Sept. 15, 1959 R. D. PEARSON 2,904,245

PRESSURE EXCHANGERS

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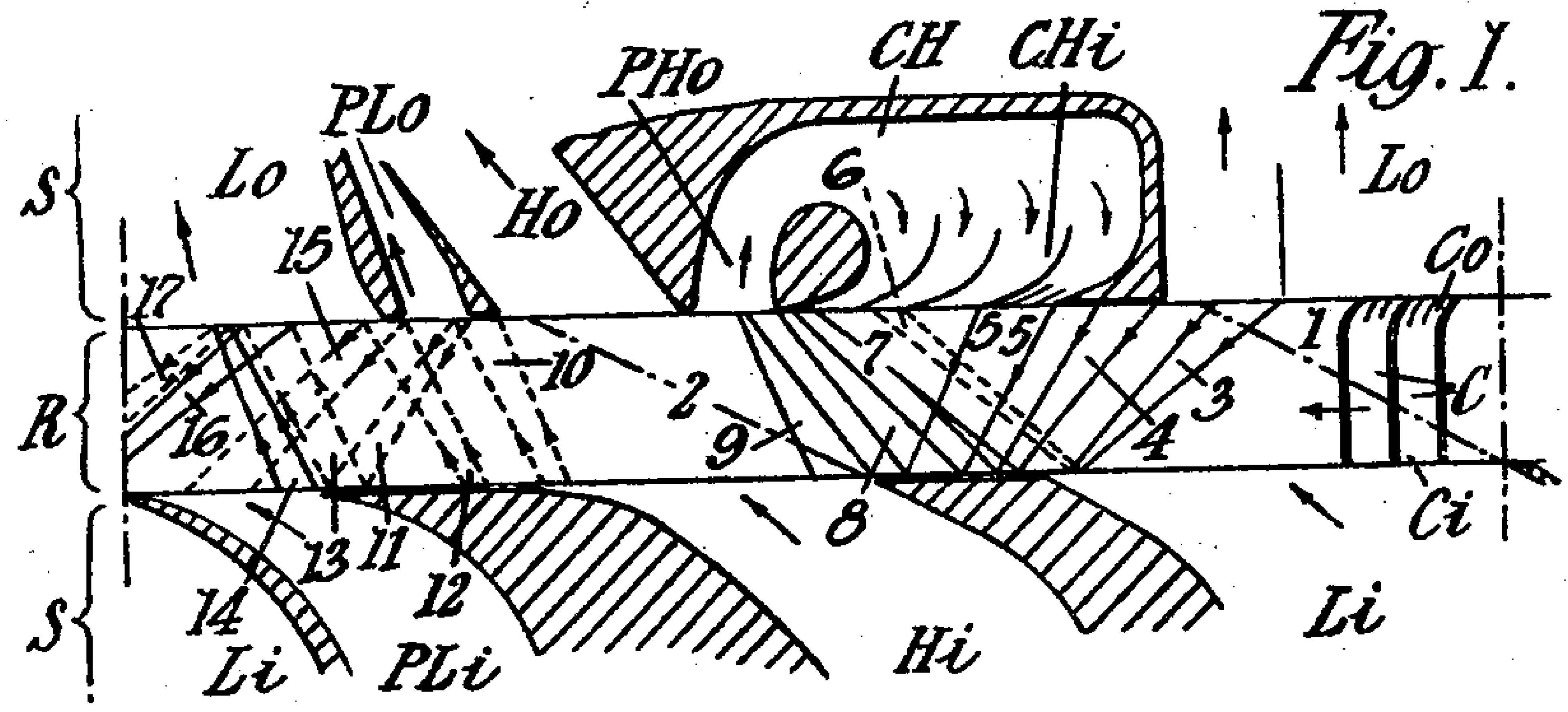

Fig. 1.

