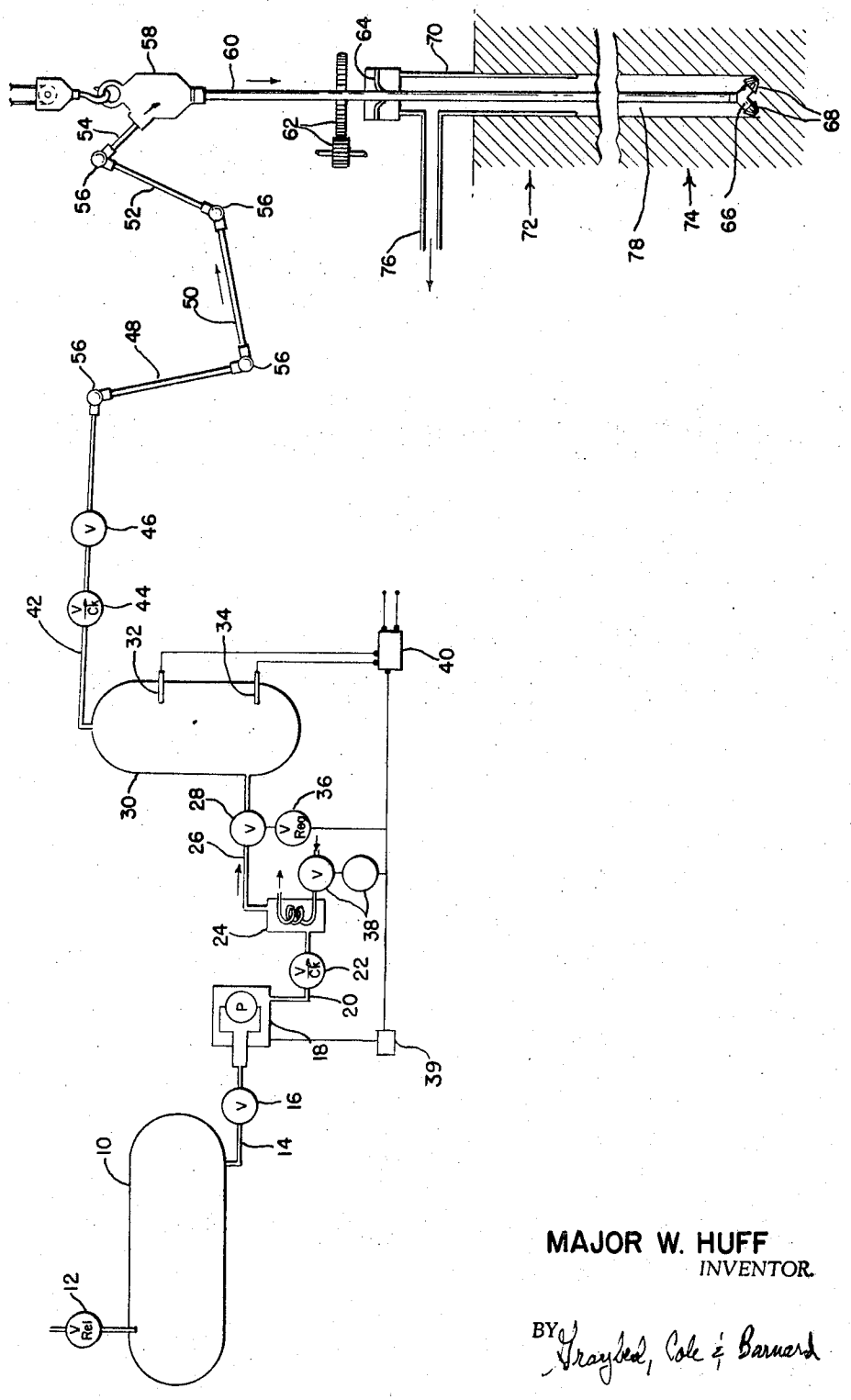
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CRYOGENIC METHOD AND APPARATUS FOR DRILLING HOT GEOTHERMAL ZONES

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CRYOGENIC METHOD AND APPARATUS FOR DRILLING HOT GEOTHERMAL ZONES

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ABSTRACT OF THE DISCLOSURE

Process and apparatus for storing cryogenic fluids in their liquid state, raising the temperature of the cryogenic fluid sufficiently to volatilize it, and then to hold the gaseous cryogen for use in the boring operation. Gaseous cryogen is directed under pressure through the drill stem of the boring apparatus. The inert cryogenic gas issues from the lower end of the drill stem cooling the cutters, providing an inert atmosphere to inhibit oxidation of the drill bits, and at the same time cooling the surrounding rock formations sufficiently so that they remain solid.

