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J. A. BARNES
PRESSURE EXCHANGERS

3,341,112

Filed Oct. 21, 1965

4 Sheets-Sheet 1

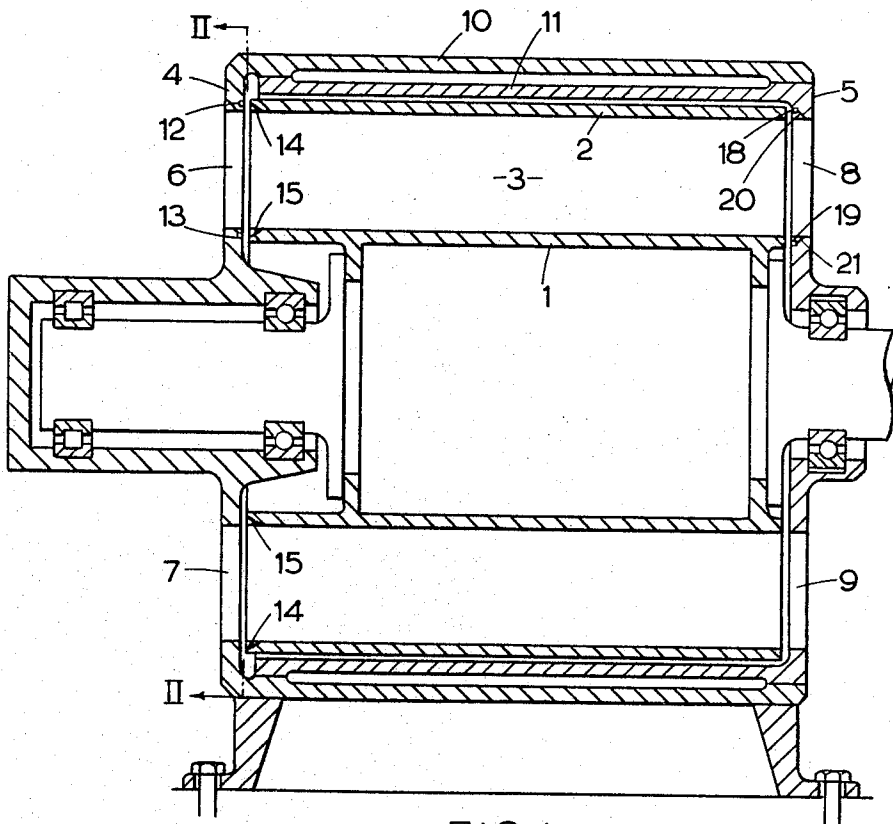


FIG. 1.

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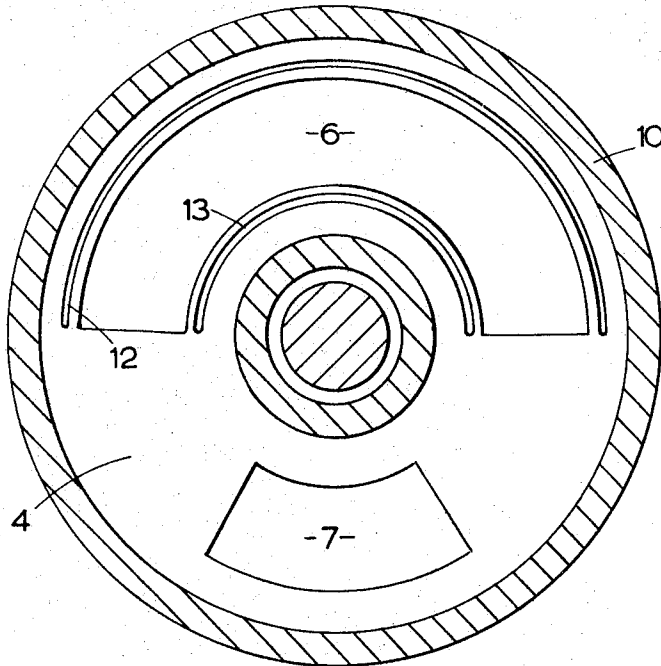


FIG. 2.

