MOISTURE EXCHANGER FOR GASEOUS MEDIUMS

Filed Feb. 2, 1955 4 Sheets-Sheet 1

Fig.1

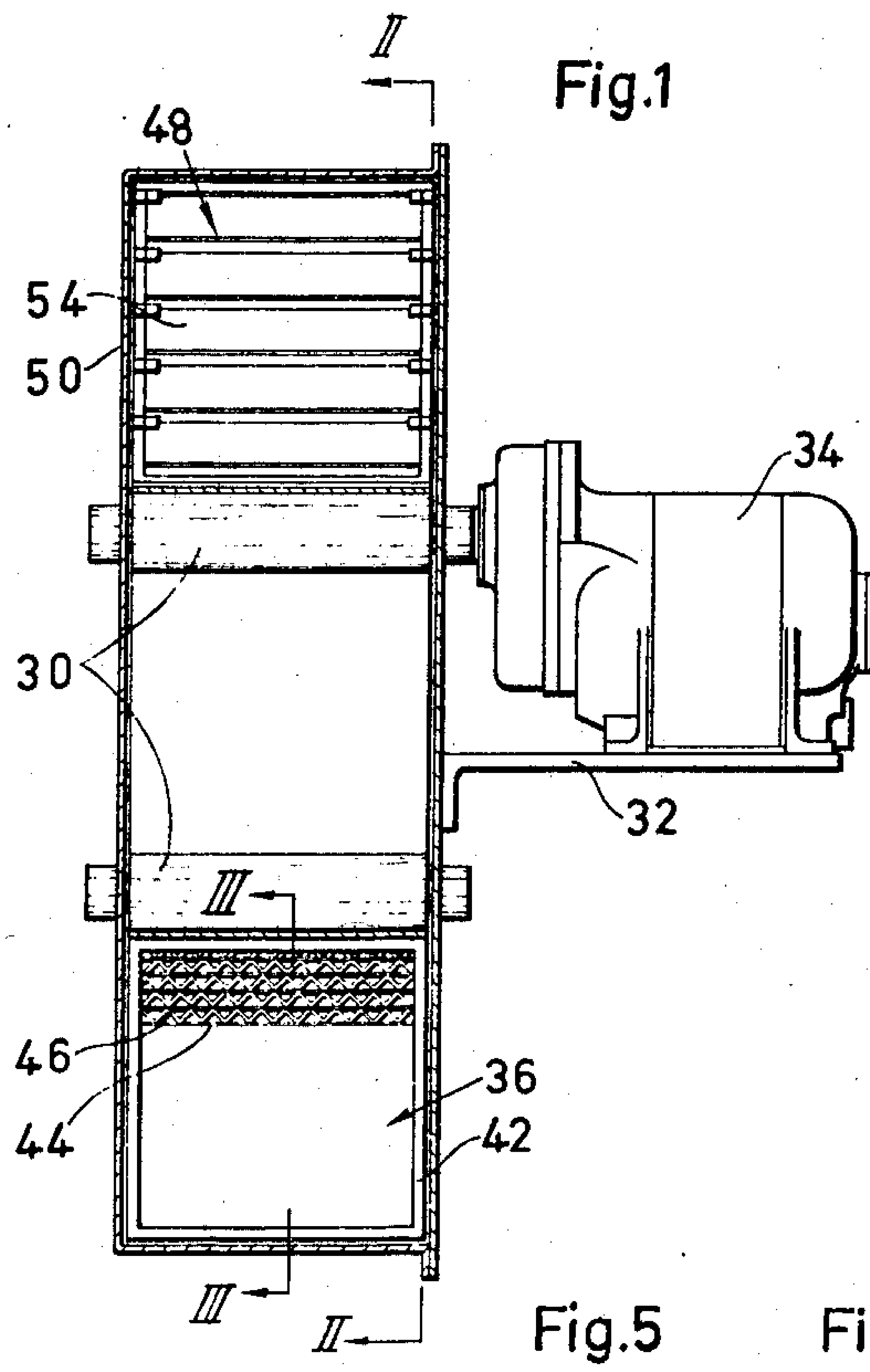


Fig.4

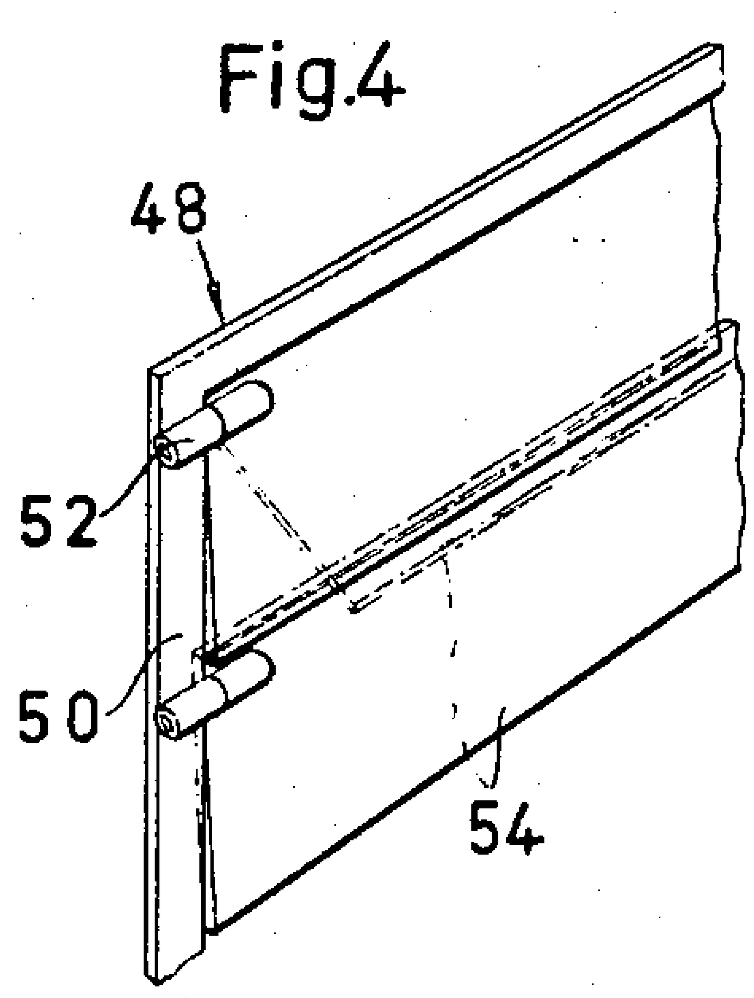


Fig.5

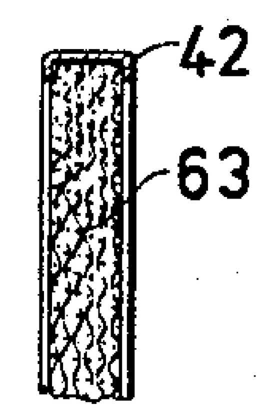
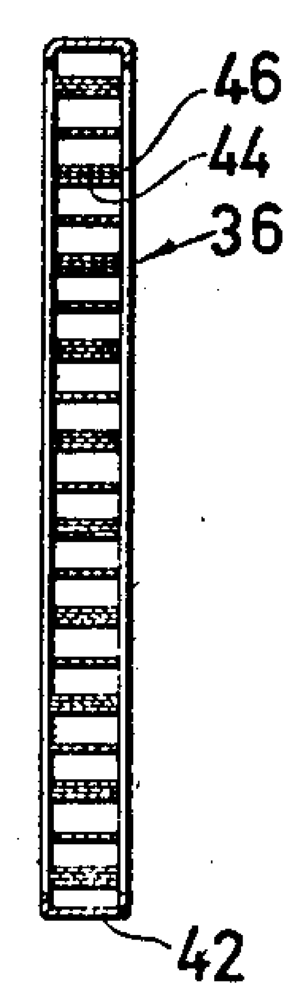


