

Sept. 6, 1960

F. G. BOUCHER
GAS DRILLING APPARATUS

2,951,682

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2 Sheets-Sheet 1

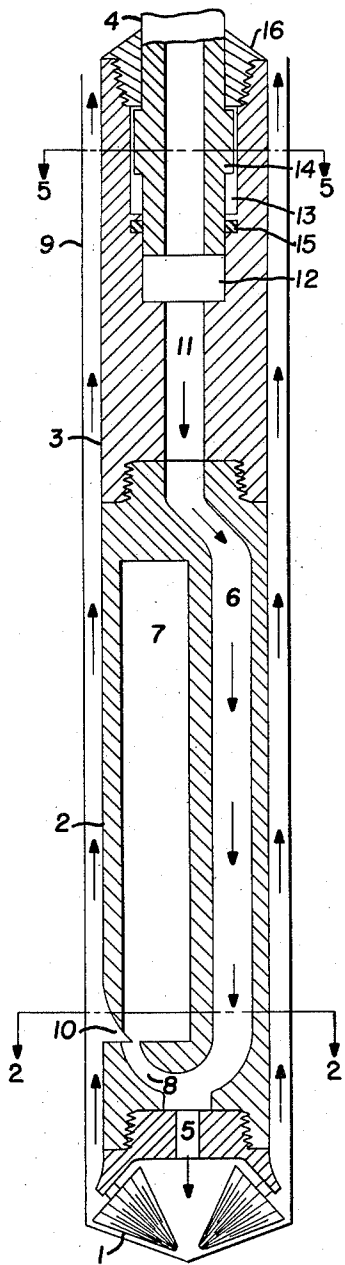


FIG.-1

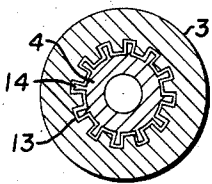


FIG.-5

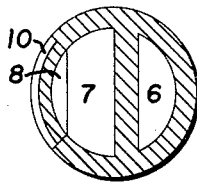


FIG.-2

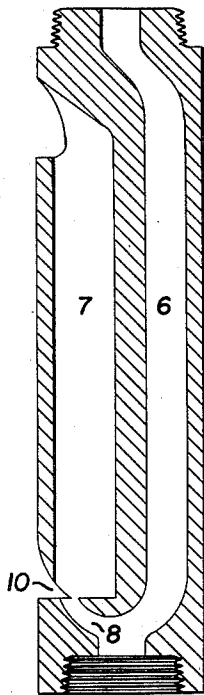


FIG.-3

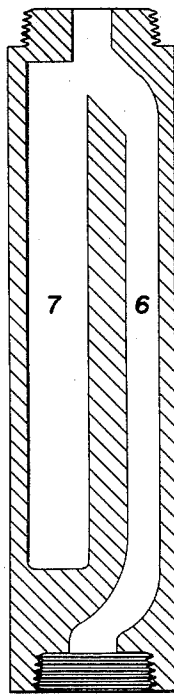


FIG.-4

Frank G. Boucher

Inventor

By *W. D. T. Heilman*

Attorney

Sept. 6, 1960

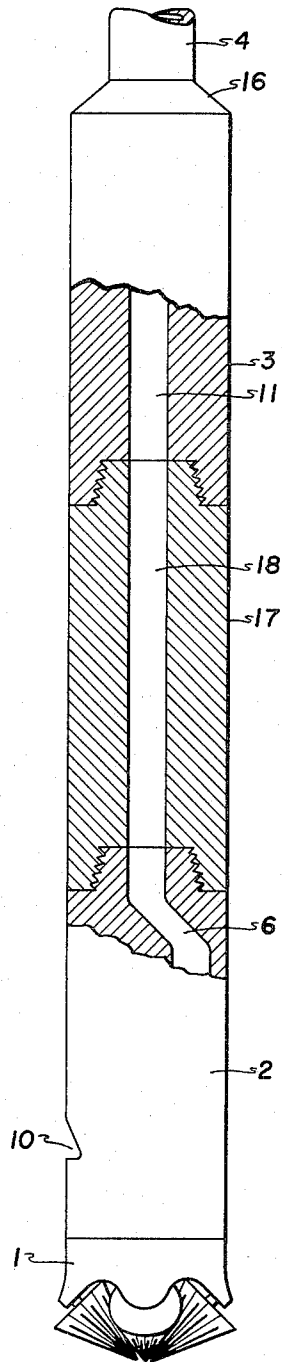
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2 Sheets-Sheet 2

