Ditch Pumps

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We have an irrigation ditch that supplies us with water for irrigation and we use it to water our lawn. The tool of choice for this is a ditch pump since we can't flood irrigate.

For a variety of reasons, we've had to replace the pump a number of times and I had to rebuild the setup once, so I feel I've developed a little experience in dealing with these ditch pumps. I thought I'd write down these experiences in the hope they'll help someone else.

We live on a one-acre lot (4047 m^2) and 70% of that is lawn. It would bankrupt me if I had to water this with city water because we technically live in a desert area that can get hot and dry in the summer (summer temperatures can get up to around 105 °F (40 °C) and occasionally beyond). Fortunately, ditch water is available, irrigation taxes aren't horrible, and the cost of electricity to run a ditch pump isn't terribly expensive (it costs about $8 per month in electricity to run our sprinklers). The cost of the pump and installation get amortized out over a few years.

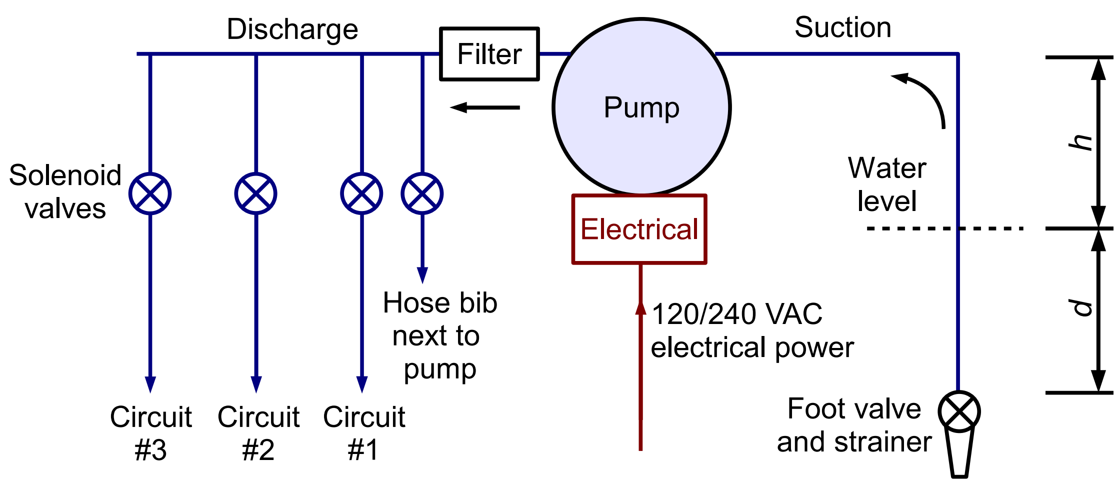
Prices given are in US dollars and are approximately correct at the time of writing in the US (June of 2013). I'll use " to denote dimensions in inches and ' to denote dimensions in feet.

Principles

A ditch pump is a pump that is typically used to pump water from a ditch or lake for irrigation purposes. These pumps typically can't draw water from too deep of a supply, so are not suitable for use on deep wells.

I will reference the Franklin Electric manual for RLSP "Lawn and Turf Pumps" (these are sold under the Red Lion brand). Our particular pump is the RLSP-100, a 1 horsepower (0.75 kW) pump.

Here's a schematic diagram of the typical ditch pump system (the sprinkler valve controller is not shown):



The distance *h* is called the head and is how far vertically below the pump's inlet the water level is. For my setup, the head is about 0.3 m (maximum *h* for these pumps is 25 feet (7.5 m)). The distance *d* is how far below the static water level the foot valve is. The usual recommendation is around 2 feet, but the cistern I use limits this to about 14 inches. If the intake is too close to the water surface, a whirlpool can form and you can suck air into the pump, which can substantially reduce the flow and might damage the pump over time.

These pumps are not self-priming, which means the pump won't work if the suction line and pump are not full of water. That also explains the need for a foot valve, which is a check valve with a strainer -- it lets the water flow to the pump, but when the pump's suction stops, the valve closes, maintaining the pump's prime. Thus, it's important to have a suction line that doesn't leak and a foot valve that closes correctly. In the strainer on the 2 inch foot valve we have, the strainer is a piece of stamped stainless steel with holes about 2 mm in diameter. Typical foot valves are made from cast bronze or brass.

The 1 hp ditch pump cost $230 at a local supply house. Both of the places I like to go to get plumbing and electrical stuff stock Red Lion pumps. Most importantly, when something goes wrong and the pump is under warranty, these dealers will instantly give you replacement parts or even a replacement pump (they know it can be critical to get a pump working again).

