G. L. BADGER.

PNEUMATIC HAMMER.

APPLICATION FILED AUG. 19, 1908.

998,226. Patented July 18, 1911.

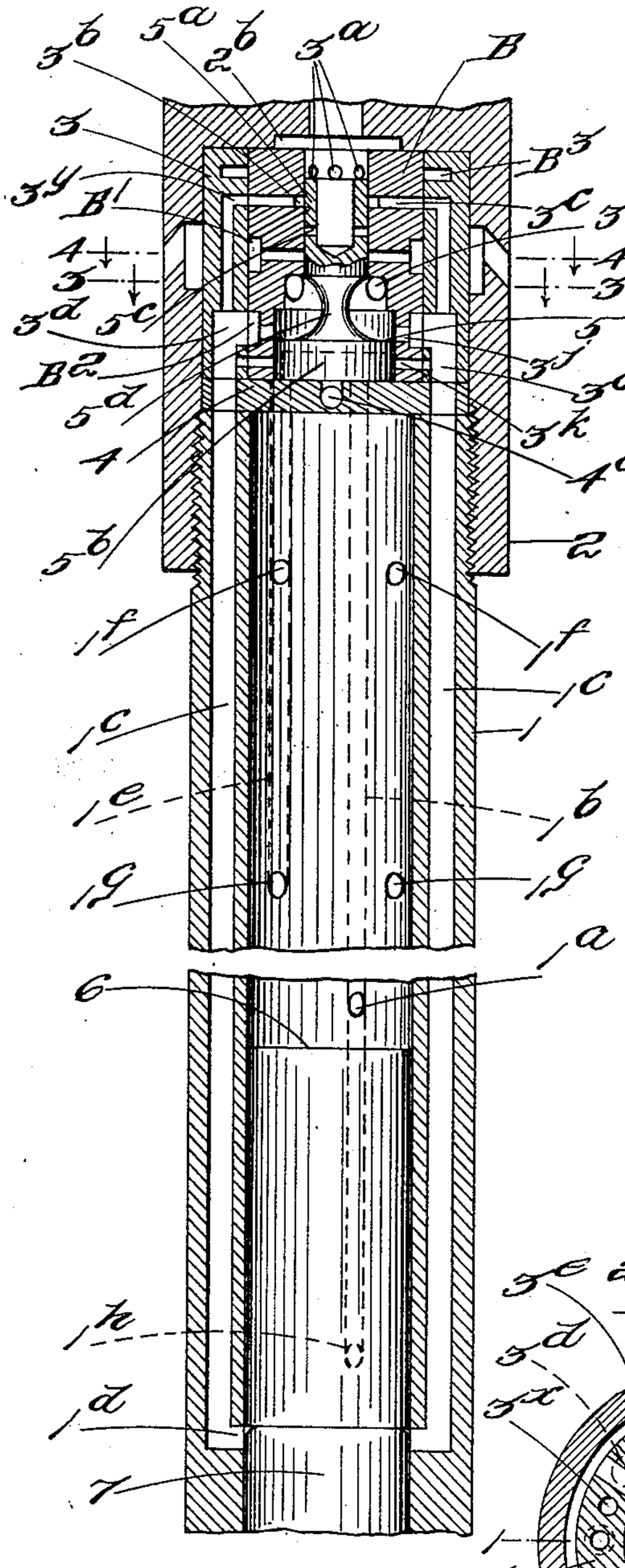

Fig. 1.

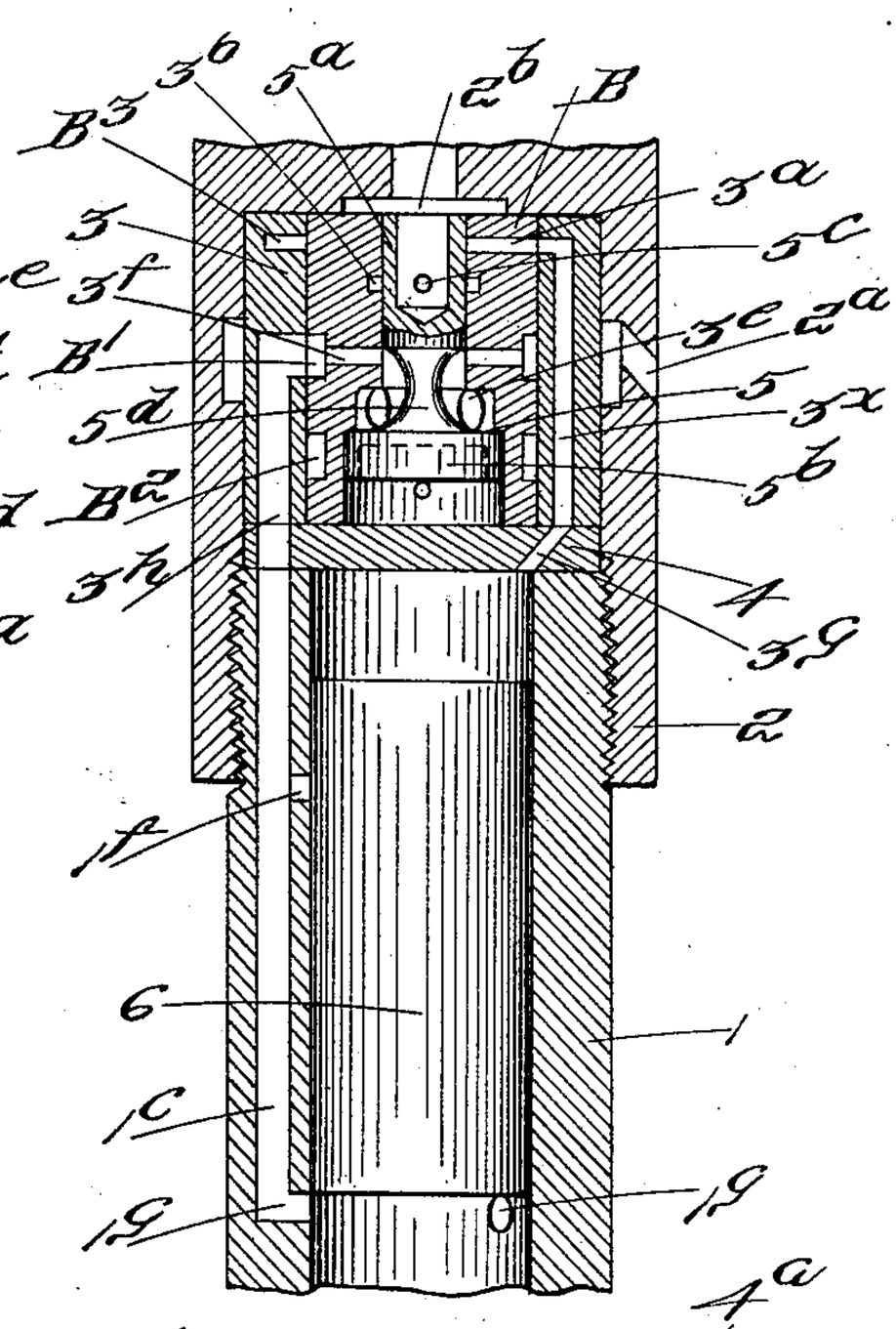

Fig. 2.

