

Dec. 22, 1936.

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2,064,976

REGULATION OF FREE-PISTON MOTOR COMPRESSORS

Filed Feb. 23, 1935

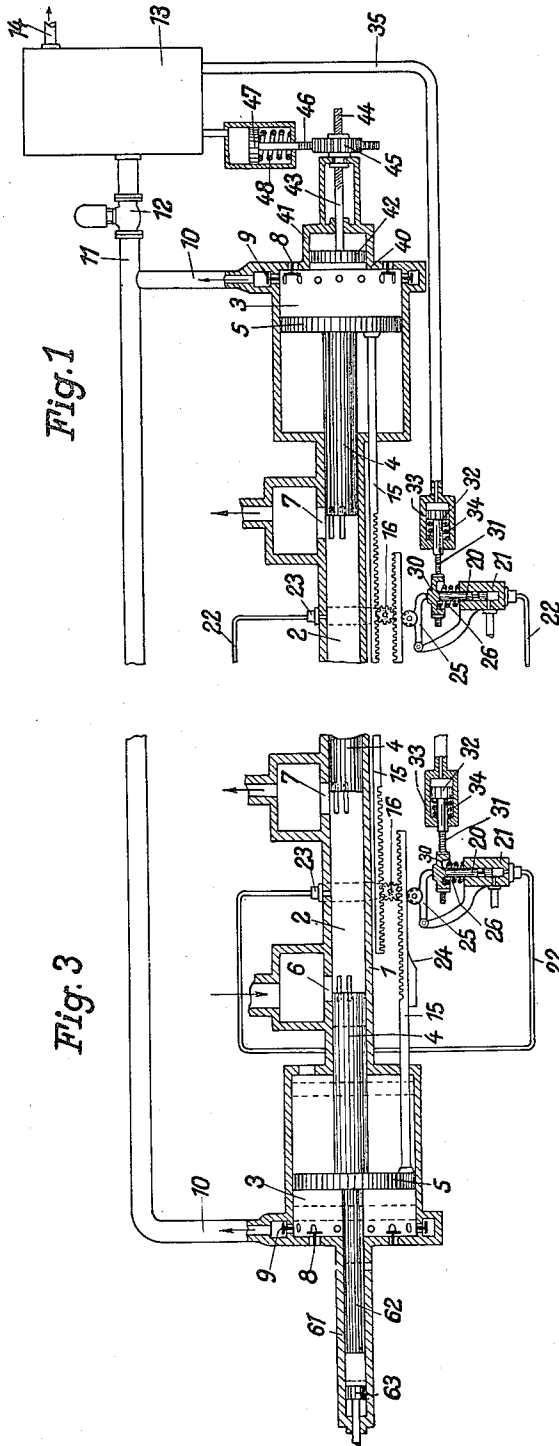


Fig. 1

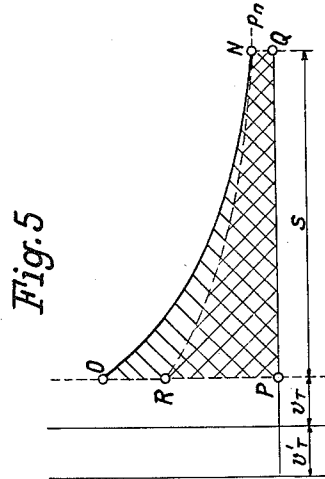


Fig. 5

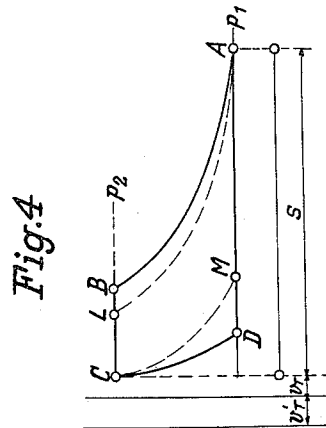


Fig. 4

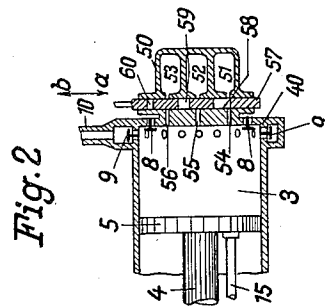


Fig. 2

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UNITED STATES PATENT OFFICE

2,064,976

REGULATION OF FREE-PISTON MOTOR
COMPRESSORSHermann Jänicke, Dessau, Germany, assignor to
Therese Junkers, Gauting, near Munich, Ger-
manyApplication February 23, 1935, Serial No. 7,786
In Germany March 9, 1934

10 Claims. (Cl. 230—56)

My invention relates to free piston motor com-
pressors and has for one of its objects to pro-
vide means whereby the power absorption and
delivery of the compressor chambers and/or ad-
ditional chambers including pneumatic or other
buffers can be controlled and regulated in a
manner such that the output of the compressor
can be adapted to the requirements of each
individual case.

In my copending U. S. application Serial No.
710,483 I have disclosed a method of controlling
a free piston motor compressor by varying the
length of stroke and the pressures thereof, e. g.
the suction or discharge pressure, or both these
pressures combined. My copending U. S. appli-
cation Ser. No. 7,787 discloses the regulation of
a free piston motor compressor by means of a
variation of the pressures, i. e. the suction or de-
livery pressure or both these pressures combined,
and of the fuel supply to the motor cylinder of
the motor compressor in a manner such that
the piston stroke remains always approximately
constant; while my copending U. S. application
Ser. No. 7,788 discloses the regulation of a free
piston motor compressor by the simultaneous
variation of at least two of the variables, which
at a predetermined constant stroke of the piston
determine the output of the compressor as well
as the return energy in such a manner that
the portion of the total return energy which is
available for the compression of the motor
charge must always remain approximately con-
stant.

In free-piston motor compressors comprising,
