Improving Pump Performance

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Charles M. Burt, Professor of Irrigation
BioResource and Agricultural Engr. Dept.; Chairman, Irrigation Training and Research Center (ITRC), California Polytechnic State Univ., San Luis Obispo, CA 93407 cburt@calpoly.edu
Franklin Gaudi, Senior Irrigation Engineer, ITRC
Daniel J. Howes, Senior Irrigation Engineer, ITRC

Abstract. *Options can be specified to minimize power consumption by vertical pumps – both when new and over the life of the pump. Options discussed include bowl coatings, proper well development, improved suction screens, using closed impeller designs, increasing column size, using new bearings, providing proper bearing lubrication, impeller balancing, and polishing impellers. The proper TDH and flow rate must be specified, and the advantages of VFD controls are covered.*

Keywords. pump, efficiency, power, VFD, irrigation

Introduction

On the surface, the basics of good pump performance are relatively simple. They are:

1. Select a high quality pump.
2. Select a pump that operates at a high efficiency at your desired flow rate and pressure.

However, in practice, pump efficiencies are not as simple to achieve as it might appear. In December of 2003, ITRC published the report "California Agricultural Electrical Energy Requirements" (Burt et al, 2003) for the Public Interest Energy Research Program of the California Energy Commission that included the following two figures, demonstrating that average pump efficiencies are not as uniform they should be throughout California.

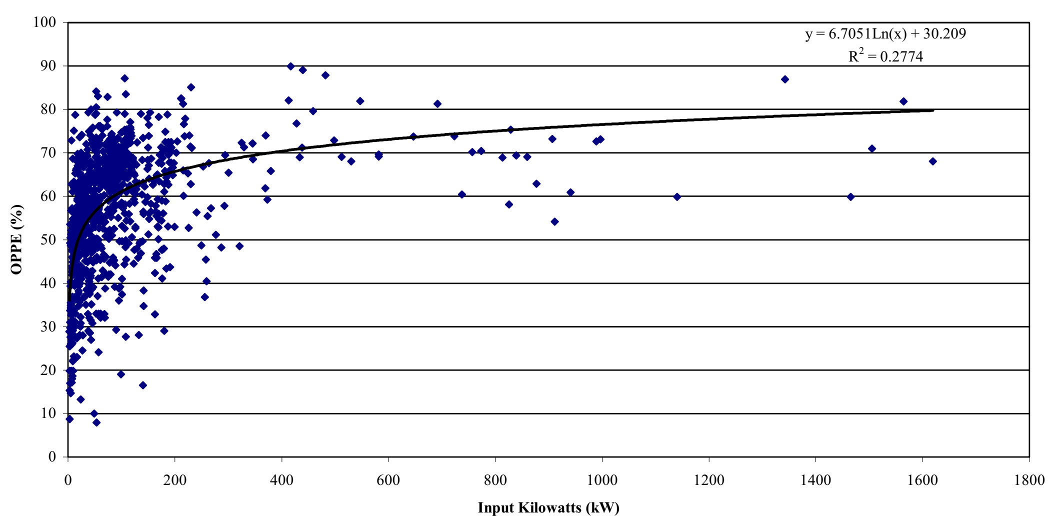

Figure 1. Pumping plant efficiency as a function of motor input kW for each pump tested – irrigation districts. Data collected by Cal Poly ITRC. Average efficiency is about 64%.

