Feb. 5, 1957 G. JENDRASSIK 2,780,405

PRESSURE EXCHANGERS

Filed April 30, 1951 3 Sheets-Sheet 1

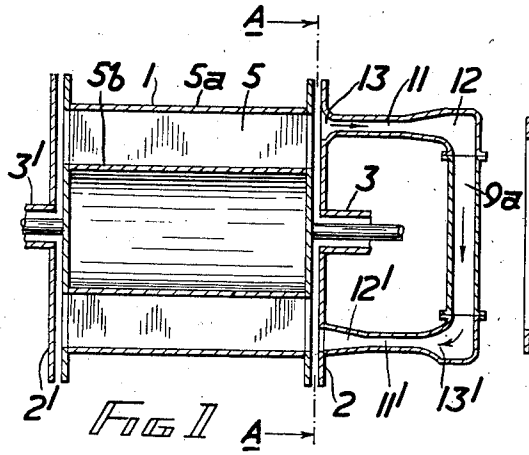


FIG. 1

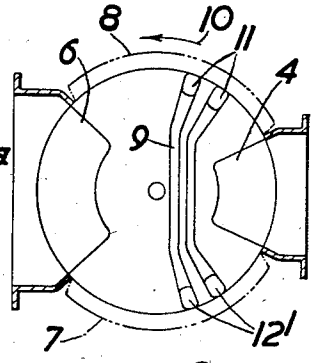


FIG. 2.

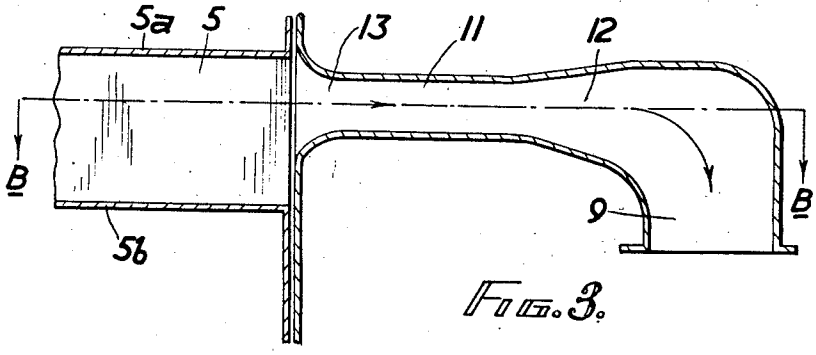


FIG. 3.

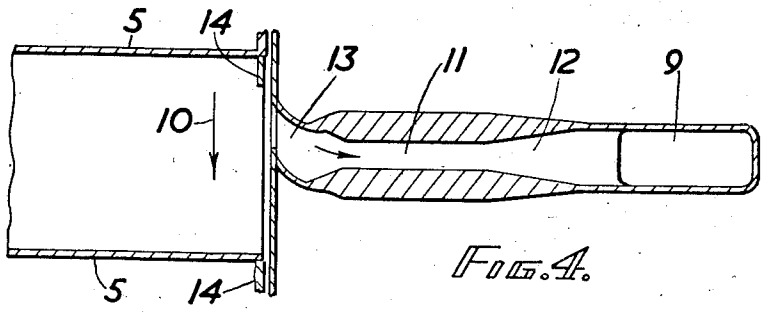


FIG. 4.

