Petroleum and Coal

Article **Open Access**

Comparison between Well Control Methods During Oil Well Drilling for Small and Large Open Hole in Egypt Western Desert by Using Drilling Simulator

Mahmoud Fathi[1,2], Yahia M. Al-Nady[1], Taher El-Fakharany*[1]*

[1] Mining and Petroleum Department, Faculty of Engineering, Al-Azhar University, Cairo, Egypt
[2] Kuwait Oil Company, KOC, (Development Drilling & Workover department)

Received December 15, 2019; Accepted February 4, 2020

Abstract

The key to effective pressure control is preparation and vigilance on the part of those who are responsible for controlling formation pressures. Taking into account the formation pressures and the confidence that comes from training and practice in controlling pressures are the elements that minimize the frequency and severity of well control issues, which may lead to blowouts. Nearly every well drilled has the potential to kicked and blowout. Experience has shown kicks occur as the result of human error and/or mechanical failures of well control equipment. However, a carefully planned, continuously supervised pressure-control program will lessen the possibility of well control kick and blowout considerably.

The two widely used constant bottom hole pressure (BHP) methods are the driller's method and the wait and weight (W&W) method. Well control experts are often strongly opinionated on selecting the better method to circulate an influx out of the wellbore. The purpose of this paper is to highlight the preferred well control method that has to be followed while killing the well with small and large open hole cases.

***Keywords**: Oil well drilling, Well control methods. Wait& Weight and Driller's method.*

1. Introduction

Well control is described as the safety applied for the human factor, which is at the rig or platform. It contains a range of elements under the term of well barriers that are used to avoid the influx of unwanted fluids in the wellbore. These barriers should be functional to achieve their objective. The barriers elements are controlled by the human factor thus it's very vital to the persons working on the rig or the platform to fully understand these elements and to know how these elements work to be able to control at time of failures as soon as possible; thus it's vital for everybody to fully understand the well control process during the drilling operations [1-2].

The oil and gas industry has been continuously changing as many theoretical and technical elements has been implemented over time due to advancement in technology and knowledge. This advancement has led to the discovering of more reserves in the world. These industries have been improved due to the high demand for energy sources worldwide, so the investment and research in the oil and gas industries have advanced a lot to meet the increasing demands. In comparison with the well control from the past, the well control has improved significantly nowadays although the use of drilling mud was done at the past to stabilize the formation pressure, its effectiveness was much lower. A blowout can cause serious damage to human life, environment, and country economics; thus, more researches must be done to improve the safety of the drilling process [3-4].

After a well kick, the basic sequence of control is the to keep the hydrostatic pressure against the kick formation at a sufficient value to prevent influx entry from formation and

below the pressure that could fracture happens, simply is generally emphasized because decisions have to be taken as quickly as possible when a well kicks and many people should be involved in the well control procedure [5].

The basic principle of well control methods is to keep bottom hole pressure (BHP) constant at or, preferably, slightly above the formation pressure, which represented by two methods Driller's and Wait & Weight method. During the Driller's method, the kick is circulated out of the hole using the existing mud weight. The mud weight is then increased to the calculated required mud weight and circulated across the well. Two complete circulations are required as a minimum for driller's method. Since it deals separately with the removal of the kick and the addition of kill weight mud, it is generally considered as the most simple well control method, and it requires the least calculation [6].

However, in this method, the well being circulated under pressure for a moderately long time, so it's possibly the longest methods, with an increased opportunity of choke problems. Moreover, the annular pressures created during the first circulation more higher than annular pressure with any other method.

In general, this method is most commonly used on small land rigs where the driller may have little help and limited equipment. A variant of this method is also used in some workover operations [6].

The Wait and Weight method is also called sometimes as the 'Engineers Method'; it does kill the well in one circulation. This is the preferred method used by most operatives and recommended by most of well control experts. Its principal advantage is that it provides the lowest annular pressures during the well circulation of the killing mud making it the safest of the commonly used killing methods, once the well is shut-in and pressures are stabilized, the shut-in drill pipe pressure is used to calculate the kill mud weight. Mud is built-in mud pits to the required calculated kill mud weight by following killing sheet calculations.

