June 28, 1960 R. W. BECK 2,942,851

PERCUSSIVE ROTARY ROCK DRILLING TOOL

Filed Jan. 13, 1958 3 Sheets-Sheet 1

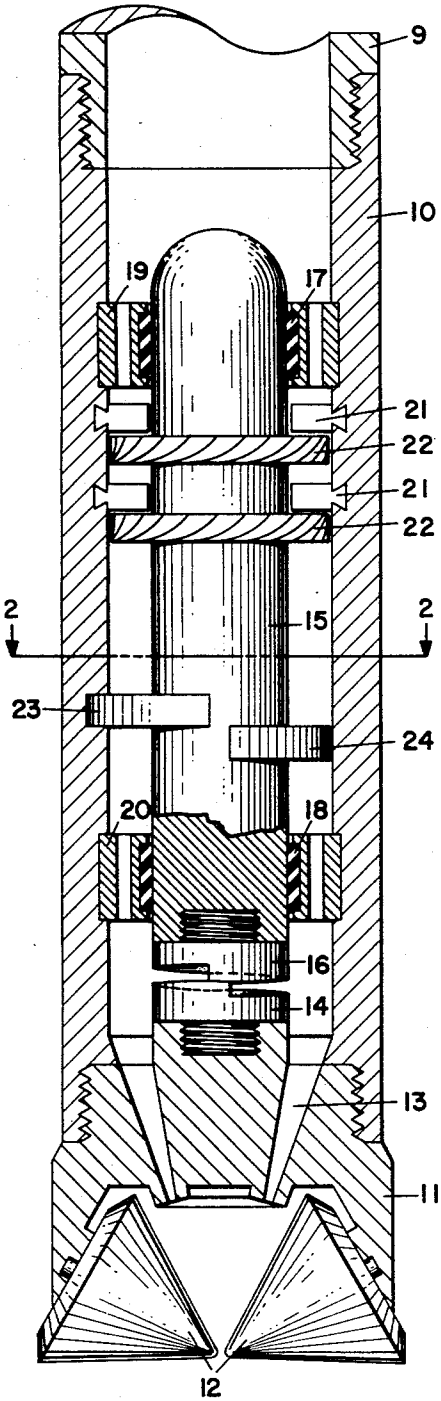


FIG.-1

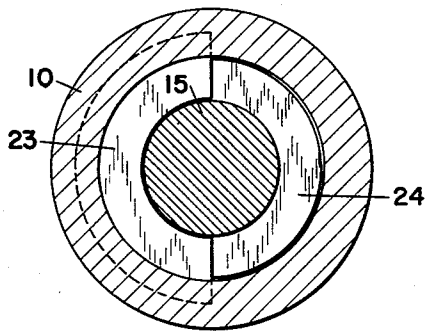


FIG.-2

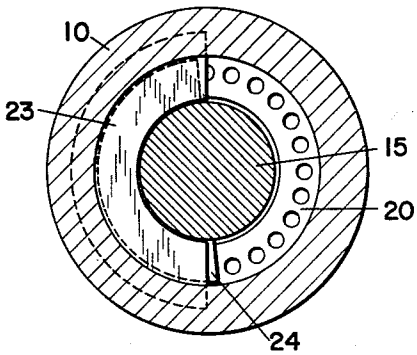


FIG.-3

Robert W. Beck Inventor

By W. O. Feilmer Attorney

June 28, 1960 R. W. BECK 2,942,851

PERCUSSIVE ROTARY ROCK DRILLING TOOL

Filed Jan. 13, 1958 3 Sheets-Sheet 2

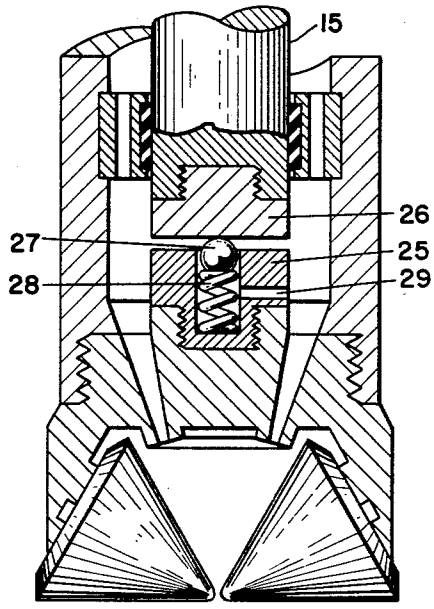


FIG.-4

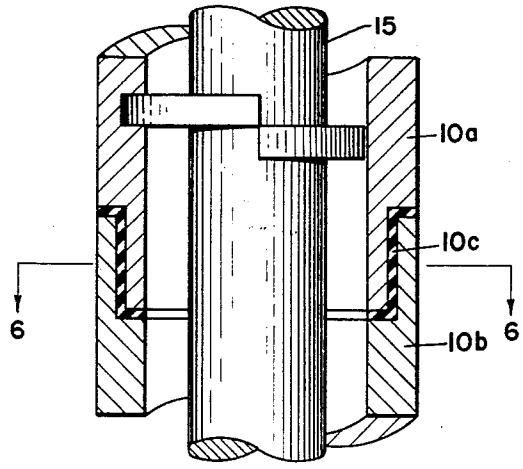


FIG.-5

Robert W. Beck Inventor

By W. O. Hellman Attorney

June 28, 1960 R. W. BECK 2,942,851

PERCUSSIVE ROTARY ROCK DRILLING TOOL

Filed Jan. 13, 1958 3 Sheets-Sheet 3

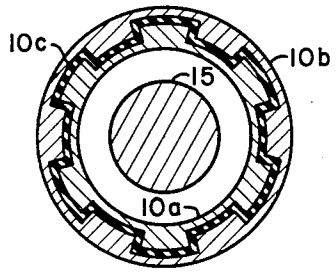


Fig. 6

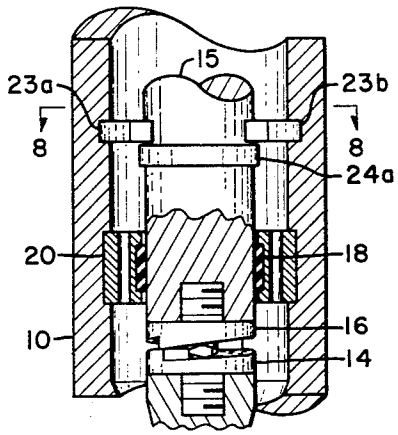


Fig. 7

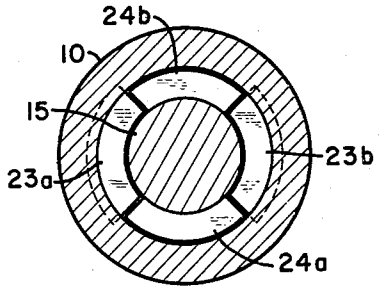


Fig. 8

Robert W. Beck Inventor

By James E. Reed Attorney

United States Patent Office 2,942,851 Patented June 28, 1960

2,942,851

PERCUSSIVE ROTARY ROCK DRILLING TOOL

Robert Wm. Beck, Caracas, Venezuela, assignor, by mesne assignments, to Jersey Production Research Company

Filed Jan. 13, 1958, Ser. No. 708,501

12 Claims. (Cl. 255—4.4)

This invention relates to drilling apparatus for deep bores such as oil wells. It relates more particularly to drilling apparatus for such deep bores which must penetrate rock formations. It relates still more particularly to drilling apparatus in which a periodic percussive force is applied to the cutting elements or rock drill bit while these elements or this bit are being driven in rotary fashion; and it relates even still more particularly to drilling apparatus in which a hammer mechanism supplying periodic percussive forces to a rock drill bit is actuated by fluid furnished to displace the drilling debris while the drill bit itself is rotated by other, independent means.

It is a well established fact that the addition of a percussive force to a drill bit during rotary drilling increases greatly the rate of drill penetration, particularly when the material being drilled is hard rock. A number of apparatuses for effecting this percussive action have been disclosed. Several of these have comprised hammer mechanisms in which energy for the lifting stroke of the hammer has been supplied by debris displacing fluid known and hereinafter referred to as drilling fluid. Features of known mechanisms of this nature have included complex valving, ball and roller bearings, and close clearances of sliding and rotating parts, all undesirable because of being required to operate or exist while subject to submergence in abrasive drilling fluid.

