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Cherrington

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[54] **APPARATUS AND PROCESS FOR DRILLING UNDERGROUND ARCUATE PATHS**

[76] Inventor: **Martin Dee Cherrington,** 7398 San Joaquin St., Sacramento, Calif. 95825

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[52] **U.S. Cl.** **175/45;** 175/61; 175/73; 175/107

[51] **Int. Cl.** **E21b 47/02**

[58] **Field of Search** 175/61, 73, 75, 101, 103, 175/74, 76, 45, 107

[56] **References Cited**

UNITED STATES PATENTS

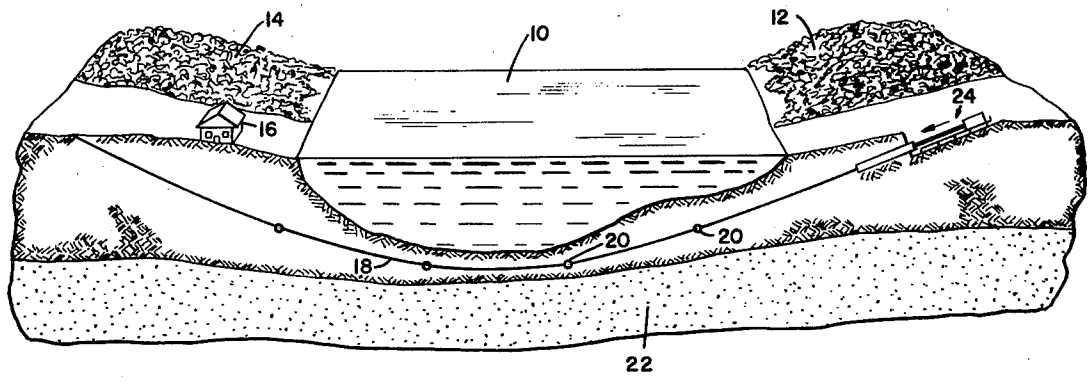
2,565,794	8/1951	Young	175/61
3,118,509	1/1964	Adams et al.	175/62 X
3,326,008	6/1967	Baran et al.	175/61
3,667,556	6/1972	Henderson	175/107 X
3,713,500	4/1970	Russell	175/73
3,720,272	3/1973	Hunter	175/75

Primary Examiner—Frank L. Abbott
Assistant Examiner—Richard E. Favreau
Attorney, Agent, or Firm—Townsend and Townsend

[57] **ABSTRACT**

An improved apparatus and process for drilling an inverted underground arcuate path is disclosed. A drill rig having an acute angle of attack from the horizontal is placed interiorally of a pit where it enters the ground typically normal to the sidewall of the pit. A drill string powering a motorized drill is urged downwardly into the ground by the drill rig. The drill at the drilling end of the drill string has a slight angle imparted thereto. As the drill string is urged into the ground and the drill is angularly aligned with respect to the string, an inverted arcuate path is bored by the drill so as to enter the ground downwardly and angularly at an entrance point and to exit the ground upwardly and angularly at an exit point with an inverted arcuate path therebetween. Parameters for controlling the arcuate path without withdrawing of the drill string to change drills or drill alignment are disclosed. Specifically, by slowing drill speed, increasing thrust on the drill string, and/or aligning the angularlity of the drill to vector upwardly the radius of curvature of the drill path can be decreased. Conversely, by increasing rotational drill speed, decreasing thrust on the drill string, or aligning the bend of the drill string to vector horizontally or downwardly, the radius of curvature of the inverted arcuate path can be increased.

