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ENERGY EFFICIENCY IMPROVEMENTS FOR PCP SYSTEMS

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COST OF ELECTRICITY

- **If you have a 75 kW (100 hp) motor operating at full power, if it has 95% efficiency, and if you pay $0.15 / kWh, then you are paying $103737 per year for electricity**
- **Each percentage point of efficiency lost or gained is worth over $1000 per year**
- **Each percentage point of required power output is also worth over $1000 per year**

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› WHAT IS ENERGY EFFICIENCY?

- **Two ways of looking at it:**
  - Energy Out / Energy In
  - Theoretical Energy / Energy In
- **For a pump alone, this is simple – if you are pumping an incompressible fluid**
- **But we are looking at a whole artificial lift system**
  - We pump from a reservoir at some pressure to a surface tank or pipeline
  - There is a change in both pressure and elevation
  - Gas in solution can provide some driving force, as does free gas in the tubing
  - Do we consider the initial point to be reservoir pressure or FBHP?
- **Conclusion: there is not a well-defined definition of energy efficiency in an artificial lift system**

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› PCP SYSTEMS VS OTHER ALS

- **This reference doesn't define how it calculates efficiency, but shows a relative performance of some common AL systems:**

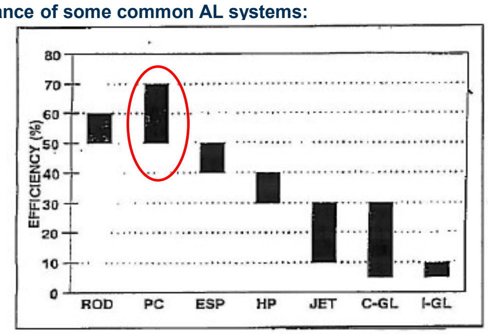

Fig. 8—Hydraulic horsepower efficiency comparisons for the major artificial-lift methods (excluding plunger lift).

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SPE 24834, "Recommendations and Comparisons for Selecting Artificial Lift Methods", by Joe Clegg, Mike Bucaram and Norm Hein, published in JPT, December 1993.

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› PCP SYSTEMS VS OTHER ALS

- **This example is real data from one specific operation – it was expressed in terms of energy to produce each barrel (the depth and conditions were not given)**
  - By looking only at energy use, there is no need to define efficiency
  - Other fields may have different results – but the trend should be similar
- **Data is expressed here in relative terms, with a standard PCP system given the value of 1.0**

AL System	Relative Energy Use
ESP	3.3
SRP	1.3
PCP	1.0
PCP w/PMM Drivehead	0.74
ESPCP	0.41

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› IMPROVING ENERGY EFFICIENCY OF PCP SYSTEMS

- **For this presentation, we will not worry about defining what is the efficiency of a PCP system**
- **We will also not compare PCPs to other AL systems (other than the previous slides)**
- **We will simply look at how we can reduce the energy input required to produce our wells at the desired rate, using PCP systems**
- **The options available to us will depend on certain things:**
  - Is the well horizontal, deviated or vertical?
  - Is there a lot of gas production?
  - How viscous is the liquid being produced?
- **Additionally, there will often be limits on what technology is available for us to use**
  - Constraints may be on the casing size, or on what equipment is available for us in the field, or on the power sources available (electricity, casing gas, diesel fuel)
  - Cost may not justify the benefits
  - There may be safety or practical reasons for excluding some options
- **We're looking at reducing energy consumption during production, but a full life cycle carbon analysis needs to look beyond this**

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› OPTIONS

- **To reduce energy consumption, we can:**

  Properly select and maintain surface equipment

  Improve the rod string design

  Adjust the tubing size

  Optimize the pump size and fit

  Consider alternative drive systems

- **For comparison, we will use a system with these features:**

  Production of 50 m³/d of liquid

  Depth of 1000 m

  Low FBHP

  Cost of electricity: $0.15 / kWh

  Calculations (up to the polished rod) done using a commonly-available PCP design software

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› SURFACE EQUIPMENT MAINTENANCE

- **If the well is vertical, pumping water, and using a PCM 24E1300, the power at the polished rod is 9330 W (12.5 hp), and the system is running at 247 rpm**
- **There will always be some friction in the stuffing box and drivehead bearings. Let's assume that there is 20 N.m of friction in an ideal case, or 40 N.m if the system is not maintained properly (e.g. stuffing box overtightened or not properly lubricated)**

