March 19, 1963 T. E. QUICK 3,081,828

METHOD AND APPARATUS FOR PRODUCING CUTS WITHIN A BORE HOLE

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Fig. 1.

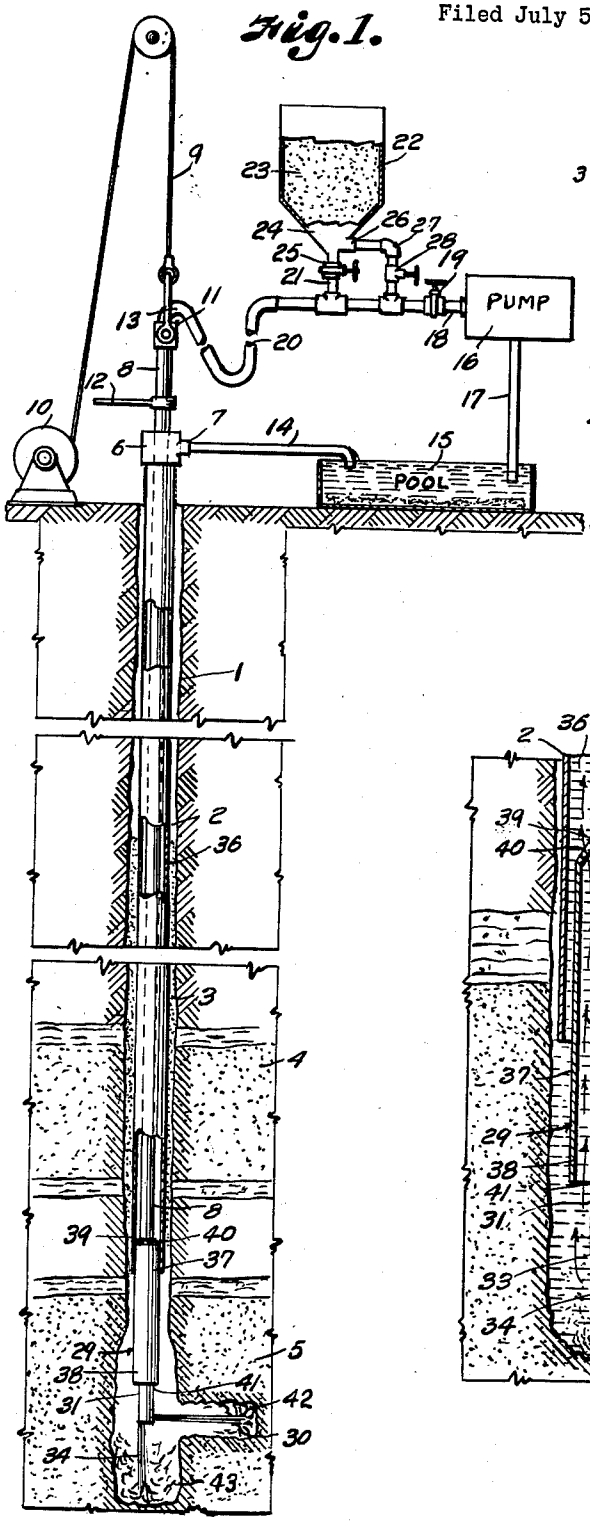


Fig. 2.

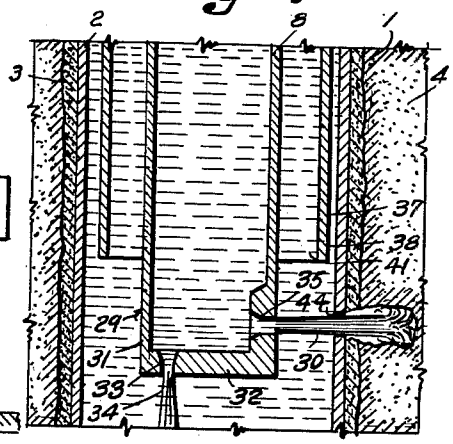
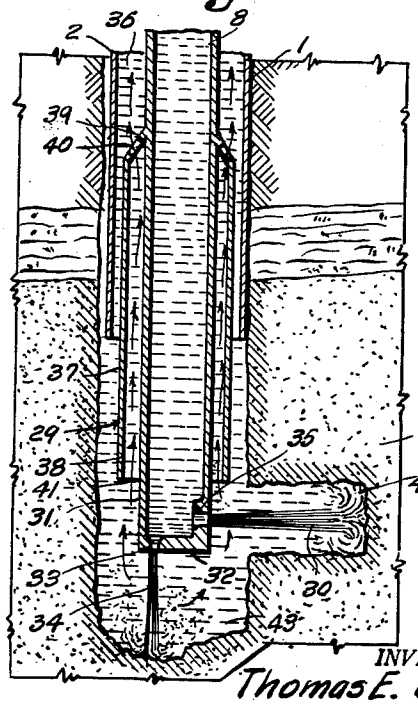


