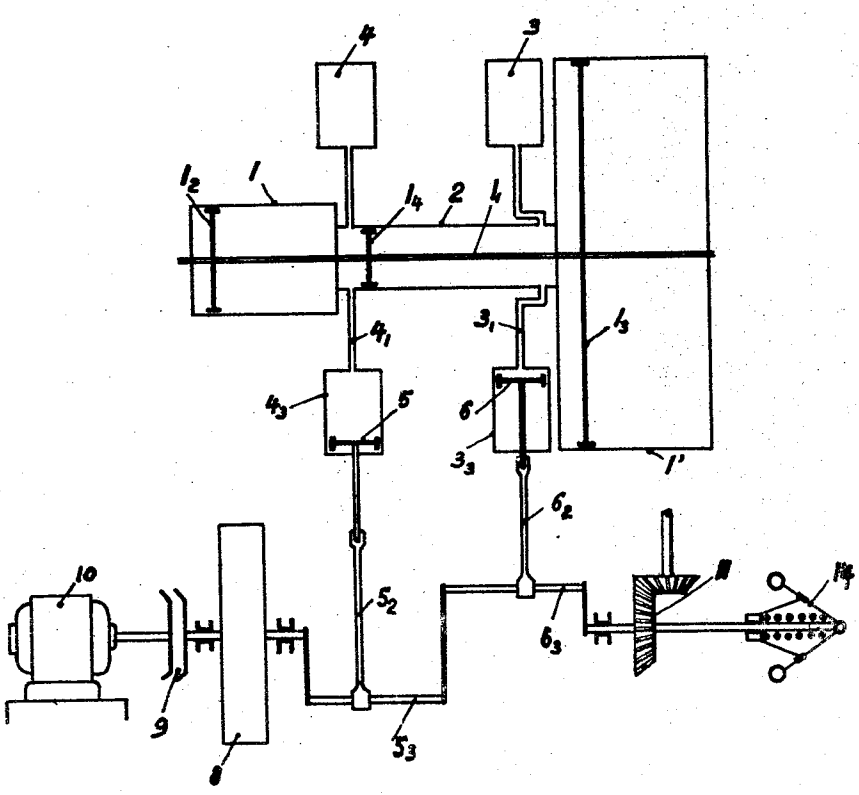
Nov. 2, 1937. G. J. P. J. J. BRUN 2,097,431

STABILIZING DEVICE FOR TWO-STROKE FREE PISTON ENGINES

Filed June 19, 1935 3 Sheets-Sheet 1

Fig. 1



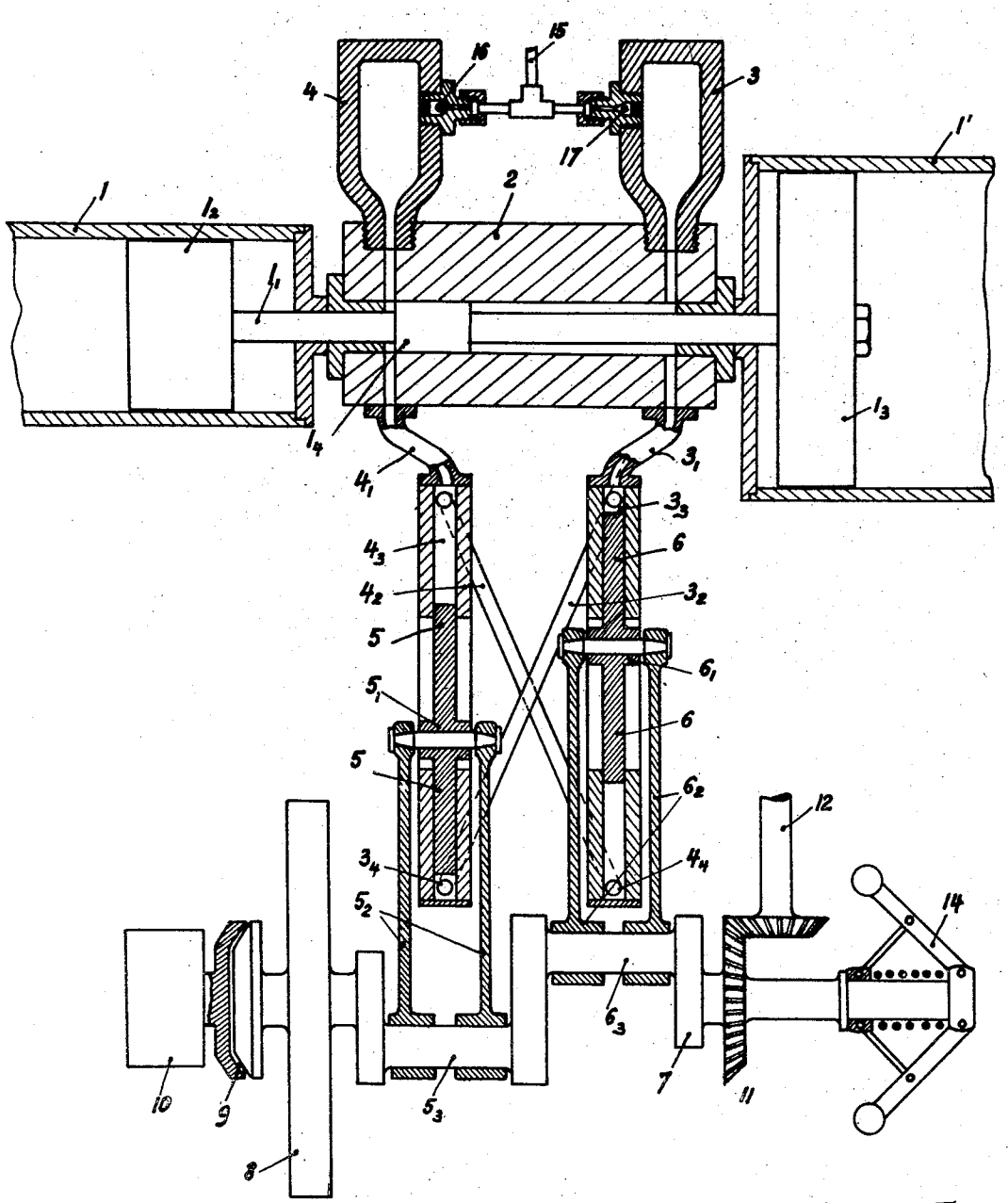
Inventor:
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STABILIZING DEVICE FOR TWO-STROKE FREE PISTON ENGINES

