A rotary drill system is disclosed wherein drill stems extending into a bore hole have secured to one end thereof a sub and drill bit. The sub includes guide rollers rotatably mounted thereon. The drill bit includes a plurality of drill cones rotatably secured thereto and incorporates a passageway extending through the stems and the sub into the bore hole through the bit for transporting air with a lubricant entrained therein. A separator is mounted in the passageway for separating air from the lubricant; the air is permitted to pass through the bit to the work area for cooling the bit and transporting materials loosened by the drill cones to the surface. The liquid lubricant entrained in the air and separated by the separator is directed to separate passageways in the bit to the bearings of the drill cones, and is directed to the guide rollers mounted on the sub.

17 Claims, 7 Drawing Figures
ROTARY DRILLING METHOD AND APPARATUS

The present invention pertains to rotary drill systems, and more particularly, to drilling earth bores with rotary drill bits.

The present invention relates to the method of using a gaseous drilling medium such as air which is circulated through a drill stem and has entrained therein a lubricating medium which would include water, oil, water and oil, other lubricants, corrosion inhibitors, and combinations thereof which have a greater specific gravity than the gaseous drilling medium and the separation of at least a portion of the lubricating medium for conduction to the bearing of a roller cutter bit on the drill stem.

Present drilling techniques frequently utilize drill bits having multiple rotary cones for breaking up rock and other earth material to effect removal of such material. Such drill bits generate substantial heat and debris in the form of particles. To remove this matter and also to assist in the cooling of the drill bit, it is common practice to force a cooling fluid, such as air, down through the hollow drill stems to the drill bit and subsequently out through openings in the drill stem to the work area. The air carries off a portion of the heat generated by the drill cone contact with the bore hole bottom and also removes the loosened debris and material at the bottom of the hole; this air is forced outwardly and upwardly from the drill bit work area and travels upwardly on the outside of the stem in the space between the drill stem and the bore hole.

The rotating cones of the drill bit incorporate bearings which obviously are called upon to work under the most unfavorable conditions for bearing life. The heat and fine particles of abrasive materials in the environment of the operation have resulted in a variety of attempts to prolong bearing life. These attempts have included solutions by way of sealing the bearings or by cooling the bearings by the fluid being delivered to the drill bit through the drill stem. It has been suggested that a lubricant be entrained in the cooling fluid such that when the cooling fluid arrives at the drill bit, a portion of the fluid can be directed to the cone bearings and thus provide lubrication.

The latter solution extends bearing life but is also very expensive. The lubricants used are frequently quite expensive since they are called upon to provide lubricating properties under conditions of extreme heat and pressure. It has been found that in the use of a conventional three cone drill bit, only approximately 35% of the total air volume flows through the bearings as a cleaning, lubricating, and/or cooling agent (approximately 12% of the total air volume to each of the bearings of the three cones). The remaining 65% of the total air volume is exhausted through the bit body to cool the bits and to act as a transport medium for the loosened material. Thus, it can be seen that if lubricant is to be entrained in the air being delivered to the drill bit, approximately 65% of the lubricant is wasted.

In co-pending application Ser. No. 388,338, filed Aug. 13, 1973 and now abandoned, I have described and claimed a system for obviating the above difficulties through the utilization of a reservoir in a sub attached to a drill bit. In that application, the reservoir is filled with lubricating fluid which is metered into a portion of the air flowing through the stems and sub and is directed specifically to the bearings of the drill cones. The present invention provides a means for eliminating the needs for a reservoir in the sub while nevertheless permitting lubricant to be directed to the bearings of the drill cones.

It is therefore an object of the present invention to provide a rotary drill bit system for efficiently utilizing a lubricating medium entrained in a gaseous drilling medium delivered through the drill stems of the system. It is another object of the present invention to provide a rotary drill bit system incorporating a separator for separating a lubricating medium from the gaseous drilling medium provided to the drill bit and for subsequently utilizing the separated lubricating medium for the drill cone bearings.

