Oct. 1, 1963 J. A. ZUBLIN 3,105,560

WEIGHT CONTROLLED VIBRATORY DRILLING DEVICE

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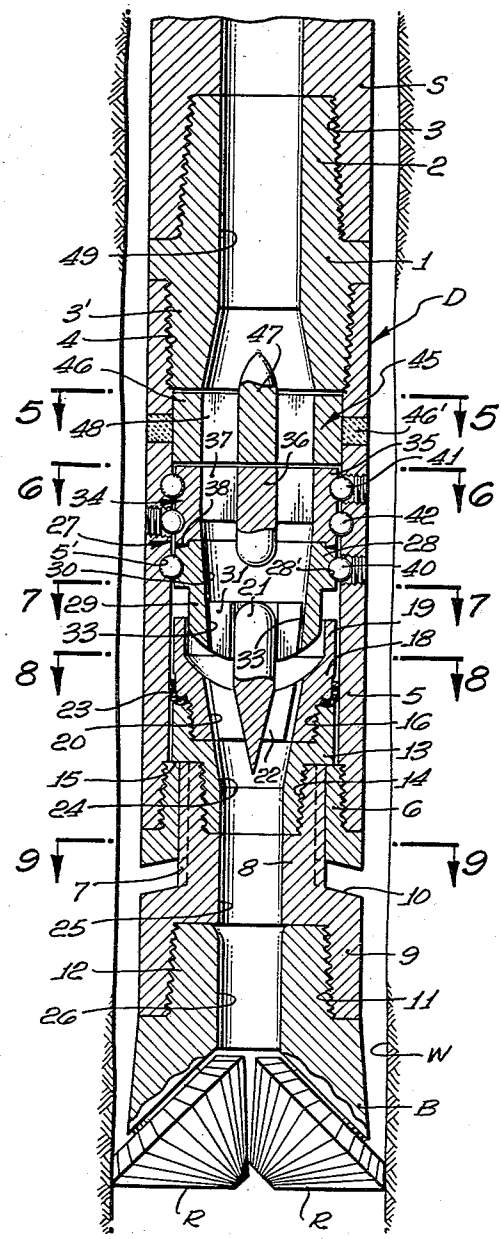


FIG. 1.

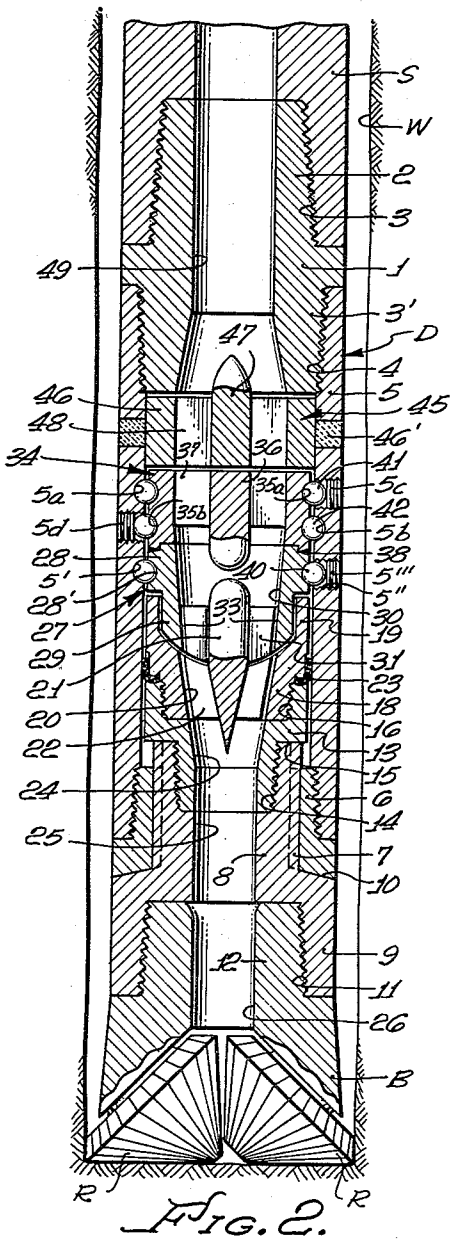


FIG. 2.

