Nov. 12, 1968 L. A. MARTINI 3,410,353

PERCUSSION TOOLS

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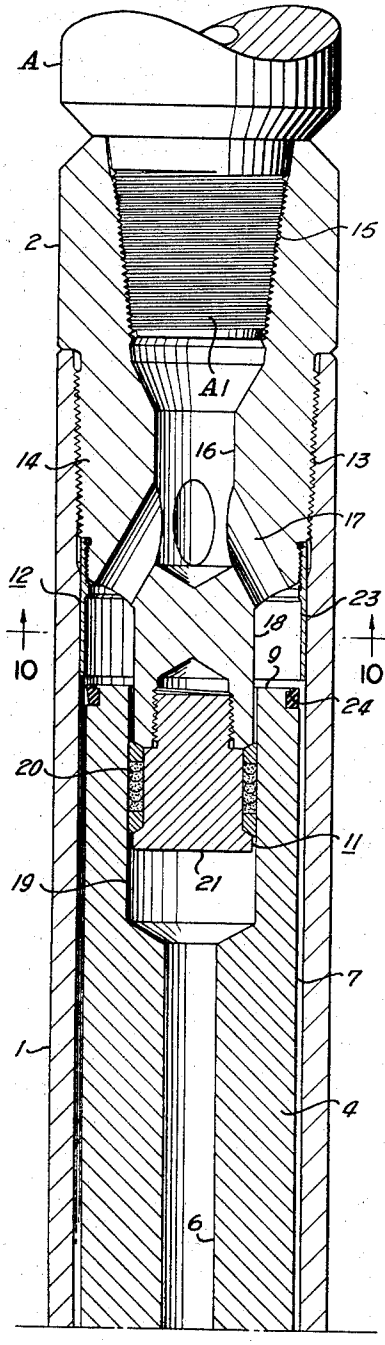


FIG. 9

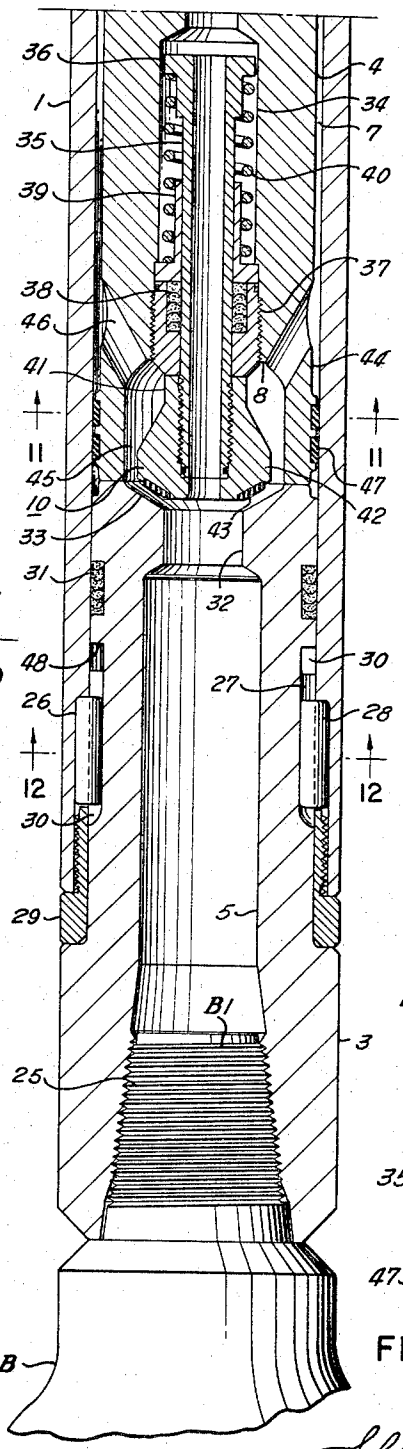


FIG. 9-A

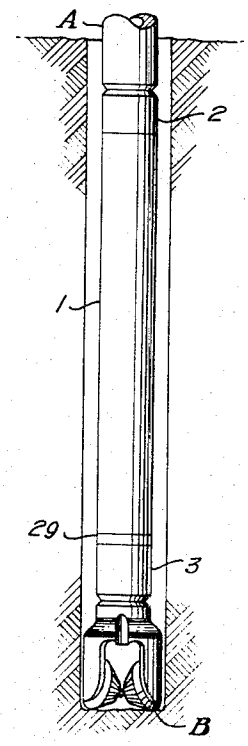


FIG. 1

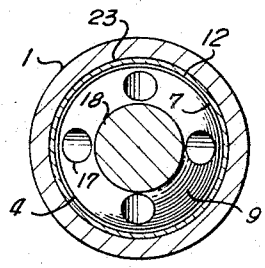


FIG. 10

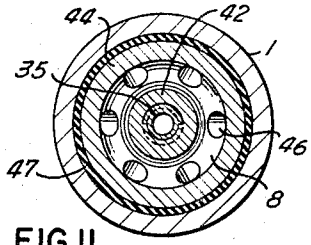


FIG. 11

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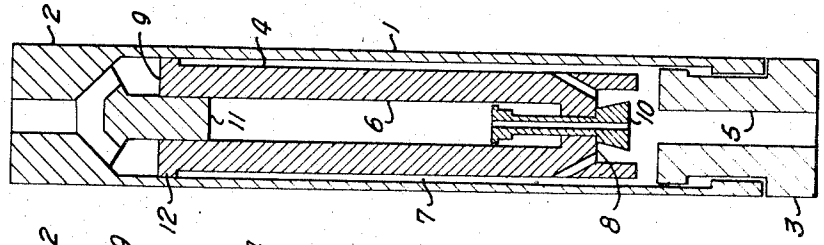