Here's the RLSP-100 pump's flow in gallons per minute (gpm) and pressure in psi (pounds per square inch):

Discharge pressure		Flow	
psi	**kPa**	**gpm**	**10^{-3} m^3/s**
10	69	63	4.0
20	138	46	2.9
30	207	38	2.4
40	276	7	0.44

The pump has a 2" US NPT hole for input and the manufacturer recommends using 2" piping (60 mm OD) for the suction line. The outlet is a 1.5" US NPT hole (48 mm OD).

The filter in the output piping is optional and is intended to keep small seeds etc. from lodging in the sprinklers. My next-door neighbors use the identical pump and don't use a filter. They apparently haven't had any problems with stuff getting in their sprinklers (we draw water from the same cistern). However, I've used the filter for 25 years and I've seen how much small crud gets filtered out by the filter, so I feel good about using it. Since I keep a spare clean filter element at the pump, it takes about 10 seconds to shut the pump off, change the filter element, and start the pump up again. I then take the dirty filter element to one of the sprinklers and clean it off in the spray. This is so easy to do that I change the filter element once or twice per week. A dirty filter can cut our flow rate in half. Every 3 or 4 years I put a new o-ring on the filter element, but otherwise they should last indefinitely.

History

We moved into this house in 1987 and the existing owners used the well to supply water for the sprinklers. Since we wanted to add watering the back half of the property, I added three new sprinkler circuits and a ditch pump to supply the water. Our next-door neighbor had a concrete cistern he had made that provided a pool of water from the ditch at the back of his property. He brought the water to the cistern through about 100' (30 m) of 12" diameter PVC pipe, so there was plenty of water. He kindly gave me permission to take the water for my ditch pump from his cistern.

At the time I installed the pump, the instructions said it was OK to use either 1.5" or 2" pipe for the suction piping. I chose to use 1.5" and we used this setup successfully for about 23 years.

We had two pumps crack because of an early freeze in the fall, so this cost us time and money to replace the pumps. To avoid the early freezes, I removed the four bolts holding the pump together and broke the two pump halves apart to drain the water from the pump after the ditch water is turned off in the fall. Eventually I installed a 3/8" valve on a 6" nipple that lets me just open the valve to drain the pump in the fall (so I don't have to take the pump halves apart anymore). These early pumps were the Water Ace brand.

In 2009, the cistern somehow cracked and leaked water. I had mounted our pump on a plywood platform about 3 inches below ground level to minimize the head. Unfortunately, the leaking cistern meant the pump's motor was flooded with enough water to ruin the bearings. Thus, we had to replace the pump for the third time and the local supply place was now carrying Wayne pumps. I rebuilt the whole ditch pump setup and set the pump on a platform that is supported by four cinder blocks, so this flooding of the pump will never happen again.

In the summer of 2012, our Wayne ditch pump failed for an electrical problem (the motor blew out), so we had to buy a new pump. Our local dealer said they quit carrying Wayne pumps because they had too many electrical problems and started selling Red Lion, so we bought the Red Lion pump. I installed it in early August 2012 and it ran fine through the remainder of the season (our ditch water is turned off around mid-October).

In May 2013, I started the pump up and it ran fine for about two weeks. Then one day we noticed the sprinklers weren't running when they should have been. The symptom was that the circuit breaker would blow as soon as you flipped it back on. This almost certainly meant a locked rotor in the motor, which was in fact what I found when I tried to turn the motor shaft (you pry off the plastic plug on the back of the motor and there's a screwdriver slot in the shaft to turn the rotor/impeller -- it should turn freely when the pump is OK). When I took the pump apart, I found the plastic impeller welded to the diffuser (the diffuser is the shroud around the impeller). Somehow, they came in contact and the friction welded them together.

As the pump was in warranty, the local dealer said I could either exchange the whole pump or get a pump rebuild kit; I chose the pump rebuild kit. The new impeller ran for 3.5 weeks before failing again (this time my wife was standing next to one of the sprinklers we were adjusting when the pump failed). The failure mode was identical (impeller welded to diffuser).

My wife took the whole pump back and got a new replacement pump. Unfortunately, this one ran for only 5 days before failing with the locked impeller. Clearly, we had some kind of class problem and I needed to get to the bottom of it. I spent about an hour on the phone with the Red Lion tech support -- the guy was patient and helpful. His hypothesis for what was occurring was that our pump was cavitating because we used a 1.5" suction line instead of 2". I pointed out that this setup had worked fine for 24 years -- and another data point is that our neighbor with the cistern uses the identical pump with a 1.5" suction line (but with 1.25" discharge piping).

Since I needed to get the pump working quickly, I asked the tech what things I should do. Since my discharge line is 1.5" for about 6 feet, then reduces down to 1.25" black poly pipe at a 1.25" gate valve, he suggested closing down the valve to lower the flow rate through the pump; this would cut down on cavitation. The local store gave me a new impeller and diffuser and I rebuilt the pump (I'm an expert at this stuff now!). I opened the valve 1.5 turns (it's 8 turns to fully open) and ran our sprinklers for a day and a half at reduced flow. This let me buy the parts for a 2" suction line and get it installed.