  The extra 20 N.m of torque, at 247 rpm, requires an extra 517 W of power → $680 / year

- **Well maintained and properly aligned the belt/pulley system may be up to 98% efficient. But if the belts are not tightened properly, if the sheaves are worn, or if the sheaves are misaligned, the efficiency may be only 90%.**

  98% efficiency has loss of 190 W, 90% has loss of 1037 W → difference is 847 W, $1113 / year

- **Effects multiply, not add:**

  Power input for 20 N.m friction and 98% efficient belts = 10048 W

  Power input for 40 N.m friction and 90% efficiency belts = 11516 W

  Difference = 1468 W ($1929 per year) not the 1364 W ($1793) we would get from adding

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Image from https://www.efficientplantmag.com/

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❯ SURFACE EQUIPMENT SELECTION

- **Hydraulics systems are almost never efficient compared to belts/pulleys**

  Even with 92% efficiency on the hydraulic pump and motor, the best efficiency is <85%, before counting losses in hoses, filters, and valves

- **Gears are about as efficient as belts**

  Don't have to worry about alignment or minor wear

  But when used together with belts, the multiplicative effect applies: 96% x 96% = 92%

  On our 9330 W system, that is a difference of 422 W or $532 per year

- **Type of belt matters**

  Standard V-belts are good

  Notched V-belts are better

  Synchronous (timing) belts are best ***for efficiency***

- **A permanent magnet motor can have 5-10% higher efficiency**

- **A PMM drivehead eliminates losses from belts and/or gears**

  Compare: 95% PMM with 90% induction motor + 96% efficient belts

  Difference is 978 W → $1285 per year

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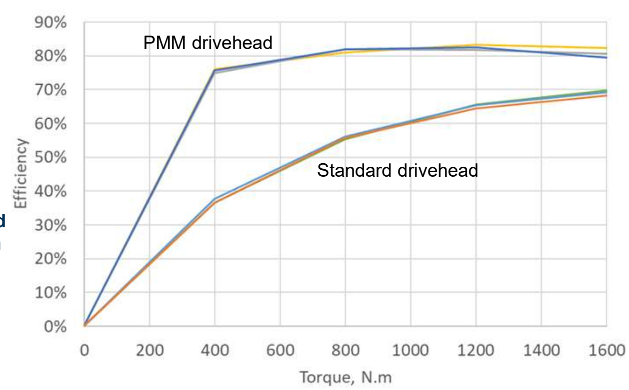
❯ EFFICIENCY COMPARISON

- **Comparing a PMM drivehead against a standard drivehead (with belts/pulleys and induction motor)**
- **Each is tested at three speeds (100, 150, 200 RPM)**
- **Yearly savings if operated at 200 RPM and 1200 N.m is $10533 (at $0.15 per kWh)**



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❯ ROD STRING DESIGN

- **Friction of rod string on tubing wall**

  Occurs in deviated well

  Torque increases with contact load, contact diameter, and friction factor (and power loss increases with speed)

  → Can decrease using spin-through rod centralizers or continuous rod

  → Example: When our comparison well (with 24E1300 at 247 rpm) has 5°/30 m from 400 m to 800 m (pump at 1000 m MD, 795 m VD), then rods have 137 N.m torque with full size couplings, 126 N.m with slimhole couplings, 73 N.m with spin-through centralizers, 61 N.m with continuous rod (with 85% efficient drive system, cont. rod saves $3067 per year)

- **Viscous drag on rod rotation**

  There is torque required to rotate a rod in fluid

  Proportional to viscosity and speed

  Smaller effect of rod and tubing sizes – except if there is small clearance (e.g. large couplings)

  →Example: in our comparison well, with 1000 cp fluid, 66 N.m of viscous drag torque; change pump from a 24E1300 to a 63E1200, this is 25 N.m of viscous drag torque (25 N.m @ 94 rpm compared to 65 N.m @ 247 rpm → $2254 per year

❯ TUBING SIZE

- **Larger tubing → lower pressure loss → lower pump load**

  In our viscosity example on the previous page, the torque at the polished rod was 487 N.m

  Changing to 4.5" tubing reduces this to 432 N.m →savings of $2200 per year (assuming 85% efficient drive)

- **Smaller tubing → higher pressure loss → higher pump load**

  Instead, if we used 2-7/8" tubing (and used 1" continuous rod to avoid problems with the connections), the torque increases to 578 N.m → an extra cost of $3638 / year

