Dec. 9, 1941. H. JÄNICKE 2,265,285

MEANS FOR STARTING FREE PISTON ENGINES

Original Filed May 17, 1934 2 Sheets-Sheet 1

Fig. 1

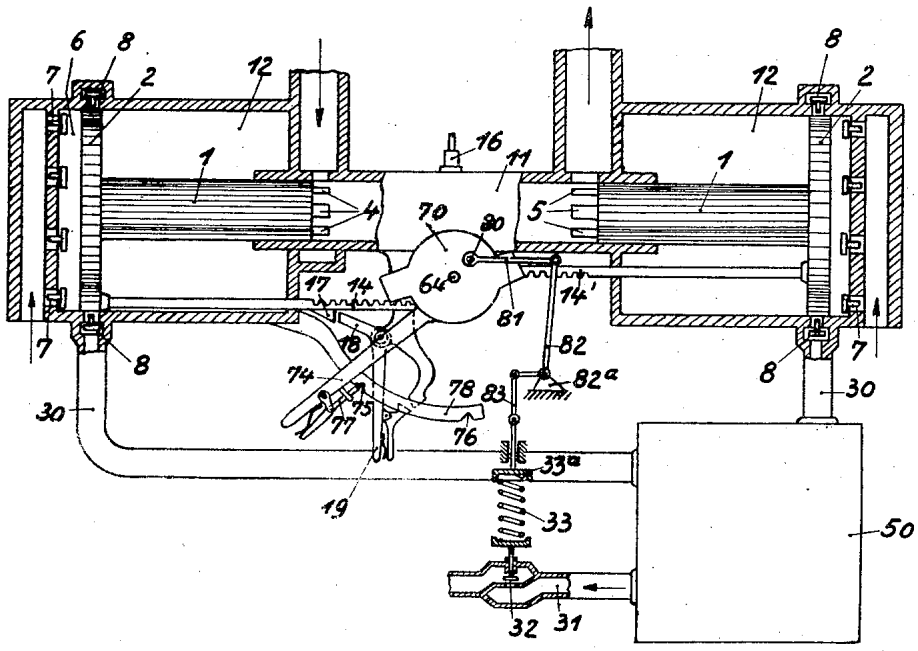

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Fig. 2

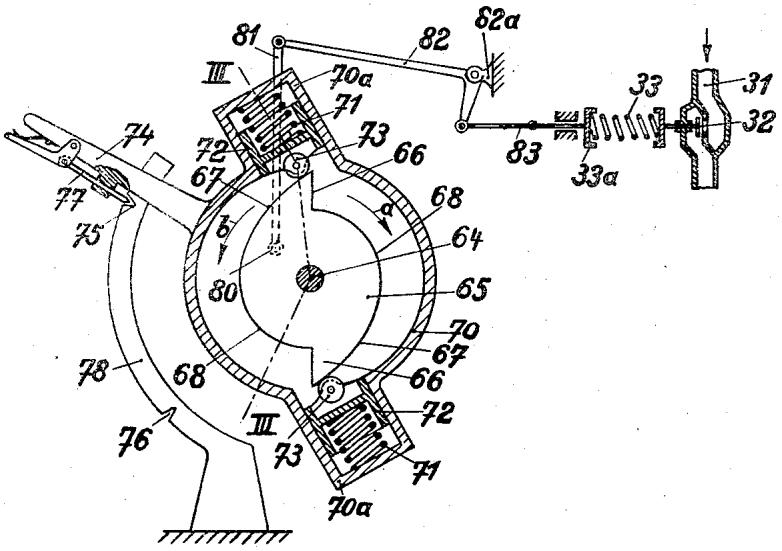
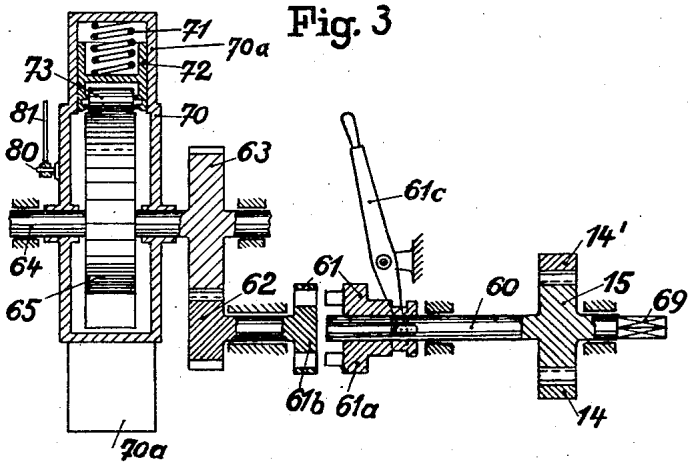