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Fig. 2



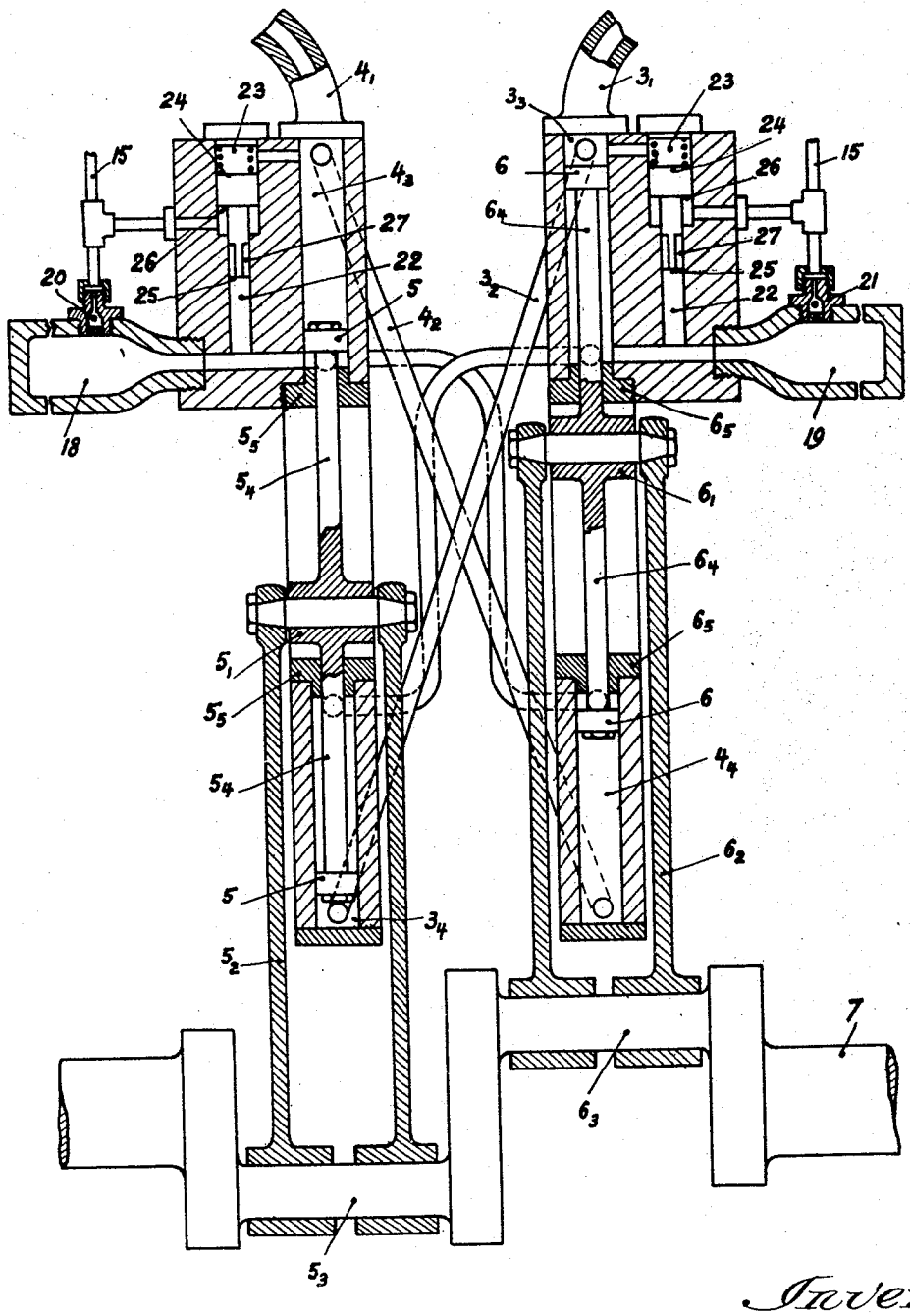
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STABILIZING DEVICE FOR TWO-STROKE FREE PISTON ENGINES

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Fig. 3



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UNITED STATES PATENT OFFICE

2,097,431

STABILIZING DEVICE FOR TWO-STROKE FREE PISTON ENGINES

Georges Jean Pierre Jules Joseph Brun, St. Etienne, France

Application June 19, 1935, Serial No. 27,292
In France June 20, 1934

15 Claims. (Cl. 230—56)

This invention relates to a stabilizing and regulating device for free piston engines, particularly, adapted for compressed gas generators, in which the working and compressor pistons are arranged in tandem on the same rod, and in which the entire combustion energy is used for actuating the compressor.

In the construction of free piston engines and particularly of motor compressors of the aforementioned type, the problem of the continuity and of the stability of the working pistons gives rise to considerable difficulty, such as during a single stroke of the movable member of the engine, the driving work produced on one of the pistons balances the resisting work produced on the other. At the end of each stroke a certain amount of energy is collected in pneumatic form in the free space of the cylinders. The pneumatic energy at the end of a stroke and the kinetic energy at mid-stroke are approximately equal to the driving work per stroke.

Any change of this work, such as is never avoided in internal combustion motors, reacts immediately on the velocity of the movable member of the engine and on the compression of the gas at the end of a stroke; consequently on the subsequent working of the motor.

The working of double-acting motor compressors, such as comprise double-acting and two stroke working and compressor pistons is difficult to stabilize.

