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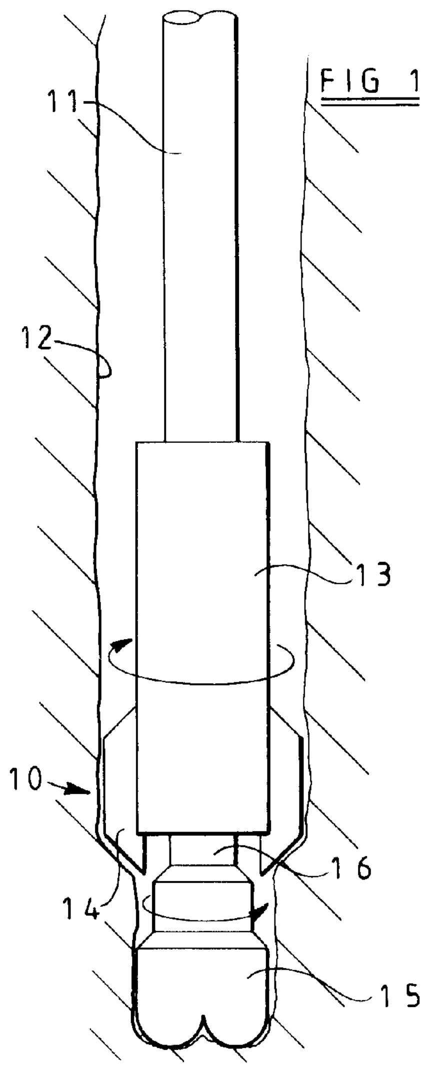
(54) A drilling assembly for use in drilling holes in subsurface formations

(57) A drilling assembly for connection to a drill string, for use in drilling holes in subsurface formations, comprises a drill bit (15) carrying cutters located and orientated to perform cutting action on the formation as the drill bit rotates anti-clockwise relative thereto. A drive unit (13), such as an hydraulically driven positive displacement motor or turbine, or an electric motor, is operatively coupled to the drill bit (15) to rotate the drill bit anti-clockwise relative to the drive unit, and a hole opener (14) is coupled to the drive unit for rotation therewith. There may be provided two drive units in series, comprising a first drive unit (20) operatively coupled to the drill bit to rotate the drill bit in one direction relative to the first drive unit, and a second drive unit (23) operatively coupled to the first drive unit to rotate the first drive unit in the opposite direction relative to the second drive unit. A hole opener is coupled to at least one of the drive units for rotation therewith.

FIG 1



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Description

The invention relates to a drilling assembly for connection to a drill string for use in drilling holes in subsurface formations.

As is well known, in rotary drilling rotation is imparted to the drill bit by rotating the drill string by means of a rotary table or top drive at the surface. In motor drilling the drill bit is rotated relative to the drill string by a drive unit, such as a positive displacement motor or turbine, mounted at the lower end of the drill string. In this case the drill string itself may also be rotated either to reduce the frictional restraint to longitudinal movement of the drill string and/or to negate the effect of a steering assembly, such as a bent sub, when steering is not required.

In either case, both the drill string and drill bit rotate clockwise as viewed looking down the borehole and the reactive torque from the drill bit is transferred to the drill string.

US Patent No. 4862974 discloses a drilling assembly incorporating a motor driving a drill bit where stabilisers and cutters are mounted on the housing of the motor, the cutters on the housing extending radially outwards to a diameter which is greater than the diameter of the drill bit. During drilling the motor housing and the drill bit both rotate in the same, clockwise, direction.

European Patent No. 0400921 discloses a drilling assembly incorporating two concentric rotatable cutting elements which are rotatable at different speeds in the same, clockwise, direction.

The present invention sets out to provide improved drilling assemblies where the reactive torque transferred to the drill string may be reduced. The invention may also provide other benefits such as allowing a reduction in cutting speeds and an increase in the available torque and/or power for drilling.

According to one aspect of the invention there is provided a drilling assembly for connection to a drill string for use in drilling holes in subsurface formations, the assembly comprising a drill bit carrying cutters located and orientated to perform cutting action on the formation as the drill bit rotates anti-clockwise relative thereto, a drive unit operatively coupled to the drill bit to rotate the drill bit anti-clockwise relative to the drive unit, and a hole opener coupled to the drive unit for rotation therewith.

In this specification references to clockwise and anti-clockwise rotation refer to the direction of rotation as viewed looking down the borehole.

