Aug. 18, 1964 G. W. MEEK 3,144,901

MOVABLE AIR CONDITIONING APPARATUS

Filed May 13, 1960 4 Sheets-Sheet 1

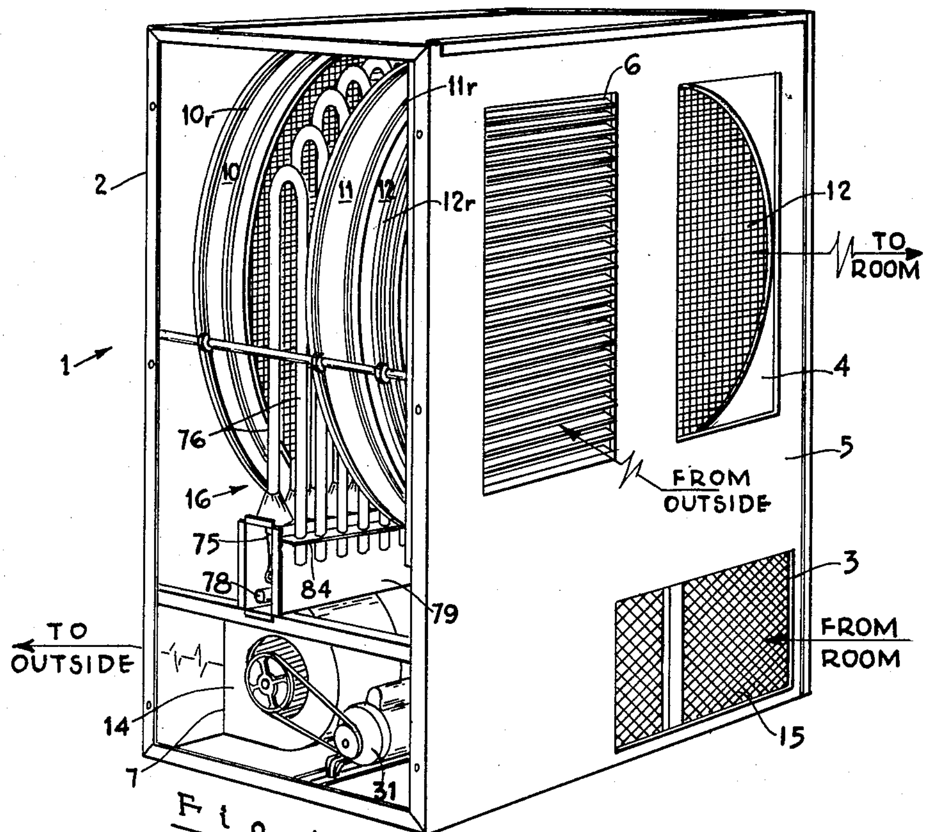

Fig. 1

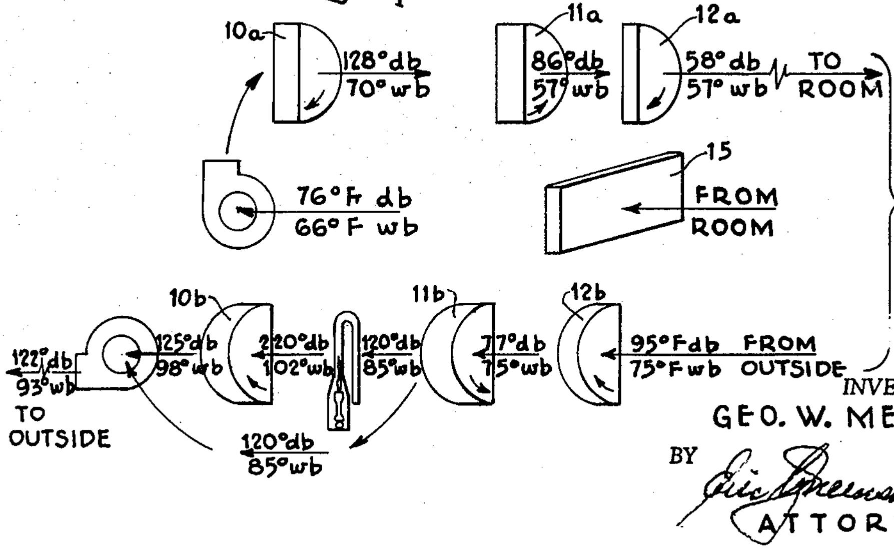

Fig. 2

INVENTOR.
GEO. W. MEEK

BY [signature]
ATTORNEY

MOVABLE AIR CONDITIONING APPARATUS

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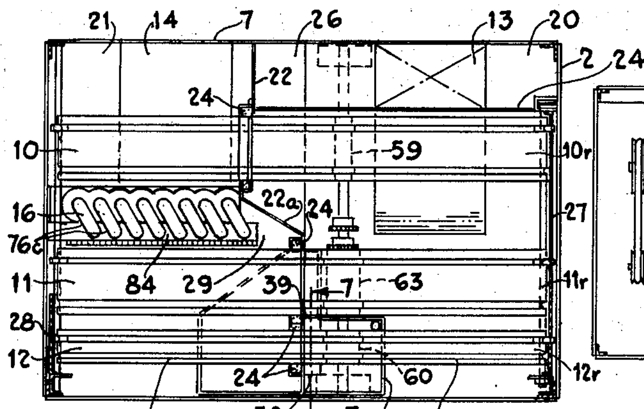

