Gas Lift in the Bakken

(Gas-Lift System with Capillary)

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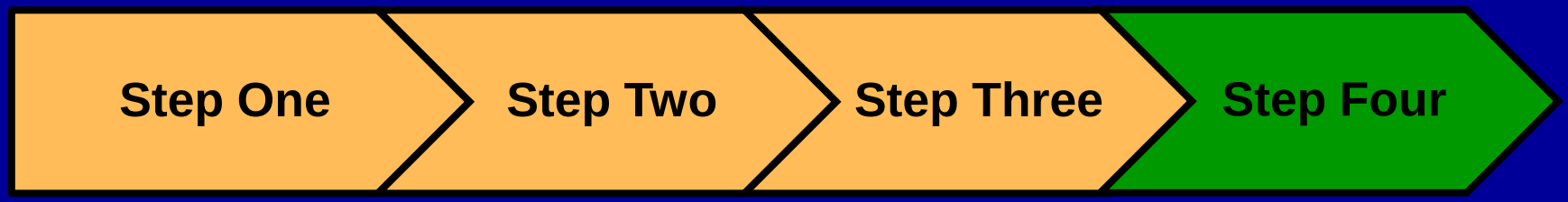
Weatherford Artificial-Lift Systems

Gas Lift In the Bakken Shale – North Dakota

Lift Selection and Progression



Identify the most economical lift method

- Rod pump
- Electric submersible pump (ESP)
- **Gas lift**

Well evaluation

- Required fluid production
- Scale/paraffin/ salting issues?
- Completion tools
- **Capillary injection**

Execution

- Install completion to required specifications based on the design

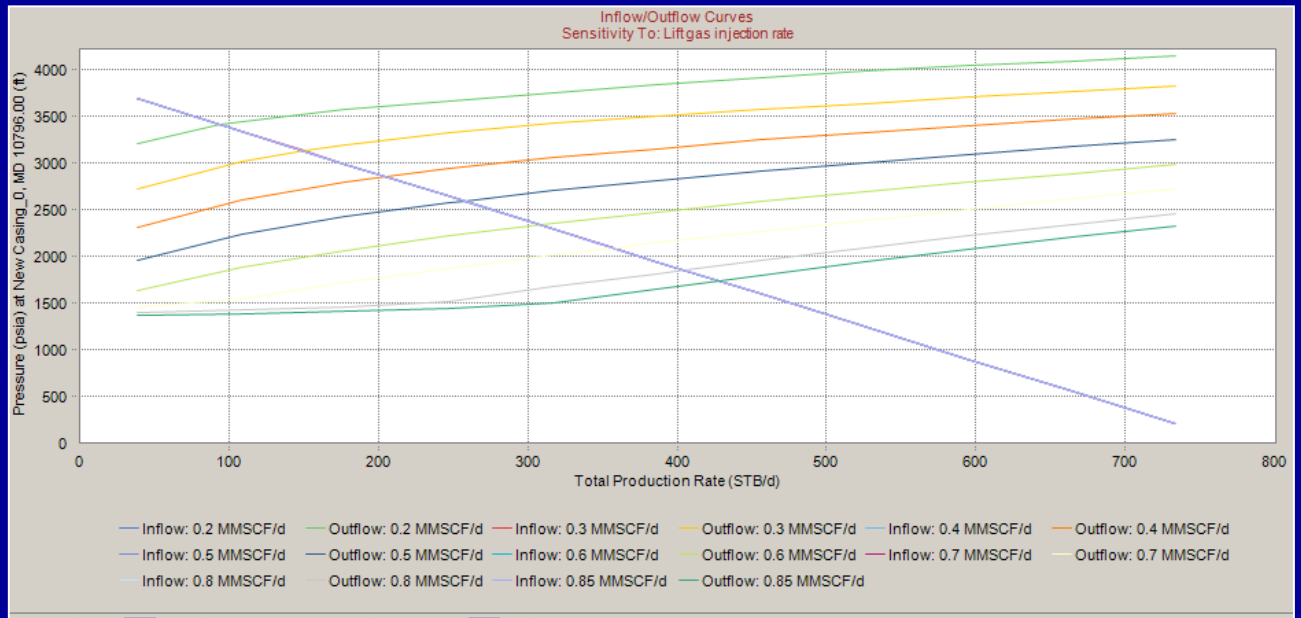
Optimization

- Continuously monitor the well
- Monitor injection rates
- Scaling and salting issues

Why Gas-Lift Solution?

