

[54] **LOW VOLTAGE SPARK DRILL**

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[51] Int. Cl. **E21b 7/00**

[58] Field of Search **175/2, 11, 19, 16; 123/169; 315/35**

[56] **References Cited**

UNITED STATES PATENTS

3,158,207 11/1964 Rowley **175/16**

3,679,007 5/1970 O'Hare **175/16**
2,953,353 9/1960 Allen **175/16**
3,500,942 3/1970 Smith **175/16**
2,963,620 12/1960 Knudson et al. **123/169 R**

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[57] **ABSTRACT**

A spark drill for subterranean drilling is disclosed which may be attached to a standard or continuous drill string. The drill is characterized by multiple electrodes having a layer of semiconductor material between them which provides an electrical shunt path and further includes a trigger circuit for initiating the spark.

14 Claims, 5 Drawing Figures

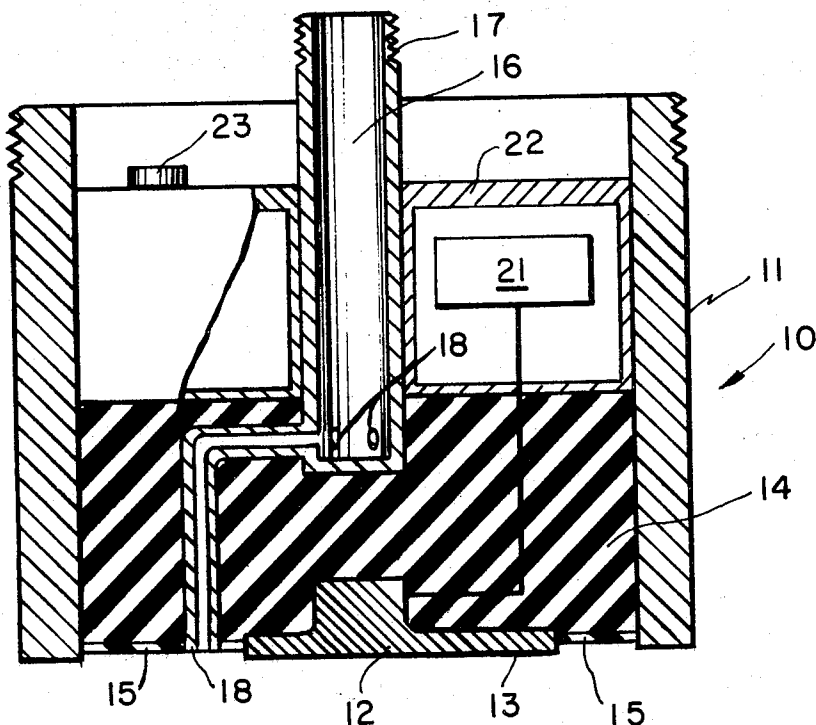


Fig. 1

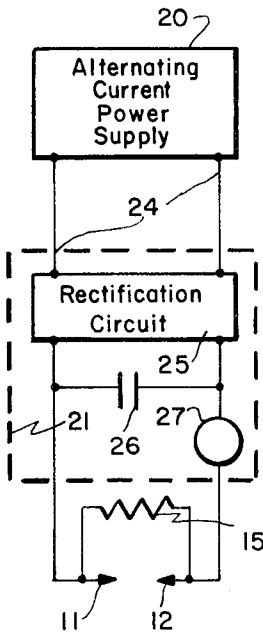
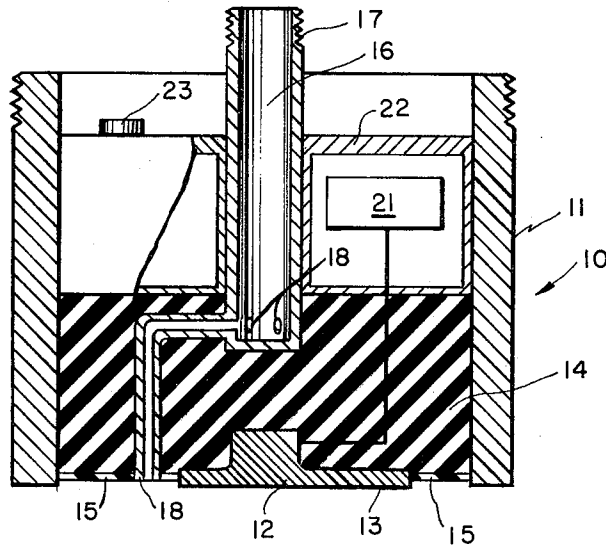


