Sept. 24, 1963 C. R. OVERLY 3,104,707

FREEING PIPE STUCK IN A BOREHOLE

Filed Jan. 18, 1960 2 Sheets-Sheet 1

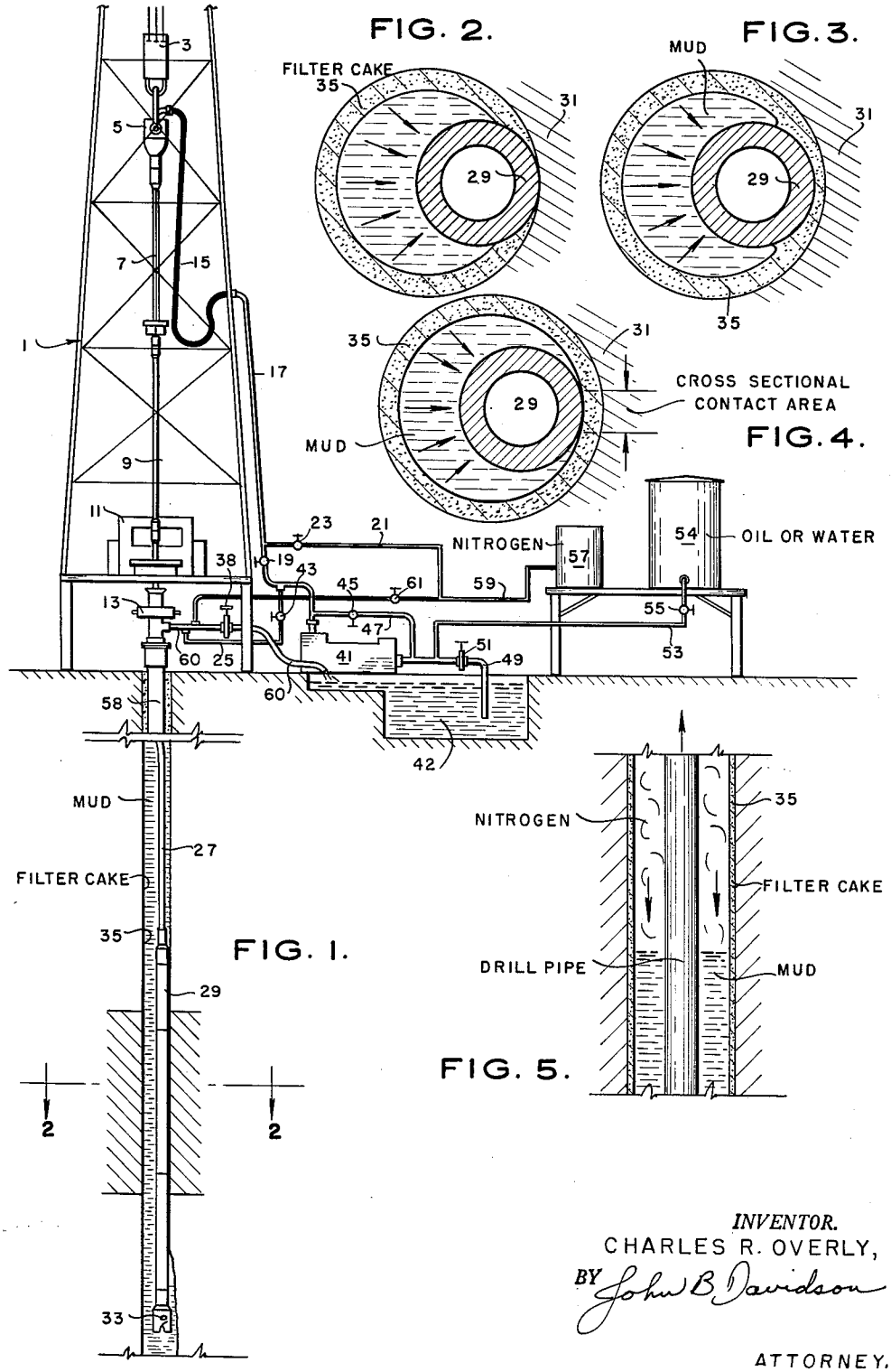


FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

FIG. 5.

