Controlling PCP Wells Using Automated Liquid Inflow Determination in Raton Basin

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Objectives for Field Operators of PCP wells

- Maintain minimum bottom hole pressure
- Protect system components (Rods, Pump, Drive System)
- Maximize production (Fluid and Gas)
- Extend mean time between failure
- Log and report data to a control center
How do operators attempt to optimize a PCP well

- Fluid Shot
- Set Pumping Speed
- Bucket Test
- Wait for Production to Normalize

Repeat often
Why is automating PCP wells necessary?
SCADA Host

Artificial Lift Advisor Dashboard

Production Details

<table>
<thead>
<tr>
<th>Well</th>
<th>Acc Gross Prod</th>
<th>Yest Gross Prod</th>
<th>Yest Gross Prod - 30 Days AVG</th>
<th>Yest Gross Prod - 30 Day Diff</th>
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<tr>
<td>Allibi-23-2</td>
<td>72.44 bbl/d</td>
<td>460.27 bbl</td>
<td>464.34 bbl</td>
<td>4.07 bbl</td>
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<tr>
<td>Amore 32.9</td>
<td>39.88 bbl/d</td>
<td>41.26 bbl</td>
<td>41.26 bbl</td>
<td>0.00 bbl</td>
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<tr>
<td>Barrow</td>
<td>169.88 bbl/d</td>
<td>265.46 bbl</td>
<td>265.46 bbl</td>
<td>0.00 bbl</td>
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<tr>
<td>Bilbo</td>
<td>73.95 bbl/d</td>
<td>472.76 bbl</td>
<td>488.65 bbl</td>
<td>15.90 bbl</td>
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<tr>
<td>Jakarta</td>
<td>4.28 bbl/d</td>
<td>35.61 bbl</td>
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<td>0.58 bbl</td>
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<tr>
<td>Lorencito</td>
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<td>19.99 bbl</td>
<td>174.97 bbl</td>
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<tr>
<td>Lynn 32.4</td>
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<td>90.31 bbl</td>
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<tr>
<td>SunDog</td>
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<td>4.63 bbl</td>
<td>8.13 bbl</td>
<td>3.56 bbl</td>
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<tr>
<td>TriMax</td>
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<td>133.35 bbl</td>
<td>128.32 bbl</td>
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Alarm Details

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<tr>
<th>Well</th>
<th>Down Time</th>
<th>Status</th>
<th>Controller Alarms</th>
<th>Host Alarms</th>
<th>Comm Failures</th>
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</table>
Automated Method for Optimizing PCP Systems

Advanced controller architecture

Remote Monitoring & Control

Customer Inputs

Pressure Sensors

Flow Meter

RPM Sensor

Data collected from the KUDU advanced controller.
Inflow Control Method (ICM)

- To determine the inflow value the well has to be pumped down to the pump intake level (pump off condition). At this condition the maximum flow that can be obtained from the well will match the inflow from the reservoir to the well bore. Therefore the measurement of the outflow will equate to the inflow at that moment.
- The ICM starts by understanding the PC pumps capability using a model of the pump to understand pump displacement and slippage. It then uses this information to calculate Cavity fillage and theoretical flow for the desired speed range.
- Comparing the result of the model with the actual outflow during a slow ramp in speed we are able to create a controlled pump off condition within a safe range of cavity fillage. When well inflow is determined the speed is set to maintain a percentage margin of the inflow.
- The inflow test is performed periodically monitoring for changes in inflow and tracking changes in conditions such as pump swell and wear.
- The controller will also react to abnormal conditions like intake obstructions, sudden reduction in inflow, stuck pump and torque increase etc.
Automated Method for Optimizing PCP Systems

- Using the data entered by the operator combined with sensor data, a pump slippage test is conducted.
Automated Method for Optimizing PCP Systems

- The controller slowly ramps up the speed monitoring flow and cavity fillage until inflow is detected.
Well Inflow Test

Current Flow drops below Theoretical Flow deadband

RPM reduces to match Inflow
Well Inflow Test
SCADA Trends: Well Inflow Test

Yesterdays Production

Current Production

RPM

Calculated Inflow
Normal Operations

Trace

- Yesterday Total Production (Point limit exceeded - displaying processed min/max data, ... Raw Historic (*)
- Rod Torque (Point limit exceeded - displaying processed min/max data. Zoom in to view raw ..., Raw Historic (*)
- Rod RPM (Point limit exceeded - displaying processed min/max data. Zoom in to view raw ..., Raw Historic (*)
- Inflow (Point limit exceeded - displaying processed min/max data. Zoom in to view raw ..., Raw Historic (*)

