This invention relates to the art of recovering core samples from a borehole, and more particularly relates to a tool for recovering core in such a manner that it can subsequently be oriented with respect to magnetic north.

Geologists have long recognized the value of oriented cores. The initial and most obvious use of oriented cores is to determine the dip and strike of inclined strata which permits a more complete interpretation of structural complications. Secondary recovery programs such as water flooding have also shown that it is highly desirable to know the extent and direction of any preferential permeability which formations may exhibit. The great mass of subsurface geological data obtained over the past several years in the concerted geologic research efforts of most oil companies have amplified the need for oriented subsurface data of every type. It has been suggested that the next major oil-finding and oil-development tool will be based upon the accurate spatial orientation of data based on cores recovered from well bores. This potential is not restricted to the petroleum industry, but is equally applicable wherever drilling cores are obtained, such as in the exploration for development of uranium, metallics, non-metallics and other minerals, the engineering and construction of dam sites, tunnels, bridges and the like, quarrying operations, and many others. However, this data is of use only when drilled cores are oriented with the utmost accuracy and then only when the orientation can be accomplished economically.

Several core orientation techniques and tools have been proposed and used, but none of these have been entirely satisfactory and are of somewhat questionable accuracy. In general, core is cut from a well bore by means of an annular, diamond-studded coring bit which is connected to and rotated by the drill string through an outer barrel. As the outer barrel is rotated and the bit cuts downwardly, an upstanding central core remains which is received in an inner barrel as the barrel passes down over the core. A suitable core catcher is provided at the lower end of the inner barrel which prevents the core from falling out when the coring tool is retrieved from the borehole. Although the inner barrel is generally considered to be stationary as the outer barrel rotates around it, its relative position is unknown. Further, the core may from time to time break or the inner barrel may slowly rotate around the core as a result of friction with the rotating outer barrel.

In the perfection of directional drilling techniques, dowehole instruments have been developed for periodically recording the position of the case of the tool with respect to the vertical and with respect to magnetic north. This is accomplished simultaneously by periodically photographing a target suspended like a pendulum and mounted on a compass. The target has concentric rings extending from the center incident of the axis of the target upwardly, and a compass rose to indicate the rotational position of the instrument relative to magnetic north. The great difficulty lies in constructing a coring tool in which the relative position of the recording instrument with respect to a reference mark on the core is maintained while the core is being cut so that the recovered core can be oriented. This problem is materially complicated by the fact that the core is immediately received within a wholly enclosed inner barrel, which in turn is wholly contained within an outer barrel.

Further, in order to be practical, the inner barrel must be of considerable length before coring operations can be carried on economically. It is necessary for both the inner and outer barrels to be made up of a number of tubular sections which can, as a practical matter, be interconnected only by threads. Therefore the primary object of the present invention is to provide an improved tool for cutting oriented core from a borehole.

Another object of the invention is to provide such a tool which orients the core with improved accuracy.

Another object of the invention is to provide such a tool which is comprised of a plurality of parts which may be transported to a drilling rig, assembled and accurately aligned using conventional tools.

Another object of the invention is to provide a tool of the type described which may be economically manufactured and easily assembled and serviced.

These and other objects of the invention are accomplished by a coring tool comprised of a conventional outer barrel which may be rigidly connected to and rotated by the drill string. A conventional coring bit is connected to the lower end of the outer barrel. An inner barrel is disposed within the outer barrel and has a core catcher and a scribe means at the lower end for scribing the core as it enters the inner barrel and for retaining the core as the tool is recovered from the borehole. A bearing shaft is connected to and extends from the upper end of the inner barrel. A midpoint of the bearing shaft is rotatably connected by a bearing assembly to the upper end of the outer barrel which transmits thrust both downwardly and upwardly. The upper end of the bearing shaft is connected through a mule shoe and another tool to a detecting and recording instrument disposed in the drill string which detects and records the position of its housing with respect to magnetic north at predetermined time intervals.

