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2,962,272

PRESSURE EXCHANGER WITH REGENERATIVE HEAT EXCHANGER

Filed Feb. 24, 1956

2 Sheets-Sheet 1

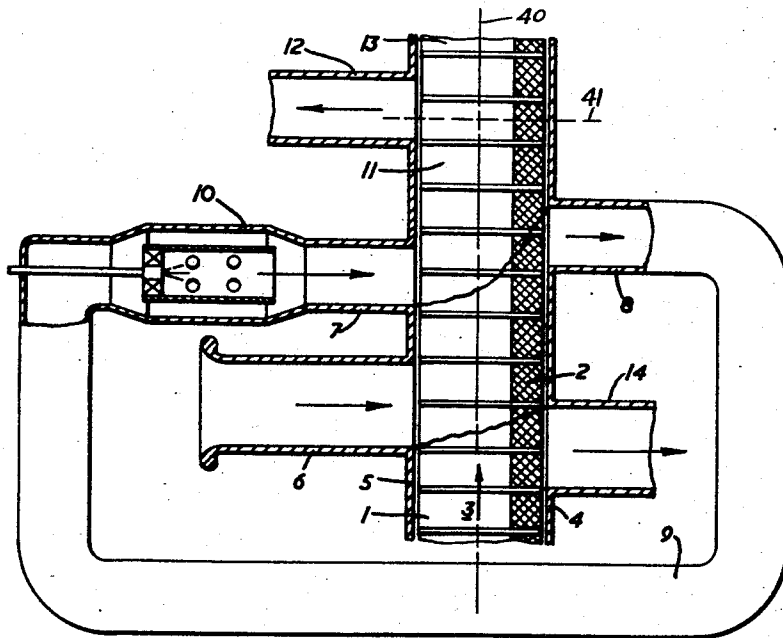


FIG. 1.

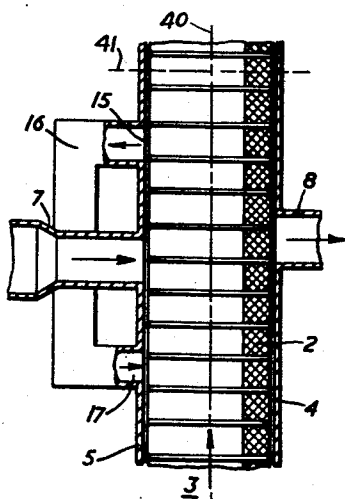


FIG. 2.

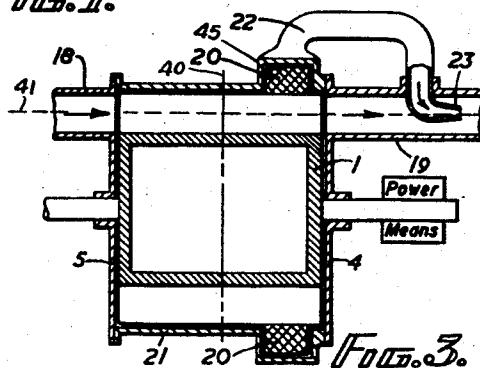


FIG. 3.

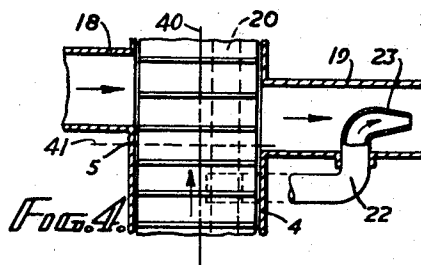


FIG. 4.

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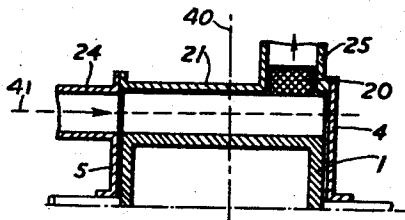


FIG. 5.