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WEIGHT CONTROLLED VIBRATORY DRILLING DEVICE

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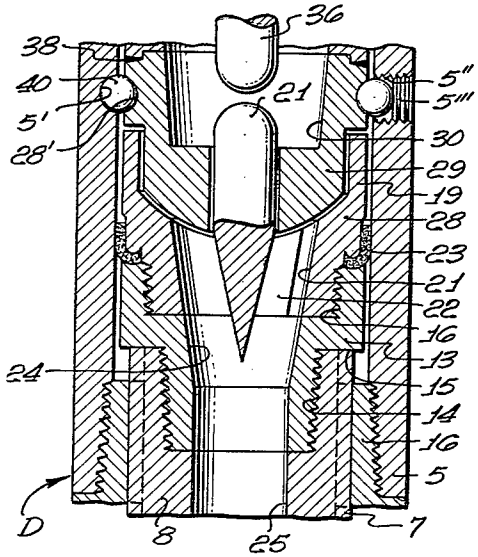


FIG. 3.

FIG. 4.

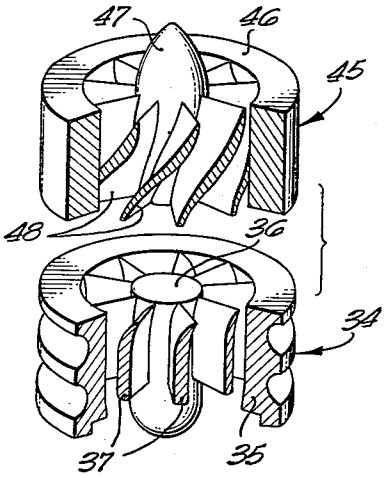


FIG. 6.

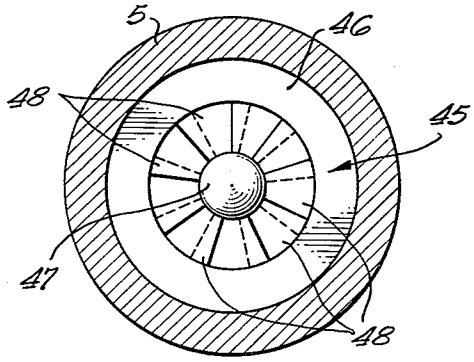
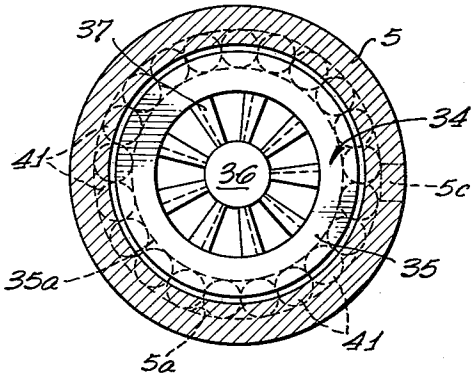


FIG. 5.



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WEIGHT CONTROLLED VIBRATORY DRILLING DEVICE

Filed Jan. 4, 1960 3 Sheets-Sheet 3

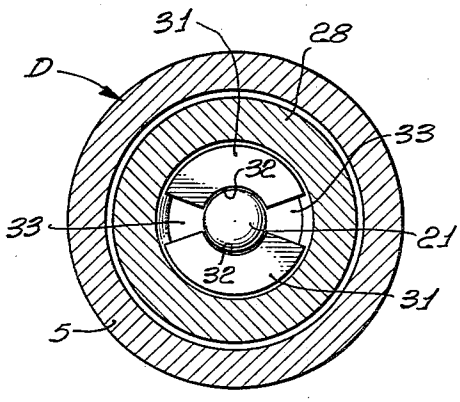


FIG. 7.

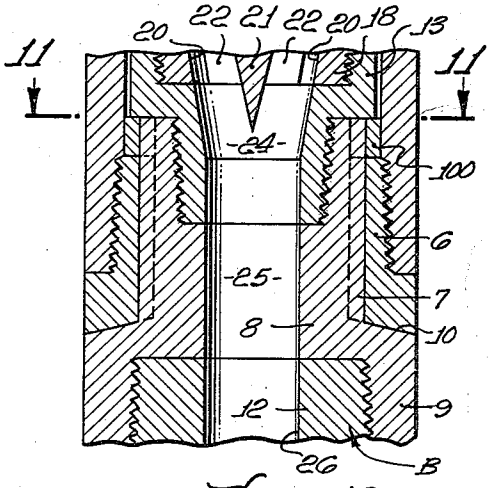


FIG. 10.