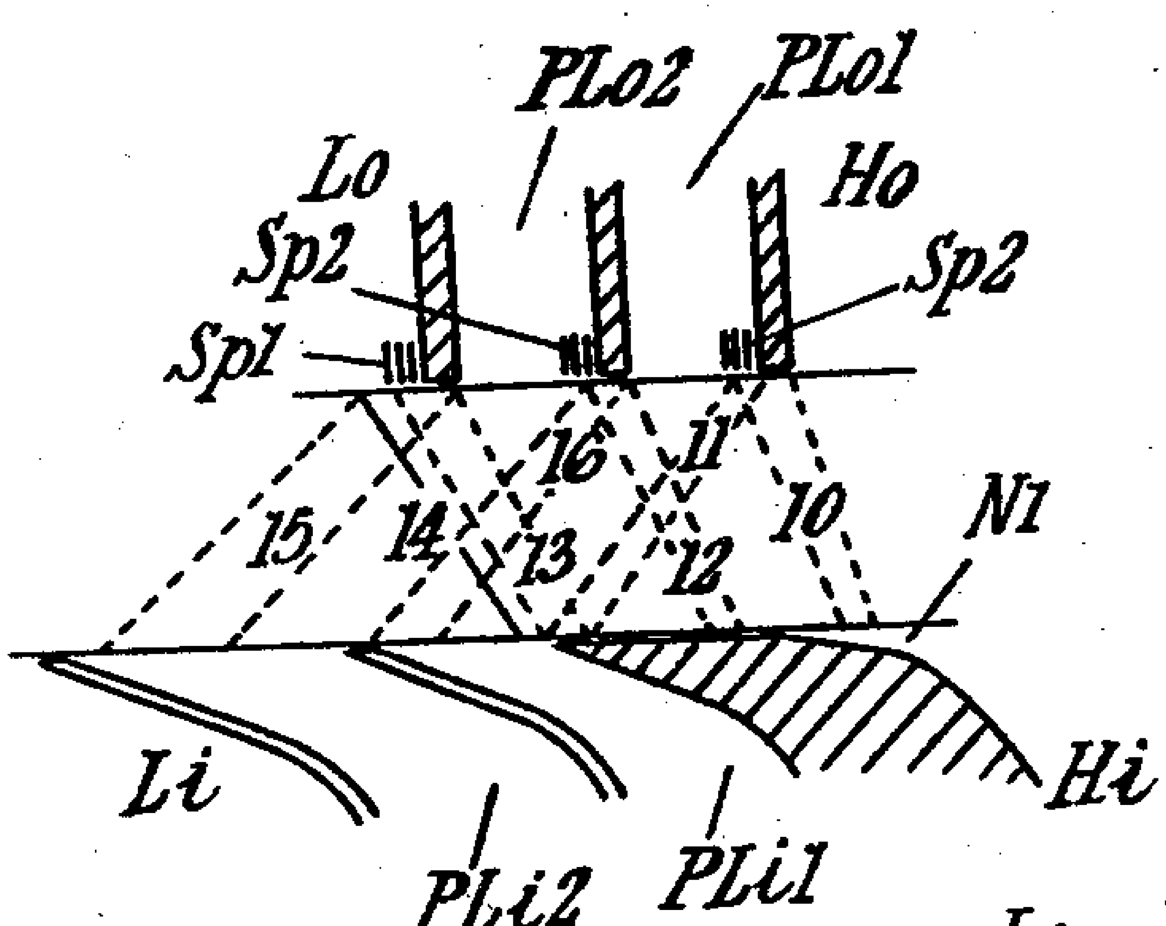

Fig. 2.

