

June 23, 1953

R. RIGBY ET AL

HEAT EXCHANGER

2,643,098

Original Filed July 23, 1947

3 Sheets-Sheet 1

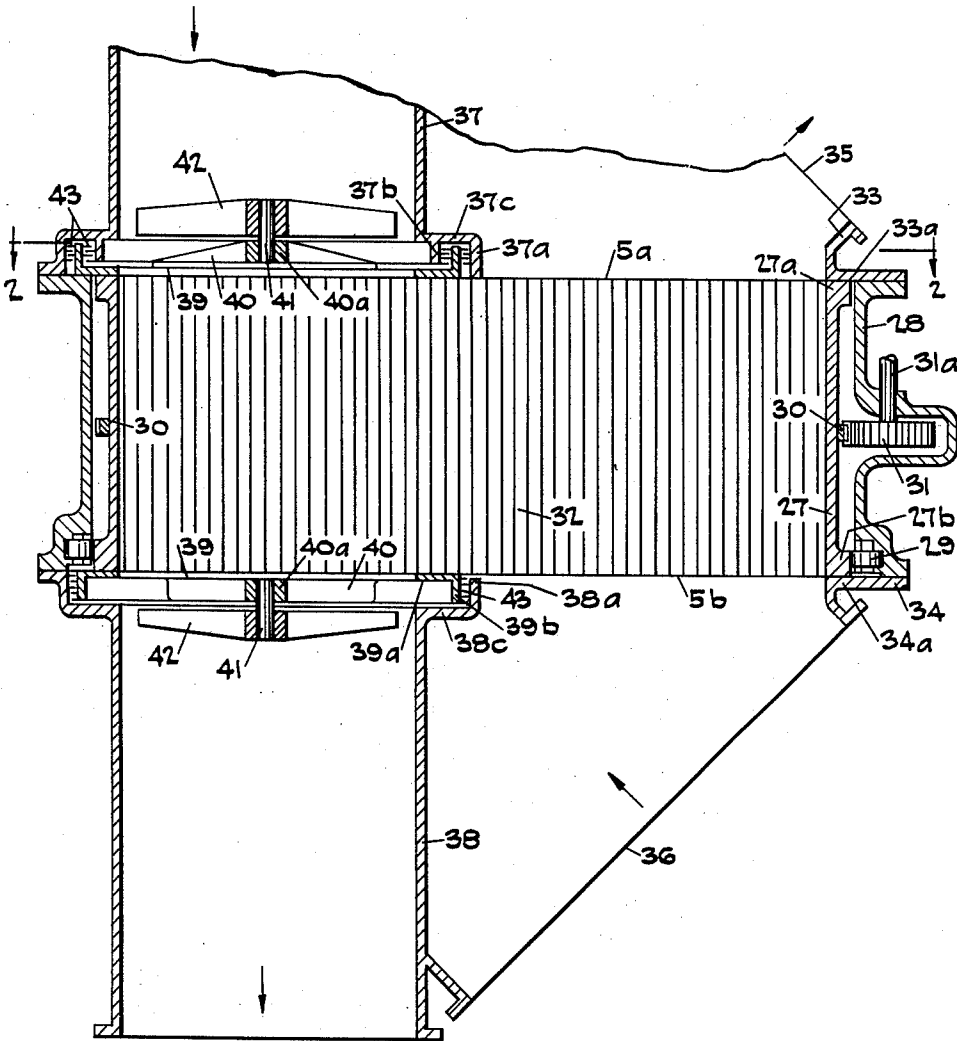


FIG. 1

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3 Sheets-Sheet 2

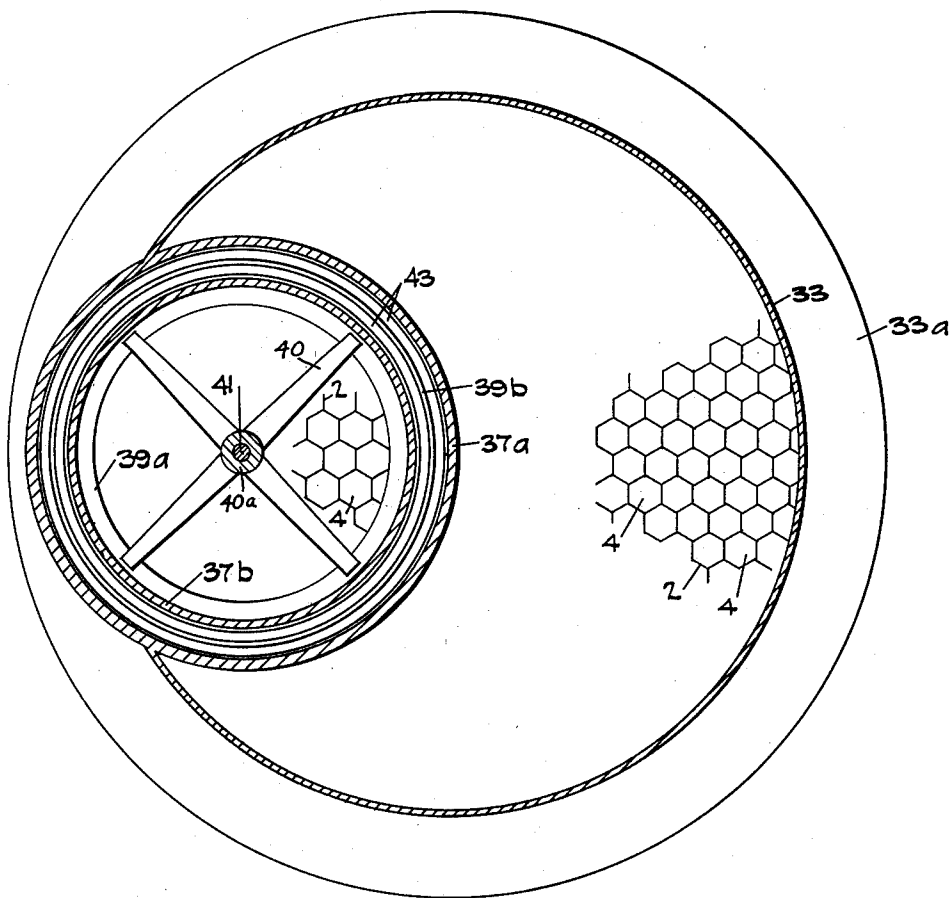


FIG. 2

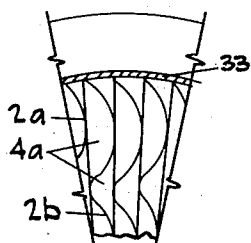


FIG. 3

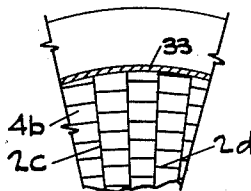


FIG. 4

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3 Sheets-Sheet 3

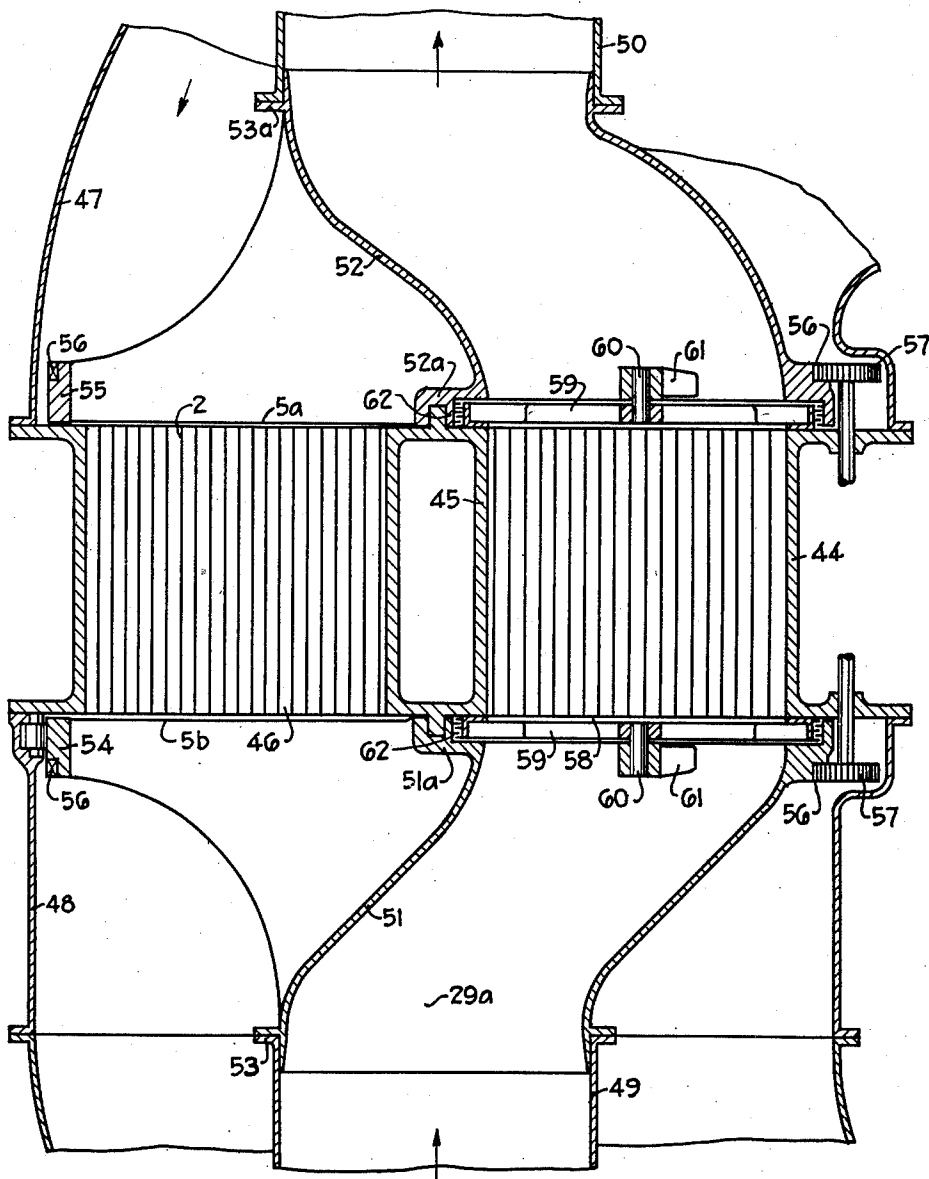


Fig. 5

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HEAT EXCHANGER

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763,054. Divided and this application May 21,
1951, Serial No. 227,316. In Great Britain
January 16, 1947

16 Claims. (Cl. 257-6)

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This invention relates to heat exchangers of the class comprising heat accumulators adapted to absorb heat from a stream of relatively warmer fluid and to transfer heat to a stream of relatively cooler fluid, and means operating continuously or intermittently for progressively alternating the exposure of the accumulators to the respective fluids. Heat exchangers of this class are, in this specification and claims, designated as accumulator heat exchangers. The heat accumulators in such heat exchangers are usually in the form of a bank of heat-transfer elements having fluid passages through the elements from one end of the bank to the other, and such passages are sealed one from another so that different streams of fluid may pass through different groups of passages simultaneously without being commingled.

