Dec. 26, 1967 E. W. GAYLORD 3,360,059

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Filed Dec. 27, 1965

3 Sheets-Sheet 1

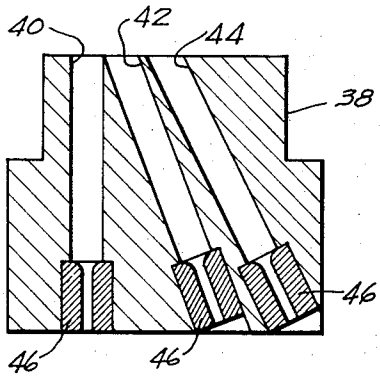


Fig. 6

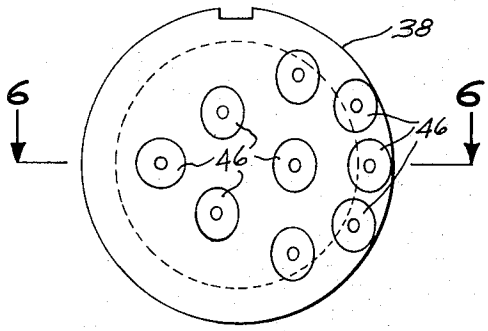


Fig. 5

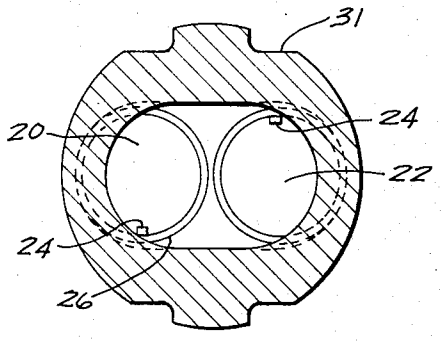


Fig. 4

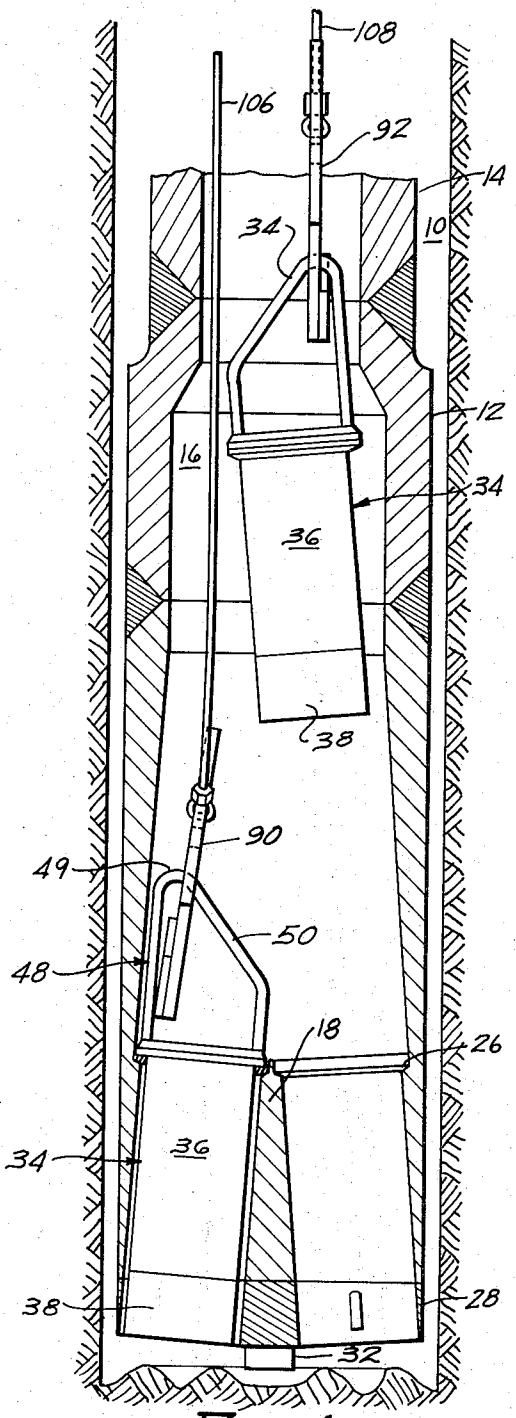


Fig. 1

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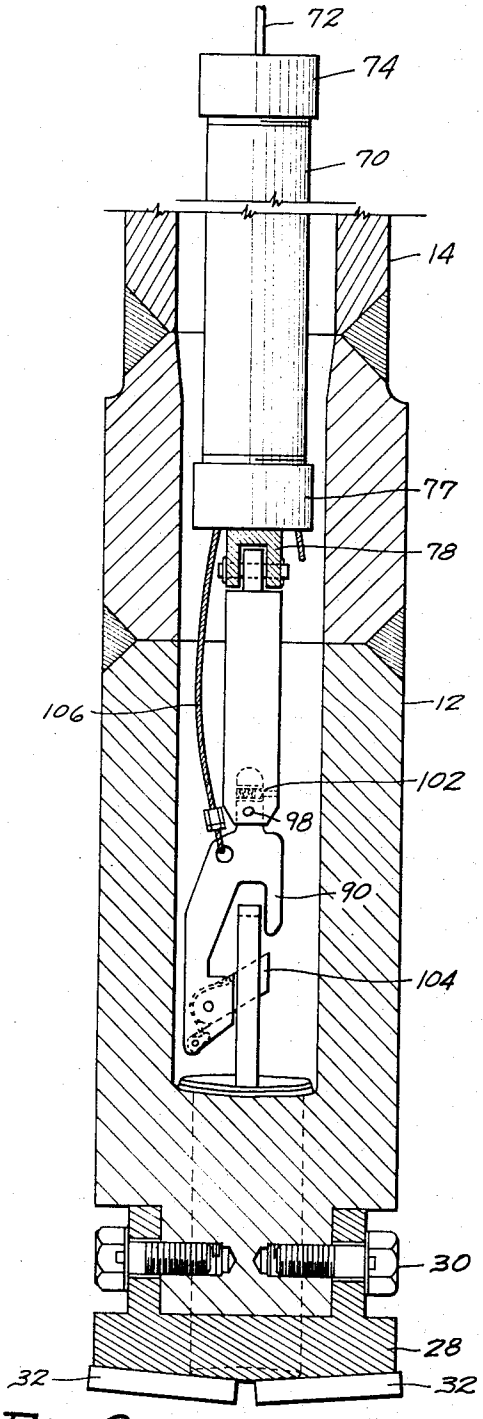


