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Dec. 19, 1961   C. V. ADAMS   3,013,541

PILE DRIVING HAMMER
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Campbell & Adams by Mason, Hedman, Rathburn & Myers
This invention relates to a power or percussion type hammer such as pile driving hammers, and more particularly to pile driving hammers of the internal combustion compression-ignition type.

Although the power hammer of the present invention in the preferred embodiment is particularly well adapted for pile driving and is of the compression-ignition powered type, it will be apparent to those skilled in the art that the invention is not limited to such an application or embodiment. Compression-ignition powered pile driving hammers have certain inherent advantages over pile driving hammers which are powered by steam, compressed air, or other fluids but have heretofore encountered considerable difficulty in obtaining sufficient compression pressure to cause ignition of injected fuel when attempting to initiate starting thereof in soft soils and further in failing to ignite injected fuel due to insufficient compression pressure during continuous operation whenever the pile being driven penetrates a soft stratum of soil. Inability to obtain required compression pressure for ignition results from an embedment movement of the pile when pressure in the combustion chamber, acting between the descending ram and alidade inserted lower head of the cylinder resting on top of the pile, exceeds that offered by the resistance of the soil opposing movement of the pile. Other inherent limitations are also imposed in combining a heavy ram with a high frequency of blows without detrimentally affecting the maximum force of the blow. It will be appreciated that in double-acting pile driving hammers only the dead weight of the stationary parts thereof resists the upward thrust, and such dead weight must be commensurate with the energy to be produced. One of these limiting factors is concerned with the maximum total weight of the apparatus, which is limited within certain classes, for practical purposes, by the capacity of available handling equipment which is employed with existing steam and compressed air powered pile driving hammers. Another well-known factor is that with a given, limited weight of ram, a heavy blow requires extended travel of the ram, whereby the frequency of the blows is reduced, although this limitation has been partially overcome by some prior art developments. Still another limitation on the capacity of compression-ignition powered pile driving hammers concerns the difficulty in obtaining effective scavenging or otherwise providing adequate air for complete fuel combustion in what is necessarily a two-stroke cycle, particularly in view of weight and size limitations of the over-all machine.

A compression-ignition powered pile driving hammer constructed in accordance with the present invention avoids any theoretical limitation on the force or frequency of the pile driving blows while observing the prescribed weight and size limitations. It also provides adequate air for fuel combustion without significant increase in weight or size.

Accordingly, it is an object of the present invention to provide an improved power hammer of the internal combustion type in which burned gases are properly scavenged.

It is a still further object of the invention to provide an improved power hammer of the internal combustion type in which additional air for combustion is obtained through supercharging.

Another object of the invention is to provide an improved compression-ignition powered pile driving hammer having various of the advantageous characteristics specified above.

A further object of the invention is to provide an improved compression-ignition powered pile driving hammer having various of the advantageous characteristics specified above while being light in weight, small in size, reliable in operation and inexpensive to manufacture.

A further object of the invention is to provide an improved power hammer of the internal combustion type having various of the advantageous characteristics specified above and capable of positive starting and uninterrupted functioning regardless of intensity of soil resistance opposing the pile during embedment thereof by the power hammer.

Further features of the invention pertain to the particular arrangement of the elements of the power hammer, whereby the above outlined and additional features thereof are attained.

The invention, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following specification, taken in connection with the accompanying drawing, in which:

FiG. 1 is a top plan view of a compression-ignition powered pile driving hammer constructed in accordance with the present invention;

FiG. 2 is an elevational view partially in section taken generally along the line 2-2 of FIG. 1;

FiG. 3 is an elevational cross-sectional view taken in the direction of the arrows along the line 3-3 of FIG. 1;

FiG. 4 is a fragmentary diagrammatic view of suitable fuel injection means for the hammer of the present invention; and

FiG. 5 is an enlarged fragmentary sectional view taken along the line 5-5 of FIG. 3.

As indicated above, the present invention is well adapted to a compression-ignition powered pile driving hammer, and the invention is illustrated in such an application herein but could readily be arranged for spark or other forms of ignition. It will be apparent to those skilled in the art, however, that the invention is not limited to such use but is of broad applicability.