Fig. 5

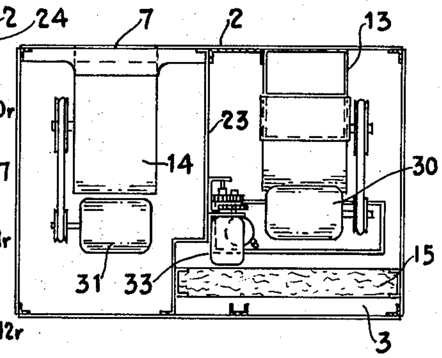

Fig. 6

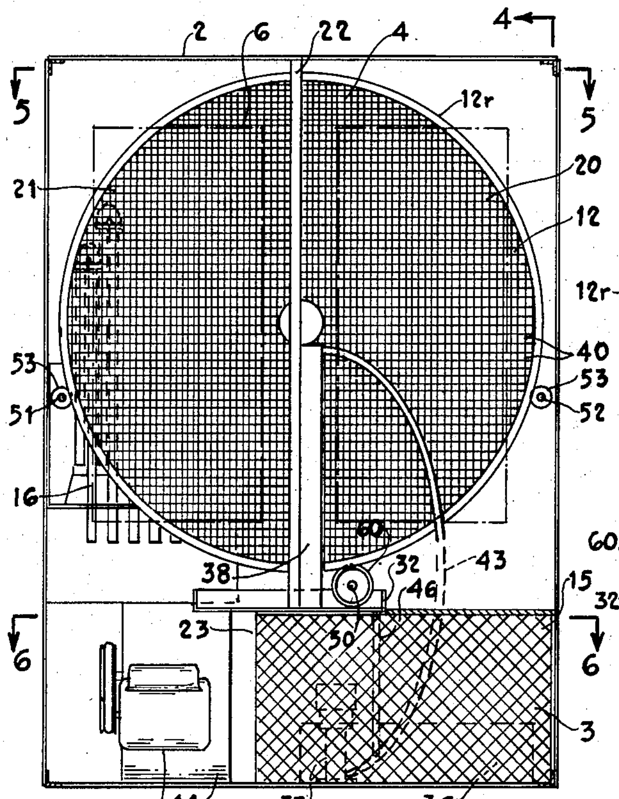

Fig. 3

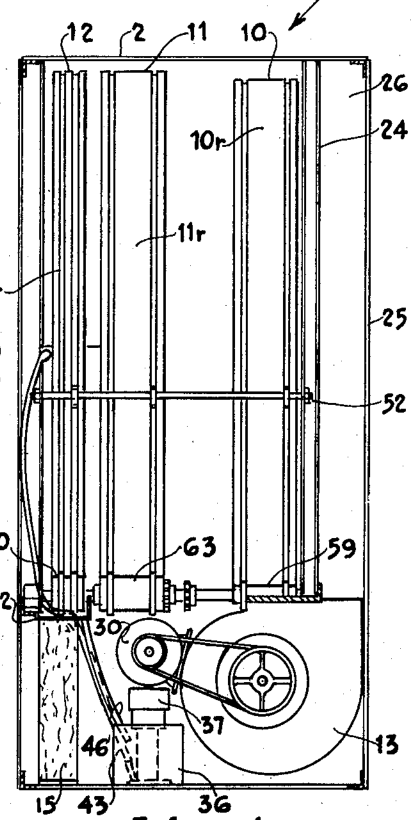

Fig. 4

INVENTOR.
GEO. W. MEEK
BY
ATTORNEY

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MOVABLE AIR CONDITIONING APPARATUS

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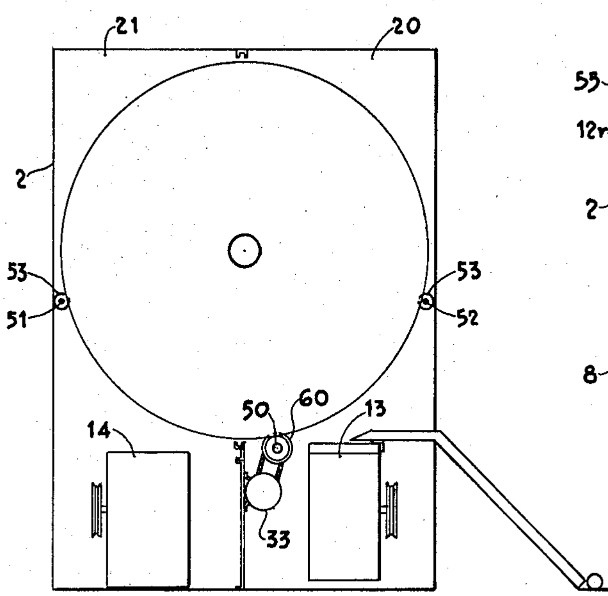

