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Norton

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[54] STEERING SUB FOR UNDERWATER DRILLING APPARATUS

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[52] **U.S. Cl.** **175/5,** 175/321

[51] **Int. Cl.** **E21b 7/12,** E21c 19/00

[58] **Field of Search** ..... 166/.5, .6, 226; 175/5, 317, 175/231, 267

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[57] **ABSTRACT**

A tubular steering sub, connected adjacent a drill bit at the bottom of a drill string, steers the bit into alignment with an underwater well. The steering sub comprises an inner barrel splined to an outer barrel to permit axial relative movement between the barrels so that laterally disposed jet ports of the inner barrel and the outer barrel move in and out of alignment. When the jet ports are aligned, a lateral steering force on the bottom of the drill string is generated by pumping fluid down the drill string and out the jet ports. A releasable spring latch closes the steering sub by securing the barrels in fixed relation with their jet ports out of alignment.

16 Claims, 3 Drawing Figures

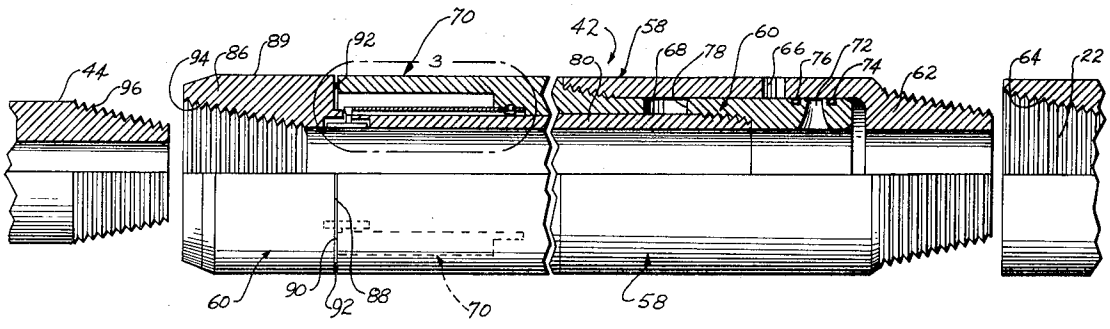


FIG. 1

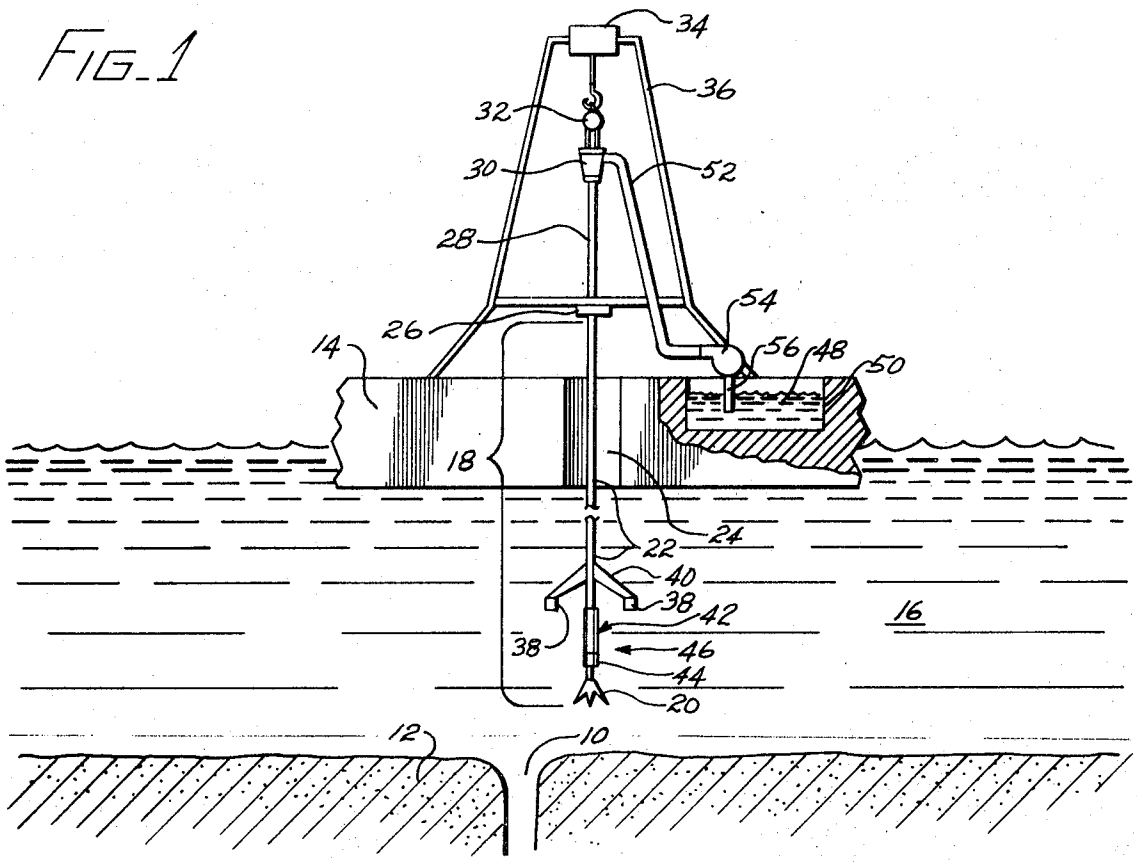
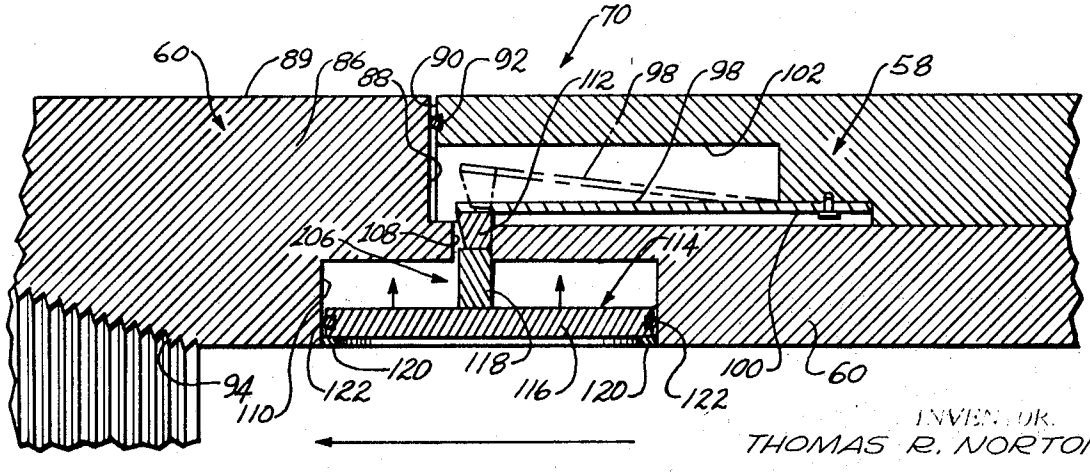