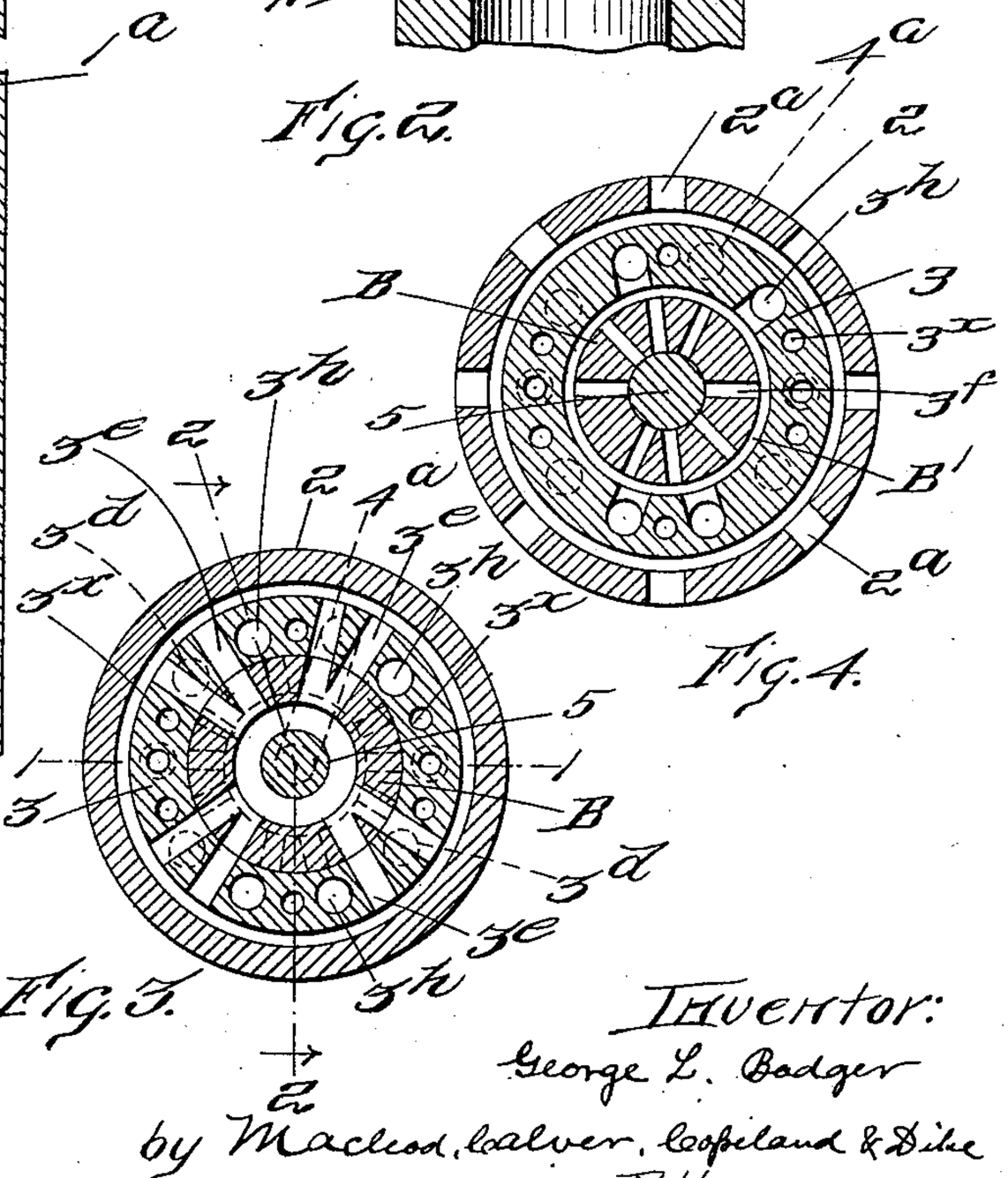

Fig. 3.

Fig. 4.

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PNEUMATIC HAMMER.

998,226. Specification of Letters Patent. **Patented July 18, 1911.**

Application filed August 19, 1908. Serial No. 449,230.

To all whom it may concern:

Be it known that I, GEORGE L. BADGER, citizen of the United States, residing at Quincy, in the county of Norfolk and State of Massachusetts, have invented a certain new and useful Improvement in Pneumatic Hammers, of which the following is a specification, reference being had therein to the accompanying drawings.

This invention relates to improvements in reciprocating tools having a fluid actuated valve and piston and is shown as applied to a long stroke pneumatic hammer.

The objects of the invention are to improve and simplify the operation of pneumatic hammers; to make the action more reliable and efficient; to provide a valve of simple and durable construction which is moved and held firmly in its opposite positions by fluid under normal pressure, its movements not being influenced or affected by the fluid compressed by the piston on its rearward stroke; to provide a hammer having a comparatively short piston with a stroke as long as desired, embodying novel features in design and construction which assure the proper operation of the valve and a full and positive stroke of the piston at each reciprocation under the varied conditions that obtain in the practical operation of such hammers.

The invention further consists in novel features of construction which will be hereinafter described and pointed out in the claims.

In some types of long stroke hammers, the fluid driving the piston rearward is exhausted from the forward end of the piston shortly after its movement is initiated, through exhaust-ports which are open to the atmosphere and which are controlled and uncovered by the piston on its rearward stroke. This reduces the fluid pressure maintaining the valve in position to supply fluid to the forward side of the piston, and the valve shifts to admit fluid pressure to the rear end of the piston. The distance the piston will travel rearwardly, or the length of the stroke, depends upon and varies greatly with the conditions under which the tool is being operated. In order to prevent a waste of fluid on the forward stroke of the piston, the above mentioned exhaust ports must be so located that when the piston is at the forward end of its stroke, the rear end of the piston does not uncover said exhaust ports, and in the design of the tool, when the length of the stroke is increased, the length of the piston should be increased to maintain the proper relation between the length of piston stroke, and the time of opening the said exhaust-ports. In some styles of this type of tool, the valve is not subjected to a constantly acting pressure tending to move it in one direction. When the piston on its rearward movement uncovers the exhaust-ports that are open to the atmosphere, the fluid pressure that was acting on a large pressure area of the valve holding it in position to admit fluid to the forward end of the piston is reduced, since the fluid can escape from the forward end of the piston-chamber faster than it is being supplied thereto, but the valve does not shift until the piston approaches the rearward limit of its stroke, when in some cases, the fluid compressed in the rear end of the piston-chamber by the momentum of the piston is admitted to a smaller pressure area of the valve to move or to assist in moving the valve to its opposite seated position; and in other cases, the admission of fluid to the smaller pressure area of the valve is controlled by an auxiliary-valve which is moved either by direct contact with the piston, or by the fluid compressed by the piston at the end of its rearward stroke. This manner of operating the valve is not as reliable in action under varying conditions as the operation of a valve which is positively retained in seated position by fluid under normal pressure, as will be hereinafter explained, and the method is less efficient on account of the waste of fluid that occurs after the forward end of the piston passes the exhaust-ports which waste continues until the piston approaches the rear end of the cylinder and acts to allow the valve to shift and cut off the admission of fluid to the forward end of the cylinder.

