Aug. 23, 1960 J. G. SCOTT 2,950,088

ELECTRIC SOLENOID ACTUATOR

Filed March 25, 1957 2 Sheets-Sheet 1

Fig. 1

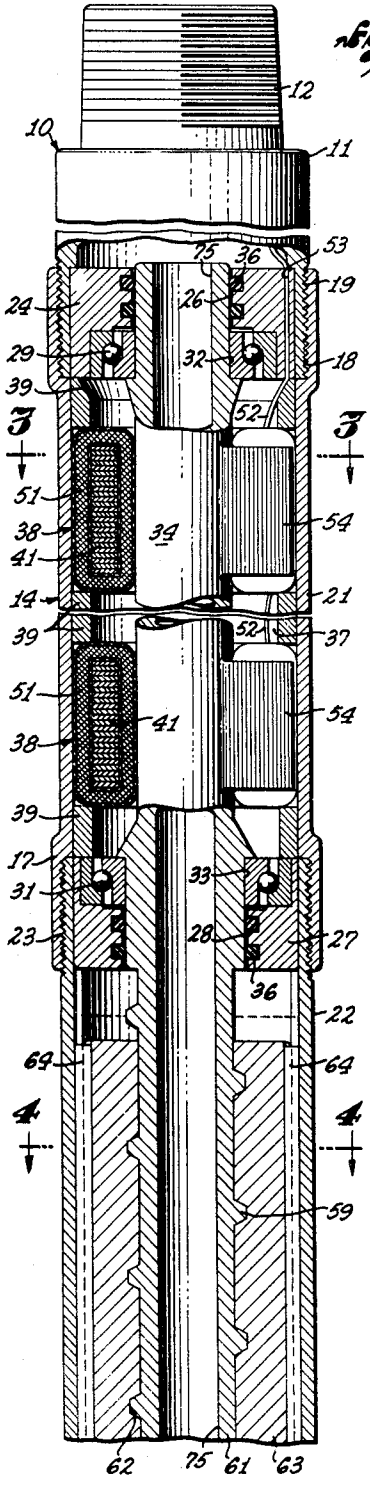


Fig. 3

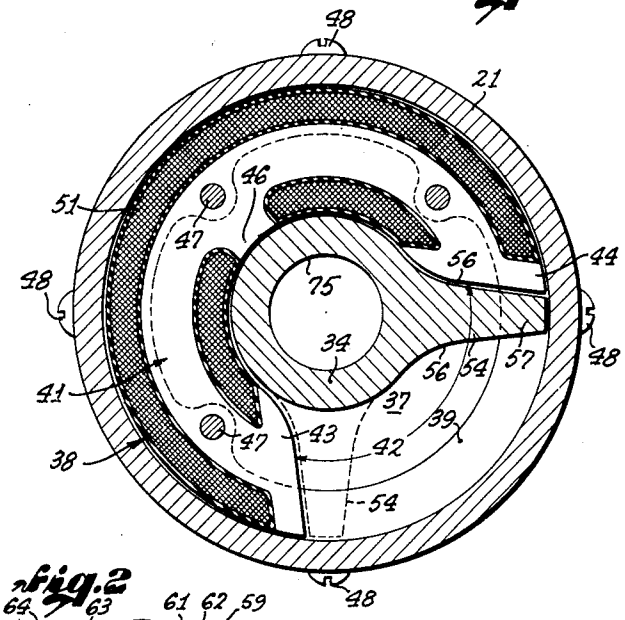


Fig. 2

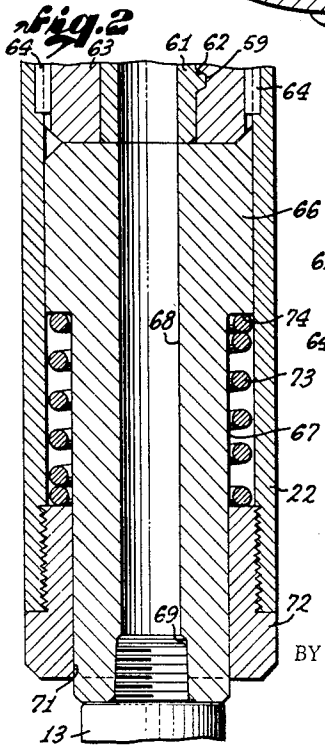
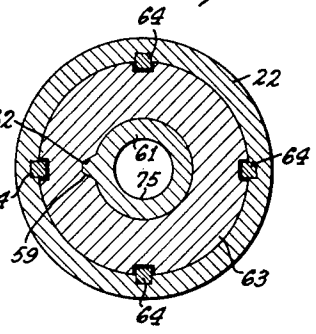


