July 9, 1946. H. F. CAUDILL 2,403,582

POWER HAMMER

Filed Sept. 16, 1942 2 Sheets-Sheet 1

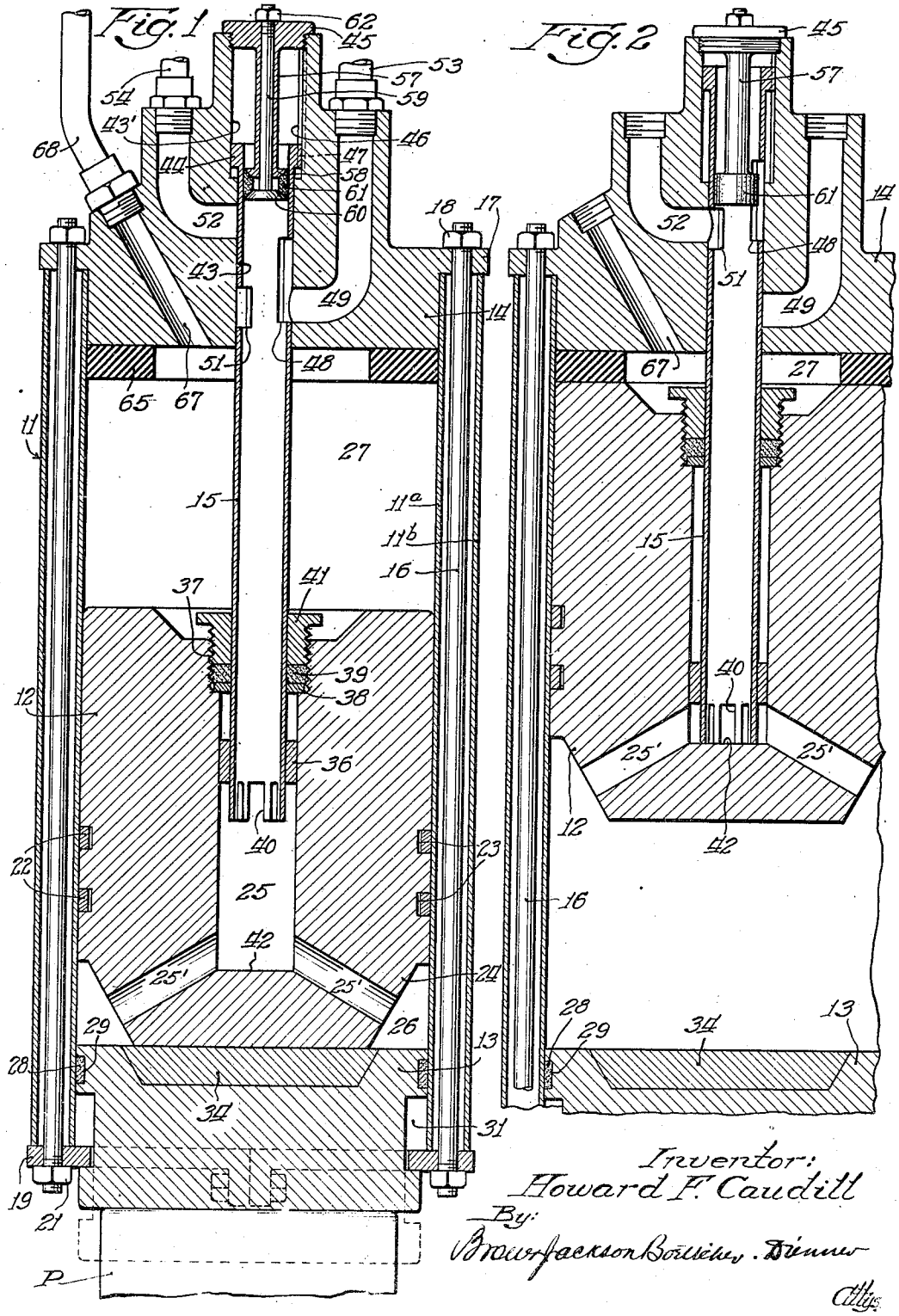

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