Fig. 8

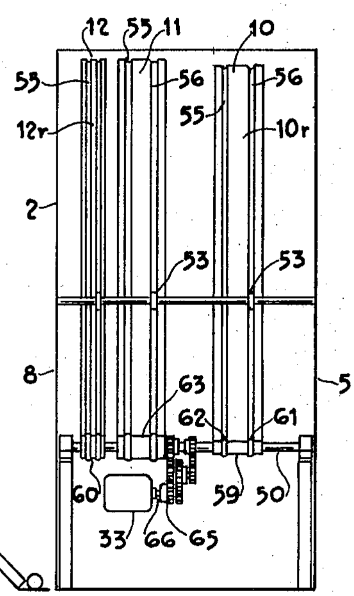

Fig. 9

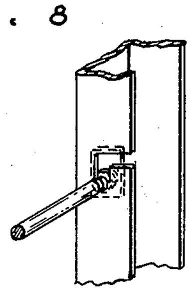

Fig. 11

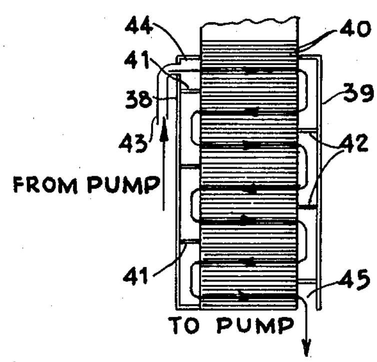

Fig. 7

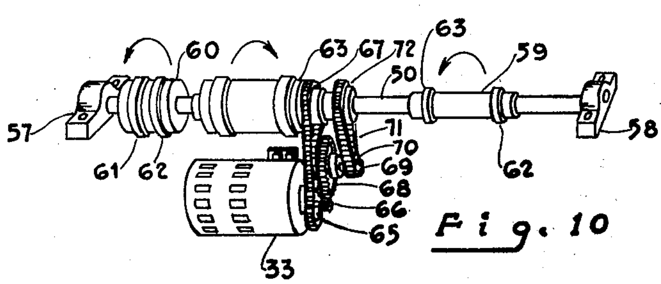

Fig. 10

INVENTOR.
GEO. W. MEEK
BY
ATTORNEY

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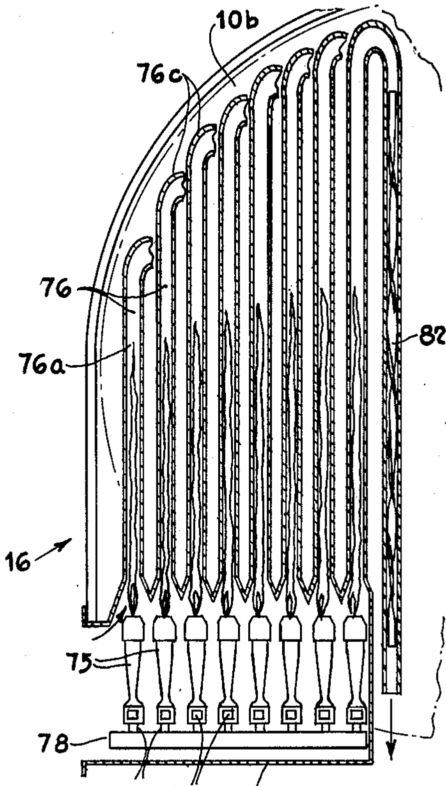

Fig. 12

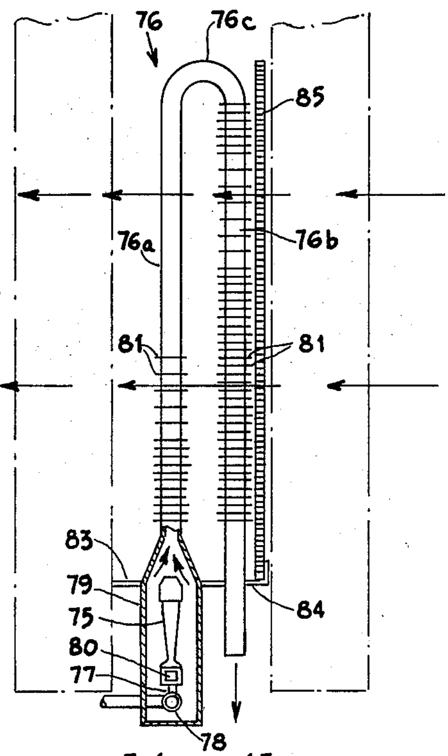

Fig. 13

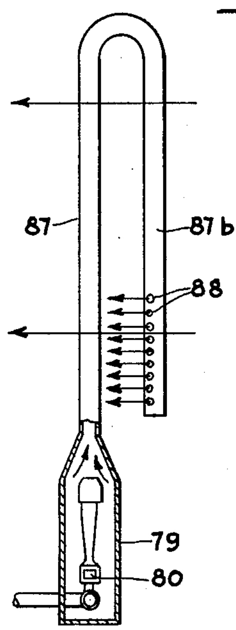

Fig. 14

INVENTOR.
GEO. W. MEEK
BY
ATTORNEY

United States Patent Office

3,144,901

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MOVABLE AIR CONDITIONING APPARATUS

George W. Meek, Fort Myers, Fla., assignor to Lizenzia A.G., Zug, Switzerland, a Swiss corporation

Filed May 13, 1960, Ser. No. 29,061
4 Claims. (Cl. 165—6)

The present invention relates to air conditioning and more particularly to improvements in air conditioning apparatus of the type in which moisture and heat are transferred from one stream of air to another by elements moving cyclically between the air streams.

Apparatus of this type is described and claimed in U.S. Letters Patents to Pennington, 2,723,837, issued November 15, 1955, and Munters, 2,926,502, issued March 1, 1960, among others. In the air conditioning apparatus illustrated in the Pennington patent the air to be conditioned flows through and contacts one side of a rotary wheel of an air pervious hygroscopic material which absorbs moisture from the air. The dried air then flows through and contacts one side of a rotating wheel to remove sensible heat from the air. The dried and cooled air is then further cooled to the required temperature and relative humidity by evaporating water therein. The moisture and heat removed from the air to be conditioned is transferred by the rotating wheels to another stream of air flowing through the other sides of the wheels.

One of the objects of the present invention is to provide an improved construction in air conditioning apparatus of the type indicated which operates more efficiently to air condition an enclosure.

Another object is to provide an improved air conditioning apparatus in which air to be conditioned is continuously circulated in one path through the apparatus and outside air is continuously circulated in another path through the apparatus.

Another object is to provide an improved apparatus in which the air to be conditioned is dried, cooled and rehumidified by contact with successive wheels arranged in aligned side-by-side relationship in an enclosing casing.

Another object is to provide an improved heater for heating the stream of air used to regenerate the moisture transfer wheel.

Still another object is to provide an improved apparatus of the type indicated which is of a more simple and compact construction and adapted to be manufactured more economically than prior constructions and one which is reliable in operation and facilitates servicing and repair.

These and other objects will become more apparent from the following description and drawings in which like reference characters denote like parts throughout the several views. It is to be expressly understood, however, that the drawings are for the purpose of illustration only and are not a definition of the limits of the invention, reference being had for this purpose to the appended claims. In the drawings:

FIGURE 1 is a perspective view of an air conditioning apparatus incorporating the novel features of the present invention and illustrated with an end panel removed to show the three wheels mounted in side-by-side relation in the enclosing casing;

FIGURE 2 is a diagrammatic view illustrating the separate paths of flow for air to be conditioned and outside air, respectively, through opposite sides of the wheels;

FIGURE 3 is a side elevational view of the apparatus as viewed from the right in FIGURE 1 and shown with the wall of the casing removed to illustrate the relationship of the elements;

FIGURE 4 is a sectional end elevational view taken on line 4—4 of FIGURE 3 and showing the path of flow for air to be conditioned and pump circuit for circulating water through the evaporating wheel;

FIGURE 5 is a sectional plan view taken on line 5—5 of FIGURE 3 and showing the partitions in the casing cooperating with the faces of the wheels to form the separate air paths and the heater between two of the wheels;

FIGURE 6 is a sectional plan view taken on line 6—6 of FIGURE 3 to show the partitions dividing the casing below the wheels and the relationship of the fans in the separate paths of flow;

FIGURE 7 is a sectional view taken on line 7—7 of FIGURE 5 and showing the liquid distributing headers at opposite sides of the evaporating wheel for circulating water therethrough.