besides the combustion chamber of the motor one
or more compressor chambers, and one or more
freely reciprocating pistons, it has already been
suggested to vary the length of stroke of the
pistons in order to vary the performance of the
compressor. However such variation of stroke
involves certain drawbacks as thereby the con-
trol of the motor part which is derived from the
movement of the pistons, is subjected to unde-
sirable variations.

It is an object of the present invention to
render possible a variation of the compressor
performance within wide limits while keeping
the stroke substantially constant.

I effect this, according to the present inven-
tion, by varying the volume of that portion of
the compressor chambers which makes up the
dead space or clearance, and, at the same time,
influencing the supply of fuel to the combustion
chamber of the motor in such manner, that the

stroke of the pistons nevertheless remains sub-
stantially constant.

In some cases the amount of energy taken up
or delivered by additional (subsidiary) cham-
bers such as for instance pneumatic buffers,
which store compression energy during one
stroke and deliver it during the subsequent
stroke may be varied in a similar manner and
for the same purpose, the energy thus deliv-
ered together with the energy which is released
during the return stroke in the compressor
proper serving to compress the charge in the
motor cylinder.

The regulations to be effected according to this
invention, i. e., the variation of the clearance
and of the quantity of fuel supplied to the motor
cylinder per power stroke, may be effected either
manually or automatically, or one of them may
be effected manually, the other automatically.

Manual regulation is adopted, for instance, if
there arise comparatively few or slow variations
of the demand for compressed gas, or if the
requirements as to the exactitude of regulation
are not high. In such regulation the variation
of the clearance volume as well as the variation
of the fuel supply may be effected by one and
the same regulating member (a hand wheel, a
lever, or the like) so that each regulating oper-
ation requires only the actuation of this member.