The installation of the 2" line was straightforward and I immediately started running our sprinklers with the 1.25" valve fully open. Both my wife and I noticed that we were getting better distance from our sprinklers than we had before. As of May 2014, the system has been running without problems, so I'm hoping we've fixed the root cause. This concerns me a little bit, as it shows that there's very little margin in the design of these pumps (the previous pumps ran fine on the 1.5" suction piping).

Installation

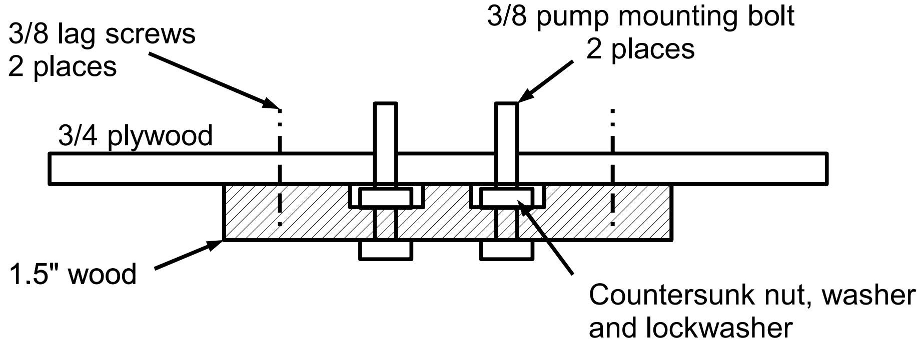
I'll give wood dimensions in the screwball US customary sizes. Dimensioned lumber like 2x4 is actually about half an inch under the nominal dimensions, so a 2x4 is actually a piece of wood with dimensions 1.5 x 3.5 (38x89 mm). To make sure it's an officially screwball system, some material like a 1x4 (another common board size) is 1/4 inch undersize in the 1 inch dimension and 1/2 undersize in the 4 inch dimension.

Pump mounting

The pump's platform is made from 3/4" (19 mm) plywood. The plywood sits on four cinder blocks and there are two 2x4's underneath that are bolted to the plywood to clamp it rigidly to the cinder blocks. This works well, yet can be taken apart easily and the pump moved if necessary.

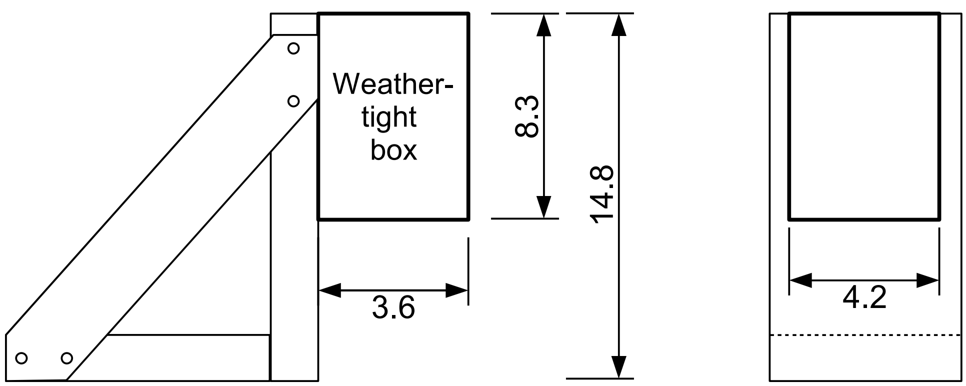
My favorite method of mounting is to have two studs embedded in concrete. Since the pump is on a plywood platform, this isn't practical. Instead, I used some 1.5" stock that's 9" wide and mounted some long 3/8" bolts to it and tightened the nuts sufficiently so that these bolts won't rotate.

I made countersinks for the nuts so the board would sit flush with the bottom of the plywood platform. Then this board was lag screwed to the bottom of the plywood. The 3/8" bolts stick up and let me bolt the motor to the platform by just using a small wrench:



As these 3/8 bolts fit into slots instead of holes on the motor's cast iron base, the pump will turn out from under them when applying sufficient force to the vertical discharge plumbing with a pipe wrench. To counteract this torque, I apply a ratcheting strap to the end of the motor and anchor it to the platform.