It is still another object of the present invention to provide a rotary drill bit system wherein a lubricating medium may be entrained in the gaseous drilling medium being delivered through the stems to the bit while directing such entrained lubricating medium to the bearings in the drill system.

A further object is to provide an improved method of utilizing a lubricating medium entrained in the gaseous drilling medium at the surface to lubricate the bearings of the roller cutters of a rotary drilling system in which only a minimum amount of lubricating medium is used.

These and other objects of the present invention will become apparent to those skilled in the art as the description thereof proceeds.

The present invention may more readily be described by reference to the accompanying drawings, in which:

FIG. 1 is a sectional view of the improved drill bit of the present invention showing the structure for directing lubricating medium to the bearings of the roller cutters.

FIG. 2 is a transverse sectional view taken along line 2—2 on FIG. 1 to illustrate the arrangement of the passages to the bearings and to the bit nozzles.

FIG. 3 is another sectional view taken along line 3—3 in FIG. 1 showing the separator structure.

FIG. 4 is a side elevation view partly in section, showing a rotary drill bit system incorporating the teachings of the present invention.

FIG. 5 is a sectional view of FIG. 4 taken along line 5—5.

FIG. 6 is a perspective view of the lubrication tube as shown in FIG. 4.

FIG. 7 is a perspective view of the divider plate supporting the upper end of the tubes conducting the lubricating medium to the bearing passages.

In the preferred form of the invention shown in FIG. 7 a rotary drill bit includes the body 100 and the roller cutters 102 which are each rotatively supported on a journal 104 extending downwardly and inwardly from a leg 106 of the drill bit 100 by the bearings 108. The drill bit 100 has a central cavity 110 which communicates with the nozzles 112 so that circulated gaseous drilling medium flowing through the bore 114 of the pin 116 of the drill bit 100 is jetted into the formation face during drilling.

Since it is an object of the present invention to separate the lubricating medium entrained in the gaseous drilling medium for lubricating the bearings 108 of the roller cutters, the passage 118 extends from the central cavity through the leg 106 and journal 104 into communication with bearings 108. The separator assembly 120 is supported in bore 114 and causes a substantial portion of the lubricating medium to be separated from the gaseous drilling medium and directed to the bearings 108. The separator assembly 120 includes the con-
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ical dome 122 supported by the tabs 124 above the cylindrical tube 130 which is suitably secured in bore 114 as hereinafter explained. The tube 130 defines two passageways 132 and 134 with passageway 132 communicating with central cavity 110 and passageway 134 communicating to the bearings 108 of the roller cutters 102. The tube 130 extends through plate 136 and is secured therein by welding or other suitable means. Plate 136 is secured in bore 114 by split rings 138 and 140. The plate 136 includes three openings 142, 144 and 146 into which one end of the tubes 148 are positioned. The other ends of tubes 148 are positioned within the ends of passageways 118.

With this structure, the circulating drilling fluid with a lubricating medium entrained therein is circulated downwardly through the drill stem into the bore 114 of drill bit 100. The gaseous drilling medium is deflected by the conical dome as hereinafter described more fully and the heavier lubricating medium enters the passageway 134 and the gaseous drilling medium flows into the passageway 132.

In the modified form of the present invention shown in FIGS. 4-7, a drill stem 10 is shown threadedly coupled to sub 12 and providing a central passageway 14 communicating with the surface in a manner well known in the art. The gaseous drilling medium is normally pumped through passageway 14 into the bore hole to cool the drill bit and to carry loosened rock and earth upwardly externally of the drill stem. A sub, such as sub 12, is usually connected to the bottom stem such as the stem 10 for numerous reasons, not the least of which is the fact that the sub 12 is generally less expensive than a conventional stem; since replacing drill bits requires threading and unthreading the drill bit from the sub, the wear on the threads as well as the possibility of cross-threading sometimes results in the requirement to replace the sub. If the drill bit were connected directly to the stem, the stem would have to be replaced and it is therefore economically more feasible to utilize a sub. Further, the sub may be provided with guiding rollers as will be described more fully hereinafter to help maintain the center positioning of the drill bit as it deepens the bore hole.