If both regulations are carried out automati-
cally, they may be influenced by variations of a
single source of power, for instance by the pres-
sure existing in a storage tank arranged in series
with the compressor. It is however also possible
to render the two regulations dependent from
two separate sources of power, for instance to
vary the clearance volume in dependency from
the pressure in the storage tank, while regulat-
ing the fuel supply to the motor cylinder in de-
pendency from the stroke in such manner that
the stroke remains substantially constant.

I will now describe my invention more fully
with reference to the drawing affixed to this
specification and forming part thereof, which
illustrates diagrammatically by way of example
several embodiments of this invention.

In the drawing,

Figs. 1 and 3 are longitudinal sections of one
half of a free-piston compressor with pistons
reciprocating in opposite directions.

While Fig. 2 is a partial longitudinal section
of another form of the compressor proper.

Fig. 4 is a diagram showing pressures plotted
against stroke, for a compressor as shown in
Figs. 1 or 2,

Fig. 5 is another diagram showing pressures plotted against stroke for the pneumatic buffer illustrated in Fig. 3.

Referring to the drawing and first to Figs. 1 to 3, 1 is the casing forming a centrally disposed combustion chamber 2 and a compressor chamber 3 at either end. Each of the two freely moving masses substantially consists of a motor piston 4 and a compressor piston 5 which are directly connected. In order to time the opposite reciprocatory movements of the masses for exact synchronization, the masses are connected by suitable mechanism such as for instance a rack 15 connected to each mass, the two racks meshing at diametrically opposite points with a pinion 16 which is mounted to rotate in a fixed position at the casing 1. The left hand motor piston 4 (Fig. 3) controls the scavenging ports 6, and the right hand motor piston 4 (Fig. 1) controls the exhaust ports 7 formed in the wall of the motor cylinder. The residual compressed gas which remains over in the clearance spaces of the compressor chamber at the end of each power stroke, expands and forces the masses (pistons) 4, 5 towards each other. When the pressure in the compressor cylinders has dropped to equal the suction pressure, fresh gas is drawn in through the suction valves 8 and, at the same time, the charge in the combustion chamber 2 of the motor cylinder is compressed. Toward the end of the return stroke liquid fuel is injected into the combustion chamber through pipe 22 and injection nozzle 23 by means of a fuel pump having a piston 20 and a cylinder 21, and the mixture is ignited. The fuel pump which is more fully described in my copending application Ser. No. 710,483, is operated by a cam 24 formed on the rack 15 which, when the piston is near the end of its inward stroke, turns a rocker 25 which displaces the pump piston 20 against a spring 26. The products of combustion in the motor cylinder now force the pistons apart, the gas which has been drawn into the compressor cylinders, is compressed and conducted to a storage tank 13 through delivery valves 9, delivery pipes 10 and delivery main 11. A pipe 14 distributes the compressed gas to the individual stations where it is required. A spring-loaded check valve 12 is provided in the main 11 for maintaining the compression pressure in the compressor cylinders 3 at a definite minimum even if the pressure in the tank 13 should be lower than this minimum, for instance in consequence of heavy tappings of compressed gas, or when the compressor is started. The check valve 12 may simply consist of a valve body which a spring tends to close, while the gas pressure prevailing in the main 11 tends to open the same. Since the force of the spring acting upon the valve body always can be maintained constant, the gas pressure prevailing in the main 11 also must have a predetermined minimum value in order to lift the valve body from its seat so as to open the valve. The amount of fuel supplied to the motor cylinder per power stroke is here controlled automatically in a known manner in dependency from the pressure in the storage tank 13 by turning the pump piston. To this end a spur gear 30 is rigidly connected to the pump piston 20. A rack 31 meshing with this spur gear supports a piston 32 mounted to slide in cylinder 33. A compression spring 34 acts on one face of the piston while the pressure in the tank 13 through pipe 35 acts on its other face. In this

manner the position of the piston 32 is determined by the pressure in the tank 13 and consequently the amount of fuel delivered at each stroke of the pump is a function of this pressure.

Figs. 1 and 2 also illustrate examples for the regulation of the compressor performance by a variation of the clearance volume.

