July 6, 1965 J. M. CLEARY 3,193,024

PERCUSSION DRILLS WITH EXHAUST PASSAGE IN HAMMER

Filed Jan. 18, 1962 4 Sheets-Sheet 1

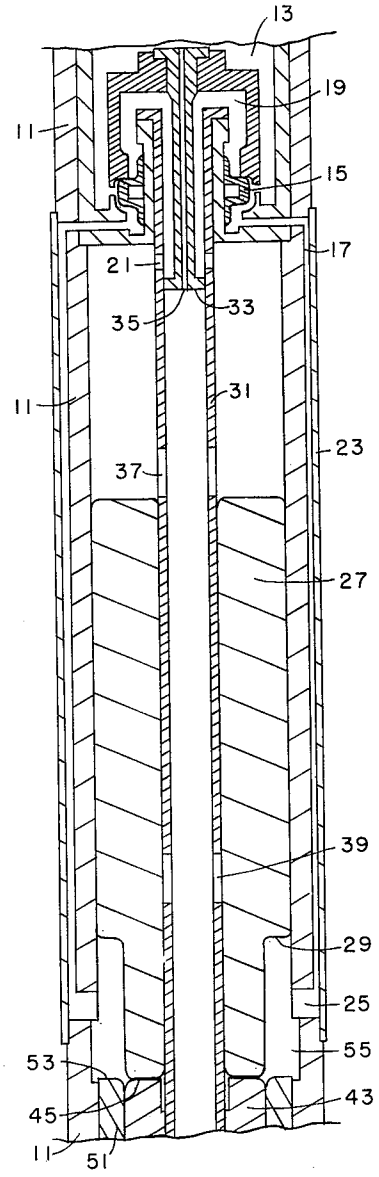


FIG. 1

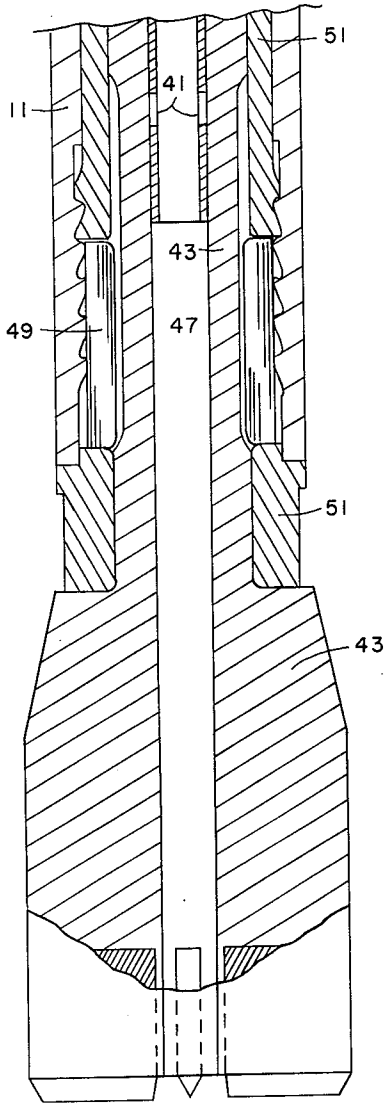


FIG. 2

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PERCUSSION DRILLS WITH EXHAUST PASSAGE IN HAMMER

Filed Jan. 18, 1962 4 Sheets-Sheet 2

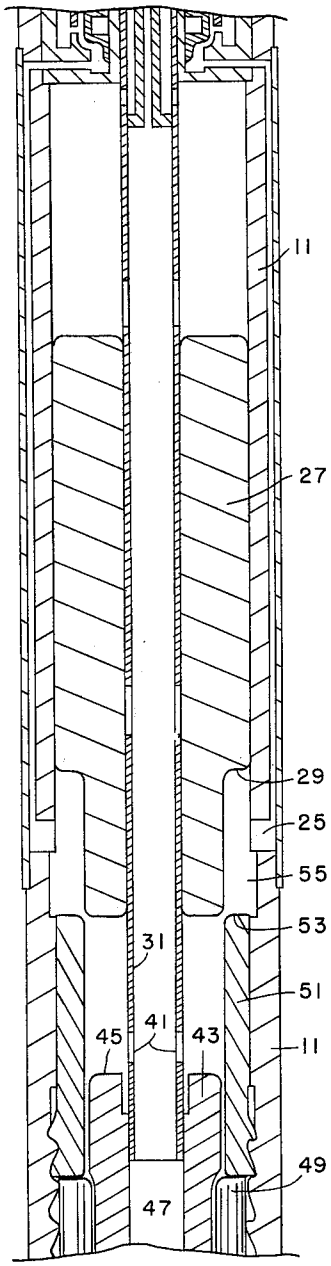


FIG. 3

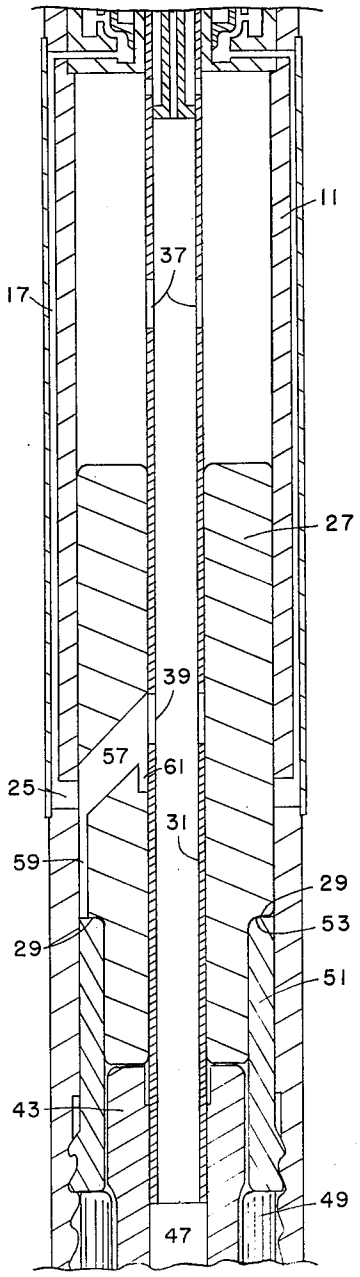


FIG. 4

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PERCUSSION DRILLS WITH EXHAUST PASSAGE IN HAMMER

Filed Jan. 18, 1962 4 Sheets-Sheet 3

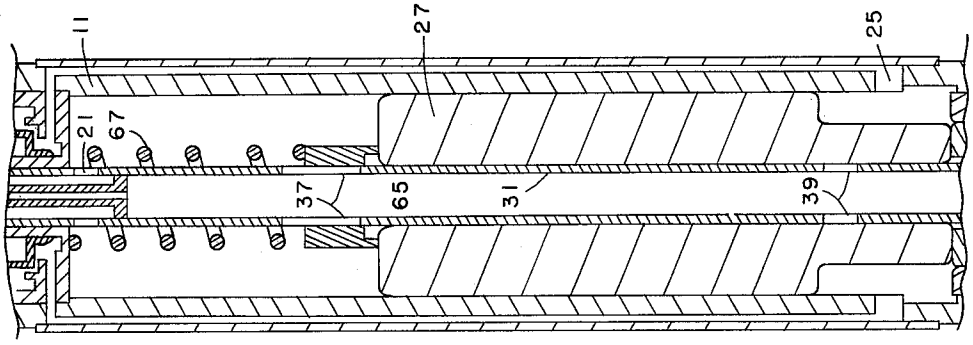


FIG. 7

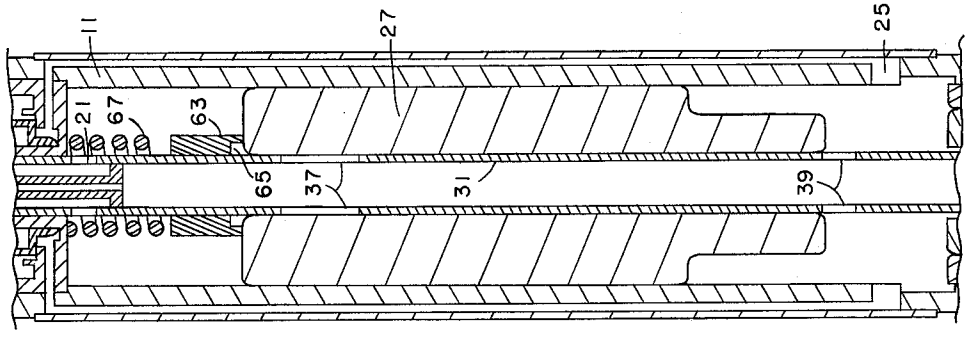