Accumulator heat exchangers according to this invention may be used, for example, for preheating air by means of hot waste gas.

Accumulator heat exchangers in common use, such as those of the Ljungstrom or rotating drum type, effect the heating and cooling alternation by the rotation of a suitably partitioned drum containing the heat transfer elements. When considerable pressure difference exists between the two gas streams the rotating drum type of heat exchanger presents difficulties in sealing, these difficulties being accentuated with time by the greater wear of the sealing means on the outside of the drum, and the lesser wear of the sealing means about the center.

This is a division of our joint application Serial No. 763,054, now sole Patent No. 2,578,945 in which there is described and claimed a heat exchanger that is the invention of one of us in which the fluid passages through the heat accumulator are progressively and alternately exposed to the respective fluids by the provision of valves or shutters, adapted to sweep in coordination the respective end faces of the accumulator. The fluid passages are defined by partition walls that terminate in planes to form flat contact faces and each shutter is in rubbing contact with one of these faces over an extended annular area presented by the contiguous rubbing or sealing face of the shutter. Each shutter has a central passage or space for the flow of a fluid and separate spaces traversed by the respective fluids outside of the accumulator; it thus provides a moving boundary seal between groups of fluid passages brought into registry with the separated spaces by the moving shutters. Such shutters make it possible to operate at higher pressure differences between the two fluid streams than in prior accumulator heat exchanger constructions because the differential pressure may act to urge the shutter against the contact face of the accumulator, thereby improv-

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ing the sealing action as the pressure difference increases.

In specific embodiments according to the said parent application shown in Figs. 1-6 thereof, which are also the sole invention of one of us, the bank of elements is in the form of a drum and the shutters are in the form of rings that are capable of rotation about their own axes upon the occurrence of relative rotary motion between the shutter and the accumulator drum; hence, as the shutters sweep the contact faces, each shutter effects a creeping rotation about its own axis and over a period of time every point on the sealing face of the shutter rubs against every point on the corresponding contact face of the drum, thereby achieving a grinding-in action and resulting in more uniform wear.