Fig. 3.



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METHOD AND APPARATUS FOR PRODUCING CUTS WITHIN A BORE HOLE

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This invention relates to a method and apparatus for producing lateral cuts within a bore hole that has been drilled into an earth formation for the recovery of water, gas, oil, minerals, and the like.

For example, when wells have been drilled into producing formations, it is desirable for cutting away and opening up of the producing formation to establish an increased flow production into the well. Also, when wells have been drilled through producing formations to greater depths for seeking other and more productive formations, it is desirable to open up the bypassed formations by forming holes in the casing or cutting out portions of the casing extending through the bypassed formation and to open the casing without damaging the cement that shuts off fluids from the upper fluid bearing formations.

It is also desirable in cases of declining production caused by clogging of the pores of the sand, limestone, or other producing structure immediately in the vicinity of the bore hole, to cut away and open up the clogged formations.

Also, in the rotary drilling of bore holes, the drilling fluid drives the production fluids back into the formation and plasters over the wall of the bore hole, so that it is necessary to clean off or cut away the formation to establish flow of formation fluids into the bore hole.

It is also desired to cut off the casing from cemented-in portions thereof, as when salvaging casing from an abandoned bore hole.

With these and other conditions in mind, it is the object of the present invention to provide a method and apparatus utilizing a pressure medium in conjunction with an entrained abrasive for producing such lateral cuts in a bore hole and for removing the debris.

Other objects of the invention are to provide an apparatus including a tool having one or more cutting jets and which is adapted to be accurately located with jets directed to make the cuts at the desired places without damaging the casing or the cement in which the casing is set; to provide a tool with a tubular guard that in effect forms an extension of the casing when the tool is used in uncased portions of the bore hole to facilitate removal of the debris; to provide an apparatus wherewith the abrasive jets can be rotated through a full 360° to produce completely circular cuts or to make holes in any radial direction; and to provide an apparatus that is of simple construction and easily controlled to make cuts in remote parts of a bore hole.

It is also an object of the invention to provide the tool with an auxiliary jet to keep the cuttings and debris in agitation so that the fluid medium can more readily pick up the particles and carry them from the bore hole. In this way the cuttings do not settle out in the bottom of the bore hole to cause clogging thereof.

In accomplishing these and other objects of the invention, I have provided an improved method and apparatus illustrated in the accompanying drawings, wherein:

FIG. 1 is a longitudinal section through a bore hole equipped with a cutting and reaming apparatus constructed in accordance with the present invention.

FIG. 2 is an enlarged section through the cutting tool for cutting through a section of casing.

FIG. 3 is an enlarged section through the cutting head of the tool, showing the use thereof for reaming and

cleaning out debris from the production strata of a well.

Referring more in detail to the drawings:

1 designates a bore hole which is equipped with a casing 2 that extends from the surface of the ground through the bore hole and which has been set in cement 3 to seal off one or more fluid bearing formations 4 from a producing formation 5. The upper end of the casing 2 carries a casing head 6 having an outlet connection 7. Extending through the casing in accordance with the present invention is a jet tube 8 that is rotatably sealed at its upper end within the casing head 6 and which is adapted to be raised and lowered therethrough by a hoisting cable 9 that is operated by a hoisting drum or windlass 10, the cable being connected with the tubing by a swivelhead 11. The tubing 8 is also provided with a suitable rotating mechanism such as a lever 12. The swivelhead 11 has a connection 13 for the admission of a pressure fluid and abrasive medium in accordance with the present invention. The outlet 7 of the casing head 6 is connected by a duct 14 with a tank or pool 15 in which the pressure fluid carrying the debris is allowed to settle and separate. In the case of a pressure fluid, the sediment tank 15 is connected with a fluid pump 16 through a suction pipe 17 and the outlet of the pump is connected through a duct 18 having a control valve 19 therein and which connects with the inlet 13 of the swivelhead through a flexible connection 20 for supplying fluid under pressure to the tubing 8. Connected with the duct 18 is a duct 21 through which an abrasive is supplied to the pressure fluid from a container 22 which is closed to hold a pressure sufficient to balance the pressure of the pump discharge for containing a supply of abrasive material 23. The abrasive material 23 flows from a hopper-like bottom 24 of the container through a control valve 25 to the connection with the duct 18. In order to provide pressure fluid for the container 22, the container has an inlet 26 that is connected with a duct 27 that may be in turn connected with the pressure duct 18, whereby a portion of the pressure fluid may be supplied to the container 22 under control of a valve 28.