Fig. 3

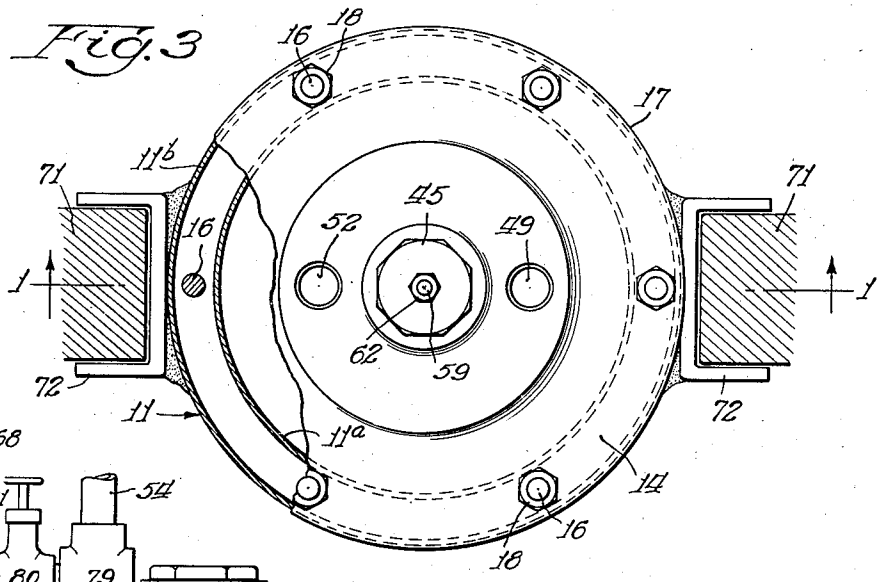


Fig. 4

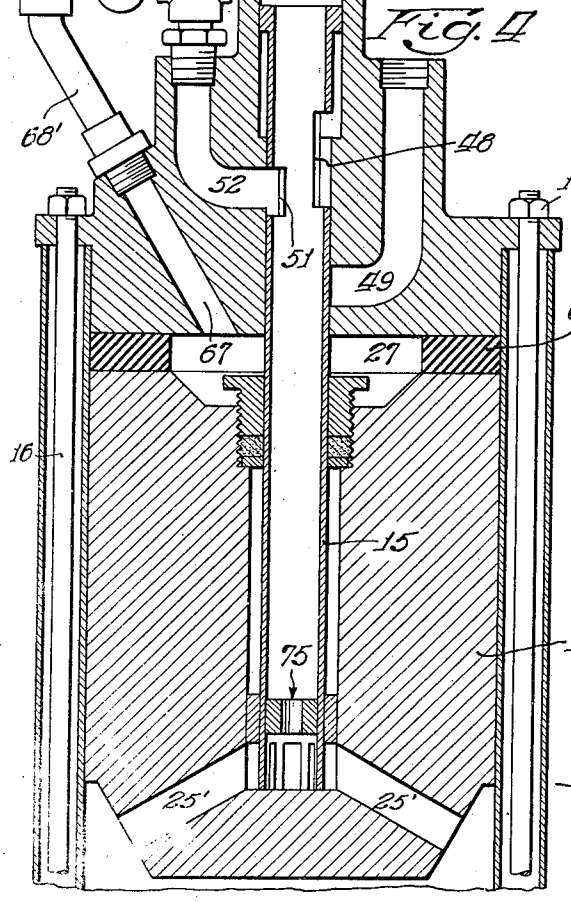
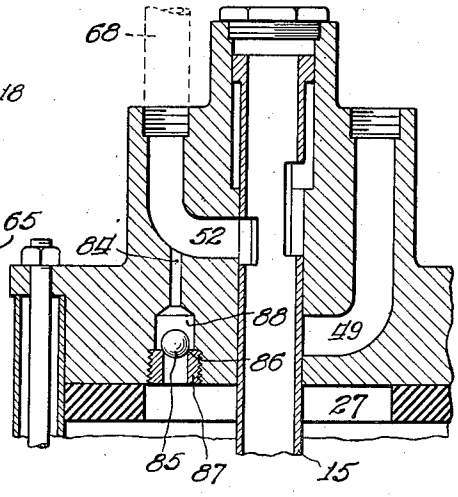