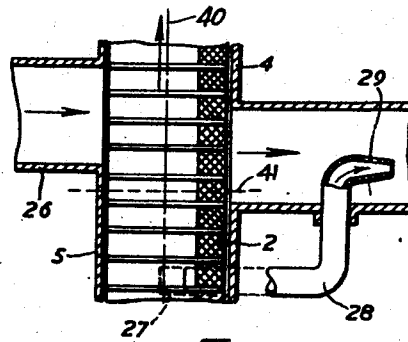


FIG. 6.

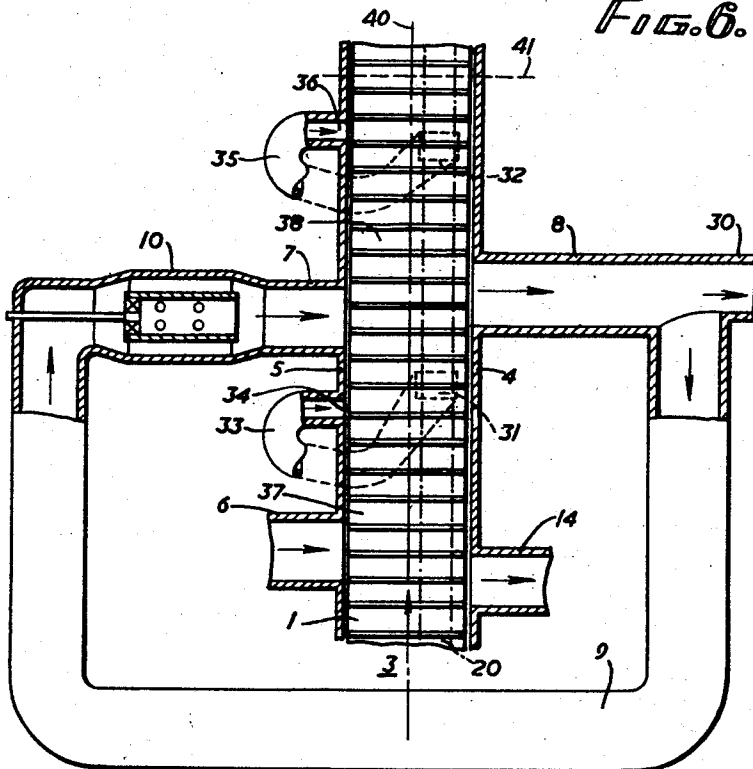


FIG. 7.

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PRESSURE EXCHANGER WITH REGENERATIVE HEAT EXCHANGER

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7 Claims. (Cl. 263—19)

The invention relates to pressure exchangers.

Pressure exchangers are machines having cells for the compression and expansion of gas, ducting to lead gas to and from the cells at least at a low pressure scavenging stage and optionally also at a high pressure scavenging stage, and means for effecting cyclic communication between the cells and the ducting. Normally the cells are mounted around the periphery of a rotor and the ducting is stationary.

In the thermodynamic cycle of a pressure exchanger it may, on occasion, be desirable to incorporate a heat exchanger, for the same reasons as such apparatus is often incorporated in gas turbine plants. However heat exchangers are commonly cumbersome pieces of equipment and could add inconvenient complication to essentially simple pressure exchanger installations. Moreover unexpected advantages accrue when the pressure exchanger and heat exchanger are integrated into one machine.

The invention provides a pressure exchanger characterized by the provision of a heat-storing matrix located successively in the paths of two fluid streams leaving the cells at different stages of the cycle of operation whereby heat exchange between the streams can be effected.

The heat storing matrix may be situated within or alongside a common wall of the cells. Preferably it is of the order of 5% in flow path length compared with a cell length. A fluid stream leaving through the matrix may re-enter the pressure exchanger and it may be desirable to allow two streams to pass through appropriately positioned closed ducts to re-enter in this way. Ejector interaction may be provided between a stream leaving the cells through the matrix and another flow leaving through an unobstructed duct.

Embodiments of the invention will now be described by way of example only with reference to the accompanying drawings in which:

Fig. 1 shows a peripheral development of a pressure exchanger which incorporates a matrix in the cells providing for the useful recovery of exhaust heat.

Fig. 2 shows a part peripheral development of the same pressure exchanger but modified to incorporate a single transfer channel or duct.

