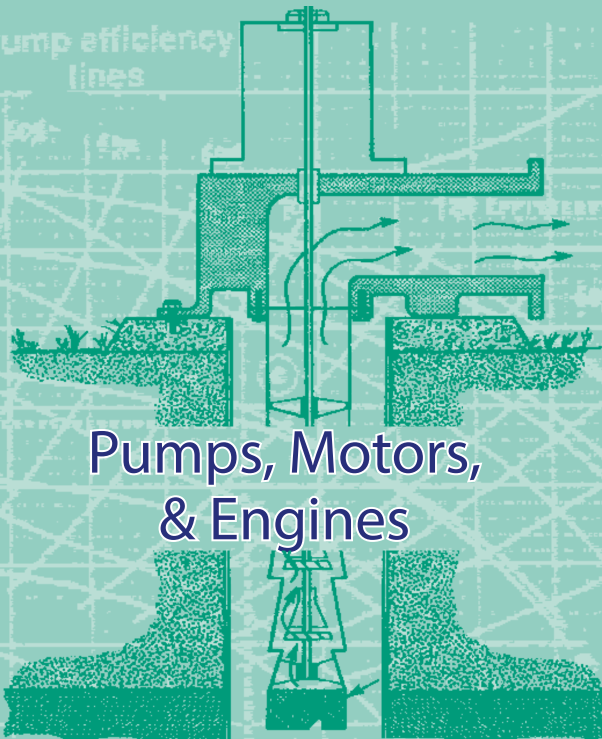
The California Microirrigation Pocket Guide



Pumps, Motors, & Engines

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Pumps, Motors, & Engines
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Handy Conversions and Formulas

1. Recommended Installations

IDEAL

Introduction

The *Pumps, Motors, & Engines* half of this book includes:

- Descriptions and diagrams of recommended pumping plant installations.
- Suggestions for improving water and energy efficiency.
- Detailed instructions for equipment maintenance, broken down by how frequently they need to be done.
- A troubleshooting guide for pumps and motors.
- Dozens of frequently used conversions and formulas (in the center of the book).

The wrench symbol indicates maintenance tasks.

The exclamation mark indicates safety hazards, potential equipment damage, possible harm to crops, or other situations calling for extra caution. Consult your owner's manual and always follow the manufacturer's instructions if they differ from the ones in this guidebook.

Please note that the reverse side of this book covers basic maintenance procedures for a microirrigation system, including filtration, flushing lines, checking for leaks, inspecting emitters, and other important topics.

No one knows more than you do about your fields and irrigation system. So adjust or reject any suggestion in this book if it doesn't fit your situation or doesn't seem to be working. Proceed cautiously and test every recommendation with direct observations in the field.

Centrifugal Pumping Plant Installation with Electric Motor

In this book, the term ***pumping plant*** refers to the irrigation pump and motor or engine, considered together. If you have an older system, your pumping plant may look like Figure 1, ***Poor***, on the discharge side. It's a false economy to install undersized valves and fittings. You'll only cause greater friction loss and higher pumping costs. The next time you rebuild your pump, replace the fittings so your plant looks like Figure 1, ***Ideal.***

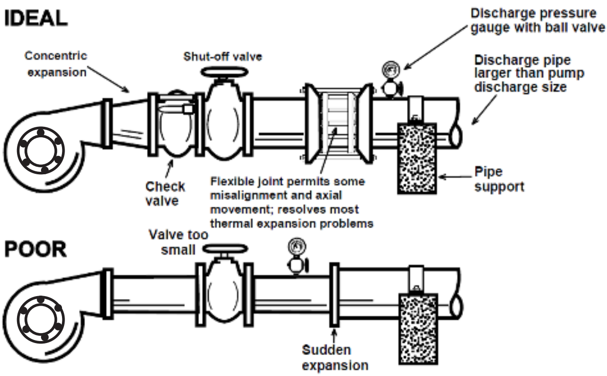


Figure 1. Ideal and Poor Installations

An ideal installation should have:

- A discharge concentric expansion instead of an abrupt change in pipe diameter to minimize head loss, turbulence, and air pockets.
- A discharge valve the same diameter as the mainline.

Figure 2 on pages 4-5 shows what your pumping plant should look like when pumping from a surface source such as a river or canal.

A well-designed pumping plant should have:

Suction Side of Pump

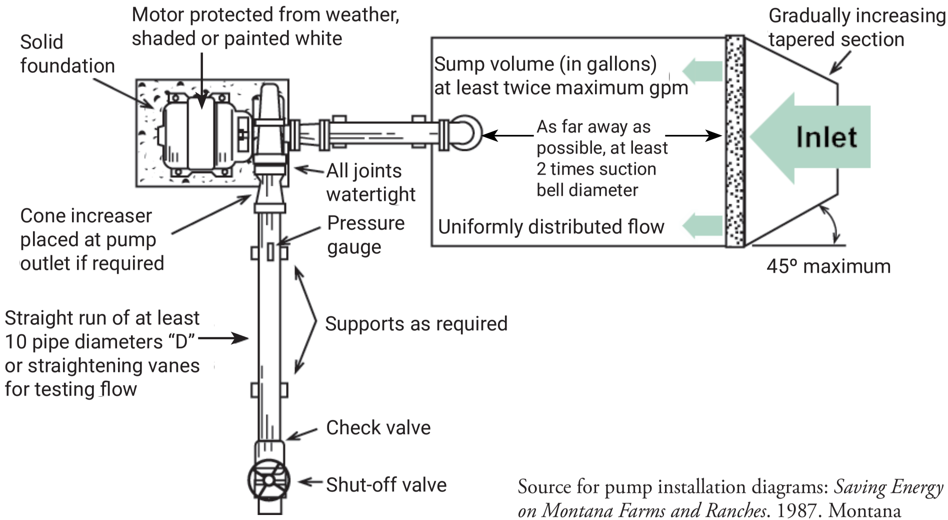
- A screened sump that keeps trash away.
- Suction line joints that are airtight under a vacuum.
- No high spots where air can collect.
- A suction line water velocity of five feet per second or less. Two to three feet per second is best.
- A suction entrance at least two pipe bell diameters from sump inlet.
- A suction lift (vertical distance from water surface to pump impeller) less than 15 to 20 feet.
- An eccentric reducer to keep air from becoming trapped in the reducer fitting.
- A vacuum gauge to indicate whether the primer is pulling a vacuum or just moving air through the pump.

Discharge Side of Pump

- A valve the same size/diameter as the mainline.
- A non-slam check valve to prevent back spin of the pump when shutting pump off.
- An air-relief device when a buried mainline is used.
- A discharge line water velocity of less than seven feet per second. Five feet per second is best.
- An energy-efficient 1800 rpm motor with 15% safety factor.
- A simple shade over the motor.

! Figures 1 and 2 show only components directly related to energy efficiency and don't show pressure relief valves, air vents, or other features necessary for safety and performance.

Top View



Source for pump installation diagrams: *Saving Energy on Montana Farms and Ranches*. 1987. Montana Department of Natural Resources and Conservation.

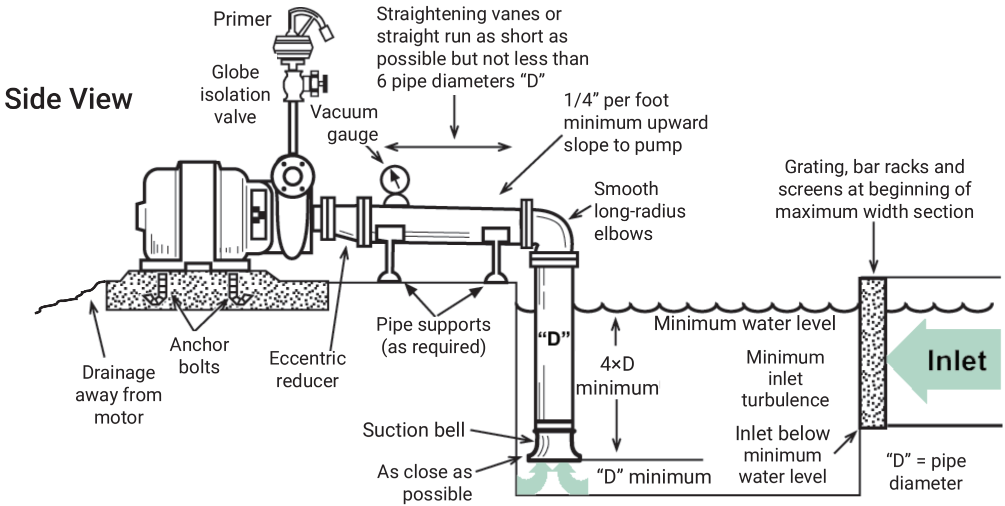


Figure 2. Recommended Pump Installation, Top and Side Views

About Pressure Gauges

A good quality oil- or glycerin-filled pressure gauge on the discharge side of the pump will tell you a lot about your system's condition. If operational pressure stays close to the original design pressure, the pump is probably in good working order. Pressure changes can indicate clogged suction screens, leaks, pump wear, worn nozzles, or other problems. Use the gauge when filling the mainline to reduce demand and water hammer. Extend the life of your gauge by installing a ball valve on the riser. Keep the valve closed except when referring to the gauge. With a ball valve in place, you also have the option of removing the gauge during the winter.