Fig. 5



Inventor:
Howard F. Caudill
By:
Brownson Boettcher & Dienner
Attys

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2,403,582

POWER HAMMER

Howard F. Caudill, Oak Park, Ill., assignor to Western Foundation Company, Chicago, Ill., a corporation of Illinois

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7 Claims. (Cl. 121—30)

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The present invention relates to power hammers of the type which derive their operating energy from fluid pressure, such as steam or compressed air. In the preferred embodiment herein shown, the hammer is of the drop type wherein the ram or hammer element is raised to an elevated position by fluid pressure, and is then dropped to deliver the hammer blow.

One of the distinctive features of the invention is the fact that a single reciprocating element serves both as the piston and as the driving ram, this piston ram being completely enclosed within the working cylinder, and the fluid pressure being admitted into the working space at the lower end of the cylinder below the piston ram for forcing the ram up to its elevated position within the cylinder.

Another feature of the invention resides in an improved impact head which closes the lower end of the cylinder. This impact head is capable of endwise motion relatively to the cylinder under the driving blows of the piston ram, but said impact head nevertheless maintains a fluid tight seal with the lower portion of the cylinder so that no appreciable leakage will occur between the cylinder and the head in the back and forth shifting movement of the head relatively to the cylinder. When the piston ram reaches the top of its stroke and the fluid pressure is exhausted from the working space below the ram, the ram falls and delivers its hammer blow to this impact head. Because this impact head can be driven downwardly relatively to the cylinder, the entire kinetic energy of the piston ram is imparted directly to the work, and no appreciable portion of this energy is absorbed in the inertia of the cylinder and its associated parts.

Another feature of the invention resides in a very simplified valve mechanism employing a reciprocating sleeve valve actuated by the piston ram and arranged whereby admission of steam occurs downwardly through the sleeve and through the body of the ram into the working space below the ram, and whereby exhaust of the steam occurs upwardly through the ram and through this same sleeve valve to the exhaust outlet at the upper end of the cylinder. This valve mechanism is of very simple construction requiring only one moving part, viz., the valve sleeve.

An optional feature which may be employed in connection with this valve mechanism, if desired, is the provision of a pressure responsive restriction in the sleeve valve which serves as a pressure responsive detent for alternately holding the sleeve valve in each of its two extreme positions,

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i. e., first in its lower steam admitting position, and then in its upper steam exhausting position. When the steam is passing downwardly through the sleeve in the admission half of the cycle, a greater pressure exists above the restriction than below, and hence this pressure differential tends to hold the valve down in its admission position, notwithstanding the fact that the ram is then moving upwardly. Conversely, when the steam is passing upwardly through the sleeve in the exhaust half of the cycle, a greater pressure exists below the restriction than above, and hence this pressure differential tends to hold the valve up in its exhaust position, notwithstanding the fact that the ram is then dropping downwardly.

Another optional feature which may be employed, if desired, is the provision of a cushioning space at the upper end of the cylinder for cushioning the upper limit of movement of the piston ram. This cushioning space may be arranged to trap air (and possibly a small amount of leakage steam) in the upper end of the cylinder, which trapped fluid would cushion the act of stopping the piston ram at the upper limit of its movement and starting it down again through its free fall down against the impact head at the lower end of the cylinder.

The several features which I have enumerated above result in a fluid operated power hammer which can be made of relatively short over-all length, and which is of very simple construction, having only two moving parts—the piston ram and the sleeve valve. Furthermore, my improved construction of hammer can be operated with entire success while completely submerged in water, which is a very important advantage for driving bearing piles, sheet piles and other like structures below water level. It is only necessary to extend the appropriate connections to the hammer unit when it is desired to operate it in submerged locations.

