Reference Document

Well Integrity

- High standards of well integrity ensure long-term safe and environmentally responsible operations.
- The industry uses three levels of construction and testing to ensure fluids and gases are contained:
    1. Wells are designed and built using multiple layers of steel pipe and cement;
    2. Pressure testing is used to confirm casing and cement integrity; and
    3. Acoustic testing is used to verify the cement bonding.
- Maintenance over the working life of the well ensures it operates as designed.
- Comprehensive remediation makes the well safe for the future generations.
- Reviews of well performance over decades of operation reveal very low rates of well integrity failure.

1. Introduction

An oil or gas well is a technically advanced bore hole which reaches hundreds to thousands of meters beneath the earth's surface to tap petroleum resources. In Australia, wells are typically 2,000 to 4,000 meters deep, although some may be as shallow as 300 meters. For the industry these are not particularly challenging depths, as overseas wells beyond 10,000 meters are becoming more common. Water wells for agriculture or domestic use are usually less than 100 meters deep.

Controlling the gases and liquids as they are brought to the surface relies upon long-term well integrity. Not only does the well have to contain the petroleum products inside the well, it must also ensure that subsurface rock layers and any related aquifers penetrated by the well remain isolated from each other. Achieving all this requires high standards of well design and construction.

2. Well Design

Before a well is drilled, it is carefully designed to make sure it meets the highest safety standards and can withstand challenges such as pressure, corrosion, high temperatures, and fluid flows that may erode pipes. The design also accounts for maintenance programs over the life of the well, which is usually decades-long.

Several international standards[1] guide good oil field practice in well construction.

[1] http://www.ogp.org.uk/pubs/485.pdf

3. Well Integrity

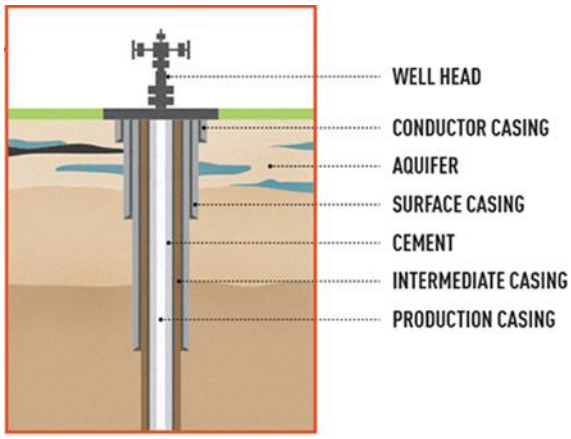
The industry uses three levels of construction and testing to ensure that wells meet required standards:

- multiple pipe casings;
- pressure testing; and
- cement bond logs.

3.1 Multiple pipe casings

The well is lined with multiple layers of pipe (also called 'casing').

Figure 1: Multiple Pipe Casings and Cementation:



Using several casing strings helps back up the integrity of the well if one of the pipes fails. Cement is pumped into the casing between the well and the rock, and between the various strings of casing. This isolates rock or aquifer zones, and prevents unwanted flow between rock zones or inside the well itself. This use of multiple casing strings and cement is the first line of defence for well integrity.

3.2 Pressure testing

Once a casing has been put in place and cemented, it is pressure-tested to confirm its integrity, or ability to hold pressure. This test is done in steps up to 80% of the maximum pressure rating of the casing to confirm the cement and casing integrity (Figure 2). If further drilling is desired, then the first few metres of rock below the bottom of the casing are drilled and another pressure test is performed. This pressure test is used to confirm that the cement behind the casing can hold pressure up to the point where the rock itself will break down and the pressure leaks off (Figure 3). In other words, a 'good test' signifies that the cement between the rock and the casing can hold pressures higher than the rock itself.

Figure 2: Examples of **'good'** and **'poor'** well pressure tests to confirm well casing integrity:

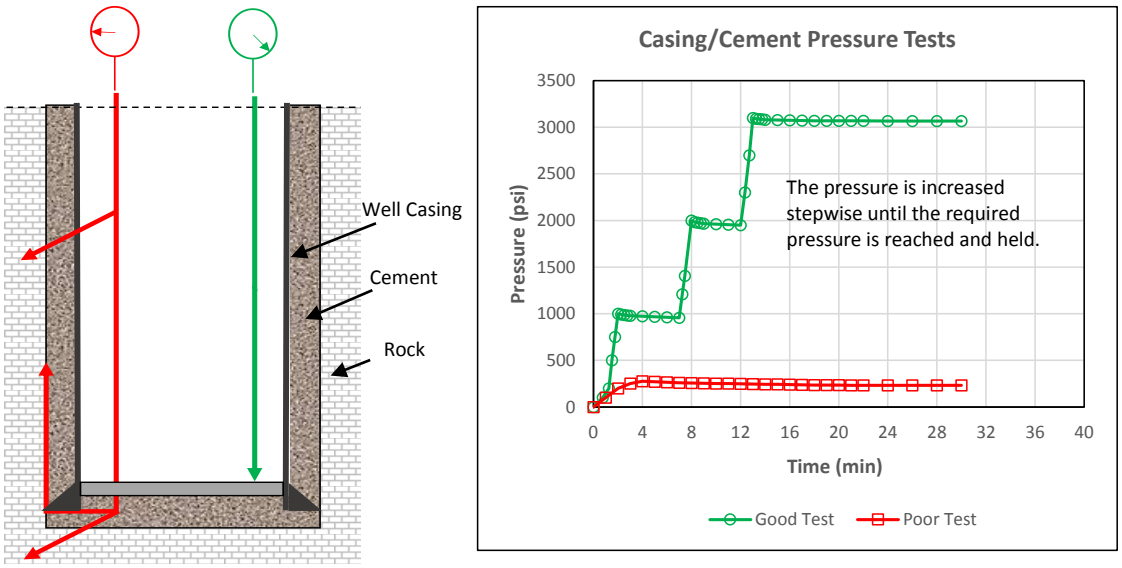
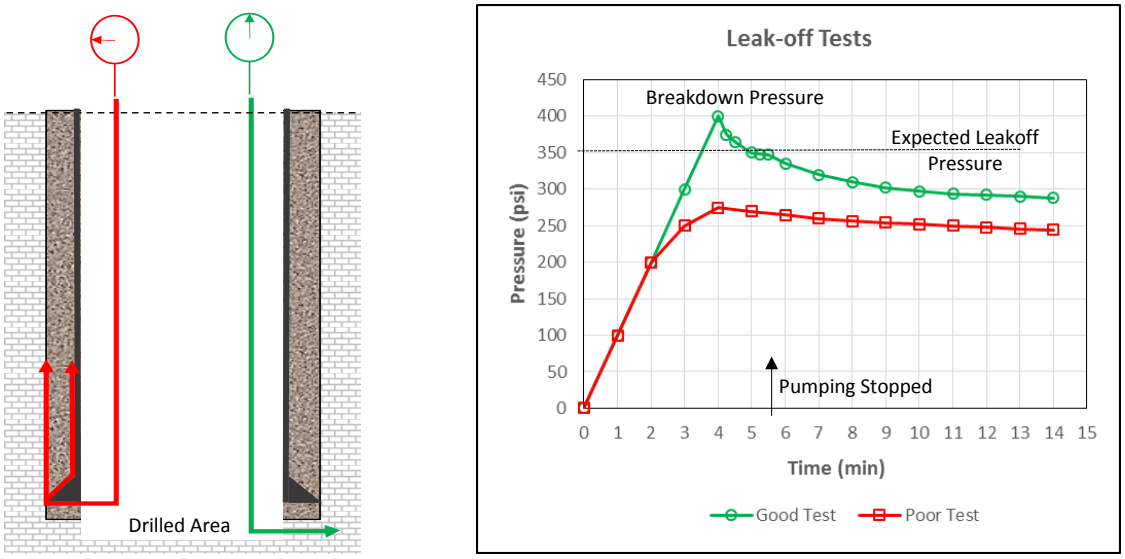


Figure 3: Examples of **'good'** and **'poor'** well pressure tests on cement after drill-out operations:



After Postler, 1997[2]

3.3 Cement bond logs

The third level of well integrity involves measuring the consistency and quality of the cement between the cement, pipe and surrounding rocks. Electronic measuring tools are lowered into the well to measure or 'log' the cement along the depth of the well. Sound waves are used to look at how well the casing is held or bonded to the cement.

The sound waveforms on the log (Fig 4) are evaluated for how well the sound waves travel from a transmitter through the pipe, cement and rocks before returning to receivers along the tool.[3] If

