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NSW Agriculture

How efficient is your pump?

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Random tests of pumps in many New South Wales river valleys found that about half were not performing efficiently, either because the wrong pump had been chosen for the job, or because the pump was worn.

If the pump is not doing its job, this can increase pumping costs and reduce productivity. To contain costs, you need to monitor your energy usage regularly and repair and maintain the pump to operate efficiently.

This Agfact describes a simple way to work out the efficiency of your electric pump. More information is given in the companion Agfact *How much does it cost to pump?*

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When you have determined the pump efficiency, you can compare it to the manufacturer's figures to decide when repair or replacement is cost-effective.

IS THE PUMP EFFICIENT ?

The aim of careful pump selection and regular pump maintenance is to have the pump performing as efficiently as possible, because this gives the lowest running costs.

To calculate pump efficiency, you need to know the flow rate (Q; see also the Agfact *How much does it cost to pump?*) and the pump pressure, or total head (H) of the system. The pressure and flow that a pump is working at is called the **duty**. Efficiency changes with the range of possible duties for any specific pump.

When you have calculated the pump duty, you can compare it to the manufacturer's specifications shown in the pump's performance curves. By seeing the efficiency that the pump was designed to operate at, you can find out if you can improve its efficiency and thereby reduce pumping costs.

Pump efficiency measures how well the pump converts electrical power to useful work moving the water.

Pump efficiency = power output ÷ power input

An acceptable efficiency for a single impeller centrifugal irrigation pump, for example, is above 65%. A figure below this means either the wrong pump was chosen for the job, or the pump is worn and needs repair.

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AGDEX 753

PUMP EFFICIENCY CALCULATIONS

Step 1. Measure power consumed

(See the Agfact *How much does it cost to pump?* for how to obtain these figures.)

Power usage = (N x 3600 x M) ÷ (R x T)

Step 2. Measure flow rate

Flow rate (Q) = litres pumped ÷ time in seconds

Calculating duty in surface systems

For surface irrigation systems, an adequate estimate of total head is the height in metres from source water level to the end of the discharge pipe, or, if the discharge is submerged, to the height of the water above the discharge, plus suction losses.

Skip steps 3 and 4 if you are calculating pump efficiency in a surface system.

Step 3. Determine pressure head

Total head (H) is discharge head plus suction head.

Discharge head, or **pressure head**, is the pressure read from the pressure gauge fitted at the pump when the system is at full operational pressure.

Take this reading while you are measuring the flow rate.

Tip: use a temporary pressure gauge.

New pumps usually have a pressure gauge installed but they often suffer physical damage quickly. A better method is to weld or braze a small nipple and gas cock onto the delivery side of the pump where you can temporarily install a pressure gauge whenever you want to take a reading. The gauge can be easily detached when not needed.

A change in pump operating pressure through the season or between seasons immediately tells you something has changed:

- A sudden reduction usually indicates a new leak.
- A gradual reduction usually indicates wear of the impeller or sprinkler nozzles.
- An increase usually suggests a blockage somewhere.

Equivalent metres of head

The pressure gauge reading needs to be converted to equivalent metres of head.

Head (m)	5	10	15	20	25	30
Pressure (kPa)	50	100	150	200	250	300

If your pressure gauge reads only in psi, convert psi to kPa by multiplying by 6.9.

Example: 40 psi = 40 × 6.9 = 276 kPa = 27.6 m head

Overall pressure or total dynamic head is the pressure at the pump plus the height from the water level to the centre line of the pump (the suction lift) and suction losses.

Pressure can be thought of as equivalent to a pipe of water of a certain height in metres. This is referred to as 'head' (H). At sea level, the pressure at the bottom of a pipe of water 10 metres high is about 100 kPa.

Step 4. Determine suction head

Suction head is the distance between the centre line of the pump and the water level plus losses in the suction pipe. Typical suction head figures are between 3 and 5 metres. Add this to the pressure head to give **total head.**

Most problems with pumps occur in the suction line. Common problems include:

- blocked inlet
- pipe diameter too small
- pipe damaged or crushed
- suction height too great
- air trap at connection to pump.

Step 5. Determine motor efficiency

Electric motors have an efficiency value (Me): that is, they lose some of the energy going into them as heat. This energy loss changes with the size of the motor and the load on the motor, but you can assume an efficiency of 85% for motors up to 15 kW, and 90% above 15 kW.

