

July 2, 1957

B. A. SWANSON
ENGINE OF HIGH SPEED AND LOW VOLUME CONSUMPTION OF
FLUID PRESSURE MEDIUM
Filed May 24, 1954

2,797,664

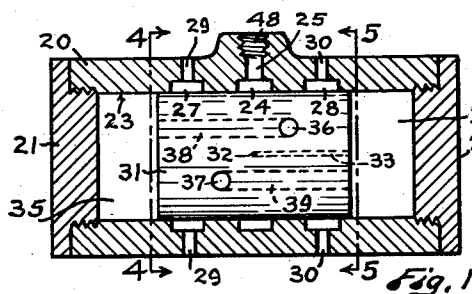


Fig. 1

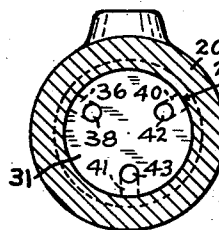


Fig. 4

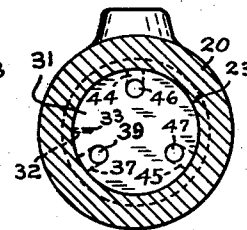


Fig. 5

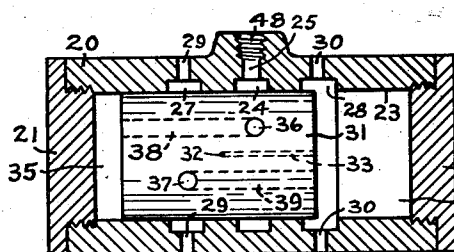


Fig. 2

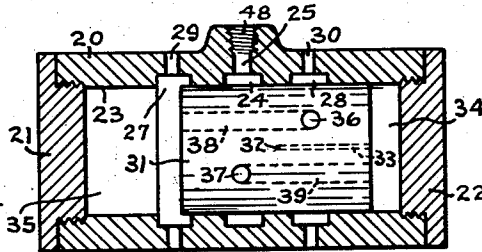


Fig. 3

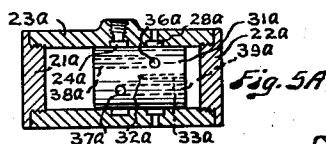


Fig. 5A

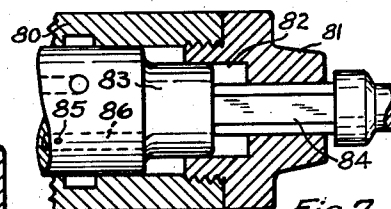


Fig. 7

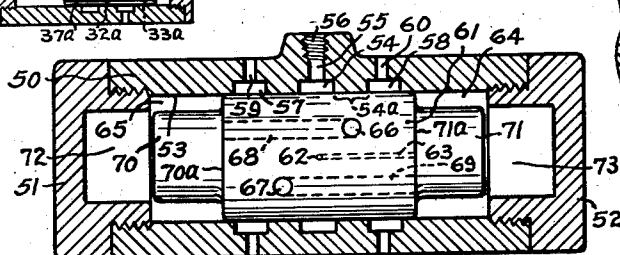


Fig. 6

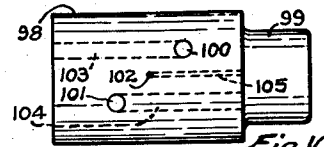


Fig. 10

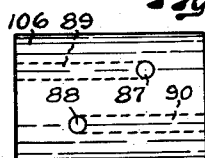


Fig. 8

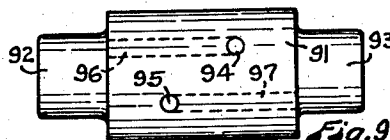


Fig. 9

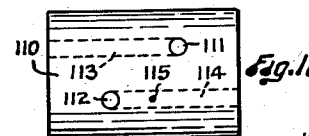


Fig. 11



Fig. 13

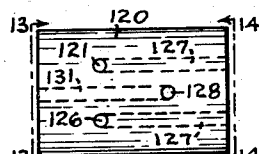


Fig. 12

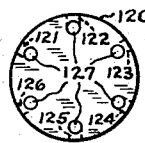


Fig. 14

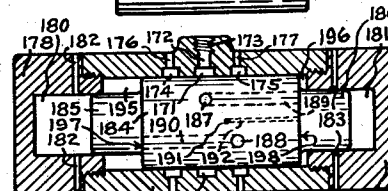


Fig. 16

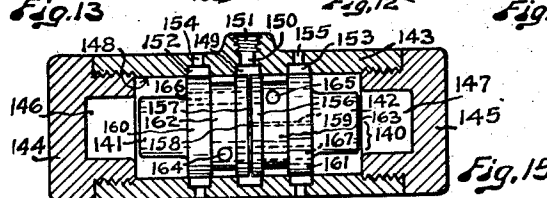


Fig. 15

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ENGINE OF HIGH SPEED AND LOW VOLUME CONSUMPTION OF FLUID PRESSURE MEDIUM

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Application May 24, 1954, Serial No. 431,662

18 Claims. (Cl. 121-17)

My invention relates to a fluid pressure medium reciprocating engine characterized by its high speed, power and low volume consumption of said fluid medium.

More particularly, my invention relates to a fluid pressure medium valveless reciprocating piston engine operating both in the fields of hammer and vibratory mechanisms characterized by a construction providing higher speeds, greater power and a lower volume consumption of said medium than in said devices as heretofore commonly designed and used.

One of the great objections to fluid pressure operated devices and particularly pneumatic operated devices, is the relatively very high consumption of the fluid pressure medium in the operation of tools and vibrators. The equipment to provide the necessary volume of fluid pressure medium is expensive and requires extensive space in plants where space ordinarily is at a premium. However great these objections may be, they are exceeded by the very heavy cost of maintenance of the compressor supplying the pressure medium and the high cost of operation of such equipment required in operation of fluid pressure tools of modern and common design found in commercial use. More specifically, on most tools in common practice and of large special design, the maintenance cost may be in the order of thousands of dollars per year while the original cost of the tools is of the order of hundreds of dollars. The primary expense is thus clearly indicated to be the expense of providing the necessary volume of pressure of the fluid medium in maintaining in operation the tools. In contrast, the tool embodying my invention and discovery herein set forth, weighing many times less, performed approximately the work of a tool in the market weighing much more and consumed a plurality of times less the volume of compressed fluid for its operation.

The successful operation of the tools embodying my invention is in measure due to the fact that they are built for a given type of work. I have found that the different types of work to be performed by the fluid pressure devices, whether it be in the "vibrator" or in the "hammer" field of operation or wherever vibrations are to be employed in accomplishing a given task, there should be taken into consideration the particular types and conditions of work involved. For example, by way of illustration, if a device is to operate as a vibrator as applied to a piece of work weighing twelve tons as may be the case in the manufacture of thirty feet long concrete pipe as a water main, such product with its forms will have its own natural rate of vibration, and for the tool to work at its maximum efficiency, it ordinarily should have a rate of vibration substantially equal to the natural vibration rate of the mass to be vibrated. Furthermore, in creating such vibration rate in the production of a product having such magnitude of weight, the different kinds of work involve a particular type of vibration. In short, the various applications to which the tools or vibrating means may be applied have different character of materials, different weights or masses and each requires for

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maximum efficiency its own particular type and rate of vibration frequency. For instance, the large mass type above referred to may involve a sudden sharp hammer-like blow or shock of vibration whereas other types may require a cushioned type of vibration. Furthermore, in providing such vibration impulses, there must be considered the frequency of vibration impulses as well as the amplitude of the stroke of the vibrating means, and also the type of vibration may require a balanced or unbalanced vibration. All of the above indicates clearly that the device must be one so constructed as to provide a controlled predetermined rate and character of vibration.