This invention relates to a new and novel process for boring holes into hot geothermal zones such as volcanoes and the like. More particularly does this invention relate to a new and novel process by which cold cryogenic fluids are evaporated to provide cooling gases for drill pipe and the cutting edges of boring tools and to remove cuttings from the bottom of the hole and carry them to the earth's surface.

In present day rotary drilling, it is common to circulate water or air through the drill pipe and boring tool as a coolant and to bring the cuttings from the bottom of the hole to the surface after they have been broken up by the boring tool. These known methods are, however, not well suited to drilling materials that are at temperatures above the boiling point of water. They become very inefficient when the temperature of the material being drilled approaches that of molten glass as would be found in volcanoes and other high temperature rock masses. Much thought has been given by science to the tapping of natural high temperature sources for the provision of heat as a basic power source for electricity and other uses. Water based drilling fluids are objectionable at such high temperatures since they turn to steam and pressures become excessive. Other fluids are either too costly or have properties that support combustion with the attendant possibility of fire. Air as a working medium requires compression and cooling before it can be used to cool the drilling tools, and it must be thoroughly dry to eliminate the possibility of steam pockets being formed from entrained water vapor. Moreover, air provides an oxidizing medium that is injurious to the cutting edges of the boring tool bits at elevated temperatures. Efforts have been made to apply refrigeration and drying methods to these drilling fluids and gases, and inert gases have been substituted for air. However, these applications have always been accompanied by the objectionable requirements of compression, cooling and drying equipment which are both cumbersome and costly.

This invention overcomes the disadvantages, difficulties and other impractical considerations inherent in conventional methods and apparatus. Inert cryogens have extremely low temperatures in the liquid state and it is known that these super-cold liquids can be pumped or poured like any other fluid. Furthermore, they can be stored for considerable periods of time in insulated vessels under slight pressure. According to the present invention storage is provided as are means to raise the inert cryogenic fluid to slightly above its critical temperature to

volatilize it to gas. The gas is then directed to a receiver tank where it is metered into the drill hole through the boring tool and over the cutting edges of the bit. In addition to providing cooling in the high temperature earth or rock mass so that a solid hole can be formed the gas provides an inert atmosphere around the cutting edges of the drilling tool bit. It then expands into a zone of lesser pressure outside the drilling stem and is carried back to the surface along with the drilling tool cuttings. This unique method of tapping the hitherto unutilized source of heat that resides in volcanoes and other high temperature earth and rock masses provides a new, novel and operable system for obtaining power from nautral sources.

Accordingly it is a prime feature of this invention to provide cryogenic drilling method and apparatus that will keep the drill pipe and boring tool cool and also maintain the surrounding rock fromations at a low enough temperature to remain in a solid state. Another feature of this invention is to provide cryogenic drilling method and apparatus whereby the drilling tools are kept cool and in which the drilling tool bits are maintained in an inert atmosphere to prevent oxidation of the cutting edges. Still another feature of this invention is to provide cryogenic drilling method and apparatus which is of compact design, efficient, automatic, and which requires no separate auxiliary equipment such as pumps and compressors. Yet another feature of this invention is to provide cryogenic drilling apparatus and method which is economical to in stall and operate and which offers ease of maintenance.

These and other objects, advantages and features will become apparent in the following description of the invention. Reference will be had to the appended drawing which shows schematically the equipment required and the steps involved in the utilization of cryogenic fluid.