FIGURE 8 is a view similar to FIGURE 3 and showing the three point cradle mounting and driving means for the wheels and removable ramp for rolling the wheels into and out of the casing;

FIGURE 9 is a side elevational view of the wheels and driving means illustrated in FIGURE 7 and showing the driving hubs and sleeve for rotating the wheels at different speeds;

FIGURE 10 is a perspective view of the drive shaft and sleeve and showing the gearing for driving the shaft and sleeve at different rotative speeds;

FIGURE 11 is a perspective view showing the detachable connection of one shaft of the cradle mounting at one side of the wheels to adapt the wheels to be inserted into and removed from the casing;

FIGURE 12 is a side elevational view of the burners and heat transfer tubes of the heater for heating the air to regenerate the moisture transfer wheel;

FIGURE 13 is an enlarged view of one burner and heat transfer tube and showing the U-shaped form of the tube and fin arrangement to produce uniform heat transfer throughout its length;

FIGURE 14 is a view similar to FIGURE 13 showing a burner and heat transfer tube of modified construction having a perforate end for producing an induced draft of the flue gases by the flow of regenerating air to the moisture transfer wheel.

The air conditioning apparatus of the present invention is adapted for air conditioning an enclosure, such as a residential home, and may be located in the basement of the home or out of doors and connected by ducts to the rooms to be conditioned. The conditioner may be arranged for alternate operation with a heater in an existing air duct system or may be connected in a separate duct system for supplying cool and or dehumidified air to an enclosure during the summer months. Air is circulated through ducts from the room or enclosure to be conditioned in one path through the air conditioner and outside air is circulated through ducts in another path through the air conditioner from and to the atmosphere.

Referring now to the drawings, the air conidtioner 1 comprises an enclosing casing 2, shown in FIGURE 1 with an end panel removed, having a lower air inlet opening 3 and an upper air outlet opening 4 for room air at one side 5. Outside air from the atmosphere is supplied to the air conditioner 1 through an air inlet opening 6 in side 5 and is discharged through an air outlet opening 7 in the side 8 of the casing opposite the side 5. A plurality of wheels 10, 11 and 12 are rotatably mounted in casing 2 in side-by-side relationship in substantially axial alignment with the wheel 12 overlying the outlet opening 4 for room air and inlet opening 6 for outside air. Partitions in the casing 2, later to be described in detail, cooperate with the faces of the wheels 10, 11 and 12 to divide the wheels and casing into separate chambers constituting separate paths of flow for the room air and outside air. Fans 13 and 14 are mounted in the air conditioner 1 below the wheels 10, 11 and 12 which circulate the opening 4 for room air and inlet opening 6 for outside air. room air and outside air through the wheels in the respective paths of flow. As shown in FIGURES 1 and 2, air from the room being conditioned is drawn through the air inlet opening 3, a filter 15, then along a path under the wheels 10, 11 and 12 and into a fan 13. Fan 13 delivers the air into a plenum chamber at the far side of the wheel 10 which then flows forwardly through one side of the successive wheels 10, 11 and 12 and through the outlet 4 back to the room or enclosure to be conditioned. Outside air is drawn through the inlet opening 6 and opposite sides of the wheels 10, 11 and 12, successively, by fan 14 in a direction countercurrent to the direction of flow of the air being conditioned and is then discharged by the fan back to the atmosphere through the air outlet 7.

The wheels 10, 11 and 12 may be of any suitable air permeable construction to adapt the air to flow therethrough in a direction parallel to its axis. Preferably, the wheels comprise alternate plain and corrugated sheets wound helically about a central axis to form tubular openings or flutes between the corrugations of the plain and corrugated sheets. Such a wheel construction is described and claimed in a copending application of Carl Munters, Serial No. 442,687, filed July 12, 1954, now abandoned. The wheel 10 is a moisture transfer wheel and is preferably formed of plain and corrugated sheets of asbestos paper wound helically as described above and impregnated with a hygroscopic substance, such as lithium chloride or lithium bromide salts. Thus, the wheel 10 is adapted to absorb moisture from the air to be conditioned and transfer the absorbed moisture to the stream of outside air at high temperature. The wheel 11 constitutes a heat transfer wheel and may comprise plain and corrugated sheets of paper, metal foil or plastic sheets. The wheel 12 constitutes an evaporator for evaporating water into the separate streams of room air and outside air and preferably comprises helically wound plain and corrugated sheets of absorbent paper. Each of the wheels may be impregnated with other materials to render them resistant to bacteria and increase their strength. The edges of the face areas of the wheels engaged by the partition seals also may be impregnated with suitable chemicals, such as sodium silicate or an organic plastic, such as a phenolic resin, to render them hard and wear-resistant. Each of the wheels 10, 11 and 12 has a peripheral rim 10*r*, 11*r* and 12*r* of a hard wear resistant material and shaped to provide an annular traction surface for engagement by driving and guiding rollers, as later described more in detail.

A heater 16 is located between the heat transfer wheel 11 and moisture transfer wheel 10 in the passageway for outside air at the left hand side of the air conditioner 1 as viewed in FIGURE 1. Heater 16 heats the outside air flowing through the moisture transfer wheel 10 to a high temperature at which its vapor pressure is lower than the vapor pressure in the hygroscopic material of the wheel 10 so that moisture flows from the wheel to the air.