When the kill mud is ready, it will be pumped down through the drill pipe. At beginning, enough drill pipe pressure should be held to circulate the mud, plus a the value equivalent to the shut-in drill pipe pressure (SIDPP) this total progressively decreases as the mud circulated down to the bit, once the kill mud at the bit, the required pressure is simply that needed to pump kill mud around the well, the choke is adjusted to reduce drill pipe pressure while killing mud is pumped down to the string due to hydrostatic pressure increase which substituting the drill pipe pressure. With kill mud at the bit, the static head of mud in the drill pipe balanced with the formation pressure. For the remains of the circulation, as the influx is pumped to the surface followed by killing mud, the drill pipe pressure is held at the final circulating value by adjusting the choke in one stage as per step down chart [7-8].

All drilling organization or oil company can implement a policy of recommending just one well control method so that everybody in the organization can be competent in at least one method in spite of we may face some limitation to use on of the killing method. This may help in avoiding confusion in the field and promote understanding of how to efficiently circulate a kick out of the wellbore without creating major well control problems [9].

For standard wells, the Wait and Weight method is preferred. When a kick is being displaced from the well constant BHP will be maintained. Priority will be given to maintaining constant BHP even if the Maximum Allowable Annular Surface Pressure MAASP is exceeded. However, all efforts should be made to minimize the risk of MAASP being exceeded when the kick is in the open hole [10].

2. Simulation & methodology

This paper will apply some assumptions for well control methods that will commonly used in well killing operations methods (Driller's method & Wait and Weight method) and the effect of each method on Maximum Allowable Annular Surface Pressure (MAASP) with below cases and situation.

2.1. Small open hole (large/ small influx)

Small open hole volume, when the capacity of open-hole volume is less than string volume, then we will assume that we have taken a gas kick then will discuss the output data for killing operation carried by the simulator. Well data for the small open hole: string volume 218 bbl's/ open hole volume 162.5 bbl's, casing setting depth 9150 ft

2.2. Large open hole

Large open hole volume, when the open hole volume is greater than the string volume, then we will assume that we have taken a gas kick with a small influx volume than will discuss the output data for killing operation carried by the simulator. Well data for the large open hole will assume that casing setting depth @ 5500, so open hole volume 320 BBL's and string volume 218 bbls. 9-5/8" casing setting depth 5500 ft.

2.3. Case#01 small open hole/small influx volume

2.3.1. Driller's method (small open hole/small influx volume)

In this case, we have taken a kick volume 12.8 bbls, and then we shut in the well and recorded shut-in drill pipe pressure (SIDPP), and shut-in casing pressure (SICP) as follows:

SIDPP = 1100 psi (from remote choke panel); SICP = 1240 psi (from remote choke panel).

When the circulation is started, the influx out with original mud weight, and we can notice that the MAASP limitation to get a leak below the shoe at the time of shut-in = 1553 psi, as shown in Figure 1.

From Figure 1, the top of influx at casing shoe, then MAASP tolerance value was 1159 psi, so we still have tolerance influx 1159 psi in the casing to break the formation at casing shoe depth.

From Figure 2, we can notice that when we have taken a small influx volume (reflect as a height in annulus), we will get less value for SICP and have a safety limit between MAASP and casing shoe pressure while killing operation (second circulation).