FIG. 3



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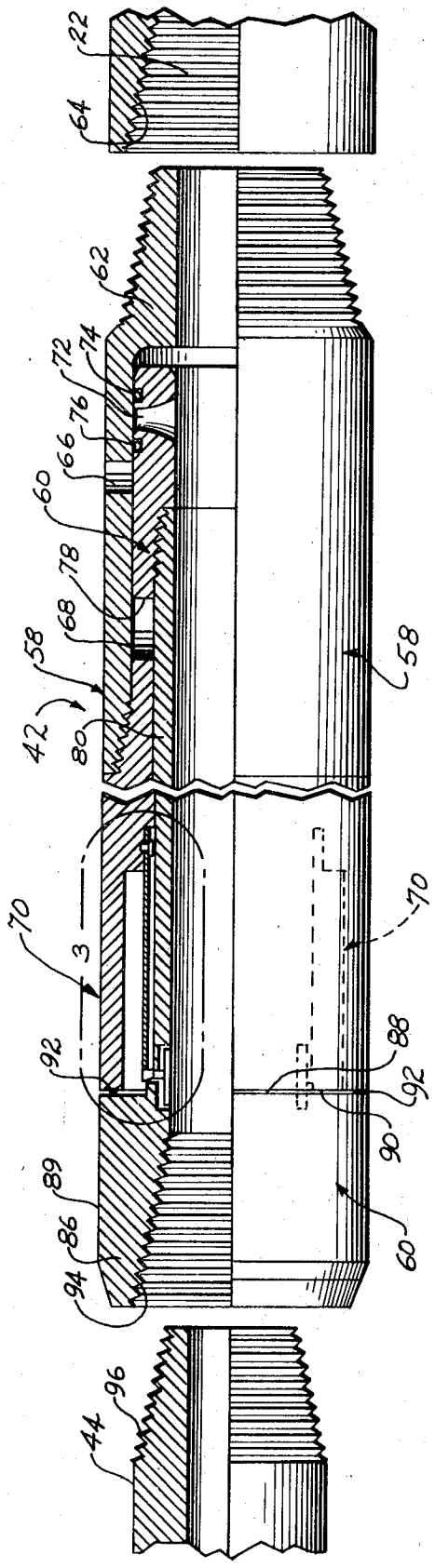

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FIG. 2

STEERING SUB FOR UNDERWATER DRILLING APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to underwater drilling apparatus, and more particularly to a steering sub located near the bottom of a drill string for steering a drill bit into contact with an underwater location such as a well or the like.

2. Description of the Prior Art

During underwater well drilling operations, a length of drill string is lowered from a floating vessel to an underwater formation and a drill bit at the bottom of the drill string drills a well in the formation. During drilling, contact between the bit and the well is often interrupted, and as a result, a substantial amount of drilling time may be required to realign the drill bit with the well hole. These realignment procedures are time consuming because the large inertia of the long drill string makes it difficult to accurately steer the drill bit in substantial depths of water. The steering problem is further compounded by wave action which causes the floating vessel to move relative to the well.

In the past, the problems associated with steering a drill string into alignment with a well have been relieved somewhat by the use of steering mechanisms attached to the drill string for producing lateral forces adjacent to its lower end. Some steering mechanisms have motor-driven propellers and the like mounted near the bottom of the drill string. Other steering mechanisms comprise special attachments mounted outboard of the drill string for producing water jets or the like to propel the bottom of the drill string laterally through the water. These prior art devices have not been particularly satisfactory because they are relatively expensive to construct and because they contribute substantial additional weight to the drill string; also, and perhaps more importantly, they hinder reentry of the drill string into the hole once proper alignment has been achieved. Construction costs and weight are increased by the jet-type steering devices which ordinarily require the use of auxiliary conduits and valve apparatus. Furthermore, the previous steering device structures are ordinarily spaced outboard of the drill string, with the result that the inertia of the drill string lower end is increased, thereby making it more difficult to move the drill string laterally through the water.

Realignment problems are greatest in the early stages of drilling a well. Once a wellhead landing base has been placed, guide cables between the base and the vessel make it possible to guide the drill string to the well hole. Reentry is also a considerable problem in coring for bottom samples. No landing bases are used in conventional coring operations and reentry using conventional steering devices is extremely difficult.