As illustrated diagrammatically in FIGURE 2, the right hand side 10*a* of the wheel 10 absorbs moisture from the air being conditioned as it flows therethrough to reduce its moisture content and relative humidity to a low value. The side 11*a* of the heat transfer wheel 11 absorbs sensible heat from the air to be conditioned. At least part of the heat absorbed by wheel 11 is latent heat of condensation converted to sensible heat by absorption of moisture from the air. The relatively dry and partially cooled air then flows through the side 12*a* of the wheel 12 where moisture is evaporated into the air to further cool the air and adjust its humidity to desired comfort conditions. Simultaneously, outside air passing through side 12*b* of wheel 12 is saturated with moisture evaporated from the wheel which cools it to a temperature closely approaching its wet bulb temperature. The cooled outside air flowing through the side 11*b* of the heat transfer wheel 11 cools the wheel and removes the heat absorbed at the other side 11*a* of the wheel. The heated outside air is then further heated to a high temperature by the heater 16 between the sides 11*b* and 10*b* of wheels 11 and 10. The flow of the high temperature outside air through side 10*b* of moisture transfer wheel 10 regenerates the moisture transfer wheel by removing the moisture absorbed at the opposite side 10*a* of the wheel. The outside air is then discharged back to the atmosphere by the fan 14.

As shown in FIGURES 3 to 6 the casing 2 is divided into separate passageways 20 and 21 for air to be conditioned and outside air, respectively, by partitions 22 and 23. Partition 22, see FIGURES 3 and 5, has successive sections positioned between adjacent wheels 10, 11 and 12 which cooperate with the faces of the wheels to form the passageways 20 and 21. Each section of the partition 22 has flexible seals 24 engaging the faces and peripheries of the wheels to prevent air from flowing from one passageway 20 or 21 to the other. As will be observed in FIGURE 5, the section 22*a* of partition 22 is offset between the heat transfer wheel 11 and moisture transfer wheel 10 to provide a larger portion of the moisture transfer wheel contacted by air to be conditioned than the portion contacted by the outside air to regenerate the wheel. Wheel 10 has a hub and a seal 24 which extends vertically across the wheel as a chord to provide a generally rectangular space for the heater 16 and insure exposure of each flute in the wheel for a sufficient period to insure the necessary moisture removal.

The partition 23, see FIGURE 6, is located below the wheels 10, 11 and 12 and constitutes an extension of the partition 22. As shown in FIGURES 3 and 6, the partition 23 is offset to the left to provide an enlarged air inlet opening 3 for room air and to accommodate a filter 15 of the size required.

A vertical partition 24*a* at right angles to partitions 22 and 23, see FIGURE 4, overlies the rim of the wheel 10 and is spaced from the end wall 25 of the casing 2 to provide a plenum chamber 26 into which the fan 13 discharges the room air to be conditioned. The vertical partition 24*a* has a semicircular opening corresponding to the face of the wheel 10 through which the air in the plenum chember 26 flows into the side 10*a* of the moisture transfer wheel 10. Arcuate partition walls 27 and 28, see FIGURE 5, are provided between the rims 10*r*, 11*r* and 12*r* of adjacent wheels to complete the passageways 20 and 21.

Arcuate partitions 28 do not extend between the sides 10*b* and 11*b* of the wheels 10 and 11, but the heater 16 has partitions which restrict flow from between the wheels and cause it to flow through the wheels successively, see FIGURE 5. However, the partitions formed by heater 16 are so arranged as to adapt approximately half of the outside air to by-pass the side 10*b* of the moisture transfer wheel 10. In other words, a certain volume of outside air is required to remove the sensible heat from the heat transfer wheel 11, but only half the amount of this air is sufficient to regenerate the moisture transfer wheel 10. Thus, to provide for more efficient operation, only half of the air is heated to a high temperature and caused to pass through the moisture transfer wheel 10 and the other half by-passes the wheel. This by-passing of part of the stream of outside air can be accomplished by providing partitions with an opening of the proper size. However, in the construction as illustrated, the heater 16 itself is so constructed and arranged as to permit air to escape downwardly from between wheels 10 and 11 and flow directly to the fan 14. As shown in FIGURE 5, the space 29 between the section 22*a* of the partition 22 and the heater 16 and between the heater and sides of the heat moisture transfer wheels 11 and 10 provide a leaking seal to permit the proper amount of air to escape downwardly into the fan 14.

The arrangement of the fans 13 and 14 and other auxiliary elements are also shown in FIGURES 3 to 6. Fans 13 and 14 are driven by motors 30 and 31, respectively, which are mounted on the fan casings. Underlying the evaporator wheel 12 is a drip pan 32 for collecting excess water as it drains from the wheel. In FIGURE 6, a motor **33** is shown mounted on the partition wall **23** for operating the drive shafts for rotating the wheels **10**, **11** and **12**, at later explained in detail.

Water is continually supplied to the evaporation wheel **12** by a system including a tank **36** in the base of the air conditioning unit and having a pump **37** for delivering water to a water distributing device for continuously circulating water through the openings in the wheel. The water circulating device may be of the same type as that described and claimed in my copending application for patent Serial No. 797,465, filed March 5, 1959, now Patent No. 3,065,956, although not necessarily restricted thereto. As shown in FIGURE 3, 4, 5 and 7, the water distributing device comprises hollow radial headers **38** and **39** of relatively narrow width positioned at opposite sides of the wheel **12** and extending vertically from the periphery of the wheel to its axis. The sides of the headers **38** and **39** adjacent the wheel **12** are opened so that water supplied to the headers can flow through the tubular openings **40** in the wheel to the other header. Each header **38** and **39** has baffles **41** and **42** offset vertically relative to the baffles in the other header for forming chambers to which water flows through the wheel **12** in a zig-zag path from adjacent the axis of the wheel to its periphery. The pump **37** supplies water through the line **43** to a chamber **44** at the upper end of header **38** and the water is discharged from a chamber **45** to drip pan **32** and from the latter through a line **46** back to the tank **36**. Thus, the material of the wheel **12** is saturated with water for evaporation into the air streams in the separate passageways **20** and **21**.

