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WELL CONTROL CONSIDERATIONS

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ABSTRACT

Well control considerations are a vital need in the proper conduct of oil and gas discovery specially during drilling operations. Kick detection techniques such as one circulation or two circulations methods are examined. From these two methods the best method for well control are also examined. Several elements are reviewed which collectively form an effective well control system. It is concluded that these effective considerations are essential to keeping drilling risks and how to controlled it and minimized. It is considered that the best method for well control depends on Time, Surface pressures, and downhole stresses

KEY WORDS: Well control, Kick detection, Circulation, shut-in, hydrostatic pressure

INTRODUCTION

Well control and blowout prevention have become particularly important topics in the hydrocarbon production industry for many reasons. Among these reasons are higher drilling costs, waste of natural resources, and the possible loss of human life when kicks and blowout occur. Blowouts occur rarely in hydrocarbon industry, It is our goal to eliminate them. A well out of control posses a very serious threat to people, equipment and the environment. On the other hand drilling wells has always been a difficult undertaking and a certain amount of risk is inherently involved. We all share in this risk taking and our common aim is to develop new reserves while keeping this drilling risk controlled and minimized. This paper addresses well control generally with special emphasis on kick detection.

MATERIALS AND METHODS

Many well-control procedures have been developed over the years. Some have used systematic approaches, while others are based on logical, but perhaps unsound, principles. The systematic approaches will be presented here.

With the constant-bottomhole-pressure concept, the total pressures (e.g., mud hydrostatic pressure and casing pressure) at the hole bottom are maintained at a value slightly greater than the formation pressures to prevent further influxes of formation fluids into the wellbore. And, because the pressure is only slightly greater than the formation pressure, the possibility of inducing a fracture and an underground blowout is minimized. This concept can be implemented in three ways:

- Two-Circulation, or Driller's, Method. After the kick is shut in, the kick fluid is pumped out of the hole before the mud density is increased.
- One-Circulation, or Wait-and-Weight, Method. After the kick is shut in, weight the mud to kill density and then pump out the kick fluid in one circulation using the kill mud.

START UP PROCEDURE

It is important to understand the kill start up procedure for bringing the pump up to kill speed. Irrespective of kill method, pump should be brought to kill speed gradually maintaining casing pressure constant.

During this period, if the casing pressure is allowed to increase, it can cause formation breakdown. If the casing pressure is allowed to decrease, it can cause entry of more influx into the wellbore. To prevent this, following procedure is suggested.

1. Bring the pump to kill speed in steps holding casing pressure constant by gradually opening the choke.
2. When the pump is at desired kill speed follow the pressure schedule according to the kill method being used.

Note: while bringing the pump to kill speed keeping casing pressure constant, there might be slight reduction in bottom hole pressure due to expansion of gas but this is compensated by the annular pressure losses.

DRILLER'S METHOD OR TWO CIRCULATION METHOD

Well is killed by two cycle circulation as follows

- In first circulation the influx is removed from the well bore using original fluid density.
- In second circulation the kill fluid replaces the original fluid and restores the primary control of the well

FORMULAE REQUIRED

$$\text{Kill fluid density} = \frac{\text{SIDPP}}{\text{TVD x 0.052}} + \text{Original fluid density}$$

$$\text{Initial circulating pressure(ICP)} = \text{SIDPP} + \text{kill rate pressre}$$

$$\text{Final circulating pressure(FCP)} = \frac{\text{kill fluid density}}{\text{original fluid density}} \text{ x kill rate pressre}$$

$$\text{Surface to bottom strokes} = \frac{\text{Drill string volume}}{\text{pump output}}$$

$$\text{Annulus strokes} = \frac{\text{Annulus volume}}{\text{pump output}}$$

KILLING PROCEDURE

DRILLER' METHOD

In this method the well is killed in two circulations.

- **First circulation**

1. Bring the pump up to kill speed in steps of 5 SPM, gradually opening the choke holding casing pressure constant.
2. When the pump is up to kill speed, maintain drill pipe pressure constant.
3. Circulate out the influx from the well maintaining drill pipe pressure constant.
4. When the influx is out, stop the pump reducing, reducing the pump speed in steps of 5 SPM gradually closing the choke, maintaining casing pressure constant. Record pressure SIDPP and SICP should be equal to original SIDPP.