Fig. 2

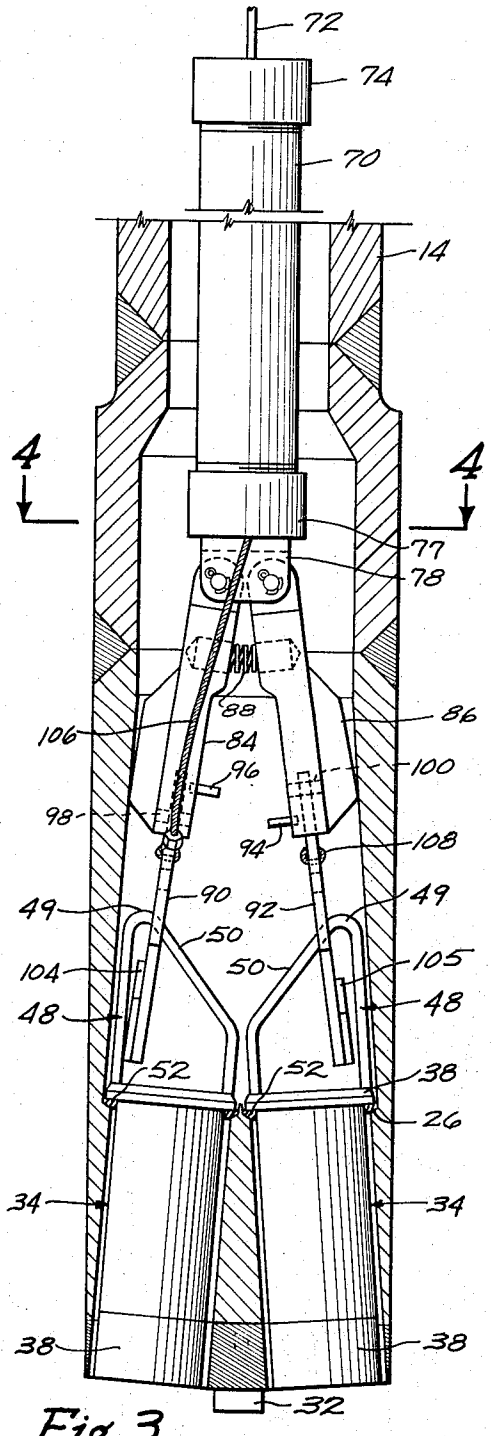


Fig. 3

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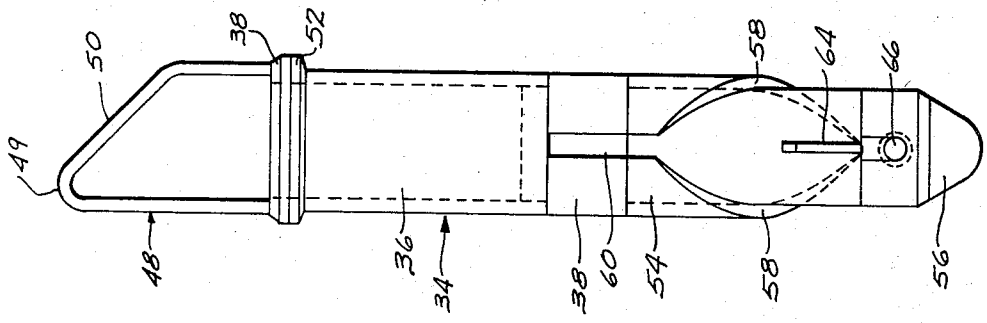


Fig. 8

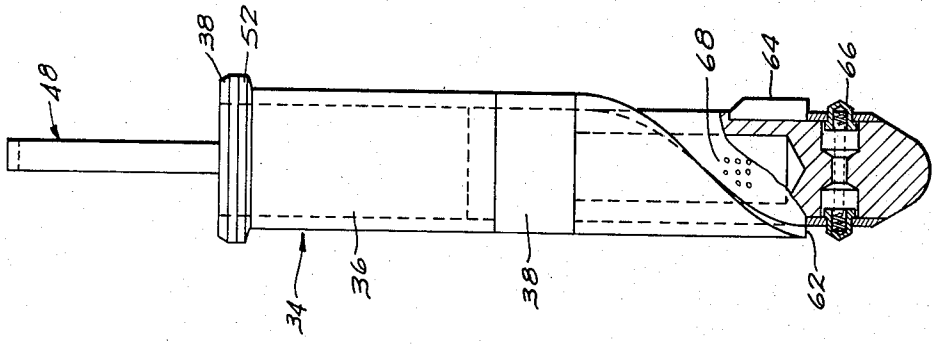


Fig. 9

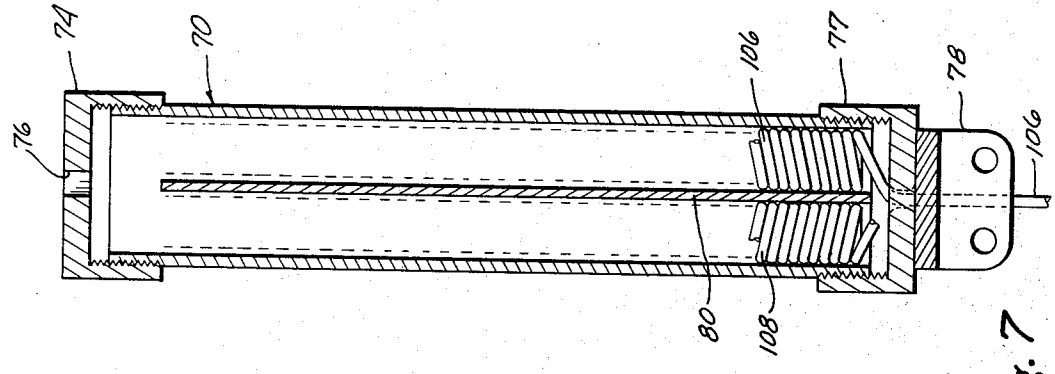


Fig. 7

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United States Patent Office 3,360,059 Patented Dec. 26, 1967

3,360,059

RETRIEVABLE BIT

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Filed Dec. 27, 1965, Ser. No. 516,533
10 Claims. (Cl. 175—259)

This invention relates to wells for the production of fluids from subsurface strata, and more particularly to apparatus for hydraulic jet drilling of such wells.

A method has been developed recently for the drilling of wells through extremely hard formations in which an abrasive-laden slurry is pumped down a well through drill pipe and discharged downwardly against the bottom of the borehole at an extremely high velocity through nozzles in a bit mounted on the lower end of the drill pipe. The bit is rotated during the drilling operation whereby the streams of abrasive-laden slurry impinge against the bottom of the borehole along a circular path. The number and location of the nozzles will determine whether the abrasive-laden stream cuts the rock over substantially the entire area of the borehole or in a series of concentric grooves separated by narrow intervening ridges which can be readily broken. The abrasive-laden liquid and the cuttings are circulated up the well around the drill pipe and discharged at the surface for removal of cuttings prior to recirculation of the abrasive-laden liquid.

