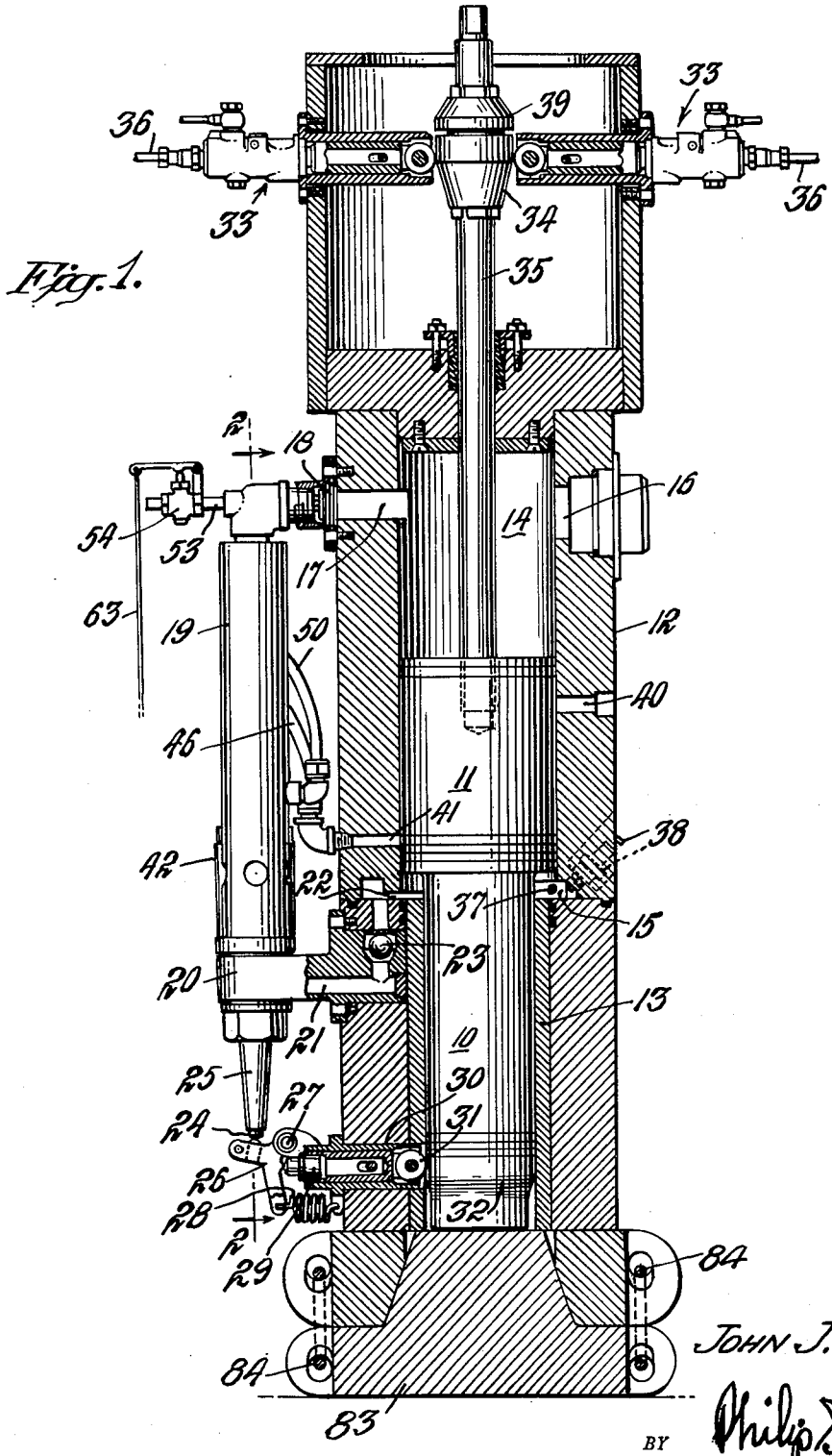
July 24, 1956 J. J. KUPKA 2,755,783

FREE PISTON INTERNAL COMBUSTION PILE HAMMER

Filed June 18, 1953 4 Sheets-Sheet 1



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Fig. 2.

