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Down Hole Flow Assurance

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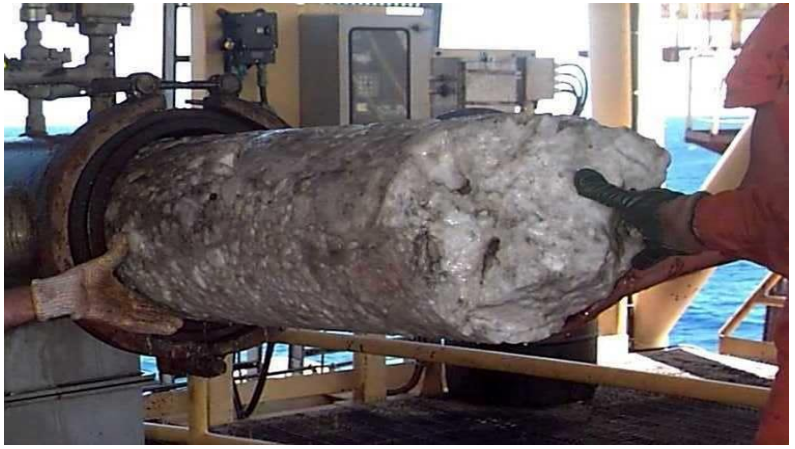
Flow Assurance Key Words

- **SCSSV Setting Depth**
- **SITP**
- **Scale**
- **Hydrate**
- **Wax**
- **Corrosion**
- **Asphaltene**
- **Chemical Injection**
  - Methanol
  - Glycol
  - LDHI
  - Corrosion Inhibitor
  - Scale Inhibitor
- **Gas Lift**
- **ESP**
- **Scale Squeeze**
- **Acid Job**
- **Sand**
- **Slugging**
- **Erosion**
- **JT Cooling/Heating**
- **Water Hammer**
- **VIT**
- **Insulation**
- **Proppant**
- **Annulus Management**
- **SCSSV Testing**
- **Cooldown time**
- **Warmup time**
- **Maximum Temperature**
- **Minimum Temperature**
- **OHTC**
- **Fluid & Material Compatibility**
- **C-Factor**
- **Multiphase Flow Correlations**
- **OLGA**
- **Fluid properties**
- **Geothermal Temperature Gradient**
- **Emulsion**
- **Souring**
- **Etc.**