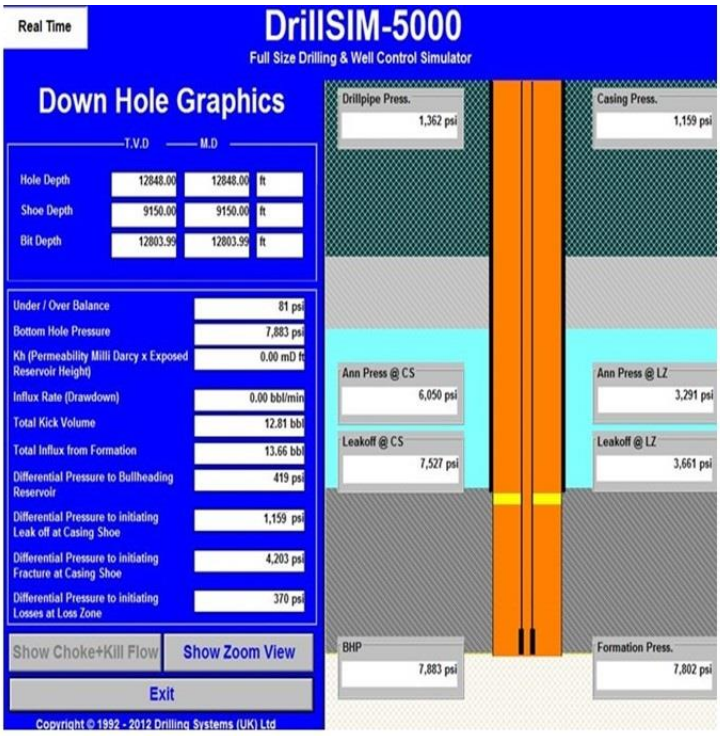

Figure 1. Driller's method, small open hole, small influx volume, top influx at the casing shoe

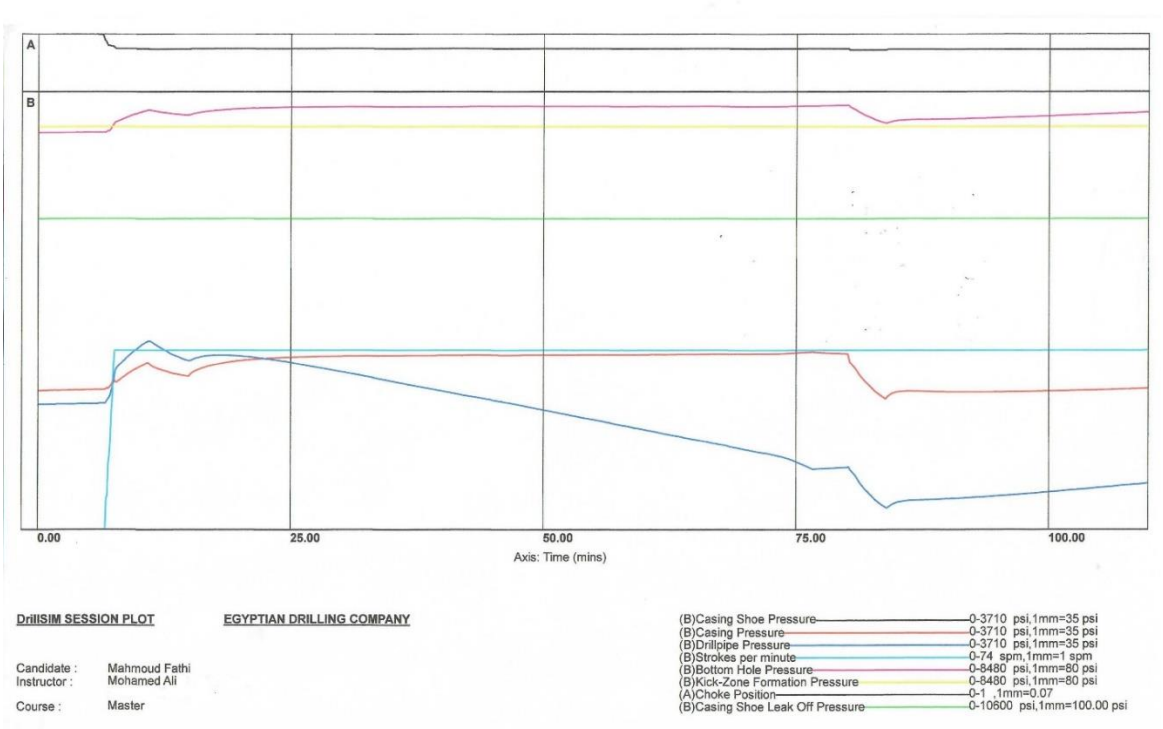

Figure 2. Driller's method, small open hole, small influx volume
where: X-axis describes the time for killing operation in minutes; Y-Axiss describes pressure in psi while killing operation (all scales as per table at the bottom of figure)