In motors with a high compression, the volume of the combustion chamber is small with respect to the swept volume, so that a small increase of the stroke causes a considerable increase of the compression ratio and of the driving work. In order to stabilize the working, the resisting work of the compressor must be raised at least in the same proportion—the compressor must be adapted therefore for high delivery pressures and provided with wide free spaces at the end of the stroke, resulting in a low volumetric efficiency. The stability of double-acting motor-compressors with a delivery pressure ranging from 4 to 5 kgs. is always rather unsatisfactory, and a single spark failure is frequently sufficient to cause their stopping.

In single-acting motor-compressors, comprising single acting two-stroke working and compressor pistons, in which the working surfaces are opposite one another, a proper practical stability may be ensured by actuating the reverse stroke of the working piston towards the cylinder head by means of the combined action of a pneumatic recuperator and of a compressor with a wide free space. Such constructions disclose, however, numerous difficulties, such as the moving member is made heavy; the average velocity is reduced; the specific losses of the recuperator reduce the efficiency of the compressor.

It has also been suggested to connect the common rod of the working and compressor pistons with a fly-wheel by means of a rod and crank system. Such an arrangement, however, deprives the device of its essential character of a free-piston engine and renders it similar to ordinary motor-compressors. Moreover, it necessitates providing a rotating shaft and large and heavy rods, adapted to offer a sufficient mechanical resistance to the violent and irregular strains caused by the different laws of motion of the rods and of the piston device. This results in a great inertia, which precludes elevated linear velocities of the pistons, which form one of the advantages of the free piston motors.

The object of my invention is to obviate the afore-said difficulties.

The invention is characterized in that a rotating shaft, provided with a fly-wheel is connected with the rod carrying the pistons by means of a hydro-elastic transmission, comprising a double-acting auxiliary piston, (or two opposite single-acting pistons), termed a recuperator piston, mounted on said rod, and moving inside a cylinder, filled with oil, constantly communicating, at each of its ends, on one hand with a container provided with an automatic feeding device, and on the other hand, with one or several bores, in which move pistons, connected by means of connecting rods with the cranks of said rotating shaft.

The relation of the volume swept by each surface of the recuperator piston with the total volume swept by the corresponding rod controlled pistons is superior to 1, and equal to 2. The volume of each container being selected in a manner, that the relation of the work produced on the recuperator piston during a single stroke, by the expansion of the liquid compressed in said recuperator, and by the rod connected pistons, and of the driving work produced during a single stroke on the piston of the movable member, should be of a sufficient value, preferably approaching 1.

This device gives the free piston engine as satisfactory a regularity and stability as those of an engine with rod controlled pistons and moreover lightens the engine and increases the speed of the pistons. It also facilitates the control of the distributing devices, which is particularly diffi-

cult in free piston engines with high piston velocity.

It is known that if the piston velocity of a motor is doubled, and the velocity of the gases when passing through the apertures is maintained constant, the maximum kinetic energy of the valves is multipled by 22. Engines with high piston velocity therefore require particularly powerful controls, but in free piston motors, a rotating shaft, which is practically indispensable in such cases, is not provided. The device according to the invention also greatly facilitates, owing to the hydro-elastic coupling with a driving shaft, the starting of such engines, which is generally difficult owing to the high value of the impulsion necessary for starting their movable member.

One embodiment of the invention is hereinafter described, by way of example, and illustrated in the accompanying drawings.

Figure 1 is a diagram of the device according to the invention;

Figure 2 is an elevational view of the engine in axial section;

Figure 3 is an axial sectional view of the stabilizing device shown in Figure 2, but provided with various improvements.

Figure 1 shows an engine comprising a working cylinder 1 and a compressor cylinder 1', inside which move respectively the working piston 1_2 and compressor piston 1_3, keyed in tandem on a rod 1_1.

This rod also carries a third piston 1_4, moving in a cylinder 2, which has no communication with the others. This cylinder will hereinafter be referred to as a recuperator cylinder. The recuperator cylinder is filled with a compressible liquid, such as oil, and is in constant communication at each of its ends, on one hand with the isolated containers 3 and 4, equally filled with oil, and, on the other hand, by means of pipings 3_1 and 4_1 with the cylinders 3_3 and 4_3, in which move the pistons 5 and 6, connected by means of rods 5_2 and 6_2 with the opposite cranks 5_3 and 6_3, of a crank-shaft carrying a fly-wheel 8. This shaft is coupled by means of a clutch 9 with an electric starter 10, and controls, by means of bevel pinions 11, a distributing shaft 12; it carries moreover a centrifugal governor 14.

The motor-compressor having been started by means of the starter 10, the crank-shaft and the fly-wheel are driven at the speed of the motor, the dead points of said shaft coinciding with those of the movable member, while the elasticity of the hydraulic transmission constituted by cylinders 2, 3_3, 4_3 and pistons 1_4, 5 and 6 as described above eliminates strong strains on the connecting rods and on the shaft. Therefore the engine may be constructed lightly. If, for some reason, a disturbance is caused in the working of the compressor, the dead points of the rod 1_1 are shifted in respect of those of the rod-controlled pistons 5 and 6, but the recuperator piston 1_4 is then subjected to thrusts from the fly-wheel 8, by means of the compressed liquid, said thrusts tending to synchronize its motion and to avoid thus exaggerated shifts between the dead points of said rod and pistons. If the disturbance persists, the velocity of the rotating shaft is increased or reduced according to the nature of the disturbance, and the regularity of the working is then reestablished by the governor. Speed regulation by governors of this type will be found described in Dyke's Automobile and Gasoline Engine Encyclopedia, 16th Edition, published by the Goodheart-Wilcox Company, Inc., Chicago, Illinois, pages 100, 946, 947, and on the insert between pages 960 and 961; and in the Mechanical Engineers' Hand Book by Lionel S. Marks, 2nd Edition, published by the McGraw Hill Book Company, page 829.