It is the object of the present invention to provide a hammer means for applying a percussive force to a rotary rock drill bit, which means will be actuated by drilling fluid independently of the drill bit drive, and which will be of simpler and more reliable construction than any previously disclosed hammer means for the same purpose and similarly actuated. The invention and its object will be more fully understood from the following description when it is read in conjunction with and with reference to the accompanying drawings in which:

Fig. 1 represents a vertical section through a rotary rock drilling tool showing the fluid-driven hammer mechanism of this invention.

Fig. 2 represents a transverse section through a rotary rock drilling tool taken along the line 2—2 of Fig. 1 showing a sectorial fluid flow restrictor in closed position.

Fig. 3 represents a transverse section through a rotary rock drilling tool on the same plane as Fig. 2 showing a sectorial fluid flow restrictor in open position.

Fig. 4 represents a vertical section through the lower end of a rotary rock drilling tool showing an alternate form of the anvil and hammer head of Fig. 1.

Fig. 5 represents a vertical section through an intermediate length of a rotary rock drilling tool otherwise according to Fig. 1 showing shock absorber means.

Fig. 6 represents a transverse section through the apparatus shown in Fig. 5 taken along the line 6—6.

Fig. 7 represents a vertical section through the lower end of a rotary rock drilling tool showing an alternate form of the fluid-driven hammer mechanism.

Fig. 8 represents a transverse section through the apparatus shown in Fig. 7 taken along the line 8—8.

Referring now to Fig. 1, the percussive rotary rock drilling tool of this invention is shown attached to the bottom of a pipe string or drill collar 9 by a threaded joint. Any other suitable means of attachment may be used as well. In the tool itself 10 is a drill bit holder making connection at its upper end with the drill collar. This holder is generally tubular in form, and may be suitably parted and have appropriate joining means to allow installation of internal fittings. At its lower end holder 10 is threaded or otherwise suitably prepared to retain a replaceable drill bit assembly. This assembly comprises a base member 11 and cutting elements 12. Base member 11 has a central crown formation on its upper surface extending within drill bit holder 10, and around this crown has a plurality of fluid passageways 13. The crown of base member 11 is centrally drilled and tapped to receive a hardened replaceable anvil 14. The impact surface of this anvil is cut helically to provide at least one abrupt step as shown.

Within the holder 10 a turbine spindle assembly of which the cylindrical member 15 is the shaft is located concentrically and is supported by anvil 14. The outside diameter of shaft 15 is appreciably less than the inside diameter of holder 10 to provide an annular fluid passageway of substantial cross section area between the spindle shaft and the holder. At its lower end, spindle shaft 15 is drilled and tapped to receive a hardened replaceable hammer head 16. On its impact surface this head is cut helically to provide at least one abrupt step, the same number as those on anvil 14 cut in such sense that the hammer head and the shaft to which it is affixed will rise smoothly and then drop abruptly on the anvil as spindle shaft 15 is rotated.

The spindle assembly is guided vertically and concentrically in holder 10 by upper and lower bearings 17 and 18. These bearings are preferably rubber and cutless, and are fitted in retainer segments 19 and 20 which are located in grooves in the wall of holder 10. Segments 19 and 20 are extensively perforated vertically to provide fluid passageways in the bore of holder 10. At least one row of radially extending fluid guide vanes or blades 21 is set in drill bit holder 10. These are formed and spaced in such relation to an equal number of rows of radial blades 22 on shaft 15 that 21 and 22 comprise the fixed and moving blade elements of an axial flow hydraulic turbine. Spacing of vanes 21 and blades 22 must be such that the spindle assembly can rise and fall due to the interaction of hammer head 16 and anvil 14 without spindle blades striking holder vanes.

A flow restrictor sector 23 fitted in holder 10 extends inward horizontally. Likewise a restrictor sector 24 on spindle shaft 15 extends horizontally outward. Fig. 2 shows shaft 15 so turned in holder 10 that restrictor sector 24 is entirely out from under restrictor sector 23, and downward flow of fluid through the annular space between holder 10 and spindle shaft 15 is substantially blocked. Fig. 3 shows the spindle assembly turned approximately 180° from its position in Fig. 2 to bring the restrictor sectors substantially into line vertically and provide the greatest clear passage for flow of fluid past these restrictors. Referring back to Fig. 1, note that anvil 14 and restrictor sector 23 are stationary with respect to holder 10, and hammer head 16 and restrictor sector 24 on spindle shaft 15 are so installed that the sectors reach their closed position as shown in Fig. 2 at approximately the same time the hammer head drops off the high point of the anvil.