The tubing 8 is composed of interconnected sections of pipe to provide the length necessary for the particular cutting job to locate a cutting nozzle or tool 29 on the lower end thereof, so that a jet 30 therefrom is at the desired location and may be raised or lowered through the desired range by adding to or removing sections of pipe from the tubing, if the desired range is greater than the lift that can be effected by the cable 9.

The tool 29 preferably includes an elongated tubular body 31 conforming to the diameter of the tubing. The lower end of the elongated body of the tool is closed by a plug 32 having a discharge orifice 33 offset radially from the axis of the tubing to discharge a downwardly directed jet 34. The wall portion of the lower end of the tool is also provided with one or more laterally directed orifices 35 for discharging one or more of the lateral jets 30. In order to facilitate return flow of the pressure fluid and debris carried therewith upwardly through the annular passageway 36 that is provided between the casing 2 and the tubing 8, the tool 29 also includes a tubular guard 37 that terminates at its lower end 38 above the lateral orifices 35 and which extends upwardly along the body of the tool to, in effect, form a continuation of the casing 2 where it is connected with the tubing 8 or with the tubular body of the tool by a spider 39 having openings 40 therein for passing the returning fluid and debris into the casing 2. The lower end 38 of the tubular guard 37 freely encircles the body of the tool and forms an annular inlet opening 41 for the returning fluid and debris.

In using the apparatus, for example in cleaning and reaming a producing formation and for deepening the

bore hole to increase declining production of a well, the tool 29 is connected with the first stand of jet tubing 8 and lowered into the bore hole 1 through the casing 2. Subsequent stands of jet tubing 8 are connected thereto as in standard practice in running a drilling string, until the jets of the tool are located in the site of operation in the bore hole. With the swivelhead 11 connected to the duct 18, and the pump 16 in operation with the valve 19 open, and the valves 25 and 28 closed, clear fluid, such as water, is discharged through the duct 18, hose 20, swivelhead 11 and jet tubing at high velocity under pressures that may be greater than five thousand pounds. The fluid is discharged from the bottom of the jet tubing through the jet orifices 33 and 35 and flows upwardly within the annular space 36 to the casing head 6 and is discharged through the duct 14 into the pool 15.

After the return flow of fluid has been established, the abrasive material 23, which may be sand, is fed gradually from the container 22 upon opening of the valves 25 and 28. The abrasive materials thus are entrained with the fluid flowing through the conduit 18 to be discharged with the fluid at the high velocities through the lateral jet orifice 35 to supplement the cutting action of the jet in cutting out and breaking down the hard formation and produce lateral holes 42, as shown in FIGS. 1 and 3. If desired, the jet tubing 8 may be turned by the device 12 to change the radial position of the jet 30 in the hole, whereby a circular series of holes 42 may be produced around the circumference of the bore hole, or, if desired, a continuous rotation will effect circumferential cutting away of the formation at the level that the jet is discharged. In increasing the height of the lateral cuts, the jet tubing 8 may be raised and lowered by the hoisting device 10, whereby a greatly enlarged pocket is provided for subsequently receiving the increased flow of formation fluid by opening up the formation incidental to removal of the clogging materials, such as asphalt, paraffin, and like materials.