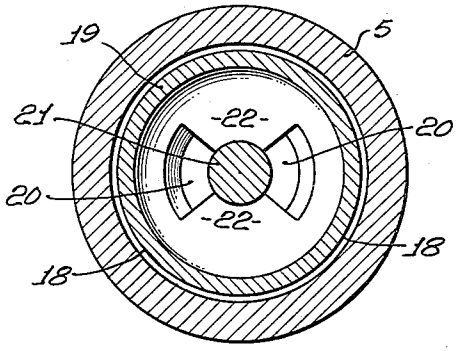


FIG. 8.

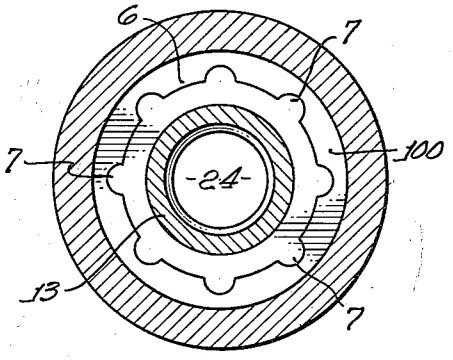


FIG. 11.

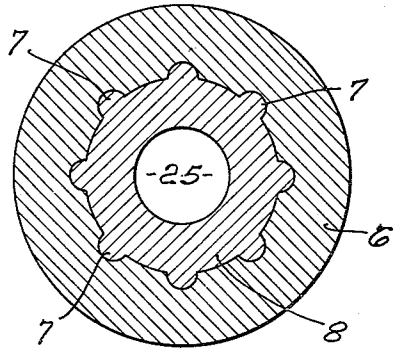


FIG. 9.

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United States Patent Office 3,105,560 Patented Oct. 1, 1963

3,105,560
WEIGHT CONTROLLED VIBRATORY DRILLING DEVICE

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Filed Jan. 4, 1960, Ser. No. 334
15 Claims. (Cl. 175—56)

The present invention relates to vibratory drilling devices and more particularly to an improved drilling device which takes advantage of the substantial and significant energy potential of the drilling fluids ordinarily circulated through a drill string in the drilling of oil and gas wells and the like.

It is the conventional practice in the case of drilling oil and gas wells, and more particularly in the drilling of oil and gas wells by what is commonly called the "rotary" drilling method, to circulate down through the drill string or drill pipe so-called drilling fluids which serve to flush to the earth's surface cuttings occasioned by penetration of the bit as the bore hole progresses. Obviously, the drilling fluid so circulated has substantial energy potential which in conventional rotary drilling methods is not utilized in the advancement of the drill bit.

Among the primary objectives of the present invention is the provision of a vibratory drilling device which avails of the energy potential of the drilling fluid to effect or assist in the drilling operation.

In my Patent No. 2,743,083 dated April 24, 1956, for Apparatus to Impart Vibrating Motion to a Rotary Drill Bit, there is disclosed an apparatus for imparting vibrating motion to a rotating drill bit including a rotatable fluid flow interrupter for intermittently interrupting the flow of drilling fluid through the string of drill pipe to the drill bit. This interrupter is driven by a portion of the drilling fluid flowing through the drill string, and as a result of the interruption to the flow of drilling fluid high frequency vibrations are created so as to vibrate the drill bit during the drilling operation, thus to advance the bit into the earth formation.

In the drilling of oil and gas wells, particularly at substantial depths, there is a substantial kinetic energy available by reason of the circulation of drilling fluid, and inasmuch as the kinetic energy or inertia force available is proportional to the velocity of the circulating drilling fluid the kinetic energy may be availed of by the partial and intermittent interruption of the fluid flow without adversely curtailing or diminishing circulation to the surface through the bore hole outside the drill string. However, unless means be provided for varying the extent to which the circulation of fluid is interrupted, then the only practical way to vary the application of available kinetic energy on the drill bit is to vary the interruption cycle time by varying the velocity of the circulating fluid since the mass of the drilling fluid is more particularly determined by the variable well conditions, as for example, the down hole pressure conditions which may be encountered and which must be overcome by the drilling fluid in order to prevent the well from blowing out. On the other hand, the velocity of the drilling fluid cannot be varied except within the practical limits dictated by the type of formation being drilled through, since the velocity of the fluid returning to the surface must be sufficient to carry specific cuttings to the surface without permitting such cuttings to fall out or settle to the bottom of the hole.

