Well Integrity Assurance

Reservoir Related Aspects

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1. Introduction
Well Integrity Assurance Reservoir Related Aspects

- Healthy Wells: Integrated Approach To improve Oil Productivity
- Drilling In Exploratory & Development Areas
- Reservoir Health, IOR/EOR Processes
- Drilling In Old Aging Brown Field
- Healthy Drilling, completions & production Practices
- Drilling & Completing High Tech Wells / Multi Layered/Multilaterals
- Use of Latest tools & Technology & Real Time monitoring
Well Integrity Assurance – Reservoir Related Aspects

- Well Integrity is the application of technical, operational and organizational solutions to reduce risk of uncontrolled release of formation fluids throughout the life cycle of the well.

- As the field matures, to sustain production over the life span, it needs to focus on integrity related issues, proper acknowledgement & subsurface integrity assurance activities.

- Diagnostic surveys & integrity logging to evaluate the current condition of completion strings, casing & cementation.
Well Integrity Assurance – Reservoir Related Aspects

Implications

• Any lapses in well integrity can cause unintentional leaks, resulting well control situation in terms of safety.
• Surface & sub-surface exposed to deteriorating conditions associated with producing corrosive fluids from well, the possibility of accidents increases with time.

Measures to take

• Proper well integrity can reduce operating costs associated with post incident rectification.
• Well integrity monitoring program focuses on preventing & detecting range of potential integrity problem at surface & down-hole components of a well.
2. Factors Affecting Well Integrity
Factors Affecting Well Integrity

- **Underweight** mud can cause blow-out and **overweight** mud can damage the well bore with +ve skin resulting the performance of well in longer period.

- **Hole angle, cement channel angle and casing eccentricity** are the parameters which can make wellbore unstable/failure

- **Poor cementation** behind casing leads to channeling/leakages

- Quality of **water injection** too affects the wellbore.

- **Corrosion:** rate increases as temp, pressure & stress increase during production

- **Scale deposition** across completion/production facilities introduces high risks for well operations integrity.

- **Continuous Monitoring Program** tackles the integrity issue. (Reservoir monitoring, good cementation behind casing and penetration of exact formation)
3. Reservoir Engineering Aspects
IT IS VERY IMPORTANT TO HAVE RESERVOIR UNDERSTANDING TO MANAGE A HEALTHY WELL

Key Reservoir Parameters

**Static/Flowing Reservoir Pressure:** Regular pressure recording FBHP/ SBHP/ PBU/ RLT/ Isobar

**Productivity Index, PI**

**Skin Factor:** additional resistance to the flow due to damage calculated from Build-up study (+ve/-ve).

**Permeability:** ability to move oil/gas/water through the system

**Porosity:** void space in the rock.
Type of Reservoirs

- **Sandstone Reservoir:**
  - All Quartz grains
  - Porosity ranges 10 – 30%
  - Made of hard, stable, insoluble and without crystal characteristics

- **Carbonate Reservoir:**
  - Complex & heterogeneous geological & petrophysical characteristics
  - Naturally fractured & complex porosity
  - Mainly shales, sands and made of calcium carbonate
  - Porosity ranges 1-35%; Dolomite: 10%; Limestone: 12% (Avg.)
  - Great producibility than sandstone reservoir
Type of Reservoirs

• Fractured Reservoir:
  – Natural fractures from the interaction of earth stresses while man-made fractures result from drilling activities, increase in pore pressure in injection operations, reservoir cooling during water flooding
  – Naturally fractured reservoirs contain secondary or induced porosity in addition to their original primary porosity.
  – Porosity in the actual fracture is still very small.
  – Naturally fractured reservoirs behave differently than unfractured reservoirs with similar porosity, due to the relative high flow capacity of the secondary porosity system.
Understand Well Behavior

Keep tab on the issues:

- Daily operational field data monitoring.
- Monitor sudden *water cut* rise/increase in *GOR* in a short period.
- Monitoring of *Reservoir Pressure*
- Monitoring of *Water injection*
- Simultaneous water injection and oil production leads to leakage problem (*Dual Completion*).
- With increase in water cut and drop in oil production can be due to hydrostatic pressure in annulus that significantly reduce oil column in string overtake by water.
- Visible evidence of deteriorate sub-surface well integrity.
- Rise could be due to leakage in well string.
Understanding Reservoir

