Feb. 25, 1964 J. KOCH 3,122,200

DYNAMIC SEALING MEANS FOR ROTARY REGENERATIVE HEAT EXCHANGERS

Filed May 24, 1960 3 Sheets-Sheet 1

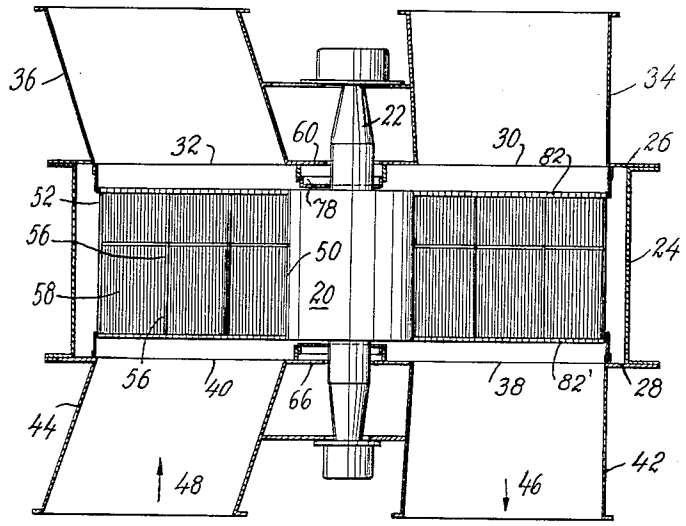


Fig. 1

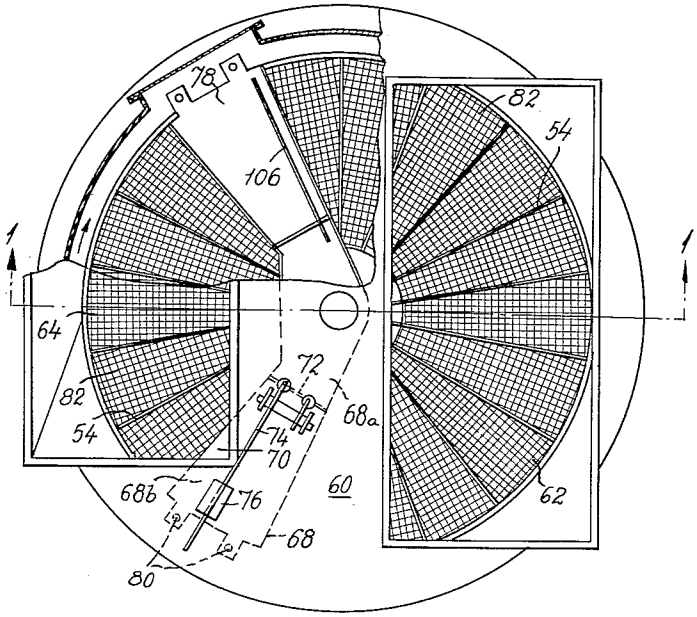


Fig. 2

INVENTOR.
Jakob Koch
BY
Darwin Marble
his attorney

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DYNAMIC SEALING MEANS FOR ROTARY REGENERATIVE HEAT EXCHANGERS

Filed May 24, 1960 3 Sheets-Sheet 2

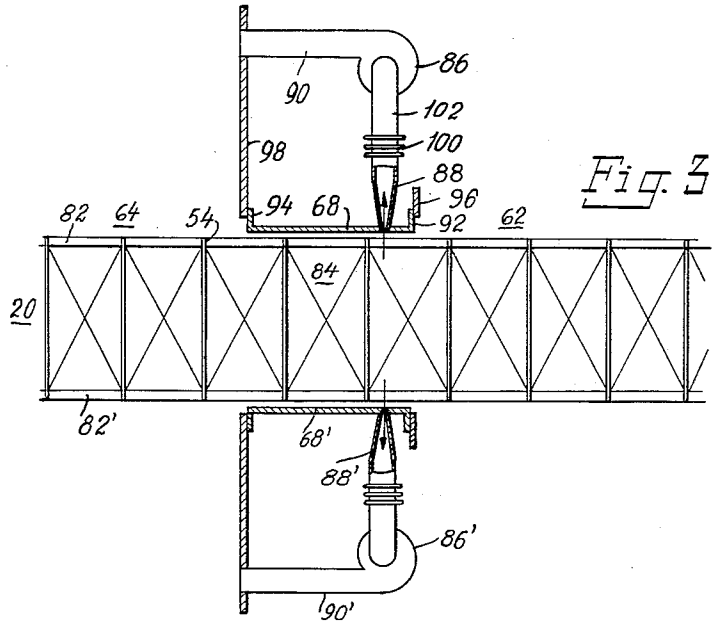


Fig. 3

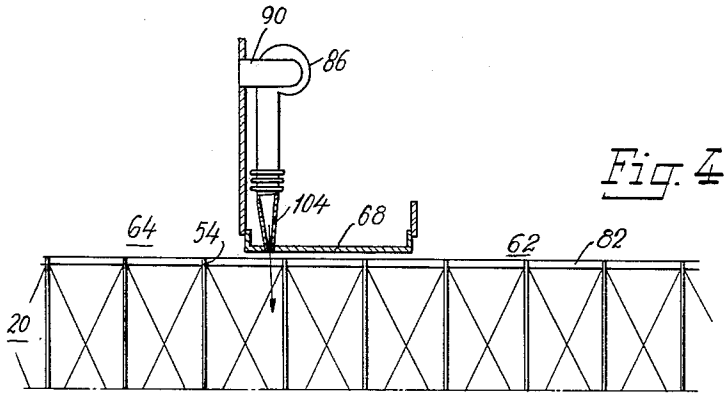


Fig. 4

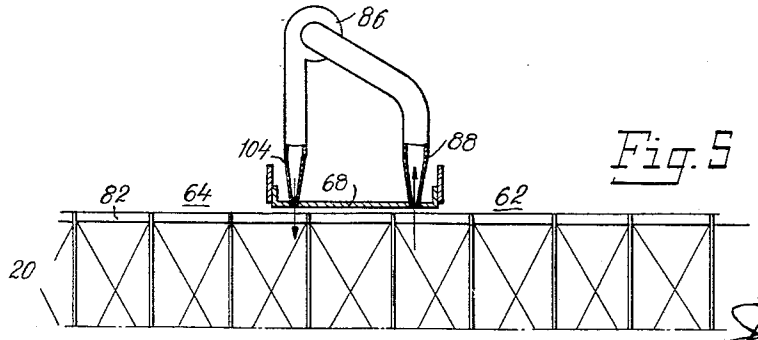


Fig. 5

INVENTOR.
Jakob Koch

BY
Edmund Marbella
His Attorney

Feb. 25, 1964 J. KOCH 3,122,200

DYNAMIC SEALING MEANS FOR ROTARY REGENERATIVE HEAT EXCHANGERS

Filed May 24, 1960 3 Sheets-Sheet 3

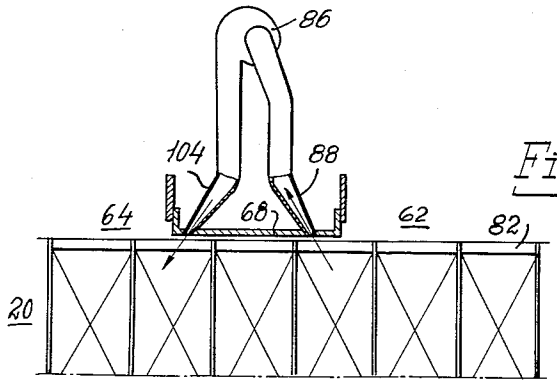


Fig. 6

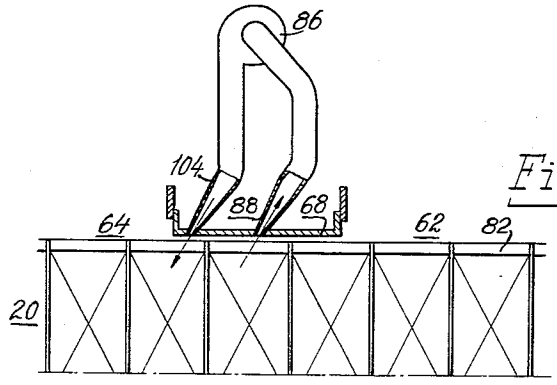


Fig. 7

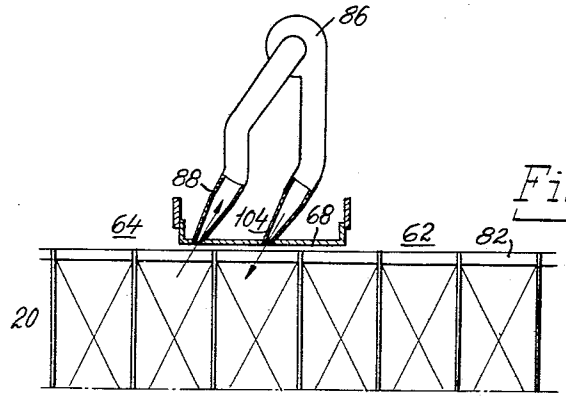


Fig. 8

Jakob Koch INVENTOR.

BY

Jarvis & Martin
his attorney

United States Patent Office 3,122,200 Patented Feb. 25, 1964

3,122,200

DYNAMIC SEALING MEANS FOR ROTARY REGENERATIVE HEAT EXCHANGERS

Jakob Koch, Heidelbergerstrasse 27, Edingen, near Heidelberg, Germany

Filed May 24, 1960, Ser. No. 31,414
9 Claims. (Cl. 165—9)

This application is a continuation-in-part of application Serial No. 598,571, filed July 18, 1956, now abandoned.

This invention relates to regenerative heat exchangers having a rotor or heat absorbing and heat rejecting mass enclosed in a stationary housing structure including axially aligned sector shaped end plates which define two channels for flow of fluids of different pressures through the exchanger.