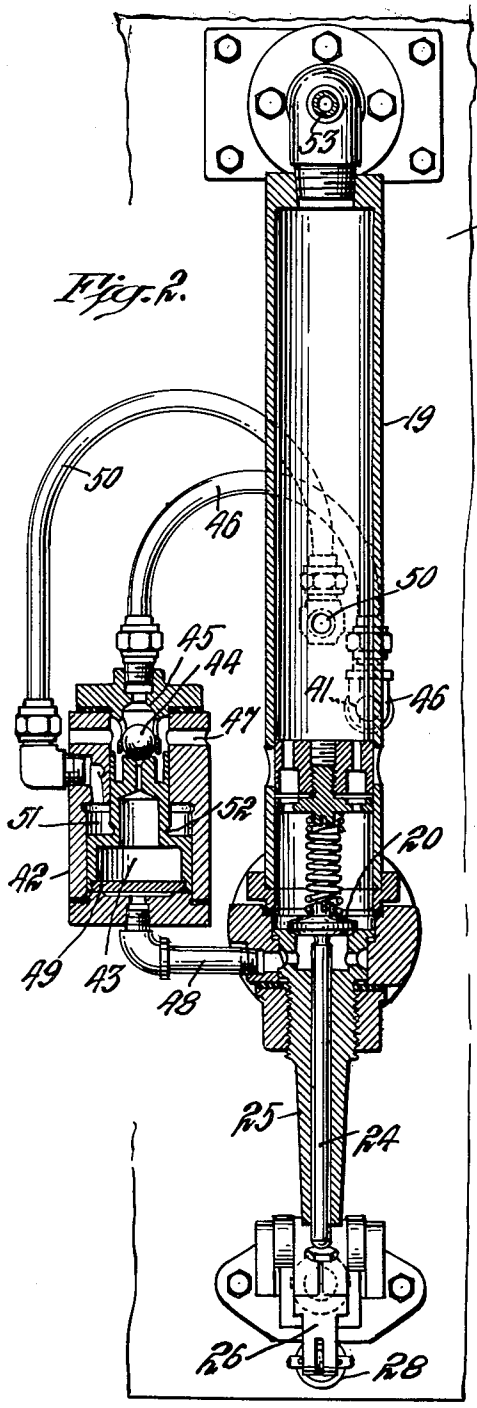
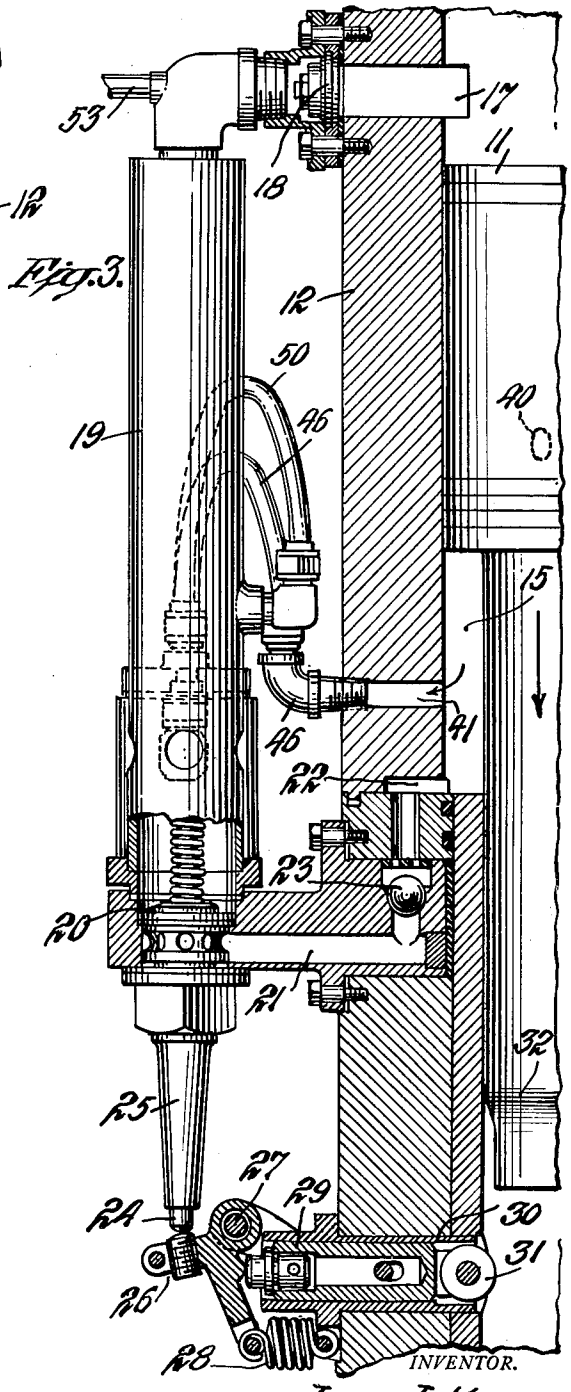


Fig. 3.