NOTE: In case recorded SIDPP and SICP are equal but more than original SIDPP value, it indicates trapped pressure in well bore. Whereas if SICP is more than original SIDPP, it indicates that some influx is still in the well bore.

CASING PRESSURE GRAPH

A-B Casing pressure rises as influx expands in drill collar annulus.

B-C Casing pressure decreases as influx crosses over from drill collar annulus to drill string and losses height.

C-E Casing pressure again rises as influx now expands in drill pipe annulus and becomes maximum when influx reaches surface at point 'E' on the graph,

E-F Casing pressure reduces sharply as influx is removed from the well bore.

DRILL PIPE PRESSURE GRAPH

I-J Drill pipe pressure is held constant till the influx is removed from the well bore.

- <u>**Second circulation**</u>

1. Line up suction with kill fluid.
2. Bring the pump up to kill speed in steps of 5 SPM, gradually opening the choke holding casing pressure constant.
3. When the pump is at kill speed, pump kill fluid in drill string from surface to bottom maintaining casing pressure constant.

4. Pump kill fluid in the annulus from bottom to surface, maintaining drill string pressure constant equal to FCP.
5. When the kill fluid reaches surface, stop the pump, reducing the pump speed in steps of 5 SPM, gradually closing the choke maintaining casing pressure constant. Record pressures, SIDPP and SICP both should be equal to zero.

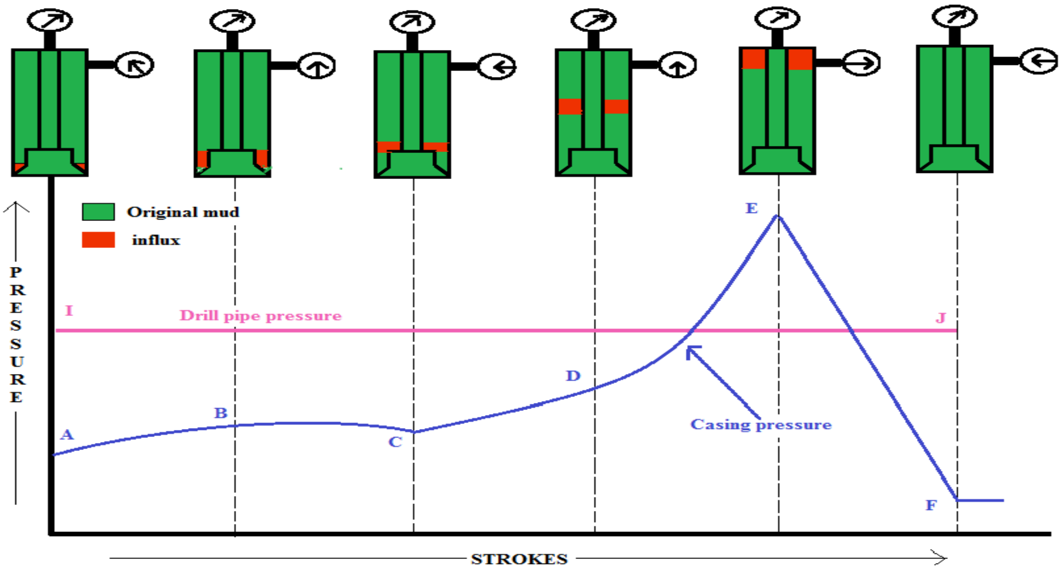

Figure 1- Drill pipe pressure or casing pressure graph of first circulation of well control