Submersible motors are generally 4 points lower than other motors: for example, for a 22.4 kW 2-pole submersible, motor efficiency is 86%.

Step 6. Determine transmission losses

If the motor is not directly coupled to the pump, there is a loss of energy through the transmission.

Our calculations can include this loss by using a drive factor (Df). For example, if the loss of energy through the transmission is 5%, then the drive factor (Df) is 0.95.

- For V-belt drives, Df is 0.9.
- For gear drives, Df is 0.95.

Step 7. Calculate pump efficiency

Pump efficiency = (Q × H) ÷ (power used × Me × Df)

(Pump efficiency (Pe) is expressed as a percentage.)

This example includes the data from all the steps we have discussed:

Step 1. *Power consumed*	**42** kW
Step 2. *Flow rate (Q)*	**58** L/s
Step 3. *Pressure at pump*	**276** kPa = 276 × 0.1 m = 27.6 m head
Step 4. *Suction lift*	**4** m
Total head = pressure head + suction lift = 31.6 m	
Step 5. *Motor efficiency*	**0.9** Me
Step 6. *Transmission loss*	**0.9** for V-belt Df
Step 7. *Pump efficiency*	= (Q × H) ÷ (power × Me × Df) = (58 × 31.6) ÷ (42 × 0.9 × 0.9) = **53.9**%

Step 8. Calculating cost saving

A typical centrifugal pump is designed to operate above 65% efficiency.

The pump in this example is only about 54% efficient. If we checked the manufacturers' specifications for this pump, and found that this pump is designed to operate at 70%, we could now calculate the savings we could make if we repaired or replaced the pump.

If the pumping cost is $24.12/ML, how much would be saved by improving the efficiency to 70%?

Saving per ML = **$24.12 – ($24.12 × 54 ÷ 70)**
= **$24.12 – $18.61**
= **$5.51**

Notice that reducing pump efficiency by 16% (70% to 54%) increases the cost of pumping by 30% ($18.61 to $24.12).

For a season where 400 ML are pumped, the total cost saving would be $5.51 × 400 = $2204.00

If impeller wear was the problem, then, with a replacement cost of $1500, the improvement would pay for itself in less than one season. After that, the savings would increase the enterprise profit.

Pump speed

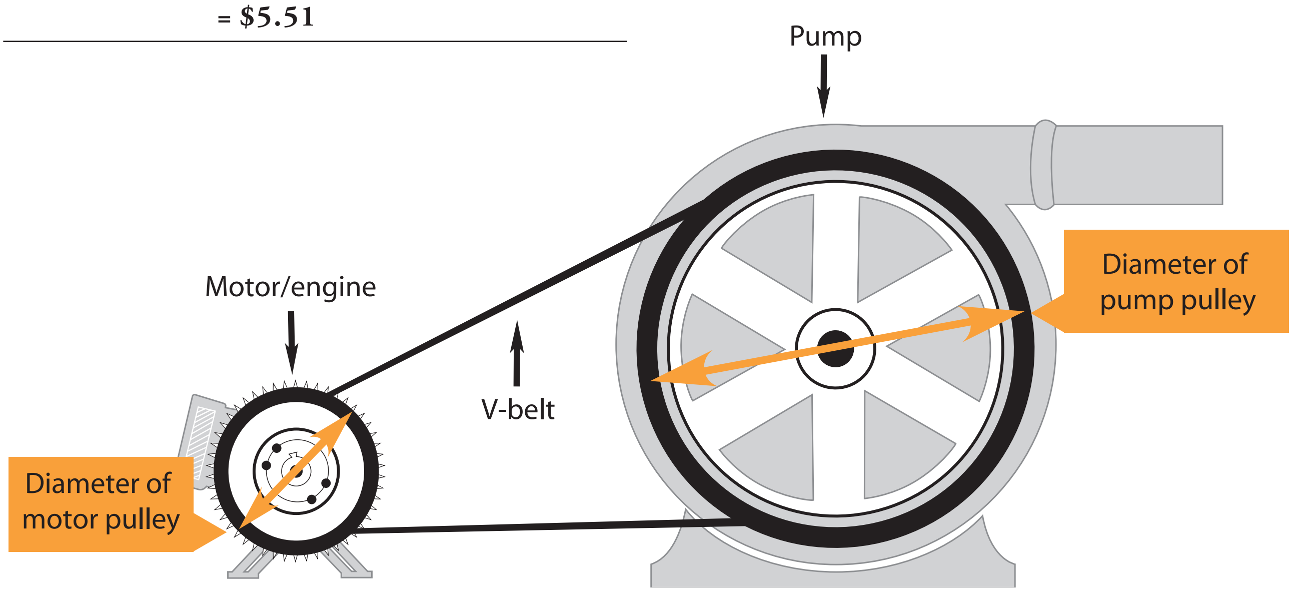
Two other variables affect cost and pump efficiency: pump speed and impeller size.