**Build up Studies:**
Analysis of Pressure Build-up Data by
- Miller, Dyes & Hutchinson method (MDH)
- Horner method

These methods provide a means of measuring
- effective reservoir permeability,
- degree of damage around wellbore (Skin effect, S),
- any interference between producing wells,
- limits of the reservoir where there is no strong water drive or no large aquifer than the hydrocarbon reservoir,
- inherent flow capacity of the undamaged formation (kh) and
- static reservoir pressure.
A general equation for pressure build-up was presented by Horner:

$$p_{ws} = p_i - \frac{q \mu B \cdot 1.15}{2\pi kh \log \frac{t_p + \Delta t}{\Delta t}}$$

where,

- $P_{ws}$ = Static pressure, psi
- $P_i$ = Initial pressure, psi
- $q$ = Liquid rate, bbl/day
- $B$ = Formation volume Factor
- $\mu$ = Viscosity, cp
- $kh$ = Permeability-thickness, md-ft
**Productivity Index (J) & Skin Factor (S):**

Measurement of the severity of the formation damage or the reduction in the formation permeability compared to the original permeability is expressed in a dimensionless quantity called skin.

(+ve) skin means the formation is damaged.  
(-ve) skin shows undamaged / stimulated formation.

Productivity Index (PI) of a specific well can be considered as the proportionality constant, J in deliverability equation between production rate and driving force (pressure drawdown):

\[ q = J \times \Delta p \]

where,

- \( q \) = Flow rate  
- \( J \) = Productivity index  
- \( \Delta p \) = Pressure drawdown

During its life span, a well is subject to several changes with respect to flow conditions.
Understanding Reservoir water injection

Water injection has two purposes,

- **Sweeping** of oil to the producers and
- **Maintaining reservoir pressure**.
- **maximizing overall recovery** so that an evenly distributed water front sweeps the remaining hydrocarbons towards the producers,
- **Accelerating hydrocarbon** production by maintaining high reservoir pressure & sweeping oil, rather than water, towards the producers,
- Improving both **environmental and technical** profile of company by re-injecting produced water into the reservoir.
Understanding Reservoir

Water Flooding:
4. Well Performance Monitoring
Well-Performance Monitoring

- Reservoir engineer is used to monitor well performance quickly with the help of material-balance (p/z vs. cumulative production) plot.

- The data must be analyzed based on the history & production performance.

Performance Plot, Mumbai High
5. Surface & Sub-surface Integrity Diagnosis
Surface & Subsurface Integrity Diagnostics

- Drilling & Completion
- High Casing Pressure
- Reservoir Saturation Monitoring
- Well Head Pressure Monitoring
- Abnormal Reservoir Pressure
- Temp Survey
- Well Work-over
Drilling and Completion

- Procedures for drilling and completing well are designed such that no pressure should be seen on any of the annuli during well operation phase.
- This pressure should not recur once they are bled-off.
- Annulus communication can be caused by loss of hydraulic seal zone isolation by cement, inadequate cement height outside production casing.
High Casing Pressure

Daily Surveillance on well parameters such as
- FTHP/FTHT/PCP to identify anomalies in well condition
- Sign of communication between casings can be confirmed by bleeding off pressure at annulus and if again builds up

Communication between annulus can be caused by:
- Loss of hydraulic seal zonal isolation by cement outside production casing
- Inadequate cement height outside production casing
- Production or Surface Casing leak
- Temp expansion due to dynamic change in production/injection condition.
Abnormal Reservoir Pressure

• If the reservoir producing under natural depletion without water injection support and pressure not declining, leakage can be suspected.