In the hydraulic jet drilling method, it is essential that the abrasive-laden slurry be discharged at a velocity of at least 500 feet per second from nozzles having outlets in the range of ½ inch to 1¼ inches from the rock at the bottom of the hole. Nozzle outlet velocities exceeding 600 feet per second are preferred. A pressure drop of the order of 4000 pounds per square inch, and preferably 5000 pounds per square inch or more, across the orifice is required to impart the desired velocity to the abrasive-laden liquid.

It is apparent that the nozzles in the drill bit through which the abrasive-laden liquid is discharged are subjected to extremely severe erosion. Even though the nozzles are constructed of a hard material, such as tungsten carbide, the severe, highly erosive conditions quickly enlarge the diameter of the nozzles, thereby decreasing the velocity of the abrasive-laden slurry discharged from the nozzles and making necessary frequent replacement of the nozzles. With the apparatus heretofore available, it has been necessary to pull the drill pipe from the hole and replace the bit with a bit having nozzles of the proper internal diameter. Thus, a round trip in the hole has been necessary at frequent intervals in hydraulic jet drilling processes to maintain the high drilling rates that are possible with the hydraulic jet drilling process. In deep wells, a large part of the total drilling time may be used for round trips to replace the bits; hence, it is desirable to provide a bit with retrievable nozzles which may be removed quickly and replaced without pulling the drill pipe from the hole.

This invention resides in apparatus for hydraulic jet drilling of wells in which a drill bit secured to the lower end of drill pipe has chambers to receive and orient nozzle holders delivered down the drill pipe. The nozzle holders have a fishing head for engagement with a wireline operated fishing tool for removal of a plurality of nozzle holders sequentially during a single trip into the well.

In the drawings:

FIGURE 1 is a fragmentary longitudinal view, partially in cross section, showing the nozzle holders being withdrawn from a drill bit connected to the lower end of drill pipe in the borehole of a well.

FIGURE 2 is a longitudinal sectional view of the drill bit with the fishing tool in engagement with the nozzle holders prior to removal of the nozzle holders from the drill bit.

FIGURE 3 is also a longitudinal sectional view, taken at right angles to the view in FIGURE 2, showing the fishing tool in elevation.

FIGURE 4 is a horizontal sectional view of the drill bit taken along the section line 4—4 in FIGURE 3 after removal of the nozzle holders.

FIGURE 5 is a view of the bottom of the nozzle holder.

FIGURE 6 is a vertical sectional view through the base plug of the nozzle holder showing an arrangement of passages in the nozzle holder to nozzles from which the abrasive-laden liquid is discharged.

FIGURE 7 is a longitudinal sectional view through a cable container forming a part of the apparatus for fishing the nozzle holders from the drill bit.

FIGURE 8 is a side view of the nozzle holder with a guide in place for proper positioning of the nozzle holder in the drill bit.

FIGURE 9 is a side view, partially in section, of the nozzle holder with the guide attached as viewed at right angles to FIGURE 8.

Referring to FIGURE 1 in which the lower end of the borehole **10** of a well is illustrated, a hollow bit body **12** is shown secured by suitable means, such as welding, to the lower end of drill pipe **14**. The drill pipe **14** is adapted to be rotated by a conventional rotary table and kelly arrangement. The upper end of the drill pipe **14** is connected through a swivel with a conduit from one or more high pressure pumps for delivery of an abrasive-laden liquid to the bit body **12**. The rotary table, kelly, and swivel are not shown in the drawings, as this invention is not dependent on specific means for rotating the drill pipe or delivering drilling liquid to the drill pipe. The central opening **16** extending longitudinally in the drill bit body **12** expands along one diameter from a circular opening at its upper end where connected to the drill pipe **14** to an elliptical opening, shown in FIGURE 4, near its lower end to aid in the alignment of a fishing tool for retrieving nozzles from the drill bit in the manner hereinafter described.

Drill bit body **12** is closed at its lower end by a thick bottom member **18**. In the embodiment of the invention illustrated in the drawings, the bottom member **18** is drilled to provide two downwardly extending chambers **20** and **22** aligned with their centers on the major axis of the elliptical cross section of the drill bit **12**. Chambers **20** and **22** provide support for retrievable nozzle holders. A key **24** extends from the wall of each of the chambers **20** and **22** to orient the nozzle holders properly in the drill bit body **12**. The upper end of each of the chambers **20** and **22** is recessed to provide a shoulder **26**.

