March 25, 1958 W. W. SIMMONDS 2,827,764

POWER SYSTEM FOR A DROP HAMMER

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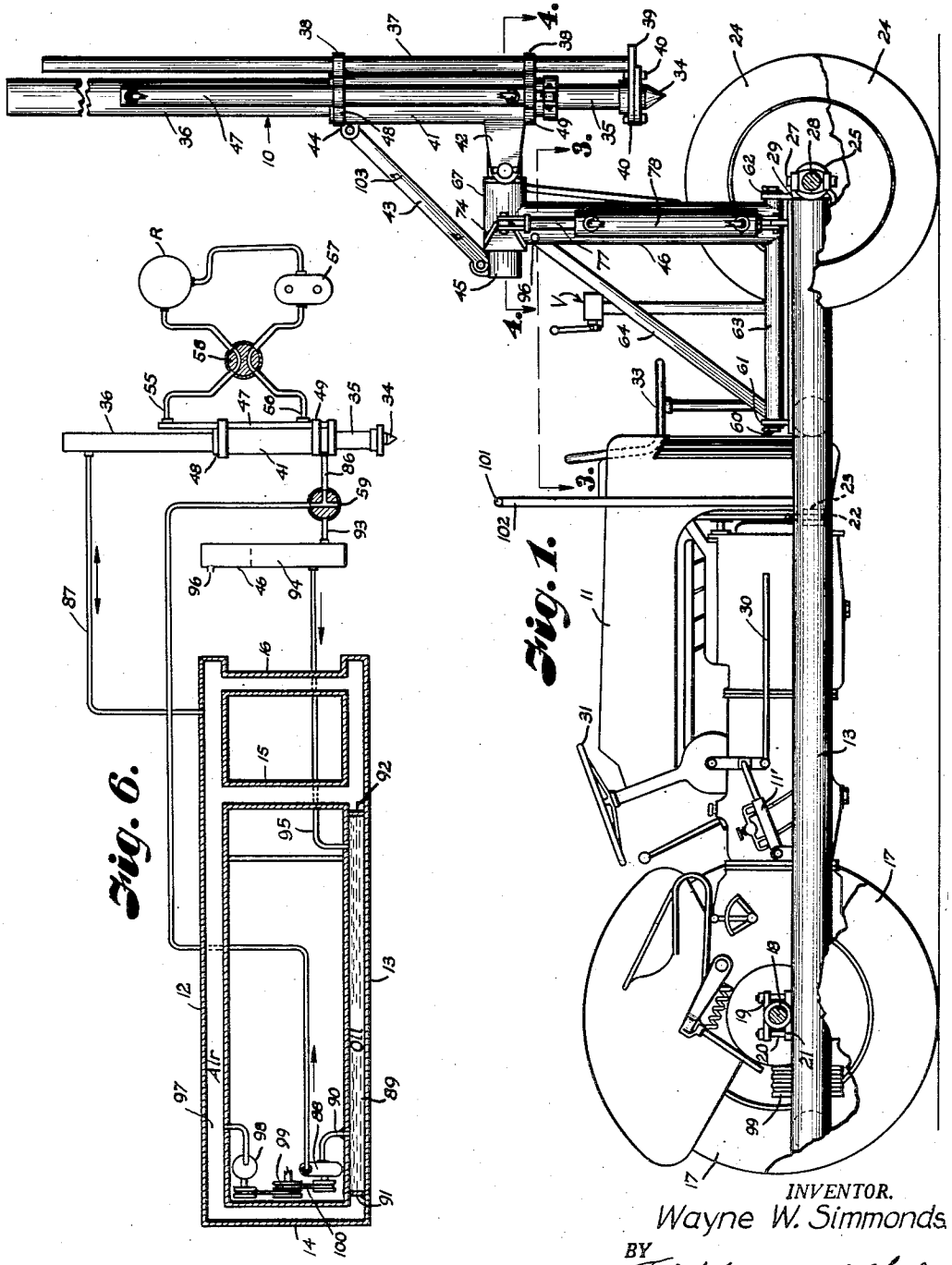


Fig. 1.

Fig. 6.

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Fig. 2.