Accordingly, the present invention contemplates as an object the provision of a vibratory drilling device having means operated by the circulation of drilling fluid through

the device for intermittently partially interrupting the flow of drilling fluid through the device so as to impose on the drill bit beneath the device significant fluid inertia forces causing high frequency vibrations of the drill bit to effect penetration of the bit through the earth formation, wherein the device is so constructed as to vary the extent or degree to which the circulation is interrupted, as a function of the weight of the drill string or drill pipe above the drilling device.

In the drilling of oil and gas wells as is well known to those skilled in the art, it is the practice to support the drill stem at the earth's surface so that the string of pipe is in tension down to a predetermined point known as the neutral point, below which point the drill string is in compression. Thus, from the neutral point in the drill string to the present vibrating device, the weight of the drill string will be imposed on the device, and as more or less of the drill string is supported in tension the weight on the device will be proportionately varied. Therefore, it is another object of the invention to provide a drilling device of the type aforementioned having a fluid flow interrupter providing a flow passage which is varied so as to vary the extent or degree to which the circulation of drilling fluid through the device is interrupted, upon variation in the weight of the drill string which is imposed upon the device. In this connection, it is contemplated that on the order of 80% of the circulation of drilling fluid through the interrupter of the invention may be interrupted per interruption cycle while the remainder of the fluid is free to circulate so as to carry formation cuttings to the surface. The percentage or degree of circulation interruption may be decreased by reducing the weight of the drill string which is imposed upon the drilling device so that less of the circulation is interrupted with resultant reduction in the inertia force or kinetic energy employed to effect vibration of the drilling device and thus to effect advancement of the drilling bit.

Yet another object of the invention is to provide a drilling device which is extremely rugged yet easy to manufacture and install in a string of drill pipe.

Other objects and advantages of the invention will be hereinafter described or will become apparent to those skilled in the art, and the novel features of the invention will be defined in the appended claims.

Referring to the drawings:

FIG. 1 is a longitudinal sectional view through a vibratory drilling device made in accordance with the invention and disposed in a well drilling string with the interrupter parts shown in a position for effecting a minimum interruption to the circulation of drilling fluid through the device during each interrupter cycle;

FIG. 2 is a view corresponding to FIG. 1 but showing the interrupter parts in condition for effecting a maximum interruption to the flow of circulation of drilling fluid through the device during each interrupter cycle;

FIG. 3 is an enlarged fragmentary detail view in longitudinal section more particularly showing the interrupter device with the parts in position for interrupting the flow of fluid therethrough;

FIG. 4 is a detail view in perspective of the turbine drive means for the interrupter with certain of the parts broken away and shown in section;

FIG. 5 is a transverse sectional view on a slightly enlarged scale as taken on the line 5—5 of FIG. 1;

FIG. 6 is a transverse sectional view on a slightly enlarged scale as taken on the line 6—6 of FIG. 1;

FIG. 7 is a transverse sectional view on a slightly enlarged scale as taken on the line 7—7 of FIG. 1;

FIG. 8 is a transverse sectional view on a slightly enlarged scale as taken on the line 8—8 of FIG. 1;

FIG. 9 is a transverse sectional view on a slightly enlarged scale as taken on the line 9—9 of FIG. 1;

FIG. 10 is a fragmentary view in section of a modification of the interrupter device; and

FIG. 11 is a transverse sectional view as taken on the line 11—11 of FIG. 10.

Like reference characters in the several views of the drawings and in the following description designate corresponding parts.

Referring to FIG. 1, the drilling device of the invention is generally designated at D and is installed in a drilling string between a conventional bit B and the lower end of a drill string S which may be constituted by a so-called drill collar. A drill collar, as well recognized in the art, is a rigid, hollow, relatively heavy length of pipe adapted to provide a rigid support for a drill bit. Any number of drill collars may be employed above the device in order to assure directional control of the hole being drilled and if desired to afford additional weight to be imposed upon the drilling device for a purpose which will hereinafter be more particularly described. In addition, if desired, a further drill collar or bit sub may be installed between the bit B and the device D.

