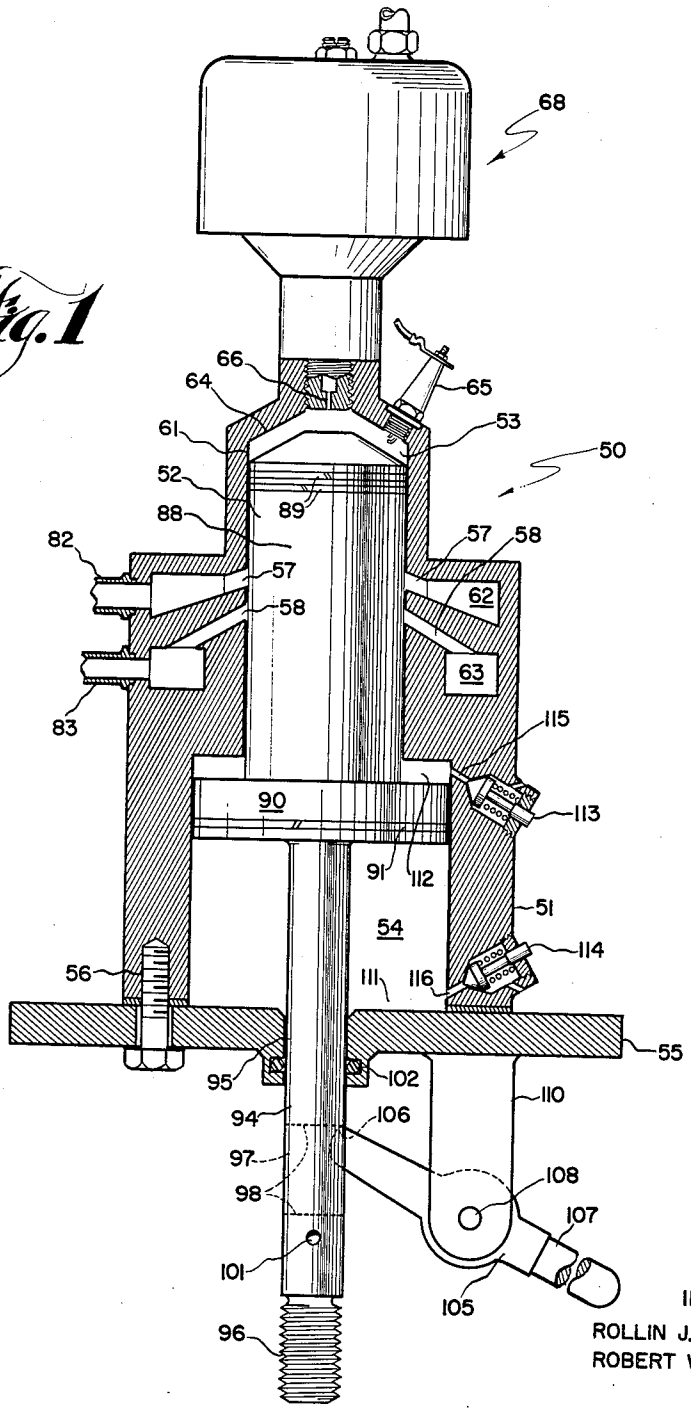
July 17, 1962 R. J. McCRORY ET AL 3,044,452