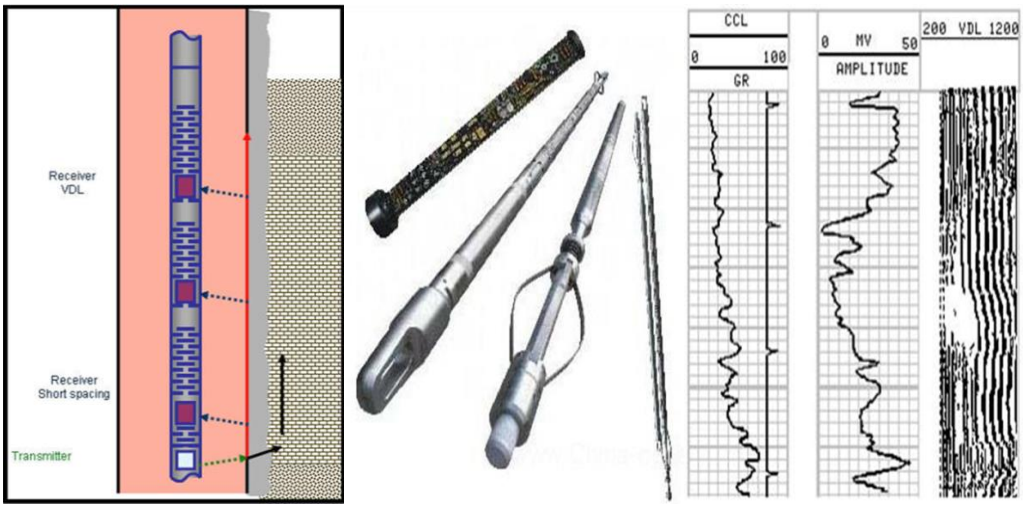
[2] Postler, D.P.: "Pressure Integrity Test Interpretation," paper, SPE-37589-MS, presented at the SPE/IADC Drilling Conference, 1997.

[3] http://pa.water.usgs.gov/projects/energy/stray_gas/presentations/3_920_Sutton.pdf

cement bonding is good, sound will not easily transmit through the pipe. Conversely, if cement bonding is poor, the pipe is free to vibrate, allowing for easy transmission of sound.

Cement bond logs are not run in every well, but are a very useful back-up if a pressure test indicates a concern with cement placement, or there are particularly sensitive sections of rock that must be isolated. If a cement bond log shows a large section of poor bonding or quality across an important area, the operator may perform a well maintenance operation with a rig (called a 'workover') to inject cement (called a 'squeeze job') into the problem area.

Figure 4: Cement Bond Logging equipment and survey data:



4. A well's life

4.1 Production phase

Once the well has been properly constructed, and its integrity verified, it is then brought into production. The productive life of a well is usually measured in decades. The oldest continuously producing oil well[4] in the world is McClintock Well No. 1 in Pennsylvania which has been producing for over 150 years.

4.2 Well maintenance

Each producing well has a maintenance program used to monitor its integrity and schedule regular servicing. Major maintenance programs can occur every few years when a workover rig is brought in to service the well. A measurement of pressure build up in a casing string (called "sustained casing pressure") for example, would indicate that a well needs attention. The workover may involve replacing internal piping, testing pressure seals and measuring or logging well parameters such as flow rates and temperatures in the well, fluid sampling and pipe integrity. These measurements can indicate if further tests or repairs are needed, and are a normal part of the well maintenance program that continues for the producing life of the well.

4.3 End of well life remediation

Once a well has reached the end of its useful life, it must be remediated (the industry term is 'plugged and abandoned'). Steps taken to remediate a well are usually well defined by the relevant regulator. A typical well remediation requires using a drilling rig to remove any equipment in the

[4] http://www.titusvilleherald.com/articles/2011/08/16/news/doc4e4b452d3c518727905287.txt

wells, such as subsurface pumps and pipe tubing. The rig then pumps cement into the well and sets mechanical plugs as a back-up, to create long-term barriers to fluid flow and isolate rock zones.

Once this is done, the well-head is removed, and in onshore wells it is cut off below ground level so that past practices such as agriculture can resume over the well site.

A well that has been properly remediated is very different to a producing well that needs regular measurement and monitoring. A remediated well is designed to be safe and pose no material threat to safety and the environment for future generations.

5. The facts about well integrity

How often do wells fail?

The United States has the world's longest history of oil and gas production, and the most intensive drilling programs. The Ground Water Protection Council in the US examined more than 34,000 wells drilled and completed in the state of Ohio between 1983 and 2007, and more than 187,000 wells drilled and completed in Texas between 1993 and 2008. Included in the study period were more than 16,000 horizontal shale gas wells, with multi-staged hydraulic fracturing stimulations, completed in Texas.

The data[5] shows only 12 incidents in Ohio related to failures of (or graduate erosions to) casing or cement – a failure rate of **0.03%**. In Texas, the failure rate was only about **0.01%**. Obviously zero is the aim, but this is still a very low percentage considering the number of wells drilled.

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[5] http://fracfocus.org/sites/default/files/publications/state_oil__gas_agency_groundwater_investigations_optimized.pdf