In other types of long stroke hammers the fluid pressure is admitted to the forward end of the piston-chamber for nearly the full length of the rearward stroke of the piston, and the fluid is not exhausted from said forward end of the piston-chamber until the piston has nearly reached the rear end of the piston-chamber and a full rear-

ward stroke of the piston is thus obtained without waste of fluid. The valve is arranged to be moved to its opposite seated position wholly or partially by the fluid that is compressed by the piston in the rear end of the piston-chamber. The action of the valve when operated in this manner, however, is often unsatisfactory under varying degrees of fluid pressure and other conditions. The valve has a pressure surface against which the fluid in the rear end of the piston-chamber acts tending to move and retain the valve in one direction; said surface is necessarily subjected to the varying fluid pressure at the rear of the piston when the latter is either making its forward or rearward stroke and the speed at which the valve moves in either direction and also the pressure tending to hold the valve in its proper position is affected by the variation in pressure from the normal fluid pressure which is supplied to the tool.

In my invention, the operation of the valve is not affected by the varying fluid pressure in the rear of the piston, and the tool may be designed so that any predetermined amount of compression will be obtained on the rearward stroke of the piston to check the momentum of the latter, before the valve is moved by the constantly acting pressure thereon to admit motive fluid to the rear of the piston, and without affecting the operation of the valve.

The fluid is exhausted from the rear end of the piston-chamber through two sets of ports communicating with passages leading to ports in the valve-chamber which are controlled by the valve. The forward set of cylinder ports are arranged to be uncovered by the forward end of the piston on its rearward stroke after the rear end of the piston has moved any desired and predetermined distance past the rear set of ports. The distance that the piston laps over the rear ports before the forward ports are uncovered by the piston determines the amount of compression to check the speed of the piston before the valve shifts to admit motive fluid to the rear of the piston to drive the latter forward.

The use of a light, short piston having a long travel is of great advantage in many cases, more work being performed with less jar to the operator than is possible under other conditions.

In the drawings,—Figure 1 represents a longitudinal central section of the cylinder and valve of a pneumatic hammer taken on the line 1—1 of Fig. 3, partly broken away, some portions of the tool whose functions are well understood and whose specific embodiment does not constitute essential features of the present invention, not being shown. Fig. 2 represents a longitudinal section taken on the line 2—2 of Fig. 3. Fig. 3 represents a horizontal section on the line 3—3 of Fig. 1. Fig. 4 represents a section on the line 4—4 of Fig. 1.

Referring to the drawings,—the cylinder 1 is provided with a head 2 (shown partly broken away) which is in threaded engagement with the cylinder and serves to hold in assembled position on the cylinder the valve-casing 3 and the partition or plate 4 which separates the large bore of the valve-chamber from the piston-chamber and limits the forward movement of the valve. The valve-casing 3 is for convenience in drilling ports provided with a bushing B pressed tightly into the casing and forming an integral part thereof having external exhaust grooves B′ and B². The casing is provided with the annular groove B³ which registers with the ports 3ª.

A valve 5 having bearing surfaces of two diameters and provided with the annular groove 5ᵈ serves to control admission and exhaust ports in the valve-casing and the small end 5ª is always subject to fluid pressure tending to move the valve in a forward direction. The opposite end 5ᵇ is of larger area and fluid is intermittently admitted thereto to move the valve in a rearward direction.

When the valve is in its forward position as shown, the fluid passes from the supply passage 2ᵇ in the head through a series of ports 3ª passages 3ˣ and passages 3ᵍ from the rear end of the valve to the rear end of the piston-chamber to drive the piston 6 forward to strike the working tool 7. When the piston approaches the forward end of its stroke, the small port 1ª in the side of the cylinder is uncovered by the rear end of the piston, and a portion of the fluid passes through the passage 1ᵇ (indicated by dotted line in Fig. 1) and the passage 4ª in the partition 4 to the large area 5ᵇ of the valve, forcing the latter rearward against the constantly acting pressure on the small area 5ª.

When the valve moves rearwardly, it closes the ports 3ª, and the motive fluid then passes through the small ports 5ᵉ in the side of the valve into the groove 3ᵇ, ports 3ᵉ, small passages 3ʸ and passages 3ᵈ in the valve-casing, to the passages 1ᵉ in the cylinder and through ports 1ᵈ to the forward end of the piston 6. Two of the passages 3ᵈ which are located diametrically opposite as shown in Fig. 1 are connected by ports 3ᵏ with the large bore of the valve-casing and open into the valve-chamber near its forward end to admit fluid from the said passages 3ᵈ to the large end of the valve for a purpose that will be hereinafter described.

In the rearward position of the valve while the ports 3ª are closed, the exhaust-ports 1ᵍ and 1ᶠ leading from the rear of the piston-chamber are, by the groove 5ᵈ in the valve, put in communication with open ex-

haust-ports 3^e in the valve-casing. The exhaust from the rear of the piston passes through the ports 1^g and 1^f into the passage 1^e in the side of the cylinder through passages 3^h in the valve-casing to the groove B′ in the valve-casing and through ports 3^f and the groove 5^d in the valve to the atmosphere by ports 3^e in the valve-casing and the passages 2^a in the head 2. After the ports 1^f are closed by the rear end of the piston, as shown in Fig. 2, the ports 1^g are uncovered by the forward end of the piston and the fluid being supplied through the ports 5^c of the valve, as hereinbefore described, to drive the piston rearwardly, is then exhausted from the forward end of the cylinder and the pressure on the large area 5^b of the valve is reduced by the fluid escaping to the piston-chamber through the passage 4^a, passage 1^b and ports 1^a and 1^h, thus allowing the constantly acting pressure on the small area of the valve to move the latter forward. It will be seen that when the rear end of the piston passes the ports 1^f the compression of the fluid trapped in the rear end of the cylinder cannot reach the area 5^a of the valve as the ports 3^a are then closed by the sliding surfaces of the valve and the fluid in passages 3^x and ports 3^a simply presses against the sides of the small bearing surface of the valve. As shown in Fig. 3, the several passages 3^x are arranged so that the side pressure on the valve due to the pressure of the fluid in the ports 3^a will be balanced. It will also be seen that there is no tendency for the fluid which is being compressed by the piston to move the valve in either direction, and that the valve is free to move forward under the constantly acting pressure on the small area when the pressure on the large area is exhausted.