Fig.3



Inventor
Carl Georg Munters
By
His attorney

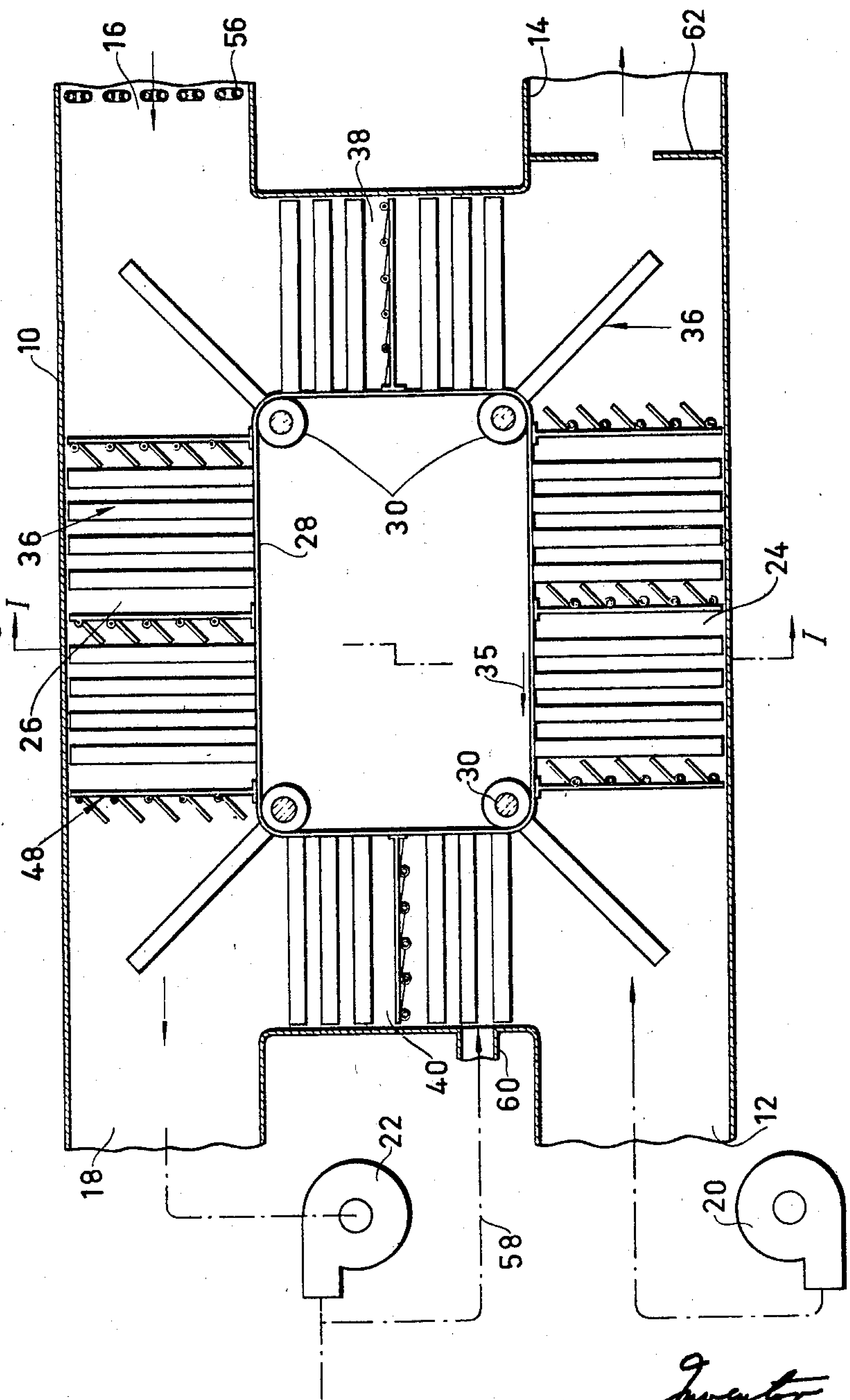


Fig. 2

Inventor
Carl Georg Munters
By [illegible]
his attorney

Feb. 23, 1960 C. G. MUNTERS 2,925,880

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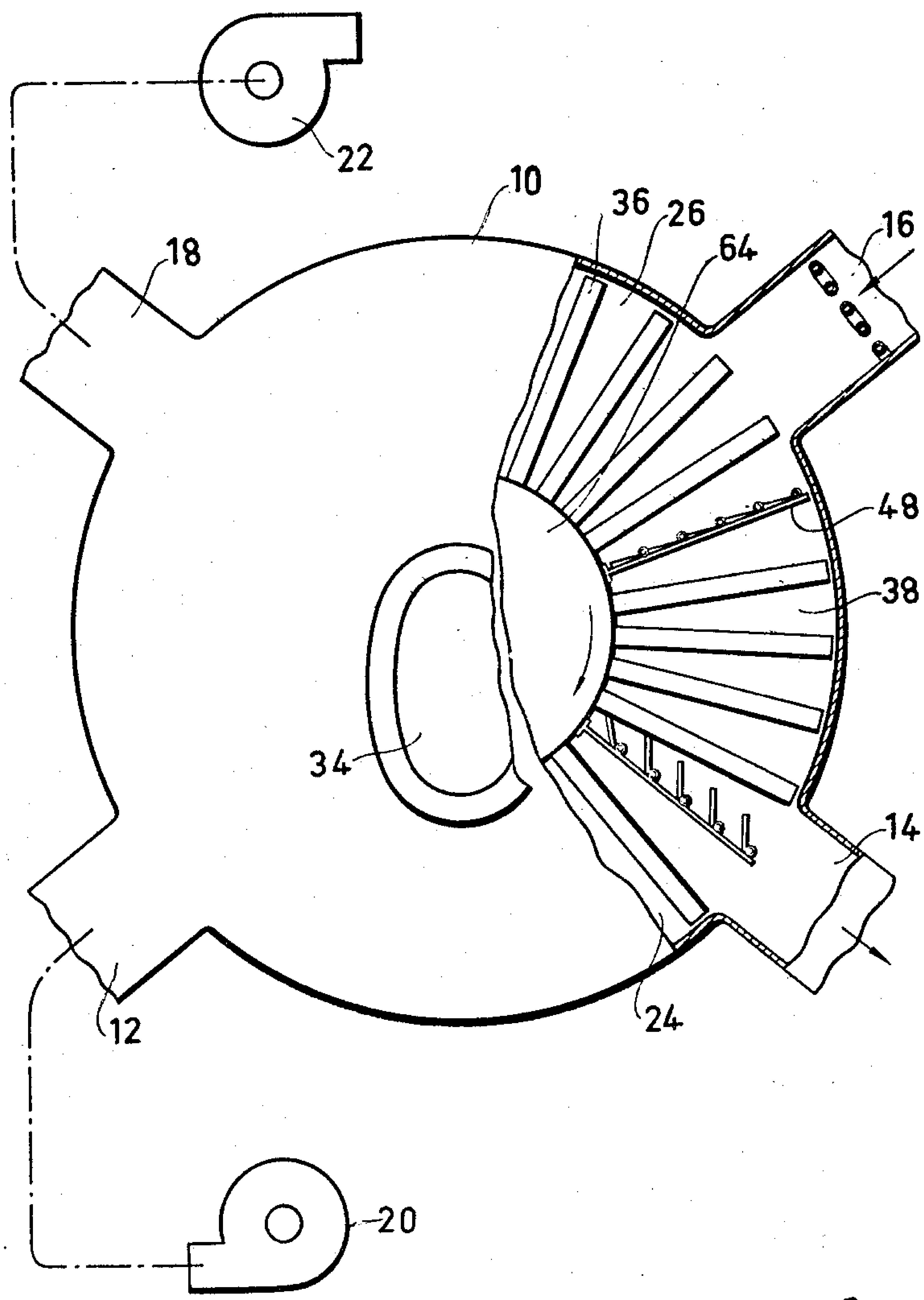
Fig.6