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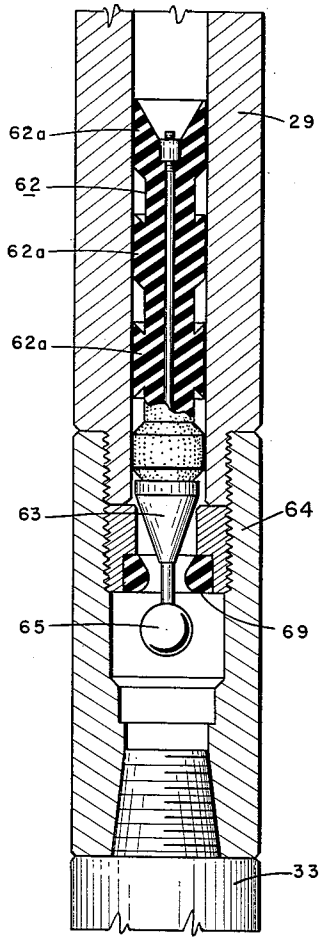


FIG. 6.

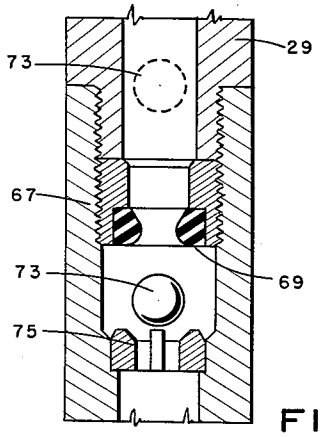


FIG. 7.

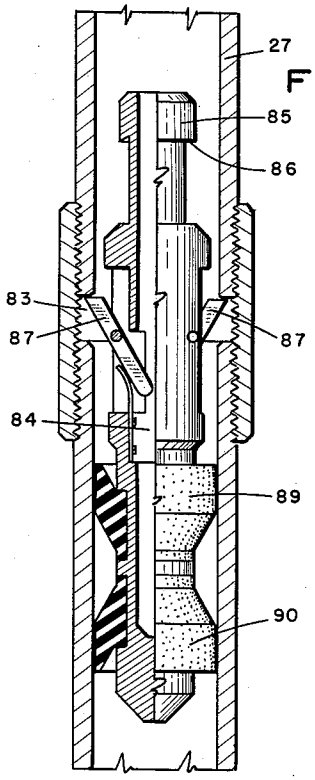


FIG. 8.

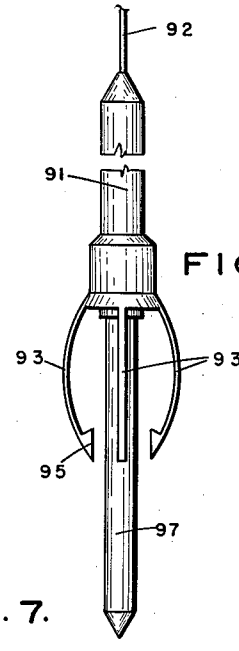


FIG. 9.

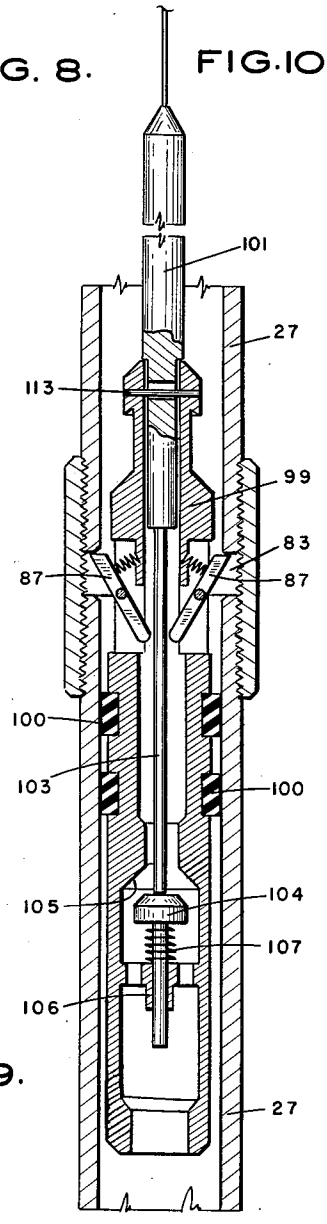


FIG. 10.