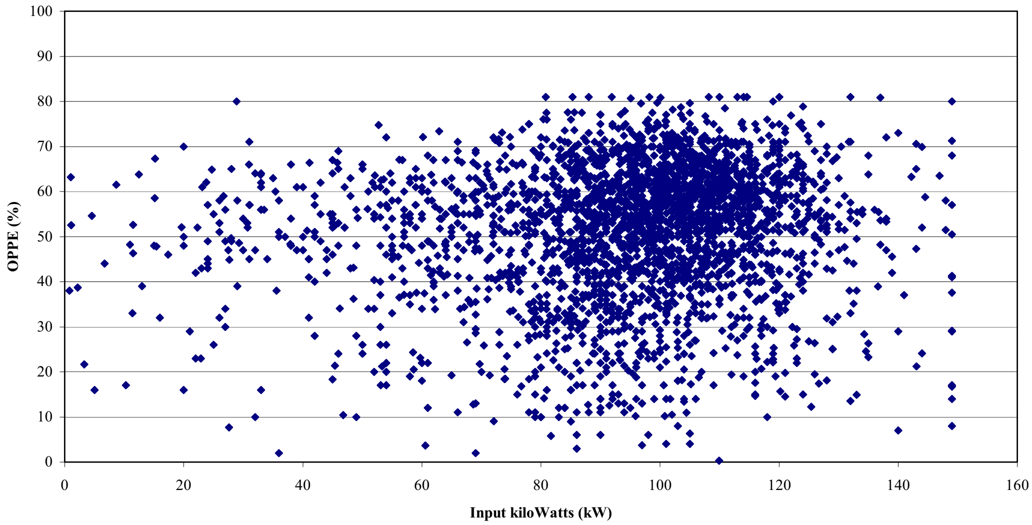

Figure 2. On-farm pumping plant efficiency as a function of motor input kW for each pump tested. Data collected by CIT. Average efficiency is about 48%.

So, if the basics of pump performance are so simple, why are overall pumping plant efficiencies so low? The answer includes a blend of the following factors:

- Energy prices have historically not been high enough (relative to overall farming costs) for farmers to pay more attention to obtaining higher efficiencies.
- Irrigation pump dealers appear to believe that agricultural customers will price-shop and therefore they will only be able to sell bare-bones equipment to farmers.
- Both farmers and pump dealers are often unaware of pump options that could be specified to improve or maintain high pump efficiencies.
- Some major pump companies have in recent years moved their foundries overseas and some of the previous "standard" options that were important for high efficiencies have been eliminated.
- There has not yet been widespread usage of variable speed drive controllers, which can be very helpful in (a) increasing well life, (b) reducing water hammer, and (c) perhaps most importantly for this paper, allowing the pump to operate without producing more pressure or flow than is needed on any particular day.

In agriculture, we typically use four general types of pumps:

1. Vertical line-shaft turbines in wells
2. Submersible motors for pumps in wells (usually called "submersible pumps" because the package often includes an impeller/bowl assembly that is custom-made for submersible motors).
3. Above-ground horizontal "booster" pumps – typically either end suction or split case.
4. Propeller pumps for low lift, often high volume applications.

Furthermore, there are two ways to power most pumps:

1. Electric motors (required for submersible pumps, obviously)
2. Engines

This paper focuses on one combination: **Vertical line-shaft turbine pumps with electric motors.** The authors address two important issues:

1. What options are important to include in a new pump purchase?
2. What options will help keep power consumption (per acre-foot pumped) low for 5 to 10 years after the initial purchase?

Minimizing Initial Power Bills with a New Well Pump

Note that the essence of the words above are "minimizing power bills" rather than "maximizing efficiency". It is always important to select an efficient pump, but putting an emphasis *only* on "maximizing efficiency" ignores several important concepts:

- Electric power bills can often be reduced if a farmer can avoid pumping during some hours of the day or week. Utilities offer special "time of use" electric rates for pumping during off-peak electrical usage hours only.
- A pump may be producing a pressure and flow rate with a very high efficiency, but if there is excess pressure that is being dissipated through pressure regulators, the "power utilization efficiency" (PUE – a new term by the authors) is much lower than the "pumping plant efficiency".
- The design pressure requirement may be greater than is necessary. For example, the column pipe diameter may be too small.
- Power can be minimized if the well is properly designed to minimize drawdown in the well.

Selecting an efficient pump

- It's not a question of whether or not the "pump is efficient". Rather, it's a question of whether the pump operates efficiently at the ***specified*** ***pressure and flow rate***. In other words, someone who understands hydraulics, well drawdown, and irrigation system pressure and flow requirements needs to get together with the pump supplier and provide the correct flow and pressure specifications.
- ***Use line shafts with enclosed oil-lubricated*** bearings rather than product (water) lubricated shaft bearings. If you are not allowed to use standard oil lubrication, instead select 10 weight food grade oil. The motor must provide the power to overcome the mechanical bearing friction, which is typically in the neighborhood of 1-2 HP per 100 feet of shaft with drip feed oil lubrication. This HP requirement can double with standard rubber water lubricated bearings – usually not at first but with time due to abrasion with sand. If there is no sand in the water, product lube can be fine.
- ***Coat the interior of pump bowls with Scotchkote 134 (SK134) fusion bonded epoxy*** per the manufacturer's specifications. It is approved for potable water, and will typically provide an improvement in efficiency of 2% minimum, with 4-5% reported in some cases. Costs vary from about $500 - $650/stage for 10" and 14" bowls, respectively.