Inventor
Carl Georg Munters
By [illegible]
his attorney

Feb. 23, 1960 C. G. MUNTERS 2,925,880

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Fig. 7

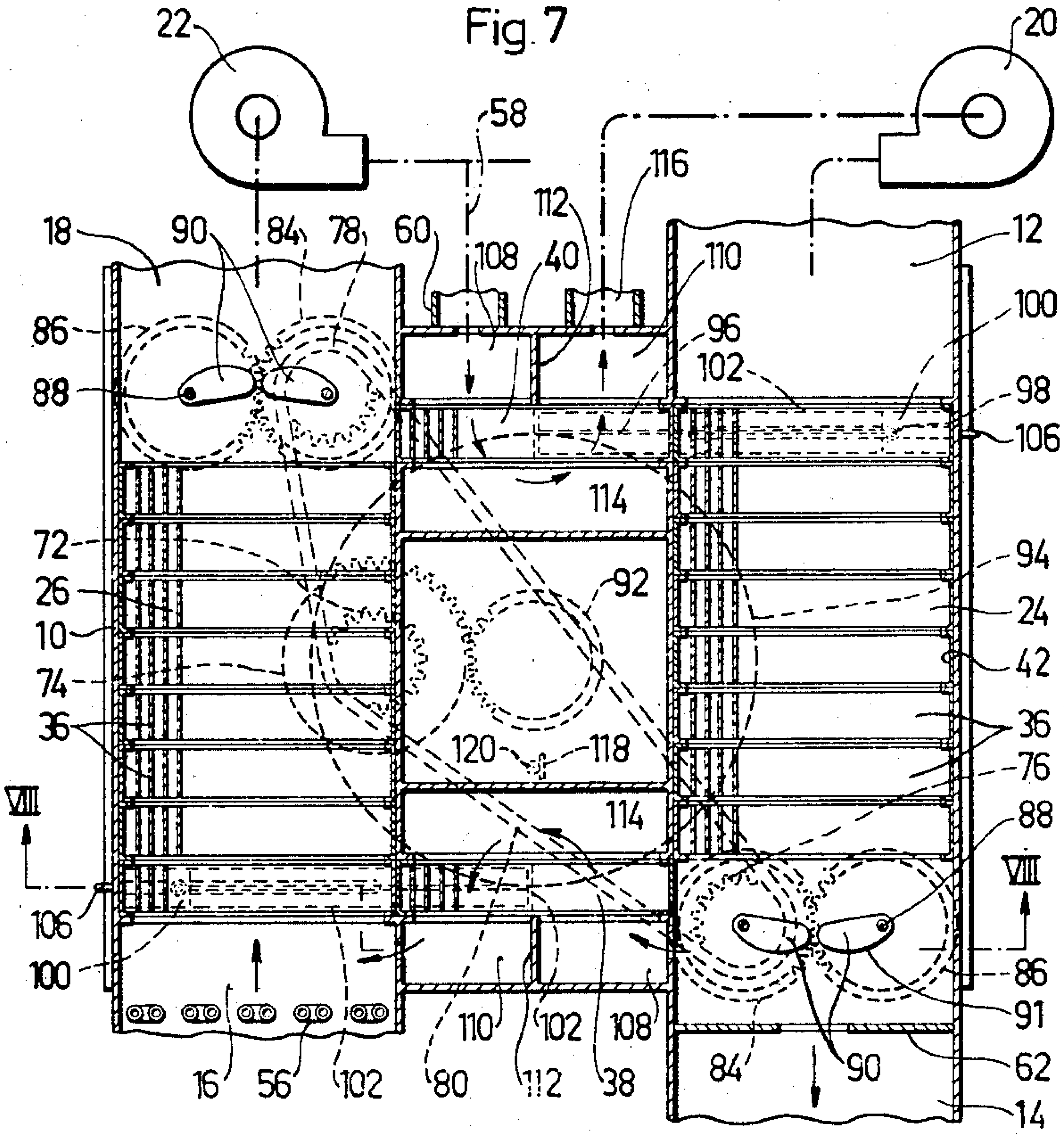
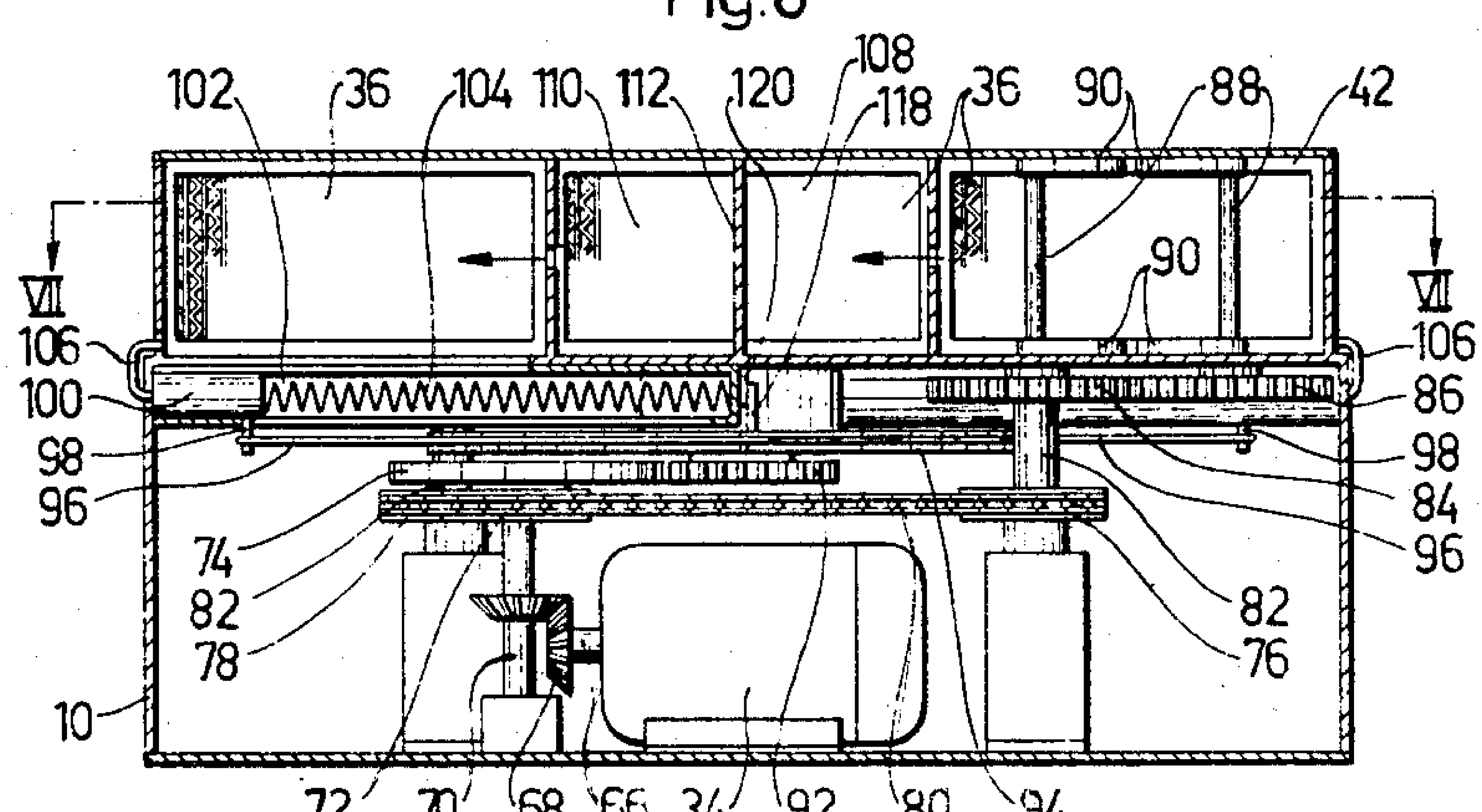


Fig. 8



Inventor
Carl Georg Munters
By [illegible]
his Attorney

United States Patent Office

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2,925,880

MOISTURE EXCHANGER FOR GASEOUS MEDIUMS

Carl Georg Munters, Stocksund, Sweden

Application February 2, 1955, Serial No. 485,632

Claims priority, application Sweden February 3, 1954

4 Claims. (Cl. 183—4.6)

My invention relates to devices for exchanging physical properties between gaseous mediums.