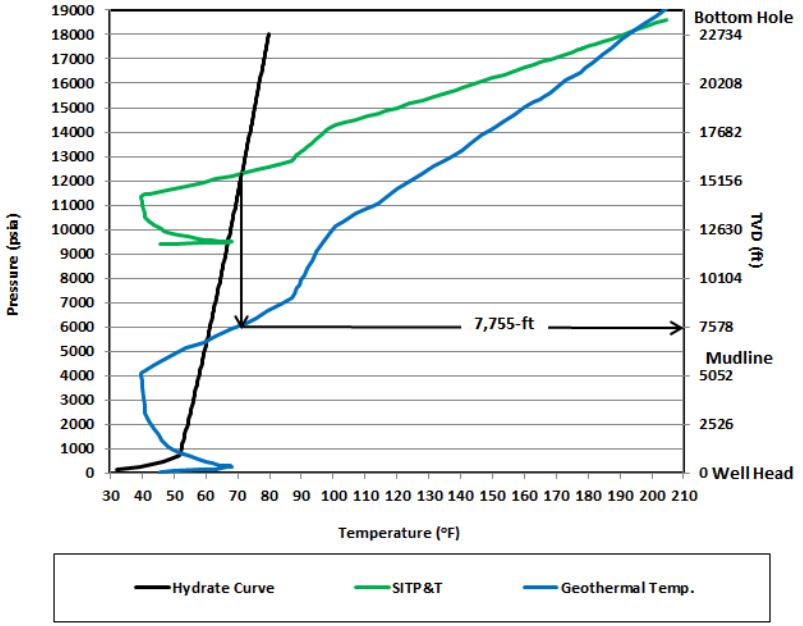
Hydrates

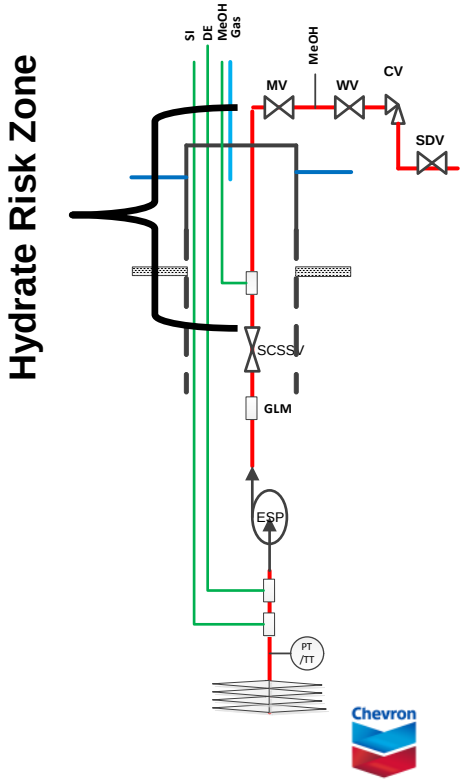
- **Hydrate Formation Locations**
  - Tubing
  - Annulus
  - Safety Valves
  - Well Servicing Well Control Equipment
    - Wireline Lubricators
  - Wellheads and Trees
  - Chokes
  - Chemical Injection Lines
  - Outside of well



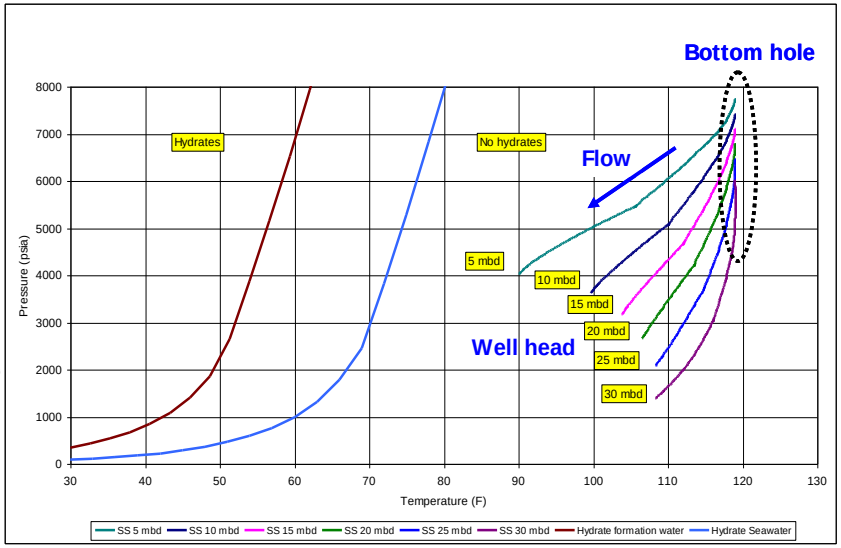
Petrobras

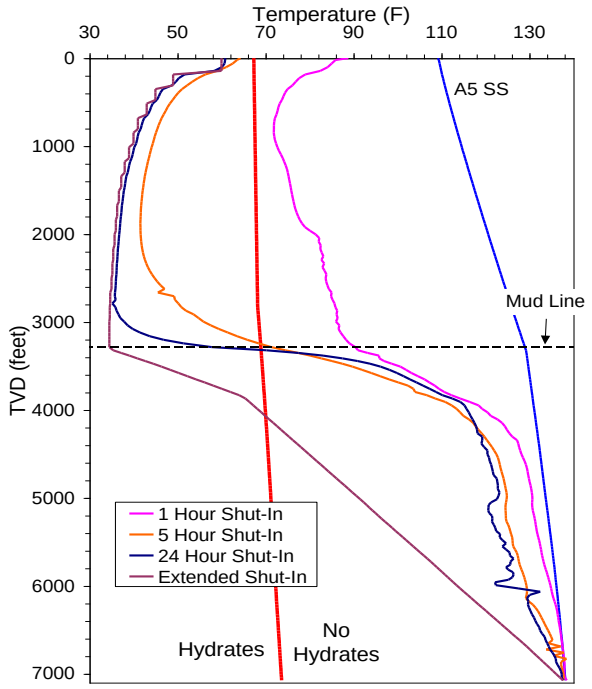
- **Hydrate Risk Zone and SCSSV Setting Depth**
  - Compare hydrate curve, SITP conditions and geothermal temperature gradient.
  - Determine hydrate formation temperature, pressure, and depth.
  - From geothermal temperature gradient, determine boundary depth for hydrate risk zone.
  - Consider effect of
    - Gas lift
    - ESP