As shown in Fig. 1, a cylindrical extension 41 is provided on the cover 40 of the compressor cylinder and a piston 42 is mounted to slide in this extension. The rod 43 of the piston is threaded at 44 and engages in the threaded boss of a spur gear 45 which is held against axial movement. A rack 46 on the rod of a piston 47 engages in the spur gear. The piston 47 is acted upon by the pressure in tank 13, against the action of a spring 48. If the pressure in the tank 13 rises beyond the normal, i. e., if the output of the compressor exceeds the demand for compressed gas, the piston 47 is moved downwardly against the pressure of spring 48 and turns the spur gear 45, whereby the piston 42 is moved to the right, the clearance of the cylinder is increased and the output of the compressor is reduced in proportion.

In the modification illustrated in Fig. 2 a casing 50 mounted on the cover 40 of the compressor cylinder forms three compartments 51, 52, 53. Each compartment communicates with the compressor chamber 3 through a port 54, 55, 56, respectively. These ports are controlled by a slide valve 57 which is formed with slots 58, 59, 60 differing in length. When the slide valve descends in the direction of arrow *a*, the compartments 51, 52, 53 are successively connected to the compressor chamber, while, when the slide valve rises in the direction of arrow *b*, they are cut off in the opposite sequence. By the connection and disconnection of these compartments the clearance of the compressor is varied. The slide valve 57 may be actuated by hand or it may, for instance like the rack 46 in Fig. 1, be controlled automatically in dependency from the pressure in the tank 13.

In Fig. 4 the variation of the diagram showing pressures plotted against strokes is illustrated for the regulation of the performance by variation of the clearance. The lines A B C D A show the compressor diagram for normal performance. The gas is compressed from the suction pressure p_1 to the delivery pressure p_2 . The volume of the clearance corresponds to line V_T. On increasing the clearance V_T for normal operation by the amount v_r , the new diagram A L C M A is obtained. The performance represented by line L C is less than the normal performance corresponding to line B C.

Fig. 3 shows a free-piston compressor in which, in addition to the compressor space 3, a pneumatic buffer is provided comprising a cylinder 61 and piston 62. The amount of energy absorbed by the buffer during the outward stroke of the piston and delivered to it during the return stroke is regulated by varying the buffer clearance at substantially constant stroke of the flying mass. To this end the cover of the buffer cylinder is formed as a piston 63, which may be adjusted by hand or automatically, like the piston 42 in Fig. 1 for instance in dependency upon the pressure in storage tank 13.

Instead of the slidable cylinder cover separate compartments might be provided for connection and disconnection, as described above.

Fig. 5 shows the diagram of such a buffer with

pressures plotted against stroke. Assuming the initial pressure p_n to be constant, if the clearance has the small volume V_T , compression occurs along line N O and the energy absorbed and delivered by the buffer then corresponds to the area N O P Q N. If the clearance volume is increased by $v'T$, compression occurs along the line N R which extends below line N O, and the lower energy of the buffer is now represented by the area N R P Q N.

I wish it to be understood that I do not desire to be limited to the exact details of construction shown and described for obvious modifications will occur to a person skilled in the art.

I claim:—

1. A free piston motor compressor comprising in combination a motor cylinder and at least one compressor cylinder arranged on either side thereof, and at least one buffer cylinder and a member adapted to regulate both the variation of volume of the clearance in said compressor cylinders and said buffer cylinder and the fuel supply to said motor cylinder.

2. A free piston motor compressor comprising in combination a motor cylinder, and at least one compressor cylinder arranged on either side thereof, members for varying the clearance volume in said compressor cylinders and for regulating the fuel supply to said motor cylinder, means for storing gas compressed in said compressor cylinders and a common means arranged to be influenced by the pressure in said gas storing means for moving both said members.