The electrical box support is made from 2x6 and 1x4 material:

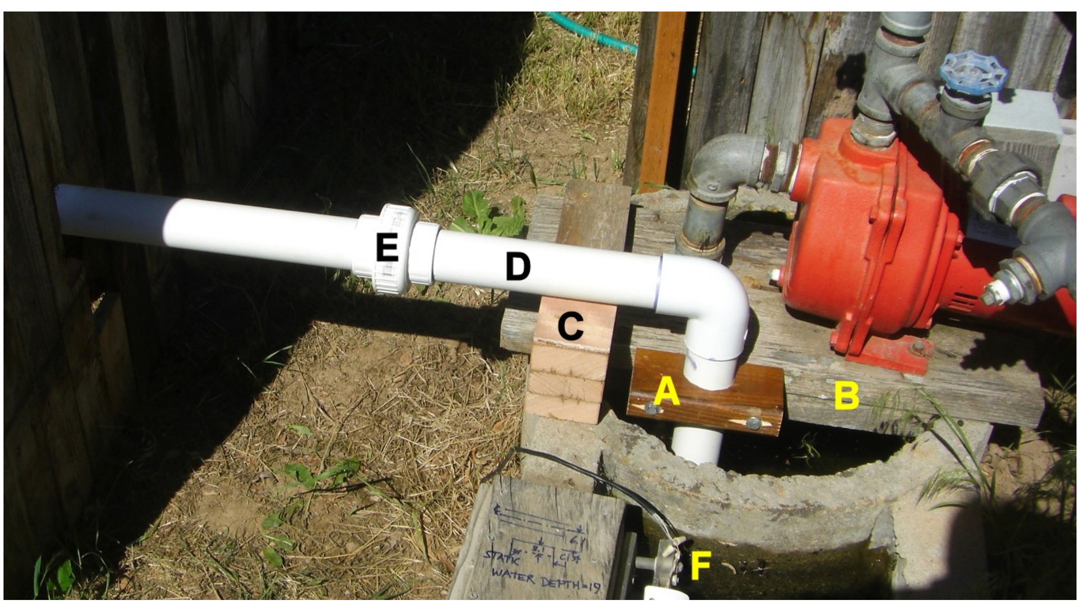


Suction

Here's a picture of the suction side of the pump:

The suction piping D is 2" PVC pipe with a threaded union C to allow for disassembly. You can also see the green handle of the 3/8" valve B at the bottom of the pump casting for draining the pump and the blue handle of the 3/4" valve A on the discharge plumbing. I use the 3/4 valve for priming the pump, as this is easier than removing the pipe plug in the pump's casting. You can also see the filter F next to the galvanized tee in the discharge line. Under the housing E in the ground is the 1.25" gate valve. This 1.25" pipe leads away to an underground box containing the sprinkler solenoid valves.

Here's the suction side on the other side of the fence going into the concrete cistern. A piece of wood A clamps the 2" pipe D to the wooden base B that the neighbor's pump sits on. You can see part of the home-made float switch at F. Part C is made from scrap 2x4 material and is a support for the 2" pipe.



The final task was to put window shade material over the PVC pipe to protect it from the sun. Here's a picture of the suction line covered in fabric.

Discharge

Here's a picture of the rear of the pump in 2012 -- this had some flexible PVC 1.5" pipe for the suction line (it's covered in duct tape). It illustrates the plumbing used for the discharge side, including the 1.5" PVC filter. The 3/8 drain valve for the pump body isn't installed yet (it goes in the bottom of the casting where the pipe plug is). In June of 2013 I needed to rebuild the discharge plumbing because I broke it at the left-most steel threaded union. I was able to chuck the filter PVC body in my lathe well enough to allow me to bore the plastic out to a 2° taper. This let me re-glue the filter with new pipe and parts (these filters have tripled in price in the last 25 years and I didn't want to have to buy a new one).

Electrical

Here's a picture of the inside of the rain-tight electrical box:

The 120 VAC wiring for the motor is 12 gauge solid copper and the 24 VAC wiring is 20 gauge solid copper.

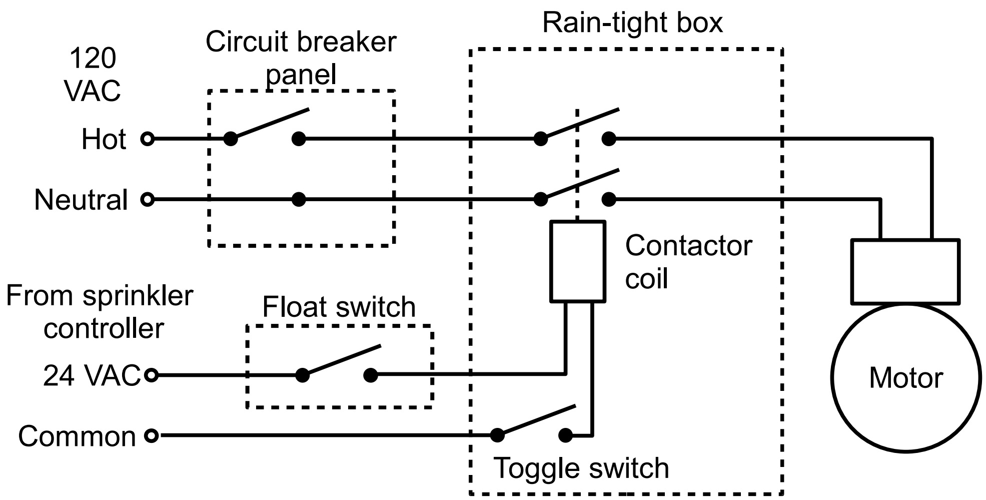
Note the switch on the right -- it's in series with the 24 VAC signal from the sprinkler controller that turns the pump on (the float switch is also in series with this circuit). This switch is quite convenient, as it lets me turn the pump on and off. The rubber cover for the toggle switch came from a PPI display for a US Navy radar set from World War 2 and is still in excellent condition.