22 Claims, 5 Drawing Figures



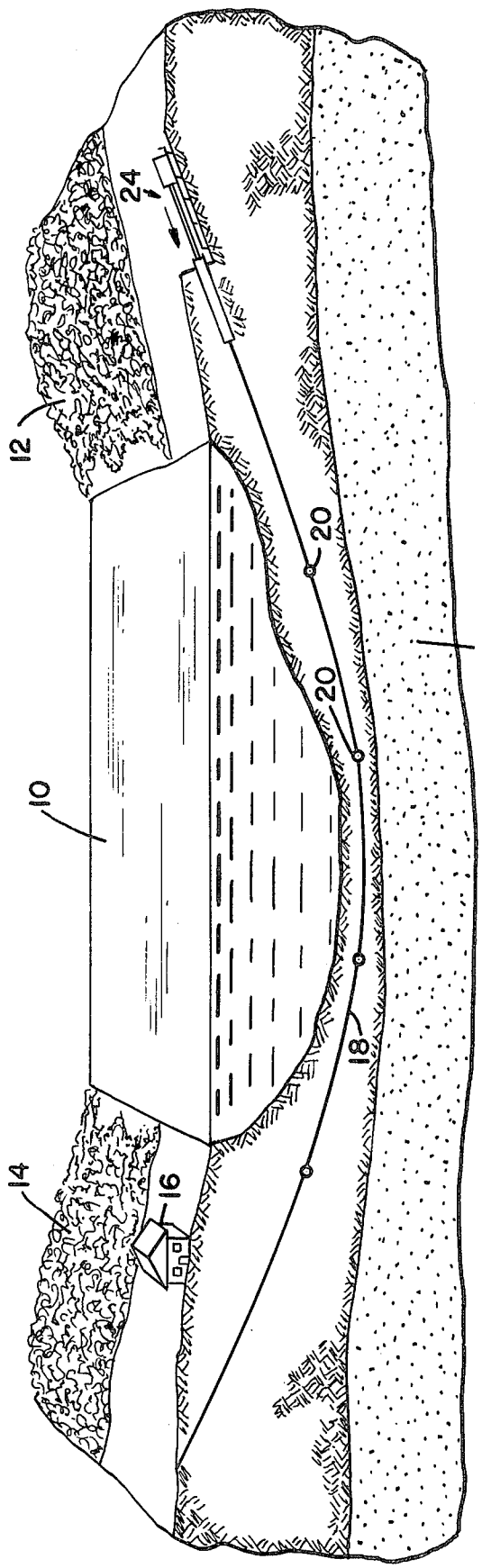

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FIG_1

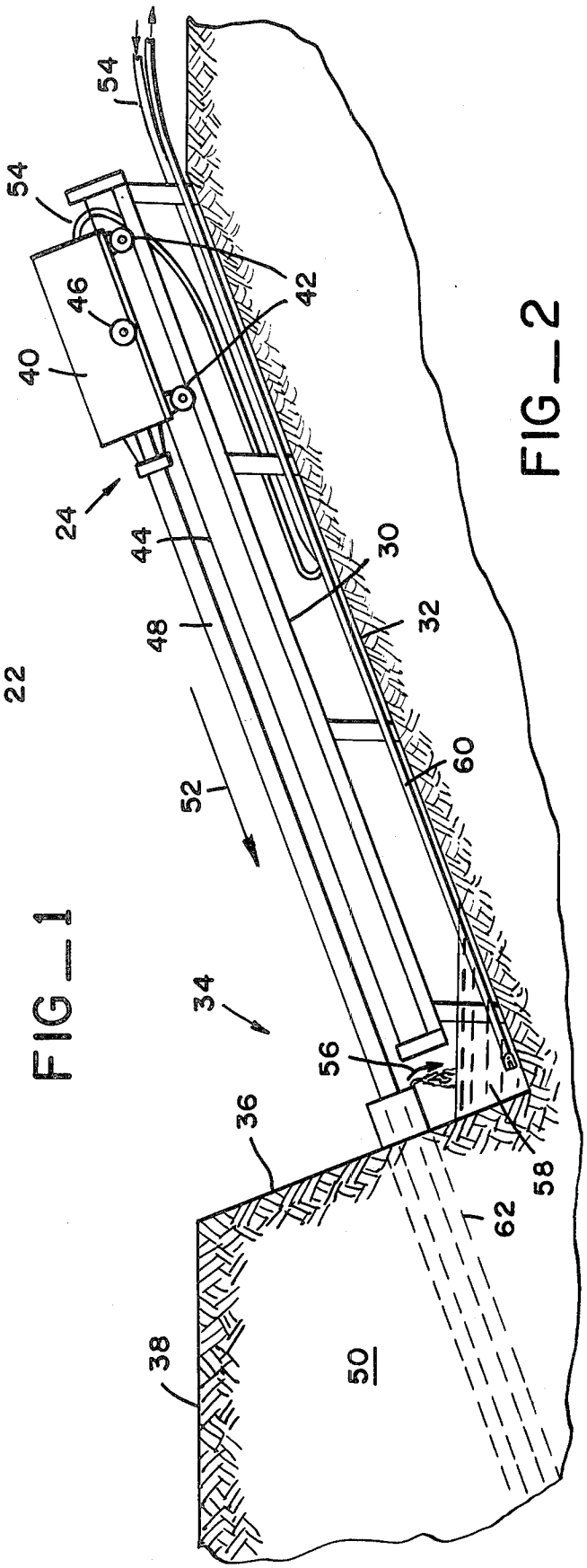

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FIG_2

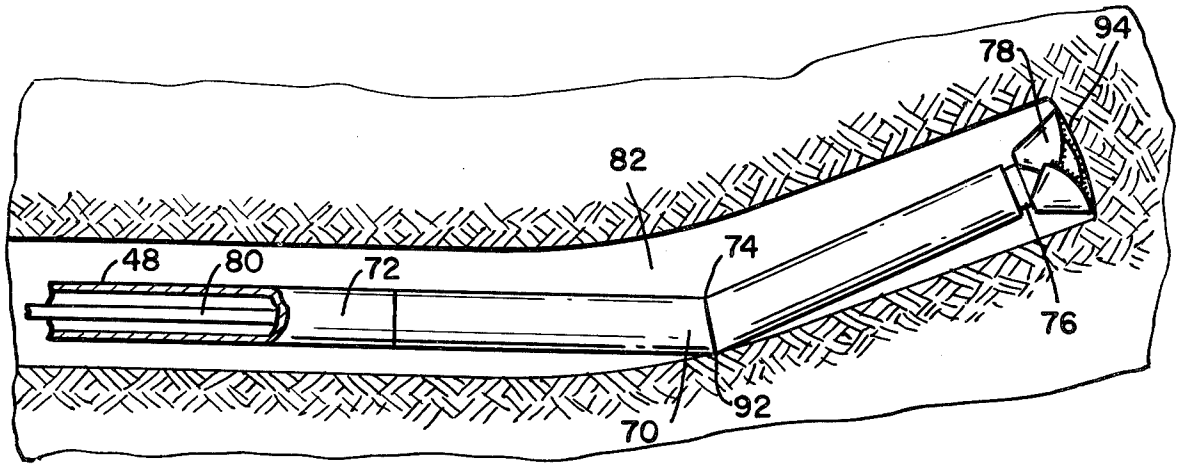


FIG_3

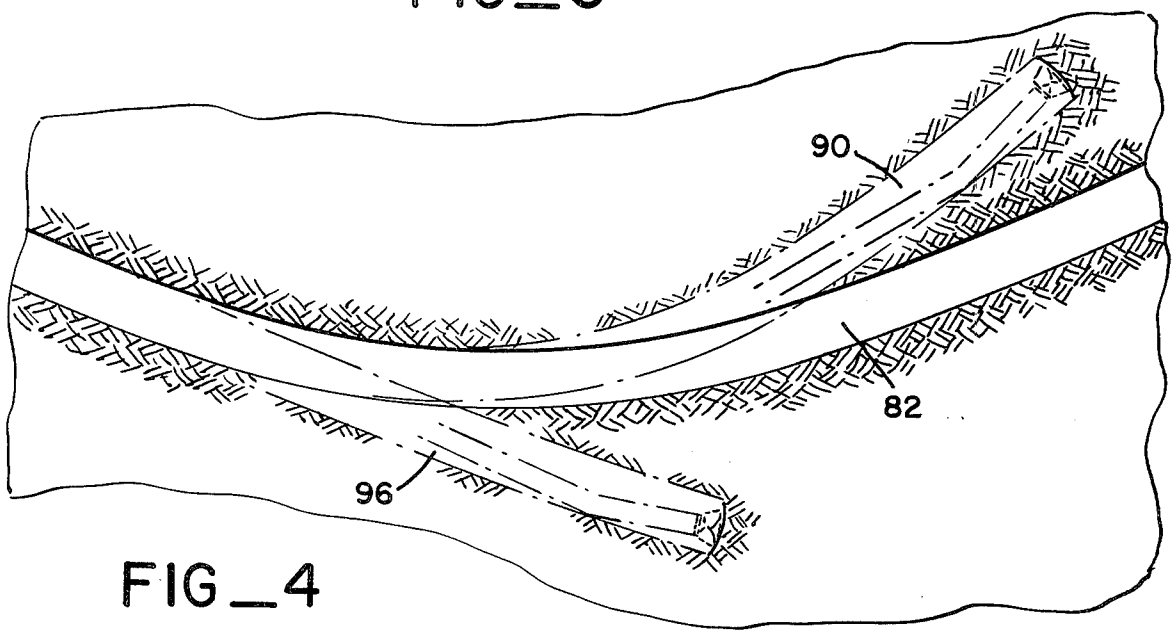


FIG_4

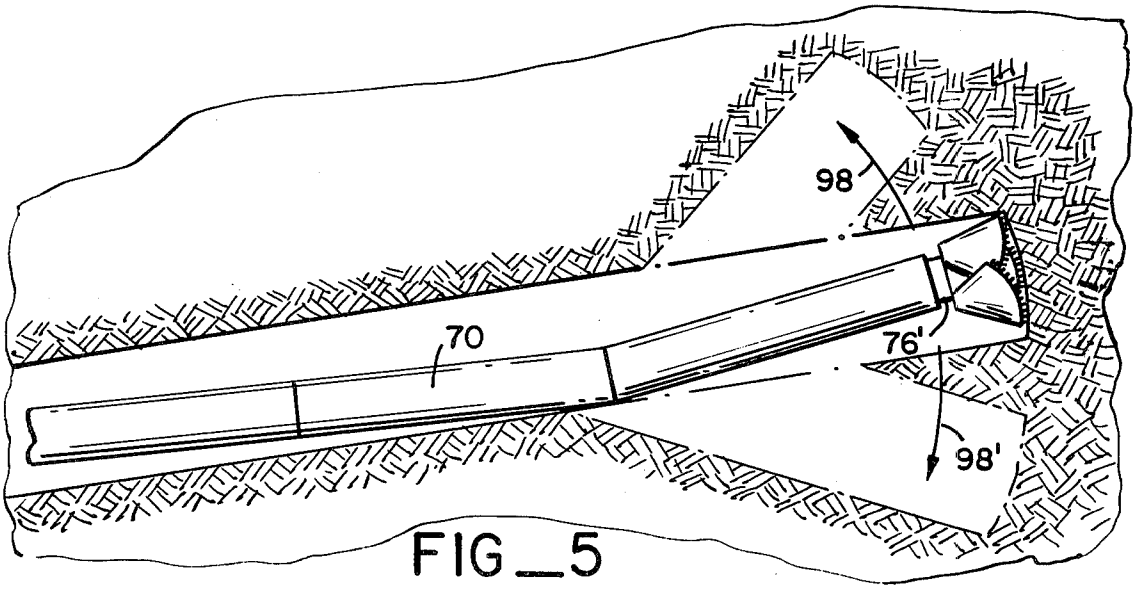


FIG_5

APPARATUS AND PROCESS FOR DRILLING UNDERGROUND ARCUATE PATHS

BACKGROUND OF THE INVENTION

The present invention relates to drilling inverted underground arcuate paths from one surface point to another.

The traditional method for laying pipelines, telephone cables and other underground conduits is to dig an open trench, lay the conduit in the trench and then close the trench. This method is quite efficient in general, but problems arise when an obstacle such as a water course or a heavily traveled road is encountered, and the conduit must traverse the obstacle.

When a road is encountered, the road must either be closed, the traffic diverted, or parts of the road closed and the conduit laid in sections, all of which are inconvenient and interfere substantially with the use of the road. When a conduit must span a water course, other problems arise. First, the trench must be dug to a depth considerably below the level at which the conduit is to be laid since the current will partially fill the trench before the conduit can be inserted. This