Fig. 4



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Fig. 7

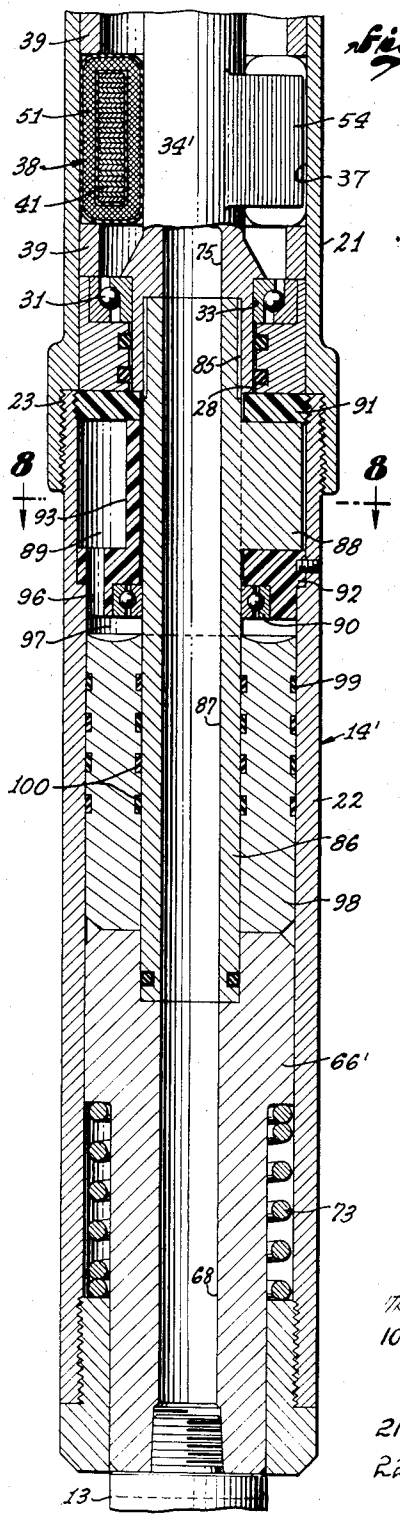


Fig. 8

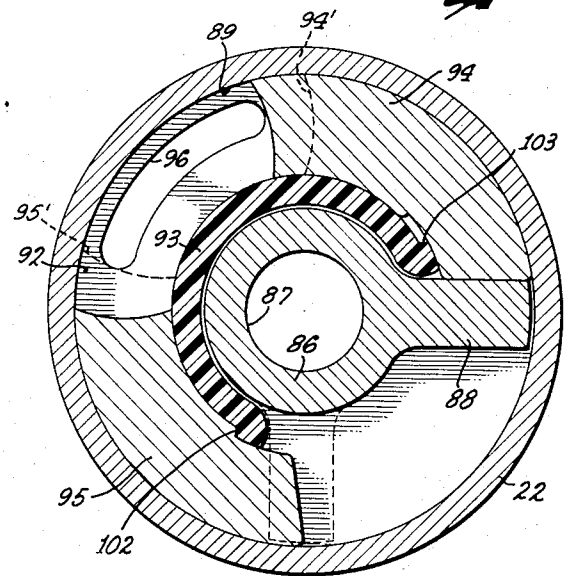


Fig. 6

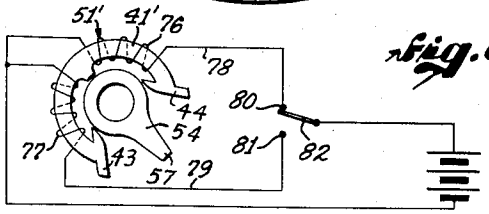


Fig. 5

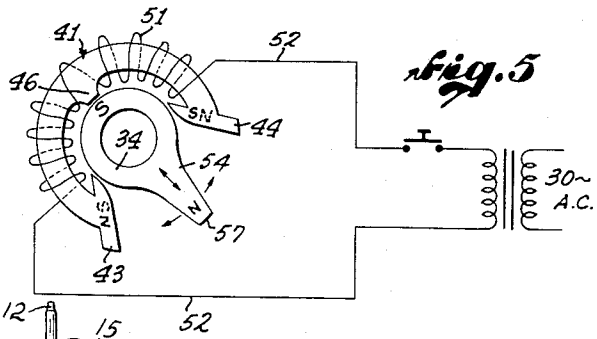
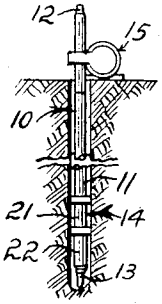


Fig. 9



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ELECTRIC SOLENOID ACTUATOR

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15 Claims. (Cl. 255—4.4)

This invention relates to an actuator and more specifically to an electric solenoid actuator for effecting a pulsating or jackhammer-like movement of a tool for improved drilling operation.

Drilling tools of the rotary type are extensively used in drilling oil and water wells. Wells of this type are generally drilled to great depth, necessitating the use of great lengths of tubular sections fixed together to form an elongated string of such sections, with a drilling tool fixed to the lower end thereof. Rotational force is generally applied to the uppermost section to rotate the string and/or drilling tool to bore through the ground.

Such rotational force is sometimes inadequate to penetrate the ground because obstructions such as stone or other hard formations in the ground are frequently encountered during the drilling operation. Such encounters often result in considerable delay because the drilling operation is hindered or halted.

It has been discovered that a practically more efficient and desirable method of drilling the well as described is to provide a pulsating or jackhammer like movement to the drilling tool to effect an impacting force in place of or in addition to the rotational force. Such a pulsating movement assists the tool to break through any hard formation encountered during the drilling operation, and further, improves drilling through normal earth deposits.

Whereas it is conceivable that the entire string of tubular sections may be reciprocated to effect such a pulsating movement, it is more practical and desirable and therefore among the objects of this invention to provide an actuator which is capable of transmitting such a desired pulsating movement directly to the drilling tool.

More specifically, in view of the above and other considerations, it is an object of this invention to provide a new and improved actuator which is capable of producing an oscillating force which is readily converted into a reciprocal force transmitted to a tool for improved drilling operation.

It is another object of this invention to provide a new and improved actuator of the character described which may be used in combination with a rotary movement of the drilling tool.