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Fig. 4.

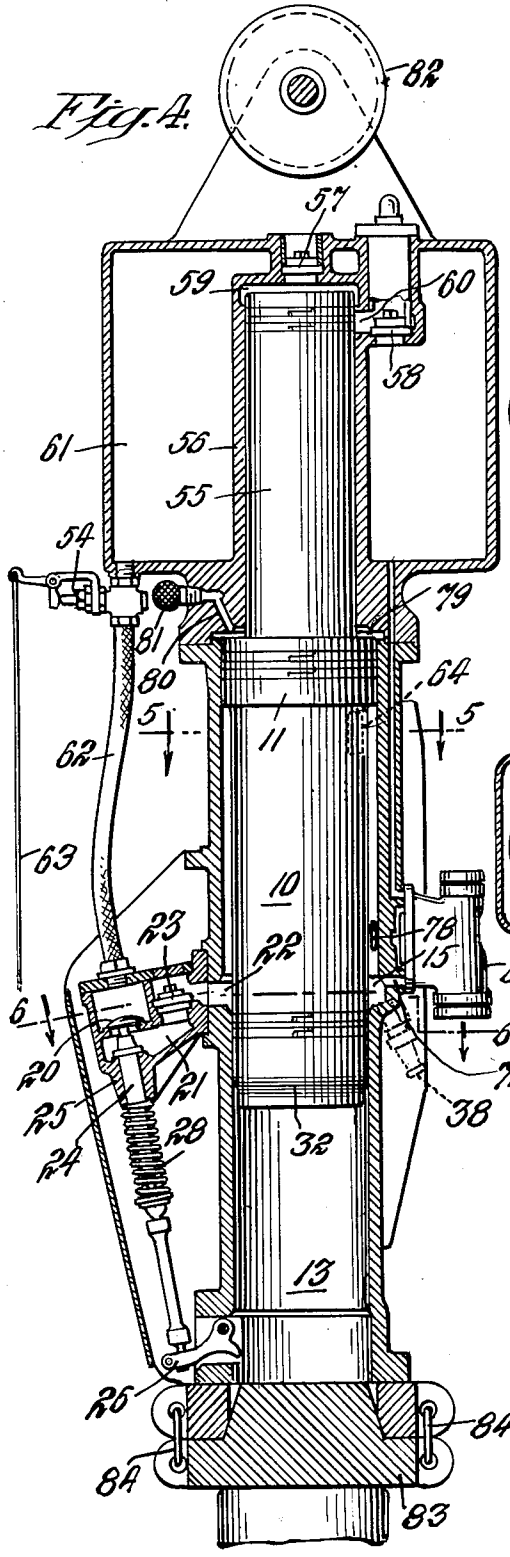
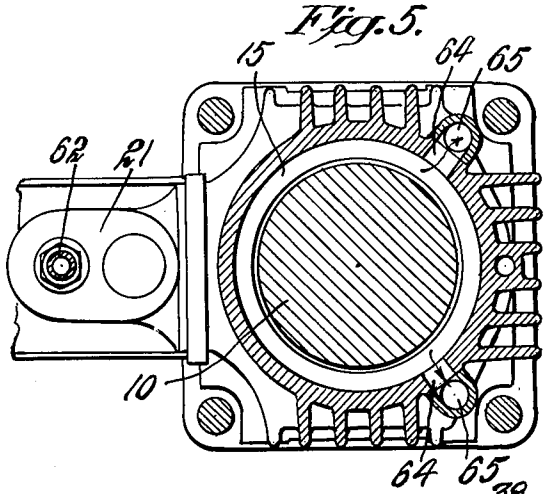


Fig. 5.