In the arrangement according to the first aspect of the invention the counter-rotation ofthe drill bit and hole opener has the effect of at least partly cancelling out the opposed reactive torques transmitted to the drill string by the drill bit and hole opener respectively. It will be appreciated that in order for the drill bit to rotate anti-clockwise relative to the formation the anti-clockwise speed of rotation of the drill bit relative to the drill string must be greater than the clockwise speed of rotation of the drill string. Preferably the speed of rotation of the drill bit relative to the drill string is greater than twice the speed of rotation of the drill string.

As is well known, drag-type drill bits may employ cutters which are polycrystalline diamond compacts (PDC). It is known that PDC wear-resistance decreases with rise in temperature which depends, at least to some extent, on the surface speed of the cutters through the formation. It has been shown that cutter wear-resistance can be reduced by a catastrophic 80% when a critical surface speed is exceeded. The critical speed under downhole conditions almost certainly depends on rock type, drilling mud type, downhole temperatures etc., but it is considered that bit life may be substantially improved if the surface cutting speed is kept below 50m/min (3ft/sec). The reduced cutting speed may also reduce impact damage to the cutting structure. The arrangement of drilling assembly according to the invention allows the available torque to be increased, and the cutting speed to be reduced, when compared to conventional drilling systems where the drill bit rotates at the same speed as the drill string, as in rotary drilling, or at a greater speed, as in motor drilling. The increase in available torque will allow the weight-on-bit to be increased to give increased depth of cut.

The invention allows any desired trade-off between torque, power and cutting speed to give a desired result. For example, by using a smaller diameter bit and larger diameter hole opener the string torque, drilling torque and total power may be increased. In some formations, such as soft formations, it may be preferred to allow an increase in cutting speed to achieve more power.

The counter rotating arrangement may also help in breaking up vibrational pattems which may develop in bit assemblies, and aid stability. This advantage may be enhanced by providing the drill bit and hole opener with different numbers of blades on which their respective cutters are mounted.

According to a second aspect of the invention, there is provided a drilling assembly for connection to a drill string for use in drilling holes in subsurface formations, comprising a drill bit, a first drive unit operatively coupled to the drill bit to rotate the drill bit in one direction relative to the first drive unit, a second drive unit operatively coupled to the first drive unit to rotate the first drive unit in the opposite direction relative to the second drive unit, and a hole opener coupled to at least one of said drive units for rotation therewith.

The drill bit may be rotated anti-clockwise by the first drive unit, the first drive unit being rotated clockwise by the second drive unit.

It will be appreciated that, in order for the drill bit to rotate in the opposite direction to the hole opener, the speed at which the drill bit is rotated by the first drive unit must be greater than the speed at which the second drive unit rotates the first drive unit.

Such counter-rotating arrangement may also provide the advantages referred to above in relation to the first aspect of the invention. However, the second aspect of the invention is also applicable to drilling systems where the drill string does not rotate during drilling, such as steering or coiled tube applications where the drill string comprises tubing fed continuously without axial rotation from a coil.

In both forms of drilling assembly referred to above, in accordance with the invention, at least one drive unit may comprise an hydraulically driven displacement motor, an hydraulically driven turbine, or an electrically driven motor. The drive unit which is operatively coupled to the drill bit may include an outer housing on which the hole opener is directly mounted. Alternatively the hole opener may be a unit separate from the drive unit housing but connected to rotate therewith. The hole opener may be a symmetrical hole opener or an eccentric hole opener.

The terms "hole opener" and "drill bit" are used above to define different components of the drill bit assembly but it is not intended that these components should necessarily correspond in detailed design to existing components referred to as drill bits and hole openers. For example, the "hole opener" may comprise a component which surrounds the "drill bit" so as to form a single unit having an inner portion which rotates in one direction and a surrounding annular portion which rotates in the opposite direction. However, the invention does include arrangements where the drill bit and hole opener are separated axially along the assembly.

In conventional arrangements where the drill bit and hole opener rotate at the same rotational speed, the outer cutters on the hole opener will move at a linear speed which is greater than the outer cutters on the drill bit. The counter rotating arrangements according to the invention allow the rotational speed of the two components to be adjusted so that, if desired, the cutting speed of the outer elements on the hole opener may be substantially the same as the cutting speed of the outer elements on the drill bit. This may reduce the increased rate of wear of the outermost elements which can occur in prior art arrangements.

The maximum linear cutting speeds of the cutters on the drill bit and hole opener respectively, relative to the formation, are preferably within 60% of each other, and more preferably essentially the same.

