

May 25, 1965

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3,185,227

WELL DRILLING APPARATUS

Filed March 2, 1962

2 Sheets-Sheet 1

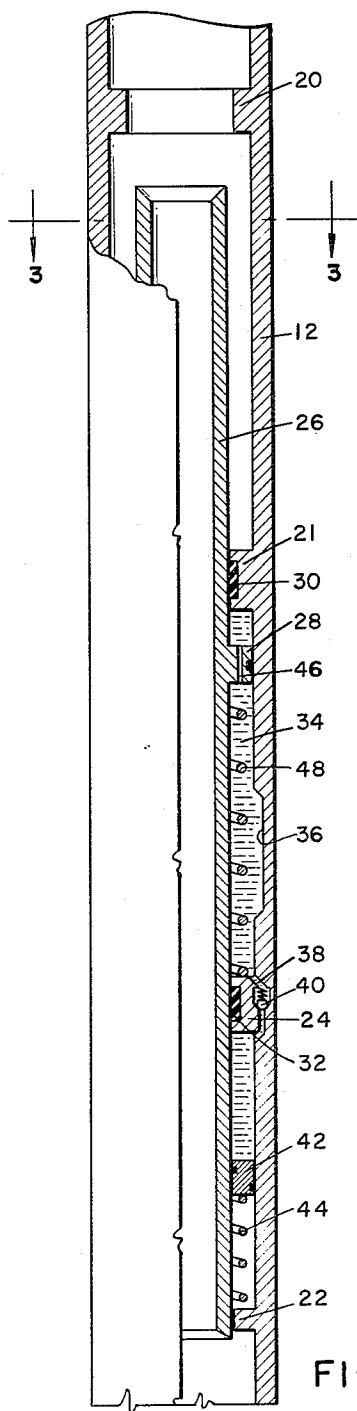


FIG. 2.

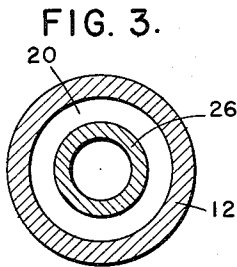
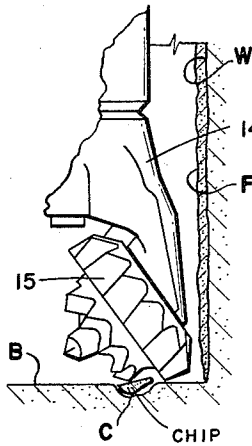


FIG. 11.

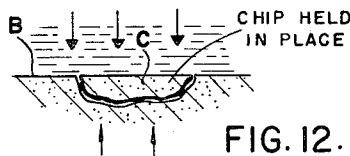


FIG. 12.

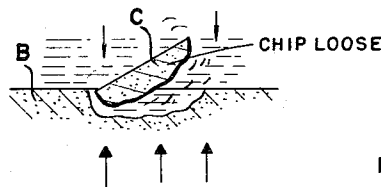


FIG. 13.

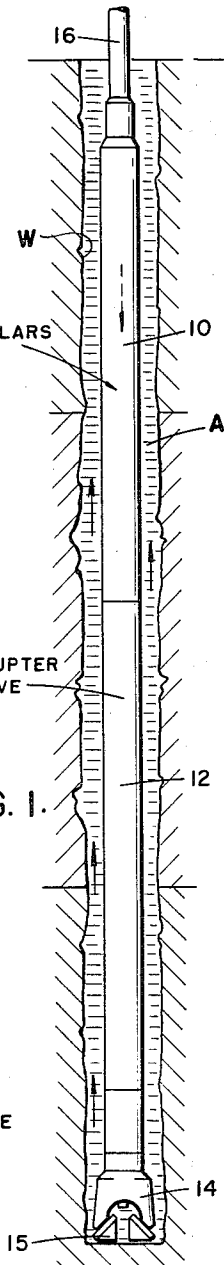


FIG. 1.

