

(((ECHOMETER)))

Echometer TechNote: Pump Card Shapes

This TechNote covers the following topics.

- Downhole Problems: What downhole problems can be identified by recognizing diagnostic Pump Card shapes? Why is it sometimes difficult to diagnose downhole problems using measured polished rod surface dynamometer cards?
- Example pump card
- Generalized Synthetic Pump Cards
- Special Conditions

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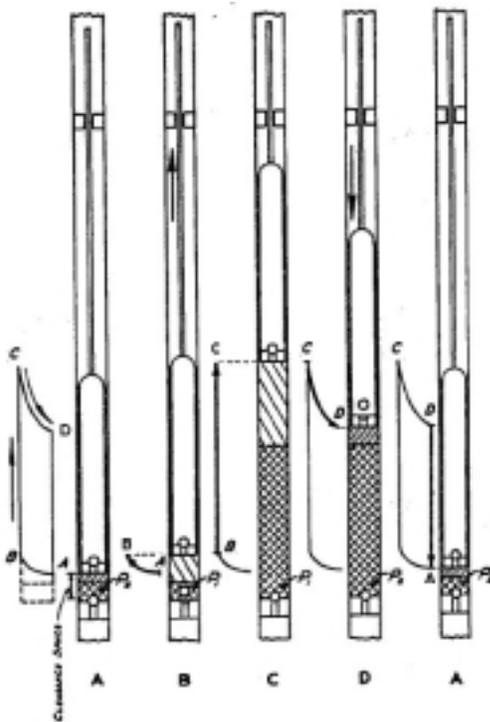
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Downhole Problems

A **surface dynamometer card** is the plot of the measured or predicted 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. The **pump dynamometer card** is a plot of the calculated loads at various positions of pump stroke and represents the load the pump applies to the bottom of the rod string. Identifying how the pump is performing and analysis of downhole problems is one of the primary uses of the pump dynamometer card. Dynamometer cards are displayed by predictive and diagnostic software for the purposes of design and diagnosing Sucker Rod Pumping Systems.

Polished rod surface dynamometer cards do not always allow complete performance diagnostics about the sucker rod lift system. Measured surface dynamometer cards are valuable for diagnosing rod, structural, and torque loads on the unit and prime mover. When attempting to diagnose downhole pump problems, a visual inspection of the surface dynamometer card is usually not sufficient to determine what conditions exist at the pump. Some diagnostics can be done through practical experiences where certain downhole problems are associated with certain surface dynamometer card shapes. In shallow to medium depth wells, interpretation of the surface dynamometer card may be reasonably effective in diagnosing pump performance. In deeper wells, however, the complex nature of the lift system leaves something to be desired in diagnosing pump performance from surface dynamometer cards.



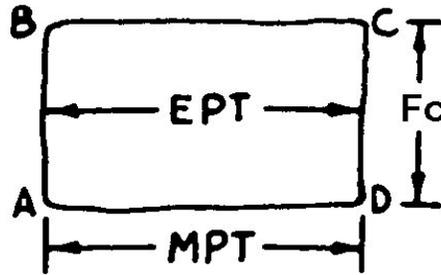
Visual Pump Cycle

Recognizing that downhole problem diagnosis from surface dynamometer cards is often impossible; downhole pump dynamometers were developed. They provided an accurate representation of pump loading and a valuable insight into pump mechanics. However, because of cost everyday use was impractical for all wells. One of the early pioneers in pump dynamometer card interpretation was W.E. Gilbert of Shell. In 1936 he published a classic on the interpretation of actual pump dynamometer cards. The figure to the left is taken from reference (API Drilling & Production Practice, 1936) shows the pump action during one pumping cycle.

During the time period of 1961 S.G. Gibbs of Shell Research reasoned that by obtaining a precise surface dynamometer card and knowing most of the important system parameters; it was mathematically feasible to "wave down" these parameters, thereby synthesizing a precise and reliable downhole dynamometer card. The ability to calculate the downhole card and interpret its various configurations became the basis of the pump card diagnostic analysis.

A sucker rod pump is designed primarily to lift fluids to the surface. The pump is also required to handle some free gas; performing the function of a liquid pump plus a gas compressor. The work on the fluid done per cycle may be determined from the area of the pump card. Compression of the gas to a pressure greater than the pump discharge pressure is required before the traveling valve will open and allow fluid from the pump barrel to enter the tubing. The work done by the pump in compressing gas is not entirely lost, since the gas introduced into the tubing tends to reduce the pump discharge pressure by lightening the gradient of the fluid column, thus reducing the fluid load and returning energy to the pumping system. Since the pump does not have a good compression ratio to handle excessive amounts of gas, use of a good downhole gas separator is recommended to prevent gas lock conditions and other problems related to gas compression. During the pumping cycle the gas bubbles in the liquid tend to rise to the top of the pump. At slow pumping speeds, this separation of gas and liquid may be complete; or in handling "fluffy" fluids, it may be negligible, but it is reasonable to consider the gas as completely separated from the liquid and under the traveling valve.

