March 3, 1964 W. B. BUCK 3,123,159

JET UNDERREAMING

Filed Oct. 2, 1961 3 Sheets-Sheet 1

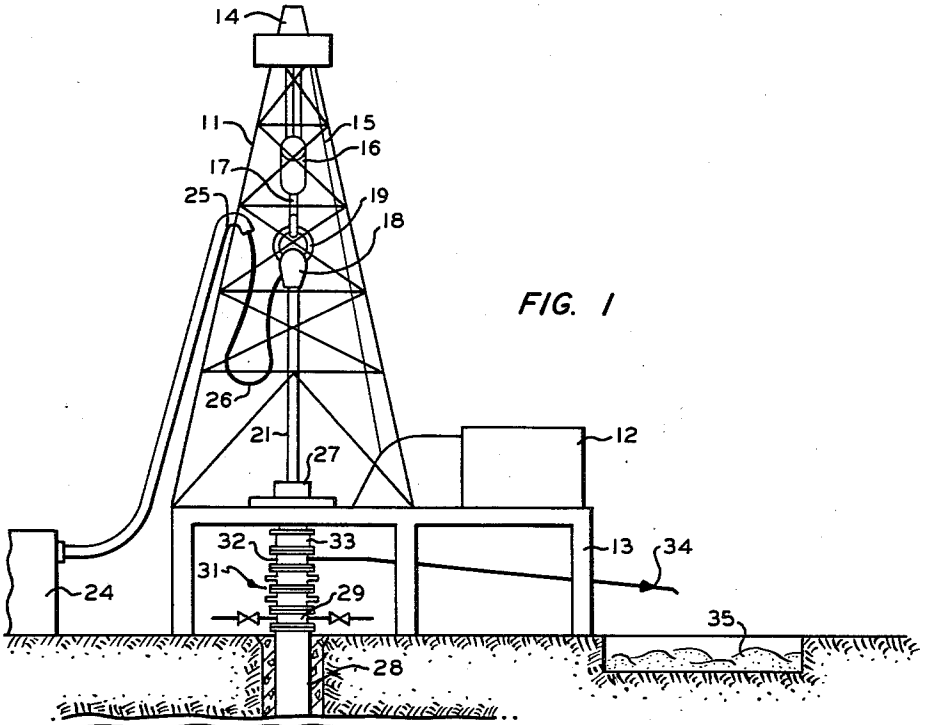
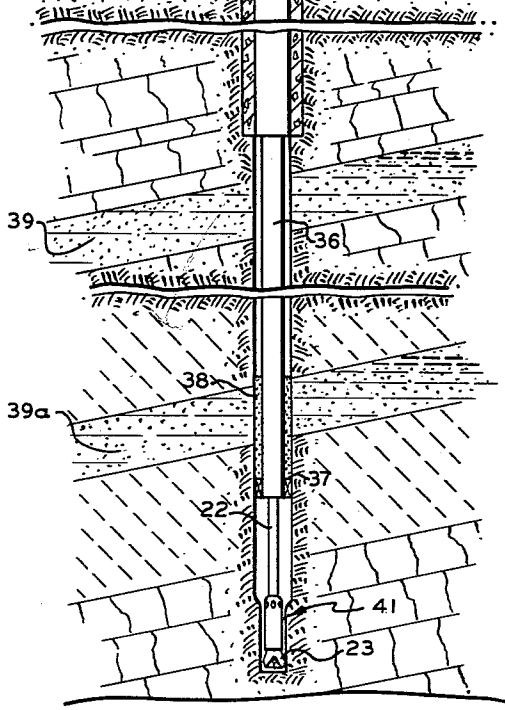


