Formation Fracture Gradient

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Learning Objectives

- At the end of this section you should be able to describe the following, as well as performing the presented calculations:
  - Formation Fracture Pressure
  - Kick Tolerance
  - Considerations prior to pressure test.
  - Considerations during pressure test
  - Interpreting results
- Finally, you will know and understand the various tests used for pressure evaluation.

Formation Fracture Pressure

- Formation Fracture pressure is the amount of pressure necessary to permanently split or break the rock structure of a formation.
- Just overcoming formation pressure is normally not enough to create a fracture.
  - Porous permeable formations allow formation, or pore fluid to flow
  - As such, fluids must be pumped into it
  - The pore fluid flow rate is limited
  - Once the pore fluid flow (if any) rate is exceeded the formation rock becomes stressed and may deform, then fracture

Formation Fracture Pressure

- Fracture gradients normally increase with depth because of the increasing overburden (rock layers) pressure.
- Deep and/or tightly-compacted formations may need higher fracture pressures to overcome existing formation pressure and resisting rock structure.
- Less compacted formations fracture at lower pressure.

Fracture Data

- General Fracture Data is known for formations in various parts of the world. These have been determined by various types of tests that are typically conducted during drilling. Some tests are performed on completed wells, and some during well servicing operations.
- The data from these tests assists in the calculation of casing depths, well control options, formation fracture pressures and maximum fluid weights.

Formation Fracture Pressure

- *REMEMBER:* Even though data from a field may exist, each well is unique and should be treated as such.
- *REMEMBER:* Always “Think Downhole” as it is the total pressure against the formation that causes leakage and fracture. That is, the hydrostatic pressures plus applied pressures.

Kick Tolerance

- Kick Tolerance – the estimated volume of a kick that can be taken when initially shut-in before formation fracture may occur.
  - May be expressed in ppg, bbls or combination.
- Based on calculations from fracture and test data, and existing conditions (present mud weight and formation pressure).
- If kick tolerance is exceeded, formation failure may occur if:
  - Exceeding maximum mud weight.
  - Kick is ***below*** the weak or fracture zone.

Determining Fracture Pressure

- Fracture Pressure – maximum surface pressure that can be applied to a casing *full of a known fluid* without fracturing the formation below it.
- Weakest zone is usually the shallowest exposed formation below the casing shoe.
  - In some cases may be deeper than the formation below the casing shoe.
- Generally based from leak off or formation competency tests to determine the strength and stability of a formation.

Formation Competency Test

- A formation competency test or “jug test”, is performed when there is a risk of formation damage.
- During this test, the wellbore is pressured to a pre-determined pressure that the formation should be able to endure.

Formation Competency Test

- If Fracture mud weight or gradient is known, the Surface Test Pressure (STP) to stay below can be calculated as follows:

$$\mathbf{STP_{psi} = 0.052 \times Casing\ Depth_{ft} \times (Fracture\ MW_{ppg} - Present\ MW_{ppg})}$$

or,

$$\mathbf{STP_{psi} = Casing\ Depth_{ft} \times (Fracture\ Gradient_{psi/ft} - Present\ Mud\ Gradient_{psi/ft})}$$

- If this test is run without fracturing the formation, the test is called "good."
  - Advantage: formation not damaged.
  - Disadvantage: maximum formation strength not determined.

Leak-Off Test (LOT)

- A Leak-Off Test is performed to estimate the maximum amount of pressure or fluid density that the test depth can hold before leakage and formation fracture may occur.
- Depending on how this test is performed, various mud properties must be taken into account.

Leak-Off Test (LOT)

- There are various LOT techniques that depend on how pressure is applied to the formation and may yield slightly different results. These include:
  - Pump down string
  - Pump down casing
  - Circulate through choke

Conducting Leak Off Tests

- No matter which method or test is used, the following should be performed:
  - Fluid conditioned.
  - Well shut in.
  - Use proper pressuring technique.
  - Pump SLOW and begin recording pressure.

Leak-Off Test (LOT)

- According to test type:
  - LOT: Pressure to point where formation begins to take fluid.
  - Competency-test: Pressure to predetermined point.
  - Test pressures typically are held for a minimum of 5 minutes.
- Bleed pressure off.
- Repeat to verify.

Maximum Allowable

- Maximum Allowable is the combination of the hydrostatic pressure of a fluid plus an additional pressure that results in unwanted leak off or formation damage.
- Maximum Allowable Mud Weight (MAMW) or frac mud weight is the total pressure, represented as fluid density, above which leak off or formation damage may occur. It is calculated from LOT data and can be calculated as follows:

$$\mathbf{MAMW}_{ppg} = \mathbf{Test\ MW}_{ppg} + \frac{\mathbf{Applied\ Pressure}_{psi}}{\mathbf{0.052 \times TVD}_{ft,\ shoe}}$$

Maximum Allowable

- Maximum Allowable Surface Pressure (MASP) can be calculated if the fluid density in the well changes from the test fluid density by the following:

$$\mathbf{MASP}_{psi} = \mathbf{0.052 \times (MAMW}_{ppg} \mathbf{- MW}_{ppg}\mathbf{) \times TVD}_{shoe}$$

REMEMBER: Calculated maximum pressures and densities are only good if the casing is full of the same fluid from the casing shoe to surface!