It is a primary object of my invention to provide a device which may be controlled in creating predetermined types of vibration to meet definite purposes of operation and at the same time preeminently to have such devices operate with a minimum of volume of fluid pressure medium. In this wise, the cost of operation and maintenance is greatly reduced and extensive economies made in manufacturing expenditures.

A primary and fundamental object of my invention is to provide a pneumatic engine which employs a minimum volume of fluid medium for developing a given force or to perform a given work, i. e., for a given unit of work being done. To this end I provide, as one feature, a smooth piston, one having its outer surface which comes into sliding contact with the cylinder bore entirely smooth from end to end of the piston with the exception of inlet-exhaust ports for compressed fluid medium. Such a piston contributes to the saving of fluid pressure medium and is characterized by its high speed of operation. Such smooth surfaced piston is in contrast to the so called in the trade "hill and valley" type, that is a piston which has its circumferential surface grooved or cut to provide channels having lugs or hills at the end and central portions. Also, such smooth surfaced piston provides for less piston and cylinder wear and therefore more efficient operation and longer life as well as higher speed of operation. As a second feature, I further provide a stepped piston having a stepped piston portion slightly smaller than the diameter of the main piston body itself and the cylinder for said stepped piston having a stepped piston bore fittingly registering with the diameter of said stepped piston portion.

In achieving a plurality of times the reduction of the volume of the fluid medium required in the operation of said fluid pressure engines or mechanism, I have discovered that such volume of fluid pressure required to operate a given fluid pressure mechanism for a given work may be reduced by providing the piston with a smooth even surface from end to end without interruptions of said cylinder face excepting for ports for the inlet and exhausting of the fluid medium. Moreover, in further providing for the reduction of the minimum of volume of fluid pressure medium required for operation of a given tool for a given work, I have invented and discovered a particular type of piston to work in a new functional relationship with said "smooth" piston type of piston characterized by its "stepped" character, i. e. slightly smaller diameter in the end portion than the diameter of the piston proper and the providing for the reception of this stepped piston portion in a stepped portion of the cylinder, which stepped portion of the cylinder fittingly receives said stepped portion of the piston. Moreover, said stepped part of the cylinder forms a closed chamber properly proportioned to the rest of the cylinder in which closed chamber pressure may be developed causing the piston to reverse its direction. Thus, only a portion of fresh inlet air is required to operate the piston due to the relatively narrow annular pressure sur-

face exposed on the end of the piston about the stepped part of the piston.

This stepped part of the piston functions in two capacities, one, to reduce the area against which the inlet pressure is to operate, and secondly, to add weight to the piston in providing for a power stroke which to some degree makes up for the decrease in the pressure area on the end of the piston proper. It will be remembered that also there is the supplementary built up pressure on the end of the stepped portion of the piston. It will be noted that by providing the stepped part of the piston that the volume of air required to build up the full intake pressure against the narrow annular pressure area is greatly reduced without cutting down the magnitude of the pressure per unit area while involving a greatly reduced volume in the cylinder for said intake pressure to operate. It will be further noted that by the reduction of the volume in the end of the cylinder to which the annular pressure area of the piston is exposed automatically greatly increases the effectiveness of the newly admitted fluid medium by reason of the fact that not having such a large volume to be introduced greatly enhances the speed (i. e. reduces the time element to supply the necessary reduced volume) of the application of the full force of the newly admitted intake pressure medium. It does not require the time to fill a large volume in the end of the cylinder as is the case where there is no stepped member of the piston to reduce the volume to be filled with fluid medium.

The smooth piston of my invention and discovery has no circumferential channels to be filled with newly admitted fluid pressure medium so that it is exceptionally sensitive to said newly admitted fluid pressure and starts moving immediately in response thereto as no time is required to fill said channels in the face of the piston. Since the "smooth" surface of the piston renders the piston very sensitive as it were, i. e. very prompt in action to respond to the newly admitted fluid medium directly from the source of said fluid pressure, such "smooth" piston makes it possible to secure efficient cooperation with said stepped piston end members. The stepped end pistons provide for the compression of the trapped fluid medium in the stepped-piston-cylinder bore and thereby cause trapped air to function as a reversing means and provide a rebound as it were of the piston. To take advantage of this it requires a split second timing for the application of the newly admitted inlet pressure fluid medium, and this I secure by means of the very prompt response of the smooth piston to the newly-admitted fluid pressure medium. In short, my invention and discovery involves a new functional relationship between the newly-admitted inlet pressure fluid medium in timing the application of said pressure fluid medium to driving the piston after it has been reversed in its reciprocation by means of the trapped fluid pressure medium. In addition to such advantage in one modified form having inlet-outlet passageways for the stepped-piston bore chambers, the stepped-piston end portion in conjunction with the stepped-piston-cylinder bore also provides an efficient means for adjusting the length of stroke and the providing of a type of vibration which may be required for a given work.

It is a further object of my invention to provide for the stepped member of the piston to build up pressure of the trapped air in the closed stepped part of the cylinder thereby causing the piston to rebound in response to such built-up pressure and reverse its direction without consumption of fresh inlet medium for this purpose, thereby making it possible to use the full force of the freshly admitted fluid pressure to the area of the piston, which may be termed the annular end or shoulder end of the piston, to cause the piston to be actuated by the full force of the freshly-admitted intake pressure medium without the consumption or expenditure of part of its force in reversing the piston. This makes even the piston with its increased weight provided by the stepped portions of the

piston to operate at a high speed and therefore give a heavy blow either as a vibrating means or in the hammer field in actuating the hammer or chisel or like tool.

Briefly summarized and therefore incompletely stated, the invention herein disclosed relates to a fluid pressure operated reciprocating engine characterized by its high speed and greatly reduced consumption of fluid pressure involved in its operation. These advantages being achieved in part (a) by a smooth piston, one having its outer surface which comes into sliding contact with the cylinder bore entirely smooth from end to end of the piston with the exception of inlet-outlet or exhaust ports for compressed medium. Also, said advantages are achieved in part (b) by providing a stepped-piston, the advantage of the stepped-piston being applicable both to the smooth piston type of engine and to the "hill and valley" type of piston.

The above mentioned general objects of my invention together with others inherent in the same are attained by the mechanism illustrated in the accompanying drawings, the same being preferred exemplary forms of the embodiment of my invention throughout which drawings like reference numerals indicate like parts:

Figure 1 is a view in longitudinal section of a piston and cylinder embodying my vibratory character of invention with the piston located in the center of the cylinder longitudinally considered, the same being of the smooth type;

Fig. 2 is a view in longitudinal section of the same with the piston disposed in the left hand end portion of the cylinder;

Fig. 3 is a view in longitudinal section of the same with the piston disposed in the right hand end portion of the cylinder;

Fig. 4 is a view in cross-section of said invention on dotted line 4—4 in direction of the arrows of Figure 1;

Fig. 5 is a view in cross-section of said invention on dotted line 5—5 in direction of the arrows;

Fig. 5A is a view in longitudinal section of a modified form of my invention having exhaust means on one end only;

Fig. 6 is a view in longitudinal section of a modified form of the device of my invention of the vibratory character showing a double ended stepped-piston with the piston located in the center of the cylinder longitudinally considered;

Fig. 7 is a partial view in longitudinal section of a modified form of a stepped-piston with a tool adaptor secured to one end to hold a tool when the engine of the hammer character is to be employed as a driver or hammer means and with the starter orifice leading directly to an inlet-exhaust passageway instead of the starter having its own individual passageway;

Fig. 8 is a view in elevation of a modified form of my invention having a smooth surfaced piston as employed in the device shown in Figs. 1, 2 and 3 excepting the said piston has no starting orifice;

Fig. 9 is a view in elevation of a modified form of my invention having a smooth surfaced piston provided with a double stepped-piston having no starting orifice;

Fig. 10 is a view in elevation of a modified form of my invention having a smooth surface piston provided with a single stepped-end portion which may be employed in special tools where a heavy blow or drive is required in special tools;

Fig. 11 is a view in elevation of a modified form of my invention having a smooth surface piston having a starting orifice communicating directly with one of the longitudinal inlet-exhaust passageways instead of having its separate longitudinal passageway;

Fig. 12 is a view in elevation of a further modified form of the smooth surface piston of my invention;

Fig. 13 is a view of the modified form of piston of Fig. 12 looking in the direction of the arrows 13—13 showing ends of three of the passageways of said piston;

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Fig. 14 is a view of the opposite end of the piston of Fig. 12 showing six ends of the passageways looking in the direction of the arrows 14—14;

Fig. 15 is a view in longitudinal section of a still further modified form of my invention in which the piston is of the hill and valley type; and

Fig. 16 is a view in longitudinal section of a modified form of my invention having inlet-outlets in stepped-piston-cylinder portions.

