Quick Rod (QROD) String Design Tools

Ken Skinner, Lynn Rowlan & James N. McCoy
QRod - Free Simple User-friendly Practical Beam Pumping Design Program

- State of the Art Beam Pumping Design Technology
- Design and Predict Performance of Sucker Rod Pumping Systems
- Wave Equation Predicts Surface Dynamometer Loads and Polished Rod Position
- Immediately Evaluate Effect of Changing Tubing Anchor, Stroke Length, SPM, Pump Diameter
- Slippage Calculator from pump clearances ties the pump efficiency to the predicted pump displacement.
- Sinker Bar length calculator determines the sinker bar length as pump diameter or pump depth changes,
- Results can be shown in any system of units.
- Dynamometer measured surface DYN files can be imported and plotted on top of the predicted surface dynamometer card.
**Definition of Terms for Example Well**

**Surface Card**

- **Fo** – Fluid Load the Pump Applies to Rod String and caused by the differential pressure (PDP-PIP) acting across the pump plunger.

**PDP** – Pump Discharge Pressure

**PIP** – Pump Intake Pressure

**Ap** – Area of the Plunger

**Pump Card**

- **SV Open Upstroke**: 
  \[ Fo = (PDP - PIP) \times Ap \]

- **TV Open Downstroke**: 
  \[ Fo = 0 \]
Example Well

1. 5000 ft pump depth, 100 in surface stroke (s), 50 psi tubing and pump intake pressure

2. 2 inch diameter plunger with anchored tubing
   a) $F_o$, Fluid Load 6896 lbs

3. Tubing Fluid Gradient 0.433 psi/ft

4. 76 API Designation Rod String Taper
   a) 41.2% - 7/8” and 58.8% - 3/4” rods
   b) Weight Rods in Fluid – 8,288 Lbs
   c) $K_r = 254 \text{ lb/in} \& SK_r = 25400 \text{ lb}$
   d) $F_o/SK_r=0.271 \sim 27.1\%$ of Surface Stroke lost to Stretch
Tool: Tubing Fluid Specific Gravity Calculator
Simple to Determine for any System of Units

Tubing Fluid Specific Gravity Calculator

- Oil Gravity: 30.00 deg.API
- Water Cut: 85.3%
- Water Specific Gravity: 1.02 Sp.Gr.H2O
- Fluid Specific Gravity: 0.4330 psi/ft

Units:
- deg.API
- psi/ft
- Sp.Gr.H2O
- kPa/m
- Pa/m
- g/cm^3
- psi/100ft
- lbm/ft^3
Tubing Fluid Specific Gravity

Used in Calculation of Wrf, PDP, and Fo

1. **Wrf**
   - Weight of Rods in Fluid

2. **PDP**
   - Pump Discharge Pressure

3. **Fo**
   - Fluid Load Pump Applies to the Rods

Fo = (PDP – PIP) x Ap
Fluid Load, Fo, Decreases as Pump Intake Pressure, PIP, Increases

- PPRL = 15,601 Lbs
- MPRL = 6,576 Lbs
- Fluid Load = 5482 Lbs
- Pump Stroke = 80.7 inch
- Pump Stroke Length = 80.72 in
- Static Stretch = 21.56 in
- Fo/Skr = 0.216
- Kr = 254 lb/in
- Kt = 894 lb/in
QRod Calculates Full Pump Cards:

1. Pump full of Liquid with NO gas in Pump.
2. Valves Not Leaking and pump functioning properly.

Anchored Tubing

Rods Stretch to Pickup Fo

Unanchored Tubing

Tubing Moves as Fo Picked Up by Rods
Tubing Unanchored?

Pump Intake pressure is 319 and pump is full of fluid. Tubing Anchor depth is 2914, but anchor appears to not be set.

**Measured**
PPRL 7415 Lbs

**Pump Stroke** 48.4 inches

**Anchored**

**Unanchored**

Good Match with Dyn File Import and Predicted Card

Sept. 25 - 28, 2012 Sucker Rod Pumping Workshop
Simple User-Friendly Practical Beam Pumping Design Program

Dynamometer Cards

- Rod Load (lb)
- Position (in)

PPRL 17,112 psi ▼ MPRL 6,496.5 lb ▼ Fo 6,895.8 lb
Pump Stroke Length 74.57 in ▼ Static Stretch 27.12 in ▼ Overtravel 1.70 in
Fo/Skr 0.271 Kr 254 lb/in ▼ Kt 894 lb/in

Pump Velocity vs Position

- Pump Velocity (fps)
- Position (in)

(59.03 in, 17.629 in/s)
# Rod String from API Rod Number

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- All 5/8"
- Top 3/4" with 5/8" on bottom
- All 3/4"
- Top 7/8" with 3/4" in Middle and 5/8" on bottom
- Top 7/8" with 3/4" on bottom
- All 7/8"
- Top 1" with 7/8" in Middle and 3/4" on bottom
- Top 1" with 7/8" on bottom
- All 1"
- Top 1 1/8" with 1" in Middle and 7/8" on bottom
- Top 1 1/8" with 1" on bottom
- All 1 1/8"
- Top 1 1/4" with 1 1/8" in Middle and 1" on bottom
- Top 1 1/4" with 1 1/8" on bottom
Example Well

Dynamometer Cards at Pumping Speed of 5 SPM

Pump Stroke Length = Surface Stroke
- Static Stretch + Overtravel
Rod strings behave as a slender Euler column. Buckling occurs under small compressive loading.

