THE VIKING EXPLORER
INSIGHTS TO THE OIL & GAS INDUSTRY

MAY 2020

LEASE & ASSET PRESERVATION CONSIDERATIONS DURING SHUT-IN

PART 1 : MANAGING RISK & REDUCING DAMAGE FROM WELL SHUT-INS

Managing Flow System Risks from Well Shut-in to Start-Up

The current global over supply of crude oil and soft demand will result in oil companies shutting wells in to prevent destroying value and to protect their balance sheets. The time frame, until production startup becomes economic, is uncertain and therefore it is imperative that appropriate actions are taken to maintain and manage the integrity of the available Installed Production Capacity during shut-in. Consideration of many factors within the entire flow system, from reservoir to off-take mechanism, is necessary to manage the risk of temporary or permanent damage to the near-wellbore, wells and surface facilities.

Additionally, an extended shut-in period offers the opportunity to perform certain key actions and collect pieces of information that will help maximize the future potential for well, reservoir and field production during well and field restarts. This series will focus on some of the key technical areas including well productivity to maximizing individual well performance, well integrity to reduce risk of failures and downtime and reservoir characterization to maximize ultimate oil recovery. In addition, these series will include surface facility considerations from an asset integrity and system debottlenecking standpoint.

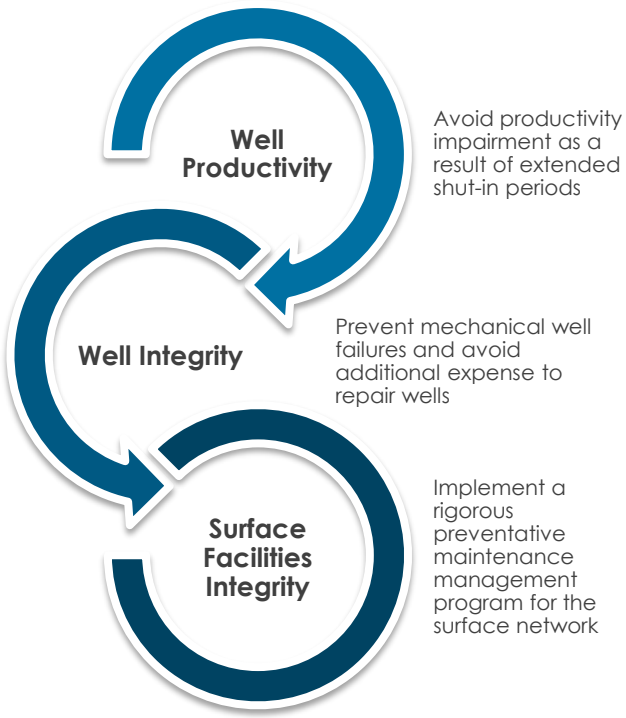
Managing Risk from Well Shut-ins

Shutting in wells for any reason has a risk of diminished flow when the wells are restarted. The entire flow system from the formation to the off-take mechanism should be considered. Some systems, such as high-pressure dry gas may accept a simple valve closure as a shut in without much restart risk, but other wells may be much more sensitive. Risk of temporary or permanent damage usually increases in long-term shut-ins and fast start-ups.

A shut-in well is not a dead well and some of the following phenomenon may take place:

- **Density segregation continues:** Gas breaks out of static fluids and formation gas percolates to top with a liquid column underneath and many times as a result, fluids are pushed back into the reservoir.
- **Gas rises and pressure builds:** Static wellbore liquids (gas, water and aggregated asphaltenes or precipitated paraffins) are pushed back into the production formations.
- **Precipitates and sludges form:** Stabilized sludge-type emulsions can be formed with solids and components such as CO_2 and Iron rich waters acting as catalysts.
- **Flow path blocks occur:** Risk of creating flow-blocking mechanisms rises sharply if the liquids enter the matrix and mix with connate fluids. This may negatively impact the productivity of the well at restart.