In providing an engine characterized by its high speed and low consumption of fluid pressure, my invention and discovery involves two features, that is I provide the ultimate advantage of high speed and low consumption in my invention and discovery by a smooth surfaced piston and this supplemented by a stepped piston.

Referring to Figs. 1 to 5, an engine having the smooth piston feature is shown. This feature comprises an engine having a cylinder 20 which has end members 21 and 22 both as here shown being preferably of separate construction as respects the cylinder proper, thus providing for ease of machining. Manifestly one end could be integrally formed with the cylinder. In the cylinder in its bore face portion 23 annular inlet channel 24 is cut of relatively broad width. Said channel has radial passageway 25 communicating with threaded opening 48 which receives a conduit (not shown) from a suitable source of fluid pressure.

On each side of inlet channel 24 and in spaced relation thereto, are annular exhaust channels 27 and 28 in the bore face portion 23. Said exhaust channels 27 and 28 have radial exhaust passageways 29 and 30.

Within cylinder 20 is reciprocally disposed a smooth surfaced piston 31 having a very small starting opening or orifice 32 in the longitudinal central portion of the piston 31 which has its separate starter longitudinal passageway 33 in the piston and which communicates through the end of the piston 31 with the cylinder end portion chamber 34. This separate starter longitudinal passageway 33 could communicate with the opposite cylinder end portion chamber 35 instead of chamber 34. Inlet-exhaust ports 36 and 37 are spaced equidistantly and longitudinally of starter orifice 32. These ports 36 and 37 respectively have longitudinally directed passageways 38 and 39 communicating respectively through the ends of the piston with cylinder end chamber 35 and 34. Preferably there are a plurality of said inlet-exhaust ports and passageways. As here shown in Figs. 4 and 5 there are two additional ports 40 and 41 with their longitudinal passageways 42 and 43 respectively leading to the cylinder end chamber 35. Also, there are two additional ports 44 and 45 with their longitudinal passageways 46 and 47 leading to cylinder end chamber 34. Said ports 40 and 41, and 44 and 45 are equidistantly spaced with respect to the starter orifice 32.

The modified form of the device of my invention and discovery in Fig. 5A shows the device with exhaust means on one end only. There are situations where it is not only convenient but where it is necessary for the engine to exhaust at one end only. The device of my invention has such adaptability that it can operate with such single exhaust means. Such form has cylinder 23a with end members 21a and 22a and inlet channel 24a and exhaust channel 28a. The piston 31a has inlet exhaust ports 36a and 37a with passageways respectively 38a and 39a. Starter orifice 32a has passageway 33a. An example of an application where such form is particularly adapted is in rock drilling.

In the modified form of Fig. 6, the cylinder 50, having end members 51 and 52 both as here shown, are preferably of separate construction as respects the cylinder proper for ease of machining. Manifestly one end could be integrally formed with the cylinder. In the cylinder 50 in its bore face portion 53, annular inlet channel 54 is cut of relatively broad width. Said channel has radial passageway 55 communicating with threaded opening 56

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which receives a conduit (not shown) from a suitable source of fluid pressure.

On each side of inlet channel 54 and in spaced relation thereto, are annular exhaust channels 57 and 58 in the bore face portion 53. Said exhaust channels 57 and 58 have radial exhaust passageways 59 and 60. Within cylinder 50 is reciprocally disposed, a smooth surfaced piston 61 having a very small starting opening or orifice 62 in the longitudinal central portion of the piston 61 which orifice has its separate starter longitudinal passageway 63 in the piston and communicating through the end of the piston 61 with the cylinder end portion chamber 64. This separate starter longitudinal passageway 63 could communicate with opposite cylinder end chamber 65 instead of cylinder end chamber 64.

Inlet-exhaust ports 66 and 67 are spaced equidistantly and longitudinally of starter orifice 62. These ports 66 and 67 respectively have longitudinally directed passageways 68 and 69 communicating respectively through the ends of the piston with cylinder end portion chamber 65 and 64 respectively. Preferably there are a plurality of said inlet-exhaust ports and passageways as set forth for piston 31 and as shown in Figs. 4 and 5.

The second feature of my invention and discovery by which high speed and low consumption of fluid pressure medium is realized, namely the stepped-piston, will next be set forth. This feature is shown in Fig. 6. The piston 61 is provided integrally with stepped-pistons 70 and 71 on each end thereof having annular shoulders 70a and 71a. The end members 51 and 52 have cylinders stepped-end portions 72 and 73 which are respectively a continued portion of the cylinder proper. These cylinder stepped-end portions may be referred to as supplementary cylinder-bore chambers and are of less diameter than the cylinder-bore proper but not less than half of said diameter of the cylinder proper. The diameter of the stepped-piston end portions or stepped-end piston portions 70 and 71 may be of a length when the center of the piston is in register with the inlet channel 54 that they extend slightly short of the entrance to the supplementary cylinder-bore chambers 72 and 73. This provides for the annular shoulders or face 70a and 71a between the cylinder-bore and the stepped-end piston portions 70 and 71 which is a reduced pressure area of the piston. If the diameter of the piston projections or stepped-end piston portions 70 and 71 are of less diameter than one-half of the piston, then there is little or no advantage by way of saving of fluid pressure medium. Of course, this also applies to the diameter of the supplementary cylinder-bore chamber in which the stepped-end piston portions operate. By having the starting orifice and its longitudinal passageway communicate with an annular face of the stepped-end piston portion of the piston, then the fluid pressure medium entering through the starting orifice and the longitudinal passageway has a relatively small chamber to fill and thereby is made much more effective in starting the piston than where no stepped-end piston portion is involved.

As stated above, annular channel 54 is of relatively wide width in proportion to the diameter of the inlet-exhaust ports of the piston, i. e. ports 66 and 67. As shown, the said width of inlet channel 54 is substantially twice the diameter of each of said ports. This relationship is particularly appropriate for semi high speed operating tools as required in metal and wood working chisels. It will be understood that the more nearly the width of the channel 54 is reduced to approximate the diameter of the ports 66 or 67, the slower speeds and longer strokes will result. For the higher speeds, the width of the channel 54 may be several times wider than the diameter of the ports 66 or 67. Such increased width of the channel renders the tool in its operation characterized by a shorter stroke and higher speed. For a given width of inlet channel 54 and given distance 54a between inlet channel 54 and exhaust channel 58 if the diameter of ports 66 or 67

are "lessened," then the stroke will be longer and the speed slower, because the piston will be required to travel further before it receives a charge of inlet pressure fluid medium. On the other hand, if the diameter of the ports 66 or 67 are increased with respect to said given channel 54 and distance 54a, then the stroke will be shorter and the speed higher, because the piston will be required to travel a shorter distance before a change in portage occurs. Such description relative to the relationship of the width of the channel 54 to the inlet-exhaust ports 66 and 67 applies also to the disclosure of inlet channel 24 with respect to its inlet-exhaust ports 36 and 37, as will all similar portings.