The pump is a 1 hp pump and is on a 20 A circuit breaker. I run the pump at 120 VAC because that's the only voltage that was run to the outbuilding where the breaker is (I would have much preferred to have 240 VAC out there, but it was built before we bought the house). I ran 12/2 Romex with ground 32.7 m from the circuit breaker panel to the pump. This panel is in an outbuilding that is 42.4 m from the house and is connected to a 30 breaker in the house. I don't know the incoming wire gauge but assume it's about 10 gauge. From the circuit breaker in the outbuilding to the pump, I see a voltage drop of 10-12 V.

The pump manufacturer's technical support has told me that the nameplate voltage specs are ±10%, so I'm within allowable boundaries. However, an electric motor that is run below its rated voltage won't run as efficiently as at its rated voltage and will probably draw more current and run hotter.

If at all possible, run your pump on 240 VAC if you can -- you'll be able to use smaller wiring and save a little money. In my case, this was impossible, as the small outbuilding I had to get my pump's power from only had 120 VAC in it. So that's what I used. Some day if I find some extra cash, I may find a suitable autotransformer to step the voltage up to 240 VAC, as all that's needed to run the pump at this voltage is to change a jumper in the motor. Another alternative would be to put in a 10% boost transformer.

Here's an electrical diagram of the pump setup:



Not shown in the diagram is the safety electrical ground wire which comes from the circuit breaker panel and is connected to the rain-tight box and the motor's frame.

I chose to wire the pump with 12/2 Romex with ground. This means two conductors of 12 gauge (0.0808 inches diameter or 2.05 mm) and a 12 gauge bare ground wire. The wire was run underground in 3/4" PVC pipe to a rain-tight electrical box where I installed a 24 VAC 1 hp motor contactor to turn the motor's power on and off. This is needed because the sprinkler controller puts out an "ON" pump signal of 24 VAC and the contactor draws about 150 mA RMS of current. The contactor is basically a DPST (double-pole single-throw) relay that switches the hot and neutral lines of the 120 VAC circuit.

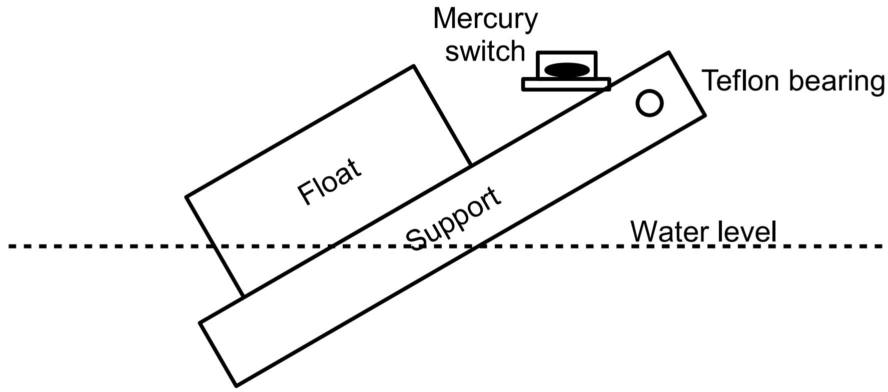
I've measured the current that the pump draws when running under a load and it's usually between 14 and 14.5 A. At 108 V RMS, this means 1500 VA. Since the pump is nominally 1 horsepower (750 W), this means the power factor is around 0.5. However, I've not actually measured it.

Float switch

I'd recommend you buy a commercial float switch.

However, 25 years ago I chose to design and build one because I had a chunk of Teflon bar stock that made a great bearing. I also had a mercury switch like the ones used in thermostats before they were legislated away. The design is a pivoting arm that used a discarded plastic bottle as a float[1], held onto a support arm with a couple of tie wraps:

1 The floats sun-rot out every 5 years or so.



The support arm is a chunk of 1/4 inch thick polycarbonate that I had as some scrap.

This switch has worked flawlessly during that time, so I have no reason to change the design. It is screwed to the side of a wooden saddle that sits on the edge of the concrete cistern.

