System Efficiency of Sucker Rod Pumping

Lynn Rowlan

ECHOMETER
Efficiency

1. Power Input into Sucker Rod Lift System
   a) System Does Works to Add Energy to Fluids
   b) Fluids then flow to the Surface

2. Discuss Surface & System efficiency

3. Use Fluid Level, Dynamometer, and Power Surveys to Determine Efficiency

4. Low Efficiency Used to Identify Problems

5. How to maintain a high producing efficiency in sucker rod lift operations
Net Lift ~ System Efficiency Equation

System Efficiency = \frac{HHP}{INPUT\ HP}

HHP = \frac{SG \times BPD \times (Net\ lift)}{135,800}

INPUT\ HP = Motor\ Power

SG = Specific\ Gravity\ of\ Fluid

1\ HHP = 27\ BPD \times 5000\ Ft
<table>
<thead>
<tr>
<th>WELL NAME</th>
<th>UNIT TYPE</th>
<th>MOTOR MAKE &amp; HP</th>
<th>TOTAL FLUID</th>
<th>PROD FLUID LEVEL</th>
<th>PWR COST</th>
<th>Meter kWh Use</th>
<th>COST/BBL</th>
<th>Tbg Psi</th>
<th>Avg Fluid Grad</th>
<th>Aprox Hyd Hp Req</th>
<th>System Eff (%)</th>
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<tr>
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<td>50 HP-RM</td>
<td></td>
<td>1828</td>
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<td>$820.78</td>
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<td>60</td>
<td>0.433</td>
<td>9.86</td>
<td>36.31</td>
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</tbody>
</table>
Measure Motor Input = 13.9 kW

Acquire:
- RMS (thermal) motor current
- Average (real) motor current
- kW during a pump stroke cycle.
Pump Intake Pressure = 730.7 Psig  133 BOPD  
Tubing Fluid Gradient = 0.335 psi/ft  241 BWPD  
Pump Depth = 5059 ft  

Net Lift 94 Ft?
Determine:
1. Input Kw
2. PR Hp
3. Pump Hyd Hp

\[ \eta_{\text{system}} = \left( \frac{Q}{BPD} \right) \left( \text{Depth} - \frac{\text{PIP}}{.433 \times \text{SG}} \right) \times \text{SG} \times (7.368 \times 10^{-6}) \]

Surface Efficiency 1-2
System Efficiency 1-3
System Efficiency Calculation

Theoretical amount of work required to lift the liquid from the intake pressure at the pump to the surface divided by the energy supplied to the motor.

Measure:

- Pump Intake Pressure from Acoustic Liquid Level

\[
\text{Net Lift} = \frac{P \text{ Depth} - \text{PIP}}{0.433 \times \text{SG}} = 5059 - \frac{730}{0.335} = 2880 \text{ ft}
\]

- Fluid Volumes and Properties
- Motor Input Power Measurement
55% System Efficiency

### Monthly Operation Costs (30 Days per Month):

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Run Time</td>
<td>24 hr/day</td>
</tr>
<tr>
<td>Cost With Gen. Credit</td>
<td>$349.96</td>
</tr>
<tr>
<td>Cost No Gen. Credit</td>
<td>$453.69</td>
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<tr>
<td>Demand Cost</td>
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<td>Oil Prod. Cost</td>
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<td>Liquid Prod. Cost</td>
<td>$5.6 c/bbl</td>
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<tr>
<td>Oil Production</td>
<td>133 BBL/D</td>
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<tr>
<td>Water Production</td>
<td>241 BBL/D</td>
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### Recommended Minimum NEMA D Motor

- Rated HP: 44.76 KW

### Power Results

- Rated Full Load AMPS: 75
- Thermal AMPS: 45.1

### Average Power

- With Generation Credit: 13.9 KW
- No Generation Credit: 18.0 KW
- Avg. Power Factor: 56.4 %
- System Efficiency: 55.0 %

![Graph of Power (KW) vs. Current (Amp)](image)
Why is Efficiency a Useful Benchmark?

• Measure of work input (power requirements) relative to useful output (liquid production).
• Directly related to operating costs
• Relatively easy to measure
• Generally accepted guidelines

Efficiency

- System Efficiency should be > 50%
- Surface Efficiency should be > 80%
Power, Fluid Level and Dynamometer Surveys Answers Following Questions:

1. Is the well being produced at its maximum production rate?
2. Does a fluid column exist above the pump intake?
3. Is the pump completely filled with liquid?
4. Is *low efficiency* caused by incomplete pump fillage due to over-pumping the well or due to gas interference?
## Acoustic and Power Surveys Show System Efficiency Less Than 35%