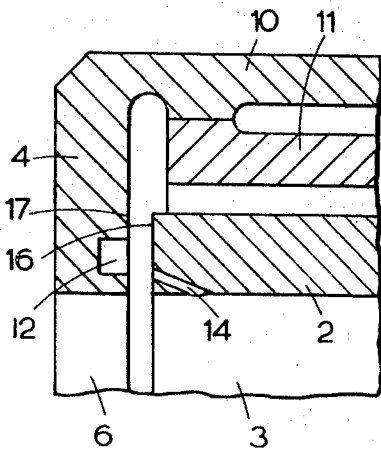


FIG. 3.

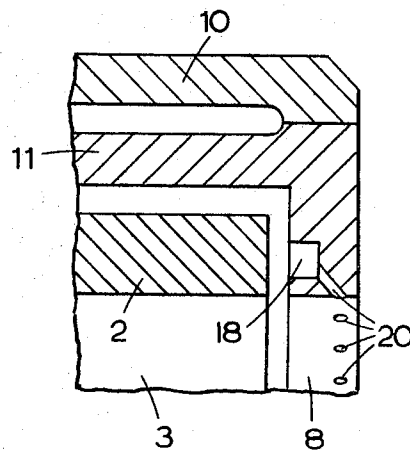


FIG. 4.

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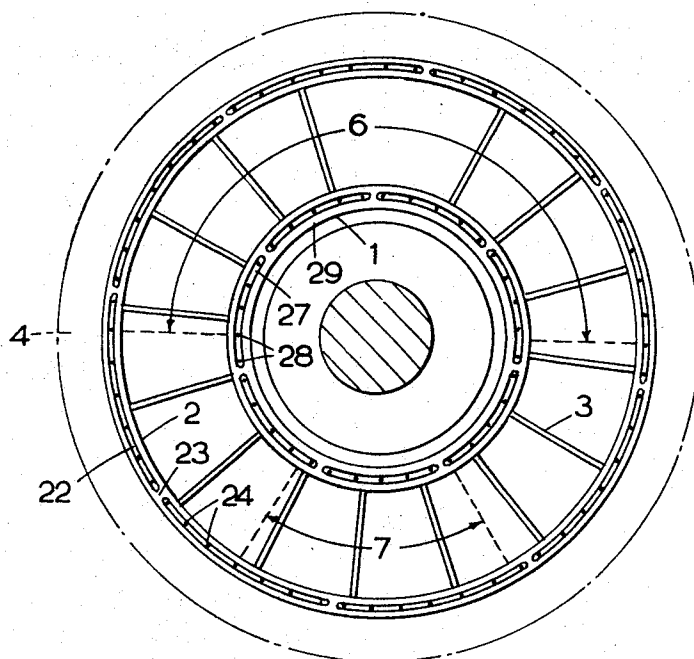


FIG. 5.

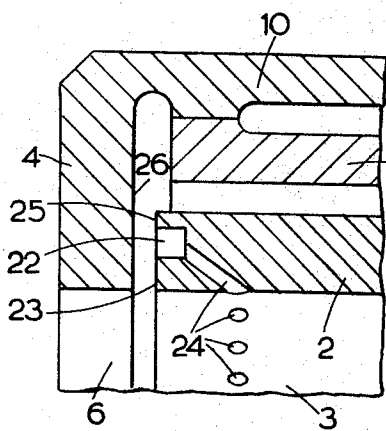


FIG. 6.

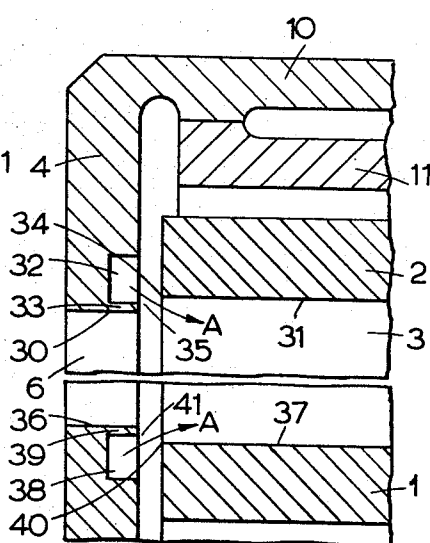


FIG. 7.