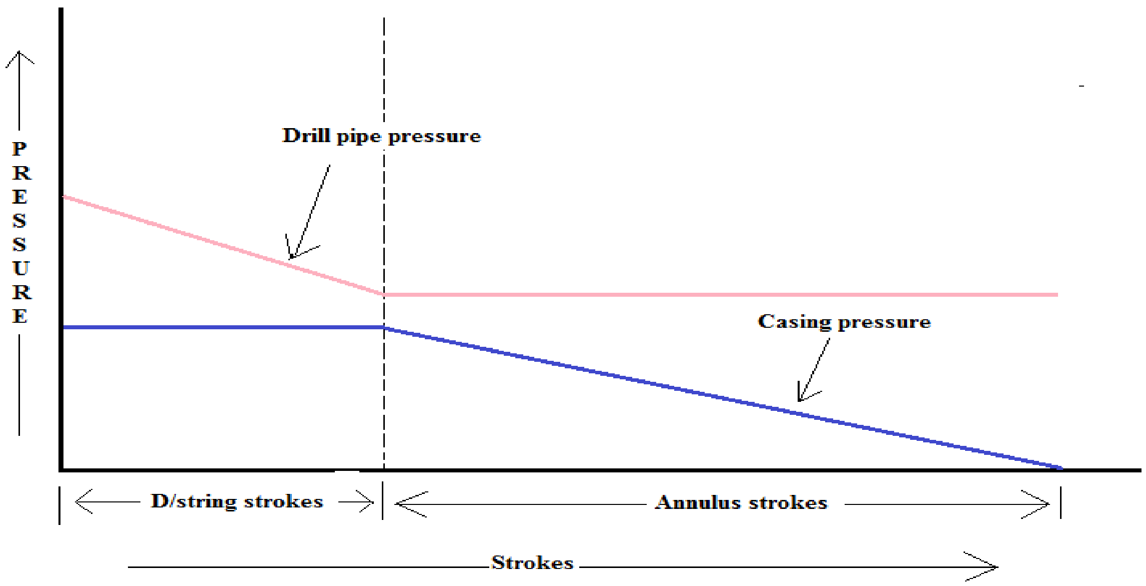

Figure 2 - Drill pipe pressure or casing pressure graph of second circulation of well control

WAIT & WEIGHT METHOD OR ONE CIRCULATION METHOD

- In Wait and Weight method well is killed in one circulation using kill fluid.
- In this method operation are delayed (wait) once the well is shut in, while a sufficient volume of kill (weight) fluid has been prepared.
- As the kill fluid is pumped to the drill string bottom the hydrostatic pressure in the drill string increases, this causes the drill string surface pressure to fall.
- At the same time, influx which is on its way up the annulus expands continuously and gains volume / height, thereby causing the

hydrostatic pressure in annulus to fall and casing pressure to rise.

- Because of this, for maintaining BHP constant a calculated step down plan for the Drill string pressure must be used while pumping the kill fluid from surface to the Drill string bottom.

FORMULAE REQUIRED

$$\text{Kill fluid densit} = \frac{\text{SIDPP}}{\text{TVD x 0.052}} + \text{Original fluid density}$$

$$\text{Initial circulating pressure(ICP)} = \text{SIDPP} + \text{kill rate pressre}$$

$$\text{Final circulating pressure(FCP)} = \frac{\text{kill fluid density}}{\text{original fluid density}} \text{ x kill rate pressre}$$

$$\text{Surface to bottom strokes} = \frac{\text{Drill string volume}}{\text{pump output}}$$

$$\text{Annulus strokes} = \frac{\text{Annulus volume}}{\text{pump output}}$$

KILLING PROCEDURE

WAIT & WEIGHT METHOD

One circulation

1. Line up suction with kill fluid.
2. Bring the pump up to kill speed in steps of 5 SPM, gradually opening the choke holding casing pressure constant.
3. When the pump is at kill speed, pump kill fluid in drill string from surface to drill string bottom maintaining Drill string pressure as per step down schedule(during this step drill pipe pressure will fall from ICP to FCP).
4. Pump kill fluid in the annulus from bottom to surface, maintaining drill string pressure constant equal to FCP.
5. When the kill fluid reaches surface, stop the pump, reducing the pump speed in steps of 5 SPM, gradually closing the choke maintaining casing pressure constant. Record pressures, SIDPP and SICP both should be equal to zero.