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2 Sheets-Sheet 2

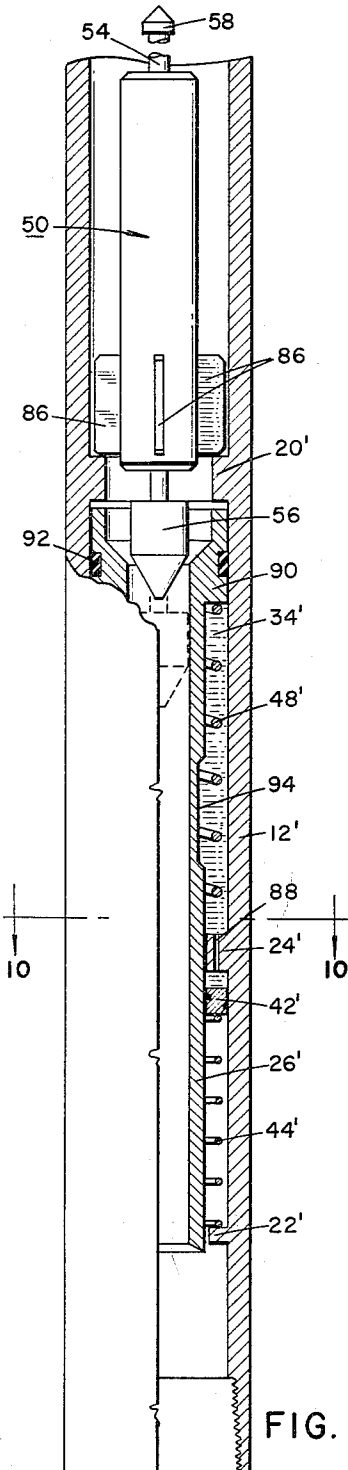


FIG. 8.

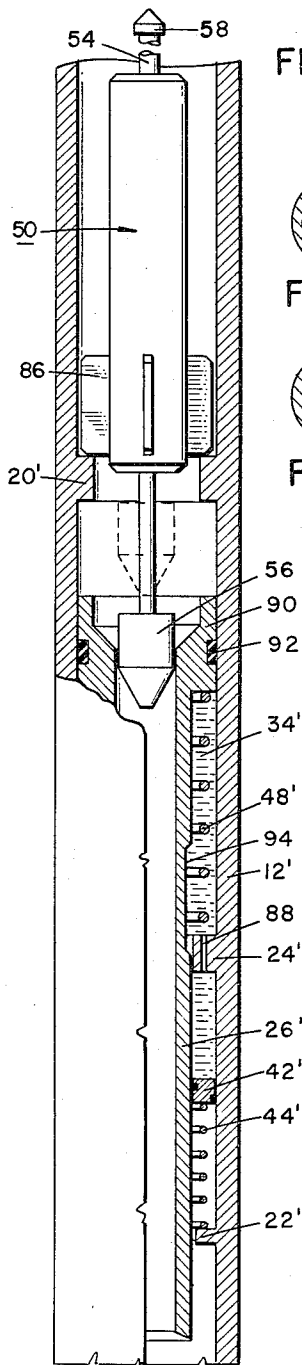


FIG. 9.

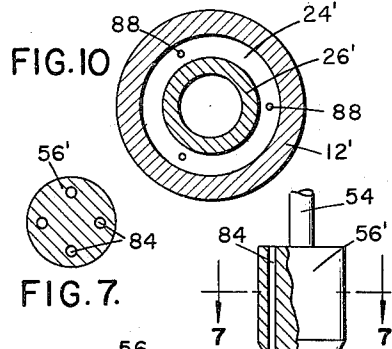


FIG. 10.

FIG. 7.

FIG. 5.

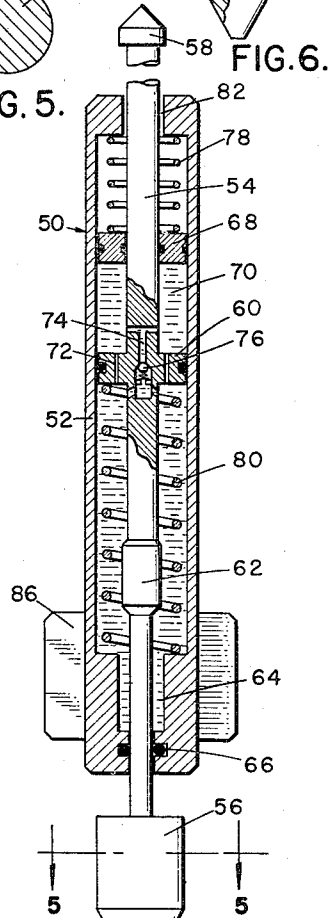


FIG. 4.

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3,185,227

WELL DRILLING APPARATUS

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8 Claims. (Cl. 175-243)

This invention relates to the drilling of wells, such as oil and gas wells, and more particularly to apparatus for increasing the rate of penetration of earth formations in the carrying out of rotary type well drilling operations.

In the drilling of wells by the rotary drilling process it is customary to make use of a drilling bit which is attached to the lower end of a tubular drilling string through which drilling fluid is circulated downwardly through the bit and upwardly in the annulus surrounding the same to lubricate the bit and carry away the cuttings formed.

The drilling string employed for this purpose usually includes a number of drill collars connected into the string immediately above the bit and which are substantially larger in diameter than the string above the collars and smaller in diameter than the bit so that an annulus is formed in the bore about the string through which the drilling fluid may circulate upwardly.