More particularly the invention relates to a means for improving the efficiency of heat exchange in such apparatus.

For taking an example from the practice such as an air preheater, in the same high pressure air is heated by hot flue gases from the boiler plant and it is well known in the art that the efficiency of such air preheater is considerably reduced in that the high pressure air is trapped in the compartments of the rotor, and as the rotor revolves the entrained air is escaping through the low pressure or flue gas channel into the stack. Means have therefore been proposed to exhaust the entrained air and return it to the high pressure air channel. In the known arrangements, adjacent to the admittance duct for the high pressure air a suction device was provided for exhausting the air and returning it back to the high pressure air channel.

In such rotary regenerative heat exchangers, however, apart from the air trapped in the rotor compartments, severe leakage losses are occurring as a result of high pressure medium escaping by leakage from the high pressure channel to the low pressure channel. It has been difficult to avoid that leakage currents are flowing through the clearance gaps between the channel or zones of different pressures. To at least reduce to a minimum the losses due to such leakage escape it has been proposed to narrow the width of the leakage gap between each end face of the rotor and the confronting end plate of the housing as much as possible. However, operational safeties impose a limit in this respect, particularly if the size of the rotor is large. Since the rotor is liable to warp and distort considerably under the influences of varying temperatures, clearances must be at least sufficient to prevent jamming under the most adverse conditions.

Even by means of most elaborate mechanical seals it has been proved impossible to avoid these leakage losses seriously affecting the efficiency of the heat exchange.

In fact it can be established that these leakage losses caused by the high pressure medium flow through the clearance gaps between the channels or zones of different pressures preponderate over the entrain losses and hence it is most desirable and important to eliminate as far as possible any leakage escape through the clearance gaps.

As these gaps communicate between zones of different pressures a leakage current will flow with a velocity component directed from the high to the low pressure zone.

According to the invention a fluid current is created across each such gap which opposes or may operate to reduce, suppress or reverse said velocity component of flow from the high to the low pressure zone.

The sealing current may be generated either by blowing or by suction. In the former case, the pressure at the point of injection is preferably so determined as to exceed the pressure on the high pressure side of the gap. Similarly, when using suction, it is preferable to create a

suction head over and above the low pressure prevailing on the low pressure side.