The lower surface of the bottom member **18** is covered by a backsplash plate **28** held in place by securing means such as studs **30**. A stand-off bar **32** protrudes downwardly from the lower surface of the backsplash plate **28** to fix the spacing of the outlets of the nozzles from the bottom of the borehole. Stand-off bar **32** and backsplash plate **28** are of a hard abrasive-resistant material such as tungsten carbide. The outer surface of drill bit body **12** has a plurality of flutes **31**, illustrated in FIGURE 4, extending along its length to the upper end to provide passages for the flow of drilling liquid.

As is best shown in FIGURE 3, each of chambers **20** and **22** receives and supports a nozzle holder **34**. Each of the nozzle holders **34** comprises a sleeve **36** with a collar **38** around its upper end supported by the shoulder **26** to limit downward movement of the nozzle holders in

the chambers. The lower end of the sleeve **36** is closed by a base plug **38** of erosion-resistant material having a plurality of passages indicated by reference numerals **40**, **42**, and **44** extending downwardly therethrough. The passages **40**, **42**, and **44** are positioned in the base plug and directed in a manner to direct streams of abrasive-laden liquid at intervals against the bottom of the borehole. The outwardly slanting passage **44** is positioned to cut in the bottom of the borehole a groove having a diameter large enough to permit passage of the drill bit body **12** downwardly through the borehole. The nozzles **40** and **42**, illustrated in the drawings, are positioned and oriented to cut a plurality of grooves along the bottom of the borehole with thin intervening ridges shown in FIGURE 1 that can be readily broken by the stand-off bar **32** as the bit is rotated. The number of passages through the base plug **38** can be varied to cut any number of desired grooves with thin intervening ridges in the bottom of the borehole or to cut overlapping grooves whereby substantially all of the rock removal from the bottom of the borehole is accomplished by the abrasive-laden liquid. Secured in each of the passages through the base plug is a nozzle insert **46** which, like the base plug, is constructed of a hard, erosion-resistant material such as tungsten carbide. Base plug **38** can be a single piece of erosion-resistant material, such as tungsten carbide, with nozzles molded right in the plug. Such structure allows greater freedom than nozzle inserts in location of the nozzles.

Extending upwardly from the upper end of each of the nozzle holders is a suitable fishing head to be engaged by a fishing tool for removal of the nozzle holder from the drill bit body. In the embodiment of the invention illustrated in the drawings, the fishing head is a bail **48** extending upwardly from the collar. As shown in FIGURES 3 and 9, bail **48** has an upper surface **50** sloping from a peak **49** downwardly toward the center of the drill bit body when the nozzle holder is in place in chamber **20** or **22**. Immediately below the collar **38** is a gasket **52** of a suitable material such as Neoprene which is compressed between the collar **38** and shoulder **26** to prevent flow of abrasive-laden liquid between the outer surface of the nozzle holder and the wall of the chamber.

Referring to FIGURES 8 and 9, a nozzle holder **34** is shown with an elongated tubular guide **54** attached to its lower end. The lower end of guide **54** tapers to a conical nose **56** adapted to guide the nozzle holder into one of the chambers **20** or **22**. A portion of the outer surface of the guide is cut away to form an inclined cam surface **58** sloping downwardly from a keyway **60** which extends upwardly along the outer surface of base plug **38**. The cam surface **58** continues completely around the guide **54** to a lowest point **62** on the opporite side of the guide from the keyway **60**. Opposite the point **62** is a lug **64** which prevents tilting of the guide **54** and nozzle holder **36** as they enter the chamber in the drill bit. Hanging of the guide member **54** on the shoulder **26** at the upper end of the chamber or on the key **24** is prevented by means of spring-loaded deflectors **66** positioned directly below point **62** and lug **64**. Guide members **54** are constructed of an easily eroded material such as a soft metal or plastic to facilitate their removal from the lower end of the nozzle holder by the abrasive-laden liquid after the nozzle holders are in place. A plurality of perforations **68** may be provided in the wall of the guide members to allow flow of the abrasive-laden liquid outwardly through the guide members and aid in their removal after the nozzle holders have been positioned in the drill bit.