More particularly my invention relates to exchangers for changing the vapour content of a gaseous medium by means of another gaseous medium.

One example of such vapour-containing gaseous medium is air containing water vapour. This example where the moisture content of an air current is to be changed by means of another air current will hereinafter be described in order to elucidate the invention, it being, however, understood that the vapour may be some other than water vapour and the gas some other than air. The air which upon adjustment of its vapour content is to be employed for specific purpose will hereinafter be termed as primary air, and the other air which forms a kind of auxiliary medium will be termed as secondary air.

The novel exchanger is of the general type comprising one passageway each for each of said air currents and a body or rotor provided with a multitude of channels and movable along a closed circular path between said passageways. The channels in one part of the body when positioned in one of said passages are traversed by the one air current and in the other passage by the other air current. In a moisture exchanger said body is made so as to absorb moisture from the incoming air current having the higher relative moisture content and to deliver said moisture to the incoming air current having the lower relative moisture content.

The difference between known exchangers and the exchanger constructed in accordance with the present invention will be understood best when assuming the air currents to meet one another in counter-current contact and the ratio between the magnitudes of said both air currents to be dimensioned for high economy. As a result of the counter-current principle the theoretical optimum would be attained in the drying of the primary air, for example, if the secondary air when leaving the body or rotor would have the same relative moisture content as the primary air had when entering said body or rotor. Irrespective of how much one will succeed in approaching said optimum, it is a matter of fact that in all known exchangers each particle will be conveyed from a zone having a certain relative moisture in the one air current to a zone having a but insignificantly differing relative moisture in the other air current, which implies that the particle in question during the rotation will not but slightly change its humidity. The particle moves hereunder in a plane vertical to the direction of flow of the air currents adjacent said particle. Because of the small quantity of moisture which each individual particle is capable of transferring during one revolution large quantities of solid substance conveyed between the both air currents are required per unit of time in order to transfer a predetermined quantity of moisture. Mostly the air currents at corresponding points, which means

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points swept over by the same particle during its rotation, have quite different temperatures. Differences in temperature of between 50 and 150 centigrades are not unusual. Since at the same time the quantities of solid substance conveyed per unit of time are large, a non-desired heat transfer will be caused between the gas currents.

One object of my invention is to eliminate the inconveniences inherent to moisture exchangers hitherto known.

According to one feature of my invention the moisture exchanger adapted to change the vapour content of a gas current by means of another gas current and comprising a housing provided with a separate inlet and a separate outlet and a separate passageway for each of said gas currents, and a transfer body formed with a multitude of open channels, said housing on the one hand and said body on the other hand undergoing relative movement along a closed path, each of said gas currents being conducted through said channels when positioned in said passageways, is constructed so that the main directions of the movable part of the exchanger and at least one of said gas currents are parallel to one another during the flow of the gas current from the inlet to the outlet of the respective passageway, the transfer body having hygroscopic material which through condensation below the saturation point absorbs vapour from the gas current having the higher relative vapour content and delivers said vapour by evaporation to the gas current having the lower relative vapour content. "Parallel" is to be understood in this connection to mean that the portion of the body positioned in one passageway is exposed over a larger range to be influenced by the vapour content of the gas current. Therefore if it is a question of an exchange of moisture between two air currents the individual particles of the body will be influenced or actuated by the total difference in relative moisture existing when the two currents enter their respective passageways and not as hitherto by a small fraction of said difference only. The consequence is that a rotor having a certain mass will be capable with the same number of revolutions to transfer a many times larger quantity of moisture than known exchangers. The number of revolutions of the rotor may be reduced correspondingly. The advantage with low numbers of revolutions is particularly evident when transferring a vapour from one gas current to another when at the same time the gas currents have different temperatures and a heat transfer between the currents would mean an inconvenience. Of course, the mass of the body has a definite heat capacity, but due to the slow rotation the quantity of mass conveyed per unit of time between the passages is so small as to render the heat transfer insignificant.

Further objects and advantages of my invention will be apparent from the following description, considered in connection with the accompanying drawings, which form part of this specification and of which:

Fig. 1 is a view of a section taken along line I—I of Fig. 2 through a moisture exchanger constructed according to my invention.

Figs. 2 and 3 are sections on lines II—II and III—III, respectively, of Fig. 1; the latter section being presented in a larger scale.

Fig. 4 is a partial perspective view of a partition wall.

Fig. 5 is a sectional view of a part of a transfer body corresponding to that shown in Fig. 3.

Fig. 6 is a lateral and partly sectional view of a modified embodiment of the invention.

Fig. 7 is a section along line VII—VII of Fig. 8 through still another modified embodiment of the invention, and Fig. 8 is a partial sectional view following line VIII—VIII of Fig. 7.

In all figures corresponding parts are denoted by the same reference numerals.

Referring to the drawings, 10 designates the housing of the exchanger, said housing being provided with an intake opening 12 for primary air to be dried in the exchanger, 14 designating the outlet for said air. Secondary air is introduced into the exchanger through an intake opening 16 and escapes through an outlet 18. Each of the air currents is guided through the apparatus by a separate fan 20, 22, respectively. The pressure side of the fan 20 is preferably connected to the intake 12 and the suction side of the fan 22 to the outlet 18. Between the intake 12 and the outlet 14 is a passageway 24 to be traversed by the primary air, and between the intake 16 and the outlet 18 is a passageway 26 for the secondary air.