In the event that anvil 14 and hammer head 16 are each provided with more than one step on their matching surfaces, the restrictor sectors should be redesigned accordingly. For example, if there be two steps on the hammer head and anvil as shown in Figures 7 and 8 of

the drawing, holder **10** and spindle shaft **15** should each be fitted with two restrictor sectors **23A** and **23B** and **24A** and **24B** each of 90° arc and symmetrically spaced. If the hammer head and anvil have three steps each, the holder and spindle assembly should each have three equally spaced 60° restrictors. Restrictors **23** and **24** must be so spaced vertically that they will not come in contact as the spindle assembly rises and falls.

The operation of this invention as so far disclosed will now be considered. Drilling fluid such as drilling mud flows downwardly under pump pressure through the pipe string and into the bore of drill bit holder **10** while this holder and the bit assembly are being rotated by means not shown. After passing through bearing retainer **19**, the fluid enters the first row of guide vanes **21** which direct it against the first row of blades **22** on spindle shaft **15** imparting rotary motion to the spindle assembly relative to the drill bit holder **10**. The fluid then flows through any succeeding rows of vanes and blades giving up further energy to the spindle assembly. As this assembly rotates it will alternately rise and fall as hammer head **16** rides up and then drops abruptly on anvil **14**. This abrupt drop will provide a hammering action on the anvil, and a periodic percussive force will be transmitted to the cutting elements **12** with a frequency equal to the number of steps in anvil **14** times the rate of revolutions of spindle assembly with respect to bit holder **10**. Total weight of the hammer will be the sum of the weights of spindle shaft **15**, hammer head **16**, blades **22**, and flow restrictor **24**.

After leaving the last row of blades on spindle shaft **15**, the drilling fluid must flow through openings between sectorial flow restrictors **23** which are continuously being covered and uncovered as restrictor sectors **24** on the spindle shaft turn past them. When the openings past restrictors **23** are covered, fluid flow will be substantially blocked momentarily, and full fluid pumping pressure will be exerted on the upper surfaces of restrictors **24**. This pressure will impart a powerful downward thrust to the whole spindle assembly constituting the hammer just as high points on hammer head **16** ride off corresponding points on anvil **14**, and the hammer impact on the anvil and the percussive force transmitted to the cutting elements will be increased accordingly. Once past the flow restrictors, the drilling fluid will continue down through bearing retainer **20**, through drill bit base member **11**, around cutting elements **12**, and then up the annular space between the pipe string and the wall of the hole being drilled to carry out its normal function of displacing the drilling debris.

Fig. 4 shows a design of anvil and hammer head which supposes that all hammering force is to come from action of flow restrictors **23** and **24**. In this figure anvil **25** and hammer head **26** both have flat instead of helical and stepped impact surfaces. The hammer head is normally held out of contact with the anvil by a hardened ball **27** which is backed by compression spring **28** set in a bottomed axial hole in the anvil. This ball must have a diameter less than that of the axial hole in the anvil. The spring must be compressible to a height allowing full containment of the ball in the hole, and must be sufficiently strong to sustain the weight of the entire spindle assembly with anything less than nearly full fluid pump pressure on this assembly. At least one hole **29** is drilled radially through the anvil member to connect the annular fluid passage with the spring recess in the anvil. This hole allows fluid to flow freely in an out of the spring hole in the anvil with motion of the ball and spring.

With the anvil and hammer head arrangement of Fig. 4 substituted for that of Fig. 1, the spindle assembly will be driven down by fluid pumping pressure to compress spring **28** and deliver a blow on anvil **25** as shaft **15** turns to bring the flow restrictors into the closed relation to Fig. 2. As shaft **15** continues to turn and the flow restrictors assume the open relation of Fig. 3, static fluid thrust on the spindle assembly will be relieved to allow spring **28** to separate the hammer head and anvil. Accordingly, the spindle assembly will rise and fall and deliver blows on anvil **25** without any cam action but simply through the working of the sectorial flow restrictors and spring **28**.

