Formation Pressure Evaluation: Acquisition and Interpretation
Overview

Following topics will be addressed in this course:

• Formation pressure in virgin reservoirs and potential pressure variations caused by overpressured zones, and compartmentations caused by faults.
• Formation pressure behind the casing in un-perforated zones.
• Pressure variations in the formations caused by uneven depletions and low Kv/Kh. This need to be made in open hole or in producing zones in cased hole.
• Fluid sampling in both open hole and in un-perforated zones in cased hole.
• Spectroscopy analysis downhole for fluid chemical analysis and for obtaining uncontaminated formation fluid.
• Well Testing: Pressure transient analysis to evaluate reservoir parameters such as pressure, drainage area, skin.
Formation Pressure Evaluation: Acquisition and Interpretations

Formation pressure evaluation in open hole: Wireline Formation Testing (WFT) have progressed considerably in the last two decades. The standard WFT operations will be presented in details, and its applications for formation pressure evaluation, fluid sampling and downhole spectroscopy.

Formation pressure evaluation in open hole: High technology tools: Saturn-3D added a new dimension to formation pressure evaluation and sampling for measurement in very low permeabilities of the order of 1 mD and high viscosity oil of the order of 1000 cp.

Formation Pressure Evaluation in Cased Hole: WFT equivalent in cased hole, termed Cased Hole Dynamic Tester (CHDT) added a new dimension to formation pressure evaluation and sampling. This allowed uneven pressure variations to be measured and also to located missed/by-passed hydrocarbon zones.

Uneven pressure gradients caused by uneven depletion: Running production logs at 2 different chokes allows both the zone by zone formation pressure to be estimated, as well as the productivity index for each zone. This is the only practical method to estimate zone-by-zone formation pressure in perforated and commingled zone.

Formation pressure evaluation in open hole using LWD: LWD technology has advanced considerably and formation pressure can be made with special LWD tools while drilling.

Well Testing Overview: Transient pressure well testing is an important tool in formation pressure evaluation and in estimating reservoir parameters. This will be discussed in some details.
The WFT is an important tool for formation pressure evaluation.

- The WFT is run in open hole before setting the casing.
- Different probe configuration can be customized for specific formations.
- A pretest, sampling 20 cc of fluid, is used to estimate permeability and formation pressure.
- Large formation fluid samples can be quality controlled using a resistivity sensor in water based mud, and optical sensor in oil-base mud, to avoid filtrate sample contamination.
Fluid spectrum analysis downhole is an additional feature of some WFT tools.

- Spectrum analysis can initially be used to make sure a clean (filtrate free) sample can be obtained in oil base mud.

- The spectrum can be used to determine at downhole conditions:
  - GOR
  - C1, C2, … C6+
  - Free Gas detection
  - CO2 evaluation.
  - Phase separation

- This could be useful to avoid long delays from standard PVT analysis.
Pressure Gradients and Zone Connectivity

- Formation pressure plots as a function of depth is a classic output of WFT applications.
- Fluid densities and free fluid contacts can be obtained.
- Pressure gradients can also be used to detect overpressured zones.
- Another major application is to determine zone isolations and connectivity, caused by faults and other structural features. This is important for field development planning.
Two of the 4 Probes

High Technology WFT: Saturn 3D

- The standard WFT tools had severe limitations at low permeability and high oil viscosity.
- The modern WFT (Saturn 3D) is a new game changer. It increased the scope of lower permeability to 1 mD and viscosity as high as 1000 cp.
- Sampling times have also decreased by 1-2 orders of magnitude. This minimised the possibility of the tool getting stuck.
- This new performance is facilitated by an increased area of sampling from four probes that is 800 times more than that of a standard WFT probe.
Cased Hole Dynamic Tester (CHDT)

- The need for a WFT tool that can operate in cased hole is obvious, with applications to monitor changes in pressure, sample fluid and detect by-passed hydrocarbon zones.
- The Cased Hole Dynamic Tester (CHDT) was designed for this purpose.
- The tool sets in a single casing:
  - drills a hole and access the formation behind the casing and cement.
  - does multiple pre-tests at different sampling rates.
  - Obtains a large fluid sample
  - Plugs the whole and un-sets.
- This has unlimited scope of applications in depleted reservoir and even in old abandoned reservoirs where poor fluid sweep had taken place.
With increased applications of Logging While Drilling (LWD) and corresponding advances in technology, FPWD was a natural step in expanding LWD applications. This requires that the drill string is kept stationary and the tool is set hydraulically, pre-tests are made and the data is transmitted in real time to the surface. This data can be used to optimise the mud weight, and also to optimise the location of the casing shoes. The pressure gradients as a function of depth can be used in the same manner ans with the WFT to determine fluid contacts and fluid densities.
Uneven Depletion and Variations in Zone Pressures.

- The production profiles shown above are for the same well taken 12 years apart.
- This data is obtained by running two production logs, including pressure measurements, at two different chokes.
- This will give two (production rate, and flowing pressure) coordinates.
- The bottom plot gives both the PI and above all the zone pressure.
- This is the only technique that can give each zone pressure from perforated and commingled zones.
- The shut-in pressure (Px) can also be determined and cross-flow estimated, by equating the flow rates to zero. In the above example A and B are flowing into C and D.
Transient pressure testing is also another process that will help to evaluate many reservoir parameters, including pressure, skin, permeability thickness, drainage area, etc..

However, the data obtained is the average for all the perforated intervals, or the open hole producing interval if the well is not cased.
Agenda

Day 1
- Overview of open hole logging.
- Parameters affecting invasion profiles.
- Depth Control.
- Porosity and lithology.
- Resistivity measurements.
- Computing porosity, volume of shale and water saturation.

1 hour workshop on open hole interpretations.

Day 2
- Pressure measurements in Open Hole.
- Well Head Pressure.
- Wireline Formation Testing: Overview.
- Modular Dynamic Tester: Hardware and applications:
  - Tools and hardware functionalities.
  - MDT run with standard logging tools.
  - MDT used to estimate zone permeability.
  - MDT pressure gradient analysis.

1 hour workshop on WFT pressure gradient analysis.

Day 3
- Modular Dynamic Tester: Hardware and applications- continues:
  - Formation supercharging.
  - MDT Sampling.
  - MDT Optical spectroscopy.
  - Saturn-3D: Modern WFT tools.

1 hour workshop on WFT sampling and supercharging.

Day 4
- Modular Dynamic Tester: Hardware and applications- continues:
  - MDT applications in depleted reservoirs.
  - Sampling and pressure monitoring behind casing.
  - Pressure measurements with the LWD during Drilling.
  - PVT Express: Wellsite fluid PVT analysis.

1 hour workshop on WFT in depleted reservoirs.

Day 5
- Production Logging Overview.
- Production logging in depleted reservoir.
- Estimating PI and Pr (layer pressure) for each zone.
- Estimating uneven pressure variations and volume of cross-flow.
- Well Testing and its applications:
  - Estimating Permeability thickness.
  - Reservoir pressure.
  - Skin values.

1 hour workshop on production logging and Well Testing.

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