FIG. 6

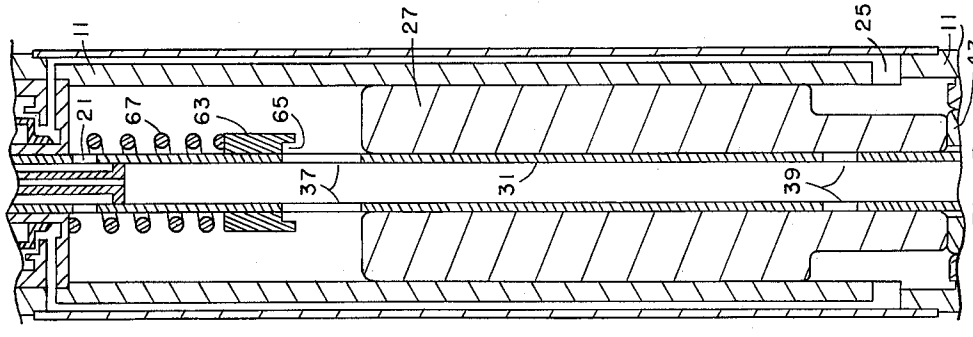


FIG. 5

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PERCUSSION DRILLS WITH EXHAUST PASSAGE IN HAMMER

Filed Jan. 18, 1962 4 Sheets-Sheet 4

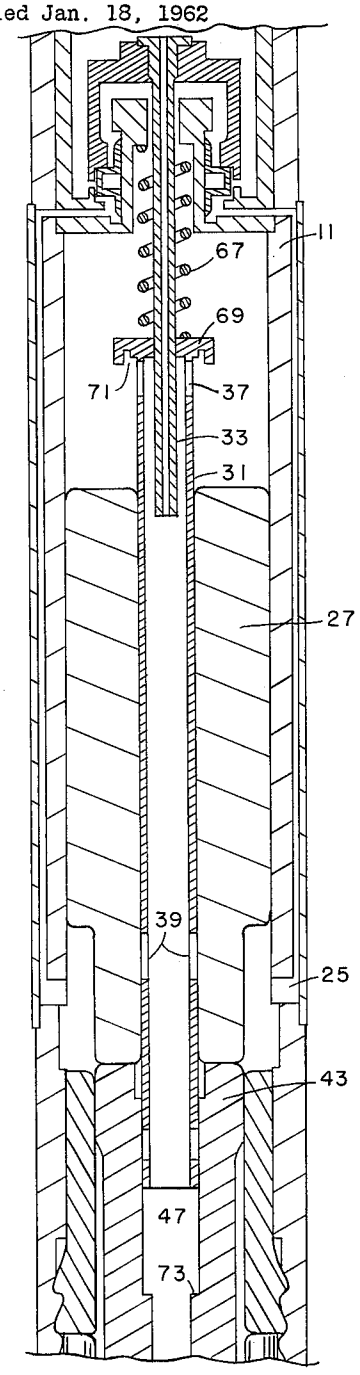


FIG. 8

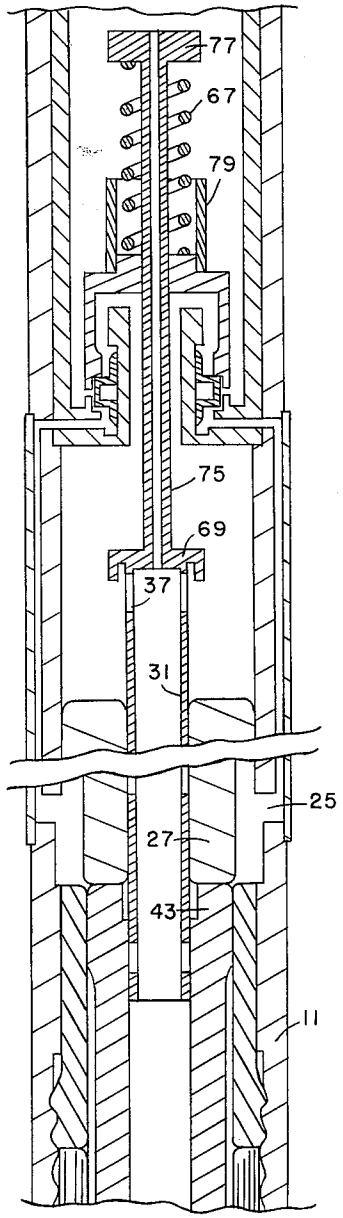


FIG. 9

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3,193,024

PERCUSSION DRILLS WITH EXHAUST PASSAGE IN HAMMER

James M. Cleary, Dallas, Tex., assignor to The Atlantic Refining Company, Philadelphia, Pa., a corporation of Pennsylvania

Filed Jan. 18, 1962, Ser. No. 167,121
8 Claims. (Cl. 173—17)

This invention pertains to fluid-actuated, percussive drills employed in earth drilling.