Other features, objects and advantages of the invention will appear from the following detailed description of certain preferred embodiments of the invention. In the accompanying drawings illustrating such embodiments:

Figure 1 is a fragmentary axial sectional view through the hammer, taken approximately on the plane of the line 1—1 of Figure 3;

Figure 2 is a fragmentary sectional view showing the piston and sleeve valve in their upper positions at the upper end of the stroke;

Figure 3 is a plan view of the hammer unit, showing one method of guiding the unit between the vertical leads of a pile driver;

Figure 4 is a fragmentary sectional view of a modified construction wherein the sleeve valve is provided with the aforementioned pressure responsive restriction for alternately holding the sleeve valve in its upper position and in its lower position; and

Figure 5 is a fragmentary sectional view of another modified construction wherein a check valve controlled restricted vent is employed for creating a pneumatic cushioning action in the upper end of the cylinder.

Referring first to Figure 1, the main elements of the hammer assembly comprise the cylinder 11, the piston ram 12, the lower impact head 13, the upper valve housing head 14 and the sleeve valve 15. The cylinder 11 comprises spaced inner and outer cylindrical shells 11*a* and 11*b* having a series of tie bolts 16 passing down between the shells (Figure 3). The upper ends of the tie bolts 16 pass upwardly through an outer flange 17 formed on the valve housing head 14, and the threaded extremities of the tie bolts receive nuts 18 above the flange. The lower ends of the tie bolts pass through a retaining ring 19 which is clamped against the lower end of the shells by the nuts 21. This double wall construction enables the cylinder to be made of relatively thin inexpensive stock while still possessing the necessary rigidity. For example, the inside shell 11*a* can be made of machined pipe stock, and the outside shell 11*b* can consist of a length of ordinary steel pipe. The spaced relation between the shells reduces thermal conductivity through the sides of the cylinder, and also permits the outer shell to be dented or injured in handling the hammer without causing injury of the inner shell. The reduced thermal conductivity resulting from the double wall construction with intervening dead-air space is very advantageous when it is desired to operate my improved hammer totally submerged in water. In the case of the ordinary steam operated hammer, the heat dissipation to a surrounding body of cold water may be so rapid that the steam condensate quickly causes the hammer to become water logged and to therefore cease operating.

The hammer element 12 consists of a large cylindrical casting having a moderately close sliding fit within the cylinder 11, this casting serving both as a piston and as a ram. A plurality of piston rings 22 seat in grooves 23 in the hammer, these rings being of any preferred construction, typically illustrated by the conventional steam piston rings used in hoist engines. The lower end of the piston ram is formed with a conical striking portion 24 which delivers the impact blows to the impact head 13. Extending axially of the piston ram is a passageway 25 for the steam or compressed air, this axial passageway opening into two or more diagonal passageways 25' which open out through the impact head 24. These passageways 25, 25' have continuous communication with the cylinder space 26 defined below the piston ram 12, this lower space constituting the working space in which the steam or compressed air performs its work of lifting the ram. The upper space 27 between the upper end of the piston and the upper head 14 may be arranged to function as a cushioning chamber if desired, as I shall later describe.

The impact or driving head 13 is arranged so that it is capable of limited endwise motion in the lower end of the cylinder 11. At the same time, this driving head must maintain a steam tight closure of the lower end of the cylinder, and

