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BOREHOLE DRILLING SYSTEM

Filed May 1, 1961 2 Sheets-Sheet 1

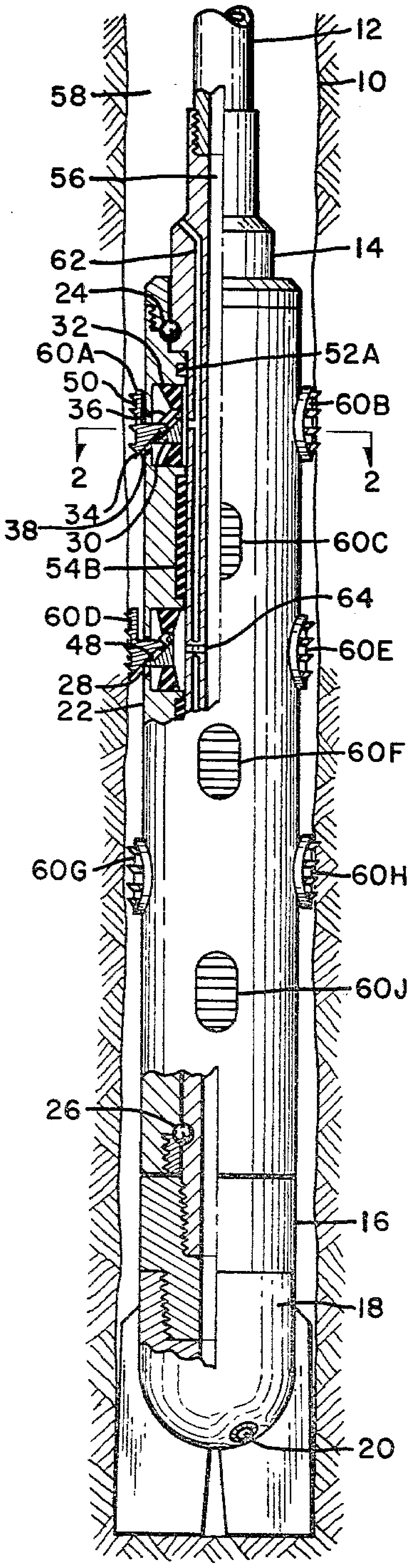

FIG. 1

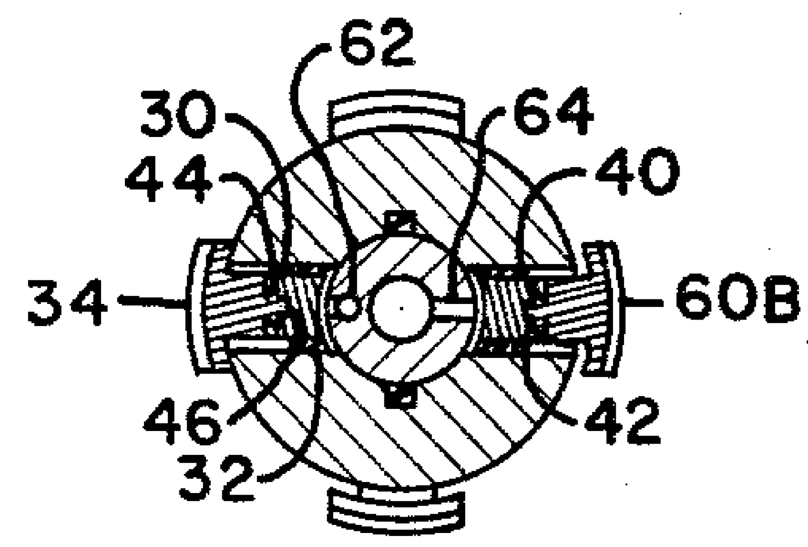

FIG. 2

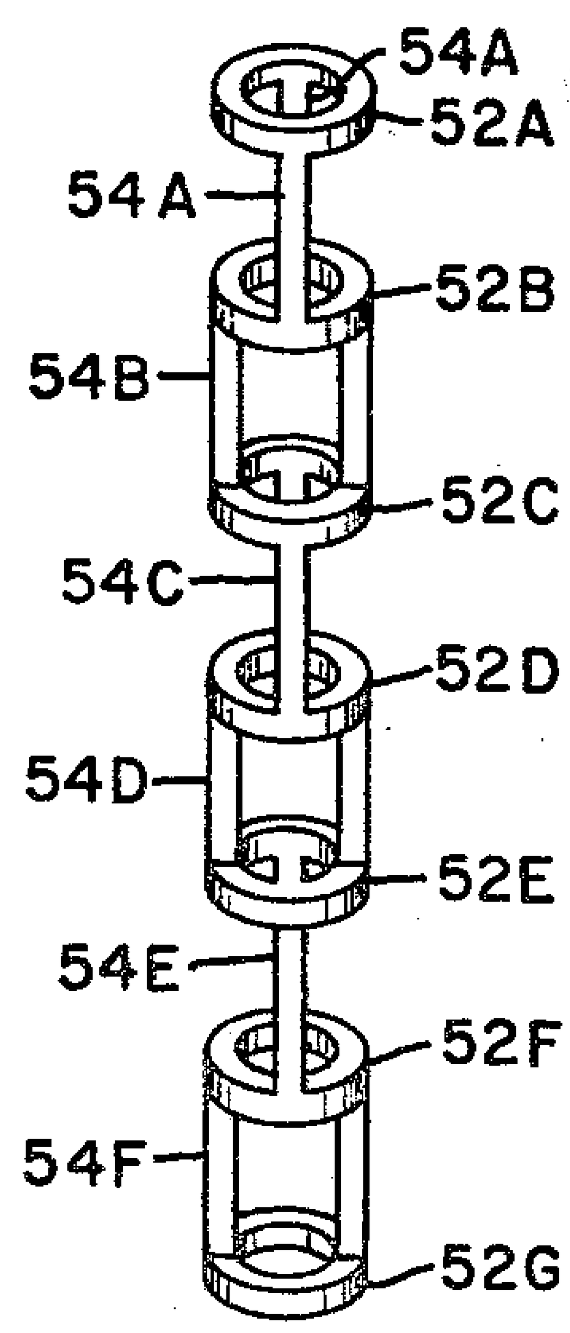

FIG. 3

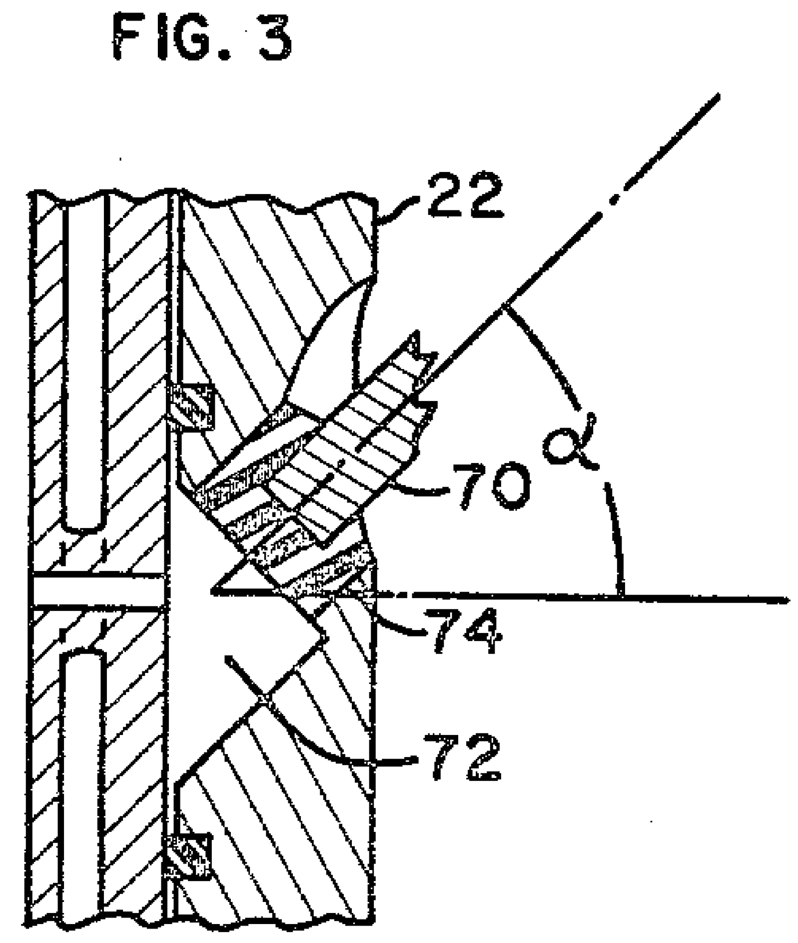

FIG. 4

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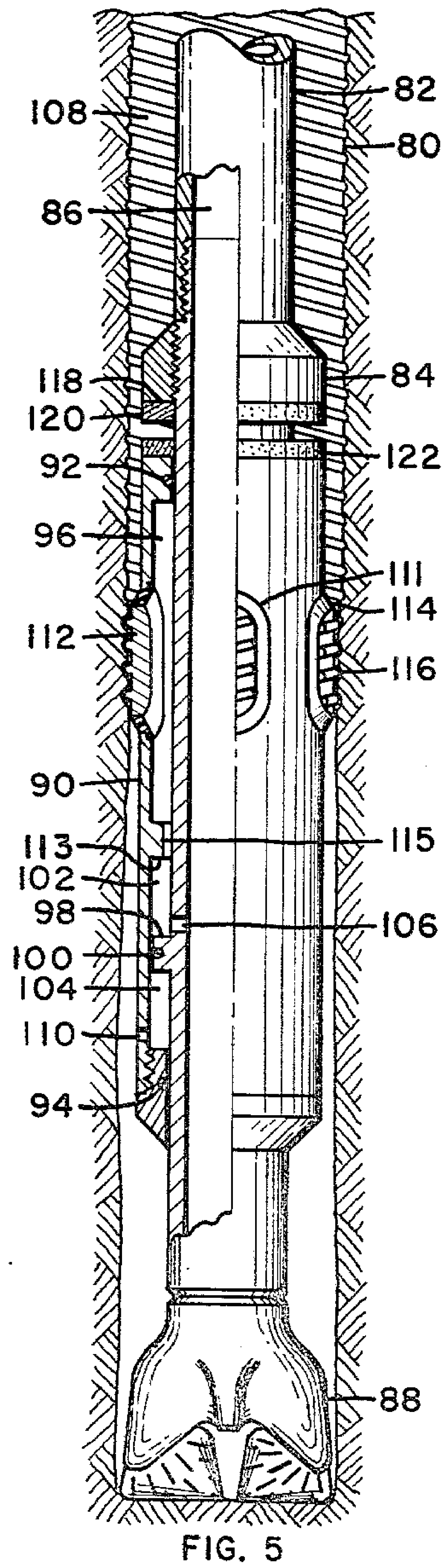

FIG. 5

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BOREHOLE DRILLING SYSTEM

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The present invention relates to the drilling of wells and similar boreholes and more particularly relates to an improved system for the application of force to a bit during the drilling of such boreholes. In still greater particularity, the invention relates to a method and apparatus for continually urging a drill bit against the bottom of a borehole by the application of upward force against the borehole wall.

Systems currently in use for the drilling of wells and similar boreholes require that a string of drill pipe and a rotary or percussive drill bit be suspended in the borehole by means of a suitable drilling rig. The pipe and bit are generally rotated in the hole by a rotary table on the rig floor while drilling fluid is circulated through the pipe and surrounding annulus by pumps or compressors in order to cool the bit, prevent the entry of fluids into the hole, and carry cuttings to the surface. In such systems, the force applied to the formation at the bottom of the hole by the bit is controlled by means of heavy drill collars connected between the drill pipe and the drill bit. These drill collars are generally several hundred feet in length and may weigh fifty thousand pounds or more. The collars concentrate