FIG. 6

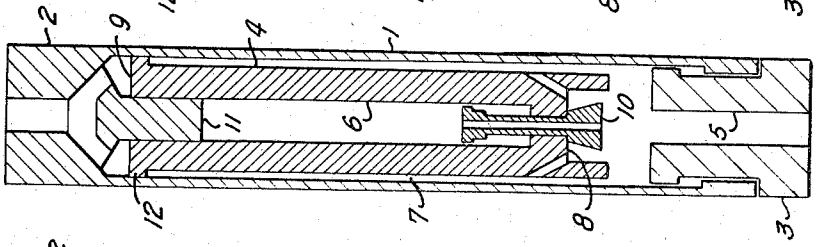


FIG. 5

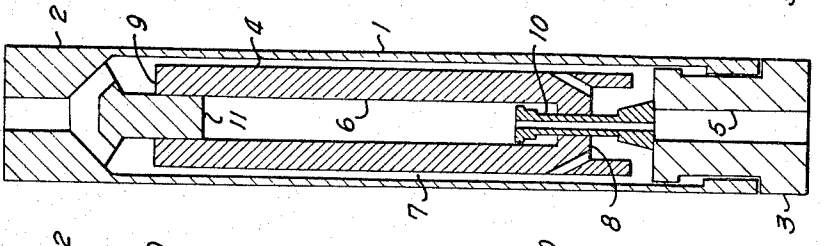


FIG. 4

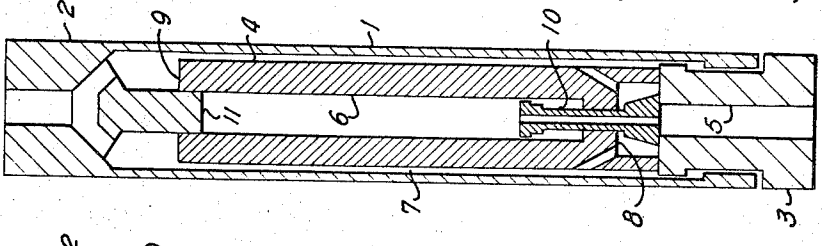


FIG. 3

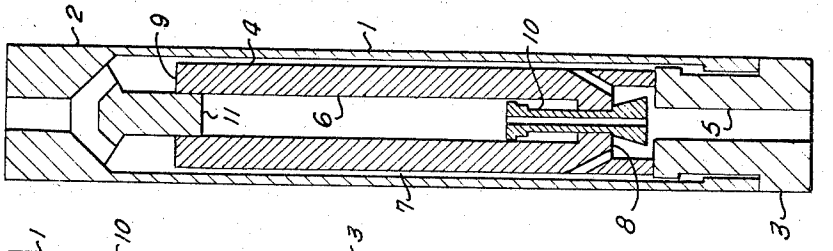


FIG. 2

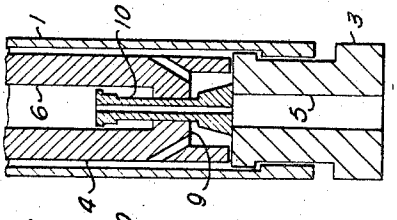


FIG. 8

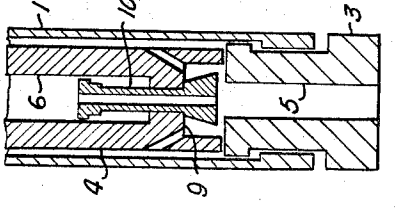


FIG. 7

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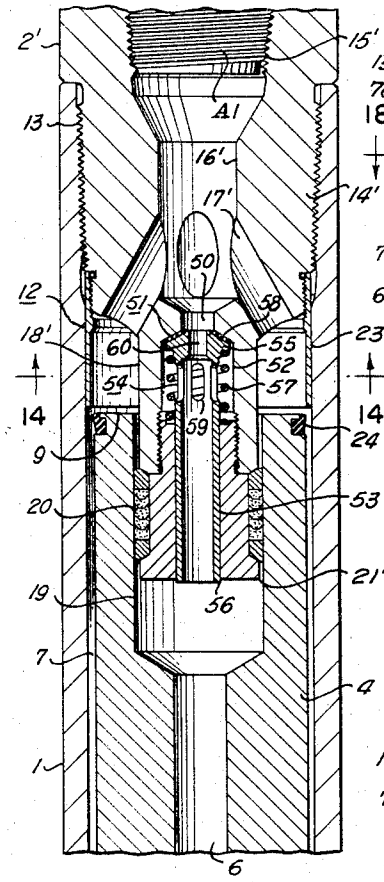


