New dynamic low choke method kills wells at balance point using surface-applied pressure

By Javed Shah, Well Control Group

IN A WELL control situation when the casing pressure reaches the maximum allowable casing pressure (MACP), the choke operator reacts by opening the choke to keep casing pressure at MACP, thus reducing the bottomhole pressure (BHP) and inducing a bigger kick. Even when the gas is at surface, the casing pressure is kept at MACP, making the situation worse.

The low choke method of well control — used in killing wells where the casing pressure is at MACP — has major shortcomings, such as what shut-in drill pipe pressure (SIDPP) is being killed by pumping heavier-density mud and what is happening to the hydrostatic pressure in the wellbore.

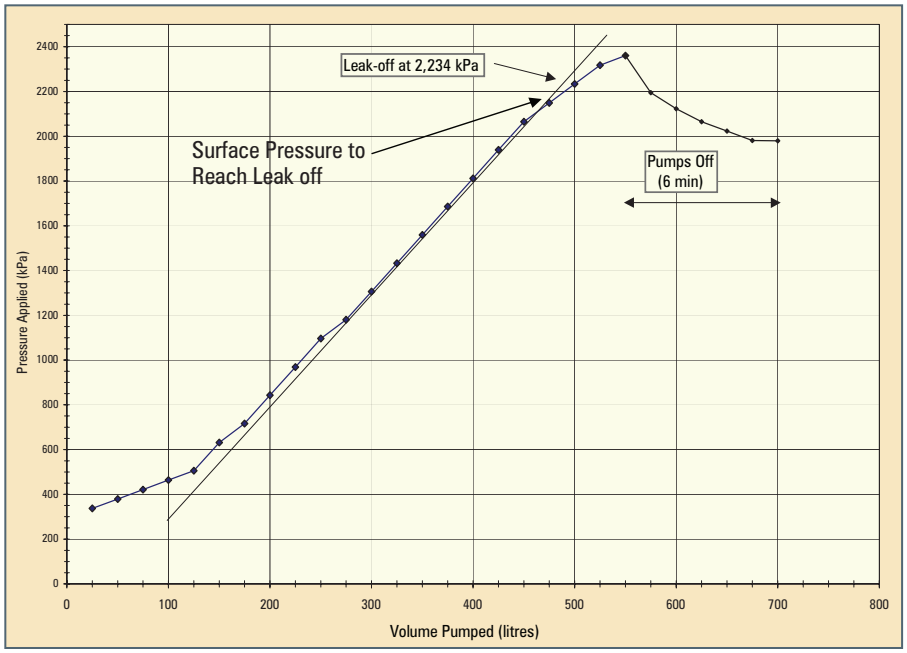
A new approach to well control has been developed to address the situation when the casing pressure reaches MACP while circulating a gas kick. It allows operators to control the well and kill the well at a balance point — exactly increase the mud density in the well to balance the SIDPP after the kick has been circulated out of the wellbore. This method was developed to utilize surface-applied pressure to control bottomhole pressure.

This article describes the sequence of pressures being applied to the wellbore as the drilling continues and after the kick is taken. The pressure applied at the casing shoe and the bottomhole pressure are presented during the kick circulation. Details will be provided on the well control method as applied to circulate the kick out and control bottomhole pressure by exceeding the MACP (with gas at surface) without losing control of the well or compromising wellbore integrity.

DRILLING, PLANNING

When the drilling of a well is undertaken, certain guidelines must be established in order to drill the well without setbacks that can lead to the total loss of the well. The drilling program specifies the casing setting points, the drilling fluids to use, the types of bits to be used, well head equipment and the desired pressure rating of the well control equipment.

The drilling rig and well control equipment selection is based on expected



If a formation leak off test, shown in graph above, is required in the drilling program, the wellbore is pressured up to the point of breakdown.

total depth of the well and pressure prediction of the formations to be drilled. The rig selection process ensures that the rig will be capable of drilling the well safely and efficiently. The pressure rating of the well control equipment, such as blowout preventers and choke manifold, deployed, while drilling the well, is capable of containing the expected formation pressures. The well control equipment installed should be able to shut in the well and contain the well pressures with or without the drill string in the hole.

A well-trained drilling crew will recognize the kick warning signs and be able to shut in the well in case an influx of the formation fluid enters the wellbore.