Referring now to the drawing, there is illustrated a compression-ignition powered pile driving hammer generally indicated at 9, comprising an anvil 10, this anvil being arranged to rest on, be secured to, or otherwise engage the upper end of a pile or similar device, not shown in the drawing. A base 12 encircles an upwardly protruding central portion of the anvil, the anvil and the base having tapered sides 10a and 12a, respectively, whereby the base 12 may readily be placed in proper, centered position with respect to the anvil 10. In order that the anvil may be moved with the hammer 9 it is suitably connected thereto by a flexible member such as the rope 13 which rope provides the necessary play between the anvil 10 and base 12.

For the purpose of relating the base 12 to the remainder of the apparatus 9, there are provided a plurality of vertically disposed columns or guide members 14 having their lower ends secured to the base 12. The hammer 9 also includes vertically disposed guides 15. The columns 14 serve as guides for the reciprocal movement of a ram 16. Preferably, the guide members 14 are circular in cross section, the ram 16 having openings therethrough which freely receive the guide members 14 whereby the
which defines a single upper cylinder interior portions of the engine housing be removed to permit inspection erably integral therewith, is a and an upper piston portion conical housing are provided including a piston rod preferably being provided with suitable rings, are identical, so a detailed description that is, for substantially replacing the residue of gaseous combustion products with clean air. These scavenging means include the housing 26 which serves as a storage chamber for containing air to be compressed therein. Since the cylinders 23 and 32 open into the chamber 82 defined by the closed 26, the open end portions of these cylinders comprise a portion of the storage chamber. Upon each upward stroke of the piston means 40 the volume of the storage chamber is decreased by an amount equal to the length of the stroke of the piston means multiplied by the difference between the cross-sectional areas of the two cylinders 23 and 32. Air pressure within the storage chamber is accordingly increased by a proportionate amount. It has been found that a pressure of the order of several pounds per square inch gauge is thereby obtainable within the housing 26 in the illustrated embodiment of the invention.

In order to reciprocate the ram 16, piston means 40 are provided including a piston rod 42, a lower piston 44 and an upper piston 46, the two pistons 44 and 46 being cooperable with the cylinders 23 and 32, respectively, and preferably being provided with suitable piston rings, as shown. For the purpose of relating the piston means 40 to the ram 16, a collar 48 is secured to the piston rod 42 in any suitable manner and, in turn, has secured thereto a yoke 50. As illustrated, the respective ends of the yoke 50 are connected by any suitable means such as the pins 52 to the rods 55, only one of said rods being visible in FIG. 3 of the drawing. As further illustrated, the two rods 55 and their connection with the rest of the apparatus are identical, so a detailed description of one will suffice. Thus, each of the rods 55 extends through an opening in 56 in the engine block 19 and through an opening 58 in the ram 16, which opening 58 includes a portion 58a of larger diameter.

To connect the rods 55 to the ram 16a, a head 62 is secured to or formed on the lower end of each rod 55, these heads 62 being freely slidable within the enlarged portions 58a of openings 58. Springs 64 and 66 are arranged above and below the head 63 in each enlarged portion 58a of the opening 58, the lower spring 66 being coiled around a plug 68 which is threadedly received in the lower end of the opening portion 58a. It will now be seen that the ram 16 will be caused to move with the piston means 40, the springs 64 and 66 providing a resilient connection therebetween whereby the jar of the impact of the ram 16 against the anvil 10 will be softened as far as transmission thereof through the rods 55 to the piston means 40 is concerned.

Suitable fuel injecting means 70 must be provided for injecting fuel alternately into the closed ends of the cylinders 23 and 32 as the corresponding piston 44 or 46 reaches or closely approaches and/or recedes from the end of its compression stroke. Since these fuel injecting means may be of conventional form, they are illustrated only diagrammatically in FIG. 4 of the drawing. They may be as shown. More specifically, as shown, a rack 72 movable with the piston means 40 or the cross head 50. As illustrated in FIG. 4, a pair of pinions 74 and 78 cooperate with the rack 72 and drive the fuel pump 76a for the lower cylinder 23 and fuel pump 76b for the upper cylinder 32. In the event cam followers and associated linkage would replace pinions 74 and 75. Suitable conduits 77, 76 and 78 connect the fuel injecting means respectively to the cylinders 23 and 32, and to a fuel tank, not shown in the drawing but contained within the hammer 9. It will be appreciated that suitable means will be provided to insure the necessary quantity of fuel at the proper time.