In the modified form shown in Fig. 7, one end portion of the cylinder 80 of the engine is shown specially adapted for use as a pneumatic hammer and is provided with an end enclosure or tool adapter 81 having a stepped-cylinder 82 wherein the stepped piston 83 operates to strike and drive the shank 84 of a tool. The piston in this modified form of the device of Fig. 7 is shown with the starter orifice 85 disposed in direct communication with inlet-exhaust passageway 86 instead of said orifice having its own individual passageway. This type is not quite as efficient for starting as where the starter orifice has its own longitudinal passageway and particularly is this true where high speeds are involved.

In the modified form of the piston 106 shown in Fig. 8, the smooth surfaced piston having inlet-exhaust ports 87 and 88 and longitudinal passageways 89 and 90 is illustrated without any starter orifice. Such a piston may well be employed in the situation where the cylinder may be moved or caused to operate in a vertical position.

In the modified form of the piston 91 shown in Fig. 9, the piston having stepped end portions 92 and 93 has inlet-exhaust ports 94 and 95 which directly communicate with longitudinal passageways connected therewith respectively, namely 96 and 97. This piston is illustrated without any starter orifice and may be employed where the cylinder may be moved or caused to operate in a vertical position.

In the modified form of the piston 98 shown in Fig. 10, the piston has the stepped end member 99 on one end, said piston having inlet-exhaust ports 100 and 101 and also starter orifice 102 of very small diameter. Inlet-exhaust ports 100 and 101 directly communicate with longitudinal passageways 103 and 104 respectively. The starter orifice 102 has its own individual longitudinal passageway 105. This providing of the starter orifice with its own longitudinal passageway makes practically positive the starting of the device under all conditions.

In the modified form of the piston of my invention, Fig. 11, the smooth surfaced piston 110 has inlet-exhaust ports 111 and 112 which directly communicate with longitudinally directed passageways 113 and 114 respectively. In this form the starting orifice 115 may directly communicate with longitudinal passageways 114.

In the modified form of the piston 120 of my invention illustrated in Figs. 12, 13 and 14, there is illustrated a smooth surfaced piston having a plurality of inlet-exhaust ports as follows: exhaust-inlet ports 121, 122, 123, 124, 125 and 126 each of which ports having longitudinal passageway 127 all of which are alike and open at one end of the piston. In Fig. 13 are shown inlet-exhaust ports 128, 129 and 130 in the opposite end of piston 120, each directly communicating with a longitudinal passageway 131 all of which are similar. The unequal number of said inlet-exhaust ports and passageways provides one type of an unbalanced motor which may be important in some applications as for illustration where a heavier and faster vibration in one direction than in the other is desired. This may occur in moving materials in certain directions as is found in the vibratory field.

In Fig. 15, the feature of my invention and discovery of the stepped-piston is shown as a modified form wherein the piston 140 is of the hill and valley type, that is, a

piston having lugs and channels therebetween and is provided integrally with stepped piston end portions 141 and 142. Cylinder 143 has end members 144 and 145 provided with cylinder stepped end portion or chambers 146 and 147. In the face 148 of the bore of the cylinder 143, fluid pressure inlet channel 149 is provided, which has short passageway 150 leading to threaded opening 151 which receives a standard conduit (not shown) from a suitable source of fluid pressure.

On each side of inlet channel 149 are disposed preferably equidistantly, exhaust channels 152 and 153 which respectively have radial exhaust passageways 154 and 155.

The piston 140 has a central lug 156 which may have and preferably does have a starting groove 157 with a starting port of very small diameter, i. e. an orifice 158 which as shown has its own communicating passageway 159 opening into the end portion of cylinder 143. Also, said piston has end lugs 160 and 161 with channel 162 disposed between lug 160 and central lug 156, and channel 163 disposed between lug 161 and central lug 156. In these piston channels 162 and 163 are located inlet-exhaust ports 164 and 165 respectively, and these ports respectively have longitudinally extending passageways 166 and 167.

The mode of operation of this stepped-piston 140 of the hill and valley or lug and channel type is in general the same as that of the engine shown in Fig. 6, but with this very important difference: The channels 162 and 163 require to be supplied with fluid pressure medium each stroke. This takes time, short though it may be and at the high speed of reciprocations which is sought in my invention and discovery we are dealing with short periods which must be eliminated unless they are efficiently contributing and are positively required. Also, the said channels in requiring volumes of compressed fluid medium to fill them are wasteful, and it is the purpose of my invention and discovery to eliminate all such waste. The smooth type of piston of my invention and discovery has no channels to be filled, so both time of filling is saved and the unnecessary consumption of fluid pressure medium is avoided. Thus, is provided a very sensitive piston promptly responsive to the inlet fluid pressure as no time is lost in filling channels in the piston and no waste of such medium occurs.

In the modified form of my invention and discovery shown in Fig. 16, cylinder 170 has relatively wide inlet fluid pressure medium channel 171 with passageway 172 leading to threaded portion 173 by which a standard conduit (not shown) leading to a source of compressed fluid medium may be connected. On each side of said inlet channel 171 are exhaust channels 174 and 175 having exhaust passageways 176 and 177 respectively. Cylinder 170 has end members 178 and 179 threadedly secured having stepped-cylinder end portions or chambers 180 and 181 respectively and inlet-outlet passageways 182 and 183.

In cylinder 170 and stepped-cylinder end portions or chambers 180 and 181 is reciprocally located piston 184 having stepped-end portions 185 and 186. Also, said piston 184 has inlet-exhaust ports 187 and 188 positioned equidistantly on each side of the longitudinal center—said ports having communicating passageways 189 and 190 opening into stepped chambers 180 and 181. Starting orifice 191 is disposed at longitudinal center with passageway 192 leading to annular face 193 of piston 184—it could lead to annular face 197 of piston 184.

In the modified form of the invention, Fig. 16, the stepped-end portions 185 and 186 are proportioned to have the said stepped-end portions of the piston during reciprocation always partly within the stepped-piston cylinder chambers 180 and 181, thereby maintaining a separation of the trapped fluid medium in the stepped-piston-cylinder chambers 180 and 181 from the portion of the cylinder 195 and 196 having the annular faces 197 and 198 respectively. In this modified form inlet-

outlet passageways 182 and 183 are provided intermediate the length of the stepped-piston-cylinder chamber 180 and 181. In this form the piston, upon commencement of the stroke, will meet with substantially no resistance of the air confined in the chamber in the stepped-piston-cylinder chambers 180 and 181 as the fluid medium will exhaust through the inlet-outlet passageways 182 and 183. This permits easy starting of the piston whereupon as soon as the piston moves, cutting off the inlet-outlet passageways 182 and 183 respectively, upon each reciprocation, it then promptly builds up the pressure to cause a reversal of direction of reciprocation of the piston and to cause it to rebound. It will be understood that different types of work, as explained elsewhere herein, require different types of vibration. The length of the stroke of the piston may be varied by having the inlet-outlet passageways 182 and 183 located at different distances from the end of said chambers 180 and 181. The closer these inlet-outlet passageways 182 and 183 are to the end of said chambers 180 and 181, the longer and slower are the strokes and thus is provided a different type of vibration. Accordingly, a very ready means is provided for adjusting the device to provide different types of vibration.

