



PRODUCTION AND OPERATIONAL ISSUES

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Audience and Date

March 2, 2016

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

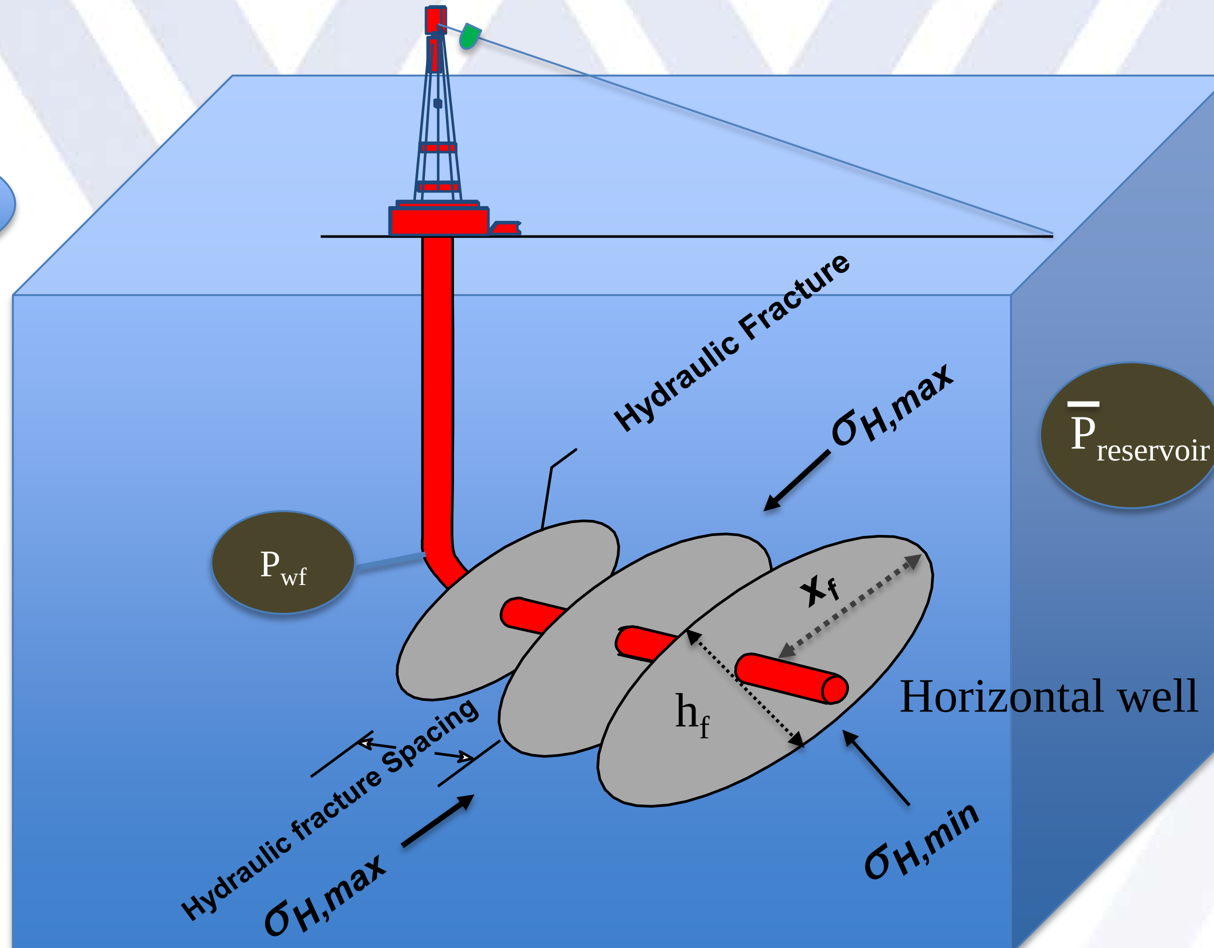
Production rate

Drawdown

$$q = J\Delta p$$

Productivity Index

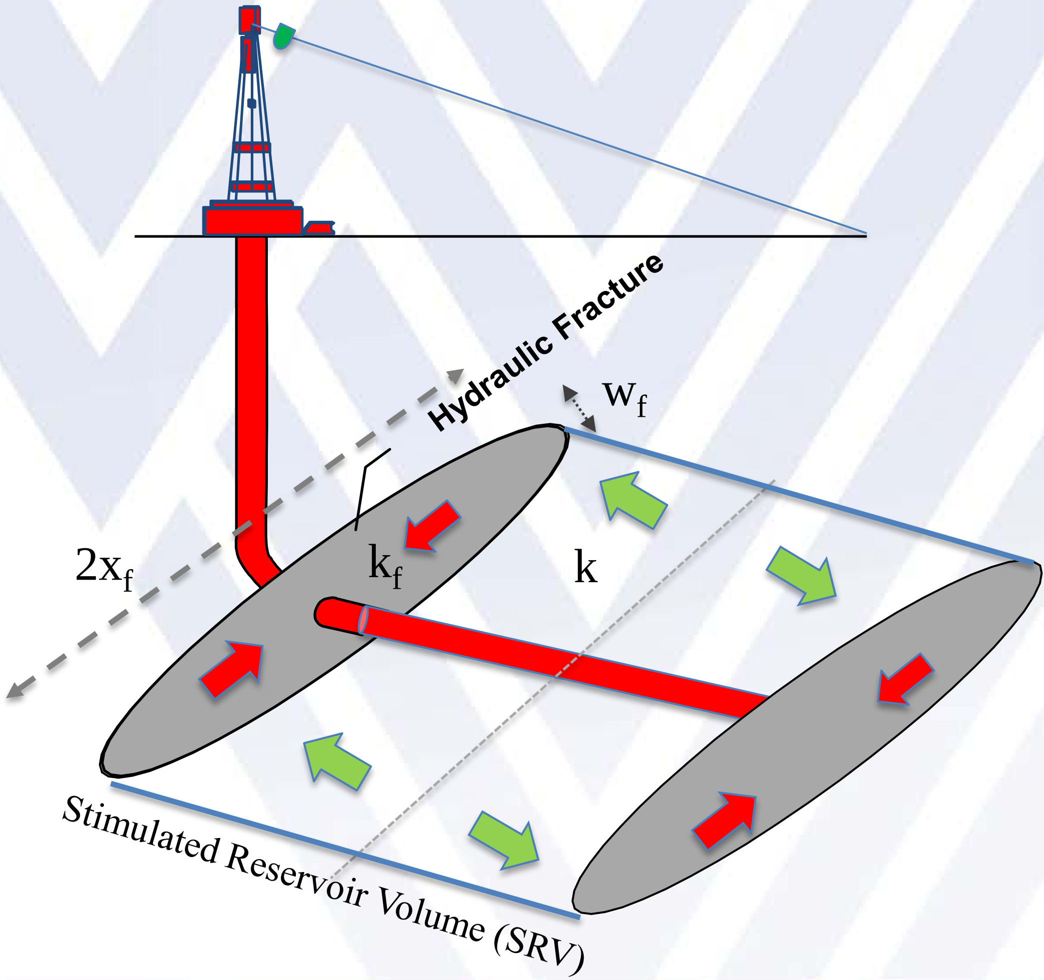
$$\Delta p = \overline{P}_{reservoir} - P_{wf}$$



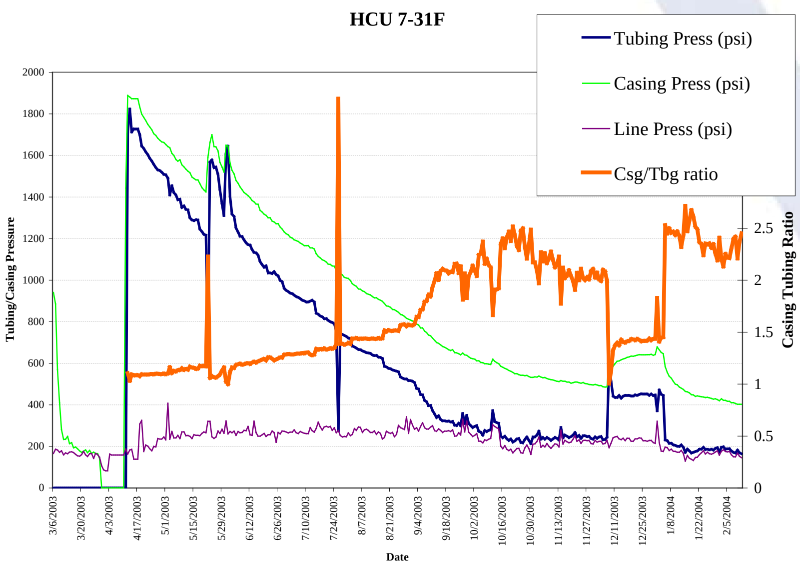
Hydraulic fracture Conductivity (Cont.)