It is a further object of this invention to provide an actuator of the character described which incorporates a new and improved electric solenoid and armature combination which provides maximum efficiency in the form of greater thrust for a given size of coil.

Another object of this invention is to provide a new and improved actuator that is economical to manufacture and capable of interchangeability of parts thereof.

A still further object of this invention is to provide a new and improved electric solenoid actuator that is readily interposed between a conventional drilling stem and a tube, and is capable of transmitting fluid therethrough during the drilling operation.

It is a general object of this invention to provide a new and improved electric solenoid actuator which overcomes disadvantages of previous devices heretofore intended to accomplish generally similar purposes, including breaking up and loosening of ore bodies in hard-mining operations.

These and other objects of this invention will be more apparent from the following description considered in the light of the drawings and appended claims.

In the drawings:

Figure 1 is a vertical sectional view, with parts shown in elevation, of the upper portion of an embodiment of this invention;

Figure 2 is a vertical sectional view of a lower portion of the embodiment shown in Figure 1;

Figure 3 is an enlarged horizontal sectional view as taken on a line 3—3 of Figure 1;

Figure 4 is a horizontal sectional view as taken on line 4—4 of Figure 1;

Figure 5 is a diagrammatic view of the core associated with an electric circuit according to this invention;

Figure 6 is a diagrammatic view similar to Figure 5 showing a modified form of the electric circuit;

Figure 7 is a vertical sectional view similar to Figure 1 showing a modified embodiment of the actuator according to this invention;

Figure 8 is an enlarged sectional view as taken on a line 8—8 of Figure 7; and

Figure 9 is a schematic diagram, in reduced scale illustrating the invention as adapted to a drill stem and illustrating a rotating means therefor.

Referring more particularly to the drawings, there is shown by way of illustration, but not of limitation, a drill stem generally referred to by the numeral **10**, including a plurality of tubular sections, the lowermost of which is indicated at **11**. The sections like **11** are preferably secured together as by threads **12** to form the drill string or stem **10** which may be lengthened as desired by the addition of other sections like **11**.