FIG.-6



Frank G. Boucher, Inventor
By *W.O. Heilman* Attorney

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GAS DRILLING APPARATUS

Frank G. Boucher, Catoosa, Okla., assignor, by mesne assignments, to Jersey Production Research Company

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5 Claims. (Cl. 255—4.4)

The present invention is concerned with an improved apparatus for the drilling of bore holes in the earth and is more particularly concerned with an improved drilling apparatus for use in air or gas drilling by which both a rotary drilling action and a longitudinal vibratory drilling action are provided. The invention is of particular application in the exploration for and production of petroleum. In accordance with the invention, the drilling apparatus contains a resonance chamber by means of which the drill bit is set into vibratory motion as air or a gaseous drilling fluid is passed at high velocity through the apparatus.

Rotary drilling using air or gas as a drilling fluid in place of the traditional heavy drilling mud is known in the art and has been found to permit high drilling rates because of the decreased hydrostatic head at the bottom of the bore hole. Gases suitable for use as a drilling fluid include, in addition to air, natural gas, methane, nitrogen and various inert gases. In this method of drilling high velocity air or gas is supplied to a rotary bit at the bottom of a bore hole and cuttings from the bit are entrained and carried by the air or gas stream out of the hole through the annular space between the drill string and the bore hole wall. Vibratory drilling has also been found to permit high drilling rates. Various mechanical devices have been utilized to create vibratory motion of the drill bit. It has been suggested that vibratory motion be generated by a magnetostriction motor positioned on the drill string or by a hydraulic device located on the earth's surface and operating on the "water hammer" principle.

The present invention provides an improved method for generating vibratory motion in a drill bit and combines vibratory motion and rotary motion in order to achieve increased drilling rates. A portion of the energy of the high velocity air or gas stream circulated through the bore hole in rotary drilling using air or gas as a drilling fluid is utilized to create vibrations in a column of air or gas contained in a resonance chamber located in one section of the drill collar. These vibrations are of a frequency substantially in resonance with the natural frequency of the drilling apparatus and result in vibratory motion of the drilling tool. This motion enhances the cutting action of the rotary bit and leads to improved drilling rates.

The exact nature of the invention can perhaps be best understood by referring to the accompanying drawings, in which:

Figure 1 represents a drilling apparatus embodying the invention;

Figure 2 is a cross-sectional view of the drilling apparatus taken along the line 2—2;

Figure 3 depicts a drill collar having an open pipe resonance chamber;

Figure 4 represents a drill collar having a closed pipe resonance chamber;

Figure 5 represents a cross-sectional view of the drilling apparatus taken along the line 5—5; and

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Figure 6 represents a drilling apparatus employing additional drill collars in order to achieve substantial resonance.

The general drilling apparatus illustrated in Figure 1 comprises a rotary drill bit 1 attached to a vibratory drill collar 2 which is connected by means of a connecting drill collar 3 to drill pipe 4. Drill pipe 4 extends vertically to the surface of the earth, where it is supported by a rotary drilling rig, which is not shown. Drill bit 1 has cutters of the conventional rotary type and may be a fishtail, disc, cone or roller bit. Figure 1 shows a cone type bit. The stem of the bit is externally threaded and contains an axial passage 5 through which air may be admitted to the area beneath the cutters.

Vibratory drill collar 2 contains an internal conduit 6 through which drilling fluid may be passed and a resonance chamber 7. These are shown in cross-section about the line 2—2 in Figure 2. Chamber 7 has a configuration similar to that of an organ pipe and may be of the closed pipe type, as shown in Figure 1, or may be of the open pipe type, as shown in Figure 3. The mouth of the resonance chamber may be near the lower end of the resonator section of the drill collar, as indicated in Figures 1 and 3, or near the upper end as in Figure 4. Other possible arrangements of the resonance chamber will be apparent to those skilled in the art. Resonance chamber 7 is fluidly connected to conduit 6 by passage 8 and to the annular space between the outer surface of resonator section 2 and bore wall 9 through opening 10. The upper end of the vibratory drill collar 2 has a decreased outer diameter and is threaded externally to permit its connection to another drill collar. The lower end of the vibratory drill collar contains an internally threaded recess to permit its connection to either another drill collar or to rotary bit 1. The vibratory drill collar may thus be connected between other drill collars or between another drill collar and the rotary bit, as shown in Figure 1.