The device at its upper end includes a coupling 1 having an externally threaded pin 2 engageable in the internally threaded box 3 at the lower end of the drill string S. At its lowered end the connector 1 has an externally threaded pin 3' adapted to be threadedly received in the internally threaded upper end 4 of a tubular housing 5. At the lower end of the housing 5 there is appropriately provided or threadedly attached an externally threaded abutment sleeve 6 composed of hard material capable of withstanding heavy loads without adverse effect. Reciprocably disposed in the sleeve 6 and keyed thereto so as to preclude relative rotation as by a plurality of inter-fitting splines or ribs and grooves as indicated at 7 is the neck 8 of a connector sub 9 having a shoulder 10 opposed to the lower extremity of the sleeve 6 for abutting engagement therewith to limit movement of the device D downwardly relative to the connector sub 9. In the illustrative embodiment the connector sub 9 is provided with an internally threaded box 11 adapted for connection to the stem 12 of the bit B.

Movement of the connector sub 9 downwardly relative to the housing 5 is limited by a coupling 13 threadedly connected to the neck 8 of connector sub 9 as by a threaded connection 14 and having a shoulder 15 engageable with the inner end of the sleeve 6. Thus, it is apparent that the connector sub 9 and the housing 5 are interconnected for relative reciprocation, but the spline connections 7 preclude relative rotation therebetween.

Threadedly connected to the connector 13 as at 16 is an interrupter stator 18 having an upstanding hollow section 19 and a pair of gradually tapered flow passages 20 therethrough at the opposite sides of an upstanding pin 21 supported in the body of the interrupter stator by a pair of opposed webs 22, as best seen in FIG. 8. Interposed between the connector 13 and the interrupter stator 18 is a packing ring 23 which prevents the passage of drilling fluids between the interrupter stator and the housing 5. Thus, it becomes apparent that the interrupter stator by virtue of the provision of the sealing ring 23 constitutes a piston reciprocable in the housing 5, and the neck 8 of connector sub 9 constitutes a rod connecting the piston to the bit B. The piston is ported, however, by means of the passageways 20 which lead to a tapered passage 24 through the connector 13 and thence into a bore 25 through connector sub 9 and through a bore 26 in the neck 12 of bit B from whence fluid passes into the well bore generally designated W so as to pass upwardly in the well bore outside the device and then to the top of the well.

A rotor assembly is generally designated at 27 and includes an interrupter rotor section 28 having a downwardly extending portion 29 disposed in the upstanding annular portion 19 of interrupter stator 18. The interrupter rotor 28 has a downwardly tapering passage 30 therethrough partially closed at its lower end by arcuate segments 31 (see FIG. 7) disposed in diametrically opposed relation and having arcuate inner peripheries 32 disposed about the upstanding interrupter stator pin 21. These arcuate rotor segments 31 constitute valves which will upon rotation of the interrupter rotor 28 partially interrupt the flow of drilling fluid through passages 20 in interrupter stator 18, and between the arcuate segments 31 are flow passages 33 which when aligned with flow passsages 20 in the interrupter stator 18 enable a free flow of fluid through the interrupter assembly for drilling fluids circulating through the device. The rotor assembly 27 above the interrupter rotor 28 has an interrupter drive turbine rotor 34 (see FIG. 4) comprising an annular body 35 having a hub 36 and a plurality of circumferentially spaced radiating fins 37. Preferably, the turbine rotor 34 is welded as at 38 to the interrupter rotor 28, but of course, other suitable assembly means may be availed of.

Means are provided for rotatably supporting the rotor assembly 27 in the housing 5. In the illustrative embodiment such means are composed of a series of bearing balls. The interrupter rotor 28 is provided with an outer peripheral annular ball race 28' and the housing 5 is provided with an opposing ball race 5' in which is a plurality of bearing balls 40. These balls 40 are supplied to the opposing races 5' and 28' through an opening 5'' in the housing 5 which is closed by a plug 5''' after insertion of a suitable number of the balls 40. Similarly, a purality of balls 41 and 42 are disposed in vertically spaced races *5a*, *5b* and *35a* and *35b* in the housing 5 and the turbine rotor 34, respectively, the balls 41 being retained in the races by plug *5c* and the balls 42 being retained in their races by a plug *5d*.