SHALLOW GAS ZONES, DIVERTER PROCEDURES

The surface hole is drilled using a conductor set and cemented at a depth of 20 m (±60 ft) to 30 m (±100 ft). There is no well control equipment installed at this time. If shallow gas zones are expected, a diverter is installed to divert the unwanted influx from shallow gas zones away from the rig. The well is never shut in to avoid gas broaching around the conductor. If the integrity of the conductor shoe is lost, the gas would broach to surface around the conductor, and all well control would be lost. Therefore, the well is never shut in, wellbore fluids are diverted away from the rig, and the well is circulated over to heavier drilling mud to control the formation pressure and kill the well.

Pumping of the kill mud takes place at a high rate of circulation to outrun the unwanted influx entering the well. The shallow gas zones are limited in extent and usually deplete soon. Most operators avoid drilling in areas that are prone to shallow gas-bearing zones.

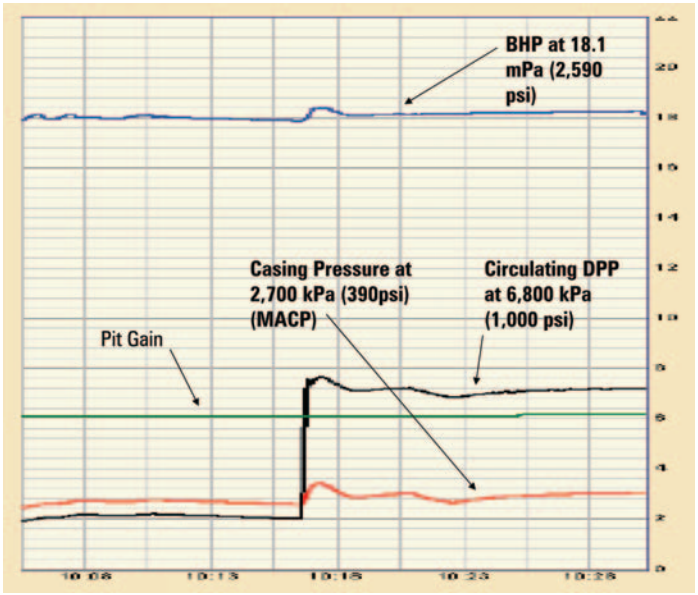
Surface hole drilling continues to the surface casing setting point. At this time, surface casing is run into the hole and cemented in place. The program-recommended BOP stack arrangement is rigged up and pressure-tested as per regulatory standards. The stack will usually contain an annular BOP, one or two sets of pipe ram BOPs (to close in the well around the drill pipe to be used), and one ram BOP having blind rams (to close in on the open hole) when the drill string is out of the hole.

TESTING

After the surface casing shoe is drilled out and 5-10 m (15-30 ft) of new hole is drilled, the drill cuttings are circulated

out of the well. Using a high-pressure, low-volume pump, the formation strength (of the formation exposed below the casing shoe) is established by carrying out a formation integrity test (the pressure being applied at the casing seat is predetermined, usually in the range of 18.1 kPa/m (0.8 psi /ft), and the pump is stopped when this pressure gradient is reached).

If the drilling program calls for a formation leak off test, the wellbore is pressured up to the point of breakdown. The pressure applied at the casing shoe at this time is the sum of hydrostatic pressure (HP) (at the casing seat) and the surface-applied pressure.



In Pressure Test #3 on the wellbore, with circulation started, the pressure applied to the open hole during kick circulation is SIDPP + HP + APL + overkill.

Leak Off Pressure (LOP at casing shoe) = Surface Applied Pressure (from the graph) + HP (at the casing seat).

These pressure tests are used to establish the MACP by using the following equation:

MACP = LOP – HP (at the casing seat of the drilling mud in use).

The MACP information is updated for the drilling crew as the drilling densities change with the wellbore depth. A new leak off pressure is only established after the intermediate casing string is installed/cemented in the well and the intermediate casing shoe is drilled out.

When a unwanted influx enters the well, the appropriate BOP is closed to contain the wellbore pressures and to prevent the wellbore fluids from venting at the rig floor. The release of the fluids (under pressure) is facilitated using the choke at the choke manifold, which is located usually about 25m (75 ft) away from the drilling rig and the well centre.

PRESSURE TESTS

Pressure test #1: Until the well experiences a kick, the only pressure test on the well is hydrostatic pressure and the annular pressure loss (friction pressure lost while pumping the drilling mud from total depth to surface).

Pressure Test #2: After the kick is taken, the well is shut in, and the pressures are allowed to stabilize. The pressure test at this time on the well is:

Hydrostatic Pressure + Shut In Drill Pipe Pressure.

This test is like a reverse leak off test. Pressure is applied by the formation instead of a high-pressure pump. If the wellbore integrity is lost at this time, the drill pipe pressure would drop from a higher pressure to a lower pressure.