In accordance with an important aspect of the invention, the outer barrel may be easily disconnected from the bearing means so that the inner barrel may be removed to expose the scribe means at the lower end. The half of the mule shoe connected to the bearing shaft may be adjusably positioned with respect to the bearing shaft and is disposed above the bearing means such that it may be easily aligned with the scribe means, then secured to the bearing shaft. The instrument is then retained in predetermined relationship with respect to the scribe means by the mating halves of the mule shoe which are connected to the inner barrel and to the instrument, respectively.

Additional important aspects of the invention concern the manner in which the components hereabove described may be assembled and will hereafter be described in greater detail and pointed out by the appended claims.

Additional aspects, objects and advantages of the invention will become more evident from the following detailed description and drawings, wherein:

FIGURES 1A–1C, in combination, are a longitudinal sectional view of a coring tool constructed in accordance with the present invention;

FIGURE 2 is an end view of the scribe shoe shown in section in FIGURE 1A; and,

FIGURE 3 is a schematic drawing illustrating the manner in which the tool of the present invention is assembled and aligned.

Referring now to the drawings, and in particular to FIGURES 1A–1C, a coring tool constructed in accordance with the present invention is indicated generally by the reference numeral 10. The coring tool 10 is comprised of an outer barrel, indicated generally by the reference numeral 12, and an inner barrel, indicated generally by
the reference numeral 14, which is rotatably connected to the outer barrel 12 by a bearing assembly, indicated generally by the reference numeral 16.

A conventional diamond coring bit 18 is threaded onto the lower end of the outer barrel 12. The outer barrel 12 is comprised of a lower joint 22 which is connected to an upper joint 24 by an adapter coupling 26. The joints 22 and 24 will customarily be on the order of 25 feet in length and provide a total barrel length of 50 feet. More or less than the two joints 22 and 24 can be employed as required. The upper end of the joint 24 is connected by a second adapter coupling 27 to the lower end of a safety joint box member 28 of a safety coupling. The upper end of the safety joint box member 28 threadedly receives the safety joint pin member 30. In the broader sense, the safety coupling, including the box member 28 and pin member 30, may be considered as part of the outer barrel.

The inner barrel 14 is comprised of a conventional core catcher 32 which is threaded into a scribe shoe 34. The scribe shoe 34 has a suitable means for scribbling a reference line on the core as it enters the inner barrel 14, and preferably has three scribing knives 36, 37 and 38 as can be seen in FIGURE 2. It will be noted that the knives 37 and 38 are relatively close together and that the knife 35 is located opposite the outer joint between the knives 37 and 38 for easy identification. A reference line 42 is scribed on the outer surface of the scribe shoe 34 in register with the knife 36 to facilitate alignment of the knife 36 with a mule shoe as will hereafter be described in greater detail. The knives 36, 37 and 38 are preferably inserted of very hard steel or other material which may be brazed or soldered in recesses formed in the interior surface of the cylindrical sleeve of the shoe 34. The knife inserts may then be easily removed and replaced when they become worn without replacing the entire shoe. The scribe shoe 34 is also preferably separate from the core catcher 32 so that either of these members becomes inoperative, both need not be replaced. The scribe shoe 34 is threaded onto a lower joint 44 of the inner barrel 14. The lower joint 44 is connected by a threaded coupling 46 to an upper joint 48 which in turn is threaded into the lower end of a bearing shaft member 50 by the threaded coupling 51.

The bearing shaft member 50 has a cylindrical surface 52, an annular upward-facing shoulder 54, a cylindrical surface 56 about which bearings 58 and 60 are disposed, a threaded section 62 for receiving a nut 64, and an extension 66 which extends above the upper end of the safety pin 38, as can be seen in FIGURE 1C. A second threaded portion 67 is provided near the upper end of the extension 66 for receiving a lock nut 68 and the lower half 70 of a conventional mule shoe, indicated generally by the reference numeral 72. The mule shoe 72 has an inclined surface 71 leading to a keyway so that a key contained in the upper half of the mule shoe will automatically be directed into the keyway and thereby automatically orient the upper half in a predetermined relationship to the lower half. The upper end 74 of the extension 66 preferably extends above the lower half 76 of the mule shoe substantially as illustrated in FIGURE 1C.