The shutter rings in those specific embodiments may be movably mounted in chambers between the end contact faces of a stationary accumulator and stationary caps provided at the ends of the heat exchanger that have flat internal faces parallel to the contact faces of the accumulator, each shutter ring being provided with a telescoping part that rubs against the said internal face; such caps may have central ports communicating with the inside of the corresponding shutter ring for the passage of the first fluid and additional ports toward their peripheries for the passage of the second fluid. The central port in the cap is always in communication with the passage through the shutter ring, and this is effected by making the diameter of the ring more than half of the diameter of the drum. This in turn makes it impracticable to pass the second fluid through the central part of the accumulator drum, and a central cylindrical dead space is provided within the accumulator that does not contain heat transfer elements and is traversed by neither fluid. When such an arrangement is used for supplying fluids to the spaces within and outside of the shutter rings a somewhat restricted central port is usually employed to avoid an unduly large dead space at the center of the accumulator drum; at high rates of fluid flow this presents resistance to fluid flow.

According to the present invention, which is an improvement over the heat exchanger according to the said sole invention and advantageously incorporates shutters in accordance with the said sole invention, the fluid inlet and outlet arrangements at each end of the heat exchanger are modified so that the casing wall of the duct for the passage of the first fluid, which is to pass through the shutters, and which casing wall separates that fluid from the passageway for the second fluid at the same end of the heat exchanger, terminates in close proximity to the corresponding end contact face of the accumu-

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lator or bank of heat transfer elements, the shutter being mounted on the said duct at its port adjacent to the end contact face of the accumulator.

This improvement materially simplifies the arrangement of the shutters; permits the use of a duct for the first fluid that is larger in diameter, e. g., equal to that of the shutter, and permits the ducts for both fluids to be streamlined and to approach the heat accumulator in a substantially axial direction, thereby reducing turbulence and fluid friction and the consequent pressure drops; and it permits the central hollow dead space in the accumulator drum to be made as small as possible, e. g., eliminated entirely. Other advantages, such as a simplification of the driving mechanism and shaft sealing arrangements, will be apparent from the following description.

By the arrangement according to the instant invention the duct for the first fluid, at the port of which the shutter ring is mounted, may be substantially of the same diameter throughout as the port and the shutter ring, the external diameter of the latter being approximately equal to or slightly greater than the radial extent of the bank of heat transfer elements. These elements may occupy all of the space within the cylindrical outline of the heat accumulator drum or may occupy only an annular space between the outer cylindrical wall of the accumulator and a hollow central cylindrical drum. In the former arrangement the external diameter of the shutter is substantially equal to or slightly greater than half the diameter of the heat accumulator drum; in the latter arrangement it is equal to or slightly greater than the half of the difference between the diameters of the outer wall drum and the central hollow drum. The former arrangement is in some cases preferable as the amount of unused space around the axis of the drum is reduced to a considerable extent while nevertheless insuring that the termini of all of the passages through the accumulator drum are adequately swept by the shutter during relative movement between the shutter and the drum. However, in certain cases the latter arrangement is preferred for constructional reasons. The two types will be illustrated in connection with two specific embodiments of the invention.

In one preferred embodiment according to the invention, the ducts for the passage of the fluid that is to pass through the shutters are in the form of stationary cylindrical tubes having their common axis parallel to that of the heat accumulator drum and being substantially tangent to the exterior of the drum. Sweeping of the bank of heat transfer elements is achieved by rotating the drum about its central axis through any suitable drive, such as a toothed wheel engaging a peripheral gear rack on the outside of the drum, and the shutters are maintained in stationary locations.

In another embodiment of the present invention the said ducts are arranged so that their common axis, at the ends remote from the drum, is in line with the central axis of the drum, and the parts of the ducts that approach the drum are bent laterally so that, where they meet the drum, they become tangent to the exterior of the drum as in the previous embodiment. The ducts are so shaped as to present the minimum restriction to flow of fluid. Sweeping of the bank of elements is achieved by rotation of the ducts about the central axis of the drum by means of toothed wheels engaging gear racks carrying the

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ends of the respective ducts, the drum being maintained stationary.

It is clear that, in either embodiment of the invention, the outside drive obviates the necessity of having any internal driving mechanism, thus enabling further use to be made of the space around the axis of the drum.

The invention is illustrated in the accompanying drawings forming a part of this specification, wherein:

Fig. 1 is a longitudinal sectional view of a heat exchanger according to one embodiment of the invention;

Fig. 2 is a transverse sectional view, taken on line 2—2 of Fig. 1;

Figs. 3 and 4 are fragmentary cross-sectional views corresponding to Fig. 2 showing modified forms of heat transfer elements in the accumulator; and

Fig. 5 is a longitudinal sectional view of a heat exchanger according to another embodiment.