As shown by Fig. 3, the several passages 3^d and the ports 3^j connected therewith are arranged so that the side pressure on the valve due to the pressure of the fluid in the several ports is practically balanced. When the valve moves forward to the position shown in Fig. 1, it closes the exhaust-ports 3^f to the valve-chamber, and the fluid is supplied through the ports 3^a and passages 3^g to the rear of the piston-chamber.

When the piston moves forward, the front end closes the ports 1^g before the rear end uncovers the ports 1^f, thereby preventing the escape of fluid through the passage 1^e to the forward side of the piston which in this position of the valve is open to the atmosphere through the ports 1^d, passages 1^e in the side of the cylinder, passages 3^d to the groove B^2 and through ports 3^j in the valve-casing to the groove 5^d in the valve and the exhaust-ports 3^e and passages 2^a in the head 2. A series of passages similar to the passages 1^e which are shown in Fig. 1 lead from the forward end of the cylinder to the groove B^2 in the valve-casing having a series of ports 3^j which in the same way are closed to the valve-chamber by the valve when the latter is in its rearward position and are open to the groove 5^d in the valve and in communication with the exhaust-ports 3^e when the valve is in its forward position. They thus serve to exhaust the fluid from the forward end of the cylinder when the piston moves forward and also serve to exhaust the fluid from the large area of the valve, through the passage 1^b and the ports 1^h and 1^a, said passage and the port 1^h acting to relieve and prevent any accumulation of pressure on the large area of the valve on the forward stroke of the piston until the piston approaches the end of its forward stroke when port 1^h is closed by the piston just before the port 1^a is opened by the rear end of the piston to admit fluid to the passage 1^b to move the valve rearward.

It will be seen that I have provided a valve and valve-casing of simple construction, which are efficient and reliable in operation. The valve is light, strong and durable having comparatively wide bearing surfaces of but two diameters, which are separated by a wide groove or neck, so that there are no shoulders and the valve may be easily ground after it is hardened. The bore of the valve-chamber can also be easily finished to size after hardening since it has but two bearing surfaces of different diameters. The valve-chamber has one annular groove in the small diameter of the bore with long bearing surfaces on each side. By limiting the number of bearing surfaces of the valve-chamber and valve to two only, and having but a single groove in the bore of the valve-chamber and one groove in the valve, a simple construction is obtained, and the expense of manufacturing is appreciably reduced.

The valve is shown with a recess in each end in order to lighten it, but the recesses may be omitted and the end 5^a provided with a small hole adapted to register with the ports 5^c in the side of the valve.

As hereinbefore mentioned, it is desirable to supply only a comparatively small amount of fluid to the forward end of the cylinder, so that the piston will not be driven rearwardly with too great force, and the ports 5^c can be made quite small so that they do not appreciably weaken the valve, as is the case with valves of comparatively small diameter through the side of which it is necessary to supply the whole of the fluid to drive the piston forward, since in the latter case, it is desirable that the total area of the ports through which the fluid is supplied to drive the piston forward shall be of comparatively large capacity.

In order to obtain satisfactory results in long stroke pneumatic hammers, it is neces-

sary to have a free exhaust from the front side of the piston when the latter is moving forward. When the tool is not provided with exhaust-ports, controlled by the piston and located near the forward end of the cylinder and all, or the greater part of the exhaust, must pass through ports in the valve-chamber, the latter and the valve must be designed to have a comparatively large area of exhaust-port opening. As it is not desirable to increase the travel of the valve, which would be necessary if wide ports were provided, and since it would be difficult and expensive to drill a large number of small passages in the wall of the cylinder from the rear to the forward end, I obtain the necessary port area by connecting the five passages 3^d in the valve-casing, which are in communication with the five passages 1^c in the wall of the cylinder and the groove B^2 in the bushing B to the large bore of valve-chamber, by a plurality of ports 3^j of smaller diameter. As hereinbefore mentioned two of the passages 1^c in the cylinder (as shown in Fig. 1) also serve to conduct the motive fluid from the valve to the forward end of the cylinder.

When it is possible to provide sufficient port area, it is desirable to employ valves having comparatively small diameters and wide bearing surfaces. It will be understood that valves of small diameters, when worn so that they are not a tight working fit in the bore of the valve-chamber, do not permit so great a waste of motive fluid as valves of larger diameters under the same conditions. With valves of equal length I have found in practice a further advantage in using valves of small diameters as such valves do not have the tendency to tilt and wear the valve-chamber out of true as is commonly the case with valves of larger diameter.

With the improved valve shown herein the fluid is supplied to and exhausted from the rear end of the piston-chamber exteriorly to the valve, and it will be seen that I have provided a valve of comparatively small diameter at one end, having a wide bearing surface that controls the admission of motive fluid to opposite ends of the cylinder and that said surface is the only bearing surface of the valve past which the motive fluid can constantly leak or escape to the atmosphere when the valve becomes worn. This is a great improvement over other forms of valves that are largely employed, some of which have three short bearing surfaces of comparatively large diameter and past each of which surfaces the fluid can constantly escape directly from the supply passages to the exhaust when the valves become slightly worn so that they are not a proper working fit in the bore of the valve-casing.

It results from the construction of the tool herein shown and described, that the valve is held firmly seated at the end of its opposite movements by the motive fluid, and that fluttering and incomplete movements of the valve which cause the jumping and jarring so common in tools of this character is prevented. If a valve does not work regularly and uniformly, opening and closing the ports at the proper time, the movements of the piston will be irregular. When the piston is moving forward, the valve should be firmly held to its seat so that the exhaust-ports will remain wide open to permit the free escape of the fluid from the forward side of the piston in order that the speed of the piston will not be decreased and that the force of the blow will not be reduced by the back pressure of the fluid in the forward end of the cylinder.

The type of long stroke tools in which the valve is seated wholly or partially by the pressure of the fluid in the piston-chamber acting on a reduced pressure area or surface of the valve, are influenced or affected in operation by the variation of pressure in the piston-chamber during the forward stroke of the piston, especially if the valve moves when shifted in the same direction that the piston is moving as is usual in tools in which the valve is moved in one direction wholly or partially by the fluid compressed by the piston. When the tool is held vertically above the work, the weight of the valve, in addition to any fluid that may escape or leak past the sliding surfaces thereof and also past the joints and fluid distributing passages of the tool to the large area of the valve, tends to move the latter in the wrong direction when the piston is making its forward stroke. When tools of this character are employed for riveting, it is desirable to strike the rivet lightly at first to prevent driving the rivet out of place before the metal has been upset sufficiently to form a shoulder tending to retain the rivet in position, and the tool should be reliable in action when throttled to operate at reduced speed. The action of the last mentioned type of tools is not reliable in starting when the fluid supply is throttled to reduce the speed of the piston and strike lightly, especially when the forward end of the tool is held down and the fluid is admitted to the front of the piston for nearly the whole length of the rearward stroke before being exhausted.