The drilling fluid which is commonly used as a circulating medium in rotary type well drilling operations of this kind is composed of mud which serves to lubricate the bit, to suspend and carry away the cuttings formed and to coat the wall of the well bore to lubricate the string and seal off porous formations. The pressure exerted by the drilling mud normally exceeds the pressure in the surrounding formation, so that due to the differential pressure thus created, there is frequently a tendency for the drill collars to adhere to wall of the bore, and such adherence, called "differential pressure sticking," may at times be sufficiently great to prevent longitudinal movement of the string or rotation of the same in the bore. The hydrostatic pressure of the drilling fluid on the formation at the bottom of the hole, under such differential pressure conditions, may also substantially reduce the rate of penetration of the bit, such pressure having a tendency to prevent the breaking away of chips and to hold the chips against the bottom of the bore.

Various expedients have been and are being employed to overcome the reduction in drilling rate caused by drilling muds. The use of "jet" bits to scour the bottom of the hole below the bit to dislodge chips is very common. In areas where the formation pressures permit, the use of clear water or air or gas as the drilling fluid permits increased drilling rate because these fluids do not hold the chips down against the bottom as effectively as a drilling mud does. The use of gas or clear water is limited to areas where the formation pressures are low and there is no danger of a blow-out. The use of "jet" type bits is a compromise, and is not nearly as effective as using gas or water, but where the increased fluid density is required to overcome formation pressures, it is one of the few methods available.

It is a prime purpose of the present invention to provide well drilling apparatus which includes means for reducing the pressure at the bottom of the bore whereby the tendency of the drilling fluid to retard breaking away of the formation and to hold the chips against

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movement away from the bottom of the bore is overcome, thus substantially increasing the rate of penetration of the bit.

The invention also contemplates the provision of well drilling apparatus embodying means for reducing the hydrostatic pressure exerted by the drilling fluid on the wall of the well bore to prevent differential pressure sticking of the drilling string or to release the string when such sticking occurs.

A further object of the invention is to provide mechanism for incorporation in a drilling string which operates to alternately close or partially close and reopen the string to interrupt or restrict the flow of fluid there-through at a location to cause a reduction in the pressure exerted by the drilling fluid against the formation in the well bore.

Another object of the invention is the provision of fluid flow interrupting or controlling mechanism for use in a drilling string which operates under the influence of the rate of flow of the circulating fluid in the string to interrupt or restrict the flow to produce a water hammer effect on the drilling bit and a reduction in the pressure exerted by the fluid on the bottom of the bore to increase the rate of penetration of the bit.

A further object of the invention is to provide fluid flow control mechanism for use in a drilling string which includes valve means movably disposed in the string for movement under the influence of the rate of flow of the drilling fluid to one position to close or partially close the string and to another position to open the same and embodying means for preventing the parts from being subjected to impact upon such movement of the valve means.

Another object of the invention is the provision in fluid flow control mechanism of the type mentioned for use in a drilling string of means operable under the influence of the flow of drilling fluid through the string for causing the closing or partial closing of the valve means with a snap action and for returning the valve means to open position.

A still further object of the invention is to provide fluid flow control mechanism of the kind referred to for use in a drilling string, which is of rugged construction and which may be easily connected into the string in assembling the same.

The above and other important objects and advantages of the invention may best be understood from the following detailed description when considered in conjunction with the annexed drawings illustrating a preferred embodiment of the same.

In the drawings:

FIGURE 1 is a vertical central, cross-sectional view, on a reduced scale illustrating a preferred embodiment of the invention and showing the same in operating position in a well bore;

FIGURE 2 is a fragmentary, side elevational view, partly broken away and partly in cross-section and on a somewhat enlarged scale, illustrating a preferred form of one portion of the flow control mechanism of the invention showing the same in a non-operative condition in the drilling string;

FIGURE 3 is a cross-sectional view, taken along the line 3-3 of FIGURE 2, looking in the direction indicated by the arrows;

FIGURE 4 is a side elevational view, partly broken

away and partly in cross-section and on an enlarged scale, illustrating a preferred embodiment of the actuator of the flow control mechanism of the invention, showing the same separated from the remainder of the mechanism;

FIGURE 5 is a cross-sectional view, taken along the line 5-5 of FIGURE 4, looking in the direction indicated by the arrows;

FIGURE 6 is a fragmentary side elevational view, partly broken away and partly in cross section illustrating a somewhat modified form of the valve element of the actuator;

FIGURE 7 is a cross-sectional view, taken along the line 7-7 of FIGURE 6, looking in the direction indicated by the arrows;

FIGURE 8 is a side elevational view similar to that of FIGURE 2 illustrating a somewhat modified form of the invention and showing the actuator of the fluid flow control mechanism with the valve thereof in partially closed position;

FIGURE 9 is a view similar to that of FIGURE 8, showing the valve of the actuator in flow interrupting position;

FIGURE 10 is a cross-sectional view taken along the line 10-10 of FIGURE 8, looking in the direction indicated by the arrows;

FIGURE 11 is a fragmentary, side elevational view, on an enlarged scale, showing a portion of the bottom of a well bore with a drilling bit in operating engagement therewith and illustrating the manner in which the invention operates; and

FIGURES 12 and 13 are fragmentary cross-sectional views, on a greatly enlarged scale of a portion of the formation at the bottom of a well bore illustrating the effect of the use of the invention on the removal of chips.