Referring to the drawings in detail, and particularly to Figs. 1 and 2, 27 is the heat accumulator drum, formed of a metal cylindrical shell rotatably mounted within a casing 28 by means of rollers 29, and provided with a peripheral gear rack 30. The drum may have flanges 27a and 27b at the ends. A spur gear 31, mounted on a shaft 31a journaled in the casing, engages the gear rack and rotates the drum upon being driven continuously or intermittently by any source of power, not shown. The drum carries a bank of heat-transfer elements 32, disposed about the drum axis. These heat-transfer elements provide separated passages 4 through the bank, coaxial with the axis of the drum or substantially so and open at the ends of the drum. The walls 2 of these passages terminate in planes to form flat end contact faces 5a and 5b. The passages may take any desired form and the heat-transfer elements may be of any type known per se. The heat-transfer elements may be arranged in partitioned sectors of the bank and may be made of ceramic material but preferably are of metal. The passages may be packed with heat absorbing material in the form, for example, of fine wires, wire mesh, grains, pellets, hollow cylindrical pieces, beads, or rings, or of any other suitable kind. Alternatively, the individual passages may be suitably sized so that their walls constitute an effective and suitably proportioned heat-transfer packing. In the form shown in Fig. 2 the passages are honeycombed, while in the modification shown in Fig. 3 they are formed of radial partitions 2a with corrugated inserts 2b subdividing each sector into smaller passages 4a. As shown in Fig. 4, radial partitions 2c with segmental partitions 2d forming passages 4b may also be used. The specific types of heat-transfer elements and their arrangement form no part of this invention.

A pair of low-pressure stationary ducts 33 and 34 of large diameter are fixed to opposite sides of the casing 28, sealing the latter against the outside. Flanges 33a and 34a of the ducts are situated in close proximity to the movable annular end flanges 27a and 27b of the drum and prevent or minimize the flow of fluid between the casing and the drum. Outlet and inlet ports 35 and 36 permit the inflow and discharge of low pressure fluid.

High pressure stationary ducts 37 and 38 are provided within and eccentric to the ducts 33 and 34, respectively. These ducts have a common axis eccentric to the axis of the accumulator drum.

and terminate in close proximity to the contact faces of the drum opposite the termini of the same partial group of passages 4. The ducts have laterally widened parts 37c and 38c near their ends, carrying short cylindrical flanges 37a and 38a with diameters larger than that of the ducts and forming port sections adjacent to the drum. These flanges provide recesses containing shutter rings 39. These rings have radial sealing flanges 39a with flat faces directed to the accumulator drum to form sealing faces in rubbing engagement with the end contact faces 5a and 5b of the accumulator drum, and cylindrical walls 39b extending away from the drum in telescoping relation to the ducts. The shutter rings are mounted in spiders 40 which have hubs 40a and are pivotally supported by means of studs 41 from a support structure including spiders 42 or similar apertured frames fixed within the ducts 37 and 38. The shutter rings 39 are urged against the end contact faces 5a and 5b by fluid pressure on the radially inwardly directed sealing flanges 39a, this sealing pressure being greater as the pressure difference between the high pressure and the low pressure fluids increases. Spring as illustrated in the said parent application may, of course, also be used to urge the shutter rings against the drum. Fluid flowing through the ducts 37 and 38 is prevented from passing outside of the shutter rings 39 into the ducts 33 and 34 and into that part of the accumulator not covered for the time being by the ducts 37 and 38 by sealing labyrinths 43 or other sealing means. The enlargement at the duct port may be provided with a second cylindrical flange 37b, spaced inwardly from and concentric with the flange 37a, to provide an intervening annular space for receiving the cylindrical wall 39b of the shutter ring; double labyrinth seals located both on the inner and outer sides of the wall 39b may thereby be provided, as shown, although a single labyrinth, shown at the enlargement 38c, may be used when lower pressure difference prevails. The ducts 37 and 38, in the ports of which the shutter rings 39 are mounted, are each of substantially the same diameter throughout as the passage through the shutter rings 39; the external diameter of these rings is approximately equal to or slightly greater than half of the diameter of the accumulator drum. The shutter rings thus surround the adjacent termini of the said partial group of passages 4 and the sealing faces of the flanges 39a, being of appreciable width as shown, effectively isolate the said partial group of passages 4 from the remainder of said passages.

