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[54] CRYOGENIC DRILLING METHOD
11 Claims, 1 Drawing Fig.

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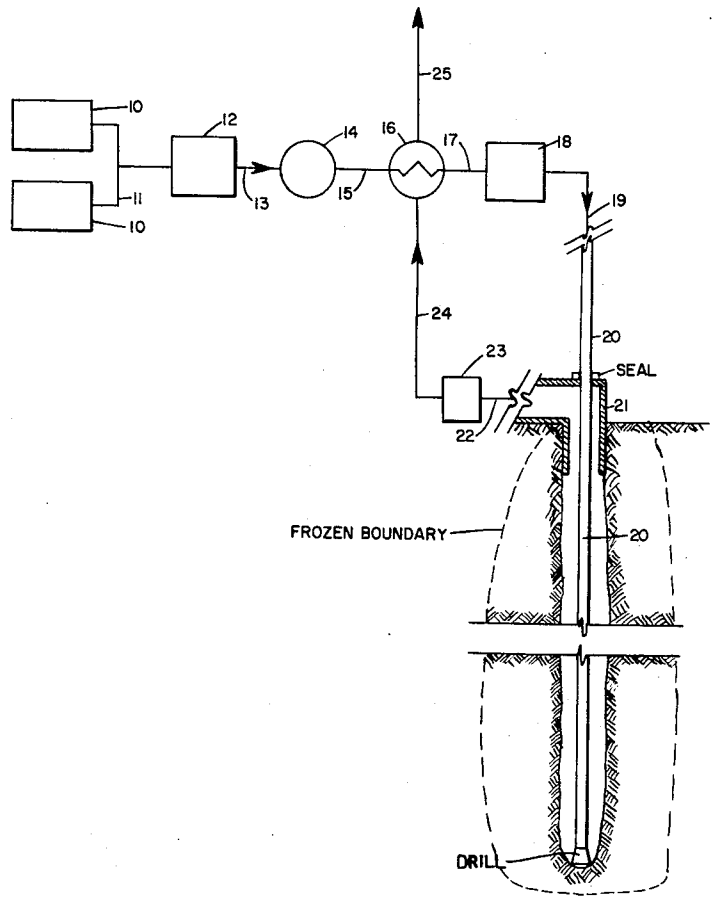
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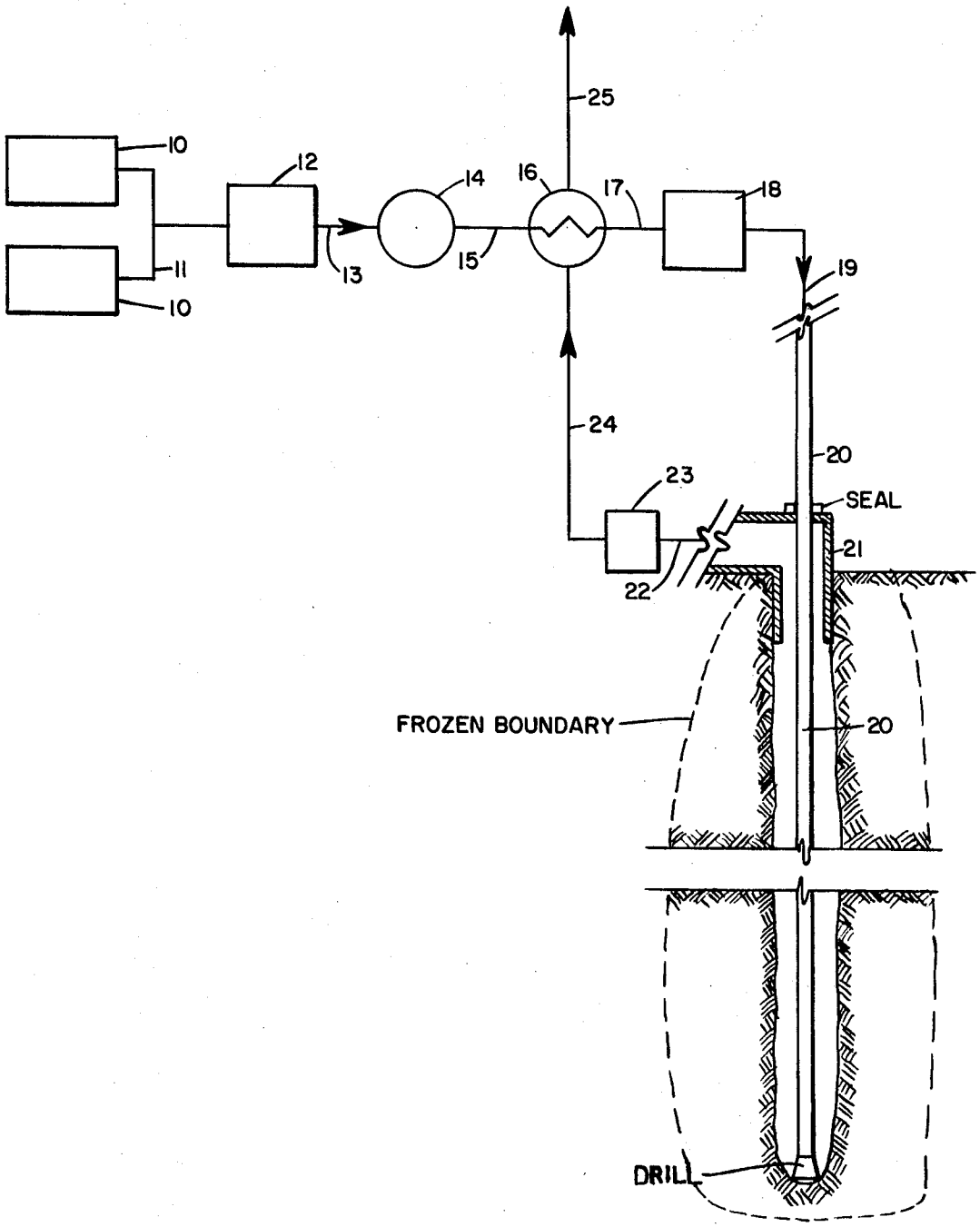
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ABSTRACT: A process for air drilling by cooling the air to cryogenic temperatures, forcing the cooled air down the drill column and up the well bore. The cold air will cause the well bore to freeze eliminating many of the problems in air drilling such as water influx and sloughing of shale. The process will also permit efficient use of the electric drill. The process may also be applied to other gaseous drilling fluids such as, for example, natural gas, nitrogen, propane, neon and the like.



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CRYOGENIC DRILLING METHOD

PRIOR ART

Air or Gas Drilling is a recent technique wherein air or gas is substituted for the drilling muds circulated during the drilling of a well for the purpose of removing chips broken loose by the drill. Air or gas drilling (hereafter referred to as gas) has a significantly greater penetration rate than mud drilling for many well known reasons. Since penetration rate is one of the most significant factors in determining the cost of drilling a well, gas drilling should have become widely used; however, gas drilling has some rather serious drawbacks that have prevented acceptance of the method except where certain strict conditions are met. Where, for example, excessive water influx occurs into the low pressure well bore, large amounts of gas are required to lift the water from the hole. Also where certain shales swell or hydrate in the presence of an influx of water into the well bore, the shale will become loosened and slough into the hole necessitating large quantities of shale and cuttings to be lifted out of the well bore. If enough shale is loosened, the drill pipe may even become stuck.

While a number of techniques have been developed such as setting packers and squeezing cement into water-bearing formations to seal off the water, none of these methods are very successful, and all of them require discontinuing the drilling operation, isolating the water area, then commencing the drilling operation again. Plugging agents can likewise be used; however, none of the above techniques are of any use if the volume of water becomes too large or is being produced from too many individual zones, or if the zone or zones producing the water cannot be located.

SUMMARY OF THIS INVENTION

All of the disadvantages set out above are eliminated and in addition several advantages are realized by utilizing the technique described and claimed herein which consist of cooling the air circulating in the gas drilling method to cryogenic temperatures and dehydrating same prior to injection into the well bore. The cold gas will freeze the water as it is encountered. The water which is present in the pores adjacent to the well bore will become frozen and thus block these pores and prevent subsequent influx of water.

The cold temperature will also permit faster rotation of the drill bit without developing excessive heat and may also permit use of electric drilling techniques since the failure of this method has been primarily due to the excessive drill bit heat.

It is therefore a feature of this method to cool the circulating gas in a gas drilling method to cryogenic temperature.

It is a further feature of this method to prevent excessive water influx into a well bore during the process of gas drilling. It is a still further object of this invention to prevent sloughing of shale into the well bore by eliminating the water absorbed by the shale during the process of drilling.

It is another object of this invention to permit an increase in the rotational speed of a gas drill by cooling the area surrounding the bit to near cryogenic temperatures. It is also an object of this invention to improve the electrical drilling technique by increasing the horsepower through cooling of the armature and surrounding portions of the electrical drill.

It is the main purpose of this invention to make a method of air drilling widely used for many jobs heretofore impossible, principally due to the influx of water into the well bore and the sloughing of shale into the well bore causing sticking of the drill and loss of efficiency to this system due to the vast quantity of shale and water that needed to be lifted from the well bore.

These and other objects of this invention will become apparent when reference is made to the drawing in which a block diagram is shown outlining the methods of this invention.

Referring to the drawing, the adaption of the invention will be described wherein a pair of compressors **10**, which may be of the type that compresses atmospheric air to 600 to 1,500 pounds per square inch, is connected through pipes **11** to a booster **12**. The outlet of booster **12** is connected through a pipe **13** to a dehydrator **14** which removes all of the water from the compressed air stream. The outlet from dehydrator **14** passes through a pipe **15** to a heat exchanger **16** and through a pipe **17** to a turboexpander **18**. Turboexpander **18** expends the compressed air through a polytropic process to an outlet pressure between 50 and 100 pounds per square inch absolute. Since the turboexpander permits work to be done by the expanding air stream, the temperature of the air stream and the outlet end of the turboexpander can be reduced to cryogenic temperatures of approximately minus 200° F. and perhaps lower. The cooled air is then injected through a pipe **19** to a drill pipe **20**; where it is permitted to circulate around the drill bit and up annulus **21** between the walls of the hole and the drill pipe. The cooled air from annulus **21** passes through a pipe **22** to a cutting trap and filter **23**. The outlet of the cutting trap and filter is piped through **24** to heat exchanger **16** and thence to pipe **25** for discharge into the air.

OPERATION

The incoming air is compressed by compressors **10** to a pressure of approximately 300 pounds per square inch and then transferred through pipes **11** to the booster **12** which increases the pressure from 300 p.s.i. to between 600 and 1,500 p.s.i., to dehydrator **14**. The dehydrator removes all of the water from the compressed air stream. The dehydrated air is then passed through heat exchanger **16** to turboexpander **18**. The heat exchanger operation will be explained subsequently in the specification. The turboexpander expands the inlet air pressure using a polytropic process; so that the outlet pressure will be between 50 and 100 pounds per square inch absolute. The turboexpander will cause work to be done by the expanding air stream therefore the temperature of the air stream at the outlet of the turboexpander will be reduced to cryogenic temperature of approximately minus 200° F. The cooled air is then injected down the drill pipe **20** and up the annulus **21**. As the air passes up the annulus **21**, the formation will be cooled since the air stream will be absorbing the heat therein. The cooled air is likewise consolidating any water leaking into the formation by freezing the area. When the cooled air stream reaches the top of the bore hole, it passes through cutting trap and filter **23**, which removes all of the particles cut away by the air drill at the bottom of the hole. Once the cuttings are removed, the cooled air is passed through the heat exchanger **16** and exhausted to the open air. Any remaining cool air, as it passes through the heat exchanger, will draw heat from the air entering the heat exchanger through pipe **15**; thus, the heat exchanger serves to increase the efficiency of the overall system.

It is, of course, obvious that any high-pressure system can be used in place of compressors **10**; for example, high-pressure gas can be used. The majority of the equipment required in this process is similar to that required in any air drilling process. The main differences are the dehydrator to remove the water from the air which, of course, will cause ice to form in the turboexpander; the heat exchanger which improves the efficiency of the overall system; the cutting trap which is used to remove the cuttings prior to the air entering the heat exchange and the turboexpander.

The booster is still required to compress the air or gas to 1,500 pounds per square inch. Its function is changed; however rather than using the booster to compress gas in order to remove water and chips from the hole, the booster is used to achieve a pressure drop across the turboexpander.

The cryogenic temperature used for drilling, however, causes certain differences in construction of some of the apparatus used in this process. For example, the low-carbon steel used in present drill pipe becomes too brittle at cryogenic temperatures; therefore, aluminum drill pipe or steel pipe containing 9 percent or more nickel should be used. Also the conductor pipe, casing head, bits, rotary hose and circulating head rubbers will have to be modified for cryogenic service.

The process described in this specification has the added advantage that as soon as porous formations containing water are penetrated, the water seeping into the well bore will be immediately frozen. Also, all of the previous formations penetrated by the drill pipe will likewise be frozen. Since shales, which heave or slough during drilling operations due to excessive absorption of water, will now be frozen, and the water cannot penetrate the shale, these formations will, of course, be consolidated; therefore, they will no longer become a serious problem in the air drilling operation. Also, shale that tends to be weakened and fall into the well bore because of differential pressure between the well bore and the formation, will be likewise strengthened since the weak shale will be frozen into place by the cryogenic temperatures used during the drilling process.

Since the shale will be consolidated during the drilling process, one of the difficult air drilling problems will likewise be solved, that is the formation of larger holes or voids caused by the sloughing of shale and other consolidated material. These large holes require large volumes of air in order to obtain sufficient velocity for the removal of chips. The invention described in this specification will reduce or eliminate the hole erosion thereby reducing to a large extent the large volume of air required in air drilling.

It is obvious, of course, that the cooler temperatures at the bit will permit higher rotation of the bits since the heat created by the drilling process will be nearly eliminated. It is also possible that the extreme cooling of the bit will permit different steels to be used which will likewise increase the penetration rate of the drill. One advantage of the cryogenic temperature is, as previously mentioned, the cooling that will take place during the use of electrical drills or turbines. The cool air will permit much higher horsepowers to be developed by these drills and much higher rotations per minute can likewise be expected, particularly since the heat generated will be removed by the cryogenic temperatures. Example; if the well depth is 5,000 feet and the hole size is 7 inches and the bottom hole temperature 1 10° F. and the surface ground temperature approximately 60° F., the temperature of the injected air is calculated as follows:

$$\frac{T_2}{T_1}=\frac{(P_2)}{P_1}\,\frac{n-1}{n}$$

where:

T_2 = outlet temperature of turboexpander, °R.

T_1 = inlet temperature of turboexpander, °R.

P_2 = outlet pressure of turboexpander, p.s.i.a.

P_1 = inlet pressure of turboexpander, p.s.i.a.

n = exponent for polytropic process

where:

$n = 1.4$ and where the turboexpander has an efficiency factor of 89 percent, the following pressures and temperatures can be expected:

Turboexpander inlet temperature 20° F.

Turboexpander inlet pressure 1,500 p.s.i.a.

Turboexpander outlet pressure 75 p.s.i.a. Substituting this in the above equation, T_2 becomes 270° R. or a minus 225° F.

In view of the foregoing it is also obvious to use other refrigerated gasses such as liquefied nitrogen which would vaporize after leaving a cryogenic pump while entering the well bore. Other liquid gasses can also be used.

The extremely cold temperature of the gas striking the bottom of the well will also cause thermoshock to the rock since the temperature will be changed by as much as 300 to 500° in an extremely short period of time. The combination of thermostresses superimposed on the mechanical stresses created by the drill on the formation should significantly increase the penetration rate of the drill.

Other modifications and changes obvious to those skilled in the art can be made and still be within the spirit and scope of this invention as described in this specification and claimed. Other gases may be used instead of air, for example: natural gas, methane, propane, neon, and the like. Also liquids such as liquefied propane, methane, natural gas, and the like.

What I claim is:

1. A method of gas drilling wherein gas is compressed and passed down a drill string in a well bore for lifting chips out of said well bore, an improvement comprising

a. dehydrating said compressed gas,

b. cooling said dehydrated gas to at least minus 175° F. whereby said cooled gas when lifting chips out of said borehole will cool the walls of said borehole thereby freezing the water therein and preventing sloughing a shale of infiltration of water into said borehole.

2. A method as described in claim 1 further characterized by precooling said compressed gas by the exhausted gas from said borehole.

3. A method, as described in claim 2 wherein said exhausted gas is filtered prior to cooling said compressed gas.

4. A method as described in claim 1 wherein said gas is cooled to at least minus 200° F.

5. A method as described in claim 1 wherein said gas is air.

6. A method as described in claim 1 wherein said gas is natural gas.

7. A method as described in claim 1 wherein said gas is inert gas of the class consisting of nitrogen, neon and the like.

8. A method as described in claim 1 wherein said gas is compressed to approximately 600 to 1,500 p.s.i. and said compressed gas is cooled by turboexpander polytropically to between 50 to 100 p.s.i.a.

9. In a method for gas drilling a well utilizing an electric drill motor connected to a drill string on the down hole end; an improvement comprising

a. injecting a gas having a temperature of at least minus 175° F. at the up hole end of said drill string whereby said cryogenic gas will cool said drill, cool said well bore, freezing said water in said well bore wall and lift the chips fractured by said drill out of said well bore.

10. A method as described in claim 9 wherein said cooled gas is made by

a. compressing a gas

b. dehydrating said compressed gas

c. expanding said gas to a pressure wherein the temperature of said gas is at least minus 175° F. or colder.

11. A method as described in claim 9 wherein said gas is from a class consisting of nitrogen, propane or natural gas.