The stem **10** may be optionally rotated at an upper end thereby by a motor **15** located on the surface of the ground and connected to the stem in any suitable manner to selectively rotate a drill bit **13**, normally disposed in the lower end of the stem.

In accordance with this invention, a solenoid actuator generally referred to by the numeral **14** is preferably interposed between the lowermost section **11** of the drill stem and the tool bit **13** to transmit pulsating or jackhammer like impulses to the tool for improved drilling actuation.

Referring to Figures 1 through 5, a first preferred embodiment of the solenoid actuator **14** is shown comprising an elongated tubular housing **17** secured at its upper end to the lowermost section **11** of the drill stem **10** as by internal threads **18** engaging corresponding external threads **19** of the section **11**.

The housing **17** includes upper and lower tubular portions **21** and **22** respectively which are joined as by a threaded connection **23** at an intermediate portion of the housing **14**.

A transverse wall or sleeve **24** is fixed by welding or the like within the lower end of the section **11** and includes an axial bore **26**. A similar sleeve **27** is fixed as by welding or the like within the upper end of the lower housing portion **22** and includes an axial bore **28**. The sleeves **24** and **27** are provided with frictionless thrust bearings **29** and **31** respectively, to rotatably support a hollow shaft **34** at bearing portions **32**, **33**. A plurality of sealing rings **36** are preferably disposed around the shaft **34** within the sleeves **24**, **27** to effect a moisture-proof solenoid compartment **37**, defined by the sleeves **24**, **27** and the annular wall of the tubular portion **21**.

Transversely fixed within the compartment **37** is a plurality of solenoids **38** which are held in spaced relation-

ship as by annular spacers 39. The solenoids 38 comprise toroid-like cores 41 of laminated or other construction. Each core 41 is formed with a gap 42 therein of approximately 90°, defining a pair of enlarged ends 43 and 44. The cores 41 are preferably provided with inwardly extending projections 46, and are fixed in aligned relationship, as by pins or bolts 47 anchored in the spacers 39, with the gap 42 of one core aligned with the gap of another core. The spacers 39 are non-rotatably fixed to the tubular portion 21 as by set screws 48 or the like, to prevent rotational movement of the solenoids.

A coil means 51 is disposed around each core 41 and is adapted to be connected to an electric current preferably in parallel arrangement as by lead wires 52 extending through a passage 53 of the sleeve 24. The coil means 51 effects a magnetic flux in the cores 41 when an electric current flows through the coils as will be hereinafter explained.

A plurality of clappers or armatures 54, corresponding in number to the solenoids 38, extend radially from the shaft 34. Each armature 54 is disposed within a gap 42 of a core 41 to oscillate between the ends 43, 44 of the core. The armatures are preferably permanently magnetized in a substantially horizontal plane to form a magnetic pole such as the north pole indicated at N in Figure 5 at the outer end 57 of each armature. An opposite pole S will thus be formed at a point of the shaft 34 opposite of the end 57, substantially adjacent to the projection 46 of a core 41 when the armature is midway of its corresponding gap 42.

The armatures 54 preferably correspond in their axial dimension or width to the full thickness of the cores 41 to effect a maximum attraction by the magnetic flux of the cores. In transverse cross-section, the sides 56 of the armatures preferably conform substantially in configuration to the inner vertical surfaces of the enlarged ends 43, 44.

Referring to Figure 5, it will be seen that when an electric current such as a 30 cycle alternating current is applied to a coil 51 through the leads 52, a magnetic flux is induced into the core 41. This magnetic flux alternately reverses the polarity of the ends 43, 44 from a north pole to a south pole, and vice-versa.

As an example, at an instant when an end like 43 is induced to form a north pole, it repels the north end 57 of the armature 54 away from it. At the same instant, an end like 44, is a south pole and thereby attracts the armature end 57. As the magnetic flux of the core is reversed by the alternating circuit the core end 43 becomes a south pole attracting the armature end 57, causing the armature to return to a position adjacent to the end 43. Thus, the armature is oscillated within the gaps 42 to oscillate the shaft 34 in a transverse plane.