Turbine Pump Installation

Refer to the left half of Figure 3 on page 7 for a properly installed turbine pump in a well. Many of these same principles apply to turbine pumps in sumps.

A properly designed well should also:

- Be at least six inches in diameter larger than the outside diameter of the well casing when a gravel pack is required.
- Have horizontal well screen slots that continue below the pumping water level. The openings should hold back at least 85 percent of the surrounding material.

The poorly constructed well in the lower right side of Figure 3 shows a well casing that is not centered in the well. Vertical slotted pipe perforations are also above the minimum water level, creating cascading water.

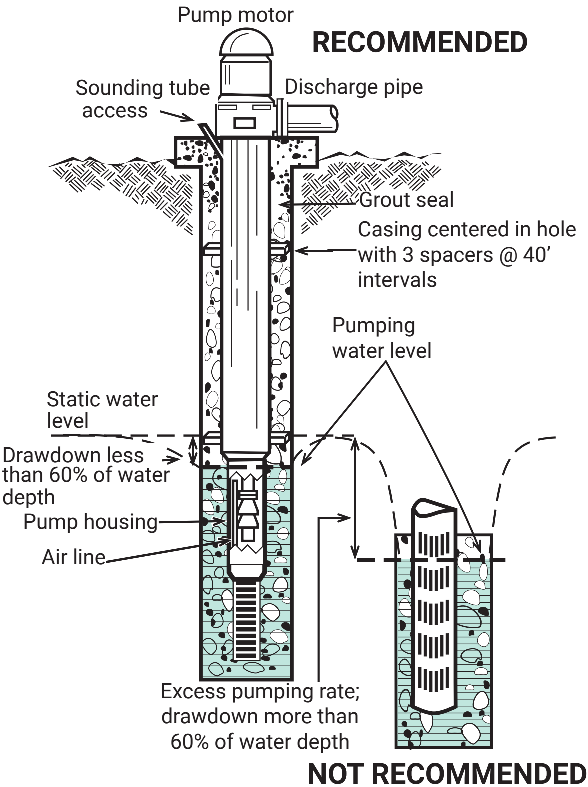


Figure 3. Deep Well Turbine Pump

Control Panel for Electric Motors

The importance of a properly installed control panel cannot be overemphasized for protecting your personal safety and your investment in your pump and motor.

Your control panel should:

- Have a shade over it to cool thermal breakers.
- Be mounted on secure poles or foundation.
- Have any missing knockout plugs and other holes in the starting switch box replaced and screened or puttied against rodents, insects, and dirt.
- Have a small hole (3/16-inch diameter) in the bottom of the panel to allow moisture to drain.
- Have circuit breaker(s) for overload currents.
- Have a lightning arrester.
- Have a surge protector.
- Have a phase failure relay, to protect the motor from phase reversal or failure and from low voltage.
- Have a pressure switch to shut off the motor if pumping pressure drops to undesirable levels.

Choosing Gaskets

Gaskets often leak because they are put into couplings for which they were not made.

Flat gaskets: Most are made of neoprene and used on flanged, bolt-together fittings. They normally fail by "creeping" out of their fitting. Look for new neoprene gaskets that contain a cotton backing sandwiched in the gasket to reduce the creeping action.

Shaped gaskets: The three most common materials are styrene-butadiene (SBR), ethylene-propylene (EPDM), and polyethylene (poly). SBR and EPDM have much better resistance to cracking, abrasion, ozone, and weathering resistance than poly gaskets. They are more expensive than poly but will last longer. When buying shaped gaskets, look for gaskets that are dull. This indicates that little or no plasticizer has been added to the gasket. Plasticizers significantly reduce gasket life.

2. Pumping Plant Maintenance

Follow a regular maintenance plan and see reduced repair costs, lower operating costs, longer system life, and less stress for you.

! The recommendations below are not comprehensive and may not be correct for all systems. Consult your owner's manual and always follow the manufacturer's instructions if they differ from the ones in this guidebook.

Electric Motors

An electric motor is an air-cooled piece of equipment and needs all the ventilation it can get. Excessive heat is the main cause of reduced motor life. Motors also like to be dry. Keep motor windings dry by keeping pump packing in good condition. Even if windings are protected from moisture, minerals in water can attach to them, causing early failure.

Regular maintenance is especially critical for 3600 rpm motors and pumps. Motors that operate at 3600 rpm experience twice as much wear as motors operating at 1800 rpm.

General Points

- ✓ Make a habit of checking to be sure the motor is securely bolted to its platform. Mounting bolts can vibrate loose.
- ✓ Also make sure rotating parts aren't rubbing on stationary parts of the motor, causing damage.

Maintenance Tasks

At season startup:

- ✓ Remove tape on all openings. Clean out rodents, insects, and debris.
- ✓ Locate the motor drain hole on the base or support for the base and clean it out so water won't be trapped and held directly under the air intake.

- ✓ Change oil in reduced-voltage starters using an oil recommended by the manufacturer. Be sure to clean the oil pan before refilling.
- ✓ Use vacuum suction or air pressure to remove dust and debris from moving parts of motor. (Don't exceed 50 psi of air pressure.)
- ✓ Especially on large motors, you may want your electrician to do an annual Megger check on the control panel, motor, conduits, and other electrical connections. The Megger device applies a small voltage to an electrical component and measures electrical resistance. Tracking changes in readings over time allows you to diagnose looming failures due to degrading insulation.

Periodically:

- ✓ Clean grass and debris from air ventilation openings on and around the motor to allow a full flow of cooling air.
- ✓ Check screens on motor ventilation openings. Replace with machine cloth (¼-inch mesh) as necessary.
- ✓ At end-of-season shutdown, cover the motor with a breathable, water-resistant tarp.

Motor Electrical System

Over time, normal temperature changes can cause electrical connections (especially in aluminum wire) to expand and contract, loosening connectors and causing heat buildup and arcing at electrical terminals.

The voltage drop across loose connections also causes the motor to operate at less than its rated voltage, increasing internal motor temperature and breaking down motor winding insulation, resulting in electrical shorts and motor failures. A loose or broken connection can also unbalance the phases of three-phase power and damage the motor windings.

! Before conducting any of the maintenance tasks below, be sure power is off at the utility disconnect switch. You may need to have your electric utility shut off the power.

Maintenance Tasks

At season startup:

✓ Inspect motor winding insulation. If windings are excessively grease-covered, consult your motor repair shop for direction.

✓ Check all safety switches following manufacturer's directions.

Twice per year:

✓ Check electrical connections from meter loop to motor for corrosion and clean if necessary. Coat the wiring (especially aluminum) and connectors with an antioxidant that meets electrical code requirements.

✓ Check electrical connections from meter loop to motor for tightness. Tighten and re-tape if necessary.

✓ Replace overheated connections or wires with new material. Overheated connections will show heat damage such as burnt insulation on wires.

Motor Bearings

Lubricate motor according to manufacturer's instructions. Lubrication intervals will vary with motor speed, power draw, load, ambient temperatures, exposure to moisture, and seasonal or continuous operation. Electric motors should not be greased daily. Bearings can be ruined by either over- or under-greasing.

Fill a grease gun with electric motor bearing grease and label it so it won't be confused with other types of grease.

! Follow instructions in owner's manual if different from the ones given here. Newer motors may have sealed bearings that cannot be lubricated.

Recommended Re-greasing Periods for Motors

	Horsepower Range		
Type of Service	**1 - 9**	**10 - 40**	**50 - 150**
Normal Duty (8-hour day)	8 months	6 months	4 months
Heavy Duty (24-hour day)	4 months	3 months	2 months

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Maintenance Tasks

At recommended intervals:

✓ Change grease to remove any accumulated moisture:

- Remove the bottom relief plug and clean hardened grease out of passageway.
- Using a grease gun, fill housing with approved high-temperature electric motor bearing grease until old grease is appears at the bottom grease port (pressure relief port). Refer to the manufacturer's manual for API number of grease.

! If old grease is not expelled as new grease is pumped in, stop adding grease and have your motor checked by a qualified repair person. Adding new grease without old grease being removed could blow seals and push grease into the motor. Grease forced into motor windings will cause the motor to overheat and reduce service life. Do not overgrease your motor!

- Run motor until all surplus grease is thrown out through the bottom grease port (may take 5 to 10 minutes).
- Shut off motor and use a screwdriver or similar device to remove a small amount of grease from the grease port to allow for grease expansion during full load operation.
- Replace grease plug.

Control Panel

Control Panel Safety Precautions

! Never use the main disconnect to start or stop your motor. It's not meant for this purpose and abusing it in this way will cause excessive wear of the contacts and arcing. Use the start and stop button.

