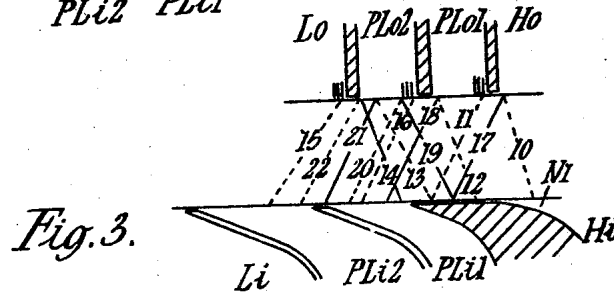
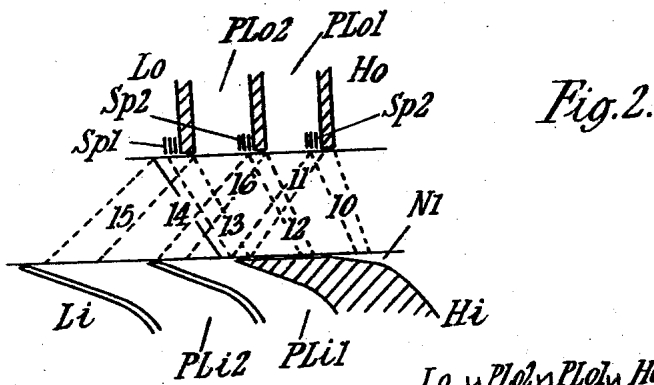
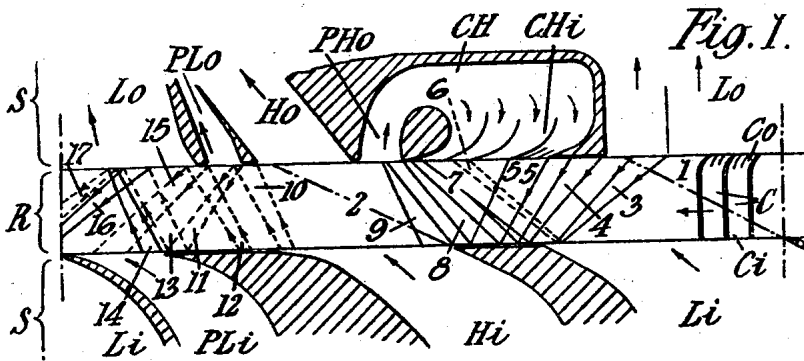


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PRESSURE EXCHANGERS

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7 Claims. (Cl. 230—69)

This invention relates to machines, hereinafter referred to as pressure exchangers, in which each of a plurality of cells serves cyclically to receive gas from a source of lower pressure and discharge it to a pressure-increasing means, and to receive gas from said pressure-increasing means and discharge it to a region of lower pressure. The cells are arranged around the periphery of a rotor mounted to pass over appropriate permanently-open ports in a stator. (Of course, the terms rotor and stator are used relatively, the one to the other, so that it might be that the "rotor" is stationary in space and that the "stator" rotates about the rotor). The admission and discharge of the gas to and from the cell in the lower and in the higher pressure stages is hereinafter referred to as "scavenging"; being defined as a condition in which both ports of the cell being open together for a sufficient duration of time, there occurs a displacement of a substantial part of the former contents from the cell, and their replacement by fresh gas.

The pressure-increasing means is conveniently a combustion chamber wherein the received gas is made to burn with a fuel to increase both its volume and temperature.

Conveniently, too, but not necessarily, the motion of the gas into and out of the cell in both of the scavenging stages is unidirectional, so that it is possible to speak of an inlet to and an outlet from the cell, the inlet being on one flank of the rotor and the outlet on the other flank.

When the machine is arranged as an engine, it serves to convert some of the pressure energy from said pressure increasing means into kinetic energy.

It is desirable that immediately before a cell reaches a scavenging stage, the gas in the cell should be accelerated towards that port, usually the cell outlet, from which the gas is to be discharged in said stage. Hereinafter this acceleration is referred to as "prescavenging," and its main function is to prevent the formation of unwanted compression or rarefaction pulses which would adversely affect the functioning of the subsequent scavenging stage.

A somewhat fuller exposition of the working of such machines may be found in copending applications Serial Nos. 594,461 and 594,462, both filed June 28, 1956.

It will be understood that at the instant when one of the ports of the cell is opened, either to a region of higher pressure than that obtaining in the cell or to a region of lower pressure than that obtaining within, then a wave will travel through the cell from that newly-opened port towards the other port, at a velocity comparable with that of the velocity of sound, being in the first case a compression wave and in the second case a rarefaction wave. When the wave reaches the far end, it will be reflected; if the far end is closed, the reflected wave will be of the same sense as the incident wave, compression-compression or rarefaction-rarefaction; while if the far end is open, the reflected wave will be of opposite sense.