For the purpose of permitting the escape of gaseous combustion products as the corresponding piston 44 or 46 approaches the end of its power stroke, exhaust vents 80 and 82 are provided. Means are also provided for scavenging the lower cylinder 23, that is, for substantially replacing the residue of gaseous combustion products with clean air. These scavenging means include the housing 26 which serves as a storage chamber for containing air to be compressed therein. Since the cylinders 23 and 32 open into the chamber 82 defined by the closed 26, the open end portions of these cylinders comprise a portion of the storage chamber. Upon each upward stroke of the piston means 40 the volume of the storage chamber is decreased by an amount equal to the length of the stroke of the piston means multiplied by the difference between the cross-sectional areas of the two cylinders 23 and 32. Air pressure within the storage chamber is accordingly increased by a proportionate amount. It has been found that a pressure of the order of several pounds per square inch gauge is thereby obtainable within the housing 26 in the illustrated embodiment of the invention.

Air at this pressure is fed to the cylinder 23 from the housing 26 through a passage 84 in the engine block 20. The passage 84 opens into the cylinder 23 just below the piston 44 when the latter is in its uppermost position, whereby air may pass from the lower end of the cylinder 23 only at the end of the power stroke of the piston 44. Attention is directed to the fact that the exhaust vent 80 should be uncovered by the piston 44 to permit substantial exhaustion of gaseous combustion products substantially simultaneously with the uncovering of the cylinder port of the passages 84. It should be understood that valve means may be included in passageway 84 which are actuated at the proper time if desired rather than employing the piston 44 as a valve member.

A one-way valve 88 is arranged on the wall of the housing 26 to permit entrance of air into the housing during the downward stroke of the piston means 40. This one-way valve may be of conventional construction and, accordingly, is not disclosed in detail herein. It will be understood that this valve prevents the flow of air out of the housing 26 during the downward stroke of the piston means 40. Means may also be provided to store a portion or all of the scavenging air and divert the same to upper cylinder 32. Separate means may also be provided for scavenging cylinder 32 as described hereinafter.

In accordance with the present invention, supercharging means are provided to accelerate the piston means in both directions by injecting compressed air into both of the cylinders 23 and 32 during the compression strokes of the corresponding pistons 44 and 46. As illustrated, a reciprocating type of supercharging means is provided,
arranged radially around the axis of the cylinders 23 and 32. These supercharging means include cylinders 89 and 90 formed within the engine block 19, and pistons 91 and 92, whereby air is driven through the piping 94 into the closed end of the lower cylinder 23 during the downward or compression stroke of the piston 44.

In order to permit the entrance of air from the atmosphere to recharge the superchargers, a one-way valve 110 is provided for each of the cylinders 89 and 90. Since these valves may be of conventional type, they are not described in detail herein. It will be understood that the valves 110 open to permit the entrance of air into the associated cylinders 89 or 90 when the associated pistons 91 or 92, respectively, have completed their supercharging operation, and are closed when the pressure within the cylinders 89 or 90 is raised by movement of the pistons 91 and 92. Preferably, the valves 110 are arranged closely adjacent the associated supercharger cylinders 90, as shown, to reduce line pressure drop during the recharging strokes of the supercharger.

One-way valves 112 and 113 are also provided in the piping 93 and the piping 94 closely adjacent the respective power cylinders 32 and 23 to permit passage of air into the power cylinders and to prevent reverse flow of air or gaseous combustion products during the power stroke of the associated engine cylinders.

From the above description it will be appreciated that with the supercharging means described above arranged in horizontal positions no appreciable reaction to the vertically movable piston means 40 is involved, which is very desirable. This would also be true if rotary pump type superchargers were employed.