to this end it is provided with a sealing ring 28 confined in an annular groove 29 formed in the upper portion of the driving head. This ring 28 may consist either of a ring of steam packing material, or a piston ring. Below the sealing ring 28, the head 13 is formed with an annular groove 31 into which extends the retaining ring 19 secured to the lower end of the cylinder 11. Said retaining ring is divided into two or more sections having spaced holes therein through which extend the vertical tie bolts 16, these tie bolts serving to hold the ring sections together. If desired, the ends of the ring sections may have bolting lugs for receiving bolts to aid in holding the ring sections together. Normally the weight of the cylinder and the associated parts holds the retaining ring 19 down against the bottom shoulder of the groove 31. When the piston ram strikes its driving blow against the driving head 13, this head is hence free to move downwardly relatively to the cylinder in transmitting the driving blow to the pile P or such other work as is being driven. The ability of the driving head 13 to move downwardly relatively to the cylinder at the instant of impact prevents the impact shock being transmitted to the cylinder, its valve gear and associated parts, and also avoids loss of energy in overcoming the inertia of the cylinder. If desired, a readily renewable wear plate 34 may be secured to or recessed into the upper surface of the drive head 13, which wear plate receives the blows of the piston ram directly, and which can be readily renewed after continued service.

The valve sleeve 15 is provided with a collar 36 at its lower end which has a free sliding fit in the axial passageway 25 of the piston ram. The upper end of the passageway 25 is formed with a threaded counterbore 37 in which engages an abutment ring 38, a gland packing 39 and a gland packing nut 41. The abutment ring 38 functions as an upper stop shoulder carried by the piston ram and operative to strike the upper end of the sleeve collar 36 for forcing the sleeve valve downwardly to exhausting position just as the piston ram is approaching the bottom of its free falling movement. Formed in the lower end of the axial passageway 25 is an abutment surface or surfaces 42 adapted to strike the lower end of the sleeve valve 15 for shifting the sleeve valve upwardly to exhausting position just as the piston ram approaches the upper limit of its upward movement. Ports 40 in the lower end of the sleeve maintain communication between the interior of the sleeve valve and the piston passageway 25 when the end of the sleeve valve is abutting the valve actuating surface 42.

The upper portion of the valve sleeve 15 has a snug sliding fit in a vertical axial bore 43 formed in the upper cylinder head 14. An enlarged counterbore 43' extends upwardly from the bore 43 for receiving a motion limiting collar 44 secured to the upper end of the valve sleeve 15. The upper end of the counterbore 43' is closed off by a closure plug 45 which either threads into the end of the counterbore or is bolted to the cylinder head. Extending lengthwise of the counterbore 43' is a guide key or rib 46 which engages in a guide groove 47 in the collar 44 for preventing the sleeve from rotating within the bore 43. Cut in one side of the sleeve is an admission port 48 which is adapted to register with an admission inlet 49 which is cored out in the upper head 14. Cut in the other side of the sleeve is an exhaust port 51 which is adapted to register with an exhaust

outlet 52 cored in the other side of the head 14. A fluid pressure supply pipe 53 connects with the upper end of the inlet passage 49. The outlet passage 52 may vent directly to atmosphere; or, if the hammer is to be used under water, a conduit 54 is extended from this outlet passage up to atmosphere. When the piston drops down the ring 38 strikes the collar 36 and drives the sleeve valve 15 down to its lower steam admitting position, and when the piston goes up the surface 42 strikes the lower end of the sleeve valve and drives the valve up to steam exhausting position.

Detent mechanism is preferably provided for releasably detaining or holding the sleeve valve 15 substantially in each of these two extreme positions, i. e. in the lower position shown in Figure 1 with the inlet valve port 48 in registration with the supply passage 49, or in the upper position shown in Figure 2 with the outlet valve port 51 in registration with the exhaust passage 52. In the embodiment illustrated in Figures 1 and 2 I have shown this detent mechanism as being of the friction type, and in the embodiment illustrated in Figure 4 I have shown this detent mechanism as being of the fluid pressure responsive type. Referring first to the friction type shown in Figures 1 and 2, this comprises a long tube 57 extending downwardly from the closure plug 45 into the upper end of the sleeve valve. The lower end of this tube is formed with an upwardly flaring conical head 58. Mounted for sliding adjustment within this tube is a rod 59 provided with a conical head 60 at its lower end which flares downwardly, oppositely to the other conical head 58. Confined between these two conical heads is an expansible ring 61 of friction material, such as brake band material or the like. This expansible ring has conical ends bearing against the conical heads 58 and 60 and has its cylindrical outer surface bearing frictionally against the cylindrical inner surface of the sleeve valve 15. A nut 62 screws over a thread on the upper end of the rod 59 and bears against the top of the closure plug 45. By screwing this nut downwardly along the rod, the lower conical head 60 can be drawn upwardly for expanding the friction ring 61 outwardly against the inner wall of the sleeve valve with substantially any desired pressure. This frictional pressure is adjusted so that it is just adequate to hold the sleeve valve in each of its extreme positions, but is capable of being readily overcome by the reciprocating motion of the piston without materially impeding such piston motion. As wear of the friction detent ring 61 occurs, the rod 59 is adjusted upwardly to expand the ring outwardly to its desired gripping radius.