FIG. 1



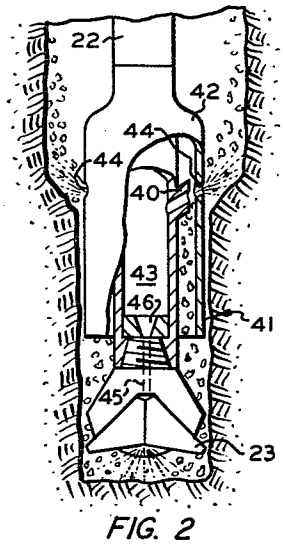


FIG. 2

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FIG. 3

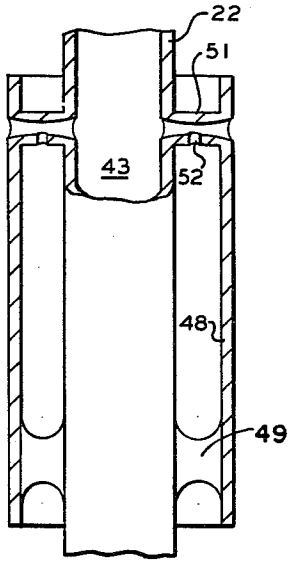

FIG. 4

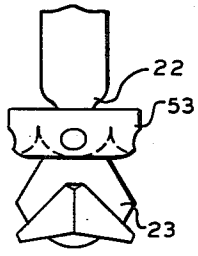

FIG. 5

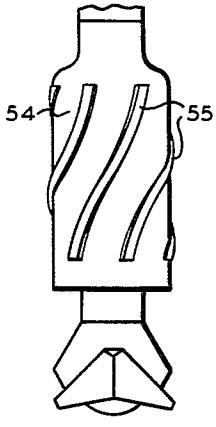

FIG. 6

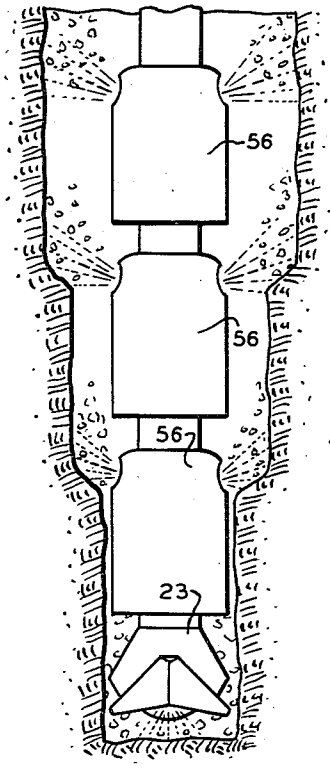

FIG. 7

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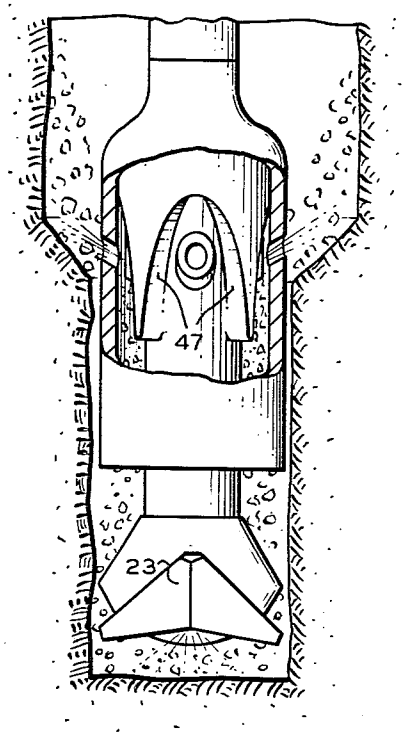

FIG. 8

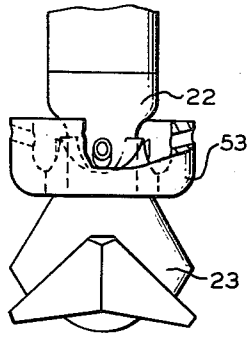

FIG. 9

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United States Patent Office

3,123,159

Patented Mar. 3, 1964

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JET UNDERREAMING

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Filed Oct. 2, 1961, Ser. No. 142,161

16 Claims. (Cl. 175—67

This invention relates to a method and apparatus for drilling wells. In one aspect the invention relates to a method and apparatus for concurrent drilling and underreaming, the underreaming being effected by projecting jets of drilling fluid containing entrained drill cuttings against the wall of the borehole. In another aspect this invention relates to a method and apparatus for drilling with gaseous drilling fluids, concurrently drilling and underreaming and periodically lowering a casing into the underreamed portion of the hole.