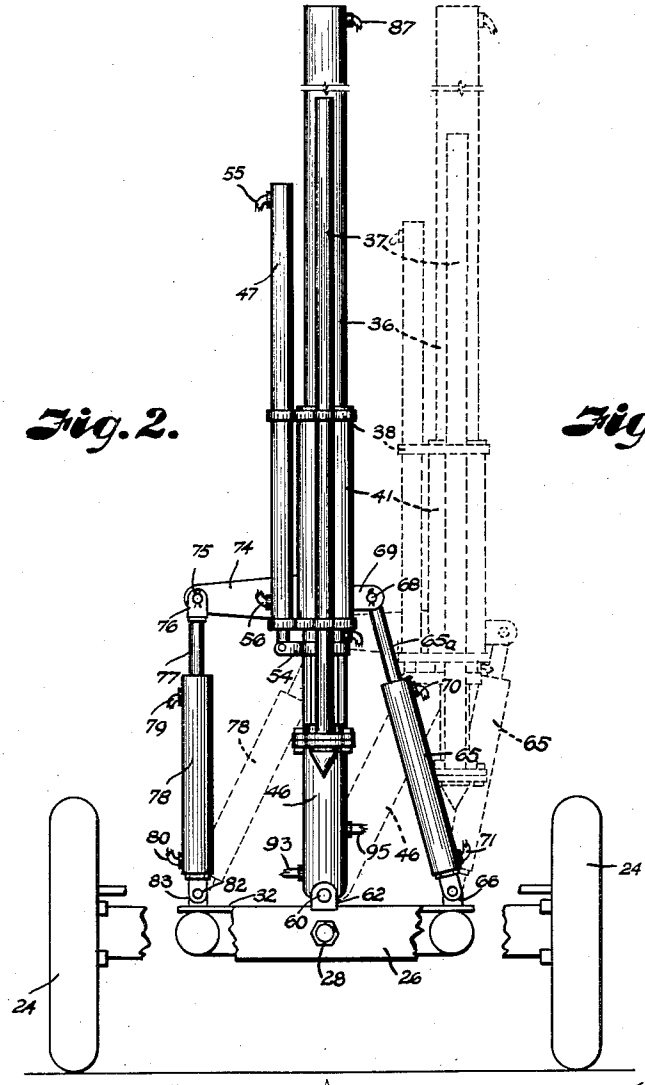


Fig. 5.

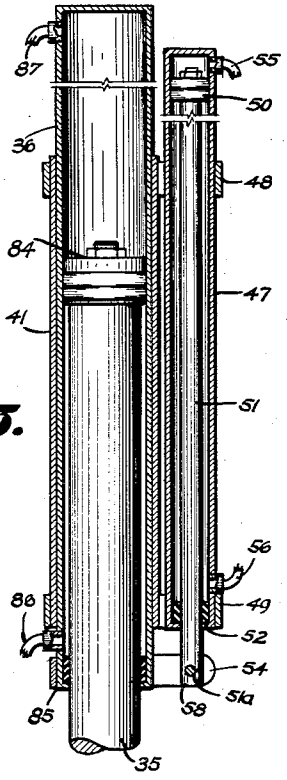


Fig. 3.

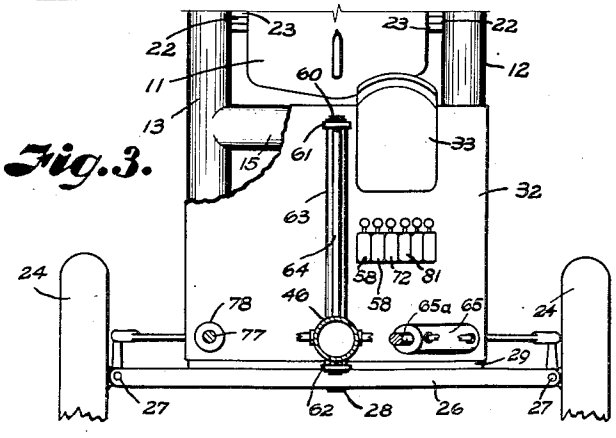
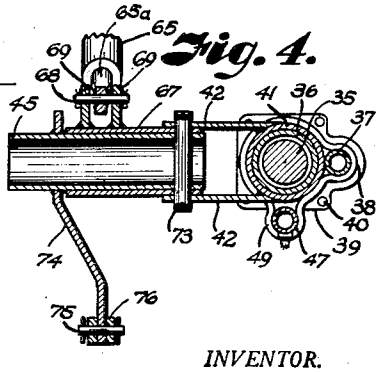


Fig. 4.