2.3.2. Wait and Weight method small open hole, small influx volume

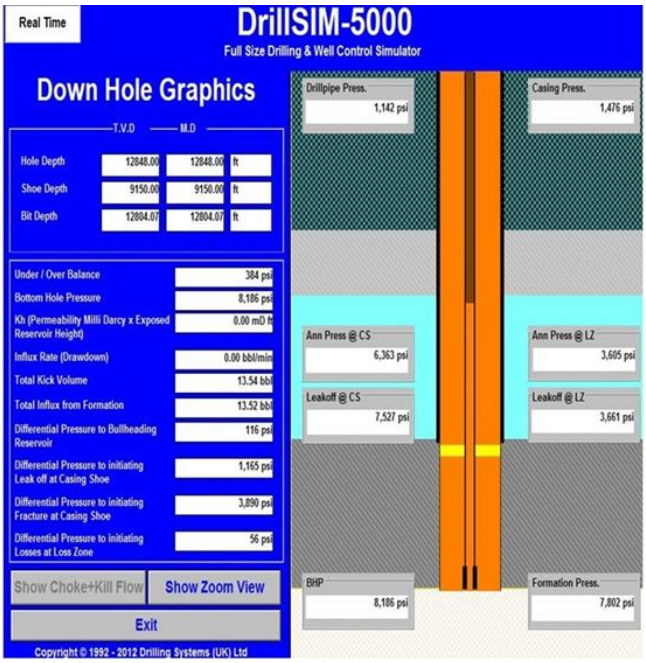

Figure 3. Wait &Weight method, small open hole, small influx volume, top influx at the casing shoe

In this case, we assumed that we had taken a kick volume 12.8 bbl., and the well was shut in and recorded shut-in drill pipe pressure (SIDPP) and shut-in casing pressure (SICP) as follows: SIDPP = 1140 psi (from remote choke panel); SICP = 1475 psi (from remote choke panel).

After starting the circulation, the influx out with original mud weight, and we can notice that the MAASP limitation to get a leak below the shoe at the time of shut-in is 1553 psi, as shown in Figure 3. From Figure 3, when influx top at casing the MAASP tolerance is 1165 psi, and we got almost the same tolerance value in driller's method.

2.4. Large open hole/Large influx volume

2.4.1. Driller method: Large open hole/Large influx volume

In this case, we have taken a kick volume 80 bbl's, then the well shut-in and recorded shut-in drill pipe pressure (SIDPP) and shut-in casing pressure (SICP) as follows:
SIDPP = 1140 psi (from remote choke panel); SICP = 1900 psi (from remote choke panel).

When we start circulating the kick influx out of the hole with original mud weight, then we can notice that the MAASP limitation is very near to get a leak below shoe at the time of shut-in is 306 psi shown in Figure 4.

Figure 5 shown that, when the influx top reached the casing shoe the MAASP tolerance value was only 68 psi with keeping overbalance 150 psi, this MAASP tolerance value is very low and will be very difficult to control this small tolerance value on rig site while killing the well which may lead to a high probability to break the formation below the casing shoe.

In addition to we will notice from killing operation shown in Figure 6 that the shut-in casing pressure (SICO) trend is very close to MAASP value during killing process which is very critical and may cause excessive stresses on casing shoe especially in case of any downhole equipment failure encountered during killing, moreover if there is any delay in response to close or open remote choke valve will affect directly on annulus pressure value below casing shoe and may lead to breaking the formation below casing shoe.

From all data collected from below graphs will notice that we have low tolerance between SICP and MAASP when compared with wait and weight method due to the high gas expansion while circulating the gas influx out of the well this happened due to large open hole and large influx and will be considered as a severe situation to control the well as per shown in Figure 6.