Fig. 3



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MEANS FOR STARTING FREE PISTON ENGINES

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Original application May 17, 1934, Serial No. 726,167. Divided and this application June 21, 1940, Serial No. 341,680. In Germany May 23, 1933

6 Claims. (Cl. 230—56)

My invention relates to means for starting free piston engines. It is an object of my invention to provide improved means for starting such engines.

This application is a division of my copending application for U. S. Letters Patent Ser. No. 726,167, filed May 17, 1934.

In free piston engines provided with springs connected to the reciprocating bodies of the engine and serving for storing, during the working stroke, the energy required for compressing the charge in the motor cylinder and feeding it back during the return stroke, the engine is started by placing the springs under tension by means of an outer force and releasing the reciprocating bodies. This arrangement, however, involves the drawback that the springs used as permanently operating energy storers must be very large and heavy.

It has been further proposed to provide an energy storing device comprising springs merely for starting purposes, the device being automatically coupled to the reciprocating bodies, while the springs are placed under tension, and being disengaged from these bodies after having re-fed the stored energy during the first compression stroke.

The principal difficulty, however, with the starting methods and devices hitherto known resides in that they impart to the reciprocating bodies only a single impulse, so that during the second part of the initial reciprocation, i. e. by the end of the first working stroke operating conditions must be provided which guarantee the further operation of the engine under ordinary conditions on the motor side as well as on the compressor side. With the spring starters hitherto known it is altogether impossible to obtain in all stages of a multi-stage free piston compressor already during the first compression stroke sufficiently high pressures for obtaining from the compressor during the subsequent return stroke the energy required for compressing the charge in the motor cylinder so that the engine will not come to a standstill. In engines of this kind means should be provided for extending the starting period from a plurality of strokes before changing over to normal operation.

It is an object of my invention to provide starting means which avoid the drawbacks discussed above and effect starting in a safe manner and with a minimum demand of energy.

In order to accomplish this I provide a mechanical energy storer coupled with the reciprocating bodies and charged with the necessary starting energy, this device reciprocating during at least the first stroke in such manner that only the storer receives, stores and feeds back the energy required for maintaining the reciprocation of the reciprocating bodies, while the energy consumer, for instance the compressor, reciprocates idle. Thereafter the receiving and feeding of energy is transferred gradually, i. e. during a plurality of strokes, from the storer to the energy consumer by gradually diminishing the energy to be stored and fed back by the storer, and correspondingly increasing the amounts of energy delivered to the energy consumer and re-fed from the consumer to the reciprocating bodies, until the storer is altogether released and merely runs idle. The gradual loading of the energy consumer may be carried out automatically in dependency upon the unloading of the storer, or vice versa, the storer may be gradually unloaded in an automatic manner in dependency upon the increasing loading of the energy consumer. After reaching normal operation, the starting storer may further reciprocate idle or may be disconnected from the reciprocating bodies.

Preferably the reciprocating bodies are arrested during the charging of the storers by means of locking devices, the starting stroke beginning after these locking devices have been released.

In order to avoid an energy discharge during the initial strokes and to reduce the amount of energy required for starting, blocking devices, for instance valves, may be inserted in the delivery pipe of the engine or between the stages of a multi-stage compressor, such blocking devices or valves being preferably opened gradually during the changing over to normal operation.