Referring now to the drawing it will be seen that an insulated storage tank **10** is provided to receive and store the liquid cryogenic material. The cryogenics which may be considered for use in this method and apparatus include nitrogen, argon, neon, helium, krypton, xenon, and mixtures thereof. It is well known to those skilled in the art that cryogenic materials in the liquid state are supercold but that they can be pumped or poured like any other fluid. The temperature in tank **10** is maintained at around minus 292° F. for nitrogen, for example, so that the resultant vapor pressure of gaseous nitrogen over liquid nitrogen will be approximately 60 p.s.i. Storage tank **10** has a safety release valve **12**. Liquid cryogen is taken out of tank **10** through a line **14** which has a shut-off valve **16**. A pump **18** specifically adapted to the pumping of cryogenics provides the means by which the liquid is removed from tank **10**. From the pump **18** the fluid passes into line **20** having a check valve **22** therein and thence into an evaporator means **24**. Pump **18** preferably is of the controlled variable volume type. It will be understood in using liquid nitrogen as an example that the temperatures and pressures herein stated are merely by way of example and are considered non-limiting. It is important that the cryogen be stored as a liquid. In an evaporator device **24**, preferably utilizing electric heat, the temperature of the liquid nitrogen is raised to its critical temperature or just above minus 232° F. at which the vapor pressure of the nitrogen gas will be in the order of 492 p.s.i. From evaporator **24** the gas passes through line **26** through a back pressure regulating valve **28** and thence into an insulated receiver vessel **30** equipped with cryogenic temperature and pressure sensors **32** and **34**, respectively, which in turn control the operation of the liquid nitrogen feed apparatus and the evaporator temperature. The compensating type back pressure regulating valve **28** is electrically operated as by means **36** while the evaporator heat control is estab-

lished with controls **38**, and the variable volume cryogenic pump is regulated with volume control **39**. The sensors **32** and **34**, of course, are connected through pressure and temperature control relay **40** to the various elements on the upstream side of the receiver vessel **30**.

The gas passes from the receiver through an outlet line **42** having a spring loaded check valve **44** and a gas flow control valve **46**. From line **42** the gas passes into and through a series of insulated pipes **48**, **50**, **52** and **54**, connected by flexible ball joints **56**, and into a drill pipe swivel joint **58**. The cold gas then passes down the inside of drill pipe **60** where it becomes further pressurized as it picks up heat from the formations being drilled. It will be seen that the drilling components are conventional such as means **62** for rotating the drill, drill seal **64** and the boring tool **66** with drill bits **68**. Surface casing pipe **70** is cemented or attached to surface rock **72** in the formation while the lower end of the drilling stem, of course, will extend into the hot geothermal zone **74**. As the gas passes through drill pipe **60** and boring tool **66**, past and around bits **68**, it returns to the surface outside the drilling pipe carrying with it the cuttings from the bottom of the drill hole. The gas and cuttings are taken out of the hole by a discharge line **76**. In the boring tool **66** and bits **68** the compressed gas issues from appropriate orifices and expands into a region of lesser pressure outside drill pipe **60** generally designated by the number **78**. As the gas issues from the boring tool it expands and cools the cutting edges of the bits. This high velocity gas also keeps the bits clean and free of damaging effects of oxidation at the temperatures at which the boring tool works.

The foregoing is considered as illustrative only of the principles of this invention. Numerous modifications and changes will occur to those skilled in the art, and hence it is not desired to limit the invention to exact construction, operation and method shown and described. Accordingly, all suitable modifications and equivalents may

be resorted to which fall within the scope of this invention.

What is claimed is:

1. A method of drilling through hot geothermal zones such as molten lava and the like with a hollow rotary drill stem having a ported bit at its inner end, comprising:

cooling, cleaning and providing an inert atmosphere in and around the drill stem, and solidifying the portions of the geothermal zone contiguous the drill stem, by flowing a super cold, inert, cryogenic gas, first through and then back along the outer surfaces of the drill stem;

rotating said drill stem while moving it endwise into the thus solidified geothermal zone; and

removing the used gases and the cuttings from the drill hole.

2. The method of claim **1**, comprising storing the cryogenic gas in the liquid state within an insulated tank; removing such liquid from said tank at a controlled rate; and heating said liquid to change its state to that of a supercold gas.

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