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FREEING PIPE STUCK IN A BOREHOLE

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7 Claims. (Cl. 166—46)

This invention relates to the loosening and freeing of stuck drill pipe and equivalent strings of pipe, casing, or tubing which have become stuck during the course of well operations.

There have been a number of theories evolved to explain the sticking of a pipe string in a borehole. The various theories involve the concept of caving-in of the sides of a borehole to form a bridge, differential sticking as the result of damage or imperfect formation of the filter cake lining the borehole, and formation of key seats that tend to prevent or impede vertical movement of the pipe string. Prior art methods of dealing with the problem are described in U.S. Patents No. 2,808,887, Erwin, and No. 2,865,454, Richards.

During the course of freeing a drill pipe that has become stuck in a well, it is usually necessary to apply a very substantial lifting force to the pipe string by means of a derrick at the wellhead. Derricks are available at the present time that can apply to a pipe string a relatively tremendous lifting force that is sufficient to rupture a stuck pipe string. Therefore, considerable care must be exercised to prevent pipe string rupture. If such care is not exercised, expensive fishing operations may be required. Manifestly, it is desirable to increase the lifting force on a pipe string during a freeing operation without stressing the metal in the pipe string beyond its elastic limit.

In accordance with one aspect of the present invention, a fluid having a specific gravity substantially less than the specific gravity of the drilling mud in a well bore is injected into the annular space surrounding a stuck pipe string to displace drilling fluid up through the pipe string into the mud pit. Sufficient drilling fluid is displaced to substantially lower the differential pressure between the interior of the borehole and the earth formation at the depth at which sticking has occurred. The differential pressure should be reduced to a pressure less than the difference between the lifting force available to the pipe and the weight of the pipe, divided by the product of the area of the drill pipe estimated to be held against the side of the borehole and the coefficient of friction between the drill pipe and the well bore. Preferably, this is done by injecting a gasiform fluid, such as nitrogen or air, into the annulus surrounding the stuck pipe string. After a desired quantity of drill fluid has been displaced out of the borehole, lifting force is exerted on the pipe string and the pressure of the gasiform fluid in the annulus around the pipe string is lowered, gradually reducing the differential pressure until the pipe string is free.

In order to impart additional lifting force to the pipe string without exceeding a safe stress in the pipe string, the fluid in the pipe string is displaced into the annulus around the pipe string or otherwise removed from the interior of the pipe string. Preferably, this is done by inserting a check valve into the pipe string near the bottom thereof to prevent fluid flow up into the pipe, and injecting a gasiform fluid, such as nitrogen or air, into the pipe string to force the drilling fluid through the check valve and out into the annulus. Additionally, the fluid in the pipe string may be removed by swabbing. The hydraulic head of the drilling fluid in the annulus and force of gaseous pressure above the topmost level of the drilling fluid act to impart a substantial lifting force on the lower part of the drill string to supplement the hoisting force of the wellhead derrick.

The invention will be explained in greater detail with reference to the accompanying drawings, wherein:

FIG. 1 is a schematic diagram of apparatus suitable for use in connection with the present invention;

FIGS. 2, 3 and 4 are cross-sectional views taken along section 202 of FIG. 1 for the purpose of illustrating the differential sticking phenomenon;

FIG. 5 is a fragmentary view of the borehole of FIG. 1 during one of the steps of the present invention;

FIGS. 6, 7, 8, and 10 illustrate apparatuses that may be used for preventing fluid flow up a drill pipe in accordance with one aspect of the invention. The various apparatuses are shown in place in the drill pipe; and

FIG. 9 illustrates an apparatus for retrieving from the drill pipe the apparatus shown in FIG. 8.