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United States Patent Office 2,827,764
Patented Mar. 25, 1958

2,827,764

POWER SYSTEM FOR A DROP HAMMER

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Application December 13, 1955, Serial No. 552,852

3 Claims. (Cl. 60—51)

This invention relates to power hammers of the type generally used for breaking concrete slabs or other relatively hard road surfaces or for tamping earth fills, digging trenches, and other like tasks.

This application is a continuation-in-part of my copending application, Serial No. 305,349, filed August 20, 1952, and issued January 24, 1956, as Patent No. 2,731,892.

It is a principal object of the invention to provide a reciprocating hammer suitable for the above purposes which is powered by a unique combination of hydraulic and pneumatic forces, and which, as a result, has a greatly improved operational efficiency.

It is another object of the invention to provide a power hammer mounted upon a traveling carriage which can be driven to the site of operations and maneuvered with relative ease while the hammer is being used. In this connection, it is a further object to provide a unique means for mounting the hammer on the carriage so that the hammer may be adjusted from side to side with respect to the normal path of travel of the carriage and yet maintained in an upright position. Means are also provided for pivoting the hammer with respect to the carriage so that the hammer can be tilted to any desired position independent of the disposition of the carriage. This finds primary advantage in situations where the carriage is resting on uneven terrain or on inclined surfaces.

Still another object is to provide a frame which can be mounted on a conventional tractor to convert the tractor into a suitable carriage for the hammer, the parts of the frame also serving as reservoirs for storing the hydraulic and pneumatic fluids which are utilized as power sources for the hammer. It is also an object to provide suitable pumps on the frame which can be driven concurrently from the power take-off unit of the tractor.

Other and further objects, together with the features of novelty appurtenant thereto, will appear in the course of the following description.

In the accompanying drawings which form a part of the specification and are to be read in conjunction therewith, and in which like reference numerals indicate like parts in the various views,

Fig. 1 is a side elevational view of a preferred embodiment of my invention, the outer wheels being broken away for purposes of illustration;

Fig. 2 is a front elevational view of the hammer mechanism and support frame, the tractor not being shown;

Fig. 3 is a view taken along the line 3—3 of Fig. 1 in the direction of the arrows;

Fig. 4 is a cross-sectional view taken along the line 4—4 of Fig. 1 in the direction of the arrows;

Fig. 5 is a longitudinal sectional view through the hammer cylinder and vertical adjustment cylinder; and

Fig. 6 is a schematic diagram showing the hydraulic-pneumatic system for the hammer, and the independent hydraulic system for the vertical adjustment cylinder.

Referring to the drawings, and more particularly to Fig. 1, the hammer mechanism, generally indicated at 10, is carried at the forward end of a support frame adapted to be affixed to a tractor 11, the latter being conventional except that the front wheels have been removed. The basic construction of the frame is shown schematically in Fig. 6, and consists principally of two

elongated side members 12 and 13 (in the form of hollow, cylindrical tubes) which are jointed to one another fore and aft of the tractor by cross-members 14, 15, and 16 to provide a rigid, unitary structure. These cross-members are also hollow, cylindrical tubes, and communicate with the side members to form a continuous, air-tight cell which, as will be hereinafter shown, is partitioned and utilized as storage tanks for both the hydraulic fluid and the compressed air used to operate the hammer.

The side members 12 and 13 are disposed on opposite sides of the tractor 11 inside the rear wheels 17 and as shown clearly in Fig. 1, are hung from the rear tractor axle 18 by means of an upper clamping bar 19 resting on top of the axle and connected with the frame member 13 by bolts 20. The bolts 20 are carried by a bar 21 welded or otherwise affixed to the top of the frame member 13 and bearing against the underside of the axle. It will be understood that while in Fig. 1 only one side of the unit is shown, the method of attachment just described is the same on both sides.