- **Identified gas lift as a successful lift type**
  - **Successful between natural flow and reciprocating rod lift due to high gas/oil ratio (GOR) and reservoir pressure**
  - **Can handle a wide range of production rates**
  - **Continuous flow can handle sand**
  - **Gas lift used with capillary injection for proper chemical or fresh-water treatment**
  - **Production packer critical in the completion**

Gas-Lift Inflow/Outflow



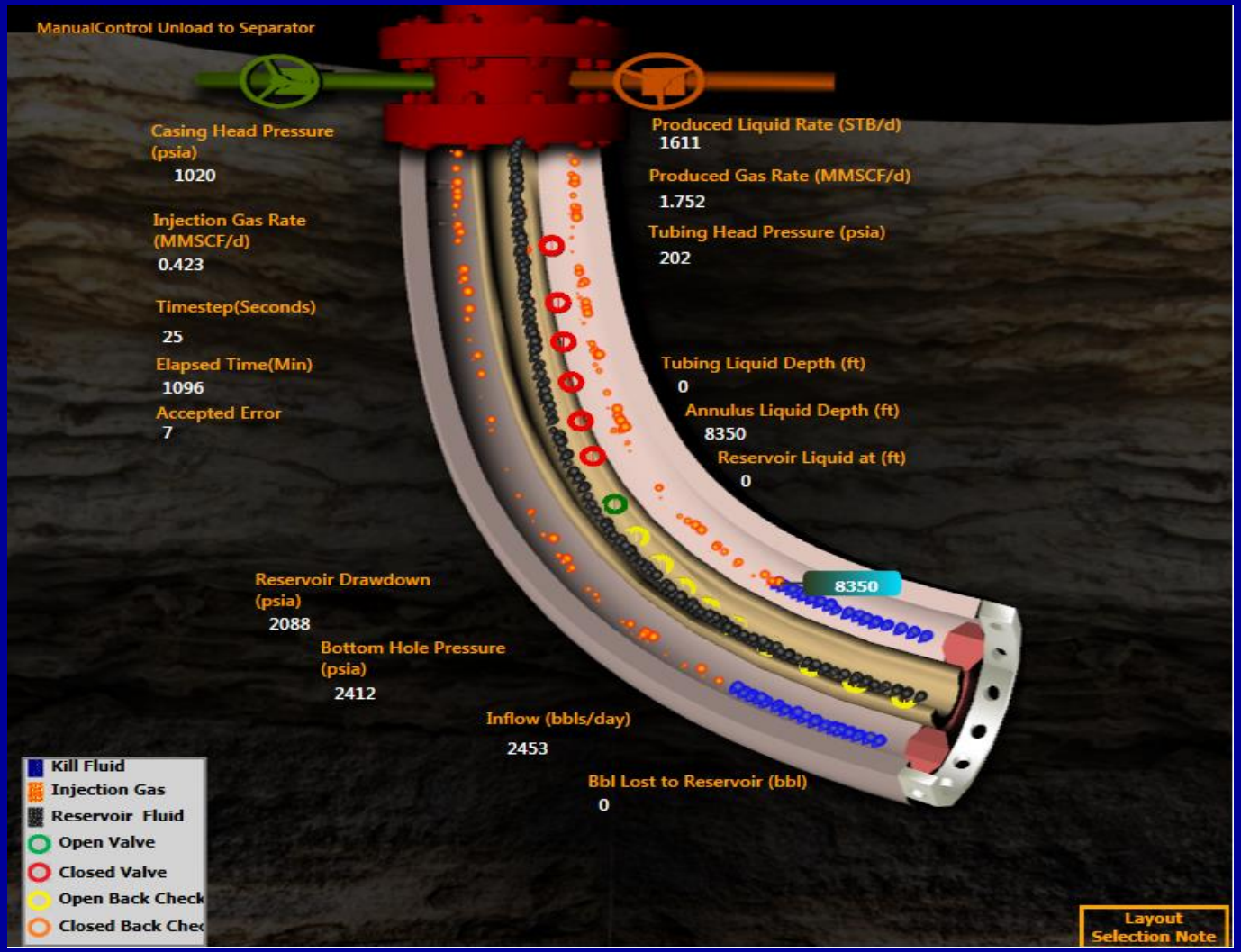
Operating Pressure	Liquid Rate	Oil Rate	Water Rate	Formation Gas Rate	Injection Gas Rate	Water Cut	Produced GOR	Injection MD	Payback Ratio	Status	Sens 1:Lift gas injection rate
(psia)	(STB/d)	(STB/d)	(STB/d)	(MMSCF/d)	(MMSCF/d)	(Fraction)	(SCF/STB)	(ft)	(STB/MMSCF)		(MMSCF/d)
3406.9	93.8	51.6	42.2	0	0.2	0.45	3876.55	5169.44	312.63	Stable	0.2
3122.69	150.6	82.9	67.8	0	0.3	0.45	3620.78	5878.67	297.43	Stable	0.3
2852.3	204.7	112.6	92.1	0	0.4	0.45	3552.45	6556.85	289.15	Stable	0.4
2589.43	257.3	141.5	115.8	0	0.5	0.45	3533.23	7219.32	281.85	Stable	0.5
2333.2	308.5	169.7	138.8	0	0.6	0.45	3535.68	7867.34	272.38	Stable	0.6
2085.59	358.1	196.9	161.1	0	0.7	0.45	3554.45	8495.63	259.86	Stable	0.7
1849.35	405.3	222.9	182.4	0	0.8	0.45	3588.69	9096.73	248.42	Stable	0.8
1736.43	427.9	235.3	192.6	0	0.85	0.45	3611.74	9384.35	None	Stable	0.85