- **Hydrate Management**
  - Shutdown – Cooldown time
  - Re-Start – Warmup time
  - Inhibitor Injection: rate, duration, volume
  - Insulation
  - Bullheading
  - Depressurization
  - Coiled Tubing



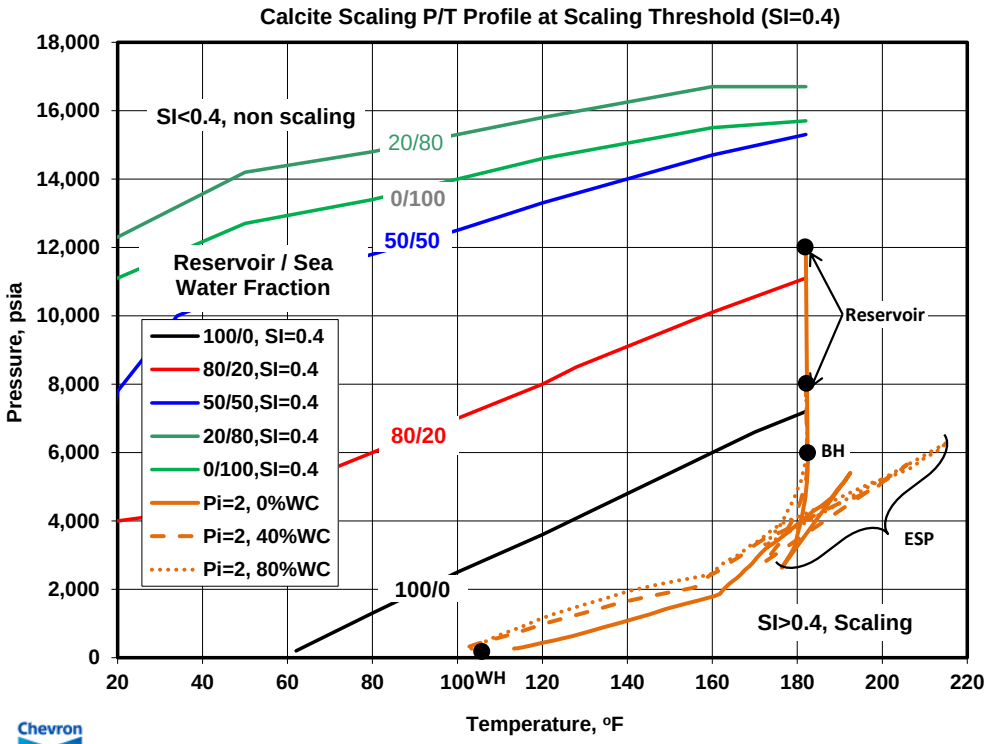


Scale

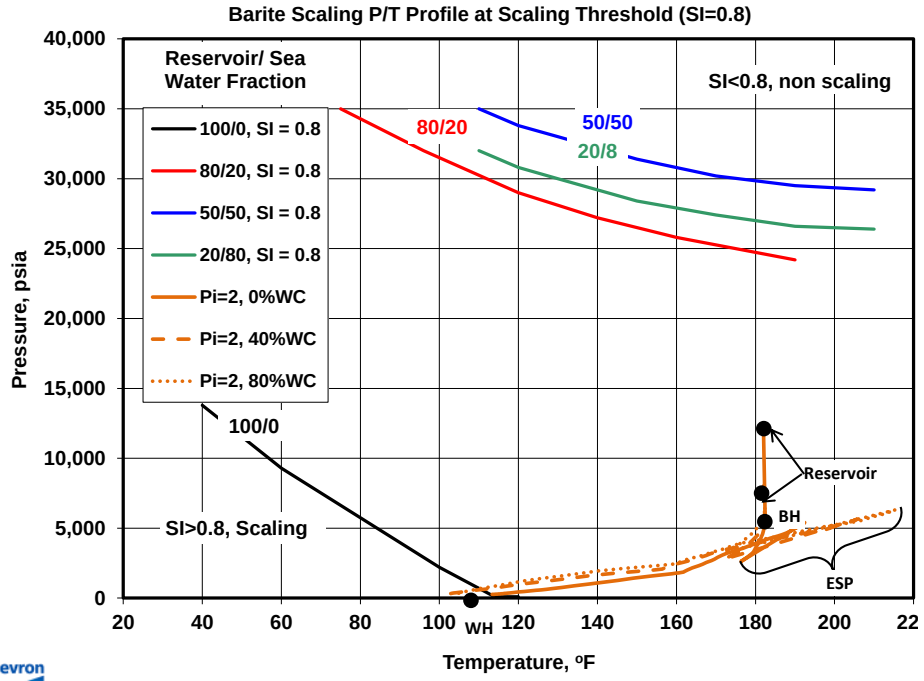
- **Precipitation and deposition of inorganic minerals within the production wells and processing equipment.**
  - Depends on several of factors
    - Water Composition
    - pH
    - Pressure
    - Temperature
    - CO_2 Concentration
    - Compatibility of Waters
    - Chemicals Affecting Solubility Limits

