PRODUCTION AND OPERATIONAL ISSUES

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Summary

- **Production and Operational Issues**
  - Shale gas reservoir production is highly rely on efficiency of hydraulic fracturing treatment and optimum operational conditions
  - Deficiencies in planning and execution of either one results in partial or complete loss of reservoir deliverability
  - In this lecture major factors impacting reservoir permeability and hydraulic fracture conductivity/geometry will be discussed
  - Major production and operational issues are divided in:
    - Pressure draw down
    - Liquid loading
    - Hydrate formation
    - Infrastructure deficiencies
PRESSURE DRAW DOWN
Hydraulic fracturing

\[ q = J\Delta p \]

\[ \Delta p = \overline{P}_{\text{reservoir}} - P_{wf} \]
Hydraulic fracture Conductivity (Cont.)

\[ C_{fD} = \frac{k_f w_f}{k x_f} \]

\( C_{fD} \) = Hydraulic fracture conductivity
\( k \): Matrix permeability
\( k_f \): Hydraulic fracture permeability
\( x_f \): Hydraulic fracture half length
\( w_f \): Hydraulic fracture width
Pressure Draw Down

High pressure draw down
High flow rate

Intermediate pressure draw down

Low pressure draw down

Surface line pressure

Tubing pressure

Date

Tubing/Casing Pressure


Tubing/Casing Ratio

Tubing Press (psi)
Casing Press (psi)
Line Press (psi)
Csg/Tbg ratio

High pressure draw down
High flow rate

Low pressure draw down

Surface line pressure

Tubing pressure

Date
Pressure Draw Down (Cont.)

- Higher pressure draw down leads to:
  - Higher production rate
  - Faster pressure decline after reaching the surface line pressure
  - Lower ultimate gas recovery (UGR)
    - Proppant crushing and embedment
    - Loosing hydraulic fracture conductivity
  - Sand production and surface facility corrosion
    - Significantly damage surface facilities specially when Ceramic proppants have been used

![Graph showing production rate (q) versus time](image)
Proppant Placement

Ideal proppant placement

Real proppant placement

During fracturing

During Production

During fracturing

During Production
Proppant Crushing Embedment

Early Time (or low pressure drawdown)
Slightly impaired Fracture conductivity

Mid Time (or intermediate pressure drawdown)
Moderate impaired Fracture conductivity

Late Time (or high pressure drawdown)
Highly impaired Fracture conductivity

Hydraulic fracture during production
Optimum Pressure Draw Down

• Optimum pressure draw down is a function of:
  – Fracture closure pressure
  – Proppant density, size and strength
  – Formation mechanical properties Young's modulus and Poisson’s ratio
  – Natural fracture density
  – Multi-stage hydraulic fracturing interactions
LIQUID LOADING
Liquid loading in a Gas Well

- Liquid loading is an accumulation of water, gas condensate or both in tubing.
- Liquids can enter the well directly from reservoir or condense from the gas in the wellbore due to pressure drop.
- Almost always we do have liquid (water or condensate or both) production.
- The major cause of liquid loading is low gas flow rate or velocity.
Typical Gas Well History

- There is a critical gas velocity below which liquid cannot be transferred to the surface.
- Liquid will accumulate at the bottom of the tubing when gas flow rate is not enough.
- Liquid accumulation "liquid loading" will decrease the production rate and if not corrected kills the well.

Dead well due to liquid loading

Liquid is represented in Blue
Gas is represented in Red

Gas flow rate

TIME
Diagnostic of Liquid Loading

• The easiest technique is surface monitoring
  – High tubing/casing differential pressure
• High flowing bottom hole pressure
• Observed slugging from well
• Rapid increase in decline rate
Liquid Loading Remediation

- Using Velocity String
  - Running smaller diameter tubing leads to increase in gas velocity and higher liquid lift capacity
Liquid Loading Remediation (Cont.)

- **Soaping**
  - Adding surfactant at the bottom of tubing generates foaming that helps removing water build up
  - Is not as effective in condensate loading
Liquid Loading Remediation (Cont.)

- **Venting**
  - Dropping the surface pressure to atmospheric pressure to maximize gas velocity
- **Compression**
  - Dropping the surface pressure below line pressure to increase gas velocity
Liquid Loading Remediation (Cont.)

• Plunger lift
  – Using mechanical plunger to avoid liquid accumulation downhole

• Using Downhole pumps
GAS HYDRATES
Fire in Ice

In essence, hydrates are ice with fuel inside – they can be lit by a match! (Naval Research Laboratory)
What is a Gas Hydrate?

- Solid Water Structure
- Methane
- 1ft$^3$ hydrate at res conditions
  
  =

  160 scf of gas
Flow Assurance

- Suitable conditions for gas hydrate formation commonly occur during hydrocarbon production, operations, where the hydrates are a major flow assurance problem and serious economic/safety concerns
- The gas hydrates can block pipelines
- Gas hydrates can damage valves, elbows, etc

A large gas hydrate plug formed in a sub sea hydrocarbon pipeline (Petrobras, Brazil)(Naval Research Laboratory)
How to Reduce Gas Hydrate Problems

• At fixed pressure, operate at temperatures above the hydrate formation temperature. This can be achieved by insulation or heating of the equipment.

• At fixed temperature, operating at pressures below hydrate formation pressure.

• Dehydrate, i.e., reduce water concentration to an extent of avoiding hydrate formation.

• Use chemicals such as methanol and salts for the inhibition of the hydrate formation conditions.

• Prevent, or delay the hydrate formation by adding kinetic inhibitors.

• Prevent hydrate clustering by using hydrate growth modifiers or coating of working surfaces with hydrophobic substances.
INFRASTRUCTURE DEFICIENCIES
Pipeline Design

- Surface pipelines are designed based on production forecasts
- Inaccurate production forecast leads to
  - large pipe size design that is costly and not economical (optimistic production forecast)
  - smaller size pipeline design which is not able to deliver real field production (pessimistic production forecast)