The second point of attachment of the frame with the tractor is located just rearward of the nose of the latter, and, as in the case of the rear mounting, may be of any suitable construction. The preferred form I have adopted is to weld support brackets 22 to side members 12 and 13, and attach these brackets by bolts or otherwise to the downwardly extending legs 23 of the axle on which the wheels of the tractor are normally mounted.

To replace the front wheels of the tractor and support the unit at its forward end are two wheels 24 mounted on pin axles 25 which in turn are secured to the ends of a main axle 26 through king pins 27. Axle 26 is centrally pinned to the forward cross tube 16 by means of a pin 28. A plate 29 (see Fig. 3) spans the side members 12 and 13 intermediate the axle 26 and the cross tube 16, being welded or otherwise secured at its ends to the side members. This plate serves as additional support for pin 28, which passes therethrough, and also as a bearing plate against which the axle 26 will rub when the unit is passing over rough ground. While not shown in detail, the tractor steering rods 30 are connected with wheels 24 through suitable extensions to provide directional control of the unit by operation of the tractor steering wheel 31.

The forward part of the frame ahead of the nose of the tractor 12 is provided with a flat deck 32 which rests upon and is secured to the side members 12 and 13 and the forward cross tube 16 to form a floor or platform for the operator of the hammer. A seat 33 is mounted on this platform and within easy reaching distance of the seat is a bank of valves, generally indicated at V, through which operation of the unit is controlled. As will be described later, those valves in valve bank V which are identified by specific reference numerals play a part in the positioning and operation of the hammer mechanism 10; the remaining valves are connected with other hydraulic cylinders, for example, such as that seen at 11' in Fig. 1, which are utilized to provide control over the steering mechanism and transmission of the tractor from the operator's chair 33. However, inasmuch as these latter features form no essential part of the present invention, they will not be dealt with in detail.

Supported at the front end of the frame and between the wheels 24 is the hammer mechanism 10. While the construction and mode of operation of the hammer will be set forth in more detail hereinafter, it should perhaps be noted here that the mechanism comprises a hammer head 34 secured to the lower end of a piston shaft 35 which, in operation, is vertically reciprocated in a cylinder 36 to cause the hammer head 34 to deliver a series of impacts to the surface being worked. A guide rod

37 is spaced laterally from the hammer piston 35 and extends upwardly alongside cylinder 36 where it is slidably received in vertically spaced guide members 38. The lower end of guide rod 37 is rigidly secured to a plate 39 which in turn is secured to piston 35 and hammer head 34 by bolts 40; thus it reciprocates with the piston and serves to maintain the latter in proper alignment with cylinder 36.

It will be seen from Figs. 1, 4 and 5 that the hammer cylinder 36 is not rigidly attached to the supporting structure rising from the front of the frame, but is carried inside a coaxial cylindrical sleeve 41 which is supported in an upright position by laterally projecting brackets 42 welded to its lower end and a two-part diagonal brace member 43 connected to an ear 44 affixed to its upper end. Brace 43 and brackets 42 are attached to the opposite ends of a horizontal spindle 45 which is carried at the upper end of a post unit 46 mounted on the frame, and the hammer is thus normally stabilized in an upright position.

Referring now more particularly to Figs. 5 and 6, positioned alongside sleeve 41 and paralleling the hammer cylinder 36 is a double-acting hydraulic cylinder 47 through which vertical adjustment of the hammer cylinder with respect to sleeve 41 may be obtained. The adjusting cylinder 47 is rigidly affixed to sleeve 41, preferably by means of upper and lower collars designated respectively at 48 and 49, and slidably received therein is a piston head 50 from which extends a piston shaft 51. Shaft 51 extends through the lower and of cylinder 47 through a pressure-tight packing 52, and is provided at its lower end with a flattened portion 51*a* bolted at 53 to an ear 54 extending laterally from and secured to the lower end of the hammer cylinder 36. Hydraulic lines 55 and 56 communicate respectively with the interior of adjusting cylinder 47 above and below the piston 50, and fluid for actuating the piston head is supplied from the standard hydraulic pump unit 57 (Fig. 6) of the tractor 12 through a conventional four-way valve 58. To shift the hammer cylinder 36 downwardly with respect to sleeve 41, valve 58 is positioned to introduce fluid above the piston 50 through line 55 and allow withdrawal through line 56; conversely, upward shifting of the hammer cylinder 36 is accomplished by reversing the hydraulic flow, fluid entering through line 56 and withdrawn through line 55.