Secured to the under side of the upper cylinder head 14 is a ring 65 composed of cushioning material, such as rubber, leather, fiber, or the like. This cushioning ring is adapted to absorb the shock of impact in the event that the piston ram 12 should overtravel in its upward movement and strike the top of the cylinder. In the normal operation of the hammer, the piston ram will stop its upward motion short of the under side of the cushioning ring 65.

The cushioning area 27 between the piston ram and the upper end of the cylinder may have a relatively wide-open outlet connection as shown in Figures 1 and 2, or it may have a relatively restricted outlet connection as shown in Figures 4 and 5. In the construction shown in Figure 1, the breather passageway 67 has a threaded

outlet so that a breather pipe 68 can be extended upwardly therefrom for adapting the hammer unit to operation under water, such breather pipe 68 extending to atmosphere.

The hammer is capable of a wide variety of uses, such as driving steel or wood piling, driving sheet piles, driving the casings and mechanical digging units used in sinking oil wells or water wells, etc. By reason of the fact that the hammer can be operated under water it is very adaptable to driving piles under water and performing driving operations in oil wells and water wells. Figure 3 illustrates a typical mounting of the hammer unit between the vertical guide leads 71 of a pile driver derrick. Two sections of heavy channel 72 are welded to the outer shell 11b of the cylinder at diametrically opposite sides to function as guide followers to travel along the leads 71. This merely illustrates one typical mounting of the hammer unit for use on a pile driver, but it will be understood that various other mounting and supporting arrangements may be employed, depending upon the type of work to be performed.

Referring now to the operation of the hammer, it will be seen that when steam is admitted to the inlet passageway 49 it travels through admission port 48 and down through sleeve valve 15 and passageways 25, 25' into the working space 26 below the piston ram. The pressure and expansion of the steam in this working space drives the hammer upwardly, during the course of which the hammer moves through a substantially predetermined range of lost motion or free travel relatively to the sleeve valve 15, or until the abutment surface 42 strikes the lower end of the sleeve valve 15 and drives the sleeve valve upwardly concurrently with the hammer during the remainder of its upward travel. This upward motion of the sleeve valve closes the admission port 48 and carries the exhaust port 51 up into registry with the exhaust passageway 52, the momentum of the ram and the expansion of the steam continuing the upward travel of the ram and sleeve valve after the admission port 48 has been carried up out of registry with the admission passageway 49. When the exhaust port 41 registers with exhaust passageway 52 the steam confined below the ram is free to discharge upwardly through passageways 25', 25 and sleeve valve 15 into the outlet passage 52. Thereupon, the piston is free to fall and deliver its hammer blow to the driving head 13. The sleeve valve remains in its raised position until the abutment ring 38 carried by the piston strikes the upper end of the sleeve valve collar 36 in the downward motion of the ram. Thereupon, the sleeve valve is quickly moved downwardly from its upper exhausting position into its lower admission position. The hammer strikes its blow before any substantial steam pressure can be transmitted down through sleeve valve 15 and passageway 25, 25' to the working space below the cylinder. Immediately after the blow has been struck, however, the entering steam builds up pressure again in the working space 26 for again moving the hammer upwardly in a repetition of the cycle. The valve inlet port 48 is preferably made sufficiently long to maintain registration with the steam admission passage 49 during the time that the driving head 13 is being driven down relatively to the cylinder 11 under the driving force of the hammer. Upon cessation of the driving blow, the cylinder 11 drops down

or follows down along the driving head 13 to the position shown in Figure 1.