The detailed construction and the working of the apparatus, the principle of which has just been explained, are hereinafter described with reference to Figures 2 and 3 of the drawings.

Figure 2 is a general view in section of the devices ensuring the hydro-elastic coupling. The movable member of the free piston engine is formed by a rod 1_1, at the ends of which are keyed the working and compressor pistons 1_2 and 1_3 (the working and compressor cylinders are not illustrated in this figure). A recuperator piston 1_4, movable in the bore of the recuperator cylinder 2, is also fixed on said rod 1_1. The bore of the cylinder 2 is in constant communication, at its right end, with the container 3, and by means of the conduits 3_1 and 3_2, with the ends of bores 3_3 and 3_4. At its left end, said bore is in permanent communication with the container 4, and, by means of conduits 4_1 and 4_2, with the ends of the bores 4_3 and 4_4. The bore of the cylinder 2, the containers 3 and 4, and conduits 3_1—3_2, 4_1—4_2, and the bores 3_2—3_4, 4_2—4_4 are constantly filled with a compressible liquid, generally with oil.

The bores 3_4 and 4_3 on one hand, and 4_4 and 3_3, on the other, are respectively co-axial and their heads are opposed. A double-acting piston 5 is connected by means of the crosshead 5_1 and the connecting rods 5_2 with the crank-pin 5_3 of the crank-shaft 7. A double-acting piston 6, moving in the bores 3_3 and 4_4, is connected by means of the crosshead 6_1 and the connecting rods 6_2, with the crank-pin 6_3 of said shaft 7. The crank-pins 5_3 and 6_3 are keyed at 180° to one another, so that the pistons moving in the bores 3_3 and 3_4 are displaced in the same direction in respect of the heads of said bores, said direction being opposite to that of the pistons moving in the bores 4_3 and 4_4.

The engine illustrated in Figure 2 is provided with a shaft, comprising two crank-pins. It should be understood that it may also comprise four, six, or eight such crank-pins, according to the value of the power exchange between the engine shaft and the rod 1_1 carrying the pistons, one half of said crank-pins being always keyed at 180° in respect to the other half.

The shaft 7 carries a fly-wheel 8 and it may be connected by means of a clutch 9, with a starting motor 10; the engine is easily started by throwing in gear the motor 10 with the shaft 7; said shaft is set into rotation, thus causing the alternating motion of the rod 1_1 carrying the pistons. When the stroke of said movable member attains a sufficient value for causing in the working cylinder the compression required for ignition, the fuel is sprayed into said cylinder and the rod 1_1 carrying the pistons then drives the shaft 7, at normal speed.

The shaft 7 is connected, by means of bevel gears 11, with a distributing shaft 12, and which may also carry a centrifugal governor 14; the distributing device, which has not been illustrated in the drawings, may be of any usual type.

The filling of the containers 3 and 4, and of the bores communicating with the containers, with compressible liquid, is performed through a pipe 15, leading to the containers 3 and 4 by means of ball valves 16 and 17. These valves

let the liquid supplied through the pipe 15 penetrate into the containers but prohibit its reverse motion. The pipe 15 is connected with a tank containing oil at low pressure.

The constructive characteristics of the hydro-elastic coupling are:

1. The volumes v and v' swept respectively by the left and right faces of the recuperator piston;

2. The volumes V and V' of the containers 4 and 3;

3. The volumes w and w' swept by the sets of rod-controlled pistons communicating respectively with the left and right faces of the recuperator piston.

The volumes v and v' are always greater respectively than the volumes w and w'.

The working of the device varies slightly according to whether the motor-compressor is double or single acting.

In a double-acting compressor, the forces applied to the movable member, during a simple stroke, are the same, whether said member moves from left to right or from right to left.

Therefore:—$v=v'$

$$V=V'$$

$$w=w'.$$

When the engine is working permanently at normal speed, the work produced on the working piston in a simple stroke balances the resistant work of the compressor piston. As the shaft rotates in synchronism, the dead points of the movable member coincide automatically with those of the rod controlled pistons. When, for example, the recuperator piston is at the end of its stroke towards the left, the rod controlled pistons moving in the bores 4_3 and 4_4 are at the end of their stroke in the direction opposite to the heads of said bores. The pressure of the liquid on the right side of the recuperator piston is reduced to a minimum and is brought automatically to the value of the pressure in the conduit 15, which approaches 0.

On the left side of the recuperator piston, the pressure rises to a value p, resulting from the compression, in the container of a volume equal to V, of the volume $v-w$, that is of the excess of the volume discharged by the recuperator piston over the volume admitted behind the rod controlled pistons.

At the next simple stroke, the pressure on the left side of the recuperator piston falls from p to 0, and that on the right side of said piston rises from 0 to p. The action of the recuperator on the movable member of the compressor is similar to that of a very powerful spring, and the kinetic energy of said movable member at mid-stroke is increased by $\frac{1}{4}\ pv$ is one part of which, equal to $\frac{1}{4}\ pw$ being provided by the work of the rod-controlled pistons during the single half-stroke, and the rest equal to $\frac{1}{4}\ p\ (v-w)$ by the expansion of the compressed oil in the containers.

The fly-wheel slows the motion during the first half of the single stroke, accelerates it during the second half, and possesses at the end of said stroke the same kinetic energy as at the start.

In the occurrence of a disturbance, the work on the working piston becomes higher or lower than the resistant work of the compressor piston, and the dead points of the movable member are shifted in respect of those of the rod-controlled pistons, being in advance in the first case and late in the second. Calculation shows that almost no change occurs in the stroke of the movable member and in the compression.

The shifting of the dead points produces at mid-stroke maximum working pressure, in opposite directions on both sides of the recuperator piston. This pressure slows the motion of the movable member, when the driving work exceeds the resistant work, and accelerates said motion in the opposite case. Conversely, this pressure accelerates or retains the motion of the fly-wheel, which provides automatically the supplementary work required for bringing the device back to equilibrium. If the disturbance continues, the speed of the shaft is accelerated or reduced, and equilibrium is then established by the governor.