The means for supporting and driving the wheels **10**, **11** and **12** is illustrated in detail in FIGURES 8, 9 and 10, and comprises at least one shaft **50**, preferably under lying the wheels to support them, and having hubs for driving the wheels by peripheral contact therewith. In the illustrated embodiment, each wheel **10**, **11** and **12** is supported at three points of peripheral contact below its axis as illustrated in FIGURE 8. To this end, three shafts **50**, **51** and **52** extend between the sides **5** and **8** of the casing **2** and form a cradle for the wheels **10**, **11** and **12**. The shaft **50** underlies the wheels **10**, **11** and **12** at one side of the partition **22** and constitutes the drive shaft. The other shafts **51** and **52** constitute guide shafts and have rollers **53** thereon engaging the peripheral rims **10*r***, **11*r*** and **12*r*** of the respective wheels. As shown most clearly in FIGURE 9, the rims **10*r***, **11*r*** and **12*r*** of the respective wheels have spaced peripheral grooves **55** and **56** engaged by the rollers **53** on the shafts **51** and **52**.

As most clearly shown in FIGURE 10, the drive shaft **50** has its ends mounted in bearings **57** and **58** and has driving hubs **59** and **60** engaging the rims of the wheels **10** and **12**, respectively. Each hub **59** and **60** is fast on the drive shaft **50**, in frictionally driving engagement with the rims **10*r*** and **12*r*** of the wheels **10** and **12** and each has spaced annular ribs **61** and **62** projecting into the spaced grooves **55** and **56**. Driving hub **59** has a smaller outside diameter than the driving hub **60** to rotate the moisture transfer wheel at a slower speed than the evaporator wheel **12**.

The heat transfer wheel **11** is driven by frictional driving engagement with a sleeve **63** rotatably mounted on the shaft **50** and the sleeve also has spaced annular ribs **61** and **62** projecting into the grooves **55** and **56** in the rim of its wheel. The sleeve **63** and drive shaft **50** are driven by the motor **33** through gearing to rotate the heat transfer wheel **11** at a considerably higher rate of speed than wheels **10** and **12**. Sleeve **63** is driven from motor **33** through a sprocket **65** on the motor shaft, a chain **66** and a sprocket **67** on the sleeve. Chain **66** also engages a sprocket **68** on a counter shaft **69** which, in turn, has a sprocket **70** for driving a chain **71** and sprocket **72** fast on the drive shaft **50**. It will be noted that the chain **66** drives a large sprocket **68** on the counter shaft **69** which, in turn, rotates a small sprocket **70** connected to a large sprocket **72** on the drive shaft **50** by chain **71** to rotate the drive shaft at a much lower speed than the driving sleeve **63**. While the speed of the wheels **10**, **11** and **12** may have other ratios, the wheel **10** is preferably rotated at $\frac{1}{15}$ of a revolution per minute, the heat transfer wheel **11** at three revolutions per minute and the evaporator wheel **12** at $\frac{1}{5}$ of a revolution per minute.

The heater **16** for heating the stream of outside air between the heat transfer wheel **11** and moisture transfer wheel **10** to regenerate the latter is illustrated in detail in FIGURES 12 and 13. The heater **16** is of a unique construction to uniformly heat the stream of outside air to a high temperature in a minimum space between adjacent wheels **10** and **11**. The heater **16** is direct fired and comprises a plurality of burners **75** with a flue tube **76** projecting from each burner. Burners **75** and flue tubes **76** may have other shapes and positions, but as illustrated, the burners are arranged vertically and the flue tubes are U-shaped having an up-leg **76*a*** and down-leg **76*b***. The burners **75** may be of any suitable construction for burning any suitable fuel and in the embodiment illustrated, they are of the Bunsen type for burning a combustable gas. The burners **75** are mounted on spuds **77** projecting upwardly from a pipe **78** for supplying fuel gas to all of the burners. The supply pipe **78** and gas burners **75** are enclosed in a box **79** having an open end extending through an opening in a side wall of the casing **2** to provide primary and secondary air for all of the burners. Primary air enters each burner **75** through an opening **80** and flow is induced by the flow of a jet of gas through the spud **77** to provide a combustible mixture at the outlet at the top of the burner **75**. The flame from each gas burner **75** projects upwardly in the upright leg **76*a*** of its flue tube **76** and draws an envelope of secondary air around the flame as illustrated in FIGURE 12.

Each U-shaped flue tube **76** has an upright leg **76*a*** into which the flame is propagated, a downwardly extending vertical leg **76*b*** and a connecting bent loop **76*c*** at the top of the legs. The lower ends of the upright legs **76*a*** of all of the flue tubes open into the top of the box **79** over its respective burner **75** and the lower ends of the legs **76*b*** are open and positioned below the top of the burners **75**, at a location subjected to the suction pressure of the fan **14**. The successive tubes **76** extend upwardly to higher levels to substantially cover the entire face area of one side **10*b*** of the moisture transfer wheel **10** and the connecting loops **76*c*** of the flue tubes project at an angle from the upright legs **76*a*** so that the down leg **76*b*** of each tube is positioned between and forwardly of the upright legs of adjacent tubes in the direction of air flow as illustrated in FIGURE 5. This arrangement of the flue tubes **76** provides a maximum heating surface in a minimum space and insures a turbulent flow and contact of the air with all of the heating surfaces.