The reactive torques of the drill bit and hole opener are preferably balanced to within less than 40% of each other, and more preferably are essentially balanced.

Preferably the diameter of the drill bit is less than 90% of the diameter of the hole opener. For example, it may be less than 50%, or less than 30%, of the diameter of the hole opener.

In the case where the drill bit is of insufficient size to handle the volume of fluid flow desirable for the purposes of an hydraulically driven drive unit or units, means may be provided for the controlled venting of a proportion of the flow of drilling fluid between the output shaft of the drive unit which is coupled to the drill bit and the drill bit itself, so as to reduce the flow of drilling fluid passing to the face of the drill bit.

In any of the above arrangements the drilling assembly may comprise part of a larger bottom hole assembly for connection to the drill string, the bottom hole assembly further including, for example, a thrust unit, one or more further hole openers, one or more stabilisers, or other components of known kind which may be incorporated in a bottom hole assembly.

According to the first aspect of the invention, the drill bit is rotated anti-clockwise relative to the drill string and will normally therefore also rotate anti-clockwise relative to the formation. The present invention therefore further includes within its scope a drill bit comprising a main body having means for connection to another component of a drill string or bottom hole assembly, and a plurality of cutters mounted on said main body, said cutters being located and orientated to perform cutting action on the formation as the drill bit rotates anti-clockwise relative thereto, and said connection means being suitable for anti-clockwise rotation.

Similarly, in some arrangements according to the second aspect of the invention, the hole opener coupled to the first drive unit may rotate anti-clockwise relative to the formation, whereas in prior art arrangements hole openers are designed to rotate clockwise relative to the formation. Accordingly, the invention also includes within its scope a hole opener comprising a main body having means for connection to another component of a drill string or bottom hole assembly, and a plurality of cutters mounted on said main body, said cutters being located and orientated to perform cutting action on the formation as the hole opener rotates anti-clockwise relative thereto.

The invention also includes within its scope an hydraulically driven positive displacement motor or turbine, or an electrically driven motor, suitable for use as a drive unit for a drill bit in a downhole drilling assembly for use in drilling holes in subsurface formations, and comprising a housing and an output rotor, wherein the output rotor rotates anti-clockwise.

The invention is particularly applicable to drag-type drill bits having PDC cutters, but the drill bit may also be of any other suitable form, for example it might be a roller cone bit, a diamond bit or combination bit. Similarly, the cutters on the hole opener may be PDC, diamond, or of any other suitable form.

The following is a more detailed description of embodiments of the invention, by way of example, reference being made to the accompanying drawings in which:

Figure 1 is a diagrammatic side elevation of one form of drill bit assembly, according to the invention, shown in a borehole,
Figure 2 shows a modification of the assembly of Figure 1, and
Figure 3 is a similar view of a drill bit assembly according to the second aspect of the invention.

Referring to Figure 1: the drill bit assembly 10 is connected to the lower end of a rotary drill string 11 at the bottom of a borehole 12. The drill string 11 and assembly 10 are rotated clockwise from the surface in a well known manner.

In accordance with the invention the drill bit assembly 10 comprises a drive unit 13 mounted on the lower end ofthe drill string 11 using a conventional coupling device. The drive unit 13 may be a turbine or positive displacement motor and a hole opener assembly 14 is mounted on the housing of the drive unit. The blades of the hole opener may be of known design, carrying cutters or abrasion elements of PDC, diamond or other suitable types of cutting element.

A drill bit 15 is coupled to the output shaft 16 of the drive unit 13, again using a coupling device of well known form. The design of the drive unit 13 is such as to rotate the drill bit 15 anti-clockwise relative to the drive unit housing and drill string 11 at a rotational speed which will normally be greater than the clockwise rotational speed of the drill string, so that the drill bit will rotate anti-clockwise with respect to the formation at the bottom of the borehole 12.

Conventional drill bits are normally designed to rotate clockwise so that the bit 15 may require to be of special anti-clockwise design. For example, it may be a drag-type drill bit in which the lower face of the bit has mounted thereon PDC cutters each of which comprises a preform element, for example in the form of a circular tablet, having a front facing table of polycrystalline diamond or other superhard material bonded to a substrate of less hard material, such as cemented tungsten carbide. Since the front cutting surfaces of the cutters must face in the direction of rotation, the cutters of the drill bit 15 will be located and orientated so as to face in the opposite circumferential direction to the corresponding cutters on a conventional clockwise drill bit.