Fig. 3 shows how the heat exchanging matrix may be incorporated in an outer side pocket of the cells and a manifold in a common wall of the cells, this view being a sectional elevation with one set of scavenging ducts only included.

Fig. 4 shows a part peripheral development of the scavenging stage of the pressure exchanger shown in Fig. 3 and it is indicated how an outlet taken through the matrix provides ejector action for assisting the scavenging process.

Fig. 5 is a half sectional elevation of a pressure exchanger with the heat exchanger matrix in the side pocket and manifold and with scavenging flow passing through the matrix.

Fig. 6 shows a part peripheral development of the low pressure scavenging stage of the pressure exchanger

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in which scavenging is assisted by ejector action, the flow for which is extracted from cells approaching the scavenging stage via a side outlet.

Fig. 7 is a peripheral development of a pressure exchanger incorporating a heat exchanger matrix in a side pocket and manifold and showing how this provision can permit the inclusion of closed heating and cooling circuits in the cycle.

Parts having the same structural function in the different embodiments carry the same reference numerals.

In Figure 1, the developed cell wheel 1 carries a ring of cells each having an open space therein and in each of which is a heat exchanger element such as 2. The elements are porous matrices of wire mesh, and fill only part, say 5%, of the length of the cells. In Figure 1, as in the case of the other embodiments, it will be seen that the matrix lies totally on the opposite side from the inlet ducts of a transverse common central plane 40 perpendicular to the longitudinal axis of each cell (illustrated in the case of one cell by the dashed line 41) and is spaced from the plane. The cell wheel is driven by external power as seen by Figure 3 or by the gas flow passing between appropriately shaped cell walls, and the cells move in the direction of the arrow 3, between common end walls 4 and 5.

Consider a cell being filled with fresh air from the port of the inlet duct 6. The matrix 2 is hot, as it has been heated in a manner that will be described later. The cell containing fresh air progresses and reaches a duct 7 from the port of which hot gas at a high pressure flows into the cell, compressing the fresh air towards the end of the cell containing the hot matrix. The path of the boundary between air and gas is shown by an irregular line. As a result of the influx of high pressure gas, there will be a build-up of stagnation pressure in the cell to a value somewhat above that of the stagnation pressure in the duct 7. The cell is then opened to the port of the outlet duct 8, and the compressed air passes through the hot matrix into the duct, receiving heat and cooling the matrix. Having been pre-heated in this manner, it flows through a connection 9 to a combustion chamber 10, where it is further heated by the combustion of fuel therein, and then it passes back to the cell wheel.

Any cell at position 11 thus contains hot high pressure gas, which expands into the port of the outlet or delivery duct 12, by which it is led, still at a useful pressure, to a consuming device such as a turbine or chemical process. The hot gas remaining in the cell at 13 is carried around to the port of the exhaust duct 14, into which it expands down to atmospheric pressure, giving up a substantial part of its heat to the matrix. The expansion of the exhaust gases causes a depression in the cell which encourages the in flow of fresh air through duct 6. The line of demarcation between the exhaust gas and fresh air input is indicated here again by an irregular line. The cycle then begins again for that cell. The ports of outlet ducts 8 and 14 can be thought of as a first number of outlet ports terminating at the common wall 4 and separated from the cell spaces by the matrix 2.

The relative positions of the duct ports or openings, their widths and their relation to the cell size, are so chosen that compression and expansion waves are established in the cells when gas flows into or out of them. Such wave processes have been previously described elsewhere.

It is also well-known to incorporate transfer channels or ducts in pressure exchangers by means of which expansion of gas from a cell which has passed the high pressure scavenging stage is utilized to compress gas in another cell approaching that stage. In Figure 2 there is shown the manner in which a transfer channel may be added to the pressure exchanger of Figure 1. When a

cell proceeding in the direction of the arrow 3 has passed out of communication with the port of duct 8, it becomes open at the end opposite from the heat exchanging matrix 2 to a port 15. This port leads to a transfer channel 16 by means of which gas is allowed to expand from the cell through the port 15 to enter another cell via the port 17 before that other cell reaches the high pressure scavenging ducts 7 and 8.