One class of percussion earth drills utilizes a power impact unit made up of a power fluid inlet, a valving arrangement for controlling passage of the power fluid through the power unit, a cylindrical chamber section and a power fluid outlet. Mounted in the chamber section is a piston-like hammer which undergoes vertical reciprocation to impact an anvil member to which a drill is connected. Usually, the anvil member is splined or grooved to cooperate with grooves or splines in the chamber section so that the drill bit and anvil are rotated by rotation of the chamber section. Usually, such percussive devices are rotated so that the cutting elements of the drill bit are indexed in a new position each time the hammer strikes the anvil. In operating the power unit, the power fluid is applied alternatively between endwise surfaces of the hammer to urge the hammer in both its power and its return strokes. The hammer, therefore, is fluid-operated in two directions to undergo longitudinal, reciprocal movement within the chamber. When the power fluid is applied to the lower end of the hammer between the anvil and hammer, the hammer is accelerated in an upward direction until entry of the power fluid no longer acts on the lower end of the hammer. The hammer's momentum causes the hammer to continue to travel in an upward direction compressing the power fluid until the power fluid reverses the direction of movement of the hammer. The hammer, therefore, has a fluid cushion at the top of its stroke. At the top of the stroke, the valving arrangement switches flow of the power fluid to the upper end of the hammer causing the hammer to accelerate in a downward direction. The hammer moves downward and strikes directly on the anvil element. Such downward percussive force or impact is transmitted to the drill bit and drives the cutting elements of the drill axially into the formation. In this manner, the hammer is reciprocated causing a series of impact blows to the drill bit.

In percussive drills, it is desirable that all of the power fluid be discharged through the bit to cool and lubricate the bit and flush the cuttings out of the borehole.

Moreover, since the hammer and anvil are impacted many times per minute and could be knocked out of alignment, it is desirable that the hammer and anvil have a relatively rigidly controlled relationship.

As the drill bit advances into a borehole, the back pressure or external head pressure on the drill bit increases and it is necessary to increase the power fluid inlet pressure. This pressure increase decreases the force of the impact and lessens the efficiency of the percussion tool. It is desirable to have a power unit that is readily adjusted or tuned to changing operating conditions.

When the pressure increase just described occurs, one method of increasing the force of the impact is to increase the power fluid volume above the hammer. But, this method decreases the efficiency of the power unit since more power fluid must be used per impact. It is desirable to provide means for increasing the length of the power stroke of the hammer without increasing the volume of power fluid above the hammer.

In many devices, the hammer must expend work in compressing power fluid trapped between the hammer and anvil during the power stroke of the hammer. It is desirable to provide a power fluid exhausting arrangement wherein substantially all of the power fluid may be discharged without the need for unnecessary compression.

In many prior devices, the flow of the power fluid to the hammer on its power stroke is ceased well before the hammer-anvil impact. In these tools, the momentum of the hammer causes the hammer to continue its downward travel. It would be desirable to provide a valving and exhausting arrangement wherein the flow of power fluid may be continued until anytime before the instant before the hammer strikes the anvil.

During drilling, there are periods during which it is desirable to cease drilling while maintaining fluid flow through the bit. In additoin, it is always desirable to establish fluid circulation before commencing operation of the power unit. Moreover, there may be periods during drilling wherein the drill bit advances appreciably faster than the drill string. In all of these cases, if the power unit were operated, the force or energy of the impact blows would be exerted on the bottom of the power unit chamber and damage the power tool. In such instances, it is highly desirable to have a percussion tool that automatically ceases operation without interruption of the flow of power fluid through the bit.

It is desirable that all of the above objects be accomplished with a minimum number of parts, which are readily fabricated, assembled and adapted to changing operating conditions. Such parts should be of simple, rugged construction and provide a maximum efficiency.

Accordingly, it is one object of this invention to provide a novel valving and exhausting arrangement designed to direct all of the exhaust power fluids through the drill bit.

Another object of this invention is to provide a novel valving arrangement utilizing an exhaust tube that maintains the alignment of the hammer and anvil elements.

Still another object of this invention is to provide a novel valving and exhausting arrangement wherein the percussion tool is readily adjusted to changing operating conditions.

Yet another object of this invention is to provide means for increasing the length of the power stroke of the hammer without increasing the volume of power fluid above the hammer and without loss of operating efficiency.

A further object of this invention is to provide a power fluid exhausting arrangement wherein substantially all of the power fluid below the hammer may be discharged without the need for unnecessary compression.

Another object of this invention is to provide a valving and exhausting arrangement wherein the flow of power fluid may be continued until anytime before the hammer strikes the anvil.

Yet another object of this invention is to provide means for automatically ceasing hammer operation without momentarily ceasing the flow of power fluid.

Still another object of this invention is to provide percussion tools of simplified design which operate with less down time while providing greater drilling efficiency than heretofore experienced.

Other advantages and objects of this invention will become apparent by reference to the accompanying drawings, appended claims and following specification.

In the drawings:

FIGS. 1 and 2 are elevational, partial, cross-sectional views showing the internal construction of one form of percussive drill described herein.

FIG. 3 is an elevational, partial, cross-sectional view showing the position of the hammer and anvil when the power fluid continues to flow through the power unit of FIGS. 1 and 2 and the drill bit is not bottomed in a borehole.

FIG. 4 is an elevational, partial, cross-sectional view showing an alternative construction for exhausting power fluid through the power unit when the bit is not on bottom of a borehole.

FIGS. 5, 6 and 7 are elevational, partial, cross-sectional views illustrating various operating phases of a means for lengthening the power stroke of a hammer of a percussive tool.

FIG. 8 is an elevational, partial, cross-sectional view showing the internal construction of a second form of percussive drill described herein.

FIG. 9 is a fragmented, elevational, partial, cross-sectional view showing the internal construction of a third form of percussive drill described herein.

Briefly, one form of this invention covers a power unit for a percussive drill which unit has an exhaust tube extending through the center of a hammer slidably mounted thereon to open and close ports in the exhaust tube. The discharge end of the exhaust tube extends into the upper portion of an anvil slidably mounted in the drill bit end of the power unit. There is also provided a power fluid escape opening which normally remains closed until the anvil extends a predetermined distance from the lower end of the power unit. At such time, the escape opening allows the power fluid to flow through the power unit without operating the hammer. In one embodiment of this invention, the escape opening is formed by ports near the end of the exhaust tube. In a second embodiment of this invention the escape opening is a port through the wall of the hammer.

In a second form of this invention, there is provided a spring-biased ring which coacts with the hammer to increase the duration of power fluid flow to the end of the hammer during its power stroke.

A third and fourth form of this invention provide a movable, spring-biased exhaust tube which is reciprocated with movement of the hammer to open and close exhaust ports in the tube.

These and other forms of this invention are now described in more detail. For simplicity's sake, the following description of this invention will be confined to operation of the percussion drill in a substantially vertical position with the bit at the bottom of the percussion drill. This invention, however, is suited to operation in positions other than vertical.

Referring now to FIGURES 1 and 2, there is shown a housing for a percussive drill formed by casing **11** whose upper end (not shown) is adapted to be removably connected to a rotary drill string (not shown). The rotary drill string has the usual flow passage therethrough designed to conduct power or actuating fluid, e.g., air, from a suitable source to the percussive drill. The upper end of casing **11** communicates with this passage in the drill string.

Near the upper end of casing **11** is a valving arrangement forming a power fluid inlet section. The valving arrangement is made up of power fluid inlet passage **13** and fluid-operated slide valve **15** which opens and closes the inlets to passages **17** and **19** so power fluid flows through either passage **17** or **19** and not through both at the same time. When the fluid pressure in passages **17** and **19** is equal, slide valve **15** is biased in such manner as to close the inlet to passage **19** and open the inlet to passage **17**. Slide valve **15** can be any suitable form of pressure responsive valve, e.g., a flapper valve, a slide valve, a ball check valve and other similar valving devices. The inlets to passages **17** and **19** may be modified to correspond to the type of valve being used.

