IRRIG8Quick

Irrigation Energy Quick Test

Pump Efficiency Guidelines

PAGEBLOOMER

What is the Irrigation Quick Test about?

The purpose of this Irrigation Quick Test is to determine the energy efficiency of the motor and pump combination feeding the irrigation system.

IRRIG8Quick is designed so irrigation managers can do testing and calculations themselves. As well as this guideline, a worksheet is available to assist. If findings are unexpected, or suggest low performance, consider getting professional advice.

A full irrigation pump performance test must be performed by a trained service provider with appropriate testing equipment.

Why check pump performance?

Profitability – Incorrectly sized or physically deteriorated pumps will waste energy and money. A good pumping system saves money!

Sustainability – efficient pumping minimises energy use and carbon emissions. A good pumping system saves the environment!

Pump and motor selection are important system design considerations. Incorrectly sized pumps and/or motors will not operate at their most efficient points. So they will waste energy.

Low pressure is a common cause of poor irrigation uniformity which reduces overall system effectiveness and efficiency. The pump must provide adequate pressure and flow to ensure the system operates as designed.

Excessive pressure affects performance and wastes energy. Pump selection will usually allow about 5% extra pressure capacity to allow for slippage with time. But excessively oversized pumps are major energy wasters.

What is involved?

Measured flow rates are combined with energy consumption information. This allows calculation of the energy efficiency of the motor and pump combination, operating as tested.

The process should be repeated if there are significantly different operating conditions, essentially varying flow and/or pressure.

NOTE: Using this method, the intake pipe efficiency is included as part of the overall pump efficiency calculated.

In multiple pump systems, it is possible to analyse each pump separately if pressures between pumps can be measured.

What will the testing show?

The main things the Quick Test will show are:

Energy Consumed – The kWh or diesel energy used to run the system; hourly and annually.

Pump Efficiency – How much of the energy consumed (and paid for) is used to do useful 'work' driving the irrigation system.

Pump Performance – How well the pump compares with typical values for that type and size of equipment.

Annual Energy Cost and Savings – How much energy and money would be saved if the pump was operating at typical performance levels.

What needs to be done?

1. Gather information about the system
2. Record the data on the worksheet
3. Calculate answers using the worksheet & guide

When should testing be done?

Complete the efficiency test when commissioning a new system and after any major changes to the pump or irrigation system.

Testing should be repeated as part of system checks at the start of every season. Compare with past results to identify slippage or failures.

What are the Quick Test's limitations?

The Quick Irrigation Pump Efficiency Test will only provide information for the conditions measured, running at a given flow and pressure with a given depth to water. The energy use and efficiency will change if system pressure or flow changes or if the water table moves up or down.

The efficiency value determined is for the motor and pump combination. It is not easy to separate the individual performance of the motor or the pump. By looking at typical values, some indication is possible.

Get professional help if your results show low efficiency.

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What is acceptable?

Using an oversized pump will result in higher operating costs. The pressure at the nozzle (the end nozzle if there is more than one) gives best guidance to adequacy of system pressure.

New pumps may have spare capacity to allow for wear. However, if the system pressure is more than 5% over the sprinkler operating requirement, or if partially closed gate valves or pressure regulators are installed to 'burn-off' pressure, it is likely you are wasting energy and money.

It is usually more economical in the long term to select the most efficient pump, even if it requires higher initial outlay. Replacing incorrectly sized motors or pumps can often have a quick payback.

The efficiencies of both the pump itself and the motor are combined for overall efficiency. So, for example, a 90% efficient motor on a 70% efficient pump is only 63% efficient overall (0.9 x 0.7 = 0.63).

Check manufacturer's data sheets to determine the expected efficiency of your pump-motor combination. They should be selected to operate at or near their maximum efficiency points as much as possible.

Table 1 below gives guidelines for expected efficiencies, based on motor size and assuming the pump is matched appropriately to the motor.

Why does efficiency change?

There are two basic reasons for a pump being inefficient:

1) it has physically deteriorated, and/or

2) it is not suitable for the required operating conditions (i.e. required flow and pressure).

Most irrigation systems are powered by electric motors or internal combustion engines, sometimes both. In general, electric motors are more energy efficient than diesel engines, which are usually more efficient than petrol engines.

Differences in potential efficiencies between standard electric motors are generally small (1-5%), but as the motor is at the start of the drive train the savings achieved by an efficient motor and motor operating at its best efficiency point can be substantial.

Changing flow or pressure requirements will change the pump operating point, and can move from its optimum to a less efficient performance.