Mode of operation

The mode of operation of the engine of my invention and discovery has been set forth in part above with the description of the construction of the same. The annular inlet channel 24 provides a reservoir, as it were, of fluid pressure medium about the smooth surfaced piston 31 providing equal fluid pressure about the piston. The smooth surfaced piston 31 provides a very positive separation of the inlet channel 24 from the exhaust channels 27 and 28, i. e. the smooth surfaced piston 31 provides a better seal than most other type of piston in fluid pressure operated motors. Said fluid pressure medium in said channel 24 is immediately available to enter registering ports and enters the very small starter orifice or opening 32 which builds up pressure in cylinder end 34 in case the piston 31 has stopped on dead center and thus said piston 31 is moved to the opposite end of the cylinder as shown in Fig. 2, thereby bringing inlet-exhaust port 36 in register with said annular inlet channel 24 from which a charge of pressure fluid medium is communicated through longitudinal passageway 38 and into cylinder chamber end 35. The term "inlet-exhaust" is employed because ports 36 and 37 alternately function as an inlet port for fluid pressure and as an exhaust port during that part of the reciprocation when said port is in registration. In the meantime, compressed fluid medium in cylinder chamber end 34 is exhausting into and out of annular exhaust channel 28 and also momentarily out through radial passageway 36, inlet-exhaust port 37, channel 27 and passageway 29. Thus is provided a very rapid double exhausting system to reduce the pressure in cylinder chamber 34 to an unobjectionable degree of pressure. The live pressure fluid medium charge through port 36 provides a sudden build up of pressure in chamber 35 which suddenly reverses the piston 31 forcibly driving it towards the opposite end, namely cylinder chamber 34. The instant the piston 31 starts back from the position shown in Fig. 3, port 36 is cut off from exhaust channels 28 and the medium in the chamber end 35 is subjected to an increasing pressure and as soon as port 36 registers with inlet channel 24, then the pressure in chamber end 35 is as stated, suddenly raised to a high magnitude, thereby providing a great force in reversing the piston and causing it to deliver a heavy blow if used in the hammer field or a severe vibration in the vibratory field. Ordinarily, this piston does not contact the end plates. This suddenness in the vibrator type of my invention supplies the long desired operation in mechanisms in the vibrator field with a minimum volume of fluid pressure medium.

As the piston 31 is driven back, inlet-exhaust port 37 registers with inlet channel 24 thereby providing a charge of live pressure fluid in cylinder end 34 and the cycle of operation is repeated for said end as has just been set forth for cylinder end 35 and so such description will not be repeated.

Such construction and operation greatly reduces the volume of fluid pressure medium employed because the volume of said medium required for filling the wide channels in the piston of the hill and valley type is avoided. Likewise, the speed of reciprocation is greatly increased because there is not the time delay in filling the said wide channels in the piston of the hill and valley type. It will be understood that the inlet air expands and thereby reduce its effective pressure is filling said wide channels of said piston of the hill and valley type. Next, said volume of fluid pressure medium must be exhausted from said wide channels of the piston of the hill and valley type. Thus, time is lost in both filling and exhausting from said wide channels of said piston of the hill and valley type. Let it also be noted that all the volume of said fluid pressure in said wide channels of the piston of the hill and valley type must be exhausted each passage of the piston, i. e. twice for each cycle of reciprocation of the piston. Hence it is manifest that there is a far greater volume of said pressure fluid exhausted from said wide channels of the hill and valley type than in the case of the smooth surfaced piston of my present invention and discovery, wherein the only volume of air exhausted is that in the cylinder end chambers 34 and 35. Such volume is also to be exhausted from the ends of the cylinder of the hill and valley type of piston operation so that there is no loss of fluid pressure medium in the smooth piston type. Such type provides a positive saving over that of the hill and valley type.

From the above, it is manifest that the sum total of the volume of fluid pressure medium exhausted from the device of the hill and valley type of piston equals the volume filling the wide channels on each end of the piston and the volume filling the cylinder end chambers. In contrast, the only volume of fluid pressure medium exhausted from the smooth piston type of device of my invention and discovery is that medium from the cylinder end chambers 34 and 35 because there are no wide channels in the piston to be emptied. In both types, my invention and discovery does use a portion of the fluid medium which is trapped in the chamber ends 34 and 35 in building up pressure for the reciprocation of the piston.

The beneficial results from such saving of volume of fluid pressure medium is not only said volume occupying the wide channels of the hill and valley type of piston but the increase speed characterizing the smooth surfaced piston of the present application due to the lack of drop (even if ever so small) in the fluid pressure which occurs in filling wide channels of the piston of the hill and valley type as well as the time required in the exhausting of such volume of fluid medium from said wide channels. In this field of reciprocating engines, small quantities and details are of utmost importance as appears in the great saving achieved in the device of my invention and discovery. Also, be it noted that when the piston 31 is returning from the cylinder chamber 34 and has reached the position shown in Figure 1 that the inlet channel 24 and the exhaust channels 27 and 28 are all closed so that it is the momentum of the piston 31 which is compressing the unexhausted fluid pressure medium which is trapped in cylinder end chamber 35. Thus, this increased speed functions to impart a momentum to the piston 31 which is utilized in my invention in compressing the trapped fluid medium in the chamber ends 34 and 35. This medium is compressed and put under pressure due to said momentum of said piston 31 during the travel of said piston until inlet-exhaust port 36 reaches inlet channel 24, whereupon a charge of live fluid

pressure medium is suddenly supplied to the already compressed fluid in chamber 35. Thus the full value of the live fluid pressure may be immediately in action in either stopping, reversing, and driving said piston 31 to the opposite end, namely cylinder chamber 34 or may be wholly applied to driving said piston 31 after being reversed by the compressed entrapped fluid medium. The compressed residual medium in chamber 35 reduces the volume by so much of the live fluid pressure newly admitted through inlet-exhaust port 36, all of which contributes and cooperates functionally in reduction of the volume of fluid medium required for the very efficient operation of the smooth surfaced piston of my invention and discovery herein set forth. One of the costly features in operating fluid pressure motors is the cost of the original compressor installation of relatively large capacity to meet the requirements of tools of the prior art and particularly is the maintenance of such installation most costly. Also in addition, is the cost of continued operation involved in supplying such fluid pressure.

Be it also noted, that the full advantage of the momentum of the piston 31 is fully utilized because its full weight for its size, that is, its diameter is not reduced by cutting out wide channels as occurs in the hill and valley type of piston. Thus, it is manifest that the smooth surfaced piston 31 of my invention and discovery with its definitely arranged inlet-exhaust ports and longitudinal passageways within the piston function in operation with the cylinder 20 to provide not only one but several advantages over the piston of the hill and valley type.

Referring to the mode of operation of the modified form of smooth piston 61 as shown in Fig. 6: This modified form may be referred to as the "double ended stepped-piston." It will find its primary field of use especially in large units in the vibrator field or in pumps (see Fig. 12). It is manifest that the stepped-piston end portions 70 and 71 occupy space in cylinders 72 and 73 and therefore reduce the cubic volume thereof so that the volume of fluid pressure medium to fill the same is reduced. In short, here again the volume of fluid pressure medium required to operate the piston is reduced. The area upon which the fluid pressure medium operates is reduced to an annular ring surface or shoulders 70a and 71a respectively. The inlet annular channel provides a uniform reservoir of fluid pressure medium entirely around the piston 61 so that it functions to floatingly mount the piston and reduces friction incident to its reciprocation.

All through the specification it will be noted that the invention and discovery herein set forth relates to providing a reciprocating fluid pressure engine characterized by its high speed in comparison to fluid pressure engines of standard construction and in common practice.

The smooth type of piston of my invention is particularly characterized by high speed of the order of 75,000 or more reciprocations per minute in small units. In giving figures as to speeds, in comparing there must be kept in mind several factors, namely, length, diameter, weight, and design of piston.

Of the smooth type piston, it is noted above that we have two types. In addition to the plain smooth type shown in Figure 1, we have the smooth type with a stepped-piston portion of the form shown in Fig. 6. Both of these types are faster than the hill and valley piston of Fig. 15 where said factors are similar. Fig. 15, the hill and valley type, of my invention and discovery, is also much faster than any other fluid pressure reciprocating engine presently in use.