With either of the hammer and anvil arrangements shown in Figs. 1 and 4, it is possible that undesirable shocks will be transmitted up the pipe string. This will depend on, among many things, the magnitude and frequency of the hammer impact and the dimensions of the pipe string. To localize hammer effects shock absorber means may be provided. A possible means is shown in Figures 5 and 6. In this figure **10***a* and **10***b* represent upper and lower drill bit holder sections. These sections are splined or otherwise flexibly connected longitudinally so that torque needed for the drill bit may be transmitted from upper section **10***a* to lower section **10***b*. A suitably formed shock absorbing element **10***c* made of rubber or other appropriate material is interposed between the upper and lower drill bit holder sections. This element will dampen any shock waves passing upward from drill bit holder lower section **10***b*. The shock absorber element may be bonded to the upper and lower drill bit holder sections by appropriate means to prevent fluid leakage between these sections.

The advantages of the hammer mechanisms which have been disclosed are numerous. Excepting the ball **27** and spring **28** of Fig. 4 which move only slightly, the sturdy turbine spindle assembly is the sole moving part. The cutless rubber bearings which guide this spindle are particularly well suited to operate submerged in a somewhat abrasive fluid. Fine clearances between spindle shaft and bearings are not needed, and fluid passages in general are of relatively generous size. A particular advantage is that the percussive force provided by this mechanism is not a function only of the drop of a static hammer weight through a given distance. The weight effect is augmented by hydraulic thrust accelerating the hammer as provided by operation of the sectorial flow restrictors. Indeed it has been shown that periodic percussive force on the drill bit may be provided by such operation alone.

What is claimed is:

1. A percussive rotary rock drilling tool comprising a tubular drill bit holder for attachment to the lower end of a pipe string; a drill bit assembly removably secured to the lower end of said holder and having a plurality of fluid passages therein to form continuations of the bore of said holder; a hardened anvil member with upper surface helically cut to provide at least one abrupt cam step removably secured in the center of the upper surface of said drill bit assembly within the bore of said holder; a spindle assembly freely guided vertically and concentrically in said holder, supported rotatably on said anvil member, and adapted to rise gradually upon and fall abruptly onto said anvil member in the course of rotation relative thereto, whereby providing percussive action through at least its own weight upon said anvil member, said spindle assembly comprising a shaft having an outside diameter appreciably less than the inside diameter of said holder whereby an annular passageway for fluid flow between said shaft and said holder is formed, a hardened hammer head member with lower surface cut similarly to the upper surface of said anvil member but to the opposite hand removably secured to the lower end of said shaft, and at least one row of projections set circumferentially around said shaft and extending outwardly therefrom, said projections being shaped appropriately for moving blades of a fluid powered axial flow turbine; and a number of rows of projections equal to the number on said shaft set circumferentially around the inner wall of said holder and extending inwardly therefrom, said projections being shaped appropriately for stationary blades of a fluid

powered axial flow turbine, and said rows of projections in said holder being set at such height and with such spaced relation therein to mesh with said rows of projections on said shaft as fixed and moving blade elements of an axial flow turbine operable by drilling fluid flowing downwardly through said drill bit holder.

2. A percussive rotary rock drilling tool according to claim 1 in which said spindle assembly is freely guided vertically and concentrically within said drill bit holder by upper and lower bearing assemblies set circumferentially in longitudinally spaced relation in said holder and extending into and extensively perforated for fluid flow in the bore of said holder.

3. A percussive rotary rock drilling tool according to claim 2 in which said bearing assemblies comprise bearing retainer segments and cutless rubber bearing elements.

4. A percussive rotary rock drilling tool according to claim 1 in which said drill bit holder comprises upper and lower sections having a longitudinally flexible joint capable of transmitting torque needed for said drill bit from said upper section to said lower section, and shock absorbing means interposed between said upper and lower sections.