- ✓ Multiple Nodal Sensitivities must be run to determine performance over the life of the well
  - Required for optimized valve placement
  - Ensures proper transfer as the well depletes

Gas-Lift Design Considerations

- **Designs to produce from 3,500 down to 200 B/D (556.5 to 31.8 m^3/d) in 2.875- or 2.375-in. tubing**
  - **1-in. outside-diameter (OD), wireline-retrievable equipment for life-of-well scenario**
    - Enables design changes
    - Ability to dummy upper valve stations to gain differential pressure later, if needed
    - Tungsten-carbide seats for wet gas gravities (>0.75 SG)
  - **Conventional tubing-retrievable gas-lift equipment**
    - 1.5-in. OD valves in most cases
  - **Designed to operate through the reservoir decline**
    - 2.875- or 2.375-in. tubing will experience some instability at 300 to 200 B/D (31.8 to 47.7 m^3/d)
      - Convert to rod lift

Design Verification with Dynalift™ Software



Capillary

- **Used for fresh-water injection to eliminate salt buildup and bridges**
  - **Multiple size cap strings up to 5/8 in., depending on water volumes**
    - 120 to 125 B/D (19.1 to 19.9 m^3/d) fresh water
  - **Run on outside of production tubing and terminate at the injection mandrel**
    - Injection depth just above above production packer
    - No lift-gas interference
    - Not fighting high fluid levels
    - Enables correct volumes of fresh water or chemical to be delivered precisely at the required depth

Packer Completions

- **Typical wellbore**
  - **7-in. casing in vertical section**
  - **4.5-in. liner at kickoff point**
- **AS-1X production packer**
  - **Wireline set with pump-out plug**
    - Enables well control when installing tubing
    - Kill fluid not required
  - **Set in vertical section of the wellbore (7-in. casing)**
    - Minimizes mechanical risks
    - Minimizes gas lift valve exposure to reservoir fluids
    - Injection pressure not fighting reservoir pressures while lifting

Compression (Commonly 2 Options)