Inventor
George Jendrassik
By Stevens, Davis, Miller & Mosher
his Attorneys

Feb. 5, 1957 G. JENDRASSIK 2,780,405

PRESSURE EXCHANGERS

Filed April 30, 1951 3 Sheets-Sheet 2

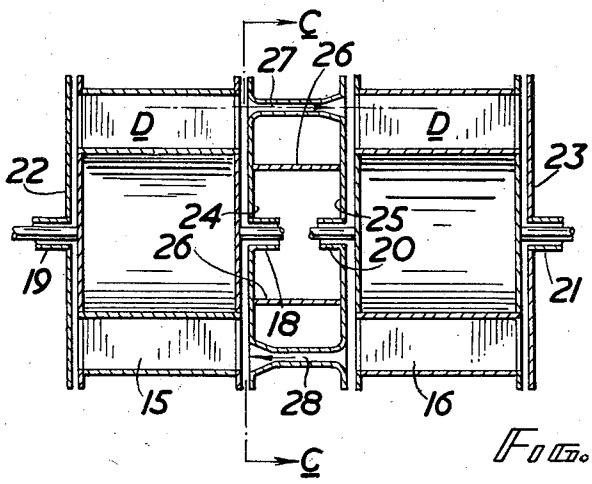


FIG. 5.

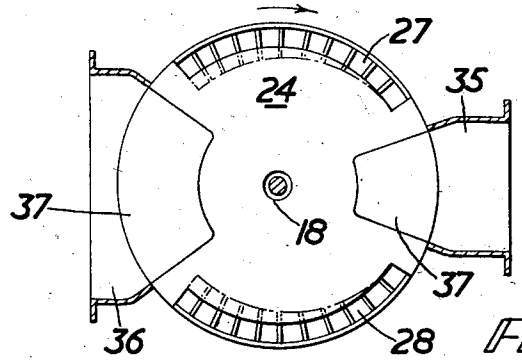


FIG. 6.

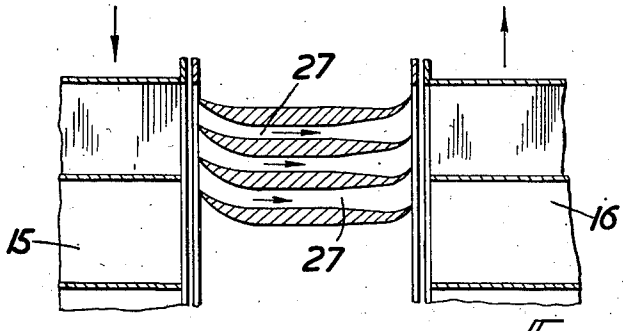


FIG. 7.

Inventor
George Jendrassik
By Stevens, Davis, Miller & Mosher
Its Attorneys

Feb. 5, 1957 G. JENDRASSIK 2,780,405

PRESSURE EXCHANGERS

Filed April 30, 1951 3 Sheets-Sheet 3

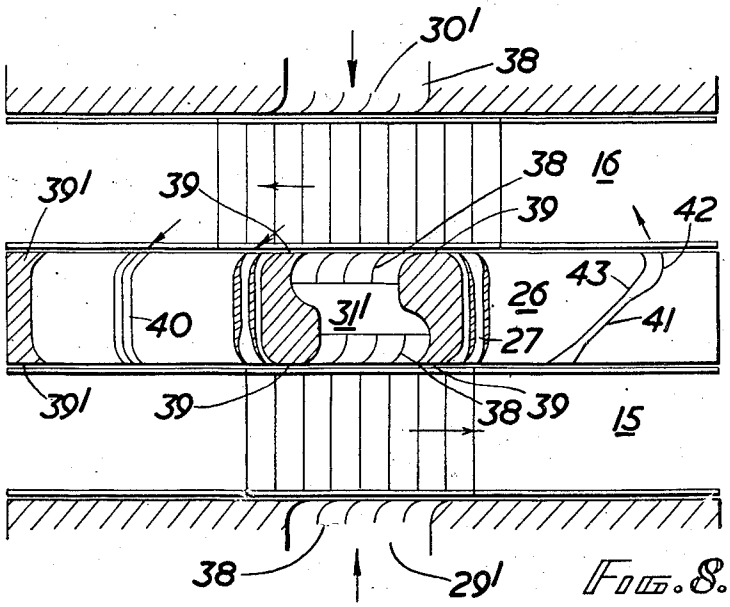


FIG. 8.