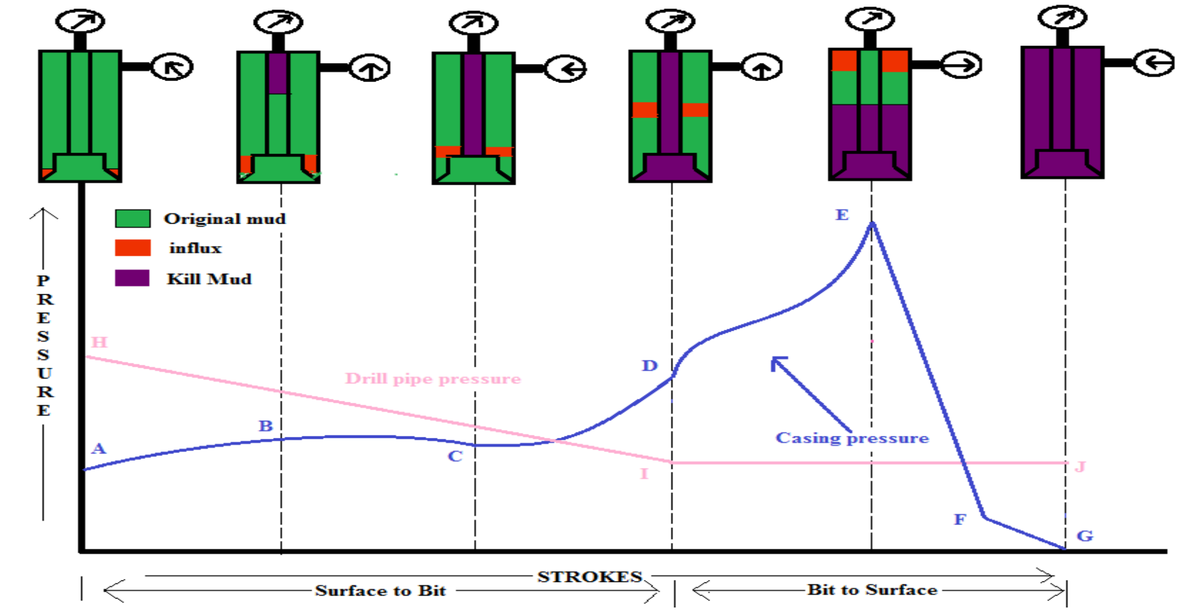

Figure 3 - Drill pipe pressure or casing pressure graph of first circulation of well control wait & weight method.

CASING PRESSURE GRAPH

A-B Casing pressure rises as influx expands in drill collar annulus.

B-C Casing pressure decreases as influx crosses over from drill collar annulus to drill string and losses height.

C-D Casing pressure rises as influx rises and expands in drill pipe annulus.

D-E Casing pressure continues to increase but at a slower rate as kill fluid starts entering annulus. Later on it increases at faster rate due to rapid expansion of gas.

E-F Casing pressure decreases sharply as influx is removed from the well bore.

F-G Casing pressure further reduces to zero as original mud is replaced by kill mud.

CHOOSING THE BEST METHOD FOR WELL CONTROL

Determining the best well-control method for most situations involves several considerations including the time required to execute the kill procedure, the surface pressures from the kick, the complexity relative to the ease of implementation, and the downhole stresses applied to the formation during the kick-killing process. All points must be analyzed before a procedure can be selected. The following list briefly summarizes the general opinion in the industry regarding these methods:

TIME

Two important considerations relative to time are required for the kill procedure: initial wait time and overall time required. The first concern with time is the amount required to increase the mud density from the original weight to the final kill-weight mud. Because some operators are very concerned with pipe sticking during this time, the well-control procedure that minimizes the initial wait time is often chosen. This is the two-circulation method. In both procedures, pumping begins immediately after the shut-in pressures are recorded.

The other important time consideration is the overall time required for the complete procedure to be implemented. **Figure-1** shows that the two-circulation method requires the annulus to be displaced twice, in addition to the drillpipe displacement, While the **Figure-2** shows that the one-circulation method requires one complete fluid displacement (i.e., within the drillpipe and the annulus), that the one-circulation method requires one complete fluid displacement (i.e., within the drillpipe and the annulus). In certain situations, extra time for the two-circulation method may be extensive with respect to hole stability or preventer wear.

SURFACE PRESSURES

During the course of well killing, surface pressures may approach alarming heights. This may be a problem in gas-volume expansion near the surface. The kill procedure with the least surface pressure required to balance the bottomhole formation pressure is important.

Figures-4 shows the different surface-pressure requirements for several kick situations. The first major difference is noted immediately after the drillpipe is displaced with kill mud. The amount of casing pressure required begins to decrease because of the increased kill-mud hydrostatic pressure during the one-circulation procedure. This decrease is not seen in the two-circulation method because this procedure does not circulate kill mud initially. In fact, in the two-circulation method, the casing pressure increases as the gas-bubble expansion displaces mud from the hole.