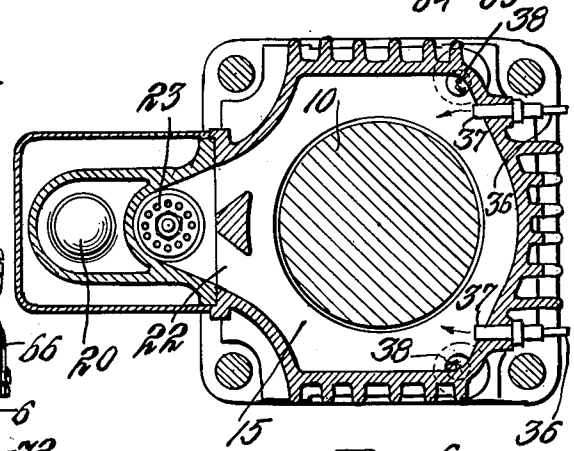


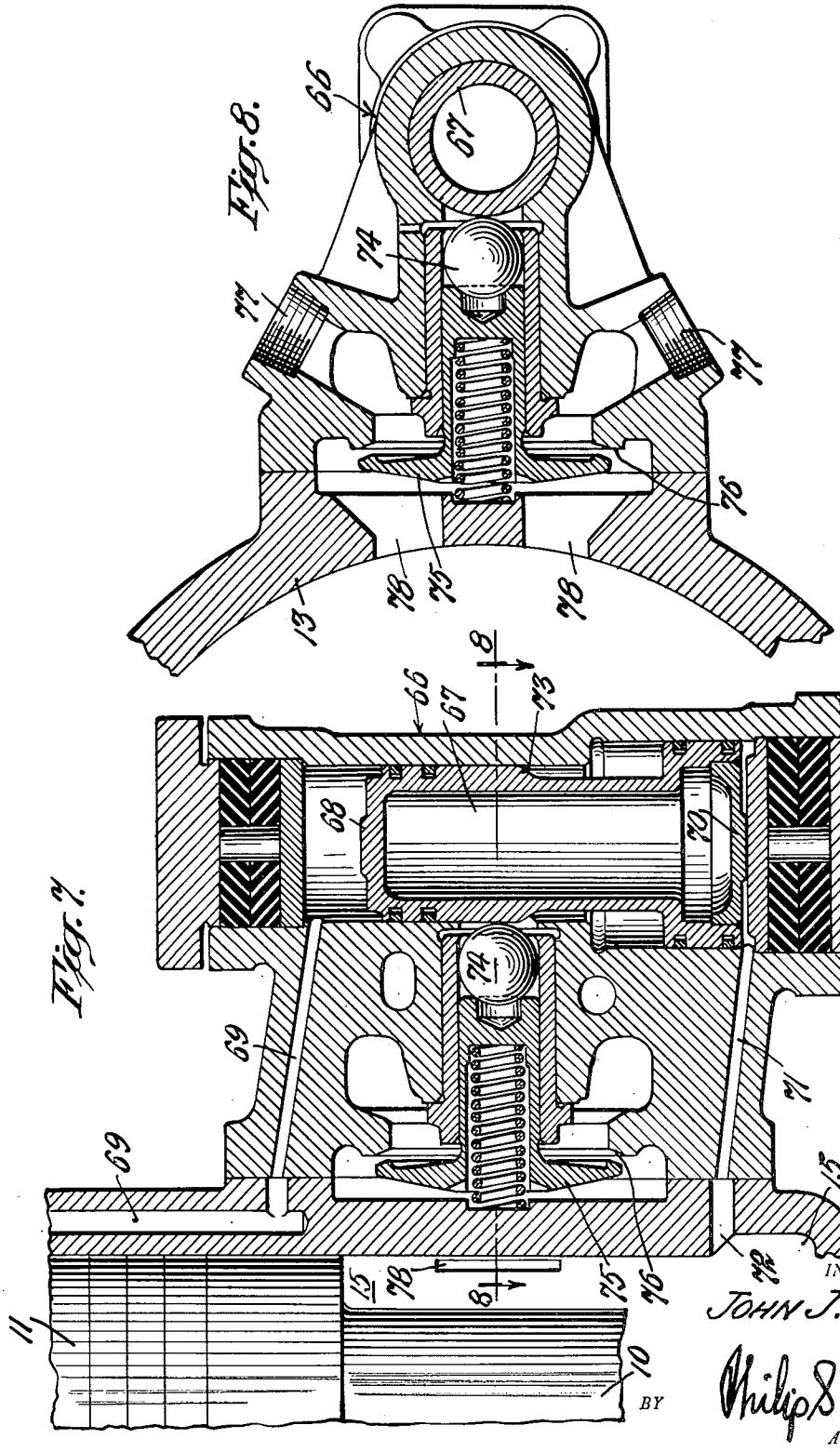
Fig. 6.

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Filed June 18, 1953 4 Sheets-Sheet 4



United States Patent Office 2,755,783 Patented July 24, 1956

2,755,783

FREE PISTON INTERNAL COMBUSTION PILE HAMMER

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Application June 18, 1953, Serial No. 362,532

7 Claims. (Cl. 123—7)

The invention disclosed in this patent application relates to power hammers of the free piston type but differs from prior constructions primarily in operating on a new principle by which power is applied to accelerate the action of the free falling piston and slowdown which would result from cushioning the down stroke is practically avoided.

Objects of the invention have been to provide a simple, practical, rugged, efficient form of construction to carry out this new cycle of operation.

