June 26, 1951 F. M. LEWIS 2,557,982

STARTING MEANS FOR FREE PISTON MACHINES

Filed Nov. 20, 1946 2 Sheets-Sheet 1

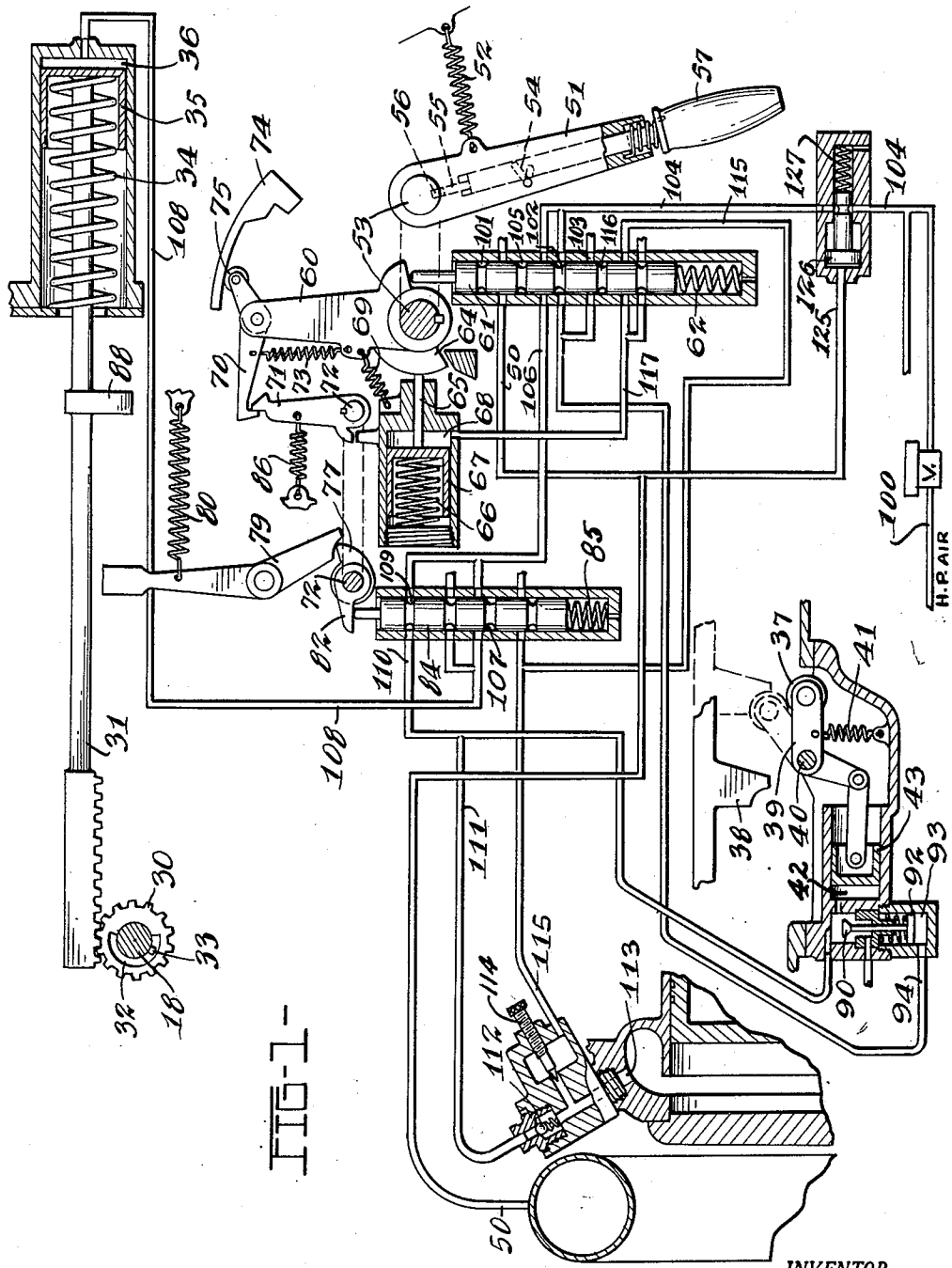


FIG-1-

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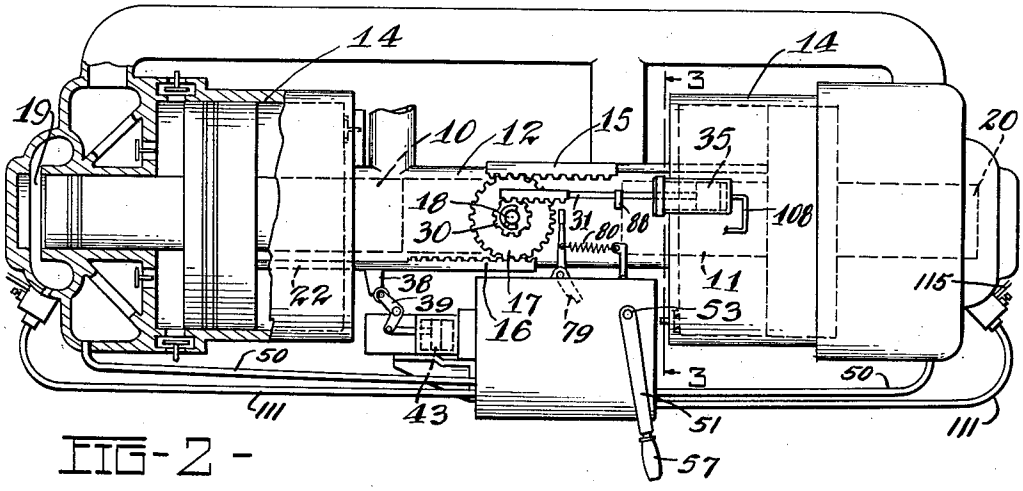


FIG-2-

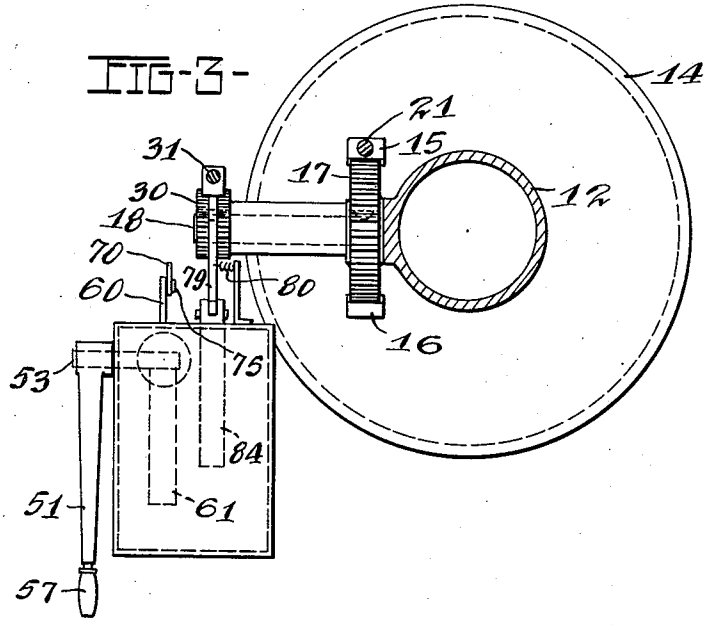


FIG-3-

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STARTING MEANS FOR FREE PISTON MACHINES

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9 Claims. (Cl. 60—14)

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This invention relates to a mechanism for starting free piston machines and has for its primary object to provide a device which is completely automatic in its performance of the necessary sequential operations, once the operator has moved a simple starting handle.

In starting a free piston engine operating either as a power gas generator or compressor it is necessary to exhaust or vent the compressor cylinders, to move the piston or pistons outwardly to their farthest position, then to lock the pistons in the outer position while accumulating a charge of high pressure starting air in the compressor space behind the pistons. When the starting air has reached a satisfactory pressure the piston locking device may be released so that the pistons fly in on a compression stroke and a charge of fuel is introduced into the firing cylinder between the pistons. The velocity imparted to the pistons on this initial stroke must be comparable to normal running so that pressures and temperatures of sufficient values will be generated in the combustion chamber. Combustion of the initial fuel charge causes an outward movement of the pistons and the starting mechanism must be released so that normal engine operation can be established.

The present invention comprises a novel mechanism for carrying out the foregoing operations, and is described in detail in the following specification, reference being had to the accompanying drawings in which:

Fig. 1 is a diagrammatic view of an apparatus constructed in accordance with the present invention; Fig. 2 is a diagrammatic side elevation, with parts in section of a free piston engine embodying the invention; and Fig. 3 is a section on line 3—3 of Fig. 2.

