Well Integrity Briefly Explained – Focusing on Cement

WIP WELL INTEGRITY PLATFORM

WIP Knowledge

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One of the most important element of a well completion design - because it is most difficult and costly to repair in case of a failure - is the proper selection of casing and cement and the right placement of cement slurries in the annulus to ensure that effective barriers between fluids from rock formation and the wellbore are established (zonal isolation) over the life-time of an installation and beyond.

During completion and well production the loss of well integrity is complex and has numerous manifestations. It can include more frequently phenomena that lead to communication between the production string and casing or between various casing strings due to corrosion or leaking connections. Also communication between production intervals and 'A-Annulus[1]' (between tubing and production casing) via leaking packers are often observed. Less frequently (but much more costly to repair) is gas flow along badly cemented liners and across leaky liner hangers. All above issues result in undesired "sustained casing pressure" (SCP) at the surface (strictly speaking SCP is not a well integrity failure but a barrier failure as long as the wellhead seal prevents release of fluids into the environment). Loss of well integrity can also be manifested by flow of fluids from shallow gas formations along a badly cemented casing into aquifers, which is then a well known theme in public discussions.

However, summing up several individual barrier failures can even result in disasters as demonstrated with a 'Swiss Cheese Model' for the Macondo Blowout[2], illustrated in Figure **1**. In this case a light-weight cement slurry did not provide a primary barrier against high pressure formation fluids.

The reasons for the loss of well integrity are various. Improper placement of cement or casing in the annulus, lost circulation problems during cement slurry pumping, wrong selection of slurry systems, long-term chemical and physical degradation and aging of set cement (especially important for carbon capture and storage wells), cement shrinkage, external stresses on casing due to life-time operations on the one hand side (resulting in fatigue cracks along the casing/cement interface and within the cement), long-term stresses on cement at the vicinity of the wellbore due to rock-mechanical phenomena on the other side (resulting in interfacial weakening and de-bonding between cement/formation), corrosion of casing and tubing, leaky connectors, failures in packers and downhole valves and others.

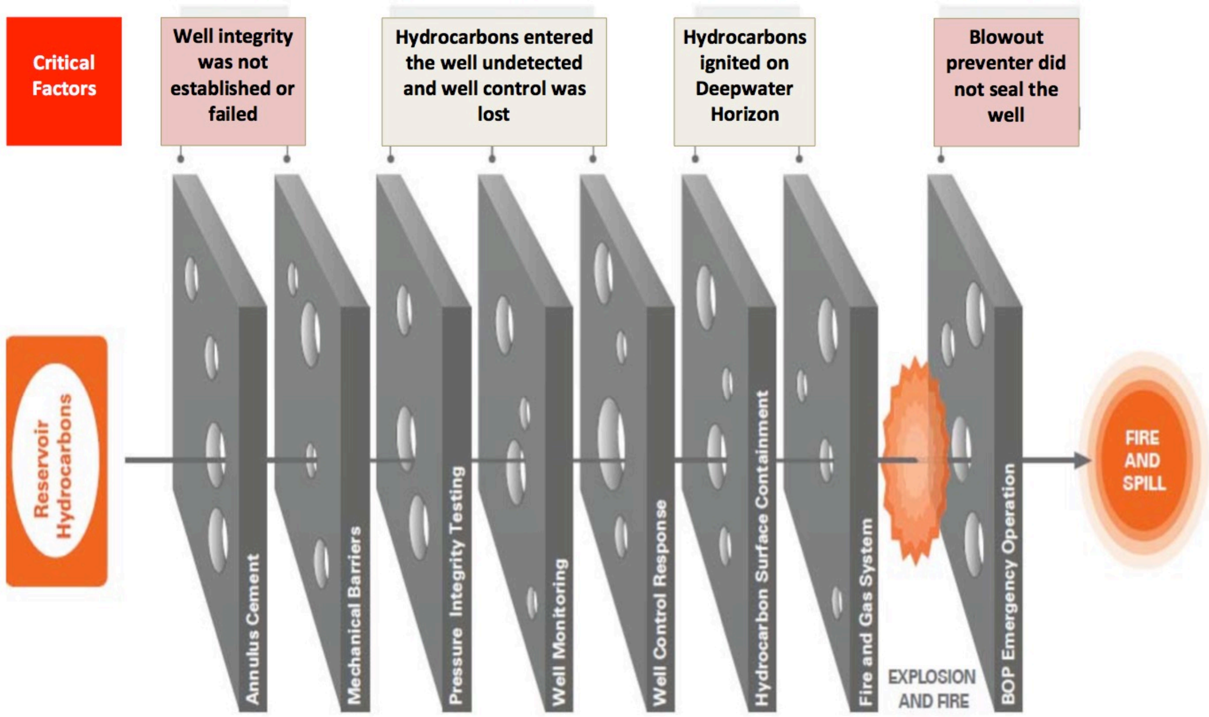

Figure 1: BP's analysis of defensive barrier penetration leading to the Macondo blowout[2]

For the simple cases when wells show non-tolerated "sustained casing pressure" during their production phase or when operators have to prove proper well integrity during de-commissioning of non-economic wellbores, leakage pathways have to be repaired which may become an economic challenge. Also uncertainties among operators arise as more and more regulations are on the way, however they are not consistent and authorities are overloaded with verifications in many cases. This is considered to be one of the major shortcomings for proper well integrity management in the US today.

References

1. NORSOK D-010, Well integrity in drilling and well operations, Rev. 3, August 2004
2. BP, Deepwater Horizon Accident Investigation Report, September 2010