Passage **19** forms a power fluid, power stroke, inlet flow channel for conducting power fluids to power stroke inlet ports **21**.

Passage **17** forms a power fluid, return stroke, inlet flow channel for conducting power fluids downward between outer sleeve **23** and casing **11** to return stroke inlet ports **25**.

Below the power fluid inlet section, slidably mounted for reciprocal movement within casing **11** is piston-like hammer **27** which has a central bore longitudinally traversing the hammer. Hammer **27** is preferably of one piece construction and is formed of any suitable material capable of withstanding the energy of repeated impact blows. The lower portion of hammer **27** is of smaller diameter than the upper portion thereby forming shoulder **29** at a point intermediate of the ends of the hammer.

Hammer **27** is slidably mounted about exhaust tube **31** which extends from inside the lower end of the power fluid inlet section through hammer **27**. The upper end portion of exhaust tube **31** forms part of one wall of power stroke inlet passage **19** and contains power stroke inlet ports **21**. Extending into the upper end of exhaust tube **31** is blowing power fluid tube **33**. The outer edge of the lower end of blowing power fluid tube **33** is sealed against the inner wall of exhaust tube **31** just below power stroke inlet ports **21**. Blowing power fluid tube **33** thereby forms part of power stroke inlet passage **19**. The upper end of blowing power fluid tube **33** is sealed in the power fluid inlet section above the valve and communicates with power fluid inlet passage **13**.

Preferably, as shown, blowing power fluid tube **33** has a central bore passage **35** for allowing part of the power fluid to pass directly from the inlet section to exhaust tube **31** thereby supplying a continuous stream of power fluid for cleaning and flushing the drill bit. If desired, however, this bore may be sealed. The blowing power fluid tube may be omitted by sealing the bore of the exhaust tube just below the power stroke inlet ports.

Through the wall of exhaust tube **31** at a point below the end of blowing power fluid tube **33** are power stroke exhaust ports **37**. Spaced a predetermined, longitudinal distance below power stroke exhaust ports **37** are return stroke exhaust ports **39**. The distance between the top of power stroke exhaust ports **37** and the bottom of the return stroke exhaust ports **39** is controlled by factors hereinafter described. Now it is sufficient to note that the distance between the extremities of the exhaust ports is designed according to the length of hammer and the operating conditions of the power fluid. These exhaust ports may be any form of opening through the wall of exhaust tube **31**. If desired, the ports could be formed by one slot traversing the desired distance.

Near the lower end of exhaust tube **31** are power fluid escape ports **41** which are normally sealed because the lower end of exhaust tube **31** telescopes slidably into the upper end of bit-anvil unit **43** which is slidably mounted in the lower end of casing **11** below hammer **27** for limited reciprocal movement therein.

Bit-anvil unit **43** is formed of a drill bit, a shank portion, and anvil surface **45**. The drill bit can be any suitable form of percussive drill, e.g., a rock bit, a fishtail bit or a rotary-percussive bit. Longitudinally traversing bit-anvil unit **43** is central, bit-anvil bore passage **47** whose lower end communicates with the usual fluid discharge passages in the drill bit and whose upper end is in axial alignment with the bore passage passing through hammer **27**.

Bit-anvil unit **43** has anvil surface **45** designed to receive the impacts of hammer **27**. Preferably, anvil surface **45** will be as large as practical so that the amount of energy per square inch of surface is maintained at a level below which the upper end of bit-anvil unit **43** would distort. The area of anvil surface **45** is largely controlled by the diameter of the power unit and the diameter of exhaust tube **31**. It is desirable that the diameter of exhaust tube **31** and the area of anvil surface **45** both be as large as spacing permits.

As shown, the upper end of bit-anvil bore passage **47** is of slightly larger diameter than the rest of the bore passage. This allows some play between exhaust tube **31** and the upper end of bit-anvil unit **43** and prevents

pinching should anvil surface 45 be distorted by the impact blows of hammer 27.

The outer surface of the shank portion of bit-anvil unit 43 has the usual grooves which cooperate in slidable relationship with longitudinal insert type splines 49 so that splines 49 engage bit-anvil unit 43 and cause it to rotate with rotation of casing 11. The upper ends of splines 49 also act as stops to limit the downward travel of bit-anvil unit 43 whenever the bit is raised from the bottom of the borehole or the bit can freely travel downward faster than the drill string. Splines 49 are held in place by insert ring 51 which is threaded into the lower end of casing 11. The upper portion of bit-anvil unit 43 is slidably mounted in insert ring 51. Bit-anvil unit 43 may be made to rotate with casing 11 in other ways not described herein since such methods are well known.

Insert ring 51 is also designed to receive the lower, smaller diameter portion of hammer 27 whenever the percussive drill is suspended and no power fluid is passing through the drill. Upper end surface 53 of insert ring 51, therefore, acts as a stop and limits the downward movement of hammer 27 by engaging with shoulder 29 whenever the hammer moves downward beyond its normal operating path.

Returning now to the return stroke inlet ports, reference should be had to FIGURES 1 and 3. In FIGURES 1 and 3, return stroke inlet ports 25 are formed by a slot or hole through the wall of casing 11. Beginning at the bottom of these ports, the inside diameter of casing 11 is enlarged to form under-reamed portion 55 which extends downward to a point at least below upper end surface 53 of insert ring 51. Actually, return stroke inlet ports 25 could be enlarged and lengthened to cover this distance, but this would result in unnecessary weakening of the walls of the casing. Another alternative would be to lower the entire inlet ports to this position. Regardless of the exact position or size of these inlet ports, in the embodiment of FIGURE 3, it is necessary that return stroke inlet ports always communicate in some fashion with upper end surface 53 of insert ring 51. The reason for this is best illustrated by the following description of another feature of this invention.

As mentioned in the introductory description of this invention, it is desirable to provide means for automatically ceasing operation of the hammer without shutting off circulation of power fluid through the percussive drill. FIGURE 3 shows one embodiment of this invention for accomplishing this object. Whenever the percussive unit is raised off the bottom of the borehole or the bit advances much faster than the drill string, bit-anvil unit 43 drops until splines 49 prevent additional downward movement. When bit-anvil unit 43 falls, power fluid escape ports 41 near the end of exhaust tube 31 are exposed to permit free and continuous passage of power fluid to bit-anvil bore passage 47. These ports, thereby, provide an opening to permit escape of the power fluid.

If desired, the same object could be attained by shortening exhaust tube 31 and eliminating power fluid escape ports 41. In this manner, when the anvil unit drops the end of exhaust tube 31 would be exposed since the exhaust tube would no longer extend into bit-anvil unit 43. Preferably, however, exhaust tube 31 should always extend into bit-anvil unit 43 to act as a rigid guide for maintaining alignment of the anvil and hammer elements.