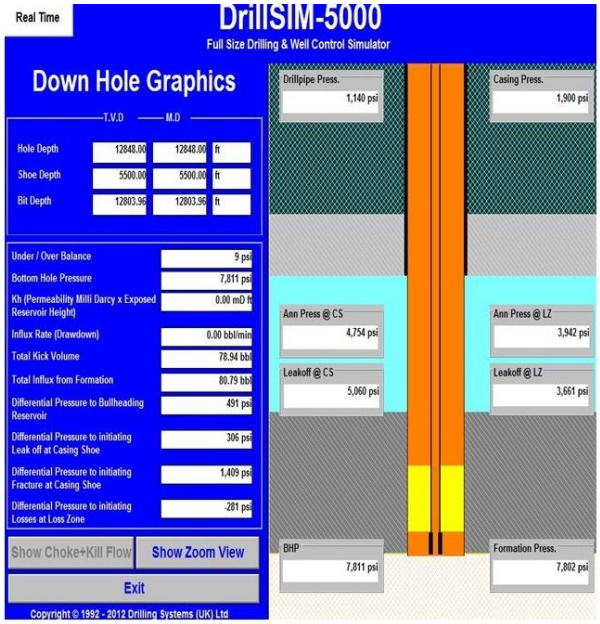

Figure 4. Driller's method, large open hole, large influx volume, after well shut-in

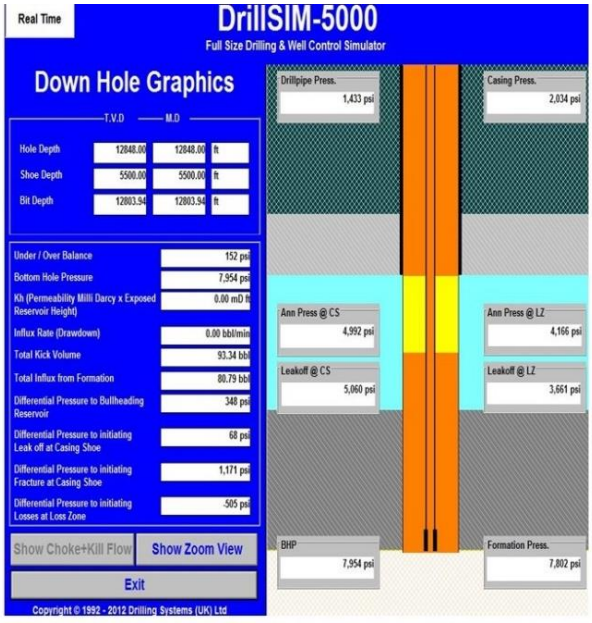

Figure 5. Driller's method, large open hole, large influx volume, Top influx at the casing shoe