A drill bit 16 is threadedly secured to the bottom of the sub 12 and includes a plurality of drill cones 18 rotatably mounted on bearings 20.

The gaseous drilling medium sent through the stem 10 and the sub 12 to the bottom of the bore hole is frequently utilized to entrain water for suppression of dust and to aid in the cooling of the drill bit, it has been found that the gaseous drilling medium may also be utilized to entrain a lubricating medium to provide lubrication for the bearings such as those shown at 20, to reduce the friction and decrease the heat generated by such friction. The cost of such lubricating medium dictates that it be used sparingly; however, the requirement for lubrication in the bearings also dictates a minimum amount of lubricating medium that may be supplied to prevent early bearing failure. As a result, prior art techniques have incorporated excess lubricant which is simply wasted in the bore hole to insure that sufficient lubrication, entrained in the gaseous drilling medium, is provided to the bearings. The present invention incorporates a centrifugal separator 25 formed by a conical dome 26 supported by metal tabs 27, 28 and 29 above a cylindrical tube 30 which is welded or otherwise fixed in the passageway 14. The tube 30 thereby defines two passageways, 32 and 33. The separa-

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ator 25 is positioned in the passageway 14 and may conventionally be placed in the sub as shown in FIG. 1; however, it will be obvious to those skilled in the art that an appropriately designed drill bit may incorporate the separator entirely within the bit and the passageway 14 would then extend directly into the bit to the separator. The gaseous drilling medium and lubricant medium mixture impinging on the conical surface 26 is forced to rapidly change direction causing the lubricating medium to be collected on the conical dome 26 and subsequently entrained in the gaseous drilling medium passing into the passageway 32. The gaseous drilling medium that finds its way into the passageway 33 has been "separated" from the lubricating medium.

The passageway 33 extends from the separator 25 downwardly through a splitter tube 35 that is positioned against a washer 40 and held firmly in place by a compression spring 41 while being maintained in axial alignment by radially extending guides 43 and 44 (typically, three such guides will be used, spaced 120° apart). The washer 40 is a rubber covered steel washer that forms a sealing engagement with the end of the splitter tube 35 and has a central opening 45 corresponding to the internal diameter of the splitter tube 35 to thereby provide a continuation of the passageway 33 down through openings 46 in the drill bit 16. It may therefore be seen that gaseous drilling medium impinging on the centrifugal separator 25 is separated from lubricating medium entrained therein and the "dried" gaseous drilling medium then exits through the drill bit to help cool the bit and carry dislodged material upwardly and exteriorly of the bit and stems.

Passageway 32 is separated from passageway 33 at the upper portion thereof by the cylindrical tube 30 and at the lower portion thereof by the splitter tube 35. Therefore, the gaseous drilling medium passing in the passageway 32 has a substantially increased concentration of lubricating medium entrained therein; the passageway 32 communicates with the respective bearings, such as bearing 26, after the passageway is divided into three parts (one for each bearing) by the separator 25. The washer 40 includes guiding rollers 50, 51 and 52, each of which accepts the rectangular end of an air passage tube, such as that shown at 60 in FIG. 2. The gaseous drilling medium and lubricating medium travelling in passageway 32 is thus delivered to the bearings of the drill cones 18.