STARTING DEVICE

Original Filed May 16, 1958 2 Sheets-Sheet 1

Fig. 1



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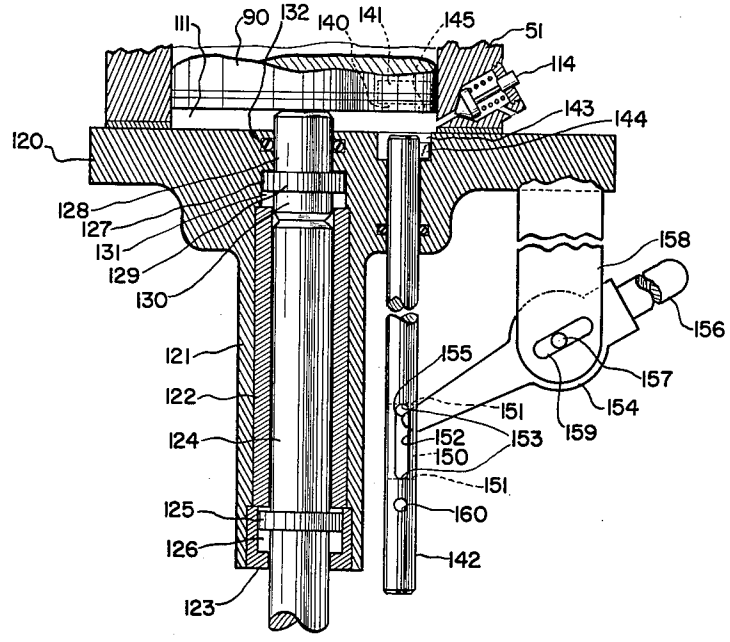
By Gray, Mase and Dunson, Attorneys

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Fig. 2



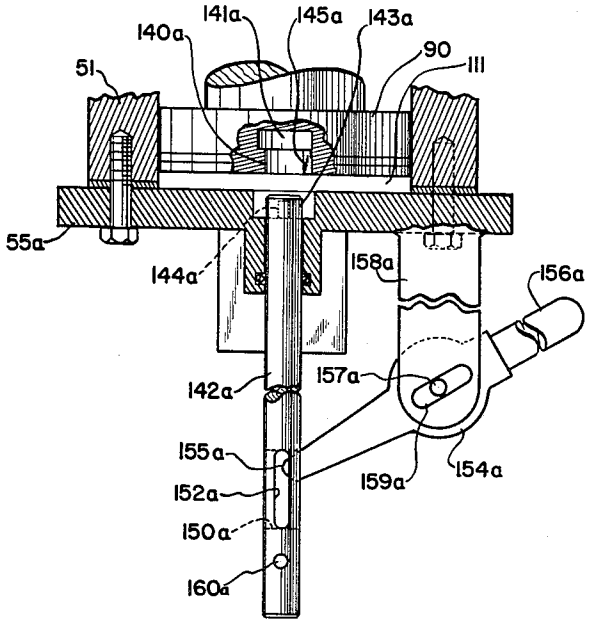


Fig. 3

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3,044,452
STARTING DEVICE

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Original application May 16, 1958, Ser. No. 735,795, now Patent No. 2,959,159, dated Nov. 8, 1960. Divided and this application Mar. 16, 1960, Ser. No. 15,464
2 Claims. (Cl. 123—7)

This invention relates to a starting device for internal-combustion engines of the free-piston type, and, particularly, to a starting device adaptable to free-piston engines having various constructions for meeting the requirements of different types of driven devices. This is a divisional application for our copending application entitled "Free-Piston Internal-Combustion Apparatus," Serial No. 735,795, filed May 16, 1958, now Patent No. 2,959,159.

Free-piston engines are those in which the reciprocating motion of the piston, or pistons, is not mechanically restrained by the conventional connecting rod and crankshaft. Although most of the multipiston free-piston engines have mechanical connections between the pistons to maintain the proper phasing between the pistons, the end positions of the piston stroke are not established by the mechanical connections. The end positions of the piston stroke are established on each engine cycle by the energy released to the work article or load that is being driven by the engine and the energies of the combustion process and the resilient rebound system.

Conventional starting mechanisms do not utilize the features of a pneumatically controlled free-piston engine. The starting mechanism herein described is especially adaptable to a free-piston engine having a pneumatic rebound system. It will be seen from the description to follow, that this invention may be utilized in a variety of constructions of free-piston engines and is adaptable, for example, to engines for acivating compressors, tools, anvils, etc.

Briefly described, the starting mechanism comprises a support member fastened to the frame of an internal-combustion engine having a reciprocating free piston. A starting rod reciprocable in the frame is in communication with the piston and has a longitudinal slot in its side. A lever, pivotally supported on the support member has a handle at one end and a tip at the opposite end. When the lever is rotated the tip intersects the path of the slot in the reciprocating starting rod. Operating the handle rotates the tip engaged in the slot so as to reciprocate the piston and start the engine.

