MIDDLE EAST WELL INTEGRITY WHITEPAPER

Konstantinos Christou
Research PG Engineer | University of Aberdeen

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Table of Contents

Introduction

There are different definitions of Well Integrity. The most widely accepted definition is given by NORSOK D-010: "Application of technical, operational and organizational solutions to reduce risk of uncontrolled release of formation fluids throughout the life cycle of a well". Another accepted definition is given by ISO TS 16530-2 "Containment and the prevention of the escape of fluids (i.e. liquids or gases) to subterranean formations or surface''. Well Integrity is undoubtedly a multidisciplinary approach. Therefore, well integrity engineers need to interact constantly with different disciplines (e.g. well intervention and drilling) to assess the status of well barriers and well barrier envelopes at all times.

A well intervention, or well work as it is commonly referred, is any operation carried out on an oil or gas well during or at the end of its productive life, which alters the state of the well and/or well geometry, provides well diagnostics, or manages the production of the well. To guarantee integrity assurance a synergy between operational well intervention programs and well integrity technology is critical.

In the Middle East region, and specifically the Gulf Cooperation Council states (GCC), there are particular technical and geological factors that are increasing the criticality of well integrity management practices. These include, but are not limited to:

- Fields being much older than people think. For example, the Burgan Oil Field in Kuwait was discovered in 1938 and started commercial production in 1946 and still produces 1,200,000 barrels per day. It's common that integrity issues increase with older assets, however the 70 years of continuously high production rates of Burgan is not an isolated example in the Middle East. There are multiple fields across the GCC which began production at the same time and are still a cornerstone of the region's production figures.

- Old fields were completed using old, and now often obsolete technology, causing them to suffer from significant technology gaps. For example, if a field began production in the 1940s, 1950s or even the 1960s it is unlikely that stainless steel is present as it was not commonplace in the commercial completion industry of the time. This means corrosion management challenges are heightened, and issues with wellhead loading and locating an applicable access system (e.g. the Tree Running Track) become extremely limiting factors.

- Finally the Arabian Peninsula sits on top of a large saline aquifier. Without the use of modern stainless steel and heat treated technologies, when wells encounter the concentrated salt water the corrosion behavior advances more rapidly than in other regions.

This paper concentrates on the importance of well integrity and intervention within the Middle East – noting global best practice which could be utilized on both offshore and onshore assets.

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Background and History of Technology Development

There has been a significant technological evolution in the drilling industry over the past 30 years. The early platforms on the Norwegian Continental Shelf were designed for wells with a reach of 3 km from the platform. Several platforms were often required to cover a large reservoir - for example Statfjord A, B and C and Gullfaks A, B and C. As these platforms were very expensive, alternative solutions were pursued such as subsea installations and extended reach wells (in the Middle East extended reach wells with large horizontal sections are common). Today it is possible to reach targets 12 km from the platform. One new platform can replace three old platforms from a reservoir coverage point of view.

This technical evolution in the drilling industry has placed further demands on well services for the assets' production life and retirement. Constant development and improvement across tooling and technologies for each and every part of the well's life cycle must be developed - obviously since the wells are much longer and more complex, the risk of failure is also increased. Unfortunately, the high number of elements that can possibly fail makes the integrity analysis incredibly difficult.

Well Integrity can in its simplest definition be defined as an operating well that has full functionality and two qualified well barrier envelopes. Any deviation from this state is a minor or major well integrity issue. Common integrity issues are often related to leaks in tubular or valves, but can also be related to reservoir issues such as loss of zonal control. Any factor that leads to a functional failure is a loss of well integrity. The challenge is of course to define all possible scenarios.

History shows some severe examples of losing integrity in wells such as the Phillips Petroleum's Bravo blowout in 1977, Saga Petroleum's underground blowout in 1989, Statoil's blowout on Snorre in 2004, and BP's Macondo blowout in the Gulf of Mexico in 2010. These serious accidents remind us of the potential dangers in the oil and gas industry and they are some of the main drivers for the focus on well integrity, safety and training.