The essential data of a hydro-elastic coupling are:—

1. The relation

$$\frac{v}{w}$$

of the volume swept by the recuperator piston and that swept by the rod controlled pistons;

2. The relation

$$\frac{\frac{1}{4}pv}{t}$$

of the work transmitted at mid-stroke by the recuperator piston to the movable member and the driving work t per single stroke.

If the relation

$$\frac{v}{w}$$

approaches 1, the coupling is insufficiently supple as the motion of the rod-controlled pistons is practically sinusoidal, whereas that of the movable member is not sinusoidal, as its acceleration at the dead points is generally much greater than that of a sinusoidal motion of same frequency and amplitude. This produces, in addition to the oil compression from one dead point to the other, the occurrence of pressure variations of multiple frequency, the amplitude of which depends eventually on the relation

$$\frac{v-w}{v}$$

If v is almost equal to w, these pressure variations will be of considerable amplitude, and the rod controlled pistons will be practically directly subjected to the forces acting on the movable member. The efforts and factors of wear at the articulations of the rod-crank transmissions are increased and the crank-shaft has to be very strong to provide an appropriate factor of safety.

If, on the contrary, w is but a small fraction of v, the connection is too elastic and the shifts between the dead points of the rod-controlled pistons and those of the movable member, in case of unbalancing, are too wide; if the shift of the cranks articulated on the controlled pistons is greater than 90° when the movable member is at dead point, the working becomes unstable, and the crank-shaft falls out of step.

Similarly, if the ratio

$$\frac{\frac{1}{4}pv}{t}$$

is very high, the shifts between the dead-points in case of disturbance are small, but the energy provided by the controlled pistons, before and after the dead point is high, and the crank-shaft required for transmitting this work with an appropriate safety is very cumbersome. If, on the contrary, the ratio

$$\frac{\frac{1}{4}pv}{t}$$

is small there is a risk of the crank shaft falling out of step.

These different necessities are met by selecting in a suitable manner the afore-mentioned relations. By way of example if

$$\frac{v}{w}=2,$$

and

$$\frac{\frac{1}{4}pv}{t}=1,$$

the shifts of the cranks at the dead points of the movable member do not exceed 30°; in the worst of cases, i. e. in case of a complete spark failure, the fly-wheel provides the entire driving work.

On the other hand, if $v=2w$, the amplitude of the pressure variations of higher frequency is smaller in respect of p, and the hydro-elastic coupling of a motor-compressor with elevated compression and with a piston velocity approaching 20 metres per second does not require more than 4 crank-pins.

If the motor-compressor is single-acting, its working is practically the same, with the following exceptions, supposing that in a single-acting engine the working face of the working piston is directed to the left, and the working face of the compressor piston to the right:

1. The strains applied to the movable member during a single stroke from left to right, that is an expansion stroke, are different from those during a stroke from right to left, namely a compression stroke.

2. The energy accumulated at the end of the expansion stroke is reduced, owing to the absence of the pneumatic recuperator, to the energy accumulated in the free space of the compressor, which is generally considerably smaller than the energy accumulated at the end of the compression stroke in the free space of the working cylinder. The hydro-elastic coupling enables a very simple working of the engine in these circumstances; it is sufficient to give the volumes v', V', w' slightly higher values than those of volumes v, V, w, so that the movable member is retained by the recuperator during the expansion stroke, and receives a thrust from said recuperator during the compression stroke, whereas the energy provided in this case, which is equal to $\frac{1}{2}(p'v'-pv)$, compensates the difference between the compression work in the working cylinder and the expansion work of the compressor cylinder.

Moreover the hydraulic recuperator may be combined with a pneumatic recuperator collecting, at the end of an expansion stroke, the necessary energy for producing further compression. In that case the volumes v, V, w are equal respectively to v', V', w', as in the double-acting engine.

The movable member of a single-acting engine is always possessed with a higher velocity at the middle of the expansion stroke than at the middle of the compression stroke. This causes the dead points of the movable member to be shifted at permanent normal working in respect to those of the controlled pistons; the dead point of the movable member, at the end of the compression stroke, is late, whereas it is in advance at the end of the expansion stroke. By selecting suitably the values of

$$\frac{v}{w}$$

and

$$\frac{\frac{1}{4}pv}{t},$$

these shifts may be reduced to a few degrees, and the working of the single-acting engine becomes thus almost similar to that of the double-acting engine, hereinbefore described. In permanent normal working the fly-wheel provides finally no work during a double stroke. In disturbed working, said fly-wheel provides the required supplement, while maintaining the strokes and the compressions at practically constant values.

An accessory device hereinafter described, permits an almost total elimination of the exchanges of energy between the fly-wheel and the movable member during the normal working of the engine, said fly-wheel intervening thus only in the occurrence of disturbances.

As explained above, the pressure on a controlled piston, during permanent working, rises from 0 to a maximum value p, when said piston passes from its dead point adjacent to the cylinder head to its opposite dead point. The object of the device hereinafter described is to balance said pressure by the reaction of an auxiliary hydraulic recuperator.

An engine, provided with controlled pistons and with such a device is illustrated in section in Figure 3 of the accompanying drawings.