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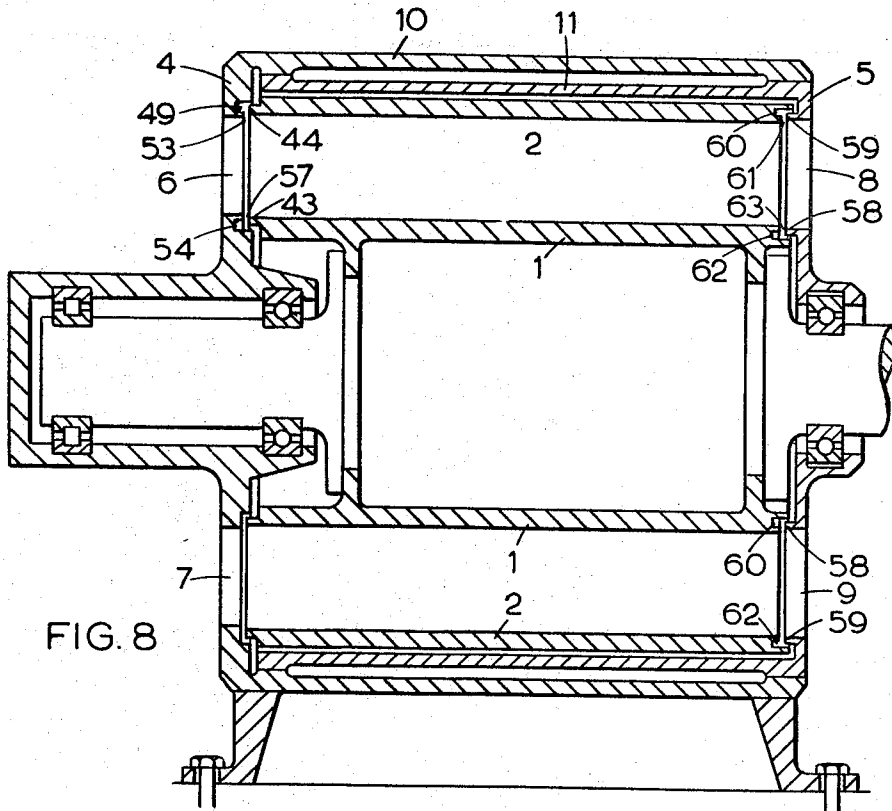
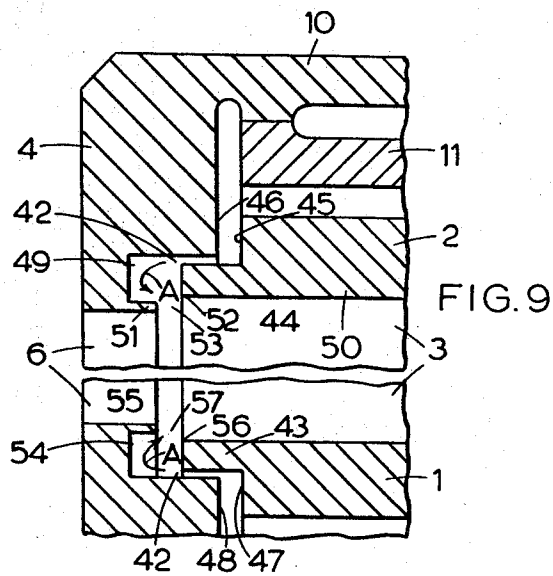
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3,341,112

PRESSURE EXCHANGERS

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Claims priority, application Great Britain, Sept. 10, 1965, 38,853/65

6 Claims. (Cl. 230—69)

ABSTRACT OF THE DISCLOSURE

To reduce the interaction between gas leaking from the high pressure zone through the clearance between the adjacent surfaces of the cell ring and the end plate in a pressure exchanger, with the gas flow in the low pressure zone, an expansion zone providing a local increase in volume is provided in the end plate while the adjacent end of the cell ring incorporates means to place the expansion zone in communication with the low pressure zone to direct the leakage gas in the same general direction as the flow of gas in the low pressure zone.

The present invention relates to pressure exchangers.