• If quality of water injection not monitored, it affects the wellbore, resulting pressure maintenance issue to the nearby wells and loss of productivity.
Temperature Survey

Temp survey in oil wells based on the frequencies:

- Well age <7 yrs – Survey should be twice a year
- Well age >7 & <13 yrs – Survey should be thrice a year
- Well age >13 yrs – Survey should be 4 times a year
Well Work-over

- Down-hole condition is further confirmed based on the completion string and well accessories retrieved at the surface.
- In case of multiple completion strings, the corrosion aggravated by:
  - high CO\(_2\) production
  - high water cut
  - dual utility well
  - erosive production environment due to sand production
6. Mud Analysis
Mud Analysis

- Drilling mud provides hydrostatic pressure to prevent formation fluids from entering into the well bore.
- Design of the mud should be based on formation pressure.
- Failure of mud can prove extremely costly in terms of materials and time.
- Major problem could be stuck pipe, kicks or blow-outs.

_The type of muds are:_

- Water based mud
- Oil based mud
- Emulsion mud
- Gas based mud
7. Formation Damage
Formation Damage

Formation damage is a process of initial permeability reduction. The factors affecting formation damage are:

- The degree of formation damage depends upon the nature and characteristics of drilling fluid, formation properties and operating conditions.

- In *overbalanced drilling (OBD)*, formation damage is caused by the presence of filter cakes and invading drilling fluid in porous media.

- In *underbalanced drilling (UBD)*, drilling fluid invasion into reservoir can occur due to the presence of capillary pressure.

- Both OBD and UBD can induce near-wellbore formation damage.
Formation Damage

- **Formation damage** is often a major factor in reducing the **productivity** or **injectivity** of a well. Stimulation is the operation to improve well productivity well around wellbore.
- Successful stimulation of reservoir for **removal of wellbore damage**. Such impairment is reflected in terms of **“Skin Factor”**.

**Drilling:**

- Exposure of reservoir with **external fluid** causes drilling damage.
- To **balance the formation pressure**, the pressure of the drilling mud column must exceed by at least 200 psi.
- The **horizontal drilling** requires more concern for formation damage, as it makes the formation to be exposed to mud for longer period.
- **Under pressured reservoirs** are also significantly more susceptible to formation damage.
Formation Damage contd....

**Invasion of mud solids & filtrates:**
Objectives are to balance the reservoir pressure and to create filter cake at the formation face thereby reducing the filtrate losses in the formation. But these mud solids can progressively fill the porosity of the reservoir rock if forced in to the pay zone. Subsequent production or injection will cause the material to bridge and severely decrease the permeability of the near-wellbore area.

**Casing/Cementation:** Cement or mud solids may
- plug large pores, vugs and induced fractures.
- bring about changes in the producing formation from high fluid loss cement slurries.

**Completion:** Damage during perforation
While running tubing and packer

**Hydraulic Fracture:** Incompatibility between fluids
Fluid retention
Residue in matrix or fracture
Formation Damage contd…

**Polymer Invasion:**
- Polymers may cause damage due to improper selection of the additives and their composition.
- These are precipitated or scaled cause damage to the formation.
- Presence of asphaltene, wax and resin increase the chances of scale formation.
Formation Damage

Diagnosis of Formation Damage:

• Formation damage can be found out through well tests such as injectivity test or productivity test.

• Analysis of pressure buildup or fall-off tests may indicate the relative magnitude of the damage/skin effect.

• Production logging surveys may show zones not contributing to the total flow stream.

• Comparison of productivity of the subject well with productivities of surrounding wells can provide clues.
Stimulation:

Stimulation jobs are usually done in wells with or without work over rigs.

- Acidization.
- Hydraulic fracturing
- Solvent job.
- Surfactant job.
- High energy gas stimulation (HEGS).
- Explosive stimulation.
8. Conclusions
Conclusions

• Understanding reservoir behavior as well as well behavior.
• Reservoir related integrity issues such as well performance, formation damage, logging, injection, pressure maintenance should be monitored regularly.
• Quality of water injection and continuous monitoring of reservoir parameters with various diagnostic tools on regular basis.
• Constant monitoring reduces cost not only for a particular well, future course of action.
• Based on fluid designing, formation damage can be minimized.
• To minimize the damage, mud preparation has significant role to complete a healthy well and blow out can be averted.
• Corrosion of surface and sub-surface equipment, preventing & detecting range of potential integrity problem at surface.
Thank you