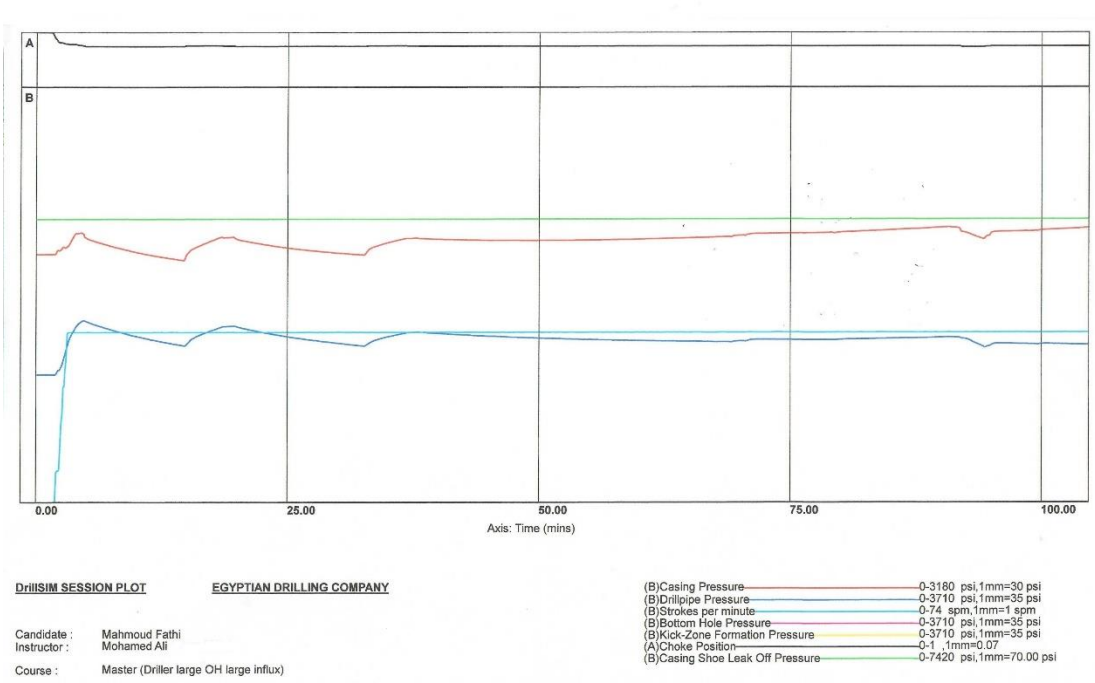

Figure 6. Driller's method, large open hole, large influx volume
where: X-axis describes the time for killing operation in minutes; Y-Axis describes pressure in psi while killing operation (all scales as per table at the bottom of figure)

2.4.2. Wait &Weight method (Large open hole/Large influx volume)

In this method, assumed that we have taken a kick volume 80 bbl's, then the well is shut-in and recorded shut-in drill pipe pressure (SIDPP) and shut-in casing pressure (SICP) as follows: SIDPP = 1210 psi (from remote choke panel); SICP = 1950 psi (from remote choke panel).

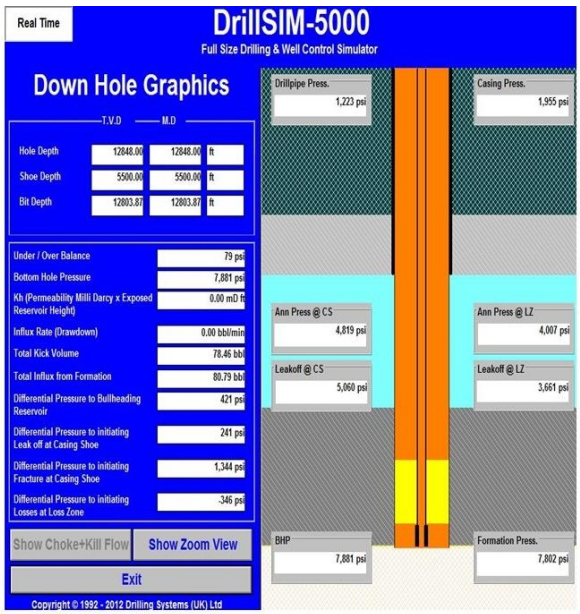

Figure 7. Wait &Weight method, large open hole, large influx volume, after well shut-in

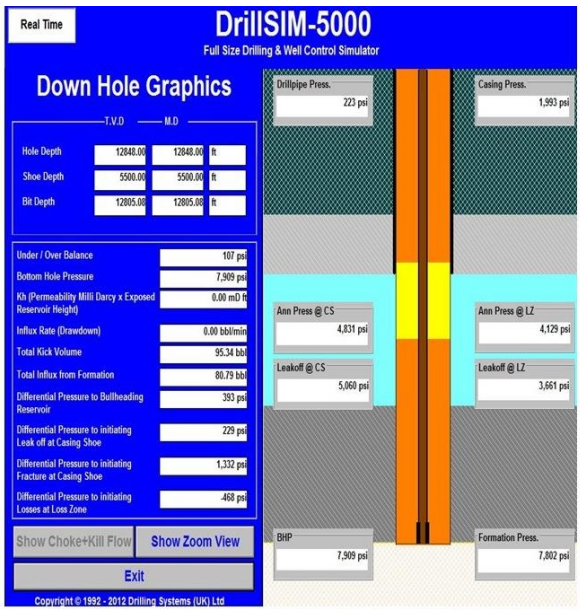

Figure 8. Wait &Weight method, large open hole, large influx volume, top influx at the casing shoe

When we start to circulate the influx out with original mud weight, we can notice that the MAASP limitation to get a leak below shoe at the time of shut-in is 241 psi shown in Figure 7.