The industry, as a general rule, emphasizes not exceeding MACP while circulating the kick out of the well. This leads to the problem of not even exceeding the MACP with the gas at surface, as no guidelines are available.

Usually a MACP number with gas at surface is posted at the drilling rig on the assumption that all mud from the annulus has been displaced by gas. This would be possible if the well were opened up completely and all the wellbore fluid is blown out of the well. The new MACP is calculated (with gas at surface) by multiplying the leak off gradient with the shoe depth. In this approach, gas density is ignored, with no consideration being given to the amount of gas in the returning mud, giving a very high number for MACP.

In reality, after setting the casing, usually a leak off test is not done, and all the MACP calculated numbers are based on assumed leak off gradient. Usually the leak off gradient is 18.1 kPa/m (0.8 psi /ft). The formation may or may not hold this equivalent leak off gradient. In the absence of a leak off test, the casing cement job integrity is also questionable. Even if a leak off test is conducted, as soon as the drilling continues further, the open hole section exposed below the shoe does not get tested to more than the annular pressure loss and the hydrostatic pressure unless open hole leak off tests are done and MACP adjusted accordingly to a higher or lower value.

Choices for well control methods, under normal conditions, have been:

1. DRILLER'S METHOD

The driller's method is simple and done in two steps. First, the gas influx is circulated out. Second, the well is displaced to kill mud density to balance the shut-in drill pipe pressure. This method's big advantage is that the circulation can start as soon as the well shut-in pressures have stabilized.

2. WAIT AND WEIGHT

The wait and weight method applies when the casing shoe is set deep in the well. There is no concern with the casing pressure reaching MACP. Usually the formations exposed below the casing shoe have high fracture pressure. If the well is a high-pressure, high-temperature prospect, the drilling fluid density is quite close to the maximum fluid densities that can be used in the well. Therefore, there is still a chance that the formation might break down. Since the well is deep, there is no chance for the fracture to broach to surface. Loss of circulation can be treated with loss-circulation material. As the well is deep, the kick will be circulated out and the well displaced to kill fluid at the same time.

3. CONCURRENT METHOD

The concurrent method of well control is designed to circulate the kick out and partially kill the well in the first circulation. In subsequent circulations, the well can be balanced and mud system evened out. As the weight material is added to the mud being pumped down the drill pipe, the mud properties have to be conditioned for the drilling to continue.

Choice of the well control method depends on the surface casing setting depth, the surface shut-in pressures, migration rate of the gas influx, and barite mixing capabilities of the rig.

All these methods can be implemented if there is a big difference between the SICP (shut-in casing pressure) and the posted MACP. Most often the room to MACP (difference between SICP and MACP) is a function of kick volume in the well and not a function of abnormal formation pressure. The volume of kick in the annulus dictates the SICP. Therefore the larger the kick volume in the annulus, the more chances that casing pressure will reach MACP during the circulation. During the initial start of circulation of the kick, the well is subjected to Pressure Test #3, in which the pressure applied to the open hole during kick circulation is SIDPP + HP + APL + overkill.

Once the initial circulation pressure is established, with no drop in the drill pipe pressure, it can be said that the open hole is capable of handling this applied pressure.

Established pressure is RSPP + SIDPP + APL + Overkill (if any is used).

There have been no guidelines for the operators to follow when the casing pressure is close to MACP or is going to exceed MACP on initial shutting-in of the well. All established well control procedures emphasize not exceeding the posted MACP, when the casing pressure reaches this pressure. This could happen on initial shutting in of the well or during the circulation of the initial kick. While circulating the influx out of the wellbore, if the MACP is reached, the rig crew controls the casing pressure at the MACP by keeping the casing pressure constant.

The only available method of well control has been the low choke method of well control. This method calls for increasing the pump speed to drilling rate, hold casing pressure at the posted MACP and start adding barite to increase the density of the mud in the well.

LOW CHOKE METHOD

The method calls for opening the choke, holding casing pressure at MACP, starting pump at drilling rate and adding barite at ±2 sacks of barite per minute. It further calls for the crew to keep pumping the heavy fluid into the well until the well is killed.

Draw back to this approach has been:

• Barite should be available on location.

• At higher rates of pumping, what is the probability to wash out the choke or surface equipment?

• What happens to the hydrostatic pressure in the well when the crew adds ±2 sacks of barite in the mud system through the hopper?

• The barite-carrying capabilities of the mud is not even considered, so it could settle out as soon as the circulation is stopped.