! If overhead lines to your control panel's service are obstructed by tree branches or other items, have your utility company clear the lines.

Have an electrician inspect your panel to ensure that:

- Control circuits are protected with the correct size and type of fuse.
- Lightning arresters are properly installed on meter and motor side of buss and breaker and mounted in a secure box to protect you if they blow up.
- The service panel is properly grounded, independently from the pumping plant.
- Service head grommets are in place and in good condition.

! After opening the control panel but before touching controls inside, use a voltmeter to BE SURE the incoming power is disconnected or turned off. If necessary, have your utility disconnect the power. If you have any doubts about the safety of your control panel, WALK AWAY and call a qualified electrician. Even a current of 15 milliamps (one milliamp is one one-thousandth of an amp) can cause serious injury or death. Always play it safe!

Maintenance Tasks

At season startup:

✓ Replace fuses after checking to be sure they aren't blown. Never use oversized fuses.

✓ Operate disconnect switch slowly to check for alignment of blades and clips. Open and close the switch several times to clean oxide from contact points.

✓ Clean contacts of dust and dirt. Use very fine sandpaper or a fine file for copper contacts. Never file silver or silver-plated contacts! Replace pitted or burned contacts. Leave contacts clean and dry so dust won't collect.

✓ If accessible, check magnetic starter switch contact points.

✓ Clean out debris, rodent droppings, and nests and insects. Make sure the drain hole is open.

Periodically:

✓ Any time the main disconnect switch has been left open or off, operate it several times before leaving it closed or on. Copper oxide can form in a few hours and result in poor contact, overheating, poor grounding, and direct or high-resistance shorts.

At shutdown (end of season):

✓ Make sure switches are in the off or open position. Lock panel in the off position and remove fuses to prevent accidental startup, vandalism, and corrosion.

✓ Protect exposed control boxes against moisture and dust with a waterproof tarp.

Engines: Diesel, Gasoline, Liquid Propane Gas (LPG), and Natural Gas

General Points

Make a habit of checking to be sure the engine is securely bolted to its platform. Mounting bolts can vibrate loose. Regularly check coolant, oil levels, fuel, and fan belts. If coolant or oil level is down, check lines for leakage. On diesel engines, check injectors and fuel lines for leaks.

If you have a natural gas engine, note that natural gas has a higher octane value than gasoline. You can increase engine efficiency and reduce fuel consumption by setting ignition timing to take advantage of the higher octane. Consult the engine manufacturer for instructions on how to do this.

Maintenance Tasks

At season startup:

- Remove tape on all engine openings and distributor cap and tighten belts.
- Charge batteries and connect them.
- Open fuel tank shutoff valve.
- Before starting the engine, override safety switches that protect against low water pressure, loss of oil pressure, and overheating. After engine has reached operating speed, activate the safety switches.

✓ Run engine for 10 minutes, then turn it off and check oil and coolant levels.

✓ Check engine and pump for leaks caused by drying gaskets.

! Engines are affected by altitude and air temperature. Derate engine power output by 3.5% for every 1,000-foot increase in altitude over 500 feet above sea level and by 1% for each 10-degree increase in air temperature above 85°F.

Engine Air System

Maintenance Tasks

At season startup:

✓ Clean and refill filter bath in oil-bath air cleaners and reassemble air cleaner.

Periodically:

✓ Brush blockage off screen if the air-induction system is equipped with a pre-screener.

✓ Change air filter only when the service indicator signals that it's time to change it:

- Turn off the engine before changing air filter.
- Wipe the outside of the cover and housing with a damp cloth and remove the cover.
- If the cover is dented or warped, replace it.
- Use extreme care when removing the filter to prevent dirt from falling into the intake duct. Use a clean, damp cloth to wipe inside of filter housing.
- Install new air filter.

! Always replace disposable air filters with new ones. Cleaning distorts filters and allows more dirt to enter.

Engine Electrical System

Maintenance Tasks

At season startup:

- ✓ Inspect breaker points for wear and replace if needed.
- ✓ Set the gap or dwell angle and lubricate rotor.
- ✓ Check timing and adjust if necessary.
- ✓ Clean all connecting terminals; cover with protectors.
- ✓ Spray silicone on electrically operated safety switches and ignition system to prevent corrosion.

Twice per year:

- ✓ In engines that have spark plugs, clean and re-gap them or replace with plugs in the recommended heat range.
- ✓ Check all terminals and electrical connections for tightness and corrosion and spray with corrosion inhibitor (NOT grease).
- ✓ Remove the distributor cap and lubricate governor weights with silicone (NOT oil).

Engine Oil and Lubrication

Have a sample of engine oil analyzed for contaminants, which signal abnormal wear. Frequency of testing depends on the engine, and these tests may not be cost-effective for small engines. Equipment dealers should know where oil can be analyzed and how often this should be done.

! Use only oil recommended by the manufacturer. Tag each engine with a label identifying the proper oil.

Maintenance Tasks

Twice per year:

- ✓ If engine was not protected during shutdown, or if oil has not been changed within the last year, change the crankcase oil and oil filter.
- ✓ Lubricate all engine accessories such as the driveshaft and U-joints.

Engine Fuel and Coolant

Maintenance Tasks

Twice per year:

✓ Remove and clean or replace the fuel filter.

Periodically:

✓ Check to be sure the fuel tank cap and oil filter cap are on tight and that gaskets aren't cracked.

✓ Check to be sure fluid level and degree of coolant protection are adequate. Make sure the radiator cap is on tight and gaskets aren't cracked.

At shutdown (end of season):

✓ Drain all fuel from the tank and lines and shut off the fuel valve. If LP gas is used, drain vaporizer-regulator. (Drain both fuel and water lines.)

✓ Remove spark plugs. Pour a tablespoon of clean motor oil into each spark plug hole. Position spark plug wire away from cylinder opening and rotate crankshaft by hand to lubricate piston and rings. Replace spark plug.

✓ Seal distributor cap with a sealant appropriate to your climate, where the cap joins the distributor housing.

✓ Seal all openings in the engine with a sealant appropriate to your climate, including air cleaner inlet, exhaust outlet, and crankcase breather tube.

✓ If the engine coolant is water, drain and refill the cooling system with water, a rust inhibitor, and antifreeze.

✓ Remove tension from belts.

✓ Remove and store batteries in a cool but not freezing location. Never store batteries directly on concrete.

✓ If engine is outdoors, cover with a water-resistant tarp.

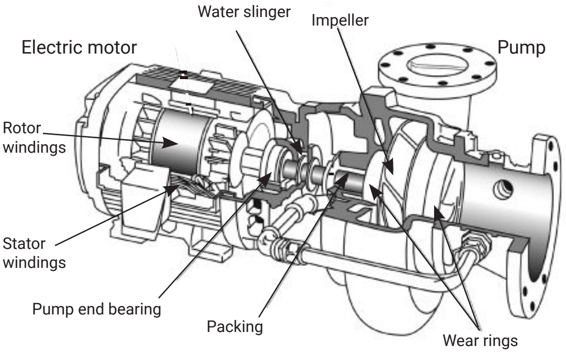

Figure 4. Centrifugal Pump and Electric Motor

PUMPING PLANT

Centrifugal Pumps

General Points

To avoid water leaks, make sure all gaskets are the correct ones for the coupling or flange. (See sidebar on gaskets on page 8.) Eliminate air leaks in your pump's suction line by coating threaded connections with pipe cement or white lead and drawing them tight. Also examine suction line welds for cracks that allow air leaks.

If the pump isn't delivering water, verify that the pump shaft is turning in the direction of the arrow on the casing. As viewed from the motor end, rotation is usually clockwise, but check instructions that came with the pump. On three-phase motors, swap any two power leads to change rotation direction. It is recommended that a qualified electrician perform this task.

If the pump doesn't prime, check for air leaks on discharge valves. Many all-metal, gate-type valves won't seal properly to create a vacuum. Sand or other debris between the rubber flap and the valve seat will also prevent check valves from sealing and forming a tight joint. If the rubber face is cracked or chipped and not seating, replace the gate valve or check valve. Check connections between pump and primer. On a hand primer, if grass or other debris is lodged in the check valve, air is pulled back into the pump at every stroke and the pump won't prime. After proper priming, fill the system slowly.

Maintenance Tasks

At season startup:

- ✓ Using new gaskets and pipe dope, reconnect to the pump any piping removed during shutdown.
- ✓ Re-install the primer and priming valve if they were removed during shutdown.
- ✓ Check to be sure the pump shaft turns freely and is free of foreign objects. Applying power could break the impeller if it's rusted to the case.
- ✓ Check pump for leaks caused by drying gaskets.
- ✓ Check intake and discharge piping for support. Make sure pump is securely bolted to platform.
- ✓ Clean drain hole on the underside of the pump.

Twice per year:

- ✓ Thoroughly clean suction and discharge piping and connections of moss and debris.
- ✓ Tighten all drain and fill plugs in the pump volute case to avoid air and water leaks. Use a pipe thread compound on all pipe threads.
- ✓ Check for cracks or holes in the pump case.
- ✓ Clean trash screening device and screens on suction pipe.