Figure 8 shown that when influx top at the casing, the MAASP tolerance was 230 psi with overbalance 150 psi, which is a low tolerance for MAASP, which is better than the driller's method.

In addition, we will notice from killing operation shown in Figure 9 that the SICP line has more MAASP tolerance rather than driller's method SICP values.

In spite of killing mud interred annulus, we still have low tolerance between SICP and MAASP due to the high gas expansion while circulating the gas influx out of the well. We have a huge gas expansion due to a large open hole and getting high SICP value during killing due to large open hole and large influx, which is considered as a severe situation to control. The MAASP tolerance value is greater than the driller's method when the kill mud weight in annulus contributes to decreasing the pressure in the casing, which will make killing operation with Wait &Weight method become preferable than driller's method as shown in Figure 9.

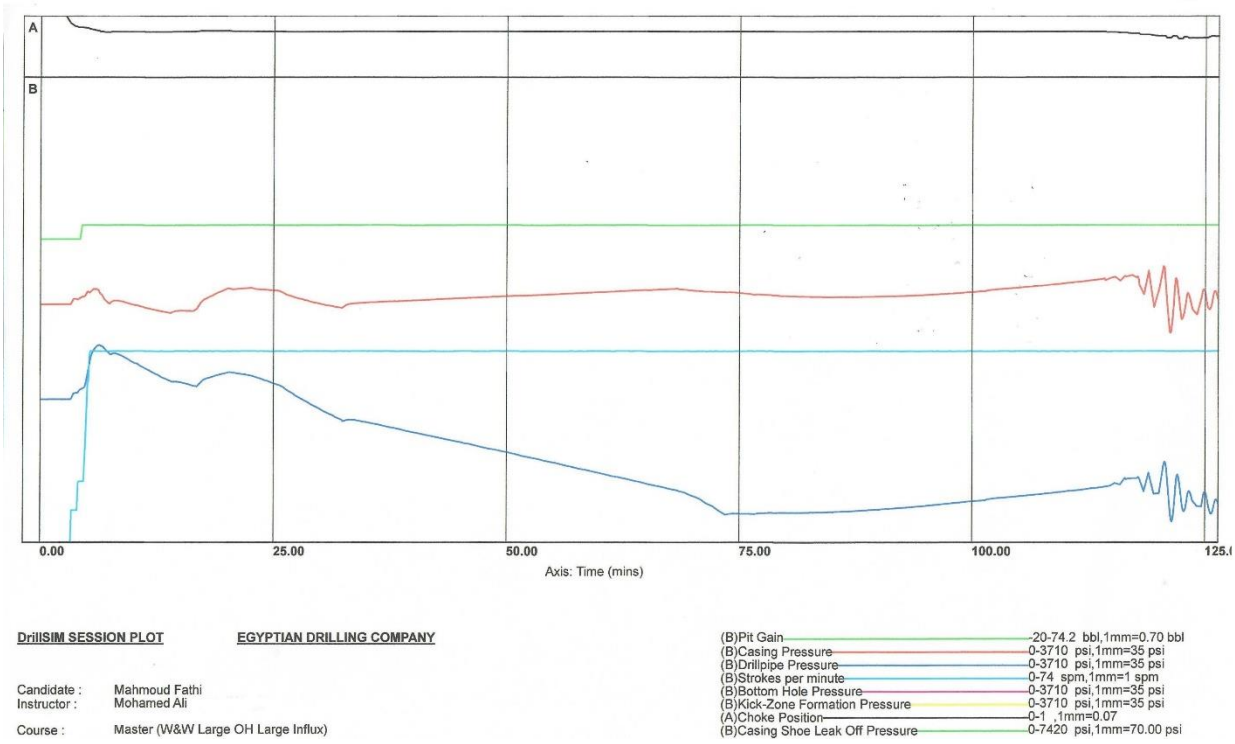

Figure 9. Wait &Weight method, large open hole, large influx volume
where: X-axis describes the time for killing operation in minutes; Y-Axiss describes pressure in psi while killing operation (all scales as per table at the bottom of figure)

