Over Travel ~ Under Travel
Fo/Skr & N/N'o Limits

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ECHOMETER
Introduction

1. API RP 11L - Figures
2. Discuss Properties of Dynamometer Surface and Pump Card
3. Define Fo/Skr & N/N'o
4. Discuss How Increased SPM increases Overtravel
5. Does Fo/Skr & N/N'o Limits Impact Rod Failures
6. Discuss ALEOC Failure Frequency Plot
Dynamometer Cards Definition

1) **Surface dynamometer card** is the plot of the measured rod loads at the various positions throughout a complete stroke; the load is usually displayed in pounds of force and the position is usually displayed in inches.

2) **Pump dynamometer card** is a plot of the calculated loads at various positions of pump stroke and represents the fluid load the pump applies to the bottom of the rod string.
Normal Pump Card Fluid Load, $F_o$

$F_o$ – Fluid Load the Pump Applies to Rod String and caused by the differential pressure ($P_{dis} - P_{intk}$) acting across the pump plunger.

$P_{dis}$ - Pump Discharge Pressure  
$P_{intk}$ - Pump Intake Pressure  
$A_p$ - Area of the Plunger

**SV Open Upstroke**:  
$F_o = (P_{dis} - P_{intk})A_p$

**TV Open Downstroke**:  
$F_o = 0$

Surface Card

$F_o$, Fluid Load
**PPRL** Peak Polished Rod Load experienced during a stroke.

**Wrf + Fo Max (TV)** Weight of Rods in Fluid plus the fluid load applied to the rods by the pump.

**Wrf (SV)** Weight of Rods in Fluid, TV open and plunger is applying no load to the rods.

**MPRL** Minimum Polished Rod Load experienced during the pumping cycle.
**TV** Weight of Rods in Fluid, $W_{vf}$, plus the Fluid Load, $F_o$, plunger is applying to the rods.

**$W_{ra}$** weight of the rod string suspended in air.

**$W_{rf} = W_{ra} - Buoyancy**

**$F_o$** fluid load the pump applies to the rod string.

**$F_1$** dynamic force required at the surface to apply a static force $F_o$ at the pump.

**$F_2$** dynamic surface force due to transferring the $F_o$ carried by the traveling valve to the standing valve.
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) Fluid Load 6802 lbs

3. Tubing Fluid Gradient 0.433 psi/ft

4. 76 API Designation rod string
   a) 41.2% - 7/8” and 58.8% - 3/4” rods
   b) Weight Rods in Fluid – 8,288 Lbs
   c) Kr = 254 lb/in & SKr = 25400 lb
   d) Fo/SKr =0.268 with 26.8 in of Stroke lost to Stretch
Example Well
Dynamometer Cards at Pumping Speed of approximately 0

Peak PR Load, PPRL = Wrf + Fo
Min. PR Load, MPRL = Wrf

SPM = 0

Fo/Skr = 0.268

PPRL 15,089 lbs
Pump Stroke 73.2 in
Fo/Skr 0.268

MPRL 8,288 lbs
Static Stretch 26.8 in

Fo 6,802 lbs
Overtravel 0.0 in

Kr 254 lb/in
Kt 894 lb/in
Example Well
Dynamometer Cards at Pumping Speed of approximately 5 SPM

**Peak PR Load, PPRL = Wrf + F1**

**Min. PR Load, MPRL = Wrf – F2**

Wrf = 8,288 Lbs
F1 = 8700 Lbs
F2 = 1775 Lbs

**PPRL 16,988 lbs**
**MPRL 6,513 lbs**
**Fo 6,802 lbs**

**Pump Stroke 75.0 in**
**Static Stretch 26.8 in**
**Overtravel 1.7 in**

**Fo/Skr 0.268**
**Kr 254 lb/in**
**Kt 894 lb/in**
Rod String 76 Design loaded to 100% of the Allowable Modified Goodman Stress

\[
PPRL = Wrf + F1
\]

\[
MPRL = Wrf - F2
\]

\[
SPM = 11
\]

Wrf = 8,288 Lbs
F1 = 11,378 Lbs
F2 = 4,100 Lbs

PPRL = 19,666 lbs
Pump Stroke = 87.1 in
Fo/Skr = 0.268

MPRL = 4,188 lbs
Static Stretch = 26.8 in
Kr = 254 lb/in

Fo = 6,802 lbs
Overtravel = 13.8 in
Kt = 894 lb/in
No - Undamped Natural Frequency
Synchronous Speed of Straight Uniform Sucker Rod String

\[ \text{No} = 15 \frac{v_s}{L} \]

\[ \text{No} = 15 \times 16300 / 5000 = 48.9 \]

\( \text{No} \) – Undamped natural frequency, SPM
\( v_s \) – Velocity of Sound in Steel, ft/sec
\( v_s = 16,300 \text{ ft/sec} \)
\( L \) – Length of Rod String, Ft
\( N \) – Current Pumping Speed, SPM

\[ \text{N’o} = 1.093 \times 48.9 = 53.4 \]

\( \text{N’o} \) – Natural Frequency adjusted for Taper – \( Fc \times \text{No} \)
\( Fc = 1.093 \)

\[ \frac{N}{N’o} \] - Dimensionless Speed Ratio
Compares the Plunger Stroke Factor, Sp/S, where Sp is plunger stroke and S is surface stroke to Fo/SKr and N/No'. N/No' is the ratio of the current pumping speed to the harmonic pumping speed, No'.

As the value of Fo/SKr goes up, then more of the surface stroke is lost to static stretch.
NO – Do Not Design Rods Here Due to **Overtravel**

NO – Do Not Design Rods Here Due to **Undertravel**

**1st Company**

Note: The analog computer dynamometer cards on this exhibit were conceived by Sucker Rod Pumping Research, Inc., and publication is made possible by cooperation of the American Petroleum Institute.
NO – Do Not Design Rods Here

2nd Company Says Never Design Rods Here

BAD

NO – Do Not Design Rods Here

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### Fo/Skr & N/No' Rod Design Practice

1st company’s rod design practice where:

\[ \text{Fo/SKr} < 0.2 \text{ and } \text{N/No'} < 0.2 \text{ Maximum} \]

2nd company designed rod strings where:

\[ \text{Fo/SKr} > 0.2 \text{ and } \text{N/No'} > 0.2 \text{ Minimum} \]

Did design practice impact failure Rates?
Both had 0.4 Failure Frequency.
What did Companies have in Common?

1. **Active Program where Technicians:**
   a) Acquired Data
   b) Analyzed Problems
   c) Followed-up Recommendations

2. **Practiced a “Company” Methodology to Analyze, Optimize, and Trouble Shoot Wells**

3. **Tracked Cause and Condition of Failed Downhole Equipment in a Failure Data Base**

4. **Determined to investigate Root Cause of Failure and Correct the Problem.**
What does the ALEOC Failure Data Show?

1. Making an effort to analyze the well’s operation and **taking action** to fix problems discovered is the **MOST important requirement**

2. Everyone in the study group **recognized their performance could be improved** and they took action to reduce failures

3. Their **different actions** with-in their individual companies **resulted in a reduction of failures** for all companies in the study group

4. **Expect a 0.4 Failure Frequency in Your Field**
Is Overtravel Good or Bad?

1. **Good** because Pump Displacement Increases with Increase in SPM

2. **Bad** because Failures “tend” to increase with increased SPM

3. Operating within a pumping speed 5-10 SPM range is common practice and failures rates should not increase when pumping within this speed range.
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