At shutdown (end of season):

- ✓ Remove suction and discharge piping in areas where ice is a problem. Make sure drain valves aren't plugged and drain water from the pump.
- ✓ Cover any exposed metal, such as the shaft, with protective lubricant to prevent corrosion.
- ✓ Cover all oil- or grease-lubricated bearings with lubricant so moisture won't rust and pit them.

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Net Positive Suction Head (NPSH) and Cavitation

A centrifugal pump doesn't pull water from a source; it can only pump water that is delivered to it. When air is removed from a suction pipe, for example by a primer pump, the weight of the earth's atmosphere forces water to rise into the pipe. The maximum height that water can rise in a pipe under a given set of conditions is known as ***Net Positive Suction Head,*** or NPSH.

Under a perfect vacuum and at sea level, atmospheric pressure can theoretically force water to rise 34 feet into a pipe, but this number drops with any increase in elevation, water temperature, or pipe friction. Practically speaking, centrifugal pumps more than 20 feet above a source water are likely to experience problems.

Insufficient NPSH often occurs when starting pumps. Since the pump is working against low pressure, it moves a larger-than-normal volume of water, increasing friction losses in the suction line and reducing NPSH. Insufficient NPSH leads to water vaporizing in the eye of the impeller, causing *cavitation*—a noisy condition where vapor bubbles collapse violently in the pump.

If cavitation is allowed to continue, the pump impeller and pump casing can become pitted and damaged. To stop cavitation that is occurring, close the discharge valve. To eliminate pump cavitation and water hammer, and to prevent high amperage draw on demand meters, open the discharge valve SLOWLY to fill the mainline every time you start the pump.

! Never let the pump run more than two minutes with the discharge valve closed.

- ✓ Remove tension from any belts.
- ✓ Open petcock and drain diaphragm-type hand primer.
- ✓ If discharge primer valve is equipped with a rubber seat, coat it with rubber preservative.
- ✓ Any rubber parts in a flexible coupling connecting the pump to the driver should also receive a coating of preservative.
- ✓ Make sure the ball valve on pressure gauge riser is closed. Remove the gauge and store it indoors.
- ✓ Seal all openings, including suction, discharge, and primer, to keep out rodents and foreign material.
- ✓ Cover the pump with a waterproof tarp.

! It is critical that all water be drained from pumps in locations where freezing is a possibility.

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Servicing Impeller and Wear Rings

If you suspect your impeller is clogged with foreign matter, damaged, or has worn wear rings, you can dismantle the pump. This is not easy and best done in the shop. Or have a qualified pump repair shop undertake this procedure. Follow the directions in the manufacturer's manual, if available, instead of the simplified directions below.

- Remove suction cover or volute case.
- Remove debris from impeller and volute. Remove pebbles lodged between vanes.
- Check wear at impeller eye and vanes. If worn, repair or replace the impeller.
- Re-machine or replace wear ring if clearance is more than 1/32 inch per side.

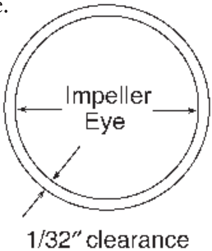

Figure 5. Impeller Eye and Wear Ring

- Replace suction cover or volute. Use a new gasket.

PUMPING PLANT

Servicing Pump Packing

A properly adjusted pump with shaft sleeve and packing in good condition shouldn't require constant readjustment but should be checked daily. If proper leakage (about 8 to 10 drops per minute) isn't running through the packing box, the packing will get overheated and dry out, eventually burning and scoring the shaft sleeve. Excessive dirt, silt, or sand in the water can also score the sleeve.

Check for an improperly greased or worn rotary shaft seal by running the pump and squirting oil on the shaft just outside the seal. Oil drawn into the seal indicates a leak.

If the pump has been out of service, the packing may be dried and hardened. Air can leak into the pump through the packing box and the pump can lose prime..

Pump Packing Maintenance Tasks

Annually:

✓ Grease packing box with a proper pump packing grease. Less frequent maintenance causes grease to harden, making this task very difficult.

- If packing box is equipped with a grease cup or zerk, apply a couple pumps of grease to the box to force out the remaining water and protect the packing.
- For a packing box without a grease cup or zerk, remove the last two packing rings and pack packing grease into the packing box until full. Add two new rings and tighten the packing gland slightly to force the grease into the subsequent packing rings. Then loosen the gland.

Replacing the Packing

Old packing should be replaced completely if you can't reduce leakage by adding new packing rings to the old ones or if packing is dried up, scorched, or leaking excessively.

! Never let the pump run more than two minutes Caution: This task is difficult. Have a qualified pump repair shop do it. Or if attempting to do it yourself, do it in the shop rather than in the field. Helpful videos are available on the Internet showing the procedure.

- Remove packing box gland nut with a wrench. Remove gland and packing, twisting two packing pullers 180 degrees apart into the exposed packing ring to pull each ring out of the packing box until all are removed. The lantern ring has two holes 180 degrees apart and can be removed with packing pullers.
- Replace shaft sleeve if worn or grooved. This usually requires pump disassembly. Once packing is burned and the shaft sleeve is scored, no amount of adjustment will maintain proper leakage for any length of time.
- Before replacing packing, insert the packing gland to make sure it enters freely to the gland's full depth. If it doesn't, clean out fragments of old packing and debris that may be obstructing it.
- Install new packing rings as far forward as you can reach. Install only the type and size of packing recommended by the manufacturer.
- Insert each ring separately. Push it securely into the box and seat it firmly. A small amount of packing grease applied to the packing will make this job a little easier. Never use sharp points to push the packing into the box. Use the packing gland, a wooden dowel, pliers handle, fingers, or other blunt object. Successive rings of packing should be installed so the joints are 120 degrees apart.
- Reinstall lantern ring (if required) in proper position to the packing rings as shown on your manual's parts page.
- Install packing gland so it enters the stuffing box straight and with all packing under uniform pressure.
- Seal gland with clip, stud, and nut.
- If packing box is equipped with a grease fitting, add a shot of grease. If there's no grease fitting, pack grease into the packing box until it's full, before inserting the last two packing rings. Add the last two rings and tighten the packing gland slightly to force the grease into the subsequent rings of packing. Then loosen the gland.

- Start pump with the packing gland loose so there is initial leakage. Tighten the packing gland only enough to draw the necessary vacuum for priming.
- Tighten gland nuts slightly and evenly every 15 to 20 minutes until leakage is reduced to 8 to 10 drops per minute or until water leaking from the box is cool.

! **Caution: Don't stop leakage entirely.**

Vertical Turbine Pumps

Vertical turbine pumps are centrifugal pumps whose impellers are connected by a vertical drive shaft to an above-ground motor or engine. They may have more than one impeller (***multi-stage***), and the drive shaft is either enclosed in a tube and oil-lubricated or else exposed and lubricated by water. Pumps less than about 50 feet in length are often called ***short-set*** while longer pumps are often called ***deep well, deep-set,*** or ***long-set***.

General Points

✓ Make a habit of periodically checking that discharge piping is firmly supported in the area near the pump. Make sure the pump is securely bolted to its platform.

✓ If your pump is installed over a well, and you've experienced water supply problems, check static level and drawdown in the well. A deeper pump setting might be required.

Maintenance

Maintenance procedures vary depending on pump length, whether it's water- or oil-lubricated, and other factors.

At season startup:

✓ For water-lubricated pumps, pre-lubricate line shaft bearings with light oil.

✓ For oil-lubricated pumps, change oil in the oil bath or reservoir for the upper bearings. Fill with approved turbine oil almost to the top of the sight of glass so bearings are covered. Make sure excess oil doesn't get on or in the motor.

✓ For oil-lubricated short-set pumps, start oil flowing to the pump one hour before starting the pump. Check to be sure the oil tube is filled before running the pump. The pump needs about 10 drops per minute.

✓ For oil-lubricated deep well pumps, start lubricating the shaft up to a week before starting the pump, or until the line shaft and column are full of oil and the oil begins to run out at the top near the stretch assembly. During this first week, allow 4 to 5 drops of oil per minute. After starting, increase to 10 to 15 drops of oil per minute. Check manufacturer's instructions to be sure of the requirement. (Oil will drip slower at night when it cools down.) The viscosity rating of the oil should be 9 or 10.

Annually (or according to manufacturer's instructions):

✓ Change bearing oil in vertical hollow shaft motors. Follow your motor manufacturer's instructions for the correct oil.

Periodically:

✓ Grease lower bearings. Refer to electric motor bearing greasing instructions on pages 11-12 and check your manufacturer's operation and maintenance literature for specifics to your equipment.

✓ Maintain packing as described on pages 22–24.

✓ Maintain bearing oil at the proper level. Overfilling the reservoir can cause oil to overflow when the motor heats up during operation. Excess oil will adhere to the motor and ventilation screens, collecting dirt and debris and reducing the motor's ability to dispel heat.