In operating the heat exchanger the high pressure or first fluid may be introduced through the duct 37 and discharged through the duct 38, whilst the low pressure or second fluid may be flowed countercurrently to the former, being introduced at 36 and discharged at 35. Concurrent flow is, however, possible by feeding the low pressure fluid at 35 and discharging it at 36. By rotating the shaft 31a the drum 27 is rotated, causing the shutters 39 to sweep the end contact faces and vary the partial group of passages surrounded. The shutter rings rotate about their own axes during such sweeping action. High pressure fluid therefore flows through a variable partial group of passages sealed off by the shutters and low pressure fluid flows through the variable remainder of the passages. Since the shutter ring 39 has a diameter approximately half of the diameter of the accumulator drum, less than half of the passages through the drum are sealed

off by the shutter ring, resulting in unequal exposure of the heat-transfer elements to the two fluids. Since the high pressure fluid is passed through the shutters, this arrangement provides a shorter residence time for the fluid under high pressure, assuming flow of equal volumes. The higher pressure, however, reduces the volume of the high pressure gas, tending to equalize the residence time.

It is evident that the heat exchanger, aside from providing an effective seal between the groups of passages through the heat accumulator traversed by the two fluids, permitting operation at moderately high pressure differences between the two fluids, considerably simplifies the arrangement at the ends of the accumulator drum and provides a labyrinth seal to reduce leakage of fluid. The axial approach of the fluids to the accumulator through relatively large diameter ducts, without constrictions, materially reduce pressure losses. Further, the driving arrangement has the advantage that the only running seal required is at the place where the shaft 31a emerges from the casing 28.

In the embodiment shown in Fig. 5 the heat accumulator is mounted in a stationary cylindrical shell 44 having a smaller hollow central drum 45. The annular space between the drums 44 and 45 is filled with heat-transfer elements 46 provided with walls 2 to form axial passages as described for the previous embodiment. A pair of stationary outer ducts 47 and 48 are fixed to the ends of the shell 44, arranged so that their ends remote from the accumulator are curved away from the central axis of the shell. High pressure stationary ducts 49 and 50 are provided coaxially with the axis of the shell 44, extending through the outer wall of the ducts 47 and 48 in a manner shown in Fig. 1. A pair of rotatable ducts 51 and 52 have their ends remote from the drum connected to the ends of the ducts 49 and 50 by means of sealing flanges 53 and 53a for rotation about the central axis of the drum. The other ends of the rotatable ducts extend laterally outwardly and their ends near the accumulator are substantially tangent to the drum 44 and terminate in close proximity to the end contact faces of the accumulator. These ends have annular rings 54 and 55 with gear teeth 56 which mesh with spur gears 57. By turning the spur gears in synchronism the ducts 51 and 52 may be rotated to cause their ends nearer the accumulator to sweep the latter, these ends being thereby relatively fixed to be always opposite the termini of the same partial group of passages through the accumulator.

The ports of the ducts 51 and 52 are enlarged as shown at 51a and 52a to provide short cylindrical port sections of increased diameter. These port sections provide annular spaces containing the shutter rings 58 constructed and mounted as described for Fig. 1. These rings have their flat sealing faces in rubbing engagement with the end contact faces of the accumulator and are rotatably supported by means of spiders 59 fixed to the rings, studs 60, and perforated supports 61 fixed in the rotatable ducts 51 and 52. Fluid flowing through the ducts 51 and 52 is prevented from passing outside of the shutter rings by sealing labyrinths 62.

The ducts 49, 50, 51 and 52 are so shaped as to present a minimum of obstruction to the flow of fluid. Sweeping of the bank of heat-transfer elements is achieved by applying power to the gears 57, causing rotation of the annular racks

or gear rings 54 and 55, thereby swinging the crank-like ducts 51 and 52. For countercurrent flow, the fluid at higher pressure is fed in through duct 49 and discharged through duct 59, while the lower pressure fluid is introduced through duct 47 and withdrawn through duct 48. The resulting coaction between the shutter ring and the heat accumulator or bank of heat transfer elements is the same as that described for Fig. 1, except that the shutters are moved eccentrically and the heat accumulator is stationary. It will be noted that the internal diameters of the ducts 49, 50, 51 and 52 are all substantially the same, this being equal to the radial distance between the drums 44 and 45, whereby the ducts are streamlined for minimum opposition to the flow of the fluid, and the area of the end face of the accumulator bank sealed off by the shutter ring is again less than half of the total annular area between these drums; however, the ratio of the number of passages sealed off by the shutter to the total number of passages in the drum is somewhat higher in this embodiment and it is possible to select the value of this ratio by a choice of diameter for the inner drum. The general observations previously made for Fig. 1 are also applicable to this embodiment, except that the drum 45 imposes a small dead space.