Special objects of the invention have been to eliminate the need for hoisting the piston forming the hammer, as has heretofore been necessary in machines of this type, and to make the hammer self-starting and readily controllable, after the manner of a steam hammer.

Further special objects of the invention have been to accomplish all these results in a compact, unitary structure suited to the various requirements of pile driver operations.

Other desirable objects attained by the invention are set forth and will appear in the course of the following specification, wherein the novel features of the invention are more fully described and broadly claimed.

In the drawings accompanying and forming part of the specification, there are illustrated several different embodiments of the invention, but it is realized that structure may be modified and changed, all within the true intent and scope of the invention as hereinafter defined and claimed.

Fig. 1 in the drawings is a broken vertical sectional view of a form of the invention, showing the piston at the bottom of its down stroke and acting to open a valve for injecting a charge of combustion supporting compressed air beneath the head of the piston;

Fig. 2 is an enlarged broken sectional view taken substantially on the plane of line 2—2, Fig. 1, and showing details of the injection valve, in this case in closed condition, and at the left of that, the differential pressure valve supplied from the same source of compressed air and operating to automatically release fluid trapped beneath the piston head which otherwise would act with cushioning effect to retard and slow down the down stroke of the piston;

Fig. 3 is a broken part sectional view of the same parts in a plane at a right angle to the plane of Fig. 2, also showing the injector valve in closed condition. In both this and Fig. 2 the differential valve is open to release pressure beneath the piston head, as in down stroke of the piston.

Fig. 4 is a broken vertical sectional view illustrating another form of the invention and showing the piston or ram at the top of its stroke, with a cushion of air trapped above the upper, air compressor end of the piston to cushion the up stroke and to add power impetus to the down stroke;

Figs. 5 and 6 are enlarged cross sectional details as on the planes of lines 5—5 and 6—6, respectively, of Fig. 4, the first through the main exhaust ports and the second across the annular combustion chamber;

Fig. 7 is an enlarged broken vertical sectional view of the differential valve used in the Fig. 4 construction, showing the differential piston lowered by a superior pressure from the compressed air storage reservoir to hold the relief valve open during down stroke after closure of the main exhaust ports by the descending piston head;

Fig. 8 is a broken horizontal section of the same parts, as on substantially the plane of line 8—8 of Fig. 7.

In Fig. 1 the invention is shown as comprising a dual diameter piston having a lower ram forming portion **10** and an upper enlarged head portion **11**, operating in a two-diameter cylinder **12** having a lower guide section **13** and an upper, larger diameter air compressor chamber forming section **14**. This combination provides at the juncture of the larger and smaller cylinder sections, an annular combustion chamber **15** beneath the head of the piston.

The upper, air compressor chamber **14** is shown as having a valved air inlet port **16** in one side and a discharge port **17** in the opposite side, both near but far enough below the top to trap a cushioning body of air after overtravel of the ports by the piston.

The discharge port is equipped with an unloading valve **18** opening into a pressure reservoir **19**, providing the source for combustion supporting compressed air.

Compressed air reservoir **19**, as shown more fully in Figs. 2 and 3, has a spring closed valve **20** at the foot of the same controlling an air injection passage **21** opening at **22** into the annular combustion space **15** and equipped with ball check valve **23**.

The stem **24** of air injector valve **20** projects down through a guide **25** into position for actuation by a bell crank rocker **26** pivoted at **27** and held by spring **28** against the outer end of a pusher **29** guided in a transverse bearing **30** and carrying a roller **31** at the inner end for engagement by a cam **32** on the lower end of the piston.

Fig. 1 shows this cam as having engaged the roller on the lower end of the pusher slide, and the latter as having operated the rocker **26** to lift and open the air injector valve.

In Fig. 1, fuel injector pumps are indicated at **33**, operable by a conical cam **34** on the upper end of rod **35** attached to the head of the piston, these pumps being connected by tubing **36** with suitable nozzles discharging into the combustion space at **37**.

This view shows the cam **34** as having actuated the fuel pumps to inject fuel such as gasoline into the annular combustion chamber substantially at or immediately after the instant of impact.

A spark plug is indicated at **38** for firing the combustible mixture of compressed air and fuel injected beneath the piston head at the approximate end of the down stroke.

The timing of the ignition may be effected by contact closing or breaker actuating cam indicated on the upper end of the cam rod at **39**.

An exhaust port is shown provided at **40**, Fig. 1, in the side of the larger cylinder section, at a level to be uncovered by the piston head near the upper end of its stroke.

