Why Is Well Integrity Good Business Practice?

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Background

There have been a number of very recent catastrophic events which have raised the profile of the concept of well integrity. One of these events occurred in Australian territorial waters at the Montara oil field, offshore northern Australia. The second accident occurred two weeks ago, in the offshore Gulf of Mexico, with the blow-out, fire and subsequent loss of the *Deepwater Horizon* semi-submersible drilling unit. In the second event 11 lives were reportedly lost. Both events resulted in significant uncontrolled releases of hydrocarbons into the environment.

Both of these high profile events occurred due to a loss of well integrity during drilling operations, resulting in a loss of well control. The severity of the events escalated as a result of subsequent ignition of a combustible mixture of air and hydrocarbons. Although the root causes of these catastrophes are yet to be formally determined and published, the consequence is a further blemish on the reputation of our industry, and ultimately will result in increased costs, scrutiny and regulation relating to the exploration and exploitation of hydrocarbons.

From public domain information the direct and consequential damages from these two recent events alone (remediation cost, equipment damage, loss of reserves, reputational damage), it should be very evident that a failure of well integrity is damaging not only to individual operators but the industry as a whole. This article seeks to explore why effective well integrity is good business practice and what we really mean when we discuss the concept of well integrity.

Well integrity—a definition

Wells in the oil and gas industry are physical assets which connect the reservoir to the surface, and through which we produce oil, gas, water reservoir fluids and contaminants. By connecting the surface (above the sea or at ground level) with a source of energy (the reservoir pressure), it is vital that the well is designed and installed so that it provides sufficient barriers to effectively contain and control the flow of fluids resident in the formations and reservoirs which the well penetrates. Wells have a finite life, which commences with the initial drilling operation. Thereafter, the well may be exposed to various well 'activities', such as completion, stimulation, intervention, workover, maintenance, suspension and ultimately abandonment. Effective management of well integrity needs to consider this range of well activities as well as steady state production.

Integrity is variously described in dictionaries as a state which provides veracity, reliability, honesty and uprightness; a state which can be relied on as an accurate condition at any point in the life of a well.

The following description of well integrity is offered for consideration:

> *'The instantaneous state of a well, irrespective of purpose, value or age, which ensures the veracity and reliability of the barriers necessary to safely contain and control the flow of all fluids within or connected to the well.'*

In the views of this author, well integrity resides as a subset of a broader concept which is described as production assurance. Production assurance encompasses such related concepts as flow assurance, well integrity and commerciality:

> *'Production assurance is the continuous optimisation of production from oil and gas assets which is achieved in the following manner:*
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> - *Without harm to people or the environment;*
> - *Delivered with technical conformance to regulatory and statutory frameworks;*
> - *With a comprehensive understanding of the physical constraints and data constraints of the operating environment;*
> - *Recognises the requirement for continuous improvement in the delivery of engineering equipment and services relating to well and production activities.'*

If one were to accept these definitions, then production assurance cannot be delivered without assuring the integrity of the well (and supporting production facilities). If we measure the economic success of an operator of an oil and gas production facility through their ability to deliver production assurance, then according to the definitions above, well integrity is essential, in fact critical, to good business practices and sustainability of the E&P business.

Well integrity—industry inconsistency

In October 2007, the Western Australia chapter of the Society of Petroleum Engineers (SPE) hosted an Applied Technology Workshop (ATW) focused on well integrity. The workshop was well attended with over 60 representatives from both local operating companies and a number of the largest IOCs and NOCs. It may be both interesting and concerning to most readers that participants at this SPE ATW could not refer to one agreed definition of or standard for well integrity. This was much debated however the workshop was unable to conclude with agreement on this basic matter.

It seems strange and concerning that we focus so much energy and effort on effective quality, health, safety and environmental management systems in such a huge global industry, yet for one of the single most important factors which can impact on all of those business-critical areas—well integrity—we cannot offer a common definition or set of industry approved standards.

The concept of barriers

It is doubtful there are many people working in our industry who have not attended HS&E 101 to understand the concept of barriers or controls and their importance in prevention of incidents and accidents. Ensuring the integrity of at least one barrier ensures that the 'Swiss cheese' holes do not align, resulting in an occurrence of an unplanned event. The concept of multiple barriers reduces the statistical probability that an unplanned event will occur.