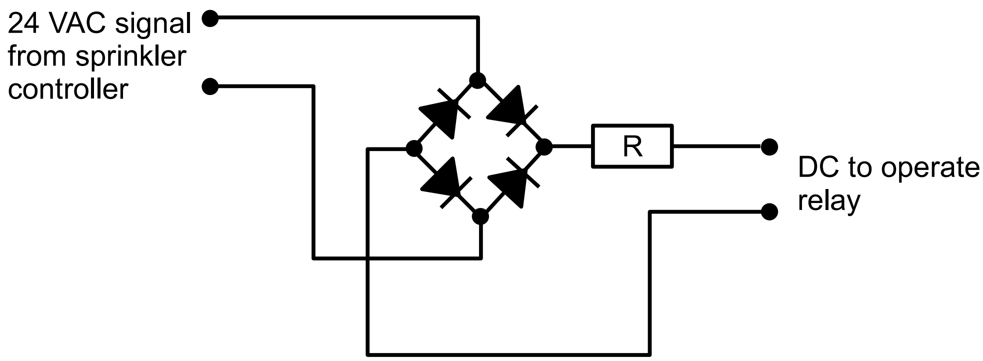
Here is a view looking down on the switch and float:

The mercury switch is under the white chunk of PVC pipe to protect it from the sun. You can see that it's about time I replaced that Gatorade bottle. This float switch has at least 25 years of trouble-free use, so it was a good design.

Pairing up circuits

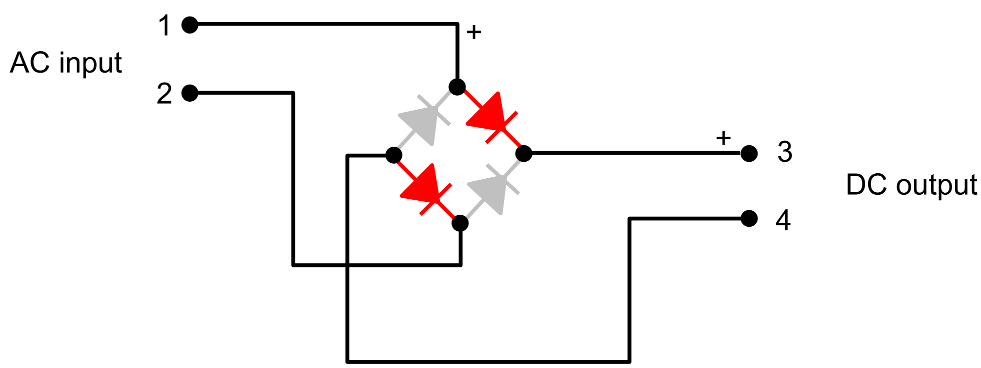
Older sprinkler controllers often had enough current output to allow you to manually run two solenoids from one controller circuit. The Orbit controller we're using (as of June 2013) doesn't allow this -- its maximum output is 250 mA per circuit and each of our solenoids requires 240 mA of current. This is an indication as to how much cost-reduction pressure has been put on manufacturers; things rarely have anywhere near the design margins they had decades ago.

If you want to run multiple solenoids on one circuit, you'll need to use some kind of switch and a separate 24 VAC transformer. I chose to use two small Potter and Brumfield 12 V DC relays I had on-hand (I would have rather used 24 VAC relays, but I didn't have two of them and I needed two, as I wanted to combine two pairs of circuits). This was straightforward to do with a full-wave rectifier and a resistor:

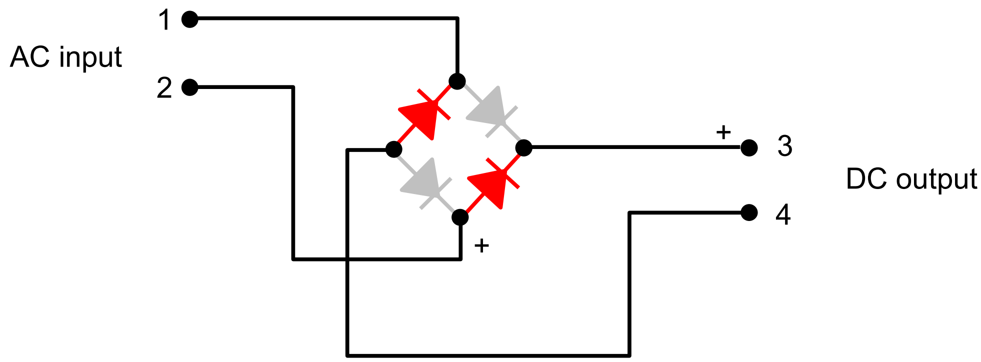


Here, the 24 VAC from the sprinkler controller is rectified into a DC voltage to operate a DC relay. The resistor R is used to drop the voltage output of the bridge to that needed to operate the relay. The relays I used required 16 mA of current to operate, so there was no significant load on the controller circuit. I used 750 Ω for R to get 12 V across the relay; the power dissipated in the relay is $0.016^2(750)$ or 0.2 W. I used a 1/2 W resistor, as that's what I had on hand. For the bridge, I used some small signal silicon diodes I had on-hand.