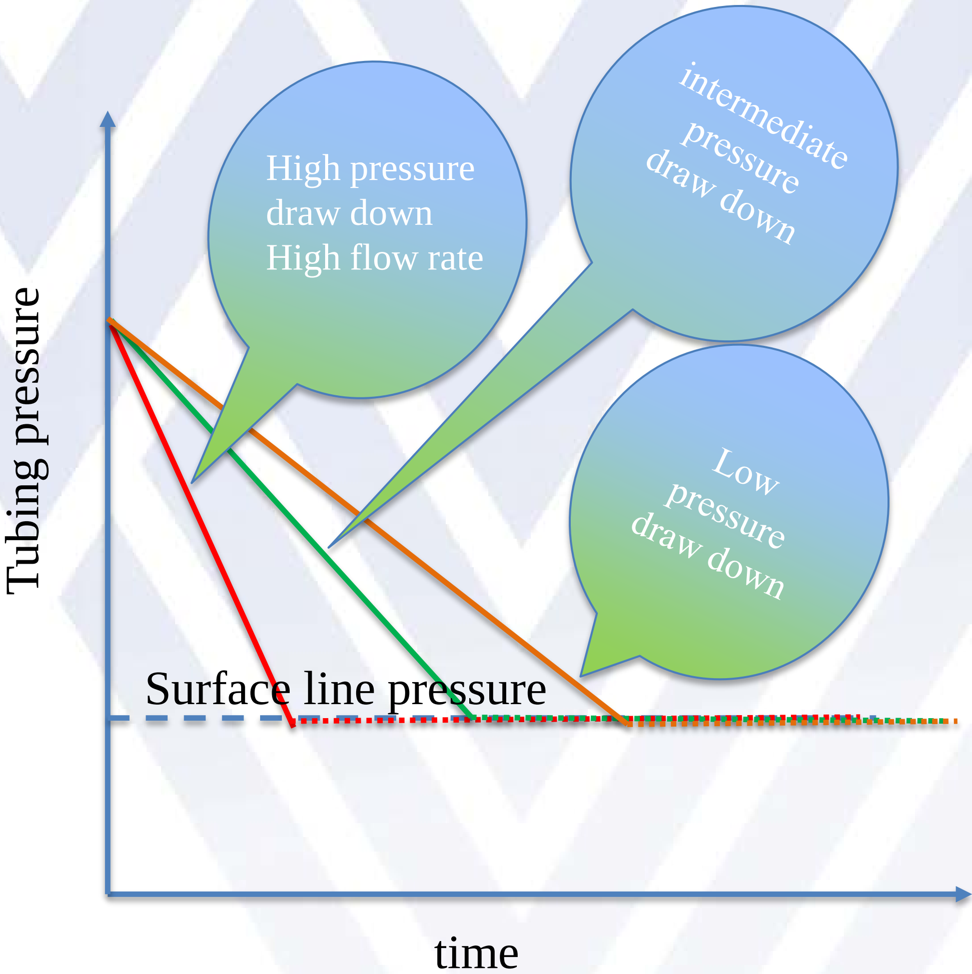
$$C_{fD} = \frac{k_f w_f}{k x_f}$$

C_{fD}= Hydraulic fracture conductivity
k: Matrix permeability
k_f: Hydraulic fracture permeability
x_f: Hydraulic fracture half length
w_f: Hydraulic fracture width