If pump loads fluctuate widely or if pumps are often run at partial loads, adding a variable speed drive may be cost effective since it closely matches output to actual demand. An alternative is to use multiple pumps turning on or off to optimise to different operating conditions.

Table 1. Typical Electric Motor and Pumping Plant Efficiencies by Motor Size

Electric Motor kW	Full Load Motor Efficiency %	Matched Pump Efficiency %	Overall Pump Efficiency %
2 – 4	80 – 86	55 – 65	44 – 56
5 – 7.5	85 – 89	60 – 70	51 – 62
10 – 22	86 – 90	65 – 75	56 – 68
30 – 45	88 – 92	70 – 80	62 – 74
> 55	90 – 93	75 – 85	68 – 79

Source: North Carolina Cooperative Extension Service, Publication Number: AG 452-6

NOTES:

Pump type variations

1. Values shown are typical for centrifugal pumps.

- Under 55kW submersible pumps range 3 - 5 % higher and turbine pumps range 5 - 10 % higher.
- Above 55 kW, centrifugal pumps may approach efficiencies of 88%, whereas large submersible and turbine pump efficiencies peak at about 90 %.

2. Overall Pump Efficiency ranges are obtained by multiplying the Full Load Motor Efficiency range by the Matched Pump Efficiency range e.g. 80% x 55% = 44% (on a calculator 0.80 x 0.55 = 0.44)

Converting values for typical fossil fuels to usable energy values:

1. NZ Diesel contains 10.4 kWh per litre but only about 3.5 – 4.0 kWh / L of useful energy are generated.
2. NZ 91Petrol contains 9.69 kWh per litre but only about 2.5 – 2.8 kWh / L of useful energy is generated.

- The usable energy values for diesel and petrol above are already adjusted for engine efficiency. If using them as 'Power Conversion' factors in Step 1B: Fossil Fuel, use values from the *Matched Pump Efficiency* column rather than the *Overall Pump Efficiency* column as the 'Typical' Pumping Plant Efficiency in Step 4.

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Example Worksheet for IRRIG8Quick Pump Efficiency Test

Enter times, meter readings, elevation and pressure data
Complete the calculations as directed
Enter information using the measurement units (e.g. kWh or metres) specified
to ensure calculated answers have the correct units.

Determining Performance

The effective efficiency of your pump and motor combination can be estimated from power readings, flow rates and pressures. The information should be easy to obtain, and calculations needed are set out below

What equipment will you need?

- This guide and the worksheet
- Stop watch
- Measuring jug (for fuel tank topping)
- Pressure gauge
- Tape measure
- Pen or pencil

Field measurements

- Test duration
- Power meter readings
- Fuel used
- Water meter readings
- Pressure generated
- Height from water level to pump outlet

Step 1: Energy Use

The rate of energy use is measured in kilowatts (kW) and whether your pump runs on electricity or fuel or both, you need to calculate the kilowatt consumption.

If you have more than one pump, add the energy use rates to get a total. It doesn't matter if you have a combination of electric and diesel, because we calculate energy use rate in the same units (kW).

A Electricity meters show energy consumption in kilowatt hours (kWh) – the combination of energy use rate (kW) and time (hours). Watch though, many have a 'multiplier value' you must include.

Divide kilowatt hours consumed by hours taken to calculate the kilowatts. (kWh / h = kW).

B Diesel and petrol engine fuel use is most easily measured by measuring the amount required to refill the tank. Do this accurately after a set running time.

Convert fuel energy to kWh equivalent values.

Step 2: Water Consumption

Hopefully there is a correctly calibrated water meter in the system to show flow rate.

If so; follow **Step 2** to record and calculate water use.

If not; determine flow rate from field measurements by doing an IRRIG8Quick irrigation calibration.

Step 1 A: Electricity		Pump 1	Pump 2
a	Test Duration (hours)	*1.0*	
b	Meter kWh Start	*34,657.8*	
c	Meter kWh End	*34,712.5*	
d	Meter kWh Used [c – b]	*54.7*	
e	Meter multiplier	*1.0*	
f	Power Used kW [d x e / a]	*54.7*	
g	Energy Cost $/kWh	*0.12*	
h	Annual Run Time h	*1,500*	
j	Annual energy cost $pa [f x g x h]	*9,846*	

Step 1 B: Fossil Fuel		Pump 1	Pump 2
a	Test Duration (hours)	*1.0*	
b	Fuel Used (L)	*20.0*	
c	Power conversion (kWh/L)	*4.0*	
d	Power Used (kW) [b x c / a]	*80.0*	
e	Energy Cost ($/L)	*1.1*	
f	Energy Cost ($/kWh) [e / c]	*0.275*	
g	Annual Run Time (h)	*1,500*	
h	Annual energy cost ($pa) [d x f x g]	*33,000*	