**Notice:**
- 200 Lbs. Buckles > 50 feet of 1 ½ Inch Dia. Rod
TTU Slippage Test: Stroke #36 08/25/06 18:24:56

1. 76 Rods – 1.5” Pump – 7.046 SPM – 0.005” Clearance
2. Measured Slippage 21.4 BPD – Pump Efficiency 88.2%

QRod - Predicted

Measured Load Cell
Tool: Dyn File Overlay and Comparison

DYN File Comparison

<table>
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<tr>
<th>Position (in)</th>
<th>Rod Load (lb)</th>
<th>QRod</th>
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<th>% Difference</th>
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Peak Load | 11,097.3 | 11,413.9 | 316.6 | 2.8 % |
Minimum Load | 4,533.0 | 5,044.4 | 511.4 | 10.7 % |
Stroke Length | 105.00 | 105.60 | 6.85 | 0.6 % |
Polished Rod Power | 5.9 | 5.7 | 0.2 | 3.2 % |
### Slippage Calculator

#### QRod Inputs
- **Pump Diameter (D)**: 1.500 in
- **Pump Depth**: 3,896 ft
- **Tubing Pressure**: 13.00 psi
- **Pump Intake**: 116.80 psi
- **Stroke Rate (SPM)**: 7.045 SPM
- **Pump Displacement**: 182 BBL/D
- **Fluid Specific Gravity**: 1.00 Sp.Gr H2O

#### User Inputs
- **Clearance (C)**: 0.005 in
- **Fluid Viscosity (μ)**: 0.76 cP
- **Plunger Length (L)**: 48.000 in

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#### Calculate from SPM or Target Rate

- **Stroke Rate (SPM)**: 7.045 SPM
- **Target Rate**: 164 BBL/D

#### Pump Volumetric Efficiency
- 89.79%

**Rate (100% pump volumetric eff.):** 182 BBL/D
**Rate (90% pump volumetric eff.):** 164 BBL/D
Slippage Plot vs Clearance

Slippage 19 BBL/D
Pump Volumetric Efficiency 89.79 %
Pressure Differential (P) 1,583.05 psi
Tubing Fluid Gradient 0.4330 psi/ft

Patterson Equation Pump Slippage vs Clearance

Slippage = \left[ \left(0.14 \cdot SPM \right) + 1 \right] 453 \frac{DPC^{152}}{L \mu}

(0.005 in, 19 bbl/d)
In-balance 180 Kin-lbs

TTU Test Well
7.04 SPM 1.5” Plunger Clock-Wise Rotation

Compare Predicted to Measured Net Gearbox Torque

QRod Predicted
Minimum API Pumping Unit Description

Min API Unit Rating: 228-119-105

Design Inputs:
- Unit: CWEConv
- Pump Depth: 3,099 ft

Results:
- Rate (100% pump volumetric eff.): 182 BBL/D
- Rate (100% pump volumetric eff.): 164 BBL/D
- Rod Torque: 34.0%, 66.0%

Torque Graph:
- RMS
- AVG

Peak GearBox Torque: 204 Kin-lb
Counter Balance Moment: 509 Kin-lb
Counter Balance Effect: 10,222.6 lb
<table>
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<tr>
<th>Computer:</th>
<th>HP = CLF * PRHP / Unit Efficiency</th>
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<td>QRod uses:</td>
<td>CLF = \textit{RMS Torque/Average Torque}</td>
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<td>RMS Power/Average Power is OK.</td>
<td>(don’t use CLF based on motor current)</td>
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<td>OR:</td>
<td>Gault: HP = 2. * PRHP</td>
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<td>Unit Efficiency:</td>
<td>95 % for “Large” Units</td>
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<td>80 % for “Small” Units</td>
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</table>
NEMA D Efficient Under Cyclic Loads
8-13% Slip ~ 275% Starting Torque

HP = CLF * PRHP / Unit Efficiency

Min NEMA D Motor Size
Polished Rod Power

10.4 HP
5.9 HP

Surface Unit Efficiency
95%

CLF
NEMA D Motor
TTU Well 9.72 SPM – Compare Plunger Velocity
QRod - Most Widely Used Program for the Design and Predicted Performance of Sucker Rod Beam Pumping Installations.

- Allows Either English or Spanish Display of Input/output
- Helps the beam pumping system designer implement state of the art design technology without getting buried with details
- Wave equation solution to accurately predict the surface dynamometer loads, gearbox torque and pump capacity, with a minimum amount of input
- Immediately Evaluate Effect of Changing Tubing Anchor, Stroke Length, SPM, Pump Diameter
- Slippage Calculator from pump clearances ties the pump efficiency to the predicted pump displacement.
- Sinker Bar length calculator determines the sinker bar length as pump diameter or pump depth changes,
- Results can be shown in any system of units.
- Dynamometer measured surface DYN files can be imported and plotted on top of the predicted surface dynamometer card.

Download free of charge from: www.echometer.com\software\index.html
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