Causes of Incomplete Pump Fillage

- Both gas and liquid are present at the pump intake: gas interference.

- Not enough liquid to fill the pump barrel: pump flow rate greater than well production, well pumped off.

- Flow restriction at the pump intake: flow through SV less than plunger displacement.
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.
Fluid Pound & Gas Pounds

A gas pound (Lower Left) does not move progressively to the left. It moves back and forth and jumps around on the trace as more or less gas enters the pump and changes where the valves close and open during the downstroke portion of the pumping cycle.
Fluid Load, \( F_o \), Has Two Reference Lines

**Fluid Load** is the load that the Pump applies to the rod string.

\[
F_o = F_{o\text{Up}} - F_{o\text{Dn}}
\]

- **Upstroke**: \( F_{o\text{Up}} = (P_{\text{dis}} - P_{\text{intk}}) \times A_p \)
- **Downstroke**: \( F_{o\text{Dn}} = 0 \)

**Two reference lines**

1. **\( F_{o\text{Max}} \)**
   - \( F_{o\text{Max}} = P_{\text{dis}} \times A_p \)
   - \( F_{o\text{Max}} \) is the maximum load that the pump would apply to the rod string assuming pump intake pressure is zero. The well would provide no help in lifting the fluid to the surface.

2. **Zero Load Line**
To Open TV
Increase PIP to PDP
Fo - Differential Load Required to Open TV

**Fo (Pump Card)**: \( (Fo_{Up} - Fo_{Dn}) \)

**Fo (Valve Test)**: \( (TV - SV) \)

**PIP** = Tubing Pressure + Tubing Gradient * Pump Depth (TVD) – Fo / Plunger Area

**PDP** = Tubing Pressure + Tubing Gradient * Pump Depth (TVD)
1) Main valve components in the pump are the standing and the traveling valve.

2) **Standing valve**, intake valve, fixed to tubing considered to be stationary, and acts as a check valve to keep well fluid in the tubing on the downstroke.

3) **Traveling valve**, discharge valve, moves with the rod string. Acts as a check valve to keep well fluid in the tubing on the upstroke.
A) Start of the upstroke, the traveling valve and standing valve are both closed.

B) Standing Valve opens, when rods stretch to pick up fluid load, Fo, from tubing.

B-C) Fluid load, Fo, is carried by the rods as well fluids are drawn into the pump.

C) Standing valve closes, and the traveling valve remains closed. C-D pressure inside the pump increases until it is slightly greater than the pump discharge pressure.

D) Pump discharge pressure (Pd) equals the static tubing pressure (Pt), and the traveling valve opens. Fluid load, Fo, is carried by tubing.

D - A, the fluid in the pump is displaced through the traveling valve into the tubing and ZERO fluid load is on rods.
Synthetic Pump Cards: Gas Interference

Gas Interference is causing decrease of EPT. Pump components functioning properly. Usually unstable pump fillage and EPT changes from stroke-to-stroke. When gas interference is present expect increased rod-on-tubing wear due to rod buckling compressing gas in pump barrel.

Tubing anchored, EPT<MPT. Unanchored tubing, EPT<MPT
Gas Interference: Incomplete Pump Fillage and High Fluid Level

### Graph
- **Wrf + Fo Max**
- **TV (measured)**
- **Wrf**
- **SV (measured)**
- **Fo Max**
- **Fo Well**
- **Fo From Fluid Level**
- **Fo Rods**

### Table

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<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tr>
<td>PPRL</td>
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<td>PPUMPL</td>
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<td>MPRL</td>
<td>7946</td>
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<td>Calculated Fluid Load Max</td>
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<td>Polished Rod Power</td>
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<td>Polished Rod / Motor Eff.</td>
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<tr>
<td>Strokes Per Minute</td>
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<td>Pump Card HP</td>
<td>8.2 HP</td>
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<td>Pump / Motor Eff.</td>
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<td>Pump Intake Pressure</td>
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<td>Damp Up</td>
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<tr>
<td>Damp Down</td>
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<tr>
<td>Tubing Head Pressure</td>
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<td>Effective Plunger Stroke</td>
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<td>Stroke</td>
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<tr>
<td>Approx. Best Pos.</td>
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</table>

### Additional Information
- **Well State:** Producing
- **Annular Gas Flow:** 126 Mscf/D
- **% Liquid:** 28
- **Pump Intake Pressure:** 730.7 psi (g)
- **PBHP:** 732.3 psi (g)
- **Reservoir Pressure (SBHP):** 2764 psi (g)
Gas Interference

Traveling valve opens when pressure in barrel exceeds the pressure at the pump discharge at the bottom of the tubing.
Effect of PIP on Gas Interference and Fluid Pound

Pump-Rod Load on Downstroke as a Function of Pump Intake Pressure for 50% Liquid Fillage and 2000 psi Discharge Pressure, 1.5 inch Plunger, 90 inch Pump Travel

\[ ND = \frac{MR - GS \left( \frac{PIP}{Pbt} \right)^{1/2}}{1 - \left( \frac{PIP}{Pbt} \right)^{1/2}} \]

\[ GS = 90 \text{ inches} \]
\[ ND = 45 \text{ inches} \]

MR depends on Pump Intake Pressure

Load Applied to Rods by Pump Lbs.