FIG. 1 illustrates apparatus which may be used for carrying out the present invention. There is shown the usual drilling apparatus 1 comprising a derrick, a traveling block 3, a swivel 5, a kelly joint 7, a pipe hoisting apparatus 11, and blowout preventors 13. A new joint of pipe 9 is shown as being held at the bottom end of the kelly joint 7 during a drilling operation. It may be assumed that the drill collar 29 of the pipe 27 has been stuck while new joint 9 was being added to the pipe string by differential pressure between the borehole and a porous, low pressure formation 31. At the bottom end of drill collar 29 is the usual bit 33 which may be a rock bit, a fish tail bit, or any other type of earth boring bit. A mud pump 41 is connected to the swivel 5 through the usual standpipe 17 and flexible coupling hose 15. A valve 19 is connected in the standpipe 17 for reasons that will become apparent from the following discussion. The mud pump 41 is coupled to the mud pit 42 through the usual pump section line 49 having a valve 51 therein.

Also provided with the drilling equipment is a source of pressurized gas such as nitrogen or air 57 and a source 54 of oil, water, or other fluid lighter than drilling fluid. Nitrogen source 57 is fluidly coupled to the drill pipe below the blowout preventors through line 59, valve 61, and line 60. Line 60 opens into the annulus below the blowout preventors 13 between the drill pipe 27 and surface casing 58. Surface casing 58 is shown as having been cemented to bond it to the surrounding earth formations. A source of oil or water 54 is coupled to the suction line 49 through line 53 and valve 55.

Pipe member 47 connects together the inlet and outlet of mud pump 41 for the purpose of by-passing drilling mud around the mud pump for reasons that will become apparent below. Valve 45 is closed while the mud pump is circulating drilling fluid during normal pumping operations. A fill-up line 25, having a control valve 43, is provided for connecting the outlet of the mud pump to line 60.

As mentioned above, in FIG. 1 it is assumed that the drill collar 29 is held against the side of the borehole by differential pressure between the interior of the borehole and a low pressure formation 31. The three circumstances under which this can occur are illustrated in FIGS. 2, 3, and 4.

In FIG. 2 the filter cake 35 lining the uncased borehole is shown to be broken or worn away so that the drill pipe or drill collar 29 contacts the earth formation 31. Probably it is more usual that a drill collar will break through the formation to contact the earth formation inasmuch as the diameter of a drill collar is substantially larger than the diameter of a drill pipe. If the filter cake is sufficiently soft, the breakthrough can occur during normal drilling operations. The breakthrough also can occur while the drill pipe is being raised up through the borehole after drilling operations have been stopped

temporarily for replacement of a bit. It ie belived that during such a raising operation, a drill collar can scrape off part of the filter cake, particularly if the bore hole is crooked, so that there is a differential pressure exerted across the drill collar to hold the entire drill string in the borehole. The other extreme is illustrated in FIG. 4 where the filter cake has not been damaged but where the force distribution within the filter cake is distorted as a result of imperfect formation of the filter cake. Lines of equal force in the filter cake may extend to the inner surface of the cake so that substantially formation pressure appears just within the inner surface of the cake. If a drill collar should touch the surface of the cake at such a point, the lines of equal force within the filter cake will be rearranged so as to hold the drill collar securely against the filter cake. FIG. 3 illustrates a situation intermediate the extremes illustrated in FIGS. 2 and 4.

In accordance with one aspect of the invention, it is necessary to prevent flow of fluids from the annulus between the drill pipe and the borehole into and up the drill pipe. Various types of apparatus that can be used for this purpose are illustrated in FIGS. 5, 6, 7, 8, and 10.

The apparatus shown in FIG. 6 comprises a rubber plug assembly **62** having a plurality of annular sealing sections **62***a* adapted to provide a fluid seal between the body of the assembly and the interior ofthe drill stem as the assembly is pumped down the drill stem. The lower end of the assembly includes a metal head **63** to which is affixed a metal ball **65**. A valve sub **64** connects the drill bit sub to the drill collar **29** and houses a rubber seat **69** that is shaped to permit the ball **65** to pass therethrough down into the space immediately therebelow, and a metallic shoulder for housing the rubber seat. A small force is needed to cause the metal ball to pass down through the seat **69**, but a relatively large force is needed to cause it to pass up through the seat.