It has been found that in certain types of formations and in certain areas it is highly advantageous to utilize a gaseous drilling fluid rather than drilling mud. For example, in certain hard formations higher rate of penetration and reduced bit wear accompanying the use of a gaseous drilling fluid such as air or natural gas. However, in using a gaseous drilling fluid a serious problem occurs when a water-bearing formation is encountered. Water entering the borehole wets the fine drill cuttings, thus causing these cuttings to tend to adhere to each other and to the borehole walls, the bit and the drill string. This reduces the rate of drilling and, in severe cases, can cause a complete stoppage of the circulating flow.

If a casing string is run each time a water-bearing formation is encountered, in many instances several strings are required in drilling a relatively short length of borehole. This causes extra expense occasioned by the excessive amount of pipe in the well and the necessity for drilling with unusually large diameter bits during the beginning of the drilling operation. Alternatively the hole is reduced in diameter beyond a practical limit.

These difficulties can be avoided if ways can be found to lower a casing periodically as the well drilling operation continues and to form a seal between the casing and the well bore below each water-bearing formation as it is encountered and penetrated. This requires that the hole be underreamed prior to lowering the casing since the drill bit of necessity must be small enough to lower and raise through this pipe.

An object of my invention is to provide improved method and apparatus for concurrent drilling and underreaming.

Another object of my invention is to provide a method and apparatus for drilling wells with gaseous drilling fluid in areas wherein water-bearing formations are encountered.

Other aspects, objects and the advantages of my invention are apparent in the written description, the drawing and the claims.

According to my invention concurrent drilling and underreaming are accomplished by producing a pilot hole by physical contact of mechanical drilling means with a formation to be penetrated and simultaneously entraining drill cuttings in a stream of drilling fluid and directing the stream containing the cuttings against the wall of the borehole. Following the combined drilling and underreaming operation to penetrate a water-bearing formation, a casing is lowered through this formation, a seal formed between the casing and the wall of the borehole below the formation, and the drilling operation continued.

I have provided improved well drilling apparatus comprising means for drilling a pilot hole by physical contact with a formation to be penetrated and means for entraining drill cuttings in a stream of drilling fluid and for projecting the stream containing the cuttings against the wall of the borehole. According to my invention, means are provided for supplying drilling fluid to the drill string, for discharging a portion of the drilling fluid to remove drill cuttings from the vicinity of the bit and means for discharging drilling fluid above the bit in a jet, entraining a portion of the drill cuttings in the jet and discharging them against the wall of the borehole to effect the desired underreaming. A shell is provided surrounding the drill string providing a passageway for the drill cuttings, a flow nozzle provided through the wall of the drill string communicating with the fluid passageway therein, and an opening in the shell corresponding to each flow nozzle through which the jet is directed against the borehole. Means are provided for lowering a casing and for providing a seal between the casing and the borehole wall.

In the drawing, FIGURE 1 is a schematic elevation, partly in cross section, illustrating the over-all operation according to my invention.

FIGURE 2 is an elevation, partly in cross section, of the lower portion of the borehole, the drill string and the combined drilling and underreaming apparatus.

FIGURE 3 is a modification of the apparatus in FIGURE 2 including guide vanes.

FIGURE 4 is another embodiment of my invention in which the shell is open at the top and bottom and in which venturis are used as the jet nozzles.

FIGURE 5 is another embodiment of my invention in which the shell comprises an inverted skirt.

FIGURE 6 illustrates the use of hard-surfaced ribs on the outside of the underreamer.

FIGURE 7 illustrates the use of a plurality of underreamers in which drill cuttings are used more than once on the way to the surface of the ground.

FIGURE 8 is an enlarged view of a portion of FIGURE 3, partially broken away to reveal the guide vanes therein.

FIGURE 9 is an enlarged view of a portion of FIGURE 5, partially broken away to reveal the guide vanes therein.

In the drawing a derrick 11 and draw works 12 are supported on a substructure 13. Derrick 11 is provided with a crown block 14 through which drilling line 15 is run to support traveling block 16. Traveling block 16 is provided with a hook 17 which in turn supports swivel 18 which includes bale 19. Supported in turn below swivel 18 are kelly 21, drill string 22 and drill bit 23. A source of drilling fluid under pressure, for example compressor 24, is provided and connected with swivel 18 by standpipe 25 and rotary hose 26. Rotary table 27 is provided to rotate kelly 21 and suspended drill string 22. Suitable driving means, not shown, are provided for rotary table 27 and draw works 12.

