

Feb. 27, 1962

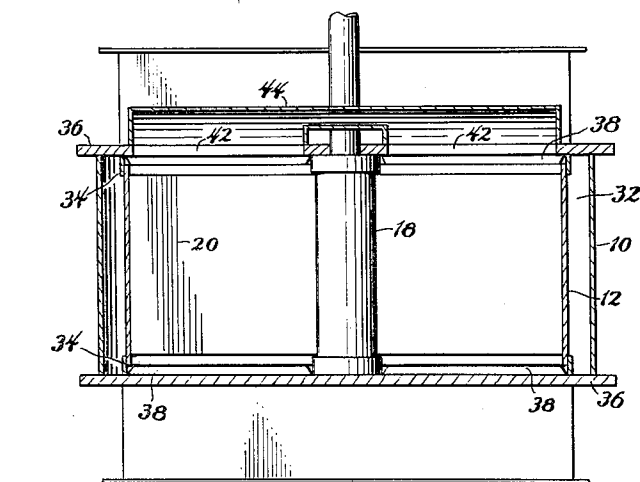
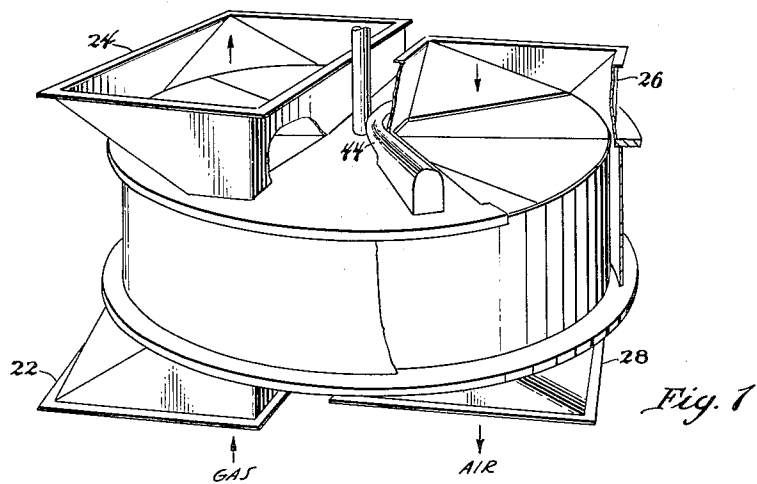
R. H. MULLER