Nalco

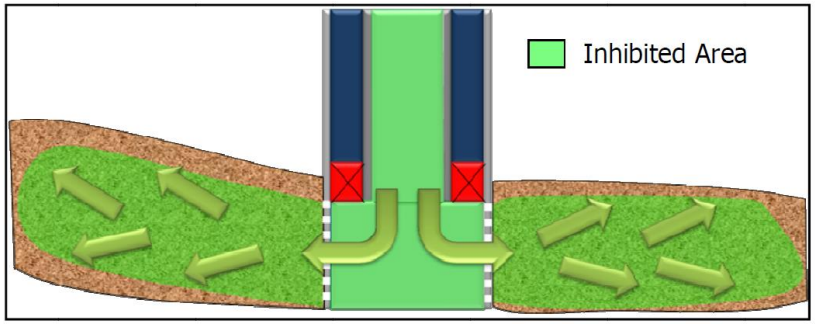
- **Calcite Scaling**
  - Calcite scaling tendency increases with increasing temperature and decreasing pressure.
    - High up in the tubing due to lower pressures
    - Around ESP due to high temperature
    - At downhole flow restrictions (Perforations, nipples, etc.)
  - Precipitation can occur as the pH of the brine increases. Unlike many salts, the solubility of $CaCO_3$ decreases at higher temperature
    - Resulting in precipitation in heat transfer equipment or ESP's
  - Mixing incompatible waters can also increase carbonate scaling tendency.
  - Carbonate Scales can develop low in the well, clogging downhole equipment, and plugging perforations.



- **Barium Sulfate Scaling**
  - Barite scaling tendency increases with decreasing temperature or decreasing pressure with temperature having a greater effect.
    - It is generally a problem in the upper well bore or production facilities.
  - Mixing sulfate-rich seawater with barium-rich formation water most common risk.
    - Seawater injection can lead to sulfate scaling in the reservoir due to water incompatibility
    - When seawater is used in a workover or completion operation, sulfate scales are also a risk then
  - When water flooding with seawater, there typically is a risk of Sulfate Scales
    - It is common to remove sulfate from seawater if it will be used for water flooding



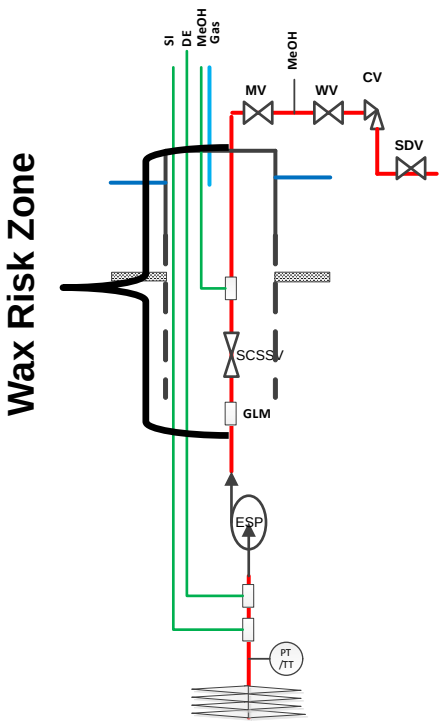
- **Scale Mitigation and Remediation**
  - Preemptive Scale Squeeze
  - Down Hole Scale Inhibitor Injection
  - Scale Squeeze
  - Acid Injection
  - Coiled Tubing