Connecting drill collar 3 is shown in Figure 1 connected between vibratory drill collar 2 and drill pipe 4. Connecting collar 3 contains a central conduit 11 through which drilling fluid may be passed. The upper end of connecting collar 3 contains a central chamber 12 adapted to receive the lower end of drill pipe 4. Grooves 13 in the upper part of the chamber and matching splines 14 on the outer surface of the pipe cause the collar to rotate as the pipe is rotated and yet permit vertical movement of the collar relative to the pipe. Figure 5, taken about the line 5—5, shows the splines of pipe 4 and the grooves of collar 3, in cross-section. The lower end of pipe 4 below splines 14 extends downward in chamber 12 below grooves 13. The inner wall of the chamber below the grooves contains an annular recess fitted with a seal ring 15 designed to prevent escape of the drilling fluid. Ring 15 may be of rubber, lead, hemp, plastic or similar material. The upper end of chamber 12 above grooves 13 is threaded to receive retainer ring 16, which fits closely about pipe 4 above splines 14 and retains the lower end of the pipe within the collar. The lower end of collar 3 is threaded internally to permit its connection to vibratory collar 2 or to another drill collar.

Auxiliary drill collars, such as collar 17 in Figure 6, may be used in conjunction with the vibratory and connecting collars shown in Figure 1 in order to increase the weight and length of the drill string. The auxiliary collars contain a central conduit 18 for the passage of drilling fluid and the upper and lower ends of the collar match those of the vibratory collar, permitting auxiliary collars to be connected between the bit and vibratory collar, between the vibratory collar and connecting collar, and to each other. The number of auxiliary collars used in the collar and bit assembly will depend in part upon the

weight which must be exerted upon the bit in order to secure efficient rotary drilling action and in part upon the vibratory characteristics of the resonance chamber 7 and the bit and collar assembly, as will be explained later. The overall length of the assembly, including auxiliary drill collars, may be as much as 100 feet or more and the combined weight may be several tons. The use of auxiliary collars simplifies handling of the bit and collar assembly as well as facilitating adjustment of the weight and length.

In drilling with the apparatus of the invention, the drill pipe, drill collars and drill bit are rotated in the bore hole from the surface by means of conventional rotary drilling equipment which is well known in the art and need not be described. Only vibratory drill collar 2 and connecting collar 3 will be referred to in describing the drilling operation but it will be understood that one or more auxiliary collars may be used. Air or gas is continuously pumped as a drilling fluid into the bore hole through drill pipe 4, conduit 11 in connecting collar 3, and conduit 6 in vibratory collar 2. A portion of the drilling fluid thus introduced passes from conduit 6 through opening 5 in drill bit 1 to the cutting area beneath the bit. This fluid flows outward and upward around the cutters of the bit, cooling the bit and entraining the cuttings from the formation. The fluid and entrained cuttings then pass upward through the annular space between the drill collar and pipe and the bore hole wall to the earth's surface. The remainder of the fluid conducted into conduit 6 in vibratory collar 2 enters passage 8 and travels across the mouth of resonance chamber 7 through opening 10 to the annular space between collar 2 and bore hole wall 9. This fluid then mixes with the fluid and entrained cuttings ascending from beneath the drill bit 1 and assists in conveying the cuttings to the surface. In order to maintain the entrainment of the cuttings and prevent their settling and accumulating in the bore hole, it is essential that the drilling fluid be circulated at a high velocity.

The passage of drilling fluid at high velocity across the mouth of resonance chamber 7 sets up violent vibrations in the air or gas contained in the chamber. These vibrations are transmitted into vibratory collar 2 in the form of pulsating shock waves which travel upward into connecting collar 3 and downward into drill bit 1. The downward moving waves upon reaching the formation at the end of the drill bit are reflected back up the drill collar. Similarly, the upward moving waves upon reaching the top of connecting collar 3 are reflected back downward because of the splined connection between connecting collar 3 and drill pipe 4. This connection permits rotation of the collar and bit assembly by the drill pipe and at the same time effectively isolates the assembly from the drill pipe in so far as longitudinal vibratory motion is concerned. The increased flexibility and decreased cross-sectional area of the drill pipe as compared to the collar and bit assembly also serve to curb any tendency toward vibration of the pipe.