The solenoid compartment 37 is effectively sealed by the aforementioned sealing rings 36 to form an air-tight chamber. As the armatures 54 oscillate toward the ends 43, 44 an air gap is formed between the faces 56 and the ends to cushion the striking force of the armature against the ends. If desired, a cushioning material may be applied to the ends and/or armature. Optionally the cushioning effect can be omitted.

The shaft 34 extends through the sleeve 27 into the tubular portion 22 and is provided with external spiral threads 59 at a lower end 61 thereof to engage complementary internal spiral threads 62 of a sleeve 63. The sleeve 63 is slidably disposed within the tubular portion 22 and is prevented from rotating as by longitudinal keys or splines 64. As the shaft 34 oscillates, the sleeve is reciprocated within the tubular portion 22 forming a hammer means to actuate an anvil 66.

The anvil 66 is slidably disposed in the tubular portion 22 adjacent the sleeve 63 and comprises a reduced portion 67 and an axial passage 68. The lower end of the passage 68 is preferably internally threaded as at 69 to receive the externally threaded tool bit 13 therein.

The reduced portion 67 is slidably disposed within a bore 71 of a threaded bushing 72 provided at the lower end of the tubular portion 22. A compression spring 73 is provided around the reduced portion 67 and bears at one end against the upper surface of the bushing 72, and at the other end against a shoulder 74 of the anvil 66 to urge the anvil toward the hammer means or sleeve 63. The passage 69 of the anvil 66 communicates with the axial bore 75 of the hollow shaft 34 to transmit fluid from the tool to the string of sections 11.

It will now be apparent that as the shaft 34 oscillates when the armatures oscillate between the ends 43, 44 of the coils 41, the sleeve 63 is reciprocated, alternately extending the anvil 66 when the sleeve is extended and permitting the spring 73 to retract the anvil 66 when the sleeve is retracted, resulting in a rapid reciprocating or pulsating movement of the tool bit 13.

Referring to Figure 6, a modified form of the electric circuit is shown, wherein coil 51′ comprises a pair of coils 76, 77 disposed around the core 41′. An end of each coil is, in this form, preferably connected as by leads 78, 79 respectively, to contacts 80, 81 respectively of a switch 82. The blade of the switch 82 is connected to a source of D.C. or rapid-cycle A.C., electric current. The switch 82 may be actuated by means not shown to alternately energize the coils 76, 77 and induce a magnetic flux in a half-portion of the core to oscillate the armature.

Referring to Figures 7 and 8, there is illustrated another modified embodiment of the actuator indicated at 14′, wherein like parts are referred to by like numbers. The actuator 14′ includes upper and lower tubular portions 21, 22 respectively secured together as by a threaded connection 23.

The upper tubular portion 21 is similar in detail to the first form described, inasmuch as it includes a solenoid chamber 37 in which a desired plurality of solenoids 38 are mounted, to oscillate the armatures 54 and a hollow shaft 34′ in the manner heretofore described.

In the instant form, the shaft 34′ is preferably terminated adjacent to the bearing portion 33 to facilitate assembly of the component parts of the actuator. The lower end adjacent to the bearing portion 33 is preferably provided with an enlarged portion 85 of the shaft bore 75 having a splined or other non-circular configuration. A hollow shaft 86 is provided with a corresponding spline at the upper end thereof to be received within the enlarged portion 85 in sliding relationship and form an extension of the shaft 34′.

The shaft 86 includes an axial passage 87 communicating with the bore 75 and a radially extending web or piston actuating hammer 88 similar in configuration to the armature 54. The radial web 88 extends into an upper fluid chamber 89 of the tubular portion 22 and is adapted to oscillate with the oscillating movement of the armatures 54 and shaft 34′.

The chamber 89 is formed by the annular wall of the tubular portion 22 and is closed at its upper and lower ends by bearing walls 91, 92 respectively. The walls 91, 92 are preferably formed of a suitable bearing material such as nylon, or the like. The lower wall 92 preferably includes an upwardly extending arcuate flange 93 to form an inner wall for the chamber 89, substantially coaxial with the annular wall of the tubular portion 22. A non-friction bearing 90 is preferably formed in the wall 92 to journal the shaft 96.

The piston-actuating hammer 88 actuates a pair of arcuate piston means 94, 95 slidingly disposed within the chamber 89 to convert the oscillation of the shaft 86 to a fluid pressure within the chamber 89.