The amount of starting energy of the storing device may be further reduced by decreasing the resistances to be overcome during the starting stroke, for instance by reducing the gas volume to be compressed in the motor cylinder by discharging part of the charge by means of suitable controlling devices, preferably operating in dependency upon the charging over of the transfer of energy from the storing device to the energy consumer. If desired, a control of the fuel fed to the motor cylinder may be connected with these devices, for instance by adjusting the fuel delivery in such manner that a small amount of fuel is fed during starting, the amount of fuel being gradually increased during the changing over.

In the drawings affixed to this specification and

forming part thereof one embodiment of an engine provided with a starting device according to my invention is illustrated diagrammatically by way of example.

In the drawings,

Fig. 1 is an axial section of one embodiment of a free piston engine comprising a mechanical energy storing device,

Fig. 2 is an elevation, partly in section, of the mechanical storing device shown in Fig. 1, while

Fig. 3 is an axial section along the line III—III in Fig. 2.

In Figs. 1 to 3 corresponding parts are marked with the same reference numerals.

Referring to the drawings, and first to Fig. 1, the free piston engine includes two reciprocating bodies, each comprising a motor piston 1 and a compressor piston 2, reciprocating in opposite directions in a motor cylinder 11 and compressor cylinders 12, respectively. 4 and 5 are inlet and exhaust ports provided in the wall of the motor cylinder 11. The compressor cylinders 12 are provided with suction valves 7 and pressure valves 8. In order to secure exact opposite reciprocation, the reciprocating bodies are coupled with each other by means of a coupling device comprising toothed racks 14, 14' each connected to one of the compressor pistons 2, and a pinion 15 (shown in Fig. 3) engaging the toothed racks and rotatably secured in the engine casing (not shown). 16 is an inlet nozzle for delivering fuel into the cylinder 11. The reciprocating bodies can be arrested by means of a locking device comprising a latch 18 releasable by means of a spring loaded hand lever 19 and cooperating with a locking tooth 17 provided on the rack 14. With the position of the locking device shown in Fig. 1 the reciprocating bodies are locked approximately in their outer dead center positions.

The connecting pipes 30 are connected to the discharge pipe 31, leading to the consumer (not shown), through a container 50 which is so dimensioned as to be charged to normal operating pressure within a predetermined number of strokes following the start of the engine. A valve 32 loaded by a spring 33 is provided in the discharge pipe 31 in a manner such that it will open when normal pressure has been established in the container 50.

Referring now to Figs. 1, 2 and 3, the pinion 15 of the coupling gear has a shaft 60 to which the movable member 61 of a coupling is secured so as to be axially displaceable by means of a hand lever 61c. The other coupling member 61b is connected to a toothed wheel 62 engaging a toothed wheel 63, the shaft 64 of which carries a cam disc 65 comprising a plurality of cams 66 uniformly distributed along a circumference thereof. The step-down ratio of the toothed wheels 62 and 63 and the shape of the cams 66 are chosen in a manner such that the angle of rotation of the wheel 63 and the cam disc 65 corresponding to the maximum stroke of the reciprocating bodies is approximately equal to the angle corresponding to the arc occupied by the inclined portions 67 of the cam, cylindrical portions 68 being provided between the cams 67 occupying angles of at least the same magnitude. 70 is a casing rotatable about the shaft 64 of the disc 65 and provided with suitably arranged extensions 70a, in which springs 71 are arranged which press sliding members 72 provided with rollers 73 against the circumference of the cam disc 65. The force exerted by the springs 71 on the cam disc 65 tends to rotate the disc in the direction of the arrow *a*. The casing 70 can be rocked by means of a hand lever 74 provided with a spring-loaded latch 77 adapted to engage two recesses 75 and 76 formed in the arc-shaped portion of a stationary member 78, so that the casing 70 may be locked in two positions corresponding to the engagement of the latch 77 and the recesses 75 and 76, respectively. The position shown in Fig. 2 in which the latch 77 engages the recess 75, corresponds to starting, the other position, in which the latch 77 engages the recess 76, corresponds to normal running. 80 is a pin suitably secured to the casing 70 and connected to a member 33a, against which the spring 33 abuts, by means of suitably arranged links 81, 83 and a crank lever 82 pivoted to a stationary member 81a, so that the tension of the spring and thereby the force exerted by the spring on the valve 32 are varied in accordance with the position of the casing 70. Obviously this force is small when the casing is in its starting position shown in Fig. 2, and increases to a value balancing the normal pressure existing in the pressure chambers of the engine, when the casing is rocked into the normal running position, in which the latch 77 engages the recess 76.