The direction of the sealing current may vary according to circumstances. For instance, the sealing current may be blown or exhausted in a direction perpendicular to the main direction of the leakage gap, but it is generally an advantage to produce the sealing current at an inclination to the gap in such a manner that a velocity component is produced directed away from the low pressure side and towards the high pressure side of the gap. This component will then oppose the velocity component of the leakage current caused to flow by the differential pressure between the two ends of the gap.

It is, of course, possible to combine dynamic seals of similar or different nature with a view to augmenting their effect.

It is already known in rotary regenerative air preheaters to provide an exhaust and/or blowing slot along the two edges of a plate covering a neutral sector, the object being to return the entrapped air as well as the leakage air. An air preheater provided with a leakage seal according to the present invention differs in principle from such known types of air preheaters in that the present case leakage loss is reduced or entirely suppressed. The known method is not applicable to the prevention of leakage loss. If the method according to the invention was employed merely to reduce instead of to suppress entirely the leakage loss, there would be no reason why the known method should not be employed in combination with the present method to return the remaining leakage air together with the air entrapped in the chambers. The injection and/or exhaust slots required for the application of the known method can actually be so arranged and adapted as to supply simultaneously the sealing current for creating a dynamic seal according to the present invention.

It is a further major characteristic of the invention that the axially pair-wise aligned sector shaped end plates have their means for creating the sealing fluids also aligned but operating opposite to each other. Thus is obtained effective sealings in the leakage gaps between the zones of different pressures, that is to say most effectively created barring fluids in combination to avoid any leakage surpasses. The novel arrangement in this respect implies that aligned sealing current creating means are provided in the transition zones operative in counter-action so as to effectively bar any leakages through the gaps but to avoid unduly expenses for recovering entrained high pressure air. Parenthetically, common recover devices applied only to a single end of the rotor result in mere inefficiency.

Therefore it is explanatory that the balanced sealing curtain effect obtained according to the invention can be hereinafter referred to as "dynamic sealing."

The invention will be hereinafter more fully described with reference to the embodiments thereof shown by way of example in the accompanying drawings, in which:

FIG. 1 is a vertical section taken on line 1—1 of FIG. 2 of a rotary regenerative heat exchanger embodying the invention.

FIG. 2 is a top end view, partially broken, of the exchanger shown in FIG. 1.

FIG. 3 is a partial schematical view of a rotor of an air preheater according to an embodiment of the invention with its circumferential surface and movable sealing plates at both ends thereof developed in the plane of the drawing, said movable sealing plates being provided with suction means required for creating by suction of sealing currents.

FIG. 4 is a view similar to that of FIG. 3 of the upper end of an embodiment with the movable sealing plate

provided with injector means for the creating by injection of a sealing current.

FIG. 5 is a view similar to that of FIG. 4 of the upper end of an embodiment with the movable sealing plate provided with devices for the creating of two sealing currents of different kind, that is currents created by pressure and by suction.

FIG. 6 is a view similar to that of FIG. 5 of an embodiment with an injector and a suction device with nozzles inclined towards the high pressure and the low pressure sides, respectively, of the movable sealing plate.

FIG. 7 is a view similar to that of FIG. 6 of a modified embodiment in which the suction nozzle instead is located in the central region of the movable sealing plate.

FIG. 8 is a view similar to that of FIG. 7 with the modification that the locations of the injection and suction nozzles are reversed.

In the air preheater according to FIGS. 1 and 2 the rotor 20 is carried by a central shaft 22 rotatably mounted in a stationary housing structure 24 encircling the rotor and provided with an upper and a lower end plate 26 and 28, respectively. End plate 26 is provided with two openings or ports 30 and 32 located generally on opposite sides of a diametral plane through the rotor. These ports are connected respectively with ducts 34 and 36 for conducting one of the heat exchanging fluids to the rotor and the other fluid from the rotor. Plate 28 is likewise provided with ports 38 and 40 aligned with ports 30 and 32 in plate 26 and communicating respectively with ducts 42 and 44 for conducting the first mentioned fluid from the rotor and said other fluid to the rotor. Countercurrent flow of the two fluids provides for most efficient heat transfer and in accordance with that practice the apparatus illustrated is advantageously connected so that for example hot gas to be cooled is admitted through duct 30 and port 34 to the top of the rotor and after being cooled is discharged therefrom through port 38 and duct 42, as indicated by arrow 46, while cold air to be heated enters through duct 44 and port 40 to flow upwardly through the rotor in the direction of arrow 48 and be discharged through port 32 and duct 36.

