IRRIGATION SYSTEMS/ CONVERSIONS
PUMPING PLANTS

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WHICH IS BEST, ELECTRIC MOTOR OR COMBUSTION ENGINE?

The most appropriate power source for your irrigation system is most likely dictated by economics or simply by availability. The least expensive alternative depends upon many things, most significantly the cost of energy, whether you buy by the kilowatt hour (electric), thousand cubic feet (gas), or gallon (diesel, propane or gasoline). For short-term installations, the higher cost of a fuel like gasoline or propane may seem inexpensive compared with the cost of delivering electricity or natural gas to the site. This paper addresses primarily the engineering aspects of pumping plants since Dr. Norm Klocke will provide detailed comparisons of the economics of changing power sources and upgrading pumps during the one-on-one sessions at this conference.

Aside from the cost of energy, there are several other factors to be considered when choosing a power source for irrigation. Electrical powered units operate at virtually a fixed efficiency over a wide range of motor sizes (ranging from 85% for a 10 horsepower to 93% for a 250 horsepower motor) and motor loads (a 100 horsepower will give about 90.5% at full load and 89% at half load). Thus, there is little maintenance required. Most electric pump motors are designed to be operated at maximum air temperatures of 40°C (104°F), thus it is often necessary to provide shade for the pump motor. Although motors normally feel hot to the touch, each 10°C (18°F) increase in the operating temperature reduces the life expectancy by half. The primary culprit leading to overheating is overloading of the motor. The speed of an a.c. electric motor will vary very little with changes in load, so for practical purposes the pump will run at a constant speed.

Of course, not all the electrical power you purchase from the utility company is consumed by the pump motor. A certain amount of loss in the feeder lines from meter to motor is unavoidable, but similar to pressure losses in a pipe, a larger wire usually means smaller losses. It is common for an electrically powered center pivot system, for example, to lose 5 to 8% of the power purchased between the meter and the motor. Electric motors start almost instantaneously with a push of a button (no jumper cables needed!) and lend themselves readily to automation, such as interlocking with the irrigation system so that the pump won't run if the pivot stops and *vice versa.*

Combustion engines have an apparent advantage of being readilly able to change the pump speed by simply adjusting the throttle. Thus, if the groundwater level drops or the sprinkler nozzles wear enough to reduce the operating pressure, one may be able to pull the throttle back and think he has restored the pumping plant to its best operation. Whether diesel, natural gas, propane or gasoline, combustion engines often look attractive from the cost of fuel alone. However, one must consider that maintenance-- oil changes, spark plugs or injectors, valve jobs and general overhaul are a reality for engines. In theory, engines can be started automatically (emergency generators, etc.), but in the irrigation environment they do tend to deteriorate which often necessitates the use of jumper cables at the very least. Seldom are automotive type engines the most economical alternative, either from life expectancy or from fuel efficiency, for combustion engine power plants. The choice of electric power or combustion engines is not one to be taken lightly if one has a choice.

WHAT PUMP IS BEST FOR MY IRRIGATION SYSTEM?

Pumps used for irrigation, whether vertical turbines, submersibles, or "centrifugal" operate on the principle of centrifugal force applied by a rotating impellor which provides energy to the water in the form of velocity and pressure. Because of this method of operation, the flow rate, head (pressure, lift or friction), efficiency, impellor size, speed and power requirements are all interrelated in a predictable manner. Each pump manufacturer makes many sizes of pumps, with several models within each size, each having different characteristics. Thus, using a pump that is ideal for one application for a different application can be very expensive.

At least within the recommended operating range, irrigation pumps will always deliver more water when the operating head (pressure) is reduced. Thus, if you convert from a high pressure center pivot to a LEPA system, the pump will deliver too much water (if the entire system is pressure regulated, the pivot pipe pressure will remain about the same as before, thus saving nothing in energy).

Vertical turbine pumps usually deliver a relatively small head (pressure) for each "stage" of the pump. In order to lift water tens or hundreds of feet and also have pressure to operate a sprinkler irrigation system, it is necessary to stack several of these stages, one on top of another. Thus, when the design conditions for a pump change, for example converting to low pressure, it is necessary to change the character of this "multi-stage" pump. When it is satisfactory at all to retain the old pump, there are several changes that may be made to ensure efficient operation. Stages may be removed to reduce the operating pressure. Pressure and flow rate is also dependent on the diameter of the impellors, and it may be possible to further "fine tune" the pump by reducing the impellor diameter in a lathe.

The flow-pressure characteristics of an irrigation pump are also dependent on speed of the pump. Where Hollowshaft motors are mounted directly on the pump shaft, electric motors do not allow significant speed changes. Belt driven electric powered units and combustion engine powered units, however, give quite a bit of flexibility, particularly if flow rate and/or pressure are to be decreased. The best alternative for changing the speed of a combustion engine powered pump, except for minor changes, is to change the gearhead so that the engine can be operated near its point of maximum fuel efficiency.

One must keep in mind, however, that the power consumed by a pump increases much more rapidly than the speed. Increasing the speed of a pump by only 26% doubles the power required! Perhaps even more important when considering changes to a pumping plant is the effect of the proposed change on the energy efficiency of the overall plant. Of course engine efficiency depends on speed and load among other things (does the gas mileage of your pickup change as you go from a steady 45 mph to 85 mph). Each pump is likewise designed to operate at a particular flow rate and pressure. Conditions that cause the pump to operate at some other point increase the efficiency of the pump, requiring more energy to pump a given amount of water. Thus, it may be more economical to replace a pump rather than attempt to modify it when changes are made to an irrigation system.