In order to permit the development of a large amount of power by the upper cylinder 32 and piston 46 during each power stroke of the piston means 40, it is preferred that the fuel injecting means 70 be arranged to inject the fuel into the cylinder 32 during any portion of the power stroke of the piston 46. While this is recognized as being relatively inefficient in terms of fuel consumption, this relatively unimportant disadvantage is greatly outweighed by the fact that greater power, and hence a heavier blow, can be obtained due to the achievement of a higher mean effective pressure without the creation of excessive initial gas pressure within the cylinder 32.

In the illustrated embodiment of the invention, means are provided for further distributing gas pressure over the full power stroke of the piston means 40. The gas pressure may be burned and more power may thereby be developed during each stroke of the piston 46 due to the achievement of a higher mean effective pressure without the creation of excessive initial gas pressure within the cylinder 32. Such means may include a suitable expansion chamber in the form of an annulus or the like surrounding the cylinder 32 at the upper end or, as shown in the illustrated embodiment, may comprise several expandable chambers 120 (best shown in FIG. 5), or a combination of an annulus as mentioned above combined therewith, each comprising a cylinder 123 and a piston 124. One end of each cylinder opens into the closed end of the cylinder 32, and a heavy spring 126 urges each piston 124 toward that end of the cylinder 32. The springs 126 are of such strength that they resist outward movement of the pistons 124 until the gas pressure within the cylinder 32 becomes high enough to overcome the spring tension. They then yield and permit outward movement of the pistons 124. Preferably adjustable means 125 are provided to adjust the spring tension to any desired value. Storage means are thereby provided for storing air without affecting the dead weight of the device which comprises expandable chambers opening into the closed end of the cylinder 32, the springs 126 providing resilient and adjustable expandable chambers.

In the operation of the illustrated embodiment of the invention, it is intended, as previously indicated, that the anvil 10 loosely secured to the base 12 by means 13 be.
...placed on the upper end of a pile to be driven. Also, as previously noted, the lower end of the pile driving ham- "...mer may be initiated by lifting the ram 16, with an automatic engaging and releasing device, this being readi- "...y accomplished by the same hoist employed to lift the pile..."...screws on the exterior thereof, and such screws are..."...ent, the air in the upper cylinder 32 will be..."...ker chambers 120 will recede, against the action of the springs 126, to relieve the pres- "...n with a shield 128 located in a quite air for combustion of large quantities of fuel. This..."...whence the springs 126 force the pistons 124 back to their normal positions. The energy..."...be to the preferred embodiment of the invention, as fall within the true spirit and scope of the invention."

...When or not fuel is injected over a substantial por- "...force the pistons within the expandible chambers 120 will recede, against the action of the springs 126, to relieve the pressure. If an annulus shaped chamber of larger diameter than cylinder 32 is provided at the closed end of this cylinder it will initially relieve such pressure. Moreover, the springs 126 may be adjusted not only to relieve the explosive force within cylinder 32 but also to limit the compression force to a predetermined value. As the piston 46 moves downward the pressure within the upper cylinder decreases, whereupon the springs 136 force the pistons 124 back to their normal positions. The energy stored in the expandible chambers 120 or other suitable cylinder volume controlling means is thereby returned to the cylinder 32 and serves to drive the piston means and the ram more forcibly downward.

...Downward movement of the piston means 40 is accom- "...tions may be made therein, and it is intended to cover..."...ats, and the associated one-way valve 113 preventing the entrance of gaseous combustion products. At the same time air pressure within the housing 26 rises by virtue of the effective reduction in the volume of the chamber 32 defined by the housing 26 and the open ends of the cylinders 23 and 32, the cylinder port of the passage 84 opening to the open end of the cylinder 23 at first and then being covered by the piston 44 or controlled by suitable separate valve means if desired...

...As the piston means 40 approach maximum height, the exhaust port 80 is uncovered such that gaseous combustion products may be exhausted. Subsequently, the cylinder port of the passage 84 is rendered effective and scavenging air from the housing 26 flows into the closed end of the cylinder 23 to scavenge the same.