Key Focus Areas to Manage Risk During Shut In

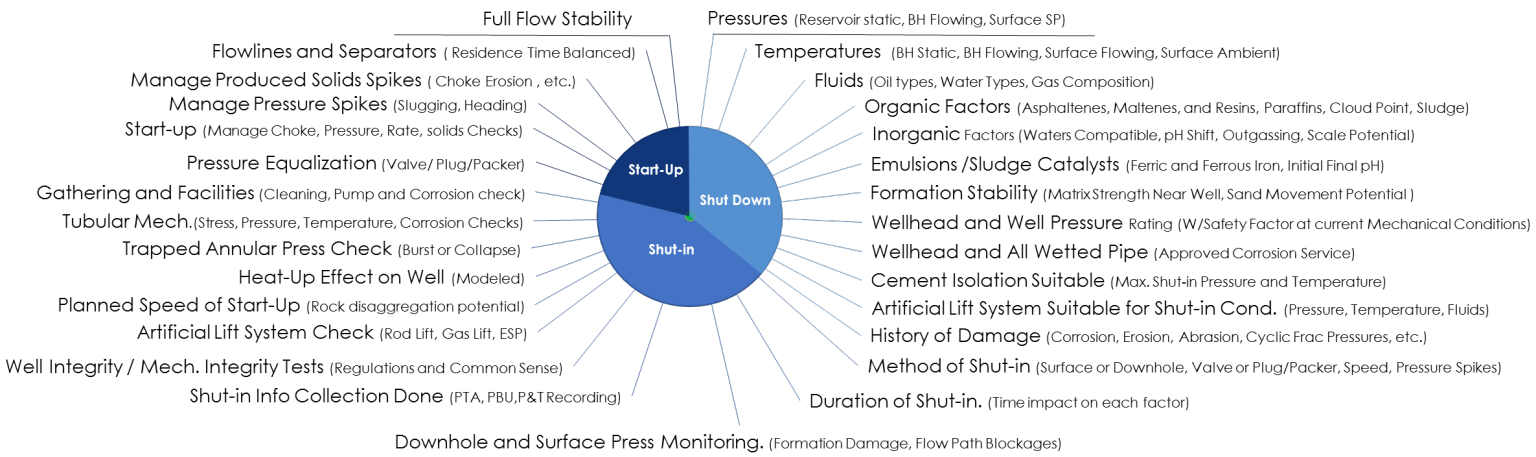


Factors That Affect Risk at Shut-in

There are many factors that affect risk at shut-in; among them:

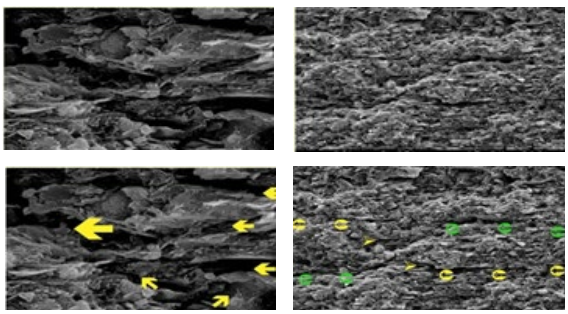
- **Reservoir Pressure**
  - Pressure depletion in a reservoir substantially increase damage risk.
  - Low pressure wells susceptible to capillary blocking effects.
  - Relative permeability problems as water, oil or gas values change.

Factors to Consider on Shut-in and Start-up



- **Crossflow**
  - Multiple producing layers or even widely varying permeability crossflow from high pressure to low pressure starts when production stops.
  - Permeability variances create groups of low-pressure, high permeability and high-pressure, low permeability zones.
  - Mixing of gases, oils, waters from different zones can create difficult-to-remove problems.
- **Multiple Source Rocks and Organic Fluids**
  - Different sources may feed into layers within a single reservoir and some wells penetrate and produce from multiple layers.
  - Mixing of asphaltic oils in a well may create downhole and/or in-situ organic precipitates.
  - Additional trigger mechanisms for asphaltene precipitation are influx of water with high iron contents, shifts in the pH of fluid from a specific rock layer or outgassed oils missing important short chain and aromatic hydrocarbons that flashed-off during initial production.
  - Paraffins may be "chilled" into precipitating by cooler fluids falling back and mixing with oil in the well or the near wellbore.
- **Variance in Connate Waters**
  - Multiple produced water sources within a well may create inorganic scales.
  - Remixing waters that have flashed-off CO_2 during production can form concentrated ion waters (super-saturated) and form scales.
  - Clay interactions with mixed waters are possible, resulting in damage from clay swelling.
- **Ductile and Unstable Formations**
  - Production affected by changes in flowing conditions.
  - Initiation of flow from "soft" or ductile formations is best achieved by controlled drawdown and flow that is as steady as possible.
  - Changes in flowing conditions may produce a spike in the flow of solids before reaching a semi-steady state of flowing equilibrium.
  - Shutting in these wells must be done carefully and restarts must be initiated in very controlled manners.

