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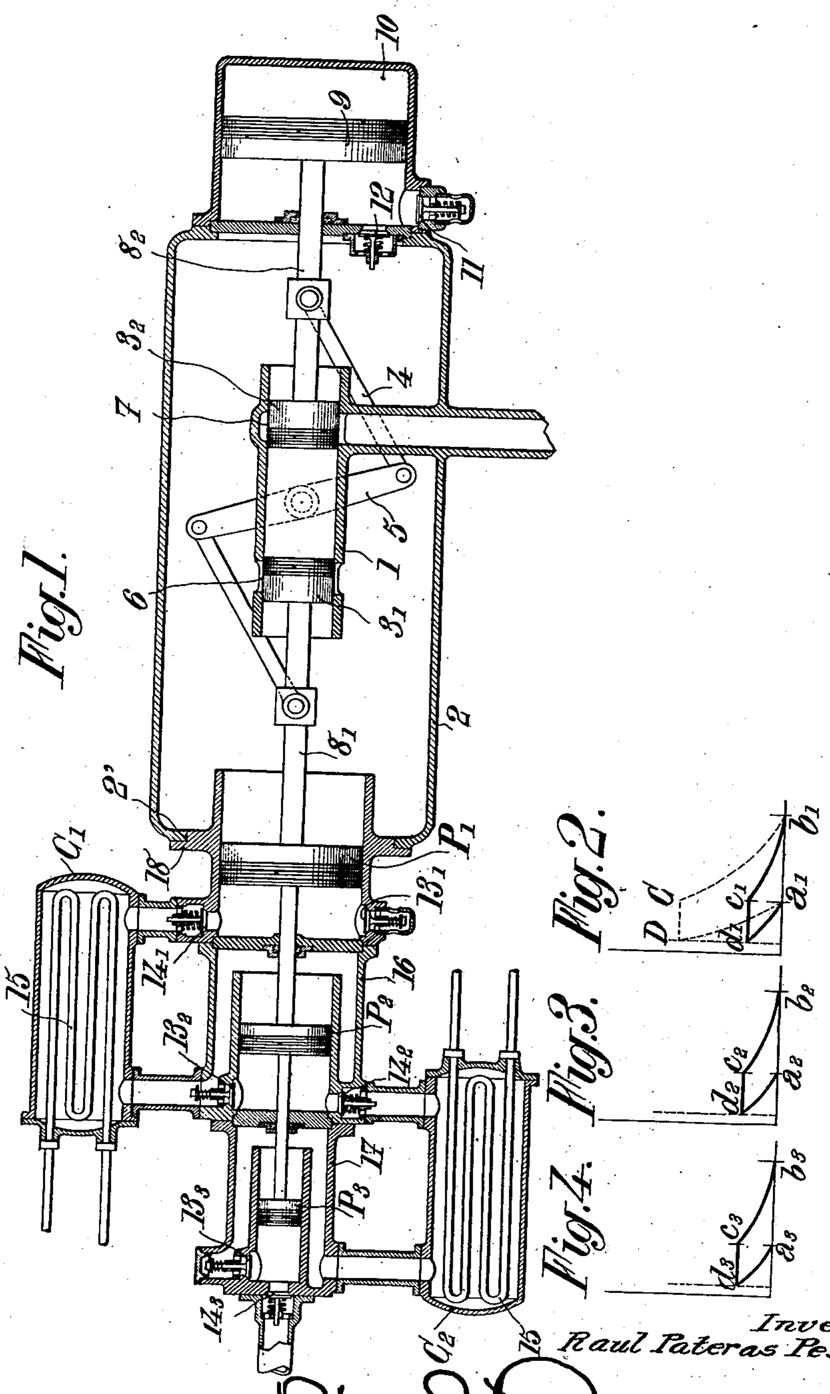

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MOTOR COMPRESSOR OF THE FREE PISTON TYPE

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The present invention relates to motor compressors of the free piston type having several stages of compression, that is to say to multiple stage motor compressors the pistons of which are of freely variable stroke.