In the modified construtión illustrated in Figure 4 I have shown a pressure responsive restriction 75 located in the sleeve valve 15 at any desired point between the lower end of the sleeve valve and the ports 48 and 51. This restriction functions as a pressure responsive detent for alternately holding the sleeve valve in each of its two extreme positions, i. e., first in its lower steam admitting position, and then in its upper steam exhausting position. When the steam is passing downwardly through the sleeve valve 15 in the admission half of the cycle, a greater pressure exists above the restriction 75 than below, and hence this pressure differential tends to hold the valve down in its admission position, notwithstanding the fact that the ram is then moving upwardly. Conversely, when the steam is passing upwardly through the sleeve valve 15 in the exhaust half of the cycle, a greater pressure exists below the restriction 75 than above, and hence this pressure differential tends to hold the sleeve valve up in its exhaust position, notwithstanding the fact that the ram is then dropping downwardly. This pressure responsive restriction 75 may be formed with a single calibrated passageway or a plurality of small calibrated passageways having an aggregate area which is proportioned with respect to steam pressures and other factors. This pressure responsive detent 75 may be employed in lieu of the friction detent 58—60, or it might be employed as an adjunct to the friction detent.

As previously described, the upper cylinder area 27 containing the cushioning ring 65 may have a relatively wide-open outlet connection, or it may have a relatively restricted outlet connection so as to trap air therein on the upstroke of the piston, whereby to exert a pneumatic cushioning action for resiliently stopping the piston at the upper end of its travel and quickly starting it down on its power stroke. In Figure 4 the venting passageway 67 communicates through pipe 68' with a T connection 78. A T connection 79 is also interposed in the steam exhaust pipe 54. Interposed between the lateral ports of these two T connections is a regulating valve 80. When this valve is wide open the outflow of air through passageway 67 passes substantially without restriction through valve 80 and into steam exhaust pipe for discharge to atmosphere. If pneumatic cushioning action is desired, the valve 80 is throttled down to obtain any desired degree of outlet restriction from the cushioning area 27. If, on the other hand, it is desired to have maximum freedom of outflow through both the steam exhaust connection and the air breather connection, the plug 81 can be removed from the upper end of the T connection 78 for connecting a separate breather pipe 68 leading to atmosphere. In Figure 5 I have shown another modified construction in which a restricted breather connection 84 leading from the cushioning chamber 27 is provided with a check valve 85. This restricted breather connection may lead to an air outlet pipe 68 if desired, although for simplicity I have shown it opening into the steam exhaust passage 52. The ball normally seats on a valve seat 86 formed at the upper end of a retaining ring 87 which screws into a counterbore 88 coextensive with the restricted breather connection 84. The check valve prevents exhaust steam from flowing downwardly through passage 84 into the cushioning chamber, while still permitting outflow of air from the cushioning chamber near the upper end of the hammer stroke for exerting an air check action on the hammer at this time. The above described air venting arrangements shown in Figures 4 and 5 are each operable when the hammer is submerged below water level. Either of these air venting arrangements can be used with the friction detent mechanism 58—60 Figures 1 and 2, or with the pressure responsive detent 75 of Figure 4, as desired.

While I have illustrated and described what I regard to be the preferred embodiments of my invention, nevertheless it will be understood that such are merely exemplary and that numerous modifications and rearrangements may be made therein without departing from the essence of the invention as defined in the claims.

