Rod Pumping Diagnosis & Optimization

FL Shots + Dyno Tests + Rod Pumping *gnosis*

Course Outline – Sections:

1. **Introduction** (1-hr)
2. **Rod Pumping Overview** (1-hr)
3. **Intro to Optimization & Fluid Level/Dyno Tests** (1-hr)
4. **Fluid Level Shots (pt. 1) – Basics** (6-hr)
5. **Downhole Pumps & Pump/Rod Operation** (2-hr)
6. **Dynamometers (pt. 1) – Card Interpretation** (7-hr)
7. **Fluid Level Shots (pt. 2) – Over-Time** (5-hr)
8. **Dynamometers (pt. 2) – Over-Time** (9-hr)
9. **Echometer Equipment & Software** (3-hr)
10. **Gas & Solids – Separation & Handling** (6-hr)
11. **Run Time Control – Timers, POC & VSD** (6-hr)
12. **Other Topics (Context, Chemical, Pump Action)** (2-hr)
13. **Optimization & Troubleshooting Wells** (4-hr)
14. **Final Quiz** (5-hr)

Course Outline – Details:

1. Introduction:

a. My Biography
b. Overview of Course & Sections
c. Overview of Permian Basin & Oil Price

2. Rod Pumping Overview

a. Quick Overview: Rod Pumping System & Components
b. Deeper Overview of Concepts and Components:
    i. **Pumping Units:** Different PPU Geometries & Counter-Balance
    ii. Sucker Rods & Tubing
    iii. Gas Separation
    iv. Surface Components & POC's/Timers

3. Intro to Optimization & FL/Dyno Tests:

a. Goals of Optimization
b. FL Shots & Dynamometers: Quick Overview
c. Optimization Examples x3
d. Types & Causes of Downhole Failures

Video #

4. Fluid Level Shots (pt. 1) — Introduction

- a. Intro to Fluid Level Shots: Theory, Components, Steps & Types of FL Guns — 4.1
- **b. FL Shot Theory:**
  - i. Acoustic Trace & Reflections — 4.1
  - ii. Polarity of Kicks — 4.2
  - iii. Acoustic Trace Examples - Interpreting Kicks — 4.2
  - iv. Multiphase Flow, CP Build-Up Test & GFLAP Calculation — 4.3
- c. Examples: FL Shots & CP Build-Up Tests — 4.3
- d. Three Scenarios: Flumping, Pumped Off & Holding GFLAP — 4.3
- **e. Three Methods for Calculating Acoustic Velocity:**
  - i. Collar Count (Default) — 4.3
  - ii. Downhole Marker — 4.4
  - iii. Specific Gravity or Manual Entry of AV — 4.4
- **f. Other Considerations for FL Shots:**
  - i. Implosion vs Explosion — 4.5
  - ii. Charging Gas: CO2 & N2 — 4.5
  - iii. Background Noise — 4.5
  - iv. Shot Size: ΔP — 4.5
  - v. WH Connection & Distance — 4.6
  - vi. FL at Surface & Troubleshooting — 4.6

5. Downhole Pumps & Pump/Rod Operation

- a. Introduction to Pumps: Videos & Components — 5.1
- b. Explanation of Pump Cycle & Fluid Load (F_O) — 5.1
- c. Types of Rod Pumps — 5.1
- d. Pump Slippage — 5.1
- e. Calculating Production — 5.1
- f. Fluid Load on Plunger — 5.1
- g. Elasticity — 5.2
- h. Fluid Load Transfer: Rod-to-Tubing & Tubing Breathing — 5.2
- i. Rod Loads on Up-Stk & Down-Stk — 5.2
- j. Rod Stretch & Downhole SL: Over- vs Under-Travel Cards — 5.2
- k. Rod Stress Waves — 5.2

6. Dynamometer's (pt. 1) — Card Interpretation

- a. Application of Dyno Tests — 6.1
- b. Dynamometer Plots — 6.1
- **c. Surface Card Insights:**
  - i. Ideal Surface Card: 0.1 SPM — 6.1
  - ii. Stuffing Box Friction — 6.1
  - iii. Identifying Light Tags — 6.1
- d. Wave Equation: Surface to Pump Card — 6.2
  - i. Friction: Fluid Friction & Mechanical Friction — 6.2
  - ii. Pump Cards — 6.2