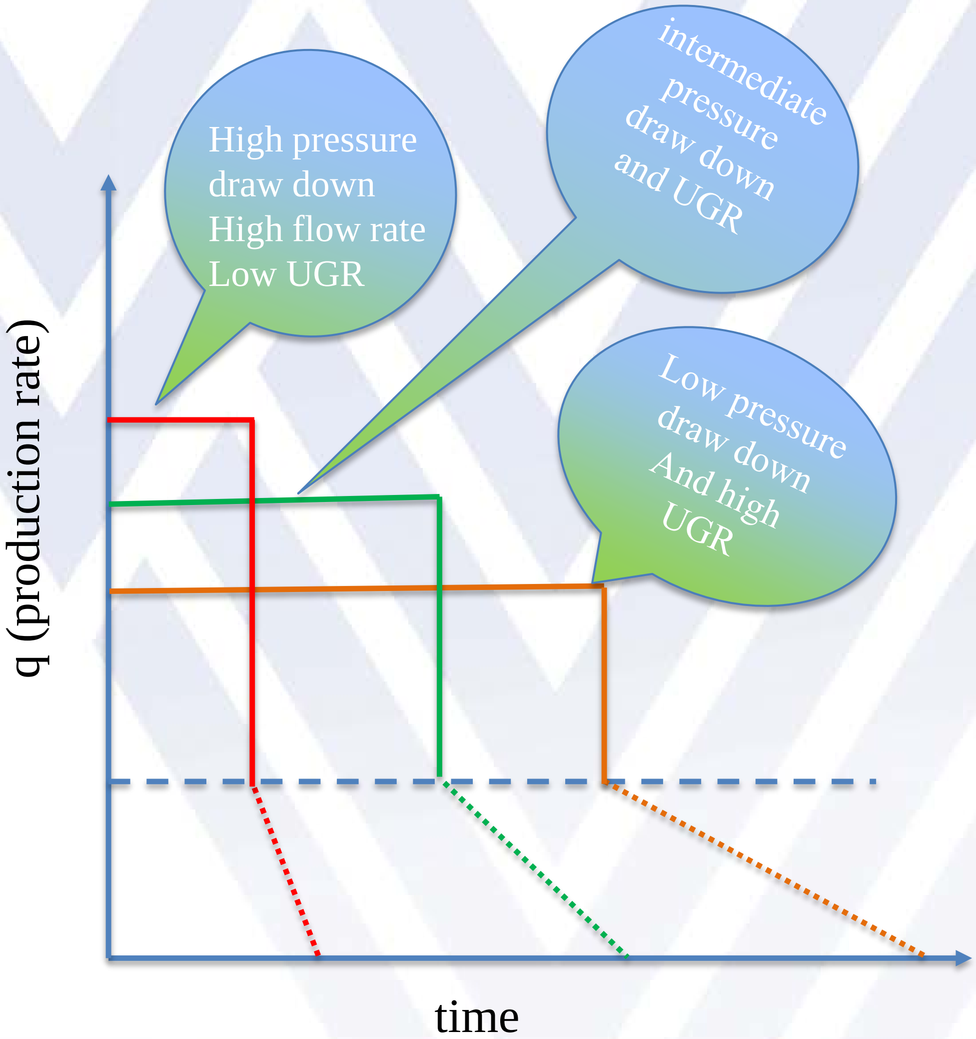
Pressure Draw Down



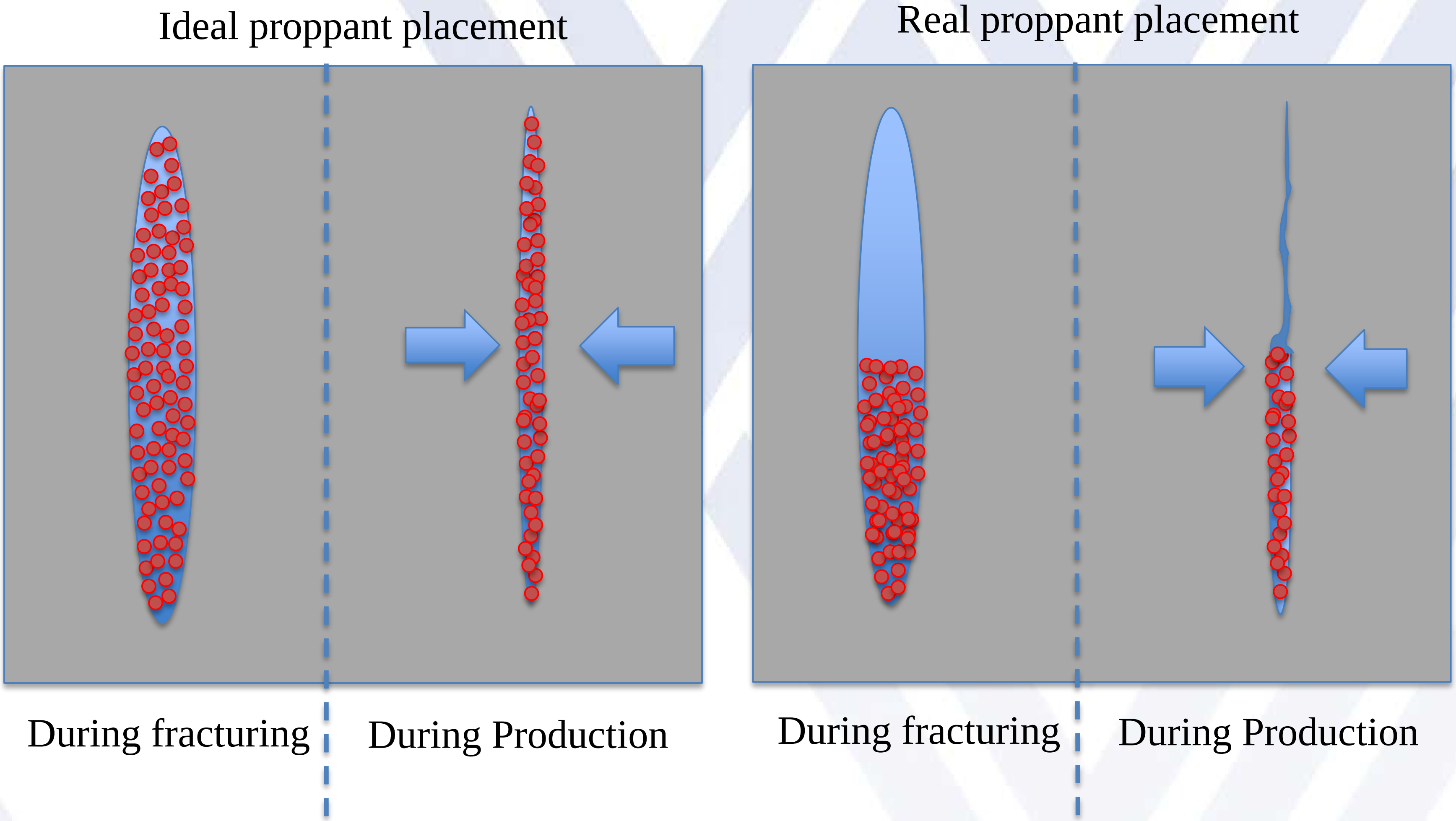


Pressure Draw Down (Cont.)

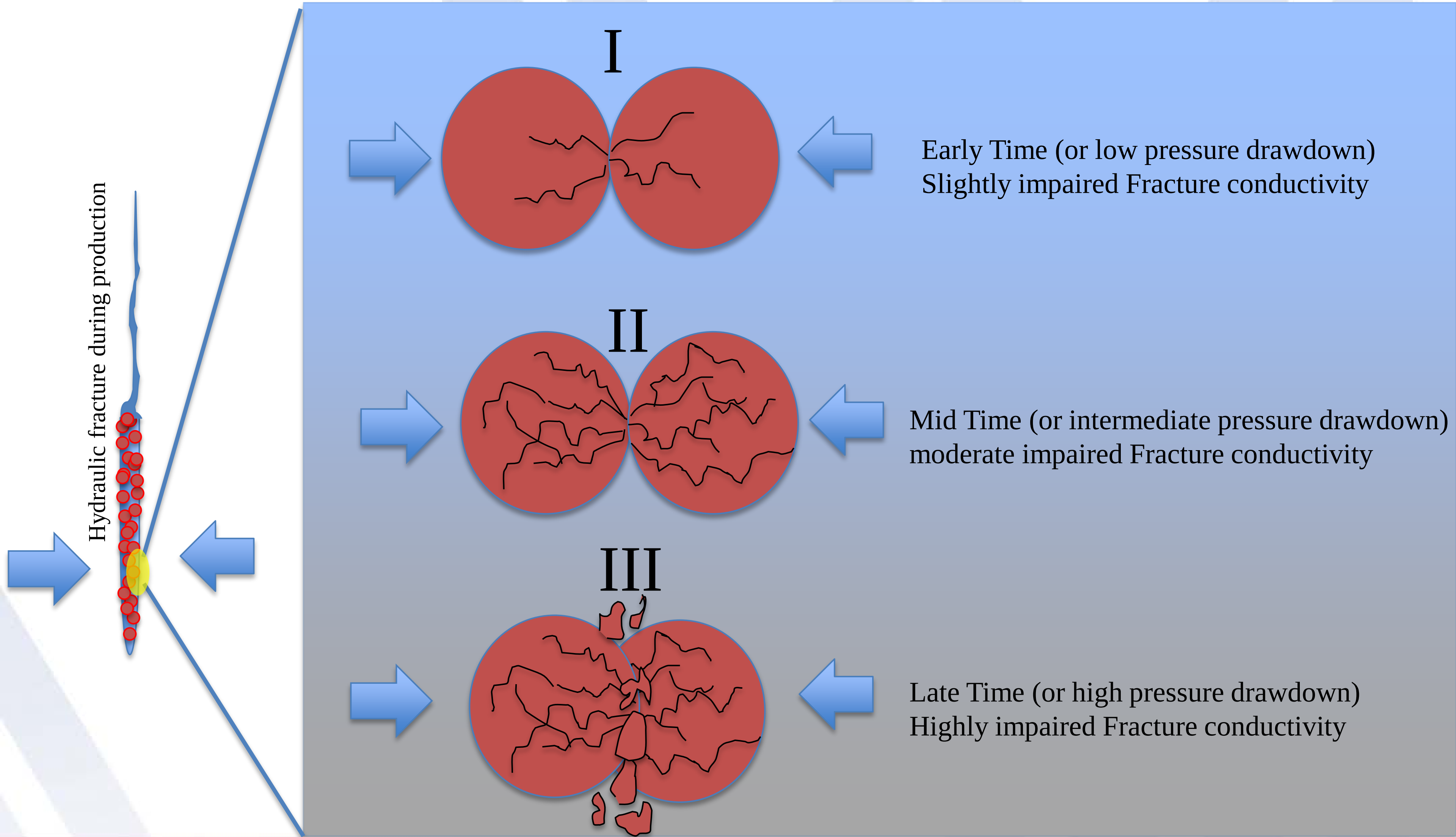
- Higher pressure draw down leads to:
  - Higher production rate
  - Faster pressure decline after reaching the surface line pressure
  - Lower ultimate gas recovery (UGR)
    - Proppant crushing and embedment
    - Loosing hydraulic fracture conductivity
  - Sand production and surface facility corrosion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