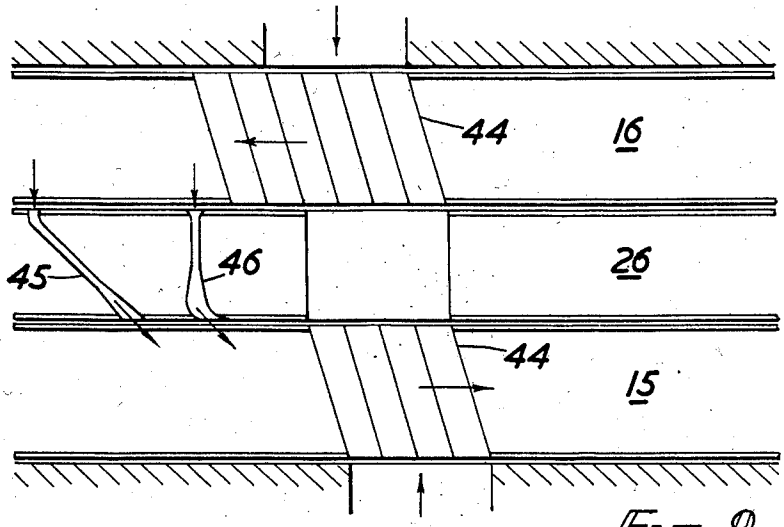


FIG. 9.

Inventor
George Jendrassik
By Stevens, Davis, Miller & Mosher
his Attorneys

United States Patent Office

2,780,405

Patented Feb. 5, 1957

2,780,405

PRESSURE EXCHANGERS

George Jendrassik, London, England; André G. T. Boszormenyi and Clara Jendrassik, executors of said George Jendrassik, deceased, assignors, by mesne assignments, to Jendrassik Developments Limited, London, England

Application April 30, 1951, Serial No. 223,677

Claims priority, application Great Britain May 9, 1950

14 Claims. (Cl. 230—69)

This invention relates to rotary pressure exchangers of the kind comprising at least one ring of cells for the compression or expansion of gas, and pressure exchange duct means which operate to interconnect pairs of cells between which pressure exchange is to occur.

When the interconnection of a pair of cells is established the gas in the cell at higher pressure expands and thereby effects compression of the gas in the other cell, with a consequent flow of gas, hereinafter for convenience called "transfer gas," through the duct means.

In the kind of pressure exchanger referred to above each ring of cells may be rotary and the pressure exchange duct means may be non-rotary, or the converse arrangement may be adapted, the requirement in such cases being only for relative rotation between the duct means and the cells.

In known pressure exchangers the so-called exchange of pressure between any two cells in communication through the pressure exchange channels is not, properly speaking, an exchange of pressure in the sense that the gas in the cell initially at the higher pressure is expanded down to the initial pressure of the gas in the low pressure cell while the latter gas simultaneously acquires the initial pressure of the high pressure cell. In practice this pressure exchange in known machines is no more than an equalization of pressure between the cells in communication, so that no "compression" cell can reach the highest pressure of the cycle (i. e. the pressure of the fresh gas introduced at high pressure scavenging) and no "expansion" cell can reach the lowest pressure of the cycle (i. e. the pressure of the fresh gas introduced at low pressure scavenging).

The present invention has for its main object to reduce the losses inherent in the operation of such machines by so arranging matters that a complete exchange of pressure between any two communicating expansion and compression cells is more nearly approached.

The present invention provides a pressure exchanger of the kind referred to, wherein the pressure exchange duct means comprises separate passages each having a kinetic-energy storing portion along which the cross-sectional area is substantially unvarying and which portion is so dimensioned that in operation the flow of transfer gas persists after the pressure in the interconnected cells has substantially equalised, and wherein the connection between a cell and any one passage is severed before the direction of gas flow in the passage is reversed.

Preferably, in operation, each cell taking part in the pressure exchange process is in communication simultaneously with a plurality of said passages.

