Feb. 19, 1963

D. B. SPALDING

PRESSURE EXCHANGER

3,078,034

Filed March 29, 1957

4 Sheets-Sheet 1

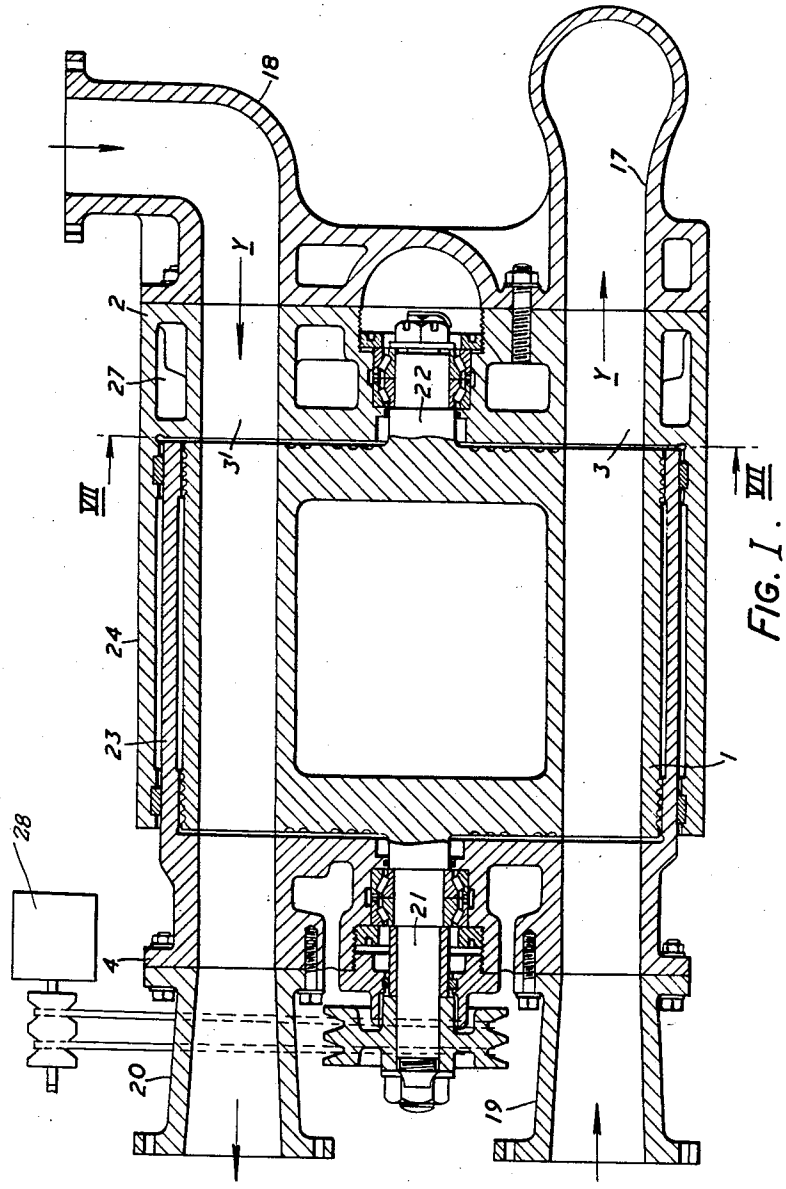


FIG. 1.

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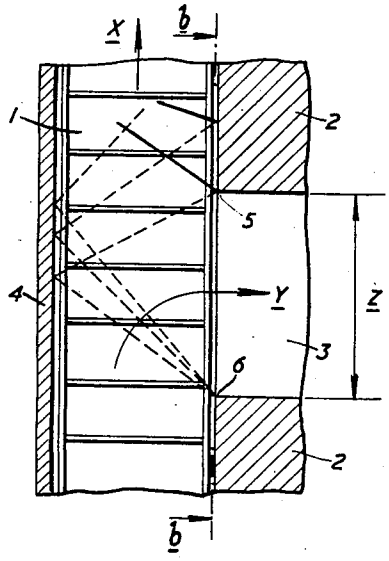


FIG. 1a.