Proppant Placement

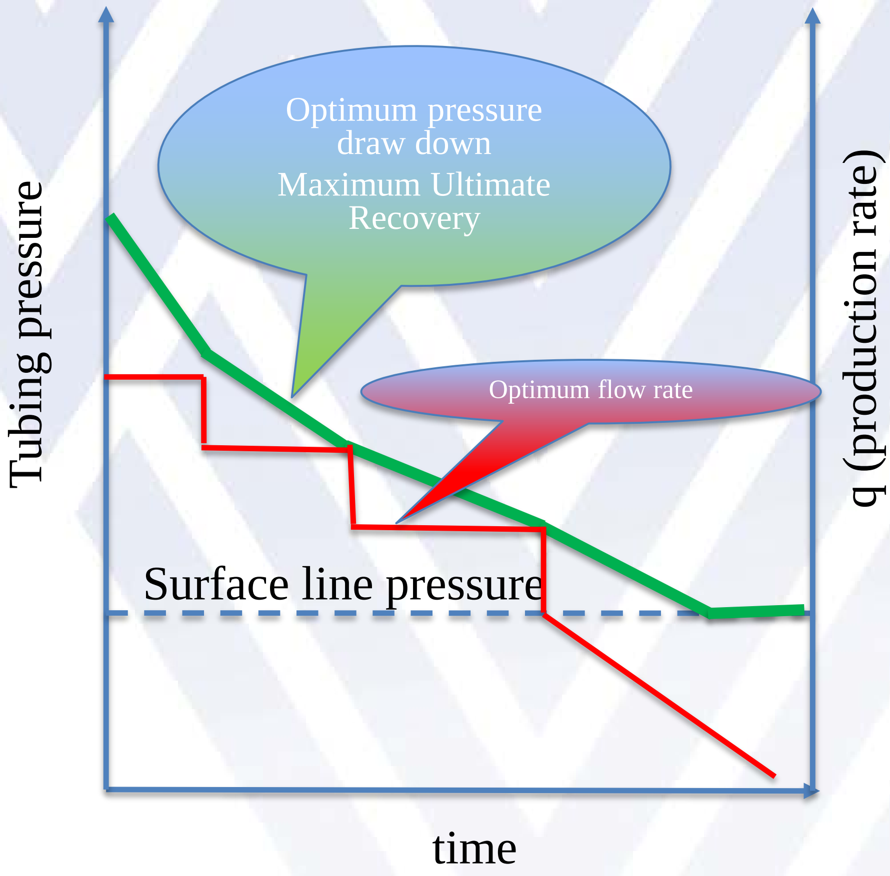


Proppant Crushing Embedment



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

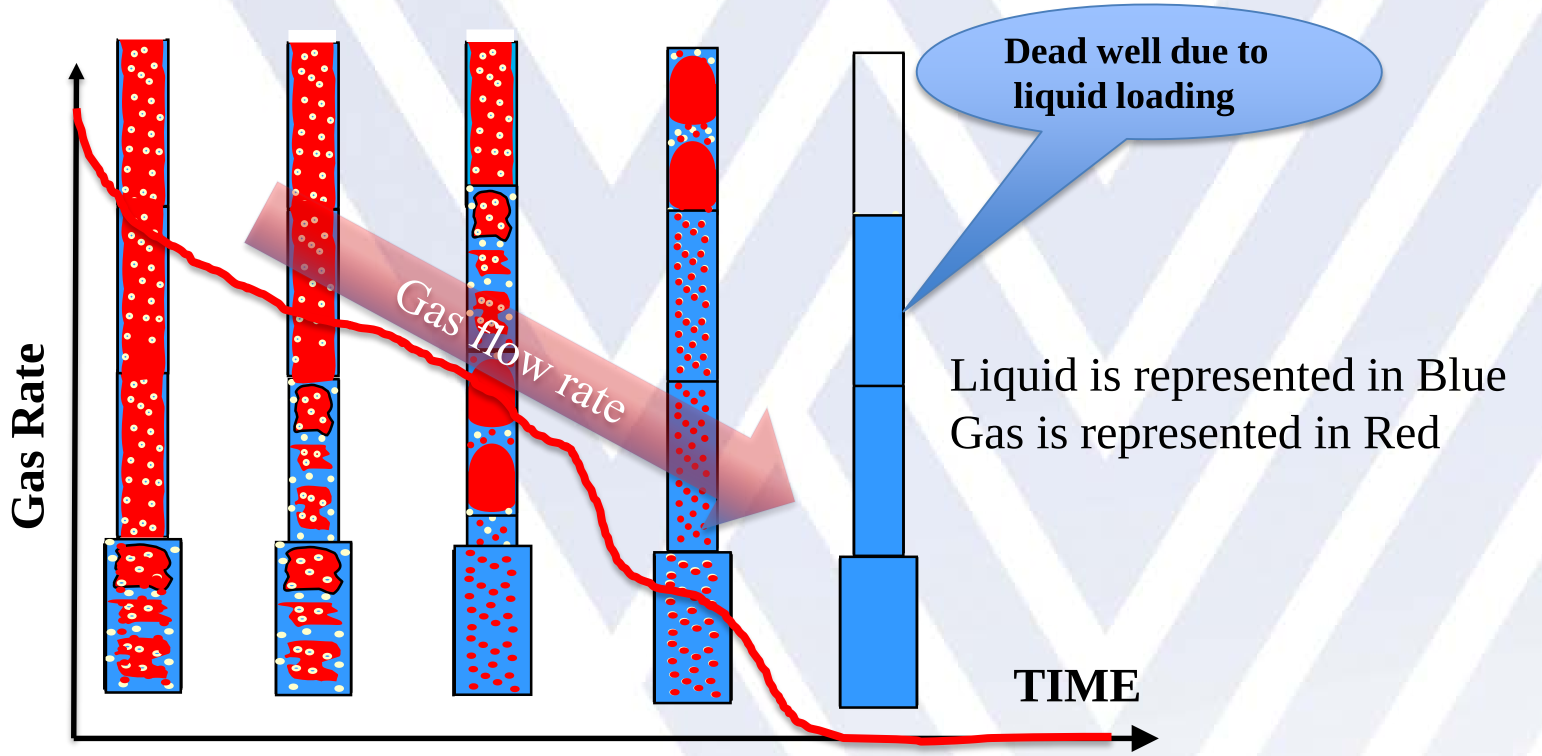


LIQUID LOADING

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