One form of pressure exchanger according to the invention may comprise a single ring of cells forming a rotor, and non-rotary pressure exchange duct means, wherein each passage of the duct means comprises two kinetic-energy storing portions traversed in series by the transfer gas, each portion having a convergent entry and/or a divergent exit, the exit of the upstream of the two portions being connected to the entry of the downstream portion by a connecting passage of larger cross-section than the kinetic-energy storing portion.

Another form of pressure exchanger according to the invention may comprise two contra-rotating substantially co-axial rotors each comprising a ring of cells, and non-rotary pressure exchange duct means forming structure separating the rotors, wherein the duct means over one arc of rotation of the rotor consists of passages designed for gas flow in one direction while the remaining passages, which are arranged over an arc circumferentially offset relative to the first, are designed for gas flow in the opposite direction.

In a further possible alternative to which the present invention is applicable, the machine may comprise two contra-rotating substantially co-axial rotors arranged closely adjacent without intervening stator structure, each rotor comprising a ring of cells. In such a pressure exchanger the duct means may be divided into two parts each part integral with the cell structure of one of the rotors, the arrangement being such that during the rotation of the rotors the two parts register and operate as continuous duct means conveying transfer gas across the small axial gap between the rotors.

In pressure exchangers according to the invention, when a cell at higher pressure comes into communication with a cell at lower pressure, then during the first part of the pressure exchange process the speed of the transfer gas flow in the passage or passages affected will progressively increase due to the pressure difference, until the pressures in the cells become equal. After this, due to the continuing flow of gas in the energy-storing portion of the passage or passages the pressure exchange process further continues, but as the pressure difference now acts against the gas flow the velocity of such flow decreases until it reaches its lowest value, at which moment the exchange of pressure between the two cells under consideration is completed, so far as complete exchange is possible when unavoidable losses are taken into account.

In an ideal case where there are no losses it would be theoretically possible to compress the gas in the compression cell up to the initial pressure of the expanding cell, the latter being expanded down to the initial pressure of the compressed cell (provided the volumes of the cells are equal).

It appears to be important to arrange matters so that the passages are, as far as possible, continually in contact with cells so that the gas velocity in the channels is maintained.

To permit pressure exchange beyond the equalisation point the contact between cells and passages naturally has to be maintained after the pressures at the ends of the channels have become equal.

It may be possible that due to abrupt opening and closing (partial or complete) of the passage ends waves of compression and rarification may shoot along the passage of passages but this will not materially alter the pressure exchanging process, especially if good diffusers are arranged at the outflow end of the passages. The waves of compression and rarification will also contribute to the process of energy storage and restoration.

For proper functioning and in particular the avoidance of reverse flow in the pressure exchange channels it is preferable that the design of the pressure exchanger be in accordance with the equation:

$$\left(\frac{t.a}{l}\right) \leq C.\left(\frac{v}{Ve}\right)^{\frac{1}{2}}$$

where:

a=speed of propagation of sound in the energy storing portion of the passage.

t=time during which one passage is in contact with a cell.

l=length of the energy-storing part or parts of the passage.

v=volume of a cell.

Ve=sum of the volumes of the energy-storing parts of the passages in communication with one cell.

C=a constant equal to about 2.5

The formula has the physical meaning that the time during which a channel remains in contact with a cell must not be longer than half of the time of a full cycle of the resonant system composed by the communicating cells and the channel, or channels, connecting them.

If the time is longer than corresponds to this limit then losses will increase rapidly.

Some constructional examples according to the invention will now be described in further detail with reference to the accompanying diagrammatic drawings in which:

Figure 1 is a longitudinal section of a pressure exchanger with one cell rotor.

Figure 2 is a cross sectional view of Figure 1 on the line A—A.

Figure 3 is an enlarged view of one of the channels shown in Figure 1.

Figure 4 is a fragmentary section along the circumferential plane B—B of Figure 3.

Figure 5 is a view similar to Figure 4 but showing a pressure exchanger with two cell rotors.

Figure 6 is a section along the line C—C of Figure 5.

Figure 7 is a fragmentary section on the circumferential plane D—D of Figure 5.