Normally, when bit-anvil unit 43 drops, hammer 27 will also tend to overtravel its normal downward operating position with its lower end entering insert ring 51 until shoulder 29 rests on upper end surface 53 of insert ring 51.

Assuming that shoulder 29 is resting on the top of insert ring 51 as it does when the unit is suspended off the bottom of the borehole and no power fluid is being transferred to the power unit, it will be seen that power fluid entering return stroke inlet ports 25 passes to the junction of shoulder 29 and insert ring 51. The power fluid acts upon shoulder 29 to lift hammer 27 until the lower end of the hammer passes out of insert ring 51 and the power fluid is exhauste to bit-anvil bore passage 47 through power fluid escape ports 41. Hammer 27 tends to return to insert ring 51 and shut off passage of power fluid. When the hammer reduces the flow of power fluid, the pressure below shoulder 29 builds up and the hammer is raised. In this manner, the hammer is suspended by the power fluid and will not undergo reciprocation. As a result, there is provided an automatic arrangement for ceasing operation of the hammer whenever desired by simply lifting the bit off bottom. Similarly, if the bit should hit an underground cavern or cavity or advance too easily into the borehole, operation of the hammer will automatically cease until the bit-anvil unit is pushed far enough into the power unit to close the end of exhaust tube 31. In this manner, there will be no impacts wherein the energy is applied to insert ring 51 or splines 49 which impacts if not controlled would cause damage to the power unit.

Another arrangement for accomplishing a similar purpose is illustrated in FIGURE 4. In this embodiment, there is bypass port 57 extending through the wall of hammer 27. During normal operation, hammer 27 reciprocates on exhaust tube 31 and bypass port 57 remains closed, but when bit-anvil unit 43 falls beyond its normal operating position, hammer 27 also overtravels exposing return stroke inlet ports 25 and return stroke exhaust ports 39 to bypass port 57. When this occurs, power fluid is discharged through return stroke inlet ports 25 through bypass port 57 to return stroke exhaust ports 39 down exhaust tube 31 and through the bit. The operation of the hammer will only be resumed when bit-anvil unit 43 is pushed far enough into the unit to cause hammer 27 to move upward closing bypass port 57. The bypass port could be a port in return stroke inlet passage 17 designed to communicate with power stroke exhaust ports 37 when the hammer overtravels in a downward direction beyond its normal operating path. This arrangement is not illustrated in the drawings. When the arrangement of FIGURE 4 is used, to be sure that hammer 27 ceases reciprocation without interruption of the flow of power fluid, bypass port 57 communicates with power fluid escape passages 59 and 61. These passages are formed in such manner as to permit power fluid trapped under shoulder 29 to be discharged through return stroke exhaust ports 39 when the hammer overtravels its normal operating path. If power fluid escape passages 59 and 61 were not present, the hammer might continue to reciprocate since power fluid would be trapped below the hammer. Without these passages, shoulder 29 of hammer 27 after passing return stroke inlet ports 25 would trap power fluid between bit-anvil unit 43 and the underside of hammer 27. The momentum of the hammer compresses this trapped fluid. If the energy of the compressed fluid is great enough, the fluid could expand causing the hammer to spring upward reopening return stroke inlet ports 25 and closing bypass port 47 and the hammer could continue to reciprocate. With power fluid escape passages 59 and 61, most of the fluid that would normally be trapped under shoulder 29 is permitted to escape to return stroke exhaust ports 39 and the hammer will not bounce back.

Considering now the normal operation of the percussive drill, reference should be had to FIGURES 1, 2 and 3. Normally, the percussive drill is connected to a rotary drill pipe and the drill lowered into the borehole. Usually, with the drill off bottom, power fluid circulation is established before commencing reciprocation of the hammer. In the off bottom position before power fluid circulation is started, bit-anvil unit 43 will be in its lowest position as controlled by the top of splines 49. Likewise, hammer 27 will be in its lowest position with shoulder 29 resting on upper end surface 53 of insert

ring 51. Slide valve 15 is biased so that power fluid flows into return stroke inlet passage 17 out return stroke inlet ports 25 and between shoulder 29 and insert ring 51. The power fluid lifts hammer 27 until the lower end of the hammer leaves insert ring 51 allowing power fluid to pass under the hammer to bit-anvil bore passage 47 and out of the drill bit to return to the surface. Once power fluid circulation is established, the drill pipe is rotated thereby rotating casing 11. When casing 11 rotates, splines 49 engage complementary grooves in the shank portion of bit-anvil unit 43 and cause the bit to rotate therewith. The bit is then lowered and bottomed in the borehole. The downward force of the drill string causes bit-anvil unit 43 to slide upward around the lower end of exhaust tube 31 shutting off power fluid escape port 41.

If blowing power fluid tube 33 is open, part of the power fluid will bypass the power unit and flow directly through the exhaust tube to the bit to flush cuttings from the bit and clean and lubricate the bit.

The remainder of the power fluid acting on the bottom of the hammer accelerates the hammer rapidly in an upward direction on its return stroke. As the hammer moves rapidly upward it opens return stroke exhaust ports 39 and closes power stroke exhaust ports 37, the power fluid is exhausted and the power fluid pressure below the hammer drops to the exhaust pressure.

When the power stroke exhaust ports 37 close, the power fluid above the hammer is compressed and the hammer starts to de-accelerate. This compression causes the power fluid pressure above the hammer to be greater than the pressure below the hammer so that the fluid pressure inside power stroke inlet passage 19 is greater than the fluid pressure inside return stroke inlet passage 17. This pressure difference causes slide valve 15 to move downward closing return stroke inlet passage 17 and opening power stroke inlet passage 19. The flow of power fluid is thereby switched so that power fluid passes out power stroke inlet ports 21 to the top of the hammer accelerating the hammer downward in its power stroke.

As the hammer moves downward, the hammer closes return stroke exhaust ports 39 and opens power stroke exhaust ports 37. When power stroke exhaust ports 37 open, the power fluid is exhausted and the power fluid pressure above the hammer drops to the exhaust pressure.

When return stroke exhaust ports 39 close, the power fluid below the hammer is compressed. This compression causes the power fluid pressure below the hammer to be greater than the pressure above the hammer so that the fluid pressure inside return stroke inlet passage 17 is greater than the fluid pressure inside power stroke inlet passage 19. This pressure differential causes slide valve 15 to move upward closing power stroke inlet passage 19 and opening return stroke inlet passage 17. The flow of power fluid is thereby switched so that power fluid passes out of return stroke inlet ports 25 to the underside of the hammer. The hammer's momentum causes it to continue its downward travel until it impacts on anvil surface 45. This causes bit-anvil unit 43 to move sharply downward driving the cutters of the bit into the formation. In this fashion, the hammer reciprocates causing a series of impact blows on the bit-anvil unit.

From the above description, it can be seen that the unique exhaust tube of this invention not only provides a means for exhausting the power fluid, but it also provides a rigid guide for the hammer and the bit-anvil unit. In addition, the hammer is guided in such manner that the striking surface of the hammer lies flat when it strikes the anvil surface, thereby providing for more uniform energy per square inch of surface. This uniformity of energy distribution prevents distortion of the anvil and hammer units.