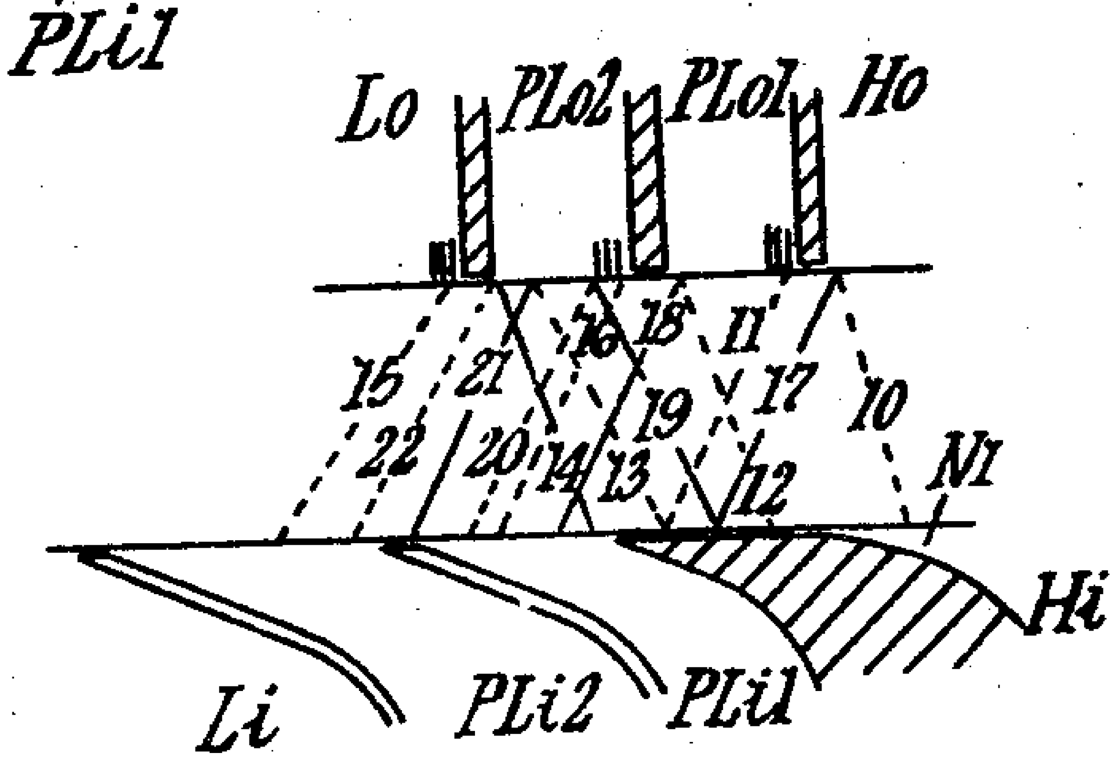

Fig. 3.

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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.

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 *Ci* and outlet *Co*. In their motion the cell ports sweep over the mouths of certain ducts in the stator. Thus the cell inlet *Ci* 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 *Ho*, 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 PLo_1 and PLo_2 wherein especially at low speed PLo_2 has a pressure below that existing in PLo_1.

At low speed in Figure 3 flow is substantially arrested when wave **13** is reflected in PLo_2 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 PLo_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 PLo_2 from the low pressure scavenging discharge duct Lo; but at lower speeds, it falls within the duct PLo_2, and flow reversal may occur. To prevent flow reversal at all speeds the areas of either the cell outlet Co or of the discharge ducts PLo_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 Ci to the high pressure scavenging delivery duct Hi is substantial, care must be taken that at the design speed the dividing wall when fitted between the two ducts PLo_1 and PLo_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 PLo_1 from PLo_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 PLo_1 and PLo_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 Lo, PLo_1 and PLo_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 PLo_1 and PLo_2 feed the delivery ducts PLi_1 and PLi_2 only and in fact PLo_1 will usually transfer gases elsewhere for instance to effect compression whilst the duct PLo_2 will usually supply gases for use elsewhere in addition to feeding the delivery duct PLi_1 or PLi_2.

As shown in Figs. 2 and 3, the low-pressure prescavenging delivery ducts PLi_1 and PLi_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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