The starting device shown in the drawings operates as follows:

In order to start the engine, the casing 70 is positioned as shown in Fig. 2, the latch 77 engaging the recess 75, and the coupling 61 is brought to engagement by suitably rocking the lever 61c. Thereafter the reciprocating bodies are brought into starting position, for instance by means of a hand crank applied to the square end 69 of the shaft 60, so that by suitable rotation the crank pin 15 is rotated and the racks 14, 14' are shifted to bring the free pistons into their outer dead centre positions. By this rotation of the shaft 60 the cam disc 65 is rotated in the direction of the arrow *b* shown in Fig. 2, so that the springs 71 are compressed by the cams 66. Now the free pistons are released, for instance by releasing the locking device 18, 19 shown in Fig. 1, and in consequence thereof the springs 71 rotate the cam disc 65 in the direction of the arrow *a* shown in Fig. 2, which is transferred to the free pistons by means of the coupling gear 14, 14', 15, so as to cause the pistons to approach each other and to compress the charge in the motor cylinder. At the end of this inward stroke the charge is ignited and during the following outward stroke the springs 71 are compressed again, the compressor running idle, since the spring 33 of the valve 32 is not compressed. After some starting strokes the casing 70 is slowly rocked in the direction of the arrow *b* (shown in Fig. 2) by means of the hand lever 74, so that the springs 71 are gradually unloaded.

Simultaneously with the displacement of the casing 70 the tension of the spring 33 of the pressure regulating valve 32 inserted in the supply piping is varied, through rods 81, 82 and 83, in such a manner that, beginning with a small starting value, this load gradually increases. In this manner the compressor starts to operate against a small resistance, i. e. it must take up only little energy, while in the further course of the starting process this work gradually increases, until finally the storer ceases to take up any energy, which is taken up completely by the compressor. When the other end position of the

casing 70 is reached, in which the latch 77 engages the recess 76, the engine is running in normal operating condition and the starting device runs idle, the rollers 73 engaging only the cylindrical portions 68 of the cam disc 65. After the changing over from starting to normal running the coupling 61 may be disengaged in order to stop the starting device.

In the device shown in the drawings the compressor is gradually loaded in dependency upon the unloading of the storing device. If desired, however, the storing device might be unloaded in dependency on the gradual loading of the compressors, for instance by rocking the casing 70 by means of a piston influenced by the gradually increasing pressure in the compressor chambers.

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 engine, comprising in combination, a free piston including a motor piston arranged for operation in a motor cylinder and a compressor piston arranged for operation in a compressor cylinder, a mechanical energy storer adapted to supply, during several initial strokes, to the free piston the energy required for maintaining the reciprocation thereof, means for gradually unloading said energy storer until it runs idle in such manner that it is partly unloaded during each stroke leading to a compression of the motor charge, but is reloaded, during each stroke allowing said charge to expand, up to a value which is somewhat lower than the value existing at the beginning of the preceding stroke, said energy storer comprising a spring, said spring abutting, on the one hand, against an abutment, and, on the other hand, against a movable part adapted to follow, at least during the initial strokes, the movement of the free piston, said abutment being so adjustable that the energy, which with each stroke following a stroke due to the action of the spring, is returned by the free piston to the spring, is gradually reduced, and means connected with the abutment, said last-named means adjusting the compressor, in dependency upon the adjustment of said abutment, for an output gradually increasing from zero to normal output in proportion to the unloading of the energy storer.