The bearing shaft member 50, and therefore the inner barrel 14, is rotatably connected to the outer barrel 12 by the bearing assembly 16. The bearing assembly 16 has a pair of bearings 58 and 60 which are disposed around the surface 56 of the inner barrel and within a bearing housing 80 which is threaded onto the lower end of the safety joint pin member 39 by coupling 82. The bearing 58 is secured between the shoulder 76 of the housing 80 and the shoulder 54 of the bearing shaft 58. The bearing 60 is secured between the shoulder 79 of the housing and the nut 64 which should be keyed to prevent loosening. Thus the weight of the inner barrel 14 is transmitted from the nut 64 through the bearing 60 to the shoulder 78 of the bearing housing, then to the safety joint pin member and the drill string as will presently be described, so that the inner barrel and any core contained therein may be lifted from the well bore. The weight of the drill string is transmitted from the shoulder 76, the lower bearing 58, and to the shoulder 54 of the inner barrel to force the joints 22 and 24 cut. Upper and lower fluid packings 84 and 86 of any suitable design are provided to seal the bearings 69 and 58 from the well fluids. A grease fitting 88 is provided for filling the cavity between the seals 84 and 86 with grease. A check valve 89 is provided in the lower end of the pin member 30 to permit fluid to escape as the core enters the inner barrel.

The upper end of the safety joint pin member 30 is connected to a sub 90 by a threaded coupling 92. The upper end of the sub 90 is connected to a non-magnetic sub 94 by a threaded coupling 96, and the sub 94 is in turn connected to the drill string 98 by a threaded coupling 102. Drilling fluid passes down through the drill string 98 into the central bore 101 of the safety joint pin member 30, and crosses over through a plurality of bores 103 to the annulus formed between the inner barrel 14 and outer barrel 12. The drilling fluid then passes out the lower end 106 of the outer barrel through the coring bit 18 to wash the cuttings from the borehole in the conventional manner.

The lower portion 70 of the mule shoe 72 is threaded onto the shaft 66 as previously described. The rotational position of the lower half 70 may be rigidly secured with respect to the extension 66 by means of the lock nut 68 which may be rotated until it tightly abuts the lower end of the half 70. The nut 68 is also keyed in position by a key (not illustrated). Further, the lower half 70 of the mule shoe is preferably secured in position by a pair of Allenhead set screws 106. The upper half 106 of the mule shoe 72 is connected to the reference shaft 110 of a conventional survey instrument 112 by a threaded coupling 114. The shaft 110 may be provided with a small shoulder at 116 against which the upper end of the upper half 106 of the mule shoe may be tightly abutted and secured in place so as to provide a predetermined rotational position when tight, but may be merely a conventional threaded coupling.

The survey instrument 112 is rigidly connected to the shaft 110 and may comprise any conventional instrument which records the rotational position of the shaft 110, and therefore that of its own housing, relative to magnetic north or to another reference direction. For example, an Eastman Multiple Shot Survey Instrument manufactured by Eastman Oil Well Survey Company and used to determine the inclination of a borehole with respect to the vertical can be used in the present device. The Eastman survey instrument contains a compass card which remains oriented in one position relative to magnetic north as the case of the instrument rotates. A reference pointer is attached to the case of the instrument and is superimposed over the card. An eight millimeter camera which runs continually for about 24 hours is focused on the card and reference mark. The instrument has a light which flashes at timed intervals, usually every four minutes, so as to photograph the position of a compass card and the reference pointer connected to the housing of the instrument each time the light flashes and thereby record the position of the instrument along with respect to magnetic north at that time. The instrument also includes means for determining the degree of inclination of the instrument and therefore of the borehole. Suitable spacer pins 118 are provided at the upper end of the instrument for maintaining it properly centered within the non-magnetic sub 94. A stringer 120 is provided at the upper end of the instrument so that the instrument can be retrieved by a wire line when desired. The upper portion 106 of the mule shoe 72 is secured to the lower portion 70 by a pair of Allenhead shear pins.
12 which are sufficiently strong to prevent the well fluids from floating the instrument upwardly as the drill string is lowered into the hole, yet are sufficiently weak as to be easily sheared when it is desired to retrieve the instrument 112 by a wire line. The instrument 112 has a reference mark 124 on the outer surface of its housing which is aligned with the reference pointer within the housing which is photographed.