Fig. 3

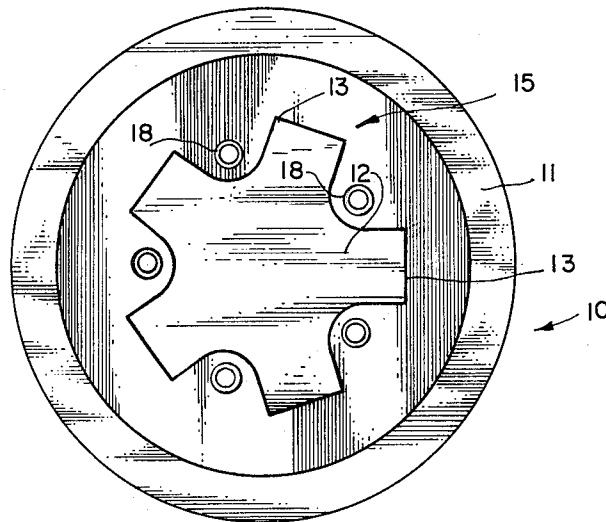


Fig. 2

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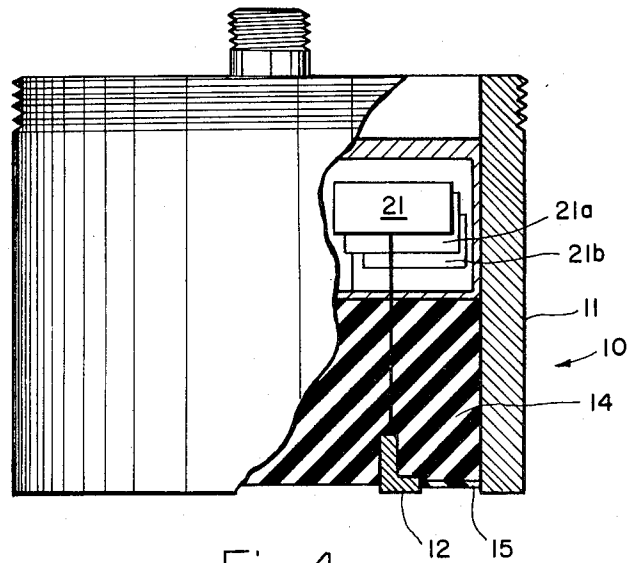


Fig. 4

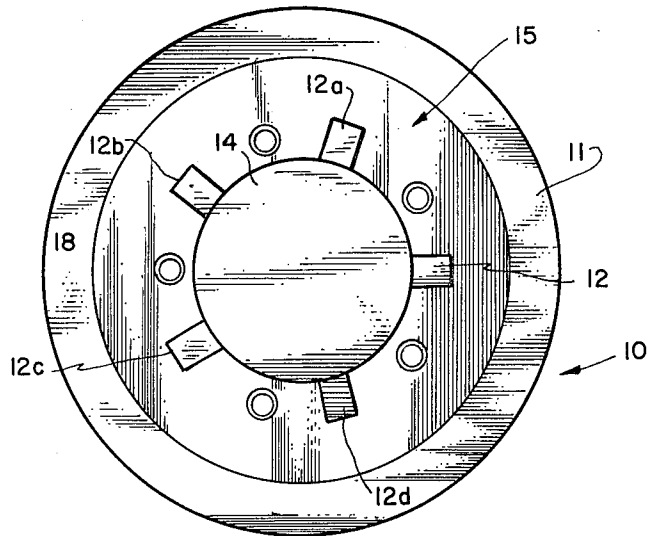


Fig. 5

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LOW VOLTAGE SPARK DRILL

BACKGROUND OF THE INVENTION

The present invention relates generally to drilling equipment and more particularly to spark discharge drills designed to create pressure waves in a drilling fluid which fracture the subterranean structure.