e. Fillage: Effective vs Maximum Plunger Travel (EPT vs MPT)
f. Standard Pump Card Shapes: — 6.2
   i. Incomplete Fillage:
      1. Fluid Pound
      2. Gas Interference
      3. Gas Lock
   ii. Slippage Cards (Worn Pump) — 6.3
   iii. Leaking Standing Valve
   iv. Tagging: Hitting Bottom & Top
   v. Solids in Pump — 6.4
      1. Propped Off Seat
      2. Delayed TV (& SV) Closure
      3. Solids Sticking/Grinding
      4. Plunger Seized Up
   vi. Unanchored Tubing
   vii. Hole in Pump Barrel
   viii. Tight Spot in Pump Barrel
   ix. Fluid Inertia Effects (Hydraulic HP)
   x. Shallow Friction Cards — 6.5
   xi. Heavy Oil Cards (Viscous Friction)
   xii. Paraffin Sticking Rods
   xiii. Not Pumping Cards
   xiv. Combination Cards (Various Combinations of Prior Cards)
   xv. Errant Cards:
      1. PPU/Extraneous Noise
      2. Stroke Processing Error
      3. Bad Input Data
g. **Types of Loadcells:** Donut (POC), Horseshoe, Polished Rod Transducer (PRT) — 6.6
   i. Differences in How They Measure Load
   ii. Stacking Out the Rod String
   iii. PRT Cards – Zero-Load Line & How it Computes Dyno Cards
   iv. PRT & Polished Rod Bending Distortion; Deramp

7. Fluid Level Shots (pt. 2) — Over-Time!

a. FL Shots - Troubleshooting Features: — 7.1
   i. Acoustic Filters – High & Low Pass Filters
   ii. Depth Reference Line
   iii. Folding Traces
   iv. Overlay Prior Shots
   v. Apply Troubleshooting Features on Various Examples
b. Complicated Repeats/Kicks: Interpretation Examples — 7.2
c. Implosion Shots w/ 1500# Gun
d. Calculating BHP (Bottom Hole Pressure)
   i. Specific Gravity & Hydrostatics Calculations

- **e. Echometer's 'S Curve' & Effective Liquid Fractions (GFLAP)** — 7.3
  - i. Assumptions
  - ii. Errors When High Gassy Liquid Column
  - iii. Walker Fluid Level Depression Test
- f. Estimated MCFPD: Calculations & Assumptions — 7.4
- **g. Producing & Static BHP**
- **h. Inflow Performance Relationships**
  - i. Vogel & Productivity Index
- i. Nuances of Shooting Different Forms of AL — 7.5
  - i. ESP, Gas Lift, PCP, Plunger Lift, Flowing Dry Gas, TA Wells (H-15 Test)

8. Dynamometers (pt. 2) — Over-Time!

- **a. Rod Loading:**
  - i. Predictive vs Diagnostic
  - ii. Rod Manufacturing Process: Steel & FG
  - iii. Stress-Strain Diagram — 8.1
  - iv. Modified Goodman Diagram (MGD Loading)
  - v. Caution on Using HS Rods — 8.2
  - vi. Service Factor (Derating for Corrosion)
- **b. Valve Tests:**
  - i. Theory & Factors Affecting Slippage
  - ii. Procedure of Test & Assumptions
  - iii. Examples: Worn Pump, SV Leak, Friction Stick-Slip Release — 8.3
  - iv. Special Topics:
    1. Echometer's PRT Dyno - Temperature Drift
    2. Gas in Pump: Delaying Calculated Leakage
    3. Residual Friction
- **c. Downhole Friction, Friction Factors & Deviated Wellbores:**
  - i. Fluid & Drag Friction
  - ii. Well Deviation, Dogleg Severity & Side Loads — 8.4
  - iii. Adjusting Damping Factors
  - iv. "Trash Can" Effects (Miscalculated Cards by Wave EQ)
- **d. Load Reference Lines**
  - i. W_{RF}, W_{RF} + Fo Max, Fo from FL, Fo Max
  - **ii. Recognizing the Cause of Failures:**
    1. True Loadcell Dyno – Rod Part, Tbg Leak or Pump Failure — 8.5
    2. True (Buoyant) Load vs Effective Load
    3. Comparing Failure Cards to Saved Reference Cards
  - iii. K_T - Tubing Spring Constant (Unanchored Tubing) — 8.6
  - iv. K_R - Rod Spring Constant (Rod Stretch)
- **e. Dyno Calculations:**
  - i. Gas Free Fillage Line
  - ii. Dyno Estimated Production — 8.7
  - **iii. Dyno Estimated PIP**

1. Comparing with PIP from FL Shot
2. PIP Issues Related to Sand

8.7

f. Dyno Quiz!!! 8.8 & 8.9

9. Echometer Equipment & Software

a. Wired vs Wireless Equipment: Comparison
b. TWM vs TAM: Comparison
c. Video Overview: Navigating Software & Options
   - **i. TWM (Total Well Management) – Wired Equipment**
     1. Build a Well File from Scratch
     2. Analyze a Data Set: FL Shot, Dyno Test & Valve Test
   - **ii. TAM (Total Asset Management) – Wireless Equipment**
     1. Build a Well File from Scratch
     2. Analyze a Data Set: FL Shot, Dyno Test & Valve Test
     3. How to Import TWM Data to TAM
     4. Utilities Options: Import/Export Data