Disposed in the housing 5 above the rotor assembly 27 and more particularly in close proximity to the turbine rotor 34 is a turbine stator 45 (see FIG. 4) composed of an annular body 46, a central hub 47 and radiating fins or vanes 48 spaced circumferentially and extending radially between the hub 47 and the body 46. The turbine stator 45 is suitably secured in the body 5 as by plug welds at 46' or, of course, may be otherwise secured in place.

Leading through the connector 1 is a fluid passage 49 which carries drilling fluid from the drill string S to the turbine stator 45. It will be noted that the turbine stator fins or vanes 48 are angularly disposed so as to impart a circumferential component of motion to drilling fluid passing therebetween, which fluid impinges upon the vanes 37 of the rotor 34 so as to drive the rotor assembly 27 with consequent rotation of the interrupter rotor 28. Thus, during circulation of drilling fluid through the device the rotor assembly 27 will continuously revolve and fluid will pass downwardly through the segmental passages 33 lying between segmental webs 31 and thence through openings 20 in interrupter stator 18.

In the operation of the device it will be run into the well on the drill string S with the parts in the condition shown in FIG. 1, shoulder 10 of connector sub 9 being spaced downwardly from sleeve 6, and with a resultant maximum spacing and free flow area between interrupter rotor 28 and interrupter stator 18. When the bit B is landed at the bottom of the well W as shown in FIG. 2, the weight of the drill string above the device will cause the housing to move downwardly relative to connector sub stem 8 until sleeve 6 abuts with shoulder 10 at which time there will be a minimum axial spacing between interrupter rotor 28 and interrupter stator 18 as shown in FIG. 2.

Accordingly, circulation of drilling fluid through the device will cause rotation of the turbine rotor 35, thus causing interrupter rotor segments 31 to pass over ports

or passageways 20 through interrupter stator 18 to partially interrupt the flow of drilling fluid through the device with resultant water hammer effect proportional to the mass and velocity of the drilling fluid. The extent or degree to which circulation of fluid will not be interrupted is governed by the axial clearance between the interrupter rotor 28 and the stator 18. The kinetic energy of drilling fluid interrupted by the interrupter device will, of course, be imposed upon the piston constituted by the interrupter stator as referred to above to force the bit into the formation with powerful rapid shocks of a frequency determined by the velocity of the drilling fluid acting on the interrupter drive turbine and of a magnitude proportional to the velocity of the fluid and its mass, under the control of the driller or operator of the drill string at the surface, who can by conventional methods control the portion of the weight of the drill string which is imposed upon the device D and more particularly which is imposed upon the housing 5 so as to hold the interrupter rotor 28 in a desired relation to the stator 18 to vary the axial spacing therebetween.

It should be noted that the interrupter rotor 28 is substantially convex on its lower surface and is opposed by a complemental concave surface of the interrupter stator 18. The fluid passing between these opposed concave and convex surfaces when rotor elements 31 are in overlying relation to stator passages 20 travels in an arcuate downward path. Therefore, while fluid velocity through these parts is at its peak when the flow is at a minimum, the resultant fluid erosion is significantly reduced. In addition, the stator pin 21 affords a blockage against the flow of fluid in a short direct path from rotor passages 30 to stator passages 20 when rotor elements 31 partially block stator passages 20, the fluid being forced to flow circumferentially about the pin 21 to stator passages 20 which, as aforementioned, taper downwardly. By reason of this structure, sharp changes in the direction of fluid flow are minimized, the life of the parts is enhanced since they are not subjected to the otherwise severe wearing effects of high velocity abrasive drilling fluid.

It will be apparent that as the flow of fluid is interrupted through the device, the hydraulic forces derived from the circulating fluid, while acting downwardly on the piston constituted by the interrupter stator 18, will also act upwarly on the drill string. The extent that this upward component of force on the drill string is effective to enable actual separation of the interrupter rotor and interrupter stator will be dependent upon the weight of the drill string which is imposed upon the device D. Therefore, under the control of the driller significant and effective successive intermittent water hammer effects will be created for vibrating the bit B or imposing intermittent fluid inertia forces thereon to drive the bit into the formation.