The starting orifice 62 of Fig. 6 that is, as applied to the piston having the stepped-end, provides a new functional relationship resulting in prompt effectiveness in starting the engine. Particularly in fluid pressure reciprocating engines, there is considerable trouble in get-

ting the same started. One of the objects of my invention is to overcome this feature. The stepped-piston 61 of my invention and discovery is particularly adapted for use in large units because it operates to cut down the consumption of fluid pressure medium. In fact, it makes possible the use of the fluid pressure type of engine in large units because it cuts down the volume consumption of fluid pressure medium required for its operation. In case the piston stops at dead center, the starter orifice with its passageway to one end of the principle body portion of the piston, the application of inlet air promptly provides pressure in chamber 64 which is relatively small compared to the area of the piston when it does not have the stepped-piston end portion member 71 so that the small volume of air which is admitted through the starting orifice 62 is very effective due to the fact that it does not have to build up pressure in a large space at the end of the piston. Thus, the stepped-end portion of the piston 61 cooperates with the starting orifice in providing for very effectively starting the mechanism and thus a new functional relationship results between the starting orifice 62 and the stepped-end portion 71 of the piston in providing for such effective starting of the device even though it is in a relatively large unit. This is true either in the stepped-piston type of the smooth body portion as well as in the stepped-piston type of the hill and valley type of piston. In the form of the piston 31, Figure 1, where is shown the smooth piston without the stepped-end portion and while the invention does not have the cooperation of the stepped-end portion member in reducing the volume of the space to be filled in building up the starting pressure, however, there is still the new functional relationship for effective and prompt starting of the piston. One of the outstanding characteristics of the smooth surfaced piston is that even after extended operation it does not become worn near as fast as does the hill and valley type. Thus, a close fit is maintained between the smooth surfaced piston 31 and its cylinder bore 23 over a very extended period. Thus, in the event that the smooth surfaced piston becomes stalled on dead center the admission of air to the starting orifice is permitted to build up pressure in the cylinder chamber 34 and since the smooth surfaced piston does not become worn for a relatively extended period of use, it forms an effective seal and prevents the pressure in the said chamber from escaping around the circumference of the piston and therefore provides for a new functional relationship which confines the fluid pressure medium entering through the starting orifice definitely to the chamber 34 of the cylinder. This results in the piston starting promptly although it is not as prompt as in the case of the stepped-end piston portion 71 of Fig. 6, where the cylinder chamber 64 is of reduced volume.

The piston, in being forced to one end, compresses the air or fluid medium within the stepped-piston bore chambers 64 and 65 and such compression reverses the piston. At the same moment that the reversing takes place, fresh live compressed fluid is admitted to the chamber having an annular pressure area 71a and 70a so that the full force of the said live pressure is applied to the annular pressure face 71a and 70a of the piston and its force upon the piston is thus relieved primarily of any reduction in reversing the direction of the piston so that its full effectiveness is applied to the piston in boosting the force of its blow.

In my invention and discovery, the providing of the smooth body portion of the piston in all of its forms renders it particularly sensitive or reactive to the inlet fluid pressure. This is due to the fact that there are no wide circumferential channels or ducts 162 and 163 of the piston as in the hill and valley form, Fig. 15, which have to be filled with fresh inlet fluid pressure medium on each reciprocation. Furthermore, the passageways in the smooth portion of the stepped-piston through which the

inlet air must pass is reduced in length as these passageways only extend the portion of the piston 61 which comprises the main body part. By providing the extensions or stepped-end portions or members 70 and 71 on the main body of the piston 61, the reciprocating member as a whole is operating to compress the entrapped stepped-fluid medium in the supplementary cylinder-bore i. e. cylinder end portions or chambers 72 and 73 in advance of the admission of the fresh inlet fluid pressure medium. Thus, it requires a very prompt application of the fresh inlet fluid pressure medium in order to operate in timed sequence with the stepped-piston members 70 and 71, that is, to take the full advantage of the rebound of the piston. The application of the fresh inlet fluid pressure medium must be very precisely timed and this is made possible in my invention and discovery by the fact that the smooth piston body portion 61 renders the application of the fresh inlet fluid medium very prompt in performing its function and in being applied to the reduced annular pressure area 70a and 71a, i. e. the area on the "shoulder" as it were of the piston 61. If said piston was not promptly sensitive to the inlet fluid medium, it would be quite difficult if not impossible to time its action to take advantage of the rebound of the piston which rebound results from the compression of the entrapped fluid medium.

It was unexpected and most surprising that the stepped-piston of large proportions starts and operates much more efficiently and on a multiple times less volume of fluid pressure medium than the non-stepped type of piston.

In conclusion, my invention and discovery has a higher speed and greater power than reciprocating devices as heretofore commonly designed and used. The tool embodying my invention and discovery herein set forth, weighing many times less, performed approximately the work of a tool in the market weighing much more, and the tool of my invention consumed a plurality of times less the volume of compressed fluid for its operation.

I claim:

1. A fluid pressure valveless reciprocating engine comprising a cylinder having an exhaust annular channel located in the bore portion between the longitudinal center and the end portion of said cylinder; an exhaust passageway leading from said exhaust annular channel; end members closing the end of said cylinder, one of said end members having stepped-piston supplementary cylinder-bore chamber of less diameter than the cylinder bore; an inlet annular channel disposed in the bore face portion of said cylinder substantially at said longitudinal center; a passageway connecting said inlet channel to a suitable source of fluid pressure medium; and a piston having substantially its entire length contacting the face of the cylinder bore, said face being substantially smooth and continuous from end to end and said piston having integrally projecting stepped-end-piston portion on one end thereof which is slidably, fittingly registrable within said stepped-piston supplementary cylinder-bore chamber in automatically trapping air therein and providing an annular pressure face between the cylinder-bore and the stepped-end-piston portion, said piston having inlet-exhaust ports disposed in spaced relation between the ends of said piston and a longitudinal passageway within said piston extending from each of said inlet-exhaust ports to said annular pressure face most remote thereto, the spacing of said inlet-exhaust port with respect to the inlet annular channel being of a magnitude to admit live fluid pressure substantially after the compressed trapped air in said cylinder-bore chamber has reversed the piston and while said compressed air is acting on the end of said stepped-end-piston portion whereby the said compressed trapped air is employed to supplement the live fluid pressure acting upon the annular pressure face in reciprocating the piston.

2. A fluid pressure valveless reciprocating engine com-

prising a cylinder having an exhaust annular channel located in the bore portion between the longitudinal center and the end portion of said cylinder, an exhaust passageway leading from said exhaust annular channel, end members closing the end of said cylinder, one of said end members having a stepped-piston supplementary cylinder-bore chamber of less diameter than the cylinder-bore, an inlet annular channel disposed in the bore face portion of said cylinder substantially at said longitudinal center, and a passageway connecting said inlet channel to a suitable source of fluid pressure medium; and a piston having substantially its entire length contacting the face of the cylinder bore, said face being substantially smooth and continuous from end to end, an integrally projecting stepped-end-piston portion on one end thereof which is slidably, fittingly registrable within said stepped-piston supplementary cylinder-bore chamber providing an annular pressure face between the cylinder-bore and the stepped-end-piston portion, said piston having inlet-exhaust ports disposed in spaced relation between the ends of said piston, and a longitudinal passageway within said piston extending from each of said inlet-exhaust ports to that end of the piston most remote thereto.

3. A fluid pressure valveless reciprocating engine comprising a cylinder having an exhaust annular channel located in the bore portion between the longitudinal center and the end portion of said cylinder, an exhaust passageway leading from said exhaust annular channel, end members closing the end of said cylinder, one of said end members having stepped-piston supplementary cylinder-bore chamber of less diameter than the cylinder bore, but not less than half of said diameter, an inlet annular channel disposed in the bore face portion of said cylinder substantially at said longitudinal center, and a passageway connecting said inlet channel to a suitable source of fluid pressure medium; and a piston having substantially its entire length contacting the face of the cylinder bore, said face being substantially smooth and continuous from end to end, an integrally projecting stepped-end-piston portion on one end thereof which is slidably, fittingly registrable within said stepped-cylinder supplementary cylinder-bore chamber providing an annular pressure face between the cylinder bore and the stepped-end-piston portion, said piston having inlet-exhaust ports disposed in spaced relation between the ends of said piston, and a longitudinal passageway within said piston extending from each of said inlet-exhaust ports to that end of the piston most remote thereto.