The coupling between the drill bit 15 and the drive unit 13 will normally be in the form of a tapered threaded pin on the drill bit which engages within a corresponding threaded socket on the output shaft 16 of the drive unit. Such couplings normally have a right hand thread so that clockwise rotation of the drill bit by the drive shaft tends to tighten up the coupling. In a drill assembly according to the present invention, however, such coupling will preferably have a left hand thread so as to tend to remain tight during anti-clockwise rotation of the drill bit. Alternatively the coupling may be of a non-threaded type, for example a bayonet-type coupling, so that there is no tendency for the rotation to tend to disconnect the coupling.

Instead of being a PDC drag-type drill bit, the bit 15 might also be a natural diamond bit, a roller-cone bit, or a combination bit. Some conventional diamond bits and roller-cone bits may be suitable for rotation in either the clockwise or anti-clockwise direction, and thus may be used in the present invention, for anti-clockwise rotation, without significant alteration. However, in this case it is still preferable for the threaded coupling between the drill bit and the drive shaft 16 to have a left hand thread, rather than the conventional right hand thread, or to be of a non-threaded type, so as to be suitable for anti-clockwise rotation.

As previously described, the hole opener 14 and bit 15 may be so designed as to substantially balance the opposing torques transmitted to the drill string. The relative speeds of rotation of the drill string and the drill bit 15 are selected so as to give a desired maximum linear cutting speed of their respective cutters relative to the formation, as previously described. Preferably the maximum linear cutting speeds of the cutters on the drill bit and hole opener are similar, or at least within a maximum of 60% of each other.

In the arrangement of Figure 1 the hole opener 14 is shown as being mounted on the housing of the drive unit 13. However, it will be appreciated that the hole opener could be a separate, perhaps conventional, unit located above the drive unit 13 in the bottom hole assembly. The bottom hole assembly may, of course, also incorporate any of the other types of component commonly used in such bottom hole assemblies for various purposes. For example the assembly might include a thrust unit, one or more further hole openers, one or more stabilisers, or any other components of known kind which may be incorporated in a bottom hole assembly.

Figure 2 shows a modification of the arrangements shown in Figure 1 in which the hole opener 17 is an eccentric hole opener rather than being of the symmetrical type shown diagrammatically in Figure 1. The construction of hole openers and drill bits are well known and will not be described in further detail.

Figure 3 shows an arrangement in accordance with the second aspect of the invention where a drill bit 18 is coupled to the output shaft 19 of a first drive unit 20. A hole opener 21 is carried by the outer housing of the drive unit 20.

The drive unit 20 is coupled to the output shaft 22 of a second drive unit 23 which is coupled to the lower end of the drill string 24.

In this case, the second drive unit 23 rotates the first drive unit 20 clockwise relative to the drill string 24 and the first drive unit 20 rotates the drill bit 18 anti-clockwise relative to the housing of the first drive unit. Normally the speed of rotation ofthe drill bit relative to the first drive unit 20 will be greater than the clockwise speed of rotation of the drive unit 20 by the second drive unit 23, so that the drill bit 18 rotates anti-clockwise relative to the formation of the bottom of the borehole 25. The drill bit 18 may be a PDC drag-type drill bit, a diamond bit, a roller-cone bit or combination bit. However, the invention includes within its scope arrangements where the drill bit rotates clockwise relative to the formation.

As before, the counter rotation of the bit 18 and drive unit 20 serves to balance, or at least partly balance, the reactive torques transmitted to the drill string. However, in the arrangement of Figure 3 this may be achieved without any rotation of the drill string 24, so that the arrangement is particularly applicable for use with drilling systems where there is not a constantly rotating drill string, such as coiled tube systems.

As in the previous arrangement, the hole opener 21 need not be mounted on the housing of the first drive unit as shown, but may comprise a separate component which is coupled to the drive unit 20 so as to be rotatable therewith. Again, other conventional bottom hole assembly components may be combined with the assembly shown in the drawing. Preferably stabilisers 26 are mounted on the housing of the second drive unit 23 to stabilise it in the borehole. Alternatively, a hole opener may be mounted on the housing of the second drive unit 23, instead of, or in addition to, the hole opener 21 on the drive unit 20.

The drive units may each comprise an hydraulically driven positive displacement motor or turbine driven by the flow of drilling mud under pressure through the unit. The drilling mud may flow through the drive units in parallel, but preferably flows through the units in series. Alternatively, the drive units may comprise electrically driven motors.