A conductor casing 28 is cemented in place as shown and supports a casing head 29, blowout preventers 31, flow nipple 32 and rotating head 33. A flow line 34 is directed to a pit 35.

An inner casing 36 is provided with packer 37 and is

supported in casing head 29. Packer mud 38 is spotted above packer 37. Water-bearing formations are indicated at 39 and 39*a*

Preferably packer 37 is a hook wall type so that the casing can be set a short distance above the bottom of the hole, approximately 5 to 10 feet for example. This permits the underreaming operation to the started below the lower end of the casing, which reduces the possibility that there will be a small ledge immediately below the casing to prevent lowering it. However, if preferred, a suitable anchor packer can be used.

Underreaming apparatus 41 is provided in the drill string immediately above bit 23. This underreaming apparatus, as illustrated in more detail in FIGURE 2, comprises a shell 42, in the form of an inverted skirt, slightly smaller in diameter than bit 23, attached to drill string 22 at its upper end which is thereby closed. A flow nozzle 40 is threaded into the wall of the drill string as illustrated and thus provides communication with fluid conduit 43 inside drill string 22 and with the space outside drill pipe 22, in this embodiment discharging within shell 42. An opening 44 is provided in shell 42 in line with the discharge from flow nozzle 40. More than one flow nozzle 40 and corresponding openings 44 can be provided. Drill bit 23 is provided with the usual flow passage 45 and is threaded to drill string 22 as shown. An orifice 46 is placed above bit 23. In some instances flow passages 45 are sized with respect to flow nozzle 40 to provide the proper flow distribution without orifice 46. If desired, a suitable flow control valve, for example a spring loaded valve, to replace orifice 46 or a plurality of flow control valves, one for each flow passage 45, can be used. In the operation of the invention as illustrated in FIGURES 1 and 2, after conductor pipe 28 is cemented in place and the equipment installed thereabove as shown, drilling normally is continued using a bit somewhat larger than inner casing 36 and the drilling proceeds in the usual manner, withdrawing the drill pipe to change the bit as necessary and circulating air from compressor 24 through standpipe 25, rotary hose 26, swivel 18, kelly 21 and drill string 22 to remove cuttings back to the surface of the ground and through flow line 34 to pit 35, until a water zone 39 is encountered. If necessary, chemicals or water can be added to assist in drilling during passage through this zone or, alternatively, mechanical means can be used to control the water while zone 39 is being drilled. After zone 39 has been penetrated completely and a suitable casing seat is encountered, drill string 22 is pulled from the hole and casing 36 lowered into place. An amount of packer mud is spotted just above the bottom of casing 36 in the annulus around this casing and packer 37 is set. Preferably, the packer is set some distance, for example 5 to 10 feet, above the bottom of the hole at this point. The drill string then is made up by picking up in order bit 23, underreaming apparatus 41, drill string 22 and kelly 21. Drilling is continued, but now concurrent underreaming is accomplished. A portion of the drilling fluid circulates through flow passages 45 as before. However, orifice 46 maintains a substantial pressure drop through this area thus permitting a relatively high pressure to be maintained in fluid conduit 43 and thus a substantial portion of the drilling fluid supplied at the surface of the ground is forced through flow nozzle 40. Cuttings removed from the formation by bit 23 are circulated through shell 42 to the vicinity of flow nozzle 40 at which point these cuttings are entrained in the high velocity jet issuing through flow nozzle 40 and the jet with the entrained cuttings passes through opening 44 and impinges against the wall of the borehole, thus eroding the wall causing an enlarging or underreaming action. Thus, the drilling is continued until a second water-bearing formation, such as formation 39*a*, is encountered. After this formation is drilled and a suitable casing seat reached, the drill string is withdrawn from the hole, casing string 36 manipulated to disengage packer 37 and then lowered into position with packer 37 below formation 40. At this time a slug of packer mud is circulated down casing 36 and spotted just behind the bottom of this pipe, following which packer 37 again is set. Usually when a well is being drilled with a gaseous drilling fluid, a supply of mud is kept at hand for emergency use. This mud can be used to circulate behind the packer mud to spot this mud in place following which the drill pipe is run and the mud remaining in the hole circulated out by the gaseous drilling fluid. The operation of drilling and concurrent underreaming followed by unseating of the packer 37 and lowering of the casing 36, respotting an amount of packer mud and reseating packer 37 can be repeated as often as necessary to seal off water-bearing formations as they are encountered.