It will be understood that valve 58 is located in the valve bank V (Fig. 3). All of the remaining valves in the bank, with the exception of valve 59, are similar four-way valves connected by means of a common manifold to the same hydraulic pump unit 57 installed as standard equipment in most conventional tractors, and the return lines are likewise connected to a single receiver R, as is schematically shown for the cylinder 47 in Fig. 6. Valve 59, the exception referred to above, operates the hammer mechanism proper, and forms a part of a hydraulic-pneumatic system which is completely independent of that just described and which will be discussed more fully hereinafter.

The entire hammer mechanism 10 is carried at the top of the upwardly extending hollow post unit 46 which is pivoted, as shown in Fig. 2, about an axis substantially in line with the path of travel of the tractor. The pivotal support for the post unit 46 comprises an elongated pivot pin 60 supported at its ends in brackets 61 and 62, these being attached respectively to the deck 32 and the cross-brace 29 spanning the front of the frame. The post unit 46 is mounted on pin 60 by means of an elongate tube 63 which rotatably fits in pin 60 and has a length substantially equal to the spacing between brackets 61 and 62. Tube 63 is secured at its forward end to the lower end of post unit 46, preferably by welding, and a diagonal brace 64 extends from the rearward end of the tube to the upper end of the post unit to give the structure additional strength.

Positioned to one side of post unit 46 and serving as an adjustable link by which the post may be inclined to either side of the vertical is another double-acting hydraulic cylinder 65 (Fig. 2). Cylinder 65 is pivotally connected at its lower end with a bracket 66 welded or otherwise secured to the deck 32, and the piston shaft 65*a* emerging from the upper end of the cylinder is hingedly connected with a horizontal sleeve 67 welded to the top of a post to form therewith the post unit 46. As shown in Fig. 4, the pivotal connection of the piston shaft 65 with sleeve 67 is by means of a pin 68 carried between two legs 69 secured to the side of the sleeve. It will be understood that hydraulic cylinder 65 is similar in construction to the vertical hammer adjustment cylinder 47, hydraulic lines 70 and 71 being provided for supplying fluid on either side of the piston under control of a four-way valve 72 located in the valve bank V previously described.

To maintain the hammer mechanism 10 in a vertical position with respect to the ground plane upon sidewise swinging of post 46, and also to provide an independent means for inclining the line of impact of the hammer, I have developed the following arrangement. As hereinbefore noted, the vertical sleeve 41 within which the hammer cylinder 36 is carried is connected directly to a horizontal spindle 45 rotatably supported at the top of post unit 46 in sleeve 67. As will be particularly noted from Fig. 4, the spaced parallel brackets 42 extending laterally from the hammer carrying sleeve 41 provide the primary connection to the spindle 45, the brackets 42 lying on opposite sides of the spindle and being pivotally pinned thereto by a pin 73. Spindle 45 extends through its sleeve 67, and affixed to the other end is a laterally extending arm 74. As may best be seen in Fig. 2, the outer end of arm 74 is pivotally connected at 75 with a yoke 76 carried at the upper end of a reciprocable piston shaft 77 extending upwardly from a double-acting hydraulic cylinder 78. Cylinder 78 is identical in construction to those previously described, having hydraulic lines 79 and 80 for controlling the displacement of the piston shaft 77 in either direction through the operation of valve 81 (Fig. 3). The lower end of the cylinder 78 is pivotally connected as at 82 with a bracket 83 rigidly affixed to the deck 32 by any suitable means, preferably welding.

It will be understood that with valve 81 set in a neutral position, piston shaft 77 is immobilized within cylinder 78, and thus the shaft and cylinder in this condition serve as a rigid, articulating link serving to maintain the hammer mechanism 10 in a relatively vertical position despite pivoting of the post 46 in either direction. This can be best appreciated by referring to Fig. 2, wherein the hammer mechanism 10 is shown in broken lines as shifted to one side of the center line of the tractor 12. The cylinder 78 forms one side of an articulated parallelogram linkage which has for its opposite side the pivotal post 46, the remaining sides being defined by arm 74 and the deck 32. As the post unit 46 is shifted, the arm 74 is maintained parallel to the deck 32 by cylinder 78; this has the effect of causing relative rotation between spindle 45 and its journal sleeve 67 and allowing the post 46 to swing to its inclined position without disturbing the relative disposition of the hammer mechanism 10 with respect to the ground plane. On the other hand, it will be obvious that under the control of cylinder 78, the hammer mechanism 10 can be rotated about the axis of the spindle 45 independently of the shifting of the post unit 46. The particular advantages of this latter feature will be made clear presently.