In the embodiment illustrated in Figs. 1–4 an endless flexible belt 28 made for instance of rubber, is placed around four rolls 30, one of which is driven by means of a geared motor 34 (Fig. 1) which is carried by a bracket 32 and the driving shaft of which rotates with a very low number of revolutions. The endless belt 22 which by the rolls 30 is given a substantially rectangular path of travel is thus advanced by the motor 34 with a speed which is correspondingly low and may amount to one or a few revolutions only per minute. The direction of travel of the belt is indicated by the arrow 35.

Rigidly secured to the belt 28 are member units or packs generally designated by 36 and occupying substantially the entire transverse section of the passageways 24 and 26 as well as that of transit passages or zones 38, 40 interconnecting said passageways 24 and 26. Each member unit may be composed of a frame 42 (Fig. 3) of sheet metal or like material with inwardly bound side edges and a pack or layers enclosed by said frame and composed of foils or sheets of a hygroscopic material, for example some definite paper qualities, which are particularly hygroscopic if wool fibres or fibres of other highly hygroscopic materials are contained in the paper. A wool fibre absorbs twice as much moisture as does a wood or cellulose fibre. In books of reference the hygroscoposity is defined by the quantity of water which a substance is capable of absorbing when having a predetermined relative moisture content, for example grams of water per 100 grams of the substance calculated in completely dry state.

The layers may even consist of a sheet or foil-shaped carrier having an addition or a cover of a hygroscopic material, such as finely grown slica gels. According to the invention the material may be water-soluble, as is the case with some salts since there will not occur any displacement of said salts as frequently occurs in known exchangers. Every second sheet 44 may in this connection be plane and every second sheet 46 corrugated. The channels or clearances formed by the pack or layer are continuous, and as they occupy the entire transverse area of the passageways 24, 26 the air currents are forced to pass through said channels or clearances. The channels are preferably narrow, and the spacing between the plane sheets 44 may thus be less than 2 to 3 millimetres. In this way very high coefficients of moisture transfer are obtained, as is described more detailed in my co-pending patent application Serial No. 442,687, filed July 12, 1954, which is referred to for a more detailed explanation of the phenomenon in question.

The member units 36 are divided into compartments separated from one another by partitions 48 which also are secured onto the belt 28 and project at right angles therefrom. The partitions act as a kind of valves, which during the travel when occupying some predetermined positions are open and when occupying other positions are closed. For simplicity the partitions have been illustrated as frames 50 and louvers 54 mounted therein by means of hinges 52. Said louvers are made of such light materials that they are caused to open and to close in response to variations in pressure produced in the exchanger.

A heating element 56, for example operated by electricity, is disposed in the intake opening 16. A conduit 58 extends preferably from the outlet side of the fan 22 and opens at 60 into the transit passage 40 at the base thereof as illustrated in Fig. 2. At least one partition 48 is always to be available within the passage 40 above the mouth 60. A possibly adjustable throttling passage 62 may be disposed in the outlet opening 14.

By way of example it may be assumed that the exchanger has for its object to dehydrate the air in a room conditioned during summer, the temperature in which room thus is to be kept below that of the atmosphere. This primary air which may have a temperature of +20° C. is introduced by the fan 20 through the intake 12 and flows thereupon through the passageway 24 to the outlet 14. The atmospheric air, the temperature of which is higher, for example +30° C., is sucked in by the fan 22 through the intake 16. Said secondary air is heated by the heating element 56 to +60° C., for example, or even higher and conducted through the passageway 26 to escape through the outlet 18. The air in the room has initially a high relative moisture content, such as of 80%, for example, and under its travel through the channels of the individual units 36 slowly moving in a countercurrent to the direction of flow of the air the moisture is absorbed so as to reduce the moisture content of said air current when arriving at the outlet 14 to 20% only, for example. At the same time heat has been set free and the temperature of the air current has been raised to about 33° C. The individual layers in the units 36 thus absorb a quantity of moisture corresponding to said difference in the moisture content of the air. The member units enriched by moisture are conveyed through the transit passage 40 upwards into the passageway 26 where they are moved opposite to the current of secondary air. The moisture content of said secondary air was initially 60%, for example, but by the heating in the element 56 said content is reduced to about 15%. The secondary air thus has obtained a drying capacity. The moisture absorbed in the passageway 24 is delivered to the secondary air in the passageway 26 by the individual layers in the rotating body. By this action heat is consumed so that the temperature of the secondary air discharged at the outlet 18 is lower than it had been at the intake.

A member unit 36 passing over from one of the four passageways to the adjacent one due to its position directly in front of roll 30 is given a relatively high angular speed for which reason it is quickly displaced between the passageways which is of importance as the channels of the units during the transit movement have an inclined position relatively to the main direction of the air currents. The partitions 48 are placed relatively one another so as to cause at least one such partition always to be available in the transit passages 38 and 40, respectively, in order to minimize direct overflow from one air current into the other. As the pressure side of the fan 20 communicates with the intake 12 for the air escaping from the room, whereas the suction side of the fan 22 communicates with the outlet 18 for the secondary air, the light louvers 54 will be closed by the difference in pressure caused due to said arrangement during the travel of the partitions through the transit passage 40. In the passageways 24 and 26 the registers are opened by the force of the current. In the passage 38 the louvers are forced into sealing position by the force of gravity, it being assumed that Fig. 2 is a vertical section.

Between the intake side for the air from the room and the outlet side for the atmospheric air the example described hereinbefore assumes a difference in temperature of about 30° C. to exit. Since some heat capacity of the member units 36 is inevitable said difference of temperature implies that quantities of heat are transferred to the dried primary air. In order to minimize such heat transfer a predetermined minor percentage of said last-mentioned air may be caused to flow upwardly in the passage 38 so as to cause the units to be cooled here by evaporation from the same. A required difference in pressure for said flow may be produced and controlled by the throttling passage 62. As the dried air of the room must be returned into said room, a corresponding quantity of air must be supplied at the intake side 12. This is effected by means of the conduit 58, in which a pressure superior to that at the inlet of the passageway 24 has been produced by means of a throttling passage (not shown) disposed in the escape conduit from the fan 22 behind the place where the conduit 58 is branched off. The additional air streaming through the conduit 58 is also caused to traverse the units 36 entering into the passage 40, said units cooling the additional air and reducing the vapour pressure thereof by absorption to said units prior to the intermixing of said air with the primary air.