Figures 8 and 9 are both developments into a circumferential plane of the two rotor type of machine and are for the purpose of showing various modifications in a purely diagrammatic fashion.

The pressure exchanger shown in Figures 1 and 2 comprises a single rotor **1** having a series of cells arranged in circular disposition and formed by partition walls **5** extending in a generally radial direction between an outer drum **5A** and an inner drum **5B**. The rotor is rotatably mounted in bearings at **3**, **3'** arranged in stationary end plates **2**, **2'** and is rotated according to the arrow **10** in Figure 2. The scavenging ducts for the high pressure scavenging zone **4** communicate through the end plates with the cells, and the same applies to the low pressure scavenging ducting **6**. When the machine is in operation compression takes place in cells over the sector **7** and expansion in cells over the sector **8** (Figure 2). In order to establish communication between "compression" cells and "expansion" cells so as to permit the exchange of pressure between them, pipes or passages **9** are arranged so that one end of them communicates with cells on the compression sector and the other end with cells on the expansion sector. Each pipe or passage comprises straight portions **11**, **11'** of practically constant cross section, diffusers **12**, **12'** and convergent portions **13**, **13'**. To avoid shock losses the portions **12'** and **13** are shaped where they open into the cells in such manner as to remove or put on the tangential component of the velocity of the transfer gas. A section **9a** of constant but larger cross section connects the part **12** to the part **13'**.

In Figure 2 the spacing apart of the pipes **9** is somewhat exaggerated.

The machine operates as follows:

As the rotor **1** rotates the cells leaving the low pressure scavenging zone **6** come into contact with the ends **12** of the pipes **9** and gas enters such cells compressing their contents. On the other hand the cells leaving the high pressure scavenging zone **4** come in contact with the pipe ends **13** and discharge into the pipes gas which flows into the "compression" cells. Due to the functioning of the pipes or passages the cells arriving at the high pressure zone **4** contain gas at nearly the high pressure prevailing at **4**. Such gas will be used according to

the application of the pressure exchanger. In general, if used for generation of pressure gas, then heat is introduced (e. g. by combustion) and gas extracted, if as a heat pump then gas is introduced and heat extracted. In the present case (used as a source of pressure gas) it is assumed that the gas removed at **4** is heat-energised by combustion and a portion of such gas is returned to the cells for expansion. The cells arriving at the low pressure scavenging zone **6** contain gas expanded nearly down to the pressure prevailing in the zone **6** and such gas is also handled according to application of the pressure exchanger. In the present case it is assumed that such gas is removed and replaced by fresh gas to be compressed.

The functioning of the pipes or passages **9** is as follows:

When a cell destined to undergo expansion comes in contact with a pipe or passage **9** then in general the pressure in that cell is higher than the pressure at the other end of the pipe. Therefore transfer gas flows through the channel owing to the pressure difference, is accelerated, and kinetic energy thus is stored up. The storage takes place mostly in the kinetic energy storing portion **11** or **11'** in which the speed will be the highest. The convergent portion **13** ensures a smooth entrance and directs the flow as required. At the end of the energy storing part the diffuser **12** reduces the speed of the leaving gas so that little kinetic energy should leave the channel part **11**. The portion **9a** remains at a constant intermediate pressure. The gas flow is again accelerated in **13'** and **11'** and storage of kinetic energy takes place therein. The diffuser **12'** reduces the amount of kinetic energy leaving the storage part by reconversion to pressure energy. The gas speeds in **11** and **11'** increase only until the pressures in the cells connected become equal with the pressure in **9a**, after which the speed decreases and energy is restored by compressing the cell under compression above the pressure of the expanding cell.

In a modification, an energy-storing portion (corresponding to **11** or **11'**) may be provided in lieu of the portion **9a**. The channels **11** etc. may also be inclined with reference to the end plate (as at **41** in Figure 8).

It is possible to provide the pipes or passages at both ends of the cell rotor.