...cylinders 90 which serve the upper cylinder 32. An ade-quate quantity of air is thereby compressed within the closed end of the upper cylinder for burning of a large charge of fuel. The fuel pump 70b injects fuel which is ignited by the high temperature of the air compressed within the cylinder 32.

...Whether or not fuel is injected over a substantial portion of the power stroke of the piston 46, if sufficient fuel is injected then the pressure within the cylinders 124 while the lower cylinder is operated to develop a..."...gases through Venturi 81 aspirate the air over the fins. As illustrated, a Venturi above is provided with superchargers which assure ade-quate air for combustion of large quantities of fuel. This..."...sufficient air for combustion of large quantities of fuel. This causes automatic firing of the gases in upper cylinder 32 to initiate the operation.

...Preferably the upper piston 42 and cylinder 32 are used for controlling the power developed or intensity of the blow by varying the amount of fuel supplied thereto, while the lower cylinder is operated to develop a substantially constant power just sufficient to always project the ram 16 upwards to the full length of the compression stroke. Consequently, the fuel adjustment for the lower cylinder 23 may remain fixed after initial adjustment to suit fuel being used or other requirements.

...As the ram 16 drops against the anvil 10, the piston 44 compresses air in the closed end of the cylinder 23 and fuel is injected by the fuel injecting means 70. Additional air is injected by two opposed superchargers through piping 94, the cam 42 actuating those opposed superchargers during the downward movement of the ram 16 and the piston means 40. The air in the lower end of the cylinder 23 is thus heated to such a temperature as to cause ignition of the injected fuel with the resultant upward force on piston 44 pulling ram 16 along. As the piston means 40 and the ram 16 drive downwards, the ram 16 is lifted in preparation for a powered pile driving stroke. It should be noted that the over-all length of the apparatus is considerably shortened by the fact that the ram 16 is recessed as indicated at 127 to receive the lower end of the cylinder 23 when the ram is thus lifted and which also by displacing air in such recess 127 increases the velocity of the air flowing past the cylinder which preferably is provided with cooling fins, as shown, thereby improving heat dissipation. The same effect occurs when the ram moves in the other direction. Increased cooling of the cylinder 23 can be provided by encasing the fins on the outside thereof with a shield 128 open at the upper end and inducing air to flow therebetween at an increased velocity and volume by arranging means for utilizing the energy of exhaust gases from this cylinder to aspirate the air over the fins. As illustrated, a Venturi device 112 associated with the exhaust port 82 is located in alignment with exhaust gas vent 82 whereby the flow of exhaust gases through Venturi 129 causes cooling air to flow along the outside of cylinder 23.

...As the piston means 40 rises, those superchargers comprising cylinders 99 which serve the lower cylinder 23 are recharged, the cam 42c of FIG. 2 permitting the supercharger pistons 91 to move inwardly, the one-way valves 110 permitting the entrance of air, and the associated one-way valve 113 preventing the entrance of gaseous combustion products. At the same time air pressure within the housing 26 rises by virtue of the effective reduction in the volume of the chamber 32 defined by the housing 26 and the open ends of the cylinders 23 and 32, the cylinder port of the passage 84 opening to the open end of the cylinder 23 at first and then being covered by the piston 44 or controlled by suitable separate valve means if desired...

...As the piston means 40 approach maximum height, the exhaust port 80 is uncovered such that gaseous combustion products may be exhausted. Subsequently, the cylinder port of the passage 84 is rendered effective and scavenging air from the housing 26 flows into the closed end of the cylinder 23 to scavenge the same.