Although only two drive units are shown in Figure 3, the invention also includes arrangements where three or more drive units are coupled in series between the drill string and the drill bit, alternate drive units rotating in opposite directions. \hole openers may be mounted on any or all of the housings of the drive units so as to rotate therewith.

As previously explained, the present invention allows any desired trade-off between torque, power and cutting speed to give a desired result. The following Example I gives, for comparison purposes, operating parameters for a typical prior art set-up for a conventional motor drilling assembly, without the counter-rotating feature of the present invention. Examples II-V then give the corresponding operating parameters for typical alternative set-ups for the basic counter-rotating system according to the present invention, as described above with reference to Figure 1. Examples II-IV provide, respectively, reduced string torque, reduced cutting speed, and increased power. Example V relates to a compromise set-up providing some improvement to all of these parameters.

EXAMPLE I

Conventional Motor Drilling (Prior Art).		
A typical set-up for drilling a section of a borehole could be:		
Motor:	9 5/8" DYNADRILL F2000S (5/6 lobe)	
Flow:	1000 US gal/min	
Speed:	120 rpm	
Motor Pressure Drop:	450 psi	
Motor Operating Torque:	9200 ft.lb	
Motor Power Output:	192 HP	
Drill String Speed:	50 rpm	
Bit Diameter:	12 1/4"	
From the above parameters:	Bit Speed	170 rpm
	Bit Torque	9200 ft.lb
	Drilling Power:	298 HP
	Max. Cutting Speed:	166 m/min (9.1 ft/sec)

In this conventional prior art arrangement, the rotating drill string needs to counter the motor reactive torque, overcome the friction between the drill string and the well bore, and rotate the bit at 50 rpm against the formation.

i.e. 9200 ft.lb + 1300 ft.lb (estimated) + 9200 ft.lb (all at 50 rpm)

Total drill string torque is : 19700 ft.lb

Total drill string power is: 187 HP

EXAMPLE II

Counter-rotating set-up for reduced string torque.

Motor:	Anti-clockwise equivalent of DYNADRILL F2000S

Flow:	1000 US gal/min		
Motor Speed:	-120 rpm		
Motor Pressure Drop:	450 psi		
Motor Operating Torque:	9200 ft.lb		
Motor Power Output:	192 HP		
Drill String Speed:	50 rpm		
Bit Size:	9 5/8"		
Hole Opener Size:	12 1/4"		
From the above parameters:	Bit Speed:	-70 rpm	
	Bit Torque:	9200 ft.lb	
	Power to Bit:	122 HP	
	Max. Cutting Speed:	53.7 m/min (2.94 ft/sec)	
	Hole Opener Speed:	50 rpm	
	Hole Opener Torque:	7900 ft.lb*	
	Power to Hole Opener:	75 HP	
	Hole Opener Cutting Speed:	48.9 m/min (2.67 ft/sec)	
	Total Power for Drilling:	197 HP	
Total String Torque is:	7900 + 1300 - 9200 = ZERO		

* Torque to hole opener is based on bit torque (determined by the motor torque) for a given penetration rate, taking into account the relative areas and the effective cutting radius of the bit and hole opener.

In this case the total drilling power is reduced, but the string torque is minimised. This would be useful, for example, in coiled tube applications.

The motor torque in this case is applied to a 9 5/8" bit rather than the 12 1/4" bit in the conventional set-up. This will allow a greater depth of cut, which is more efficient, and which will partly compensate for the reduced overall power.

EXAMPLE III

Counter-rotating set-up for reduced cutting speed.

Motor:	Anti-clockwise equivalent of DYNADRILL F2000S	
Flow:	1000 US gal/min	
Motor Speed:	-120 rpm	
Motor Pressure Drop:	450 psi	
Motor Operating Torque:	9200 ft.lb	
Motor Power Output:	192 HP	
Drill String Speed:	50 rpm	
Bit Size:	8 1/2"	
Hole Opener Size:	12 1/4"	
From the above parameters:	Bit Speed:	-70 rpm
	Bit Torque:	9200 ft.lb
	Power to Bit:	122 HP
	Max. Cutting Speed:	47 m/min (2.6 ft/sec)
	Hole Opener Speed:	50 rpm
	Hole Opener Torque:	18200 ft.lb*
	Power to Hole Opener:	173 HP
	Hole Opener Cutting Speed:	48.9 m/min (2.67 ft/sec)
	Total Power for Drilling:	295 HP
Total String Torque is:	18200 + 1300 - 9200 = 10300 ft.lb	

* Torque to hole opener is based on bit torque (determined by the motor torque) for a given penetration rate, taking into account the relative areas and the effective cutting radius of the bit and hole opener.

