The Benefits of a Well Integrity Program: A Case Study

Identification of risk associated with any business, and the management of that risk, are important aspects of business management in today’s competitive world. It is even more relevant when we talk about the oil and gas exploration and production field. Boots & Coots was asked by a North African national oil company to help it identify potential risks associated with aging production wells in close proximity to villages, industrial facilities, and environmentally sensitive areas.

Recognized by the client that a well integrity program is a key part of any oil and gas company’s risk management program, Boots & Coots worked with the company to define well integrity management as being the application of technical, mechanical, and operational solutions to reduce the risk of uncontrolled release of well fluids through the life of a well.

Boots & Coots as part of the project established a well audit and database to help in managing a well integrity program. The auditing and database program was developed to meet several basic needs:

- Standardized method for evaluating mechanical integrity
- Consistent risk assessment methodology
- Easy access to well history data
- Problem well prioritization

To meet these needs, an audit program was developed and modeled after Society of Petroleum Engineers paper 72325. The audit program addresses several parameters that represent the probability of failure and the consequence of these failures. These parameters include:

**Probability of Failure**
- Mechanical condition
- Downhole condition
- Pipe and packer age
- Release to atmosphere
- Annular pressure
- Gate valves operable/inoperable
- Surface and wellbore corrosion
- Wellhead & wellbore configuration

**Consequence of Failure**
- Absolute open flow (AOF)
- Social impact
  - Nearest structure
  - Size of structure
  - Distance to roads/access
- Environmental impact
  - Waterways
  - Wetlands
The audits were separated into two different sections: pre-inspection information and site inspection. Pre-inspection information included a well data summary, maximum historical rate, current rate, primary and secondary fluid composition, tubular record, formation record, and completion/workover record. These parameters were reviewed and a risk factor assigned.

On-site inspection was performed once the surface wellhead equipment and cellar were cleaned adequately to allow for accurate flange size identification, identification by manufacturer of wellhead components, and visual inspection for immediate and potential hazards down to the surface casing. Where applicable, on-site inspection also consisted of fully functioning and in-flow integrity testing of all wellhead assembly gate valves and surface safety equipment. As requested by the client, wellhead annular voids were evaluated for communication to ensure integrity of primary and secondary seals. Where possible, flowing and/or static pressure and annulus pressure surveys were conducted and recorded. All data and on-site inspection findings were thoroughly documented to be implemented into the client database.

Equipment discrepancies were identified and evaluated, and comprehensive repair solutions were documented. Formal reports were then presented to and reviewed with the client to formulate safe and economical remediation solutions.

The audit assigns a numerical value based off risk to each condition within the parameters. The auditor then tabulates the scores from each parameter to determine a total risk factor score.

A wellhead database was established as a tool to be used to manage the well integrity program. The database was designed so that the client could review a field at a quick glance and determine a field-specific risk. Each well is then assigned a risk score, and those wells with a high risk profile are color coded based on their level of risk. (Figure 1)

Wells can be sorted and reviewed by well number or risk profile score, enabling the user to look at each specific well’s information. This screen includes several parameters specific to that well. Each well has five specific parameters: basic well information, well audit scores, assessment recommendations, photos and consequence analysis. (Figure 2)

Basic well information is collected so that a chronological history can be kept on each well. This enables users to review the well history in a timely fashion as well as compare it with other wells.

The well audit score enables the user to review the score of each key parameter: mechanical condition, pressure and volume risk, property liability, and potential impact. Each field audit completed on the well can be reviewed as well as any updates.

Any identified equipment discrepancies and the recommendations to address those
issues are found in the recommendation section, which can be easily updated as issues are addressed.

Photos of each well are taken from each direction and labeled to show distance to potential impact areas. Photos can be printed with a well report and used in workover planning and contingency planning.

The last parameter is the consequence analysis, in which each well is modeled for radiant heat, gas plume and explosion, be it a vertical or horizontal release. (Figure 3)

This information is used to determine the potential social and property impact, which is used in the well scoring. The information also enables the user to establish emergency management plans and, in the case of an incident, use the information as an emergency response tool in determining safe zones and readily available well information. The database has been found to be readily modifiable to account for other risk factors and to meet other individual needs as they arise.

Those discrepancies found to be critical during the audit revealed the need to form a Well Intervention team capable of performing hot taps, gate valve drilling, freeze jobs, and other well intervention techniques. The Intervention team used the wellhead audit scores to determine the well intervention order off the numerical score.

