IEAGHG Information Paper; 2013-IP32; North American Wellbore Integrity Workshop - October 16th - 17th, 2013

This two day meeting was the seventh Wellbore Integrity Workshop. It was held in Denver, Colorado on 16th – 17th October 2013. The objective of these workshops is to bring developers, researchers, regulators and service companies together to review the current status of wellbore integrity. The workshops also explore the technical and regulatory practices that lead to the adoption of best practice completion and the minimization of leakage. Wellbore integrity in the oil and gas industry, and for CO_2 storage, is essential to limit the uncontrolled release of hydrocarbons or stored CO_2. The former has become more contentious in recent years because of the burgeoning shale gas sector in the USA and Canada. Long-term CO_2 storage also depends on the integrity of old wellbores in depleted oil and gas fields which are prime candidates for storage. This latest meeting included contributions from academia, regulators, research organisations, service companies and one operator.

The regulatory environment for well construction is rapidly changing at city, state and federal levels. One of the main reasons for this change of scene in North America is the necessity to protect water resources and prevent infringement of mineral rights. Companies directly involved in the provision of wellbore installation stressed the importance of planning casing and cementation in advance of drilling. Ideally conditions need to be predicted so that suitable cement compositions can be selected from the variety now available. Mud removal is also essential to ensure good cement bonding which can be achieved by controlling fluid rheology.

There are several reasons for cement failures including incomplete mud removal, poorly centred casing, equipment failure and lack of contractor competency all of which could compromise the wellbore but need to be anticipated. Other conditions also need to be considered. Hydraulic fracturing, for example, will induce cyclical loading which can induce stress related cracking. Another common problem is channeling within the cement although this feature can be interpreted from a suite of logs. Multiple measurements may be necessary to detect patterns which reveal channeling or other conditions within the cement.

Anticipating conditions that could occur in the annulus will help to avoid poor cementation. Changes in thermal conditions could lead to a reduction in cement pressure and therefore an ingress of formation fluid under high pressure during this transition. If the reservoir pressure is high it could squeeze out the setting cement. Consequently the cement's critical Gel Strength needs to be high enough to withstand the formation pressure. Cement compositions can be formulated to accelerate the liquid to solid transition. Additives such as dispersants and anti-gelling gents can be used but the down hole borehole temperature needs to be known. Foamed cements can also be used to counteract different down hole conditions. Adding latex and micro-silica to cement can help to reduce permeability.

Leakage from wellbores has been widely reported particularly following the development of shale gas in some US states. A retrospective review of well reports from a database compiled for wells drilled in Pennsylvania since 2001 showed that the failure rate of new shale gas wells in the state is 2% but as high as 10% after 3 years. In the north-east of the state the leakage rate is even higher. Leakage is attributed to the inability to apply zonal isolation and local geological influences. Natural seeps are well known in this region but poor environmental regulation has also been acknowledged as a factor. However, it would be misleading to think that this situation is representative of shale gas development elsewhere. In contrast virtually all the reported pollution incidents in the state of Texas are due to transport spills or leaking fuel tanks. 40 – 50 oil leaks are reportedly from wells across the state. Improvements could be made with a better maintenance culture especially with better quality inspections (see paper SPE 166142). Given that there are 1,000,000 water wells which supply 85% of the state's water supply wellbore integrity is essential.

Baseline studies are advocated to determine the origin of naturally occurring methane. However production gas cannot simply be compared with shallow biogenerated swamp gas. Gas isotope signatures can show that gas can originate from a number of different horizons for example in the Horn River Formation in Alberta. There are phenomena which change isotope patterns complicating interpretation. Isotope reversal, for example, can occur where the ratio of alkane gases changes due to thermal maturation within closed formations. To identify the origin of gas from production wells baseline surveys need to include isotope mud gas profiles consisting of C_2+ isotopes and not just methane. Recommendations for the control of fugitive gas are discussed in:
http://www.onepetro.org/mslib/servlet/onepetropreview?id=SPE-134257-MS

Damage to casing can induce corrosion especially where steel has been stressed causing corrosion pits to form. Pressure testing is therefore essential to ensure casing integrity. Wellbores with damaged casing or poor cement bonds can be rectified. Squeeze cementing is one method for repairing wellbores. It can also be used to isolate abandoned production zones or corroded casing. Squeeze materials can include specialist additives including:

- Resins
- Micro-fine cements (10 microns)
- Polymers
- Slurry oil

Uncemented casings, especially in upper hole sections, have been advocated by some practitioners because the annulus can be monitored. If a problem is detected remedial action can be implemented such as cutting out affected casing, plugging and recasing.

Conventional Geothermal wellbore integrity faces the same issues as oil and gas. All casing is cemented to the surface because the heat causes the casing to expand. In volcanic formations, where geothermal is developed, vertical permeability dominates and therefore casing has to withstand high pressure and temperature conditions. Problems can be caused by high pressure (~1,000 bar), caused by water trapped between two different casing strings, which can lead to casing collapse.

Research is being directed towards improvements in cement and leak detection in a number of different areas including:

- New cement formulations to allow setting without the deterioration of properties under changing P/T conditions.
- Evaluation of saline infusion, under pressure, to determine changes in cement permeability under laboratory conditions.
- Novel Remedial Technologies (NRT) e.g. nano particles activated by setting cement and biomineralization.
- Sophisticated acoustic detection systems to detect leaks behind an annulus.
- Experimental biomineralization using Ureolytic bacteria which hydrolyse urease to form ammonia. This increases pH which induces bicarbonate (HCO_3 -) to form causing calcite precipitation and sealing.

The meeting also discussed other measures to improve wellbore integrity including:

- More evaluation of long-term integrity of casing and cement over decades.
- Application of different cements with specific properties which can achieve highly durable seals.
- Replacement or improvements to conventional materials specifically steel casing and cement which can offer better durability.

Shale gas and oil has led to tightened regulations in the USA and Canada. The biggest risk in Alberta is inter-wellbore communication followed by aquifer contamination. There are 150,000 wells and a population of 3.5m in the province leading to a greater density of wells and proximity to residential properties. Consequently new directives are being introduced to cope with the increase in new wells. Wells must now be capped and vented to avoid gas accumulation. If a leak is detected then it must be repaired at considerable cost. There are also changes in requirements for injection wells. Pressurisation of formations can induce a pressure field over a distance of 1,000m, but monitoring can help to build a picture of the pressure field within different formations.

Wellbore integrity remains a key topic for both hydrocarbon exploration and production and CO_2 storage. It is clear from this latest meeting that technological advances, good industry practice and constructive engagement with regulators can ensure high quality wellbore emplacements. Ongoing research has highlighted the necessity for robust scientific investigation to determine the origin of hydrocarbons. Evidence from the state of Texas suggests leakage from wellbores is minor compared with surface installations.

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December