Referring to FIGURES 2 and 3 in which a fishing tool for removal of the nozzle holders is illustrated, a cable container **70** is shown suspended from the lower end of a wire line **72**. Cable container **70** is a tubular member threaded at its upper end to receive a cap **74** having a hole **76** extending therethrough for the wire line **72**. The lower end of cable container **70** is threaded to receive a lower cap **77** having a clevis **78** secured to its lower surface. A partition **80**, best shown in FIGURE 7, extends longitudinally through the cable container **70** to divide it into two cable compartments for storing cables **106** and **108**. The lower end of one of the cables extends through a hole in the lower cap **76** on one side of the clevis and the lower end of the cable in the other container extends through the hole in lower cap **76** on the other side of the clevis. The upper end of each of the cables is enlarged or secured within the cable compartments to prevent their passing through the openings in the lower cap.

Pivotally suspended from the clevis **78** is a pair of opposed arms **84** and **86**. A helical spring **88** seated in inwardly opening sockets in each of the arms **84** and **86** urges the arms apart. Slidably fitting within a downwardly opening socket in the lower end of each of the arms **84** and **86** are hooks **90** and **92**, respectively. Hooks **90** and **92** are held in place as the fishing tool is lowered in the well by pins **94** and **96** which extend into sockets **98** and **100** in the hooks **90** and **92**, respectively. Engagement of the hooks with the wall of the drill pipe holds the arms **84** and **86** together with the pins **96** and **94** extending into the sockets **100** and **98**. When the fishing tool enters the drill bit, the compressed spring **88** forces the arms outwardly against the inner wall of the drill bit and causes rotation of the fishing tool to orient the arms along the major axis of the elliptical opening in the drill bit. As arms **84** and **86** are spread apart by spring **88**, the pins **96** and **94** no longer extend into the sockets **100** and **98**. Spring-loaded detents **102** prevent the hooks **90** and **92** falling from the arms **84** and **86** after the tool enters the drill bit and the pins **96** and **94** are disengaged.

At the lower end of the hooks **90** and **92** are upwardly rotating latches **104** and **105** spring biased in a downward direction. Cable **106** extends downwardly from one of the compartments in the cable container **70** and is securedly attached to the hook **90**. Cable **108** extends downwardly from the other compartment in the cable container and is connected to the hook **92**.

In the operation of the drill bit of this invention, the drill bit is secured to the lower end of drill pipe and run into the borehole of the well. Ordinarily, the well will be filled with a liquid as the bit is lowered to the bottom of the borehole. The drill pipe and bit are then lifted a short distance, approximately equal to the length of the guide members **54**, and an assembly of a nozzle holder with a guide member attached to its lower end is dropped or pumped down the drill pipe. When the guide member **54** enters the drill bit, the conical nose on the lower end of the guide member guides the nozzle holder into one of the chambers in the base of the drill bit. The key **24** extending outwardly from the wall of the chamber engages the cam surface **58** and rotates the nozzle holder to a position in which the key **24** enters the keyway **60**. In this position, the bail **48** is oriented with its peak **49** near the wall of the drill bit and the surface **50** sloping toward the center of the drill bit.

A second nozzle holder is dropped or pumped down the well behind the first nozzle holder. The nose of the guide member on the second nozzle holder is directed by the sloping surface **50** on the first nozzle holder into the unoccupied chamber. The cam surface **58** on the second nozzle holder engages the key **24** extending from the wall of the chamber and rotates the nozzle holder to the desired orientation in the drill bit.

During the drilling operation, the drill bit is rotated by engagement of a kelly attached to the upper end of the drill pipe with a rotary table, and an abrasive-laden liquid, for example, a liquid containing about one to four percent by volume of ferrous abrasive having a particle size in the range of 7 to 80 mesh is pumped down the drill pipe **14** and into the drill bit **12**. The abrasive-laden liquid enters the upper end of the nozzle holders and flows downwardly therethrough to the

passages 40, 42, and 44 in the base plug 38. The abrasive-laden liquid is discharged at a velocity of the order of 600 feet per second or more from the nozzle inserts and is directed against the bottom of the borehole to cut grooves in the underlying rock formation. The stand-off bar 32 rides on the ridges between the grooves to fix the distance from the outlet of the nozzles to the bottom of the borehole and to break the ridges as drilling progresses.

Drilling is continued until the pressure on the drilling liquid drops and thereby indicates that the diameter of the nozzle orifices has become enlarged. Pumping of the drilling liquid and rotation of the bit are stopped and the fishing tool is run into the well on the wire line 72.