Spark discharge drills and other drill types are generally discussed in the book publication entitled *Novel Drilling Techniques* by William C. Maurer, Pergamon Press, 1968. The present state of spark drill technology is also shown in the U.S. Pat. to Smith, Jr., No. 3,500,942, issued Mar. 17, 1970.

In general, drilling tools excavate rock by one of four basic mechanisms, namely, mechanically induced stresses, fusion and vaporization, and chemical reactions. The spark drill is one of several drills that fall into the class of drills operating to produce mechanically induced stresses. The spark drill requires a working fluid that fills the region between the electrodes and the work surface. Sparks discharged between the electrodes are believed to create pressure waves which impact the work surface thereby transmitting energy into the subterranean structure causing it to fracture.

The fractured structure is then flushed away by a fluid that is generally pumped downward within the drill string to the work region and recirculated to the surface along the exterior of the drill string. In spark drill technology, it is typical to have the flushing fluid serve as the working fluid in which the pressure or shock waves are generated.

Spark drills are particularly advantageous because they efficiently transfer input energy to the subterranean structure. A primary disadvantage of such drills has heretofore been the necessity for high voltages which typically are of a 50 kilovolt magnitude. Voltages of this magnitude are difficult to handle and control in oil exploration fields. Furthermore, excessive losses would be incurred in transmitting such energy levels of direct current from surface equipment to a spark drill which may be several thousand feet beneath the surface.

Spark plug technology includes the use of a semiconductor material between the spark plug electrodes to prevent spark plug fouling and finds particular application in the aircraft fields where reliability is an important factor. A device of this type is shown in the U.S. Patent to Knudson et al., No. 2,963,620, issued Dec. 6, 1959.

Applicant has discovered that the use of a semiconductor shunt path between the electrodes of a spark drill not only permits the generation of a spark, but provides certain nonfouling characteristic when operated in a liquid and further enables the operation of the spark drill at much lower voltage levels, namely in the order of magnitude of 5 kilovolts and lower. This has important implications in the field of subterranean drilling technology. For instance, these voltage levels are presently found in many drilling applications. Also, present technology permits of efficiently transmitting such low voltage alternating current voltage levels to the drill. This being the case, the associated spark initiating circuitry having means for rectification, energy storage, and discharge may be incorporated in the drill portion or another portion of the drill string near the drill. The initial breakdown gap voltages heretofore required to operate a spark drill in fluids would require

such a large capacitor that space limitations would prohibit such circuitry at the drill.

While spark drills are known to provide higher drilling rates than conventional drills, the high voltages required have made them impracticable for competitive use in view of insulation requirements and energy leakage. The higher drilling rates associated with the practical implementation of the spark drill as disclosed herein provides exceptional economic advantages, for example, high drilling rates cut rental time which may range from one to thirty thousand dollars per day.

It is accordingly an object of the present invention to provide a spark drill for subterranean drilling which is not subject to the foregoing problems and shortcomings of the prior art.

Another object of the present invention is to provide a spark drill which requires relatively low voltages for operation.

Still another object of the present invention is to provide a spark drill assembly which includes spark initiating circuitry.

SUMMARY OF THE INVENTION

The present invention contemplates a spark drill for subterranean drilling which comprises at least a pair of electrodes between which is provided a shunt path composed of semiconductor material. The drill further includes means for conducting a drilling fluid into the region between the electrodes and the work surface. While various configurations may be constructed, the basic scheme permits the use of relatively low operating voltages. Furthermore, circuitry may be located in close proximity to the drill for converting low voltage alternating current to a relatively high voltage direct current spark.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a view in elevation and partial cross section of a spark drill in accordance with the principles of the present invention;

FIG. 2 is a plan view of the lower end of the spark drill shown in FIG. 1;

FIG. 3 schematically illustrates a block diagram of an electronic circuit suitable for use as the trigger circuit for the spark drill of FIG. 1; and

FIGS. 4 and 5 are a diagram of an alternative embodiment of the spark drill shown in FIGS. 1 - 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings in which like characters refer to like parts, and in particular to FIGS. 1 and 2, there is shown a spark drill 10 particularly suitable for attachment to the lower end of a drill string as used in oil exploration. The spark drill 10 includes a cylindrically shaped housing 11 which serves as one of at least 2 electrodes. The housing or electrode 11 is threaded at its upper end for threaded engagement with the lower end of the drill string.