In the embodiment of the underreaming apparatus illustrated in FIGURE 3 and FIGURE 8 guide vanes 47 are provided to direct the cuttings lifted from the bottom of the hole to the various flow nozzles. These vanes are designed so that substantially the entire bottom opening of the shell is unobstructed while being shaped to guide the cuttings to the flow nozzles. The number of guide vanes required, of course, is determined by the number of flow nozzles used.

In the embodiment illustrated in FIGURE 4, the outer shell is a substantially cylindrical member 48. In this embodiment support vanes 49 hold the lower end of the shell in position around drill string 22 while the upper end is held in place by venturi flow nozzles 51 which extend through from fluid conduit 43 to the space outside shell 48. Each of these nozzles is provided with an entraining passage 52 which connects the annular space between drill string 22 and shell 48 with the throat of the venturi flow nozzle. Thus, this annular space is connected with a locus of low pressure so that the drill cuttings which are lifted from the bottom of the well are readily entrained and discharged against the wall of the hole.

In the apparatus illustrated in FIGURE 5 and FIGURE 9 the outer shell comprises an inverted skirt 53. Skirt 53 is attached to drill string 22 immediately above bit 23, thereby being closed at its lower end, the upper open end of skirt 53 helping to form a location of reduced upward velocity in the borehole. Drilling fluid discharging through bit 23 entrains the drill cuttings and lifts them upward in the hole. As the cuttings pass the upper edge of skirt 53 they enter the zone of reduced upward velocity of the drilling fluid (due to the enlarged annular area) and the lifting force is reduced so that the larger particles are allowed to drop into skirt 53 wherein they fall downward and are engaged by drilling fluid 37 and then lowered into position with packer 37 below flowing through suitable flow nozzles and directed against the wall of the borehole.

In FIGURE 6 the outer shell 54 is provided with a plurality of ribs 55 which are surfaced with a hard, long-wearing material, as for example silicon carbide, and thus this shell serves not only as the skirt of the underreaming apparatus but also serves as a stabilizer, the outer diameter of the shell including the ribs being substantially equal to the bit gauge.

In the embodiment of FIGURE 7 a plurality of shells 56, two or more, are spaced vertically above bit 23 thus serving to recirculate the drill cuttings and reuse them as they pass toward the surface of the ground, enlarging the borehole in steps.

A suitable packer mud can be made from the following ingredients:

200 bbls. water (fresh)
3500 lbs. bentonite
150 lbs. HV Driscose
50 lbs. caustic
600 lbs. Soltex
1000 lbs. Arcochrome
300 lbs. cottonseed hulls

HV Driscose is a sodium carboxymethylcellulose additive and Soltex is a modified high molecular weight hydrocarbon, both available from Drilling Specialties Company.

Arcochrome comprises leather shavings and is available from Arnold & Clark Chemical Company.

The properties of this mud are:

Weight	8.4 lbs./gal.
Funnel viscosity	131 seconds/quart.
Plastic viscosity	40 centipoise.
Yield point	38 lbs. per 100 sq. ft.
Initial gel strength	5 lbs. per 100 sq. ft.
10 min. gel strength	28 lbs. per 100 sq. ft.
Water loss	3.4 cc. API fluid loss.
Cake thickness	1/32 inch.
pH	9.
Chlorides	300 p.p.m.
Calcium sulfate	nil.