is a significant problem because such trenches have a generally triangular cross section, and the volume of dirt which must be removed increases with the square of the depth of the trench. Such trenching also stirs the alluvium at the bottom of the water course interfering with the natural flora.

Even after a trench has been dug in a water course, difficulties arise in placing the conduit therein. One method of placing the conduit is to float it across the span of the water course and then remove its buoyancy to sink the pipe into the trench. The difficulty with this method is that the water course must be closed to traffic, floating objects are trapped by the floating conduit, the current of the river bends the conduit, and when the conduit is sunk, it quite often misses the trench. A second method is to attach a sled or skid to the leading end of the conduit, and drag this leading end through the trench to lay the conduit. With this method, the conduit must be coated with a substance to give it negative buoyancy, and this coating is quite expensive since the entire length of the conduit must be so coated.

Traditional methods of digging wells cannot be adapted to digging arcuate paths such as that required for implacing a pipeline or other conduit under an obstacle. Such methods utilize a drill string which enters the ground substantially normal to its surface, and the path must undergo a 180° turn to span the obstacle. Such a path would result in the drill string extending vertically upwardly at the other side of the obstacle with the weight of the drill string acting against the forward motion of the drill. Since the weight of the string is used to drive the drill, such a method cannot be used.

Traditional well drilling methods rely on the weight of the pendant drill string to achieve a substantially vertical hole. When an angular bend in the hole was desired, it was formerly the practice to lower a whip stock shim into the bottom of the hole which forced the drill off at an angle. Later methods utilize a self-powered drill which has a drill stem slightly angularly inclined with respect to the drill string. The problem with both of these methods is that the entire drill string must be removed from the hole, either to lower the whip stock or to mount the inclined drill. After the angle has been made, the entire drill string must be withdrawn again to

remove either the whip stock or the inclined drill. This is extremely time consuming and inefficient since drill strings may be many thousands of feet in length. Furthermore, these methods provide no means for controlling the bend along its length other than removing and replacing the drill string whenever a change in angle is desired. Hence, these methods are unacceptable for drilling controlled arcuate paths and can only be used for intermittent bends and/or constant radius turns.