Step 2: Water Use		
a	Test Duration (hours)	*1.0*
b	Meter m^3 Start	*4,126,585*
c	Meter m^3 End	*4,126,777*
d	Meter m^3 Used [c – b]	*192*
e	Meter multiplier	*1*
f	Water Used m^3 [d x e]	*192*
g	Water Flow Rate m^3/h [f / a]	*192*
h	Annual Run Time h	*1,500*
j	Annual Water Use (m^3 pa) [g x h]	*288,000*

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Step 3: Rate of Work Done

The rate of work done by a pump is calculated from the water flow rate, lift (change in elevation x specific gravity) and increase in Pressure Head.

Elevation Head (lift)

Elevation head refers to the lift from the source water level to the pump discharge. It is the lift from the actual water level when the pump is running (drawn down) to the centre of the pump outlet.

Elevation head is usually positive, but if the water level is higher than the pump (e.g. a dam), the elevation change is recorded as a negative value.

Specific Gravity (SG) accounts for the force of gravity. SG = 9.8, but you could just multiply metres elevation change by 10 to get approximate kilopascals Head.

In these calculations, a further adjustment of 3600 is required to convert flow per hour to flow per second.

Pressure Head Increase

The system intake is usually not pressured. (Water depth above intakes or submerged pumps is taken into account already, as we measure from the water surface level to the pump for Elevation Head.)

However, if there is positive head on the intake from a primary pump, this pressure needs to be subtracted to get the increase in pressure generated by the pump you are testing.

The pump is working to overcome friction in the intake side of the headworks. To account for this, add the friction determined using the IRRIG8 Delivery System Efficiency guidelines.

Outlet Pressure

The outlet pressure is read directly from a pressure gauge mounted at the pump outlet. Most systems have this facility, but make sure the gauge is in good condition. Replace it if necessary.

Step 4: Pump Efficiency

Pump efficiency shows how much of the energy consumed does useful work. It is usually given as a percentage.

In the examples here, energy use rate (kW) is easily compared to calculated work done. (The example calculation values in Fossil Fuel Use are ignored.)

Relative Performance

Select a reasonable value for your situation from Table 1 and compare it with the calculated efficiency for your actual pumping plant. The relative performance is usually given as a percentage.

Efficiency Cost

The potential savings are calculated from the annual cost and the relative performance value determined.

In the worked example, the cost of energy for a pumping plant with 48.6% efficiency is 44% more than a typical plant running at 70% efficiency.

Step 3: Work Done

a	Elevation Change (m)	*7*
b	Elevation Head (kPa) *[a x SG]*	*69*
c	System Intake Pressure (kP)a	*0*
d	Pump Outlet Pressure (kPa)	*414*
e	Pressure Head (kPa) *[d – c]*	*414*
f	Inlet-side friction (kPa) *[from Delivery Efficiency Worksheet]*	*16*
g	Total Dynamic Head (kPa) *[b + e + f]*	*499*
h	Water Flow Rate (m^3/h) *[g from Step 2]*	*192*
j	Work Done (kW) *[g x h / 3600]*	*26.6*
k	Design Outlet Pressure (kPa) *[from Design Details]*	*445*
m	Outlet Pressure Deviation kPa *[d – k]*	*15*
n	Outlet Pressure Deviation % *[m / k x 100]*	*3.4*

Step 4: Pump Efficiency

a	Electric Power(kW) *[from Step 1 A: f]*	*54.7*
b	Fossil Fuel Power (kW) *[from Step 1 B: d]*	*alternative option*
c	Total Power (kW) *[a + b]*	*54.7*
d	Work Done (kW) *[from Step 3: h]*	*26.6*
e	Overall Pump Efficiency % *[d / c) x 100]*	*48.6*
f	Typical Efficiency *[from Table 1]*	*70.0*
g	Relative Performance % *[e / f x 100]*	*69.4*

Efficiency Cost

h	Electricity Cost ($ pa) *[from Step 1 A: j]*	*9,846*
j	Fossil Fuel Cost ($ pa) *[from Step 1 B: h]*	*alternative option*
k	Total Energy Cost $ pa *[h + j]*	*9,846*
m	Typical Efficiency Cost $ pa *[k x g / 100]*	*6,833*
n	Annual Cost Saving $ pa *[d – e]*	*3,013*
p	Annual Water Use (m^3 pa) *[from Step 2: j]*	*288,000*
q	Pumping energy cost ($/$m^3$) *[k / p]*	*0.034*
r	Power demand (kW/m^3) *[pump kWh / water m3/h]*	*0.285*

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