"Lands" or sealing portions such as **14** are provided to reduce the leakage around the edges of the cell walls.

The inlet and outlet ends of the pipes may be connected to the end-plate at different radii.

In Figures 5, 6 and 7, the machine comprises two cell rotors **15** and **16** (each substantially similar to the rotor **1** described above) rotated in opposite directions and supported in bearings at **18**, **19**, **20**, **21** arranged in stationary end plates **22**, **23**, **24**, **25**, the two latter being united by intermediate structure **26**. The direction of rotation of each rotor is indicated in Figure 7 by the arrows. Between the two rotors are arranged pressure exchange pipes or passages **27**, **28** permitting transfer gas to pass from the expanding cells of one rotor into the compression cells of the other.

The functioning of this kind of machine is very similar to the one described above, except that in the two-rotor machine the expanding cells of one rotor work with the compression cells of the other rotor, an arrangement which permits a much simpler design for the pressure exchange passages and has the great advantage also that the duct area for scavenging at the pressure extremes are not so much obstructed by constructional parts. In Figure 7 is shown a channel arrangement which takes care of the tangential components of velocity and at the same time is adapted also for energy storage during pressure exchange. The passages have at one end a convergent portion and on the other a diffuser. The functioning of the passages themselves is, in principle, described with reference to Figures 1–4.

The passages **27** may have a greater cross-sectional area

at the low pressure region than at the high pressure region, as indicated for example in broken lines in Figure 6.

In Figures 8, 15 and 16 are the cell rotors, 30', 31', 29' the high pressure scavenging ducts, 38 guide vanes to direct the scavenging flow, 39, 39' are sealing lands on the intermediate structure 26. As examples a variety of modified types of passages are shown in Figure 8. 27 are passages as described above with reference to Figure 7, 40 are passages which are formed to avoid shock due to the peripheral speed of the cell rotors, but without special diffusers or convergent portions. These passages will preferably have nearly the same radial dimension as the cells of the wheels and so no great change of velocity will take place when gas enters or leaves them. Passages 41 have a convergent entrance portion lying in the direction of the velocity of the gas leaving the cell rotor, a diffuser 43, and a curved outlet 42 to impart an appropriate peripheral velocity. The scavenging is in parallel, the gas entering on each side as shown by the arrows, and leaving centrally by the duct 31'.

In Figure 9 the cells are formed by helicoidal partitions 44. These may have such direction that the gas leaving a cell towards the pressure exchange passages will have chiefly axial velocity only, the peripheral component being reduced. The passages at 45 have a curved inlet, whereas passages 46 have a curved outlet.

The guide vanes 38 may also be arranged in the cell rotors, or the ends of the partition walls of the cells may have the curved form required.

It is possible to use more than two substantially co-axial cell rotors, alternate rotors rotating in one direction, while the others rotate in the opposite direction. Passages may be arranged between each adjacent pair of rotors for the pressure exchanging process, and ducts may be arranged between the rotors for inlet or outlet to the low and high pressure scavenging spaces.

In any construction described above the radial cell walls may be so shaped that the scavenging gases entering or leaving the cells produce a turbine effect which rotates the rotor or rotors.

What I claim is:

1. A transfer gas passage arrangement for a pressure exchanger having at least one ring of cells, a system of ducting to supply gas to and from the cell-ring, passages to interconnect pairs of cells to permit transfer gas flow from one cell of a pair to the other and means for effecting relative rotation between the cell-ring on the one hand and the said ducting system and the said passages on the other hand, during which relative rotation there is momentary communication between cells containing gas at different pressures, so that the pressure in one cell of an inter-communicating pair falls while that in the other rises with consequent flow of gas by way of the said passages, in which arrangement each of the said passages comprises a kinetic-energy-storing portion along which the cross-sectional area is substantially unvarying and a convergent inlet portion to the said kinetic-energy-storing portion, whereby in the designed conditions of operation the gas flow between interconnected cells persists after the pressure in them has substantially equalized.

