OOPS! Now what? Or How Fast is a Blowout anyway?

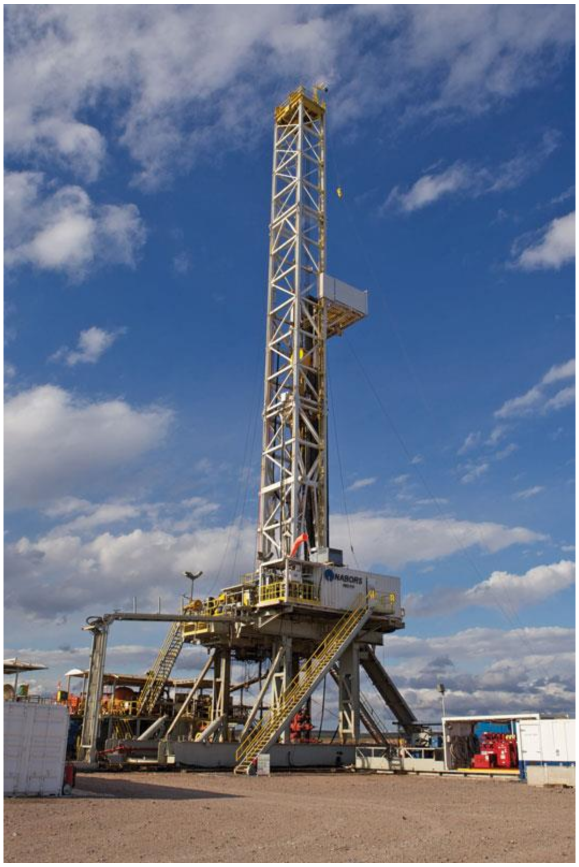
For anyone in the oil and gas industry from the assistant water hauler to the CEO's of some of the world's largest companies, and for the public from fisherman to computer analysts a blowout is universally a bad thing. The exact consequences and feelings are different for different groups, but the desire on the part of everyone is the same: Don't let it happen. What will you do about it if things go badly on your wellsite? What are your plans? This started as an article about well control and well barriers in general, but the more it developed, the more I realized that understanding the time available to act is more important than almost any other factor. For our analysis today, you will need a bottle of beer in a clear or light colored bottle. If you don't have a beer you are stuck with your imagination.

What is well control?

The simplest definition of well control is: measures taken to prevent the influx of oil and gas by maintaining sufficient hydrostatic and backpressure to balance the formation pressure. This simple definition leaves out a lot of things. You cannot maintain pressure of some sort without something to contain it in. Open a bottle of beer and the carbonated bubbles start coming out (do not open your bottle of beer yet). In order to maintain pressure control there must be a series of objects processes and measurements which combine to keep the pressurized fluid where it is or moving to and from known places at known rates. For the beer, the bottle and the cap, before it gets opened is the beer barrier envelope, and it keeps the beer inside. For a well, the things that keep the fluids inside of are the **well barrier envelope**. Any time fluid is moving around in the well to or from an unknown place, and/or at an unknown rate there is some sort of a well control issue involved because the well barrier envelope has been broken.

Why is well control so hard?

Make certain to prevent the well from flowing at all times. Unless you want it to flow. And here come the complicating factors. We do not want a static situation. The static situation is oil and gas in the ground minding its own business. We want to make a change and get it to surface where it can be used. Every time a change is made the potential for an error in timing, communication, materials, measurements or a thousand other things introduces the potential for a problem. Just as bottles of beer don't usually spontaneously burst so to wells don't usually spontaneously blow out. Some other action and change to an otherwise stable system has to take place to set off a problem.



How do we get from point A: To point B?

The True enemy of well control: gas expansion!

The reason that beer can fizz up and make a mess if it is opened improperly is because it contains a volume of CO_2 gas dissolved in the liquid phase of the beer. This CO_2 gas is kept in the liquid phase of the beer because it is being held under pressure. The pressure was applied when the beer was put in the bottle, and held in place with the cap. Oil in a well works the same way, except that most of the gas dissolved in oil is wonderfully flammable methane – aka natural gas aka CH_4. Oil and gas have an extra trick though – when it is under a high pressure, natural gas doesn't merely get dissolved into the oil – it actually joins the liquid phase completely in solution. Now we come to where beer and hydrocarbons in the well start to differ. Beer is bottled at 10-15 psi of pressure – about 1 atmosphere (atm) and contains ~ 2.5 units of CO2 gas for every unit of liquid beer – certainly enough to empty the bottle or keg if its opened up and all the gas is discharged at once, but it only gradually comes out of solution unless shaken or agitated in some way to increase the diffusion rate of the gas through the liquid, and chilling it in a refrigerator is sufficient to ensure that it comes out of solution so slowly that it doesn't build up any considerable flow capability. Oil typically is at somewhere around 4,000 psi of pressure – about 275 atmospheres, and while it varies a lot commonly contains somewhere in the range of 100 units of methane gas for every unit of liquid oil. This is 275 times the pressure of the beer, and about 40 times as much gas. These differences matter a lot. When the pressure is decreased, the gas comes out of solution much more easily because the amount of gas is much larger, and the potential differences in pressure between the steady state starting pressure and other possible pressures is so much greater. The following set of diagrams illustrate how this process occurs as a very small kick is circulated from bottom to the surface, if no remedial actions are taken, using a 1 unit kick in a system 100 units in size:

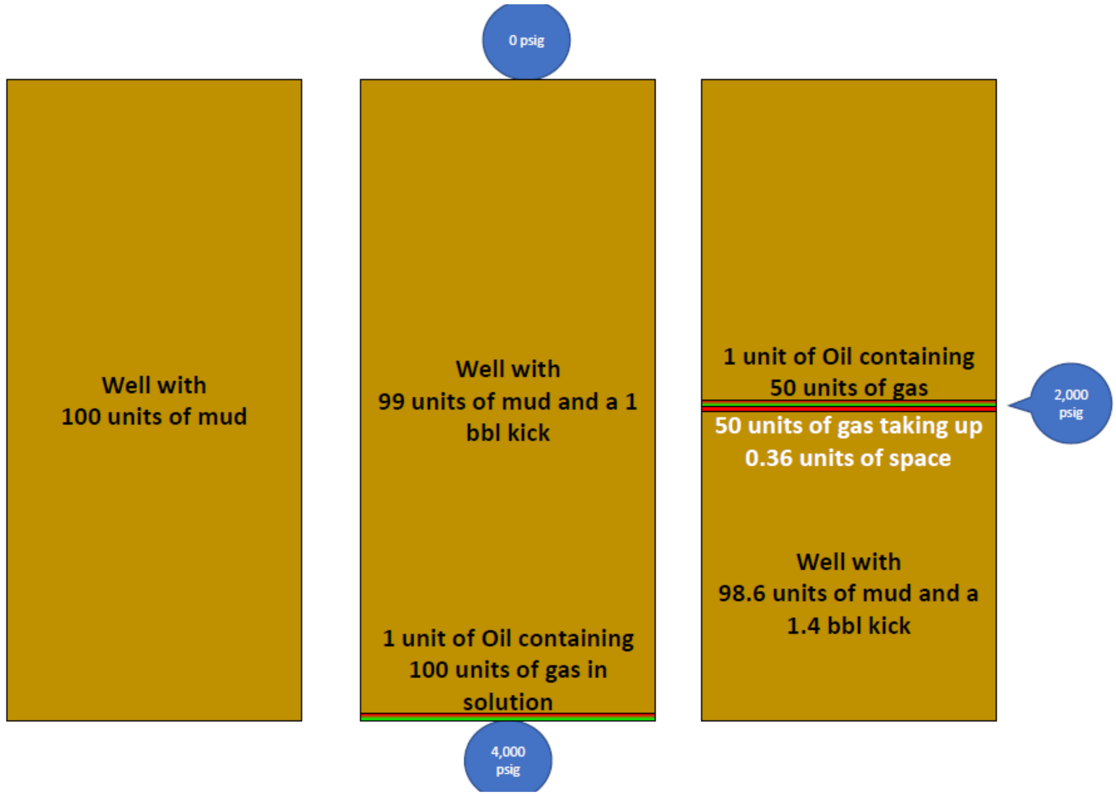


Figure 1: A kick 1 unit in size is taken on bottom while circulating. The gas dissolved in the oil begins to come out of solution and expand as it moves up the hole, and the confining pressure from the column of fluid above it decreases.

Figure 2: The remaining gas in solution leaves the oil and continues expanding at a much more noticeable rateas it comes close to surface.