The small particles of debris dislodged by the jet or jets 30 which have a sinking velocity less than the flow velocity of the returning fluid will be lifted out of the well after dislodgment, but the larger particles of debris which have a sinking velocity greater than the velocity of the returning fluid will remain in the agitating zone 43 in the bottom of the bore hole until they have been eroded and ground down to the size where their sinking velocity is less than that of the returning fluid, whereupon they will be readily lifted by the returning fluid and discharged into the pool 15. The debris on reaching the pool will settle to the bottom and be removed from time to time. The small jet 34 which is discharged through the orifice 33 hastens the breaking down of the particles by increasing the agitation in the bottom of the bore hole to keep the particles in suspension so that the fluid under discharge through the bore hole can more readily pick them up and prevent possibility of clogging the bottom of the bore hole with the abrasive or debris.

The feed of the abrasive is, of course, controlled by the valve 25 to keep the abrasion and removal of the particles in proper balance. To conserve the jet nozzles, the abrasive may be used only sufficiently to expedite the cutting action of the jet, however, in many cases the dislodged formation debris may supply sufficient abrasion for a fast cutting action. It is also understood that the volume pressure of the fluid may be controlled along with control of the feed of the abrasive, so that the volume and pressure of the fluid is best suited for a particular cutting job.

As the jet 30 cuts the formation further back from the nozzle or orifice 35, the dislodging rate will diminish and the returning fluid will have less and less debris. After the returning fluid appears sufficiently clean so that there is very little or no debris in the returning fluid when the jet has swept the entire desired cleaning zone, then the operation may be stopped and the jet tubing 8 and tool 29 removed without danger of sticking in the hole.

In opening up a production formation in a newly drilled well, the apparatus may be used in the same manner as when cleaning out and increasing production of a well having declining production.

The apparatus may also be used in cutting holes 44 through the walls of the casing 2 to open up the casing to production formations that have been bypassed in drilling of the bore hole to greater depths, as, for example, the formation 4 may be opened to production through the casing by using the apparatus for making the holes 44. In this instance the tool 29 will be lowered through the casing only to the level of the producing zone 4, so that when the apparatus is in operation, the jet 30 will be discharged against the casing wall as shown in FIG. 2 to bore holes 44 through the casing and through the cement 3. If desired, the holes may be continued back into the formation to provide pockets for exposing greater surface areas of the formation through which the formation fluids may flow into the casing.

The holes 44 may be produced in a circular series about the casing by turning the jet tubing with the turning device 12. A plurality of holes may also be produced by raising and lowering the jet tubing in the casing until the depth of the formation 4 has been covered. Attention is particularly directed to the fact that the holes may be formed through the casing without cracking the cement or otherwise interfering with the seal of the cement above or below the producing formation 4.

The apparatus may be used for cutting off a casing, as when salvaging the casing from an abandoned well, by using it in the same manner as drilling the holes 44, however, in this instance the tool is lowered to the point where the casing is to be severed and the tubing supported in position while it is being rotated by the device 12 until the jet has penetrated the casing throughout the entire circumference thereof.

It is obvious that the cutting apparatus embodying the present invention may be used in other remote cutting operations that need to be made within a bore hole.

It is also obvious that during the cutting operation an operator may raise or lower or turn the jets at will to direct the jets to any desired location.

A tool with one, two, or more jets may be used and the volume and pressure may be selected to suit the desired size of a reaming job and the particular hard or soft formation to be cut.

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

1. A method of producing cuts at substantial depth within a bore hole extending from the surface through formations of the earth, including discharging a pressure fluid containing an abrasive in the form of a jet at the site of the cut in a direction laterally of the axis of the bore hole, removing the fluid through the bore hole at a velocity to elevate the abrasive and those cuttings that are of a particle size having a sinking rate less than the velocity of the fluid being removed, and discharging a supplementary jet generally downward into the bore hole below said lateral jet to break up debris resulting from the cutting step to a particle size having a sinking rate less than the velocity of the fluid being removed from the bore hole to remove the debris through the top of the bore hole.

2. A method of producing cuts at substantial depth within a bore hole that extends from the surface through formations of the earth, including discharging a pressure fluid containing an abrasive in the form of a jet at the site of the cut in a direction laterally of the axis of the bore hole, removing the fluid through the bore hole at a velocity to elevate the abrasive and those cuttings that are of a particle size having a sinking rate less than the velocity of the removed fluid, discharging a supplementary jet in a generally downward direction into the bore hole

below said lateral jet to break up large debris resulting from the cutting jet to a particle size also having a sinking rate less than the velocity of the fluid being removed from the bore hole to elevate the debris along with the abrasive particles, and moving the cutting jet within the bore hole to produce the desired size of the cut.