Pump Plunger Position from Bottom of Stroke, inches.
Effect of PIP on Pump Card

Pump Card as a Function of Pump Intake Pressure for 50% Liquid Fillage and 2000 psi Discharge Pressure, 1.5 inch Plunger (1.77 Sq. In.), 90 inch Pump Travel

$F_o \text{ Max} = (2000 - 10) \times 1.77$
$= 3534 \text{ Lbs}$

Load Applied to Rods by Pump, Lbs.

$F_o$, Calculated Fluid Load, Lbs:
$F_o = (P_{\text{dis}} - P_{\text{intk}}) \times A_p$

Where:
$F_o = \text{Fluid Load Pump Applies To Rods, Lbs}$
$P_{\text{dis}} = \text{Pump Discharge Pressure, Psi}$
$P_{\text{intk}} = \text{Pump Intake Pressure, Psi}$
$A_p = \text{Area of the Plunger, inches}$

Pump Plunger Position from Bottom of Stroke, Inches.

Gas

Gas Interference

Liquid

Fluid Pound

PIP 500

PIP 10
Synthetic Pump Cards: Gas Locked Pump

Gas Locked Pump...Both valves remain closed because the static tubing pressure, \( P_t \), is greater than the pump discharge pressure, \( P_{\text{barrel}} \), which is also greater than the pump intake pressure, \( P_{\text{int}} \). The compression ratio of the sucker rod pump is too small, with the result that neither valve opens until the clearance space between valves fills by leakage of fluids past the plunger, or the fluid level is allowed to rise so that a smaller compression ratio is required to force gas from the pump into the tubing. The pressure relations are:

\[
P_t > P_{\text{barrel}} > P_{\text{int}}
\]

\[
P_t > P_{\text{barrel}} \text{ at bottom of stroke}
\]

\[
P_{\text{barrel}} > P_{\text{int}} \text{ at top of stroke}
\]
Gas interference?
High Pressure - Almost Gas Locked
Low Pressure Gas Lock

1) Surface dynamometer card located near the calculated traveling valve load test line.
2) Both the standing and traveling valves remain closed.
3) Gas lock condition caused by having too low a compression ratio in the pump when producing both gas and liquid.
4) Waste space in the pump, too short a valve rod or pull tube, or a the rod string not being spaced out properly when the pump is seated usually causes the low compression problems.
5) Liquid Slippage into Pump Prevents Gas Lock
**Fluid Slippage**

**Slippage:** Is fluid that passes through the plunger only to fallback between the plunger OD and the barrel ID into the chamber between the standing and traveling valve.

**Function of:** Primarily plunger/barrel clearance, depth, and fluid viscosity. It is also a function of pump holdown position and temperature.
Synthetic Pump Cards: Fluid Pound

Severe fluid pound, well is being pumped off. Pump components functioning properly. BUT, sudden unloading of rods results in reduced equipment life! Shoot fluid level to verify pump intake not blocked and fluid level at pump intake.
Same Well with Full Pump

Pump Capacity Exceeds Inflow of Fluids from Well.

Controlling Pump Run time Improves Efficiency by Matching Pump Displacement To Inflow of Fluids from Well.
Fluid Level @ Pump - Fluid Pound?
Timer or Pump Off Controller Candidate

![Graph and data table]

Load (K-Lbs) vs Position (in)

**Fluid Pound**
Rods Buckle (Train Wreck Effect)

Pump Load & Velocity

Plunger Slows to Open TV

Fluid Pound

Plunger Slows to Open TV

Polished Rod Velocity (in/sec)

Plummeted Rod Velocity (in/sec)

Elapsed Time (Sec)

Wrf

Wrf + Fo Max

Fo Max
Rods Buckle (Train Wreck Effect)

**Rods Buckle (Train Wreck Effect)**

**Pump Load & Velocity**

- Plunger Slows to Open TV
- Polished Rod Velocity (in/sec)

**Gas Interference**

- Wrf + Fo Max
- Wrf
- Fo Max
- Fo From Fluid Level
- Gas Interference

**Graphs**

- Plunger Velocity vs. Elapsed Time (in/sec)
- Pump Load vs. Elapsed Time (lbs)
- Fo From Fluid Level vs. Elapsed Time (sec)

**Table**

- Pump Load & Velocity
- Plunger Slows to Open TV
- Gas Interference
Predicted Surface Dynamometer Card

Intake Pressure: 80 psig  Pump Fillage: 50%  SPM: 8

Load (1000 lbf)

Position from Bottom of Stroke (in)

CASE12.ACP: 8.00 SPM, 144.000 in Stroke, Production = 159.1 bbl/d
Gas Interference

- Gas in Pump is the Most Common Operational Problem
- Results in Lost Pump Displacement
- Pump and Rod Weight must Compress Gas Inside Pump Barrel on Down Stroke
- SR Pump is Inefficient Compressor
- Increased Rod and Tubing Failures
Questions ?