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In the same way waves are generated at the instant of closing of a port which had been open.

The present invention is concerned with improving a pressure exchanger in respect of certain wave occurrences within the cells, especially over a wide speed range.

The following description relates to the accompanying drawing wherein is shown, by way of example only, one embodiment of the invention. In the drawing,

Figure 1 is a developed view of a pressure exchanger as more fully described and claimed in the above-mentioned copending applications;

Figure 2 is a developed view of part of such a pressure exchanger modified in accordance with the present invention; and

Figure 3 is the same as Figure 2 but showing the operation at a speed less than the design speed.

In Figure 1 a rotor R comprises a plurality of cells C moving from right to left as indicated by the arrow between the two flanking parts of a stator S. The general flow of gas through the cells is in the upward direction, so that the cell ports may be identified as inlet C_i and outlet C_o . In their motion the cell ports sweep over the mouths of certain ducts in the stator. Thus the cell inlet C_i passes over the low pressure scavenging delivery duct L_i , the high pressure scavenging delivery duct H_i , and the low pressure pre-scavenging delivery duct PL_i . Similarly the cell outlet C_o passes over the low pressure scavenging receiving duct L_o , the compression delivery duct CH_i , the high-pressure prescavenging receiving duct PH_o , the high-pressure scavenging receiving duct H_o , and the low-pressure prescavenging receiving duct PL_o . Various compression and rarefaction waves are generated and reflected, some being desirable, to be utilised, and others being undesirable, to be suppressed if possible. Further details of such a pressure exchanger are to be found in the specifications of the above-mentioned copending applications.

A possible disadvantage of the arrangement shown in Figure 1 concerns the rarefaction wave 11 and its reflection as rarefaction wave 13. In the high-pressure scavenging stage, when there is a steady flow through a cell from H_i to H_o , as the cell outlet moves out of communication with H_o and into communication with duct PL_o at a lower pressure than the duct H_o , a rarefaction wave 11 will travel back through the cell, accelerating the outflow. If this wave be reflected from the far end, now closed, as a rarefaction wave 13, then on reaching the outlet that reflected rarefaction wave will be reflected as a compression wave 16, and will decelerate the outflow. That deceleration, superposed upon the deceleration following the rarefaction wave 12 created by closing the inlet H_i , may cause flow reversal.

To prevent this flow reversal, to make the pressure exchanger suitable for higher pressure ratio working and to prevent pulse 16, 17 as in Figure 1 it is preferred in accordance with the present invention to add at least one more receiving duct to give two or more such ducts as indicated at PL_{o1} and PL_{o2} wherein especially at low speed PL_{o2} has a pressure below that existing in PL_{o1} .

At low speed in Figure 3 flow is substantially arrested when wave 13 is reflected in PL_{o2} as 21. In Figure 1 duct PL_o is made narrower than one which would receive wave 13 so that this wave is not received over a substantial speed range.

Another disadvantage of the expansion stage of Figure 1 is that at speeds below the design speed the said rarefaction wave 13 and a compression wave 14 generated on opening of the cell inlet C_i to the prescavenging duct PL_i , no longer coincide and cancel but become increasingly separated, thereby creating a rarefaction pulse which is repeatedly reflected from the ends of the cells and thus

interferes with the flow in the low pressure scavenging stage L. If no dividing wall exists in PL_{O_2} and the reflected rarefaction wave 13 is, at the design speed, received at the outlet of the cell on a duct wall dividing the low pressure pre-scavenging discharge duct PL_{O_2} from the low pressure scavenging discharge duct L_0 ; but at lower speeds, it falls within the duct PL_{O_2} , and flow reversal may occur. To prevent flow reversal at all speeds the areas of either the cell outlet C_0 or of the discharge ducts PL_{O_2} must be reduced, as in the one case by bending back the trailing edges of the cells and in the other case by reducing the annular height of the duct mouths in the stator, the result in either case being that the pressure difference between duct and cells is reduced substantially to zero on wave arrival.

Again, if the wave 12 generated by closing of the cell inlet C_i to the high pressure scavenging delivery duct H_i is substantial, care must be taken that at the design speed the dividing wall when fitted between the two ducts PL_{O_1} and PL_{O_2} be positioned at the point of reception of said wave 12.

In Figure 3 is shown the operation of the two-stage system of Figure 2 at a speed below the design speed, each wave being here shown by a single line only. The rarefaction waves 10, 12, 13 and 15 all fall well within the ducts, instead of coinciding with the walls; and all except 15, which is substantially neutralised, are reflected as compression waves.

If the wave pattern is balanced in that waves 10, 11, 12, 13 and 18 are all equal then the amplitude as measured by change of particle velocity at each wave is only one half of the velocity in the cells towards the rear ends. On reflection of these rarefaction waves as compression waves of equal amplitude at the open outlet ends of the cells the flow is reduced to zero, but no flow reversal occurs even though the outlet ends of the cells are unrestricted. Flow reversal begins to occur when speeds are reduced below half the design speed.