Due to the propagation of the flame and combustion of the gas in the lower end of the upright legs **76*a*** of the flue tubes **76**, the temperature varies along the length of the flue tubes. For example, the portion of the upright leg **76*a*** of each flue tube **76** immediately above the burner operates at a lower temperature than the upper part of the leg. This is due to the envelope of secondary air surrounding the flame. When all of the gas has been burned in the secondary air, the products of combustion immediately above the flame have a maximum temperature. The temperature of the products of combustion then decreases along the down leg **76*b*** in accordance with the heat transfer. Fins **81** are mounted on each tube **76** in a number and spacing corresponding to the temperature of successive sections to provide for uniformly heating the air flowing through the heater **16**. For example, the section of each tube immediately above the burner has fins **81** which are spaced progressively wider to a point generally corresponding to the end of the flame, as shown in FIGURE 13. From the end of the flame upwardly and around the connecting bend 76c no fins are provided. The down leg 76b immediately adjacent the return bend 76c has fins 81, but the spacing is progressivly increased and then decreased to its lower end. The down-legs 76b of the flue tubes 76 each have a helical metal baffle 82 therein, see FIGURE 12, to further increase the transfer of heat from the products of combustion to the tube walls. Thus, air flowing from the heat transfer wheel 11 to the moisture transfer wheel 10 first contacts the down legs 76b of the flue tubes 76 and is preheated by contacts with the exterior of the tube and the fins. The air then contacts the up-legs 76a of the flue tubes where it is further heated to the high temperature required and the spaced fins at the lower ends of the up-legs augment the heat transfer to uniformly heat all of the air.

The heater 16 including box 79, burners 75 and flue tubes 76 are joined together for insertion into and removal from the air conditioner as a unit. The unit includes a transverse partition 83, see FIGURE 13, positioned between one side of the box 79 and the face of the moisture transfer wheel 10 and a partition 84 positioned between the opposite side of the box and the heat transfer wheel 11. The ends of the down legs 76b of the flue tube 76 extend from passageway 21 through the partition 84 to subject the flue gases to the negative pressure at the suction side of the fan 14 to induce flow through the tubes and exhaust the gases directly into the fan. Thus, the flue gases are discharged with the air from the side 10b of the moisture transfer wheel 10 back to the atmosphere. Also mounted on the heater assembly 16 is a heat reflecting shield 85 positioned between the heat transfer wheel 11 and flue tubes 76. Shield 85 is composed of a perforated mass of a construction similar to the wheels 10, 11 and 12 of metal or asbestos paper, coated or uncoated, to reflect radiant heat from the heater.

FIGURE 14 illustrates a flue tube 87 generally similar to that illustrated in FIGURES 12 and 13 but having perforation 88 at the lower ends of the down legs 87b through which the flue gases escape directly into the heated air used to regenerate the moisture transfer wheel. Thus, all of the heat of the flue gases is used in regenerating the moisture transfer wheel 10. Furthermore, the perforations 88 being located on the rearward side of the flue tube 87 in the direction of flow of the stream of air produces an induced draft to draw the products of combustion from the end of the tube. As the moisture transfer wheel 10 rotates in a clockwise direction as viewed in FIGURE 12 and moves upwardly through a considerable arc after passing the lower ends of the flue tube 87 having perforations 88, the flow of air through the wheel above the perforations insures a complete flushing of all products of combustion before the wheel enters the passage 20 in which the room air is being circulated. Thus, contamination of the air being conditioned by flue gases from the passage 21 is entirely eliminated. One form of the invention having now been described in detail, the mode of operation is now explained.

The apparatus is started by initiating operation of the motors 30 and 31 for driving the fans 13 and 14, the motor 33 for driving the drive shaft 50 and pump 37 for circulating water. Rotation of the motor 33, see FIGURE 10, is transmitted by the chain 66 to rotate the sleeve 63 and through the sprockets 67, 68 and chain 71 rotates the drive shaft 50 in the opposite direction from the sleeve and at a much lower rate of speed. The driving hubs 59 and 60 on the drive shaft 50 then rotate the wheels 10 and 12 at a slow speed in one direction by peripheral contacts with the rims 10r and 12r of the wheels and the heat transfer wheel 11 is rotated by the driving sleeve 63 in the opposite direction at a much higher speed. As stated above, the moisture transfer wheel 10 is rotated at 1/15 of a revolution per minute, the heat transfer wheel 11 is rotated in the opposite direction at 3 revolutions per minute and the moisture evaporating wheel 12 is rotated 1/5 of a revolution per minute.

Fan 13 draws air from a room or enclosure into the air inlet opening 3 across the bottom of the air conditioner and discharges it under pressure into the plenum chamber 26. The air then flows forwardly through the sides 10a, 11a and 12a of the wheels 10, 11 and 12 successively and through the air outlet 4 back to the room or enclosure to be conditioned. During the passage of the air through the moisture transfer wheel 10 moisture is absorbed from the air. During the movement of the air through the heat transfer wheel 11 sensible heat is removed from the air. During the passage of the air through the moisture evaporating wheel 12 the air is further cooled by evaporative cooling and the air is thus cooled and humidified to desired conditions.

As each increment of the wheels 10, 11 and 12 move cyclically between the passageway 20 and passageway 21 it transfers the moisture and sensible heat removed from the air to be conditioned to the stream of outside air flowing to the sides 12a, 11a and 10a of the wheels, respectively. The stream of outside air is drawn into the apparatus through the inlet opening 6 by the fan 14 and passes through the wheels 11 and 12, successively. As the outside air passes through wheel 12 it is cooled by the evaporation of water therein. As the air passes through wheel 11 the sensible heat therein is transferred from the wheel to the air stream which preheats the air. At this juncture half of the outside air by-passes the heat transfer wheel 10 and flows directly to the fan 14 and the other half of the air is heated by the direct fired heat 16 to a high temperature. The high temperature air at a low relative humidity flowing through the moisture transfer wheel 10 removes the moisture therefrom and the moisture ladden air is discharged from the apparatus back to the atmosphere by the fan 14.

Due to the manner in which the wheels 10, 11 and 12 are mounted and driven, they may be easily and quickly mounted in and removed from the casing 2. To this end, the panel at one end of the casing may be removed, as shown in FIGURE 1, and the shaft 52 detached from its mounting in the side walls 5 and 8 of the casing and removed therefrom. The temporary ramp 89 may then be placed in the open end of the casing as illustrated in FIGURE 8 and a wheel rolled from the casing 2 along the ramp and onto the floor. When the wheels 10, 11 and 12 are removed from the casing all of the other elements are readily available for replacement or repair.