Various combinations of the elements of the various modifications of the underreaming apparatus illustrated in FIGURES 2 through 7 are within the scope of my invention as well as modifications such as changes in dimension, shape, etc. Flow nozzles discharging within the shell such as illustrated in FIGURE 2 can be substituted for the venturi flow nozzles 51 in FIGURE 4 and a venturi nozzle on the other hand can be used with the skirt type shell of FIGURE 2 and FIGURE 3. Either type of nozzle can be used in the embodiments of FIGURE 5, FIGURE 6 and FIGURE 7. Guide vanes 47 likewise can be utilized wherever necessary in any of the embodiments as can the ribs 55 illustrated in FIGURE 6. In the embodiments illustrated, the outer shell of the underreaming apparatus is larger than that portion of the drill string 22 in that vicinity. In all instances, particularly where heavy drill collars are utilized at the lower portion of the drill string, a reduced diameter portion may be used in the immediate vicinity of the underreaming apparatus to leave room for the circulation of drill cuttings. If desired, the outer shell can be made substantially the same diameter as the drill collars above.

In all of the embodiments most of the underreaming action is accomplished by the larger drill cuttings. In normal drilling practice there is some recirculation of drill cuttings in the immediate vicinity of the drill bit until such cuttings are reduced in size enough to reduce the weight-to-surface area ratio sufficiently that the particles are lifted by the ascending drilling fluid. Where a light weight, low viscosity fluid is used, especially when the fluid is gaseous, the amount of circulation and regrinding of cuttings is increased. By the practice of my invention this recirculation is appreciably reduced. This is accomplished by the action of the underreaming operation by which the larger particles are caught up in the outwardly directed streams of drilling fluid and impinged upon the wall of the borehole, thereby breaking up the larger particles. In some instances it is desirable to direct the flow nozzles at an angle upwardly in the hole to assist in the upward circulation of the entrained drill cuttings. This is particularly true in the use of multiple units as shown in FIGURE 7, although in all of the embodiments of my invention underreaming action is obtained when the flow nozzles are directed straight out at right angles to the drill string as well as when they are directed downward at a slight angle. Where insufficient underreaming is obtained through the use of drill cuttings alone or when otherwise desirable, additional solid material can be supplied from the surface of the ground to augment the underreaming action. Concurrent drilling and underreaming thus is obtained utilizing a combination of drill cuttings and solids supplied from the surface.

Reasonable variation and modification are possible within the scope of my invention which sets forth method and apparatus for concurrent drilling and underreaming by jet impingement of drill cuttings against the wall of the borehole and method and apparatus for drilling with gaseous drilling fluid by concurrent drilling and underreaming by jet impingement of drilling cuttings on the borehole wall and periodic lowering of a protective casing.

I claim:

1. A method for concurrent drilling and underreaming comprising the steps of producing a pilot hole by physical contact of mechanical drilling means with a formation to be penetrated, and simultaneously underreaming by entraining in a stream of drilling fluid cuttings produced by said physical contact and directing said stream containing said cuttings in a high velocity jet directly against the wall of the borehole.

2. A method for concurrent drilling and underreaming comprising the steps of producing a pilot hole by contact of a drilling bit with a formation to be penetrated, circulating a drilling fluid through said bit to remove cuttings from the immediate vicinity of said bit and lift said cuttings upward, discharging a stream of said drilling fluid above said drilling bit, entraining a portion of said cuttings in said stream and directing said stream and entrained cuttings in a high velocity jet directly against the wall of the borehole to effect underreaming.

3. Well drilling apparatus comprising means for drilling a pilot hole by physical contact with a formation to be penetrated, comprising a drill string and a drill bit, means to supply drilling fluid to said bit, means in said drill string above said bit for entraining in a stream of drilling fluid cuttings produced by said bit and for directing said stream containing said cuttings in a high velocity jet directly against the wall of the borehole, and means to direct said cuttings to said means for entraining.

4. Well drilling apparatus comprising means for drilling a pilot hole by physical contact with a formation to be penetrated, comprising a drill string and a drill bit, means in said drill string above said bit for supplying a gaseous drilling fluid to said means for drilling, means for entraining in a stream of said drilling fluid cuttings produced by said bit and for directing said stream containing said cuttings in a high velocity jet directly against the wall of the borehole, and means to direct said cuttings to said means for entraining.