If the wave system is unbalanced then a degree of restriction of the outlet ends of the cells is required in order to give complete freedom from flow reversal over a 2:1 speed range, the amount required being increased with increase of unbalance. It is not essential in this stage to prevent flow reversal completely and losses caused are small providing that transition from forward to reverse flow is made gradual since under such conditions the gases sucked back into the cells are those just discharged at low relative velocity and so are still moving substantially with the rotor blades. This condition is obtained by the use of waves having non-steep fronts and by receiving ducts having no obstructions such as groups of splitters at the side nearest to the low pressure scavenging stage.

At these reduced speeds of operation pressure pulses formed by pairs of compression and expansion waves 17—11, 16—18, 20—21, and 21—22, traverse the cells, but all are finally substantially neutralised when they encounter the inlet nozzles so that a substantially pulse-free flow is produced within the low pressure scavenging stage at all speeds. In producing wave neutralisation the gas velocity leaving the nozzles is caused to vary and this effect though undesirable is not generally serious.

The two stage expansion system in which a double set of expansion waves is employed at the design speed has the advantage of enabling good performance to be obtained under off design conditions without need for excessive outlet velocities from the cells at the design speed. The method could be extended to multiple stage expansion systems in which either the same wave pattern is continued and a corresponding extra number of ducts added or the number of waves produced and number of ducts required within a given space may be increased.

A similar multiple pattern could be employed in the compression process.

The duct dividing wall separating PL_{O_1} from PL_{O_2} is best made of a width less than that of the cells or of

subsidiary cell channels in order to prevent formation of a compression pulse at design speed.

The total width, circumferentially, of the two successive receiving ducts PL_{O_1} and PL_{O_2} is approximately equal to that of a single duct which would be capable of receiving within itself a rarefaction wave 11 caused by opening of the cell to said single duct and reflected as wave 13 at the cell inlet.

Splitters Sp_1 and Sp_2 are placed at the "upstream" side of the ducts L_0 , PL_{O_1} and PL_{O_2} so as to reduce opening loss. Each splitter is formed of a number of thin partition strips arranged in spaced parallel relation with the duct wall at the mouth of the duct.

It is not essential that the receiving ducts PL_{O_1} and PL_{O_2} feed the delivery ducts PL_{i_1} and PL_{i_2} only and in fact PL_{O_1} will usually transfer gases elsewhere for instance to effect compression whilst the duct PL_{O_2} will usually supply gases for use elsewhere in addition to feeding the delivery duct PL_{i_1} or PL_{i_2} .

As shown in Figs. 2 and 3, the low-pressure pre-scavenging delivery ducts PL_{i_1} and PL_{i_2} have their inlets inclined to the cells in the rotor in order to neutralize waves therein.

What I claim is:

1. In a pressure exchanger, a rotor provided with a plurality of cells formed about its periphery, two stator parts between which the rotor is mounted to rotate, said stator parts each provided with a duct communicating with said cells and cooperating to form a low-pressure scavenging stage, first and second low-pressure pre-scavenging delivery ducts formed in one stator part in advance of said scavenging stage, and first and second pre-scavenging receiving ducts formed in the other stator part in advance of said scavenging stage and in advance of said pre-scavenging delivery ducts.

2. A pressure exchanger according to claim 1 wherein the total width circumferentially of two successive pre-scavenging receiving ducts is approximately equal to that of a single duct capable of receiving within itself a rarefaction wave caused by opening the cell to said single duct and reflected at the cell inlet.

3. A pressure exchanger according to claim 1 in which the low-pressure pre-scavenging delivery duct inlets to the cells are highly inclined to the cells in the rotor whereby waves in the cells are neutralised.

4. In a pressure exchanger, a rotor provided with a plurality of cells formed about its periphery, two stator parts between which the rotor is mounted to rotate, said stator parts each provided with ducts communicating with said cells and cooperating to form a low-pressure scavenging stage followed by a high-pressure scavenging stage, a plurality of low-pressure pre-scavenging delivery ducts formed in one stator part between said scavenging stages, and a plurality of receiving ducts formed in the other stator part between said scavenging stages but in advance of said pre-scavenging delivery ducts.

5. A pressure exchanger according to claim 4 in which the dividing wall between said receiving ducts between the high and low pressure scavenging stages is made narrower than the width of a cell.

6. A pressure exchanger according to claim 4 and including a wave splitter located at the upstream side of each pre-scavenging receiving duct located between said scavenging stages, each splitter comprising a plurality of thin partition strips arranged in spaced parallel relation with the upstream wall of the duct at the mouth thereof.

7. A pressure exchanger according to claim 4 in which the pre-scavenging receiving ducts located between the two scavenging stages are operated at successively lower pressures.

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