9.1

9.2

d. Advanced Options in TAM:
   - i. Reprocess Stroke Data (for noisy acceleration data)
   - ii. Clear Channel Analysis (if bad wireless signal)
   - iii. Dynamometer Analysis Plots

9.3

e. Other Free Echometer Software:
   - i. **QRod** - Rod Design Software
   - ii. AWP2000 – BHP Calculations

10. Gas & Solids: Separation and Handling

a. Intro & Problems of Gas Interference
b. Gas Separation Theory
   - i. Gas Compressibility
   - ii. Gravity Separation & Bubble Rise Velocity
   - iii. Downward Fluid Velocity Calculations

10.1

c. Factors Affecting Gas Separation
   - i. Separation Area
   - ii. Production Rate
   - **iii. Other Factors:**
     1. Gas in Solution
     2. PIP: Path of Least Resistance
     3. Emulsion/Foam
     4. Horizontal Slugging
     5. Gas Blow-By: Gas Velocity by Separator
     6. TAC Bottleneck (Liquid Hold-Up)

10.2

d. Gas Separator Designs/Models:
   - i. Sumped Pump & Poor Boy
   - ii. Packer Separators
   - iii. Vortex/Centrifugal Separators

iv. Thin-Wall or Decentralized
v. Multi-Stage Separators

e. Sand Separators/Solids Control:
i. Issues Created by Solids: Wear, Valve Fouling, Sticking, Fishing, etc.
ii. Vortex Desanders
iii. Filtration: Tubing Screens
iv. Solids Diversion: Solids Weir

10.3

f. Pump Compression Ratio & Pump Spacing

g. Pump Design/Components – Handling Gas
i. Reduce P. on TV
ii. Specialty Gas Pumps
iii. Mechanical Actuation of TV – Ball Knockers

10.4

h. Tubing Back Pressure: Purpose & Functions
i. Pump Action, SBox Lubrication, ΔP for Slip-Stream
ii. Downsides of High TP

i. Pump Design/Components – Handling Solids
i. Plunger Clearance (Tight vs Looser Fit) & Solids Size
ii. Specialty Sand Pumps & Components

10.5

11. Run Time Control: Timers, POC & VSD's

a. Purpose of Regulating Run Time & F# Damage

b. Time Clocks:
i. Three Types: Percentage, Pin, & Variable Timers
ii. Pump Off Ratio Test: Calibrating Timer to Match Reservoir Inflow

c. POC: Pump Off Controllers
i. Types of POC's:
1. Rotational/Motor Speed
2. Surface Card Control
3. Pump Fillage Control

ii. Main Control Settings:
1. Fillage Set Point, Low Fill Stks, Down-Time, & Min Strokes
2. POC Settings: Pumped-Off vs Gas Interference
3. Setting Fill SP: How Fast Does Fillage Drop?

11.1

iii. Fill Base: Ensuring Correct Fillage Computed on POC
iv. Load Violations: Min/Peak Load, Malfunction SP & Fluid Load

v. POC: Load & Position Measurements
1. Components/Methods: Measuring Load & Position
2. Card Rotation: Position Data Out of Phase with Load Data
3. **Verifying/Calibrating POC Cards:** Correct Well Data, Accurate Position w/ Hall Effects Sensors, & Phase Shift on Position Data

11.2

11.3

vi. Controlling RT Based on PIP (not fillage)

d. VSD: Variable Speed Drives
i. Theory of Operation & Control Parameters
ii. Benefits & Downsides

11.4

iii. Setting Main Control Parameters
iv. Cornering / Sectional Speed Change

e. POC/VSD Historical Data: 11.4

i. Analyzing Daily Run Time and Run Cycle Trends
ii. Historical Data Plots on POC & Insight from Them
iii. Shut-Down Cards
iv. Saved Standard Cards – Reference for Failures

11.5

f. Automation for FL Shots

12. Other Topics

a. Interpreting FL/Dyno Data in Context
b. Tabulating & Applying FL/Dyno Data

12.1

c. Chemical Treatment:

i. Different Forms of Chem Treatment
ii. Applying FL Shots to Determine Proper Chem Treatment

12.2

d. **Pressure Gauge:** Pump Action vs Rod Action
e. Rod Rotators

13. Optimization & Troubleshooting Wells:

a. Optimizing Wells:

i. Optimizing Workflow
ii. Rod & Tubing Designs: Tips & Tricks

13.1

iii. **Specialty Equipment:** Guides, COROD, Poly-Lined Tbg, Tbg-Rotators, etc.

13.2

iv. 'Long & Slow' Pumping

v. Limitations on Max & Min SPM; PR Velocity Comparisons

13.3

vi. Adjusting Displacement to Match Production

b. Troubleshooting Wells: 15 Real World Examples 13.4

14. Final Quiz: Test Your Knowledge

a. **Test** (on all important concepts) 14.1 – 14.4
b. Thanks!