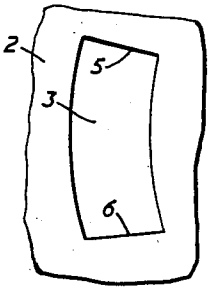


FIG. 1b.

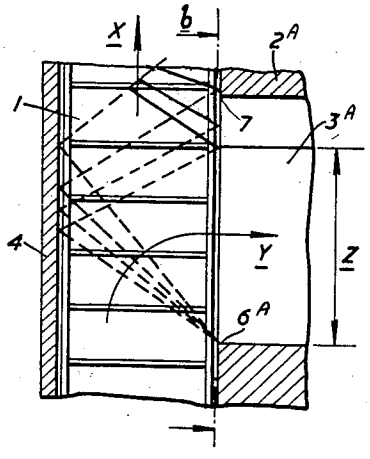


FIG. 2a.

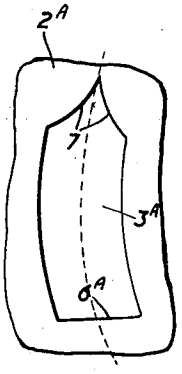


FIG. 2b.

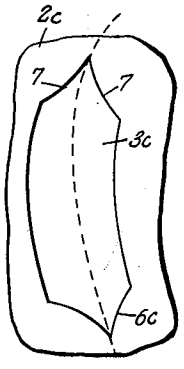


FIG. 6

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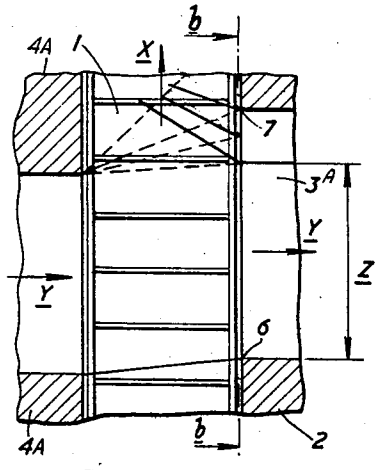


FIG 3a

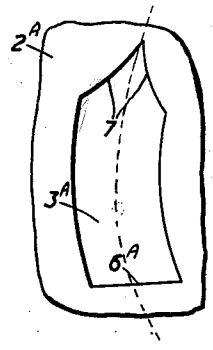


FIG. 3b.

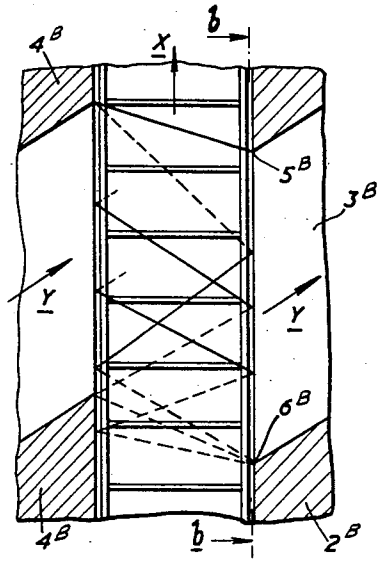


FIG. 4a.

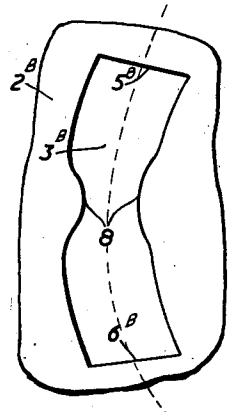


FIG. 4b.