In this case the total drilling power is similar to the conventional prior art set-up, but the maximum cutting speed is drastically reduced, and in addition the string torque is reduced. The reduced cutting speed will delay the onset of significant wear and reduce impact damage to the cutters, allowing for a longer period of fast rates of penetration.

The motor torque in this case is applied to a 8 1/2" bit rather than the 12 1/4" bit in the conventional set-up. This will allow a greater depth of cut, which is more efficient, and which will give a greater rate of penetration than the conventional set-up.

EXAMPLE IV

Counter-rotating set-up for increased power for drilling.

Motor:	Anti-clockwise equivalent of DYNADRILL F2000S	
Flow:	1000 US gal/min	
Motor Speed:	-500 rpm	
Motor Pressure Drop:	750 psi	
Motor Operating Torque:	4000 ft.lb	
Motor Power Output:	380 HP	
Drill String Speed:	170 rpm	
Bit Size:	6 1/4"	
Hole Opener Size:	12 1/4"	
From the above parameters:	Bit Speed:	-330 rpm

Bit Torque:	4000 ft.lb
Power to Bit:	251 HP
Max. Cutting Speed:	164.6 m/min (9.00 ft/sec)
Hole Opener Speed:	170 rpm
Hole Opener Torque:	12700 ft.lb
Power to Hole Opener:	411 HP
Hole Opener Cutting Speed:	166.2 m/min (9.1 ft/sec)
Total Power for Drilling:	662 HP

Total String Torque is: 12700 + 1300 - 4000 = 10000 ft.lb

In this case the power for drilling is more than twice that available in the conventional motor drilling set-up for a similar maximum cutting speed, and reduced string torque.

The flow of 1000 US gal/min is too much for a 6 1/4" bit, so a proportion of the flow will be vented out between the motor output and the drill bit. This can be controlled by chokes in the bit.

EXAMPLE V

Counter-rotating - Compromise set-up.

Motor:	Anti-clockwise equivalent of BLACK MAX 9 5/8" 4 stage ML motor
Flow:	1200 US gal/min
Motor Speed:	-235 rpm
Motor Pressure Drop:	600 psi
Motor Operating Torque:	6100 ft.lb
Motor Power Output:	273 HP

Drill String Speed:	90 rpm	
Bit Size:	7 7/8"	
Hole Opener Size:	12 1/4"	
From the above parameters:	Bit Speed:	-145 rpm
	Bit Torque:	6100 ft.lb
	Power to Bit:	168 HP
	Max. Cutting Speed:	91.1 m/min (4.98 ft/sec)
	Hole Opener Speed:	90 rpm
	Hole Opener Torque:	15100 ft.lb
	Power to Hole Opener:	259 HP
	Hole Opener Cutting Speed:	88 m/min (4.81 ft/sec)
	Total Power for Drilling:	427 HP
Total String Torque is:	15100 + 1300 - 6100 = 10300 ft.lb	

In this case, compared to conventional prior art motor drilling, the total drilling power is increased (+43%), the cutting speed is reduced (46%), and the string torque is reduced (-48%). This will result in faster drilling and longer life.

Claims

1. A drilling assembly for connection to a drill string for use in drilling holes in subsurface formations, the assembly comprising a drill bit carrying cutters, a drive unit operatively coupled to the drill bit to rotate the drill bit relative to the drive unit, and a hole opener coupled to the drive unit for rotation therewith, characterised in that the drive unit is operatively coupled to the drill bit to rotate the drill bit anti-clockwise, and in that the cutters are located and orientated to perform cutting action on the formation as the drill bit rotates anti-clockwise relative thereto.

2. A drilling assembly according to Claim 1, wherein the drill bit and hole opener are provided with different numbers of blades on which their respective cutters are mounted.

3. A drilling assembly for connection to a drill string for use in drilling holes in subsurface formations, comprising a drill bit and a first drive unit operatively coupled to the drill bit to rotate the drill bit in one direction relative to the first drive unit, characterised in that there is provided a second drive unit operatively coupled to the first drive unit to rotate the first drive unit in the opposite direction relative to the second drive unit, and a hole opener coupled to at least one of said drive units for rotation therewith.