An opening 96 in the wall 92 communicates with a lower fluid chamber 97 of the tubular portion 22, in which an annular piston 98 is disposed circumjacent the lower portion of the shaft 86, forming hammer means func-

tionally equivalent to the hammer means **63** of the first embodiment.

The piston or hammer means **98** has a sliding fit with the wall of the portion **22** at its outer diameter, the shaft **86** at its inner diameter, and is preferably provided with sealing rings **99**, **100** in suitable annular grooves.

When the piston-actuating hammer **88** is oscillated by the shafts **86** and **34'**, it strikes a piston like **94** to move said piston arcuately from a position indicated by the dotted lines **94'** to the position indicated by solid lines. The piston **95**, at this instant is immovable against a stop **102** formed in the flange **93**. Therefore, a fluid pressure is built up in the chamber **89** which is transmitted through the opening **96** moving the fluid pressure into the chamber **97** to act on the upper surface of the piston **98** to move the annular piston **98** downwardly. The piston **98** bears against an anvil **66'** similar to anvil **66**, to extend the tool bit **13**.

As the piston-actuating hammer **88** is oscillated by the shafts **86** and **34'** in response to a reverse action of armature **54**, the hammer **88** is rotated away from the face of the piston **94** which is then free to move arcuately to the position **94'**. A spring **73** urges the anvil **66'** upwardly to return the anvil **66'** and the piston **98** to their uppermost positions and the fluid volume into chamber **89**. This action reverses the fluid pressure to act on piston **94** and return the arcuate piston **94** to the original position **94'** against a stop **103** of the flange **93**. Fluid pressure is relieved in chamber **89** immediately upon removal of the hammer **88** from the piston **94**. The fluid, being incompressible, is shifted from the chamber **89** to the chamber **97** by movement of the pistons **94** and **95** and alternately moved from the chamber **97** into the chamber **89** by the upward movement of the anvil **66'** and piston **98** caused by the spring **73** when the piston-actuating hammer **88** is oscillated away from the pistons **94** and **95**.

The hammer **88** continues in an arcuate path to strike the piston **95**, moving it to a position **95'** indicated in dotted lines, to again create the fluid pressure in the chamber **89** which is transmitted through the opening **96** to the chamber **97** and piston **98** to repeat the extending movement of the anvil **56'** and tool **13**. As the hammer **88** continues to oscillate, alternately moving the pistons **94**, **95** a pulsating or jackhammer like movement will be imparted to the tool **13**.

While I have herein shown and described what I conceive to be the most desired form of my invention, it is to be understood that alterations and modifications thereof may be made in a manner to satisfy the spirit of my invention which is intended to comprehend any and all equivalent devices as comprehended in the following claims.

What I claim as new and desire to secure by Letters Patent is:

1. An actuator comprising rotatable shaft means, solenoid means circumjacent said shaft means for oscillating said shaft means, non-rotatable hammer means circumjacent said shaft means and spaced from said solenoid means and means operatively associated with said shaft means and said hammer means for translating oscillation of said shaft means into an axial movement of said hammer means.

2. An actuator comprising rotatable shaft means having radially extending clapper means thereon, toroid-like solenoid means circumjacent said shaft means and adapted to be electrically energized by an electric alternating current for oscillating said clapper means thereby to oscillate said shaft means, hammer means circumjacent said shaft means and adapted for reciprocal axial movement thereon; means operatively associated with said shaft means and said hammer means for translating oscillation of said shaft means into reciprocal axial movement of said hammer means, anvil means adjacent said hammer means adapted to hold a drilling tool, spring means for biasing said anvil means toward said hammer means, said anvil means being extended by said hammer means and retracted by said spring means to pulsate said tool.

3. An electric solenoid actuator comprising a toroid-like core having a gap therein, said gap defining two ends on said core comprising opposed radial pole faces, coil means around said core, means for applying an alternating current to said coil means thereby to effect an alternately reversing magnetic flux in said core, shaft means rotatably mounted coaxially of said core, permanently magnetized armature means radially extending from said shaft means to the radially outer edges of said pole faces for oscillation within said gap between said ends when the polarity of said magnetic flux is reversed, to oscillate said shaft means.