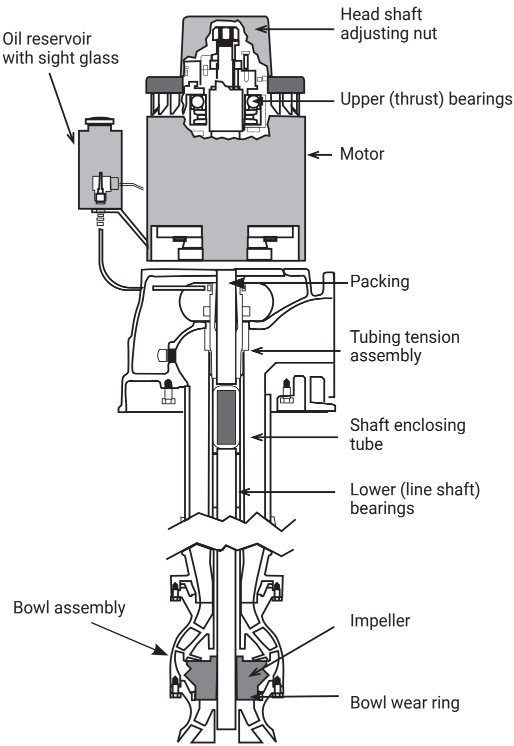

Figure 6. Oil-Lubricated Turbine Pump

Shaft Lift Adjustments

Impellers need to be positioned so they can spin freely, without rubbing on the top or bottom of the bowl. Raising or lowering impellers within their bowls can also improve pump efficiency and performance and is critically important for pumps with ***open impellers***, ones whose vanes are exposed on the suction side.

This is not something you should need to do often, but impellers should be checked and adjusted about every three to five years, or more often if you are pumping sand. On some vertical turbines, especially short-set pumps with ***closed impellers***, the adjustment is relatively straightforward and you may be able to do it yourself, using the head shaft adjusting nut, which is accessed by removing the top motor cover.

The adjustment procedure varies depending on the pump but usually involves raising the impellers an exact distance (or number of turns of the adjusting nut) from the bottom of the bowl. (Sometimes the procedure involves lowering the impellers an exact distance from the top of the bowl.) Follow your manufacturer's instructions or consult your pump dealer. Helpful videos are also available on the Internet showing the procedure.

! Caution: Pumps more than about 100 feet long experience shaft stretch or elongation, and only qualified service personnel should try to adjust the shaft lift on deep well turbines. Deep well pumps require advanced maintenance skills and adjustment must be very precise. Even a small miscalculation can cause severe pump damage.

! Caution: If, after adjusting, you can't turn the shaft easily by hand, remove the pump, disassemble, and inspect for damage or debris. If you have any questions about this procedure consult your pump dealer.

For Further Reading

A.W. Chesteron Company pump maintenance videos
youtube.com/@AWChestertonCompany/videos
Includes a five-part series on pumping packing installation

Cornell Pump. **Packing and Lantern Ring: Installation, Removal, and Grease Cup** (video). youtube.com/watch?v=uZRg4RAgdFQ

The **Hydraulic Institute** website. pumps.org/
Largest association of pump manufacturers in North America, offering application guidebooks, online tools, and calculators.

Intro to Pumps website. introtopumps.com/
Introduction to pump fundamentals, offering education and engineering training through online courses and other resources.

Scherer, Thomas. 2022. **Irrigation Water Pumps**. North Dakota State University publication AE1057. ndsu.edu/agriculture/sites/default/files/2022-02/ae1057.pdf
Overview of operating characteristics, power requirements, design considerations, and maintenance for all types of irrigation pumps.

USDA Natural Resources Conservation Service. 1997. **Irrigation Guide:** Section 15 of the **National Engineering Handbook**. directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17837.wba
*Comprehensive guide to all aspects of irrigation system design and management. See especially the discussion of pumps and motors in **Chapter 12, Energy Use and Conservation**.*

Vogel, Eugene. 2020. Pumps & Systems website. **Making Shaft Lift Adjustments in Vertical Turbine Pumps**. pumpsandsystems.com/making-shaft-lift-adjustments-vertical-turbine-pumps

Submersible Pumps

A submersible pump is a turbine pump that is close-coupled to a submersible electric motor. Since both pump and motor are suspended in water, the drive shaft and bearings required for a deep- well turbine pump are eliminated. The pump is located above the motor and water enters the pump through a screen located between the pump and motor.

Submersible pumps use enclosed impellers. The motors are smaller in diameter and longer than turbine pump motors. Inadequate circulation of water past the motor may cause it to overheat and burn out. The riser pipe must be long enough to keep the bowl assembly and motor completely submerged at all times. The well casing must be large for water to flow easily past the motor. Electrical wiring from the pump to the surface must be watertight with sealed connections.

Troubleshooting

Find your symptoms and then look across the table to see possible causes. Most often, suction problems are the cause. Contact your pump repair shop for additional help.

! This guide is general and does not cover all possible system configurations or problems.

Symptoms

Causes of Suction Problems	Pump does not deliver water	Pump has insufficient capacity (gpm)	Pump loses prime after starting	Pump has insufficient pressure	Pump requires excessive power	Packing box leaks water excessively	Packing box has short life	Pump vibrates or is noisy	Bearings have short life	Pump overheats and seizes
Pump not primed	•	•								•
Insufficiently submerged suction pipe inlet	•	•	•							
Pump or suction pipe not completely filled with water	•	•	•					•		
Insufficient Net Positive Suction Head (NPSH — See page 20 for explanation)	•	•						•		•
Suction line, strainer, or centrifugal pump balance line plugged		•					•			
Air leaks into suction line		•	•							
Air leaks into pump through packing box		•	•							
Excessive air or gas in the water		•	•	•						
Foot valve too small, insufficiently submerged, or partly clogged				•				•		

Causes of System Problems

Causes of System Problems	Pump does not deliver water	Pump has insufficient capacity (gpm)	Pump loses prime after starting	Pump has insufficient pressure	Pump requires excessive power	Packing box leaks water excessively	Packing box has short life	Pump vibrates or is noisy	Bearings have short life	Pump overheats and seizes
Speed (rpm) too low	●	●		●						
Parallel operation of pumps unsuitable	●	●		●						●
Total system head higher than pump design head	●	●		●	●					
Wrong direction of pump rotation	●			●	●					
Speed (rpm) too high					●					
Total system head lower than pump design head					●					

Causes of Pump Problems

Causes of Pump Problems	Pump does not deliver water	Pump has insufficient capacity (gpm)	Pump loses prime after starting	Pump has insufficient pressure	Pump requires excessive power	Packing box leaks water excessively	Packing box has short life	Pump vibrates or is noisy	Bearings have short life	Pump overheats and seizes
Rotary shaft seals (packing) leak air	●									
Foreign matter in impeller	●	●			●			●		
Wear rings worn				●	●					
Impeller damaged				●				●		
Defective pump casing gasket allowing internal leakage				●						
Misaligned pump & driving unit					●	●	●	●	●	●
Bent shaft between pump & motor / engine					●	●	●	●	●	
Rotating part rubbing stationary motor part					●			●	●	●
Packing gland too tight. No flow to lubricate packing and shaft.					●		●			
Packing worn, improperly installed, or wrong for operating conditions					●	●	●			
Cooling water not getting to water-cooled packing boxes							●			
Packing forced into pump interior						●	●			
Shaft or shaft sleeves worn or scored at the packing						●	●			

Causes of Pump Problems, continued

Symptoms

Causes	Pump does not deliver water	Pump has insufficient capacity (gpm)	Pump loses prime after starting	Pump has insufficient pressure	Pump requires excessive power	Packing box leaks water excessively	Packing box has short life	Pump vibrates or is noisy	Bearings have short life	Pump overheats and seizes
Shaft running off-center						•	•	•	•	•
Impeller or rotor (electric motors) out of balance						•	•	•	•	•
Bearings worn							•	•	•	•
Foundation or platform not rigid or mounting is loose								•		
Pipe not supported								•	•	
Under- or over-greasing of bearings or greasing sealed motor bearings								•	•	
Condensation of atmospheric moisture in bearing housing								•	•	
Lack of or improper lubrication								•	•	
Scoring or rusted bearings (turbine pump)								•	•	
Improperly installed bearing, incorrectly assembled stacked bearings, unmatched bearings used as a pair (turbine pump)								•	•	
Excessive thrust, seen as shaft movement from mechanical failure or failure of hydraulic balancing device								•	•	•

Pumping Plant Maintenance Form

Field # ____ Year ____ Begin date ________ End date ________

Date pump start-up ______ Beginning PSI ____________

Midseason PSI __________ Date ____________________

End of season PSI ______ Date ____________________

Motor amps ____________ Test date ________________

Motor amps ____________ Test date ________________

Pump:

Installation Date ________

Dealer ________________

Mfr. __________________

Model _________________

Serial no. _____________

Rated head ____________

Rated flow ____________

Repair date ___________

By ____________________

Desc. of repair __________

____

Motor:

Installation date ________

Dealer ________________

Mfr. __________________

Model _________________

Serial no. _____________

Rated horsepower ________

Service factor __________

Repair date ___________

By ____________________

Desc. of repair ________

____

Date Replaced / Serviced	System 1	System 2
Gauges		
Motor bearings		
Pump packing		
Oil change		
Filters		
Hoses		
Cooling system		
Lube		
Adjust turbine bowls		
Primer pump		

PUMPING PLANT

3. Saving Energy

Pumping water for irrigation is the largest on-farm use of energy in California agriculture. While microirrigation offers many energy-saving advantages, these advantages do not come automatically. They all depend on having a system that's properly designed, installed, and maintained.

