preventing continuation of exothermic gas reactions in the material entering the heat exchanger.

8. A heat exchanger according to claim 1 wherein said three-dimensional structure is constructed as a cylindrical ring, and a non-rotating wall dividing the center of the ring into at least two channels.

9. Apparatus for moving a plurality of streams of gaseous material at least one of which has a different temperature than the other(s) while transferring heat from at least one of said streams to the other(s), comprising a housing,

a rotor member rotatably disposed within said housing, said rotor member comprising a plurality of strands interconnected at junctions to form a reticulated three-dimensional network, at least some of said strands being spaced-apart from other strands not joined thereto at a junction by a distance of at least as great as the thickness of the strands, whereby at least some of said strands lie downstream of others and are disposed in the path of gaseous material having micro-turbulence generated by said others,

a first plurality of duct means to introduce a plurality of separate streams of gaseous material into circumferentially spaced, radially inward portions of said rotor member during its rotation, whereby motion is imparted to said gaseous material due to centrifugal force effects created by said strands of said rotor member, and whereby heat is transferred from at least one of said streams to the other(s) by means of changes in temperature of said strands, and

a second plurality of duct means communicating with said housing at circumferentially spaced, radially outward positions about the periphery of said rotor member, each of said duct means being adapted to receive gaseous material from one of said separate streams.

10. Apparatus according to claim 9, wherein said rotor member is comprised of reticulated polyurethane foam having a plurality of strands connected at junctions so as to form a three-dimensional structure, said strands comprising micro-turbulence generators.

11. Apparatus according to claim 9, wherein said rotor member includes an annular element of reticulated material, said element being arranged for rotation about its axis.

12. Apparatus according to claim 9, wherein said first plurality of duct means includes a first input duct adapted to draw gaseous material from an enclosed space, and a second input duct adapted to draw gaseous material from the atmosphere.

13. Apparatus according to claim 12, wherein said second plurality of duct means includes a first exhaust duct adapted to receive gaseous material from said housing which was introduced to said rotor member by said first input duct, and a second exhaust duct adapted to receive gaseous material from said housing which was introduced to said rotor member by said second input duct.

14. Apparatus according to claim 13, wherein said first exhaust duct is adapted to feed gaseous material back into said enclosed space, and said second exhaust duct is adapted to feed gaseous material back to the atmosphere.

15. Apparatus according to claim 9, wherein said first plurality of duct means includes:

a first input duct adapted to draw gaseous material at a first temperature from an enclosed space, and

a second input duct adapted to draw gaseous material at a second temperature from the atmosphere, and

said second plurality of duct means includes:

a first exhaust duct adapted to receive gaseous material from said housing at a temperature less than said first temperature, which gaseous material was introduced at said first temperature to said rotor member by said first input duct, and a second exhaust duct adapted to receive gaseous material from said housing at the temperature greater than said second temperature, which gaseous material was introduced at said second temperature to said rotor member by said second input duct.

16. Apparatus according to claim 9, wherein said first plurality of duct means includes:

a first input duct adapted to draw gaseous material at a first temperature from an enclosed space, and

a second input duct adapted to draw gaseous material at a second temperature from the atmosphere,

and said second plurality of duct means includes:

a first exhaust duct adapted to receive gaseous material from said housing at a temperature greater than said first temperature, which gaseous material was introduced at said first temperature to said rotor member by said first input duct, and

a second exhaust duct adapted to receive gaseous material from said housing at the temperature less than said second temperature, which gaseous material was introduced at said second temperature to said rotor member by said second input duct.

17. Apparatus according to claim 9, wherein at least one of said second plurality of duct means communicates with at least one of said first plurality of duct means so that gaseous material received by at least one of said second plurality of duct means is fed through said rotor member at least one additional time to accomplish additional transfer of heat from one of said streams to the other(s).

18. Apparatus according to claim 9, wherein an evaporative liquid is introduced into said rotor member along with at least one of said streams of gaseous material, whereby cooling of said rotor member is promoted by withdrawing the latent heat of vaporization of said liquid from said rotor member.

19. In a rotary regenerator adapted to transfer heat from one stream of gaseous material having a given temperature to another stream of gaseous material having a temperature lower than said given temperature, the improvement comprising

a rotatable permeable heat exchange element comprising a plurality of strands interconnected at junctions to form a reticulated three-dimensional network, at least some of said strands being spaced-apart from other strands not joined thereto at a junction by a distance of at least as great as the thickness of the strands, whereby at least some of said strands lie downstream of others and are disposed in the path of gaseous material having micro-turbulence generated by said others.

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20. The improvement in a rotary regenerator according to claim 19, wherein said rotatable heat exchange element is comprised of reticulated polyurethane foam having a plurality of strands connected at junctions so as to form a three-dimensional structure, said strands comprising micro-turbulence generators.

21. In a rotary regenerator adapted to move a plurality of streams of gaseous material at least one of which has a different temperature than the other(s) while transferring heat from at least one of said streams to the other(s), the improvement comprising:

a rotatable permeable element comprising a plurality of strands interconnected at junctions to form a reticulated three-dimensional network, at least some of said strands being spaced-apart from other strands not joined thereto at a junction by a distance of at least as great as the thickness of the strands, whereby at least some of said strands lie downstream of others and are disposed in the path of gaseous material having micro-turbulence generated by said others, whereby motion is imparted to said gaseous material due to centrifugal force effects created by said strands

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of said element, and whereby heat is transferred from at least one of said streams to the other(s) by means of changes in temperature of said strands.

22. The improvement in a rotary regenerator according to claim 21, wherein said rotatable permeable element is comprised of reticulated polyurethane foam having a plurality of strands connected at junctions so as to form a three-dimensional structure, said strands comprising micro-turbulence generators.

References Cited

UNITED STATES PATENTS

2,680,008	1/1954	Karlsson	165—8
3,177,661	4/1965	Hasbrouck et al.	165—8

ROBERT A. O'LEARY, Primary Examiner

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U.S. Cl. X.R.

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