The chief object of the present invention is to provide a compressor of this type which is better adapted to meet the requirements of practice than those used up to this time.

According to an essential feature of the present invention, I provide all the compression stages on the same side of the motor element of the generator, and at least one energy accumulator on the other side of said motor element, and, on the other hand, I provide means for applying, on the non-active face of at least one of the compressor pistons of the machine, a pressure higher than atmospheric pressure, this pressure being, for instance, supplied, for each compression stage, by the next lower stage of compression.

Other features of the present invention will result from the following detailed description of some specific embodiments thereof.

A preferred embodiment of the present invention will be hereinafter described, with reference to the accompanying drawing, given merely by way of example, and in which:

Fig. 1 is an axial section diagrammatically showing a multiple stage motor compressor with free pistons made according to the present invention;

Figs. 2 to 4 inclusive are diaphragms illustrating the operation of the various stages of this motor compressor, these diagrams being intended to facilitate the understanding of the invention.

According to the present invention, in order to provide a multiple stage motor compressor of the free piston type, I proceed in the following manner:

The motor element of this machine is made in any suitable usual manner, for instance including at least one motor cylinder 1, surrounded by a fluidtight casing 2, and two pistons 3_1 and 3_2 synchronized by means of a system of connecting rods 4 and lever 5. When nearing the outer end of their outward stroke, these pistons open inlet ports 6 and outlet ports 7.

According to the essential feature of the present invention, all the compressor pistons to be provided in the different stages of compression, that is to say the three pistons, P_1, P_2, P_3 in the case of the three stage motor compressor given by way of example, are controlled by the same motor piston. For instance these compressor pistons are mounted on the rod 8_1 of piston 3_1. The other piston 3_2 is connected to an energy accumulator which can be constituted, for instance, in the usual manner, by providing on the rod 8_2 of said piston 3_2, a piston 9 cooperating with a cylinder 10 so as to form a pneumatic energy accumulator, and also, advantageously, on the other side of said last mentioned piston, owing to the action of valves 11 and 12, a scavenging pump adapted to ensure the feed and scavenging of the motor cylinder.

I further provide means for subjecting the non-active face of at least one of the three pistons P_1, P_2, P_3 to the action of a compensating pressure higher than the atmospheric pressure.

It will be readily understood that, with such an arrangement, by suitably choosing the characteristics of the compressor portion of this machine, and in particular the values of sections s_1, s_2, and s_3 of the compressor pistons same as the values of the compensating pressure or pressures, the algebraic sum of the stresses acting upon the active and non active faces of said compressor pistons can be made substantially equal to the resultant of the efforts exerted on the two faces of the compressor piston of a motor compressor of the same power having a single stage of compression and the motor portion and the energy accumulator of which would be identical to those of the machine that is being considered.

Therefore, it will be possible, with a machine made according to the present invention, to obtain a satisfactory coaction of the motor and accumulator elements of said machine with any of a plurality of single or multiple-stage compressor elements provided that, for all these compressor elements, the sum of the efforts transmitted to the corresponding motor piston is substantially the same.

Also, it should be noted that it is still possible to maintain this characteristic of interchangeability of the compressor portion of the machine by complying only with a relative approximation to the condition of equality of the resultant efforts above mentioned, for instance by complying with this condition with an approximation of about 20%.

I will now indicate, by way of example, a solution which permits of obtaining, with compressor elements having different numbers of stages, the constancy of the resultant efforts applied to the rod of the corresponding motor piston.

Designating by p_0 the feed pressure of the machine (p_0 being, as a rule, and as it will be assumed, equal to 1) and by p_n the discharge pressure of the last stage, I may arrange that the compression effort developed in each stage is identical.