Protect Flow Paths Sensitive to Blockage

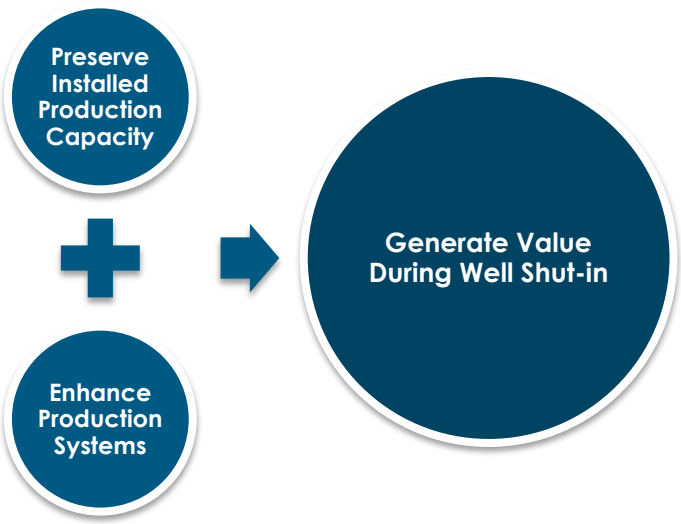


- **Corrosion**
  - Well integrity impacts from corrosion or historical events like erosion or abrasion are important and should be considered.
  - Anticipated shut-in durations and production conditions should be taken into account.

- Critical factors such as static fluid pH, CO_2/H_2S levels, chlorides, and other fluid and material characteristics, should be monitored.
- Viking Explorer Series #2 will focus on Well Integrity and will contain information on the above mentioned issues.

- **Surface Facilities**
  - Gathering systems and facilities can be impacted on shut-in and start-up.
  - Needs may include treating and shutting down/isolating flowlines, pipeline segments and facilities.
  - Viking's Series #3 newsletter will focus on Surface Facility Integrity and Optimization.

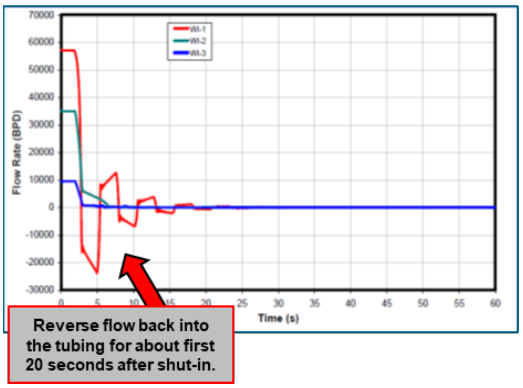
Value Proposal for Shut-in Production System



Water Injector Shut-In Considerations

High rate water injection wells, particularly in soft or poorly consolidated formations, are subject to backflow from a short-lived but damaging over-pressured event. These problems, often mislabeled as waterhammer events, occur where high-rate water injection is stopped suddenly, allowing momentum of the injected water to pressure up the near-wellbore, temporarily creating a lower pressure in the tubing before pressure is equalized by flowing back into the well. This produces an instantaneous backflow surge from the formation that can carry water and formation sand into the well and can fill hundreds of feet of tubing with sand.

Reverse Flowback after an Injector Well Shut-in



Examples of Better Shut-In Practices

Although "Best Practices" are formation and well specific, the following list provides a number of key considerations:

- Consider downhole shut-in when displaced water may damage the formation.
- Isolate zones of incompatible fluids downhole and minimize crossflow wherever possible.
- Consider loading fractures with a fluid that does not soften the formation.
- Scale and corrosion inhibitors may be needed as a pre-shut-in fluid.
- Formation mineralogy - know what clays are in the near wellbore and how to best protect them.
- Pore-space clay growths (authogenic) are detrimental / clay in the matrix away from the pores (detridal) is more ideal.
- Water compositions that are different from connate water in layer may react with the clays to block flow paths.
- Consider maximizing reservoir pressure characterization via pressure transient analysis during shut-ins. Viking's Series #4 will focus on this topic.

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