SUMMARY OF THE INVENTION

This invention contemplates a drill string subunit adapted for steering the lower end of the string into alignment with a well hole. The subunit, hereinafter referred to as a steering sub, produces lateral steering forces for the lower end of the drill string without the use of expensive auxiliary steering mechanisms such as motor-driven propellers. The steering sub is relatively small in size and is simple in construction. As a result, it is substantially less expensive and lighter in weight than previous steering devices. Further, the steering sub is an integral part of the drill string and contains no structural components disposed outboard of the drill string. Thus, the inertia of the drill string base is not perceptibly increased, and no auxiliary conduits or valve apparatus are required. Moreover, the steering sub does not hinder reentry of the drill string into the hole once proper alignment has been achieved. Thus, the realignment problems associated with coring operations and with the early stages of well drilling operations are substantially avoided.

Briefly, the steering sub apparatus includes an outer barrel, a hollow inner barrel inside the outer barrel arranged to move axially relative to the outer barrel between a first position and a second position. Releasable latching means normally maintain the inner barrel and the outer barrel in their first relative position, and means for releasing the latching means is operative to permit relative movement of the barrels to the second relative position. In the second relative position, the inner barrel and the outer barrel define a lateral fluid flow passage through the barrels. In use, pressurized fluid flowing to the interior of the inner barrel is expelled through the lateral fluid flow passage to the body of water externally of the outer barrel to thereby exert a reactive lateral steering force on the sub and the portion of a drill string in which the sub is incorporated in use.

In the preferred form of the invention, the releasable latching means comprises a spring biased into engagement with cooperatively arranged keeper means for latching engagement between the inner barrel and the outer barrel in the first relative position of the barrels. Preferably, the means for releasing the latching means includes pressure responsive means such as a piston arranged for movement between a first position permitting latching engagement of the keeper means and a second position disabling latching engagement of the keeper means.

During use, the latching means preferably is released so that the inner and outer barrels assume their second relative position as the drill string is lowered from the floating vessel to the underwater formation. Thus, lateral steering forces are applied adjacent to the lower end of the drill string as desired by pumping fluid down the drill string and out the lateral flow passage. Once the drill string has entered the well, the steering sub may be closed by applying weight on the drill bit to move the inner barrel and the outer barrel relative to each other until they reach the first relative position where the keeper means secures the barrels together and closes the lateral flow passage. If it later becomes necessary to realign the drill bit with the well, the steering sub may be opened by moving the movable element of the latch releasing means to its second position to release the keeper means from latching engagement with the barrels, thereby permitting the barrels to move to the second relative position so that fluid can be ejected from the lateral flow passage.

BRIEF DESCRIPTION OF THE DRAWINGS

The above-mentioned and other features of the invention are more fully set forth in the following detailed description of that embodiment of the invention which is presently preferred, such description being presented with reference to the accompanying drawings, wherein:

FIG. 1 is an elevation view, partly broken away, showing the steering sub connected to a length of drill string extending downwardly from a floating vessel toward an underwater formation;

FIG. 2 is an enlarged side elevation view, partly in section, of the steering sub; and

FIG. 3 is a further enlarged sectional elevation view of the structure shown within area 3 of FIG. 2.

DETAILED DESCRIPTION OF A SPECIFIC EMBODIMENT

Referring to the drawing, FIG. 1 shows a well **10** being drilled in an underwater formation **12** from a drilling vessel **14** floating on a body of water **16**. An upright, elongated hollow drill string **18** extends downwardly from vessel **14** through the body of water to well **10**. A rotary drill bit **20** on the lower end of drill string **18** drills well **10**. An upper section **22** of drill string **18** is supported in a cellar **24** which opens centrally through drilling vessel **14**. A conventional rotary table **26** is mounted directly over cellar **24**. An elongated, hollow kelly joint **28** cooperates with a kelly bushing (not shown) in the center of the rotary table so that rotary motion of the bushing is transferred to the kelly joint, thereby to rotate drill string **18**, and drill bit **20**, which is connected to the lower end of the kelly joint in the conventional manner. The kelly joint **28** is

coupled at its top to a swivel **30** supported by a travelling block **32** suspended from a stationary crown block **34** at the top of a derrick **36** mounted on the deck of floating vessel **14**.