The temperature of the air escaping through the outlet opening 14 may be cooled prior to the return of the air into the room below the temperature of room in known manner by means of a cooling element and thereupon additionally by moisturing with water.

As illustrated in Fig. 5, the interior of the member units is occupied by a filamentous mass 63 having hygroscopic properties, said mass otherwise, if desired, being of the kind described in my co-pending patent application Serial No. 387,656, filed October 22, 1953, now abandoned.

The embodiment presented in Fig. 6 does not substantionally differ from the preceding one except that the moisture transferring body performs a purely rotational movement. Said body is in this connection formed as a drum of hub 64, carrying the member units 36 and the partitions 48 secured thereto. Due to the spacing of the units from one another the air introduced through the intakes 12 and 16 can easily be distributed over the individual channels of the units. In this case the passageways 24 and 26 and the transit passage 38 together form an annular room.

It is easily understood that according to the invention each front layer or unit 36 in the transferring body at a certain moment, for example when the layer leaves a passageway, has the same or at least almost the same temperature over its total surface area, a feature of great value for both moisture exchangers and pure heat exchangers. In the known exchangers of the type mentioned in introduction of this specificaiton the temperature of such front layer varies in response to the intake and outlet temperatures of the gases because the direction of the gas currents coincides with the plane of the front layer.

In the embodiment illustrated in Figs. 7 and 8 the members 36 have the shape of individually separate rectangular units. Though it does not constitute a condition, particular transit passages or zones 38 and 40 are in this embodiment also arranged between the passageway 24 for the primary air and the passageway 26 for the secondary air. Said transit passages have such dimensions as to be capable of containing one member unit at a time.

The motor 34 the driving shaft 66 of which rotates with a low number of revolutions such as 10–20 revolutions per minute, for example, drives a shaft 70 through bevel gears 68. The shaft 70 carries a sprocket 72 and a toothed wheel 74 the gearing of which is interrupted and thus extends over a part of its circumference only. An endless sprocket chain 80 runs about said sprocket 70 and two sprockets 76 and 78 located outside the outlet ends of the passageways 24 and 26, respectively, for the air currents. Each of said sprockets 76, 78 is mounted on its shaft 82 carrying also a pinion 84 engaging a gear 86. The gears 84, 86 are geared to shafts 88 carrying feeding arms 90 and together with said arms disposed inside the passageways 24, 26 so as to be located in front of the frames 42 of the member units 36. Each shaft 88 carries two feeding arms. The gears 84, 86 performing one rotation, the arms 90 actuate the member units 36 in each of said passageways and advance them for a distance corresponding to the thickness of one member unit. The feeding arms may have an outwardly bent face 91 with which they during the displacement of the units 36 in the passage in question bear against the frames 42.

The toothed wheel 74 when rotated one revolution, will during a part of said revolution cause its teeth to engage a toothed wheel 92 mounted on the same shaft as a pulley 94. The toothed wheel 92 is thus turned only as long as said engaging contact lasts. Two wires 96 partly and in mutually opposite directions wound around said pulley are each secured by means of a tap 98 to a piston 100. Said pistons are movable within cylinders 102, one of which is disposed adjacent the passageway 24 at the intake opening 12 thereof and the other adjacent the intake opening 16 of the passageway 26, each cylinder further containing a return spring 104. A hook-shaped catcher arm 106 extends from the piston 100 towards the external front face of the member units 36. Axial slots are provided in the wall of the cylinder 102 to permit the tap 98 and the arm 106 to follow any displacement of the piston 100 within the cylinder housing said piston.

Adjacent the external wall of each of the passages 38 and 40, respectively, a plurality of chambers, in the presented embodiment case two such chambers denoted by 108 and 110, are arranged separated from one another by a partition 112, a further chamber 114 extending along the entire passage being disposed along the internal wall of each of said passages. Said chambers are open towards the passages 38 and 40, respectively. The branch current of secondary air introduced from the pressure side of the fan 22 through the conduit 60 into the chamber 108 traverses a portion of the member unit 36 located in the passage 40 at a right angle to the longitudinal extension of said unit and flows into the chamber 114 and thereupon in the opposite direction through the remaining portion of said member unit into the chamber 110. This latter may be in open connection with the intake 12, but according to a preferred construction said chamber communicates through a conduit 116 with the suction side of the fan 20. In this latter case the pressure drop available for producing a branch current streaming through the member unit 36 positioned in the transit passage 40 will be large enough to permit correspondingly small dimensioning of the conduits.

On the opposite side of the apparatus, part of the primary air streams into the chamber 108 and therefrom through a portion of the member unit 36 positioned in the passage 38 into the chamber 114 to return through another portion of the same member unit into the chamber 110 and finally to escape through the outlet 16.

On clockwise rotation of the shaft 70 and the chain wheel 72, viewed in the plane of Fig. 7, the teeth of the toothed wheel 74 engage the toothed wheel 92 so as to cause the pulley 94 to start a rotatory movement. By said movement the wires 96 are wound on the pulley and carry the pistons 100 with them. The catcher arms 106 secured to said pistons push each outermost member unit 36 hitherto positioned in the passageways 24 and 26, respectively, into the transit passage, the member hitherto positioned in said passage at the same time being driven into the opposite passageway 26 or 24, respectively. The member unit 36 positioned adjacent the outlet 12 is thus moved to the left, seen in the plane of Fig. 7 and the member positioned adjacent the intake 16 is displaced to the right. The toothed segment of the wheel 74 leaving the rim of the toothed wheel 92, the movement of said last mentioned wheel is discontinued and the springs 104 return the pistons 100 to their starting position while the wires 96 are unwound from the pulley 94. This latter is stopped by a shoulder 118 provided on the pulley and a co-operating stationary shoulder 120.