The vibrations in resonance chamber 7 must be substantially in resonance with the natural frequency of the drill collar and bit assembly. The resonance chamber must therefore have a frequency substantially equal to the fundamental or a harmonic frequency of the assembly. The harmonic frequencies are whole multiples of the fundamental frequency. Under resonant conditions the reflected waves at the ends of the collar and bit assembly will be additive at those points and the vibratory motion will be greatly intensified. The motion of the bit thus produced against the formation and the vibratory energy transferred to the rock assist in shattering the formation beneath the bit and results in an accelerated drilling rate.

Substantial resonance is obtained by adjusting the frequency of the drill collar and bit assembly. This frequency is inversely proportional to the length of the collar and bit assembly and therefore may be changed by altering the length. The length of the collar and bit

is extended or shortened by adding or removing auxiliary drill collars such as section 17 in Figure 6 until the optimum drilling rate is obtained. Generally several auxiliary collars are used. The vibratory collar may be placed at any point in the assembly, although it is usually preferred to place it at the bottom just above the drill bit. The vibratory collar may be equipped with a splined connection and used at the top of the assembly, eliminating the connecting collar, if desired.

The number of auxiliary drill collars necessary to obtain substantial resonance will depend in part upon whether the resonance chamber 7 is of the open pipe or the closed pipe type. An open pipe chamber has a fundamental frequency one-half that of a closed pipe chamber of the same length. It may therefore be advantageous to use a vibratory collar having an open pipe resonance chamber when drilling in formations in which a heavy drill string must be used for efficient rotary bit action. Such a heavy drill string would necessitate a long drill collar assembly having a low fundamental frequency. If a relatively high frequency vibratory collar were used, it might be impossible to establish substantial resonance without sacrificing much of the weight required for rotary bit action. Conversely, a vibratory collar having a closed pipe chamber may be preferable where a light drill string is to be used. It should be understood that absolute resonance between the collar and bit assembly and the chamber can seldom be obtained by merely adding or removing drill collar sections but that it is sufficient if there be substantial resonance.

It is within the scope of the present invention to utilize more than one vibratory collar in the collar and bit assembly as well as more than a single auxiliary drill collar. Numerous modifications of the invention will be apparent to those skilled in the art and it is intended that the invention be limited only by the scope of the appended claims.

The nature and objects of the invention having thus been fully described and illustrated, what is claimed is:

1. A drilling apparatus of a character to be suspended at the lower end of a string of drill pipe comprising in combination a rotary drill bit; a drill collar connected to said drill bit having an internal passage therethrough from one end to the other and an internal longitudinal fixed volume resonance chamber responding to a frequency substantially equal to the longitudinal fundamental frequency of the drilling apparatus, said resonance chamber having a mouth in fluid communication with said passage, said mouth being arranged such that when fluid flows through said passage said chamber will vibrate at its fundamental frequency.

2. A drilling apparatus of a character to be suspended at the lower end of a string of drill pipe and being further adapted to be connected at its lower end to a rotary drill bit comprising in combination a drill collar assembly including a plurality of drill collars, at least one of said collars containing a substantially longitudinal passage therethrough and an internal organ pipe type fixed volume longitudinal resonance chamber responding to a frequency substantially equal to the longitudinal fundamental frequency of the drilling apparatus, said chamber having an opening in fluid communication with said passage, said opening being arranged such that when fluid flows through said passage said chamber will vibrate at its fundamental frequency.

3. An apparatus as defined by claim 2 wherein said resonance chamber is of the closed pipe type.

4. An apparatus as defined by claim 2 wherein said resonance chamber has a port spaced from said opening establishing fluid communication between said chamber and the exterior of the drill collar.

5. A drilling apparatus adapted to be connected to the lower end of a drill string which comprises in combination a drill bit having a longitudinal conduit therethrough, a vibratory drill collar of a character to be connected to said drill bit and having an internal pas-

sage therethrough from one end to the other and communicating with the conduit of said bit and a lateral passageway fluidly connecting said passage and the exterior of said collar, said drill collar also having spline means for connecting to the lower end of said drill string, a fixed volume resonance chamber within said drill collar spaced laterally from said passage and having an opening fluidly communicating with said passageway, said opening being of a character such that when fluid flows through said passage said chamber will vibrate at its fundamental frequency, said chamber also

being designed to respond to a frequency substantially equal to the longitudinal fundamental frequency of the drilling apparatus.

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