Referring to the drawings, the invention is shown as applied to a free piston engine having opposed pistons 10 and 11 operating in a power cylinder 12 and in compressor cylinders 14 and having extensions into direct bounce chambers 19 and 20. Depending on the desired output pressure of the machine the end of the pistons working in the compressor cylinders may be larger or smaller. The disclosure of the engine and compressor parts is illustrative for the purpose of describing the starter elements.

The pistons 10 and 11 are synchronized in the movements by synchronizing racks 15 and 16 each of which meshes with a common pinion 17 carried by a shaft 18 at a side of the engine. The racks may be attached to the pistons in any suitable manner and extend from the pistons outwardly through the ends of the respective compressor cylinders, being surrounded by suitable stuffing boxes.

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Mounted loosely on shaft 18 is a positioning pinion 30 which cooperates with a positioning rack 31. A portion of the hub of pinion 30 is cut away to form an arcuate recess 32 in which a dog 33 operates. Dog 33 is fixed to shaft 18 and hence follows the movement of that shaft as it is turned by the synchronizing pinion 17. At one extreme of its movement therefore, the position of dog 33 represents the innermost position of pistons 10 and 11 and at the other extreme, the outermost position of these pistons. With the positioning rack withdrawn, the positioning pinion assumes a relation to shaft 18 such that dog 33 is free to move without contacting either end of recess 32, but when the positioning rack is moved, dog 33 is engaged by the end wall of the recess 32, and shaft 18, synchronizing pinion 17 and synchronizing racks 15 and 16 are all moved so that pistons 10 and 11 are forced to their outermost position. The positioning rack 31 is urged to its withdrawn position by a spring 34 which bears against any suitable stationary guiding support and against a piston 35 disposed in an air cylinder 36. When air is admitted to cylinder 36 piston 35 moves outwardly in the cylinder and the positioning rack and pinion force the working pistons 10 and 11 to the outer position in their cylinders by acting through the synchronizing racks to which the pistons are connected.

Once the desired outer position of the pistons is attained, they may be locked in this position by a locking roller 37 movable into and out of the path of a dog 38 carried by each of the synchronizing racks, only one unit being shown in the interests of clarity. The roller is carried at an end of a bell crank lever 39 pivoted at 40 and is normally held out of the path of movement of dog 38 by a spring 41. An air cylinder 42 containing a piston 43 may serve as an actuator for the bell crank 39, so that whenever air is introduced into the cylinder 42, locking roller 37 will engage dog 38 and hold the pistons in their outer positions. The air cylinder 42 acts as a trigger to release the locking roller 37 as hereinafter described.

Prior to and during the movement of the working pistons 10 and 11 to the outer position, the compressor cylinders are vented through passages 59, and direct bounce chambers 19 and 20 are vented through passages 115. The valve control for these venting operations will be later described.

With the pistons locked in the outer position by locking roller 37 starting air is admitted to the compressor cylinders or to the space behind pis-

tons 10 and 11 and when a predetermined pressure has been attained the locking roller is released and the pistons allowed to move rapidly in on their first compression stroke.

The sequence of operations is initiated by a starting handle 51 normally held in inoperative position by a spring 52 and preferably mounted loosely on a shaft 53. Connection between the handle and its shaft may be established temporarily by any suitable means such as a pin and helical slot connection 54 between an internal plunger 55 and the body of the handle. Plunger 55 engages in a recess 56 in shaft 53 whenever the plunger is turned and thus forced longitudinally of the handle by the helical pin and slot connection 54. The screw connection is operated by rotation of a hand piece 57, only then may the handle 51 be used to turn shaft 53, so that accidental movement of the handle will not actuate the starting mechanism.

When shaft 53 is turned by the operating handle, an arm 60 keyed to the shaft is turned and moves a first control valve 61. Valve 61 is normally held in one position by a spring 62 which is thus compressed.

A stop extension 64 is formed on the arm 60 and the rotation of the arm continues until a pin 65 can move forwardly under the extension 64. The pin is urged to its locking position by a spring 66 acting on a piston 67 to which the pin is connected. Piston 67 works in an air cylinder 68 so that when air under pressure is permitted to enter the cylinder the piston 67 will act to retract locking pin 65. A spring 69 biases arm 60 to its initial inoperative position and the arm is thus returned to that position when pin 65 is withdrawn from under the stop extension 64.