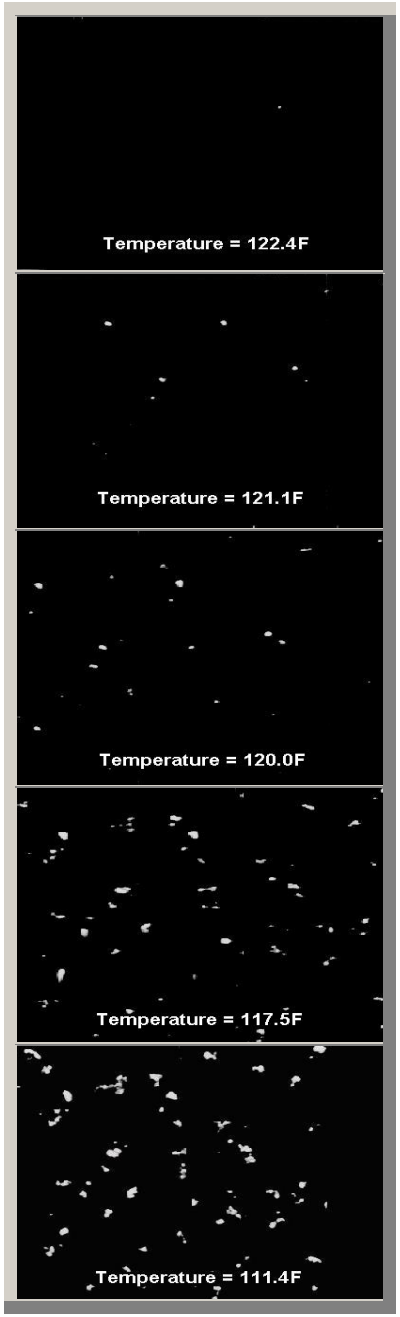


Wax Deposition

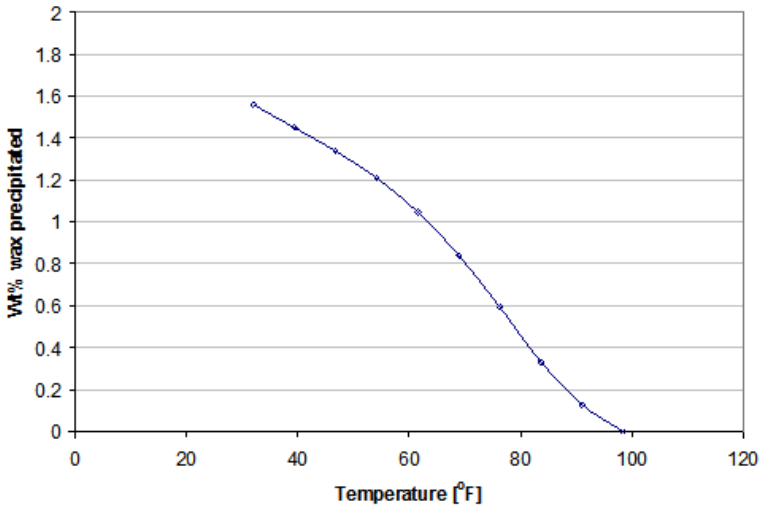
- Wax deposits in the upper portion of the wellbore, where the fluids have cooled below the cloud point or WAT.
  - WAT varies greatly in oils and condensates; it can range between 50 – 120°F
  - Pour point also varies depending of wax content. It can range 20 - 80°F.

- Wax deposition is temperature driven.
  - Temperature Control – Preventing hydrocarbons from cooling prevents wax from depositing
  - Vacuum insulated tubing
  - Insulating packer fluid
  - Low risk during shutdowns
  - High risk operating at low rates and temperatures