Causes of Wasted Energy

Lack of system maintenance

- ✓ Develop and follow a regular maintenance schedule. Impellers that are out of adjustment, plugged screens, worn nozzles, engines that need a tune-up, worn shaft sleeves, leaking gaskets, and dried out bearings or pump packing are only a few of the problems you can avoid with regular maintenance.

The wrong pump for the system

- ✓ If your pump is oversized, undersized, or just the wrong one for your system, it may never be able to operate efficiently. Oversized pumps have been called the largest source of wasted energy in California irrigation.

Pump wear from cavitation or abrasion

- ✓ Cavitation damages pump impellers, reducing efficiency. If your pump is cavitating, determine whether you have sufficient NPSH. (See page 20 for an explanation of NPSH.) You should also have a valve on the discharge side of your pump. Use it to fill the mainline slowly to avoid cavitation.
- ✓ If your water is high in sediments, re-engineer the intake structure so that sediment settles out before water enters the suction line.

Improperly sized or designed fittings

✓ Replace undersized valves and other fittings with ones of the correct size to reduce friction losses.

Water source changes

✓ If the water level in your well has dropped, you may need to reset the pump at a lower level. To compensate for the increased head, you may have to add more stages to turbine or submersible pumps.

✓ If surface water level drops, you may need to relocate centrifugal pumps closer to the water source to supply sufficient NPSH. (See page 20.)

✓ If turbine or submersible pump capacities don't fit the well characteristics, you may need to replace the bowls with new ones suited to your well capacity.

Hardware Improvements

Electric Motors

✓ Rebuild your older motor and gain several percentage points in motor efficiency. The procedure typically involves replacing the bearings, rewinding, and "dipping and baking," and is done by qualified motor repair shops.

✓ Premium efficiency motors are 2 to 4% more efficient than standard efficiency motors and usually have higher service factors, longer insulation and bearing lives, and less vibration. Consider a premium-efficiency motor in all new installations if the cost of rewinding exceeds 65% of the price of a new motor, and when replacing over- or undersized motors.

! Some premium-efficiency motors draw a higher startup current. Make sure your system can handle it.

- ✓ If you're putting in a new system, be aware that an 1800 rpm motor is more efficient than a 3600 rpm motor. For example: an open, drip-proof 3600 rpm 40-hp motor is 91.7% efficient, whereas an 1800 rpm, 40-hp motor is 93% efficient. Since an 1800 rpm motor makes half the revolutions of a 3600 rpm motor, maintenance needs are lower and motor life is longer.

- ✓ Consider a variable speed drive (also called a ***variable-frequency drive*** or VFD) if you need to produce a wide range of flows and pressures to meet varying system needs. Cost-effectiveness of a variable-speed drive will depend on operating hours, pump size, and crop value.

- ✓ ***Constant-pressure valves*** or ***pressure-compensating emitters*** may be lower-cost alternative to a variable speed drive, although they are less energy-efficient. Contact your equipment supplier for more information.

Engines

- ✓ Keep your engine drive in peak operating condition to reduce fuel costs and downtime. Refer to pages 14-17 for tune-up advice.
- ✓ If your radiator-cooled engine uses a cooling fan, 5 to 8% of the fuel going into the engine is used to run the fan, not pump water. You can install equipment that uses irrigation water to cool the engine, eliminating the need for a fan. Check with an engine equipment dealer for more information.
- ✓ Consider using the variable-speed ability of your engine to your advantage. By varying rpm, you can vary the flow rate, total dynamic head, and brake horsepower requirements of the pump to meet varying system needs and save fuel. Consult an engine equipment or irrigation equipment dealer for advice.

Centrifugal Pumps

- ✓ Rebuilding your older pump to increase its efficiency can often be a cost-effective alternative to buying a new pump. Rebuilding usually involves replacing shaft sleeves, packing, and wear rings, along with re-machining or replacing the impeller.

- ✓ For optimum efficiency, the pump must match the requirements of the water source, water delivery system, and irrigation equipment. If your pump is under- or oversized and does not match the system needs, pump replacement is the best option. Running an oversized pump with a mainline valve half-closed is like driving your car with your foot on the brake and accelerator at the same time.

Turbine Pumps

- ✓ Vertical shaft turbine pumps lose efficiency if they are not regularly adjusted. Refer to the pages 24-27 for instructions for short-coupled turbine pumps. Only qualified pump service personnel should adjust deep-well turbine pumps.

- ✓ Rebuilding your older turbine pump to increase its efficiency can be a cost-effective alternative to purchasing a new pump. Rebuilding usually involves replacing shaft sleeves, packing, and bearings, and also re-machining or replacing the bowls.

Mainlines

- ✓ Mainlines too small for the volume of water pumped contribute to high head requirements and lowered system efficiency. Water velocity through a mainline should never exceed 7 feet per second (fps). Velocities below 5 fps are best and are achievable through good design. Refer to page 49 in the ***Conversions and Formulas*** section for recommended maximum flow rates for different pipe sizes.

Electrical Use and the Charges on Your Power Bill

Electricity is measured in ***watts*** or ***kilowatts*** (equal to 1,000 watts). The number of watts is the product of operating voltage times the current (or amps) flowing to the load. A ***kilowatt-hour (kWh)*** is an amount of energy equivalent to using one kilowatt (kW) over a one-hour period. To visualize one kilowatt-hour, it may be helpful to imagine ten 100-watt lightbulbs burning for one hour.

Although billing procedures vary among electric providers and in different parts of the country, irrigation bills typically include three basic charges for electricity:

1. **Base Rate or Meter Charge.** This is either a monthly or seasonal charge. Some utilities roll this charge into the electric consumption or energy rate.

2. **Electric Consumption or Energy Charge.** This charge is based on the amount of electricity used over time as recorded on the kilowatt-hour meter, with a rate charged for each kWh consumed.

3. **Electric Demand Charge.** Many utilities charge their larger customers an amount over and above the charge for kilowatt-hour energy consumption, to maintain enough capacity to serve these large customers' needs. (Customers with small motors may not have a demand charge.)

Electric providers generally calculate the demand charge in one of two ways, each intended to give an approximation of the customer's size:

- The demand charge may be based on connected load or horsepower, with a fixed rate charged per horsepower during each billing period. This charge is usually based on "nameplate" horsepower. For example, if your demand charge is $10 per horsepower your demand charge for a 40-horsepower system would be $400.

- The demand charge may be based on maximum wattage (peak demand) during the billing period. In this approach a special ***demand meter*** takes frequent wattage measurements throughout the billing period. (15-minute intervals are common.) The demand charge is based on the interval during the billing period with highest wattage.

Example: Your demand charge is $10 per kilowatt. During March, your demand meter records 29 kilowatts during some 15-minute intervals, 30 kilowatts during other intervals, and 31 kilowatts during still other intervals. Your demand charge for the month of March is $310.

Note that, in this example, the demand charge has nothing to do with how many hours you run the system. The charge is the same whether you irrigate 15 hours or 15 days.

Make sure you know how you are charged for electricity and ask a customer service representative at your utility to explain your rate structure. Know your meter reading dates and be alert for opportunities to reduce or avoid demand charges by making small changes in the timing of your operations.

Example: You're ready to start irrigating for the year on March 30 but know that your meter will be read March 31. You wait two days and avoid paying a March demand charge.

Time-of-Use Rate Schedules

In many parts of California, irrigators can sign up for ***time-of-use*** electric rates, receiving substantial discounts in exchange for agreeing not to pump during times of the week when the demand for energy is highest. Non-pumping times are commonly noon until 6 p.m., and may or may not include weekends. Call your utility to see if a time-of-use rate schedule may work for you.

It's especially important to think about time-of-use rates when you're designing a new system. Sometimes a modest design change—such as a slightly larger pump or smaller number of zones—makes a big difference in your ability to complete irrigation cycles during off-peak times.

Causes of High Demand

Your demand meter can alert you to problems. Track the demand amount on your power bills and compare month to month and year to year.