To avoid slowdown, which would result from cushioning the down stroke or from using the down stroke for compression purposes, there is provided in the present invention a supplemental or auxiliary exhaust or relief port **41** in the side of the annular combustion chamber low enough to remain uncovered by the piston head till near or approximately at the end of the down stroke.

Means are provided to hold this pressure release port closed during the upward power stroke of the piston and to open it and hold it open during down stroke and

particularly after the main exhaust port 40 has been covered by the lowering piston head.

The means for such purpose consists in the present disclosure, of a differential valve indicated at 42, Figs. 1, 2 and 3, and containing a differential piston 43 for opening and closing a valve controlling escape of pressure from the auxiliary relief port 41.

This valve is shown in Fig. 2 as a ball 44 arranged to be lifted by differential piston 43 into engagement with a valve seat 45 at the end of the pipe connection 46 extending from port 41.

The head of the differential valve 42 in which the ball valve is located, is shown as having exhaust ports 47 open to the valve seat 45.

Hence when the differential piston is lowered as in Fig. 2, the ball valve will be open to permit free escape of gases beneath the piston head and escape will be cut off when the piston rises and closes the ball valve.

The air compressed for the starting and combustion supporting purposes is sufficient to furnish the power for actuating the differential valve.

Accordingly, a connection 48 is taken off from the pressure supply passage 21 beneath the pressure supply or injection valve 20 to conduct actuating force to the lower, larger pressure head 49 of the differential piston, and a connection is taken off at 50 from pressure reservoir 19 to the annular chamber 51 in which the upper, smaller annular head 52 of the differential piston operates.

Consequently with reservoir pressure on both sides of the differential piston 43, the piston, because of superior pressure on the lower head 49, will rise and hold the ball valve 45 closed, shutting off escape through the auxiliary relief port 41. This condition will exist while injection valve 20 is open and, after this valve is closed, so long as pressure in the combustion chamber holds the check valve 23, Fig. 3, closed.

Therefore, during injection of pressure air under the piston head and during combustion pressure in the upward power stroke of the piston the auxiliary relief or exhaust port will be kept closed. It will be noted in Fig. 1 that this port is protected against explosion pressure by being covered by the piston head at bottom stroke position.

As the piston uncovers the main exhaust port 40 in its up stroke, pressure is reduced beneath the piston head and this reduction in pressure permits check valve 23 to open, relieving pressure through passages 21, 48, on the lower head of the differential piston 43 and permitting pressure on the upper, smaller piston head to become effective to lower the piston and open ball valve 45 controlling auxiliary port 41.

This condition exists during all or practically all of the lowering movement of the piston head, thus to exhaust gases trapped beneath the piston head after down travel of the piston head over the main exhaust port 40.

Many advantages are derived from this novel cycle of operations.

With elimination of any cushioning effect on the down stroke, the ram can be operated at maximum force and efficiency. The trapped air cushion at the top of the stroke supplies rebound and downward acceleration forces so that the down stroke is actually a power stroke, accelerating the free falling action of the ram.

The release of pressure from beneath the piston head through the auxiliary exhaust in the down stroke is effected automatically and the closing off of the auxiliary exhaust at the end of the down stroke and during all the upward power stroke, prevents this auxiliary exhaust from interfering with effective combustion and power development.

The auxiliary exhaust, by disposing of the waste gases

in the down stroke of the piston, assures a more effective fuel combination, and this desirable result is further carried out by injection of fresh, clean compressed air beneath the piston head at the bottom of the stroke. By reason of this clean, uncontaminated mixture greater power is produced, and this with added power impulse provided by the trapped air cushion at the top and the free, non-cushioned down stroke, provides fast, powerful hammer action.

When the ram is down as in Fig. 1, the injector valve 20 is open. Consequently the machine is ready to be started by compressed air.

Air for the purpose may be supplied from a separate reservoir connected by piping 53 with the smaller reservoir 19 and controlled by a suitable valve 54. Started under compressed air, the machine will automatically pick up and continue operation under internal combustion, with fuel and ignition on.

The machine may be designed so as to store up compresed air during normal operating periods sufficient for all starting and operating purposes, but if found desirable another or supplementary source of compressed air may be utilized.

The modified form of the invention shown in Figs. 4 to 8 is generally similar to that described, and corresponding reference characters have therefore been applied where appropriate.

In this second illustrated form of the invention the piston is extended above the head portion 11 by a guide portion 55 of reduced diameter operating in a cylinder extension 56 and forming an air compressor having intake and unloading valves 57, 58, with an air cushion space 59 above the discharge port 60.