3. Results and discussions

3.1. Case#01 discussions

From the discussed well-killing graphs for killing the well with wait and weight method and driller's method for small open hole kick (drill string volume less than annular volume), we can notice that both methods have almost the same MAASP tolerance value as long as kill mud weight still not reached the annulus. In the W&W method, which will have values very near the driller's method, therefore the kill mud will have no effect on casing pressure as long as the gas influx already reached the casing shoe before kill mud reached the annulus. Therefore, in this case, the driller's method and wait and weight method have the same preference from well control side to kill the well in a safe way. However, if the time taken to prepare the kill weight mud is very long with the chance of gas migration, this will lead to increase shoe pressure. This will result in a force the operator to use driller's method. The waiting time for

preparing mud in the W&W method will create more shoe pressure due to the gas migration during the preparation, so the driller's method will be preferred in a small open hole case.

When hole problems were expected and a time to prepare killing fluid was long, the drill string becomes stuck due to no circulation is achieved while building mud. The driller's method will be preferred in this situation when circulating the influx out of the hole immediately after pressures stabilizing without waiting for mixing. This action will minimize the chance to get stuck because we kept circulation most of the time, and the expected hole pack off issue was avoided.

3.2 Case#02 discussions

From the previous output date from the drilling simulator, it is clear that while killing the well with the situation of the large open hole along with large influx volume, the Wait &Weight will significantly reduce shoe pressure as the kill weight mud goes into the annulus before the top of gas arrives at the shoe. In addition, the MAASP tolerance values with Wait & Weight method are suitable to kill the well with saving SICP value in order to avoid the formation fracture (leak-off) below casing shoe.

Table 1. Comparison between MAASP tolerance value for Driller's & wait & weight method (Large open hole/large influx volume)

Large open hole, Large influx volume	Driller's Method	W&W method
MAASP tolerance when top in-flux @ casing shoe	68 psi	230 psi
Overbalance while killing	150 psi	150 psi

4. Conclusions and recommendations

As long as we have small open hole regardless, we have large or small influx volume. The casing pressure value will be the same in both methods, then the top of influx reaches the casing shoe (maximum casing pressure value). The pressure will start to decrease when kill mud starts passing from the bit, but it will be useless as influx when it passed into casing shoe, this situation driller's method and wait & weight method will have the same preferences. The time and associated hole problems only will affect on the decision which method we have to apply. However, from well problems side driller's method will be preferable as circulation achieved as soon as pressure stabilized to avoid any stuck pipe issue, so Driller's method will be recommended.

As long as the well has taken a kick in Large open volume (open hole volume greater than drill string volume) in the case of the SICP, which will be greater than normal. Moreover, if we have low tolerance with MAASP value when using driller's method, this will create more SICP reading due to excessive gas expansion in annulus while circulating kick out. Wait & weight method will be recommended in large open hole volume with associated large influx volume.

As long as well open hole is considered as a long open hole section is likely to prefer the Wait & weight Method as we considered a large influx of gas that will expand in the annulus below the shoe, in addition, it has seen from simulator output data that we have more MAASP tolerance in W&W method which will let us kill the will safer than driller's method, so following W&W method is better to avoid risk of MAASP tolerance reduction.

Nomenclature

BHP	*Bottom Hole Pressure,*	*Bbl's*	*Barrel,*
W&W	*Wait and Weight,*	*SIDPP*	*Shut In Drill Pipe Pressure,*
MAASP psi	*Maximum Allowable Annulus Surface Pressure, pound per square inch,*	*SICP*	*Shut In Casing Pressure.*

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To whom correspondence should be addressed: Dr. Mahmoud Fathi, Mining and Petroleum Department, Faculty of Engineering, Al-Azhar University, Cairo, Egypt, E-mail: mahmoud.fathi111@hotmail.com