- Is demand increasing gradually even though you haven't made changes to your system? This might indicate leaks that are growing or increasing wear in the pump or motor bearings.
- Did demand take a sudden jump? This could signal a large leak or major problem such as motor overloading, inadequate bearing lubrication, voltage imbalance, or other problems.
- Is average demand too high for the connected horsepower? The demand reading on your power bill in kW should be about ¾ of your connected horsepower. For example, a 40-hp pump should have a demand reading of about 30 kW if no other loads are on this meter.

Working with Your Utility

California irrigators are fortunate to have access to some of the most comprehensive and widely available irrigation efficiency programs in the country. Services offered may include free pump testing, system evaluations, design assistance, cash incentives for retrofits, and free educational seminars.

In recent years, California utilities have offered cash incentives for a wide variety of equipment and measures, such as:

- Converting from high-pressure sprinklers to microirrigation
- Automatic control systems
- Irrigation scheduling software and hardware
- Flow measurement and soil moisture meters
- Low pressure filters and emitters
- Well cleaning to reduce draw-down
- Replacing valves and fittings that are causing pressure losses
- Retrofit or repair of pumps
- Actions that reduce air entrainment
- Premium high-efficiency motor retrofits
- Variable-frequency drives

Inquire to see if your utility is currently offering one of these programs. Make a point of getting to know the customer service representative in your area.

Handy Conversions and Formulas

Source

Most conversions and formulas in this section come from the USDA Natural Resources Conservation Service. 1997. **Irrigation Guide:** Section 15 of the **National Engineering Handbook**. directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17837.wba

Flow Rate Conversions

Gallons Per Minute (gpm)	Cubic Meters Per Hour	Acre Feet Per 24 Hours	Cubic Feet Per Second (cfs)	Acre Inches Per 24 Hours
1	0.2270	0.004	0.00223	0.05
4.403	1		0.00981	
224.4		1	0.50	11.9
448.8	101.9	2	1	23.8
673.2		3	1.50	35.7
897.6		4	2.00	47.6
1,000.0		4.5	2.23	54.0
1,122.0		5	2.50	59.5
1,346.4		6	3.00	71.4
1,570.8		7	3.50	83.3
1,795.2		8	4.00	95.2
2,244.0		10	5.00	119.0
2,692.8		12	6.00	142.8
3,141.6		14	7.00	166.6
3,590.4		16	8.00	190.4
4,039.2		18	9.00	214.2
4,488.0		20	10.00	238.0

Volume Conversions

One cubic foot per second (cfs) is a volume of water one foot wide, one foot long, and one foot high passing a given point every second.

One acre-inch is a volume that would cover one acre of land one inch deep. One acre-foot would cover one acre one foot deep.

One acre-inch per 24-hour day takes 18.7 gpm continuous flow.

A flow of one cfs for one hour = 0.99 acre-inch.

Continuous flow of 1 gpm per acre = 0.053 inches per 24-hour day.

$$\text{gpm} = \text{cfs} \times 448.8 \qquad \text{cfs} = \text{gpm} \times 0.00223$$

$$\text{Gross application of water (in acre inches per acre)} = \frac{\text{gpm} \times \text{hours}}{450 \times \text{number of acres}}$$

One milligram per liter (mg/L) = one part per million (ppm).

Liters	Gallons	Cubic Feet	Cubic Meters	Acre Inches	Acre Feet
1	0.2642	0.0353			
3.785	1	0.1337	0.003785		
28.32	7.48	1	0.02832		
1000	264.2	35.314	1		
	27,154	3,630		1	0.0833
	325,850	43,560	1233.5	12	1
	1 million				3.07

Weight Conversions

1 kilogram = 2.20 pounds = 1,000 grams

1 gram = 28.4 ounces

1 pound = 7,000 grains

1 gallon water = 8.33 pounds

1 cubic foot water = 62.4 pounds

Length Conversions

Inches	Links	Feet	Yards	Meters	Rods/ Poles	Chains	Kilo- meters	Miles
7.92	1							
12		1		0.3048				
36		3	1	0.9144				
39.37		3.28		1			0.001	0.000622
	25	16.5	5.5		1			
	100	66	22		4	1		
			1093.61	1000			1	0.62137
		5280	1760	1609	320	80	1.61	1

Area Conversions

Square Meters	Acres	Hectares	Square Feet	Square Yards	Square Rods	Square Chains
1	0.000247	.0001	10.76	1.196		
4049	1	0.405	43,560	4,840	160	10
10,000	2.471	1	107,639	11,960		

Square feet × 0.000023 = acres

Square yards × 0.00021 = acres

Square rods × 0.0062 = acres

Square chains × 0.10 = acres

Triangle area = ½ base × height

Rectangle area = length × width

Circle area = $\pi \times \text{radius}^2$ or $3.1416 \times \text{radius}^2$

Circle circumference = $\pi \times$ diameter or $3.1416 \times$ diameter

Temperature Conversions

$$°F = (1.8 \times °C) + 32$$

$$°C = \frac{(°F - 32)}{1.8}$$

Power Conversions

Kilowatt	Horsepower	BTU/hour
1	1.341	3,413
0.746	1	2,545

Electrical Formulas

Single Phase Power Supply

Electric Demand = kW = $\frac{V \times I}{1000}$

Electric Consumption or Energy = kWh = kW × hours

$= \frac{V \times I \times \text{hours}}{1000}$

Where V = voltage I = current (amps) kW = kilowatts

Three Phase Power Supply

Electric Demand = kW = $\frac{V \times I \times 1.73}{1000}$

Electric Consumption or Energy = kWh = kW × hours

$= \frac{V \times I \times 1.73 \times \text{hours}}{1000}$

Kilowatt (kW) = Electric Demand = 1000 watts

Kilowatt-hours (kWh) = Electric Consumption

= 1000 watts × hours = kW × hours

To find approximate annual operating hours for an irrigation system, divide average monthly demand from your electric bills by total kWh over the whole irrigation season (found by adding together the kWh numbers in your power bills).

Example: Average monthly demand was 25 kW and you used a total of 27,650 kWh during the irrigation season. 27,650 kWh ÷ 25 kW = 1,106 operating hours.

Pressure Conversions

Pounds per Square Foot	Inches of Head	Kilo-Pascals	Feet of Head	Inches of Mercury	Pounds per Square Inch	Atmospheres
1	0.1926	0.0479	0.01605	0.01414	0.00695	0.000473
5.1972	1	0.249	0.08333	0.07343	0.0361	0.002454
20.886	4.022	1	0.331	0.296	0.143	0.0099
62.32	12	3.024	1	0.88	0.4335	0.0295
70.7262	13.6185	3.3864	1.1349	1	0.491	0.033421
144	27.73	6.985	2.31	2.03	1	0.068
2,116.22	407.5	101.32	33.93	29.92	14.7	1

Pressure Loss: pounds per square inch (psi) lost per 100 feet of pipe

	3/4-inch pipe			1-inch pipe			1.5-inch pipe			2-inch pipe			3-inch pipe		
gpm	S	PE	P	S	PE	P	S	PE	P	S	A	P	S	A	P
2	0.83	0.45	0.39	0.26	0.14	0.12	0.03								
5	4.55	2.43	2.14	1.40	0.75	0.66	0.17	0.09	0.08	0.05	0.06	0.02			
10		8.79	7.74	5.07	2.72	2.39	0.63	0.34	0.30	0.19	0.20	0.09	0.03	0.03	
15					5.75	5.06	1.34	0.72	0.63	0.40	0.43	0.19	0.06	0.05	0.03
20						8.63	2.28	1.22	1.07	0.68	0.72	0.32	0.10	0.09	0.05
30							4.83	2.58	2.27	1.43	1.54	0.67	0.21	0.19	0.10
40							8.22	4.40	3.87	2.44	2.62	1.15	0.36	0.33	0.17
50								6.65	5.86	3.68	3.96	1.74	0.54	0.50	0.25
60									8.21	5.16	5.54	2.43	0.76	0.70	0.36
70										6.87	7.38	3.24	1.01	0.93	0.47
80												4.15	1.29	1.19	0.61

S = Steel Pipe   PE = Polyethylene Pipe A = Aluminum Pipe P = Plastic Pipe

Example: A flow of 20 gpm through 1.5-inch polyethylene pipe is losing 1.22 psi per 100 feet of pipe.

Note: Multiply psi lost × 2.31 to get feet of head lost.