During use of the drilling apparatus shown in FIG. **1**, drill string **18** and drill bit **20** are lowered from floating vessel **14** to underwater formation **12**. A locating device **38**, such as a TV camera or a sonar device, mounted near the bottom of drill string **18** by support **40**, permits viewing of the desired well site as the drill string is lowered. A tubular steering sub **42** of this invention is connected in drill string **18** essentially directly above drill bit **20** to provide alignment of the drill bit with the desired well site. As drill string **18** is lowered, steering sub **42** is maintained in an open condition to exert a reactive lateral steering force on the bottom of the drill string by directing a jet of fluid **46** laterally outwardly from its side. After drill bit **20** is located at the desired well site, steering sub **42** is closed by a latching device **70** (see FIGS. **2** and **3**) hereinafter described, and drilling operations proceed in the conventional manner by rotating drill string **18** and drill bit **20** with rotary table **26** to drill well **10**. In the event contact between the drill bit and the well is later interrupted, either deliberately or inadvertently, steering sub **42** is opened without the necessity of completely retracting drill string **18** to the vessel; this is done by using latching device **70** (see FIG. **3**) in a manner hereinafter described. With the steering sub **42** in its open position, a steering jet **46** is produced to exert a lateral force on the bottom of drill string **18** to realign drill bit **20** with well **10**. The direction of the steering jet relative to the drill string is controlled by suitably adjusting the angular position of the drill string using rotary table **26**.

During drilling, a supply of drilling mud **48** is delivered from a tank **50** aboard floating vessel **14** to a flexible mud supply line **52** by a pump **54** and a drawoff pipe **56** connected to the pump intake port. Supply line **52** extends upwardly to connect with swivel **32**. During operation of pump **54**, under normal circumstances, drilling mud travels through supply line **52**, through swivel **32**, down the interior of kelly joint **28** and drill string **18**, through closed steering sub **42**, and out drill bit **20** to clean the bit of cuttings produced by operation of the bit. When steering sub **42** is in its open condition, steering jet **46** is produced by pumping the drilling mud down the drill string and forcing it out through the side of steering sub **42** in a manner hereinafter described.

The construction and operation of steering sub **42** is best understood by referring to FIG. **2** which shows the steering sub in its closed condition. The steering sub includes an elongated outer barrel **58** and an elongated inner barrel **60** concentrically aligned with the outer barrel. The inner barrel is splined at **80** to the outer barrel to allow the barrels to move axially but not angularly relative to each other.

Outer barrel **58** defines at its top an externally threaded section **62** adapted for engagement with a conventional internally threaded section **64** at the bottom of drill string upper section **22**. Outer barrel **58** extends downwardly away from drill string upper section **22** to define a laterally disposed outer jet port **66** formed through its sidewall and an inwardly projecting annular shoulder **68** formed in its interior wall a short distance below outer jet port **66**. Preferably three latching devices **70**, hereinafter described in detail are uniformly spaced around the bottom of outer barrel **58** for use in fastening the inner and outer barrels in their closed condition shown in FIG. **2**.

Inner barrel **60** defines, near its top, a laterally disposed inner jet port **72** extending through its sidewall. A fluid-sealing upper O-ring **74** is seated in the outer sidewall of the inner barrel above inner jet port **72**, and a fluid-sealing lower O-ring **76** is seated in the outer sidewall of the barrel below inner jet port **72**. When steering sub **42** is in its closed condition, inner jet port **72** is out of alignment with outer jet port **66** at a point above lower O-ring **76**, as shown in FIG. **2**, and is sealed from communication with the outer jet port by O-rings **74** and **76**. Inner barrel **60** extends downwardly from inner jet port **72** to define an outwardly projecting annular shoulder **78** in its exterior wall, which shoulder is spaced above annular shoulder **68** of outer barrel **58** when the barrels are closed as shown. An elongated axial spline **80** is defined by the outer sidewall of inner barrel **60** and the inner sidewall of outer barrel **58** below shoulders **78** and **68** respectively. Spline **80** permits relative longitudinal movement of outer barrel **58** and inner barrel **60** between a first relative position, i.e., the closed position shown in FIG. **2**, and a second relative position, i.e., an open position (not shown) where shoulder **78** abuts against shoulder **68**. When the barrels are in their open position, inner jet port **72** is aligned with jet port **66**. Inner barrel **60** defines, at its bottom, an enlarged lower sleeve section **86** which provides an annular shoulder **88** extending to an inner barrel exterior sidewall **89** having the same diameter as outer barrel **58**. Annular shoulder **88** cooperates with an annular end surface **90** of outer barrel **58** to define the closed position of the inner barrel relative to the outer barrel. An O-ring **92** is seated in surface **90** to provide a leakproof seal between the barrels at the lower end of steering sub **42**. Inner barrel sleeve section **86** has an internally threaded lower section **94** adapted for engagement with an externally threaded section **96** at the top of drill string lower section **44**.