A compressed air reservoir 61 is shown surrounding the air compressor cylinder, with valve 58 opening directly thereinto and with a connection 62 extending from the reservoir to the air injector valve 20.

The control valve 54 which may be of the hold-open and hold-closed type, is shown interposed in this connection and provided with a pull cord 63 by which it may be tripped to start or stop the hammer.

The main exhaust ports are shown at 64, Figs. 4 and 5, protected by downwardly directed hoods 65.

The differential valve mechanism for controlling the auxiliary exhaust is indicated at 66 in Fig. 4, and is shown in detail in Figs. 7 and 8 as comprising a differential piston 67 having the upper, smaller end 68 subjected to reservoir pressure through passage 69 brought down from the bottom of the reservoir and the lower, larger end 70 subjected to combustion chamber pressure through passage 71 opening at 72 into the lower end of the annular combustion chamber space 15.

The differential piston 67 is shown in Fig. 7 as having an external cam surface 73 engageable with a ball 74 to thrust a spring load valve 75 off the seat 76 controlling escape to atmosphere at 77, Fig. 8, from auxiliary exhaust ports 78.

This form of differential valve mechanism operates in the manner described above, to hold the auxiliary exhaust ports closed in the up stroke of the piston and to open and keep these ports open in the down stroke of the piston.

Passages 71, 72, Fig. 7, enable reservoir air pressure injected by valve 20, acting on the lower, larger head of the differential piston, to overcome air pressure through passage 69 on the upper, smaller head 68, thus to lift the piston and effect closure of valve 75. This valve will then remain closed, shutting off auxiliary ports 78 until pressure in the annular working chamber 15 is reduced by opening of exhaust ports 64 by rising piston.

Then, with reduction of pressure in the working cylinder the check valve 23 will open to release air from beneath the lower head of the differential piston, and pressure then acting on top of the piston will force it

down as in Fig. 7, to open the auxiliary port valve 75 and keep this valve open during balnce of the down stroke.

This second form of the invention therefore has all the advantages of the first form described and some special advantages, such as the concentric relation of the air reservoir on the upper end of the hammer and the guiding of both ends of the piston, above as well as below the piston head.

The annular space at 79, Fig. 4, above the piston head, if not used may be vented to atmosphere through passage 80 and air strainer 81.

The sheave or sheaves 82 for suspending the hammer may be conducted directly with the air reservoir 61 and the anvil block 83 may be loosely coupled to the lower end of the cylinder by links of cable 84 or other suitable suspension means.

Fig. 4 further shows how the structure may be simplified by omission of the rocker actuating pusher 29, Fig. 3, and direct actuation of the valve lifting rocker by cam 32 on the lower end of the ram.

The ability to start immediately on compressed air is particularly advantageous, enabling the hammer to be controlled by a simple air valve. The machine consists of but relatively few parts and the stepped or shouldered forms of cylinder and piston construction are particularly practical both for production and operation.

With such construction the ram is properly guided and supported and can be kept well lubricated. The power applied beneath the radially enlarged piston head in the annular form of combustion and working chamber, with air compressor above the piston head, provides a desirable application of forces and balance of loads, promoting smooth running operation. The starting and operating under compressed air has the further desirable effect of accomplishing a scavenging of the cylinder of possibly excess oil, carbon or other undesirable elements.

The combined ram and piston or ram piston may be made all in one piece, with the lower portion serving as the ram and the enlarged portion as the piston head subject to the power impulses and operating as an air compressor in the air compression chamber provided at the upper end of the cylinder.

All three operations of compressed air admission, fuel injection and ignition are effected at or approximately the end of the down stroke and therefore may be accomplished by means of the cam on the lower end of the ram. Thus, in a construction like that shown in Fig. 4, a single rocker operated by this cam may be employed to actuate a fuel injector and an ignition switch as well as effecting the opening of the poppet valve 20.

The quick, sharp blows resulting from the power accelerated and non-cushioned down stroke and more effective combustion for the up stroke effect a faster and more efficient operation of the hammer. The rate and intensity of the blows may be governed by regulation of the fuel and, if desired, regulation of combustion supporting air admitted.

Another important feature of the new cycle of operation is that compression ratios may be relatively low, on the order of 4 or 5 to 1, as compared with diesel cycle ratios of about 18 to 1, and hence the construction may be lighter and less expensive than in hammers operating on the diesel principle.

Many advantages result from the fact that the machine is not dependent for its operation on maintaining high compression pressure.

While particularly concerned with pile hammers and generally referred to as such, it will be evident that the invention is of broader scope, relating to all kinds of percussion tools, and the claims are to be construed accordingly.