In accordance with an important aspect of the invention, the coring tool 10 can be completely disassembled and transported to the drilling rig, then reassembled and accurately aligned on the rig floor. The outer barrel is usually made up first by interconnecting the bit 18, lower joint 22, lower coupling 26, upper joint 24, upper coupling 27 and the safety joint box member 28. The outer barrel may be made up on the rig floor or may be made up in vertical position in two or more sections using the elevators and slips in the conventional manner. In any event, after the outer barrel has been made up, it may conveniently be suspended by the slips in the well bore such that the upper end of the safety coupling box member 28 is positioned approximately waist high.

The inner barrel is made up by threadedly interconnecting the core catcher 32, scribe shoe 34, lower joint 44, coupling 46, and upper joint 48. The upper joint 48 is then connected to the bearing shaft member 50 by the threads 51. The bearing shaft member 50 will usually be connected to the safety joint box member by the bearing assembly 16 in the shop and properly lubricated, so that the inner barrel is connected to the safety joint pin member as illustrated in FIGURE 3. The nut 68 is then threaded onto the bearing shaft 66 and the lower portion 70 of the mule shoe 72 threaded loosely into approximate position. The lock nut 68 is left loose so that the portion 70 of the mule shoe can be turned freely. The upper portion 108 of the mule shoe is then made up very tightly onto the shaft 110 of the instrument 112. A scribe mark 139 is then made on the outside surface of the upper portion 108 of the mule shoe in precise alignment with the reference scribe mark 124 on the outside surface of the survey instrument 112. This can be accomplished in any suitable manner while the two members are positioned in a suitable holder, or on the rig floor. The upper portion 108 of the mule shoe is then disconnected from the shaft 110, and placed over the upper end 74 of the shaft 66 in register with the lower half 70 of the mule shoe as illustrated in FIGURE 3. A target sight is then placed over the scribe mark 42 of the scribe shoe 34 and an aligning sight placed on the upper portion 108 of the mule shoe. By sighting down the aligning sight to the target sight, the two halves of the mule shoe are rotated until the scribe mark 130 on the mule shoe is precisely aligned with the scribe mark 42 on the scribe shoe. The lock nut 68 is then tightened by hand so as to prevent further rotation of the lower portion 70 of the mule shoe. Because of the substantial length of the inner barrel and the difficulty of obtaining a perfectly flat place against which to position the barrel, the reference marks 130 and 42 will be “sighted in” while the inner barrel is suspended from the elevators.

The inner barrel 14 is then lowered into the outer barrel 12 by the elevators and the safety coupling pin member 30 threaded into the safety coupling box member 28. The mule shoe 72 will then be at a convenient height and the nut 68 is further tightened and the Allenhead set screws 106 tightened to insure that the lower portion 70 of the mule shoe cannot turn with respect to the bearing shaft 66. The upper portion 108 of the instrument is then removed and threaded back onto the shaft 110 to the same degree of tightness and therefore to the same position as when the scribe mark 130 was made in alignment with the reference scribe mark 124.

The non-magnetic sub 94 and cross-over sub 90 are then threaded together and suspended from the elevators over the safety joint. The instrument 112 with the shaft 66 and the upper portion 108 of the mule shoe attached can then be inserted up into the lower end of the sub 90 and the upper portion 108 of the mule shoe dropped onto the lower portion 70. Due to the inclined surface 71, the mule shoe automatically aligns the instrument 112 in the predetermined position such that the reference mark 124 is precisely aligned with the reference mark 42. The Allenhead shear pins 122 are then tight-ened to secure the mule shoe joint together and insure that the instrument 112 is not washed upwardly as the tool is lowered through the fluids standing in the well bore. The subs 90 and 94 are then lowered and connected to the safety joint by the coupling 92. The tool is then lowered into the well bore as the drill string is made up.