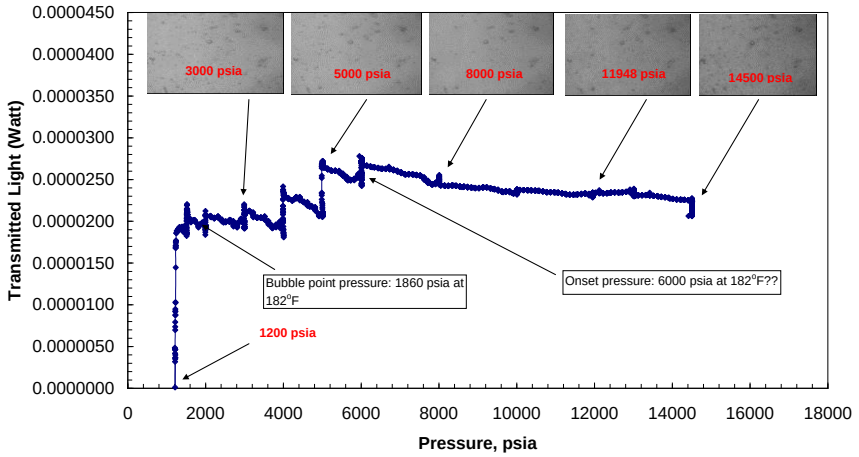


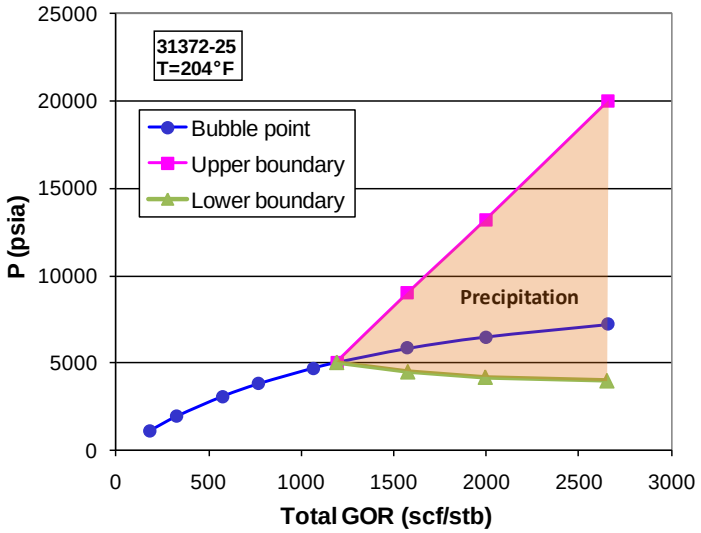
- **Wax Management**
  - Wax Inhibitors and pour point depressants (PPD) injection
  - Hot Oiling – Hot Oil is circulated in the well, melting any wax in the well, allowing it to be flowed out
  - Chemical Solvents – Terpenes or Aromatic Solvents can be effective at wax removal
  - Mechanical Removal – Slick line operation to cut was deposition from the inside of the tubing combined with solvent soaking.
    - Frequency of wire line interventions
    - Well downtime during wax cutting
    - Risk of sticking wire line tools
  - Coiled Tubing (to inject hot fluid or solvent)



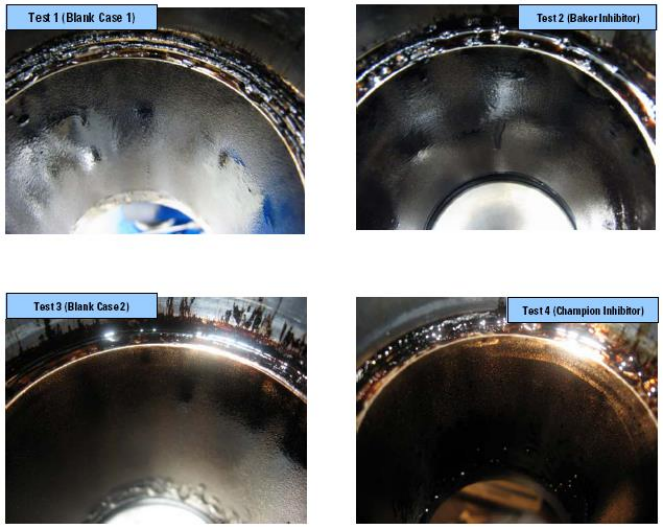
Asphaltenes

- **Asphaltenes may precipitate when the fluid conditions change (particularly pressure) or incompatible fluid streams are mixed.**
  - Transition across the bubble point results in a major change in density and thus a change in asphaltene stability
    - Further changes in pressure will result in changes in density
  - Mixing of heavy oil with lighter oil
  - Gas Lift
  - CO_2 Injection