Techniques have been developed for drilling holes along a substantially linear horizontal path for placing telephone lines under streets and the like. However, these methods employ drills which proceed in a straight line, and to achieve an arcuate path, a pothole must be dug and the drill manually redirected. Such a method is often acceptable in traversing obstructions such as a road, but cannot be used for traversing a water course because the required potholes cannot be dug.

SUMMARY OF THE INVENTION

The present invention provides an apparatus and process for drilling an inverted underground arcuate path. A drill rig having an acute angle of attack from the horizontal is placed interiorally of a pit where it enters the ground typically normal to the sidewall of the pit. A drill string powering a motorized drill is urged angularly downwardly into the ground by the drill rig. The drill at the drilling end of the drill string has imparted thereto an angle usually in the range of 1°–10° but possibly larger. As the drill string is urged into the ground and the drill is angularly aligned with respect to the string, an inverted arcuate path is bored by the drill so as to enter the ground downwardly and angularly at an entrance point and to exit the ground upwardly and angularly at an exit point with an inverted arcuate path therebetween. Parameters for controlling the arcuate path without withdrawing of the drill string to change drills or drill alignment are disclosed. Specifically, by slowing drill speed, increasing thrust on the drill string, and/or aligning the angularity of the drill to vector upwardly the radius of curvature of the drill path can be decreased. Conversely, by increasing rotational drill speed, decreasing thrust on the drill string, or aligning the bend of the drill string to vector horizontally or downwardly, the radius of curvature of the inverted arcuate path can be increased.

The present invention allows for drilling a hole beneath a surface obstacle to avoid the necessity of utilizing the standard trenching method for laying a conduit across the obstacle. When the obstacle is a road or water course, traffic along that obstacle is in no way impeded. Ecological disturbances such as interfering with the natural flora on a river bottom are minimized. The conduit can be placed far below the depth of the water course so that shifts in the water course will not expose it. Also, the entrance and exit points of the conduit can be far removed from the edge of the obstacle so that levies and natural shores need not be breached. Furthermore, all of the aforementioned difficulties associated with laying a pipe in a trench are eliminated.

The present invention provides means for controlling the course of the inverted underground arcuate hole as it is being drilled. The following parameters are utilized: thrust on the drill string, speed of the drill rotors, volume of drilling mud passed to the drill, and azimuth of the inclined drill bit. By manipulating these parameters, the pitch of the drill bit as it travels is controllable

to allow the path of the drill bit to be selectively varied as the hole is being drilled. This allows for continuous drilling of the hole from the entrance to the exit, and eliminates the necessity for removing and replacing the drill bit or other apparatus, greatly reducing the time and expense required to drill the hole.

The novel features which are believed to be characteristic of the invention, both as to organization and method of operation, together with further objects and advantages thereof will be better understood from the following description considered in connection with the accompanying drawings in which a preferred embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only and are not intended as a definition of the limits of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective schematic cross-section of the operation of the present invention in drilling an inverted arcuate hole under a water course;

FIG. **2** is a side elevation view of the inclined drill rig of the present invention;

FIG. **3** is a fragmentary side elevation section of the drill head utilized in the present invention;

FIG. **4** is a side elevation section illustrating the control over the drill head achieved by the present invention;

FIG. **5** is a plan section illustrating a different manner of control over the drill head of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The schematic view of FIG. **1** illustrates a water course **10** having banks **12** and **14.** A house **16** is located on bank **14.** An underground inverted arcuate hole along path **18** passes from adjacent the surface on bank **12** to adjacent the surface on bank **14.** A plurality of discrete survey points **20** are located along path **18.** It should be noted that path **18** passes between the bottom of water course **10** and a layer of shale **22.** The arcuate hole **18** of FIG. **1** is formed by an inclined drill rig apparatus **24** located on bank **12** of water course **10.** The hole is dug from its entrance point on bank **12** to an exit point on bank **14** past house **16** utilizing the method and apparatus of the present invention.