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❯ EFFECTS OF GAS

- **Solution gas reduces fluid viscosity → decrease pressure losses = less power required**
- **Gas bubbles in the tubing fluid reduce the average fluid density → decrease hydrostatic pressure in tubing = less power required**
- **Pump must be turned faster to produce the same liquid → more speed = more power required**
- **Or, a larger displacement pump is used → more torque = more power required**
- **Improving gas separation may increase *OR* decrease total power**

Complete analysis is required to estimate effects

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❯ ESPCP

- **Electrical submersible progressing cavity pump**
- **Most systems use a PMM → higher efficiency**
- **Avoids any rod/tubing friction**
- **Avoids friction from stuffing box (mechanical seals should be very low friction)**
- **Increased flow area reduces pressure losses in viscous fluid**

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› PUMP OPTIMIZATION

- **There are many aspects to pump optimization – this discussion will focus only on energy efficiency**
  - Other considerations may override these in some applications
- **Friction torque is a necessary side effect of an interference fit in a PCP – but it should be minimized when possible**
  - Don't select a pump with a pressure rating that is too high
  - Don't use a rotor that is tighter than it needs to be for the application
- **Other factors:**
  - Higher speeds mean more power lost to friction (in pump, between rods/tubing, and in stuffing box) and also in viscous drag in rotating the rods
  - Bigger displacement pump (running at lower speed) may require bigger rods (higher pressure losses)
  - Lower speeds may result in lower volumetric efficiency (in low viscosity fluids)
- **Diluent injection?**
  - Pumping diluent (light oil or water) down to the pump intake can greatly reduce pressure losses and viscous drag – but a larger volume of liquid needs to be pumped to surface. What is the net effect on power?

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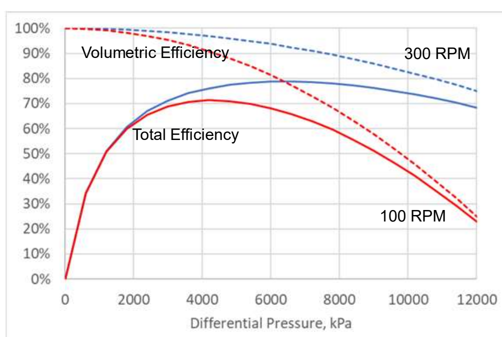
› PUMP EFFICIENCY

- **For PCPs we are used to seeing Volumetric Efficiency curves**
  - At PCM we try to size rotors to reach 75% efficiency at rated pressure and 300 RPM
  - Volumetric efficiency drops as the pressure increases
  - Volumetric efficiency increases as the speed increases (assuming no inflow problems)
- **The Energy Efficiency curves have a different shape**
  - Energy efficiency also increases with speed
  - But it increases at low pressure and decreases at high pressure – there is a maximum point



$$\eta = \frac{Q\,\Delta P}{T\,\omega}$$

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› PUMP EXAMPLE

- **Want to produce 200 m³/d of high water cut fluid from deviated well, 1000 m deep**

  We'll use 3.5" tubing, 1" drive rods (7/8" pins, high strength), and spin-through centralizers

  Volumetric efficiency is adjusted for speed as per PCM data sheets
- **Available pumps with this lift and appropriate volume are, showing their expected friction torque:**

  48E1200 (225 N.m); 60E1200 (125 N.m), 63E1200 (80 N.m), 100E1200 (150 N.m), 120E1200 (300 N.m), 150E1200 (200 N.m)
- **Assuming 85% efficiency drive system, yearly energy costs are:**

  48E1200: $54724

  60E1200: $47459

  63E1200: $43903

  100E1200: $48386

  120E1200: $54415

  150E1200: $53023

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› SUMMARY – SYSTEM DESIGN

- **High viscosity fluid – use large size tubing**
- **Deviated wells – design rod string to minimize torque from rod/tubing friction**
- **Consider ESPCP**
- **Optimize surface drive system:**

  Avoid hydraulics

  Use belts or gears, but not both; choose appropriate belt

  Use highest efficiency motor possible

  Consider PMM surface drive
- **Consider effects of gas separation**
- **Consider effects of friction torque vs. pump displacement on available pumps**

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› SUMMARY – SYSTEM MAINTENANCE

- Ensure seal or stuffing box is properly greased and/or tightened, as per manufacturer's recommendations
- Check/adjust belt tightness
- Inspect sheaves for wear and alignment
- Monitor power consumption – look for changes in time

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› QUESTIONS?

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