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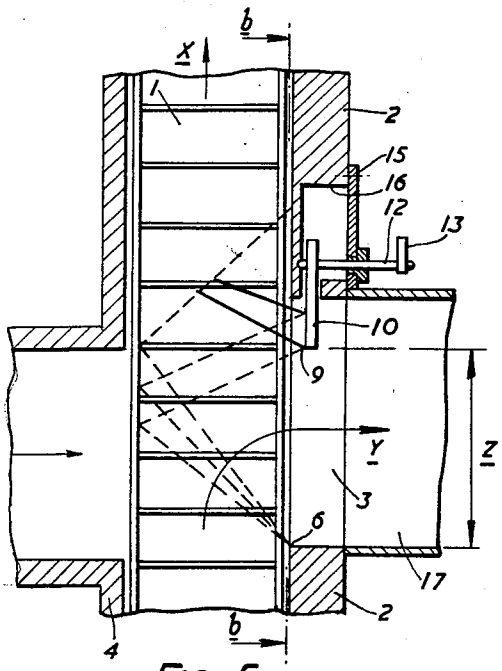


FIG. 5a.

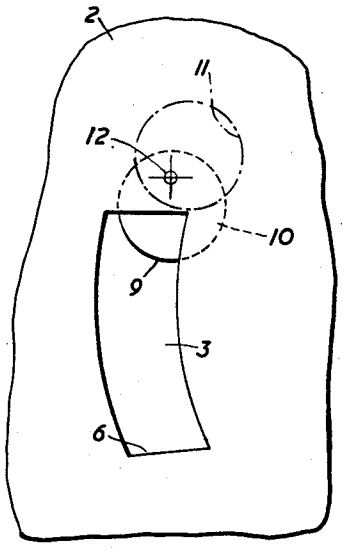


FIG. 5b.

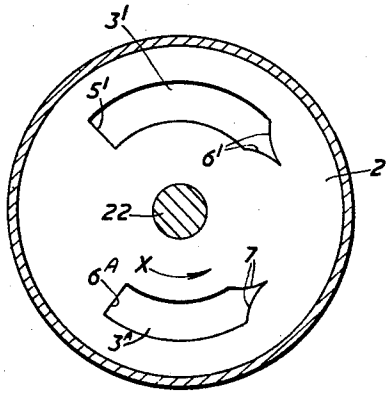


FIG. 7.

United States Patent Office

3,078,034

Patented Feb. 19, 1963

3,078,034

PRESSURE EXCHANGER

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Filed Mar. 29, 1957, Ser. No. 649,533
Claims priority, application Great Britain Mar. 29, 1956
1 Claim. (Cl. 230—69)

The invention relates to pressure exchangers and is particularly concerned with cell closure means therefor.

According to the invention, pressure exchanger cell closure means incorporate a port providing access for fluid to or from cells, of which port the dimension normal to the direction of relative motion between the closure means and the cells is non-uniform.

Pressure exchangers as previously proposed usually comprise a ring of cells rotatable relatively to ported end-plates co-operating with the ends of the cells so that the cells are opened and closed at particular time intervals and communicate through the ports in a particular sequence with ducts connected thereto. The ports in the end-plates have been hitherto in the form of arcuate slots of constant radial dimension.

It is now proposed in accordance with one aspect of the invention to provide a ported end-plate providing access for fluid to or from a ring of axially extending cells, the end-plate incorporating a port of which the radial dimension is non-uniform. Preferably the port may be in the form of an arcuate slot.

Where the port is an outlet port, through which in operation fluid flows from the cells, the port may be tapered by decrease of the radial dimension in the circumferential direction away from the leading edge of the port. Preferably the radial dimension of the port is substantially uniform over a major part of its arcuate length, the port being tapered in the region of its trailing edge. Where the port is an inlet port through which in operation fluid flows to the cells the port may be tapered by decrease of the radial dimension in the circumferential direction away from the trailing edge of the port. Preferably the radial dimension of the port is substantially uniform over a major part of its arcuate length, the port being tapered in the region of its leading edge. The leading edge and/or trailing edge of the port may be formed substantially completely by the tapered regions.

The non-uniform part of the dimension normal to the direction of relative motion may be varied. This may be carried out by constituting an edge of the port by the profile of a cam so mounted that rotational movement of the cam alters the configuration of the port.