The inclined drill rig apparatus **24** of the present invention is illustrated in more detail by way of reference to FIG. **2.** Apparatus **24** includes ramp **30** mounted to the ground **32** in a pit **34.** Forward wall **36** of pit **34** is inclined with respect to horizontal **38** and is adapted to be normal to the slope of the inclined ramp **30.** The appropriate angle of declination of ramp **30** is governed by the length and depth of the desired arcuate hole and is hence variable. Angles of declination from 5° to 35° down from horizontal have been utilized in practice with the preferred range lying between 10° and 30° to achieve the desired control over the drill head. FIG. **2** illustrates a mid-range angle of declination from the horizontal of 22°.

A power source **40** rides along ramp **30** on wheels **42.** Movement of power source **40** along the ramp is controlled by the use of line **44** which dead ends at the extremeties of the ramp, but which wraps around a powered winch **46** on power source **40.** Power source **40** is usually an internal combustion engine having a plurality of power take-off attachments, but a wide variety of power sources could be employed. Power source **40** is utilized to thrust the drill string **48** angularly downwardly into ground **50** as illustrated by arrow **52** by driving winch **46.** Controls are provided for winch **46** to control the forward thrust on drill string **48.** Drill string **48** comprises a plurality of drilling pipes as known in the oil well drilling art, and in fact, standard oil well drilling materials are used to form the drill string. In the present invention, drill string **48** ordinarily does not rotate to operate the drill, but is rotatable in azimuth about its axis to control the drill head as will hereinafter be illustrated. Hence, power source **40** is capable of providing selective rotational control over the azimuth of drill string **48** as well as thrusting the drill string into the ground by means of winch **46.**

Power source **40** is also adapted to force drilling mud through the hollow interior of drill string **48** to power the drill head and remove loosened particles from the drilled hole. A tube **54** from a source of such drilling mud (not shown) provides the drilling mud to power source **40.** Drilling mud circulates down through the hollow interior of drill string **48** and then back around the exterior of the drill string and out of the drilled hole as illustrated by arrow **56** where it is dumped in the lower portion of pit **34.** A certain amount of such mud **58** is allowed to collect in pit **34,** but most of the mud is returned to its source through tube **60.** The entrance to the drilled hole at face **36** of pit **34** is provided with a conduit **62** extending outwardly through face **36.** Drilling mud exiting the drilled hole thus does not run down face **36** of pit **34** and erode the pit, allowing the pit to retain its preferred configuration.

FIG. **3** illustrates the attachment of a drill head casing **70** to the end **72** of drill string **48** opposite power source **40.** Drill head **70** is of the type known in the art wherein the drilling mud forced through drill string **48** is used to power the drill. Drill head **70** is of the type which has an angular bend **74** with respect to the axis of drill string **48** so that the drill bit portion **76** of drill head **70** is angularly inclined as illustrated. The angular bend **74** of drill **70** can be varied, and inclinations of from 1° to 5° are well known in the art. However, it has been found advantageous in the present invention to increase the angular bend at least to 10° and possibly greater in many applications to achieve the desired control over its movement. The angular bend **74** shown in the figures is probably too large for most applications, however, and is probably an exaggeration. The upper bound of this parameter has yet to be determined. The cutting portion **78** of drill bit **76** is thus angled significantly with respect to drill string **48.** Cutting tip **78** is of the type known in the art and usually has three rotors each having a plurality of cutting teeth.

A surveying instrument **80** is adapted to slide through the hollow interior of drill string **48** to a position adjacent drill head **70.** Surveying tools **80** known in the art are primarily of the "single-shot" variety, i.e., the tool takes a single reading and is then withdrawn through drill string **48** for assessment. Surveying instrument **80** ordinarily measures the azimuth and declination of the leading end **72** of drill string **48.** This data together with the length of the string and a history of the drill path allow the current position of drill head **70** to be determined.

It should be noted by way of reference to FIG. **3** that the hole **82** dug by drill head **70** is curved along its

length as a result of angular bend **74** in drilling head **70.** Drilling head **70** rests on the bottom of hole **82** at position **92** below bend **74** when the drill head is vectored upwardly as illustrated, causing the curved path of hole. If the parameters on drill head **70** are maintained constant, hole **82** will have a constant upward curvature as illustrated by hole **82** in FIG. **4.** However, the apparatus of the present invention, as illustrated in FIG. **2,** provides means for controlling the angularity of the hole along its length and thus its eventual contour.