FIG. 13

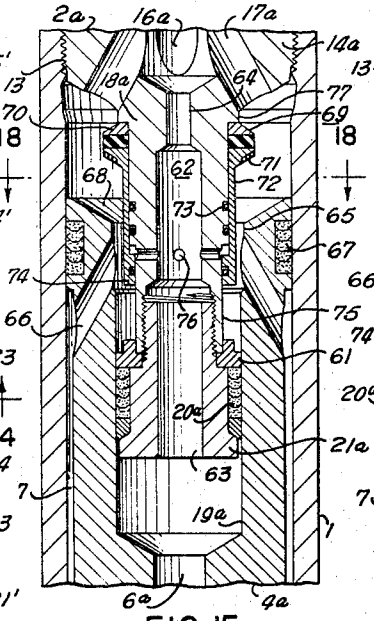


FIG. 15

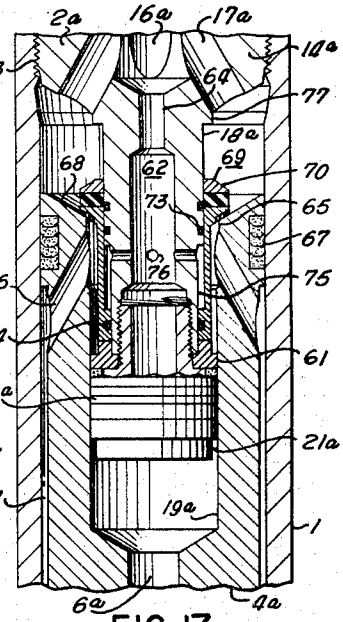


FIG. 17

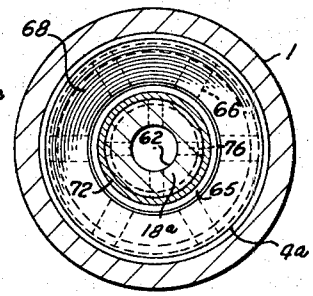


FIG. 18

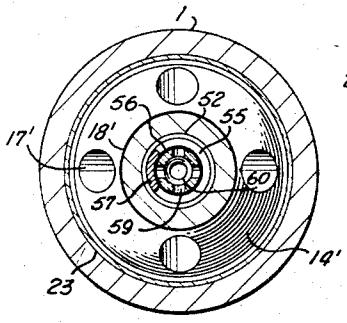


FIG. 14

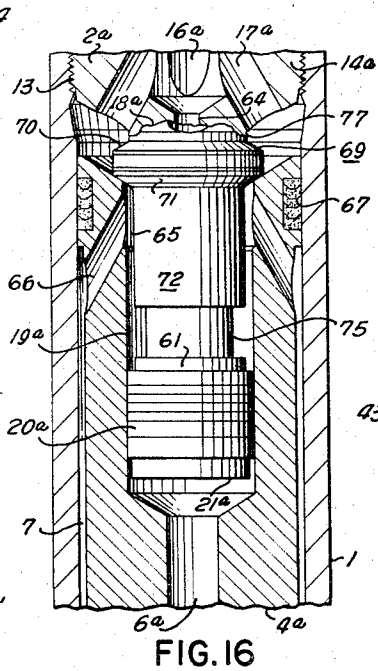


FIG. 16

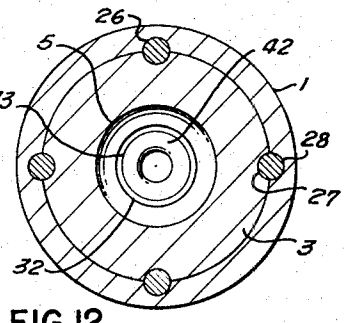


FIG. 12

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United States Patent Office 3,410,353 Patented Nov. 12, 1968

3,410,353

PERCUSSION TOOLS

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Filed Aug. 21, 1967, Ser. No. 662,072
18 Claims. (Cl. 173—73)

ABSTRACT OF THE DISCLOSURE

A percussion tool operable by air, water, drilling mud or other suitable liquid or gaseous fluid under pressure for rotary drilling of oil and water wells, geophysical shot holes, quarry boring, mining and the like having automatic cycling means for producing sustained relatively high frequency percussive blows to a drill bit so as to greatly increase its rate of penetration and produce other desirable effects.

Cross-references to related applications

Serial No. 552,219, filed May 23, 1966.

Background of the invention

Field of the invention.—Percussion tools for rotary drill strings.

Description of the prior art.—Fast drilling rotary percussion tools of the air hammer type are coming into greater use due to improved metallurgy, constructions and techniques; however, such tools, usually, are too complicated, cumbersome and/or fragile or are inoperative with non-compressible fluids which are used to drill over 90% of wells at this time. As is well-known, the cost of drilling oil wells is constantly increasing because of rising expenses, lower margins of profit, fewer discoveries of new fields and greater depth of productive formations. Accordingly, it is essential to reduce drilling costs by increasing penetration rates, decreasing drill bit wear and maintaining straighter bore holes. This objective is obtainable only by drilling wells to completion in minimum time and with minimum expense and, from a mechanical standpoint, necessitates the use of fewer drill collars, less rotary table speed and better wash of drill cuttings. Also, it is highly desirable to permit the use of solid type drill bits, such as drag or fish tail, for drilling hard formations which ordinarily require bits of the roller cone and/or hardened button or insert type without sacrificing penetration rates. Examples of the prior art are: 1,892,517, 12/32, Pennington; 2,580,203, 12/51, Topanelian; 2,661,928, 12/53, Topanelian; 2,774,334, 12/56, Cline; 2,859,733, 11/58, Bassinger et al.; 2,905,439, 9/59, Martini; 3,065,805, 11/62, Martini.

Summary of the invention

This invention relates to new and useful improvements in a percussion tool for a rotary drilling string which is adapted to be mounted immediately above the drill bit of the string and which includes a tubular piston, forming a hammer, reciprocally mounted in a housing for coacting with an annular anvil slidably connected to the lower end of the housing and rigidly connected to said bit for imparting percussive blows thereto. In order to provide a longitudinal passage for drilling fluid through the housing to the drill bit, the piston is of less diameter than the bore of said housing; and flow from the passage into the interior of said piston and through the bore of the anvil, which are in constant communication, is controlled by a valve which is preferably biased to an open position and which does not interfere with the communication between said anvil bore and piston interior. The valve and lower end of the piston are constantly exposed to the pressure

of the fluid in the housing passage whereby said valve and piston are responsive to said fluid pressure, while the upper end of said piston is constantly exposed to the pressure of the drilling fluid in the drill string thereabove. Although it may be closed, the upper end of the piston interior may have restricted communication with the drill string to constantly provide sufficient fluid to the drill bit for washing the bottom of the borehole and carrying the drill cuttings to the surface. Also, means may be provided at the upper end of the piston to bypass excessive fluid pressure through the interior of said piston so as to prevent damaging of the tool.

The valve is closed by the pressure of the fluid in the housing passage to abruptly stop flow from said passage through the bore of the anvil and into the interior of the piston, whereby a dynamic fluid shock is created due to the inertia or kinetic energy of the column of drilling fluid and the impact of this fluid shock is imparted to the anvil which transmits it to the drill bit. Since the piston interior and anvil bore are in constant communication, the closing of the valve permits dissipation of the fluid pressure within said piston interior. Upon this reduction of pressure in the piston interior, the effective upward force exerted upon the piston is greater than the downward force exerted against said piston whereby the latter is lifted by the fluid pressure within the passage; and the valve rises with said piston and opens to permit flow from said passage through the anvil bore and into the piston interior. When the piston is lifted sufficiently, communication of said passage with the drill string thereabove is stopped so as to permit the dissipation of pressure within said passage and the increase of pressure above said piston for forcing the latter downwardly to impart a sharp percussive blow to the anvil. Immediately after the downward slamming of the piston, the pressure within the housing passage equalizes with the pressure within the drill string thereabove so as to close the valve abruptly and repeat the imparting of the dynamic fluid shock impact to the anvil and drill bit. This continuous cycle of operation is repeated many times a second while the drill string is rotated continuously.