The invention also includes a pressure exchanger having cell closure means incorporating a port providing access for fluid to or from cells, of which port the dimension normal to the direction of relative motion between the closure means and the cells is non-uniform.

By way of example, certain embodiments of the invention will now be described with reference to the accompanying diagrammatic drawings in which:

FIGURE 1 is an axial sectional view of a pressure exchanger constructed in accordance with the invention.

FIGURE 1*a* shows a circumferential development of part of the pressure exchanger cell ring of FIGURE 1 and part of an end-plate associated therewith, the end-plate incorporating an outlet port of known shape;

FIGURE 1*b* is a view of the end-plate on the line *b*—*b* in FIGURE 1*a*;

FIGURES 2*a* and 2*b* are views similar to FIGURES 1*a* and 1*b* but showing a first embodiment of the invention;

FIGURES 3*a* and 3*b* are similar to FIGURES 2*a* and 2*b* but show a high pressure scavenging stage of a pressure exchanger;

FIGURES 4*a* and 4*b* are similar to FIGURES 3*a* and 3*b* and show a second embodiment of the invention in connection with a low pressure scavenging stage;

FIGURES 5*a* and 5*b* are similar to FIGURES 2*a* and 2*b* and show a third embodiment of the invention;

FIGURE 6 is a view similar to that of FIGURE 2*b* or 3*b* showing a fourth embodiment of the invention.

FIGURE 7 is a view on the line VII—VII in FIGURE 1 of an end-plate of the pressure exchanger shown in FIGURE 6.

FIGURE 1 shows a pressure exchanger having a cell ring 1 rotatable about stub shafts 21 and 22 by a driving motor 28. The stub shafts 21 and 22 are supported in bearings housed in stationary end-plates 4 and 2. Hot gas is admitted to the cell ring through a duct 18 and a port 3' in the end-plate 2. The duct 18 together with an outlet duct 20 forms part of high pressure scavenging stage ducting. An inlet duct 19 communicates with a port in the end-plate 4 and together with a port 3 in the end-plate 2 and an outlet duct 17 forms low pressure scavenging stage ducting. The end-plate 2 has been provided with cooling passage 27 through which a coolant such as water is circulated. The end plates 2 and 4 are provided with tubular extensions 23 and 24 respectively which are arranged in a telescopic manner around the cell ring 1.

In FIGURES 1*a*, 2*a*, 3*a*, 4*a* and 5*a* expansion or rarefaction waves caused by the sudden opening of cells to a duct are illustrated by broken lines. FIGURES 1*a* and 1*b* show a ring 1 of axially extending open ended cells rotatable in the direction of arrow X between stationary end-plates 2 and 4. The end-plate 2 contains an outlet port 3 which is in the form of an arcuate slot of uniform radial dimension as provided in pressure exchangers proposed hitherto. The port 3 has a leading edge 6 (i.e. the edge of the port by which a cell is opened to the port) and a trailing edge 5 (i.e. the edge of the port by which a cell is closed to the port). The port is of mean circumferential width Z. Rarefaction waves are produced as cells become open to the port 3 as shown by the broken lines. The timing of the opening and closing of the cells by the leading and trailing edges 6 and 5 respectively is very critical for correct and efficient operation of a pressure exchanger. On the opening of a cell by the leading edge 6 of the port, expansion waves are set up and these are reflected at the remote ends of the cells at the end-plate 4. The timing should be such that the head of the reflected wave will reach the end of a cell adjacent the end plate 2 just as that cell is closed by the trailing edge 5. If the timing is not quite correct, the first expansion wave may reach the end of the cell adjacent the end-plate 2 before that cell has been closed by the trailing edge 7. In this event gas would escape along the trailing edge of the port at a lower velocity than gas leaving through the rest of the port and that gas would have a lower stagnation pressure. This could lead to boundary layer break-away in a diffusing duct communicating with the port. As shown in FIGURE 1*a*, there are other expansion waves which fan from the point of opening of the cells by the leading edge 6 and which after reflection return to the end of the cells after that cell has been closed by the end-plate 2. Each time an expansion wave so reflected hits the closed end-plate 2, a compression wave, shown by full lines, is produced.