In starting, the piston and valve are both in their forward position, and when the fluid is admitted to the tool, the piston on its first movement does not always attain sufficient momentum to firmly seat the valve in its opposite position to cut off the supply of fluid to the forward end of the piston and open the exhaust therefrom; the fluid is thus

trapped in the forward end of the piston-chamber so that the piston cannot drop back to its forward position, even when the supply of fluid to the tool is cut off, until the fluid in front of the piston leaks out or escapes in some way. As hereinbefore mentioned, if the cylinder is provided with an open exhaust-port or ports located near the forward end to overcome this objection there is a waste of motive fluid on the rearward stroke after the piston uncovers the exhaust-ports, until the valve shifts when the piston approaches the end of its stroke.

With the valve shown herein it will be understood that since the cross-sectional area of the small bore of the valve-chamber through which the motive fluid is supplied to the area 5^a of the valve is much greater than the combined cross-sectional area of the ports 3^a through which fluid is conducted from said area of the valve that the variation in pressure in the piston-chamber will have practically no effect on said area of the valve; and the rush or impact of the fluid is also against said area tending to carry and maintain the valve forward when the fluid is being supplied to the rear end of the piston-chamber. When the piston is moving rearwardly to compress the fluid in the piston-chamber, the ports 3^a are closed by the sliding surface of the valve and if the limit of the pressure to which the fluid can be compressed by the piston before the valve is moved by the constantly acting pressure is less than the normal pressure, the fluid compressed will have no effect on the forward movement of the valve because the latter will be moved to its seated position before the pressure in the piston-chamber has become equal to the pressure being supplied to the tool; and if the piston continues to move rearwardly and compress the fluid in the piston-chamber above the pressure of the fluid being supplied to the tool after the valve has moved forward so that the fluid is forced rearward through the ports 3^a, it can have no effect on the valve, as the latter is then being held firmly in seated position by fluid under normal pressure.

It will be understood that it is not essential to construct the valve casing with the bushing B as shown and that the ports 3^f and 3^j communicating respectively with the passages 3^h and 3^d and the valve chamber may be arranged in any manner preferred. By using the bushing B, the shell of the valve-casing may by using a special drilling device be drilled from the interior into the passages 3^h and 3^d, thus saving the plugging of holes on the outside of the casing which would be necessary if holes were drilled from the exterior of the casing to connect the passages 3^h and 3^d respectively with the ports 3^f and 3^j. By providing the annular groove B^3, the passages 3^g can be easily connected with the ports 3^a without drilling and plugging holes on the exterior surface of the valve-casing.

What I claim is:

1. In a pneumatic hammer, a cylinder and piston, a valve having an imperforated reduced portion or neck ends of different diameters against the smaller of which the motive fluid constantly acts, the smaller diameter being provided with ports transverse to the axis of the valve and with an axial orifice terminating slightly beyond said ports, said smaller diameter of the valve on one side of said neck controlling the admission of motive fluid to opposite ends of the cylinder.

2. In a pneumatic hammer, a cylinder and piston, a valve having an exterior annular groove and sliding bearing surfaces on opposite sides of the groove, said bearing surfaces on opposite sides of the groove being of different diameters, the smaller end of the valve being constantly subject to fluid pressure and provided with an axial orifice and with ports transverse to the axis of the valve to which the motive fluid is constantly admitted, the smaller diameter of the valve on one side of said groove controlling the admission of motive fluid to opposite ends of the cylinder.

3. In a pneumatic hammer, a cylinder and piston, a valve having an exterior annular groove and sliding bearing surfaces on opposite sides of the groove, said bearing surfaces on opposite sides of the groove being of different diameters. the smaller end of the valve being constantly subject to fluid pressure and provided with an axial orifice and with ports transverse to the axis of the valve to which the motive fluid is constantly admitted. the smaller diameter of the valve on one side of said groove controlling the admission of motive fluid to opposite ends of the cylinder, and said groove acting to alternately exhaust the fluid from opposite ends of the cylinder.

4. In a pneumatic hammer, a cylinder and piston, a valve having an imperforated reduced portion or neck and sliding bearing surfaces of different diameters. the smaller end of the valve being constantly subject to fluid pressure and provided with ports transverse to the axis of the valve and with an axial orifice terminating slightly beyond said valve ports, a valve-casing provided with ports communicating respectively with opposite ends of the cylinder, one set of ports being uncovered by the small end of the valve to admit motive fluid to one end of the cylinder when the valve is at one end of its movement and the other set of ports communicating with said ports in the small end of the valve to admit fluid to the opposite end of the cylinder when the valve is at the other end of its movement.

5. In a pneumatic hammer, a cylinder and piston, a valve-casing provided with ports communicating respectively with opposite ends of the cylinder and with exhaust-ports which are always open to the atmosphere, a valve having an annular groove which acts to alternately place the respective cylinder ports in communication with said exhaust-ports, said valve having sliding bearing surfaces on opposite sides of said groove, said surfaces being of different diameters, the smaller end of the valve being constantly subject to fluid pressure and provided with ports to which the motive fluid is constantly admitted the smaller diameter of the valve on one side of said groove controlling the admission of motive fluid to opposite ends of the cylinder.

6. In a pneumatic hammer, a cylinder and piston, a valve having an imperforated reduced portion or neck and ends of different diameters against the smaller of which the motive fluid constantly acts to press the valve in one direction and to the larger of which the fluid is intermittently admitted to move the valve in the opposite direction, the smaller diameter being provided with ports transverse to the axis of the valve to which the motive fluid is constantly admitted, said smaller diameter of the valve on one side of said neck controlling the admission of fluid to opposite ends of the cylinder.

7. In a pneumatic hammer, a cylinder and piston, a valve having an exterior annular groove and bearing surfaces located respectively on opposite sides of the groove, said bearing surfaces being of different diameters, the smaller end of the valve being constantly subject to fluid pressure tending to move the valve in one direction, the larger end of the valve being intermittently subject to fluid pressure to move the valve in the opposite direction, the smaller diameter being provided with ports to which the motive fluid is constantly admitted, said smaller diameter of the valve on one side of said groove controlling the admission of motive fluid to opposite ends of the cylinder.