This application is a continuation-in-part of the applicant's patent application Ser. No. 447,382 filed on Apr. 12, 1965.

A pressure exchanger is herein defined as an apparatus comprising cells in which one gas quantity expands, so compressing another gas quantity with which it is in direct contact, ducting to lead gas at different pressures steadily to and from the cells and means to effect relative motion between the cells and the ducting.

One constructional form of a pressure exchanger as above defined includes an outer tubular member and an inner member, a plurality of walls carried by one of the members and extending therefrom to the other member to define therebetween a plurality of open-ended cells constituting a cell ring, the ends of the cells being effectively closed by end-plates.

With this form of pressure exchanger it is necessary, if loss of efficiency is to be avoided, to maintain the working clearance between the cell ring and the end-plate structure as small as possible so as to reduce the leakage of gas from a high-pressure zone to a low-pressure zone of the pressure exchanger. It has been found that when the working clearances between the relatively moving parts of the pressure exchanger have been made as small as is practical there is still a loss in efficiency which cannot be explained simply by making allowances for loss in pressure occurring at a high-pressure zone due to the escape of gas from that zone to a zone of lower pressure. This further loss in efficiency is now believed to be caused by interaction between the high-pressure gas leaking into the low-pressure zone and the low-pressure gas flowing in that zone.

For example, for one pressure exchanger it has been calculated that the leakage gas enters the low-pressure zone at a velocity of about three hundred feet per second, that is, about three times the velocity of the working gas in the low-pressure zone. If the leakage gas enters the low-pressure zone substantially at right angles to the direction of flow of the working gas, the resulting interaction between the leakage gas and working gas would create turbulences in the working gas flow, with the result that there would be a drop in the overall efficiency of the pressure exchanger.

The velocity of the leakage gas entering the low-pressure zone could be reduced by increasing the working

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clearance at that zone but it is desirable to keep the working clearance small to control the leakage of gas from the high-pressure zone.

According to the present invention a pressure exchanger includes a first structure having cells in which one gas quantity expands, so compressing another gas quantity with which it is in direct contact, a second structure having ports communicating with the cells, ducting communicating with the ports to lead gas at different pressures steadily to and from the cells, means to effect relative motion between the structures, a surface on each structure, which surfaces while defining a clearance permitting said motion, provide a path for the flow of leakage gas from a high-pressure zone to a low-pressure zone, an expansion zone formed in one of the surfaces, that is to say a zone providing a local increase in volume of the leakage path, and communication means to place the expansion zone in communication with the low-pressure zone and to direct the leakage gas in the same general direction as the flow of gas in that zone.

Advantageously the arcuate length of the expansion zone is less than the distance between adjacent ports communicating with the ducts.

Preferably the cross-sectional area of the passage or passages is such that the flow of leakage gas will have an ejector effect on the flow of working gas in the low-pressure zone.

The invention will now be described, by way of example, with reference to the accompanying diagrammatic drawings in which:

FIGURE 1 is an axial section through a pressure exchanger according to the invention,

FIGURE 2 is a section taken on the line II—II of FIGURE 1,

FIGURES 3 and 4 are fragmentary views, to a larger scale, of the left-hand and right-hand ends, respectively, of the pressure exchanger shown in FIGURE 1,

FIGURE 5 is an elevation of the left-hand end of the cell ring of a modified form of the pressure exchanger shown in FIGURE 1,

FIGURE 6 is a fragmentary view, to a larger scale, of the left-hand end of the modified pressure exchanger of FIGURE 5,

FIGURE 7 is a fragmentary view, to a larger scale, of the left-hand end of another modified form of the pressure exchanger shown in FIGURE 1.

FIGURE 8 is a view, similar to FIGURE 1, of a further modification of a pressure exchanger according to the invention, and

FIGURE 9 is a fragmentary view, to a larger scale, of the left-hand end of FIGURE 8.