Because of the exhaust tube of this invention, the percussive power unit is readily adapted to changing operating conditions. This is an important desirable feature since as hereinafter shown the operating conditions change and cause loss of efficiency and energy unless the power unit is adjusted or tuned to fit the operating conditions.

In the type of percussive power unit shown in FIGURES 1 and 2, the compressibility of the power fluid is an important factor. The distances over which the power fluid accelerate the hammer are primarily controlled by the spacing and position of the exhaust ports, the volumes of fluid above and below the hammer and the compressibility of the power fluid. For a given power fluid, the compressibility of the fluid depends, for the most part, on its pressure. As stated previously, as the depth of the borehole increases, the back pressure or exhaust pressure increases and it is standard practice to correspondingly increase the power fluid inlet pressure. As the pressure increases, the fluid becomes less compressible and usually the pressure differential between the exhaust fluid and the power inlet fluid cannot be maintained. This, in turn, reduces the peak velocity of the hammer lessening the energy per blow and also reduces the distance over which the power fluids act since the hammer will not travel as far upward past the power stroke exhaust ports.

Until the operating and exhausting pressures become excessively high, it is possible to adjust or tune the power unit to maintain the desired energy per blow by varying the spacing and position of the exhaust ports. The exhaust tube of this invention provides a readily adjustable exhausting arrangement. The tube may be readily replaced by another tube. More preferably, it is a simple matter to widen the exhaust ports or to move the exhaust ports upward or downward. The exhaust ports could be equipped with insert rings of varying width (not shown) which could be changed each time it is desirable to alter the spacing between the extremities of the exhaust ports. All of these changes are made without altering the hammer or bit-anvil unit. This is, therefore, a unique advantage of the exhaust tube of this invention.

Another method of adjusting the power unit to changing operating pressures is to adjust the volume of power fluid above the hammer. As the pressure increases and the power fluid becomes less compressible, the distance that the hammer travels upward past the power stroke inlet ports may be maintained by increasing the volume of power fluid above the hammer. Because of the exhaust tube of this invention, this volume can be readily changed without alteration of the hammer and bit-anvil units, because the length of the exhaust tube above the exhaust ports is independent of the hammer. A simple method of providing for an adjustable head volume is to lower the power stroke inlet ports 21 and place a series of removable, flat, washer-like spacer rings (not shown) about the exhaust tube above the inlet ports. In this manner, spacer rings can be removed or added whenever a change in head volume is desired.

Other arrangements for obtaining maximum efficiency and energy per hammer impact utilizing the exhaust tube of this invention are hereinafter described in detail.

In FIGURES 5, 6 and 7, there are shown several operating positions of a means for obtaining the most efficient utilization of power fluid. This means, in effect, delays the opening of power stroke exhaust ports 37 until anytime just before the hammer strikes the anvil surface. This delay is attained without reducing the duration or distance over which the return stroke power fluid accelerates the hammer in an upward direction.

Referring now to FIGURE 5, there is shown ring 63 slidably mounted for reciprocal movement on exhaust tube 31 above hammer 27. Ring 63 can be formed of any suitable material, e.g., plastic, hard rubber, metal, Bakelite and the like. As shown, ring 63 is formed by a cylindrical sleeve with edge surfaces large enough for the operation hereinafter described. The longitudinal length of the sleeve along the lengitudinal axis of the percussive

drill is variable but the sleeve cannot be as long as the distance between the top side of the power stroke inlet ports 21 and the top surface of hammer 27 when the hammer strikes bit-anvil unit 43. Otherwise, the exhaust ports would not open and the power unit would be inoperable. As described previously, due to vaying fluid operating conditions, it may be desirable to vary the length of ring 63. Because of this, ring 63 may be fashioned in a manner suitable for ready removal from the exhaust tube. The ring, moreover, could have external threads and be modified so that the ring could be made up of several removable units. In this manner, the length of the ring could be changed whenever desired. Ring 63 is adaptable to other percussive drill tools in many ways depending upon the type of tool being utilized. For example, since other tools do not have the exhaust tube of this invention, the ring could be held in proper alignment and position by placing long guide ribs on the ring.

Lower edge surface 65 of ring 63 is shaped so that its outermost periphery is lower than the rest of lower edge surface 65. Lower edge surface 65 could be made concave, or the edge surface could be slanted upwardly and rearwardly to the outer periphery, or the edge surface could be formed of two flat surfaces by enlarging the bore through the ring near the lower end of the ring.

The upper edge of ring 63 is fixed to the lower end of spring 67. The other end of spring 67 is connected to the upper end of the power stroke chamber above the hammer. The spring is mounted about exhaust tube 31. Spring 67 is designed to work both in compression and in tension and can by any suitable form of spring, e.g., a helical spring with either a round or a parallelogram cross section. Spring 67 must be powerful enough when compressed or when in tension to move ring 63 faster than hammer 27 moves during acceleration in its return and power strokes.

When spring 67 is in its relaxed position, lower edge surface 65 of ring 63 must be below the upper edge of power stroke exhaust ports 37 for reasons hereinafter shown.

Referring now to FIGURES 5, 6 and 7 the operation of ring 63 is described. In FIGURE 5, ring 63 and spring 67 are shown in their neutral positions that they occupy when the spring is relaxed. In other words, spring 67 and ring 63 always tend to return to this position. As hammer 27 moves upward on its return stroke, the upper surface of the hammer engages the lowermost outer edge of ring 63 pushing the ring upward and compressing spring 67. The compressive force of the spring causes the lowermost outer edge of the ring to form a fluid-tight seal between the hammer and ring. When the hammer reaches the upper limit of its path, as shown in FIGURE 6, it reverses direction and starts accelerating downward in its power stroke. Compressed spring 67 must then expand rapidly enough to keep ring 63 pressed tightly against the upper surface of hammer 27 and maintain the fluid-tight seal between hammer 27 and the lowermost outer edge of ring 63. As the upper surface of the hammer moves downward past the upper edge of power stroke exhaust ports 37, lower edge surface 65 of ring 63 is exposed to the low discharge fluid pressure. The uppermost surface of ring 63, on the other hand, is exposed to high pressure power fluid. At this point, this pressure differential takes over control of ring 63 and the ring is held tightly against the hammer. Just after this pressure differential is created, spring 67 passes through its relaxed position into a state of tension. The tension of the spring is not powerful enough to pull ring 63 away from the hammer since the high pressure acting on the upper edge surface of ring 63 creates a downward force greater than the upward pull of the spring. At this time, it should be noted that if the relaxed position of spring 67 placed the lower edge of ring 63 above the upper edge of power stroke exhaust ports 37, spring 67 would be placed in a state of tension before the pressure differential just described occurred and the spring would pull ring 63 away from the hammer. Because of this, as stated previously, the lowermost edge of ring 63 should extend below the upper edge of power stroke exhaust ports 37 when spring 67 is in its relaxed position.