I claim:

1. In a power hammer, the combination of a cylinder, a cylinder head secured to the upper end of said cylinder, an impact head connected with the lower end of said cylinder, said impact head being movable relatively to said cylinder under driving blows, a hammer element reciprocating in said cylinder between said heads and serving both as a piston and as a ram, admission and exhaust passageways in said cylinder head, a sleeve valve having inlet and outlet ports adapted to cooperate with said admission and exhaust passageways, said sleeve valve extending into said hammer element for conducting working fluid to and from a working space defined between said impact head and said hammer element, and means for transmitting endwise motion from said hammer element to said sleeve valve.

2. In a power hammer, the combination of a cylinder, a piston ram reciprocating in said cylinder, a cylinder head closing one end of said cylinder, an impact head closing the other end of said cylinder, tie bolts extending between said heads, said impact head receiving driving blows from said piston ram, valve means admitting and exhausting working fluid to and from a working space defined between said piston ram and said impact head, said impact head being capable of endwise movement relatively to said cylinder under said driving blows, stop means connected to said tie bolts and acting between said cylinder and said impact head for limiting such relative endwise movement, and a sealing ring for sealing the movable joint between said cylinder and said impact head.

3. In a power hammer, the combination of a cylinder, a hammer element reciprocating in said cylinder, a cylinder head at one end of said cylinder, inlet and outlet ports in said cylinder head, reciprocating valve means adapted to be reciprocated between intake and exhaust positions in communication with said inlet and outlet ports for controlling the inflow and outflow of working fluid to and from a working space defined between said hammer element and one end of said cylinder, lost motion valve actuating means for imparting reciprocating motion from said hammer element to said valve means, and detent means for holding said valve means in each of said positions until said actuating means forcibly shifts said valve means to its other position.

4. In a power hammer, the combination of a cylinder, a hammer element reciprocating in said cylinder and serving both as a piston and as a ram, a cylinder head at one end of said cylinder, an impact head at the other end of said cylinder adapted to receive the driving blows of said ham-

mer element, admission and exhaust passages in said cylinder head for conducting the working fluid, a reciprocable sleeve valve extending between said cylinder head and said hammer element, inlet and outlet ports in said sleeve valve adapted to cooperate with said admission and exhaust passages for conducting working fluid to and from a working space defined between said impact head and said hammer element, lost motion valve actuating means for transmitting reciprocating motion from said hammer element to said sleeve valve, and friction detent means carried by said cylinder head and frictionally engaging said sleeve valve for holding said sleeve valve in its intake and exhaust positions during the lost motion intervals of said valve actuating means.

5. In a power hammer, the combination of a cylinder, a hammer element reciprocating in said cylinder, a working chamber defined between said hammer element at one end of said cylinder, valve means controlling the admission and exhaust of working fluid to and from said working chamber, a cushioning chamber defined between said hammer element and the other end of said cylinder, said cushioning chamber being isolated from said working chamber and from said valve means whereby the working fluid does not enter said cushioning chamber, and means controlling the establishment of a cushioning pressure in said cushioning chamber effective against the opposite side of said hammer element.

6. In a power hammer, the combination of a cylinder, a hammer element reciprocating in said cylinder, a working chamber defined between said hammer element at one end of said cylinder, valve means comprising a sleeve extending into said hammer element controlling the admission and exhaust of working fluid to and from said working chamber, a cushioning chamber defined between said hammer element and the other end of said cylinder and surrounding said sleeve, and a valve controlled restricted vent leading from said cushioning chamber whereby a pneumatic cushioning pressure is created in said cushioning chamber when said hammer element approaches the end of its motion into said cushioning chamber.

7. In a power hammer, the combination of a cylinder, a hammer element reciprocating in said cylinder, a working chamber defined between said hammer element at one end of said cylinder, valve means controlling the admission and exhaust of working fluid to and from said working chamber, a cushioning chamber defined between said hammer element and the other end of said cylinder, said cushioning chamber being isolated from said working chamber and from said valve means whereby the working fluid does not enter said cushioning chamber, and a cushioning bumper member in said cushioning chamber for cushioning any over travel of said piston member into said cushioning chamber.

HOWARD F. CAUDILL.