In the world of well integrity, well control barriers are physical elements designed to contain and control well fluids and well pressures. Effectiveness and design of these barriers can be dependent on many factors, including but not necessarily limited to:

- The nature of the reservoir—rock constitution, depth, geology, pore pressure, thickness, geographic location;
- The nature of the reservoir fluids—oil, gas, condensate, contaminants, ease of transmissibility within the reservoir, connectivity;
- The nature of the macro-geological environment which may impact on the condition of the reservoir;
- The type of well designed to connect with the reservoir and the positioning of that well within the reservoir;
- The production condition of the reservoir—depletion, pressure support, enhanced recovery practices in practice, condition of production facilities;
- The geographic environmental setting in which the well is located—desert, forest, deep-water, near shore, urban;
- The nature of the regulatory and statutory regime in which the well is located; and
- The commercial regime which the operator is controlled by:
  - The business integrity of the operator; and
  - The professional integrity of the engineers and technicians engaged by the operator to design, plan, execute and operate the wells.

What is presumably not debatable, is that at least one 'verified' barrier is required to be in place at all times to prevent a loss of control and consequential release of combustible or harmful reservoir fluids into the environment.

The concept of 'harmful' is important as we are really describing the release or unplanned event as having the potential to harm individuals, flora and fauna, or the physical environment. Current accepted industry wisdom would indicate that no unplanned release, irrespective of size or level of potential harm, is considered acceptable. This was certainly not accepted practice as recently as 50 years ago.

How much regulation is enough?

This is the challenge that confronts our regulatory authorities, self-regulation and the long-held concept of 'good oilfield practice'. Our industry practices must change, evolve and mature in a similar way that acceptable industry practices have evolved in the aviation industry. It is simply not acceptable to the wider community for planes carrying larger and larger numbers of people to have the same probability of falling out of the sky that existed 50 years ago. Similarly, it is not acceptable for oil and gas wells to suffer a loss of integrity which results in people being killed and injured and the environment being damaged.

We know that such events are not acceptable because the authorities empowered by the community, and evolving industry practices reflecting the views of the public, have mandated that this is not acceptable. The operating regimes provided by our regulatory authorities provide guidelines, standards and definitions which define our operating practices. Our industry operates under widely accepted guidelines and standards (e.g. American Petroleum Institute [API] and International Organization for Standardization [ISO] amongst others) which determine the practices by which we will design and test equipment for use as barriers, and our equipment manufacturers comply with international standards for quality assurance and proudly advertise their conformance.

Our industry has also adopted the concept of ALARP—as low as reasonably practicable—as a framework under which we manage risks. The ALARP principles require that we diminish risks in our business activities (in this context, threats to the delivery of production assurance) to the minimum levels which are reasonably practicable (and commercially viable) to achieve.

And yet, even within this framework of enforced and self regulation, we can still have such catastrophic events occur as those we have seen in the past 12 months. How can this be possible?

The answer lies to a large degree in the interpretation of those regulations and standards and the subsequent application, engineering and implementation resultant from that interpretation.

Generally acceptable engineering practices (and some regulatory regimes) in most mature operating regions state the requirement for more than a single barrier. In the Norwegian regime, there is a requirement in certain circumstances for three independent, tested and verified barriers.

The Petroleum (Submerged Lands) Acts Schedule 'Specific Requirements as to offshore Petroleum Exploration and Production', including clauses which have now been revoked, provides similar guidelines for the Australian offshore oil and gas industry, defines a minimum requirement for two independent, verified barriers to be in place at all times. However, these provisions are now covered under the Commonwealth Petroleum (Submerged Lands) (Management of Safety on Offshore Facilities) Regulations which are less prescriptive than the previous regulatory regime.

The current regulations are designed to allow innovation or optimisation, however there is still a fundamental requirement to ensure that appropriate levels of risk assessment are is conducted and sound engineering practices are followed when designing wells and implementing well construction activities. There is a further implied requirement that changes to design assumptions, which occurs when operations are recognised, the potential impact of those changes properly assessed and appropriate responses and changes implemented. This infers a minimum requirement for management of change.

One of the issues with barriers is that they can often be interdependent or conditional on other mechanical elements of a well, and that testing and/or validation can also be complex. There are barriers which are installed on a temporary basis in order to allow other activities to occur and there are barriers required on a long-term basis. Ultimately, when a well is abandoned, the final barriers must be permanent and endure for an undefined period well into the future.

Drilling fluid is a temporary, dependent and conditional barrier allowing, for example, the drill string to be recovered from the well to change a drill bit or bottom hole assembly. It is temporary as its condition can deteriorate over time if not maintained within defined specifications. It must be monitored to ensure that the fluid level remains at the surface to provide the required hydrostatic overbalance. The overbalance provided by the fluid is dependent on the accurate prediction of the pore pressure of the formations being penetrated. In exploration wells our knowledge of pore pressure may be limited, hence our design of the fluid will be more conservative. Finally, in the event that conditions upon which we based our design change (e.g. significant losses or drilling into an over-pressured horizon), the drilling fluid can no longer be considered a barrier and we are then dependent on the drilling BOP and drill string to provide redundancy so we can shut-in and control the well.