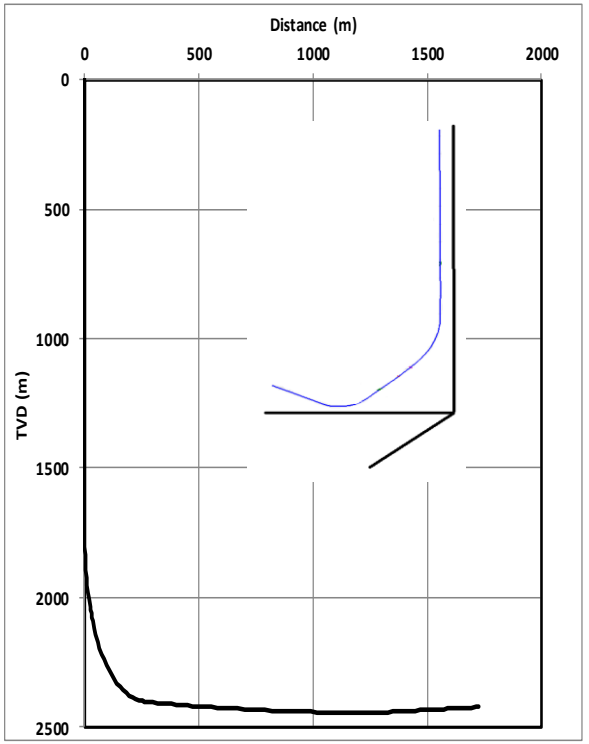
- **Asphaltene Management**
  - Asphaltene inhibitors can be injected downhole.
  - Asphaltene inhibitors do not inhibit Asphaltene precipitation, but they disperse precipitated Asphaltenes.
  - Pressure Control – Pressure decreases can cause Asphaltenes to precipitate, providing pressure support can prevent this.
  - Aromatic solvents (xylene soaking)
    - Frequency
    - Duration



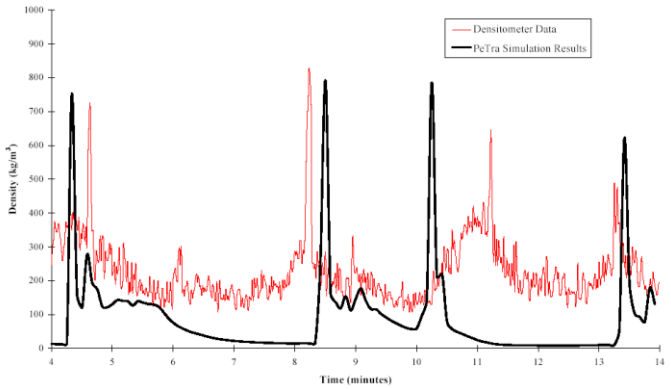
Erosion and Sand

- Sand production rate is generally an input from completions and some times it is go-by number.
- Sand production and erosional limits can be determined by using
  - API 14 E
  - TULSA Model
  - CFD
- Selecting right location for sand monitoring is key.
- In the operations phase online monitoring is used to detect sand influx.
- Production rate control is used to stay within allowable limits
- Sand prone wells can be re-completed
- Water hammer could cause fines migrations
- Bullheading through gravel pack (used to displace water below SCSSV for hydrate control) may affect completion, leading to sand production

Transient Multiphase Flow Modeling



- Slugging
  - Slug flow is the dominant flow regime in upward flow.
  - Complex well geometries, especially long horizontal wells.
    - Toe up
    - Toe down
  - Low flowrates
  - Changes in flow conditions



- Complex Thermal Modeling
  - Counter current flow

- Intervention Modeling
- Drilling
- Well kill
- Near wellbore flow modeling

Artificial Lift and Flow Assurance

- **Pumps cause major changes in downhole systems**
  - Significant Pressure increase
    - Asphaltene Deposition
    - Scale Precipitation
  - Added Heat to the system
    - ESP's generate significant heat, this can cause scale to precipitate, especially at the outer surface of the pump.
  - High viscosities due to tight emulsions also adversely affect pump efficiency
  - Erosion

Artificial Lift and Flow Assurance

- **Gas lift can also change FA issues down hole**
  - Gas lift expands hydrate formation conditions and increases risk for hydrate formation.
  - Gas lift can cause Asphaltene precipitation.
  - Gas lift injection through annulus can cause lower temperatures in the upper part of the tubing which can cause wax deposition.