As hammer 27 and ring 63 continue to move downward in the hammer's power stroke, the upper edge of ring 63 passes the upper edge of power stroke exhaust ports 37 exposing the upper edge of the ring to the same pressure as lower edge surface 65. This is shown in FIGURE 7. When these pressures equalize, the tension of spring 67 snaps ring 63 away from the hammer completely exposing power stroke exhaust ports 37. The ring and spring return to their neutral position. The hammer strikes the anvil surface and the process is repeated.

In this manner, the duration or distance over which the power fluid acts on the upper surface of the hammer is extended by the length of ring 63 and, if desired, the power fluid can be made to act on the hammer until just before the hammer strikes the anvil surface. Ring 63 thereby provides a means of increasing the efficiency of the percussion drill and tuning the percussive drill to changing operating conditions.

Referring now to FIGURES 8 and 9, two more embodiments of this invention will be described. The foregoing description of other embodiments of this invention will aid in understanding the percussive drills illustrated by FIGURES 8 and 9; however, for reasons hereinafter explained, the percussive drills hereinafter described are better suited for operation with both compressible and non-compressible power fluid.

Briefly, the percussive drills hereinafter described utilize a reciprocating exhaust tube which cooperates with a reciprocating piston-like hammer to open and close exhaust ports in the exhaust tube thereby controlling the action of the hammer.

In FIGURE 8, the upper end of exhaust tube 31 instead of being fixedly mounted in the power fluid inlet chamber is sealed by circular headpiece 69 which is slidably mounted for reciprocal movement on blowing power fluid tube 33. Headpiece 69 is placed just above power stroke exhaust ports 37. The diameter of headpiece 69 is larger than exhaust tube 31 thereby providing lower outer headpiece surface 71 which preferably is shaped in the same manner as lower edge surface 65 of ring 63 shown in FIGURE 5 and described previously. Similarly, it is also preferred that the lowermost outer periphery of lower outer headpiece surface 71 be below the upper edge of power stroke exhaust ports 37, but unlike the ring of FIGURE 5, it is not necessary that the lower outer headpiece surface be formed in this manner for reasons hereinafter stated. The upper surface of head piece 69 is connected to the lower end of spring 67. The upper end of spring 67 is connected to the upper end of the power stroke chamber above the hammer.

In both FIGURES 8 and 9, the distance between the upper edge of power stroke exhaust ports 37 and the lower edge of return stroke exhaust ports 39 is equal to the length of hammer 27 plus the desired port opening size. In other words, when hammer 27 closes power stroke exhaust ports 37, return stroke exhaust ports 39 should be open.

Returning to FIGURE 8, bit-anvil bore passage 47 contains stop 73 which limits the downward travel of exhaust tube 31. Stop 73 can be any form of stop means. As shown, the stop is formed simply by reducing the diameter of the bore passage. If desired, stop 73 can be covered by a durable material softer than steel so as to prevent damage to the lower end of exhaust tube 31.

As shown in FIGURE 8, exhaust tube 31 and spring 67 are in their neutral position that they will occupy when the spring is in its relaxed state. In this position, the distance between stop 73 and the lower end of exhaust tube 31 must be less than the distance between the upper edge of power stroke exhaust ports 37 and the top of hammer 27 when the hammer is resting on the top of

bit-anvil unit 43 and when the bit-anvil unit projects its maximum distance into casing 11. In other words, stop 73 must engage the lower end of exhaust tube 31 before the hammer strikes the anvil surface. Within this limitation, the neutral distance between the lower end of exhaust tube 31 and stop 73 can be varied to meet specific operating conditions. Usually, however, the maximum distance is preferred. If the power fluid is a non-compressible fluid, the maximum distance will usually be utilized.

In operation, during its return stroke, hammer 27 moves upward closing power stroke exhaust ports 37 and opening return stroke exhaust ports 39. The upper surface of the hammer engages lower outer headpiece surface 71. As the hammer continues its upward movement, it lifts headpiece 69 and exhaust tube 31 and compresses spring 67. A fluid-tight seal is thereby formed between lower outer headpiece surface 69 and the upper surface of hammer 27. As soon as high pressure fluid acts on the upper surface of headpiece 69 and hammer 27, there is a pressure differential between the underside of headpiece 69 inside exhaust tube 31 and the upper surface of the headpiece. This pressure difference holds headpiece 69 against hammer 27 until the seal between the two is broken. Unlike the ring of FIGURE 5, since this pressure difference is created shortly after the hammer closes power stroke exhaust ports 37 and before the upward travel of the hammer ceases, lower outer headpiece surface 71 does not necessarily need to extend below power stroke exhaust ports 37. In addition, spring 67 does not necessarily need to expand rapidly enough to hold headpiece 69 against hammer 27 when hammer 27 starts its downward stroke since the pressure difference will hold the headpiece against the hammer.

As hammer 27 reverses direction and starts its downward or power stroke, exhaust tube 31 moves with the hammer and return stroke exhaust ports 39 remain open since they too move with the hammer. Since return stroke exhaust ports 39 remain open during downward travel of the hammer, there is very little power fluid trapped under the hammer. The hammer, therefore, expends no work in compressing trapped power fluid and almost all of the downward energy is available for the impact. Also, since practically all of the power fluids below the hammer can be discharged, the percussion tool can be utilized with non-compressible power fluids.

At anytime before the hammer strikes the anvil surface, the lower end of exhaust tube 31 can be made to hit stop 73. When the lower end of the exhaust tube hits stop 73, the fluid seal between headpiece 69 and the upper surface of hammer 27 is broken since the exhaust tube can no longer move with the hammer. As soon as this seal is broken, the pressure above and below the headpiece equalizes and spring 67 snaps exhaust tube 31 back to its neutral position opening power stroke exhaust ports 37 and closing return stroke exhaust ports 39. The hammer strikes the anvil and the process is repeated.

Referring now to FIGURE 9, headpiece 69 instead of being slidably mounted about blowing power fluid tube 33 is rigidly fixed to the lower end of tube 75. New blowing power fluid tube 75 is slidably mounted for reciprocal movement through the upper end of the power stroke chamber above the hammer and extends into the power fluid inlet chamber. At the top of new blowing power fluid tube 75 is stop 77 which takes the place of the stop of FIGURE 8; consequently, there is no stop in bit-anvil bore passage 47.

Above the valving arrangement in the power fluid inlet chamber and about new blowing power fluid tube 75 is spring 67. The upper end of spring 67 is connected to the underside of stop 77 and the lower end is connected to the upperside of the valving arrangement in the power fluid inlet chamber. Preferably, as shown, about the lower portion of spring 67 is stop sleeve 79. Stop sleeve 79 limits the downward travel of new blowing power fluid tube 75 and stop 77. Stop sleeve 79 is not necessary since spring 67 could act as a stop when it is fully compressed, but for maximum spring life it is best to control the working stresses on the spring within fixed limits. As before, the stop should break the seal between hammer 27 and headpiece 69 before the hammer strikes the anvil.

The operation of the percussive unit of FIGURE 9 is quite similar to that of the unit of FIGURE 8; however, in FIGURE 9, the spring is put in tension when the hammer is raised and placed in a state of compression when the hammer is lowered. In addition, the downward travel of the exhaust tube is controlled by stop 77 which is now above the hammer and above the exhaust tube.