8. In a pneumatic hammer, a cylinder and piston, a valve having an exterior annular groove and bearing surfaces located respectively on opposite sides of the groove, said bearing surfaces being of different diameters the smaller end of the valve being constantly subject to fluid pressure tending to move the valve in one direction, the larger end of the valve being intermittently subject to fluid pressure to move the valve in the opposite direction, the smaller diameter being provided with ports to which the motive fluid is constantly admitted, said smaller diameter of the valve on one side of said groove controlling the admission of motive fluid to opposite ends of the cylinder, and said groove acting to alternately exhaust the fluid from opposite ends of the cylinder.

9. In a pneumatic hammer, a cylinder and piston, a valve having an imperforated reduced portion or neck and bearing surfaces on opposite sides of said neck of different diameters, the smaller end of the valve being constantly subject to fluid pressure tending to move the valve in one direction and the larger end being intermittently subject to fluid pressure to move the valve in the opposite direction, the smaller diameter of the valve being provided with ports to which the motive fluid is constantly admitted, a valve-casing provided with ports communicating respectively with opposite ends of the cylinder through which motive fluid is supplied, the ports communicating with one end of the cylinder being uncovered by the small end of the valve when the latter is at one end of its movement and the other ports communicating with said ports in the valve when the latter is at the end of its movement in the opposite direction.

10. In a pneumatic hammer, a cylinder and piston, a valve-casing provided with ports communicating respectively with opposite ends of the cylinder and with exhaust-ports which are always open to the atmosphere, a valve having bearing surfaces of different diameters, the smaller end of the valve being constantly subject to fluid pressure tending to move the valve in one direction and the large end being intermittently subject to fluid pressure to move the valve in the opposite direction, the smaller diameter of the valve being provided with ports to which the motive fluid is constantly admitted, said smaller diameter controlling the admission of motive fluid to opposite ends of the cylinder, said valve having an exterior annular groove located between the large and small diameters which is adapted to alternately place the respective cylinder ports in communication with said exhaust-ports.

11. In a pneumatic hammer, a cylinder and piston, a valve-casing having ports communicating respectively with opposite ends of the cylinder and with exhaust-ports that are always open to the atmosphere, a valve having an exterior annular groove which is always open to said exhaust-ports, said valve having bearing surfaces on opposite sides of said groove, the bearing surface on one side of the groove being of different diameter from the bearing surface on the opposite side of the groove and against the smaller of which the motive fluid constantly acts, the smaller diameter being provided with ports to which the motive fluid is constantly admitted, said smaller diameter on one side of

the groove controlling the admission of motive fluid to opposite ends of the cylinder and said groove acting to alternately exhaust the fluid from opposite ends of the cylinder.

12. In a pneumatic hammer, a cylinder and piston, a valve-casing having ports communicating respectively with opposite ends of the cylinder and with exhaust-ports that are always open to the atmosphere, a valve having an exterior annular groove which is always open to said exhaust-ports, said valve having bearing surfaces on opposite sides of the groove, said surfaces being of different diameters against the smaller of which the motive fluid constantly acts to press the valve in one direction and against the larger of which the fluid intermittently acts to move the valve in the opposite direction, the valve having ports located rearwardly of said groove to which the motive fluid is constantly admitted, said smaller diameter of the valve controlling the admission of motive fluid to opposite ends of the cylinder and said groove acting to alternately exhaust the fluid from opposite ends of the cylinder.

13. In a pneumatic hammer, a cylinder and piston, a valve having an imperforated reduced portion or neck and bearing surfaces on opposite sides of the groove of different diameters to the smaller of which the motive fluid is constantly admitted, a valve-casing having ports communicating with one end of the cylinder which are controlled by the smaller end of the valve, the valve being provided with ports located rearwardly of said neck to which the motive fluid is constantly admitted, the valve-casing being provided with ports communicating with the opposite end of the cylinder, said last mentioned ports being adapted to communicate with the ports in the valve to admit motive fluid to said opposite end of the cylinder.

14. In a pneumatic hammer, a cylinder and piston, a valve having an imperforated reduced portion or neck and bearing surfaces of different diameters to the smaller of which the motive fluid is constantly admitted, a valve-casing having ports communicating with the rear end of the cylinder which are controlled by said smaller end of the valve, the valve being provided with ports located rearwardly of said neck to which the motive fluid is constantly admitted, the valve-casing being provided with ports communicating with the forward end of the cylinder, said last mentioned ports being adapted to communicate with the ports in the valve to admit motive fluid to the forward end of the cylinder.

15. In a pneumatic hammer, a cylinder and piston, a valve-casing having ports communicating respectively with opposite ends of the cylinder and with exhaust-ports that are always open to the atmosphere, a valve having an exterior annular groove which is always open to said exhaust-ports and is adapted to alternately connect the ports communicating with the respective ends of the cylinder with said exhaust-ports, said valve having ends of different diameters to the smaller of which the motive fluid is constantly admitted, the valve-casing having ports communicating with one end of the cylinder which are controlled by the smaller end of the valve, said valve being provided with ports located rearwardly of said groove to which the motive fluid is constantly admitted through an orifice in the small diameter of the valve, the valve-casing being provided with ports communicating with the opposite end of the cylinder, said last mentioned ports being adapted to communicate with the ports in the valve to admit fluid to said opposite end of the cylinder.

16. In a pneumatic hammer, a cylinder and piston, a valve-casing having ports communicating respectively with opposite ends of the cylinder and with exhaust-ports that are always open to the atmosphere, a valve having an exterior annular groove which is always open to said exhaust-ports and is adapted to alternately connect the ports communicating with the respective ends of the cylinder with said exhaust-ports, said valve having ends of different diameters against the smaller of which the motive fluid constantly acts to press the valve in one direction and against the larger of which the fluid intermittently acts to move the valve in the opposite direction, the valve-casing having ports communicating with one end of the cylinder which are controlled by the smaller end of the valve, the smaller diameter of the valve being provided with ports located rearwardly of said groove to which the motive fluid is constantly admitted, the valve-casing being provided with ports communicating with the opposite end of the cylinder, said last mentioned ports being adapted to communicate with the ports in the smaller diameter of the valve to admit fluid to said opposite end of the cylinder.

17. In a pneumatic hammer, a cylinder and piston, a valve-casing provided with ports communicating respectively with opposite ends of the cylinder and with exhaust-ports which are always open to the atmosphere, a solid valve having ends of different diameter and an exterior annular groove intermediate the ends, the smaller end of the valve being constantly subject to fluid pressure tending to move the valve in one direction, the motive fluid being supplied to one end of the cylinder through ports in the valve-casing that are controlled by said end of the valve, the smaller diameter of the valve being pro-

vided with an axial orifice and with ports transverse to the axis of the valve located rearwardly of said groove to which the motive fluid is constantly admitted, the valve-casing being provided with a groove, said ports in the valve being adapted when the valve is at the opposite end of its movement to register with said groove in the valve-casing which communicates with the opposite end of the cylinder.