Chemical Injection Locations

Wellhead Injection

To support well and downstream operations

- Methanol / Glycol
- LDHI
- Scale
- Corrosion

SCSSV Injection

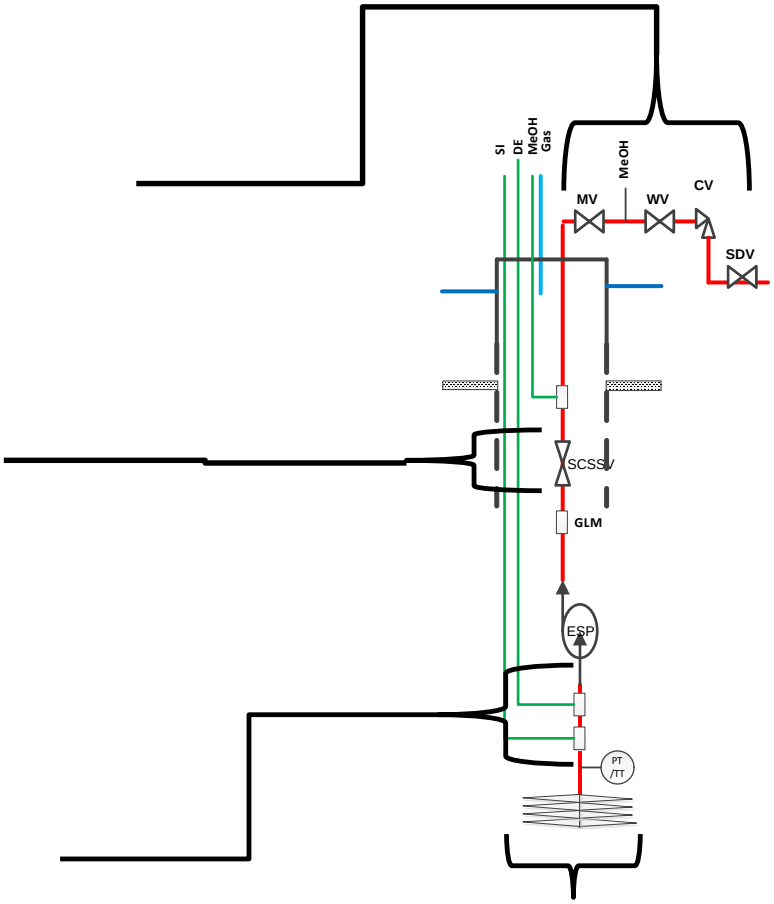
Generally for Hydrate Management

- Methanol / Glycol
- LDHI

Deep Downhole Injection

Continuous Production treatment

- Scale
- Wax
- Asphaltene
- Emulsion
- Corrosion
- H_2S Scavenger

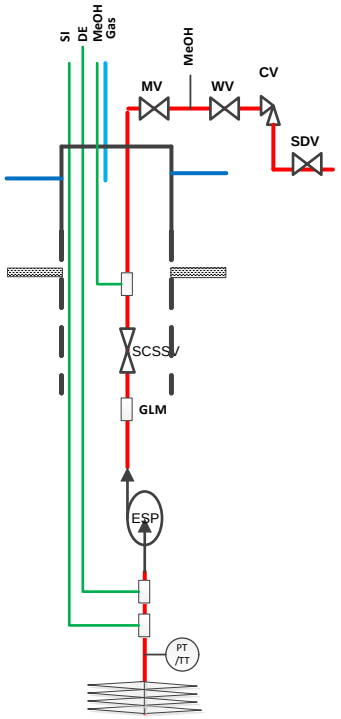


Chemical Squeezes

- Scale
- Asphaltene

Chemical Injection Design

- **Flow Assurance determine chemical injection**
  - Location
  - Control line size
  - Rate
  - Pressure
  - Time and duration (continuous vs. intermittent)
  - Operability (cracking pressure)



Flow Assurance Famous Scary Pictures

Petrobras

Hydrate

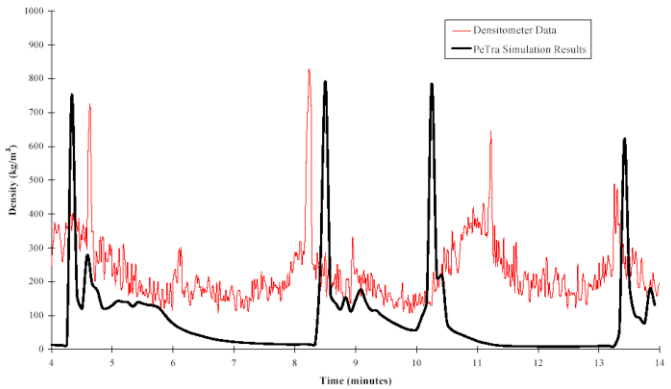
Asphaltene

Stat Oil

Wax

Nalco

Scale



Slugging

Stat Oil

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Flow Assurance Integration

- **Flow Assurance helps identify**
  - Risk
  - Mitigation/Management
  - Contingency
  - Develop Procedures
- **Flow Assurance works with interfaces**
  - Reservoir
  - Production Engineers
  - Artificial Lift
  - D&C
  - Surface and Subsea Facilities

Questions ?