Manifestly, the percussion tool greatly increases the rate of penetration of a rotary drill bit and is operable by either gaseous fluids or non-compressible liquids including but not limited to air, oil, water and drilling mud, the use of water as the operating fluid being highly desirable in mine shafts due to its noncombustibility which prevents the creation of explosive dusts and/or contamination of the breathing air supply. The tool imparts longitudinal thrusts to the drill bit and the effectiveness of these thrusts is increased by utilizing two separate and distinct force elements in rapid succession, i.e., instantaneous application of the stored inertial energy of a fluid biased mass, whose kinetic energy delivers a hammer blow, and directly applied kinetic force almost simultaneously whereby the sharp percussive force of the hammer is followed by a thrust of longer duration by the fluid mass.

As will be readily apparent, the percussion tool is of durable construction, comparatively simplified design and readily serviceable, has a high energy output and low stress level, furnishes more drilling energy to a rotary drill bit, applies energy directly to the bit by pneumatic or hydraulic means rather than by remote mechanical means at the surface, provides sufficient energy to continue drilling with a dull bit long after conventional drilling becomes inefficient, extends the life of the drill bit used per foot of hole drilled due to less drill collar weight being required for continuous exertion on said bit and the very short duration of the percussive force, allows the use of more economical and longer life drill bits of the solid, fish tail or hardened button type without sacrificing penetration rates, makes possible the drilling of straighter

boreholes by employing the pendulum method of hanging more drill string weight while maintaining greater than conventional penetration rates, exhausts pulsating drill fluid through said bit to more efficaciously clean cuttings from the bottom of the borehole and prevent the same from being "redrilled," produces a relatively high rate of impacts per minute, is compatible with conventional drilling equipment, permits the often necessary reverse circulation upwardly through the drill string when said string is inserted into and withdrawn from a fluid-filled borehole, is completely automatic in operation and shortens the well completion time so as to reduce costs and increase profits.

It is noted that the percussion tool is particularly adapted for pneumatic operation, which is most desirable due to the high penetration rate of air drilling, but is readily convertible to hydraulic operation without pulling the drill string or making any adjustment of said tool when conditions warrant such change, such as borehole flooding during the drilling of shale and other porous formations and the attendant liquid-filled areas or upon the penetration of high pressure gaseous zones which necessitates the use of heavy mud or other weighted drilling fluid. The tool is so designed as to prevent self-damaging by percussing against itself when its anvil is extended due to being out of engagement with the bottom of the borehole. In the event that the anvil is so extended, significant percussive blows cannot be effected because the hammer-forming piston moves downwardly with said anvil and the longitudinal passage of the housing of the tool remains in communication with the drill string thereabove whereby high pressure fluid is not entrapped above said piston and downward movement thereof is not accelerated. Instead, the piston falls by gravity with only the downward flow of fluid around said piston assisting such movement whereby it is necessary for the anvil to be at least partially retracted before percussive blows of appreciable magnitude can be produced.

The principle of operation of this novel percussion tool differs radically from other similar tools and does not merely consist of reciprocating a hammer-forming piston by simple valving of pressure fluid from one side of the piston to the other. The tool derives its exceptional power by utilizing dynamic pressure which is created by abruptly stopping communication of the fluid passage of said tool with the bore of the anvil as well as the interior of the piston, a time delay for static pump pressure buildup to a high level in a substantially closed system and instantaneous release of the increased pressure for acting on a relatively large piston area to accelerate downward movement of said piston to a higher velocity in an extremely brief period of time. The delay period for the pressure buildup is the same time increment as the lifting of the piston to its uppermost position whereby no frequency of cycling is lost. Also, the piston stroke is relatively short to further shorten the cycle time and minimum power is required to lift the piston to its uppermost position since only the weight of said piston resists its upward movement in the required increment of time. Inertia of the piston is employed to open the valve and decrease the force resulting from the upward movement of said piston, thereby permitting the utilization of a larger piston area to accelerate the downward movement of said piston for creating a greater percussive impact.

Constructions designed to carry out the invention will be described hereinafter, together with other features of the invention.

Brief description of the drawings

FIG. 1 is a side elevational view of a rotary drill string disposed in a well bore and having a percussion tool, constructed in accordance with the invention, mounted therein above its drill bit,

FIGS. 2–6 are reduced, diagrammatic, longitudinal, sectional views illustrating the operation of the percussion tool,

FIGS. 7 and 8 are views, similar to FIGS. 2–6, of the lower portion of the tool and showing downward movement of the anvil,

FIG. 9 is an enlarged, transverse vertical, sectional view of the upper portion of the percussion tool and a portion of the lower drill collar of the string,

FIG. 9A is a continuation of FIG. 9 showing the lower portion of the tool and a portion of the drill bit,

FIG. 10 is a horizontal, cross-sectional view taken on the line **10**—**10** of FIG. 9,

FIGS. 11 and 12 are horizontal, cross-sectional views taken on the respective lines **11**—**11** and **12**—**12** of FIG. 9A,

FIG. 13 is a transverse, vertical, sectional view of a modified upper end portion of the percussion tool having an axial bypass and a pressure relief valve,

FIG. 14 is a horizontal, cross-sectional view taken on the line **14**—**14** of FIG. 13,

FIG. 15 is a transverse, vertical, sectional view of another modified upper end portion of the percussion tool having an axial bypass and a valve for controlling flow around the piston of said tool,

FIG. 16 is a view, similar to FIG. 15, showing the piston in its uppermost position and the control valve closed,

FIG. 17 is a view, similar to FIG. 15, showing the control valve closed and in its lowermost position and the piston in a partially lowered position,

FIG. 18 is a horizontal, cross-sectional view taken on the line **18**—**18** of FIG. 15.