2. A transfer gas passage arrangement for a pressure exchanger having at least one ring of cells, a system of ducting to supply gas to and from the cell-ring, passages to interconnect pairs of cells to permit transfer gas flow from one cell of a pair to the other and means for effecting relative rotation between the cell-ring on the one hand and the said ducting system and the said passages on the other hand, during which relative rotation there is momentary communication between cells containing gas at different pressures, so that the pressure in one cell of an inter-communicating pair falls while that in the other rises with consequent flow of gas by way of the said passages, in which arrangement each of the said passages comprises a kinetic-energy-storing portion which is substantially straight and has a progressively divergent outlet portion from the kinetic-energy-storing portion, whereby in the designed conditions of operation the gas flow between interconnected cells persists after the pressure in them has substantially equalized.

3. A transfer gas passage arrangement for a pressure exchanger having at least one ring of cells, a system of ducting to supply gas to and from the cell-ring, passages to interconnect pairs of cells to permit transfer gas flow from one cell of a pair to the other and means for effecting relative rotation between the cell-ring on the one hand and the said ducting system and the said passages on the other hand, during which relative rotation there is momentary communication between cells containing gas at different pressures, so that the pressure in one cell of an inter-communicating pair falls while that in the other rises with consequent flow of gas by way of the said passages, in which arrangement each of the said passages comprises a kinetic-energy-storing portion along which the cross-sectional area is substantially unvarying, a convergent inlet portion to and a divergent outlet portion from said kinetic-energy-storing portion, whereby in the designed conditions of operation the gas flow between interconnected cells persists after the pressure in them has substantially equalized.

4. A transfer gas passage arrangement as claimed in claim 3 in which each of the said passages has an exit end so curved as to discharge the gas with a substantial component of velocity in the direction of rotation of the rotor.

5. A transfer gas passage arrangement as claimed in claim 3 in which each of said passages has an entry end so curved as to ensure substantially shockless entry of gas from the cells into said passages.

6. A transfer gas passage arrangement as claimed in claim 3 in which each of the said passages has a greater cross-sectional area at the lower pressure end than at the higher pressure end.

7. A transfer gas passage arrangement for a pressure exchanger having at least one ring of cells, a system of ducting to supply gas to and from the cell-ring, passages to interconnect pairs of cells to permit transfer gas flow from one cell of a pair to the other and means for effecting relative rotation between the cell-ring on the one hand and the said ducting system and the said passages on the other hand, during which relative rotation there is momentary communication between cells containing gas at different pressures, so that the pressure in one cell of an inter-communicating pair falls while that in the other rises with consequent flow of gas by way of the said passages, in which arrangement each of the said passages comprises two kinetic-energy-storing portions along each of which the cross-sectional area is substantially unvarying, a central connecting portion separating and interconnecting said kinetic-energy-storing portions in series relative to the gas flow through the said passage and being of larger cross-sectional area than either of said kinetic-energy-storing portions, a convergent inlet portion to each kinetic-energy-storing portion and a divergent outlet portion from each kinetic-energy-storing portion, whereby in the designed conditions of operation the gas flow between interconnected cells persists after the pressure in them has substantially equalized.

8. A transfer gas passage arrangement for a pressure exchanger having two contra-rotating co-axial rings of cells, a system of ducting to supply gas to and from the cell-ring, non-rotary passages forming structure separating the two cell-rings and interconnecting pairs of cells to permit transfer gas flow from one cell of a pair to the other and means for rotating the cell-rings, during which rotation there is momentary communication between cells containing gas at different pressures, so that the pressure in one cell of an intercommunicating pair falls while that in the other rises with consequent flow of gas by way of the said passages, in which arrangement each of

the said passages comprises a kinetic-energy-storing portion along which the cross-sectional area is substantially unvarying and a convergent inlet portion to the said kinetic-energy-storing portion, whereby in the designed conditions of operation the gas flow between interconnected cells persists after the pressure in them has substantially equalized, and in which arrangement some of the said passages are designed for gas flow in one direction therethrough while others are designed for gas flow in the other direction therethrough.

