surge in well-bore pressure due to fluid inflow from a formation penetrated by the well entering the well in what is known as a "kick".

This type of drilling is generally known as continuous circulation drilling.

Summary of the Invention

This invention comprises a method of continuous circulation drilling in which the rate of circulation of drilling mud is linked to the speed of rotation of the drill pipe.

According to a first aspect of the invention, there is provided a method of drilling a subterranean bore hole comprising:

a) pumping a drilling fluid down a drill string, the drill string having a drill bit at an end thereof,

b) rotating the drill string about its longitudinal axis to that the bit forms bore hole in the ground,

the method further comprising the steps of:

c) changing the rate of pumping of the drilling fluid into the drill string in response to a change in the speed of rotation of the drill string, and / or changing the speed of rotation of the drill string in response to a change in the rate of pumping of the drilling fluid into the drill string, characterised in that the rate of pumping of the drilling fluid is increased as the speed of rotation of the drill string is decreased, and the rate of pumping of the drilling fluid is decreased as the speed of rotation of the drill string is increased, and / or the speed of rotation of the drill string is increased as the rate of pumping of the drilling fluid is decreased and the speed of rotation of the drill string is decreased as the rate of pumping of the drilling fluid is increased.

There is also provided~~According to a first aspect of the invention we provide~~ a method of drilling a subterranean bore hole comprising:

a) pumping a drilling fluid down a drill string, the drill string having a drill bit at an end thereof,

b) rotating the drill string about its longitudinal axis to that the bit forms bore hole in the ground,

the method further comprising the steps of:

c) changing the rate of pumping of the drilling fluid into the drill string in response to a change in the speed of rotation of the drill string, and / or changing the speed of rotation of the drill string in response to a change in the rate of pumping of the drilling fluid into the drill string.

The mud pressure at the bottom of the well bore (the BHP) depends on various factors. When there is no mud flow, it is determined by the pressure from the static weight of the column of mud in the well bore. When mud is pumped down the drill pipe into the well bore, there is an increase in BHP due to frictional effects from the circulating mud. It has also been discovered that commencement of drilling gives rise to a further increase in BHP arising from additional frictional effects caused by the rotation of the drill pipe. This effect is significant as it makes up a large percentage, nominally 10% to 40% of the

previously described friction effect. Thus, by linking the rate of circulation of drilling mud to the speed of rotation of the drill pipe, the increase in BHP caused by an increase in the speed of rotation of the drill pipe can be countered by the decrease BHP caused by a reduction in the rate of circulation of drilling mud, or vice versa. As a result, improved control of the BHP may be achieved. This is critical requirement for drilling well with a small drilling window as determined by the pore pressure gradient, fracture gradient and collapse pressure of the borehole, which are dictated by the physical properties of the formation being drilled.

As mentioned in the first aspect~~In one embodiment~~ of the invention, the rate of pumping of the drilling fluid is increased as the speed of rotation of the drill string is decreased, and the rate of pumping of the drilling fluid is decreased as the speed of rotation of the drill string is increased, and / or the speed of rotation of the drill string is increased as the rate of pumping of the drilling fluid is decreased and the speed of rotation of the drill string is decreased as the rate of pumping of the drilling fluid is increased.

The method may further include the steps of:

d) stopping the rotation of the drill string,

e) pumping drilling fluid into a side port adjacent the uppermost end of the drill string,

f) ceasing pumping of drilling fluid into the uppermost end of the drill string,

g) connecting a new section of drill pipe to the uppermost end of the drill string,

h) commencing pumping of drilling fluid into the uppermost end of the new section of drill pipe,

increases the rate of pumping of the drilling fluid into the drill string in response to a decrease in the speed of rotation of the drill string, and automatically decrease the rate of pumping of the drilling fluid into the drill string in response to an increase in the speed of rotation of the drill string and / or the driver controller automatically increases the speed of rotation of the drill string in response to a decrease in the rate of pumping of the drilling fluid into the drill string, and automatically decreases the speed of rotation of the drill string in response to an increase in the rate of pumping of the drilling fluid into the drill string.

~~changes the rate of pumping of the drilling fluid into the drill string in response to a change in the speed of rotation of the drill string, and / or the driver controller automatically changes the speed of rotation of the drill string in response to a change in the rate of pumping of the drilling fluid into the drill string.~~

In one embodiment of the invention the driver controller is an electronic driver controller, and the pump controller is an electronic pump controller, there being an electrical connection between the driver controller and the pump controller, to provide for the transmission of a control signal between the top drive controller and the pump controller.

The pump controller is programmed to monitor this signal, and automatically to alter the speed of operation of the pump in accordance with the instruction given in the control signal. In one embodiment of the invention, the top drive controller would be programmed to send a control signal instructing the pump controller to reduce the speed of operation of the pump as the speed of rotation of the drill pipe increases, and to increase the speed of operation of the pump as the speed of rotation of the drill pipe decreases.

In this case, the driver controller is programmed to transmit to the pump controller a control signal instructing the pump controller to either increase or decrease the speed of operation of the pump depending on whether the rotational speed of the drill pipe is decreasing or increasing.

The pump controller may be programmed to monitor this signal, and automatically to alter the speed of operation of the pump in accordance with the instruction given in the control signal.

The driver controller may be programmed to send a control signal to the pump controller instructing the pump controller to reduce the speed of operation of the pump as the speed of rotation of the drill pipe increases, and to increase

decreasing by increasing the speed of operation of the pump, or where more than one pump is provided, one or more of the pumps, and vice versa.

14. An apparatus according to any one of claims 8 to 13~~14~~ wherein the driver controller and pump controller are integrated to comprise a single electronic controller which is operable to control the speed of operation of the pump and the speed of rotation of the drill string.

15. An apparatus according to any of claims 8 to 14 wherein the controller or one or both of the controllers has a pressure input for receipt of a signal from a pressure sensor located on the drill string which transmits a signal indicative of the fluid pressure in the bore hole to the or each controller to which it is connected.

16. An apparatus according to claim 15 wherein the or each controller having said pressure input is programmed to use this pressure signal to determine if the fluid pressure is at a desired level, and, if not, make further adjustments to the pump speed and/or speed of rotation of the drill string to bring the fluid pressure to the desired level or to within an acceptable range.

17. An apparatus according to any of claims 8 to 16 wherein the controller or one or both of the controllers has a flow input for receipt of a signal from a flow meter which transmits a signal representative of the rate of flow of drilling fluid down the drill string to the or each controller to which it is connected.

18. An apparatus according to any one of claims 8 to 17 further including an annulus return line which connects the annular space in the bore hole around the drill string with a reservoir for pressurised fluid, an adjustable choke in the annular return line, and an electronic choke controller which controls operation of the adjustable choke to vary the restriction of flow of fluid along the annulus return line.