In FIG. 7 there is illustrated a somewhat similar assembly that includes a member **75** in the lower end of the space below the rubber seat **69** in the lower end of the valve sub **67**. The passageways through member **75** permit fluid to circulate down through the valve sub **67** into the drill bit sub. Metal ball **73** can pass through the rubber seat **69** and will be held back by member **75** from passage down to the drill bit sub. The rubber shoulder **69**, however, will hold back the ball **73** when circulation of drilling fluid is reversed so that the ball **73** and shoulder **69** act as a check valve to prevent fluid flow up through the drill string.

The apparatus shown in FIG. 8 is similar to the apparatus described in U.S. Patent No. 2,897,896, Kenneday et al. The function of the apparatus is to prevent fluid flow up the drill pipe and to permit retraction of the apparatus by means of a wireline apparatus. The apparatus comprises a body member including a fishing head **85** and at least two pivoted dogs **87**. The upper portion of each dog is spring-biased outwardly so as to slip into a collar recess **83**, and the lower portion of each dog projects into a bore **84** so that it will swing inwardly to permit retraction of the drill pipe. Affixed to the lower end of the body member are sealing elements **89** and **90** which are made of rubber or rubber-like material and which are adapted to provide a fluid seal between the body member and the interior of the drill pipe. The bore **84** does not extend entirely through the body member as does the bore in the apparatus described in U.S. Patent No. 2,897,896. The apparatus of FIG. 8 is designed to cooperate with retrieving apparatus such as that shown in FIG. 9. This apparatus comprises the weight bar **91** affixed to the end of a wireline **92**. A plurality of spring arms **93** are provided with spear latch **95** adapted to slip over the fishing head **85** so as to engage the under shoulder **86** of the fishing head. The weight bar is provided at its lower end with a spear **97** adapted to engage the lower portion of the dogs **87** so as to swing inwardly the upper sections of the dogs **87**. The apparatus shown in FIG. 9 concomitantly will disengage the dogs **87** so as to permit upward movement of the apparatus shown in FIG. 8 and will latch on to the apparatus shown in FIG. 8 to retract the entire apparatus from the drill pipe.

The apparatus shown in FIG. 10 is for the purpose of sealing the interior of the drill pipe when circulation of drilling fluid is not possible. The apparatus is, in many respects, similar to the apparatus shown in FIG. 8 and comprises a body member **99** supporting sealing elements **100** and outwardly spring-biased, pivoted dogs **87** adapted to fit into collar recesses **83**. The body member **99** has a bore extending longitudinally therethrough. An elongated running tool **101** is attached to the body member by means of a shear pin **113**. Affixed to the lower end of member **101** is a stem **103** which is adapted to hold valve **104** off of seat **105**, while the assembly is being lowered into the pipe **27**. Valve member **104** is centrally positioned by means of spider member **106** and is held in an open position against the bias of spring **107**. When the dogs **87** swing into the recess **83**, an upward pull or jerk on the wireline shears the pin **113** and allows the running tool to be removed from the body **99** and also allows valve member **104** to seat and close off the bore therethrough.

Let it be assumed that as a result of drilling operations performed with the apparatus of FIG. 1, the filter cake has been damaged, as shown in FIG. 2, so that the differential pressure between the borehole and the earth formation **31** holds at least a drill collar and perhaps a portion of the drill string against the side of the borehole, preventing both rotation of the drill string and withdrawal of the drill string from the borehole. Further assume that this differential sticking has occurred at great depth whereat it is desirable to exert only a minimum lifting pull on the drill pipe. Blowout preventors **13** are closed to prevent a blowout in the event of unforeseeable difficulties. Valve **61** is opened to permit the flow of pressurized nitrogen from nitrogen source **57** down the annulus between the surface casing and the drill pipe. Drilling fluid will be forced down the annulus around the drill pipe and up the interior of the drill pipe and will flow through standpipe **17**, lines **47** and **49**, through valves **19**, **45**, and **51** into mud pit **42**. This operation is continued until the hydrostatic pressure of the drilling fluid at the depth at which differential sticking is occurring, minus the formation pressure at this depth, multiplied by the coefficient of friction between the drill pipe and the earth material against which the stuck drill pipe is bearing, times the estimated area of drill pipe stuck is less than the difference between the hoisting force available at the derrick without causing rupture of the pipe string and the weight of the drill pipe in the borehole.

