Casing and tubing integrity are essential for well performance and maximise the ultimate recovery. Factors that affect well integrity, include but not limited to: poor cementing, poor perforations, corrosion, casing leaks and uneven depletion resulting in inter-zone cross-flow.
Overview

Well integrity affects every well at some stage of the well’s operating life. Consequently, it will affect the overall field performance and ultimate recovery. :

- **Cementing**: Cementing is a critical part of any well competition and subsequently well integrity. Poor cementing is responsible for casing outer wall corrosion, leaks and subsequently casing collapse.
- **Corrosion**: Corrosion is initiated immediately after placing the casing. The rate of corrosion depends on many factors such as casing metallurgy, poor cementing and casing stresses - to quote a few.
- **Leaks**: Leaks in casings and tubing will materialize in the long run. This again is a function of the metallurgy, cementing and borehole environment.
- **Uneven Depletion**: The variations in the zone and layer permeabilities will result in large pressure differentials between the zones. When the well is shut-in, or a small choke is used cross flow inside the casing can take place. Behind casing leaks can also be increased.
- **Perforations**: Perforation efficiency also play an important role in well performance. The technology of perforations have developed multi-fold in the last 2 decades. Efficient perforations plays an important role in minimising skin and improving the Productivity Index and consequently optimising the pressure draw-down.

The course deals in details on evaluating these parameters. Field examples will be used in the daily workshops to cover those topics and provide the foundations for a solution.
Cementing:
Cement quality control and cement evaluation are important functions to preserve the well integrity. Cement evaluation with circumferential coverage has progressed to give accurate evaluations.

Corrosion Monitoring:
Corrosion will take place at some stage in the life of a well. A wide range of corrosion monitoring tools are used now to evaluate metal losses in casings and to evaluate and optimise the cathodic protection system.

Leak Detection:
Many tools, employing various technologies, are used to detect and quantity leaks inside outside the casing configurations.

Uneven Depletion:
This will be discussed in details to evaluate the PI and Pr of each zone and estimate the volume of cross flow when the well is shut-in or at various small chokes. This can be done without shutting the well.

Perforations Efficiency:
Efficient Perforations are critical to the well drainage, wellbore flowing pressure and to the field performance. This can also be covered in details outlining the new technologies used.
Poor cementing is the source of most of the well integrity related problems. Not to say that good cementing will insure eternal well integrity, but will preserve the well integrity over a longer time scan. Initially we had a CBL-VDL, which was limited scope in solving the cement quality.

- **CBL**: Amplitude of the wave that remained in the casing
- **The signal image that reflected back from the formation**
The introduction of the ultrasonic rotating tool, followed by the rotating flexural wave measurement created a quantum jump in the quality of the cement evaluations.

- Ultrasonic: Measures the acoustic impedance of the cement
- Flexural wave: measure the compressive strength of the cement.

The combination can define fluid (oil/water/gas) or solid (cement) circumferential coverage around the casing.
Corrosion Mechanisms: There are many corrosion mechanisms that take place downhole. These can be divided into 3 categories: Galvanic, Chemical, Mechanical (Stress).

Five set of tools are used to quantify inner wall corrosion, outer wall corrosion, pits and cathodic protection design and evaluation.
Well Integrity: Corrosion Monitoring

Corrosion Monitoring and Protection:

The example on the left shows a cathodic protection system evaluation giving the lowermost level of protection.

The example on the right shows the combined log data from Cement, Electromagnetic and Electrical logging data. Note the perfect correlations between corrosion metal loss (middle tracks) with poor cementing (track on left) and electrical current leaving casing- anodic points (track on the right)
Leak Detections- Temperature profiling:
There are many forms of logging that are used to detect leaks (temperature, noise, oxygen activation, Injectivity). The most effective form is temperature profiling. The examples above show:

- Permanent Temperature sensors using fibre optics: This will become almost standard in the future where the temperature profiles continuously monitored.
- Standard E-Line temperature logging: The example on the right shows the geothermal logs for 20 wells. 3 of the wells show a deviation from the geothermal. An increase above geothermal means leak up behind the casing, and a decrease below the geothermal mean leak down ward.
Well Integrity: Leak Detection / Oxygen Activation

Leak Detections- Water Flow
A burst of neutron will activate any oxygen atoms in the vicinity. The oxygen atoms will act as a radioactive source with a half-life of 7.5 sec. If the water is flowing, then GR ray detectors will detect this flow of oxygen atoms, time it and estimate the oxygen velocity. Since water is the main source of oxygen, this is essentially detects water movement inside the casing and in the annulus behind the casing.

\[
O^{\text{Activation}} \quad T_{1/2} = 7.1 \text{ s} \quad 16O + n \rightarrow 16N + p \rightarrow 16O^* + \beta \rightarrow 16O + \gamma
\]
Well Integrity: Uneven Depletion and Cross-Flow

Leak Detections- Water Flow
By running two production logs at different chokes, the pressure and flow rate for any selected interval can be measured. When plotted, the Productivity Index (PI) and Layer pressure (Pr) can be estimated for any selected producing interval.

The value of the shut-in pressure (Px) can computed. Zones with Pr > Px will flow out and zones with Pr < Px will take flow.

Graphically it can be seen that Zones A and B are flowing into zones C and D. This cross-flow can be quantified without the need to shut the well.
Perforation Efficiency:
Perforation technology have improved considerably over the last two decades. The perforation charge generates very low grain of explosive that can penetrate over 1.5 meters without damaging the formation. Transient pressures are also used to create underbalanced conditions for the duration of the perforation penetration.
Agenda

Day-1
• Introduction to Well Integrity
• Why Well Integrity
• Problems causing well integrity
• Depth control
• Well Head Pressure Control
• Leak Detection using:
  • Noise logs
  • Temperature logs
  • Oxygen activation to measure water flow
  • Communication Testing to check zonal isolation

Day-2
• Uneven Depletion:
  • Causes of uneven depletion
  • Modelling of uneven depletion
  • Estimating the inter-zone cross-flow caused by uneven depletion

Day-3
• Spinner Calibrations
  • Estimating zone flows, Productivity index (PI) and reservoir pressure (Pr) for each zone.
  • Optical Distributed Temperature
  • Permanent temperature sensors

Day-4
• Primary Cementing
• Squeeze Cementing
• Cement Evaluation Tools
• CBL-VDL
• Ultrasonic
• Isolation Scanner (Rotating Flexural wave)

Day-5
• Corrosion Monitoring
• Corrosion Mechanisms
• Corrosion Monitoring Tools
• Cathodic Protection
• Perforation Conveyance
• Perforations Efficiency

There will be daily practical workshops on each of the topics covered using field examples