Use of Explosives in Well Perforation

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I placed my hands on the tubing (carbon steel pipe) which protruded vertically from the rig floor. It was connected 2.5 km to below the surface. This was the moment I had been waiting for. Everyone went quiet. I gave the signal to release the mechanical bar to rupture the disc that would trigger a string of explosions underground. One minute… 2 minutes… 3 minutes passed. Then I felt the tubing shudder. This was an indication that the well had been perforated successfully. I beamed with excitement as this was my very first calculation of an underbalanced perforation using the Tubing Conveyed Perforation method. As a young engineer, I did not get the chance to really design, calculate, prepare and execute the procedure in the field until I had proved I was worthy of leading the whole operation. It was not an easy task; on my shoulders were the lives of the 128 people on board the drilling rig at that time. If I had made an error in calculation or if I hadn't followed the guidelines accurately or if I hadn't thought through the steps carefully, then I would be putting every single one of us in danger. As engineers, it is our responsibility to ensure the safety of everyone in all our projects.

This article is written to share the knowledge on the use of explosives in the oil & gas well perforation. Well perforation is an important segment of the process of well drilling and completion. After the drilling, running in casing and cementing are completed, the operation is shifted to completion phase.

Upon cleaning the wellbore, a gun is lowered to punch and create holes in the casing for fluids from the formation to flow in. Well perforation is complex, with many details that need to be described meticulously for a complete understanding. The writer will attempt to describe the process in a simplified manner for general understanding.

The purpose of well perforation is to provide a channel between formation (that contains hydrocarbon) and wellbore, which is separated by the cemented casing.

Figure 1 shows how this done. The first step is lowering a gun into the hole to the intended depth where there is good hydrocarbon potential. In the second step, the gun is fired, creating holes on the casing and cement to allow the communication from outside of the casing to inside. The third step shows that the holes created allows hydrocarbon to flow into the casing or wellbore area.

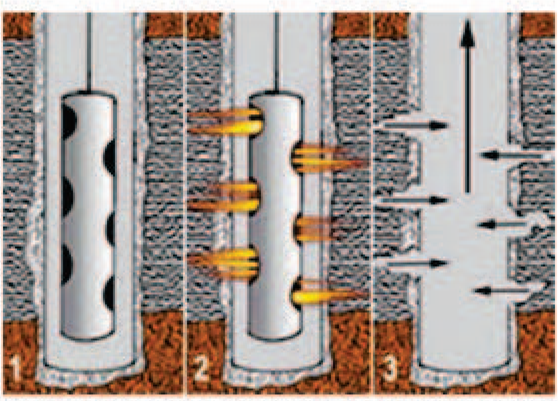

Figure 1: Gun lowered into the hole to perforate and create a channel for the flow (Source: http://mpgpetroleum.com/images/perfor.jpg)

LOWERING THE GUN

As mentioned at the start, we were performing a Tubing Conveyed Perforation. In this method, the gun is lowered to the intended depth. There are two methods to do this. The first method uses a strong wire, normally electric wireline, simply called E-Line. This line conducts electricity for information transfer to carry instruction from surface or to retrieve information from the bottom to the surface. Another is to use a wire called slickline, which is possible in newer technologies. It utilises fibre optic lines which can transmit data along the length of the slickline. This information allows very precise operations of various down-hole tools, including perforation guns.

The second method is to use either normal tubing or coiled tubing. This method is especially required when dealing with high angle wells. Imagine a piece of heavy equipment is lowered down the hole. Due to gravity and the weight of the equipment, this is naturally easy. However, high angle wells dampen this gravity effect due to contact with the hole wall and buoyancy force from wellbore fluids. So, to add the weight as well as move the equipment down the hole, solid body tubing is used instead of just wire.

PERFORATING TECHNIQUES

Another thing mentioned at the start of the article is that the perforation was done underbalanced. There are two variations in the perforating technique – overbalanced and underbalanced.

An overbalanced perforation means the casing is filled with fluids which will create higher hydrostatic pressure inside the casing compared to the formation pressure. Therefore, when holes are made during the perforation, the pressure from the inside casing will stop hydrocarbon or any other fluid from the formation to enter the wellbore. Hydrostatic pressure in the wellbore is larger than the formation pore pressure. This is to ensure the well is always under control. The complexity here is to have a good pressure difference balance between the outside and the inside of the wellbore, not too high and not too low. If the pressure difference is too high, then there is always the potential of fluids inside the wellbore to lose out into the formation. This is not desirable as fluid losses not only need to be replenished but this may also lead to formation damage.

If the pressure difference is too low, fluids from the formation may enter the wellbore, which may also result in a well control situation. Thus, correct analysis of pressure difference is very important.

On the other hand, underbalanced perforation can only be done using the tubing. This is because the tubing has to be lowered into the hole and this creates a lower pressure compared to the formation. Therefore, upon perforation, there will be a rush of pressure from the formation entering the wellbore.

Again, a balanced pressure difference is important because too great a difference will create a great push of pressure from the formation which can be dangerous if uncontrollable. If the difference is too low, it may not result in an effective underbalanced perforation which will promote better production. Underbalanced perforation is usually recommended when the formation does not have good flow potential. Underbalanced perforation will help by reducing formation damage due to invasion of fluids from the wellbore

THE GUN

The perforating gun has 4 components (see Figure 2): Conveyance for the shaped charge, individual shaped charge, detonating cord and detonator. When the gun is detonated, it will go off instantaneously with the pressure of 10-15 million psi. This pressure penetrates the casing as well as the formation, creating a radial path for hydrocarbon to flow in.