5. A percussive rotary rock drilling tool comprising a tubular drill bit holder for attachment to the lower end of a pipe string; a drill bit assembly removably secured to the lower end of said holder and having a plurality of fluid passageways therein to form continuations of the bore of said holder; a spindle assembly freely guided vertically and concentrically in said holder comprising a shaft having an outside diameter appreciably less than the inside diameter of said holder whereby an annular passageway for fluid flow between said shaft and said holder is formed, and at least one row of projections set circumferentially around said shaft and extending outwardly therefrom, said projections being shaped appropriately for moving blades of a fluid powered axial flow turbine; a number of rows of projections equal to the number on said shaft set circumferentially around the inner wall of said holder and extending inwardly therefrom, said projections being shaped appropriately for stationary blades of a fluid powered axial flow turbine, and said rows of projections in said holder being set at such height and with such spaced relation therein to mesh with said rows of projections on said shaft as fixed and moving blade elements of an axial flow turbine operable by drilling fluid flowing downwardly through said drill bit holder; means for supporting said spindle assembly on said drill bit assembly whereby said spindle can be rotated and rise and fall with respect to said drill bit and deliver a hammer blow thereon; and fluid thrust means comprising a first flow restrictor sector of approximately 180° included angle affixed to said spindle shaft and extending outwardly therefrom to a radius slightly less than the inner radius of said holder and a second flow restrictor sector of approximately 180° included angle affixed to said drill bit holder and extending inwardly from the inner wall thereof to a radius slightly larger than that of said spindle shaft and having a closely spaced axial relation to said first flow restrictor sector whereby a sectorial fluid flow passage in the bore of said drill bit holder alternately openable and closeable by rotary motion of said spindle with respect to said holder is provided.

6. A percussive rotary rock drilling tool according to claim 5 in which said means for supporting said spindle assembly on said drill bit assembly whereby said spindle can be rotated and rise and fall with respect to said drill bit and deliver a hammer blow thereon comprises a hardened anvil member removably secured in the center of the upper surface of said drill bit assembly within the bore of said holder, said anvil member having its upper surface helically cut to provide an abrupt cam step; and a hardened hammer head member with lower surface

cut with an abrupt step cut similarly to the upper surface of said anvil member but to the opposite hand removably secured to the lower end of said spindle shaft, the orientation of said anvil member with respect to said drill bit holder and of said hammer head member with respect to said spindle shaft being such that the abrupt step on said hammer head will be aligned with the step on said anvil when said first flow restrictor sector affixed to said spindle shaft is so oriented with respect to said second flow restrictor sector affixed to said holder to substantially close the bore of said drill bit holder.

7. A percussive rotary rock drilling tool according to claim 5 in which said means for supporting said spindle assembly on said drill bit assembly whereby said spindle can be rotated and rise and fall with respect to said drill bit and deliver a hammer blow thereon comprises a hardened anvil member removably secured in the center of the upper surface of said drill bit assembly within the bore of said holder, said anvil member having a flat upper surface and being provided with a bottomed axial hole opening through its upper surface and at least one radial hole from its outer side surface to said axial hole; a hardened hammer head member removably secured to the lower end of said spindle shaft, said hammer head having a flat lower surface; a compression spring seated and freely workable in said axial hole in said anvil; and a hardened ball surmounting said spring whereby it is pressed against the lower face of said hammer, said ball having a diameter less than that of the axial hole in said anvil member, and said spring being compressible to such height to allow full containment of said ball in said axial hole, and being of such strength to support said hammer head and spindle assembly out of contact with said anvil member in the absence of substantial fluid pressure on said first flow restrictor sector affixed to said spindle in its position with respect to said second flow restrictor sector affixed to said drill bit holder wherein the base of said holder is substantially closed.

8. A percussive rotary rock drilling tool according to claim 5 in which said drill bit holder comprises upper and lower sections having a longitudinally flexible joint capable of transmitting torque needed for rotation of said drill bit in normal drilling device from said upper to said lower section, and shock absorbing means interposed between said upper and lower sections.