Referring now to the drawings in greater detail, the invention is illustrated herein in connection with the drilling of a well by the rotary drilling process by the use of a drilling string having drill collars 10 and 12 to which the usual drilling bit 14 is attached at the lower end of the string for rotation therewith. The drill collars are connected to the lower end of a string of drill pipe 16 above, in the usual manner, whereby the drilling string is lowered into a well bore W to engage the bit 14 with the bottom of the bore to perform a drilling operation by rotation of the string.

In carrying out a drilling operation with equipment of the type described above, a suitable drilling fluid, such as drilling mud is circulated downwardly through the drilling string and bit and upwardly through the annulus A surrounding the string, to lubricate the bit and carry away cuttings formed thereby.

As best seen in FIGURE 11, the wall of the bore W becomes coated with the drilling mud filter cake, as shown at F, which serves to lubricate the drill collars and drill pipe and to seal off porous formations through which the bore may penetrate, and due to the fact that the hydrostatic pressure of the column of fluid in the bore is normally higher than the pressure in the surrounding formation, a differential pressure condition may prevail which tends to cause the drill collars, and sometimes the drill pipe above, to strongly adhere to the wall of the bore, thus causing the drilling string to stick in the well. Moreover, the pressure of the drilling fluid on the bottom of the bore tends to compact the formation where it is in contact with the bit, thus substantially reducing the rate of penetration of the bit and also retarding the formation, breaking away, and entrainment of the chips in the drilling fluid.

It is for the purpose of reducing the above described differential pressure sticking and increasing the rate of penetration of the bit, that the present invention has been developed.

In accordance with the invention a mechanism is included in the drilling string by which the flow of fluid

therethrough may be interrupted or restricted, to cause the fluid to exert a water hammer effect on the bit to increase the pressure of the bit on the formation, and at the same time produce a reduction in the pressure exerted by the fluid on the bottom of the bore whereby the production and removal of chips is greatly increased.

The interrupter mechanism is preferably incorporated in one of the drill collars, such as the lowermost drill collar 12, and for this purpose the drill collar or similar tubular body or housing may be provided with upper, lower and intermediate longitudinally spaced, internal, inwardly thickened, annular portions or internal restrictions 20, 21, 22 and 24, respectively. Within the body 12 an inner tubular member 26 is movably extended through the annular portions 21 and 24 for longitudinal sliding movement, which member has an external enlargement 28 thereon positioned between the internal restrictions 21 and 24 of the body.

The annular, inwardly thickened portion 21, is provided with suitable packing means, such as that indicated at 30, located in an internal groove therein to form a seal between the body and member 26, and the portion 24 is similarly provided with packing 32 positioned so that the two packings seal annular chamber 34 between the body and inner member. The body 12 is also formed with an internally enlarged, annular portion 36, in the chamber 34.

The body 12 has a by-pass passageway 38 opening into the chamber 34 and into the interior of the body beneath the internal portion 24 and within which valve means, such as that shown at 40 is located to close the passageway against the outward flow of fluid therethrough from the chamber 34, but which may open to allow an inflow of fluid into the chamber from beneath the portion 24. Between the portions 22 and 24, an annular piston 42 surrounds the inner member 26 within the body 12 for longitudinal sliding movement therein, which is provided with suitable packing means to seal the annulus between the inner member and body, and which is yieldingly urged toward the portion 24, as by means of a coil spring 44 which bears at its upper end against the piston and at its lower end is seated on the internal portion 22. The external enlargement 28 may have one or more restricted passageways, such as that shown at 46, through which fluid in the chamber 34 may flow from one side of the enlargement to the other side thereof as the inner member 26 moves longitudinally in the body. Suitable means, such as a coil spring 48 is positioned in the chamber 34 surrounding the inner member to yieldingly urge the member upwardly in the body. The chamber 34 and the annulus between the inner member and body above the piston 42 are filled with a suitable fluid, such as oil.

It will be apparent that by the above arrangement downward movement of the inner member 26 in the body from the position of FIGURE 2, will be yieldingly resisted by the spring 48 and by the fluid in the chamber 34 which must flow upwardly through the restriction 46. When the inner member has moved downwardly until the external enlargement 28 is opposite the internal enlargement 36, however, the fluid in the chamber may flow upwardly freely through the enlargement 36, so that the inner member may then move suddenly downwardly with a snap action until the external enlargement 28 moves past the internal enlargement 36. Further downward movement of the inner member when the external enlargement 28 has moved past the internal enlargement 36 will be yieldingly resisted by the flow of fluid through the restriction 46 to prevent impact of the inner member on the body.