Once the tool is on the bottom and the drill string rotated, the bit 18 cuts an annulus from the formation and leaves a cylindrical core. As the bit 18 penetrates the formation, the inner barrel passes around the core. The outer barrel 12 is rotated by the drill string and drives the bit 18. However, the inner barrel 14 remains stationary with respect to the core and therefore with respect to the formation since the core will usually remain connected to the formation as it is being cut by the bit.

Relative rotation of the outer barrel 12 about the inner barrel 14 is permitted by the bearing assembly 16, and a sufficient portion of the load of the drill string is applied to the inner barrel through the bearing assembly 16 to force the scribing knives 36, 37 and 38 down over the core to scribe three continuous grooves along the length of the core.

The light within the instrument 112 customarily flashes every four minutes, starting at a known time. Rotation of the drill string and circulation of the drilling fluid has stopped a few seconds in advance of the time when the light is to flash so that the delicate mechanism within the instrument 112 can stabilize prior to photographing the compass and inclinometer target card. The photograph reveals the position of the case of the instrument 112 relative to true north, and therefore records the position of the scribing knife 36 with respect to true north at that time. A suitable log is maintained reflecting the depth of the scribe shoe 34 at each of the four-minute timed intervals so that when the core is recovered, the position of the scribe shoe resulting from the reference knife 36 at each depth at which a photograph was taken can be determined. It is preferred to then mark true north on the core at each point where the information is available and interconnect these true north marks with a straight line. Of course, in a continuous piece of core, the true north marks should fall on a straight line extending parallel to the axis of the core. However, the scribe line formed by the knife 36 may occur at any rotational position relative to magnetic north, and may wander over the length of the core because the inner barrel, the shaft 66, the mule shoe 72, the shift 110, and the instrument 112 are free to rotate, except for the friction between the core and the core catcher 32 and the scribe shoe 34.

If it is desired to remove the instrument 112 for any reason, a wire line can be lowered through the drill string and a suitable latching apparatus used to engage the stinger 120. When the wire line is raised, the shear pins 122 will be sheared to permit recovery of the instrument.

It will be noted that the inner barrel 14 may be separated from the outer barrel 12 so that the reference mark 42 on the scribe shoe 34 is exposed for sighting, and that the subs 90 and 94 can be separated to expose the mule shoe 72. This permits the reference mark 130 on the mule shoe to be “sighted in” with the reference mark 42 while the long inner barrel is hanging from the elevators and eliminates any problems of making up the various joints between the several parts of the inner barrel to predetermined points. The adjustable connection be-
between the mule shoe and the inner barrel permits the inner barrel to be tightly made up and then make the necessary adjustments. It will be appreciated that when the parts of the inner barrel are repeatedly made up, the parts tend to assume different relative positions each time.

Although a preferred embodiment of the invention has been described in detail, it is to be understood that various changes, substitutions and alterations can be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. The orientation coring tool which comprises:
   - an outer barrel for connection to a drill string,
   - a coring bit connected to the lower end of the outer barrel for cutting a core as the outer barrel is rotated by the drill string,
   - an inner barrel disposed within the outer barrel for receiving core as it is cut by the bit,
   - scribing means connected to the lower end of the inner barrel for scribing a reference line on the core as it enters the inner barrel,
   - a bearing shaft connected to the upper end of the inner barrel and extending upwardly therefrom to a point above the upper end on the outer barrel,
   - a bearing assembly interconnecting a midpoint of the bearing shaft and the upper end of the outer barrel to permit free rotational movement of the outer barrel with respect to the inner barrel,
   - a survey instrument assembly for periodically recording the position of a reference shaft relative to true north disposed in the drill string above the bearing assembly, and
   - a mule shoe assembly adjustably interconnecting the survey instrument and the upper end of the bearing shaft such that the scribing means may be aligned with the reference shaft of the survey instrument assembly by adjustment of the mule shoe assembly after the inner barrel is assembled.

