Abstract

This white paper describes new solutions to a number of existing, long-standing, well integrity management challenges, which are prevalent in all well types.

Specifically, the paper describes new uses for existing field proven technologies, which can facilitate:

- More reliable annulus pressure monitoring
- Continuous annulus pressure monitoring
- Automatic and controlled bleed off of excessive annulus pressure
- Economic reinstatement of some wells shut due to sustained casing (annulus) pressure.

The new technologies described largely replace existing equipment, consequently the incremental cost is modest.

Well Integrity Assurance

Well integrity assurance is a fundamental need throughout the lifecycle of all wells. Definitions vary, but the universally adopted rule to facilitate this is:

“At least two tested independent (primary and secondary) barriers between a hydrocarbon source and the environment shall exist at all times”

This is often described as ‘the double barrier policy’. The Primary Barrier (in blue fig. 1) is the innermost envelope. Normally this will include:

- A cemented casing or liner above the reservoir.
- A production packer.
- Tubing and accessories above the packer.
- A Sub Surface Safety Valve.

The secondary barrier, which is of equal importance (in red fig. 1) is the outer envelope. Its role is to assure containment in the event that any of the primary barrier elements were to fail. Normally the secondary barrier will include the:

- Production casing
- Wellhead
- Annulus line valves and gauges
- Xmas tree valves and gauges
Well Integrity Monitoring Challenges

To assure the integrity of the primary and secondary barrier envelopes, it is essential to monitor A and B annulus pressure.

Traditionally, annulus pressure monitoring is achieved using pressure gauges, which are located on an instrument flange, behind one or more annulus line gate valves (fig. 2). There are a number of challenges associated with this;

Challenge 1: System Robustness

When the gate valves are opened, the secondary barrier envelope is extended to include the instrument flange and the relatively weak fittings, instrument line and pressure gauge.

Challenge 2: Data Acquisition Frequency/Availability

As the instrument lines, fittings and pressure gauge are susceptibility to collision damage (ladder, scaffold pole, dropped objects etc) most OPCO’s do not continuously monitor annulus pressures.

Gate valves are usually opened temporarily and manually only on a dayly basis in order to record the annulus pressure. This restricts the potential for meaningful analysis of data trends, which is useful for understanding the nature of developing well integrity challenges.

In the event of a well incident, most OPCO’s have a policy that the annulus line gate valves should be closed. As a result no annulus pressure data is available when it could actually be vital.
Challenge 3: System Footprint

The requirement for gate valves upstream of the instrument flange takes up a lot of space in cramped wellbays or well cellars.

Challenge 4: Data Reliability

It is widely recognised that annulus pressure data is unreliable. The instrument lines are often block from the grease used during gate valve maintenance. Fig. 3 shows a gate valve which was previously located upstream of an instrument flange being stripped down. Excess grease in the instrument line makes the pressure measurements unreliable.

![Fig. 3](image)

Challenge 5: Wells with Sustained Annulus Pressure

Arguably, the most critical limitation of the traditional approach to annulus pressure management occurs whenever a sustained annulus pressure condition exists. Such a condition could be due to a failure in the primary barrier envelope. It also occurs during gas lifting operations [1] and when pumped wells are gas vented via annulus [2].

Even when the gate valves upstream of the instrument flange are closed, this poses a significant well integrity risk because the gate valve flanges and stem seals only offer a single barrier (with no secondary backup) to flow from the annulus.

Well Integrity Monitoring Solutions

PTC has developed a unique annulus pressure (and temperature) monitoring system. The system (fig. 4) includes:

- A VR plug with an integral, nose mounted pressure and temperature sensor (VR Sensor Plug).
- A flanged housing, containing the system electronics and for wireless models a battery pack.

![Fig. 4](image)
The system provides a solution to each of the well integrity monitoring challenges listed above.

Since the need for annulus line gate valves is eliminated, the incremental cost to adopt the VR Sensor system on new projects is relatively small. An OPCO even stated that the adoption of the PTC VR-sensor system resulted in cost savings [3].

**Solution 1: System Robustness**

The VR sensor plug is installed in the VR profile of the wellhead annulus line outlet, where it provides a primary barrier to flow from the annulus. Even if the flanged housing, which provides the secondary barrier to flow from the annulus, was broken off the wellhead, it would detach from the VR sensor plug. Thus leaving the VR sensor plug inside the wellhead where it would continue to provide a fire and pressure safe barrier (Fig. 5).

![Fig. 5](image)

**Solution 2: Data Acquisition Frequency/Availability**

Since the VR Sensor plug is located within the wellhead VR profile, continuous annulus pressure monitoring is enabled. This is clearly advantageous both during normal operations and during ESD situations when the knowledge of annulus pressure can be vital.

Annulus pressures are also influenced by well temperature. The system therefore also continuously measures the annulus temperature. This means that changing pressure trends can be better understood and any integrity issues detected quickly.

The data can be transmitted via wired or wireless networks. Consequently, in addition to the elimination of the need for manually operated valves, the need for manual data logging is also eliminated.