The pressure exchanger of FIGURE 1 comprises a cell ring 1, 2 mounted for rotation between end-plates 4 and 5 which form part of a surrounding casing. The cell ring is formed by an inner member 1 located co-axially within an outer tubular member 2. A plurality of axially extending walls 3 divide the space between the members 1 and 2 into a plurality of open-ended cells which are effectively closed by the end-plates 4 and 5. Sector-shaped ports 6 and 7 in the end-plate 4 permit working gas at low and high pressures respectively to enter the cells from ducts (not shown) and sector-shaped ports 8 and 9 in the end-plate 5 permit working gas at low and high pressures, respectively, to leave the cells by way of ducts (not shown). Thus the ports 6, 8 and the cells at any one time in communication with them constitute a low-pressure zone of the pressure exchanger and ports 7, 9 and the cells at any one time in communication with them constitute a high-pressure zone.

The end-plates 4, 5 have integral cylindrical extensions 10, 11, respectively, which are a sliding fit, one within the other, to form a casing about the cell ring. The ex-

tensions 10, 11 hold the end-plates 4, 5 in axial alignment while permitting them to move axially. The cell ring is so mounted that a predetermined clearance is left between the end-plates and the cell ring, which clearance is maintained under working conditions, despite any expansion or contraction of the cell ring, since each end-plate is constrained to follow any axial movement of the associated end of the cell ring.

At the inlet end of the pressure exchanger, shown in greater detail in FIGURES 2 and 3, grooves 12 and 13 are formed in the end-plate 4 and extend over the arc of the radially outer and inner edges respectively, of the sector-shaped inlet port 6. A ring of equally spaced passages 14, 15 is formed in the adjacent ends of the members 2, 1 respectively. Each passage 14, 15 is inclined to the longitudinal axis of the pressure exchanger and opens at one end into the end-face of the member in which it is formed and at the other end into a cell of the cell ring. At any angular position of the cell ring a number of passages 14 in the member 2 define means placing the expansion zone constituted by the groove 12 in communication with its adjacent cells and the corresponding radially inner passages 15 in the member 1 define means placing the groove 13 in communication with the same cells.

As can be seen in FIGURE 3, a part 16 of the end-face of the member 2 radially outward of the passages 14 defines with an adjacent part 17 of the end-plate 4, a clearance of predetermined width through which leakage gas can flow into the low-pressure zone.

Similarly, a part of the end-face of the member 1 radially inward of the passages 15 defines with an adjacent part of the end-plate 4, a clearance of predetermined width.

At the outlet end of the pressure exchanger, shown in greater detail in FIGURE 4, grooves 18, 19 are formed in the end-plate 5 and extend over the arc of the radially outer and inner edges, respectively, of the sector-shaped outlet port 8. Passages 20, 21 are formed in the end-plate 5, at an angle to the longitudinal axis of the pressure exchanger, to place the grooves 18, 19 respectively, in communication with the port 8.

Parts of the end-plate 5 radially outward of the groove 18 and radially inward of the groove 19 define with the adjacent end-faces of the members 1 and 2 clearances of predetermined width through which leakage gas can flow into the low-pressure zone.

When the pressure exchanger is in operation some of the high-pressure working gas leaks from the high-pressure zone through the adjacent working clearances, passing radially outward into the space around the cell ring and radially inward to the space at the axis of the cell ring and then from such spaces into the low-pressure zone through the adjacent working clearances.

The leakage gas is travelling at a high velocity in a direction normal to the direction of flow of working gas in the low-pressure zone but on reaching the grooves 12, 13, 18, 19 adjacent the low-pressure inlet and outlet ports, it is diffused in the expansion zones constituted by the grooves and flows through the passages 14, 15, 20, 21 to enter the low-pressure zone in the same general direction as that of the flow of the gas in the zone. Thus the effect of interaction between the two gas streams is reduced.

In a modification, which is not illustrated, the expansion zones at the inlet end of the pressure exchanger are constituted by annular grooves formed in the end-faces of the members 2 and 1. Passages, similar to the passages 14, 15, place the grooves of each member 2, 1 in communication with the cells of the cell ring.

However, since such annular grooves would provide a path for the flow of leakage gas from the high-pressure to the low-pressure zone it is preferred to divide each groove along its length into a plurality of separate grooves.