One feature of the present invention is a free-piston-engine starting mechanism by which a lever means is used to activate a free-piston engine having pneumatic rebound.

Another feature of the present invention is a starting device particularly suited for the reciprocating motion of a free-piston engine.

Other features and objects of the invention will be apparent from the attached drawings and the following description.

In the drawings:

FIG. 1 is an elevational, partly sectioned view of a free-piston engine having the starting mechanism of this invention;

FIG. 2 is a sectional, elevational view of a portion of a free-piston engine, showing a form of starting mechanism in connection therewith; and

FIG. 3 is a sectional, elevational view of another form of starting mechanism in accordance with this invention.

Referring to FIG. 1, the free-piston engine **50** comprises a block or frame **51** and a free piston **52** reciprocal therein. The frame **51** is provided with an internally bored combustion cylinder **53** and provided in communication therewith is a coaxial greater-diameter compression cylinder **54**. Closing the compression cylinder **54** at the end opposite to the combustion cylinder **53** is a base or mounting plate **55** fastened to the block **51** by suitable means, such as screws **56**. The combustion cylinder **53** is provided with exhaust ports **57** and intake ports **58** at spaced intervals along the cylinder wall **61** thereof. An exhaust manifold **62** encircles the combustion cylinder **53** having an annular form and is cast integrally with the frame **51**. Communication is provided between the exhaust manifold **62** and the combustion cylinder **53** by means of the exhaust ports **57**.

An annular intake manifold **63** is also provided in the frame **51** at a position further removed from the head end of the combustion cylinder. Communication is established between the combustion cylinder **53** and the intake manifold **63** by intake ports **58**.

The head end **64** of the combustion cylinder **53** is provided with ignition means **65**, such as a spark plug. Centrally positioned on the axis of the combustion cylinder **53**, at the head end **64** is a fuel nozzle **66** of a fuel injector, designated generally as **68**.

The exhaust manifold **62** and the intake manifold **63** are provided with communication to the atmosphere by exhaust port **82** and air inlet **83**.

As shown in FIG. 1, piston **52** is constructed with a minor-diameter portion **88** that is adapted to reciprocate in the combustion cylinder **53**, being sealed with the cylinder wall **61** by means of piston rings **89**. At the opposite end, piston **52** is formed in a greater-diameter portion **90** which is adapted to reciprocate in a compression cylinder **54** and is sealed in connection therewith by means of the piston ring **91**.

The free-piston engine **50** shown in FIG. 1 is provided with a piston rod **94** fastened to or formed integrally with the piston **52** and adapted to protrude through the base plate **55** and reciprocate therein through a bushing **95** with a seal **102**. The piston rod **94**, shown in FIG. 1, is constructed with a threaded end **96** to receive and hold a reciprocating tool.

Piston rod **94** is also provided with a starting slot **97** passing diametrically therethrough and having oppositely disposed perpendicular ends **98**. A key bore **101** is provided through piston rod **94** at a position adjacent to and below the lower edge of slot **97**.

To cooperate with the starting slot **97**, a starting lever **105** is provided. The lever **105** is formed with a lever tip **106** and a handle **107** and is supported on a pivot **108**. Pivot **108** is located in the end of a starting lever trunnion **110**.

Compression cylinder **54** is divided by the major-diameter portion or piston flange **90** into a bounce chamber **111** on the one side (lower side in FIG. 1) and a counterchamber **112** on the other side (upper side in FIG. 1) since, in FIG. 1, the piston **52** is shown at its upper most head end position, bounce chamber **111** is at its maximum volume, while counterchamber **112** is at minimum volume.

Near each end of the compression cylinder **54**, pressure-relief valves **113** and **114** are provided in the frame **51**. Relief valve **113** is in communication with counterchamber **112** by means of a conduit **115**. Relief valve **114** is in communication with bounce chamber **111** by means of a conduit **116**.