9. A percussive rotary rock drilling tool comprising a tubular drill bit holder for attachment to the lower end of a pipe string; a drill bit assembly removably secured to the lower end of said holder and having a plurality of fluid passageways therein to form continuations of the bore of said holder; a spindle assembly freely guided vertically and concentrically in said holder comprising a shaft having an outside diameter appreciably less than the inside diameter of said holder whereby an annular passageway for fluid flow between said shaft and said holder is formed, and at least one row of projections set circumferentially around said shaft and extending outwardly therefrom, said projections being shaped appropriately for moving blades of a fluid powered axial flow turbine; a number of rows of projections equal to the number on said shaft set circumferentially around the inner wall of said holder and extending inwardly therefrom, said projections being shaped appropriately for stationary blades of a fluid powered axial flow turbine, and said rows of projections in said holder being set at such height and with such spaced relation therein to mesh with said rows of projections on said shaft as fixed and moving blade elements of an axial flow turbine operable by drilling fluid flowing downwardly through said drill bit holder; means for supporting said spindle assembly on said drill bit assembly whereby said spindle can be rotated and rise and fall with respect to said drill bit and deliver a hammer blow thereon; and fluid thrust means comprising a first set of at least two coplanar fluid flow restrictor sectors of mutually equal individual included

angles and having a total included angle of approximately 180° affixed to said spindle shaft with even angular spacing about the circumference thereof and extending outwardly therefrom to a radius slightly less than the inner radius of said holder and a second set of coplanar fluid flow restrictor sectors, the same in number as the restrictor sectors in said first set, and having mutually equal individual included angles and a total included angle of approximately 180° affixed to said drill bit holder with even angular spacing about the inner wall thereof and extending inwardly therefrom to a radius slightly larger than that of said spindle shaft and having a closely spaced axial relation to said restrictor sectors of said first set whereby at least two sectorial fluid flow passages in the bore of said drill bit holder alternately openable and closeable together by rotary motion of said spindle with respect to said holder are provided.

10. A percussive rotary rock drilling tool according to claim 9 in which said means for supporting said spindle assembly on said drill bit assembly whereby said spindle can be rotated and rise and fall with respect to said drill bit and deliver a hammer blow thereon comprises a hardened anvil member removably secured in the center of the upper surface of said drill bit assembly within the bore of said holder, said anvil member having its upper surface cut helically to provide a number of evenly spaced abrupt cam steps equal to the number of flow restrictor sectors in said second set thereof affixed to said drill bit holder; and a hardened hammerhead member with lower surface cut helically with abrupt steps similarly to the upper surface of said anvil member but to the opposite hand removably secured to the lower end of said spindle shaft, the orientation of said anvil member with respect to said drill bit holder and of said hammer head member with respect to said spindle shaft being such that an abrupt step on said hammer head will be aligned with a step on said anvil whenever said first set of flow restrictor sectors affixed to said spindle shaft is so oriented with respect to said second set of flow restrictor sectors affixed to said holder to substantially close the bore of said drill bit holder.

11. A percussive rotary rock drilling tool according to claim 9 in which said means for supporting said spindle assembly on said drill bit assembly whereby said spindle can be rotated and rise and fall with respect to said drill bit and deliver a hammer blow thereon comprises a hardened anvil member removable secured in the center of the upper surface of said drill bit assembly within the bore of said holder, said anvil member having a flat upper surface and being provided with a bottomed axial hole opening through its upper surface and at least one radial hole from its outer side surface to said axial hole; a hardened hammerhead member removably secured to the lower end of said spindle shaft, said hammerhead having a flat lower surface; a compression spring seated and freely workable in said axial hole in said anvil; and a hardened ball surmounting said spring whereby it is pressed against the lower face of said hammer head, said ball having a diameter less than that of the axial hole in said anvil member, and said spring being compressible to such height to allow full containment of said ball in said axial hole, and being of such strength to support said hammerhead and spindle assembly out of contact with said anvil member in the absence of substantial fluid pressure on said first set of flow restrictor sectors affixed to said spindle in a position with respect to said second set of flow restrictor sectors affixed to said drill bit holder wherein the bore of said holder is substantially closed.

12. A percussive rotary rock drilling tool according to claim 9 in which said drill bit holder comprises upper and lower sections having a longitudinally flexible joint capable of transmitting torque needed for rotation of said drill bit in normal drilling service from said upper to said lower section, and shock absorbing means interposed between said upper and lower sections.

References Cited in the file of this patent

UNITED STATES PATENTS

2,613,917	Postle Waite	Oct. 14, 1952
2,646,962	Wagner	July 28, 1953
2,738,956	Bielstein	Mar. 20, 1956
2,750,154	Boice	July 12, 1956
2,795,398	Ragland	July 11, 1957