It is clear from the above description that well integrity is an important safety aspect of a well. However, some of the issues are not critical, whereas some may lead to accidents. The type of well work and application will often dictate the required integrity/capability of the asset to cope with the job, whereas significant and critical elements are usually governed by regulation.

Types of Well Work in the Middle East

Pumping is the simplest form of intervention as it does not involve putting hardware into the well itself. Frequently it simply involves rigging up to the kill wing valve on the Christmas tree and pumping chemicals into the well. There are however a range of other intervention activities commonly taking place in the Middle East:

- Wellhead and Christmas tree maintenance can vary depending on the condition of the wellheads. Scheduled annual maintenance may simply involve greasing and pressure testing the valve on the hardware. Sometimes the downhole safety valve is pressure tested at this point.

- Slickline operations may be used for fishing, gauge cutting, setting or removing plugs, deploying or removing wireline retrievable valves, and memory logging.

- Braided line is more complex than slickline due to the need for a grease injection system in the rigup to ensure the BOP can seal around the braided contours of the wire. It also requires an additional shear-seal BOP as a tertiary barrier as the upper master valve on the Christmas tree can only cut slickline. Braided line includes both the core-less variety used for heaving fishing and electric-line used for logging and perforating.

- Coiled tubing is used to pump chemicals directly to the bottom of the well, such as in a circulating operation or a chemical wash. It can also be used for tasks normally done by wireline if the deviation in the well is too severe for gravity to lower the toolstring and circumstances prevent the use of a wireline tractor.

- Snubbing, also known as hydraulic workover, involves forcing a string of pipe into the well against wellbore pressure to perform the required tasks. The rigup is larger than for coiled tubing and the pipe more rigid.

- Workover in some older wells, changing reservoir conditions or deteriorating condition of the completion may necessitate pulling it out to replace it with a fresh completion.

- Subsea well Intervention is rare in the Middle East and offers many challenges that require much advance planning. The cost of subsea intervention in the past been prohibitive but is much more viable in the current climate. These interventions can be executed from light/medium intervention vessels, vessels of opportunity or mobile offshore drilling units (MODU) for the heavier interventions such as snubbing and workover.

It must be noted that the IWCF (International Well Control Forum) have discussed the larger volume of well integrity and control incidents taking place during Intervention operations, compared to drilling. Our industry has been, and even in the current climate, remains drilling focused. A rise in well production/intervention incidents suggest a renewed operational focus on the aging well stock is not only necessary for safety and integrity concerns, but also to efficiently extend the life of wells during a downturn of drilling activity.

Currently well stock in the Middle East is being pushed harder and will be running for longer, often well passed the design life. Due to this, intervention and well integrity needs to be the primary operational focus for E&P companies.

Oil Well Intervention in the Middle East

From a commercial standpoint, Well Integrity is necessary to control the risk of contaminating other producing zones, as well as increasing the lifespan of equipment and asset production as a whole. This is a major issue among the WRFM community and the reason for much intervention in the Middle East. The importance of well integrity and zonal isolation has never been more important in the region.

As such we have to ask ourselves a few questions:

- How many wells leak?

- Where, why and what is the problem?

- How efficient are my wells?

- What is special about my leaking wells?

- What are the fluid pathways?

There are a range of causes for both integrity and intervention. Some common intervention activities affect well integrity, for example washouts can erode the borehole and poor cementing jobs can threaten barrier integrity, creating huge implications for a well's production. Equally there are also types of well which are more prone to integrity issues, increasing the recurrence of intervention. Examples include the frequency of problem zones in high risk wells (HP/HT, shale formations, etc.) sometimes reaching as high as 90%. Furthermore, the rise in extended reach wells and other high risk characteristics, including HP/HT, shale formations and sour service fields, are increasing the spotlight on well integrity services in the Middle East.

In deeper and longer reach wells, modern-day cementing techniques are being pushed to the limit with integrity challenges including poor cementing, high pressures, unstable formations, and high circulation losses. Can the existing downhole technologies and methodologies meet today's challenges?