Specifically, the forward thrust on drill string **48** exerted by power source **40** through winch **46** can be increased, and such action will decrease the radius of curvature as illustrated by phantom hole **90.** The apparent reason for this fact is that drill head **70** rests at two points, the bottom of the angular bend illustrated at **92,** and the leading end of the hole illustrated at **94** in FIG. **4.** Increasing the forward thrust on drill string will apparently force drill head **70** against position **94,** reducing the gravitational load at position **92,** thereby increasing the pitch (angle from horizontal) of drill head **70.** Conversely, decreasing the forward thrust on drill string **48** exerted by power source **40** will increase the radius of curvature of the hole illustrated by the phantom hole **96.**

A further control feature provided by the apparatus of the present invention is that the forcing of drilling mud through the interior of drill string **48** by power source **40** is controllable. Increasing the force on the drilling mud has two effects on the drill; first, the speed of the drill rotors on tip portion **78** is increased; and second, the volume of drilling mud expelled through tip **78** of drill head **70** is increased. This increase in the flow of drilling mud will result in increasing the radius of curvature of the hole as illustrated by phantom **96.** Conversely, decreasing the flow will decrease the radius of curvature as illustrated by phantom **90.** The exact mechanism of this phenomena is not fully understood, but it would appear that both the increase in the speed of rotation of tips **78** and the increase in the drilling mud flowing therethrough reduces the friction at point **94,** resulting in a corresponding increase in the gravity effect at point **92,** thereby increasing the radius of curvature of the path and vice versa.

A further control feature of the apparatus of the present invention is illustrated by way of reference to FIG. **5.** Drilling head **70** is ordinarily positioned so that drill bit **76** is vectored upwardly. It is known that the azimuth of drill bit **70** can be altered by rotating drill string **48** to make horizontal turns in the drill path. However, the present invention provides the additional control of rocking drill head **70** from side to side as illustrated by arrows **98, 98'** or in a full circle in rapid fashion. This will not result in a hole which corkscrews but rather will tend to increase the radius of curvature of the arcuate path without introducing a significant horizontal turn.

In operation, the apparatus of the present invention is utilized as follows. First a pit **34** is dug at one side of an obstruction which is to be traversed with a pipeline or other underground conduit. The forward surface **36** of the pit is inclined from the vertical at a preselected angle. The angle is dependent on the depth of cut desired and the width of the obstacle. A ramp **30** is next placed in the pit, and has a lower end terminating at the forward face **36** thereof. Power source **40** is mounted on ramp **30** and the drilling of the hole is initiated. Drilling of the hole can be begun with traditional straight line drilling methods. However, the control provided by the present invention allows for the preferred method of initiating drilling with the inclined drill head **70.**

The apparatus of the present invention allows the drill head **70** to be directed in a controlled manner beneath the obstruction to surface at the other side. Controlling the thrust on drill string **48,** the force of drilling mud into the drill string, and azimuth of the drill head all can be utilized to control the direction of the drilling. Hence, the present invention provides a method whereby a hole can be drilled continuously under an obstruction from one side to the other for the laying of the conduit.

Although a preferred embodiment of the present invention has been illustrated in detail, it is apparent that modifications and adaptations of that embodiment will occur to those skilled in the art. In particular, the configuration of the drill rig apparatus can be varied, and different mechanisms employed to vary the control parameters of the present invention. However, it is to be expressly understood that such modifications and adaptations are within the spirit and scope of the present invention, as set forth in the following claims.

What I claim as new is:

1. A method for drilling underground an inverted arcuate path beneath an obstacle comprising the steps of: providing a drill string; providing a drill head having at least one cutting drill bit at the end of said drill string operative to cut independent of rotation of said drill string, said drill head having an angular axial alignment with respect to the axis of said drill string; thrusting the drill string angularly downward into the ground at an angle other than vertical; powering said drill bit through said drill string simultaneously with said thrusting step; surveying the azimuth and declination of said drill string proximate said drill head at a plurality of intervals during said drilling and measuring the length of said drill string in the ground at a correspondent plurality of intervals from entrance into the earth at one side of said obstacle to exit from the earth at the other side of said obstacle whereby the path of said drill under said obstacle can be determined; and, varying said thrust of said drill string to change the radius of curvature of said inverted arcuate path.

2. A method as recited in claim **1** wherein said varying said thrust includes increasing the force on said drill string to decrease the radius of curvature of the inverted arcuate path.

3. The method of claim **1** wherein said thrusting step includes decreasing the force on said drill string to increase the radius of curvature of the inverted arcuate path.

4. The method of claim **1** and varying the speed of said drill head to change the radius of curvature of said inverted arcuate path.

5. The method of claim **1** and wherein said powering step includes powering said drill head through said drill string by fluid supplied to a motor operatively connected to said drill bit, and including the step of varying the pressure of said fluid to said motor to change said radius of curvature.

6. The invention of claim **1** and including the step of rocking said drill head from side to side by turning said drill string to change the radius of curvature of said inverted arcuate path.