The spark drill further includes a second or central electrode 12 which is characterized by a plurality of radially extending legs 13. The outer and central electrodes are insulated one from another by a dielectric 14, except for the lower portions thereof. The radially

directed paths from the central electrode 12 to the outer electrode 11 is characterized by a layer of semiconductor material 15. It may be noted that applicant prefers to have the semiconductor layer recessed slightly from the lower surfaces of the electrodes. Each of the radially extending legs 13 taken in combination with the outer electrode 11 provides a spark gap. In operation, there is a random pattern of sparks occurring between the electrodes.

The spark drill further includes a drilling fluid supply tube 16 also having mating threads 17 for engagement with a supply line originating at the earth's surface. The fluid supply tube 16 terminates in a plurality of drilling fluid distribution tubes 18.

In operation, the spark drill is introduced into the earth and a viscous drilling fluid, sometimes called mud, is pumped downward through the supply tube 16 and distribution tubes 18 to fill the region between the subterranean structure and the electrodes. The fluid is allowed to flow upward along the exterior of the spark drill and drill string carrying with it broken particles of the subterranean structure. It is then common practice to collect the drilling fluid and recycle it.

In spark drills heretofore known, a sufficient voltage is applied between the electrodes to cause a discharge to occur between the electrodes. This discharge, when created at a high repetition rate, is believed to form shock waves that travel to and impact upon the subterranean structure immediately below the drill. Drills of this type have been experimentally shown to have superior drilling rate capabilities. However, such drills generally require high voltages, in the order of 50 kilovolts, to initiate the discharge. Voltages available in oil field applications generally do not exceed 10 kilovolts.

In the present invention, the semiconductor layer 15 provides a shunt path between the electrodes 11, 12. With such a shunt path, applied voltages of less than 10 kilovolts are required to create an electrical discharge. It is believed that a sufficient current flow is established through the shunt path to ionize molecules on the semiconductor surface. When that occurs, a very low resistance electrical path is provided and a spark will be discharged. The invention disclosed herein makes it practicable to use spark discharge devices in subterranean drilling applications.

It is believed that a drill constructed in accordance with these principles will function at voltages of 1 to 3 kilovolts which is within voltage range of conventional oil field submersible pumps and electric drills, and is compatible with conventional electrical cables and other readily available equipment.

In those applications in which direct current electrical power must be transmitted down a very long drill string, the associated large capacitance of the electrical cable may decrease the spark discharge rate. The operation of the spark drill may be enhanced by transmission of alternating current down the drill string and locating circuit means for initiating the spark discharge in the spark drill assembly or as a subassembly which forms a part of the drill string and drill combination.

Shown in FIG. 3 is a suitable circuit for this purpose. The energy, E in joules, released during a spark discharge is $E = \frac{1}{2} C V^2$ where C is capacitance in microfarads and V is the charging potential in kilovolts.

Experimental work reports show that energy from 45 to 375 joules is required for rock penetration. Thus, a 3 kilovolt power supply to a 100 microfarad capacitor would provide sufficient energy.

To this end, FIG. 3 shows an alternating current (a.c.) power supply 20, located at the well surface, coupled to a direct current power supply 21 which is coupled to the electrodes 11, 12 and the shunt path 15. The direct current power supply 21 is further represented by block 21 in FIG. 1 and constitutes a rectifying circuit and a trigger circuit to initiate the spark. FIG. 1 further shows a cylindrical container 22 for housing the electrical circuitry and an electrical connector 23 is provided as an attach point for an electrical power cable from the alternating current power supply 20.

Turning again to FIG. 3, the 3 kilovolt a.c. power supply 20 is coupled to the trigger circuitry 21 by power cable 24. The trigger circuitry comprises a rectifying circuit 25, a capacitor 26 and a trigger means 27 which may simply be a spark gap having a known breakdown voltage or a solid state control device, either of which may be selected to provide a known rate of energy pulses to be impressed upon the electrodes 11, 12.