The drill pipe is now sealed against the entry of drilling fluid thereinto. This is done by pumping one of the devices shown in FIGS. 6 and 8 down the drill pipe. The device is inserted into the drill pipe, and valve **23** is opened so that pressurized nitrogen forces the device down the drill pipe. Drilling fluid will be forced ahead of the sealing device, out through the bit, and into the space around the drill pipe. If necessary, some of the nitrogen in the space around the drill pipe may be bled off by closing valve **61** and cracking open valve **38**. If the apparatus shown in FIG. 7 is used, ball **73** may be dropped into the drill pipe and pressurized nitrogen may be used to force drilling fluid down through the drill pipe and out the lower end of the pipe. If the apparatus shown in FIG. 10 is utilized, the apparatus may be lowered into the pipe until it is seated, and the valve may be closed to seal the interior of the pipe against fluid flow thereinto from the lower end thereof. Valve **23** may now be closed, and valves **19**, **45**, and **51** may be opened to bleed off some of the pressurized nitrogen within the drill string.

Hoist **11** is activated so that hoisting force is exerted

on the drill pipe. The hoisting force may be near the maximum force to which the pipe may be subjected without exceeding its elastic limit. Valve **38** may now be opened slightly to very gradually reduce the pressure of nitrogen within the drill string borehole annulus. In due course, the differential pressure across the drill pipe at the depth of formation **31** will be decreased to free drill pipe **27** and permit its withdrawal from the borehole.

The method described above for freeing stuck drill pipe is particularly advantageous where the drill pipe is stuck as a result of both bridging and differential sticking. Under certain circumstances, it may be possible to free the drill pipe by reducing the weight of the drilling mud within the borehole. In this case, oil or water from source **54** may be injected into the annulus by closing valves **51** and **45** and opening valves **55** and **19**. Mud pump **41** is used to pump oil or water into the drill string to displace the drilling fluid therein until the total amount of fluid in the borehole is sufficiently small to free the drill string from the low pressure formation.

The invention is not to be restricted to the specific structural details, arrangement of parts, or circuit connections herein set forth, as various modifications thereof may be effected without departing from the spirit and scope of the invention.

What is claimed is:

1. In an earth drilling operation wherein an annular drill pipe string is positioned in a borehole by a pipe manipulating derrick and drilling fluid is circulated through the pipe string and the annular space therearound, the method of facilitating removal of the pipe string from the borehole with the derrick when the pipe string becomes stuck, comprising: pumping into the borehole annulus around the pipe string a fluid having a specific gravity less than the specific gravity of the drilling fluid in the borehole to displace at least a portion of the drilling fluid, until the differential fluid pressure betwen the formation at the depth at which the pipe string is stuck and the pressure exerted by the borehole fluid on the side of the borehole at the depth at which the pipe string is stuck is less than

$$\frac{H-W}{kA}$$

where "H" is the hoisting capacity of the derrick in pounds, "W" is the weight of the pipe string in pounds, "*k*" is the coefficient of friction between the pipe string and the material against which the pipe string is stuck, and "A" is the estimated area of the pipe string in contact with the side of the borehole and being acted on by the differential pressure; displacing the drilling fluid from the interior of the pipe string and preventing fluid flow of drilling fluid into the pipe string from the annular space around the pipe string; and lifting the pipe string with the derrick.

2. In an earth drilling operation wherein an annular drill pipe string is positioned in a borehole by a pipe manipulating derrick and drilling fluid is circulated through the pipe string and the annular space therearound, the method of facilitating removal of the pipe string from the borehole with the derrick when the pipe string becomes stuck, comprising: pumping into the borehole annulus around the pipe string a fluid having a specific gravity less than the specific gravity of the drilling fluid in the borehole to displace at least a portion of the drilling fluid, until the differential fluid pressure between the formation at the depth at which the pipe string is stuck and the pressure exerted by the borehole fluid on the side of the borehole at the depth at which the pipe string is stuck is less than

$$\frac{H-W}{kA}$$

where "H" is the hoisting capacity of the derrick in pounds, "W" is the weight of the pipe string in pounds,

"*k*" is the coefficient of friction between the pipe string and the material against which the pipe string is stuck, and "A" is the estimated area of the pipe string in contact with the formation and being held against the side of the borehole by the differential pressure; inserting a check valve into the pipe string near the bottom end thereof to prevent fluid flow into the pipe string from the annulus therearound; injecting pressurized gasiform fluid into the pipe string to force drilling fluid in the pipe string into the annular space around the pipe string; and lifting the pipe string with the derrick.