the weight used for the application of force to the bit near the lower end of the drill string and thus permit the relatively thin-walled drill pipe above them to be held in tension. This cuts down flexing and buckling of the pipe as the drill string is rotated, reducing the likelihood of drill string failure and minimizing the tendency of the bit to deviate from the desired direction.

Although drill collars are widely employed in the manner described above, their use is accompanied by certain disadvantages. A much larger drilling rig is required where a heavy column of drill collars is used than would be necessary if the collars did not have to be raised during trips into and out of the hole. The time and energy required to handle the collars are significant factors in determining total drilling costs. Sticking of the drill string in the borehole is often attributable to the presence of the collars. The length of the collars frequently prevents their use in drilling through hard formations lying very close to the earth's surface. These and other disadvantages will be be familiar to those skilled in the art.

Accordingly, it is an object of this invention to provide an improved method for the continuous application of force to the bit during the drilling of wells and similar boreholes which will obviate the necessity for utilizing conventional drill collars.

It is another object of this invention to provide a method and apparatus for continuously urging a bit downwardly against the formation at the bottom of a borehole by the application of force against the borehole wall.

These and objects which will be obvious from the accompanying disclosure are attained in accordance with the invention by continually applying upward force to the borehole wall at successively lower points from a limited section of the drill string located near the bit. By thus urging the drill string downwardly at a rate equal to or in excess of that at which the bit advances, the force required for satisfactory drilling rates can be applied to the bit continuously without the necessity for employing conventional drill collars. The resulting reduction in the weight of the downhole equipment permits the use of a smaller drilling rig and power source and reduces the cost of handling the string during trips into and out of the bore-

hole. Difficulties due to sticking of the string in the hole are mitigated. Problems in drilling through hard, very shallow formations are largely avoided. The net results is thus an over-all increase in drilling efficiency.

Several different forms of apparatus may be utilized in practicing the method of the invention. A preferred form includes a tubular shaft insertable in the lower part of the drill string through which fluid may be circulated to the bit and an outer sleeve surrounding the shaft in a sealing, rotatable relationship. A thrust bearing or similar means is provided to prevent or restrict longitudinal movement between the sleeve and shaft. Thrust members are mounted in the wall of the sleeve and are designed to engage the wall of the borehole and exert an upward force against it. The reaction is a downward force against the sleeve of the apparatus. This downward force is transmitted through the thrust bearing to to the shaft, thus forcing the bit connected to the shaft downwardly against the bottom of the borehole. As will be seen from the ensuing description, thrust members of various types may be utilized to apply a downward force on the bit by applying upward force against the borehole wall.