This construction is shown in FIGURES 5 and 6 where a plurality of grooves 22 are formed in the end-face 23 of the outer member 2 of the cell ring. The grooves 22 are

arranged end to end, to form a circle interrupted by lands, the arcuate length of each groove 22 being less than the distance between the ports 6, 7 in the end-plate 4 (indicated in broken lines in FIGURE 5) so that the groove cannot provide communication between the ports. Passages 24 are formed in the member 2, at an angle to the longitudinal axis of the pressure exchanger, to place each groove 22 in communication with its adjacent cells.

As can be seen in FIGURE 6 a part 25 of the end-face 23 of the member 2 defines with a part 26 of the end-plate 4, a clearance of predetermined width through which leakage gas can flow into the low-pressure zone.

Grooves 27 and passages 28, similar to the grooves 22 and the passages 24, are formed in the end-face 29 of the inner member 1.

At the outlet end of the modified pressure exchanger the construction is identical with that previously described with reference to FIGURE 4.

When the modified pressure exchanger is in operation the grooves 22, 27 adjacent the low-pressure inlet port function as the grooves 12 and 13 of FIGURE 1 to provide an expansion zone for the diffusion of the leakage gas which then flows through the passages 24, 28 to enter the low-pressure zone in the same general direction as that of the flow of gas in the zone.

If desired the grooves 22, 27 in the outer and inner members 2, 1 may be formed as a circumferentially continuous groove and sub-divided into a plurality of non-intercommunicating grooves by the roots of the cell walls 3.

In a further modification, shown in FIGURE 7, the radially outer face 30 of the sector-shaped port 6 has a radius slightly less than the inner surface 31 of the member 2 forming a "step" in the direction of flow of working gas in the low-pressure zone. A groove 32, extending over the arc of the outer edge of the port 6, is formed in the end-plate 4. The groove 32 extends radially inwardly beyond the inner surface 31 of the member 2 and is separated from the port 6 by a thin wall 33. The adjacent edge 34 and surface 31 of the member 2 cooperate with the wall 33 of the expansion zone to define a passage 35 placing the groove 32 in communication with the cells of the cell ring.

The radially inner face 36 of the port 6 has a radius slightly greater than the inner surface 37 of the member 1. A groove 38, similar to groove 32, is formed in the end-plate 4, a wall 39 of the groove 38 defining with the adjacent edge 40 of the member a passage 41 placing the groove 38 in communication with the cells of the cell ring.

Parts of the end-plate 4 radially outward of the groove 32 and radially inward of the groove 38 define with the adjacent end-faces of the members 1 and 2 clearances of predetermined width through which leakage gas can flow into the low-pressure zone.

The outlet end of the pressure exchanger is identical in form and function to that described in connection with FIGURES 1 and 4 and, therefore, in the following description of the operation of the pressure exchanger reference will only be made to the inlet end.

Leakage gas in the clearances on reaching the grooves 32, 38 diffuses in the expansion zones constituted by the grooves and flows through the passages 35, 41, as indicated by the arrows A, to enter the low-pressure zone in the same general direction as that of the gas in the zone.

The total cross-sectional area of the passage or passages leading from any one groove is made about two to three times the cross-sectional area of the clearance extending over the arcuate length of the groove. Preferably the total cross-sectional area of the passage or passages is such that the leakage gas issuing from them will promote the flow of working gas in the low-pressure zone by the ejector effect.

At the inlet end of the pressure exchanger shown in FIGURES 8 and 9, an annular rabbet 42 is cut in the end-plate 4. The members 1, 2 of the cell ring are formed

with annular, axial extensions 43, 44, respectively, which project into the rabbet 42, a clearance being maintained between the adjacent axially extending surfaces of the extensions 43, 44 and the rabbet 42 to permit the cell ring to rotate freely relative to the end-plate 4 under all operating conditions of the pressure exchanger.

A part 45 of the end-face of the member 2 radially outward of the extension 44 defines with an adjacent part 46 of the end-plate 4, a clearance of predetermined width through which leakage gas can flow into the low-pressure zone. Similarly, a part 47 of the end-face of the member 1 radially inward of the extension 43 defines with an adjacent part 48 of the end-plate 4, a clearance of predetermined width. The end-face of each extension 43, 44 also defines with an adjacent part of the rabbet 42 in the end-plate 4, a clearance of the same predetermined width as can be seen adjacent port 7 in FIGURE 8.