By choosing, for the intermediate pressures $p_1, p_2, p_3 \ldots p_{n-1}$ values which comply with the following condition.

$$\frac{p_1}{p_0}=\frac{p_2}{p_1}=\frac{p_3}{p_2}=\frac{p_n}{p_{n-1}}$$

that is to say $p_2=p_1$, $p_3=p_1^3$, etc., and by giving the compressor pistons sections $s_1, s_2, s_3 \ldots$ inversely proportional to their discharge pressures, this condition is

$$\frac{s_1}{s_n}=\frac{p_n}{p_1}$$

As a matter of fact the compression efforts developed in the successive compression stages are then:

$$f_1=p_1s_1$$

$$f_2=p_2s_2=p_1^2\frac{p_1s_1}{p_2}=p_1s_1$$

$$f_n=p_ns_n=p_1^n\frac{p_1s_1}{p_1^n}=p_1s_1$$

The sum of these elementary compressor efforts being equal to $n.p_1\ s_1$.

If it is desired to have this sum independent of the number of stages of compression, the section s_1 of the low pressure piston must be so chosen that it is inversely proportional to the number of stages, that is to say that s_1 is equal to

$$\frac{s'_1}{n}$$

s'_1 designating the section of the compressor piston of a compressor of the same power having a single stage of compression and a discharge pressure equal to p_1.

If now it is desired to have the resultant of the efforts exerted on the motor piston coupled with the compressor element independent of the number n of stages, it suffices, since the sum of the compression efforts is independent of n, to arrange in order that the sum of the efforts exerted on the non-active faces of the pistons may be also independent of n, which result can be obtained, for instance, by applying on the non-active face of each piston the discharge pressure of the next lower stage.

As a matter of fact, in this case, the efforts acting respectively on the non-active faces of each of the pistons have the following values:

$$f'_1=p_0s_1=s_1$$

$$f'_2=p_1s_2=p_1\frac{p_1s_1}{p_2}=s_1$$

$$f'_n=p_{n-1}s_n=s_1$$

and the sum of these efforts has the following value:

$$n\,s_1=s'_1$$

which value is truly independent of the number of stages of the compressor element of the machine.

In particular, for the three stage compressor which is considered, the discharge pressure of the first stage will be caused to act upon the inactive face of piston P_2 and the discharge pressure of the second stage will act on the inactive face of piston P_3.

As a matter of fact, in order to obtain a wholly accurate compensation, account should be taken of the fact that the two faces of pistons P_3 are not of the same free section, a portion of the inactive face of said piston being covered by rod 8_1. This might be compensated in many different ways, for instance by applying on the inactive faces of one of the pistons, P_2 for instance, a pressure slightly higher than the discharge pressure of the first stage.

I have shown in solid lines, on diagrams a_1, b_1, c_1, d_1, a_2, b_2, c_2, d_2, a_3, b_3, c_3, d_3 of Figs. 2 to 4 the resultant efforts as a function of the respective strokes for each of the pistons P_1, P_2, P_3. I have further shown, in dotted lines, on the diagram a_1b_1CD of Fig. 2 the sum of these three diagrams, which are identical to one another. This resultant diagram would represent the resultant of the efforts on the faces of the piston of a compressor element having a single stage of compression capable of being substituted for the three stage element that has been considered, the section of this single piston being then three times the section of the low pressure piston P_1.

I might also, taking into account the above explanations, proceed in many different ways for designing the compressor part of a machine according to the invention, and, in particular, have recourse to the embodiment illustrated by the drawing.

In this embodiment, each compressor stage includes at least one section valve 13_1, 13_2 or 13_3, and at least one discharge valve 14_1, 14_2, 14_3.

I provide, respectively between the low pressure stage and the intermediate pressure stage, on the one hand, and between the intermediate pressure stage and the high pressure stage, on the other hand, two intermediate reservoirs C_1, C_2 in which the compressed air is advantageously cooled, for instance by means of refrigerating tubes 15.