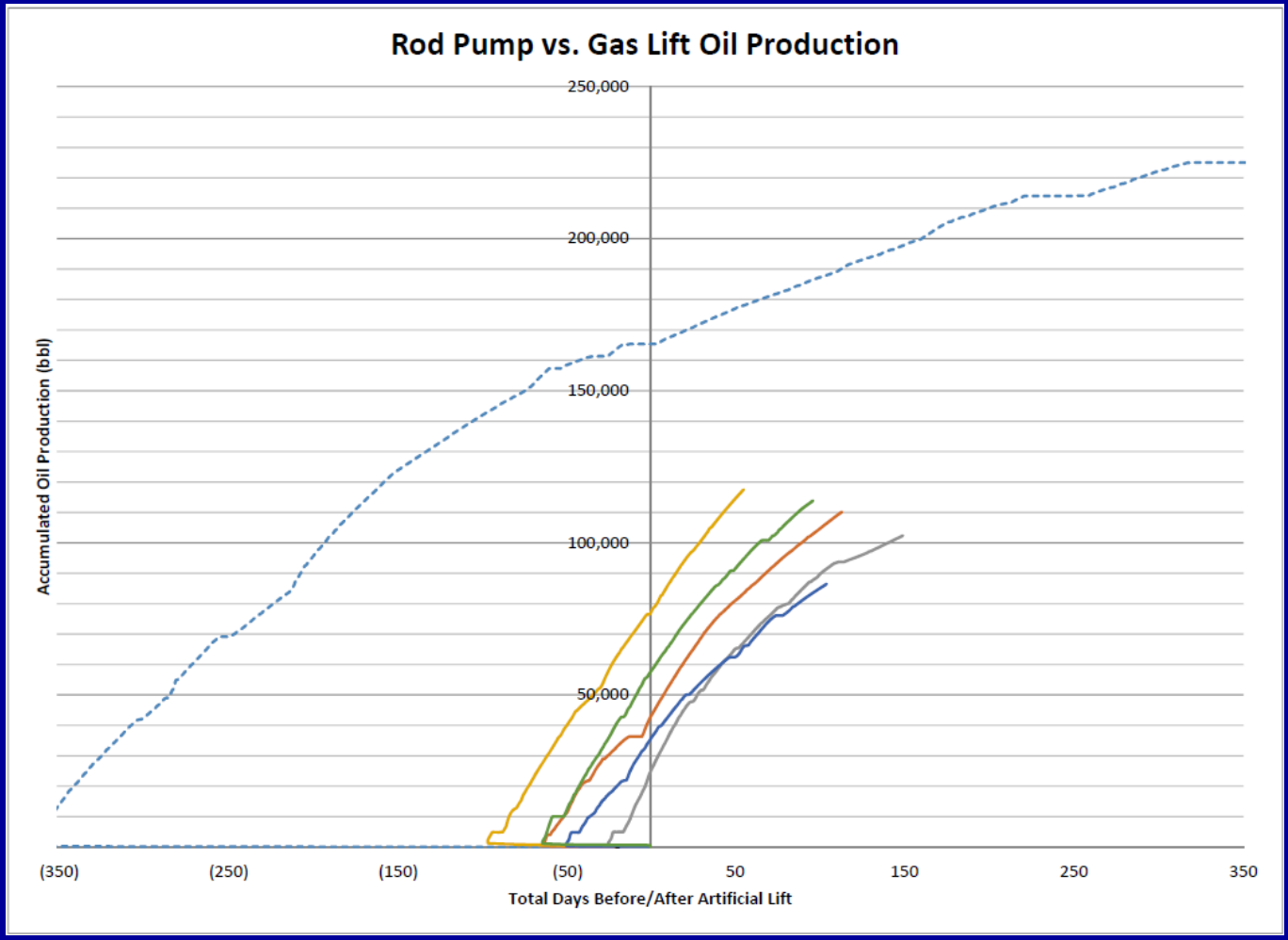
- **Centralized compression**
  - **Minimize surface foot print**
  - **Fewer deliverability issues**
- **Single pad compression**
  - **4 to 8 well pads**
  - **Winter packages**
    - Heat exchangers
    - Methanol injection
    - Building enclosures

Production and Optimization

- **Optimization**
  - **Higher water-cut reservoirs = higher gas-injection volumes**
  - **Higher formation GORs = lower gas-injection volumes**
    - Monitor production rates and adjust injection accordingly
  - **Monitor plugging in tubulars from salt/scale/sand**
    - Ensure cap string is pumping fluid
  - **Compression**
    - Monitor freezing issues
    - Monitor suction and discharge pressures
    - Flowmeters and injection chokes – properly sized to minimize well surging
  - **Sand production flows to surface, where it is removed**