Figure 3. SK134 fusion bonded epoxy application.

- Specify a C-10/C-20/C-30 polished finish on all impeller passages and removal of burrs. Some of the low-end agricultural market suppliers do not have the equipment necessary to do this. This should increase efficiency by 1-3%.

Figure 4. The thickness on the bottom of the vane is correct; the thickness must be reduced on the upper portion of the vane.

- Specify a sufficiently ***deep pump setting*** so that there will be at least 10-30 feet of water (while pumping) above the inlet to the pump bowls. One must take into account variations in well water levels from Spring to Fall, and between years. Some well pumps need even more submergence to avoid cavitation.
- Do NOT use semi-open impellers. Instead, use enclosed impellers. The performance of semi-open impellers is highly dependent upon proper adjustment of the lineshaft nut on the top of the motor, and incorrect "rules of thumb" for adjustment of the height are usually used.
- Obtain from the manufacturer the proper setting of the lineshaft for that particular installation – considering the lineshaft material and diameter, the bowls, the shaft length, and the pressure (total dynamic head). Make sure the installer uses that information.

Proper initial specifications that help *maintain* a high efficiency

- Specify that impellers be dynamically balanced to ISO 1940, Grade 6.3. The cost is about $100/stage for a 10" pump and $200/stage for a 16" pump. This minimizes the possibility of imbalance in the bowl assembly – and subsequent damage from vibrations.

- If you specify drip-oil lubrication of the shaft, make sure that the oil drips the way it should. This means you must specify a non-standard oil pot assembly. The design depicted below will maintain a fairly constant drip rate (a minimum of 6-7 drips/minute are needed) and provides a large reservoir – with the constant drip rate, the pot will empty out more quickly than standard pots with reduced drip rates over time. Another important feature can be a low wattage heater coil, covered with insulation, attached to the oil pipe above the adjustment valve.