As an alternative embodiment, the spark drill of FIGS. 1 and 2 is shown in FIGS. 3 and 4 with a plurality of first or center electrodes and a like plurality of direct current power supplies (not all shown). As shown in FIG. 4, the direct current power supply 21 is coupled to a center electrode 12 which is spaced from an outer electrode 11 having a semiconductor layer 15 therebetween. Other direct current power supplies 21a, 21b are provided to supply current pulses to other electrodes 12a - 12d shown in FIG. 5. As FIG. 5 indicates, the multiple center electrodes may be spaced around the lower surface of the spark drill. The semiconductor material layer 15 must extend from each of the multiple electrodes 12, 12a - 12d, to the outer electrode 11. The semiconductor material need not cover the central area intermediate the center electrodes and as shown, the insulating dielectric 14 is exposed. Each direct current power supply may be coupled to two or more center electrodes or may be provided in a one to one relationship.

WHAT IS CLAIMED IS:

1. A subterranean spark drill comprising:
 - a. a first electrode;
 - b. a second electrode;
 - c. a layer of semiconductor material disposed between said electrodes and providing an electrical shunt path therebetween; and
 - d. at least one fluid passageway having a port proximate said electrodes and arranged such that a drilling fluid may be distributed into the region between said electrodes and the subterranean structure whereby energy from a spark discharge between said electrodes will be transmitted through the fluid to the subterranean structure.
2. The spark drill of claim 1 wherein said first electrode substantially surrounds said second electrode.
3. The spark drill of claim 1 wherein said second electrode includes a plurality of radially outwardly extending legs, each said leg being spaced from said first electrode and each in combination with said first electrode providing a spark gap.

4. The spark drill of claim 1 wherein said first electrode is substantially cylindrically shaped and has an outer diameter approximately the same, but less than the diameter of the hole to be drilled and said cylindrical electrode is sufficiently long to include a housing 5 for associated hardware.

5. The spark drill of claim 1 further comprising a direct current electrical power supply coupled to said electrodes.

6. The spark drill of claim 5 wherein said power 10 supply does not exceed an output of 10 kilovolts.

7. The spark drill of claim 1 further comprising circuit means having the output coupled to said electrodes for impressing a direct current voltage pulse therebetween and for applying the voltage across the shunt path provided by said layer of semiconductor material, said circuit means further having an input which may be coupled to an electrical power source.

8. The spark drill of claim 7 wherein said circuit means comprises:

- a. a capacitor in parallel with said electrodes; and
- b. spark initiating means coupled in series between said capacitor and said electrodes for initiating said impressing of a voltage pulse on said electrodes.

9. The spark drill of claim 7 wherein said power supply has an output of less than 5 kilovolts, and wherein said capacitor is selected to provide discharge energy in the range of 45 - 400 joules.

10. A subterranean spark drill comprising:

- a. a first electrode;
- b. a plurality of second electrodes;
- c. a layer of semiconductor material disposed between each said plurality of second electrodes and said first electrode providing shunt paths 35 therebetween; and
- d. at least one fluid passageway having a port prox-

mate said electrodes and arranged such that a drilling fluid may be distributed into the region between said electrodes and the subterranean structure whereby energy from a spark discharge between said electrodes will be transmitted through the fluid to the subterranean structure.

11. The spark drill of claim 10 further comprising:

- a. a rectifying circuit having an input that may be coupled to an alternating current source; and
- b. a trigger circuit having its input coupled to the output of said rectifying circuit and its output coupled to said plurality of second electrodes for impressing a voltage pulse thereupon.

12. The spark drill of claim 11 wherein trigger circuit comprises:

- a. a capacitor in parallel with said electrodes; and
- b. spark initiating means coupled in series between said capacitor and said electrodes for initiating and impressing said voltage pulse.

13. The spark drill of claim 10 including:

- a. a like plurality of rectifying circuits each having an input which may be coupled to an alternating current source; and
- b. a like plurality of trigger circuits each having an input coupled to the output of one of said like plurality of rectifying circuits, and each having an output coupled to one of said plurality of second electrodes and said first electrode.

14. The spark drill of claim 13 wherein said like plurality of trigger circuits each comprises:

- a. a capacitor in parallel with one of said plurality of electrodes; and
- b. spark initiating means coupled in series between said capacitor and said one of said plurality of electrodes for impressing a voltage pulse thereupon.

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