Let's not presume that barriers necessarily infer significant cost burdens. In some cases, the verifiable lack of sufficient reservoir energy to enable hydrocarbons to flow naturally to the surface may well be an appropriate and verifiable barrier. The critical issue is can we verify this condition with sufficient confidence upon which to rely on that condition long term?

Another matter to consider in the design of barriers is the consequence of a failure of a barrier. We need to consider how long it will take to establish the secondary or back-up barrier, the consequence of failure—does it immediately escalate a threat or result in a loss of containment event and can it be reinstated.

Engineering well integrity and production assurance

Then how do we bridge the regulations and definitions into effective delivery of well integrity? This requires the establishment of procedures and management systems which enable operating companies to engineer their projects with inherent integrity. The Well Operations Management Plans (WOMP) provides the internal interpretation of the regulations and incorporate the operator-specific guidelines, procedures and work practices. In order to ensure integrity is delivered and maintained throughout the life of the well, the following areas need to be considered in construction of the WOMP and detailed procedures:

Collation, verification and presentation of information

All parties involved in the design and delivery of the well need to be assured that they are all dealing with the same information—a 'single source of truth'. They need to ensure that updates to this information are controlled and that the accuracy of the data is validated. The information needs to be captured in a form readily accessible by all parties, and appropriate design standards are referenced against which design must conform. The basis for well design is a critical controlled document which many companies use as this primary design reference tool.

Management of change

This is a crucial component of effective well integrity management. Throughout the life of a well, conditions will change, new information will become available which supersedes previous design data. This can occur during the design stage, implementation stage, or at any time between or during well-based activities. It is essential that the information or condition which changes is assessed, verified and understood in order to determine the appropriate response required.

In an operational sense, when activities are time and cost critical it is important to ensure this assessment and response process is efficient and appropriately considers all potential risks associated with this change. Decisions will be made on a quantitative risk-assessed basis. It is important that operations systems exist to enable appropriate experience and judgement to be accessed in order to make the most appropriate decisions in a timely manner. Many operating companies are now moving towards real-time data presentation from the well-site to the office in order to ensure that the appropriate levels of experience and judgement can be accessed when making such decisions.

Delivery of operations

It is vital to ensure that operations are executed as per the design and planning. The management of change regarding changes in the real-time operations environment has been discussed above. The effective handover from the 'steady-state' operations team to the well activity team is vital to ensuring the most up to date information is available at the commencement of well operations. The handover of accurate and complete documentation from operations to the well team, and from the well team back to operations is critical to the continuous delivery of well integrity.

Maintenance of the well asset

Following on from the initial well construction phase, continuous maintenance of the well integrity envelop is essential. This can encompass wellhead and Xmas tree valve maintenance, maintenance of in-well safety systems, annulus integrity monitoring and maintenance, artificial lift monitoring maintenance, and optimisation and monitoring of well performance. Production assurance and continuous well integrity can only be provided through a proactive and preventative maintenance program.

Maintenance of well assets is also critical to efficient planning and execution of well intervention and optimisation activities. Ensuring wellhead valve integrity is essential to safe and efficient well intervention activities.

Competence

A key component of a company's ability to establish and maintain well integrity is the competency of the expertise they engage to do so. Interpretation of and conformance to regulatory, statutory and industry design standards, whilst ensuring cost effective engineering solutions, is driven by the experience, knowledge and competency of the engineering team. The ability to deliver innovative engineering solutions in a quality-assured manner will be enhanced via engaging a competent and experienced technical capability.

Conformance to internal and external systems

All quality assurance management systems inherently require an audit process for verification of conformance. The same concepts should apply to the delivery and maintenance of well integrity and production assurance. Conformance monitoring will address all of the above aspects of well integrity management systems under an agreed audit schedule. The nature of the operating company, its operational activities and assets, will determine what is a fit for purpose conformance system, however with no conformance monitoring well integrity cannot be verified and assured.

Conclusions

Failure to deliver and maintain well integrity can have significant damaging effects on production, costs, reputation and credibility. Well integrity is a critical subset of production assurance and is therefore a core driver for business success.

The industry as a whole has not established clear and unambiguous definitions for well integrity, and the range of interpretation as to what constitutes effective well integrity management is huge. It is therefore difficult for regulators to mandate well integrity conformance when the industry cannot offer a common definition and framework.

Industry societies such as SPE and PESA, along with government authorities, will need to be actively involved in facilitating engagement and discussion required to establish a common framework and standards for the delivery of effective well integrity.

Unless this is achieved in the near term, potential remains for significant catastrophic events to occur with such spectacular consequences as the recent *Deepwater Horizon* and Montara events. The industry is obligated to evolve and mature through agreement and conformance to significantly reduce the potential for recurrence of such events. ■