Arm 60 carries a pivoted pawl 70 at its outer end which normally engages a detent arm 71 fixed to a shaft 72. Thus, as arm 60 is rotated with its carrying shaft 53, detent 71 moves with it and rotates shaft 72. A spring 73 urges the pawl to engaging position, but the engagement is broken towards the end of the travel of arm 60 by a stationary cam 74 which engages a follower 75 on the pawl arm. The position of the pawl is, of course, determined by the contour of cam 74 and the point of release may thus be readily changed. The pawl must remain connected to its detent 71 long enough so that shaft 72 rotates to a point such that a locking cam 77 carried by the shaft can move under an associated locking lever 79. Locking lever 79 is urged to locking position by a spring 80 and when in such position holds shaft 72 against returning to its original position. Shaft 72 also carries, intermediate its operating and locking ends, a valve operating arm 82 which overlies any suitable air circuit control device such as a multiple piston type valve 84. The air circuit control valve 84 is urged to one position by a spring 85 and is moved against this spring to another position by arm 82. The valve will remain up by the force of spring 85 until shaft 72 is permitted to return to its original position by reason of the release of locking lever 79. A spring 86 acting on detent 71 may conveniently be employed to return shaft 72 to its initial position and thus overcome spring 85 and move valve 84 down to the position shown. Locking lever 79 is released by a dog 88 carried by piston positioning rack 31 and so spaced along its length that release of lever 79 takes place only when and if the main pistons have assumed their desired outer position.

A trigger dump valve 90 is provided as a fast acting vent for air cylinder 42. This valve is normally held open by air acting on a valve control piston 92 in a control cylinder 93, air being taken from a pipe 94.

It will thus be seen that movement of the starting handle alters the position of valves 61 and 84. These valves control the passage of compressed air from a suitable source 100, and further control the venting of various chambers. As valve 61 moves down, the compressor cylinders are vented through passage 50 and valve passage 101 to atmosphere. Next, trigger dump valve 90 is closed since pipe 94 and the valve control cylinder 93 are vented through bypass passage 102 and orifice 103 in valve 61. The dump valve being closed, the trigger cylinder 93 is ready to receive air.

Air from source 100 enters through line 104, valve passage 105, line 106, through passage 107 in valve 84, pipe 108 to piston positioning cylinder 36. The piston positioning rack thus begins to move the main pistons to their outermost position through the medium of positioning pinion 30, dog 33, shaft 18, synchronizing pinion 17 and the synchronizing racks 15 and 16 to which the pistons are connected. As the positioning rack 31 moves, its dog 88 abuts against the end of locking lever 79 forcing the latter away from its locking engagement with cam 77. When such engagement is released, shaft 72 flies back to its initial position under the influence of spring 86 and valve 84 is depressed by finger 82. Should the pistons stick in their cylinders, the sequence of operation will be interrupted since lever 79 will not be tripped.

A parallel connection is established for pipe 106 through passage 109 in valve 84, pipe 110 to trigger cylinder 42. Piston 43 thus moves outwardly of its cylinder and forces roller 37 into engagement with dog 38 on one of the synchronizing racks. The pistons are thus locked in their outer position and will remain so as long as air under pressure is trapped in the cylinder 42. If more than one trigger unit is used, a single dump control valve may be employed for the entire system.

High pressure air from line 110 passes also through a branch connection 111, past a check valve 112, through passage 113 to accumulate in the space behind the main pistons 10 and 11. A needle valve or similar bleeding device 114 is interposed between passage 113 and a takeoff line 115. Line 115 communicates with the interior of locking pin control cylinder 68 through valve passage 116 in valve 61 and line 117. Thus, as high pressure air accumulates behind the main working pistons, a controlled portion of the air passes bleed valve 114 to enter cylinder 68. When the pressure in cylinder 68 is sufficient to overcome spring 66, the piston 67 in this cylinder is moved and the locking pin 65 is thus withdrawn from contact with shoulder 64. Arm 60 is thus freed.