4. A drilling assembly according to Claim 3, wherein the drill bit is rotated anti-clockwise by the first drive unit, the first drive unit being rotated clockwise by the second drive unit.

5. A drilling assembly according to any of Claims 1 to 4, wherein at least one drive unit is selected from: an hydraulically driven positive displacement motor, an hydraulically driven turbine, or an electrically driven motor.

6. A drilling assembly according to any of Claims 1 to 5, wherein the drive unit which is operatively coupled to the drill bit includes an outer housing on which the hole opener is directly mounted.

7. A drilling assembly according to any of Claims 1 to 5, wherein the hole opener is a unit separate from the drive unit housing but connected to rotate therewith.

8. A drilling assembly according to any of Claims 1 to 7, wherein the hole opener is a symmetrical hole opener or an eccentric hole opener.

9. A drilling assembly according to any of Claims 1 to 8, wherein the drilling assembly comprises part of a larger bottom hole assembly for connection to the drill string, the bottom hole assembly further including any of a thrust unit, one or more further hole openers, and/or one or more stabilisers.

10. A drilling assembly according to any of the preceding claims, wherein the maximum linear cutting speeds of the cutters on the drill bit and hole opener respectively, relative to the formation, are within 60% of each other.

11. A drilling assembly according to any of the preceding claims, wherein the maximum linear cutting speeds of the cutters on the drill bit and hole opener respectively, relative to the formation, are essentially the same.

12. A drilling assembly according to any of the preceding claims, wherein the reactive torques of the drill bit and hole opener are balanced to within less than 40% of each other.

13. A drilling assembly according to any of the preceding claims, wherein the reactive torques of the drill bit and hole opener are essentially balanced.

14. A drilling assembly according to any of the preceding claims, wherein the diameter of the drill bit is less than 90% of the diameter of the hole opener.

15. A drilling assembly according to any of the preceding claims, wherein the diameter of the drill bit is less than 50% of the diameter of the hole opener.

16. A drilling assembly according to any of the preceding claims, wherein the diameter of the drill bit is less than 30% of the diameter of the hole opener.

17. A drilling assembly according to any of the preceding claims, comprising means for the controlled venting of a proportion of the flow of drilling fluid between the output shaft of the drive unit which is coupled to the drill bit and the drill bit itself, so as to reduce the flow of drilling fluid passing to the face of the drill bit.

18. A drill bit comprising a main body having means for connection to another component of a drill string or bottom hole assembly, and a plurality of cutters mounted on said main body, characterised in that said cutters are located and orientated to perform cutting action on the formation as the drill bit rotates anti-clockwise relative thereto.

19. A hole opener comprising a main body having means for connection to another component of a drill string or bottom hole assembly, and a plurality of cutters mounted on said main body, characterised in that said cutters are located and orientated to perform cutting action on the formation as the hole opener rotates anti-clockwise relative thereto.

20. An hydraulically driven positive displacement motor, suitable for use as a drive unit for a drill bit in a downhole drilling assembly for use in drilling holes in subsurface formations, and comprising a housing and an output rotor, characterised in that the output rotor rotates anti-clockwise relative to the housing.

21. An hydraulically driven turbine, suitable for use as a drive unit for a drill bit in a downhole drilling assembly for use in drilling holes in subsurface formations, and comprising a housing and an output rotor, characterised in that the output rotor rotates anti-clockwise relative to the housing.

22. A electrically driven motor, suitable for use as a drive unit for a drill bit in a downhole drilling assembly for use in drilling holes in subsurface formations, and comprising a housing and an output rotor, characterised in that the output rotor rotates anti-clockwise relative to the housing.