When the inner member reaches the limit of its downward movement, the inner member may return upwardly under the influence of the spring 48.

The fluid flow control mechanism of the invention includes actuator mechanism such as that illustrated in FIGURE 4, which coacts with the inner member 26 to interrupt or restrict the downward flow of fluid through

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the string to cause an increase in the downward force exerted on the bit and a reduction in the pressure exerted by the drilling fluid on the formation.

The actuator mechanism generally designated 50, has an outer tubular housing 52 through which an inner mandrel 54 is slidably extended, which mandrel carries at its lower end a valve or flow restricting element 56 and is provided at its upper end with a fishing head 58 by which the actuator mechanism may be recovered from the string by a wire line or other suitable means or held in the upward position.

The mandrel 54 has an external enlargement 60 forming a piston, slidable in the housing and provided with external packing to form a seal between the piston and housing, and the mandrel also has an external enlargement 62 below the piston, which is shaped to enter a reduced counterbore portion 64 in the lower end of the housing to form therewith a dash-pot for the mandrel and prevent impact between the mandrel and the housing.

Seal forming means, such as the O-ring 66 surrounds the mandrel in an internal groove formed in the lower end portion of the housing to form a seal between the mandrel and housing and an annular floating piston 68 surrounds the mandrel in the housing above the piston 60 and is provided with sealing means between the floating piston and the housing and mandrel. An internal, fluid containing chamber 70 is thus formed between the piston 68 and O-ring 66 which is filled with a suitable liquid. The piston 60 has one or more restricted passageways 72, through which fluid may flow from one side of the piston to the other side thereof, and the mandrel is formed with a passageway 74 which opens into the chamber 70 above and below the piston 60, and within which suitable valve means 76 is movably disposed to close the passageway against the upward flow of fluid therethrough, but which will open to allow the downward flow of fluid therethrough.

The floating piston 68 is yieldingly urged downwardly in the housing by a coil spring 78, and the mandrel is yieldingly urged upwardly in the housing by a coil spring 80. At the upper end of the housing the mandrel passes through an opening 82 of larger diameter than the mandrel through which fluid may flow into and out of the housing above the piston 68.

It will be apparent that downward movement of the mandrel 54 relative to the housing 52 will be yieldingly resisted by the upward flow of fluid through the restrictions 72 of the piston 60, so that the mandrel can only move downwardly slowly, but that upon upward movement of the mandrel under the pressure of the spring 80 the valve 76 will open to allow the free flow of fluid downwardly from above to beneath the piston 60 to allow the mandrel to move upwardly quickly.

A somewhat modified form of the valve element 56' is shown in FIGURES 6 and 7, wherein the element has one or more restricted passageways 84 through which fluid may flow through the valve.

The actuator mechanism 50 may have external, radially extending, centering flanges or wings 86 positioned to hold the housing 52 centered in the barrel 12 and to support the same on the internal enlargement 20 of the barrel when the actuator mechanism is lowered into the barrel, as best seen in FIGURES 8 and 9.

A somewhat modified form of the fluid flow control mechanism is illustrated in FIGURES 8, 9 and 10, wherein the barrel 12' has upper, lower and intermediate, internal, annular, inwardly thickened portions or restrictions 20', 22' and 24'; respectively, the restriction 24' being provided with one or more restricted passageways 88 therethrough.

In this form of the mechanism, an inner annular piston 42 forms the lower end of the fluid chamber 34' and the upper end of this chamber is formed by an external enlargement 90 on the upper end of the inner tubular member 26', which carried packing means 92 to form a seal

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between the inner member and the barrel. The inner member 26' also has an externally reduced portion 94 mediate its ends in the chamber 34'. The piston 42' is yieldingly urged upwardly in the barrel by a coil spring 44' and the inner member 26' is also yieldingly urged upwardly by a coil spring 48' in the chamber 34' which seats at its lower end on the restriction 24' and bears at its upper end against the external enlargement 90.

The chamber 34' is substantially entirely filled with a suitable liquid, such as oil.

It will be apparent that due to the restricted passageways 88 of the restriction 24', longitudinal movement of the inner member 26' will be yieldingly resisted by the fluid in the chamber 34' until the reduced portion 94 reaches the restriction 24', whereupon the fluid may then flow freely past the restriction through the reduced portion to allow the inner member to move longitudinally more quickly.

The barrels 12 and 12' may, of course, be made in any desired number of sections adapted to be threadably or otherwise connected together to facilitate the manufacture and assembly of the parts of the mechanism.