A further advantage of the construction according to both embodiments resides in the elimination of internal driving mechanisms, thereby enabling other use to be made of the space near the axis of the drum at the ends of the heat exchanger.

We claim as our invention:

1. An accumulator heat exchanger comprising: a heat accumulator having a bank of heat-transfer elements mounted in a drum, said drum having a plurality of longitudinal partitions providing a plurality of separate fluid passages, the ends of said partitions terminating in planes at the ends of the drum to form end contact faces; a first pair of ducts at opposite ends of the drum having ports located eccentrically to the axis of the drum and in close proximity to said contact faces, said ports being smaller in area than said end faces and being fixed relatively to each other, said ports and drum being relatively movable; a shutter at each port having an annular sealing face in engagement with the adjoining contact face of the drum, said shutters being mounted at locations fixed relatively to the axes of said ports but movable along said axes to surround the termini of the same partial group of said passages, each shutter having an opening within said annular sealing face providing communication between said group of passages and the respective duct; a second pair of ducts at opposite ends of the drum in communication with fluid passages other than those of said partial group; and means for effecting relative movement between said drum and said ports of the first pair of ducts to effect a coordinated sweeping movement of said contact faces by said shutters and thereby vary the said partial group of passages.

2. The heat exchanger according to claim 1 wherein the said ducts and the ports are stationary and the accumulator drum is mounted for rotation about the central axis thereof to bring successive groups of fluid passages into registry with said shutters.

3. The heat exchanger according to claim 1 wherein said accumulator is stationary and the

ducts of said first pair are mounted for rotation about the central axis of the accumulator and extend laterally from said axis toward the accumulator to bring successive groups of fluid passages into registry with said shutters.

4. The heat exchanger according to claim 1 wherein said shutters are mounted telescopically with respect to the ducts of said first pair and labyrinth seals are provided between the shutters and the respective ducts.

5. The heat exchanger according to claim 1 wherein said shutters are rings mounted for rotation with respect to the ducts of said first pair.

6. The heat exchanger according to claim 1 wherein each shutter is circular and is secured to the adjacent duct of the first pair by a support fixed within by the said adjacent duct and pivotally connected to the shutter at the central axis of the shutter.

7. The heat exchanger according to claim 1 wherein the inside diameters of the ducts of said first pair are substantially uniform and substantially equal to the diameter of said opening in the shutter, said ducts being enlarged at the said ports and the shutters extending telescopically into said enlarged portions.

8. An accumulator heat exchanger comprising: a heat accumulator having a plurality of longitudinal partitions providing separate longitudinal fluid passages, the ends of said partitions terminating in planes at the ends of the accumulator to form end contact faces, said end contact faces being circular in outline; a first pair of ducts of smaller diameter than said end contact faces at opposite ends of the accumulator having their ports disposed eccentrically with respect to the said end contact faces and near to said faces; a shutter movably mounted in each of said ports, each shutter having a flat, annular sealing face in rubbing engagement with its respective end contact face and surrounding the termini of a selected partial group of said passages, said ports being disposed to place them into communication with opposite ends of the same partial group of selected passages; a second duct arranged to provide flow communication to portions of said end contact faces not covered by the said shutters, the heat accumulator and the first pair of ducts being relatively movable so as to effect a coordinated sweeping of said end faces by said shutters.

9. As a subcombination, a sealing arrangement for conducting a fluid through a duct to or from a selected variable partial group of passages extending through a heat accumulator that has a flat end contact face in which said passages have openings, comprising: a tubular duct having near one end thereof a laterally widened part and, beyond the widened part, a short cylindrical flange substantially concentric to the duct with a diameter slightly larger than that of the duct to provide a port section; and a shutter ring telescopically movably mounted within said port section in sealing relation to said flange having a flat, annular sealing face beyond the end of said port section adapted for rubbing contact with said contact face of the heat accumulator to surround the termini of a selected partial group of said passages, said shutter having a central opening to place the said selected group of passages into communication with said duct.

10. In combination with the sealing arrangement to claim 9, a labyrinth seal between said shutter ring and said cylindrical flange.