4. A fluid pressure valveless reciprocating engine comprising a cylinder having an exhaust annular channel located in the bore portion between the longitudinal center and the end portion of said cylinder, an exhaust passageway leading from said exhaust annular channel, end members closing the end of said cylinder, one of said end members having a stepped-piston supplementary cylinder-bore chamber of less diameter than the cylinder bore, an inlet annular channel disposed in the bore face portion of said cylinder substantially at said longitudinal center, and a passageway connecting said inlet channel to a suitable source of fluid pressure medium; and a piston having substantially its entire length contacting the face of the cylinder bore, said face being substantially smooth and continuous from end to end, an integrally projecting stepped-end-piston portion on one end thereof which is slidably, fittingly registrable within said stepped-piston supplementary cylinder-bore chamber providing an annular pressure face between the cylinder bore and the stepped-end-piston portion, said piston having inlet-exhaust ports disposed in spaced relation between the ends of said piston, and a longitudinal passageway within said piston extending from each of said inlet-exhaust ports to that end of the piston most remote thereto; and a starter orifice located midway between said inlet-exhaust ports having a longitudinally disposed passageway by

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which said orifice communicates momentarily with the annular pressure face of said piston.

5. A fluid pressure valveless reciprocating engine comprising a cylinder having an exhaust annular channel located in the bore portion between the longitudinal center and the end portion of said cylinder, an exhaust passageway leading from said exhaust annular channel, end members closing the end of said cylinder, one of said end members having a stepped-piston supplementary cylinder-bore chamber of less diameter than the cylinder bore, but not less than half of said diameter, an inlet annular channel disposed in the bore face portion of said cylinder substantially at said longitudinal center, and a passageway connecting said inlet channel to a suitable source of fluid pressure medium; and a piston having substantially its entire length contacting the face of the cylinder bore, said face being substantially smooth and continuous from end to end, an integrally projecting stepped-end-piston portion on one end thereof which is slidably, fittingly registrable within said stepped-piston supplementary cylinder-bore chamber providing an annular pressure face between the cylinder bore and the stepped-end-piston portion, said piston having inlet-exhaust ports disposed in spaced relation between the ends of said piston, and a longitudinal passageway within said piston extending from each of said inlet exhaust ports to that end of the piston most remote thereto; and a starter orifice located midway between said inlet-exhaust ports having a longitudinally disposed passageway by which said orifice communicates momentarily with the annular pressure face of said piston.

6. A fluid pressure valveless reciprocating engine comprising a cylinder having an exhaust annular channel located in the bore portion between the longitudinal center and the end portion of said cylinder, an exhaust passageway leading from said exhaust annular channel, end members closing the end of said cylinder, one of said end members having a stepped-piston supplementary cylinder-bore chamber of less diameter than the cylinder bore, an inlet annular channel disposed in the bore face portion of said cylinder substantially at said longitudinal center, and a passageway connecting said inlet channel to a suitable source of fluid pressure medium; and a piston having substantially its entire length contacting the face of the cylinder bore, said face being substantially smooth and continuous from end to end, an integrally projecting portion on each end thereof which is slidably, fittingly registrable within said stepped-piston supplementary cylinder-bore chamber, providing an annular pressure face between the cylinder bore and the stepped-end-piston portion, said piston having inlet-exhaust ports disposed in spaced relation between the ends of said piston, and a longitudinal passageway within said piston extending from each of said inlet-exhaust ports to that end of the piston most remote thereto.

7. A fluid pressure valveless reciprocating engine comprising a cylinder having an exhaust annular channel located in the bore portion between the longitudinal center and the end portion of said cylinder, an exhaust passageway leading from said exhaust annular channel, end members closing the end of said cylinder, one of said end members having stepped-piston supplementary cylinder-bore chamber of less diameter than the cylinder bore, an inlet annular channel disposed in the bore face portion of said cylinder substantially at said longitudinal center, and a passageway connecting said inlet channel to a suitable source of fluid pressure medium; and a piston having substantially its entire length contacting the face of the cylinder bore, said face being substantially smooth and continuous from end to end, an integrally projecting portion on each end thereof which is slidably, fittingly registrable within said stepped-piston supplementary cylinder-bore chamber, providing an annular pressure face between the cylinder bore and the stepped-end-piston portion, said piston having inlet-exhaust ports disposed

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in spaced relation between the ends of said piston, and a longitudinal passageway within said piston extending from each of said inlet-exhaust ports to that end of the piston most remote thereto; and a starter orifice located midway between said inlet-exhaust ports having a longitudinally disposed passageway by which said orifice communicates momentarily with the annular pressure face of said piston.

8. A fluid pressure valveless reciprocating engine comprising a cylinder having an inlet annular channel disposed in the bore face portion of said cylinder between the end portions thereof, a passageway connecting said inlet channel to a suitable source of fluid pressure medium, exhaust annular channels one on each side of said inlet channel in the bore portion of the cylinder in spaced relation thereto, exhaust passageways leading from said exhaust annular channels and members closing the ends of said cylinder, each of said members having a stepped-piston supplementary cylinder-bore chamber of less diameter than the cylinder bore; and a piston having substantially its entire length contacting the face of the cylinder bore, said face being substantially smooth and continuous from end to end, an integrally stepped-end-piston portion on each end thereof which is slidably, fittingly registrable within said stepped-piston supplementary cylinder-bore chamber, providing an annular pressure face between the cylinder bore and the stepped-end-piston portion, said piston having inlet-exhaust ports disposed in spaced relation between the ends of said piston, and a longitudinal passageway within said piston extending from each of said inlet-exhaust ports to that end of the piston most remote thereto.

9. A fluid pressure valveless reciprocating engine comprising a cylinder having an inlet annular channel disposed in the bore face portion of said cylinder between the end portions thereof, a passageway connecting said inlet channel to a suitable source of fluid pressure medium, exhaust annular channels one on each side of said inlet channel in the bore portion of the cylinder in spaced relation thereto, exhaust passageways leading from said exhaust annular channels and members closing the ends of said cylinder, each of said members having a stepped-piston supplementary cylinder-bore chamber of less diameter than the cylinder bore, but not less than half of said diameter; and a piston having substantially its entire length contacting the face of the cylinder bore, said face being substantially smooth and continuous from end to end, an integrally stepped-end-piston portion on each end thereof which is slidably, fittingly registrable within said stepped-piston supplementary cylinder-bore chamber, providing an annular pressure face between the cylinder bore and the stepped-end-piston portion, said piston having inlet-exhaust ports disposed in spaced relation between the ends of said piston, and a longitudinal passageway within said piston extending from each of said inlet-exhaust ports to that end of the piston most remote thereto.

10. A fluid pressure valveless reciprocating engine comprising a cylinder having an inlet annular channel disposed in the bore face portion of said cylinder between the end portions thereof, a passageway connecting said inlet channel to a suitable source of fluid pressure medium, exhaust annular channels one on each side of said inlet channel in the bore portion of the cylinder in spaced relation thereto, exhaust passageways leading from said exhaust annular channels and members closing the ends of said cylinder, each of said end members having a stepped-piston supplementary cylinder-bore chamber of less diameter than the cylinder bore; and a piston having substantially its entire length contacting the face of the cylinder bore, said face being substantially smooth and continuous from end to end, an integrally stepped-end-piston portion on each end thereof which is slidably, fittingly registrable within said stepped-piston supplementary cylinder-bore chamber, providing an annular pres-

sure face between the cylinder bore and the stepped-end-piston portion, said piston having inlet-exhaust ports disposed in spaced relation between the ends of said piston, and a longitudinal passageway within said piston extending from each of said inlet-exhaust ports to that end of the piston most remote thereto; and a starter orifice located midway between said inlet-exhaust ports having a longitudinally disposed passageway by which said orifice communicates with the annular pressure face of said piston.