In the present embodiment the rotor is formed by two concentric shells 50 and 52 connected by a plurality of radial partitions 54 dividing the annular space between the shells into a number of sectors which may be further subdivided by webs 56 into a larger number of compartments adapted to be filled with regenerative heat exchanging material 58 in accordance with well known practice.

The uncut portions of the upper end plate 26 between the ports 30 and 32 form an upper separating or cover plate 60 separating the large gas channel 62 from the small air channel 64. The corresponding aligned separating or cover plate at the lower end face of the rotor is denoted by 66. Besides said separating or cover plates 60 and 66 the air preheater is also provided with movable sector shaped sealing plates at either end face of the rotor which are in alignment each with a corresponding portion of the confronting cover plate, such as movable sector plate 68 in FIG. 2 with portion 70 of upper separating or cover plate 60. Each movable sealing plate, such as 68, is divided in radially spaced inner and outer sections 68*a* and 68*b*, respectively, and the pair of sections of each movable sealing plate is pivotally mounted by means of a joint 72 for tilting up and down. It will thus be understood that upon distortion of the rotor due to heat each of the movable sealing plate systems may follow the up and down movements of the rotor without difficulty so that the distance between the rotor end faces and the movable sealing plates will remain unchanged.

Each pair of sections 68*a*, 68*b* of an end sealing plate is suspended from or carried by one end of a double armed lever 74 the other end of which is loaded by an accurately adjustable counter weight 76 in engagement with corresponding joint 72. Due to this weight-balance each flexible and movable end sealing plate may, accordingly, very easily follow all up and down movements of the rotor.

The upper movable sealing plates 68 and 78 are connected in a manner known per se with the other movable sealing plates located on the opposite end face of the rotor and this is here effected by means of connecting rods 80. The upper and the lower movable sealing plates then follow each other in parallel in their movements corresponding to the distortions of the rotor. The described arrangement can best be described as rotor actuated floating and sealing means.

In each of the sector shaped compartments of the rotor of FIGS. 1 and 2 is inserted a grating 82 which in this example is formed of square mesh. This form of mesh offers the advantage that mass produced and therefore cheap gratings to be found on the market can be utilized. The grating sector illustrated is so arranged that the bars thereof extending in the direction towards the rotor periphery lie parallel to a line bisecting the angle of the rotor sector covered by the grating. The middle bar which therefore covers the line of bisection thus extends exactly radially, whilst the bars lying parallel thereto on both sides of the bisecting line deviate somewhat from the radial position.

If all the end edges of the heat transfer plates 58 and the partition walls 54 as well as the peripheral and intermediate walls 50, 52 and 56 respectively of the rotor would be flush with each other at respective end of the rotor, a perfect labyrinth seal at respective rotor end should be obtained in relation to the movable floating sector plates 68 and 78 defining the dead zones between the channels of both the media. Due, however, to difficulties of manufacture the transfer plate edges at respective end are not always flush with each other nor with the corresponding edges of the partition or intermediate and peripheral walls of the rotor.

For constructional reasons it may be preferable to form each grating sector as an individual constructional element and thus to subdivide the entire end face in this manner, that is in the illustrated embodiment, for each rotor end face eighteen gratings of sector shape would be used having an included angle of 20 degrees. In very large preheaters still further subdivision may obviously be undertaken, for example, as to divide a grating sector into two or even more parts which are relatively radially displaced. On the other hand, it is also possible to choose the individual structural elements of the grating sufficiently large to extend over a plurality of rotor sectors. If desired, the entire circular end face of the rotor may be covered over by a single grating formed in one piece.

Further to more fully explain the principle underlying the present invention reference will now be made to the embodiments shown in FIGS. 3 to 8 illustrating six rotary regenerative air preheaters which make use of dynamic sealing.

It is assumed in all these six embodiments that the air duct 64 is on the left hand and the flue 62 is on the right. Since the pressure of the combustion air that is to be heated exceeds the pressure of the flue gases, an air leakage current will flow from the left to the right under the movable sealing plate 68 and over the movable sealing plate 68' which movable sealing plates are intended to seal off the neutral intermediate sector 84 of the rotating regenerative heat exchanging body 20. The width of the clearance is therefore determined by the distance between the upper edges of the sector walls 54 or the gratings 82, 82' respectively and the sealing plate 68, and cannot exceed a certain minimum value for reasons of operational safety. For purpose of generating the sealing current by suction there is provided a fan 86 and 86', respectively, the low pressure side of which connects with a nozzle 88, 88', respectively, whereas the high pressure side blows through a pipe 90, 90', respectively, into the high pressure duct 64. In the illustrated examples

it has been assumed that the regenerative heat exchanging plates have been inserted into the rotor cells in parallel with the rotor periphery so that, as developed in the drawings, they present their full faces to the viewer and are secured by the gratings 82, 82', respectively.

The movable sealing plates 68, 68' have flanges such as 92, 94 in sealing engagement with the stationary members 96, 98 of the housing. The member 98 may comprise a wall of the air duct 64 and carry the fan 86, the nozzle 88 via bellows 100 and a pipe 102 being connected to the fan 86.

The construction shown in FIG. 3 utilizes at respective end only one suction opening 88, 88' which each creates a suction current forming the air seal, the current flowing in the direction indicated by the arrow. In principle, the exhausted air can be blown into the outer atmosphere, but the obvious procedure is to blow the exhausted air into the air duct 64. The suction opening has the shape of a narrow slot 106 parallel with the edge of the sealing plate denoted by 78 in FIG. 2, that is, extending approximately in the radial direction, and at a slight distance from this edge. The dynamic seal is actually more effective the wider is the leakage channel. When the distance between the edge of the plate 78 and the nozzle slot 106 for the creation of the sealing current is sufficient, the separating walls 54 on the face of the rotor 20 impart to the clearance between the rotor face and the sealing plate 68 the character of a well-defined aperture within the region of the suction slot. The leakage clearance on the side of the rotor is therefore bounded on one side by the edges of the partition walls 54 between the sectors. If the transfer plates are inserted radially, then their edges act in a similar manner.

Furthermore, it is also possible to provide well-defined boundaries for the leakage gap by means of gratings 82, 82' secured to the rotor so as to cover its end faces. All these available means allow a directed leakage current to be defined, which is very well adapted to suppression by dynamic sealing. In other words, accurate confinement of the air leakage current, such as is desirable for dynamic sealing, can be produced by arranging for at least one radial rotor edge to intervene between the edge of the sealing plate 68 and the suction slot of the nozzle 88, and it does not matter whether this edge is provided by the edges of the radial partition walls or the edges of radial bars forming part of a cover grating, or the edges of the possibly radial heat transfer plates. Since the distance between the heat transfer plates is of the order of about 10 mm., a good effect would be assured for instance in the latter case by placing the suction slot of nozzle 88 more than 10 mm. away from the right hand edge of the sealing plate 78 in FIG. 2, because the edge of at least one transfer plate would then always intervene between the nozzle 88 and the edges of the sealing plate.

The form of construction shown in FIG. 3 therefore shows that the slot of the suction nozzle 88 will create a sealing current. This sealing current is supplied on the one hand from the rotor compartment below the suction slot and, on the other hand, by the leakage current which penetrates from the air duct 64 on the left through the air leakage gap between sealing plate 68 and rotor 20 to the suction slot.

From the embodiment shown in FIG. 3 it is evident that the suction nozzles 88, 88' due to their alignment with each other in their suction counter-act and well balance each other to provide the desired dynamic sealing effect. In an alternative, the sealing plates 68, 68' may be integral with the housing end structures, for example as represented by the details 96, 98. In such construction the bellows 100 can be dispensed with. Further, it is obvious that in such alternative design the sealing plates 68, 68' need not be interconnected by additional means.