The method of the invention and the apparatus utilized in conjunction therewith can best be understood by referring to the following description and the accompanying drawing, in which:

FIGURE 1 is a vertical elevation, partially in section, illustrating a preferred embodiment of apparatus useful in practicing the invention;

FIGURE 2 is a cross-section taken along the line 2—2 of FIGURE 1;

FIGURE 3 is a schematic drawing showing a portion of the sealing lattice in the apparatus of FIGURE 1;

FIGURE 4 shows an alternate thrust member arrangement for the apparatus of FIGURE 1; and

FIGURE 5 illustrates another embodiment of apparatus which may be employed in the practice of the invention.

FIGURE 1 of the drawing illustrates the best mode presently contemplated for carrying out the invention. Depicted therein, suspended in borehole 10, is a string of drill pipe 12 to which a tubular shaft or arbor 14 is connected by suitable threads or other means. The arbor includes lateral ports and connecting conduits which will be discussed hereinafter. Attached to the lower end of arbor 14 is an adapter 16 which in turn is connected a bit 18. The arbor and adapter serve to convey drilling fluid from the drill pipe to the bit. The bit can be a conventional drag bit as shown or other rotary drilling tool, or it may instead be a percussion bit assembly including means for reciprocating the cutting elements in response to fluid flow or rotation of the drill string. The bit includes nozzles 20, only one of which appears in the drawing. Due to the pressure drop across the nozzles, the pressure within the arbor is considerably greater than the pressure in the annulus surrounding the tool.

Mounted about arbor 14 is a tubular sleeve or housing 22. Housing 22 as shown is rotatably supported about arbor 14 by upper thrust and radical bearings 24 and lower thrust and radial bearings 26. The bearings, depicted in simplified form, reduce friction between the arbor and housing and at the time prevent axial movement of the arbor with respect to the housing. Any downward force exerted on housing 22 is therefore transferred through bearings 24 and 26 to arbor section 14.

Housing 22 contains a plurality of ports 28 extending through the housing wall. These ports are spaced at intervals about the housing and are grouped in two or more vertically spaced rows. As shown in FIGURES 1 and 2, there are two ports in the upper row spaced apart 180°. The ports in the second row are likewise 180° apart but are rotated 90° with respect to the ports in the upper row. In the particular embodiment shown the ports in the top row, the third row and the fifth row are vertically aligned, and the ports in the second, fourth and sixth rows are likewise aligned vertically. A greater number of rows can be used and will usually be preferred. Each port contains a ram or piston **30** which is movable radially therein. Each piston **30** is resiliently sealed in its respective port by an elastic collar **32** which is bonded to the piston and surrounding wall of the port. The elastic collars are made of rubber or similar material impermeable to fluids to permit extension of the pistons within the ports in response to a difference in pressure across the wall of the housing.

Each of the pistons mounted in the housing has an outer, upwardly-facing surface **36** upon which is retained a slidably mounted thrust director or wedge **34**. The downwardly facing inner surfaces of the wedges and the upwardly-facing outer surfaces of the pistons, as illustrated, are inter-connected in a slidable relationship. Each upwardly-facing surface **36** contains a groove **40** within which spline **42** on downwardly facing surface **38** of wedge **34** is slidably fitted. To prevent wedge **34** from sliding off surface **36** of piston **30** each piston is provided with a retaining groove **44** into which retaining tongue **46** extends downwardly from spline **42**. Retaining tongue **46** stops the downward movement of wedge **34** when the retaining tongue contacts shoulder **48** at the lower end of retaining groove **44**.

Each wedge **34** is provided with an upwardly extending resetting arm **50**. As can be seen from the drawing, resetting arm **50** of wedge **34** contacts the outer surface of housing **22** as piston **30** moves into its retracted position and in effect forces wedge **34** downwardly on the outer surface **36** of the piston. For convenience, each port and the corresponding piston, wedge and collar will be referred to as a thrust unit. Thus the drawing shows twelve thrust units arranged in six rows, each row containing two thrust units which are spaced 180° apart. The thrust units are identified on the drawing by reference numerals **60A** through **60J**.