If the full-wave rectifier confuses you, here's a couple of diagrams that might make the operation clearer (I always have to figure it out when I look at the diagram). When terminal 1 is positive with respect to terminal 2, the diodes that are red are forward-biased and thus conducting (the grayed-out diodes are effectively open circuits). You can mentally model the diode as a switch that's either on or off; when it's on, there's 0.5 to 0.7 volts dropped across it. You then get a positive voltage on terminal 3 with respect to terminal 4 (imagine a load resistor connected to terminals 3 and 4).



For the other half cycle of the AC voltage, terminal 2 is positive with respect to terminal 1 in the following picture and the diodes that are red are forward-biased and thus conducting. You then again get a positive voltage on terminal 3 with respect to terminal 4.



In both cases, the voltage across the load is reduced by two diode drops (i.e., a bit more than 1 volt for two silicon diodes).

For many applications needing DC, you'd also see some filter capacitors to remove the ripple and a voltage regulator, but for this application, these aren't needed.

Electrical installation measurements

You'll probably find it worth your time to measure a few things concerning your ditch pump and writing them down somewhere. This information will be valuable for troubleshooting later.

If you have the ability to measure low resistances (this requires a 4-wire measurement), measure the winding resistance of the motor when it is installed. To make these measurements, I use my Fluke 83 digital multimeter and a 1 A constant current source (see `CurrentSource.pdf` at http://code.google.com/p/hobbyutil/). For the various 1 hp motors we've had, the resistance has always been 0.47 to 0.55 Ω. Red Lion tech support says 0.5 to 0.75 Ω is normal for a 1 hp motor.

> It's also worthwhile to install a short at the motor contactor terminals and measure the DC resistance of the wiring from the circuit breaker to the motor contactor[2]. This can help you determine later if you have a wiring problem.

Also measure the running current of the motor. This is easiest with a clamp-on ammeter, but you can make the measurement by putting a digital multimeter in ammeter mode in series with the motor's leads. Be careful, as this is at least a CAT II and maybe a CAT III measurement.

> I got a B&K Precision 316 clamp-on AC/DC ammeter in a trade a few years ago and it is a nice tool for such measurements, as it can resolve DC and AC currents to 1 mA. It's quite handy for e.g. finding the source of low currents in automotive circuits. It used to have a MSRP of $210, but is currently at $170 (you can find the same model sold by other vendors for $30-$40 cheaper though).

If you set your motor up to use e.g. a NEMA 15 A outlet, then you can use a Kill-a-Watt meter to measure the voltage, current, and power factor. I haven't done this, but my voltage and current measurements have indicated that the power factor of the running motor is approximately 0.5.

Finally, make sure to measure the voltage across the running motor. Make sure this is within nameplate specifications.

If you want to get geeky, you can use an oscilloscope and a pulse generator to take a TDR snapshot of the wiring from the circuit breaker panel to the motor. I haven't done this for my setup, as I know that there's only one splice in the circuit inside a building and I know the DC resistance is close to what it should be because I've measured the length of the buried wire. However, a while back the phone company was trying to fix our phone line and the first technician who came was unable to figure things out. The second tech who came admitted they didn't know where the phone lines ran, as there have been three or four different routes made over the last 25 years and the people who did the last installation didn't bother writing down where the wires went. I found this an opportunity to

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2 Obviously, turn off the power and disconnect the hot and neutral wires for the circuit inside the circuit breaker panel.

use a B&K 2542B-GEN oscilloscope to make a TDR measurement (it's a 100 MHz 2 channel digital scope with a nice built-in function generator). Because I had a known-length of the buried telephone cable, I stretched this out on the lawn and measured its length with a tape measure. This let me calibrate the scope measurements because I could measure the round-trip time of a reflected pulse. Then I measured the underground cable and observed a reflection that could have been a break. I calculated the distance and estimated where it was by pacing it off in the street next to our house. The phone tech had a fancier TDR tool and eventually found the break in the back yard of a house in the next subdivision where the owner had been rototilling in his back yard. From the street, the location was within around 10 m of where I had paced it off, so I felt pretty smug about doing this (the measured distance was about 200 m from the front of my house).

Running your sprinklers

Once the ditch pump is connected to the sprinkler solenoid valves, the controller is properly connected to the valves and the pump, and you've tested each circuit, running your sprinklers is pretty much a set-and-forget activity.

Load balancing

Our sprinkler system is a mish-mash of stuff we've added and stuff that was in the house when we moved in. Most of the gear-drive sprinklers that came with the house when we bought it have worn out or broken, so we've replaced many of them too.

Over the years, different brands and designs of sprinklers are sold by the retailers, so we have a number of different types and brands. If I was starting over again, I'd purchase one model of gear-drive pop-up sprinkler and water my whole yard with those sprinklers, changing the nozzles to get the desired flow in each circuit. I'd also buy 50% to 100% more sprinklers than needed to have spares for when the others wear out and the manufacturer has discontinued that model, which inevitably happens.