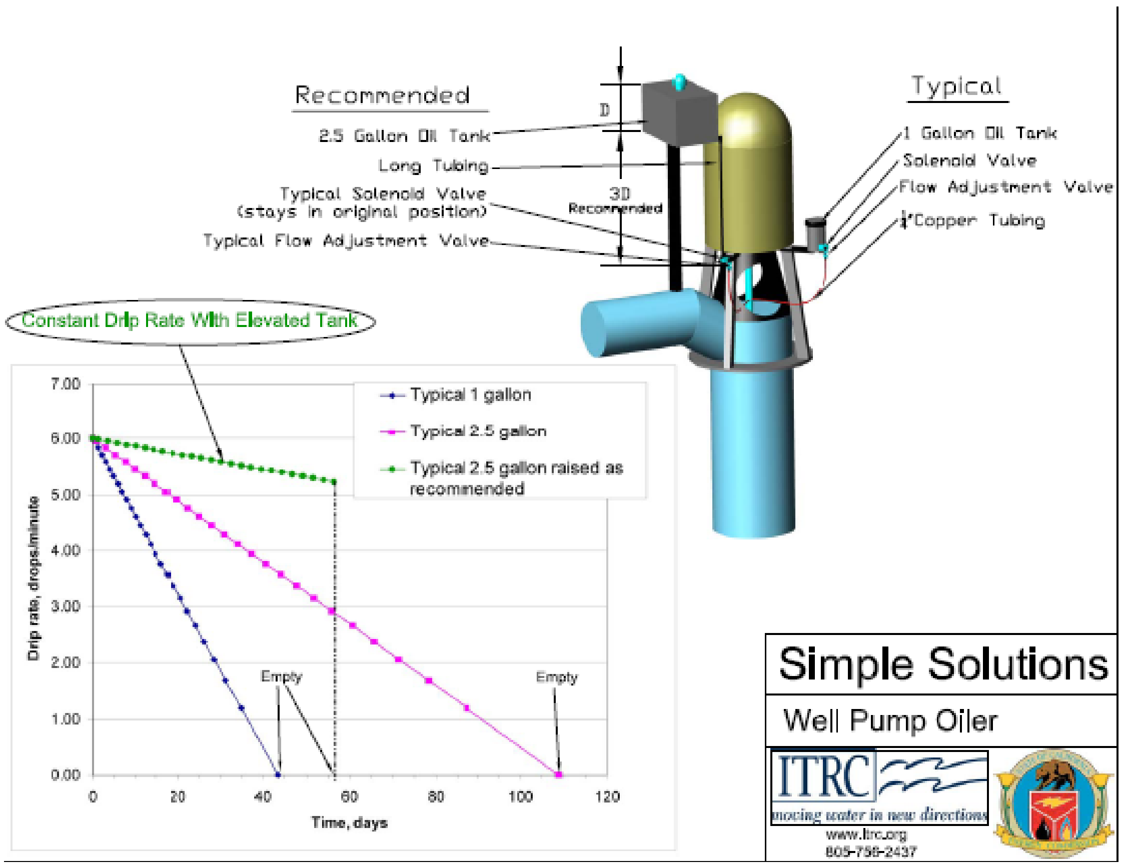

Figure 5. New well pump oiler

- Vertical hollow shaft motors require special attention. Premium efficiency motors should be specified on 150 HP or less. It is important to select the correct brand of motor. "Premium" efficiency motors by brand "X" may have a lower efficiency than standard motors from brand "Z." See later notes on motors for VFD installations.
- Motor life can be extended greatly in many cases if:
  - A space heater is provided in the motor housing to prevent condensation.
  - In areas of heavy fog, the motor is enclosed in some type of shed.
  - The motor is shaded from direct sunlight.
- A common misconception is that if a motor is oversized, the efficiency of the motor will drop. The figure below illustrates the result of ITRC testing of a variety of motors ranging from 20 HP to 100 HP.

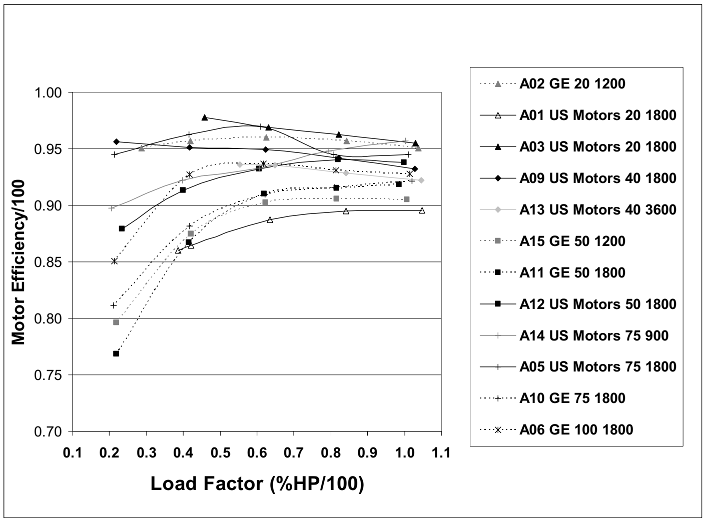

Figure 6. Efficiencies of ITRC-tested motors, across-the-line, at various relative loads.

- Install a flow meter that is robust and that is installed properly. Trying to estimate changes in pump efficiencies over time without a flow meter is problematic, to say the least.
- If there is any sand in the water, do not use bronze impellers. Instead, select Ni-Resist. Although this material requires more polishing than bronze and loses 1-2 efficiency points, it will last much longer (meaning the efficiency will not drop as much). Additional costs are about $500 - $1200 per stage for 10" and 14" pumps, respectively.
- If you want to use suction cone screens, be sure to use screens constructed of non-corrosive materials with no restriction of open area. The photo below indicates that, as screens fall apart, pieces of screen go into the impeller. Additionally, the flow opening can be drastically reduced. The reduced opening can cause pump cavitation and will always increase the Total Dynamic Head (TDH) of the pump – resulting in decreased flow rate and usually lower efficiency.

Figure 7. Corroded pump cone screen with missing sections.