3,022,983

ROTARY HEAT EXCHANGER

Filed Oct. 8, 1958

3 Sheets-Sheet 1



INVENTOR
Robert H. Muller

By *Wayne Lang*
AGENT

Feb. 27, 1962

R. H. MULLER

3,022,983

ROTARY HEAT EXCHANGER

Filed Oct. 8, 1958

3 Sheets-Sheet 2

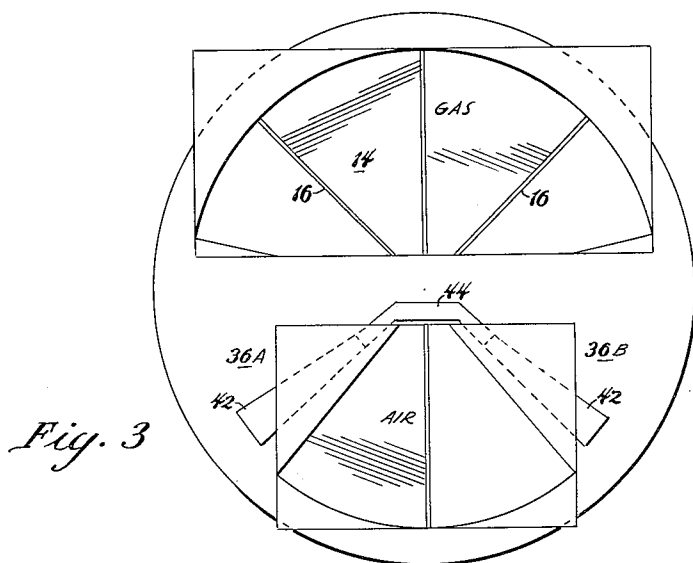


Fig. 3

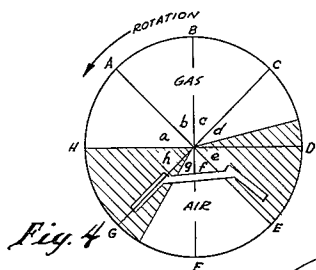


Fig. 4

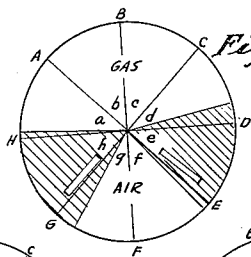


Fig 5

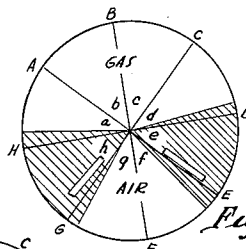


Fig. 6

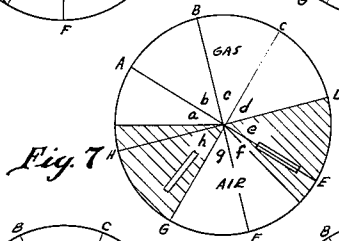


Fig. 7

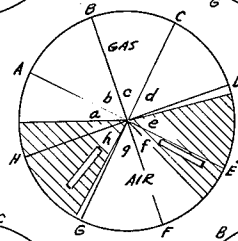


Fig. 8

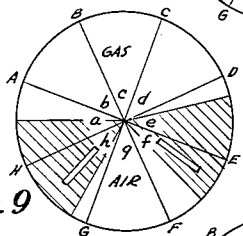


Fig. 9

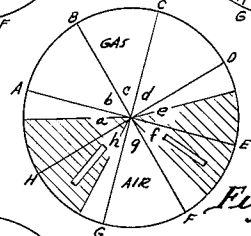


Fig. 10

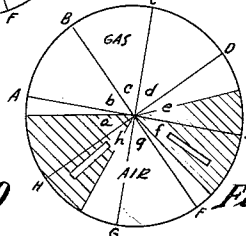


Fig. 77

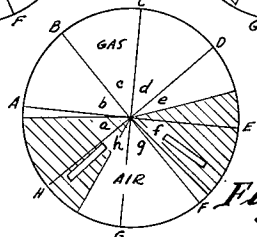


Fig. 12

INVENTOR
Robert H. Muller

By Wayne Lang
AGENT

Feb. 27, 1962

R. H. MULLER
ROTARY HEAT EXCHANGER

3,022,983

Filed Oct. 8, 1958

3 Sheets-Sheet 3

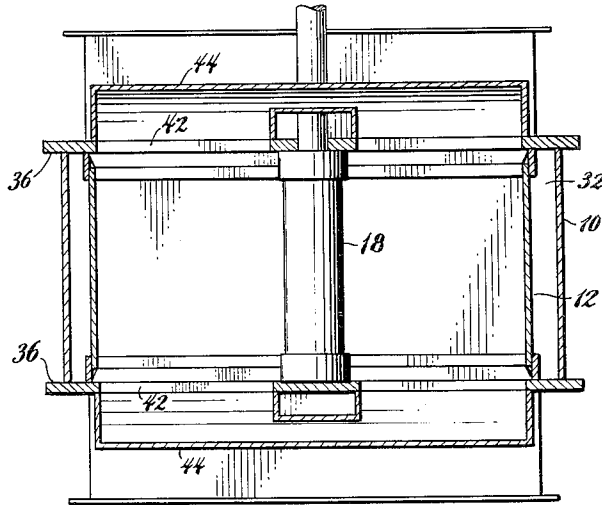


Fig. 13

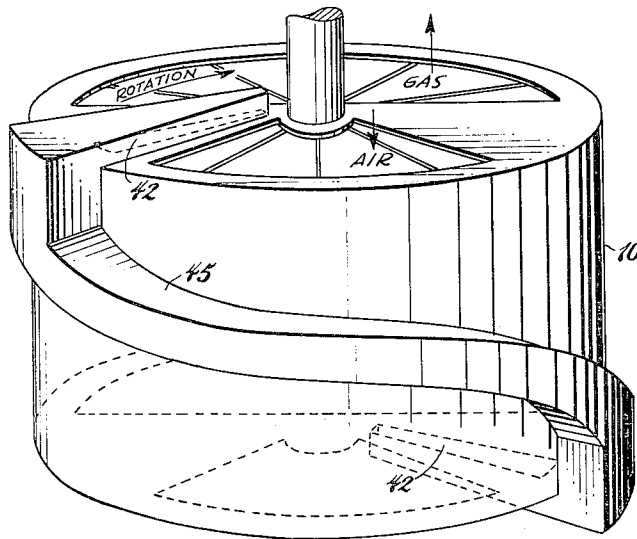


Fig. 14

INVENTOR.
Robert H. Muller
BY
Wayne Lang
AGENT

1

3,022,983

ROTARY HEAT EXCHANGER

Robert H. Muller, Wellsville, N.Y., assignor to The Air Preheater Corporation, New York, N.Y., a corporation of New York

Filed Oct. 8, 1958, Ser. No. 766,073

3 Claims. (Cl. 257-269)

The present invention relates to heat exchange apparatus and in particular it relates to an arrangement of improving the operating efficiency of a heat exchanger of the rotary regenerative type.

In rotary regenerative heat exchange apparatus a mass of heat absorbent material carried by a rotor is first positioned in a passageway for a heated fluid to absorb heat from said fluid before being carried on to a passageway for a fluid to be heated where the absorbed heat is transferred to the fluid passing therethrough. In gas turbine application where the fluid to be heated comprises cool compressed air, a quantity of such air is continuously entrapped in the rotor so that as it turns from the air passageway to the passageway for the heating fluid, the air entrapped in the rotor expands into the heating fluid and displaces a large amount of such fluid. Since the mass of the air entrapped in the rotor is of higher density than the gas that replaces it, there is a net loss of mass at high pressure resulting in the loss of a large portion of the work required to compress the air.