Such progression of the bit into the formation, it will be understood, is not dependent upon rotation of the drill string as in the rotary drilling method, but is independent of such rotation. However, if desired, the invention may be availed of while rotating the drill string to effect progression of the bit in accordance with the conventional rotary drilling method and augmenting such a progression by the successive water hammer effects created by virtue of the present invention.

Referring to FIG. 10, there is shown a modification of the invention in which a spacer 100 is interposed between the sleeve 6 and the interrupter stator 18 so as to prevent relative longitudinal movement of the bit relative to the housing 5 of the drilling device. Under these circumstances, intermittent interruptions in the flow of drilling fluid caused by the interrupter previously described will create high frequency shock waves which will be transmitted to the entire string of drill pipe and drill collars which is virtually an elastic string, thus causing high frequency vibrations of the entire drilling string mass which will create bit vibrations of increased frequency. The high frequency vibration of the entire drill string coupled with the intermittent water hammer effect created by the interrupter will further enhance the penetration rate of the bit through the formation.

While a conventional bit B has been herein shown, including toothed roller cones R, it will be understood that any conventional form of bit may be employed without departing from the spirit of the invention.

Moreover, while specific structural details have been shown and described, it should be understood that changes and alterations may be resorted to without departing from the spirit of the invention as defined in the appended claims.

I claim:

1. Apparatus for imparting vibrating motion to a drill bit, comprising: a housing adapted to be disposed in a string of drill pipe above the drill bit; means in said housing for intermittently interrupting the flow of drilling fluid therethrough including an interrupter stator and an interrupter rotor; said interrupter parts being supported in said housing for relative movement one towards the other; and a connector device connected to one of said interrupter parts for axial movement therewith and projecting from said housing for connection to the drill bit in the drill string; said housing and said connector device having coengaged means axially movable relative to one another for transmitting torque to the drill bit and for allowing movement of said interrupter parts one toward the other.

2. Apparatus for imparting vibrating motion to a drill bit, comprising: a housing adapted to be disposed in a string of drill pipe above the drill bit; means in said housing for intermittently interrupting the flow of drilling fluid therethrough including an interrupter stator and an interrupter rotor; said interrupter parts being supported in said housing for relative movement one towards the other; and a connector device connected to one of said interrupter parts for axial movement therewith and projecting from said housing for connection to the drill bit in the drill string; said connector and said housing having opposing shoulders engageable with one another upon movement of said interrupter parts one towards the other; said connector and said housing also having coengaged means axially movable relative to one another for transmitting torque to the drill bit and for allowing movement of said interrupter parts one toward the other.

3. Well drilling apparatus, comprising: a string of drill pipe; a drill bit at the lower end of said drill pipe; a vibratory device interposed in said drill pipe above said bit; said device comprising an elongated housing having a connector at one end; a connector reciprocable in said housing at the other end thereof and projecting therefrom; one of said connectors being connected to said drill pipe and the other of said connectors being connected to said bit; fluid flow interrupter means in said housing including a rotary part and a non-rotary part; one of said parts being connected to said reciprocable connector and shiftable axially in said housing relative to the other part for varying the extent of fluid interruption of said interrupter means; means for rotating said rotary interrupter part upon circulation of drilling fluid through the device; and coengaged means on said reciprocable connector and said housing for transmitting torque to said bit.

4. Apparatus as defined in claim 3, wherein the means for rotating said rotary interrupter part comprises a turbine stator carried by said housing and a turbine rotor carried by said rotary interrupter part.

5. Apparatus as defined in claim 3, wherein said interrupter parts each have arcuate openings and webs.

6. Apparatus as defined in claim 3, including a spacer blocking said reciprocable connector against movement in said housing.

7. Apparatus as defined in claim 3, wherein said axially

shiftable interrupter part is provided with means sealingly engaging said housing.

8. A well drilling apparatus for a string of drill pipe having a drill bit at the lower end of said string, comprising: an elongated housing connectable at one end in said pipe string; a connector reciprocable in the other end of said housing and projecting beyond the housing for connection in said string; a drilling fluid flow passage through said housing and said connector; a fluid flow interrupter stator on said connector and reciprocable in said housing; a fluid flow interrupter rotor rotatably mounted in said housing; said stator and rotor having flow passages cyclically aligned with one another upon rotation of said rotor; and fluid flow responsive means in said housing for driving said rotor.