5. Well drilling apparatus comprising a drill string comprising a fluid conduit extending from the surface of the ground into a borehole, a bit attached to said drill string and communicating with said fluid conduit, means for supplying drilling fluid to said drill string, means for discharging drilling fluid to remove drill cuttings from the vicinity of said bit, means for discharging drilling fluid above said bit and for entraining a portion of said drill cuttings and discharging said portion of entrained cuttings in a high velocity jet directly against the wall of the borehole to effect underreaming, and means to direct said cutings to said means for discharging and entraining.

6. Well drilling apparatus comprising a drill string having a fluid conduit therethrough extending from the surface of the ground into a borehole, a bit attached to said drill string and communicating with said fluid conduit, means for supplying drilling fluid to said drill string, means for discharging drilling fluid to remove drill cuttings from the vicinity of said bit, and means for discharging drilling fluid above said bit and for entraining a portion of said drill cuttings and discharging said portion of entrained cuttings against the wall of the borehole to effect underreaming, comprising a shell surrounding said drill string above said bit providing a passageway for said drill cuttings, at least one flow nozzle through the wall of said drill string communicating with said fluid conduit and with the space outside of said drill string, and an opening in said shell corresponding to each said flow nozzle.

7. Well drilling apparatus comprising a drill string having a fluid conduit therethrough extending from the surface of the ground into a borehole, a bit attached to said drill string and communicating with said fluid conduit, means for supplying drilling fluid to said drill

string, means for discharging drilling fluid to remove drill cuttings from the vicinity of said bit, and means for discharging drilling fluid above said bit and for entraining a portion of said drill cuttings and discharging said portion of entrained cuttings against the wall of the borehole to effect underreaming, comprising a downwardly extending skirt surrounding said drill string above said bit, said skirt being attached to said drill string thereby effecting closure of its upper end, and open at the bottom, at least one flow nozzle through the wall of said drill string communicating with said fluid conduit to discharge within said skirt, and an opening in said skirt corresponding and aligned with each said fluid nozzle.

8. Well drilling apparatus comprising a drill string having a fluid conduit therethrough extending from the surface of the ground into a borehole, a bit attached to said drill string and communicating with said fluid conduit, means for supplying drilling fluid to said drill string, means for discharging fluid to remove drill cuttings from the vicinity of said bit, and means for discharging fluid above said bit and for entraining a portion of said drill cuttings and discharging said portion of said entrained cuttings against the wall of the borehole to effect underreaming comprising a downwardly extending skirt surrounding said drill string above said bit, said skirt being attached to said drill string thereby effecting closure of its upper end, and being open at the bottom, at least one flow nozzle through the wall of said drill string communicating with said fluid conduit to discharge within said skirt, an opening in said skirt corresponding with and aligned with each said flow nozzle, and guides extending between said skirt and said drill stream to direct drill cuttings to the vicinity of each flow nozzle.

9. Well drilling apparatus comprising a drill string having a fluid conduit therethrough extending from the surface of the ground into a borehole, a bit attached to said drill string and communicating with said fluid conduit, means for supplying drilling fluid to said drill string, means for discharging fluid to remove drill cuttings from the vicinity of said bit, and means for discharging drilling fluid above said bit and for entraining a portion of said drill cutting and discharging said portion of said entrained cuttings against the wall of the borehole to effect underreaming, comprising a generally cylindrical shell open at top and bottom surrounding said drill string above said bit, at least one flow nozzle through the wall of said drill string and an opening in said shell corresponding to each said flow nozzle.

10. Well drilling apparatus comprising a drill string having a fluid conduit therethrough extending from the surface of the ground into a borehole, a bit attached to said drill string and communicating with said fluid conduit, means for supplying drilling fluid to said drill string, means for discharging drilling fluid to remove drill cuttings from the vicinity of said bit, and means for discharging drilling fluid above said bit and for entraining a portion of said drill cuttings and discharging said portion of said entrained cuttings against the wall of the borehole to effect underreaming, comprising an upwardly extending skirt attached to said drill string to effect closure of said skirt at the bottom end, and being open at the top end, at least one flow nozzle through the wall of said drill string communicating with said fluid conduit to discharge within said skirt, and an opening in said skirt corresponding with and aligned with each said flow nozzle.