Similarly, FIG. 4 shows the alternative case of a preheater using a single sealing current, the current being created in this instance by blowing instead of suction. The medium forming the sealing current may be derived either from the outer atmosphere or from the flue gas, or, as in the illustrated example, from the air duct. The sealing current is here projected by the nozzle 104 from a narrow slot transversely to the leakage gap. This blower slot is likewise arranged parallel with the edge of the cover plate 68, that is to say, approximately radially, and likewise extends roughly from the periphery to the hub of the rotor.

In the form of construction shown in FIG. 5 both methods are employed together so as to assist each other in their respective action. Substantially the same medium is therefore used in this instance to provide both the suction current as by 88 and the pressure current as by 104. It is further to be understood, that at the lower end of the apparatus reflected image devices are provided for creating the dynamic sealing effect, and in such manner that the upper and the lower suction devices are aligned mutually, as well as the upper and the lower pressure devices also are.

As previously mentioned, the sealing currents need not pass perpendicularly across the leakage gap. In practice in all the three examples described in connection with FIGS. 3 to 5 it is possible to give the sealing currents a slanting angle of incidence and, provided the corresponding dimensions are appropriate, this may be an advantage. Three modifications of such constructions based upon the joint use of a suction and a pressure current, as described with reference to FIG. 5, are shown in FIGS. 6 to 8. It should be mentioned in this connection that a plurality of sealing currents created either by suction or pressure disposed at right angles or at inclination may be employed in any desired combination. Which is the best solution depends upon circumstances and can be readily determined by experiment. The optimum is the production of an optimum seal with a minimum expenditure of power to produce it.

The construction shown in FIG. 6 is a direct development of the construction illustrated in FIG. 5 inasmuch as the two nozzles 88 and 104 and hence the sealing currents are inclined. In the plane of the leakage air gap the sealing current injected through nozzle 104 has a component which opposes the leakage air stream flowing from left to right. Since the suction current produced by nozzle 88 has a similar component, the effect at both points is additive.

In the form of construction shown in FIG. 7 the sealing current injected through nozzle 104 has a similar position and angle of inclination. However, the direction of flow of the suction sealing current through nozzle 88 has a different angle of incidence, inasmuch as its horizontal component is now directed in the same direction as the stream of leakage air. However, the suction nozzle has been moved away from the edge towards the centre of the cover plate 68. The effect of this arrangement is that any air that may have leaked past the pressure slot of nozzle 104 will be withdrawn from approximately the middle of the cover plate 68. This effect may be supported by slightly raising the level of the cover plate 68 between the two nozzle slots so that the right hand edge of the suction slot, as it were, "peels off" the leakage air current. In connection with this particular case it may be mentioned quite generally that it is not necessary in these various forms of construction to dispose the entire surface of the cover plate 68 at one and the same level.

The construction according to FIG. 8 is structurally similar to the preceding example but the direction of flow through the nozzles has been reversed. In other words, the nozzle at the left hand region of the cover plate 68 comprises the suction nozzle 88, whereas the nozzle in the central region of the cover plate 68 operates as a pressure nozzle 104.

The construction illustrated by way of example in the drawings represent only some of the possibilities, particularly the more feasible combinations, and they may be

modified in various ways. The selected examples are merely intended to illustrate that the principle upon which the invention is based can be carried into effect in a variety of ways, which may possibly include the employment of more suction and/or pressure slots distributed over the entire leakage channel. The creation of a direct sealing effect by blowing or suction is not the only matter of importance, inasmuch as the leakage losses can also be reduced by deflecting the leakage current away from its direction towards the edge, this being equivalent to reducing its velocity component in the direction of the leakage gap.

In conclusion it may therefore be said that a dynamic seal produced according to the invention enables the leakage loss to be reduced or completely suppressed. This affords the advantage that extremely narrow tolerances in deciding upon the minimum permissible clearance between the relatively moving parts are no longer essential. In fact the clearance may be conveniently a little greater than heretofore and the risk of operational breakdown is thereby diminished. This in turn tends to reduce the cost of production because the construction and assembly of air-preheaters with a relatively large clearance gap does not require the same costly accuracy and care that has been necessary hitherto. It is an advantage if the pressure and exhaust slots have the form of nozzles of minimum width so as to produce maximum velocity of a given volume of sealing gas per unit of time and an optimum dynamic sealing effect.