A sealing lattice is positioned between the exterior of arbor section **14** and the internal bore of housing **22**. A lattice-type seal which can be made of rubber or similar resilient material is illustrated in FIGURE 3. As shown, this seal comprises seven annular sections, **52A** through **52G**, which are interconnected by elongated upright sections **54**. Adjacent vertically-spaced upright sections are rotated 90° with respect to each other. Upright sections between adjacent annular sections are spaced 180° apart. Upper annular section **52A** fits in an annular groove in the inner houing wall above the uppermost row of ports in housing **22**. Lower annular section **52G** fits in a similar groove in the inner housing wall below the bottom row of ports in the housing. Intermediate sections **52D** through **52F** fit in annular grooves in the housing wall spaced vertically between the rows of ports. Grooves are similarly provided for the upright sections of the seal. The inner space between arbor section **14** and the interior bore of housing **22** is thus divided by the sealing lattice shown in FIGURE 3 into twelve pressure chambers, there being one such chamber for each thrust unit.

Passageways in the wall of arbor section **14** alternately connect the pressure chamber associated with each piston with the interior **56** of the arbor section and the annulus **58** between the exterior of the tool and the borehole wall. As shown in the drawing, the pressure chamber associated with thrust unit **60A** communicates through pressure relief passageway **62** with the annulus **58**. The piston of thrust unit **60A** in the upper row is therefore retracted inwardly. The pressure chamber associated with thrust unit **60B** communicates through pressure port or passageway **64** with the interior of arbor section **14**, as shown in FIGURE 2 of the drawing. As a result, the piston of thrust unit **60B** is extended outwardly. The pressure chamber adjacent one thrust unit in each of the lower rows communicates with the annulus so that the corresponding pistons are retracted; while that adjacent the other thrust unit in each row communicates with the interior of arbor **14** so that the corresponding pistons are extended outwardly. In order to simplify the drawing, all of the pressure ports and pressure relief passageways in the arbor section associated with the various thrust members are not shown. It will be obvious from the drawing, however, that the pressure chamber associated with each thrust unit communicates with the interior of the arbor **14** for one-half of each revolution of the arbor section and for the other half of each revolution communicates with the annulus **58**. The conduit and port arrangement of arbor **14** as shown is such that each thrust unit is oppositely actuated from the horizontally and vertically adjacent thrust members. When a pressure chamber communicates with the annulus, the resilient seal about the corresponding piston **30** retracts the piston. When the pressure chamber communicates with the interior **56** of arbor section **14**, the fluid pressure is greater than that in the annulus and the piston **30** is driven outwardly. Thus when one thrust unit is actuated, the vertically adjacent and horizontally opposite thrust units are in a retracted or retracting position because the corresponding pressure chambers are in fluid communication with the annulus **58**.

It will be recognized that the arrangement of the thrust units, the pressure ports, and the pressure relief ports of the tool may be modified from that shown in FIGURES 1 through 4 of the drawing. For example, in lieu of providing two thrust units in each row as shown, three or more such units may be located in each row. The units in adjacent vertically spaced rows may be offset from one another to attain smoother operation and better lateral stability. Further, the pressure ports and pressure relief ports in the arbor may be staggered. Thus it is seen that various suitable arrangements of the thrust units can be effected as desired to obtain optimum performance.

In the operation of the apparatus shown in FIGURES 1, 2 and 3, drilling fluid under pressure is circulated downwardly through drill string **12**, through interior **56** of arbor section **14**, out nozzle **20** of the bit and back up annulus **58**. Drilling is then commenced by rotating drill string **12** at the surface by a rotary table or similar equipment not shown. When arbor section **14** is in the position shown in FIGURES 1 and 2, thrust units **60A**, **60C**, **60E**, and **60G** and **60J** are retracted because the corresponding pressure chambers are open to annulus **58** at a lower pressure than that within the drill string. The pressure in the annulus **58** is usually 600 to 1000 p.s.i. or more below that in the drill string. When the pressure is equalized across the resilient seal of piston **30**, the elastic seal pulls the piston inwardly into its retracted position. As the piston moves inwardly, the resetting arm **50** of wedge **34** contacts the outer surface of housing **22** and limits movement of the wedge. Further inward movement of the piston results in the wedge being moved downwardly with a sliding action between surfaces **36** and **38**. The thrust wedge is thus moved downwardly with respect to the piston.

Thrust units **60B**, **60D**, **60F** and **60H** as shown are extended outwardly. This is because the corresponding pressure chambers are in fluid communication with the interior **56** of arbor section **14**, at a pressure considerably higher than that in the annulus **58**. The pistons are forced outwardly, thus forcing the associated wedges outwardly against the formation borehole. The outer faces of the wedges which contact the borehole wall may be serrated to improve their holding ability.