Description of the preferred embodiments

In the drawings, the numeral **1** designates the casing or tubular housing of a percussion tool having tubular means, adapter **2** and anvil **3**, at its upper and lower ends for communication and detachable connection with the lower drill collar A and drill bit B of a rotary drill string (FIGS. 1 and 2). The anvil **3** has splined connection with the housing **1** for limited reciprocation relative thereto and is adapted to coact with an overlying hammer **4**, in the form of a hollow or tubular piston, reciprocally mounted in said housing. A bore **5** extends axially through the anvil and has its upper end in constant communication with the lower end of the axial bore or hollow interior **6** of the hammer **4** (FIGS. 2–6). The housing has a longitudinal cylinder or passage **7** for conducting drilling fluid under pressure from the drill collar A and adapter **2**, around the hammer to the anvil **3** and drill bit B. The hammer **4** has a lower end surface **8** constantly exposed to the pressure of the fluid in the passage **7** and an upper end surface **9** constantly exposed to the pressure of the fluid in the drill string. For controlling flow of the drilling fluid from the housing passage through the bore **5** of the anvil and into the hammer interior **6** without interfering with the communication therebetween, a normally-open valve **10** is carried by the lower end of the hammer **4** for seating against the upper end of said anvil and is constantly exposed and responsive to the pressure of said fluid. The valve **10** is in relatively close proximity to the anvil so as to restrict flow from the passage **7** to the bore of said anvil. As shown at **11** in FIGS. 2–6, the upper end of the hammer interior is closed or, as will be explained, may have restricted communication with the passage and, as shown at **12** in FIGS. 5 and 6, the upper end of said passage is adapted to be closed when the hammer **4** is lifted to its uppermost position by the fluid pressure within said passage.

The percussion tool **1** is shown in inoperative condition in FIG. 2 with its hammer resting on the anvil **3** and with the valve **10** in its open, upper position so as to permit drilling fluid under pressure to flow downwardly through the housing cylinder or passage, around said hammer and through the bore of said anvil to the drill bit. The valve being open, the drilling fluid is admitted to the interior **6** of the hammer **4** whereby the entire tool is exposed to the pressure of said fluid. Since it is exposed and respon-

sive to the fluid pressure in the passage **7**, the valve **10** is forced downwardly to its closed position to prevent flow through the anvil bore **5** as well as into the hammer interior when said pressure overcomes the force holding said valve open (FIG. 3). The closing of the valve is abrupt or sudden and creates a dynamic fluid shock due to the inertia or kinetic energy of the column of drilling fluid, and the impact of this fluid shock is imparted to the anvil which transmits said shock to the drill bit B. While the fluid pressure within the housing passage increases due to the stoppage of flow therefrom and the continuing supply of drilling fluid thereto, the fluid pressure within the hammer interior **6** dissipates through the communicating anvil bore. As shown in FIG. 4, the dissipation and consequent reduction of the fluid pressure in the interior of the hammer **4** coacts with the exertion of the dynamic pressure of the fluid within the passage **7** against the hammer lower end surface **8** to lift said hammer and the valve **10** is held closed by said dynamic pressure until said hammer approaches the end of its upstroke. When this occurs, the upward travel of the hammer raises the valve and permits upward shifting thereof to its open position to re-establish communication of the passage with the anvil bore **5** as well as the hammer interior (FIG. 5). Approximately simultaneously, the upper end of the passage **7** is closed as shown at **12** to prevent flow of drilling fluid into said passage and permit the dissipation of the pressure therein through the anvil bore. Due to the sudden reduction of pressure within the housing passage, the exertion of the pressure of the drilling fluid against the upper end surface **9** of the hammer **4** is sufficient to impart rather rapid downward movement to said hammer (FIG. 6) and cause it to strike the anvil **3** a sharp percussive blow so as to drive said anvil downwardly relative to the housing **1** (FIG. 7). The valve moves downwardly with the hammer and, instantaneously after the percussive engagement of said hammer with the anvil, said valve is slammed shut by the fluid pressure within the housing passage so as to prevent flow through the anvil bore **5** as well as into the hammer interior **6** whereby said fluid pressure again imparts a dynamic fluid shock to said anvil and increases the downward movement thereof relative to the housing. The foregoing completes one cycle of operation and is followed by continuous cycles which are identical, involving the steps shown in FIGS. 3–8, and which occur at a very high rate of speed during simultaneous, continuous rotation of the drill string.

One embodiment of the invention is shown in FIGS. 9–12 wherein the housing **1** has a screwthreaded box **13** at its upper end for receiving a screwthreaded pin **14** which depends axially from the adapter **2** and which has a screwthreaded box **15** at its upper end for detachable connection with the complementary pin A1 of the drill collar A of the drill string (FIG. 9). An axial bore **16** extends through the adapter and the major portion of its pin **14** for communicating with the drill collar as well as the drill string thereabove; and a plurality of downwardly-divergent ports **17** (FIG. 10) establishes communication between the lower end of the bore and the upper end of the housing cylinder or passage **7** in which the hammer-forming piston **4** is reciprocally mounted for coacting with the tubular anvil **3** (FIG. 9A) whereby the upper end surface **9** of said piston is constantly exposed to the fluid pressure within said drill string thereabove. The means **11** for closing the upper end of the bore **6** of the piston includes an axial, cylindrical, reduced pintle or extremity **18** of the depending pin of the adapter **2** and said bore, which is of small diameter relative to the piston diameter, has its upper end enlarged to provide a coacting counterbore **19** complementary to the pintle. Suitable packing **20** for sealing off between the pintle **18** and counterbore **19** encircles and is confined upon a cylindrical gland or plug **21** screwthreaded into the lower end of said pintle.

The means **12** for closing the upper end of the passage of the housing **1** may include a cylinder liner or sleeve **23** having its upper end screwthreaded upon the lower end of the adapter pin **14** so as to depend therefrom in spaced concentricity to the pintle for reducing the diameter of the passage and for sealing engagement by the upper end portion of the piston **4** when said piston is in its uppermost position. Preferably, suitable pressure-responsive packing **24** is confined upon the upper end of the piston to ensure the prevention of communication between the passage **7** and the drill string thereabove when said piston upper end is within the liner **23**, the packing being deformed into sealing engagement with said liner by the pressure differential thereacross upon opening of the valve **10** and dissipation of the fluid pressure within said passage (FIG. 5).