...Upward movement of the piston means 40 also compresses air in the upper cylinder 32 and causes operation by the cams 420 of those superchargers comprising...
cylinder means and said ram and confining said cylinder means and said ram to linear relative movement in a direction parallel to the longitudinal axis of said cylinder, drive means interconnecting said piston means and said ram, fuel injecting means actutable upon predetermined movement of said piston means for injecting fuel into said cylinder means, means for igniting said fuel solely in dependence upon producing sufficient pressure in said cylinder, and supercharging means actutable upon movement of said piston means for supercharging said cylinder during the compression stroke of said piston means, said supercharging means including means interrelating said cylinder means and said ram to linear relative movement in a direction parallel to the common axis of said cylinders, drive means interconnecting said piston means and said ram, fuel injecting means actutable upon predetermined movement of said piston means for injecting fuel into said cylinder means, means for igniting said fuel solely in dependence upon producing sufficient pressure in said cylinder, and supercharging means actutable upon movement of said piston means for supercharging said cylinder during the compression stroke of said piston means, said supercharging means including means interrelating said cylinder means and a piston, the longitudinal axis of said piston being parallel to the longitudinal axis of said cylinder means, said supercharging means being actutable upon movement of said piston means for supercharging said cylinder during the compression stroke of said piston means, said supercharging means including means interrelating said cylinder means and said ram and confining said cylinder means and said ram to linear relative movement in a direction parallel to the common axis of said cylinders, drive means interconnecting said piston means and said ram, fuel injecting means actutable upon predetermined movement of said piston means and said ram, and fuel injecting means actutable by relative reciprocatory movement of said piston means and said cylinder means for injecting fuel into the closed ends of said cylinders alternately.

The combination as specified in claim 3 wherein supercharging means are provided for injecting air into the closed ends of said cylinders during the compression stroke of the associated piston, said supercharging means being actutable by relative reciprocatory movement of said piston means and said cylinder means.

The combination as specified in claim 3 wherein supercharging means are provided for injecting air into the closed ends of said cylinders during the compression stroke of the associated piston, said supercharging means including a cylinder and piston for each of said first-mentioned cylinders, said supercharging cylinders being mounted on said cylinder means and having their axes perpendicular to the common axis of said first-mentioned cylinders, and wherein cam means are provided for actuating said supercharging means in response to relative reciprocatory movement of said piston means and said cylinder means, said cam means including cam elements mounted on said piston means and cam followers mounted on said supercharging pistons.

The combination as specified in claim 3 wherein said cylinders are of substantially different bores, and scavenging means are provided for clearing gaseous combustion products from the larger of said cylinders when the associated piston is near the end of its power stroke, said scavenging means including a chamber enclosing the open end of both of said cylinders, conduit means connecting said chamber to said larger cylinder, valve means permitting air flow from said chamber to said larger cylinder only when the associated piston is near the end of its power stroke, and one-way valve means permitting air flow into said chamber from the atmosphere during the compression stroke of the piston associated with said larger cylinder.

7. The combination as specified in claim 3 wherein storage means are provided for limiting compressive pressure to a predetermined amount and for relieving the explosive force within the closed end of at least one of said cylinders and storing the energy thereof until the associated piston has partially completed its power stroke.

8. In a power hammer of the internal combustion type, cylinder means including axially aligned power cylinders of substantially different bores having their facing ends open and their other ends closed, piston means having a piston for each of said power cylinders, said piston means being actuatable by relative reciprocatory movement of said piston means and said cylinder means and said ram to linear relative movement in a direction parallel to the common axis of said cylinders, drive means interconnecting said piston means and said ram, and fuel injecting means actutable by relative reciprocatory movement of said piston means and said cylinder means actutable upon movement of said piston means for supercharging said cylinder during the compression stroke of said piston means, said supercharging means including means interrelating said cylinder means and said ram to linear relative movement in a direction parallel to the common axis of said cylinders, drive means interconnecting said piston means and said ram, fuel injecting means actutable by relative reciprocatory movement of said piston means and said cylinder means for injecting fuel into the closed ends of said cylinders, scavenging means for clearing gaseous combustion products from said cylinders when the associated pistons are near the ends of their power strokes, said scavenging means including a chamber enclosing the open ends of both of said cylinders, conduit means connecting said chamber to the closed end of said larger cylinder, valve means permitting air flow into said chamber to the closed end of said larger cylinder, and supercharging means being mounted on said cylinder means and having their axes perpendicular to the common axis of said power cylinders, and cam means for actuating said supercharging means in response to relative reciprocatory movement of said piston means and said cylinder means, said cam means including cam elements mounted on said piston means and cam-followers mounted on said supercharging pistons.