11. As a subcombination, a sealing arrange-

ment for conducting a fluid through a duct to or from a selected variable partial group of passages extending through a heat accumulator that has a flat end contact face in which said passages have openings, comprising: a tubular duct having near one end thereof a cylindrical port section; and a shutter ring having a cylindrical sealing wall extending telescopically within said port section in sealing relation and axially movable relatively thereto and having an annular sealing flange extending radially inwardly from said sealing wall, the outer face of said sealing flange being flat and disposed beyond the end of said port section to form a sealing face adapted for rubbing contact with said contact face of the heat accumulator to surround the termini of a selected partial group of said passages, said shutter having a central opening to place said selected group of passages into communication with said duct.

12. As a subcombination, a sealing arrangement for conducting a fluid through a duct to or from a selected variable partial group of passages extending through a heat accumulator that has a flat end contact face in which said passages have openings, comprising: a tubular duct having near one end thereof a laterally widened part and, beyond the widened part, a short first cylindrical flange with a diameter larger than that of the duct to provide a port section; a short second cylindrical flange located concentrically within and in spaced relation to said first flange extending beyond said widened part; a shutter ring having a cylindrical sealing wall telescopically mounted between said first and second flanges and having a flat annular sealing face beyond the end of said port section adapted for rubbing contact with said contact face of the heat accumulator to surround the termini of a selected partial group of said passages, said shutter having a central opening to place the said selected group of passages into communication with said duct; and labyrinth seals between said cylindrical sealing wall of the shutter and each of said cylindrical flanges.

13. As a subcombination, a sealing arrangement for conducting a fluid through a duct to or from a selected variable partial group of passages extending through a heat accumulator that has a flat end contact face in which said passages have openings, comprising: a tubular duct having near one end thereof a cylindrical port section; a shutter ring telescopically mounted in sealing relation with respect to said port section having a flat annular sealing face beyond the end of said port section adapted for rubbing contact with said contact face of the heat accumulator to surround the termini of a selected partial group of said passages, said shutter having a central opening to place said selected group of passages into communication with said duct; a framework in said duct providing a support structure substantially at said port section; and means pivotally supporting said shutter ring from said support structure for rotation about the axis thereof.

14. An accumulator heat exchanger comprising: a heat accumulator having a bank of heat-transfer elements mounted in a drum, said drum having a plurality of longitudinal partitions providing a plurality of separate fluid passages, the ends of said partitions terminating in planes at the ends of the drum to form end contact faces, said drum being mounted for rotation about the central axis thereof; a first pair of cylindrical

ducts having a common axis parallel to and eccentric with respect to that of the heat accumulator drum, said ducts having stationary ports in close proximity to said contact faces, so as to be opposite the termini of the same partial group of said passages; a shutter ring telescopically and sealingly secured to each duct at the port thereof, each shutter having an annular sealing face in engagement with the adjoining contact face of the drum and surrounding the adjacent termini of said partial group of passages and having, further, an opening within said annular sealing face providing communication between said group of passages and the respective duct; a second pair of ducts surrounding said ducts of the first pair at the opposite ends of the drum in communication with fluid passages other than those of said partial group; and means for rotating said drum for effecting relative sweeping movement between said shutters and said contact faces and thereby vary the said partial group of passages.

15. The heat exchanger according to claim 14 wherein said heat transfer elements extend substantially throughout the cross-sectional area of the drum and the diameter of said shutter ring is substantially equal to half the diameter of the drum.

16. An accumulator heat exchanger comprising: a cylindrical outer casing; a heat accumulator mounted for rotation within said casing about the central axis of the drum having a bank of heat-transfer elements mounted in a drum, said drum having a plurality of longitudinal partitions providing a plurality of separate fluid passages, the ends of said partitions terminating in planes at the ends of the drum to form end contact faces; a first pair of cylindrical ducts having a common axis parallel to and eccentric with respect to that of the heat accumulator drum, said ducts having stationary ports in close proximity to said contact faces, so as to be opposite the termini of the same partial group of said passages; a shutter ring telescopically and sealingly secured to each duct at the port thereof, each shutter having an annular sealing face in engagement with the adjoining contact face of the drum and surrounding the adjacent termini of said partial group of passages and having, further, an opening within said annular sealing face providing communication between said group of passages and the respective duct; a second pair of ducts surrounding said ducts of the first pair at the opposite ends of the drum sealed to said outer casing and in communication with fluid passages other than those of said partial group; and means for rotating said drum for effecting relative sweeping movement between said shutters and said contact faces and thereby vary the said partial group of passages comprising a peripheral gear rack on the outside of the drum and a gear meshing therewith and located within the outer casing.

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