Each latching device **70** is identical in structure and includes a resilient, downwardly extending elongated leaf spring **98** secured at its upper end to a vertically disposed shoulder **100** defined at the upper end of a recess notch **102** formed in the interior wall of outer barrel **58** near its lower end. When barrels **58** and **60** are closed, recess notch **102** provides space for permitting lateral deflection of leaf spring **98**. Latching device **70** further includes a laterally disposed passage **106** extending through inner barrel **60** for communication with recess **102**. Passage **106** defines a relatively narrow keeper bore **108** spaced slightly above lateral annular shoulder **88** and extending laterally inwardly from recess **102** where it opens into an enlarged bore **110** concentric to bore **108** and communicating with the interior of inner barrel **60**. Leaf spring **98** is normally biased inwardly toward inner barrel **60** so that a keeper catch **112** or lug, mounted to the lower end of the leaf spring, is biased into cooperative engagement with keeper bore **108** normally to maintain outer barrel **58** and inner barrel **60** in the closed condition shown in FIGS. **2** and **3**.

Each latching device **70** further includes latch releasing means preferably in the form of a high-pressure spring override element **114** disposed within enlarged bore **110**. Element **114** includes a piston **116** movable within bore **110** and a relatively narrow elongated stem **118** extending from piston **116** into cooperative engagement with keeper bore **108**. Leaf spring **98** is biased inwardly so that the inner surface of catch **112** normally maintains piston **116** resting against a a retaining ring **120** disposed about the periphery of bore **110** at its opening into the interior of inner barrel **60**. An O-ring seal **122** is seated in the outer rim of piston **116** to maintain a leakproof seal between the piston and the walls of bore **110** as the piston slides back and forth in bore **110**.

As previously described, during use steering sub **42** is maintained in its open position as drill string **18** is initially lowered to underwater formation **12**. The steering sub is opened by initially releasing each leaf spring catch **112** from engagement with its respective keeper bore **108**. This allows inner barrel **60** to slide downwardly along outer barrel **58** in the direction of the arrow in FIG. **3** so that shoulder **78** abuts against shoulder **68** to align jet port **72** with jet port **66**, as previously described. The steering sub normally maintains its open position as it is lowered to underwater formation **12** because inner barrel **60** is normally subjected to downwardly acting forces resulting from the weight of drill bit **20** and such drill collars as may be connected between the sub and the drill bit. Thus, lateral steering forces can be generated as the drill string is lowered merely by pumping drilling mud down the hollow interior of the drill string. The drill bit **20** is normally structured so that it presents resistance to flow of mud through it, and thus drilling mud pumped down the drill string is forced outwardly through the aligned jet ports **66** and **72** to produce the steering jet **46** for use in maneuvering drill bit **20** into align-

ment with the desired well site. As previously described, the direction of the steering jet is controlled using rotary table **26** to rotate drill string **18** to the desired angular orientation. When the well site is reached, the jet ports **72** and **66** are taken out of alignment by closing steering sub **42**. The steering sub is preferably closed by forcing drill string **18** downwardly against formation **12** to apply weight on drill bit **20**. This drives inner barrel **60** upwardly relative to outer barrel **58** until keeper catches **112** snap into engagement with keeper bores **108** to thereby secure steering sub **42** in its closed condition shown in FIGS. **2** and **3**.