Arrangements that permit the equalization of high and low pressure fluids in the compartments between imperforate portions of the sector plates have been proposed to change the pressure therein to an average that will in turn reduce the net weight of the high pressure fluid transported to the low pressure area. Such arrangements have always necessitated an increase in size of each sector plate to a width in excess of two adjoining compartments in order that proper pressure equalization may be effected through slots lying midway between edges of the sector plates. Increasing the size of the sector plates for a given size heat exchanger results in a reduced duct capacity.

This invention therefore is directed to an arrangement that provides an increased duct capacity together with substantial equalization of pressure to provide optimum heat exchange characteristics for a rotary regenerative heat exchanger.

The invention is further directed to an arrangement that utilizes the heat content of the equalization fluid so as to decrease even more the weight of the entrapped fluid through the judicious utilization of the fluid temperature.

The invention will be more readily understood when considered in connection with the following drawings in which:

FIGURE 1 is a perspective view of a rotary regenerative heat exchanger arranged according to this invention.

FIGURE 2 is a sectional elevation of a rotary regenerative heat exchanger.

FIGURE 3 is a top plan view of the rotor including the pressure equalizing means defined.

FIGURES 4 to 12 inclusive diagrammatically illustrate sequential phases in the rotation of a rotor relative to a slotted end or sector plate.

FIGURE 13 is a sectional elevation of rotary regenerative heat exchanger illustrating a preferred form of the invention.

FIGURE 14 is a perspective view of a rotary regenerative heat exchanger that embodies a modified form of the invention.

In the drawings a cylindrical housing 10 encloses a

2

rotor having a shell 12 divided into sector shaped compartments 14 by radial partitions 16 that connect it to a rotor post 18. The rotor post is in turn rotated about its axis by a motor and reducing gear assembly not here illustrated. The rotor compartments contain regenerative heat transfer material such as metallic plates 20 which absorb heat from hot gases entering the heat exchanger through a duct 22 and exhausting through an axially spaced duct 24. As the rotor turns about its axis, the heated plates 20 are moved into a stream of cool compressed air entering the heat exchanger through a duct 26. After passing over the plates 20 and absorbing heat therefrom, the stream of heated air is conveyed through outlet duct 28 to a combustor inlet or other point of usage.