In making use of the fluid flow control mechanism of the invention in carrying out a well drilling operation, the barrel 12 with the inner tubular member in position therein is connected into the drilling string in place of one of the usual drill collars of the string, such as the lowermost drill collar and the bit 14 is attached to its lower end. The string may then be lowered into the bore, with or without the actuator mechanism 50 in the barrel, to engage the bit with the bottom of the bore to perform a drilling action upon rotation of the string. Drilling fluid is then circulated through the string and annulus during the drilling operation.

When the actuator mechanism is in position in the barrel, the valve 56 or 56' will initially be in slightly opened position, as shown in FIGURE 8, so that the flow of fluid through the string will cause a reduction of pressure in the inner member beneath the valve to move the valve downwardly into the inner member, as shown in FIGURE 9, whereupon the downward flow of fluid will be greatly restricted, or completely interrupted, to cause a water hammer effect on the string, whereby the downward force on the bit will be increased, and a reduction in the pressure exerted by the fluid on the bottom of the bore and progressively upwardly on the formation throughout the annulus will take place.

The downward movement of the valve 56 into the upper end of the inner member may take place relatively slowly due to the yielding resistance of the upward flow of fluid in the chamber 70 through the restrictions 72 of the piston 60, and when the valve has reached closing position, as shown in dotted lines in FIGURE 8, the downward force of the fluid in the string above will be exerted on the upper end of the inner tubular member, to move this member downwardly slowly against the resistance of fluid flowing through the restriction 46 until the external enlargement 28 reaches the internally enlarged portion 36 of the barrel, whereupon the inner sleeve member 26 will move suddenly downwardly to below the valve 56 so that the fluid can flow downwardly freely and the pressure differential acting on the valve 56 is reduced, thus allowing spring member 80 to force the valve member 56 to move to its uppermost position to further open the passageway. The upward movement of valve member 56 is fast since the fluid in chamber 70 may flow downwardly through the passageway 74.

Meanwhile, the inner sleeve member 26 will be slowly returned to its uppermost position by the spring 48 against the resistance of fluid flowing downwardly through restriction 46 after the external enlargement 28 has moved upwardly past the internal enlargement 36.

When the inner sleeve member has returned to its uppermost position, it is again ready for coaction with the valve 56 to restrict or interrupt the downflow of fluid

through the string to effect another water hammer action on the bit and again reduce the pressure of the fluid on the formation.

It will be apparent that the fluid flow control mechanism may be thus operated to repeatedly apply a water hammer effect to the drilling string and to simultaneously create a reduction in the pressure exerted by the drilling fluid on the bottom of the bore to increase the rate of penetration of the bit.

In the event that it should be considered desirable to operate the fluid flow control mechanism without completely shutting off the flow of fluid when the actuator valve closes, the valve may be constructed as shown in FIGURES 6 and 7, wherein the valve 56' is provided with one or more restricted fluid passageways 84 through which fluid may continue to flow when the valve is closed.

The form of the invention illustrated in FIGURES 8 and 9 is operated in substantially the same manner as described above, the fluid in the chamber 34' flowing downwardly slowly through the restricted passageway 88 of the internal restriction 24' during downward movement of the inner member 26' until the restriction reaches the reduced portion 94 of the inner member, whereupon fluid may then flow rapidly through the reduced portion past the restriction to allow the inner sleeve member to move suddenly downwardly away from the valve 56 to open the valve. The inner sleeve member is then returned to its uppermost position by the spring 48' following the return of the valve 56 to its uppermost position.

The action of the flow control mechanism in increasing the rate of penetration of the formation is illustrated in FIGURES 11, 12 and 13, wherein the teeth of the toothed cutter elements 15 and the bit are shown in cutting engagement with the bottom B of the well bore to form chips, such as that shown at C, as the bit is rotated in the bore. As seen in FIGURE 12 the hydrostatic pressure exerted by the drilling fluid on the bottom of the bore tends to hold the chips C against breaking away from the formation and becoming entrained in the fluid. Upon the occurrence of a reduction in the pressure of the drilling fluid, however, such as is caused by the operation of the fluid flow control mechanism of the invention, as described above, the pressure tending to hold the chips against breaking away from the formation may be reduced, or the pressure of the drilling fluid may fall below the pressure of the fluid in the formation to allow the chips to separate from the formation, as seen in FIGURE 13, and to cause an increase in the rate of penetration.

In the event that it is desired to continue the drilling operation without the use of the flow control mechanism of the invention, the actuator mechanism may be retrieved from the string by wire line fishing apparatus, and the actuator mechanism may be re-inserted in the string when it is desired to resume the use of the flow control mechanism.

It will thus be seen that the invention, constructed and operated in the manner disclosed above provides fluid flow control mechanism for use in drilling strings by which the pressure of the drilling fluid may be periodically reduced to cause a reduction in the pressure of the fluid on the well formation and to increase the force exerted by the drilling bit.