As shown in FIG. 9A, a screwthreaded box **25** is provided at the lower end of the axial bore **5** of the anvil **3** for detachable connection with the upstanding screwthreaded shank B1 of the drill bit B. The splined connection between the anvil and the lower end of the housing **1** may include a plurality of semicylindrical sockets **26** extending longitudinally of the inner surface of said housing and a plurality of complementary grooves or ways **27**, of greater length, in the exterior of said anvil for coacting with the sockets to confine cylindrical splines or roller bearings **28** therebetween (FIG. 12). An annular retainer **29** is screwthreaded in the lower end of the housing to form the bottoms of the sockets **26** as well as facilitate assembly of the splined connection. The upper and lower ends of the ways **27** of the anvil **3** may be interconnected by annular grooves or recesses **30** to prevent pressure fluid resistance to movement of said anvil relative to the splines **28**, and as shown at **48** in FIG. 9A, the upper surface of the upper groove is flat and parallel to the flat, upper end faces of said splines for bearing against said faces without binding. Above its ways, the anvil carries suitable packing **31** for sealing off between the housing and anvil. As shown at **32**, the upper end of the bore of the anvil **3** is reduced so as to increase the wall thickness of the upper end portion of said anvil and thereby reinforce said end portion for withstanding the percussive blows of the piston **4** as well as permitting the provision of an annular, bevelled, upwardly-facing valve seat **33** at the upper extremity of said bore for coacting with the valve **10**.

The latter, which is carried by the piston, is mounted in a counterbore **34** at the lower end of the axial bore **6** of said piston and includes a tubular valve stem **35** having an enlarged upper end or annular head **36** slidable in the counterbore (FIG. 9A). An annular gland **37** is screwthreaded in the lower end of the counterbore **34** for confining suitable packing **38** in sealing engagement with the valve stem **35** and for supporting an annular, flanged stationary spring follower **39**. The enlarged head **36** of the valve stem which may be stepped, functions as an upper spring follower to confine a helical spring **40** in surrounding relation to said stem in coaction with the follower **39** whereby the force of the spring constantly urges the valve **10** upwardly. An annular valve member or head **41**, having an enlarged or bulbous lower end portion **42**, is screwthreaded on the lower projecting end of the stem **35** for coacting with the valve seat **33** of the anvil **3**. Due to the upward biasing of the valve, the upper end of the valve member **41** is maintained engaged with the lower end of the gland **37**. The lower end surface of the valve member is complementary to the valve seat and, preferably, has an elastic, annular seating element or ring **43** secured thereto for sealing engagement with said seat when the valve **10** is forced downwardly.

An annular extension or skirt **44** depends from the lower end of the piston **4** in concentric, spaced relation to the valve member **41** so as to provide a cavity or recess **45** in the lower end of said piston and is of sufficient length to support the upwardly-biased valve with its seating ring **43** out of engagement with the valve

seat **33** when the lower end of the skirt rests on the upper end of the anvil **3**. The skirt **44** has a plurality of downwardly-convergent ports **46** extending inwardly therethrough (FIG. 11) to maintain communication between the housing passage **7** and piston lower end cavity **45** whereby the lower end surface **8** of the piston as well as the valve member, both of which are within said cavity, are constantly exposed to the fluid pressure within said passage. Below the ports **46**, wear rings **47** may be mounted externally to center the piston in coaction with the pintle **18** as well as restrict flow between the housing and piston whereby the passage of said housing functions as a cylinder for said piston. It is noted that the upwardly-facing lower end surface of the counterbore **19** is constantly exposed to the fluid pressure within the bore **6** of the piston **4** and, when said pressure is reduced by closing of the valve **10**, coacts with the lower end surface of said piston so as to create an effective upward force greater than the downward force acting upon said piston. Manifestly, this effective upward force varies in accordance with the relative areas of the upwardly and downwardly facing surfaces of the piston as well as the pressure differentials. Even if the upper end of the piston bore is not enlarged or counterbored, the counterbore **34** at the lower end of said piston bore provides an upwardly facing surface in said bore which is exposed to the fluid pressure therein for coacting with the lower end surface **8** of the piston **4** to lift said piston when the valve is closed to reduce said pressure.

In addition to having its lower end in constant communication with the bore **5** of the anvil **3** by means of the tubular valve stem **35** and annular valve member **41**, the bore **6** of the piston **4** may have its upper end in constant communication with the bore **16'** of a modified adapter **2'** through an axial bypass orifice **50** in the latter (FIGS. 13–14) to permit the continuous supply of drilling fluid to the borehole for washing the bottom thereof and carrying the drill cuttings upwardly through said borehole to the surface. In addition to the bypass orifice, the embodiment of the invention shown in FIGS. 13 and 14 may include an excessive fluid pressure bypass **51** for permitting the venting of any destructive pressures which might occur. Since this modified tool is identical to the embodiment of FIGS. 9–12 except for its bypasses, only the modified adapter **2'** and the upper portions of the housing **1** and hammer-forming piston **4** are shown with the same numerals identifying identical parts. The depending drill collar pin A1 is screwthreaded into the box **15'** of the modified adapter which has its pin **14'** screwthreaded into the box **13** at the upper end of the housing and its ports **17'** in communication with the portion of the housing cylinder or passage **7** within the liner **23** to permit the flow of drilling fluid to said passage when the packing **24** of the piston is below said liner.

A tubular or modified reduced extension or pintle **18'** depends axially from the adapter **2'** within the circle of the lower ends of the ports **17'** and has a modfied or tubular plug **21'** connected to its lower end for confining the packing **20** in sealing engagement with the counterbore **19** at the upper end of the piston bore **6**. The pintle **18'** and plug **21'** coact to provide the excessive pressure bypass **51** and said pintle has an enlarged, axial bore or counterbore **52** communicating with the bypass orifice **50**, the upper end of the plug being screwthreaded into the lower end of the counterbore. An axial bore **53** extends through the plug for slidably supporting a valve element **54** having an enlarged, annular head **55** and a tubular stem **56** so as to permit restricted communication therethrough between the piston counterbore **19** and bypass orifice. The upper end portion of the tubular valve stem **56** projects upwardly into the counterbore **52** and has a helical spring **57** confined thereon between the plug **21'** and valve head **55** for constantly urging the valve element **54** upwardly. As shown by the numeral **58**, the upper ends of the counterbore **52** and valve head have complementary, annular, beveled seating surfaces and the valve head surface may have an elastic, annular sealing ring secured thereto for sealing engagement with the counterbore surface to control communication between said counterbore and the bypass orifice **50**. A plurality of longitudinal slots **59** extends through the stem of the valve **54** immediately below its head **55** to permit flow through the counterbore around the valve head, when the latter is unseated by excessive fluid pressure thereabove so as to open said valve, for venting such pressure through the bypass orifice and the bore of said stem. In order to prevent excessive flow through the tubular valve stem **56** when the valve head is seated, said valve head has a bore **60** of less diameter than the orifice **50**. Manifestly, the bore **60** must be of relatively small diameter so that it will not affect or interfere with the pressure fluid operation of the percussion tool.