As the fishing tool is lowered through the drill pipe, arms 84 and 86 are held by engagement with the wall of the drill pipe 14 in the retracted position in which pins 94 and 96 extend into the sockets 98 and 100 in the hooks 90 and 92 to hold the hooks firmly in place in the arms. On further lowering of the fishing tool into the body of the drill bit, the spring 88 urges the arms 84 and 86 against the inner wall of the drill bit and orients the fishing tool with the arms along the major axis of the elliptical opening in the tool. In this position, continued lowering of the tool results in the latches 104 and 105 engaging the bails 48 and being deflected upwardly to allow the bails to enter the hooks. When the fishing tool has been lowered sufficiently for the latches 104 to clear the bails 48, the latches snap downwardly into the position illustrated in FIGURES 2 and 3 of the drawings. The fishing tool is then raised by wire line 72.

On raising the fishing tool, the force resisting dislodgement of the nozzle holders 36 overcomes the spring-loaded detents 102, and the hooks 90 are pulled free of the arms 84 and 86. Continued lifting of the fishing tool causes the cable 108 to run out of the chamber until it is taut. Further lifting of the fishing tool will cause the cable 108 to lift the hook 90 and the nozzle holder from the chamber in the drill bit.

Cable 106 is enough longer than cable 108 to allow the nozzle holder engaged by hook 90 to remain in the chamber until the other nozzle holder has been lifted clear and free of the upper end of hook 90. Continued lifting of the cable container then causes cable 106 to become taut and lift the nozzle holder suspended from hook 90 clear of the chamber in the lower end of the drill bit. Because of the sequential lifting of the two nozzle holders, the nozzle holders can have a diameter substantially larger than one-half the internal diameter of the drill pipe without causing any difficulty in the removal of the two nozzle holders in a single trip into the well with a fishing tool.

In the apparatus illustrated in the drawings, both hooks 90 and 92 are detachably connected to the arms of the fishing tool. It is only essential that one of the hooks be detachable from the arms and suspended from a cable as the fishing tool is raised. The other hook can be permanently connected to one of the arms and lift a nozzle holder above the hook suspended from the cable.

When it becomes necessary to replace nozzle holders 34, they may be replaced with nozzle holders slightly shorter from the collar 28 to the bottom of plug 38 to compensate for erosion of the backsplash plate 30 and the stand-off bar 32. In this manner, the optimum spacing between the bottom of the borehole and the nozzle outlets can be maintained.

I claim:

1. In apparatus for the hydraulic jet drilling of wells by discharging suspensions of abrasive particles in liquids from nozzles at a high velocity against the bottom of the borehole of the well, means for aligning the nozzles in the well comprising a hollow drill bit body, a cylindrical chamber extending downwardly through the lower end of the drill bit body, a cylindrical nozzle holder adapted

to fit slidably within the chamber, key means extending from the surface of one of the chamber and the nozzle holders, a keyway in the other of the chamber and the nozzle holder, and an inclined cam surface extending downwardly and away from said keyway to guide the key into the keyway and thereby align the nozzle.

2. Apparatus as set forth in claim 1 in which a downwardly tapered guide of readily destructible material is mounted on the lower end of the nozzle holder to guide the nozzle holder into the chamber.

3. Apparatus as set forth in claim 1 in which the key extends inwardly from the wall of the chamber, the keyway is on the nozzle holder, and the cam surface opens downwardly from the keyway.

4. Apparatus for retrievably positioning nozzles for the hydraulic jet drilling of wells comprising a hollow bit body adapted for connection to the lower end of drill pipe, a chamber extending downwardly through the lower end of the bit body, a nozzle holder having a plurality of inclined nozzles extending through the lower end thereof positioned to discharge streams therefrom at different distances from the center of the bit body, means for aligning the nozzle holder in the chamber, a shoulder extending from the outer surface of the nozzle holder to limit downward movement thereof in the chamber, and a fishing head on the upper end of the nozzle holder.

5. Apparatus for retrievably positioning nozzles in a bit for the hydraulic jet drilling of wells comprising an elongated hollow bit body having a plurality of chambers extending through the lower end thereof, a retrievable nozzle holder in each of the chambers, a first guide means on the outer surface of the holder, second guide means on the wall of the chamber adapted to engage said first guide means to orient the holders in the chambers, and a fishing head on the upper end of each of the nozzle holders.