Ports 6 and 7 open into the rabbet 42. The height of the port 7, that is the distance between the radially inner and outer faces of the port, is substantially the same as the height of the cells, that is the radial distance between the members 1 and 2. The port 6, however, as can be best seen in FIGURE 9 is of a height less than that of the cells of the cell ring 1, 2. A groove 49, extending over the arc of the radially outer edge of the port 6, is formed in the rabbet 42 in the end-plate 4. The groove 49 extends radially inwardly beyond the radially inner surface 50 of the member 2 and is separated from the port 6 by a thin wall 51. The adjacent edge 52 and surface 52 of the member 2 cooperate with the walls 51 of the expansion zone to define a passage 53 placing the groove 49 in communication with the cells of the cell ring.

A groove 54, similar to the groove 49, extending over the arc of the radially inner edge of the port 6, is also formed in the rabbet 42, a wall 55 of the groove defining with the adjacent edge 56 of the member 1 a passage 57 placing the groove 54 in communication with the cells of the cell ring.

At the outlet end of the pressure exchanger, not shown in detail, the height of each outlet port 8 and 9 is made greater than the height of the cells of the cell ring. The end-plate 5 is formed with two annular, axial extensions 58, 59, the radially outer surface of the extension 58 being aligned with the radially inner surfaces of the ports 8 and 9 and the radially inner surface of the extension 59 being aligned with the radially outer surfaces of the ports 8 and 9. A part of the end-face of the cell ring member 2 is cut away around its inner periphery to receive the extension 59, clearances being allowed both radially and axially between the member 2 and the extension 59 to permit free rotation of the cell ring under all operating conditions. The part of the end-face of the member 2 radially outward of the extension 59 defines with an adjacent part of the end-plate 5 a clearance of predetermined width. A plurality of grooves 60 are formed in the end-face of the member 1 adjacent the end-face of the extension 59. Like the construction illustrated in FIGURE 5 the grooves 60 are arranged end to end to form a circle interrupted by lands. The arcuate length of each groove 60 is less than the arcuate distance between the ports 8 and 9 in the end-plate 5 so that a groove cannot provide communication between the ports. The grooves 60 are separated from the cells by thin walls which define with the adjacent edge of the port 8, a passage 61 placing each groove in communication with the port 8.

Similarly the end-face of the cell ring member 1 is cut away to receive the extension 58, the part of the end-face of the member 1 radially inward of the extension 58 defining with an adjacent part of the end-plate 5 a clearance of predetermined width. Grooves 62, like the grooves 60, are formed in the end-face of the member and communicate with the port 8 through passages 63, like the passages 61.

When the pressure exchanger is in operation some of the high-pressure working gas leaks from the high-pres-

sure zone through the adjacent working clearances, passing radially outwardly into the space around the cell ring and radially inwardly to the space at the axis of the cell ring and then from such spaces into the low-pressure zone through the adjacent working clearances.

The leakage gas is travelling at a high velocity in a direction normal to the direction of flow of working gas in the low-pressure zone but on reaching the extensions 43, 44, 58, 59, adjacent the low-pressure inlet and outlet ports is directed into the expansion zones constituted by the grooves 49, 54, 60, 62. The gas flows through the passages 53, 57, 61, 63, to enter the low-pressure zone in the same general direction as that of the flow of gas in the zone. Thus the effect of interaction between the two gas streams is reduced.

It will be seen that the leakage gas is directed by the extensions into the grooves at a location remote from the passages and in such a direction that the gas is caused to swirl in a sense (as indicated by the arrow A) which will assist it to enter the low-pressure zone in the required direction.

It will be appreciated that while the grooves have been shown in the drawings as of generally rectangular cross-section they may be of any suitable shape and in particular one which will facilitate the flow of leakage gas into the passages.

Preferably the cross-sectional area of the passages is such that the leakage gas issuing from them will promote the flow of working gas in the low-pressure zone by the ejector effect.