Due to the novel construction, the air conditioner 1 is of a compact construction and lightweight. In an air conditioner of this construction having a three-ton ice melting capacity, the wheels have a diameter of 46 inches. The wheel 10 has a depth in the direction of air flow of 6 inches, the wheel 11 a depth of 3 to 6 inches, depending upon the particular climate, and the wheel 12 has a depth of 3 inches. The air conditioner 1 as a result of the improved construction may be made 48 inches long, 29 to 32 inches wide and 67 inches high or less.

The flow of flue gas through the flue tubes 76 and 87 in both forms of construction, illustrated in FIGURES 13 and 14, is induced by fan 14 to insure complete combustion and thereby eliminate the need for additional equipment to induce flow. In the form of construction illustrated in FIGURES 1 and 13, the outlet ends of the tubes open into a chamber below the wheels which is subjected to the negative suction pressure of fan 14. This negative pressure of approximately .60 inch of water below the pressure of the air entering the burner 75 in the specific apparatus illustrated and described provides the draft necessary to cause the flue gases to flow through the tubes 76. In the form of construction illustrated in FIGURE 14, the velocity of the stream of regenerating air induced by the fan 14 and flowing past the perforations 88 at the end of tubes 87 induces the flow of flue gases from the tubes and into fan 14.

It is also pointed out that the arrangement of the evaporating wheel **12** and heat transfer wheel **11** recover a major portion of the loss resulting from the passage of successive portions of the evaporating wheel from one passage **20** or **21** to the other. Energy is used to dry the air to be conditioned to a low relative humidity and transfer heat to cool and dehumidify the air to, for example, 58° F. W.B., see FIGURE 2. That portion of the energy used to cool one half of the wheel **12** to this lower temperature is then transferred to the stream of outside air which would ordinarily constitute a loss in the efficiency of the system. However, the portions of the relatively cold wheel entering the passage **21** reduces the temperature of the outside air stream a corresponding amount and, in turn, cools the heat transfer wheel **11** to a corresponding lower temperature. Thus, the cooler heat transfer wheel **11** picks up more heat from the stream of air to be conditioned and compensates for the loss in the evaporating wheel **12**. In other words, the loss in cooling caused by the movement of successive cold portions of wheel **12** into the outside air stream is recovered to a large extent.

It will now be observed that the present invention provides an air conditioning apparatus which operates more efficiently than the previously known constructions. It will also be observed that the invention provides successive wheels arranged in aligned side-by-side relationship for drying, cooling and rehumidifying a stream of air circulated through a room or enclosure to be conditioned and transfers the moisture and heat to a stream of outside air continuously circulated through another passageway through the wheels. It will further be observed that the present invention provides an improved heater for heating the air in a minimum space for regenerating the moisture transfer wheel. It will still further be observed that the present invention provides an improved apparatus of a simple and compact construction adapted to be manufactured more economically than prior constructions and one which is reliable in operation and facilitates servicing and repair.

While two forms of heater are illustrated and described, it will be understood that further changes may be made in the construction and arrangement of elements without departing from the spirit or scope of the invention. For example, features of construction in the illustrated embodiment can be used in other air treating apparatus than the particular air conditioner illustrated and described, such as coolers, humidifiers and dehumidifiers using air pervious rotating wheels of the type illustrated and described. Therefore, without limitation in this respect the invention is defined by the following claims.

I claim:

1. Air treating apparatus comprising, an enclosing casing, a plurality of wheels in said casing, one of the wheels being a heat transfer wheel and another of the wheels being a moisture transfer wheel, said wheels being slightly spaced apart, each of the wheels being air permeable in

a direction substantially parallel to its axis, partitions in said casing co-operating with the wheels to divide the casing into separate air passageways at opposite sides of the wheels, fans for directing separate streams of air through the respective passageways, means for mounting the wheels for rotation in the casing, heating means in the form of a plurality of burners consisting of long tubes, the direction of said tubes being perpendicular to the direction of the air flow, said burners being located in the close spacing between the heat transfer wheel and the moisture transfer wheel, and a flue tube extending from the heating means and having its outer end in communication with the suction side of one of the fans to produce a draft through said tube and discharge the flue gas with the air for regenerating the moisture transfer wheel.

2. Air treating apparatus in accordance with claim 1 in which the end of the depending flue tube has a plurality of openings therein at the rearward side in the direction of air flow to induce the flow of flue gases through the flue tubes and into the air stream.

3. Air conditioning apparatus in accordance with claim 1 in which a plurality of the burners are provided in side-by-side relationship, an air box surrounding the plurality of burners, a flue tube for each burner, and each flue tube having a reverse bend to provide spaced legs in offset relationship to heat the air for regenerating the moisture absorbing wheel.

4. An air treating apparatus comprising a casing having air inlet and outlet openings, an air pervious moisture transfer wheel of a hygroscopic material mounted to rotate in said casing, partitions in said casing cooperating with the face of said wheel to divide said casing and wheel into separate passageways, fans for directing streams of air through said passageways, said wheel absorbing moisture from the air in one of said passageways, a direct fired heater in the other of said passageways for heating the air to regenerate the moisture transfer wheel, said heater comprising a burner and a flue tube extending from the burner across the passageway to heat the air, and the outlet end of the flue tube being located adjacent the suction side of the fan for directing a stream of air through the heater to induce the flow of flue gas from the flue tube.

References Cited in the file of this patent

UNITED STATES PATENTS

1,524,520	Junkers	Jan. 27, 1925
2,576,140	Pennington	Nov. 27, 1951
2,604,312	Andersen et al.	July 22, 1952
2,605,646	Karlsson et al.	Aug. 5, 1952
2,658,308	Fowler et al.	Nov. 10, 1953
2,687,747	Bock	Aug. 31, 1954
2,700,537	Pennington	Jan. 25, 1955
2,705,615	Rigby	Apr. 5, 1955