Guide rollers, such as the guide roller 60, are typically mounted on the sub 12 to center the sub in the bore hole. The guide rollers are usually positioned at 120° intervals about the periphery of the sub. The guide rollers 60 are mounted on shafts, such as 61, which pass through the center of the guide roller and permit the roller to rotate about the shaft and in sliding contact therewith. The shaft 61 is hollow, thus acting as a continuation of passageway 32; however, a small bleed hole 63 may be provided in the shaft 61 to permit the escape of sufficient gaseous drilling medium and entrained lubricating medium to lubricate the sliding surfaces between the shaft 61 and the guide roller 60. Lubrication of these guide rollers has been found to be important since such lubrication extends the useful life of the sub. Subs are generally manufactured with non-removable guide rollers; therefore, when the rollers, or sliding surfaces on which they are mounted, are rendered inoperative by wear, abrasion or other irreparable damage, the entire sub must be replaced.
While centrifugal separators have been utilized in the prior art, their use was predicated upon removal of water from the entrained air to prevent the water from reaching the drill bit; in contrast, the present invention specifically directs the lubricating medium such as water and a lubricant to the drill bit. In a typical application of the present invention, air may be supplied through the drill stems at a rate of 1200 cubic feet per minute while one gallon of water may be injected in the air to provide dust suppression and additional cooling capacity. Approximately one gallon of an appropriate lubricant such as Mobil Oil Company's Rock Drill Oil may be injected into the airstream every 7 hours; such injection may be accomplished by a simple line oiler used in pneumatic applications and incorporating a venturi system or may be directly injected by a chemical injector such as the type sold by McFarland Industries under the trademark "Economac." Using the same application as above but incorporating prior art techniques would require from 4 to 5 gallons of lubricant or four to five times as much lubricant as the system of the present invention to accomplish the same lubrication and cooling function.

What is claimed is:

1. In a rotary drill system of the type using drill stems extending into a bore hole and having means securing a drill bit to said stems, said drill bit including a plurality of drill cones rotatably mounted on bearings secured to said bit, said system including a passageway extending through said stems and into said bore hole for transporting air with lubricant entrained therein, the improvement comprising:
   separating means mounted in said passageway for separating said air and lubricant;
   means defining a second passageway extending from said separating means through said drill bit for carrying air from said separating means into said bore hole; and
   means defining a third passageway extending from said separating means to said bearings for carrying lubricant from said separating means to said bearings.

2. The combination as set forth in claim 1 wherein said means connecting said drill bit to said stems is a sub, and
   said separating means is mounted in said sub.

3. The combination as set forth in claim 2 wherein said separating means comprises
   a conical plate mounted on a cylindrical tube positioned in said passageway in said sub,
   said tube separating said passageway into said second passageway interior of said tube and into said third passageway exterior of said tube.

4. The combination as set forth in claim 2 wherein said sub includes
   a plurality of guide rollers rotatably mounted about the periphery thereof for contacting said bore hole and maintaining alignment of said stems and bit, and
   means communicating with said third passageway for supplying lubricant to said guide rollers.

5. The combination as set forth in claim 1 wherein said separating means is a centrifugal separator.

6. In a rotary drill system of the type using drill stems extending into a bore hole and having a sub securing a drill bit to said stems, said drill bit including a plurality of drill cones rotatably mounted on bearings secured to said bit, said system including a passageway extending through said stems and sub and into said bore hole for transporting air with lubricant entrained therein, the improvement comprising:
   separating means mounted in said sub for separating said air and lubricant,
   said sub including a plurality of guide rollers rotatably mounted about the periphery thereof for contacting said bore hole and maintaining alignment of said stems in said bore hole,
   means defining a second passageway extending from said separating means through said sub for carrying air from said separating means through said sub, and
   means defining a third passageway extending from said separating means to said guide rollers for carrying lubricant from said separating means to said guide rollers.

7. The combination as set forth in claim 6 wherein said third passageway extends through said guide rollers to said drill cone bearings for supplying lubricant thereto.

8. In a rotary drill system of the type using drill stems extending into a bore hole and having a sub securing a drill bit to said stems, said drill bit including a plurality of drill cones rotatably mounted on bearings secured to said bit, said system including a passageway extending through said stems and sub and into said bore hole for transporting air with lubricant entrained therein, the improvement comprising:
   a plurality of guide rollers rotatably mounted about the periphery of said sub for contacting said bore hole and maintaining alignment of said stems and bit in said bore hole;
   a cylindrical tube positioned in said passageway in said sub,
   said tube being axially aligned in said passageway and separating said passageway into a second passageway interior of said tube and into a third passageway exterior of said tube,
   a conical plate mounted on said cylindrical tube and axially displaced therefrom to permit air to flow over and around said conical plate to the exterior and interior of said cylindrical tube to thereby form a separating means,
   said second passageway extending from said separating means, through said drill bit for carrying air from said separating means into said bore hole,
   said third passageway extending from said separating means to said guide rollers and to said bearings for carrying lubricant from said separating means to said guide rollers and to said bearings.