This figure illustrates, similarly to Figure 1, at 4_3—4_4 and at 3_3—3_4, the bores connected respectively with the left and right heads of the recuperator cylinder, which is not illustrated in Figure 1; the pistons 5 and 6, moving in these bores, are keyed on rods 5_4, 6_4, which are movable inside guiding rings 5_5, 6_5 mortised at the ends of said bores. The spaces between the pistons and the guiding rings are filled with a compressible liquid and communicate respectively, for the pistons moving in the bores 4_3 and 4_4 with a container 18, and for the pistons moving in the bores 3_3 and 3_4, with a container 19, said containers being also filled with oil. These containers are provided with automatic feeding valves 20, 21, similar to the valves 16, 17 illustrated in Figure 2. When the pistons 5 and 6 move away from the heads of the bores 4_3, 4_4, they compress, towards the guiding rings, the liquid in the container 18, bringing its pressure from near to 0 to a value p''. Simultaneously the pressure on the opposite face of the pistons rises from 0 to p. The volume of the container 18 and the pressure p'' are selected in a manner that the value of the latter on the face of the piston turned towards the guiding ring should balance the pressure p exerted on the opposite piston. Similarly the volume of the container 19 is selected in a manner to balance the pressures on the pistons moving in the bores 3_3 and 3_4. Practically no strain is thus exerted on the pistons 5 and 6 as long as the dead points of the movable member coincide with those of the controlled pistons. The only force transmitted to the crank-pins of the shaft is the inertia of the members possessed with alternating motion. Moreover the auxiliary recuperators may be easily set to balance this force of inertia.

When the working is disturbed, the dead points of the movable member and of the controlled pistons are shifted; the controlled pistons are then subjected solely to the maximum working pressure at mid-stroke, which ensures the transmission of a certain permanent work from the fly-wheel to the movable member, or vice versa.

The auxiliary recuperators ensure the balancing except for a determined stroke of the movable member, that is for a determined velocity of same. Particularly, this balancing is not produced at the starting of the engine, when

the pressures existing in the principal recuperator are very low. In order to avoid abnormal strains on the transmission at the starting, an automatic device is provided for discharging the auxiliary recuperators. At normal working, the pressure in the auxiliary recuperator is in a determined relation

$$m=\frac{p''}{p}$$

with the pressure in the principal recuperator; the discharge is performed automatically as soon as the relation between the pressures in the auxiliary and principal recuperators rises above m. For that purpose the container 18 communicates with the head of the bore 43, that is with the principal recuperator, by means of bores 22 and 23, in which moves a differential piston, subjected on its face 24 to the pressure of the principal recuperator, on its face 25 to the pressure of the auxiliary recuperator, and on its annular face 26 to the feeding pressure, which is near to 0.

When the relation of the pressures in the auxiliary and principal recuperators exceeds the relation of the diameters of the faces 26 and 25, which is adapted to be equal to m, the differential piston is displaced upwards, and connects, by means of grooves 27, the auxiliary recuperator with the exhaust. The auxiliary recuperators are therefore automatically emptied at the start of the first revolution. The feeding valves subsequently insure a progressive filling. Their diameter being calculated in a manner, that the oil expelled at the first revolution takes some time before filling again the auxiliary recuperators.

What I claim is:—

1. In a two-stroke free piston engine, the combination comprising a working cylinder, a compressor cylinder, a rod, adapted to move freely inside said cylinders, a working piston and a compressor piston movable in said cylinders and keyed in tandem on said rod, a stabilizing device, comprising a rotatable shaft, a fly-wheel on said shaft, and means for elastically connecting said shaft with said free rod.

2. In a two-stroke free piston engine, the combination comprising a working cylinder, a compressor cylinder, a rod adapted to move freely inside said cylinders, a working piston and a compressor piston movable in said cylinders and keyed in tandem on said rod, a stabilizing device, comprising a rotatable shaft, a fly-wheel on said shaft, and means for elastically connecting said shaft with said free rod, said means comprising a hydraulic transmission device.

3. In a two-stroke free piston engine, the combination comprising a working cylinder, a compressor cylinder, a rod freely movable in said cylinders, a working piston and a compressor piston movable in said cylinders and keyed in tandem on said rod, a stabilizing device, comprising a rotatable shaft, a fly-wheel on said shaft, and means for elastically connecting said shaft with said free rod, said means comprising a cylinder, termed recuperator cylinder, a double-acting piston, termed recuperator piston, keyed on said free rod and movable inside said recuperator cylinder, subsidiary cylinders each communicating with one end of said recuperator cylinder, pistons in said subsidiary cylinders, rods connecting said pistons with said rotatable shaft, containers for a compressible liquid each connected with one end of the recuperator cylinder, and means for maintaining said containers, recuperator cylinders and subsidiary cylinders constantly filled with a compressible liquid, the volume of said recuperator cylinder and that of each of said subsidiary cylinders being such, that the volume swept by each face of the recuperator piston is at least equal to that swept by said rod-controlled pistons movable in said subsidiary cylinders communicating respectively with said faces of the recuperator piston, and the volumes of said containers being such, that the work produced on the recuperator piston, during a single stroke, by the expansion of the liquid compressed in the recuperator cylinder and by said rod-controlled pistons is approximately equal to the driving work per single stroke produced on the working piston of the engine.

4. In a two-stroke free piston engine, the combination comprising a working cylinder, a compressor cylinder, a rod freely movable in said cylinders, a double-acting working piston and a double-acting compressor piston movable in said cylinders and keyed in tandem on said rod, a stabilizing device, comprising a rotatable shaft, a fly-wheel on said shaft, a cylinder, termed recuperator cylinder, a double-acting piston, termed recuperator piston, keyed on said free rod and movable inside said recuperator cylinder, subsidiary cylinders of equal volumes, each connected with one end of said recuperator cylinder, pistons in said subsidiary cylinders, rods connecting said pistons with said rotatable shaft, containers of equal volumes for a compressible liquid each set in communication with one end of the recuperator cylinder, and means for maintaining said containers, recuperator cylinder and subsidiary cylinders constantly filled with a compressible liquid, the volume of said recuperator cylinder and that of each of said subsidiary cylinders being such, that the volume swept by each face of the recuperator piston is at least equal to that swept by said rod-controlled pistons movable in said subsidiary cylinders communicating respectively with said faces of the recuperator piston, and the volumes of said containers being such, that the work produced on the recuperator piston during a single stroke, by the expansion of the liquid compressed in the recuperator cylinder and by said rod controlled pistons is approximately equal to the driving work per single stroke produced on the working piston of the engine.