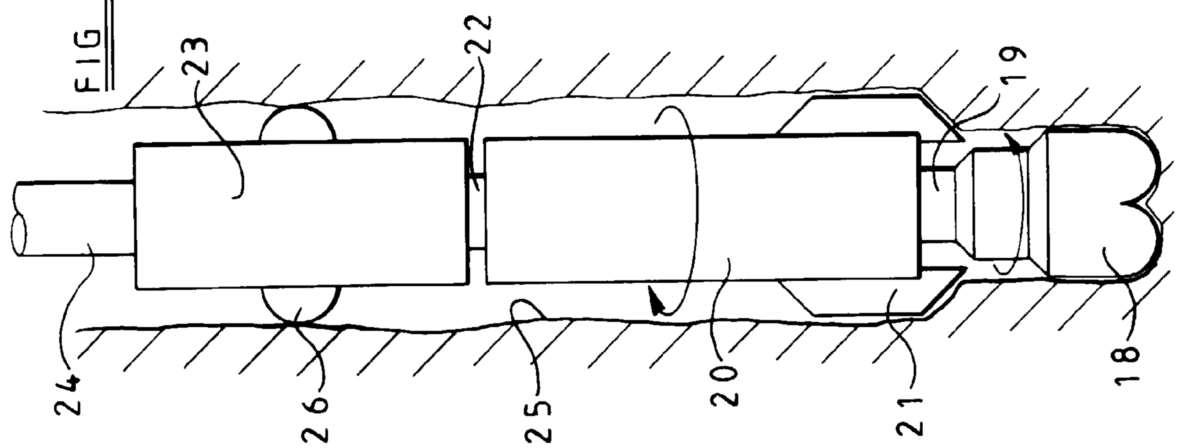

FIG 3

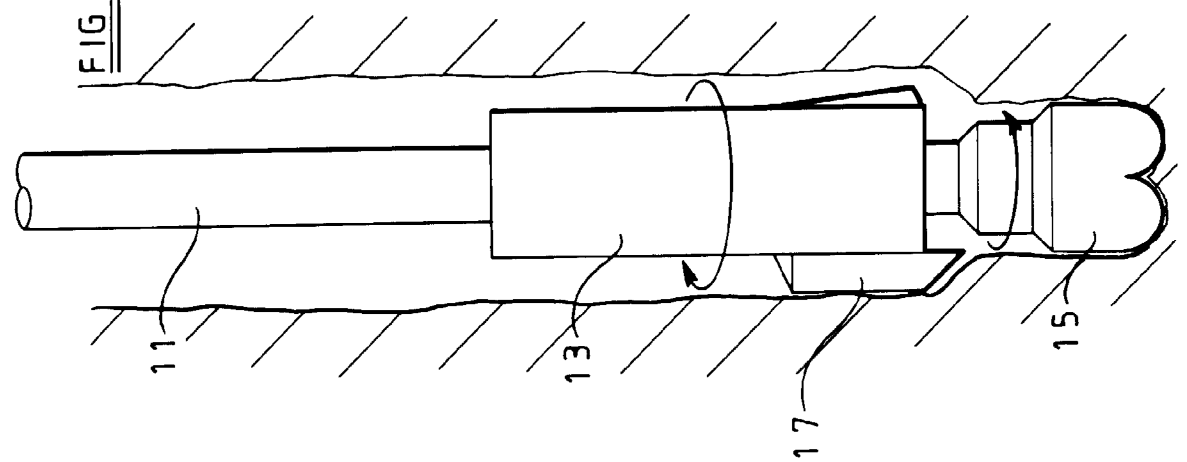

FIG 2

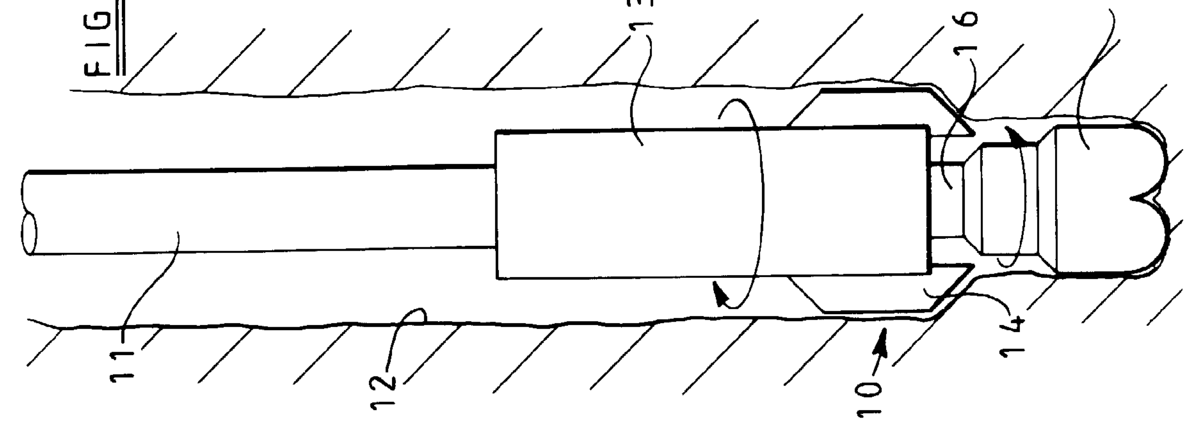

FIG 1