4. An electric solenoid actuator comprising a toroid-like core having a gap therein, said gap defining two ends on said core comprising opposed radial pole faces, coil means around said core, means for effecting an alternately reversing magnetic flux in said core, shaft means rotatably mounted coaxially of said core, armature means radially extending from said shaft means to the radially outer edges of said pole faces for oscillation within said gap between said ends when the polarity of said magnetic flux is reversed, to oscillate said shaft means.

5. An electric solenoid actuator comprising a first tubular body defining a first chamber, a second tubular body defining a second chamber and secured to said first tubular body, first sealing means to provide a fluid seal at one end of said first chamber, second sealing means to provide a fluid seal at the other end of said first chamber, shaft means extending through said first chamber and rotatably supported by said sealing means, toroid-like core means having a gap therein disposed in said first chamber circumjacent said shaft means, said gap defining a pair of ends, coil means around said core means, means for applying an alternating current to said coil means thereby to effect an alternating magnetic flux in said core means, permanently magnetized armature means extending radially from said shaft means for oscillation within said gap between said ends when the polarization of said magnetic flux is reversed to oscillate said shaft means, extension means contiguous with said shaft means extending into said second chamber and having external spiral threads thereon, hammer means circumjacent said extension means non-rotatably disposed in said second chamber means and having internal spiral threads, anvil means slidably mounted adjacent said hammer and having means for holding a tool bit, spring means for urging said anvil means toward said hammer means, said anvil means extensible from the second chamber means when the said armature means is rotated in one direction, and retractable inwardly by said spring means when said armature means is rotated in the opposite direction to pulsate the tool bit.

6. An electric solenoid actuator in accordance with claim 5 including means for rotating said first tubular body for rotary pulsating movement of said tool bit.

7. An electric solenoid actuator comprising a curved core having a body and ends, said ends defining a gap in said core and comprising opposed radial pole faces, said ends being radially enlarged relative to said body, coil means around said core, said coil being adapted to be connected to an alternating current to effect a magnetic flux in said core, shaft means rotatably mounted coaxially of said core, permanently magnetized armature means extending radially from said shaft means to the radially outer edge of said pole faces and corresponding in horizontal configuration and vertical height to said enlarged ends and having a thickness substantially less than the width of said gap, said armature means being oscillated within said gap between said ends when the polarity of said magnetic flux is reversed for oscillating said shaft means.

8. An electric solenoid actuator comprising a toroid-

like core having a gap therein, said gap defining two ends on said core, coil means around said core, means for applying an alternating current to said coil means thereby to effect an alternating magnetic flux to said core, hollow shaft means rotatably mounted coaxially of said core to transmit fluid therethrough, permanently magnetized armature means extending radially from said hollow shaft means for oscillation within said gap between said ends when the polarity of the magnetic flux is reversed thereby to oscillate said hollow shaft means, hammer means circumjacent said hollow shaft, means for converting oscillation of said shaft means into reciprocal movement of said hammer means, anvil means adjacent said hammer means having a passage therethrough and adapted to hold a drilling tool, spring means for urging said anvil means toward said hammer means, said anvil means being extended by said hammer means and retracted by said spring means to pulsate the tool, said passage communicating with said hollow shaft to transmit fluid from said drilling tool.

9. The invention of claim 8, wherein said means to convert the oscillating rotary movement of said shaft into a reciprocating movement in said hammer means comprises a spirally threaded extension of said shaft adapted to engage a complementary spirally threaded recess in said hammer means, and said hammer means is non-rotatable.

10. The invention of claim 8, wherein said means to convert the oscillating rotary movement of said shaft into a reciprocating movement in said hammer means comprises piston means operatively associated with said shaft and adapted to transmit a fluid pressure to said hammer means for extending said hammer means.

11. An electric solenoid actuator comprising: a toroid-like core having a gap therein, said gap defining ends on said core, coil means around said core; means for applying an alternating current to said coil means, thereby to effect an alternating magnetic flux in said core; shaft means rotatably mounted coaxially of said core; permanently magnetized armature means radially extending from said shaft means for oscillation within said gap and between said ends when the polarity of said magnetic flux is reversed, thereby oscillating said shaft means; external spiral threads on said shaft means and spaced from said armature means; sleeve means circumjacent said threads and having internal spiral threads engaging said external threads; and means on said sleeve means for preventing rotation of said sleeve means, said external threads cooperating with said internal threads to reciprocate said sleeve when said shaft is oscillated.