Initially when the addition of barite is started, the differential pressure between the drill pipe and annulus increases, forcing the casing pressure to increase. The choke operator is trying to keep the casing pressure at MACP, therefore the choke has to be opened more to control the pressure. As the choke opening is increased, the bottomhole pressure reduces, increasing the chances of letting more influx into the well until the heavy mud turns the corner at the bottom of the drill pipe. Whenever the low choke method is applied, sooner or later both chokes are wide open and the straight thru line in the manifold is opened. All the mud is circulated to the flare pit, and the mud volume has to be rebuilt before well control operations can continue.

The dynamic low choke method was developed to give an alternate method to apply when the shut-in casing pressure is close to MACP on initial shut-in or the shut-in casing pressure is going to exceed the posted MACP and the gas is at surface.

The method utilizes surface applied pressure to control bottomhole pressure, without barite addition. After the gas has been circulated out of hole, the mud density can be increased exactly to kill the well at a balance point as it can be based on the shut-in drill pipe pressure.

It is common knowledge that the hydrostatic pressure at the casing shoe reduces drastically once the gas is at surface. With gas at surface, if the choke is closed instead of being opened (to keep the casing pressure at MACP), the casing pressure starts to rise and MACP is exceeded. The bottomhole pressure also starts to increase, and the entry of the second kick starts to slow down and eventually stops. As soon as the drill pipe pressure reaches the original established initial circulating drill pipe pressure (Pressure Test #3), the operator can maintain the circulating drill pipe pressure.

Although the MACP has been exceeded, the well has not seen any extra pressure than what was already applied to it earlier in the circulation. If the wellbore integrity was there earlier, why should it not be there a few hours later?

In a situation where the operator is already at MACP as soon as an attempt is made to shut in the well, the same approach can be taken and casing pressure can be increased gradually.

If the drill pipe pressure keeps increasing along with a reduction in the pit volume, the wellbore integrity is apparent under dynamic conditions. If while increasing the casing pressure, no increase in drill pipe pressure is observed, partial loss circulation is indicated and the casing pressure can be backed off to cut down on the partial losses. Using the pressure approach is better to establish the true SIDPP before increasing the density. After the kick has been circulated out, the well can be shut in and the overkill bled off to establish a true shut in drill pipe pressure.

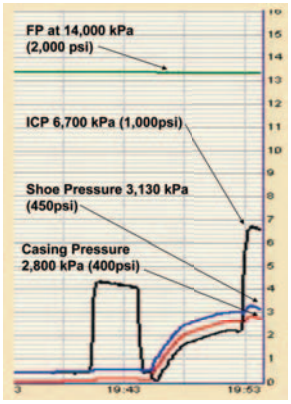
Javed Shah is a professional engineer and has 24 years of experience with well control operations and training.

This article is based on a presentation scheduled for the IADC Well Control Conference of the Americas, 28-29 August 2007, Galveston, Texas.

Dynamic Low Choke Method

Well is shut in and shut-in pressures are established, but the SICP is close to MACP (100 kPa or ±30 psi below MACP): **No gas at surface**.

1. Open the choke and bring pump to reduced speed (allows better control of choke and reduces chance of washing out surface equipment).



2 - Circulating kick (casing pressure at MACP)

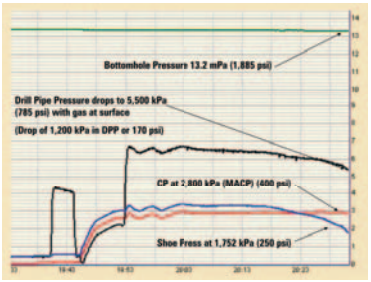
2. Hold casing pressure at MACP. Record the circulating drill pipe pressure.

As the kick is circulated to surface, the drill pipe pressure will drop and there will be a continuous feed of formation fluids into the well, making it impossible to keep bottomhole pressure above the formation pressure.

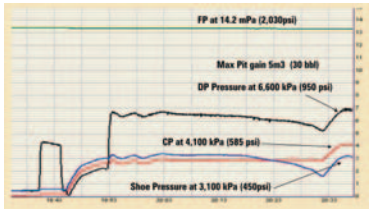
3. Once the kick is at surface, calculate the drop in circulating drill pipe pressure.

4. Start closing the choke to exceed the MACP by the amount of drop in drill pipe pressure until the drill pipe pressure is at the original circulating drill pipe pressure (recorded in step 2).

As the gas entry at the bottom of the well is stopped, the pit volume will start to reduce. This indicates that the bottomhole pressure is now higher than the formation pressure.