In order that the streams of gas and air may not bypass the heat transfer surface 20 by flowing through the annular clearance space 32, between the rotor shell 12 and the enclosing housing 10 it is customary to provide circumferential seals 34 on the end edges of the rotor shell that wipe against end plates 36 or other parts of the housing so as to seal off the annular space 32 from both ends of the rotor. Radial seals 38 fixed to the edges of radial partitions 16 wipe against the imperforate portions of the end or sector plates 36 to preclude fluid flow from one sectorial compartment to another.

In accordance with the invention the sector or end plates 36 at opposite ends of the rotor comprise a single plate having two circumferentially spaced air and gas apertures that provide the plate portions 36-A and 36-B therebetween. The plate portion 36-A and B are of substantially equal size and are provided with radially extending bleed slots 42 adapted to lie in successive alignment with each of partitions 16. A duct 44 connecting slots 42 permits equalization of pressures in the sectorial compartments 14 covered thereby. The bleed slots would be located at either one or both connecting plates as required to permit an optimum fluid flow between slots. FIGURES 1 and 2 illustrate an embodiment of the invention in which the bleed slots are located in one of the end plates 36. FIGURES 13 illustrates an embodiment of the invention in which the bleed slots are located in both of the end plates 36. The width of slots 42 determines the width of the sealing members 38 required on the radial partitions 16 since each sealing member must have sufficient width to bridge over each slot to preclude direct leakage therethrough as each partition passes by.

The width of each sector plate is determined by an economic balance of the saving in duct capacity resulting from a reduced sector plate width and the reduction of bleed down efficiency when the width of the sector plate is reduced. By utilizing high capacity bleed slots and connecting ducting, and by positioning the slots in a predetermined relationship relative to the spaced apertures for the heating fluid and the fluid to be heated, the size of the sector plates may be reduced to a minimum and the relative size of the spaced apertures and ducts may be increased without increasing the size of the rotor.

The slots in the end plate to which the duct is attached are displaced circumferentially from one of the apertures a distance at least as great as the circumferential distance between diaphragms, while the distance from the opposite aperture may be substantially less, or in the range of from .05 to .25 times the width of a sector. Thus a sector plate may be reduced in size from its usual angular width of two or more compartments 16 to slightly over one compartment, and the size of the air and gas apertures may therefore be increased without increasing the size of the housing to lower the resistance to the flow of fluid therethrough.

The slots 42 are positioned adjacent the radial edge of each sector plate portion 36-A and 36-B adjoining

either the air duct 26 as illustrated or the gas duct 24 (not illustrated) with equal effectiveness it being necessary that both slots 42 are adjacent the same duct to insure that both slots are exposed to the same fluid pressure during periods intermediate the bleed-down.

Connecting duct 44 is illustrated only in FIGURES 1 to 4 and 13, however it is to be understood that it must be present to provide means for equalizing pressure in the compartments, and it is omitted from FIGURES 5 to 12 only as a matter of artistic convenience.

In this arrangement, hot gas entering duct 22 flows over elements 20 in the sectors of the gas side. Heat from the gas is absorbed by the heating elements passing through the gas side after which they are carried by the turning rotor into contact with the cooler fluid to be heated that enters the rotor housing through a duct 26 and traverses the element filled compartments in alignment therewith.

Usually as the rotor turns on its axis and carries compressed air into a low pressure gas stream, the air expands in the gas with the resultant loss of work required for compression, however, here the duct 44 connecting spaced slots 42 in opposite portions of the sector plate provides an effective arrangement for recovering the usually lost work of compression. Thus, as may be seen in FIGURE 5, while sectors *f* and *g* are in communication with high pressure air sectors *a*, *b*, *c* and *d* are in communication with the low pressure gas, and intermediate sectors *e* and *h* are in communication with one another through duct 44 to provide a pair of oppositely disposed compartments at substantially equal pressure.

By referring to FIGURES 4 to 12 a complete cycle of operation may be graphically followed. In all conditions illustrated the rotor is turning in a counter-clockwise direction and a bleed-down duct 44 between slots permits continuous equalization of the compartments covered thereby. In each view shown the rotor is turned one-ninth the width of a sector from that shown in the preceding figure.