FIGURES 2*a* and 2*b* show a first embodiment of the invention and are similar to the FIGURES 1*a* and 1*b* showing a known arrangement, except that the port has been tapered in the region of the trailing edge. The taper extends in the direction of rotation X and itself constitutes the trailing edge. The circumferential dimension of the port is greater than in FIGURE 1. This is indicated by the dimension Z which extends from the leading edge 6A to the beginning of the tapered part. Thus more gas can be extracted through the tapered port than through the

port in FIGURE 1*a*. The tapering of the port enables the area of the cell open to the port to be gradually reduced as that cell moves past the tapered trailing edges 7. The radial dimension of the port determines the pressure on the upstream side of the port and therefore the velocity through the port. The restriction of the port at any circumferential position may be chosen to give a required velocity of flow through the port at that position. Thus the profile of the taper is so chosen that the velocity of flow through the port is substantially uniform and is not reduced in the immediate vicinity of the trailing edge 7. Boundary layer break-away is therefore less likely to occur. Alternatively the profile of the taper may be such as to increase the velocity in the immediate vicinity of the trailing edge so providing a boundary layer acceleration, which could assist diffusion. The part of the port which is not tapered is in the form of an arcuate slot of substantially constant radial dimension. The taper need not be symmetrical.

FIGURES 3*a* and 3*b* show an arrangement similar to that shown in FIGURES 2*a* and 2*b* but for a high pressure scavenging stage. The cells 1 come into communication with the inlet port in the end-plate 4A before these cells become open to the outlet port 3A in the end-plate 2A. Such an arrangement is conventional in a high pressure scavenging stage, in which the pressure of the cell contents is less than the pressure of the fluid being introduced into one end of the cells through the inlet port. The fluid is first introduced into a cell through the inlet port before the opposite end of that cell comes into communication with the outlet port. The outlet port is arranged to become open to the cells after the cells have become open to the inlet port, and ideally when the compression wave as shown in full line has reached the leading edge of the outlet port. The cells become open to the inlet port before the outlet port in order to generate the compression wave which travels through the cells to compress their contents which subsequently leave through the outlet port. The end-plate 4A has a port through which gas is introduced to the cells to enable a scavenging gas flow to occur, as denoted by arrows Y. An effect of the taper 7 is that the scavenging is achieved with a smaller pressure fall in cells passing through the scavenging stage than there would be if the trailing edge were not tapered.

FIGURES 4*a* and 4*b* show another profile for an outlet port at a low pressure scavenging stage in which the radial dimension of the port is gradually reduced and is then increased to form a constriction 8 at a central region of the port. The cells 1 communicate with the outlet port 3B in the end-plate 2B before they come into communication with the inlet port in the end-plate 4B. This is a conventional arrangement for low pressure scavenging in which the pressure of the cell contents is higher than the pressure of the fluid being introduced into one end of the cells through the inlet port. The fluid in a cell first comes into communication with the outlet port and expands, the expansion wave travelling through the cells towards the leading edge of the inlet port. By this time the pressure of the fluid to be introduced into the cells is higher than the decreasing pressure of the cell contents and the introduced fluid replaces the contents of the cells. While the expansion wave travels towards the leading edge of the inlet port the cell contents move in the opposite direction and through the outlet port. This shape of port will tend to maintain the outlet velocity uniform. Without the constriction there would tend to be a region of reduced outlet velocity in the central region of the port where the initial expansion waves are reflected, especially in the case of a port occupying a large circumferential distance. The reflection of expansion or compression waves occurs at open ended cells as well as when the waves are reflected from the surface of, for example, an end-plate. This is due to pressure discontinuities obtaining at the cell opening.