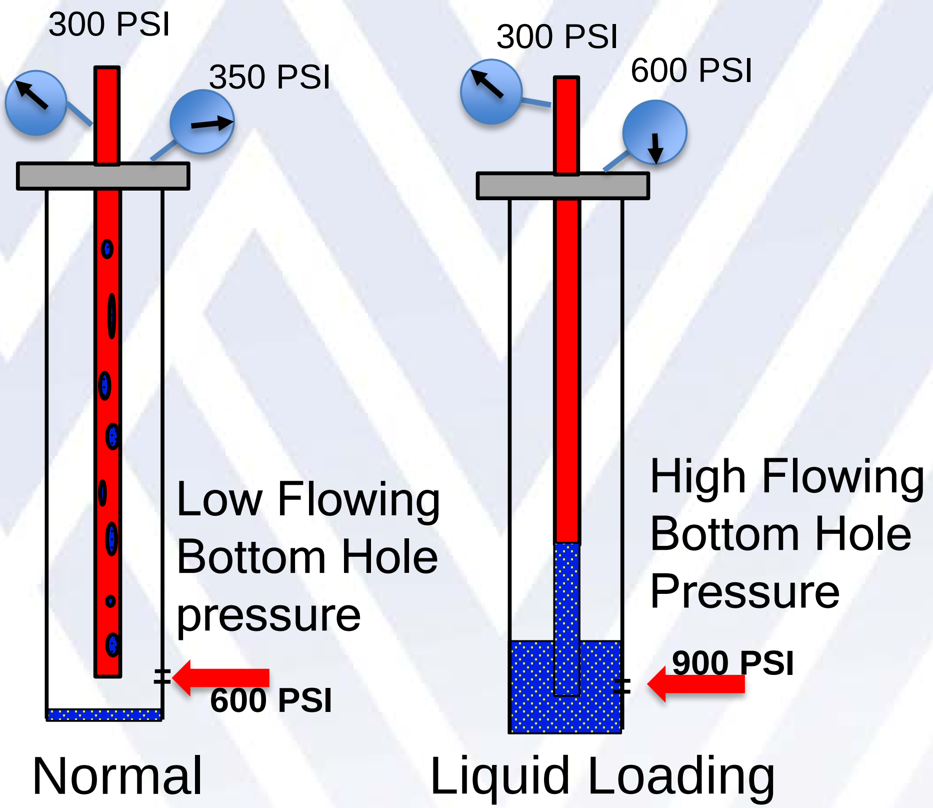
Typical Gas Well History



- There is a critical gas velocity below which liquid can not be transferred to the surface
- Liquid will be accumulated 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