As arm 60 is released, it moves quickly away from the position in which it has maintained valve 61 depressed. In so moving a connection is established between air source 100, connection 104, a valve passage 102, connection 94 and the trigger dump valve control cylinder 93. The dump valve 90 is thus opened and air vented from all of the piston locking cylinders 42. The sudden release of air permits spring 41 to thus remove roller 37 from engagement with the dog 38 on the synchronizing rack. Since this connection is broken suddenly, the high pressure starting air which has accumulated behind the

main pistons 10 and 11 is free to force these members together on a compression stroke. Fuel is injected into the working cylinder at a suitable time and in a suitable quantity by the usual injection mechanism which is not shown. The engine thus fires and runs normally thereafter under controls which form no part of the present invention. Should the engine fail to start, the operation above set forth is repeated. Once normal engine operation occurs, air from the compressor cylinder is led through the connection 125 to a shut-off valve 126 in the high pressure air line. After the engine operation has been stopped, and it is desired to start again, the cylinder of this shut-off is vented by initial movement of valve 61 which opens pipe 125 to atmosphere through passage 101 and the source 100 is again available to start the engine, valve 126 being moved to open position by a spring 127.

To summarize the operation briefly; the operator moves control handle 51 to the left in Fig. 1 thus altering the position of valves 61 and 84. Valve 84 causes air to be led to piston positioning cylinder 36 and the pistons thus are moved to their outermost positions. As this position is reached, valve 84 is restored to its normal position by release of locking cam 77 and air is accumulated in the space behind main pistons 10 and 11 through connections 111. The pistons are locked in their outer positions by air entering cylinder 42 past valve 61. A certain part of the air flowing in connection 111 is bled off to locking cylinder 68 and when a predetermined pressure is reached in this cylinder, locking pin 65 is withdrawn and valve 61 restored to its original position. This restoration admits air to the dump valve control cylinder, releasing the locking connection to the synchronizing rack dog 38 and the pistons fly together on an initial compression stroke.

While the invention has been described in connection with a specific form and disposition of the parts, it should be expressly understood that equivalent mechanisms may be substituted for those shown and that the drawings are purely illustrative. Various modifications and changes will suggest themselves to those skilled in the art, and such modifications and changes may be made without departing from the invention as defined in the appended claims.

What I claim is:

1. A fluid operated starting device for a free piston engine comprising, a positioning pinion operatively associated with the engine pistons, a positioning rack adapted to rotate said pinion and move said pistons to an outer starting position, an air cylinder having a piston therein connected to move said positioning rack, means to supply air to said air cylinder to cause piston movement, means responsive to piston movement to cut off said air supply when said pistons have reached starting position, means to lock said pistons in starting position, the operation of said last means being responsive to a predetermined movement of said piston positioning rack, means to introduce starting air behind said pistons, and means responsive to a predetermined starting air pressure to release said locking means, whereby said engine pistons are caused to make a substantially normal compression stroke by expansion of the starting air.

2. A fluid operated starting device for a free piston engine the pistons of which are connected by synchronizing racks meshing with a common synchronizing pinion, a positioning pinion operatively associated with the shaft of said synchronizing pinion, a positioning rack adapted to move said positioning pinion, and thereby to move said engine pistons to an outer starting position, pneumatic means to actuate said positioning rack, means operated by said rack to render said pneumatic means inoperative when said engine pistons have reached starting position, fluid operated means to lock said engine pistons in starting position, means to introduce starting air behind said pistons, and means responsive to a predetermined starting air pressure to release said locking means, whereby said engine pistons are caused to make a substantially normal compression stroke by expansion of the starting air.

3. A fluid operated starting device for a free piston engine comprising, piston positioning means to move the engine pistons to an outer starting position, means to lock said pistons in starting position, a starting handle, interconnected valves moved out of normal position to starting position by said handle, but adapted to be restored separately to normal position, a source of fluid under pressure, fluid connections between said source and said piston positioning means made by one of said valves in starting position, means carried by said piston positioning means to restore said last named valve to normal position and interrupt said fluid connection when the engine pistons reach starting position, means to introduce starting air behind said pistons when in starting position, and means responsive to a predetermined starting air pressure to release said locking means, whereby said pistons are caused to make a substantially normal compression stroke by expansion of the starting air.

4. A fluid operated starting device for a free piston engine comprising, piston positioning means to move the engine pistons to an outer starting position, means to lock said pistons in starting position, a starting handle, interconnected valves moved out of normal position to starting position by said handle, but adapted to be restored separately to normal position, a source of fluid under pressure, fluid connections between said source and said piston positioning means made by one of said valves in starting position, means carried by said piston positioning means to restore said last named valve to normal position and interrupt said fluid connection when the engine pistons reach starting position, connections between said air source and a space behind said pistons established when said last named valve is restored to normal position while the other said valve remains in starting position to introduce starting air behind said pistons in starting position, and means responsive to a predetermined starting air pressure to release said locking means whereby said pistons are caused to make a substantially normal compression stroke by expansion of the starting air.