9. A transfer gas passage arrangement for a pressure exchanger having two contra-rotating co-axial rings of cells, a system of ducting to supply gas to and from the cell-ring, non-rotary passages forming structure separating the two cell-rings and interconnecting pairs of cells to permit transfer gas flow from one cell of a pair to the other and means for rotating the cell-rings, during which rotation there is momentary communication between cells containing gas at different pressures, so that the pressure in one cell of an intercommunicating pair falls while that in the other rises with consequent flow of gas by way of the said passages, in which arrangement each of the said passages comprises a kinetic-energy-storing portion which is substantially straight and has a progressively divergent outlet portion from the kinetic-energy-storing portion, whereby in the designed conditions of operation the gas flow between interconnected cells persists after the pressure in them has substantially equalized, and in which arrangement some of the said passages are designed for gas flow in one direction therethrough while others are designed for gas flow in the other direction therethrough.

10. A transfer gas passage arrangement for a pressure exchanger having two contra-rotating co-axial rings of cells, a system of ducting to supply gas to and from the cell-ring, non-rotary passages forming structure separating the two cell-rings and interconnecting pairs of cells to permit transfer gas flow from one cell of a pair to the other and means for rotating the cell-rings, during which rotation there is momentary communication between cells containing gas at different pressures, so that the pressure in one cell of an intercommunicating pair falls while that in the other rises with consequent flow of gas by way of the said passages, in which arrangement each of the said passages comprises a kinetic-energy-storing portion along which the cross-sectional area is substantially unvarying, a convergent inlet portion to and a divergent outlet portion from said kinetic-energy-storing portion, whereby in the designed conditions of operation the gas flow between interconnected cells persists after the pressure in them has substantially equalized, and in which arrangement some of the said passages are designed for gas flow in one direction therethrough while others are designed for gas flow in the other direction therethrough.

11. A transfer gas passage arrangement as claimed in claim 10 in which each of the said passages has an exit end so curved as to discharge the gas with a substantial component of velocity in the direction of rotation of the rotor.

12. A transfer gas passage arrangement as claimed in claim 10 in which each of the said passages has an entry end so curved as to ensure substantially shockless entry of gas from the cells into said passages.

13. A transfer gas passage arrangement as claimed in claim 10 in which each of the said passages has a greater cross-sectional area at the lower pressure end than at the higher pressure end.

14. A transfer gas passage arrangement for a pressure exchanger having two contra-rotating co-axial rings of cells, a system of ducting to supply gas to and from the cell-ring, non-rotary passages forming structure separating the two cell-rings and interconnecting pairs of cells to permit transfer gas flow from one cell of a pair to the other and means for rotating the cell-rings, during which rotation there is momentary communication between cells containing gas at different pressures, so that the pressure in one cell of an intercommunicating pair falls while that in the other rises with consequent flow of gas by way of the said passages, in which arrangement each of the said passages comprises two kinetic-energy-storing portions along each of which the cross-sectional area is substantially unvarying, a central connecting portion separating and interconnecting said kinetic-energy-storing portions in series relative to the gas flow through the said passage and being of larger cross-sectional area than either of said kinetic-energy-storing portions, a convergent inlet portion to each kinetic-energy-storing portion and a divergent outlet portion from each kinetic-energy-storing portion, whereby in the designed conditions of operation the gas flow between interconnected cells persists after the pressure in them has substantially equalized, and in which arrangement some of the said passages are designed for gas flow in one direction therethrough while others are designed for gas flow in the other direction therethrough.

References Cited in the file of this patent

UNITED STATES PATENTS

2,045,152	Lebre	June 23, 1936
2,399,394	Seippel	Apr. 30, 1946
2,461,186	Seippel	Feb. 8, 1949
2,526,618	Darrieus	Oct. 24, 1950

FOREIGN PATENTS

553,208	Great Britain	May 12, 1943