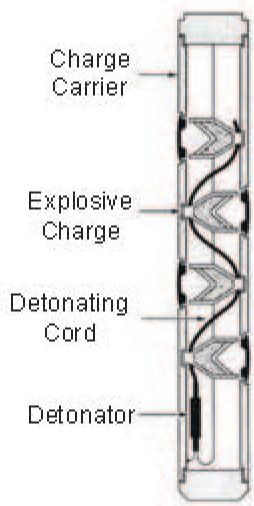

Figure 2: Perforating Gun – Hollow Steel Carrier Wireline Conveyed (Source: http://www.devonenergy.com

Figure 2 also shows the sample of perforating gun system, a hollow steel carrier wireline conveyed type. The detonator is actually below the charges by design. Some perforating systems such as Thru Tubing Wireline Conveyed Perforation as well as Tubing Conveyed Perforation commonly have the detonator above the charges.

Shaped charge plays an important role in creating the explosion to penetrate the formation. Figure 3 shows the sample of shaped charge with the cross-section figure showing the components of a shaped charge.

Thermite is a pyrotechnic composition of metal powder, fuel and metal oxide. When ignited by heat, thermite undergoes an exothermic reduction-oxidation reaction which can create brief bursts of high temperature in a small area.

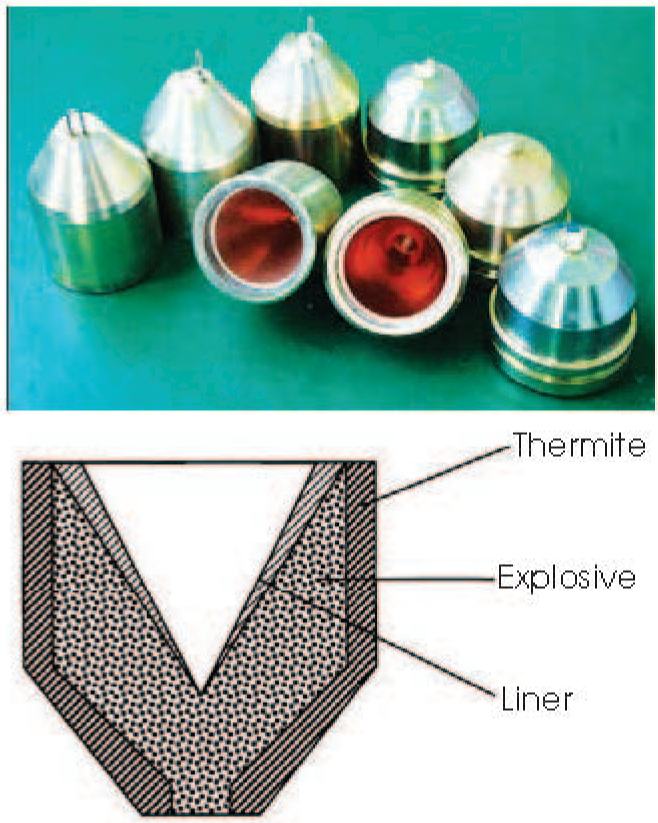

Figure 3: Shaped Charge (Sources: https://media.licdn.com/mpr/mpr/shrinknp_800_800/AAEAAQAAAAAAAAhEAAAAJDM3NWYxMDEzLWE0MmYtNGJiMS1iMzBhLWJkZmU0MTBhNDE0ZA.jpg, http://patentimages.storage.googleapis.com/US20110146519A1/US20110146519A1-20110623-D00000.png)

EXPLOSIVE TYPES

There are 3 types of explosives commonly used in well perforation: RDX, HMX and HNS. The use of these explosives is highly controlled by the operations as well as the authorities. RDX is a white solid organic compound classified chemically as nitramide, and similar to HMX. RDX is a more energetic explosive than TNT (Trinitrotoluene - yellow solid that is sometimes used as a reagent in chemical synthesis, but is best known as an explosive material that is easier to handle). RDX was popular during WWII and was secretly known as "Research Development Explosive". In well perforation usage, RDX has a 1-hr rating of 166ºC and 100-hr rating of 115ºC thermal stability.

HMX is a powerful and relatively insensitive nitroamine high explosive, chemically related to RDX. It's also known as High Melting Explosive, Her Majesty's Explosive, High-velocity Military Explosive or High-Molecular-weight RDX. Because it is more complicated to manufacture than most explosives, it's confined to specialised applications. In well perforation usage, HMX has a 1-hr rating of 204ºC and 100-hr rating of 149ºC thermal stability.

HNS (Hexanitrostilbene) is a yellow-orange solid organic compound used as a heat-resistant high explosive. Produced by oxidising TNT with a solution of sodium hypochlorite, HNS has a higher insensitivity to heat than TNT but like TNT, it is insensitive to impact. In well perforation usage, HNS has a 1-hr rating of 260ºC and 100-hr rating of 238ºC thermal stability.

There are complex simulations that can be run to determine the effectiveness of perforation or how deep the explosion can penetrate the formation. However, such simulations can only achieve limited accuracy as there are many unquantifiable factors that can impact the effectiveness such as formation hardness (grain size, porosity), explosives strength, explosive charge arrangement, casing strength, cement strength and cement hardness.

CONCLUSION

Well perforation is a significant process of completing a well for production. With the involvement of explosives, the work becomes more dangerous. Safety precautions in handling the explosives as well as perforation design planning and implementation must be observed to ensure the successful delivery of a well.

After the shudders and rumbles of the tubing had subsided, we knew it was only an indication that a successful perforation had taken place. The next question was, "Were all the guns fired? What if some of the guns did not fire?". It would be highly risky to bring a partially fired gun up to the surface as an unstable gun could potentially explode anytime if not properly secured. As the guns were reaching the rig floor, I could feel my heart pounding as if I had just completed a 100 km sprint. ■