In order to start the engine **150**, the tip **106** of lever **105** is inserted in slot **97**. The handle **107** is then drawn upward which draws the piston down toward the mounting plate **55**. This draw-down operation preparatory to starting is always necessary in a free-piston engine having

pneumatic rebound, because the engine always stops with the piston at a position above bottom or lowest piston position. Having been at rest any length of time, combustion conditions in the combustion cylinder **53** will no longer be suitable for ignition, and the engine cannot be started until the piston **52** is brought to near the lowest position.

Once the piston has been drawn to the lower position, the handle **107** is pushed briskly downward, impelling the piston upward on the first compression stroke. Sufficient stroke is given the handle **107**, when it is pushed downward, to carry the arc of tip **106** beyond the upper surface **98** of slot **97**, and therefore free of piston rod **94**, so that the first downward combustion stroke takes place free of the starting mechanism.

The free-piston engine shown in FIG. 1 activates a reciprocating tool. In this instance the piston rod **94** protruding through the base plate **55** is also used as a starting rod for the starting mechanism. In instances where the free-piston engine is used to drive an impact tool, a piston rod is unavailable as a starting rod. Such a device is shown in FIG. 2 where the lower output end of a free-piston engine **50** is integrally constructed with an impact tool.

In this construction, engine frame **51** is fastened to a base plate **120** which forms, in association with piston **90**, the bounce chamber **111**. Base **120** is constructed with a downwardly projecting cylindrical tool holder housing **121**. A tool holder **122** and a retainer **123** support and retain a a tool **124** within the tool holder housing **121**.

Tool **124** is provided with a flange **125** which controls reciprocation by means of its operation in a recess **126** of retainer **123**. The tool **124** is positioned contiguous to and below an anvil **127** comprising a striker portion **128**, a flange portion **129** of larger diameter, and a hammer portion **130**. Flange portion **129** is constructed to control the reciprocation of anvil **127** within the confines of an annular recess **131** which is formed in the base **120**. Suitable sealing means **132** is provided between the anvil **127** and base **120** to seal chamber **111** from the atmosphere.

The piston **90** is provided with a bore **140** having an annular recess **141**. A starting rod **142** is positioned for reciprocation in base plate **120**. Base plate **120** is counterbored to provide an annular recess **143** which receives a lug **144** that radially projects from the side of the starting rod **142** at its upper end. A longitudinal groove **145** connects the bottom surface of the piston **90** with recess **141** and is of a width and depth necessary to conveniently pass lug **144**. The remainder of the starting mechanism, which is in many respects the same as that for the reciprocating tool shown in FIG. 1, is supported from the base plate **120**.

Rod **142** is provided with a starting slot **150** passing diametrically therethrough and having oppositely disposed perpendicular ends **151**. In addition to slot **150**, a second slot **152** is provided in starting rod **142** disposed perpendicular to the first slot **150** and also having oppositely disposed perpendicular ends **153**.

To cooperate with the starting slots **150** and **152** a starting lever **154** is formed with a lever tip **155** and a handle **156** and is supported on a pivot **157**. Pivot **157** is located in the end of a starting lever trunnion **158**. The trunnion **158** is constructed with a slot **159** for longitudinal movement of pivot **157**.

Key bore **160** is provided on the starting rod **142** below the slots **150** and **152**.

Referring to FIG. 3, when free-piston engine **50** is constructed as an air compressor, the center position of the piston **90** may be constructed to receive a starting rod **142***a*. The construction is very similar to that of FIG. 2 except for location of some of the parts.

The piston **90** is provided with a bore **140***a* having an annular recess **141***a*. An axially disposed starting rod **142***a* is positioned for reciprocation in the base **55***a*. Base plate **55***a* is counterbored on its longitudinal axis to provide an annular recess **143***a* which receives a lug **144***a* that radially projects from the side of starting rod **142***a* at the upper end. A longitudinal groove **145***a* connects the bottom surface of piston **90** with recess **141***a*. Groove **145***a* is of a width and depth necessary to conveniently pass lug **144***a*.