In FIGURE 4 the bleed-down process is about to begin with the left side slot blocked by sealing means on radial partition *G* and the right side slot exposed to fluid in sector "*e*" that has just become sealed from the high pressure air of compartments "*f*" and "*g*." In the next FIGURE 5 air is bleeding from the right side slot into sector "*h*" that contains only gas at a relatively low pressure. FIGURE 6 shows further rotation of the rotor that provides a continuation of the bleed-down process. In FIGURE 7 the bleed-down process has stopped because the seal on partition *E* blocks the right side slot to preclude fluid flow therethrough.

In FIGURES 8 to 12 the sector designated "*h*" coming from the gas side is now connected to the air side and there is no flow in the bleed-down duct 44 connecting spaced slots since both slots are connected to the same pressure of the duct carrying the high pressure air. It will be evident that a wide sector plate will provide more time for pressure equalization or "bleed-down" than will a sector plate of less width, a constant rotor speed being considered. However, the rate of "bleed-down" is a function of the cross-sectional area of duct 44 and as such the "bleed-down" rate may be increased by increasing the area of said duct. Moreover, the greatest "bleed-down" flow occurs through duct 44 immediately after chambers 14 carrying high and low pressure fluids become interconnected, therefore by placing the slots 42 as specified and increasing the capacity of duct 44 so it will not restrict the flow of fluid therethrough, the width of sector plates 36 may be reduced to provide increased duct ca-

capacity without requiring a corresponding increase in size of the rotor and its surrounding housing.

In a rotary regenerative heat exchanger the matrix has a temperature gradient that can be used either to heat or cool the fluid flowing therethrough, depending upon the direction of fluid flow. The mass of fluid in the sector being brought to the high pressure will vary directly as the average density of the fluid and therefore, the lower the temperature the less entrained leakage will occur. A lower fluid temperature will require the use of additional fuel, however, the reduction in leakage far outweighs this disadvantage.

With this in mind, a further improvement in bleed-down efficiency may be obtained by connecting a slot in one end plate to a slot in the end plate at the opposite end of the rotor to direct the coldest fluid from the high pressure compartments to the compartment containing the hottest fluid at low pressure. This arrangement is shown generally in FIGURE 14 where the slots 42 are located in the sector plates at opposite ends of the rotor and are inter-connected by a bleed-down duct 45 that permits fluid to flow between slots and the equalization of fluid pressure in the sectorial compartments in alignment with said slots.

It is therefore evident that this and other changes may be made without departing from the spirit of the invention, and it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What I claim is:

1. Rotary regenerative heat exchange apparatus having a cylindrical rotor divided by radial partitions into sector shaped compartments that carry a mass of heat transfer material, and a housing surrounding the rotor provided at opposite ends with sector plates formed with imperforate portions between circumferentially spaced apertures that direct a low pressure heating fluid and a high pressure fluid to be heated to and through spaced portions of the rotor; sealing means mounted on the end edge of the rotor and on the ends of the radial partitions to direct the flow of fluids through predetermined apertures of said sector plates; radial slots formed in the imperforate portions of each sector plate lying between spaced apertures, said slots being displaced arcuately from one aperture a distance at least as great as the arcuate distance between radial partitions while being displaced from the other of said apertures a distance less than the arcuate distance between partitions; and duct means interconnecting said arcuately displaced slots to permit fluid flow therebetween and the equalization of pressure fluids entrained in the sector shaped compartments confronting said slots.

2. Heat exchange apparatus as defined in claim 1 wherein said duct means connects circumferentially spaced slots that lie in a single sector plate.

3. Heat exchange apparatus as defined in claim 1 wherein said duct means connects circumferentially spaced slots that lie in sector plates at axially opposite ends of the housing.

References Cited in the file of this patent

UNITED STATES PATENTS

2,468,826 Karlsson et al. May 3, 1949
2,821,367 Muller Jan. 28, 1958

FOREIGN PATENTS

82,954 Netherlands Oct. 15, 1956