11. In a fluid pressure valveless reciprocating engine the combination of a cylinder having an inlet annular channel disposed in the bore face portion of said cylinder between the end portions thereof, a passageway connecting said inlet channel to a suitable source of fluid pressure medium, exhaust annular channels one on each side of said inlet channel in the bore face portion of the cylinder in spaced relation thereto, exhaust passageways leading from said exhaust annular channels and members closing the ends of said cylinder, each of said end members having a stepped-piston supplementary cylinder-bore chamber of less diameter than the cylinder bore; and a piston having substantially its entire length contacting the face of the cylinder bore, said face being substantially smooth and continuous from end to end, said piston having inlet-exhaust ports disposed in spaced relation between ends of said piston, and a longitudinal passageway within said piston extending from each of said inlet-exhaust ports to that end of the piston most remote thereto.

12. In a fluid pressure valveless reciprocating engine the combination of a cylinder having an inlet annular channel disposed in the bore face portion of said cylinder between the end portions thereof, a passageway connecting said inlet channel to a suitable source of fluid pressure medium, exhaust annular channels one on each side of said inlet channel in the bore face portion of the cylinder in spaced relation thereto, exhaust passageways leading from said exhaust annular channels and members closing the ends of said cylinder, each of said end members having a stepped-piston supplementary cylinder-bore chamber of less diameter than the cylinder bore; and a piston having substantially its entire length contacting the face of the cylinder bore, said face being substantially smooth and continuous from end to end, said piston having inlet-exhaust ports disposed in spaced relation between ends of said piston, and a longitudinal passageway within said piston extending from each of said inlet-exhaust ports to that end of the piston most remote thereto; and a starter orifice located midway between said inlet-exhaust ports having a longitudinally disposed passageway by which said orifice communicates momentarily with the annular pressure face of said piston.

13. In a fluid pressure valveless reciprocating engine the combination of a cylinder having an exhaust annular channel located in the bore portion between the longitudinal center and the end portion of said cylinder, an exhaust passageway leading from said exhaust annular channel, end members closing the end of said cylinder, one of said end members having a stepped-piston supplementary cylinder-bore chamber of less diameter than the cylinder bore, an inlet annular channel disposed in the bore face portion of said cylinder substantially at said longitudinal center, and a passageway connecting said inlet channel to a suitable source of fluid pressure medium; and a piston having an integrally projecting stepped-end portion one end thereof which is slidably, fittingly registrable within said stepped-piston supplementary cylinder-bore chamber providing an annular pressure face between the cylinder bore and the stepped-end piston portion, said piston having inlet-exhaust ports disposed in spaced relation between the ends of said piston, a longitudinal passageway within said piston extending from each of the said inlet-exhaust ports to that end of the piston most remote thereto.

14. In a fluid pressure valveless reciprocating engine the combination of a cylinder having an inlet annular

channel disposed in the bore face portion of said cylinder between the end portions thereof, a passageway connecting said inlet channel to a suitable source of fluid pressure medium, exhaust annular channels one on each side of said inlet channel in the bore face portion of the cylinder in spaced relation thereto, an exhaust passageway leading from each of said exhaust annular channels and members closing end of said cylinder, each of said members having a stepped-piston supplementary cylinder-bore chamber of less diameter than the cylinder bore; and a piston having an integrally projecting stepped-end-piston portion on each end thereof which is slidably, fittingly registrable within said stepped-piston supplementary cylinder-bore chamber, providing an annular pressure face between the cylinder bore and the stepped-end piston portion, said piston having inlet-exhaust ports disposed in spaced relation between the ends of said piston, and a longitudinal passageway within said piston extending from each of said inlet-exhaust ports to that end of the piston most remote thereto.

15. A fluid pressure valveless reciprocating engine comprising a cylinder having an inlet annular channel disposed in the bore face portion of said cylinder between the end portions thereof, a passageway connecting said inlet channel to a suitable source of pressure medium, exhaust annular channels one on each side of said inlet channel in the bore face portion of the cylinder in spaced relation thereto, an exhaust passageway leading from each of said exhaust annular channels, and end members closing the ends of said cylinder, each of said end members having a stepped-piston supplementary cylinder-bore chamber of less diameter than the cylinder bore and having inlet-outlet passageways disposed transversely intermediate the length of said chamber, the longitudinal location of said inlet-outlet providing a means of regulating the stroke of said piston; and a piston having an integrally projecting stepped-piston portion on each end slidably, fittingly registrable within said stepped-piston supplementary cylinder-bore chamber, stepped-end-piston portion being such as to extend slightly short of the entrance to the stepped-piston supplementary cylinder-bore chamber when the longitudinal center of the piston is in the transverse plane extending through the longitudinal center of the cylinder, and said piston having inlet-exhaust ports disposed in spaced relation between the end of said piston and a longitudinal passageway within said piston extending from each of said inlet-exhaust ports to that end of the piston most remote thereto.

16. A fluid pressure valveless reciprocating engine comprising a cylinder having an inlet annular channel disposed in the bore face portion of said cylinder between the end portions thereof, a passageway connecting said inlet channel to a suitable source of pressure medium, exhaust annular channels one on each side of said inlet channel in the bore face portion of the cylinder in spaced relation thereto, an exhaust passageway leading from each of said exhaust annular channels and end members closing the ends of said cylinders, each of said end members having a stepped-piston supplementary cylinder-bore chamber of less diameter than the cylinder bore and having inlet-outlet passageways disposed transversely intermediate the length of said chamber, the longitudinal location of said inlet-outlet providing a means of regulating the stroke of said piston; and a piston having an integrally projecting stepped-piston portion on each end slidably, fittingly registrable within said stepped-piston supplementary cylinder-bore chamber, stepped-end piston portion being such as to extend for some portion thereof throughout the length of the stroke during reciprocation within said stepped-piston supplementary cylinder-bore chamber.

17. A fluid pressure valveless reciprocating engine comprising a cylinder having an exhaust annular channel disposed in the bore face of the said cylinder between the longitudinal center and the end portion of said cylinder, an exhaust passageway leading from said exhaust

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annular channel, end members closing the end of said cylinder, one of said members having stepped-piston supplementary cylinder-bore chamber of less diameter than the cylinder bore, an inlet annular channel disposed in the bore face portion of said cylinder between the end portions of said cylinder, and a passageway connecting said inlet channel to a suitable source of fluid pressure medium; and a piston having an integrally projecting stepped-end-piston portion on one end thereof which is slidingly, fittingly registrable within said stepped-piston supplementary cylinder-bore chamber, said piston also having inlet-exhaust ports disposed in spaced relation between the ends of said piston, and a longitudinal passageway within said piston extending from each of said inlet-exhaust ports to that end of the piston most remote thereto.

18. A fluid pressure valveless reciprocating engine comprising a cylinder having an exhaust annular channel disposed in the bore face of the said cylinder between the longitudinal center and the end portion of said cylinder, an exhaust passageway leading from said exhaust annular channel, end members closing the end of said cylinder, one of said members having stepped-piston supplementary cylinder-bore chamber of less diameter

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than the cylinder bore, an inlet annular channel disposed in the bore face portion of said cylinder between the end portions of said cylinder, and a passageway connecting said inlet channel to a suitable source of fluid pressure medium; a piston having an integrally projecting stepped-end-piston portion on one end thereof which is slidingly, fittingly registrable within said stepped-piston supplementary cylinder-bore chamber, said piston also having inlet-exhaust ports disposed in spaced relation between the ends of said piston, and a longitudinal passageway within said piston extending from each of said inlet-exhaust ports to that end of the piston most remote thereto; and a starter orifice located midway between said inlet-exhaust ports having a longitudinally disposed passageway by which said orifice communicates momentarily with the annular pressure face of said piston.

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