The starting mechanism of FIG. 3 is very similar to that of FIG. 2. The trunnion **158***a* is supported from the base plate **55***a* and has a slot **159***a* for longitudinal movement of pivot **157***a*. Two slots **150***a* and **152***a* are provided in starting rod **142***a* and are perpendicular to each other. Below the slots **150***a* and **152***a*, a key bore **160***a* is provided. A lever **154***a*, having a handle **156***a* at one end and a tip **155***a* at the opposite end, is supported on pivot **157***a*.

As previously described for the operation of free-piston engine **50** as a reciprocating tool, it is necessary for piston **90** to be drawn to its lower position, shown in FIGS. 2 and 3, preparatory to engine starting. To accomplish this, the starting rod **142** is raised into bore **140** by manipulation of handle **156**. In order to align the lug **144** for passage through slot **145**, starting rod **142** is rotated by means of key bore **160** ninety degrees. This aligns extractor slot **152** with lever **154** and permits the entrance of tip **155** therein. With pivot **157** at the lower position in slot **159**, starting rod **142** may be controlled and inserted in bore **140**. With starting rod **142** positioned within bore **140**, tip **155** is removed from slot **152**, permitting rotation of starting lever **142** ninety degrees. This operation of rotation moves lug **144** circumferentially in recess **141**, securing the starting rod **142**. With tip **155** engaged in slot **150**, handle **156** may be manipulated to draw the piston down to position ready for the first upward compression stroke. With piston **90** at its lower position, starting rod **142** is rotated until lug **144** aligns with slot **145** and tip **155** of lever **154** is positioned in groove **152**.

To start the engine, handle **156** is pushed briskly downward, forcing piston **90** upward on the first compression stroke. Handle **156** is pushed downward in rotation about pivot **157** through an angle great enough for tip **155** to pass out of groove **152**, so that lever **154** is free of starting rod **142** on the first power stroke. On the immediately following first power stroke, the upper end of starting rod **142** is thrown into counterbore **143** and is restrained from further downward movement by lug **144**.

It will be understood, of course, that, while the forms of the invention herein shown and described, constitute preferred embodiments of the invention, it is not intended to illustrate all possible forms of the invention. It will also be understood that the words used are words of description rather than words of limitation and that various changes, such as changes in shape, size, and arrangement of parts may be made without departing from the spirit and scope of the invention herein disclosed.

What is claimed is:

1. In a free-piston engine having a free piston reciprocable in a frame, a starting mechanism comprising: a support member fastened to said frame; a starting rod having two longitudinal slots in the side thereof, reciprocably and rotatably mounted in said frame, said rod connecting with said piston on rotation to a first position and disconnecting from said piston on rotation to a second position; a lever member pivotally supported in said support member and having a handle at one end and a tip at the opposite end, the movement of said tip in rotation about said pivot intersecting the path of reciprocation of one of said slots at said first position, said tip operable by said handle in rotation engaging said one slot and reciprocating said piston, the movement of said tip in rotation about said pivot intersecting the path of reciprocation of the other of said slots at said second position,

said tip operable by said handle in rotation engaging said other slot and moving said piston in one direction.

2. In a free-piston engine having a free piston reciprocable in a frame, a starting mechanism comprising: a support member fastened to said frame; a starting rod, reciprocably and rotatably mounted in said frame having two longitudinal slots in the side thereof and a lug on the end thereof for engaging a receptacle on said piston and connecting with said piston on rotation to a first position and disconnecting from said piston on rotation to a second position; a key bore through said starting rod for rotating said starting rod about its longitudinal axis; a lever member pivotally supported in said support member and having a handle at one end and a tip at the opposite end, the

movement of said tip in rotation about said pivot intersecting the path of reciprocation of one of said slots at said first position, said tip operable by said handle in rotation engaging said one slot and reciprocating said piston, the movement of said tip in rotation about said pivot intersecting the path of reciprocation of the other of said slots at said second position, said tip operable by said handle in rotation engaging said other slot and moving said piston in one direction.

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