5. In a two-stroke free piston engine, the combination comprising a working cylinder, a compressor cylinder, a rod freely movable inside said cylinders, a working piston and a compressor piston movable in said cylinders and keyed in tandem on said rod, a stabilizing device, comprising a rotatable shaft, a fly-wheel on said shaft, a starting device, means for throwing said shaft in gear with said starting device, means for connecting said shaft elastically with said free rod, and means for controlling by said shaft the distributing devices of the engine.

6. In a two-stroke free piston engine, a hydroelastic transmission device comprising a recuperator cylinder, a recuperator piston in said cylinder connectible with the free piston of said engine, subsidiary cylinders each communicating with one end of said recuperator cylinder, pistons in said subsidiary cylinders connectible with a stabilizing device for the engine, containers for a compressible liquid each connected with one end of the recuperator cylinder and means for maintaining said containers, recuperator cylinder and subsid-

iary cylinders constantly filled with said compressible liquid.

7. In a two-stroke free piston engine, a hydro-elastic transmission device comprising a recuperator cylinder, a recuperator piston in said cylinder connectible with the free piston of said engine, subsidiary cylinders each communicating with one end of said recuperator cylinder, pistons in said subsidiary cylinders connectible with a stabilizing device for the engine, subsidiary recuperators, each connected with the end of said subsidiary cylinders opposite to that connected with the principal recuperator cylinder, containers for a compressible liquid each communicating with one end of said principal recuperator cylinder, means for maintaining said containers, principal recuperator cylinder, subsidiary cylinders and subsidiary recuperators constantly filled with said compressible liquid and means for automatically discharging said subsidiary recuperators when the relation of the pressures existing in said subsidiary recuperators and in the principal recuperator cylinder exceeds a predetermined value.

8. In a two-stroke free piston engine the combination comprising a working cylinder, a compressor cylinder, a rod freely movable in said cylinders, a single-acting working piston and a single-acting compressor piston, movable inside said cylinders and keyed in tandem on said rod, a stabilizing device, comprising a rotatable shaft, a fly-wheel on said shaft and means for elastically connecting said shaft with said free rod, said means comprising a cylinder, termed recuperator cylinder, a double-acting piston, termed recuperator piston, keyed on said free rod and movable inside said recuperator cylinder, subsidiary cylinders communicating each with one end of said recuperator cylinder, pistons in said subsidiary cylinders, rods connecting said pistons with said rotatable shaft, containers for a compressible liquid each communicating with one end of the recuperator cylinder, and means for maintaining said containers, recuperator cylinder and subsidiary cylinders constantly filled with a compressible liquid, the volume of said recuperator cylinder and that of each of said subsidiary cylinders being such that the volume swept by each face of the recuperator piston is at least equal to that swept by said rod controlled pistons movable in said subsidiary cylinders communicating respectively with said faces of the recuperator piston, and the volumes of said containers being such that the work produced on the recuperator piston, during a single stroke, by the expansion of the liquid compressed in the recuperator cylinder and by said rod controlled pistons is approximately equal to the driving work per single stroke produced on the working piston of the engine, and the volumes swept by the two faces of the recuperator piston, the volumes of said containers, and the volumes swept in the subsidiary cylinders, corresponding to said two faces of the recuperator piston, by said rod controlled pistons, being such that the difference of the work produced on both sides of the recuperator piston, during a single stroke, is sufficient to ensure the reverse motion of said rod, carrying the working and compressor pistons of the engine, during the compression stroke of said working piston.

9. In a two-stroke free piston engine, the combination comprising a working cylinder, a compressor cylinder, a rod freely movable in said cylinders, a working piston and a compressor piston movable inside said cylinders and keyed on said rod, a stabilizing device, comprising a rotatable shaft, a fly-wheel on said shaft, a hydro-elastic coupling between said shaft and said rod comprising a cylinder, termed recuperator cylinder, a double-acting piston, termed recuperator piston, keyed on said free rod and movable in said recuperator cylinder, subsidiary cylinders communicating each with one end of said recuperator cylinder, pistons moving in said subsidiary cylinders, rods connecting said pistons with said rotatable shaft, means for balancing the thrusts applied to said rod-controlled pistons by the pressure existing in said recuperator cylinder, containers for a compressible liquid, communicating each with one end of the recuperator cylinder, and means for maintaining said containers, recuperator cylinder and subsidiary cylinders constantly filled with a compressible liquid.

10. In a two-stroke free piston engine, the combination comprising a working cylinder, a compressor cylinder, a rod freely movable in said cylinders, a working piston and a compressor piston movable inside said cylinders and keyed on said rod, a stabilizing device, comprising a rotatable shaft, a fly-wheel on said shaft, a hydro-elastic coupling between said shaft and said rod comprising a cylinder termed recuperator cylinder, a double-acting piston, termed recuperator piston, keyed on said free rod and movable in said recuperator cylinder, subsidiary cylinders each communicating at one end with one end of said recuperator cylinder, pistons movable in said subsidiary cylinders, rods connecting said pistons with said rotatable shaft, containers, termed subsidiary recuperators, filled with a compressible liquid and each communicating with the end of one subsidiary cylinder situated opposite the end communicating with the principal recuperator cylinder, the volumes of said subsidiary recuperators being such with respect to the volumes swept by said rod controlled pistons that the thrusts applied to said pistons by the liquid compressed in said subsidiary recuperators balance, at normal working, the thrusts applied to these pistons by the pressure existing in the principal recuperator cylinder, as well as the inertia of the members possessed with alternating motion, said stabilizing device comprising moreover containers for a compressible liquid each communicating with one end of the principal recuperator cylinder, and means for maintaining constantly filled with a compressible liquid said containers, principal recuperator cylinder, subsidiary cylinders and subsidiary recuperators.