3. A method of increasing flow of a fluid from a productive formation into a bore hole that extends from the earth's surface into the productive formation, including discharging a pressure fluid containing an abrasive in the form of a jet directed into the formation laterally of the axis of the bore hole, removing the pressure fluid through the bore hole to the surface at a velocity for elevating the abrasive and those cuttings that are of a particle size having a sinking rate less than the velocity of the fluid being removed, discharging an agitating jet generally downwardly into the bore hole below said lateral jet for breaking up larger debris resulting from the cutting jet to a particle size having a sinking rate less than the velocity of the fluid being removed from the bore hole to elevate the debris along with the spent abrasive particles, and changing the direction of the cutting jet for increasing the surface area of the formation exposed in the bore hole and for increasing the effectiveness of the agitating jet.

4. A method of increasing flow of a fluid from a productive formation into a bore hole that extends from the earth's surface into the productive formation, including discharging a pressure fluid containing an abrasive in the form of a jet directed laterally of the axis of the bore hole into the formation, removing the pressure fluid through the bore hole to the surface at a velocity for elevating the spent abrasive and those cuttings having a sinking rate less than the velocity of the pressure fluid, discharging an agitating jet in a generally downward direction into the bore hole below said lateral jet for breaking up the larger debris resulting from the cutting jet to a particle size also having a sinking rate less than the velocity of the pressure fluid being removed from the bore hole to elevate the debris, rotating the cutting jet circumferentially of the bore hole for increasing diameter, and lowering the cutting jet to keep the cutting jet on the debris and for deepening the bore hole.

5. A method of increasing flow of a fluid from a productive formation into a bore hole that extends from the earth's surface into the productive formation, including discharging a pressure fluid containing an abrasive in the form of a jet directed laterally of the axis of the bore hole into the formation, removing the pressure fluid through the bore hole to the surface at a velocity for elevating the spent abrasive and the particles of cuttings having a sinking rate less than the returning velocity of the pressure fluid therewith, discharging an agitating jet in a generally downward direction into the bore hole below said lateral jet for breaking up the larger debris resulting from the cutting jet to a particle size also having a sinking rate less than the velocity of the pressure fluid being removed from the bore hole to elevate the debris, changing the direction of the cutting jet for increasing the surface area of the formation exposed in the bore hole, continuing action of the jets until the returning liquid is comparatively free of debris, and suspending the action of the jets.

6. A method of cutting away the productive formation surrounding a bore hole extending from the surface of the earth to the formation, including conducting a pressure fluid from the surface to the formation, discharging a portion of the pressure fluid in the form of a cutting jet laterally of the axis of the bore hole into the formation to cut away the formation and provide a high velocity flow of returning fluid to the top of the bore hole, introducing an abrasive into the high pressure fluid being conducted into the bore hole to be discharged with the cutting jet and returned to the top of the bore hole with the returning fluid, and discharging a supplementary jet of the high pressure fluid in a generally downward direction into debris resulting from said cutting jet to reduce the particle size of the debris to a sinking rate less than the velocity of the returning fluid to remove the debris from the bore hole.

7. A method of cutting away the production formation surrounding a bore hole extending from the surface of the earth into a productive formation, including conducting a pressure fluid from the surface to the formation, discharging a portion of the pressure fluid in the form of a cutting jet into the formation laterally from the axis of the bore hole to cut away the formation and provide a high velocity flow of returning fluid to the top of the bore hole, introducing an abrasive into the high pressure fluid being conducted into the bore hole to be discharged with the cutting jet for supplementing the cutting action of the jet, returning the fluid resulting from the jet to the top of the bore hole at a velocity to remove the abrasive from the bore hole and any cuttings having a sinking rate less than the velocity of the returning fluid, introducing a supplementary jet of the high pressure fluid eccentrically of the axis of the bore hole and in a generally downward direction into debris accumulating in the bottom of the bore hole that has a particle size too great to be lifted by the returning fluid for reducing the particle size of the debris to a sinking rate less than the velocity of the returning fluid to remove the debris from the bore hole, moving the cutting jet circumferentially and vertically within the formation until the returning fluid is substantially free of debris, and then suspending the jets.