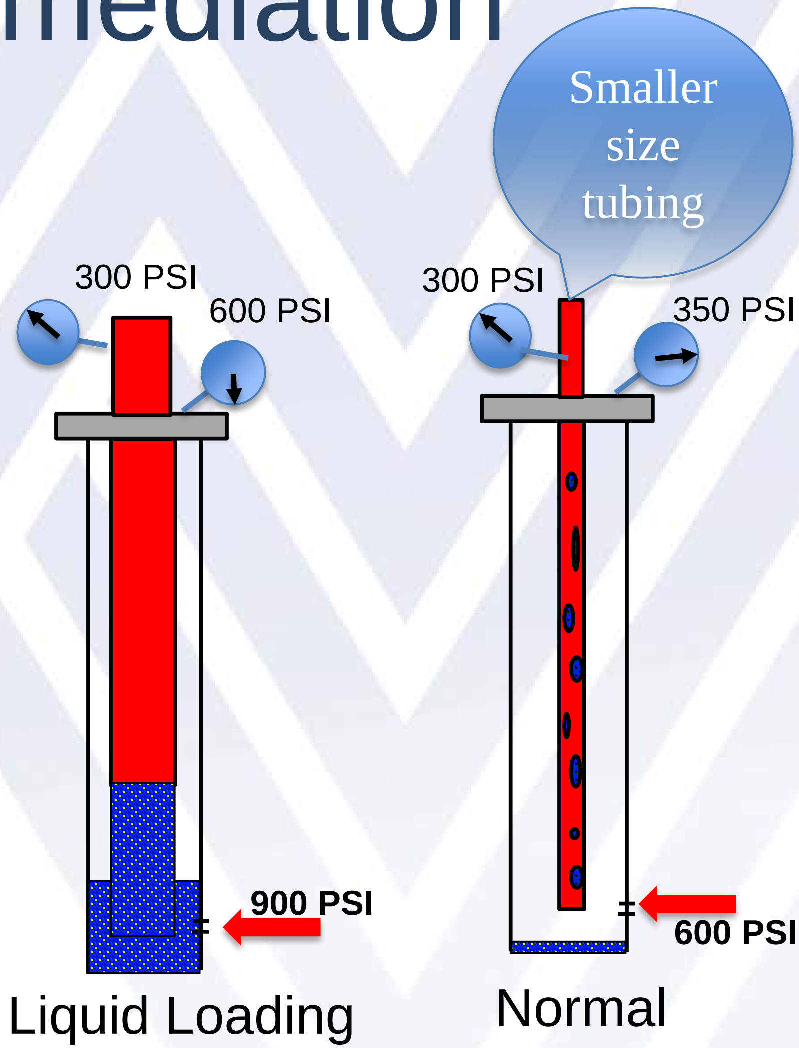
Diagnostic of Liquid Loading

- 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



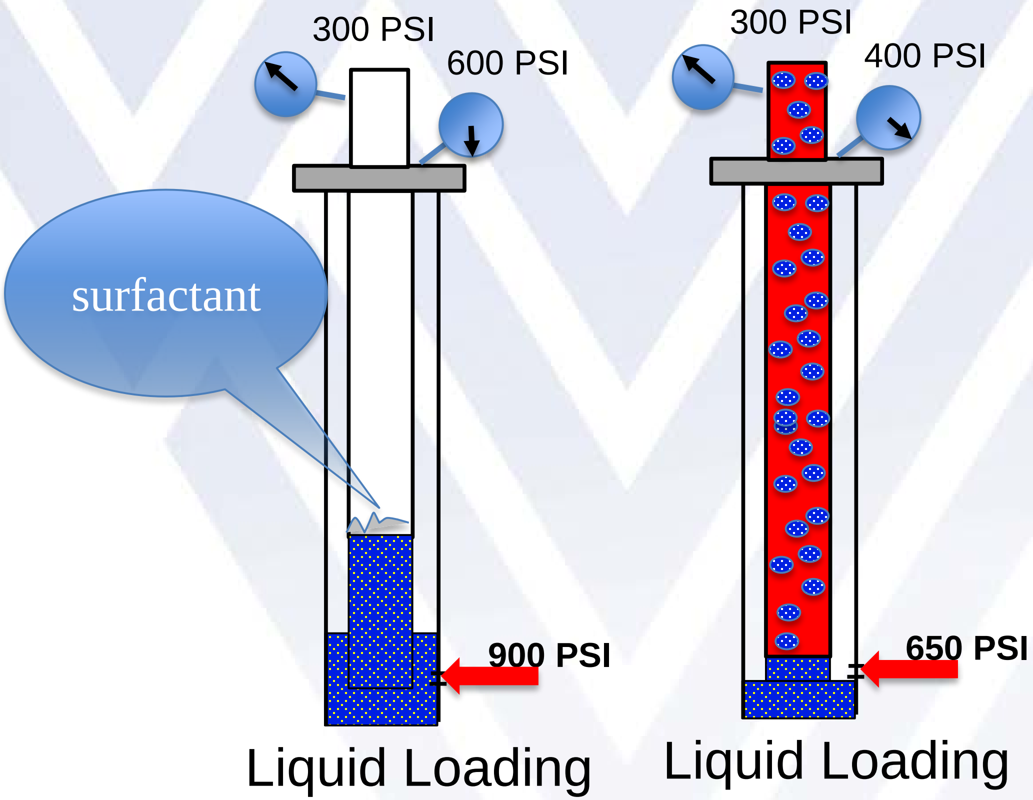
Liquid Loading Remediation

- Using Velocity String
  - Running smaller diameter tubing leads to increase in gas velocity and higher liquid lift capacity