After a wedge comes into contact with the borehole wall as described above, further outward movement of the corresponding piston tends to force the wedge upwardly. Since the outer surface of the wedge is anchored against the wall and cannot move upwardly, a downward reaction force is transferred to housing 22. Housing 22 moves downwardly in response to this force. As it moves, the pistons move outwardly and downwardly with respect to corresponding wedges. The downward thrust exerted against housing 22 is transferred through thrust bearings 24 and 26 to arbor section 14. The arbor section thus tends to move downwardly and hence force the bit against the bottom of the borehole. Continued rotation of arbor section 14 aligns pressure port 64 with the pressure chamber associated with thrust unit 60A. Discharge conduit 62 is similarly aligned with the pressure chamber associated with thrust unit 60B. When this occurs, thrust unit 60A is actuated to engage the borehole wall and thrust unit 60B is retracted. The other thrust members are alternately actuated and retracted in similar manner as the corresponding pressure chambers alternately communicate with annulus 58 and the interior 56 of arbor 14. The apparatus shown in FIGURES 1 and 2 thus permits the application of upward force to the borehole wall and downward force to the bit.

FIGURE 4 of the drawing shows an alternate arrangement of the thrust units on the apparatus described above. Piston or ram member 70 is set in radial port 72 of housing 22 and is held there by resilient sealing means 74 at an angle of approximately 45° above the horizontal plane. When extended, piston 70 contacts the borehole wall and tends to force housing 22 downwardly. This downward force is transmitted through thrust means 24 and 26 to arbor 14, thus forcing bit 18 downwardly against the bottom of the borehole. Alternate pistons 70 are retracted and reset in much the same manner as in the embodiment described above in connection with FIGURES 1 and 2. The angle α which the center line or longitudinal axis of piston 70 makes with the horizontal is usually in the range of from about 30° to about 60°. An angle of about 45° is preferred, since such an angle permits a relatively long piston stroke without requiring excessive space in the housing to accommodate the piston and related members.

The amount of downward force applied against the drill bit in the apparatus described above in conjunction with FIGURES 1 and 2 of the drawing depends on several factors. Assuming a pressure drop through the bit of 600 p.s.i., 60 1⅛ inch diameter pistons of which 30 are active at one time and a thrust unit wedge angle of 45°, 30,000 pounds downward thrust can be generated. By doubling the pressure drop through the bit to 1200 p.s.i., compatible with present practice, a downward thrust of about 60,000 pounds can be obtained. The amount of thrust can be increased or decreased as desired, of course, by varying the pressure drop across the bit, by varying the size of the thrust units, or by increasing or decreasing the number of such thrust units.

It will be obvious from the foregoing that the downward force obtained from the tool of the invention depends in part upon the length of the tool and the number of thrust units provided. In most cases the tool will be designed to provide the maximum amount of force likely to be needed. Where greater force than can be obtained by means of a tool of given size is required, two or more tools may be used in tandem.

In utilizing the tool of the invention, the drill pipe above the tool will normally be held in tension in order to prevent buckling and undue wear of the tool joints. In cases where it is desired to apply less force to the bit than is normally furnished by the tool, the tension in the drill string can be increased by applying upward force to the drill string at the surface with the rig equipment to lessen the effective force of the bit. One instance where it is frequently desirable to do this is in reaming operations. The ability to control the force applied to to the bit in this manner is a particular advantage of the tool of the invention. Reduction of force on the bit is accomplished without a reduction of the flow rate of the drilling fluid. A reduction in the quantity of fluid circulated reduces the fluid available for cooling and lubricating the bit and lifting cuttings from the borehole and is therefore to be avoided. The use of an arbor which extends through the tool and rigidly connects the drill string and bit as disclosed herein readily permits control of the force on the bit.

FIGURE 5 of the drawing illustrates still another embodiment of the invention. Shown in FIGURE 5, suspended in borehole 80, is a string of drill pipe 82. Attached to the lower end of the drill pipe is arbor section 84 containing axial passageway 86 for the circulation of fluid through the tool. The arbor section is connected at its lower end to drill bit 88. Mounted about arbor section 84 is tubular housing 90. The housing is free to rotate and move axially to the arbor. Upper and lower sealing rings 92 and 94 respectively are set in grooves in the inner wall of the housing above and below annular chamber 96 between the outer wall of the arbor section and the inner wall of housing 90. Positioned within chamber 96 is an annular piston 98 which is affixed to or constructed as an integral part of arbor section 84. Ring 100 in the outer face of the piston 98 provides a seal against the inner wall of housing 90. Chamber 96 is thus divided into an upper or power section 102 and a lower or discharge section 104. Upper section 102 communicates with passageway 86 in the arbor section through port 106. Lower section 104 communicates with annulus 108 outside the tool through port 110. A projection 115, having shoulder 113, is provided on the inner wall of housing 90 to limit the downward movement of housing 90 with respect to arbor section 84.