Turning now to a detailed description of the construction and mode of operation of the hammer mechanism 10, and referring particularly to Figs. 5 and 6, the hammer piston shaft 35 is affixed at its upper end to a piston 84 carried inside the hammer cylinder 36. An annular packing 85 surrounds shaft 35 at the lower end of cylinder 36 to provide a pressure-tight seal, and a fluid inlet line 86

communicates with the annular space thus formed between the piston and the packing. A second line 87 is connected into the top of cylinder 35 to communicate with the space above the piston 84.

The hydraulic and pneumatic system supplying the hammer is shown in Fig. 6. Line 86 at the lower end of cylinder 36 is connected with a three-way valve 59 to which hydraulic fluid, such as oil, is pumped by a conventional pump 88 located at the rear of the tractor. The pump 88 draws the fluid through line 90 as needed, from a reservoir 89 which is formed by the tubular frame member 13. It will be noted that reservoir 89 extends only between cross-members 14 and 15, pressure-tight partitions 91 and 92 being located adjacent the cross-members to form an enclosed compartment wholly within the frame member 13. A return line 93 leads from valve 59 to a secondary reservoir 94 formed by the hollow interior of the hammer-carrying post unit 46, and another line 95 leads from reservoir 94 to the main oil reservoir 89. An air vent 96 is provided near the upper end of the post unit 46 to permit free fluctuation of the fluid level therein, the advantage of which will be pointed out hereinafter.

Line 87, which is connected into the upper end of the hammer cylinder 36, communicates at its other end with an air tank 97 formed by the frame side member 12 and the cross-members 14, 15, and 16. Compressed air is supplied to tank 97 by a compressor 98 located at the rear of the tractor adjacent the hydraulic pump 88; as is conventional the compressor preferably has a built-in pressure-controlled valve which serves automatically to maintain the pressure in tank 97 at the desired value, approximately 150 p. s. i. Both the compressor and the hydraulic pump are mounted at the rear of the tractor on opposite sides of the conventional power-take-off pulley 99 and are driven by belts 100 connected therewith.

In describing the operation of the hammer, it will be assumed that the hammer head 34 has been raised to its uppermost position, as shown in Figs. 1 and 6, and that it is ready for the sharp, downward impact stroke. In this condition, piston 84 is located at the upper limit of its displacement in the hammer cylinder 36, valve 59 having been positioned to supply hydraulic fluid directly from the pump 88 to the line 86 communicating with cylinder 36 below the piston. By virtue of the open communication through line 87, the compressed air in tank 97 exerts pressure on the top of the piston 84 tending to drive the hammer downwardly; however, it will be understood that the pressure of the hydraulic fluid on the underside of the piston is more than sufficient to maintain the hammer in the upraised position.

To produce the hammer blow, valve 59 is turned 90° counterclockwise from its Fig. 6 position, which opens communication between the cylinder 36 and post unit 46 through lines 86 and 93. At the same time, the flow from the pump 88 is also diverted into the return line 93, and accordingly, the pressure inside the cylinder below the piston 84 is completely released.

Under the influence of the air pressure above the piston 84, the shaft 35 now is driven sharply downward at high speed to cause the hammer head 34 to strike the ground surface or pavement with a hard and sustained impact. The hydraulic fluid originally present in the annular space surrounding shaft 35 is forced outwardly through line 86 by the downward movement of the piston 84 and into the vertical post unit 46. The primary reason for providing this intermediate reservoir is to eliminate the flow resistance which would otherwise be encountered should line 86 return directly to the oil reservoir 89 in frame member 13. In other words, the efficiency of the hammer depends in large measure on the rapidity of the downstroke which can be attained. Any resistance to withdrawal of the fluid from cylinder 36 has the ultimate effect of slowing down the action of the hammer, and obviously, a long return line would, by virtue of the frictional flow resistance therein, serve to amplify this undesirable effect. By providing an intermediate reservoir such as the interior of post unit 46, the fluid leaving the cylinder 36 is allowed to accumulate therein after traversing the distance represented by lines 86 and 93, and then to flow by gravity through line 95 into the reservoir 89 from whence it can be drawn by pump 88 as needed. Since the post unit 46 is vented to atmosphere at 96, the sole resistance to flow out of cylinder 36 is the frictional resistance in lines 86 and 93 and the relatively small hydrostatic head developed in the post as the fluid accumulates.