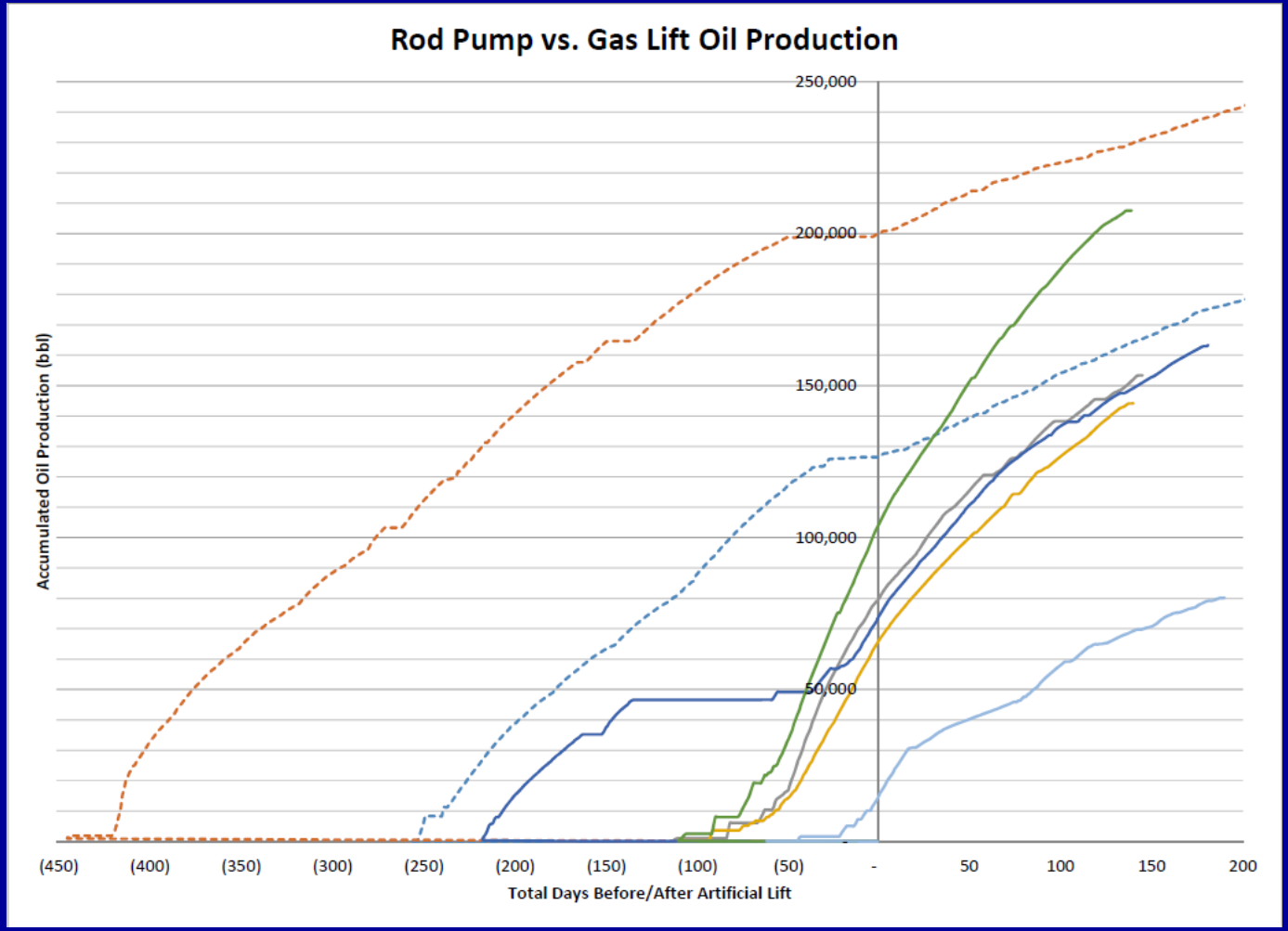
Production Results (Drilling Spacing Unit A)