A plurality of ports 111 extend through the wall of housing 90 into power section 102 above piston 98. The ports are spaced at regular intervals about the housing and may be arranged in one or more vertically-spaced rows. An extensible shoe 112 is mounted in each port by means of an elastic collar 114 of rubber or similar fluid-impervious material bonded to the shoe and the surrounding wall of the port. The outer surface of each shoe is provided with one or more curved runners or skate elements 116 which extend across the shoe at an angle to the transverse axis of the tool. The runners are preferably made of tungsten carbide or similar abrasion-resistant material. They may be welded or otherwise affixed to the shoe surface or may instead be constructed as an integral part of the shoe. When the shoes are extended, the runners contact the borehole wall. Rotation of the tool causes the runners to move down the wall along spiral paths. It is preferred that the runners on the various shoes be set to track the same grooves cut in the borehole wall. The pitch at which the runners are set will depend largely upon the speed at which the tool is to be rotated and the rate at which the bit can be expected to advance. In general, it is preferred that the runners be set at an angle of from about 1° to about 5° to the horizontal. A series of replaceable runners having various pitch angles may be provided.

A clutch arrangement in the apparatus provides for the transfer of rotary motion from the arbor section to the housing. The upper end of arbor section 84 above housing 90 is enlarged to form shoulder 118. Mounted on the lower surface of the shoulder is an annular friction plate 120 which may be made of tungsten carbide or similar abrasion-resistant material. The upper end of housing 90 is provided with an annular friction plate 122 of tungsten carbide or the like which mates with friction plate 120 to form a friction clutch.

In operating the tool shown in FIGURE 5, a drill string containing the tool is lowered to the bottom of the well bore. A gaseous or liquid drilling fluid under pressure is then circulated downwardly through arbor 84 to bit 88 and is returned to the surface through the annulus 108. The pressure in the annulus is considerably less than that within the tool because of the pressure drop across the bit. Since upper chamber section 102 is connected with passageway **86** through port **106**, the pressure in the chamber above piston **98** is also greater than that in the annulus. The fluid in section **102** tends to force piston **98** downwardly and housing **90** upwardly. It also moves shoes **112** outwardly so that runners **116** contact the borehole wall. Before the runners **116** are securely anchored to the wall of the borehole, housing **90** moves upwardly until plate **122** comes into contact with plate **120** on the arbor. The arbor is held in position by the drill string to which it is connected. After the runners have been securely anchored to the borehole wall, the reaction thrust from the downward force on piston **98** is transferred to the borehole wall through the runners and hence no axial force normally need be applied to the drill string at the surface. Drilling is commenced by rotating the drill string, arbor **84** and bit **88** from the surface. Friction between clutch plates **120** and **122** results in the transfer or torque from the arbor to housing **90**. The housing therefore rotates. Rotation of housing **90** causes runners **116** to advance down the borehole wall in a manner similar to that in which a tap advances as a hole is threaded. The rate at which the housing moves depends upon the rate at which the bit advances and the friction between the clutch plates. If the bit encounters relatively soft strata and therefore tends to advance rapidly, the bit and arbor will move downwardly relative to the housing. This increases the friction between the plates, causing the housing to rotate and move downwardly more rapidly. If the bit encounters hard strata and the drilling rate decreases, the friction between the plates will decrease. There will be a corresponding decrease in the rate at which the housing rotates and moves downwardly. The anchoring section of the tool is thus continually advanced as drilling progresses and hence a downward axial force, supplied by pressure from the drilling fluid, is applied to the bit continuously.

What is claimed is:

1. Apparatus for use in drilling a borehole which comprises in combination:
   a hollow rigid arbor section insertable in a string of drill pipe;
   a housing member surrounding said arbor section in a sealable, rotatable, non-longitudinally movable relationship therewith;
   and a plurality of thrust members mounted in the wall of said housing member, said thrust members including means for engaging the wall of said borehole and exerting an upward thrust against said wall.

2. Apparatus for use in the drilling of boreholes in the earth which comprises in combination:
   an arbor section insertable in a drill string near a bit for establishing fluid communication between said drill string and bit;
   a housing surrounding said arbor section in a sealing, rotatable relationship;
   thrust means in said housing operable to engage the wall of said borehole and exert a downward thrust on said housing;
   and thrust transfer means to transfer the downward thrust thus exerted on the housing to said arbor section.

3. Apparatus for use in drilling a borehole using a rotary bit which comprises in combination:
   an arbor section connectable to the bit;
   a housing member surrounding said arbor section in a sealing, rotating relationship;
   thrust bearings interconnecting said housing member and said arbor section;
   a plurality of ports extending through said housing member;
   a ram member having an outwardly and upwardly facing surface, said ram member being resiliently sealed in each of said ports;
   a thrust wedge having a downwardly facing surface complementing the upwardly facing surface of said ram member, said surface of said ram member and said surface of said thrust wedge being slidable with respect to each other and said thrust wedge having an upper and a lower limit of travel with respect to said ram member;
   and conduit valve means within said arbor section to alternately connect the inner side of said resiliently sealed ram member with the interior of said arbor section and with the exterior of said housing as the arbor section is rotated.