8. An apparatus for cutting the productive formation surrounding a bore hole extending from the surface of the earth into the formation, including a tubing coextensive with the bore hole for conducting a pressure fluid from the surface to the formation, a tool on the lower end of the tubing having a lateral jet orifice for discharging the pressure fluid in a jet for laterally cutting the formation and said tool having a downwardly discharging jet for reducing the cuttings made by the lateral jet, a pump at the surface, duct means connecting said pump with the tubing for supplying said fluid to the tubing at a pressure sufficient for said jet and for providing a high velocity flow of returning fluid through the bore hole, means at the surface and connected wtih the duct means for introducing an abrasive into the high pressure fluid to be discharged with the cutting jet, means for turning the tubing to change the direction of said cutting jet, means for raising and lowering the tubing within the bore hole to change the cutting height of the cutting jet, and a tubular guide carried by and surrounding the tubing and terminating above the jet in an outlet and having a bottom inlet immediately above the jet to provide an upflow passageway for the returning fluid so as to maintain velocity thereof.

9. An apparatus for cutting the productive formation surrounding a bore hole extending from the surface of the earth into the formation, including a tubing coextensive with the bore hole for conducting a pressure fluid from the surface to the formation, a tool on the lower end of the tubing having a lateral jet orifice for discharging the pressure fluid in a jet for cutting the formation, a pump at the surface, duct means connecting said pump with the tubing for supplying said fluid to the tubing at a pressure sufficient for said jet and for providing a high velocity flow of returning fluid through the bore hole, means at the surface for providing a pool for receiving said fluid, a duct connecting the pool with the pump for recirculating the fluid, means for introducing an abrasive into the high pressure fluid to be discharged with the cutting jet, said tool having an eccentric orifice offset from the axis of the tubing for discharging a downwardly directed jet of the high pressure fluid into debris resulting from said cutting jet to reduce the particle size of the debris to a sinking rate less than the velocity of the re-

turning fluid to remove the debris from the bore hole, means for turning the tubing to change the direction of said cutting jet and to sweep the bottom of the bore hole with said eccentric jet, means for raising and lowering the tubing within the bore hole to change the cutting height of the cutting jet, and a tubular guide surrounding the tubing and having a bottom inlet immediately above the cutting jet for providing an upflow passageway for the returning fluid so as to maintain velocity thereof.

10. An apparatus for cutting a productive formation surrounding a bore hole extending from the surface of the earth into the formation, including a casing in the bore hole, a tubing coextensive with the casing for conducting a pressure fluid from the surface to the formation, a tool on the lower end of the tubing having a lateral jet orifice for discharging the pressure fluid in the form of a cutting jet for cutting into the formation, a pump at the surface, duct means for connecting the pump with the tubing for supplying said fluid to the tubing at a pressure sufficient for said jet and for providing a high velocity flow of returning fluid through the casing, means connected with the duct means for introducing an abrasive into the high pressure fluid being conducted into the tubing to be discharged with the cutting jet, said tool having a downwardly directed orifice for discharging a jet of the high pressure fluid into debris resulting from said cutting jet to reduce the particle size of the debris to a sinking rate less than the velocity of the returning fluid to remove the debris from the bore hole, means for raising and lowering the tool in the formation, and a tubular guide having an inlet surrounding the tool above said jets and having an upper end in sliding connection with

the casing to provide an extension for the casing when the tool is lowered into the formation.

11. An apparatus for cutting a hole for admitting fluid from a producing formation into a casing of a well, including a tubing extending downwardly into and through the casing for conducting a pressure fluid, a tool on the lower end of the tubing having a lateral jet orifice for discharging the pressure fluid in a jet, a pump, duct means connecting the pump with the tubing for supplying said fluid to the tubing at a pressure sufficient for said jet, means connected with the duct means for introducing an abrasive into the high pressure fluid for discharge with the jet, means connected with the upper end of the tubing for lowering the tubing to position the jet at the level of the formation to cut the formation laterally of the hole, and a sleeve carried by the tool and having a lower end providing an inlet above the jet orifice and having an upper end slidable in the lower end of the casing upon lowering of the tool below the casing for conducting the fluid and particles cut from the formation into the casing for flow to the top of the bore hole.

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