While certain specific embodiments of the invention are disclosed herein it will be understood that these are for the purpose of illustration only and that various changes can be made in the construction and arrangement of the parts within the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. In well drilling apparatus a tubular drilling string adapted to be lowered into a well bore, a drilling bit

attached to the lower end of the string for rotation therewith in engagement with the bottom of the bore to form an annulus about the string and having a passageway through which fluid may flow downwardly through the string and upwardly in the annulus, a tubular mandrel movably disposed in the string for longitudinal movement therein, valve means movably positioned in the string for longitudinal movement therein in one direction to position the valve means to restrict the flow of fluid through the mandrel, yieldable means positioned for coaction with the valve means and string to hold the valve means against movement in said one direction when the rate of flow of fluid in the string is less than a predetermined rate, and to allow the valve means to move in said one direction when said rate exceeds said predetermined rate, said mandrel being movable away from the valve means when the mandrel and valve means are in a predetermined position of movement in said one direction, yieldable means positioned for coaction with said mandrel and string to yieldingly resist movement of said mandrel in said one direction during movement of said mandrel and valve means to said predetermined position, and means positioned for coaction with the mandrel and string to reduce such resistance to allow the mandrel to move away from the valve means when the mandrel and valve means reach said predetermined position.

2. In well drilling apparatus a tubular drilling string adapted to be lowered into a well bore, a drilling bit attached to the lower end of the string for rotation therewith in engagement with the bottom of the bore to form an annulus about the string and having a passageway through which fluid may flow downwardly through the string and upwardly in the annulus, a tubular mandrel movably disposed in the string for longitudinal movement therein, said mandrel and string having portions disposed in the path of movement of the mandrel positioned to limit movement of the mandrel in one direction, valve means movably positioned in the string for longitudinal movement therein in said one direction to position the valve means to restrict the flow of fluid through the mandrel and in the other direction (to position the valve means) to allow unrestricted flow of fluid through the mandrel, yieldable means positioned for coaction with the valve means and string to hold the valve means against movement in said one direction when the rate of flow of fluid in the string is less than a predetermined rate and to allow the valve means to move in said one direction when said rate exceeds said predetermined rate, said mandrel being movable away from the valve means when the mandrel and valve means are in a predetermined position of movement in said one direction, yieldable means positioned for coaction with said mandrel and string to yieldingly resist movement of said mandrel in said one direction during movement of said mandrel and valve means to said predetermined position, means positioned for coaction with the mandrel and string to reduce such resistance to allow the mandrel to move away from the valve means when the mandrel and valve means reach said predetermined position, said last named yieldable means being also positioned for coaction with the mandrel and string to resist further movement of the mandrel in said one direction when the mandrel reaches a predetermined position in its movement away from the valve.

3. In well drilling apparatus a tubular drilling string adapted to be lowered into a well bore, a drilling bit attached to the lower end of the string for rotation therewith in engagement with the bottom of the bore to form an annulus about the string and having a passageway through which fluid may flow downwardly through the string and upwardly in the annulus, a tubular mandrel movably disposed in the string for longitudinal movement therein, means forming a seal between the external surface of the mandrel and the internal wall of the string, valve means movably positioned in the string for longitudinal

tudinal movement therein in one direction to position the valve means to restrict the flow of fluid through the mandrel and in the other direction to position the valve means to open the mandrel to unrestricted flow of fluid therethrough, means for resisting movement of mandrel away from the valve means to cause the mandrel and valve means to move together in said one direction and means for causing a reduction in such resistance to allow the mandrel to move away from the valve means when the mandrel and valve means reach a predetermined position of movement in said one direction.

4. In well drilling apparatus a tubular drilling string adapted to be lowered into a well bore, a drilling bit attached to the lower end of the string for rotation therewith in engagement with the bottom of the bore to form an annulus about the string and having a passageway through which fluid may flow downwardly through the string and upwardly in the annulus, a tubular mandrel movably disposed in the string for longitudinal movement therein, means forming a seal between the external surface of the mandrel and the internal wall of the string, valve means movably positioned in the string for longitudinal movement therein in one direction to position the valve means to restrict the flow of fluid through the mandrel and in the other direction to position the valve means to open the mandrel to unrestricted flow of fluid therethrough, yieldable means positioned for coaction with the mandrel and string to yieldingly resist movement of the mandrel and valve means together in said one direction with the valve means in said restricting position and including means on the mandrel and string positioned for coaction when the mandrel and valve means reach a predetermined position of their movement in said one direction to reduce such resistance to allow the mandrel to move away from the valve means to permit unrestricted flow of fluid through the mandrel.