4. Apparatus for use in drilling boreholes in the earth with a string of drill pipe and a bit which comprises in combination:
   an arbor section insertable in said drill string near said bit to establish fluid communication between the drill string and bit;
   a housing member surrounding said arbor section in a sealing and rotatable relationship therewith, the inner diameter of said housing member being sufficiently larger than the outer diameter of said arbor section to define an annular chamber between said arbor section and housing member;
   an annular piston mounted in said chamber, said piston being attached to said arbor section;
   port means in the lower portion of said housing for establishing fluid communication between said chamber below said piston and the exterior of said housing;
   port means in the wall of said arbor section above said piston for establishing fluid communication between the interior of said arbor section and said chamber above said piston;
   shoe members resiliently mounted in ports in the wall of said housing member;
   skate elements mounted on the exterior surface of each of said shoes;
   an annular fraction plate surrounding said arbor section on the upper end of said housing;
   and a second, complementary friction plate on said arbor section above said annular friction plate for engaging said annular plate.

5. Apparatus as defined by claim 4 wherein said skate elements have a pitch of not over 5 degrees.

6. A method for drilling a borehole in the earth which comprises:
   rotating a drill bit at the end of a drill string in said borehole while circulating a drilling fluid into the hole through said drill string and bit;
   applying upward force to the borehole wall from a limited section of the drill string above the bit in response to drilling fluid pressure within said drill string;
   and thereafter applying upward force to the borehole wall at successively lower points on the wall at a rate sufficient to maintain a continuous axial force on said bit.

7. A method as defined by claim 6 wherein upward force is applied to said borehole wall at successively lower points along paths parallel to the axis of said borehole.

8. A method as defined by claim 6 wherein upward force is applied to said borehole wall at successively lower points along spiral paths on the borehole wall.

9. In a drilling method wherein a drilling fluid is circulated through a drill string suspended in a borehole and a cutting tool is connected at the lower end of the string, the improvement which comprises:
   rotating said cutting tool at the lower end of said drill string;
   applying upward force to the borehole wall at spaced points from a limited section of the drill string located a fixed distance above said cutting tool in response to fluid pressure exerted by said drilling fluid within said drill string;
   and thereafter maintaining a continuous axial force on said cutting tool by applying force to said borehole

wall at successively lower points on said wall as said borehole is advanced.

10. A method as defined by claim 9 wherein said upward force is applied to said borehole wall at successively lower points on the wall along paths on the wall parallel to the axis of said borehole.

11. A method as defined by claim 9 wherein said upward force is applied to said borehole wall as successively lower points along spiral paths on said wall.

12. Apparatus attachable to the lower end of a string of drill pipe for forcing a bit against the bottom of a borehole comprising in combination:

an arbor including means near the ends thereof for attaching said bit to said string of drill pipe;

a housing surrounding said arbor in a rotatable sealing relationship therewith;

a plurality of ports in the wall of said housing;

thrust units resiliently sealed in said ports, said thrust units including means for engaging the wall of said borehole and exerting upward force against the borehole wall;

and thrust transfer means between said housing and arbor for transmitting downward force from said housing to said arbor.

13. Drilling apparatus which comprises:

an arbor section including means located near the ends thereof for rigidly connecting a bit to a drill string and means for conveying fluid from the drill string to the bit;

a housing member surrounding said arbor section in a sealing, rotatable relationship therewith, the inner diameter of said housing member being sufficiently larger than the outer diameter of said arbor section to define an annular chamber between said arbor section and housing member;

port means in said arbor section for providing fluid communication between said chamber and the interior of said arbor section;

a plurality of ports in the wall of said housing member;

and a thrust member sealingly and resiliently mounted in each of said ports, said thrust member including means for engaging the wall of the borehole and exerting an upward force against the borehole wall.

14. Apparatus for use in drilling a borehole with a rotary bit which comprises in combination:

an arbor section connectable to said bit;

a housing member surrounding said arbor section in a sealing rotating relationship;

thrust bearing interconnecting said housing member and said arbor section;

a plurality of ports extending through said housing member;

a ram member resiliently sealed in each of said ports, the longitudinal axis of said ram member extending at an angle above the horizontal plane in the range of from about 30 degrees to about 60 degrees;

and conduit valve means within said arbor section to alternately connect the inner side of said resiliently sealed ram member with the interior of said arbor section and with the exterior of said housing as the arbor section is rotated.

15. Apparatus as defined by claim 14 in which the longitudinal axis of said ram member extends at an angle with the horizontal plane of about 45 degrees.

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