In one typical example, a Middle East operator had to seal in a 10.5" washout, where the required isolation pressures reached 5,000 psi. The operator had a completion design which included a 30,000ft horizontal section. In this case, the Metalmorphology based barrier would give the operator the ability to set everything from the surface or individually using a setting tool. As part of the morphing process, the sleeve wall thickness is reduced to 5mm to allow the expansion and contact to take place below 5000 psi. The remaining pressure (i.e. from 4000 psi to 5000 psi) is used to squeeze the isolation barrier against the formation to promote the sealing capability.

A new approach to well integrity is required in the Middle East today. With traditional technologies struggling to consistently meet these new challenges, the oil & gas industry has to implement different technologies and new methods to remain efficient and safe.

Integrity Best Practice

Starting from the planning phase with a more spherical risk assessment approach, engineers have to plan the operation properly and estimate the reservoir, well and equipment behavior by considering the local geological and environmental conditions.

Using cementing as an example, the cement barrier resilience is dependent on initial placement, microannuli, induced stresses from geomechanics and operational loading. Cement barriers rely on low matrix and interface permeability, length/surface area and an effective radial stress to maintain a seal at any interface in a well system. The original well CBL can provide evidence of placement but not long term effectiveness. The barrier is expected to avoid unplanned escapes of fluids for the life of the well and beyond. There are multiple methods for identifying the presence of cement – but how can we integrate all available well data to make the best possible assessment of cement integrity? How can we efficiently identify technologies that can be applied to improve the integrity assurance as a whole?

Operators at the recent OWI Well Intervention Conference in Aberdeen (April 26-28, 2016) discussed a range of approaches to tackle this, including but not limited to:

- Strategic thtinking combined with continuous technology improvement to simplify log interpretation and avoid divergence in analytical perspectives.
- Logging tools that detect metal loss due to corrosion or other factors in the tubing and annuli.
- Accurate models of surface casing corrosion by using embedded fibre optic lines which evaluate flow, leak diagnosis, gas lift optimization and leak detection.

The discussed approaches represent a new strategic and technical path to integrity assurance. This can be summarized into the following stages as best practice:

- Allow time to select the optimal team configuration for a peer group / pro-active assessment of potential well integrity failures.
- Create a detailed review of known failure modes, which then identifies 'Known Unknowns' and monitoring requirements, leading to a better understanding of well integrity risk.

- Rationalization of well integrity assurance tasks to only those personnel that are most effective.
- When a failure occurs deliver clear communication and understanding the risk to all levels of the company and focus risk assessment on the greatest hazards, saving time and undue alarm.
- Schedule and align rectification operations with the asset activity planning prioritization due to the corporate RAM ranking of the failures.

Conclusion

As mentioned in the introduction, the Middle East and GCC states have an interesting relationship with well integrity due to the compiling effects of old fields with old technologies, a corrosive saline aquifier and a demand to greatly extend the assets' operating life. This combination means that wells are pushed to their limits, their load handling can be questioned and risk profiles can be larger than owners would wish.

To mitigate this risk a greater focus on integrity assurance is necessary:

- All equipment and technology should be regularly checked for damages and corrosion, if any damage is found they should be replaced or repaired.
- Universally recognized specifications should be followed, as it is very helpful for engineers of different nationalities and backgrounds working in the field to have a common and globally understood set of standards.
- There should always be a clear backup plan if a significant failure/incident occurs.

This highlights the required use of best available technologies to understand the wells condition, appropriate methodologies to enter the well and correctly trained and competent staff to ensure work is executed safely and efficiently. On this note the IWCF (International Well Control Forum) recognize the necessity of the continuous improvements to well intervention training, examination and certification process. Their introduction of new ideas will improve well performance across various stages of operations, including working over wellstock with unknown or unassured integrity.

In conclusion, to achieve a full and complete understanding of well integrity a lot more research is required to improve the visibility of abnormalities with the asset. It is very common in the oil and gas industry to focus on increasing efficiency to save time and money – in the current market this is more important than ever. However it is possible to do both. By utilizing the best available and safest technology to monitor and evaluate well conditions you can identify potential hazards, understand load handling and illustrate the behavioral characteristics to not only minimize the potential for incidents, but also aid the design of a bespoke well program that offers optimized production through an efficient workover plan.

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