Although the cylinder liner **23** forms a relatively simple means for controlling communication between the upper end of the passage **7** of the housing **1** and the drill string thereabove, said skirt necessarily restricts the volume of flow around the upper end of the piston **4** and is not the most desirable control means from a durability as well as an efficiency standpoint. Preferably, the embodiments of the invention shown in FIGS. 9–12 and/or FIGS. 13 and 14 are provided with more positive means for closing the upper end of the passage without interfering with the constant exposure of the upper end of the piston to the pressure of the drilling fluid within the drill string (FIGS. 15–18). Except for a modified adapter **2*a*** and a modified piston **4*a***, the structure of the percussion tool is in accordance with the disclosure hereinbefore set forth and reference is made thereto. As shown in FIG. 15, the adapter **2*a*** has its depending pin **14*a*** screwthreaded into the box **13** at the upper end of the housing with its ports **17*a*** extending from the lower end of its axial bore **16*a*** so as to constantly communicate with the upper end of the housing cylinder or passage from which the diameter reducing liner **23** is omitted. An axial, tubular pintle or reduced extension **18*a***, of greater length than the pintles **18** and **18'**, depends from the modified adapter and has a tubular plug **21*a*** screwthreaded into its lower end for confining packing **20*a*** in sealing engagement with a counterbore **19*a*** at the upper end of the axial bore **6*a*** of the piston **4*a***, the plug, packing, counterbore and axial bore being similar to the plug **14**, packing **20**, counterbore **19** and axial piston bore **6** of FIGS. 9–12.

For coacting with the plug **21*a***, an annular retainer or stop ring **61** is confined upon said plug in overlying relation to the packing **20*a*** and may be of inverted T-shape in cross-section. As shown in FIGS. 15–18, the pintle **18*a*** and plug have communicating axial bores **62** and **63** extending therethrough to permit the constant flow of drilling fluid directly from the adapter bore **16*a*** to the piston bore **6*a*** for continuously supplying fluid to the drill bit. This constant, direct flow is restricted so as to prevent interference with the operation of the tool by reducing the diameter of the upper end portion of the pintle bore **62** to provide a bypass orifice **64** similar to the bore **60** of the valve element **54** (FIG. 13). It is noted that the counterbore **19*a*** of the modified piston is of greater length than the counterbore **19**, extending an appreciable distance above the connection of the pintle and plug **21*a***, and has a counterbore **65** at its upper end to provide an annular flow space around said pintle. Downwardly-divergent ports **66** extend from the counterbore **65** through the wall of the piston **4*a*** for conducting drilling fluid from above said piston to the housing passage **7**, the upper end of said piston being enlarged and carrying suitable exterior packing **67** for preventing such flow. An annular, upwardly-facing

valve seat **68** is formed by beveling the upper end of the piston wall and is adapted to coact with a valve **69** slidably confined upon the pintle **18***a* for preventing flow through the ports **67**.

The valve **69** has an enlarged, annular head or surface **70** for seating against the complementary valve seat **68** of the piston **4***a* and may have an elastic seating ring **71** secured to its underside for sealing engagement with said seat. A tubular valve stem or sleeve **72** depends from the valve head **70** in surrounding relation to the complementary pintle, and suitable packing **73** is interposed between the sleeve and pintle for sealing off therebetween without interfering with the relative movement of the valve. It is noted that the valve sleeve **72** is of less length than the pintle **18***a* so as to terminate above the stop ring **61** and has an annular, internal enlargement or shoulder **74** at its lower end (FIGS. 15 and 17) for coacting with the reduced lower portion **75** of said pintle. Pressure-relief openings **76** extend between the bore **62** of the pintle and the upper end of its reduced portion **75** to vent fluid from the annular space between the valve sleeve and pintle upon upward movement of the valve **69** relative to said pintle. The upper end of the pintle **18***a* has an external, radial enlargement or shoulder **77** for engagement by the valve head to limit this upward travel of the valve and prevent closing of the vent openings **76** by the valve sleeve shoulder **74** as well as shield the major portion of the upper surface of said valve head from the pressure of the drilling fluid above the piston **4***a* whereby said pressure holds said valve head in engagement with the pintle enlargement.

When the piston approaches the end of its upstroke, its valve seat **68** engages the seating ring **71** of the valve head **70** so as to close the upper end of the counterbore **65** of said piston and prevent the flow of drilling fluid through the ports **66** into the housing passage **7** (FIG. 16). Since the upper surface of the valve head is fully exposed to the pressure of the drilling fluid above the piston **4***a*, the valve is moved downwardly with the piston relative to the pintle **18***a* by said pressure fluid until the lower end of the valve sleeve **72** strikes the stop ring **61** (FIG. 17) which engagement occurs before disengagement of the valve seat of said piston from said valve head. The piston continues to move downwardly so as to unseat the valve **69** and permit the flow of drilling fluid through the piston upper ports into the housing passage as well as expose the underside of the valve head **70** to the pressure of such fluid.

Upon closing of the normally-open valve **10** as shown in FIG. 8, the pressure of the fluid pressure within the passage and thereabove increases sufficiently to lift the valve **69** to its elevated position; and this upward movement is assisted by the exposure of the lower end of the valve sleeve to said pressure after initial upward travel of the latter valve. Of course, any pressure trapped between the pintle and valve sleeve **72** is vented through the openings **76** of said pintle. Due to inertia, the piston tends to strike the valve head rather sharply on its upstroke. Accordingly, it is desirable to cushion the collision of the piston **4***a* with the valve head **70** by inserting an elastic, annular spacer or ring **77** intermediate the upper and lower portions of said valve head whereby said upper portion is separate from the lower portion but is attached thereto by the spacer. It is noted that the upwardly-facing lower end surface of the counterbore **19***a*, as well as the counterbore **19**, may be enlarged to reduce the increment of time required to lift the piston without varying the area of the upper end of said piston.