Pressure Loss: pounds per square inch (psi) lost per 100 feet of pipe, continued

	4-inch pipe			6-inch pipe			8-inch pipe			10-inch pipe			12-inch pipe		
gpm	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P
100	0.54	0.35	0.24	0.07	0.05	0.03									
150	1.30	0.75	0.51	0.16	0.10	0.07	0.04	0.03							
200	1.90	1.58	0.87	0.27	0.18	0.12	0.06	0.04	0.03	0.02					
300	4.10	2.75	1.85	0.57	0.40	0.26	0.14	0.09	0.06	0.05	0.03	0.02	0.02		
350		3.60	2.35	0.75	0.50	0.34	0.19	0.12	0.08	0.06	0.04	0.03	0.03		
400		4.65	3.20	1.00	0.65	0.44	0.24	0.16	0.11	0.08	0.05	0.04	0.03	0.02	
450			4.00	1.20	0.80	0.55	0.30	0.19	0.14	0.10	0.06	0.05	0.04	0.03	
500			5.00	1.50	1.00	0.67	0.36	0.24	0.17	0.12	0.08	0.06	0.05	0.03	0.02
600				2.10	1.38	0.95	0.51	0.34	0.23	0.17	0.11	0.08	0.07	0.05	0.03

S = Steel Pipe A = Aluminum Pipe P = Plastic Pipe

Pressure Loss: pounds per square inch (psi) lost per 100 feet of pipe, continued

	4-inch pipe			6-inch pipe			8-inch pipe			10-inch pipe			12-inch pipe		
gpm	S	A	P	S	A	P	S	A	P	S	A	P	S	A	P
700				2.80	1.85	1.25	0.70	0.45	0.31	0.23	0.15	0.10	0.10	0.06	0.04
800				3.60	2.40	1.60	0.87	0.55	0.39	0.29	0.18	0.13	0.12	0.08	0.06
900				4.40	3.00	2.00	1.10	0.72	0.50	0.36	0.24	0.17	0.15	0.10	0.07
1000					3.60	2.45	1.33	0.87	0.61	0.45	0.28	0.21	0.19	0.12	0.08
1200					5.00	3.50	1.90	1.18	0.85	0.63	0.41	0.29	0.26	0.17	0.12
1400						4.55	2.55	1.65	1.12	0.85	0.54	0.38	0.35	0.23	0.16
1600							3.20	2.15	1.42	1.10	0.69	0.48	0.45	0.29	0.20
1800							4.00	2.65	1.79	1.34	0.90	0.60	0.56	0.36	0.25
2000							4.90	3.20	2.20	1.65	1.10	0.74	0.69	0.45	0.30

S = Steel Pipe A = Aluminum Pipe P = Plastic Pipe

Example: A flow of 1,400 gpm through eight-inch steel pipe is losing 2.55 psi per 100 feet of pipe.

Water Velocity Formula

Water velocity in feet per second (fps) = 0.409 × flow in gallons per minute (gpm) divided by the pipe diameter (in inches) squared.

$$= \frac{0.409 \times \text{flow (gpm)}}{\text{pipe diameter (inches)}^2}$$

Example: 300 gpm through a 6-inch diameter pipe.

$$= \frac{0.409 \times 300}{6^2} = 3.4 \text{ fps}$$

Recommended Maximum Flow Rate by Pipe Size

Pipe diameter (inches)	2	3	4	5	6	8	10	12	16
Flow rate (gpm)	50	110	200	310	440	780	1225	1760	3140

Note: For maximum efficiency:

- Keep water velocity in suction line < 5 fps; 2-3 fps is best.
- Keep water velocity in mainline < 7 fps; < 5 fps is best.
- Increasing pipe size, reducing the flow rate, and changing pipe type can save energy by lowering water velocity.

Other Pumping Plant Formulas

Total Dynamic Head (TDH) =
Total Lift (Suction + Discharge)
+ Pressure Head
+ Velocity Head
+ Pipe Friction Loss

Discharge Lift (feet) = Distance in feet from centerline of pump impeller to pressure gauge.

Suction Lift (feet) = Distance in feet from water level on suction side of pump to centerline of pump impeller.

Pressure Head (feet) = Pressure in psi from a gauge at or near the pump discharge flange × 2.31 (psi × 2.31).

Example: If the gauge reads 20 psi, the pressure head = 20 × 2.31 = 46.2 feet.

Velocity Head (feet) = Water velocity in feet per second squared divided by 64.35 $= \dfrac{(\text{fps})^2}{64.35}$

Example: Using water velocity found on preceding page,

$$= \frac{(3.4 \text{ fps})^2}{64.35} = 0.18 \text{ feet}$$

Note: *In most pumping systems, velocity head can be ignored.*

Pipe Friction Loss (feet): See tables on pages 46-48. Multiply psi losses times 2.31 to get feet of head loss.

Example: 300 gpm flowing through 6-inch steel pipe is losing 0.57 psi or 1.32 feet of head per 100 feet of pipe. If the system is 200 feet long, Pipe Friction Loss = 2.64 feet.

Water Horsepower (WHP)

$$= \frac{\text{system gallons per minute (gpm)} \times \text{TDH (in feet)}}{3{,}960}$$

Input kW (for pumps with electric motors)

$$= \frac{3.6 \times \text{Revs} \times \text{Kh} \times \text{PTR} \times \text{CTR}}{\text{Time (seconds)}}$$

Where: *Revs* = *Number of meter revolutions (usually 10)*
Kh = *Meter Constant (noted on electric meter)*
PTR = *Transformer Ratio (usually 1)*
CTR = *Transformer Ratio (usually 1)*
Time = *Number of seconds it takes for the meter to make 10 revolutions*

Electric Horsepower (EHP) = Input kW × 1.34

Diesel Input Horsepower (IHP_{diesel})

$$= \frac{\text{gallons of diesel used per hour}}{55}$$

Propane Input Horsepower ($IHP_{propane}$)

$$= \frac{\text{gallons of propane used per hour}}{36.15}$$

Natural Gas Input Horsepower ($IHP_{natural\ gas}$)

$$= \frac{\text{dKt of natural gas used per hour}}{392.9}$$

Note: *1 dKt = decatherm = 1,000,000 Btu. Contact your natural gas supplier for a conversion to decatherms, if needed.*

$$\text{Overall Pumping Plant Efficiency} = \frac{WHP}{EHP} \quad \text{OR} \quad \frac{WHP}{IHP^{*}}$$

*Diesel, propane or natural gas

Brake Horsepower (BHP) =

$$\frac{\text{motor efficiency} \times EHP}{100} \quad \text{OR} \quad \frac{\text{motor efficiency} \times IHP}{100}$$

$$\text{Pump Efficiency} = \frac{WHP}{BHP}$$

Net water application per irrigation period (inches) =

$$\frac{\text{set time (hrs)} \times \text{flow rate (gpm)} \times 96.3 \times \text{system efficiency}}{\text{irrigated area (square feet)}}$$

Set time (hours) =

$$\frac{\text{net water application (inches)} \times \text{irrigated area (sq ft)}}{\text{flow rate (gpm)} \times 96.3 \times \text{system efficiency}}$$

A Simple Method to Estimate Your Pumping Plant Efficiency

Pumping plant efficiency measures the amount of power produced by the pump (known as ***water horsepower***) per unit of input power (known as ***input horsepower***).

When the system is operating under normal, stable conditions, follow the steps below:

Step1. Find total dynamic head (TDH) in feet.

Read pressure from gauge ______ psi × 2.31 = ______feet

Add height* if pump is above water surface + ______feet

OR

Subtract height* if pump is below water surface _ ______feet

To get total dynamic head (feet). ______TDH

*Height = distance from water surface to centerline of discharge pipe.

Step 2. Find flow rate in gallons per minute.

If your system has a flow meter, read gallons per minute (gpm). If meter reads in cubic feet per second (cfs), multiply times 448.8 to get gpm.

______ gpm

If your system doesn't have a flow meter, use one of the methods on pages 33-37 of the *System Management & Maintenance* side of this book to find your flow rate, based on direct measurements of emitters or pressure measurements.

Step 3.Find water horsepower (WHP) from Steps 1 and 2.

_____ (TDH) × _____ (gpm) ÷ 3,960 = _____ WHP

Step 4. Find input horsepower (IHP).

4a. For electric motors, locate the meter constant on the electric meter faceplate: marked Kh and followed by a number such as 57.6 or 43.2. Using a stopwatch, time the number of seconds it takes for the disk in the meter to make 10 revolutions or for the little bar to move across the screen 10 times. If your meter shows kilowatt demand, simply multiply this number times 1.34 to get input horsepower.

48.1 × ______ (Kh) ÷ ______ (secs) = ______ IHP

______ (KW) × 1.34 = ______ IHP

4b. For diesel engines, divide gallons of fuel used per hour by 55 to get input horsepower. (Divide gallons per hour by 36.2 for propane or decatherms natural gas per hour by 392.9.)

______ (gallons per hour) ÷ 55 = ______ IHP

Step 5. Determine pumping plant efficiency, using results from steps 3 and 4.

______ (WHP) ÷ ______ (IHP) = ______ % Efficiency

Step 6. Compare your efficiency to expected values below.

Rated Motor Size (HP)	Expected Efficiency (%)
3 to 5	66 %
7.5 to 10	68 %
15 to 30	69 %
40 to 60	72 %
75 +	75 %

Note: *Efficiencies are for older pumps in excellent condition. New pumps and pumps used under mild conditions or improved design will have higher efficiencies.*

Any system with pumping plant efficiency less than 65% has room for improvement. A result in the 50% range or lower indicates a significant problem requiring attention.

Note that unless hours of operation are reduced, improving pumping plant efficiency may simply increase flow rates without reducing energy consumption.