12. An electric solenoid actuator in accordance with claim 11 including: anvil means slidingly disposed beneath said sleeve means and being adapted to hold a tool bit; and spring means for urging said anvil means toward said hammer means, said anvil means being extended downwardly by said sleeve means when said armature means is rotated in one direction, and being urged upwardly by said spring means when said armature means is rotated in an opposite direction for oscillating said tool bit.

13. An electric solenoid actuator comprising: a first tubular body defining a first chamber; a second tubular body defining a second chamber and secured to said first tubular body; first sealing means to provide a fluid seal in one end of said first chamber; second sealing means to provide a fluid seal at the other end of said first chamber; shaft means extending through said first chamber and rotatably supported by said sealing means; toroid-like core means having a gap therein horizontally disposed in said first chamber circumjacent said shaft means, said gap defining a pair of ends; coil means around said core means; means for applying an alternating current to said coil means, thereby to effect an alternating magnetic flux in said core means; permanently magnetized armature means extending radially from said shaft means for oscillation within said gap between said ends when the polarization of said magnetic flux is reversed to oscillate said shaft means; transverse wall means for dividing said second chamber means into discrete compartments; extension means contiguous with said shaft means extending through said second chamber means and adapted to oscillate with said shaft means; a pair of arcuate piston means having ends horizontally and slidingly disposed in a first compartment for reciprocal movement in a horizontal plane; piston-actuating hammer means on said extension means and disposed in said first compartment between adjacent ends of said arcuate piston means and adapted to translate the oscillating movement of said extension means into an arcuate movement of each of said arcuate piston means; stop means in said first compartment and adapted to limit arcuate movement of each of said arcuate piston means in one direction while the other of said arcuate piston means is being actuated in an opposite direction by said piston-actuating hammer means; means defining an opening in said wall means and communicating between said first compartment and a second compartment, said opening communicating with an area of said first compartment between opposite adjacent ends of said arcuate piston means; annular piston hammer means vertically disposed in said second compartment and circumjacent said extension means for axial movement in said second compartment; anvil means slidingly disposed in said second compartment adjacent said annular piston hammer means; means on said anvil means for holding a tool bit; and spring means for biasing said anvil means toward said piston means, whereby oscillation of said armature means and thereby of said piston-actuating means is translated into an arcuate movement of said arcuate piston means for applying fluid pressure through said opening and to said piston hammer means to extend said anvil means against the bias of said spring means to extend the tool bit, said piston hammer means being retracted by said spring means.

14. An electric solenoid actuator comprising: a tubular body having discrete annular chambers; rotatable shaft means extending through said chambers; electric solenoid means in said first chamber circumjacent said shaft means and adapted to oscillate said shaft means; actuator means extending radially from said shaft means and axially spaced from said solenoid means and adapted to oscillate with said shaft means; arcuate piston means in a second annular chamber and circumjacent said shaft means and operatively associated with said actuator means for translating the oscillation of said actuator means into an arcuate movement of said arcuate piston means for creating a fluid pressure in said second chamber; annular piston hammer means in a third chamber and circumjacent said shaft means for reciprocal sliding movement in said third chamber and on said shaft means; passage means for transmitting fluid pressure from said second chamber to said third chamber; anvil means adjacent said piston hammer means and adapted to hold a tool bit; and spring means for biasing said anvil means toward said piston hammer means, said anvil means being extensible outwardly by said piston hammer means when said actuator means is oscillated and retractable inwardly by said spring means to pulsate the tool bit.

15. An electric solenoid actuator comprising: a toroid-like core having a gap therein, said gap defining ends on said core; coil means around said core; means for applying an alternating current to said coil means thereby to effect an alternating magnetic flux to said core; shaft means rotatively mounted coaxially of said core; permanently magnetized armature means extending radially from said shaft means for oscillation within said gap and between said ends when the polarity of the magnetic flux is reversed, thereby to oscillate said shaft means; hammer means circumjacent said shaft means; means for converting said oscillation of said shaft means into reciprocal movement of said hammer means; anvil means adjacent said hammer means and adapted to hold a drilling

tool; and spring means for urging said anvil means toward said hammer means, said hammer means being extended by said anvil means and retracted by said spring means to pulsate the tool.

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