9. A drill bit, comprising
   a body defining a recess therein and having means on one end for connecting to a drill stem,
   said end having a passage therethrough and communicating with said recess,
   a plurality of roller cutters, bearing means for rotatively supporting said roller cutters on said body,
   means for discharging gaseous drilling medium from said body in a direction toward the formation being drilled,
   means for separating lubricating medium from gaseous drilling medium being circulated to said body, and
   means for directing said separated lubricating medium to said bearing means.
10. A drill bit adapted to be used with a sub having a separator therein for directing a gaseous drilling medium in a first passage and a separated lubricating medium in a second passage, comprising a body defining a recess therein and having means on one end for connecting to a drill stem, said end having a passage therethrough and communicating with said recess, a plurality of roller cutters, bearing means for rotatively supporting said roller cutters on said body, means for discharging gaseous drilling medium from said body in a direction toward the formation being drilled, and means defining passages communicating from the first passage of a sub connected to the drill bit to said discharge means and communicating from said second passage of said sub to said bearing means.

11. The method of drilling bore holes in the earth with a drill bit having bearing supported roller cutters connected to the lower end of a tubular drill stem including the steps of rotating the drill stem with the drill bit engaging the formation to be drilled, circulating gaseous drilling medium with a lubricating medium entrained therein through said drill stem for discharge from said drill bit, separating at least a portion of the entrained lubricating medium from the gaseous drilling medium before the gaseous drilling medium is discharged from the drill bit, and conducting the separated lubricating medium to the roller cutter bearings of said drill bit.

12. The method of drilling according to claim 11 wherein said drill stem includes a sub with exterior rollers thereon and including the step of conducting the separated lubricating medium to the bearings of the sub rollers.

13. The method of drilling according to claim 12 including the step of conducting the separated lubricating medium from the sub rollers to the roller cutter bearings of said drill bit.

14. A method of drilling bore holes in the earth with a roller cutter drill bit attached to the lower end of a drill stem wherein the drill bit has a passageway leading into the interior of the roller cutter and a passageway leading to the exterior of the bit including the steps of: rotating the bit with the drill stem, circulating gaseous drilling medium through the drill stem into the drill bit, entraining lubricating medium into the gaseous drilling medium, separating said lubricating medium from said gaseous drilling medium, causing the lubricating medium to flow through the passageway into the interior of the cutter, while simultaneously discharging the gaseous drilling medium through the passageway leading to the exterior of the bit.

15. A method of lubricating a roller cutter drill bit which is adapted to receive circulating drilling fluid wherein the bit has passageways leading to the interior of the cutter and to the exterior of the bit including the steps of: injecting lubricant into the circulating fluid upstream from the bit, separating the lubricant from the drilling fluid, causing the lubricant to flow into the interior of the roller cutter, and discharging the fluid to the exterior of the bit.

16. A method of lubricating a roller cutter operably mounted on a drill stem having drilling fluid circulating therethrough including the steps of: injecting lubricant into the circulating drilling fluid, separating a substantial portion of the lubricant from the circulating drilling fluid, conducting the lubricant into the interior of said roller cutter, while discharging a major portion of the drilling fluid to the exterior of the drill stem.

17. A drilling apparatus, comprising a plurality of tubular members connected end to end to form a drill stem, a drill bit having a plurality of roller cutters rotatively mounted on said bit by bearing means, said bit being connected to the drilling end of said drill stem, said drill stem and said drill bit defining a passageway for the circulating of gaseous drilling medium to the formation being drilled, means mounted within said drill stem above said drill bit for separating a lubricating medium entrained in the gaseous drilling medium being circulated through said drill stem, and means for directing said separated lubricant to the bearing means of said drill bit.

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