The foregoing description of the invention is explanatory thereof and various changes in the size, shape and materials, as well as in the details of the illustrated construction may be made, within the scope of the appended claims, without departing from the spirit of the invention.

I claim:

1. A percussion tool for a rotary drill string having a drill bit as its lower end including

a housing mounted in the drill string adjacent the drill bit and having a passage for conducting drilling fluid from said string to said bit,

anvil means slidably connecting the lower end of the housing to the drill bit so as to be reciprocal with said bit relative to said housing and having a passage in constant communication with the interior of said bit,

hammer means reciprocally mounted in said housing for overlying engagement with the anvil means and having a hollow interior in constant communication with the passage of said anvil means,

the hammer means having an upwardly facing surface constantly exposed to the pressure fluid within the drill string thereabove and a downwardly facing surface constantly exposed to the pressure fluid within the passage of the housing,

valve means constantly exposed to the pressure fluid within said housing passage for controlling communication of said housing passage with the anvil means passage and the hollow interior of said hammer means without interferring with the communication between the latter,

the valve means being closed by the pressure fluid within said housing passage to prevent flow from said housing passage to said hammer means passage and said anvil means interior and permit dissipation of the pressure fluid within the latter,

the closing of said valve means permitting lifting of said hammer means by the pressure fluid within said housing passage,

and means for preventing communication between said housing passage and the drill string thereabove when said hammer means is lifted a predetermined amount,

said valve means opening upon lifting of said hammer means to permit dissipation of the pressure fluid within said housing passage and subsequent downward movement of said hammer means by the pressure fluid within the drill string thereabove for imparting a percussive blow to said anvil means,

the downward movement of said hammer means reestablishing communication between said housing passage and drill string to permit abrupt closing of said valve means by the pressure fluid within said passage for imparting a dynamic pressure shock to said anvil means immediately after the percussive blow.

2. A percussion tool as set forth in claim **1** wherein

the hollow interior of the hammer means has an upwardly facing surface constantly exposed to the pressure of the fluid therein whereby the reduction of said pressure, due to the dissipation of said fluid through the passage of the anvil means upon closing of the valve means, coacts with the pressure fluid within the passage of the housing in the lifting of said hammer means.

3. A percussion tool as set forth in claim **2** wherein

the means for preventing communication between the passage of the housing and the drill string thereabove is at the upper end of said passage and is adapted to seal off between the hammer means and housing.

4. A percussion tool as set forth in claim **2** wherein

the hollow interior of the hammer means has restricted constant communication with the drill string thereabove to continuously supply drilling fluid to the drill bit.

5. A percussion tool as set forth in claim **2** wherein

the hammer means has means for establishing communications between the passage of the housing and the drill string thereabove,

the means for preventing the latter communication including valve means constantly exposed and responsive to the pressure fluid within the drill string for controlling flow of said fluid through the communication establishing means of said hammer means.

6. A percussion tool as set forth in claim **1** wherein

the means for preventing communication between the passage of the housing and the drill string thereabove is formed in part by the hammer means.

7. A percussion tool as set forth in claim 1 wherein the hollow interior of the hammer means has restricted constant communication with the drill string thereabove to continuously supply drilling fluid to the drill bit.

8. A percussion tool as set forth in claim 1 wherein the hammer means has means for establishing communication between the passage of the housing and the drill string thereabove,

the means for preventing the latter communication including valve means constantly exposed and responsive to the pressure fluid within the drill string for controlling flow of said fluid through the communication establishing means of said hammer means.

9. A percussion tool as set forth in claim 1 including pressure responsive means for establishing communication between the hollow interior of the hammer means and the drill string thereabove to permit the flow of drilling fluid directly through said hammer means interior to the anvil means and drill bit in the event that the pressure of the drilling fluid becomes excessive.

10. A percussion tool as set forth in claim 9 wherein the hollow interior of the hammer means has restricted constant communication with the drill string thereabove to continuously supply drilling fluid to the drill bit.

11. A percussion tool as set forth in claim 9 wherein the hammer means has means for establishing communication between the passage of the housing and the drill string thereabove,

the means for preventing the latter communication including valve means constantly exposed and responsive to the pressure fluid within the drill string for controlling flow of said fluid through the communication establishing means of said hammer means.

12. A percussion tool as set forth in claim 9 wherein the means for preventing communication between the passage of the housing and the drill string thereabove is formed in part by the hammer means.

13. A percussion tool as set forth in claim 9 wherein the hollow interior of the hammer means has an upwardly facing surface constantly exposed to the pressure of the fluid therein whereby the reduction of said pressure, due to the dissipation of said fluid through

the passage of the anvil means upon closing of the valve means, coacts with the pressure fluid within the passage of the housing in the lifting of said hammer means.

14. A percussion tool as set forth in claim 13 wherein the hammer means has means for establishing communication between the passage of the housing and the drill string thereabove,

the means for preventing the latter communication including valve means constantly exposed and responsive to the pressure fluid within the drill string for controlling flow of said fluid through the communication establishing means of said hammer means.

15. A percussion tool as set forth in claim 1 wherein the passage of the housing is in the form of a cylinder and the hammer means is in the form of a piston mounted for reciprocation in the cylinder.

16. A percussion tool as set forth in claim 15 wherein the hollow interior of the piston has restricted constant communication with the drill string thereabove to continuously supply drilling fluid to the drill bit.

17. A percussion tool as set forth in claim 15 wherein the piston has means for establishing communication between the cylinder of the housing and the drill string thereabove,

the means for preventing the latter communication including valve means constantly exposed and responsive to the pressure fluid within the drill string for controlling flow of said fluid through the communication establishing means of said piston.

18. A percussion tool as set forth in claim 1 wherein the means for preventing communication between the passage of the housing and the drill string thereabove is at the upper end of said passage and is adapted to seal off between the hammer means and passage.

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