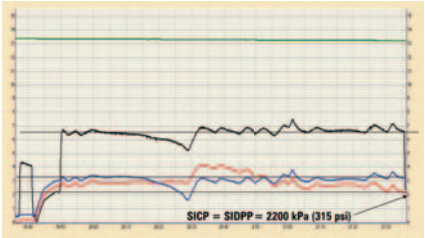
4 - Gas at surface



5- MACP exceeded by 1,200 kPa

5. Keep the drill pipe pressure constant at this pressure until all the kick is circulated from the well.

6. Stop pump and shut in the well. Check pressures. Shut-in drill pipe pressure and shut-in casing pressure should be equal.

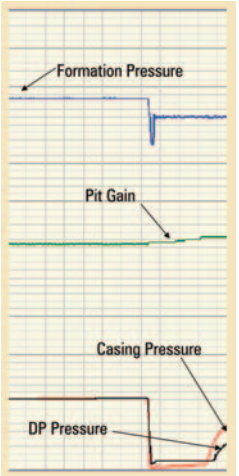


6 - Gas circulated out and well shut in

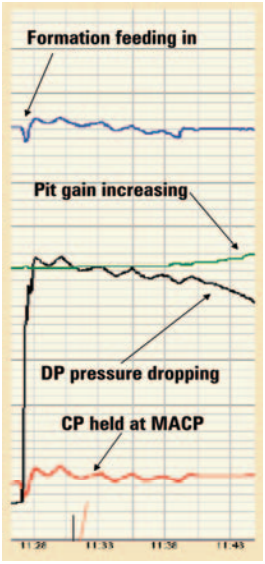
Now the kill mud density can be mixed and well circulated over to kill mud, using step 2 of the driller's method.

Unable to shut in the well: **Gas at surface**.

1. Open the choke and bring pump to reduced speed.



1 - Kick taken, CP at MACP



2 - circulating with CP at MACP

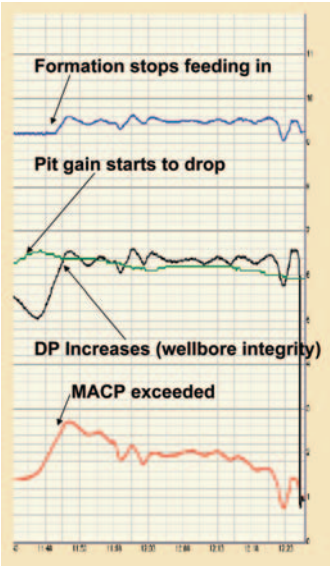
2. Hold casing pressure at MACP. Establish the circulating DP.

3. As circulation continues, close the choke and increase the CP by 200 kPa (30 psi or one gauge division) each time.

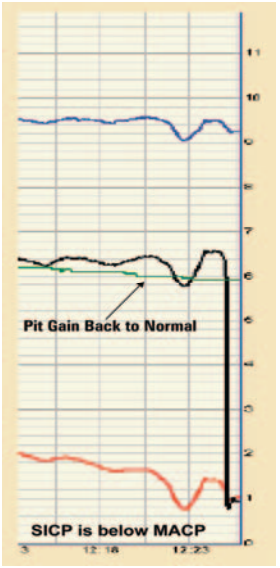
Observe the DP pressure for an identical increase (indication of wellbore integrity).

4. Keep increasing the casing pressure until the pit gain stabilizes (pit gain should stop increasing at a rapid rate as formation stops feeding gas into the well, and pit gain starts to drop, with drill pipe circulating pressure staying stable). Record the circulating DP pressure.

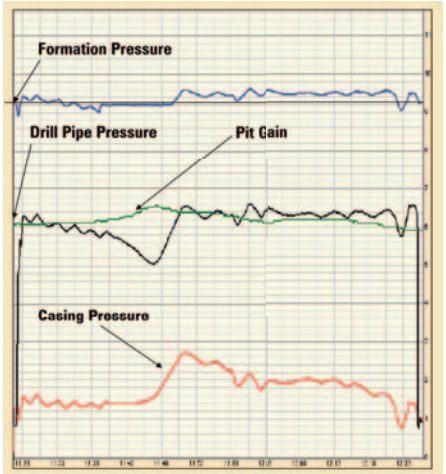
5. Now keep the DP pressure constant till all the kick is circulated out and the well can be shut in.



4 - Exceeding MACP



5 - Well shut in with CP below MACP



Dynamic low choke - with gas at surface and CP at MACP

Kill mud can be now mixed to the correct density and step 2 of the driller's method used to displace the well to kill mud.