<table>
<thead>
<tr>
<th>Drawdown</th>
<th>Low Producing BHP or Low Fluid Level</th>
<th>Low Producing BHP or Low Fluid Level</th>
<th>High Producing BHP or High Fluid Level</th>
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<td>Low Pump Fillage</td>
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<td></td>
<td>Low Priority Study Surface Efficiency</td>
<td>Potential to Improve Study Control Run Time</td>
<td>High Priority Study Gas Interference</td>
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<td></td>
<td><strong>Tubing Leak?</strong></td>
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Sept. 11 - 14, 2007
Acoustic and Power Surveys Show System Efficiency Greater Than 35%
# System Efficiency Equation using PIP

Use to Identify Wells Having Low System Efficiency

<table>
<thead>
<tr>
<th>WELL NAME</th>
<th>MOTOR MAKE &amp; HP</th>
<th>TOTAL FLUID</th>
<th>PROD FLUID LEVEL</th>
<th>PWR COST</th>
<th>Meter kWh Use</th>
<th>COST/ BBL</th>
<th>Aprox Hyd Hp Req</th>
<th>System Eff (%)</th>
<th>No Credit Inp Hp</th>
<th>W.A. Hyd hp</th>
<th>W.A. System Eff (%)</th>
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<td>50 HP-RM</td>
<td>1828</td>
<td>8300</td>
<td>$821</td>
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<td>$0.45</td>
<td>2.55</td>
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<td>36.31</td>
<td>23.10</td>
<td>11.30</td>
<td>48.92</td>
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</table>
What Should be Known in Order to Determine the Efficiency of a Well?

- Recent and/or Representative Well Test
- Fluid Properties
- Run-Time
- Producing Fluid Level ~ Pump Intake Pressure
- Dynamometer Data (Representative)
- Wellbore Description
Losses ~ System Efficiency

\[ \eta \text{ BEAM, system} = \eta \text{ surface} \eta \text{ motor} \eta \text{ unit} \eta \text{ rods} \eta \text{ tubing friction} \eta \text{ surface pressure} \]

\[ \text{Input HP} = \frac{\text{Kw}}{0.746} \]

Input HP

Output

Surface Pressure Losses
Motor Losses
Unit Losses
Rod Losses
Tubing Flow Friction
Pump Output = \( Q \times \Delta P \)
Motor Performance Data – Efficiency vs. Output Hp
Comparison of NEMA D Motors
60 Hp NEMA D Motor (Surface Efficiency) Motor Performance Data – Efficiency vs. Output Hp

Other Motor Manufacturers Efficiency may be Different

(Polished Rod Horsepower can be used to estimate for Motor)

NEMA D MOTOR HORSEPOWER RATINGS:

5  7.5  10  15  20  25  30  40  50  60  75  100
### Motor Performance – NEMA D Motors

**Minimum Surface Efficiency**

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<td>79</td>
<td>82</td>
<td>81</td>
<td>77</td>
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</table>

**Surface Efficiency** measured over one revolution of the crank is an excellent indicator of the operating performance of the surface equipment.

**Surface Efficiency** includes losses per crank revolution in wirelines, structural bearings, transmissions, V-belts, and the electric motor.

![Graph showing surface efficiency and motor efficiency](image)
Example of Low Surface Efficiency

Bad Tail Bearing Resulted in Low Surface Efficiency of 66.5%

Surface Efficiency of 83.0% After Repair of Bad Tail Bearing

Before

After
Low Efficiencies of Sucker Rod Lifted Wells Are Often Caused by Partial Pump Fillage

- More efficient operations and lower electrical power usage will result if wells are operated with a pump filled with liquid.

- Full pump fillage also requires an efficient downhole gas separation that results in a full pump if sufficient liquid is present to fill the pump.

- Full pump fillage generally requires controlling the run time of the pumping unit to match the pump capacity to the maximum well inflow rate.
Drawn Down and Pump has Incomplete Fillage?
Timer or Pump Off Controller Candidate

Fluid Pound
Timers and Pump-off Control Systems

- Both timers and pump-off control systems can be used to control a pumping unit motor.

- Timers are preset to turn the motor on and off at specific times.

- Pump-off Control systems shut down the motor when incomplete pump fillage is detected, then, turn the motor on after a preset elapsed time.
Startup Motor Power

0.7 seconds

normal operation
Startup Motor Power Consumption

1. During start-up a beam pump motor uses approximately 3 times full load power for about 0.7 seconds.

2. Electricity usage during start-up is less than electricity usage during one stroke of normal operation.
How to Operate with High Efficiency?

• Maintain a high pump volumetric efficiency:
  1. Match pumping unit capacity with wellbore inflow.
  2. Pump a Full Stroke of liquid by controlling run time with a POC or Timer
  3. Eliminate Gas interference.

• When System Efficiency is low, find and fix problem.

• Mechanically/Electrically balance pumping unit.

• Properly size pumping unit, rods and pump to match well loads.

• On severely over-sized motors where surface efficiency falls below 50%, reduce motor size.
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