Example Pump Card:



In the above diagram the maximum plunger travel, MPT, is the maximum length of the plunger movement with respect to the pump barrel during one complete stroke. The fluid load (F_o) is a force caused by differential pressure acting on the pump plunger. The differential pressure acts across traveling valve on the upstroke and is transferred to the standing valve on the down stroke. The differential pressure is the difference between the pressure due to the tubing fluids and the pressure in the wellbore. The magnitude of the fluid load is equal to the pump discharge pressure minus the pump intake pressure multiplied by the plunger area. From points B to C the rods carry the fluid load, when the traveling valve is closed. From points D to A the tubing carries the fluid load, when the standing valve is closed. The effective plunger travel, EPT, is the length of the plunger travel when the full fluid load is acting on the standing valve.

The successive steps in the pump operation are:

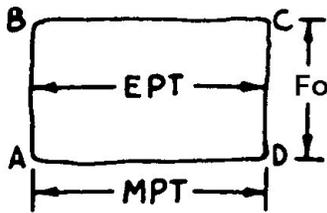
1. At the start of the upstroke (point A), the traveling valve and standing valve are both closed.
2. From point A to point B, the fluid load is fully carried by the tubing prior to point A and is gradually transferred the rods at point B. The load transfers as the rods stretch to pick up the fluid load (F_o). If the tubing is anchored, the plunger does not move relative to the tubing. The pressure in the pump decreases and any free gas in the clearance space between valves expands from the static tubing pressure (P_t) to the pump intake pressure (P_{int}).
3. The standing valve begins to open at A, allowing fluid to enter the pump when the pressure in the pump drops below the intake pressure (P_{int}).
4. From point B to C, the fluid load is carried by the rods as well fluids are drawn into the pump.
5. At C, the standing valve closes as the plunger starts down, and the traveling valve remains closed until the pressure inside the pump is slightly greater than the pump discharge pressure (P_d).
6. From C to D, gas in the pump (if present) is compressed as the plunger moves down to increase pressure on the fluid from the intake pressure (P_{int}) to the static pressure in the tubing; but the plunger does not move if the pump barrel is full of an incompressible fluid. As the fluid in the pump barrel is compressed, then the fluid load is gradually transferred from the rods to the tubing.
7. At D, the pump discharge pressure (P_d) equals the static tubing pressure (P_t), and the traveling valve opens.
8. From D to A, the fluid in the pump is displaced through the traveling valve into the tubing and the fluid load is held by the tubing.

Generalized Synthetic Pump Cards

The following pump cards are in two (2) groups: 1) the group of cards on the left has tubing anchored and 2) the group on the right has unanchored tubing. These generalized synthetic pump cards represent pumping systems experiencing some of the more common problems. The cards illustrate different pumping conditions and malfunctions of downhole equipment. The terms shown are as follows:

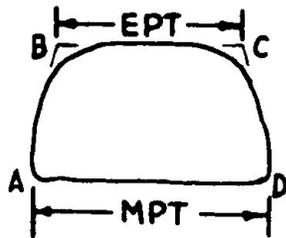
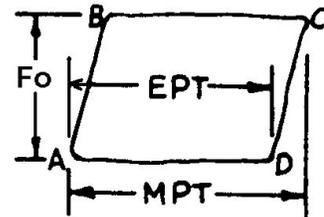
MPT = Maximum Plunger Travel
EPT = Effective Plunger Travel
F_o = Differential Load On Plunger

ANCHORED

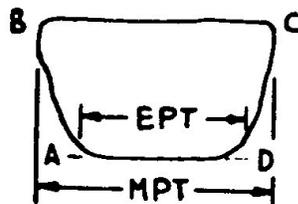
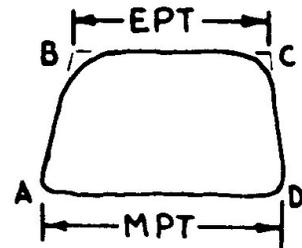


Normal Pumping-Full liquid and no gas. Pump functioning properly. With tubing anchored, $EPT=MPT$. With unanchored tubing, $EPT<MPT$.