Trace

- Discharge Pressure (Point limit exceeded - displaying ..., Raw Historic (*)
- Suction Pressure (Point limit exceeded - displaying ..., Raw Historic (*)
- Liquid Level (Point limit exceeded - displaying process..., Raw Historic (*)
- ALS.Countries,USA.Pioneer Natural Resources USA..., Raw Historic
- ALS.Countries,USA.Pioneer Natural Resources USA..., Raw Historic
- ALS.Countries,USA.Pioneer Natural Resources USA..., Raw Historic
Current Install Base

- As of February 1\textsuperscript{st}, 20 systems have been installed in the Raton Basin
- 38 Additional systems are in the process of being installed in the Raton
- Most wells are driven by IC engine hydraulic power units
- All wells in this project are CBM
- Wells are all less than 3000’ deep
- Liquid rates very across the field
Difficulties in Proving the Concept

- Fluid level shots

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**Velocity Shot (from Coiled Tubing) (7/20/2015 9:58:11 AM)**

- Gas Sp Gravity Index: 0.603
- CTBG Temperature (F): 60
- Travel Time (sec): 0.074
- Velocity (ft/sec): 1374
- CTBG Pressure (psi): 6.2

**Fluid Level Shot (7/20/2015 10:00:22 AM)**

- Fluid Level from Surf (ft): 1869
- Casing Temperature (F): 60
- Pump Depth (ft): 2450
- Travel Time (sec): 2.72
- Casing Submergence (ft): 581
- Fire Mode: Manual Vent
- Velocity @ Csg (ft/sec): 1373.5

**Pressure Buildup/PIP (7/20/2015 9:59:25 AM)**

- Pump Intake Press. (psi): 260
- Pressure Buildup (psi): -0.35
- Casing Gas Rate (Mscf/d): 0
- Liquid/Gas Grad (psi/ft): 0.433
- Gas Column Pressure (psi): 8.7
- Dead Liquid Level (ft): 1869
- Buildup Time (sec): 15
- Dead Pump Submrg. (ft): 581
- Dead Liquid Grad (psi/ft): 0.433
- Dead Liquid Level History: Saved

Currently 581 ft above pump last shot was 599 ft above pump
Bottom Hole Gauges

• To better understand what was happening bottom hole gauges were deployed

• Three wells on the work over schedule were selected

• Gauge data was tied into the Well Manager
Using BHP to Interpret Fluid Level

Actual Bottom Hole Pressure

RPM
Difficulties in Proving the Concept
The **Kudu** PCP Well Manager was installed on a well selected by Pioneer Natural Resources in the Trinidad Colorado field called Bilbo.

In addition to the Kudu PCPWM, a typical wedge flow meter was installed for the Production Optimization control method, and a 0 – 500 psi analog downhole gauge was added to measure pump intake pressure.

The controller was commissioned and placed into Production Control on October 6, 2015.

The chart above was supplied by Pioneer and shows daily values recorded by their SCADA system. The average daily gas rate in the 10 months prior to the installation of the PCPWM was 89.5 Mcf. Since installation this has risen to 141.5Mcf. This represents an increase of 58%.
Conclusion:

- The Production Control algorithm is performing as expected, and has proven to maintain the fluid level at an optimum level allowing the best inflow of both liquids and gas. Average daily water volume was almost doubled while gas was increased almost 60%. *This was all accomplished on a well that Pioneer felt was already optimized.*

- This was realised while maintaining near 100% pump cavity fillage which will extent the pump run life significantly. Another benefit that was mentioned by Pioneer was the noticeable reduction of manpower that the PCPWM has proven. This is of particular importance to them as they have reduced field staff by almost 70%.

- The supply and installation of the downhole gauge to prove the algorithm beyond question was a significant effort by KUDU that was very well received by Pioneer. As such, it has contributed to their confidence in the product.
Thanks

- We would like to thank Pioneer Natural Resources for working through this project with us and allowing us to use their well data in this presentation.
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