I connect reservoir C_1 with a fluidtight casing 16 surrounding the intermediate pressure cylinder in such manner that the pressure existing in said reservoir can act upon the non-active face of piston P_2, the high pressure cylinder being similarly surrounded by a casing 17 connected to reservoir C_2.

And preferably, I connect the whole of the compressor portion to the remainder of the machine in such manner that these two elements can easily be separated when it is desired to change said compressor portion in order to obtain another discharge pressure, for which purpose, for instance, I provide in casing 2, for the passage of the low pressure cylinder, a circular hole 2′ against the edge of which I apply a flange 18 integral or rigid with said low pressure cylinder.

Concerning the arrangement of the chamber for the compression of the scavenging air, account being taken of the fact that the pressure of the scavenging air and the volume thereof depend merely upon the characteristics of the motor portion of the machine, this chamber can be disposed either behind the low pressure piston of the compressor element or behind the piston of the energy accumulator as above mentioned.

Advantageously, the first solution will be reserved to the case of compressors having one or two stages in which the size of the low pressure compressor piston is generally sufficient for sucking in a sufficient volume of scavenging air.

On the contrary, in the case of compressors having more than two stages of compression, the size of the low pressure compressor piston would be insufficient for sucking in a sufficient volume of scavenging air. Use will then be made of the second solution and care will be taken to dimension the piston of the energy accumulator so that it can suck in through its rear face, a sufficient volume of scavenging air.

Anyway, whatever be the particular embodiment that is chosen, I obtain a free piston autocompressor the working of which results sufficiently clearly from the preceding explanations for making it unnecessary to give further explanations.

In a general manner, while I have, in the above description, disclosed what I deem to be practical and efficient embodiments of the present invention it should be well understood that I do not wish to be limited thereto as there might be changes made in the arrangement, disposition and form of the parts without departing from the principle of the present invention as comprehended within the scope of the appended claims.

What I claim is:

1. A motor compressor which comprises, in combination, a motor cylinder, at least two motor pistons freely movable in opposed relation in said cylinder, synchronizing means for coupling said pistons with each other, an energy accumulator coupled with one of said motor pistons only, and a multiple stage compressor system coupled entirely with the other motor piston, said compressor system including a plurality of compressor pistons and means for applying to the inactive face of at least one of said compressor pistons a pressure higher than atmospheric pressure.

2. A motor compressor according to claim 1 in which the last mentioned means are so devised that the pressure acting on the inactive face of at least one of the compressor pistons is of such a value that the sum of the absolute pressures acting on the whole of the inactive faces of the compressor pistons of the respective stages is equal to the absolute pressure which would act on the inactive face of the compressor piston of a single stage compressor of the same power as the multiple stage compressor that is considered and working with a discharge pressure equal to the discharge pressure of the first stage of the multiple stage compressor.

3. A motor compressor which comprises, in combination, a motor cylinder, at least two motor pistons freely movable in opposed relation in said cylinder, synchronizing means for coupling said pistons with each other, an energy accumulator coupled with one of said motor pistons only, and a multiple stage compressor system coupled entirely with the other motor piston, said compressor system including a plurality of compressor pistons, and means for applying to the inactive face of each compressor piston the inlet pressure of the corresponding stage.

4. A motor compressor which comprises, in combination, a motor cylinder, at least two motor pistons freely movable in opposed relation to each other in said cylinder, synchronizing means for coupling said pistons with each other, an energy accumulator coupled with one of said pistons including an accumulator piston coupled with said last mentioned motor piston only, and a cylinder cooperating with said accumulator piston, means adapted to cooperate with said accumulator piston for forming a scavenging pump connected with said motor cylinder, and a multiple stage compressor system coupled entirely with the other motor piston, said compressor system including a plurality of compressor pistons and means for applying to the inactive face of said compressor pistons a pressure higher than atmospheric pressure.

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