5. In well drilling apparatus a tubular drilling string adapted to be lowered into a well bore, a drilling bit attached to the lower end of the string for rotation therewith in engagement with the bottom of the bore to form an annulus about the string and having a passageway through which fluid may flow downwardly through the string and upwardly in the annulus, a tubular mandrel movably disposed in the string for longitudinal movement therein, means forming a seal between the external surface of the mandrel and the internal wall of the string; valve means movably positioned in the string for longitudinal movement therein in one direction to position the valve means to restrict the flow of fluid through the mandrel and in the other direction to position the valve means to open the mandrel to unrestricted flow of fluid therethrough, yieldable means positioned for coaction with the mandrel and string to yieldingly resist movement of the mandrel in said one direction during the movement of the mandrel and valve means to a predetermined position with said valve means in said restricting position and including means on the mandrel and string positioned for coaction when the mandrel and valve reach said predetermined position to reduce such resistance to allow the mandrel to move away from the valve means to permit unrestricted flow of fluid through the mandrel, said yieldable means also including means positioned to yieldingly resist movement of said mandrel in said one direction when the mandrel has moved away from said valve means.

6. In well drilling apparatus a tubular drilling string adapted to be lowered into a well bore, a drilling bit attached to the lower end of the string for rotation therewith in engagement with the bottom of the bore to form an annulus about the string and having a passageway through which fluid may flow downwardly through the string and upwardly in the annulus, a tubular mandrel movably disposed in the string for longitudinal movement

therein, means forming a seal between the external surface of the mandrel and the internal wall of the string, valve means movably positioned in the string for longitudinal movement therein in one direction to position the valve means to restrict the flow of fluid through the mandrel and in the other direction to position the valve means to open the mandrel to unrestricted flow of fluid therethrough, yieldable means positioned for coaction with the mandrel and string to yieldingly resist movement of the mandrel in said one direction during the movement of the mandrel and valve means to a predetermined position with said valve means in said restricting position and including means on the mandrel and string positioned for coaction when the mandrel and valve reach said predetermined position to reduce such resistance to allow the mandrel to move away from the valve means to permit unrestricted flow of fluid through the mandrel, said yieldable means also including means for yieldingly urging the mandrel toward the valve means when the mandrel has reached the limit of its movement away from the valve means.

7. In well drilling apparatus a tubular drilling string adapted to be lowered into a well bore, a drilling bit attached, to the lower end of the string for rotation therewith in engagement with the bottom of the bore to form an annulus about the string and having a passageway through which fluid may flow downwardly through the string and upwardly in the annulus, a tubular mandrel movably disposed in the string for longitudinal movement therein in radially inwardly spaced relation to the internal wall of the string, means forming seals between the external surface of the mandrel and string to form a closed annular fluid chamber about the mandrel in the string, means forming an internal enlargement in said chamber mediate the ends of the chamber, fluid flow restricting means in the chamber movable longitudinally therein in response to longitudinal movement of the mandrel in the string to yieldingly resist such longitudinal movement of the mandrel when said restricting means is opposite said enlargement, valve means movably positioned in the string for longitudinal movement into and out of a position to restrict the flow of fluid through the mandrel, said mandrel and valve means being movable downwardly together in the string under the influence of the downward pressure of fluid in the string when said restricting means is beyond said enlargement, and said mandrel being movable away from said valve means when said restricting means is opposite said enlargement, yieldable means positioned for coaction with said mandrel and string to yieldingly urge the mandrel upwardly in the string and means for yieldingly urging said valve means away from said mandrel.

8. In well drilling apparatus a tubular drilling string adapted to be lowered into a well bore, a drilling bit attached to the lower end of the string for rotation therewith in engagement with the bottom of the bore to form an annulus about the string and having a passageway through which fluid may flow downwardly through the string and upwardly in the annulus, a tubular mandrel movably disposed in the string for longitudinal movement therein, means on the mandrel positioned in the path of movement of the mandrel in either direction in the string, valve means movably positioned in the string for longitudinal movement therein in one direction to position the valve means to restrict the flow of fluid through the mandrel and in the other direction to open the valve means to allow unrestricted flow of fluid through the mandrel, yieldable means positioned for coaction with the mandrel and string to hold the mandrel against movement in said one direction away from said valve means during movement of the valve means and mandrel together in said

one direction to a predetermined position with the valve means in said flow restricting position and including means on the mandrel and string positioned for coaction when the mandrel and valve reach said predetermined position to reduce such resistance to allow the mandrel to move away from the valve means to permit unrestricted flow of fluid through the mandrel, said yieldable means including means for resisting further movement of the mandrel in said one direction when the mandrel reaches a predetermined position in its movement away from the valve means.

References Cited by the Examiner

UNITED STATES PATENTS

1,861,042	5/32	Zublin	175—187 X
2,344,725	3/44	Phipps	175—296
2,745,189	5/56	Garrison	175—317 X
2,758,817	8/56	Bassinger	175—243 X
2,780,438	2/57	Bielstein	175—92
2,989,132	6/61	Downen	175—297
3,038,548	6/62	Brown	175—296

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