6. Apparatus for fishing a plurality of elements from a well in a single trip comprising a cable container, a plurality of grasping means suspended from the lower end of the cable container adapted to engage elements to be removed from the well, at least one of said grasping means being detachably suspended from the cable container, and an extensible connector extending from the cable container to the detachably suspended grasping means whereby on lifting the cable container said detachable grasping means are disconnected from the cable container and lifted when the connector reaches its limit of extension.

7. In combination with a hollow tubular drill bit body on the lower end of drill pipe for the support of retrievable nozzle holders in a well, said drill bit body having a central opening of elliptical cross section extending downwardly therein and communicating with the drill pipe, apparatus for retrieving the nozzle holders comprising a fishing tool having a pair of pivotally mounted downwardly extending arms, and a spring engaging said arms and urging the arms apart and against the wall of the central opening in the drill bit body whereby the arms are oriented on the major axis of the elliptical opening in the drill bit body to engage the nozzle holders to be retrieved from the well.

8. Apparatus for positioning a plurality of tools at the lower end of pipe in a well and retrieving said tools from the well comprising a hollow tubular body adapted to be connected to the lower end of pipe extending down the well, a plurality of chambers extending downwardly through the lower end of said body, a key extending inwardly from the wall of each of said chambers, a keyway in the outer surface of each of the tools adapted to receive the key and orient the tool in the chamber, cam means on the outer surface of the tool opening from the lower end of the keyway to engage the key and orient the tool for the key to enter the keyway, a fishing head extending upwardly from the upper end of each of the tools, said fishing head having an upper surface inclined toward the

center of the tubular body, a fishing tool including a cable container, a plurality of grasping means suspended in the lower end of the cable container and extending downwardly therefrom for engaging the fishing head, at least one of said grasping means being separable from the cable container, and a cable extending downwardly from the cable container and connected to the separable grasping means, said cable having a length permitting other tools to be raised above the tool engaged by the separable grasping member on raising the fishing tool.

9. Apparatus for positioning and retrieving nozzle holders in a drill bit comprising a hollow drill bit body adapted to be connected to the lower end of drill pipe, a pair of chambers extending downwardly through the bottom of the drill bit body, a key extending inwardly from the wall of each of the chambers, a nozzle holder slidable in each of the chambers, a collar extending outwardly at the upper end of each nozzle holder to limit downward movement of the nozzle holder in the chamber, a downwardly tapering guide member on the lower end of each of the nozzle holders adapted to guide the nozzle holders into the chambers, a keyway in the outer surface of the nozzle holder, a downwardly facing cam surface extending from the lower end of the keyway along the outer surface of the guide to guide the key into the keyway and thereby orient the nozzle holder in the chamber, a bail extending upwardly from the upper end of each of the nozzle holders, a cable container suspended from a wire line, a pair of opposed pivotally mounted arms suspended from the lower end of the cable container, a hook extending from each of the arms adapted to engage the bail of the holder, at least one of said hooks being separable from the arm, and a cable extending from the cable container to the separable hook of a length sufficient to delay withdrawal of the nozzle holder engaged by said separable hook on lifting the cable container until after the other nozzle holder is lifted from the chamber in the drill bit.

10. Apparatus for positioning and retrieving nozzle holders in a drill bit comprising a hollow drill bit body adapted to be connected to the lower end of drill pipe, said drill bit body having a central opening of substantially elliptical cross section extending downwardly therein, a pair of chambers extending downwardly through the bottom of the drill bit body, a key extending inwardly from the wall of each of the chambers, a nozzle holder slideable in each of the chambers, a collar extending outwardly at the upper end of each nozzle holder to limit downward movement of the nozzle holder in the chamber, a downwardly tapering guide member on the lower end of each of the nozzle holders adapted to guide the nozzle holders into the chambers, a keyway in the outer surface of the nozzle holder, a downwardly facing cam surface extending from the lower end of the keyway along the outer surface of the guide to guide the key into the keyway and thereby orient the nozzle holder in the chamber, a bail extending upwardly from the upper end of each of the nozzle holders, a cable container suspended from a wire line, a pair of opposed pivotally mounted arms suspended from the lower end of the cable container, a spring engaging said arms and urging the arms apart and against the wall of the central opening in the drill bit body whereby the arms are oriented on the major axis of the elliptical opening in the drill bit body, a hook extending from each of the arms adapted to engage the bail of the holder, at least one of said hooks being separable from the arm, and a cable extending from the cable container to the separable hook of a length sufficient to delay withdrawal of the nozzle holder engaged by said separable hook on lifting the cable container until after the other nozzle holder is lifted from the chamber in the drill bit.

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