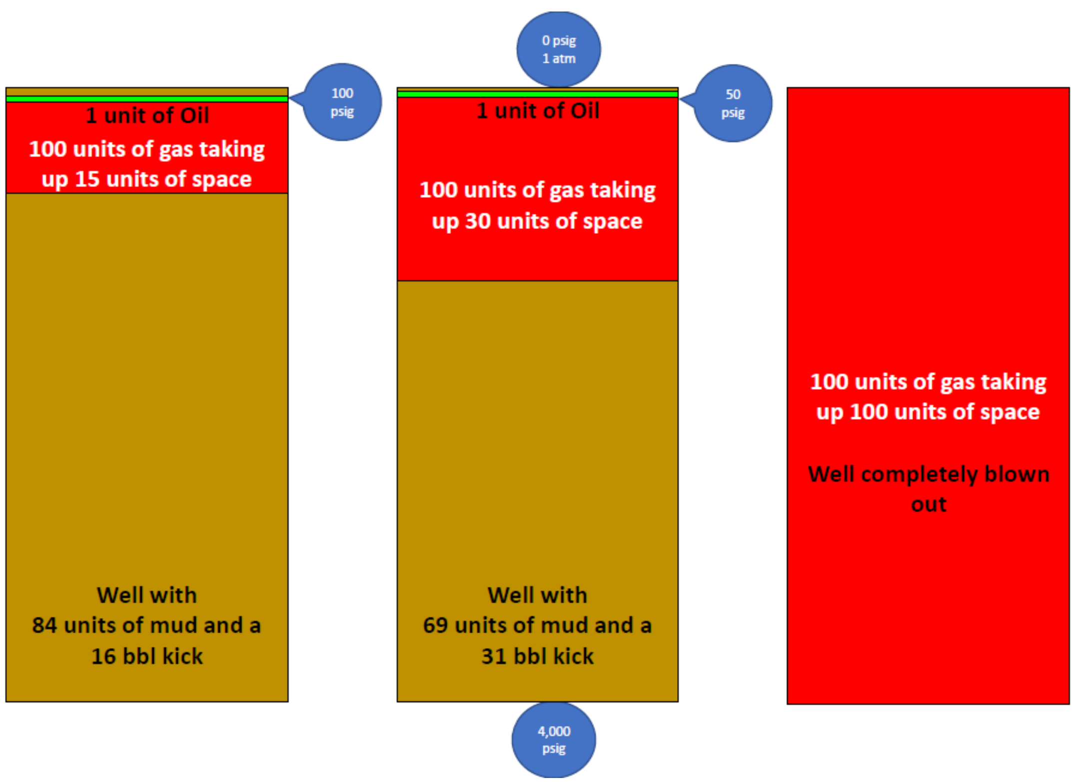


Figure 3: Expansion becomes exceedingly large and rapid immediately before the gas reaches the surface, and boom!

Diagrams like these are available in every well control textbook and class and demonstrate how the rapid expansion of gas as it nears the surface creates rapid changes in well conditions. And rapid is the key word in all this. The diagrams seem to suggest that each stage takes place over the same amount of time, but nothing could be further from the truth. Typical circulation rates in the oil and gas industry either drilling, workover or completion allow for turnover of the active wellbore volume (aka bottoms up) in the range of 1% of the well volume per minute. Under realistic field conditions, kick detection thresholds vary considerably with the equipment available, calibration, crew alertness, activity underway, weather conditions, etc. but generally kicks can be detected when a 1 or 2% change in surface volume takes place if things are working correctly. This means that the volumes in the diagrams above translate into the following sequence of events:

Time remaining	Pressure in kick	Kick size	action
100 minutes	4,000 psi (272 atm)	1 unit	Initial event, kick not detected
50 minutes	2,000 psi (136atm)	1.4 (0.4 unit increase)	Kick volume not detectable
25 minutes	1,000 psi (68 atm)	2.5 (1.5 unit increase)	***Kick detectable*** – first action threshold
12 minutes 30 seconds	500 psi (34 atm)	4 (3 unit increase)	Last opportunity to plan actions – last organized evacuation can take place
6 minutes 15 seconds	250 psi (17 atm)	7 (6 unit increase)	Last ***emergency actions*** can take place unorganized ***evacuation*** may be possible
2 minutes 30 seconds	100 psi (6.8 atm)	16 (15 unit increase)	Potential to ***run away*** quickly if conditions are excellent on land
1 minute 15 seconds	50 psi (3.4)	31 (30 unit increase)	***To late to run*** far enough to avoid serious injury from flying debris
0	0 psi (1 atm)		***Everyone nearby is dead -*** even if there isn't a fire.

The diagrams above and exact timing leave out a few details – for example more hydrocarbons will probably kick in at some point as the well begins to unload making matters worse, there are thermal effects, the gas has some density of it's own, etc. but the big picture timing and numbers remain correct. There is a window of time about 15 minutes long in which the problem must be identified, and some action taken to mitigate or reduce it before all hell will literally break loose.

Conclusions

In the event of an incursion of hydrocarbons containing gas into the wellbore during typical workover operations, there is not a lot of time to act. Prepared, trained and alert crews are one of the most critical elements of safe well work, and cannot be replaced by any amount of engineering ability, passive controls or equipment to ensure safety. The initial signs of a problem are very small and by the time they are obvious only herculean effort can get things back under control, and that is befoe even considering the risks and consequences. Now that you have completed this exercise, you may drink your beer.