To accommodate various conditions of operation, particularly different pressure ratios, the profile of the port may be made adjustable. Such an arrangement is shown in FIGURES 5*a* and 5*b* where the tapered leading edge of a port 3 in an end-plate 2 is defined by a part 9 of the profile of a cam 10. The cam 10 is housed in a recess 16 in the end-plate 2 and is pivotally mounted on a shaft 12 bearing at one end in the end-plate 2 and also supported by a cover plate 15 secured to the end-plate 2 and closing the recess 16. The cam is circular and is mounted eccentrically on the shaft 12. The shaft 12 is turned by means of a handle or crank 13. On turning the shaft 12 and therefore the cam 10, the cam can be moved between various positions in which it will overlap the port 3, which is in the form of an arcuate slot of uniform radial dimension, and a limiting position shown by reference 11 (FIGURE 5*b*) in which the cam 10 is clear of the port 3. In this way, the taper at the trailing edge of the port 3 and defined by the part 9 of the cam 10 can be varied. The cam may be set before operation of the pressure exchanger or may be adjusted during operation. The circumferential dimension Z between the leading edge 6 and the beginning of the tapered part is the same as in FIGURES 2*a* and 3*a*. The reference numeral 17 denotes a gas outlet duct connected to the port 3.

Instead of providing an adjustably tapered port, a pressure exchanger may be provided with several interchangeable end-plates, each having a port or ports of a particular shape. Profiles other than those shown in FIGURES 2*b*, 3*b* or 4*b*; but having a non-uniform radial dimension, may be employed.

In the FIGURES 2*a*, 3*a*, 4*a* or 5*a* a taper has been provided at the trailing edge of an outlet port. The outlet port 3C may also have a taper on the leading edge as shown in FIGURE 6, such taper extending in a direction opposed to the direction of rotation X. This is expected to give a high velocity at the leading edge to counteract boundary layer effects which may otherwise occur. The part of the port intermediate the tapered end regions is of substantially uniform radial dimension.

Although tapered outlet ports only have been shown, the invention may also be applied to inlet ports such as 3', as shown in FIGURE 7. In that case the taper would be at the leading edge of a port and would extend in a direction opposed to the direction of rotation of the cells. The circumferential dimension of a cell is finite and therefore gradual closing or opening of a cell to a port will occur whether a tapered profile is provided or not. With some cell widths, the gradual closing or opening of a port which has not been tapered in accordance with this invention will be found to have sufficient effect at an inlet port and that tapering there may not be necessary. However, with high pressure ratios the present proposals may be found to be advantageous.

As will be seen from the cross-sectional view, FIGURE 7, the outlet port 3A has its trailing edge tapered in the direction of rotation of the cell ring and the inlet port 3' has its leading edge 6' tapered in the direction opposed to the direction of rotation. The leading edge 6A of the port 3A and the trailing edge 5' of the port 3' are substantially radial. As in the previous drawings Y represents the direction of gas flow through the ducts and X represents the direction of motion of the cell ring.

What I claim is:

A pressure exchanger, incorporating:

(*a*) a series of cells for the compression and expansion of a fluid, the cells being arranged in a ring and having open ends;

(*b*) means defining common end walls for the cells and a series of ducts communicating with the cells at circumferentially spaced ports in the end walls;

(*c*) means for causing relative rotation between the ring of cells and the end walls;

(*d*) the said ports having leading and trailing edges having regard to the direction of rotation and being

of arcuate form with substantially constant radial dimensions over a major part of their length;

(*e*) at least one of the ports for leading fluid from the cells having a tapered extension beyond the normal position of the trailing edge of that port;

(*f*) the circumferential length of the tapered extension being determined by a span of an arriving wave front created by a preceding port edge, the wave front terminating in the vicinity of the trailing edge of the tapered extension, whereby in operation a ratio of the radial width of the tapered extension

to the radial width of a cell open to the tapered extension varies as a cell traverses this extension.

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