11. In a two-stroke free piston engine, the combination comprising a working cylinder, a compressor cylinder, a rod freely movable in said cylinders, a working piston and a compressor piston movable inside said cylinders and keyed on said rod, a stabilizing device comprising a rotatable shaft, a fly-wheel on said shaft, a hydro-elastic coupling between said shaft and said rod comprising a cylinder termed recuperator cylinder, a double-acting piston, termed recuperator piston, keyed on said free rod and movable in said recuperator cylinder, subsidiary cylinders, each communicating with one end of said recuperator cylinder, pistons movable in said subsidiary cylinders, rods connecting said pistons with said rotatable shaft, containers, termed subsidiary recuperators, connected with the end of said subsidiary cylinders opposite to that connected with the principal recuperator cylinder, means for automatically discharging said subsidiary re-

cuperators when the relation of the pressures existing in said subsidiary recuperators and in the principal recuperator cylinder exceeds a determined value, containers for a compressible liquid each communicating with one end of said principal recuperator cylinder, and means for maintaining said containers, principal recuperator cylinder, subsidiary cylinders and subsidiary recuperators constantly filled with a compressible liquid.

12. In a two-stroke free piston engine, the combination comprising a working cylinder, a compressor cylinder, a rod freely movable in said cylinders, a working and a compressor piston movable inside said cylinders and keyed on said rod, a stabilizing device, comprising a rotatable shaft, a fly-wheel on said shaft, a hydro-elastic coupling between said shaft and said rod, comprising a cylinder, termed recuperator cylinder, a double-acting piston, termed recuperator piston, keyed on said free rod and movable in said recuperator cylinder, two cylinder blocks, each comprising two bores with opposite heads, communicating at their ends adjacent to their heads respectively with the opposite ends of the recuperator cylinder, double-acting pistons in said cylinder blocks, two crank-pins on the rotatable shaft keyed at 180° to one another, rods connecting said pistons with said crank-pins, two containers for a compressible liquid, each connected with one end of the recuperator cylinder, ball-valves in said containers adapted to let the liquid into said containers and to prevent its outflow therefrom, a supply-pipe of compressible liquid at low pressure connected with said valves.

13. In a two-stroke free piston engine, the combination comprising a working cylinder, a compressor cylinder, a rod freely movable in said cylinders, a working piston and a compressor piston movable inside said cylinders and keyed on said rod, a stabilizing device comprising a rotatable shaft, a fly-wheel on said shaft, a hydro-elastic coupling between said shaft and said rod comprising a cylinder, termed recuperator cylinder, a double-acting piston, termed recuperator piston, keyed on said free rod and movable in said recuperator cylinder, two cylinder-blocks each comprising two bores with opposite heads, communicating at their ends adjacent to their heads respectively with the opposite ends of the recuperator cylinder, a rod in each of said cylinder-blocks movable in the bore thereof, pistons keyed on the ends of said rods, crank-pins keyed on said rotatable shaft, rods connecting said crank-pins with said piston-carrying rods; rings mounted at the ends of said bores opposite their heads and adapted to guide said piston-carrying rods, containers, termed subsidiary recuperators each connected with the ends opposite the heads of two opposite bores situated in different cylinder-blocks, a ball-valve in each of said subsidiary recuperators adapted to let the liquid into said recuperators and to prevent its outflow therefrom, containers for a compressible liquid each communicating with one end of the principal recuperator cylinder, ball-valves in said containers adapted to let the liquid into the containers and to prevent its outflow therefrom, a supply-pipe of compressible liquid at low pressure connected with the valves of said containers and subsidiary recuperators.

14. In a two-stroke free piston engine, the combination comprising a working cylinder, a compressor cylinder, a rod freely movable in said cylinders, a working piston and a compressor piston movable inside said cylinders and keyed on said rod, a stabilizing device comprising a rotatable shaft, a fly-wheel on said shaft, a hydro-elastic coupling between said shaft and said rod comprising a cylinder, termed recuperator cylinder, a double-acting piston, termed recuperator piston, keyed on said free rod and movable in said recuperator cylinder, two cylinder-blocks each comprising two bores with opposite heads, communicating at their ends adjacent to their heads respectively with the opposite ends of the recuperator cylinder, a rod in each of said cylinder-blocks movable in both the bores of the block, pistons keyed on the ends of said rods, crank-pins keyed on said rotatable shaft, rods connecting said crank-pins with said piston-carrying rods, rings mounted at the ends of said bores opposite their heads and adapted to guide said piston-carrying rods, containers, termed subsidiary recuperators each connected with the ends opposite the heads of two opposite bores situated in different cylinder-blocks, a ball-valve in each of said subsidiary recuperators adapted to let the liquid into said recuperators and to prevent its outflow therefrom, containers for a compressible liquid each communicating with one end of the principal recuperator cylinder, ball-valves in said containers adapted to let the liquid into the containers and to prevent its outflow therefrom, a supply-pipe of compressible liquid at low pressure connected with the valves of said containers and subsidiary recuperators, and means for automatically discharging said subsidiary recuperators when the relation of the pressures existing in these subsidiary recuperators and the principal recuperator cylinder exceeds a determined value, said means comprising a subsidiary bore in each cylinder-block, a differential piston in said bore comprising a large face, a small face, and an intermediate annular face, springs adapted to urge said differential pistons downwards, conduits connecting the large faces of said pistons with the principal recuperator cylinder, their small faces with the subsidiary recuperators, and their intermediate annular faces with the supply pipe of liquid at low pressure, the relation of the diameters of the large and small faces of said differential pistons being equal to the determined value of the relation of pressures existing in the principal and subsidiary recuperators, at which the latter are to be discharged.

15. In a two-stroke free piston engine, the combination comprising a working cylinder, a compressor cylinder, a rod freely movable inside said cylinders, a working piston and a compressor piston movable in said cylinders and keyed in tandem on said rod, a stabilizing device comprising a rotatable shaft, a fly-wheel on said shaft, and a centrifugal governor, and means for elastically connecting said shaft with said free rod.

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