9. In a power hammer of the internal combustion type, a power cylinder having one closed end, piston means receivable within said cylinder, a ram, guide means interconnecting said cylinder and said ram and confining said ram to linear relative movement in a direction parallel to the axis of said cylinder, drive means interconnecting said piston means and said ram, fuel injecting means actutable by relative reciprocatory movement of said piston means and said cylinder for injecting fuel into the closed end of said cylinder only when said piston means is near the end of its power stroke, said scavenging means including a chamber enclosing the open end of said cylinder, conduit means connecting said chamber to said larger cylinder, and supercharging means being mounted on said cylinder means and having their axes perpendicular to the common axis of said power cylinders, and cam means for actuating said supercharging means in response to relative reciprocatory movement of said piston means and said cylinder means, said cam means including cam elements mounted on said piston means and cam-followers mounted on said supercharging pistons.

10. In a power hammer of the internal combustion type, a power cylinder having one closed end, piston means receivable within said cylinder, a ram, guide means interconnecting said cylinder and said ram and confining said cylinder and said ram to linear relative movement in a direction parallel to the axis of said cylinder, drive means interconnecting said piston means and said ram, fuel injecting means actutable by relative reciprocatory movement of said piston means and said cylinder for in-
jecting fuel into the closed end of said cylinder, means for igniting said fuel solely in dependence upon producing sufficient pressure in said cylinder, and storage means for limiting the compressive pressure to a predetermined amount and for relieving the explosive force within the closed end of said cylinder and storing the energy thereof until said piston means has partly completed its power stroke, said storage means comprising an expansible chamber opening into the closed end of said cylinder, and means resiliently urging said expansible chamber toward contracted condition.

11. In a compression-ignition power pile driving hammer, cylinder means including axially aligned power cylinders having their facing ends open and their other ends closed, piston means having a piston at two opposed ends thereof receivable respectively within said cylinders, a ram, guide means interconnected said cylinder means and said ram and confining said cylinder means and said ram to linear relative movement in a direction parallel to the common axis of said cylinders, drive means interconnecting said piston means and said ram, and fuel injecting means actuated by relative reciprocatory movement of said piston means and said cylinder means for injecting fuel into the closed ends of said cylinders alternately when the associated piston is close to the closed end of the cylinder.

12. In a compression-ignition powered pile driving hammer, an anvil for engagement with a pile, said anvil having a lower portion and a raised central portion, a base arranged to rest on said lower portion of said anvil and encircle said raised central portion thereof, upper and lower axially aligned cylinders supported on said base, said cylinders having their facing ends open and their other ends closed, a ram, guide means extending between said base and said cylinder means for confining said ram to reciprocating movement and permitting impingement of said ram on said anvil, piston means having a piston at two opposed ends thereof receivable respectively within said cylinders, means connecting said piston means to said ram and permitting an impingement of said ram with said anvil when the lower piston of said piston means approaches the closed end of said lower cylinder, and fuel injecting means actuated by relative reciprocatory movement of said piston means and said cylinder means for alternately injecting fuel into the closed ends of said cylinders.

13. The combination of claim 1 wherein cam means on said piston means actuates said supercharging means.

14. The combination of claim 1 wherein storage means are provided for limiting the compressive pressure and for relieving the explosive force within the closed end of said cylinder until the piston means has partially completed its power stroke.

15. The combination of claim 7 wherein said storage means comprises an expansible chamber opening into the closed end of said cylinder, and adjustable means resiliently urging said expansible chamber toward contracted condition.

16. The combination of claim 7 wherein said storage means comprises an annulus connected to the closed end of said cylinder.

17. In a compression-ignition power pile driving hammer, cylinder means including axially aligned power cylinders having their facing ends open and their other ends closed, piston means having a piston at two opposed ends thereof receivable respectively within said cylinders, a ram, guide means interconnected said cylinder means and said ram and confining said cylinder means and said ram to linear relative movement in a direction parallel to the common axis of said cylinders, drive means interconnecting said piston means and said ram, and fuel injecting means actuated by relative reciprocatory movement of said piston means and said cylinder means for injecting fuel into the closed ends of said cylinders during a portion of the power stroke.

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