You must know the pump speed in order to read the pump curves. The curves are usually prepared for specific pump speeds and impeller sizes.

- If the pump is directly coupled to the electric motor, the speed is fixed by the speed of the motor: 2-pole motors run at 2900 rev/min and 4-pole motors run at 1440 rev/min.

Note: Because the speed of electric motors varies a little, it would be good to check your motor speed with a rev counter.

- If the motor is not directly coupled to the pump, the speed is altered by the gearing ratio of the transmission. Gear drives normally have the ratio stamped on the identification plate.
- The ratio for a V-belt and pulley drive can be calculated from the diameter of the pulleys on the motor and the pump; see diagram below.



rev/min of motor × diameter of motor pulley = rev/min of pump × diameter of pump pulley

rev/min of pump = rev/min of motor × diameter of motor pulley ÷ diameter of pump pulley

PUMP EFFICIENCY WORKSHEET

	Worked example	Your readings
Power consumed	**42** kW	
Flow rate (Q)	**58** L/s	
Pressure gauge at pump:	**276** kPa x 0.1 = 27.6 m	
Suction lift:	**5** m	
Total head (H)	= **27.6** + **5** = 32.6 m	
Motor efficiency (Me):	**70** kW motor = 0.9	
Transmission loss (Df):	V-belt = **0.9**	
Pump efficiency %	$Pe = \frac{Q \times H}{kW \times Me \times Df}$ $= \frac{58 \times 32.6}{42 \times 0.9 \times 0.9}$ = **55.5**%	

Impeller size

Impeller wear has the same effect as a reduction in size.

You need to know the size of impeller fitted to your pump to work out which performance curve applies to your pump. Sometimes the impeller size is stamped on the pump's ID plate. If not, you need to find out the size by dismantling the pump and measuring it, or asking the person who made the change.

Sometimes an impeller is deliberately reduced in diameter to adjust the pump's performance and obtain a specific duty.

To give a range of duties, manufacturers may offer impellers of different diameters for the same pump casing. Available impeller sizes are shown on the pump curves.

In conclusion

Worksheets are included with this Agfact to help you measure your pump performance and efficiency.

Keeping track of your pump's performance and costs is not difficult. It may save you a lot of money and keep your irrigation system performing properly.

Related Agfacts

Agfact E5.8 *Selecting an irrigation pump*

Agfact E5.10 *How much does it cost to pump?*

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Disclaimer

The information contained in this publication is based on knowledge and understanding at the time of writing (November 2003). However, because of advances in knowledge, users are reminded of the need to ensure that information upon which they rely is up to date and to check currency of the information with the appropriate officer of New South Wales Department of Agriculture or the user's independent adviser.

PUMP EFFICIENCY WORKSHEET

	Worked example	Your readings	Your readings
Power consumed	**42** kW		
Flow rate (Q)	**58** L/s		
Pressure gauge at pump:	**276** kPa x 0.1 = 27.6 m		
Suction lift:	**5** m		
Total head (H)	= **27.6** + **5** = 32.6 m		
Motor efficiency (Me):	**70** kW motor = 0.9		
Transmission loss (Df):	V-belt = **0.9**		
Pump efficiency %	$Pe = \frac{Q \times H}{kW \times Me \times Df}$ $= \frac{58 \times 32.6}{42 \times 0.9 \times 0.9}$ = **55.5**%		

	Your readings	Your readings	Your readings
Power consumed			
Flow rate (Q)			
Pressure gauge at pump:			
Suction lift:			
Total head (H)			
Motor efficiency (Me):			
Transmission loss (Df):			
Pump efficiency %			