2. A free piston engine, comprising in combination, a free piston including a motor piston arranged for operation in a motor cylinder and a compressor piston arranged for operation in a compressor cylinder, a mechanical energy storer adapted to supply, during several initial strokes, to the free piston the energy required for maintaining the reciprocation thereof, means for gradually unloading said energy storer until it runs idle in such manner that it is partly unloaded during each stroke leading to a compression of the motor charge, but is reloaded, during each stroke allowing said charge to expand, up to a value which is somewhat lower than the value existing at the beginning of the preceding stroke, said energy storer comprising a spring, said spring abutting, on the one hand, against an abutment, and, on the other hand, against a movable part adapted to follow, at least during the initial strokes, the movement of the free piston, said abutment being so adjustable that the energy, which with each stroke following a stroke due to the action of the spring, is returned by the free piston to the spring, is gradually reduced, and means connected with the abutment, said last named means adjusting the compressor in dependency upon the adjustment of the abutment, for an output gradually increasing from zero to normal output in proportion to the unloading of the energy storer, means for temporarily locking the free piston in substantially its outermost dead center position with respect to the motor piston, and means for rendering said locking means inoperative.

3. In a free piston engine according to claim 1, a cam disc mounted for oscillation, means for coupling this cam disc with the free piston so that the cam disc performs the oscillatory movement corresponding, or directly opposed, to the reciprocation of the free piston, the spring abutment being so arranged that it may be rocked about the shaft of the cam disc, the spring abutting, on the one hand, against said abutment and, on the other hand, against a cam of the cam disc, said latter abutment being so provided that the force of the spring acting against the flank of the cam tends to rock the cam about the shaft of the cam disc.

4. In a free piston engine according to claim 1, a cam disc mounted for oscillation, means for coupling this cam disc with the free piston so that the cam disc performs this oscillatory movement corresponding, or directly opposed, to the reciprocation of the free piston, the spring abutment being so arranged that it may be rocked about the shaft of the cam disc, the spring abutting, on the one hand, against said abutment and, on the other hand, against a cam of the cam disc, said latter abutment being so provided that the force of the spring acting against the flank of the cam tends to rock the cam about the shaft of the cam disc, and means for coupling the cam disc with the free piston, said means including a disengageable coupling device.

5. In a free piston engine according to claim 1, a cam disc mounted for oscillation, means for coupling this cam disc with the free piston so that the cam disc performs the oscillatory movement corresponding, or directly opposed, to the reciprocation of the free piston, the spring abutment being so arranged that it may be rocked about the shaft of the cam disc, the spring abutting on the one hand, against said abutment and, on the other hand, against a cam of the cam disc, said latter abutment being so provided that the force of the spring acting against the flank of the cam tends to rock the cam about the shaft of the cam disc, said cam disc being so provided, that a part of its circumference is formed by the flank of the cam, and an adjacent part is formed by a circular portion about its rocking axis, the spring abutment arranged for oscillation about the axis of the cam disc being provided in a manner such that when the cam disc reciprocates, the abutment member transmitting the force of the spring onto the cam disc, reciprocates when, in the beginning of the starting operation, the abutment is in its one end position, solely along the cam flank, when the abutment is in a medium position, partly along the cam flank and partly along the circular portion, and when, at the end of the starting process, the abutment is in its other end position, only on the circular portion.

6. In a free piston engine according to claim 1, a valve variably loaded for closing provided in the outlet from the compressor and adapted to

afford passage only when the compressor end pressure has reached the amount corresponding to the load of the valve; means for connecting the rockable abutment of the energy storer spring with the member for loading the valve in a manner such that this loading is gradually increased up to an amount corresponding to the normal compressor end pressure, when the abutment is rocked from its initial position, corresponding to a fully loaded energy storer, into its end position, corresponding to a completely unloaded energy storer.

HERMANN JÄNICKE.