What I claim is:

1. A regenerative heat exchanger comprising a first component having spaced apart parallel plane ends and providing a mass of regenerative heat absorbing and rejecting material forming a multiplicity of passages extending between said ends for flow of gaseous heat exchanging fluids from end to end through said component and a second component providing two separate ducts for flow of separate streams of different gaseous heat exchanging fluids at different pressures to and from the respective ends of said first component to cause the aforesaid flow through said passages, said second component including sector plates parallel with and closely adjacent to the respective ends of said first component, said sector plates having axially aligned sector portions separating openings for directing the different gaseous fluids in separate streams through said passages, said components being mounted to provide relative rotary movement between said regenerative material and said sector plates, and means providing a dynamic seal for reducing transverse leakage flow of gaseous fluid from the stream of fluid at higher pressure to the stream at lower pressure across the gaps between the ends of the first component and the respectively confronting sector portions of the sector plates, comprising means for producing streams of sealing fluid at a pressure higher than that of either of said streams of heat exchanging fluid, conduit means for conducting said sealing fluid to and discharging the same transversely across the gaps between the opposite ends of the first component and the respectively confronting sector plates, said conduit means terminating in injector means for discharging said sealing fluid in the form of high velocity jets located substantially along the radially extending edge of each of said sector portions of each sector plate which defines one of said openings through which the heat exchanging fluid of higher pressure is directed, whereby to provide screens of high velocity fluid flowing transversely across said gaps for obstructing leakage flow through said gaps of said heat exchanging fluid of higher pressure.

2. A regenerative heat exchanger as claimed in claim 1, in which the means for creating dynamic sealing are aligned and each comprises a device for creating a sealing current at an inclined angle relative to the main direction of the gap, in such direction that the sealing current has a velocity component directed from the low to the high pressure channel.

3. A regenerative heat exchanger as claimed in claim 1, in which in the pair of axially aligned sector shaped end plates the means for creating dynamic sealing comprise axially aligned devices for creating sealing currents of different kind, that is current created by pressure and by suction.

4. A regenerative heat exchanger as claimed in claim 1, in which the means for creating dynamic sealing currents comprise aligned injector devices for injecting sealing currents at an inclination towards the high pressure side in the region of the high pressure edge of the sector shaped end plate and aligned suction devices for withdrawing in the region of the low pressure end of the clearance gap sealing currents by suction at an angle of inclination with a velocity component opposing the velocity component of the leakage currents.

5. A regenerative heat exchanger as claimed in claim 1, in which the means for creating dynamic sealing currents comprise aligned injector devices for injecting sealing currents at an inclination towards the high pressure side in the region of the high pressure end, and in the central region of the gap aligned suction devices for creating sealing currents by suction at an angle of inclination with a velocity component in the direction of the velocity component of the leakage currents.

6. A regenerative heat exchanger as claimed in claim 1, in which the means for creating dynamic sealing current comprise aligned suction devices for withdrawing at an angle of inclination sealing currents by suction in the region of the high pressure end of the gap with a velocity component in the direction of the velocity component of the leakage currents and aligned injector devices for injecting sealing currents under pressure in the central region of the gaps in a direction producing a velocity component that opposes the velocity component of the leakage currents.

7. A regenerative heat exchanger as claimed in claim 1, in which a slot is provided in each sector shaped end plate in the shape of nozzle for creating dynamic sealing current of high velocity for a given volume of flow of sealing fluid per unit of time.

8. A regenerative heat exchanger as claimed in claim 1, in which the ends of the rotor are covered by gratings having the longitudinal edges of the bars facing the sector shaped end plates located in a plane mainly in a plane perpendicularly disposed to the rotor axis.

9. A regenerative heat exchanger as claimed in claim 8, in which the rotor by means of radial partition walls is divided into sector shaped compartments and in which each rotor end grating consists of individual sectors corresponding to the rotor compartments and flush with the ends of the radial partition walls of the rotor.

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