It was also recommended that immediate attention be initiated in the form of a more detailed investigation of subsurface factors supplemental to the wellhead audit and inspection. Boots & Coots proposed an additional subsurface review as a ‘Wellbore Audit’ component that would be used to supplement the information already acquired from the wellhead audit program currently in progress.

This ‘Wellbore Audit,’ combined with the information from the wellhead audit and inspection, can mitigate additional risk by yielding a further list of high risk wells that will require physical inspection in the form of a ‘Wellbore Inspection,’ such as cased hole logging and other remedial services, in order to determine wellbore integrity.

Some of the common discrepancies identified during audits:
- Abnormal and unexplained amounts of pressure found on casing and tubing annuli. In many cases, current annulus outlet valves where found to be deteriorated, obsolete, and in inoperable condition.
- Plugged annuli outlets, not allowing access to casing annuli, were normally found to have solid 2” LP bull plugs installed in one or more annulus outlets. A large majority of the wells audited were found to have casing heads, or starting heads, with both 2” LP outlets containing solid plugs. In these cases the only safe way to gain access to the annulus is by use of a ‘Hot Tap’. This procedure would be accomplished by the Wellhead Intervention team utilizing a ‘Hot Tap Machine’ designed to drill and contain annulus pressures if necessary.

On many cases large scale modifications would be required to the existing cellars before these critical operations can be undertaken. In addition, many flanged annulus outlet valves have been identified to have blind flanges or solid bull plugs installed on valve outlet flanges.
- Surface wellhead integrity problems stemming from lack of containment. This normally referred to open ended components located on annulus outlets or the production tree assembly. Commonly found were 2” LP companion flanges with no tapped end bull plug installed to provide containment, and typically with unserviceable outlet threads as a result. Many tree caps or top caps were also routinely identified to have open ended ½” NPT threads. The majority of these situations were quickly and safely rectified by the Wellhead Intervention team.
- Inoperable tree assembly and annulus valves. Numerous valves had been identified to be inoperable, with many found stuck in the open position. Often, the lower and/or upper master valve was found to be stuck in the open condition. Normally this has been identified on wells requiring a concentric tubing string run through the bore of the gate valves for gas lift or inhibitor injection purposes. Obviously, with the concentric tubing in place these valves are rendered inoperable and provide no barrier to the hydrocarbons flowing up the tubing. These valves should be properly maintained to operate and hold possible pressures when concentric tubing is periodically removed. Many annulus valves were identified to be stuck in both open and closed positions. In most situations these valves were obsolete or in deteriorating condition, and would require the installation of valve removal plugs and possible gate drilling to safely accomplish
replacement. The majority of all gate valve problems encountered were due to the lack of a comprehensive preventative maintenance program being in place.

- Surface safety equipment or lack thereof. Many wells were identified to be lacking any surface safety equipment, i.e. pneumatic or hydraulic controlled surface safety valves, on wells that were equipped with surface safety valves. These wells were found to be in questionable condition and a majority were unable to be function tested properly by the Wellhead Audit team. In order for compliance with industry standards, all wells should be equipped with serviceable surface safety valves, and all existing valves should be properly function tested, shell tested, and block and bleed gate tested for reliability by the Wellhead Intervention team.

Several modifications and additional information can be implemented into the database including well pad plot planning to help identify access problems and wellbore audits to address potential downhole corrosion problems. In addition, wellhead configuration schematics can be created and stored in the database for identification purposes and easily updated following any remediation activities.

The database was found to be readily modifiable to account for other risk factors and to meet individual needs as they arise.

By establishing a well auditing system and database the client recognized many benefits:

- Improved safety through increased certainty in well integrity
- Rapid and systematic identification of threats to a field’s production and the integrity of its wells
- Assessment of the consequences and the likelihood of potential integrity problems
- Designs for remedial action before well integrity becomes critical
- Time savings through not having to search for data
- Optimized workover schedules
- Audit trails to demonstrate that wells are designed, constructed, operated and maintained in a safe fashion, and that show the identification of and response to integrity problems
- Streamlined and consistent data collection, which enables efficient technical well evaluations
- Improved within-company communications among, for example, the reservoir engineering, drilling, operations, inspection and corrosion engineering departments

By using these risk management tools the client found not only a reduction in liabilities, but also a cost saving in a more efficient way to evaluate capital funding requirements and maintenance programs.

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