During use, if it becomes necessary to reopen steering sub **42**, as in the case where contact between drill bit **20** and well **10** is interrupted, such opening can be accomplished without completely retracting the drill string to drilling vessel **14**. Opening of the steering sub is initiated by operating pump **54** at such a level that the fluid passages through drill bit **20** are overwhelmed, thereby to build up high pressure levels in drill string **18**. When fluid pressure in the drill string reaches a level greater than the pressure resulting from the forces exerted by leaf springs **98** on high-pressure spring override elements **114**, the elements slide outwardly within bores **110** in the direction of the arrows shown in FIG. **3**. This lateral movement of elements **114** causes keeper catches **112** to release engagement with keeper bores **108**, thereby allowing inner barrel **60** to slide downwardly relative to outer barrel **58** in response to the action of the weight applied to the inner barrel and the mud pressure within the sub. As previously described, when inner barrel **60** is released from engagement with outer barrel **58**, steering sub **42** normally assumes its open position with jet ports **66** and **72** in alignment. In this position, fluid under pressure in the steering sub flows out through the jet ports to produce a lateral force near the bottom of drill string **18** to maneuver drill bit **20** back into alignment with well **10**.

The present invention has been described with reference to the specific structure of the best mode presently contemplated for carrying out the invention. It is to be understood that the scope of the invention is not to be limited to the details of this structure. For example, it can be seen that the structure of steering sub **42** can be altered without departing from the scope of this invention by merely rearranging the barrels to provide an outer barrel structure connected to drill bit **20** and adapted for movement relative to a stationary inner barrel structure connected to drill string upper section **22**. It is to be further understood that the particular form of latching device **70** is preferred, and that other releasable locking means for securing the barrels in either an open or a closed position can be used without deviating from the scope of this invention. Furthermore, other means for automatically opening latching device **70** can be used. For example, a ball or the like can be dropped down the hollow interior of drill string **18** to engage a detent or the like extending into the hollow interior of steering sub **42** to release leaf springs **98**.

I claim:

1. A sub for use in association with oil and gas wells and the like, the sub comprising:

a. an outer barrel;

b. a hollow inner barrel inside the outer barrel and movable axially relative to the outer barrel between a first position and a second position;

c. releasable latching means normally operative to maintain the inner barrel and the outer barrel in their first relative position;

d. means responsive to fluid pressure within the inner barrel for releasing the latching means to permit relative movement of the inner and outer barrels to their second relative position; and

e. means cooperating between the inner and outer barrels for defining a lateral fluid flow passage through the barrels only in the second relative position of the barrels.

2. Apparatus according to claim **1** wherein the outer barrel defines one end of the steering sub and the inner barrel defines the other end of the steering sub.

3. Apparatus according to claim **1** including means coupling the inner and outer barrels for only axial relative movement.

4. Apparatus according to claim **1** wherein the sub is adapted for connection in a drill string.

5. Apparatus according to claim **4** wherein the outer barrel is adapted for coupling with the upper portion of the drill string and the inner barrel is adapted for coupling with the lower portion of the drill string.

6. Apparatus according to claim **5** wherein the outer barrel has substantially the same diameter as the drill string.

7. Apparatus according to claim **1** wherein the latching means includes a keeper lug cooperating between the inner and outer barrels, and spring-biasing means cooperating with the keeper lug to maintain the barrels in their first relative position.

8. Apparatus according to claim **7** wherein the spring-biasing means maintains keeper lug cooperatively engaged with a keeper bore disposed in the inner barrel; and wherein the latch release means includes a piston adapted for engagement with the keeper lug, the piston being movable within the keeper bore in response to fluid pressure in the inner barrel to urge the keeper lug out of engagement with the keeper bore to permit relative movement of the inner and outer barrels.