9. A well drilling apparatus for a string of drill pipe having a drill bit at the lower end of said string, comprising: an elongated housing connectable at one end in said pipe string; a connector reciprocable in the other end of said housing and connectable in said string; a drilling fluid flow passage through said housing and said connector; a fluid flow interrupter stator on said connector and reciprocable in said housing; a fluid flow interrupter rotor rotatably mounted in said housing; said stator and rotor having flow passages cyclically aligned with one another upon rotation of said rotor; a drilling fluid flow responsive turbine rotor connected to said interrupter rotor; and a turbine stator in said housing adjacent to said turbine rotor.

10. A well drilling apparatus for a string of drill pipe having a drill bit at the lower end of said string, comprising: an elongated housing connectable at one end in said pipe string; a connector reciprocable in the other end of said housing and connectable in said string; a drilling fluid flow passage through said housing and said connector; a fluid flow interrupter stator on said connector and reciprocable in said housing; sealing means between said stator and said housing; a fluid flow interrupter rotor rotatably mounted in said housing; said stator and rotor having flow passages cyclically aligned with one another upon rotation of said rotor; and fluid flow responsive means in said housing for driving said rotor.

11. A well drilling apparatus for a string of drill pipe having a drill bit at the lower end of said string, comprising: an elongated housing connectable at one end in said pipe string; a connector reciprocable in the other end of said housing and connectable in said string; a drilling fluid flow passage through said housing and said connector; a fluid flow interrupter stator on said connector and reciprocable in said housing; a fluid flow interrupter rotor rotatably mounted in said housing; said stator and rotor having flow passages cyclically aligned with one another upon rotation of said rotor; said housing and said connector having opposed portions engageable for limiting reciprocation of said connector in opposite directions; said opposed portions being located to prevent said stator from engaging said rotor to enable limited uninterrupted flow through said flow passage; and fluid flow responsive means in said housing for driving said rotor.

12. A well drilling apparatus for a string of drill pipe having a drill bit at the lower end of said string, comprising: An elongated housing connectable at one end in said pipe string; a connector reciprocable in the other end of said housing and connectable in said string; a drilling fluid flow passage through said housing and said connector; said connector having a stem slidable in said body and an outward projection abutable with the end of said housing to limit inward movement of said connector in said housing; a ported stator at the inner end of said stem; means sealing said stator to said housing; and a rotor assembly rotatably disposed in said housing above said stator and including a ported member adjacent said stator and a fluid flow responsive rotor above said ported member for driving the latter.

13. Well drilling apparatus for a string of drill pipe having a drill bit on the lower end, comprising: an elongated housing connectable at its upper end to the drill string above it and having a longitudinally extending fluid passage; a fluid flow interrupter rotor rotatably mounted in the housing passage; a fluid flow interrupter stator mounted within the housing passage downstream from the rotor, said rotor and said stator each having fluid passageways therethrough cyclically intercommunicable with each other upon rotation of the rotor; and means for connecting the stator rigidly to the drill bit below the housing and supporting the stator for axial movement toward and away from the rotor for variably restricting the flow of fluid through the housing.

14. Well drilling apparatus as in claim 13 that includes sealing means carried by the last mentioned means and engaging the walls of said housing passage whereby the stator acts as a piston filling the passage and exposed to pressure of fluid therein.

15. A fluid responsive, vibratory well drilling device for a string of drill pipe having a drill bit at the lower end of said string, comprising: a housing connectable at its upper end to the drill string and defining a fluid passage therethrough; and means for intermittently restricting the flow of drilling fluid through said passage to produce variable water hammer effects responsive to variation of the weight of the drill string imposed on the device, said means including a pair of relatively rotatable interrupter parts in said passage and one of which is movable axially of the housing with respect to the other part to vary the spacing between the parts and thereby the restriction imposed on fluid flow through the passage, connector means interconnecting said movable interrupter part to the drill string below the device, and means limiting the approach of the interrupter parts toward each other to prevent mutual contact whereby a predetermined minimum flow of fluid is maintained at all times.

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