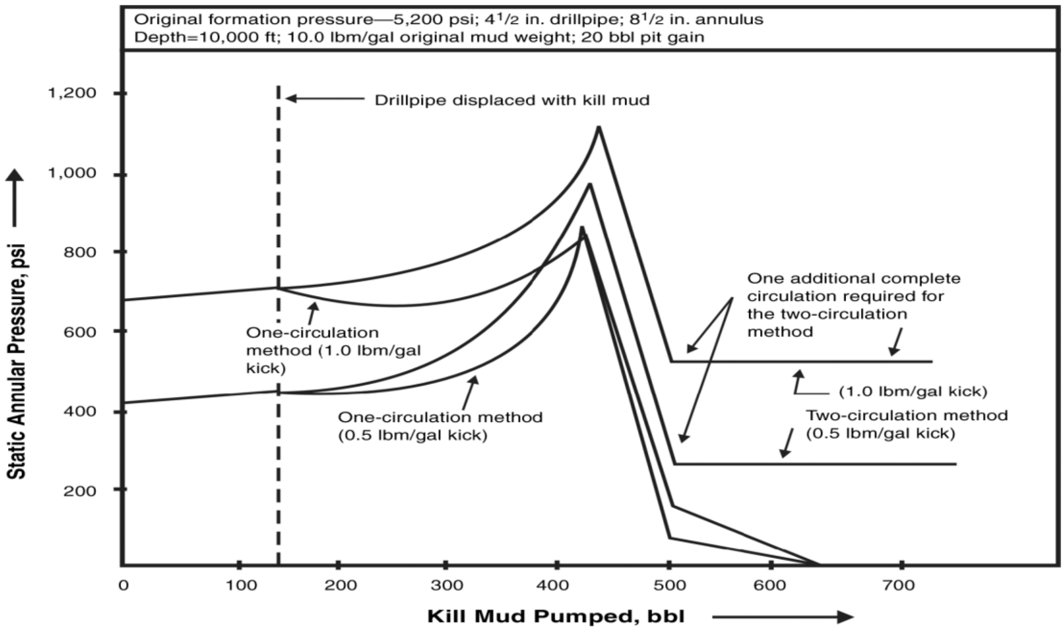

Figure-4 Static annular surface pressures for one circulation vs. two circulation method in a 10,000 ft well

The well data and figure are taken from Baker Hughes Inteq Workbook.

The second difference in pressure occurs as the gas approaches the surface. The two-circulation procedure has higher pressures resulting from the lower-density original mud weight. It is interesting to note these high casing pressures that are necessary to suppress the gas expansion to a small degree result in a later arrival of gas at the surface.

PROCEDURE COMPLEXITY

Process suitability partially depends on the ease with which the procedure can be executed. The same principle holds true for well control. If a kick-killing procedure is difficult to comprehend and implement, its reliability diminishes. One- and two-circulation methods are used more prominently because of their ease of application. In both procedures, the drillpipe pressure remains constant for long intervals of time.

DOWNHOLE STRESSES

Although all considerations for choosing the best method are important, the primary concern should always be the stresses imposed on the borehole wall. If the kick-imposed stresses are greater than the formation can withstand, an induced fracture occurs, creating the possibility of an underground blowout. The procedure that imposes the least downhole stress while maintaining constant pressures on the kicking zone is considered the most conducive to safe kick killing.

One way to measure downhole stresses is by use of "equivalent mud weight," or the total pressures to a depth converted to lbm/gal mud weight. For example,

$$\rho_e = 19.23 p\Sigma / D_e$$

Where *pe* = equivalent mud weight, lbm/gal.

De = Depth equivalent, ft and p∑ = total pressure, psi

The equivalent mud weight for the systems are presented in **Figure 5**. The one-circulation method has consistently lower equivalent mud weight throughout the killing process after the drillpipe has been displaced. The procedures generally exhibit the same maximum equivalent mud weight. They occur from the time the well is shut in until the drillpipe is displaced.