To raise the hammer for the next stroke, valve 59 is returned to its Fig. 6 position to direct the flow from pump 88 into the cylinder 36 through line 86. The hydraulic pressure displaces the piston 84 upwardly until its fully raised position is reached and the hammer ready for another impact.

As has been pointed out hereinbefore, through the mounting of the hammer mechanism 10 on the pivotal post 46, the hammer may be swung from side to side during its operation while still maintained substantially vertical. Thus successive impacts can be produced over a relatively great width without disturbing the line of travel of the tractor itself.

It is also possible to adjust the inclination of the hammer mechanism 10 with respect to the ground level or the post 46 by actuating the hydraulic cylinder 78 in the manner hereinbefore described. With this feature, two main advantages over previously known hammers of this general type are obtained. The first is fairly obvious, and rests in the ability to align the hammer in a true vertical line even though the tractor is resting on an incline, i. e., where the wheels on one side of the tractor are at a higher level than those on the other. The second, and less obvious, is that use of cylinder 78, the hammer head 34 can be given a sidewise movement after being imbedded in the ground on the downstroke to rip and tear the earth or break down the walls of a cavity which the hammer is being used to form. In other words, once the hammer head 34 is imbedded, the operator, through operation of valve 81, can cause cylinder 78 to force the complete hammer mechanism 10 to rotate about the axis of the horizontal spindle 45 and thus impart a side wise movement to the hammer head 34. This feature has particular merit where the hammer head 34 is replaced with another type of tool, such as a spade head or digging bucket. In the case of the digging bucket, the sidewise motion of the hammer produces the scooping effect necessary to remove the earth.

It will be understood that my hammer is particularly suited to digging trenches of substantial depth. The vertical adjustment of the hammer cylinder 36 within its sleeve 41 allows the hammer to be repositioned to a lower level as the dirt is removed from the trench. In other words, as the depth of the cavity increases, the hammer cylinder 36 can be lowered by actuating the vertical adjustment cylinder 47 positioned alongside sleeve 41. The sleeve 41, of course, remains stationary, the hammer cylinder 36 sliding therein as the piston shaft 51 is displaced downwardly in the adjusting cylinder.

During the transit of the unit from one location to another, and when the hammer is not in operation, the hammer mechanism 10 can be laid over in a horizontal position, with the upper part of the cylinder 36 resting on a cradle 101 which is supported by legs 102 rising from the frame on opposite sides of the tractor hood. This is accomplished by removing the retaining pin 103 from the two-part brace member 43, and swinging the hammer cylinder 36 rearwardly and downwardly about the pin 73 which connects the hammer mechanism to the spindle 45. To ready the hammer for operation, the hammer mechanism 10 is returned to its Fig. 1 position, and pin 103 reinserted in the brace to lock the hammer in its normally upright position.

From the foregoing, it will be seen that I have provided

a mobile hammer unit having both highly efficient operation and unusual adaptability to various situations which may be encountered in use. Through the unique method of mounting the hammer on the carriage and providing a hydraulic-pneumatic system for operating the hammer independently of the hammer positioning means, a high degree of flexibility in operation is obtained, making the unit readily adaptable to an infinite variety of tasks which have heretofore required specially designed units not capable of use for more than one purpose. My unit is also compact and simple, and as a result extremely economical to manufacture and maintain in repair.