**Solution 3: System footprint**

Since the requirement for gate valves upstream of the pressure sensor is eliminated, the system footprint is significantly reduced (figure 6). This can be an important benefit in camped wellbays and well cellars.

![Fig. 6](image)
Solution 4: Data Reliability

The system incorporates independent temperature and pressure sensors, with a wide operating range, excellent accuracy and no drift. Additionally, as the sensors are not located on the end of a small bore instrument line that can get clogged with grease or other well debris, data reliability is assured.

Solution 5: Wells with Sustained Annulus Pressure

The VR Sensor system provides independent double barriers to flow at the wellhead / annulus line interface.

- The sensor plug being the primary barrier.
- The flanged housing (and the ring gasket between it and the wellhead) being the secondary barrier.

The most common application for the VR Sensor system to date has been on gas lifted wells. These carry one of the highest risk of all ‘sustained annulus pressure’ wells.

Annulus Pressure Management Challenges

In addition to being a key indicator of well integrity challenges, annulus pressures can increase (beyond the tubing and casing design pressures) because of heating every time wells are opened for flow. A Maximum Allowable Annulus Shut-in Pressure (MAASP) is therefore defined for all annuli in all wells, to avoid the potential for tubing, completion accessory or casing failure.

In addition to improving annulus pressure monitoring technology, PTC also offers annulus pressure management systems, which deliver the same benefits.

Traditionally the management of the MAASP has relied on manual operations, to open annulus line gate valves (Fig. 7) whenever the MAASP is approached. This results in additional well integrity challenges:

Challenge 6: Using gate valves for bleed off duty

Gate valves are not designed for bleed off duty. A number of well incidents have occurred as a result of the flow cutting of gate valves being used in this manner.
Challenge 7: Human Error

The potential for human error exists. There are many examples where the MAASP has been exceeded resulting in a collapsed tubing or burst casing.

Challenge 8: Human Negligence

To ‘save time’ annulus line valves that should be closed, are sometimes left open, thus compromising integrity.

Challenge 9: Wells with sustained annulus pressure:

If sustained annulus pressure exists, the ring gasket and gate valve stem seal only offers a single barrier to flow.

Annulus Pressure Management Solutions

PTC have developed a unique annulus pressure management system. The PTC Master Surface Annulus Safety (MSAS) Valve system for dry tree wells.

The MSAS Valve system was originally developed for (and is widely used as) a surface annulus safety valve, in gas lifted wells.

MSAS Valve Description

The MSAS valve (Fig. 8), is comprised of:

- A dart type check valve, which is installed in the wellhead VR profile. A threaded VR profile exists on almost all wellhead side outlets.
- A ‘flow tube’ style hydraulic actuator (within a flanged spool) which is connected to the ESD system or a local hydraulic control system. The actuator opens the fail safe closed check valve.

As described below the system addresses all of the challenges listed above. it is now increasingly being used for annulus pressure management (bleed of) in naturally flowing oil and gas wells.

Solution 6: Using gate valves for bleed off duty

A choke can be fitted within the actuator ‘flow tube’ to facilitate controlled bleed off, without requiring a large differential pressure across the gate valve.
**Solution 7: Human Error**

The MSAS valve can be controlled using data provided by the VR Sensor system, so that the MSAS automatically opens prior to the MAASP being exceeded. This can be achieved by integrating the MSAS/VR Sensor into the existing wellsite data logging and hydraulic control systems. PTC also provides stand alone control systems that (Fig. 9):

- Continuously read/monitor VR sensor pressure and temperature
- Optionally transmits VR sensor readings via GSM or radio link
- Flexible levels of redundancy and ATEX classifications
- Incorporates a hydraulic control and power unit (HCPU)

If the pre-defined MAASP is reached the HCPU would actuate the MSAS valve and bleed off the pressure in a controlled manner.

![Fig 9](image)

**Solution 8: Human Negligence**

Since the system can be automated, no manual intervention is required. This makes the system ideally suited to remote or unmanned installations.

**Solution 9: Wells with sustained annulus pressure**

The MSAS system provides independent double barriers to flow at the wellhead / annulus line interface.

- The check valve being the primary barrier.
- The flanged spool being the secondary barrier.

The MSAS’ modular design ensures that the check valve remains undamaged with the VR profile where it is protected by the wellhead in the event that the hydraulic spool is damaged (fig.10).

![Fig. 10](image)
The most common application for the MSAS system, to date has been in gas lifted wells.

**Conclusions**

Petroleum Technology Company provides new solutions to a number of existing, long-standing, well integrity management challenges, which are prevalent in all well types.

Using existing, field proven technologies, the following can be achieved:

- Improved well integrity
- More reliable annulus pressure monitoring
- Continuous annulus pressure monitoring
- Reduced well-bay / well cellar footprint
- Automatic, bleed down of excessive annulus pressures
- Economic reinstatement of wells shut, due to sustained annulus pressure.

The new technologies described largely replace existing equipment, consequently the incremental cost is modest.

**References**

[1] PTC White Paper: Enhancing Gas Lifted Well Integrity
[2] PTC White Paper: Reducing ESP Completion Complexity, while Enhancing Reliability and Integrity

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