------ Rod Lift —— Gas Lift



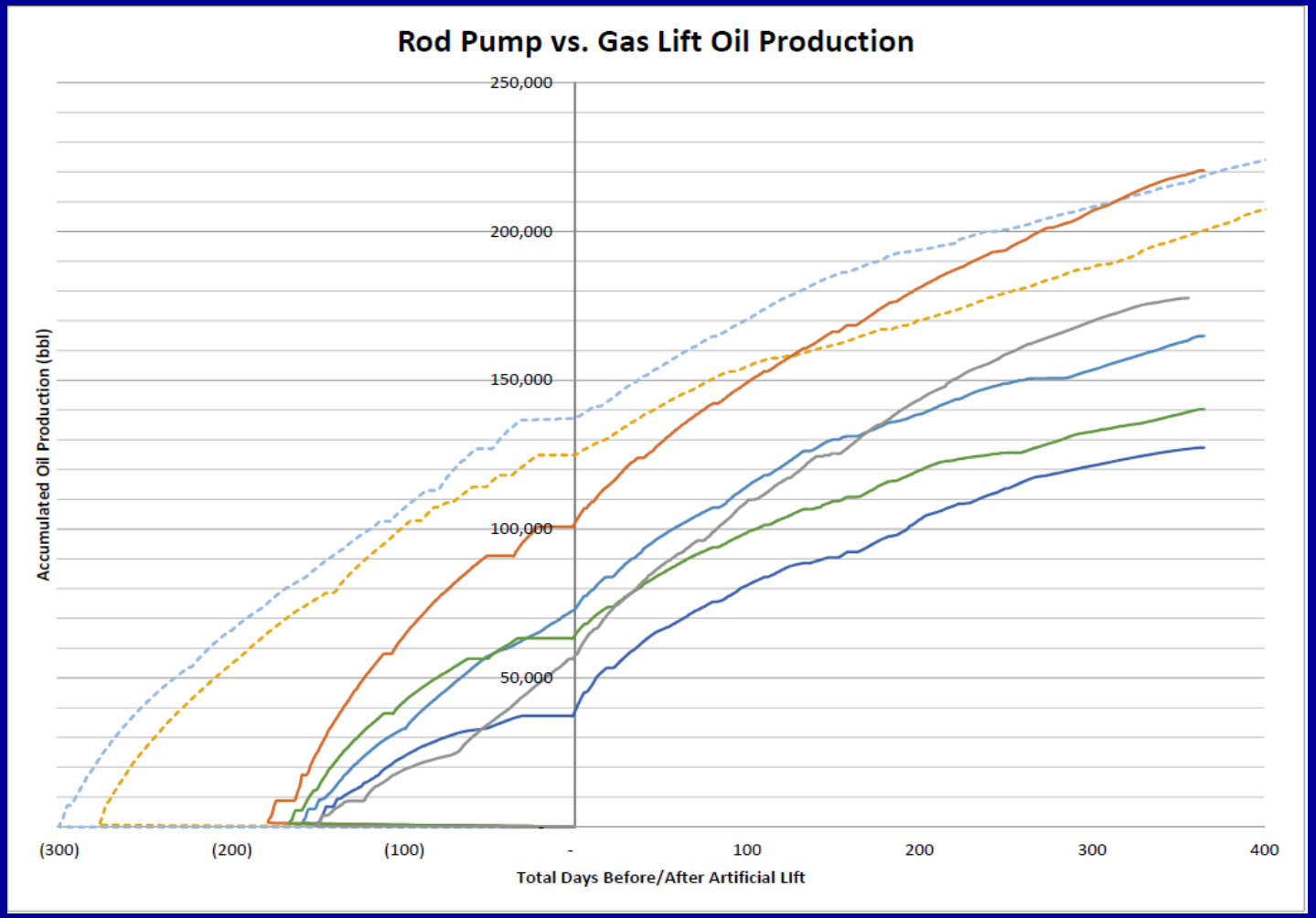
Production Results (Drilling Spacing Unit B)

------ Rod Lift —— Gas Lift



Production Results (Drilling Spacing Unit C)

------ Rod Lift —— Gas Lift



Advantages

- **While on gas lift, Operators eliminated remedial workovers from:**
  - **Rod wear**
  - **Gas lock**
  - **Salt plugs**
  - **Sandy well conditions**
  - **Changes to the gas lift design**
    - Wireline retrievable valves
- **Gas lift requires lower capital cost than rod lift or ESP**
- **Operator can use a smaller unit when the well converts to rod lift (640 Unit Vs. 912 Unit)**

Summary

- Gas lift is a good application for many Bakken wells as they begin to load during natural flow
- Gas lift will efficiently produce the well until it stabilizes at liquid and gas rates suitable for rod lift
- Capillary strings can be effectively utilized to keep tubulars clear and treat for corrosion
- Packers are a critical part of well efficiency and wellbore protection

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