From the foregoing it will be seen that this invention is one well adapted to attain all of the ends and objects hereinabove set forth together with other advantages which are obvious and which are inherent to the structure.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

As many possbile embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

Having thus described my invention, I claim:

1. Fluid actuating means comprising, an enclosed cylinder, a piston reciprocable within said cylinder and dividing same into compartments, a liquid reservoir, a second reservoir above the liquid reservoir and having an air vent in the upper portion thereof, the lower portion of the second reservoir having communication with the liquid reservoir, a gaseous fluid reservoir, means for supplying gaseous fluid to said gaseous fluid reservoir and maintaining pressure therein within selected limits, said gaseous fluid reservoir having communication with one compartment of said cylinder adjacent one end thereof remote from the piston whereby the gaseous fluid pressure acts on one end of the piston, liquid pressure means operable to move liquid under pressure from the liquid reservoir to the other compartment in said cylinder adjacent the other end thereof with sufficient pressure to effect movement of the piston in said cylinder toward said one end of the cylinder, means with a fluid passage therein connecting said other compartment in said cylinder with the second reservoir for discharge of liquid from said other compartment, and means operable to selectively control movement of liquid to and from said other compartment of said cylinder for effecting movement of the piston therein toward said one and said other end of the cylinder with the gaseous fluid pressure accelerating the movement of the piston toward said other end of the cylinder.

2. A fluid actuating means comprising, an enclosed cylinder, a piston reciprocable within said cylinder, a liquid reservoir, a second reservoir extending above the liquid reservoir and having the upper portion thereof vented to atmosphere, the lower portion of the second reservoir having communication with the liquid reservoir, a gaseous fluid reservoir, means for maintaining gaseous fluid pressure in the gaseous fluid reservoir within selected limits, said gaseous fluid reservoir having communication with the cylinder whereby the gaseous fluid pressure acts on one end of the piston, liquid pressure means operable to move liquid under pressure from the liquid reservoir to the cylinder to act on the other end of the piston with sufficient pressure to effect movement of the piston in said cylinder in one direction, means with a fluid passage therein connecting the portion of the cylinder at said other end of the piston with the second reservoir, and valve control means operable to selectively control movement of liquid to and from said portion of the cylinder at the other end of the piston whereby operation of said valve control means to connect the liquid pressure means with said portion of the cylinder at said other end of the piston and closing of the passage between said portion of the cylinder at said other end of the piston and the second reservoir provides a supply of liquid pressure which effects movement of the piston in said one direction and operation of the valve control means to stop supply of liquid to said portion of the cylinder at said other end of the piston and opening of the passage from said portion of the cylinder at said other end of the piston to the second reservoir provides for discharge of liquid from said portion of the cylinder at said other end of the piston which liquid passes through the second reservoir to the liquid reservoir and the gaseous fluid pressure accelerates the movement of the piston in the other direction.

3. Fluid actuating means comprising, an upright enclosed cylinder with an axial opening in its lower end, a piston reciprocable within said cylinder and dividing same into upper and lower compartments, a coaxial shaft secured to said piston and extending downwardly through said axial opening, a pressure-tight packing around said shaft in said axial opening forming with the piston an enclosed annular space in said lower compartment, a liquid reservoir, a second reservoir above the liquid reservoir and having an air vent in the upper portion thereof, the lower portion of the second reservoir having communication with the liquid reservoir, a gaseous fluid reservoir, means for supplying gaseous fluid to said gaseous fluid reservoir and maintaining pressure therein within selected limits, means connecting the gaseous fluid reservoir with the upper compartment of the upright cylinder for providing communication therebetween whereby the gaseous fluid pressure acts on the upper end of the piston, liquid pressure means operable to move liquid under pressure from the liquid reservoir to the annular space in the cylinder with sufficient pressure to effect upward movement of the piston in said cylinder, means with a relatively large fluid passage therein connecting the annular space in the cylinder with the second reservoir for quick release of liquid pressure and substantially free falling of said coaxial shaft, and valve control means operable to selectively control movement of liquid to and from the annular space of the cylinder whereby operation of said valve control means to connect the liquid pressure means with the annular space and closing of the passage between the annular space and the second reservoir provides a supply of liquid under greater pressure than the gaseous fluid pressure acting on the upper end of the piston and the liquid pressure effects upward movement of the piston and shaft and operation of the valve control means to stop supply of liquid to the annular space and opening of the passage from the annular space to the second reservoir provides for discharge of liquid from the annular space which liquid passes through the second reservoir to the liquid reservoir and the gaseous fluid present accelerates the downward movement of the piston and shaft.

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