11. Well drilling apparatus comprising a drill string having a fluid conduit therethrough extending from the surface of the ground into a borehole, a bit attached to said drill string and communicating with said fluid conduit, means for supplying drilling fluid to said drill string, means for discharging drilling fluid to remove drill cuttings from the vicinity of said bit, and means for discharging drilling fluid above said bit, and for entraining a portion of said drill cuttings and discharging said portion of entrained cuttings against the wall of the borehole to effect underreaming, comprising a shell surrounding the drill string above said bit providing a passageway for said drill cuttings, at least one flow nozzle through the wall of said drill string communicating with said fluid conduit and an opening in said shell corresponding to each said flow nozzle, and a plurality of hard faced ribs outside of said shell.

12. Well drilling apparatus comprising a drill string having a fluid conduit therethrough extending from the surface of the ground into a borehole, a rotary bit attached to said drill string and communicating with said fluid conduit, means for supplying drilling fluid to said drill string, means for discharging drilling fluid to remove drill cuttings from the vicinity of said bit, and means for discharging drilling fluid above said bit and for entraining a portion of said drill cuttings and discharging said portion of entrained cuttings in a high velocity jet directly against the wall of the borehole to effect underreaming, including at least one venturi flow nozzle having an inlet, an outlet and a throat having a port communicating therewith, said inlet communicating with said fluid conduit, said throat communicating through said port with the space outside said drill string and said outlet directed toward the wall of the borehole.

13. Well drilling apparatus comprising a drill string having a fluid conduit therethrough extending from the surface of the ground into a borehole, a bit attached to said drill string and communicating with said fluid conduit, means for supplying drilling fluid to said drill string, means for discharging drilling fluid to remove drill cuttings from the vicinity of said bit, and means for discharging drilling fluid above said bit and for entraining a portion of said drill cuttings and discharging said portion of entrained cuttings against the wall of the borehole, comprising a shell surrounding said drill string above said bit providing a passageway for the drill cuttings, at least one flow nozzle through the wall of said drill string communicating with said fluid conduit and an opening in said shell corresponding to each said flow nozzle, and guides extending between said skirt and said drill string to direct drill cuttings to the vicinity of each said flow nozzle.

14. A method for drilling utilizing a gaseous drilling fluid comprising the steps of producing a pilot hole by physical contact of mechanical drilling means with a formation to be penetrated, simultaneously underreaming by entraining a stream of drilling fluid cuttings produced by said physical contact and directing said stream containing said cuttings in a high velocity jib directly against the wall of the borehole, suspending the drilling operation, lowering a casing into the underreamed portion of the hole and continuing the drilling and underreaming operation.

15. A method for drilling utilizing a gaseous drilling fluid comprising the steps of producing a pilot hole by physical contact of mechanical drilling means with a formation to be penetrated, simultaneously underreaming by entraining in a stream of drilling fluid cuttings produced by said physical contact and directing said stream containing said cuttings against the wall of the borehole, suspending drilling and underreaming operations, lowering a casing into the underreamed hole, circulating and spotting a slug of casing mud adjacent the end of the casing and sealing the space between said casing and the wall of the borehole and continuing the drilling and underreaming operation.

16. Well drilling apparatus comprising a drill string having a fluid conduit therethrough extending from the surface of the ground into a borehole, a rotary bit attached to said drill string and communicating with said fluid conduit, means for supplying drilling fluid to said drill string, means for discharging drilling fluid to remove drill cuttings from the vicinity of said bit, and

means for discharging drilling fluid above said bit and for entraining a portion of said drill cuttings and discharging said portion of entrained cuttings in a high velocity jet directly against the wall of the borehole to effect underreaming, comprising a shell surrounding said drill string above said bit providing a passageway for said drill cuttings, at least one venturi flow nozzle having an inlet, an outlet and a throat having a port communicating therewith, said inlet communicating with said fluid conduit, said throat communicating through said port with the space between said drill string and said shell, and said outlet directed toward the wall of the borehole outside said shell.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,123,159

March 3, 1964

William B. Buck

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 36, strike out "means for drilling" and insert instead -- bit --; line 38, strike out "bit" and insert instead -- means for drilling --; column 8, line 50, for "jib" read -- jet --.

Signed and sealed this 21st day of July 1964.

(SEAL)

Attest:

ESTON G. JOHNSON
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents