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Weaver

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[54] **METHOD AND APPARATUS FOR DRILLING**

[76] Inventor: **Carnes W. Weaver,** 5426 Tupper Ln., Houston, Tex. 77027

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[56] **References Cited**

UNITED STATES PATENTS

3,612,192	10/1971	Maguire	175/17
2,861,780	11/1958	Butler	175/17
2,915,285	12/1959	Deily	175/17
3,424,254	1/1969	Huff	175/17
3,618,681	11/1971	Bartlett	175/72 X

FOREIGN PATENTS OR APPLICATIONS

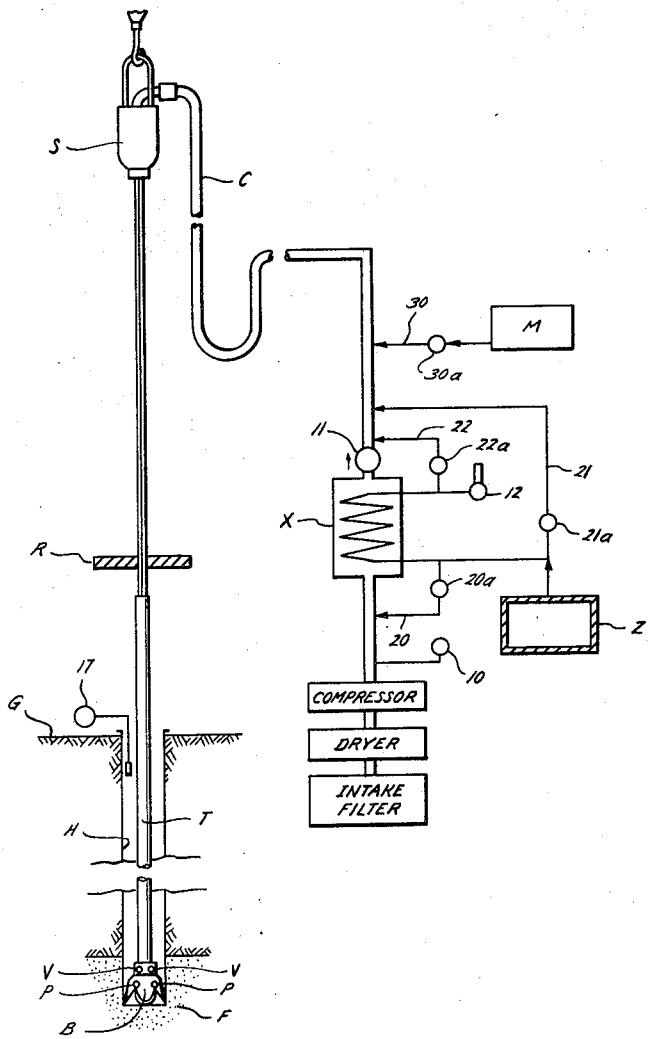
855,408	11/1960	Great Britain	175/17

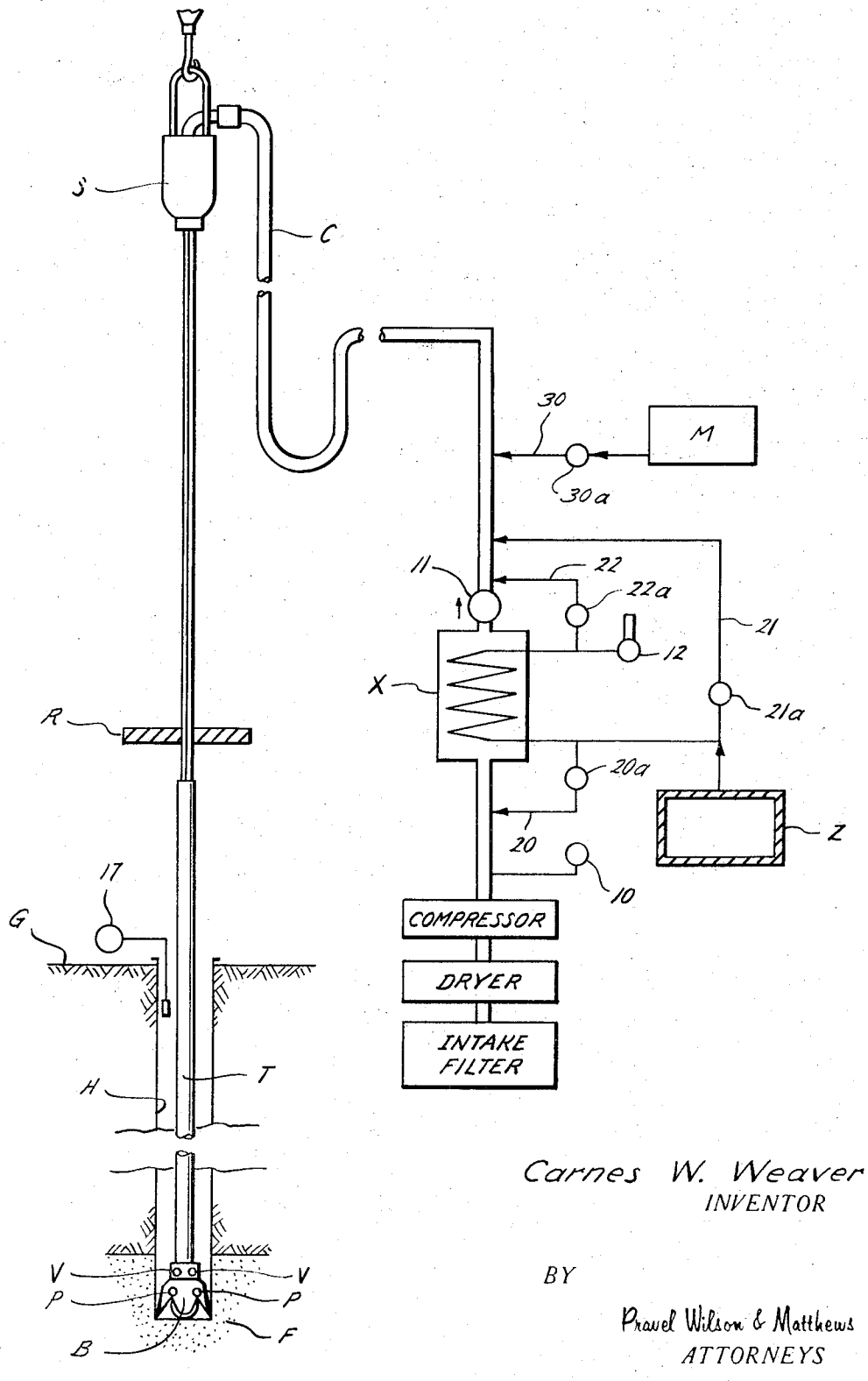
Primary Examiner—Marvin A. Champion
Assistant Examiner—Richard E. Favreau
Attorney—Pravel, Wilson & Matthews

[57] **ABSTRACT**

A method and apparatus for rotary drilling an earth formation with a cutting tool using air as a non-polluting circulating drilling fluid including expansion of cooled and compressed air to cool and clean the cutting tool, to remove cuttings from the drill hole and to freeze the moisture in the formation adjacent the drill hole to prevent sloughing of the walls into the drill hole. Side ports on the cutting tool provide additional cooling to the circulating air for cooling the walls of the drill hole. An anti-freeze solution is added to the circulating air to prevent freezing of water in the well hole. The method may also be used in obtaining core samples having the moisture therein frozen.

17 Claims, 1 Drawing Figure





Carnes W. Weaver
INVENTOR

BY

Pravel Wilson & Matthews
ATTORNEYS

METHOD AND APPARATUS FOR DRILLING

BACKGROUND OF THE INVENTION

This invention relates to the field of a method and apparatus drilling operation and for obtaining core samples.

The use of a formation water freezing fluid as a circulating medium in rotary well drilling operations was disclosed in U.S. Pats. Nos. 2,193,219, 2,621,022 and 3,424,254. These fluids polluted the environment when they escaped from the circulating system or they required large quantities of expensive or hard to store fluids. U.S. Pat. No. 2,812,160 discloses an apparatus using special coolants for obtaining frozen core samples.

SUMMARY OF THE INVENTION

This invention relates to a new and improved method and apparatus for drilling.

The method includes compressing, cooling, dehydrating and injecting a supply of air in the bore of a rotary drill string having a ported cutting tool engaging the formation. The air pressure is reduced while passing through ports in the drill bit to expand and cool the air. The expanded or reduced pressure air is directed to clean and cool the cutting tool as well as circulate formation cuttings back to the surface. The flow back to the surface along the outer surface of the drill string cools the walls of the drill hole to freeze the moisture adjacent the drill hole to prevent sloughing of the walls into the drill hole. Vent holes are provided in the drill bit to vent a portion of the air into the circulating flow from the drill bit to further reduce the temperature of the air and formation cuttings flowing from the bit. Frozen core samples may be obtained using the expansion of the air to freeze the moisture in the sample.

The drilling apparatus includes a rotary ported earth formation cutting tool, a supply of compressed air, means for cooling the supply of compressed air and means for communicating the cooled compressed air to the cutting tool. A means for venting a portion of the compressed air to cool the reduced pressure air from the cutting tool ports is also included.

An object of the present invention is to provide a new and improved drilling method.

Another object of the present invention is to provide a new and improved drilling method for use in arctic areas.

Yet another object of the present invention is to provide a new and improved drilling apparatus.

A further object of the present invention is to provide a new and improved drilling apparatus for a pollution free drilling fluid.

BRIEF DESCRIPTION OF THE DRAWINGS

The FIGURE is a schematic view illustrating an arrangement of equipment utilized in the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The drawing illustrates an arrangement of the apparatus employed in the method of the present invention. As will be explained in detail, a portion of the apparatus is located on the earth surface G and a portion is located in a drill hole H for extending the hole H into an earth formation F.

The apparatus employed in the drill hole H includes a drill string T and a formation cutting tool. The tubular drill string T has a bore therein extending the length of the drill string T for communicating with the cutting tool. The rotary cutting tool includes a core sample cutting tool or a drill bit B having a plurality of ports P located on the lower or cutting portion of the drill bit B. A plurality of vent holes V are located on the upper portion of the drill bit B. Flow passages within the drill bit B communicate the bore of the drill string T with the vents V and the ports P.

Located on the surface G is a rotary drilling rig (not shown) for hoisting and rotating the drill string T, as is well known in the art. The rotary table indicated at R provides a means for imparting rotation to the drill string T for rotating the drill bit B. The hook (not numbered) provides a support and a hoist means for the drill string T and the drill bit B. The hook is connected to a swivel S mounted with the drill string T for communicating the drilling fluid into the bore of the rotating drill string T as will be explained. A flexible conduit means C communicates the swivel S and an outlet of a heat exchanger X for enabling vertical movement of the swivel S while maintaining communication therebetween.

The drilling method and apparatus of the present invention utilizes air and mixtures thereof with other gases as a circulating drilling fluid. An intake filter is provided to initially remove solid matter from the circulating air which may damage the equipment or plug the apparatus as will be explained.

After passing through the filter, the air is communicated to a dryer means for removing moisture from the air. Preferably, the dryer is a closed container filled with any number of desiccant-type materials or drying agents. For example, calcium chloride or phosphorus pentoxide may be used. These agents are capable of reducing the water content of contacted air to a low value as is well known in the art.

After removal of moisture in the dryer, the air is communicated to a compressor which provides a supply of compressed air for enabling circulation of the air. Any type of compressor may be used, but a reciprocating-type compressor having a speed control to control the volume of air compressed is preferred. A pressure safety valve, illustrated at 10, preferably of the spring biased type is mounted with the compressor discharge conduit to prevent damage to the equipment from over pressure of the system by the compressor.

Means for cooling the supply of compressed air includes the heat exchanger X which provides cooling to the compressed air prior to flowing into the conduit. The heat exchanger X may be of any type but should have sufficient heat transfer surface area to lower to a predetermined temperature the temperature of the compressed air to enable the temperature of the air flowing from the drill hole H to be maintained below the freezing temperature of water as will be explained. Any type of coolant or cooling medium may be circulated through the heat exchanger X to reduce the the temperature of the air. The preferred embodiment utilizes a liquid cryogenic fluid contained in an insulated tank or reservoir Z as a coolant. The gaseous cryogenic fluid phase evaporating from the liquid phase is communicated through the heat exchanger X for cooling the air before venting to the atmosphere through a valve: illustrated at 12. The back pressure regulator

valve **12** maintains a selected vapor pressure on the cryogenic liquid which establishes the temperature of the cryogenic fluid in the reservoir Z as is well known.

Means to directly inject the gaseous cryogenic fluid into the stream of compressed air to provide additional cooling to the air are included. A conduit **20** having a valve, indicated at **20*a***, therein enables injection of the gaseous cryogenic fluid into the stream of compressed air prior to cooling the air in the heat exchanger X. Also, a conduit **21** having a block valve indicated at **21*a***, therein enables the injection of the gaseous cryogenic fluid into the cooled stream of air flowing from the heat exchanger X, and a conduit **22** having a block valve, indicated at **22*a***, therein enables injection of the gaseous cryogenic fluid utilized to cool the air into the stream of cooled air.

A reservoir M communicating with the conduit C through a conduit **30** having a block valve, indicated at **30*a***, therein serves as a means for adding an anti-freeze material to the stream of compressed air. The reservoir M is filled with a liquid material for lowering or depressing the freezing temperature of water when mixed therewith. For example, calcium chloride may be used as an anti-freeze material.

In the use, operation and method of the present invention the drilling rig is used to support and hoist the drill string T and drill bit B as is well known in the art. The drill string T is rotated by the rotary table R for enabling the drill bit B to move further into the formation F as the well bore is drilled to produce a drill hole H as is well known in the art.

The operation of the compressor creates an inlet suction pressure differential which enables flow of air through the filter and the dryer to the compressor inlet. Flow through the intake filter removes a portion of the solid material from the stream of air which may damage the cylinders of compressor or plug the vents V or the ports P of the drill bit B. The dryer removes moisture from the air to prevent freezing of the moisture when the air is cooled in the heat exchanger X or expanded in the drill hole H as will be explained. The dryer also reduces the quantity of anti-freeze from reservoir M required. The compressor increases the pressure of the air located in a chamber partially defined by the exchanger X, the conduit C, the bore of the drill string T and the passages of the drill bit B. By adjusting the speed of the compressor, the driller controls the volume of air compressed into the fixed volume chamber.

The relationship of pressure, volume and temperature of compressed air are all interrelated and are readily calculated as is well known. By increasing the speed of the compressor an additional quantity or volume of air is compressed to increase the pressure in the chamber. The compressor, while increasing the pressure of the air also increases the temperature of the air as is well known. The relief valve, indicated at **10,** controls or limits the compressor output from overpressuring the system and damaging the heat exchanger X or rupturing the conduit C should the flow of compressed air be blocked for any reason by venting the excess pressure from the chamber. The compressed air is then passed through the heat exchanger X to lower the temperature of the air.

The gaseous phase of the cryogenic fluid is communicated through the tubing of the heat exchanger X as a coolant to reduce the temperature of the compressed air flowing through the heat exchanger X. The gaseous cryogenic fluid is normally vented to atmosphere through the back pressure regulator valve **12.** The back pressure regulator valve **12** maintains a predetermined fixed vapor pressure on the cryogenic fluid in the reservoir Z which establishes the temperature of the cryogenic fluid in the vessel Z and the temperature of the fluid flowing through the tubing of the heat exchanger X. By adjusting the valve **12,** the driller may control the temperature of the coolant and therefore the temperature of the compressed air. The selected vapor pressure depends on the cryogenic fluid employed. Use of a cryogenic liquid as a coolant provides the driller with other advantages. If nitrogen or another inert gas is used as a cryogenic fluid, the discharge through the valve **12** will not pollute the atmosphere. If liquified petroleum gas is used as the cryogenic fluid, the discharge from the back pressure valve **12** may be contained and used as a source of energy for the drilling operation.

In normal operation, the heat transfer in the exchanger X is sufficient to cool the air flowing through the exchanger. Should abnormal drilling conditions occur, means are included for injecting nitrogen or other inert gaseous cryogenic fluids directly into the stream of compressed air for additional cooling. The valve **20a** may be opened and the cryogenic fluid injected through the conduit **20** into the stream of compressed air prior to passing through the heat exchanger X for additional cooling. The valve **21a** may be opened to enable the cryogenic gas to mix directly with the compressed air down stream of the heat exchanger X for maximum cooling. The gaseous cryogenic fluid may also be mixed with the compressed air down stream of the heat exchanger X through conduit **22** by operation of the valve **22a** to provide maximum use of the cryogenic fluid. The various arrangements of injecting the gaseous cryogenic fluid with the compressed air provides the driller with a maximum flexibility for cooling the compressed air.

The cold compressed air flows from the exchanger X through the check valve **11** into the conduit C and on into the swivel S. Flow is then communicated down the bore of the drill string T to the drill bit B. The compressed air then flows through the ports P and the vents V of the drill bit B into the drill hole H and upwardly to the surface S in the annulus between the outer surface of the drill string T and the walls of the drill hole H.

In flowing through the ports P and the vents V, the drilling fluid flows from a fixed volume area of higher pressure to an area of reduced pressure resulting in expansion of the drilling fluid. Because of the relationship between pressure, volume and temperature, this expansion further cools the compressed air drilling fluid. The size of the openings of the ports P and the vents V may be calculated to produce a desired pressure differential.

The compressed air flowing through the ports P is directed about the drill bit B for cleaning and cooling the drill bit B. This flow cools the cutting edges of the drill bit engaging the formation for removing the friction generated heat from the cutting edges to lengthen drill bit life. The cooled and expanded air flow also cools the formation adjacent the drill bit to freeze the moisture within the formation to produce an in gage drill hole H. The formation cuttings produced by the drill bit B moving into the formation F are removed from the bit B and the drill hole H with the flowing air circulating from the

ports P through an annular opening formed by the walls of the drill hole H and the outer surface of the drill string T to the surface G. The viscosity of air used as a circulating fluid also enables faster penetration of the drill bit into the formation F.

The compressed air flowing through the vents V is expanded to further cool the upwardly flowing stream of air and formation cuttings prior to flowing back to the surface. By maintaining the temperature of the air flowing upwardly through the annulus below the freezing point of water, the moisture adjacent the drill hole H is frozen and the walls are prevented from sloughing off and falling into the drill hole H. This feature will be greatly appreciated in drilling through the permafrost of arctic areas. The driller need only monitor the outlet temperature of the drilling fluid from the drill hole H with a temperature indicator **17** to determine that the walls of the drill hole H will remain frozen and in gage. Should the drilling fluid exit temperature exceed the freezing temperature of water, the driller may adjust the speed of the compressor or the valve **12** to reduce the drill hole exit temperature of the air. Various automatic control systems regulating the temperature, volume and pressure of the compressed air may be employed in the use of the present invention.

Anti-freeze injected into the conduit C from reservoir M through the conduit **30,** which may be by capillary action, is used to enable any moisture within the formation F to be removed from the drill hole H. Friction generated by the drill bit B boring through the formation F will melt some moisture in the formation F frozen by the drilling fluid from the ports P. This moisture will refreeze in the drill hole H interfering with the circulation of the drilling fluid unless the anti-freeze is added to enable the moisture to circulate out of the drill hole H with the reduced pressure air before refreezing.

The method may also be employed in obtaining formation core samples by circulating the air through properly sized ports in core sample cutting tools. The moisture in the core will be frozen in place as the core is cut by the isothermal expansion of the air providing an uncontaminated core sample. Cores of arctic permafrost may therefore be obtained without physical deterioration from melting or contaminaton of the sample.

The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape and materials as well as in the details of the illustrated construction may be made without departing from the spirit of the invention.

What is claimed is:

1. A method of drilling through an earth formation with a drill string having a bore communicating with a ported cutting tool at the formation engaging end including:

a. lowering the temperature of a supply of air;
b. communicating the air into the bore of the drill string;
c. reducing the pressure of the air adjacent the ports of the cutting tool to cool the cutting tool;
d. directing the air about the cutting tool;
e. flowing the reduced pressure air upwardly along the outer surface of the drill string away from the cutting tool; and
f. venting a portion of the air in the bore of the drill bit into the flowing reduced pressure air to cool the flow of air circulating from the drill bit.

2. A method of drilling through an earth formation with a drill string having a bore communicating with a ported cutting tool at the formation engaging end including:

a. lowering the temperature of a supply of air;
b. communicating the air into the bore of the drill string;
c. reducing the pressure of the air adjacent the ports of the cutting tool to cool the cutting tool;
d. directing the air about the cutting tool;
e. flowing the reduced pressure air upwardly along the outer surface of the drill string away from the cutting tools; and
f. venting a portion of the air in the bore of the drill bit into the flowing reduced pressure air to cool the flow of air circulating from the drill bit; and
g. adding a water freezing temperature depressant to the air injected in the bore of the drill string to enable removal of the water in the drill hole.

3. The method as set forth in claim **2,** including:

a. rotating a drill bit cutting tool while moving the bit into the formation to produce a drill hole;
b. cooling the cutting edges of the drill bit and the formation adjacent the bit with the reduced pressure air; and
c. removing the formation cuttings from the drill hole with the flowing reduced pressure air circulating from the drill bit.

4. The method as set forth in claim **2,** wherein the flowing reduced pressure air cools the walls of the drill hole to freeze the moisture adjacent the drill hole to prevent sloughing of the drill hole walls into the drill hole.

5. The method as set forth in claim **2** including:

a. rotating the cutting tool while moving the cutting tool into the formation to produce a core sample; and
b. cooling the core sample in place to freeze the moisture within the sample.

6. Apparatus for circulating a drilling fluid in an earth formation boring operation including:

a. a rotary ported cutting tool for moving into the formation;
b. a supply of compressed air;
c. means for cooling the supply of compressed air;
d. means for communicating the supply of cooled compressed air to the ports of the cutting tool wherein the cooled compressed air flows through the ports in the cutting tool to expand to a lower pressure for lowering the temperature of the air to clean and cool the cutting tool; and
e. means for venting a portion of the supply of compressed air into the lower pressure air enabling the vented portion to expand to a lower pressure for cooling the lower pressure air and cuttings below the freezing temperature of water.

7. The structure as set forth in claim **6** wherein the lower pressure air cools and circulates formation cuttings from the cutting tool.

8. The structure as set forth in claim **6** wherein a core sample cut by said cutting tool is cooled in place by the lower pressure air below the freezing temperature of water wherein the moisture in the core is frozen.

9. A method of drilling through an earth formation with a drill string having a bore communicating with a ported cutting tool at the formation engaging end, including:

a. compressing a supply of air;

b. cooling the supply of compressed air;

c. communicating the supply of air into the bore of the drill string;

d. cooling the cutting tool by expanding the air through the ports of the cutting tool;

e. freezing the moisture in the formation by expanding the air through the ports of the cutting tool to prevent sloughing of the formation into the drill hole;

f. removing formation cuttings produced by the cutting tool with the expanding air; and

g. cooling the expanding air from the cutting tool ports by expanding an additional portion of the compressed air from the bore of the drill string into the expanding air from the cutting tool ports.

10. A method of drilling in arctic regions through an earth formation with a drill string having a bore communicating with a ported cutting tool at the formation engaging and including:

a. lowering the temperature of a supply of air;

b. communicating the air into the bore of the drill string;

c. reducing the pressure of the air adjacent the ports of the cutting tool to cool the cutting tool;

d. directing the air about the cutting tool;

e. flowing the reduced pressure air upwardly along the outer surface of the drill string away from the cutting tool; and

f. venting a portion of the air in the bore of the drill bit into the flowing reduced pressure air to cool the flow of air circulating form the drill bit.

11. The method as set forth in claim 10, including:

a. rotating a drill bit cutting tool while moving the bit into the formation to produce a drill hole;

b. cooling the cutting edges of the drill bit and the formation adjacent the bit with the reduced pressure air; and

c. removing the formation cuttings from the drill hole with the flowing reduced pressure air circulating from the drill bit.

12. The method as set forth in claim 10, wherein the flowing reduced pressure air cools the walls of the drill hole to freeze the moisture adjacent the drill hole to prevent sloughing of the drill hole walls into the drill hole.

13. The method as set forth in claim 10, including:

a. rotating the cutting tool while moving the cutting tool into the formation to produce a core sample; and

b. cooling the core sample in place to freeze the moisture within the sample.

14. The method as set forth in claim 10, wherein the step of lowering the temperature of a supply of air includes:

vaporizing a supply of cryogenic liquid for cooling the supply or air.

15. The method as set forth in claim 14, including the step of:

communicating the vaporized supply of cryogenic fluid into the bore of the drill string.

16. The method as set forth in claim 14, including the step of:

using the vaporized supply of cryogenic fluid as a source of energy for the drilling operation.

17. A method of drilling in arctic regions through an earth formation With a drill string having a bore communicating with a ported cutting tool at the formation engaging end including:

a. lowering the temperature of a supply of air;

b. communicating the air into the bore of the drill string;

c. reducing the pressure of the air adjacent the ports of the cutting tool to cool the cutting tool;

d. directing the air about the cutting tool;

e. flowing the reduced pressure air upwardly along the outer surface of the drill string away from the cutting tool; and

f. venting a portion of the air in the bore of the drill bit into the flowing reduced pressure air to cool the flow of air circulating from the drill bit; and

g. adding a water freezing temperature depressant to the air injected in the bore of the drill string to enable removal of the water in the drill hole.

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