In the embodiments of the invention described above, the gas flowing out of the cells at the scavenging stages passes through the heat exchanging matrix 2. In order to reduce the pressure losses, which it is particularly important to do at the low pressure scavenging stage, it is convenient to locate the heat exchange matrix in a side pocket of the cell rotor, the matrix extending into a manifold in the common cell wall. In Figure 3 there is shown a pressure exchanger cell wheel 1 located between common walls 4 and 5 through which ducts communicate with the cells. Only two of the ducts and their ports are in fact shown in the figure and these are low pressure scavenging ducts 18 and 19. Towards one end of the cells there is mounted around their periphery an annular heat exchange matrix 20, the matrix being mounted on the cells to rotate with them and extending into the manifold 45 on common wall 21, a small clearance being retained between the cells and the matrix on the one hand and the outer casing or common wall 21 and manifold 45 thereon on the other. The matrix is divided by radial partitions forming prolongation of the cell walls. There may be additional radial partitions in the matrix. At a circumferential position of the casing preceding the position at which the low pressure scavenging ducts 18 and 19 communicate with the cells there is provided an outlet pipe 22 whose port terminates at the manifold 45 for gas from the cells to be removed via the matrix 20. The flow through the pipe is taken to an ejector nozzle 23 situated in the downstream branch 19 of the low pressure scavenging ducting. Thus flow through the matrix is used to encourage the low pressure scavenging flow. The peripheral development of the low pressure scavenging stage only of this arrangement of Figure 3 is shown in Figure 4. The position of the matrix radially beyond the cells is indicated by the chain dotted lines 20. It will be seen that cells communicate via the pipe 22 with the ejector 23 before they become open to the port of the downstream branch 19 of the low pressure scavenging ducting. The high pressure scavenging stage of such a pressure exchanger is conveniently arranged as is shown in Figure 5. The inlet branch of the high pressure scavenging ducting is shown at 24 and the outlet branch at 25 is taken from one circumferential position of the annular matrix 20. Hence if the pressure exchanger is built up with scavenging stages as indicated in Figures 3 and 5 the heat exchange matrix 20 takes up heat from the exhaust gases which pass out through the pipe 22 to the ejector 23 at the low pressure scavenging stage and gives heat to the compressed gas passing towards the combustion chamber or other heat input means in a high pressure scavenging stage. In this embodiment the wall 4 can be thought of as a second common wall, wall 21 being the first, and the ports of the ducts 22 and 25 being the first number of outlet ports as compared with the embodiment of Figure 1, the duct 19 thence being a first outlet duct terminating at the second common wall (4 in this instance) and the duct 22 itself being a second duct through which one (22) of the first outlet ports communicates with the first outlet duct 19.

The ejector assistance of scavenging described above in relation to the pressure exchanger having a heat exchange matrix in a side pocket can also be applied to the type of pressure exchanger in which the matrix is within the cells as in Figures 1 and 2. Figure 6 shows a low pressure scavenging stage of such an arrangement in which the inlet branch of the scavenging duct is shown

at 26 and the outlet branch at 27. The matrix 2 is in one end of the cells as in Figures 1 and 2. Immediately before a cell reaches the scavenging stage an additional outlet 27 is provided in the outer casing and a small supply of gas is taken via this outlet and the pipe 28 to an ejector 29 situated in the duct 27. The size of the outlet 27 is chosen so that the ejector action overcomes the resistance of the matrix 2 allowing proper scavenging to take place.

In Figure 7 there is shown the peripheral development of a complete pressure exchanger in some ways similar to that shown in Figure 1 but embodying the side pocket matrix 20 which has already been described above in relation to Figure 3. The low pressure scavenging ducts are shown at 6 and 14 and the high pressure scavenging ducts at 7 and 8. Instead of taking the supply of high pressure hot gas from the cells direct as in Figure 1, opportunity has been taken in this figure to show it taken from the high pressure scavenging ducting. The gas which passes through the branch 8 of this ducting is divided, some passing through the connection 9, combustion chamber 10 and inlet duct 7 back to the cell rotor and the remainder being taken by an outlet duct 30 to the using apparatus or process. It will of course be clear that this arrangement and that shown in Figure 1 for extracting the useful gas are alternatives.