What is claimed is:

1. Internal combustion power machine comprising a

stepped cylinder having an air compression chamber portion at the upper end and a reduced ram guiding chamber at the lower end of the same, a piston having a portion operating in said compression chamber portion and a reduced ram extension operating in said ram guiding chamber and forming with the cylinder an annular expansion chamber, said air compression chamber portion having air intake and discharge ports at the upper end of the same with the discharge port located below the limit of upward travel of the piston whereby to trap a rebound cushion of air therein on upstroke of the piston, air compressor intake and unloading valves respectively connected with said ports, air conducting connections extending from the unloading valve to said annular expansion chamber, including an air reservoir, an air injection valve for admitting combustion supporting air through said connections to said expansion chamber and a check valve faced to hold pressure in the expansion chamber, means operated by said piston for opening said air injection valve substantially at the end of the downstroke of the piston, means for injecting fuel into said expansion chamber and means for effecting ignition of same with the combustion supporting air substantially at the end of the downstroke of the piston, said cylinder having a main exhaust port controlled by the piston and positioned to be uncovered by the piston near the end of upstroke of the same, said cylinder further having an auxiliary exhaust port below said main exhaust port positioned to be covered by the piston at the bottom of its stroke, a relief valve controlling escape from said auxiliary exhaust port, a differential pressure actuator operable in opposite directions connected to and thereby arranged to close and open said relief valve, said actuator having differential pressure areas for effecting operation of the same in opposite directions and pressure conducting means connected with the expansion chamber and extended to the larger area side of said actuator for effecting the holding of the relief valve closed by pressure from the expansion chamber and pressure conducting means extending from said air reservoir to the smaller area side of said differential actuator for effecting the opening of said relief valve on reduction of pressure in the expansion chamber resulting from opening of the main exhaust port by the piston and thereby to release pressure from beneath the descending piston after closing of the main exhaust port in the downstroke of the piston.

2. Internal combustion power machine comprising a stepped cylinder having a piston head containing upper end portion and a reduced ram guiding lower end portion, a stepped piston having a head operating in said upper end portion of the cylinder and a reduced ram extension guided in said lower end portion of the cylinder and said cylinder and piston thereby forming an annular expansion chamber about the ram extension beneath the piston head, said cylinder having air intake and discharge ports at the upper end of the same with the discharge port located below the limit of upward travel of the piston whereby to trap a rebound cushion of air therein on upstroke of the piston, air compressor intake and unloading valves respectively connected with said ports, air conducting connections extending from the unloading valve to said annular expansion chamber, including an air reservoir, an air injection valve for admitting combustion supporting air through said connections to said expansion chamber and a check valve faced to hold pressure in the expansion chamber, means operated by said piston for opening said air injection valve substantially at the end of the downstroke of the piston, means for injecting fuel into said expansion chamber and means for effecting ignition of same with the combustion supporting air substantially at the end of the downstroke of the piston, said cylinder having a main exhaust port controlled by the piston and positioned to be uncovered by the piston head near the end of upstroke of the same, said cylinder further having an auxiliary exhaust port below said main exhaust port positioned

to be covered by the piston at the bottom of its stroke, a relief valve controlling escape from said auxiliary exhaust port, a differential pressure actuator operable in opposite directions connected to and thereby arranged to close and open said relief valve, said actuator having differential pressure areas for effecting operation of the same in opposite directions and pressure conducting means connected with the expansion chamber and extended to the larger area side of said actuator for effecting the holding of the relief valve closed by pressure from the expansion chamber and pressure conducting means extending from said air reservoir to the smaller area side of said differential actuator for effecting the opening of said relief valve on reduction of pressure in the expansion chamber resulting from opening of the main exhaust port by the piston and thereby to release pressure from beneath the descending piston after closing of the main exhaust port in the downstroke of the piston.

3. The invention according to claim 1 with an anvil block at the lower end of the ram guiding chamber for engagement by the ram extension of the piston.

4. The invention according to claim 1 with the chamber portion at the upper end of the cylinder and the portion of the piston operating therein substantially the same diameter.

5. The invention according to claim 1 with said air compression chamber portion of the cylinder being in the form of an extension of less than the major diameter of the cylinder and the said portion of the piston operating in said reduced diameter extension of the cylinder.

6. The invention according to claim 1 with means for injecting compressed air into the expansion chamber independently of the piston movement for effecting lifting of the piston to initiate internal combustion operation described.

7. The invention according to claim 1 with compressed air supply means including a valve connected with said compressed air reservoir and connected to admit air to the expansion chamber for lifting the piston to initiate the internal combustion operation described.

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