5. A fluid operated starting device for a free piston engine comprising, piston positioning means to move the engine pistons to an outer starting position, means to lock said pistons in starting position, a starting handle, interconnected valves moved out of normal position to starting position by said handle, but adapted to be restored separately to normal position, a source of fluid under pressure, fluid connections between said source and said piston positioning means made by one of said valves in starting position, means carried by said piston positioning means to

restore said last named valve to normal position and interrupt said fluid connection when the engine pistons reach starting position, connections between said air source and a space behind said pistons established when said last named valve is restored to normal position while the other said valve remains in starting position to introduce starting air behind said pistons in starting position, means responsive to a predetermined starting air pressure to restore the other said valve to normal position, and means operated in response to said last named valve restoration and in response to a predetermined starting air pressure to release said locking means, whereby said pistons are caused to make a substantially normal compression stroke by expansion of the starting air.

6. A fluid operated starting device for a free piston engine the pistons of which are connected by synchronizing racks meshing with a common synchronizing pinion, a positioning pinion operatively associated with the shaft of said synchronizing pinion, a positioning rack adapted to rotate said pinion and move said pistons to an outer starting position, a piston positioning air cylinder having a piston therein connected to move said positioning rack, means to lock said pistons in starting position, a starting handle, interconnected valves moved out of normal position to starting position by said handle, but adapted to be restored separately to normal position, a source of fluid under pressure, fluid connections between said source and said piston positioning air cylinder made by one of said valves in starting position, means carried by said piston positioning rack to restore said last named valve to normal position and interrupt said fluid connection when the engine pistons reach starting position, means to introduce starting air behind said pistons in starting position, and means responsive to a predetermined starting air pressure to release said locking means, whereby said pistons are caused to make a substantially normal compression stroke by expansion of the starting air.

7. A fluid operated starting device for a free piston engine the pistons of which are connected by synchronizing racks meshing with a common synchronizing pinion, a positioning pinion operatively associated with the shaft of said synchronizing pinion, a positioning rack adapted to rotate said pinion and move said pistons to an outer starting position, a piston positioning air cylinder having a piston therein connected to move said positioning rack, means to lock said pistons in starting position, a starting handle, interconnected valves moved out of normal position to starting position by said handle, but adapted to be restored separately to normal position, a source of fluid under pressure, fluid connections between said source and said piston positioning air cylinder made by one of said valves in starting position, means carried by said piston positioning rack to restore said last named valve to normal position and interrupt said fluid connection when the engine pistons reach starting position, connections between said air source and a space behind said pistons established by restoration of said last named valve to normal position while the other said valve remains in starting position to introduce starting air behind said pistons in starting position, means responsive to a predetermined starting air pressure to restore the other said valve to normal position, and means operated in response to a predetermined starting air pressure by said last named valve restoration to release said locking means whereby said pistons are caused to make a substantially normal compression stroke by expansion of the starting air.

8. A fluid operated starting device for a free piston engine the pistons of which are connected by synchronizing racks meshing with a common synchronizing pinion, a positioning pinion operatively associated with the shaft of said synchronizing pinion, a positioning rack adapted to rotate said pinion and move said pistons to an outer starting position, a piston positioning air cylinder having a piston therein connected to move said positioning rack, means to lock said pistons in starting position, a starting handle, interconnected valves moved out of normal position to starting position by said handle, but adapted to be restored separately to normal position, a source of fluid under pressure, fluid connections between said source and said piston positioning air cylinder made by one of said valves in starting position, means carried by said piston positioning rack to restore said last named valve to normal position and interrupt said fluid connection when the engine pistons reach starting position, connections between said air source and a space behind said pistons established by restoration of said last named valve to normal position while the other said valve remains in starting position to introduce starting air behind said pistons in starting position, means responsive to a predetermined starting air pressure to restore the other said valve to normal position and means operated in response to a predetermined starting air pressure by said last named valve restoration to release said locking means whereby said pistons are caused to make a substantially normal compression stroke by expansion of the starting air.

9. The combination in accordance with claim 3, and engine actuated means to cut off said source of fluid during engine operation.

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