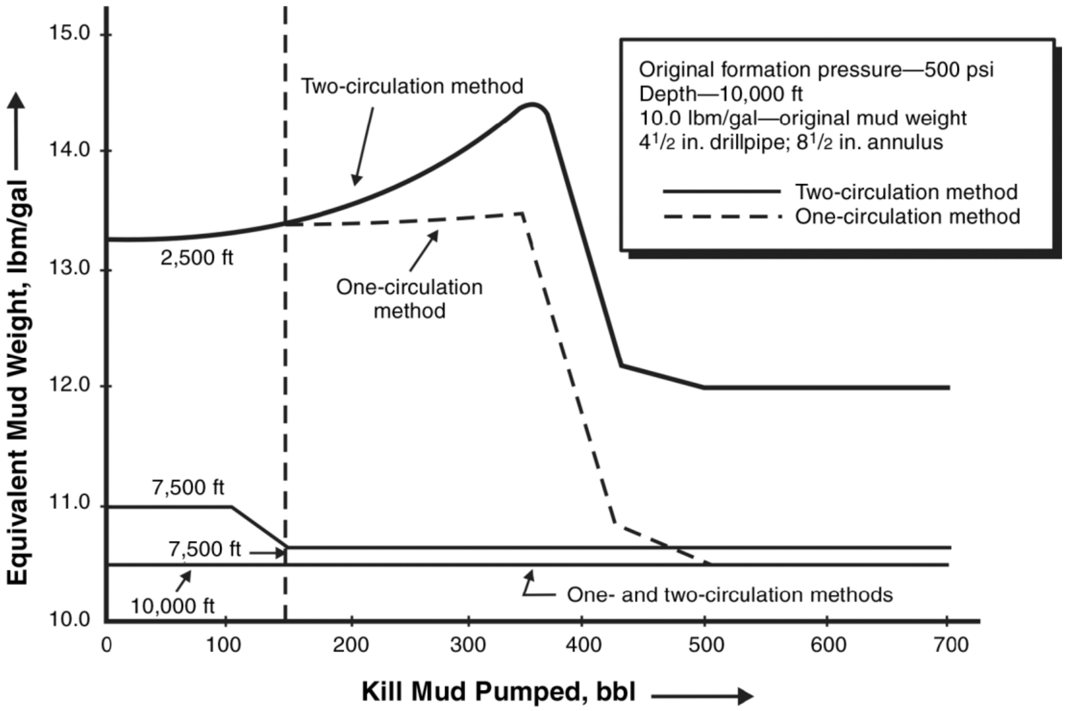

Figure 5-Equivalent mud-weight comparison for the one-circulation vs. the two-circulation kill procedure (0.5-lbm/gal kick at 10,000 ft).

The well data and figure are taken from Baker Hughes Inteq Workbook.

Figure-5 illustrates an important principle: maximum stresses occur very early in circulation for the deeper depth, not at the maximum casing pressure intervals. The maximum lost-circulation possibilities will not occur at the gas-to-surface conditions, as might seem logical. If a fracture is not created at shut-in, it probably will not occur throughout the remainder of the process. A full understanding of this behaviour may calm operators' concerns about formation fracturing as the gas approaches the surface.

4. RESULTS AND DISCUSSION

The main purpose of this paper is choosing the best method for well control and reviewed element which form an effective well control system.

According to Time, one circulation method or (wait and weight method) is the best method for kill procedure because in one circulation method the required time to kill the well is minimum in comparison to two circulation method or (driller's method). The extra time for the two circulation method may be extensive with respect to hole stability or prevent wear.

According to surface pressure, **Figure 4** shows during 1.0 lbm/gal kick, the casing pressure decreases due to increased kill mud hydrostatic pressure in one circulation method or (wait and weight method), and this decrease in casing pressure is not seen in two circulation method or (driller's method) and the same process is for 0.5 lbm/gal kick because this procedure does not circulate kill mud initially. According to this one circulation is the best method

According to downhole stresses, we measured it from well data for 10,000 ft well.. The downhole stresses increases with the increase of depth. The **Figure 5** Shows that the one circulation method (wait and weight method) has consistently lower equivalent mud weight throughout the killing process in comparison to two circulation method after the drill pipe has been displaced. This also shows that one circulation is the best method

So the final results is that one circulation or (wait and weight method) is best method and the two circulation method is more complex than one circulation method.

6. Conclusion

In present paper it is found that one circulation is best method for well control and during well kicking, well should be kill by one circulation method it takes the less time or also takes the less mud to kill the well. The proper understanding of pressure and pressure relationship is important in preventing blowout. The well control consideration responses to an identified influx and stop with goal of assisting rig personnel to identify and stop any kick without delay

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