18. In a pneumatic hammer, a cylinder and piston, a valve-casing having ports communicating with the piston-chamber, a valve controlling said ports having an area constantly subject to fluid pressure tending to move the valve in one direction and a larger area to which the fluid is intermittently admitted to move the valve in the opposite direction, the smaller area of the valve being alternately in communication with opposite ends of the cylinder, the fluid being exhausted from the large area of the valve through said valve controlled ports.

19. In a pneumatic hammer, a cylinder and piston, a valve-casing having ports communicating with the piston-chamber, a valve controlling said ports having an annular groove, and having an area constantly subject to fluid pressure tending to move the valve in one direction, and a larger area to which the fluid is intermittently admitted to move the valve in the opposite direction, the smaller area of the valve being alternately in communication with opposite ends of the cylinder, said ports being open to the groove in the valve when the piston is moving rearwardly, and acting to exhaust the fluid from the large area of the valve.

20. In a pneumatic hammer, a cylinder and piston, a valve-casing having ports communicating with the piston-chamber, a valve controlling said ports having an annular groove, and having an area constantly subject to fluid pressure tending to move the valve in one direction, and a larger area to which the fluid is intermittently admitted to move the valve in the opposite direction, said ports being open to the groove in the valve when the piston is moving rearwardly to exhaust the fluid from the large area of the valve when the piston approaches the end of its stroke, said ports being closed by the valve when the latter shifts to admit fluid to drive the piston forward, the smaller area of the valve serving to close the rear end of the piston-chamber when said ports are open to the groove in the valve.

21. In a pneumatic hammer, a cylinder and piston, a valve-casing having ports communicating with the piston-chamber, the cylinder having a cushion or compression space at its rear end, a valve controlling said ports having a pressure area constantly subject to fluid pressure tending to move the valve in one direction and a larger pressure area to which the motive fluid is intermittently admitted to move the valve in the opposite direction, the fluid being exhausted from the large area through said valve controlled ports in the valve-casing, the smaller pressure area of the valve serving to cut off communication with said cushion space when the piston is making its rearward stroke.

22. In a pneumatic hammer, a cylinder and piston, a valve-casing having ports communicating with the piston-chamber, a valve controlling said ports having bearing surfaces at each end of different diameters, the small end of the valve being constantly subject to fluid pressure tending to move the valve in one direction, the valve being moved in the opposite direction by fluid intermittently admitted to the large end of the valve, the fluid being exhausted from the large end of the valve through said valve controlled ports.

23. In a pneumatic hammer, a cylinder and piston, a valve-casing having ports communicating with the piston-chamber, a valve controlling said ports having bearing surfaces at each end of different diameters, the small end of the valve being constantly subject to fluid pressure tending to move the valve in one direction, the valve being moved in the opposite direction by fluid intermittently admitted to the large end of the valve, the fluid being exhausted from the large end of the valve when the piston approaches the end of its rearward stroke through said ports in the valve-casing, said ports being closed by the valve when the latter shifts to admit fluid to drive the piston forward.

24. In a pneumatic hammer, a cylinder and piston, a valve-casing having ports communicating with the piston-chamber, a valve having pressure surfaces against which the motive fluid acts to move the valve in opposite directions and provided with an exterior annular groove, one of said pressure surfaces being intermittently subjected to fluid pressure, the fluid being exhausted from said surface through said ports in the valve-casing which are open to said groove in the valve when the piston is moving rearward and which are closed by the valve when the latter shifts to admit fluid to drive the piston forward, the opposing pressure surface of the valve closing communication to the rear end of the piston-chamber until said movement of the valve occurs.

25. In a pneumatic hammer, a cylinder and piston, a valve-casing having ports communicating with the piston-chamber, a valve controlling said ports having opposing pressure surfaces against which the motive fluid acts to move the valve in opposite directions, one of said pressure surfaces being intermittently subjected to fluid pressure to move the valve in one direction, the fluid being exhausted therefrom through said valve con-

trolled ports, the opposing pressure surface of the valve against which the motive fluid acts to move the valve in the opposite direction being always subject to fluid pressure and serving to close the rear end of the piston-chamber on the rearward stroke of the piston.

26. In a pneumatic hammer, a cylinder and piston, a valve-casing provided with ports, a valve controlling said ports having an area subject to constantly acting fluid pressure tending to move the valve in one direction and a larger area to which the fluid is intermittently admitted to move the valve in the opposite direction, said cylinder having a cushion or compression space at its rear end, passages leading therefrom to the valve-chamber which are closed or sealed by the side walls of the valve when the piston is moving rearward to prevent the fluid compressed by the piston affecting the movements of the valve, the fluid pressure being exhausted through said valve controlled ports in the valve-casing from the large area of the valve after the piston enters said cushion space to allow the constantly acting pressure on the valve to shift the latter, the small pressure area of the valve serving to close to the rear end of the piston-chamber on the rearward stroke of the piston.

27. In a pneumatic hammer, a cylinder and piston, the cylinder having ports and passages arranged to provide a cushion space at the rear end of the cylinder, a valve-casing having ports communicating with the piston-chamber, a valve controlling said ports having a pressure surface against which the motive fluid constantly acts tending to move the valve in one direction and a larger pressure surface to which the fluid is intermittently admitted to move the valve in the opposite direction, the fluid pressure being exhausted through said valve controlled ports in the valve-casing when the piston approaches the end of its rearward stroke, the smaller pressure surface of the valve serving to close to the rear end of the piston-chamber on the rearward stroke of the piston.

28. In a pneumatic hammer, a cylinder and piston, the cylinder being provided with passages having ports opening into the piston-chamber, said ports being uncovered by the piston before it approaches the end of its forward stroke and also being uncovered by the piston when it approaches the end of its rearward stroke, a valve-casing having ports communicating with said cylinder passages, a valve controlling said ports in the valve-casing having a pressure surface against which the motive fluid constantly acts to move the valve in one direction and a larger pressure surface to which the fluid is intermittently admitted to move the valve in the opposite direction, the fluid pressure being exhausted through said valve controlled ports in the valve-casing when the piston approaches the end of its rearward stroke, the smaller pressure surface of the valve serving to close to the rear end of the piston-chamber on the rearward stroke of the piston.

29. In a pneumatic hammer, a cylinder and piston, the cylinder being provided with exhaust passages having two sets of ports opening into the piston-chamber, the rear exhaust-ports being located forward of the rear end of the cylinder, a valve-casing having ports communicating with said exhaust passages and with supply ports and passages through which the motive fluid is supplied to the piston-chamber rearward of said exhaust-ports, a valve controlling said exhaust and supply-ports which is moved in one direction by an area constantly subject to fluid pressure and is moved in the opposite direction by a larger area to which the fluid is intermittently admitted, the exhaust of intermittent pressure being controlled by the valve, the smaller area of the valve serving to close to the rear end of the piston-chamber on the rearward stroke of the piston.