3. A free piston motor compressor comprising in combination, a motor cylinder and at least one compressor cylinder arranged on either side thereof, a free piston in each cylinder, the pistons arranged on the same side of the motor cylinder being operatively connected with each other, means for varying the volume of the clearance of the said compressor cylinders and means for at the same time varying the supply of fuel to said motor cylinder in such manner as to keep the free piston stroke substantially constant.

4. A free piston motor compressor comprising in combination, a motor cylinder, at least one compressor cylinder arranged on either side thereof and at least one buffer cylinder, a free piston in each cylinder, the pistons arranged on the same side of the motor cylinder being operatively connected with each other, means for varying the volume of the clearance of the said compressor cylinders and the said buffer cylinder and means for at the same time varying the supply of fuel to said motor cylinder in such manner as to keep the free piston stroke substantially constant.

5. A free piston motor compressor comprising in combination, a motor cylinder and at least one compressor cylinder arranged at either side thereof, a free piston in each cylinder, the pistons arranged on the same side of the motor cylinder being operatively connected with each other, means for varying the volume of the clearance of the said compressor cylinders, means for at the same time varying the supply of fuel to said motor cylinder in such manner as to keep the free piston stroke substantially constant, and a single member adapted to regulate the variation of the clearance volume of said compressor cylinders as well as of the supply of fuel to said motor cylinder.

6. A free piston motor compressor comprising in combination, a motor cylinder, at least one compressor cylinder arranged on either side thereof

and at least one buffer cylinder, a free piston in each cylinder, the pistons arranged on the same side of the motor cylinder being operatively connected with each other, means for varying the volume of the clearance of the said compressor cylinders and the said buffer cylinder, means for at the same time varying the supply of fuel to said motor cylinder in such manner as to keep the free piston stroke substantially constant, and a single member adapted to regulate the variation of the clearance volumes of said compressor and buffer cylinders as well as of the supply of fuel to said motor cylinder.

7. A free piston motor compressor comprising in combination, a motor cylinder and at least one compressor cylinder arranged on either side thereof, a free piston in each cylinder, the pistons arranged on the same side of the motor cylinder being operatively connected with each other, means for varying the volume of the clearance of the said compressor cylinders, means for at the same time varying the supply of fuel to said motor cylinder in such manner as to keep the free piston stroke substantially constant, and a single source of power for moving all said means.

8. A free piston motor compressor comprising in combination, a motor cylinder, at least one compressor cylinder arranged on either side thereof and at least one buffer cylinder, a free piston in each cylinder, the pistons arranged on the same side of the motor cylinder being operatively connected with each other, means for varying the volume of the clearance of the said compressor cylinders and the said buffer cylinder, means for at the same time varying the supply of fuel to said motor cylinder in such manner as to keep the free piston stroke substantially constant, and a single source of power for moving all said means.

9. A free piston motor compressor comprising in combination, a motor cylinder and at least one compressor cylinder arranged on either side thereof, a free piston in each cylinder, the pistons arranged on the same side of the motor cylinder being operatively connected with each other, means for varying the volume of the clearance of the said compressor cylinders, means for at the same time varying the supply of fuel to said motor cylinder in such manner as to keep the free piston stroke substantially constant, and means for accumulating the gas compressed in said compressor cylinders, the pressure in said gas accumulating means constituting the only source of power for moving both the clearance volume and the fuel supply varying means.

10. A free piston motor compressor comprising in combination, a motor cylinder, at least one compressor cylinder arranged on either side thereof and at least one buffer cylinder, a free piston in each cylinder, the pistons arranged on the same side of the motor cylinder being operatively connected with each other, means for varying the volume of the clearance of the said compressor cylinders and the said buffer cylinder, means for at the same time varying the supply of fuel to said motor cylinder in such manner as to keep the free piston stroke substantially constant, and means for accumulating the gas compressed in said compressor cylinders, the pressure in said gas accumulating means constituting the only source of power for moving both the clearance volume and the fuel supply varying means.