Often, the irrigator will attempt to change the pump characteristics, particularly the operating pressure, by adjusting the bowl clearance. This may be possible for shallow pump settings, but care must be exercised that the impellor does not drag on the bowl either at the bottom when the pump is operating at full pressure or at the top when the pump is first started. The effects of bowl adjustment on operating efficiency are unpredictable, and adjusting impellor clearance to change pump characteristics is not generally recommended.

WHY DOES THE PERFORMANCE OF A PUMPING PLANT CHANGE?

Probably the most common reason for deterioration of a pumping plant in the High Plains is decline of the water table. If the pump was properly designed initially (which may not necessarily be the case, particularly for older installations), the efficiency was near its peak when it was new. However, as the water level drops, the pump must generate higher lift head (pressure) to get the water to the surface and mechanical efficiency drops.

The quality of the irrigation water also effects the long-term operation of a pumping plant. If the well yields any sand (or you pump from a sediment laden surface supply), the abrasive action of the sediments will gradually grind away the surfaces of the bowl and impellor. This may initially have a similar effect to reducing the impellor diameter in a lathe, but eventually can lead to failure to pump water at all. The combinations of pipe materials and chemicals in the water often lead to chemical decomposition of the pipes or deposits of chemicals on the inside of the pipe. The latter increases the friction in the pipes, which necessarily reduces the flow. Decomposition may reach the point that the pipe is perforated (usually occurs within the well), which allows some of the water pumped to flow right back down the well bore.

Another common reason for deterioration of pumps is that the irrigation system has been changed, resulting in different head (pressure) losses and flow rates. Of course, when a farmer converts from gravity irrigation to a center pivot, it is pretty obvious that something must be done to the pump. Not so obvious, however, are changes from open ditch to buried pipeline or gated pipe surface irrigation systems or changes in a center pivot from 45 psi for a low pressure impact system to 30 psi for a spray system or even lower for LEPA. Each time such changes are made, the irrigator is well advised to measure the performance of the pumping plant and weigh inefficiencies in fuel consumption over the expected life against the cost of having the pump modified or replaced.

HOW CAN I TELL IF MY PUMPING PLANT IS WASTING MONEY?

The simple answer is, "You can't tell by looking." In fact, you really can't tell much by watching the power meter or fuel gauge. The power required by a specific irrigation pump changes relatively little over a wide range of operating conditions. Thus, a pump that used 36000 kwh per month to pump 1075 gpm at 60 psi a few years ago may be still using 36000 kwh per month, but pumping only 920 gpm at 50 psi.

Except for such things as the sound of rushing water going back down a well or obvious corrosion or leaks, one must have a pumping plant evaluation conducted to determine how the pumping plant is performing. This test should evaluate both the power plant (motor or engine) and the pump. Because motor efficiency is virtually fixed, the efficiency of the motor is not usually tested, except to determine whether bearings are broken. Many firms and public agencies (pump installers, private consultants, Soil Conservation District personnel, and utility company personnel) provide pump testing services. Charges range from none to a few hundred dollars, and the competence of the test personnel or accuracy of the test are not necessarily reflected by the charges.

This pump test crew will obviously have to run the system in order to test it. This may influence when you want a test conducted. The test is most valid (for a well) after the pump has run for some time, preferably a few days, so that drawdown in the well is representative. For an engine powered system, the crew will probably remove the driveshaft and replace it with one of their own which is instrumented to measure power the engine generates. They will also interrupt the fuel system to insert a fuel flow measuring device to determine the energy consumed. For electric motors, the crew will measure the voltage and current (amperage) on each "leg" of a three phase system and time the rotation of the power meter disc to determine electrical energy consumption. Pump monitoring requires dropping a measuring device, either an electrical sounding wire, a steel tape, or an air line down between the column pipe and casing to measure pumping level. Water pressure must be measured near the pump outlet, and the flow rate must be measured, which may require drilling and tapping one or two holes in the pipe, depending on the method used.

These data can then be used to calculate the level of performance of the pumping plant and engine if so equipped. By comparing the measured pumping plant performance with what can be expected from a good pumping plant, one can readily determine the available margin for improvement. "Improvement" may be interpreted as pumping more water with a new or repaired pumping plant, using less fuel for the same water and pressure, or somewhere in between.

WHAT CAN I DO ABOUT A POOR PUMPING PLANT?

Interpretation of a pumping plant test to determine the reason for low efficiency requires considerable expertise. If the combustion engine is the contributor to low efficiency, your mechanic is obviously the one to call. If problems lie in the pump itself, your pump man will be the first to contact. Problems of low pump efficiency mean that the pump has deteriorated or that it is the wrong pump for the current job. Either usually means the pump must come out of the hole, no small matter in itself.

On the other hand, if pumping plant efficiency is OK but you still can't get the water or pressure you need, another consultant may be needed. In the High Plains (and other areas, of course) the aquifer itself may restrict the amount of water you can pump. Not much can be done to repair a well if the aquifer level has declined seriously. However, changes in performance may be due to corrosion or other damage to pipelines leading from the pump, too small pipes used, or numerous other reasons. Your center pivot dealer, for those systems, or other consultant may be able to help.