30. In a pneumatic hammer, a cylinder and piston, a cushion or compression space at the rear end of the cylinder, a valve-casing having ports communicating with the piston-chamber by passages provided with two sets of ports, a valve controlling said ports in the valve-casing having a pressure area constantly subject to fluid pressure tending to move the valve in one direction and a larger pressure area to which the fluid is intermittently admitted, said valve controlled ports being open on the rearward stroke of the piston and the forward set of cylinder ports being uncovered by the forward end of the piston to exhaust the fluid from the large area of the valve, the smaller pressure area of the valve serving to close communication with the cushion space when the piston is making its rearward stroke.

31. In a pneumatic hammer, a cylinder and piston, the cylinder being provided with exhaust passages having two sets of ports opening into the piston-chamber, a valve-casing having ports in communication with said exhaust passages a valve controlling said ports in the valve-casing which is moved in one direction by an area constantly subject to fluid pressure and which is moved in the opposite direction by a larger area to which fluid is intermittently admitted, the fluid being exhausted from said larger area through said valve controlled ports, the smaller area of the valve serving to close the rear end of the piston-chamber on the rearward stroke of the piston.

32. In a pneumatic hammer, a cylinder and piston, a valve-casing having ports communicating with the piston-chamber, a valve

controlling said ports having opposing pressure surfaces against which the motive fluid acts to move the valve in opposite directions, one of said pressure surfaces being intermittently subject to fluid pressure, the fluid being exhausted therefrom through said valve controlled ports, the opposite pressure surface being intermittently in communication with opposite ends of the cylinder.

33. In a pneumatic hammer, a cylinder and piston, a valve-casing having ports communicating with the piston-chamber, a valve controlling said ports having opposing pressure surfaces against which the motive fluid acts to move the valve in opposite directions, one of said pressure surfaces being intermittently subject to fluid pressure, the fluid being exhausted therefrom through said valve controlled ports, the opposing pressure surface of the valve being always subject to fluid under normal pressure and serving to close the rear end of the piston-chamber on the rearward stroke of the piston.

34. In a pneumatic hammer, a cylinder and piston, the cylinder being provided with exhaust passages having two sets of ports opening into the piston-chamber, a valve-casing having ports communicating with said exhaust passages and with supply ports and passages through which the motive fluid is supplied to the piston-chamber, a valve controlling said exhaust and supply ports having opposing pressure surfaces against which the motive fluid acts to move the valve in opposite directions, one of said pressure surfaces being intermittently subject to fluid pressure, the fluid being exhausted therefrom through said valve controlled exhaust-ports, the opposing pressure surface being always subject to fluid presure and serving to close the rear end of the piston-chamber on the rearward stroke of the piston.

35. In a pneumatic hammer, a cylinder and piston, a valve-casing located rearward of and beyond the end of the cylinder having ports communicating with the piston-chamber, a valve controlling said ports having opposing pressure surfaces against which the motive fluid acts to move the valve in opposite directions, one of said pressure surfaces being intermittently subject to fluid pressure, the fluid being exhausted therefrom through said valve controlled ports, the opposing pressure surface of the valve being always subject to fluid under normal pressure.

36. In a pneumatic hammer, a cylinder and piston, a valve-casing located rearward of and beyond the end of the cylinder having a valve-chamber which is separated from the piston-chamber by a plate or partition and provided with ports communicating with the piston-chamber, a valve controlling said ports having opposing pressure surfaces against which the motive fluid acts to move the valve in opposite directions, one of said surfaces being intermittently subject to fluid pressure, the fluid being exhausted therefrom through said valve controlled ports, the opposing pressure surface of the valve serving to close the rear end of the piston-chamber on the rearward stroke of the piston.

37. In a pneumatic hammer, a cylinder and piston, the cylinder being provided with exhaust passages having two sets of ports opening into the piston-chamber, a valve-casing located rearward of and beyond the end of the cylinder having a valve-chamber which is separated from the piston-chamber by a plate or partition and provided with ports communicating with said exhaust passages, a valve controlling said ports in the valve-casing having opposing pressure surfaces against which the motive fluid acts to move the valve in opposite directions, one of said surfaces being intermittently subject to fluid pressure, the fluid being exhausted therefrom through said valve controlled ports, the opposing pressure surfaces of the valve serving to close the rear end of the piston-chamber on the rearward stroke of the piston.

38. In a pneumatic hammer, a cylinder and piston, a valve-casing having a valve-chamber in alinement with the piston-chamber, said valve-casing comprising a shell having longitudinal passages in the walls thereof leading from the forward end and parallel with the bore, a bushing fitting the bore of the shell having the valve-chamber formed therein, and provided with an exterior annular groove which communicates with said passages in the shell, said groove being connected to the valve-chamber by a series of ports.

39. In a pneumatic hammer, a cylinder and piston, a valve-casing having a valve-chamber in alinement with the piston-chamber, said valve-casing comprising a shell having two sets of longitudinal passages leading from the forward end and parallel with the bore, a bushing fitting the bore of the shell having the valve-chamber formed therein and provided with two exterior annular grooves which communicate respectively with the longitudinal passages in the shell, said grooves being connected respectively with the valve-chamber by a series of ports.

40. In a pneumatic hammer, a cylinder and piston, a valve-casing having a valve-chamber in alinement with the piston-chamber, said valve-casing comprising a shell having an interior annular groove and longitudinal passages in the walls leading from the forward end to said groove and parallel with the bore, a bushing fitting the bore of the shell having the valve-chamber

formed therein and provided with a series of ports which communicate with said groove in the shell and open into the valve-chamber.

41. In a pneumatic hammer, a cylinder and piston, a valve-casing having a valve-chamber in alinement with the piston-chamber, said valve-casing comprising a shell having an interior annular groove, a bushing fitting the bore of the shell having the valve-chamber formed therein and provided with exterior annular grooves, said shell having a series of longitudinal passages leading from the forward end to said interior annular groove and with two series of longitudinal passages leading from the forward end parallel with the bore, said bushing being provided with two exterior annular grooves which communicate with the respective series of passages in the shell, said grooves in the bushing and said groove in the shell being respectively connected with the valve-chamber by a series of ports.

42. In a pneumatic hammer, a cylinder and piston, a valve-casing having a valve-chamber in alinement with the piston-chamber, said valve-casing comprising a shell having longitudinal passages in the walls thereof leading from the forward end and parallel with the bore, a bushing fitting the bore of the shell having the valve-chamber formed therein and provided with an exterior annular groove which communicates with said passages in the shell, said groove being connected to the valve-chamber by a series of ports, a plate or partition located between the shell and the end of the cylinder having passages therein which register with said longitudinal passages in the shell.

In testimony whereof I affix my signature, in presence of two witnesses.

GEORGE L. BADGER.

Witnesses:
GEO. W. BRIDGES,
E. C. TUCKER.