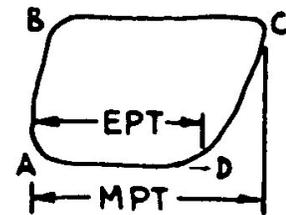
UNANCHORED



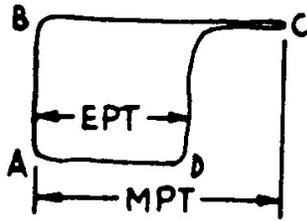
Leaking traveling valve, TV, or excessive plunger slippage causes delay in picking up fluid load from A to B and premature unloading from C to D, (the traveling valve, TV, is effective only during a portion of the upstroke).



Leaking standing valve, SV, causes premature loading of rods from A to B, and a delay in unloading from C to D, (the standing valve, SV, is effective only during a portion of the downstroke).

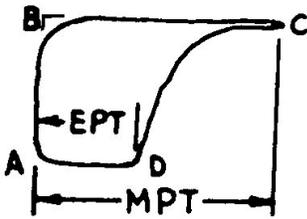
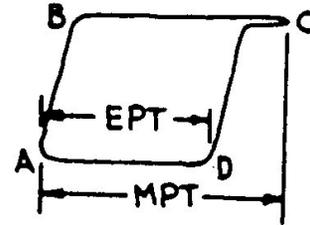


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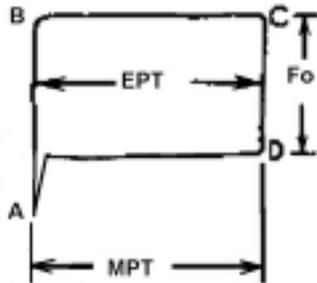
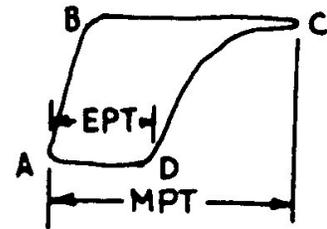


Severe fluid pound, well is being pumped off. Pump components functioning properly.

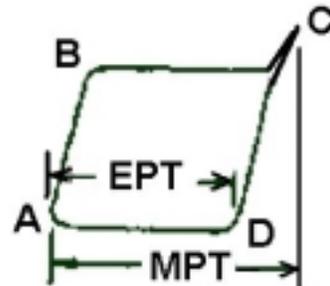
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Gas Interference is causing loss of EPT. Pump components functioning properly. Unstable well conditions exist when EPT changes from stroke-to-stroke.



Pump is tapping at bottom of stroke(left) and pump is tapping on top of stroke(right).



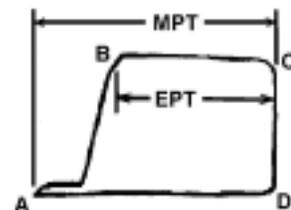
Practically any combination of the malfunctions shown above may exist in any well. The effects of these malfunctions may be superimposed on one another and the combined effect may be masked. For instance, the presence of gas interference and a tubing anchor that is has become unseated may exhibit a card whose individual effects may not readily be evident. The tubing stretch constant, K_t , superimposed on the card may afford an insight into the problem.

Anchored or Unanchored Tubing

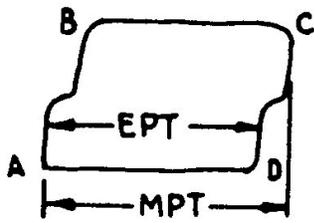


(Left) Worn out pump. No apparent tubing movement in either case.

(Right) Traveling Value not closing properly: Flow restricted by very viscous fluid in pump or flow area smaller than plunger above pump to small.

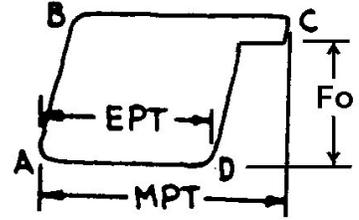


Anchored or Unanchored Tubing



(Left) Malfunctioning tubing anchor, or partial stuck tubing.

(Right) Overly-tight stuffing Box, extra height of load above F_o is usually equal to amount the standing valve test load is in excess of the theoretical rod weight buoyed in fluid. The extra friction is usually released at the top of the Stroke.

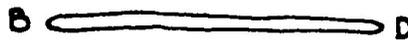


SPECIAL CONDITIONS:



Gas Locked Pump...Both valves remain closed because the static tubing pressure, (P_t), is greater the pump discharge pressure, (P_d), which is also greater than the pump intake pressure, P_{int} . The compression ratio of most sucker rod pumps 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 as follows:

$$P_t > P_d > P_{int}$$



Flumping Well...Both valves remain open because the static tubing pressure, P_t , is much less than the pump discharge pressure, P_d , which is also greater than the pump intake pressure, P_{int} . Also a deep rod part may exhibit this signature, but with valve checks this can be diagnosed quickly. The pressure relations are as follows:

$$P_t < P_d < P_{int}$$

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