While in the drawings the clearances have been exaggerated to facilitate the understanding of the invention, it will be understood that, in practice, they are made as small as possible while permitting free rotation of the cell ring when the pressure exchanger is working under operating conditions. The actual dimensions of the clearances will depend upon the size of the pressure exchanger and whether a hot working gas is used.

I claim:

1. A pressure exchanger comprising
 - (a) a first structure having cells in which one gas quantity expands, so compressing another gas quantity with which it is in direct contact,
 - (b) a second structure having ports communicating with the cells,
 - (c) ducting communicating with the ports to lead gas at different pressures steadily to and from the cells,
 - (d) means to effect relative motion between the structures,
 - (e) a surface on each structure, which surfaces while defining a clearance permitting said motion, provide a path for the flow of leakage gas from a high-pressure zone to a low-pressure zone,
 - (f) an expansion zone formed in one of the surfaces, that is to say a zone providing a local increase in volume of the leakage path, and
 - (g) means on the other of said surfaces cooperating with the expansion zone to place it in communication with the low-pressure zone and to direct the leakage gas in the same general direction as the flow of gas in that zone.
2. A pressure exchanger according to claim 1, wherein the expansion zone is shaped to promote the flow of leakage gas into the communication means.
3. A pressure exchanger according to claim 2, wherein the other surface is shaped to direct the leakage gas into the expansion zone in a direction substantially opposite to the general direction of flow of gas in the low-pressure zone to cause the leakage gas to swirl in a sense which will assist it to enter the low-pressure zone in the same general direction as that of the flow of gas in that zone.
4. A pressure exchanger comprising
 - (a) a first structure having cells in which one gas quantity expands, so compressing another gas quantity with which it is in direct contact,

- (b) a second structure having ports communicating with the cells,
 - (c) ducting communicating with the ports to lead gas at different pressures steadily to and from the cells,
 - (d) means to effect relative motion between the structures, 5
 - (e) a surface on each structure, which surfaces while defining a clearance permitting said motion, provide a path for the flow of leakage gas from a high-pressure zone to a low-pressure zone,
 - (f) an expansion zone formed in one of the surfaces, that is to say a zone providing a local increase in volume of the leakage path, and 10
 - (g) communication means opening into the other surface to place the expansion zone in communication with the low-pressure zone and to direct the leakage gas in the same general direction as the flow of gas in that zone. 15
5. A pressure exchanger comprising
- (a) a first structure having cells in which one gas quantity expands, so compressing another gas quantity with which it is in direct contact, 20
 - (b) a second structure having ports communicating with the cells,
 - (c) ducting communicating with the ports to lead gas at different pressures steadily to and from the cells, 25
 - (d) means to effect relative motion between the structures,
 - (e) a surface on each structure, which surfaces while defining a clearance permitting said motion, provide a path for the flow of leakage gas from a high-pressure zone to a low-pressure zone, 30
 - (f) an expansion zone formed in one of the surfaces, that is to say a zone providing a local increase in volume of the leakage path, and 35
 - (g) communication means to place the expansion zone in communication with the low-pressure zone and to direct the leakage gas in the same general direction as the flow of gas in that zone,
 - (h) said first structure comprising a cell ring rotatable with respect to the second structure which is maintained stationary, 40

- (i) said expansion zone being formed in said surface of said cell ring and being subdivided into arcuate lengths which are each shorter than the arcuate distance between adjacent ports in the stationary structure whereby the expansion zone is prevented from forming a flow path for gas between the adjacent ports.
6. A pressure exchanger comprising
- (a) a first structure having cells in which one gas quantity expands, so compressing another gas quantity with which it is in direct contact,
 - (b) a second structure having ports communicating with the cells,
 - (c) ducting communicating with the ports to lead gas at different pressures steadily to and from the cells,
 - (d) means to effect relative motion between the structures,
 - (e) a surface on each structure, which surfaces while defining a clearance permitting said motion, provide a path for the flow of leakage gas from a high-pressure zone to a low-pressure zone,
 - (f) an expansion zone formed in one of the surfaces, that is to say a zone providing a local increase in volume of the leakage path, and
 - (g) means to place the expansion zone in communication with the low-pressure zone at a location within one of said first and second structures and to direct the leakage gas in the same general direction as the flow of gas in that zone.

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