2. The orientation coring tool which comprises:
   - an outer barrel having a coring bit connected to the lower end for cutting core as the outer barrel is rotated, and
   - an inner barrel disposed within the outer barrel for receiving core cut by the bit and having a core catcher for retaining the core within the barrel and a scribe means for marking a reference line on the core as it enters the barrel both disposed at the lower end of the inner barrel adjacent the coring bit, and having a bearing shaft connected to the upper end of the inner barrel and extending upwardly therefrom,
   - a safety coupling comprising a tubular box portion connected to the upper end of the outer barrel and threadedly connected to a pin portion, the pin portion being rotatably connected to the bearing shaft at a point below the upper end of the bearing shaft and being connected to the lower end of the drill string,
   - one part of a mule shoe adjustably connected to the upper end of the bearing shaft above the upper end of the pin portion for selective connection to the shaft at any rotational position relative to the shaft, and
   - a recording assembly disposed in the drill string above the safety joint for periodically recording the position of a reference member with respect to true north, the other mating part of the mule shoe being connected to the lower end of the reference member whereby the reference member may be aligned with the scribe means by adjustment of said one part of the mule shoe relative to the bearing shaft each time that the tool is assembled.

3. The orientation coring tool which comprises:
   - an outer barrel having a coring bit connected to the lower end and a threaded coupling at the upper end for connection to a drill string,
   - an inner barrel disposed in the outer barrel having a scribing means at the lower end for scribing a reference line on the core as it passes into the inner barrel and a bearing shaft at the upper end extending above the upper end of the outer barrel, bearing means rotatably interconnecting the outer barrel and the bearing shaft below the upper end of the bearing shaft for permitting relative rotational movement between the two barrels, and one part of a mule shoe adjustably connected to the upper end of the bearing shaft for rigidly connecting said one part to the bearing shaft in any relative rotational position, and
   - a detecting and recording instrument for disposition in the drill string above said one part of the mule shoe for periodically detecting and recording the position of the instrument relative to magnetic north, the mating half of the mule shoe being rigidly connected to the lower end of the instrument for coupling the instrument to the bearing shaft in a fixed predetermined rotational relationship.

4. The orientation coring tool assembly which comprises:
   - a non-magnetic sub for connection to a drill string,
   - a safety joint pin member connected to the lower end of the non-magnetic sub, and
   - an outer barrel threadedly connected to the safety joint pin member at a midpoint thereof,
   - a coring bit connected to the lower end of the outer barrel for cutting a core as the outer barrel is rotated, and
   - an inner barrel disposed within the outer barrel for receiving core as it is cut, the inner barrel including a core catcher and a scribe means at the lower end thereof for retaining the core in the inner barrel and for scribing a reference line on the core as it enters the barrel, bearing shaft connected to the upper end of the inner barrel and extending upwardly through the safety joint pin member to a point above the upper end of the safety joint pin member,
   - a bearing assembly interconnecting the lower end of the safety joint pin member and the bearing shaft for permitting rotational movement of the outer barrel relative to the inner barrel, one-half of a mule shoe adjustably connected to the upper end of the bearing shaft above the upper end of the inner barrel assembly whereby said one-half of the mule shoe being selectively securable at any rotational position relative to the bearing shaft, a detecting and recording instrument disposed in the non-magnetic sub for detecting the position of a reference rod relative to magnetic north and periodically recording said position, and
   - the mating half of said mule shoe connected to the reference rod and engaging said one-half to maintain the reference rod in predetermined relationship with respect to the inner barrel at all times, whereby the outer barrel may be disconnected from the safety joint pin member and the inner barrel withdrawn to expose the scribe means, and the safety joint pin member may be disconnected from the non-magnetic sub to expose said one-half of the mule shoe, and the mule shoe aligned with the scribe means and secured in place to align the assembly.

5. The assembly defined in claim 4 wherein the safety coupling pin member includes a fluid cross-over from a central passageway to the annulus formed between the inner barrel, which cross-over is disposed above the bearing assembly and below the point where the outer barrel is connected to the safety joint pin member.

6. The assembly defined in claim 4 wherein the bearing assembly includes sealing means between the safety joint pin member and the bearing shaft above and below bearing means to provide a sealed bearing assembly.
7. The assembly defined in claim 4 wherein the inner barrel is comprised of a plurality of tubular members threadedly interconnected.

8. The assembly defined in claim 7 wherein the core catcher and scribe means are formed in separate tubular members.

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