The annular channels in the outer casing in which the matrix 20 runs incorporates two ports 31 and 32, through which gas can leave the cells through the matrix. That which passes out through the port 31 is taken via the pipe 33 to re-enter the cells through the port 34. That which passes out of the cells through the matrix and the port 32 is taken via the pipe 35 to re-enter the cells via the port 36. If a cell in the position 37 is considered, it will be clear that it is filled with fresh air for the cell has just passed the low pressure scavenging stage. At least some of the air in the cells passes through the port 31 via the matrix 20. This matrix is hot and the air re-entering the cells therefore via the port 34 has been heated by heat exchange with the matrix. Having heated the working fluid before it reaches the heat input stage proper the well-known advantages of heat exchangers accrue. The cell in the position 38 is full of hot gas and that gas in passing through the matrix and port 32 heats the matrix. The gas re-entering the cells through the port 36 is correspondingly cooler. The two sets of ports and interconnecting pipes, 31, 33, 34 and 32, 35, 36, respectively provide constant volume heating and constant volume cooling circuits. Hence it will be appreciated that rotor pressure levels are correspondingly raised and lowered by the incorporation of these two circuits.

The employment of a heat exchange matrix in an outer side pocket as has been described above has the advantage that the manifold or that part of the outer casing which covers the matrix can be made removable, thus giving access to the matrix itself. Moreover, where the matrix is made, for example, in two semi-annular halves it can be easily removed for cleaning without serious disturbance of the remainder of the pressure exchanger. Although in relation to Figure 1, it has been suggested that the heat exchange matrix should be made of wire mesh, it will be understood that the porous heat exchange element can be made in other ways. For instance, a finned or plate construction can provide longitudinal passages in the direction of the gas flow through the matrix. In one construction the fins may be carried by the cell partitions so as to extend into the flow path in the cell; if plates are used they may be built into the cell wheel as concentric cylinders where the matrix is within the cells or as radial plates where the matrix is in the outer side pocket. Care clearly has to be taken to ensure as little pressure loss as is consistent with the desired thermal ratio of the heat exchanger and the matrix should be so located and constructed that it does not seriously affect the compression and expansion waves in

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the cells during the operation of the pressure exchanger.

What I claim is:

1. A pressure exchanger having heat exchanger means integral therewith, comprising a plurality of cells each having a longitudinal axis and arranged in series with at least one common wall and each having an open space therein, said cells having a transverse common central plane extending perpendicular to the longitudinal axis of each cell, inlet means having ports therein operatively communicating with and admitting gas to said spaces, outlet means having ports therein operatively communicating with and removing gas from said spaces, at least a first number of said outlet ports terminating at said common wall, a heat-conductive matrix mounted adjacent said common wall totally on the opposite side of said common central plane from said inlet ports and spaced from said plane and separated from said inlet ports by said spaces, said matrix separating said spaces from said first number of outlet ports, and means for causing relative movement between said cells and said matrix on the one hand and said inlet and outlet means on the other hand.

2. A pressure exchanger according to claim 1 wherein said matrix has a flow-path length operatively between each said space and said first number of outlet ports of about 5% of the length of each said space along said longitudinal axis of each cell.

3. A pressure exchanger according to claim 1 wherein said outlet means includes duct means connecting one of said first number of outlet ports with one of said inlet ports, and further comprising a combustion chamber mounted in said duct means.

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4. A pressure exchanger according to claim 1 wherein said matrix is mounted in said cells coextensive with and on the opposite side of said common wall from said first number of outlet ports.

5. A pressure exchanger according to claim 1 wherein said common wall has a manifold therein and said matrix is mounted at the periphery of said cells adjacent said common wall and extends into said manifold, said first number of outlet ports terminating at said manifold.

6. A pressure exchanger according to claim 5 wherein said plurality of cells has a second common wall, and said outlet means further comprises a first outlet duct terminating at said second common wall and a second duct through which one of said first number of outlet ports communicates with said first outlet duct.

7. A pressure exchanger according to claim 6 wherein said second duct terminates in said first outlet duct at a nozzle adapted to eject said gas in a downstream direction.

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