Reducing the Total Dynamic Head (pressure) requirement

- Start with a well that has a good screen. Screens cost money up front. Holes poked in well casing are cheap, but a good screen has numerous initial and long-term advantages that save power in the long run. These advantages include:
  - They allow for good development of a well (see later section).
  - They have a large percentage of open area – easily 3-4 times as much as inexpensive slots or holes in casing. This means there is less head loss between the aquifer and the well (meaning less drawdown), and the lower velocities also help minimize corrosion and chemical blockage.
  - Good materials do not corrode. Corrosion blocks the entry of water into the well – increasing the TDH and decreasing the yield (flow rate).
- Have the well properly developed when it is initially drilled. Development is the process of cleaning out the soil immediately around the well casing to allow for free flow of water into the well (and thereby decreasing drawdown). Proper drawdown involves a lot more than just "overpumping" (the common practice), which just improves the opening of already-clean zones. See a well development specialist to learn about various techniques that are available.
- Use one larger size of column pipe and discharge head. Most customers don't know how much column friction they are paying for, but it can be substantial (a common number is about 1 foot per 100' of column). By going up one pipe size, the friction can often be cut in half. Another option is to coat the inside of the column pipe to increase the smoothness.
- Use a smart irrigation system design that does not require extra pressure for flushing filters, injecting fertilizers, or special valves.

Variable Frequency Drive Controllers

Advantages to VFD control

<u>Power Savings</u>. The key power savings advantage to using VFD control is simple – the speed of the pump will be adjusted so that the pump only provides the pressure or flow that is needed – no more and no less. For agricultural well pumps, this has huge implications because:

- Well water levels fluctuate during the year and between years.
- Irrigation systems may not always need a constant flow rate and/or pressure. For example, a drip system is typically divided into blocks that may be of different sizes and at different elevations, each requiring a different operating point.

How much savings does this represent? It is impossible to say without knowing the details of the aquifer and the irrigation system. There is an inherent extra 6% or so power requirement for VFD controllers (inefficiency plus air conditioning), so the savings have to be greater than 6% to break even. But "experience" seems to indicate that 10-15% overall savings are commonplace.

<u>Ability to use Time-of-Use (TOU) Rates with Well Pumps</u>. Every time a standard well pump is started, it has a very high initial flow rate (due to having a low initial pressure requirement). The water level in the well drops quickly, and the water on the outside of the casing takes time to "catch up" in dropping. Meanwhile, there are large inward pressures on the casing. This leads to premature well failure.

Many farmers correctly understand that their wells have a life measured in the number of startups, rather than in number of years. Therefore, these farmers will not start and stop their well pumps every day to take advantage of low power rates (TOU rates) – the risk of well failure in the middle of the summer is too great.

VFDs offer the advantage of being able to slowly start and stop the pumps – so that the well itself is not subject to violent stresses. This lengthens the life of wells. We do not have good field data on this, but it is clear that this is the case.

Reduction of Water Hammer. The slow start and stop of well pumps is a dream for minimizing water hammer problems that typically occur during rapid startup. Pipes fill up slowly.

Motor specifications for VFDs

Besides the general motor recommendations given earlier, VFD installations should include:

- Proper grounding to eliminate bearing corrosion due to stray currents. Specify a shaft grounding ring installed in the new motor.
- "Inverter duty" premium motors. These are designed to withstand the peculiar electrical stresses associated with simulated AC current.

Special lineshaft bearings for VFD applications

Because of the slow start, water lubricated bearings may spin some time before they become lubricated. If the water is very clean and and an open lineshaft is used, specify carbon bearings.

Purchasing a good VFD controller

There are large differences in quality between VFD controllers. ITRC provides guidelines for VFD specifications at www.itrc.org. A good VFD controller will:

1. Allow one to run electrical conduit more than a few feet between the controller panel and the motor.
2. Provide an excellent Power Factor.
3. Provide high quality power that helps ensure long motor life.
4. Have a very high efficiency – 98% or so.
5. Condition the power properly. For example, a good VFD controller will not be limited to the lowest voltage of the 3 leads of a 3 phase power supply.
6. Be capable of functioning with variations in voltage in the power supply.

ITRC has encountered two common VFD problems in the agricultural market:

1. The panel must be properly cooled and kept clean. Often this requires an air conditioner unit.
2. The VFD controller should usually be one size larger than the motor. For example, a 125-HP VFD controller is needed for a 100-HP motor.

Conclusion

Proper design and the addition of appropriate options can greatly maximize efficiency and minimize power bills associate with pump systems. Additionally, VFD controllers have not yet caught on in popularity, despite the powerful advantages that they bring when properly selected and installed. With rising energy prices throughout the country, it is important that farmers become aware of potential improvements to their systems.

Acknowledgement

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