The embodiment of FIGURE 9 is preferred since the stop is above the exhaust tube. In this manner, downward travel of the exhaust tube is stopped with a minimum of stress on the tube. In FIGURE 8, the end of the tube is subjected to an impact stress. Also, in the embodiment of FIGURE 9, it is easier to form a seal around the reciprocating, blowing power fluid tube than it is to form a similar seal around the fixed blowing power fluid tube of FIGURE 8 wherein the seal is placed in a reciprocating headpiece.

Although the above description was generally concerned with compressible power fluid, most of the embodiments or features of this invention are suitable for or adaptable to use with non-compressible fluids.

The above description of this invention details several embodiments capable of performing the objects set forth herein. One or more of the unique features of this invention either singularly or in combination may be incorporated into other percussion tools to improve their over-all operation and efficiency. This invention, therefore, is not limited to the specific details set forth above, but also includes all variations or modifications that are apparent to those skilled in the art.

I claim:

1. A percussive unit for a percussion drill comprising an elongated tubular casing adapted for removable attachment to the lower end of a string of drill pipe, anvil and drill bit means slidably mounted in the lower end of said casing and adapted to rotate with said casing and having a central passage therethrough, piston-type hammer means having an upper end and a lower end and slidably mounted in the central portion of said casing and adapted to strike said anvil and bit means during the power stroke of said hammer means, power fluid exhaust tube means having an upper end and a lower end and passing through said hammer means and into said passage of said anvil and bit means forming a substantially fluid tight seal therebetween at least during the normal power and return strokes of said hammer means and adapted to provide communication between said drill pipe and said passage through said anvil and bit means, first valve means adapted to alternately supply power fluid from said drill pipe to the ends of said hammer means during said power stroke and the return stroke of said hammer means respectively, port means in said exhaust tube means adapted to alternately discharge power fluid from said casing adjacent the ends of said hammer means through said exhaust tube means during at least a portion of said power stroke and said return stroke of said hammer means respectively, and second valve means above the upper end of said hammer means and adapted to cooperate with the movement of said hammer means to delay opening of said port means to the upper end of said hammer means until said hammer means has traveled a predetermined distance during the power stroke thereof and before said hammer means strikes said anvil and bit means.

2. The percussive unit of claim 1 wherein the second valve means is connected to spring means and said spring means is adapted to move said second valve means upward away from the upper end of the hammer means after a predetermined distance of travel of said hammer means during the power stroke thereof.

3. The percussive unit of claim 1 wherein the second valve means is an elongated ring-like element adapted to seal against the upper end of the said hammer means and the delay caused by said second valve means may be varied by varying the length of said ring-like element.

4. A percussion unit for a percussion drill comprising an elongated tubular casing adapted for removable attachment to the lower end of a string of drill pipe, anvil and bit means slidably mounted in the lower end of said casing and adapted to rotate with said casing and having a central passage therethrough, piston-type hammer means having an upper end and a lower end and slidably mounted in the central portion of said casing and adapted to strike said anvil during the power stroke of said hammer means, rigid power fluid exhaust tube means having an upper end and a lower end and passing through said hammer means and into said passage of said anvil and bit means forming a substantially fluid tight seal therebetween at least during the normal power and return strokes of said hammer means and adapted to provide communication between said drill pipe and said passage through said anvil and bit means, said exhaust tube means being adapted for limited vertical movement relative to said casing and to move vertically with said hammer means for a predetermined distance of travel of the power stroke of said hammer means, valve means adapted to alternately supply power fluid from said drill pipe to the ends of said hammer means during said power stroke and return stroke of said hammer means respectively, and port means in said exhaust tube means adapted to alternately discharge power fluid from said casing adjacent the ends of said hammer means through said exhaust tube means during at least a portion of said power stroke and said return stroke of said hammer means respectively.

5. The percussion unit of claim 4 wherein the limited movement of the exhaust tube means is partially controlled by spring means, said spring means engaging one end of said exhaust tube and adapted to cause the upper end of said exhaust tube to move upward away from the upper end of the hammer means after a predetermined distance of travel of said hammer means during the power stroke thereof.

6. The percussion unit of claim 4 wherein the port means in the exhaust tube means is so located as to permit discharge of power fluid from the lower end of the hammer means while said exhaust tube moves vertically with said hammer means.

7. A percussion unit for a percussion drill comprising an elongated tubular casing adapted for removable attachment to the lower end of a string of drill pipe, anvil and drill bit means slidably mounted in the lower end of said casing and adapted to rotate with said casing and having a central passage therethrough, piston-type hammer means having an upper end and a lower end and slidably mounted in the central portion of said casing and adapted to strike said anvil and bit means during the power stroke of said hammer means, power fluid exhaust tube means having an upper end and a lower end and passing through said hammer means and into said passage of said anvil and bit means forming a substantially fluid tight seal therebetween at least during the normal power and return strokes of said hammer means and adapted to provide communication between said drill pipe and said passage through said anvil and bit means, valve means adapted to alternately supply power fluid from said drill pipe to the ends of said hammer means during said power stroke and return stroke of said hammer means respectively, first port means in said exhaust tube means adapted to alternately discharge power fluid from said casing adjacent the ends of said hammer means through said exhaust tube means during at least a portion of said power stroke and said return stroke of said hammer means respectively, and power fluid escape passage extending laterally through the hammer means, said escape passage being positioned and located to connect the return stroke side of said valve means with the first port means in the exhaust tube so that power fluid is discharged from the return stroke side of said valve means to said passage of said anvil and bit means whenever said hammer means overtravels the normal operating stroke of said hammer means.

8. A percussion unit for a percussion drill comprising an elongated tubular casing adapted for removable attachment to the lower end of a string of drill pipe, anvil and drill bit means slidably mounted in the lower end of said casing and adapted to rotate with said casing and having a central passage therethrough, piston-type hammer means having an upper end and a lower end and slidably mounted in the central portion of said casing and adapted to strike said anvil and bit means during the power stroke of said hammer means, power fluid exhaust tube means having an upper end and a lower end and passing through said hammer means and into said passage of said anvil and bit means forming a substantially fluid tight seal therebetween at least during the normal power and return strokes of said hammer means and adapted to provide communication between said drill pipe and said passage through said anvil and bit means, valve means adapted to alternately supply power fluid from said drill pipe to the ends of said hammer means during said power stroke and return stroke of said hammer means respectively, first port means in said exhaust tube means adapted to alternately discharge power fluid from said casing adjacent the ends of said hammer means through said exhaust tube means during at least a portion of said power stroke and said return stroke of said hammer means respectively, second port means located above the lower end of said exhaust tube and adapted to be closed by the anvil and bit means during normal operation of the hammer means and to be opened when said anvil and bit means falls below the normal operating position thereof, and a power fluid escape passage formed between the lower end of said hammer means and said anvil and bit means, said escape passage connecting the return stroke side of said valve means with said second port means so that power fluid is discharged from the return stroke side of said valve means to said passage in said anvil and bit means whenever said hammer means overtravels the normal operating stroke of said means.

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