3. In an earth drilling operation wherein an annular drill pipe string is positioned in a borehole by a pipe manipulating derrick and drilling fluid is circulated through the pipe string and the annular space therearound, the method of facilitating removal of the pipe string from the borehole with the derrick when the pipe string becomes stuck, comprising: injecting a pressurized gasiform fluid into the annular space between the pipe string and the side of the borehole to displace drilling fluid out of the borehole until the difference between the formation pressure and the pressure exerted on the borehole wall by the remaining drilling fluid in the borehole above the depth at which the pipe string is stuck times the product of the coefficient of friction between the pipe string and the side of the borehole against which the pipe string is stuck and the estimated area of the pipe string surface stuck against the side of the borehole is less than the difference between the lifting capacity of the derrick and the weight of the pipe string in the borehole; seating a check valve in the pipe string to prevent fluid flow into the pipe string from the annular space around the pipe string; injecting pressurized gasiform fluid into the pipe string to force drilling fluid in the pipe string into the annular space around the pipe string; and slowly reducing the pressure of the gasiform fluid in the annular space around the pipe string while exerting lifting force on the pipe string with the derrick.

4. In an earth drilling operation wherein an annular drill pipe string is positioned in a borehole by a pipe manipulating derrick and drilling fluid is circulated through the pipe string and the annular space therearound, the method of facilitating lifting of the pipe string from the borehole with the derrick, comprising: pumping a pressurized gasiform fluid down the pipe string to displace drilling fluid in the pipe string; sealing the interior of the drill pipe string against drilling fluid flow into and up the pipe string from the annular space therearound; and reducing the pressure of the gasiform fluid in the pipe string.

5. In an earth drilling operation wherein an annular drill pipe string is positioned in a borehole by a pipe manipulating derrick and drilling fluid is circulated through the pipe string and the annular space therearound, the method of facilitating lifting of the pipe string from the borehole with the derrick, comprising: pumping pressurized nitrogen down the pipe string to displace drilling fluid in the pipe string; sealing the interior of the drill pipe string against drilling fluid flow into and up the pipe string from the annular space therearound; and reducing the pressure of the nitrogen in the pipe string.

6. In an earth drilling operation wherein an annular drill pipe string is positioned in a borehole by a pipe manipulating derrick and drilling fluid is circulated through the pipe string and the annular space therearound, the method of facilitating lifting of the pipe string from the borehole with the derrick, comprising: seating a check valve near the lower end of the pipe string bore to prevent fluid flow into and up the pipe string from the annular spoce therearound; pumping a gasiform fluid down the pipe string to force drilling fluid in the pipe string through the check valve into the annular space around the pipe string; and reducing the pressure of the gasiform fluid in the pipe string.

7. In an earth drilling operation wherein an annular

drill pipe string is positioned in a borehole by a pipe manipulating derrick and drilling fluid is circulated through the pipe string and the annular space therearound, the method of facilitating lifting of the pipe string from the borehole with the derrick, comprising: with drilling fluid substantially filling the pipe string and the annular space, preventing fluid flow into and up the pipe string from the annular space while permitting fluid flow from the pipe string into the annular space; pumping pressurized gasiform fluid down the pipe string to displace drilling fluid in the pipe string; and reducing the pressure of the gasiform fluid in the pipe string.

References Cited in the file of this patent

UNITED STATES PATENTS

1,774,640	Dunn	Sept. 2, 1930
1,867,832	Hill	July 19, 1932
1,903,232	Giesey	Mar. 28, 1933
2,726,063	Ragland et al.	Dec. 6, 1955
2,808,887	Erwin	Oct. 8, 1957
2,865,454	Richards	Dec. 23, 1958