7. A method for drilling underground an inverted arcuate path beneath an obstacle comprising the steps of: providing a drill string; providing a drill head having at least one cutting drill bit at the end of said drill string operative to cut independent of rotation of said drill string; said drill head having an angular axial alignment with respect to the axis of said drill string; thrusting the drill string angularly downward into the ground at an angle other than vertical; powering said drill bit through said drill string simultaneously with said thrusting step; surveying the azimuth and declination of said drill string proximate said drill head at a plurality of intervals during said drilling and measuring the length of said drill string in the ground at a correspondent plurality of intervals from entrance into the earth at one side of said obstacle to exit from the earth at the other side of said obstacle whereby the path of said drill under said obstacle can be determined; and, varying the speed of said drill bit to change the radius of curvature of said inverted arcuate path.

8. A method as described in claim 7 wherein said varying of the speed of said drill bit includes the step of increasing the rotational speed of said drill bit to increase the radius of curvature of said inverted arcuate path.

9. The method as described in claim 7 wherein said varying the speed of said drill bit includes the step of decreasing the rotational speed of said drill bit to decrease the radius of curvature of said inverted arcuate path.

10. The invention of claim 7 and including the step of varying the thrust of said drill string to change the radius of curvature of said inverted arcuate path.

11. The method of claim 7 and including the steps of powering said drill head by fluid communicated through said drill string to a motor operatively connected to said drill bit and controlling the radius of curvature of said inverted arcuate path by varying the pressure of said fluid.

12. The invention of claim 7 and including the step of rocking said drill head from side to side by turning said drill string to change the radius of curvature of said inverted arcuate path.

13. A method for drilling underground an inverted arcuate path beneath an obstacle comprising the steps of: providing a drill string; providing a drill head having at least one cutting drill bit at the end of said drill string operative to cut independent of rotation of said drill string, said drill head having an angular axial alignment with respect to the axis of said drill string; thrusting the drill string angularly downward into the ground at an angle other than vertical; powering said drill head through fluid supplied under pressure through said drill string to a motor operatively connected to power said cutting drill bit; surveying the azimuth and declination of said drill string proximate said drill head at a plurality of intervals during said drilling; measuring the length of said drill string in the ground at the correspondent plurality of intervals from entrance into the earth at one side of said obstacle to exit from the earth at the other side of said obstacle whereby the path of said drill under said obstacle can be determined; and, varying the pressure of said drilling fluid through said drill string to control the radius of curvature of the inverted arcuate path.

14. The invention of claim 13 and including the step of varying said thrust of said drill string to change the radius of curvature of said inverted arcuate path.

15. The invention of claim 13 and including the step of changing the speed of said drill head to change the radius of curvature of said inverted arcuate path.

16. The invention of claim 13 and including the step of rocking said drill head from side to side by turning said drill string to change the radius of curvature of said inverted arcuate path.

17. The method as recited in claim 13 wherein said powering step comprises increasing the pressure of drilling fluid through said drill string to increase the radius of curvature of said inverted arcuate path.

18. The invention of claim 13 and including the step of decreasing the pressure of drilling fluid through the drill string to decrease the radius of curvature of said inverted arcuate path.

19. A method for drilling underground an inverted arcuate path beneath an obstacle comprising the steps of: providing a drill string; providing a drill head having at least one cutting drill bit at the end of said drill string operative to cut independent of the rotation of said drill string, said drill head having an angular axial alignment with respect to the axis of said drill string; thrusting the drill string angularly downward into the ground at an angle other than vertical; powering said drill head through said drill string simultaneously with said powering and said thrusting step; surveying the azimuth and declination of said drill string proximate said drill head at a plurality of intervals during said drilling and measuring the length of said drill string in the ground at a correspondent plurality of intervals from entrance into the earth at one side of said obstacle to exit from the earth at the other side of said obstacle whereby the path of said drill under said obstacle can be determined; and, varying the azimuth of the drill string about the axis of said drill string by rocking said drill head from side to side by turning said drill string to change the radius of curvature of the inverted arcuate path.

20. The invention of claim 19 and including the step of varying said thrust of said drill string to change the radius of curvature of said inverted arcuate path.

21. The invention of claim 19 and wherein said powering of said drill bit is provided by pumping fluid under pressure to a motor in said drill head operatively connected to said drill bit through said drill string; and, varying said pressure of said fluid through said drill string to control the radius of curvature of said inverted arcuate path.

22. The invention of claim 19 and including the step of varying the speed of said drill bit to change the radius of curvature of said inverted arcuate path.

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