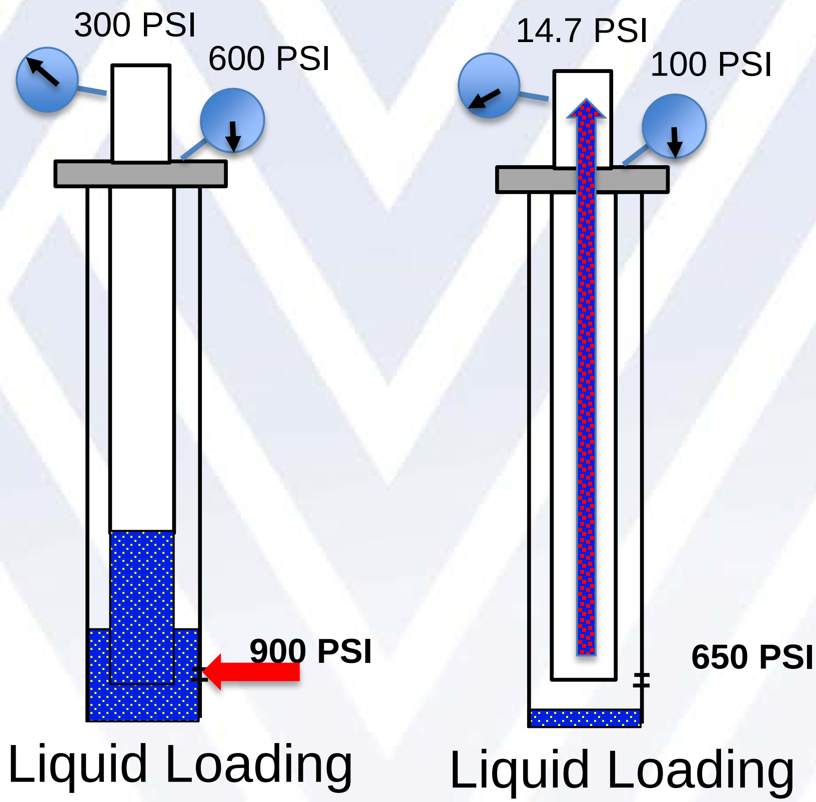
Liquid Loading Remediation (Cont.)

- **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.)

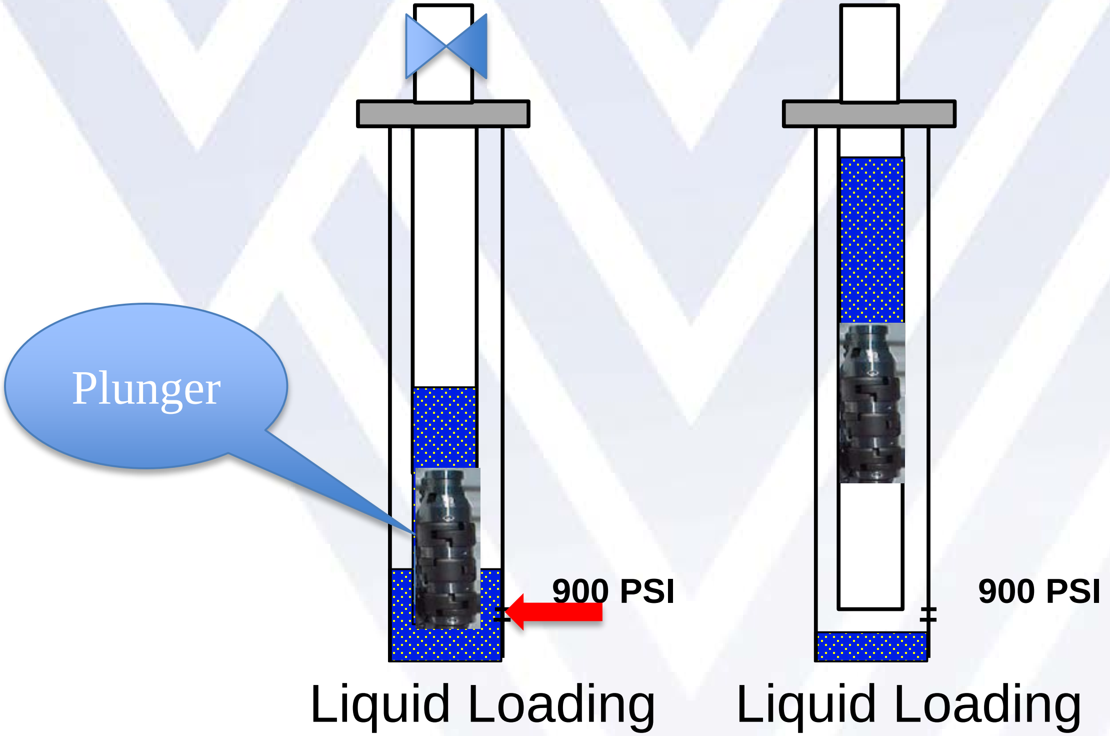
- Venting
  - Dropping the surface pressure to atmospheric pressure to maximize gas velocity
- Compression
  - Dropping the surface pressure below line pressure to increase gas velocity



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
- $1 ft^3$ 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)