The chain 80, while at the same time effecting the lateral displacement just described of the member units 36, continuously drives the two pairs of gear wheels 84 and 86 and therewith the feeding arms 90. Said wheels having been rotated for about half a revolution, the two member units 36 have been forced into the passageway 24 or 26, respectively. The arms 90 during their continuing rotation abut against said member units and advance them in the longitudinal direction of the passageways over a distance corresponding to the thickness of said units. In this way an automatic displacement of the member units from the one passageway to the other is effected simultaneously with an advance of the member units in the individual passageways. A member unit 36 when positioned in a transit passage 38 or 40 will be traversed by a branch air current which in accordance with the explanations hereinbefore in the first case will cool the member unit in question while in the latter case the branch air current can be cooled by the member unit. The result will be an additionally improved efficiency of the moisture exchanger. The intensity of the individual branch air currents can be controlled by means of throttling devices which may be adjustable in any known manner.

The reciprocal embodiment comprising a stationary transfer body and a rotatable housing is also realizable, in particular in connection with a purely rotationary movement according to Fig. 6, although said embodiment would require a relatively complicated construction. The best effect of this embodiment is obtained by the casing moving in the same direction as the gas currents in the passageways. Further, the movable part of the exchanger, for instance the transfer body, besides a main travel in a direction parallel to that of the gas currents may perform a kind of zigzag or wave movement at right angles to the direction of said main travel. If the transfer body consists of a flexible or linked belt-shaped member it may be arranged in the passageways running around rollers adapted to convey said member alternating between two opposed walls in said passageways. As an alternative adaptable to conventional exchangers of the rotary type the gas currents may be guided between the intake opening and the outlet for either or both gas currents in a kind of oscillatory movement from one lateral face of the rotor to the other. In the individual channels of the rotor the direction of flow of the gases, of course, becomes parallel with the axis of the rotor, but in spite thereof their main direction from the intake to the outlet will be parallel to the peripheral motion of the rotor.

While I have herein described the disclosed structures as being particularly adapted for moisture exchange, it will be apparent that the same may, without material modification, be employed for heat-exchanging purposes. It will therefore be understood that any specific reference made herein to moisture exchange shall also comprehend heat exchange, without departing from the spirit of the invention.

While several more or less specific embodiments of my invention have been described, it is to be understood that this is for the purpose of illustration only and that my invention is not to be limited thereby, but its scope is to be determined by the appended claims.

What I claim is:

1. A moisture or vapor exchanger for air drying and operative to change the vapor content of an air current by means of another air current, said exchanger including a housing provided with spaced pairs of separate inlets and outlets and a separate duct for each of said air currents, a transfer body operative in the housing and formed with a multitude of member units and containing a hygroscopic material, the housing and the body having relative movement and each of said air currents being led through said member units when the latter are positioned in said ducts in which the directions of movement of the body and said air currents are at least substantially parallel and opposite to one another during the passage of the air current from the inlets to the outlets of the respective ducts, the transfer body being composed of said member units disposed in series relation and individually filling up the cross section of the ducts, transverse communicating spaced passages between said ducts, said passage being normal to the direction of travel of said member units in said ducts so each passage receives a single member unit moving into said passages normal to said ducts, at least one of said passages communicating with an auxiliary air current circulated through said one passage and a member unit disposed therein, a plurality of said units being adapted to move simultaneously in each respective duct while being traversed in series by the air current therein.

2. A moisture exchanger for air drying according to claim 1 in which the transfer body and member units are effective to restrict air flow from one duct to the other as said transfer body and member units move through the transverse passages between the ducts.

3. A moisture or vapor exchanger for air drying and operative to change the vapor content of an air current by means of another air current, said exchanger including a housing provided with spaced pairs of separate inlets and outlets and a separate duct for each of said gas currents, a transfer body operative in the housing and formed with a multitude of member units containing hygroscopic material, the housing and the body having relative movement and each of said air currents being led through said member units when the latter are positioned in said ducts in which the directions of movement of the body and said air currents are at least substantially parallel and opposite to one another during the passage of the air current from the inlets to the outlets of the respective ducts, the transfer body being composed of said member units disposed in series relation and individually filling up the cross section of the ducts, transverse communicating spaced passages between said ducts, said passages being normal to the direction of travel of said member units in said ducts so each passage receives a single member unit moving into said passages normal to said ducts, a plurality of said units being adapted to move simultaneously in each respective duct while being traversed in series by the air current therein and sealing partition means interposed between successive units adapted during the movement of said units through the transverse passages connecting the ducts to close the cross section area of said passages in order to counteract leakage of air between the ducts.

4. A moisture or vapor exchanger for air drying and operative to change the vapor content of an air current by means of another air current, said exchanger including a housing provided with spaced pairs of separate inlets and outlets and a separate duct for each of said gas currents, a multitude of separate units operative in the housing, each unit comprising a frame and an air permeable core containing hygroscopic material, the housing and the units having relative movement and each of said air currents being led through said units when the latter are positioned in said ducts in which the directions of movement of the units and said air currents are at least substantially parallel and opposite to one another during the passage of the air current from the inlets to the outlets of the respective ducts, said units being disposed in series contact relation and individually filling up the cross section of the ducts with the front area of their frames, transverse communicating spaced passages between the said ducts, said passages being normal to the direction of travel of said units in said ducts so each passage receives a single unit moving into said passages normal to said ducts, a plurality of said units being adapted to move simultaneously in respective ducts while being traversed in series by the air current therein, and a portion of said frames of said units being adapted

to fill the cross section area of said passages in order to counteract leakage of air between the ducts.

References Cited in the file of this patent

UNITED STATES PATENTS

2,222,828	Guthrie	Nov. 26, 1940
2,302,807	Shoeld	Nov. 24, 1942
2,507,608	Miller	May 16, 1950
2,662,607	Moragne	Dec. 15, 1953
2,700,537	Pennington	Jan. 25, 1955

FOREIGN PATENTS

89,244	Austria	Aug. 25, 1922