9. A method for aligning with a desired location on the bottom of a body of water the lower end of a drill string pendulously supported from a drilling vessel or the like floating on the body of water, the method comprising the steps of:

a. providing in the drill string adjacent to the lower end thereof a hollow, axially extensible steering sub having a foreshortened first operative condition and an extended second operative condition and defining in the second operative condition thereof a fluid flow passage laterally therethrough from the interior of the drill string to said body of water, and including means effective in the first operative condition to maintain the sub in the first operative condition and responsive to the existence of fluid pressure within the drill string in excess of a predetermined pressure for enabling the sub to move from its first to its second operative condition;

b. disposing the sub in its second operative condition; and

c. moving the lower end of the drill string into the desired alignment by applying fluid under pressure to the drill string when the sub is in its second operative condition, thereby to produce a reactive fluid jet force laterally effective on the drill string, and adjusting the effective direction of the force by adjusting the angular position of the drill string.

10. The method according to claim **9** including adjusting the sub from its second to its first operative condition by at least partially supporting the weight of the drill string on the lower end thereof when the pressure of any fluid in the drill string at the sub is less than said predetermined pressure.

11. The method according to claim **9** wherein the sub is adjusted from its first to its second operative condition by disposing the drill string out of supportive engagement with the bottom of said body of water and producing within the drill string at the sub a fluid pressure in excess of said predetermined pressure.

12. The method according to claim **11** wherein the drill string terminates at its lower end in a rotary drill bit, and said excess fluid pressure is produced by pumping fluid down the drill string from the vessel at a rate in excess of the maximum rate at which the drill bit can pass such fluid therethrough.

13. A sub for use in association with oil and gas wells and the like, the sub comprising:

a. an outer barrel adapted for coupling with an upper portion of a drill string;

b. a hollow inner barrel inside the outer barrel and movable axially relative to the outer barrel between a first position and a second position, the inner barrel being adapted for coupling with a lower portion of the drill string;

c. releasable latching means normally operative to maintain the inner barrel and the outer barrel in their first relative position;

d. means for releasing the latching means to permit relative movement of the inner and outer barrels to their second relative position; and

e. means cooperating between the inner and outer barrels for defining a lateral fluid flow passage through the barrels only in the second relative position of the barrels.

14. Apparatus according to claim **13** wherein the outer barrel has substantially the same diameter as the drill string.

15. A sub for use in association with oil and gas wells and the like, the sub comprising:

a. an outer barrel;

b. a hollow inner barrel inside the outer barrel and coupled for only axial movement relative to the outer barrel between a first position and a second position;

c. releasable latching means normally operative to maintain the inner barrel and the outer barrel in their first relative position;

d. means for releasing the latching means to permit relative movement of the inner and outer barrels to their second relative position; and

e. means cooperating between the inner and outer barrels for defining a lateral fluid flow passage through the barrels only in the second relative position of the barrels.

16. A sub for use in association with oil and gas wells and the like, the sub comprising:

a. an outer barrel;

b. a hollow inner barrel inside the outer barrel and movable axially relative to the outer barrel between a first position and a second position;

c. releasable latching means including a keeper lug cooperating between the inner and outer barrels, and spring biasing means to maintain the keeper lug cooperatively engaged with a keeper bore disposed in the inner barrel to maintain the barrels in their first relative position;

d. means for releasing the latching means to permit relative movement of the inner and outer barrels to their second relative position, the latch release means including a piston adapted to engagement with the keeper lug, the piston being movable within the keeper bore in response to fluid pressure in the inner barrel to urge the keeper lug out of engagement with the keeper bore to permit relative movement of the inner and outer barrels; and

e. means cooperating between the inner and outer barrels for defining a lateral fluid flow passage through the barrels only in the second relative position of the barrels.

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