Because of this eclectic mix of sprinklers, I found that our 8 sprinkler circuits use significantly different amounts of water, due to sprinkler counts and types. The way I determined this is by connecting a pressure gauge to a hose bib[3] and measuring the gauge pressure[4] while each sprinkler circuit was operating. These are the data I collected:

	Pressure, psi			
Circuit	**Meas.**	**Repeat**	**Mean**	**Combine**
1	40	39.5	40	
2	40	40	40	
3	42	42	42	
4	38	38	38	
5	38	38.5	38	
6	38	38	38	
7	40	40.5	40	
8	40	40	40	
		Mean	39.5	

My mental goal was to have the system match the performance of circuits 4, 5, and 6, as I installed those and know their behavior well. They also water the largest area and utilize the largest number of sprinklers. Based on the data, I chose to combine circuits 1 and 3 into one circuit, along with combining 7 and 8 into one circuit. Here are the measurements after combining the circuits:

3 It's spelled either bib or bibb and comes from the word bibcock. Most of us probably call it a faucet.

4 Gauge pressure means the pressure is measured relative to atmospheric pressure.

Circuit	Pressure, psi
1	30
2	38.5
4	36.5
5	36
6	36
7	30

It's clear that we're now running circuits 1 and 7 with substantially more pressure drop than the other circuits. Part of the reason for this is that there is an extra significant length of pipe involved, as the circuits 1 and 7 have their solenoid valves about 70 m from the pump (plus 50 m or more runs of piping to the sprinklers), whereas circuits 4, 5, and 6 all have their solenoid valves within less than 10 m from the pump. The ultimate judge is the lawn's green color; we've adjusted the circuit timing to give us the greenness we want.

Starting up and shutting down

Starting up

In the spring, it's straightforward to start things up:

1. Check float switch
   a) At the pump, turn on the switch that controls the 24 VAC to the motor contactor.
   b) At the sprinkler controller, turn on the sprinklers.
   c) Check the float switch float (moving the float up and down causes the motor contactor to click) and replace the float if it is sun rotted.
2. Turn off the switch that controls the 24 VAC to the motor contactor.
3. Turn on the pump's circuit breaker and check that there is power at the pump.
4. Ensure the filter element is clean and in place and that the filter cover is snugly tightened.
5. Open the 3/4" valve on the top of the discharge stack and fill the pump with about 2 liters of water.
6. Open the hose bib next to the pump (this is to ensure that the pump is operating into a low resistance).
7. Close the 3/4" valve on the top of the discharge stack.
8. Turn on the switch that controls the 24 VAC to the motor contactor. This will start the pump; run the pump for about 5 seconds.
9. Turn off the switch that controls the 24 VAC to the motor contactor.
10. Repeat filling and running for 5 seconds two or three times.
11. Run the pump until the hose bib is running at full flow; this may take 15-30 seconds. You can definitely tell when the pump is running under a full load by its sound.
    a) Do not run the pump too long without it pumping water, as you will burn out the seal. The Red Lion manual says you can fill the pump with water and run it for up to 5 minutes to get it to prime, but I would never run it over 1 minute.
12. Turn off the sprinkler controller and close the hose bib. The sprinkler system is now up and running and shouldn't require any further attention over the summer except for periodically cleaning the filter.

In the old days before installing the 2" suction line, I'd also fill the suction line with as much water as I could and the pump would start pumping in a few seconds. However, I've found that I can start with a suction line full of air and just fill the pump about three times and the pump will start up.

Shutting down

In the fall after the ditch water has been shut off, I blow out the sprinkler lines (because we live in an area that gets freezing weather) and prepare the pump for the winter. The steps I use are:

1. Turn off the pump's circuit breaker. I put red tape over it to ensure nobody turns it back on.
2. Turn off the switch at the pump that interrupts the 24 VAC contactor voltage.
3. Remove the filter and make sure both filter elements are clean.
4. Close the 1.25" valve about 6' to the west of the pump's discharge.
5. Open the 3/4" valve on the top of the pump.
6. Open the 3/8" valve to drain the pump.
7. Disconnect the suction line at the threaded union by the foot valve and drain the whole suction line. Make sure the o-ring and sealing surface of the threaded union are clean, then reconnect the pipe after draining so it's ready to go in the spring. Reconnect the pipe clamp.
8. Blow out the sprinkler lines with an air compressor.
9. While there is still air pressure on the 1.25" line, open the 1.25" valve so that any remaining water comes out of the filter connection. Make sure the 1.25" valve is fully open for spring.
10. Close the 3/4" and 3/8" valves on the pump.
11. Reattach the filter with a clean filter element. Replace o-rings as needed and lubricate them with waterproof silicone grease.
12. Check the float switch float and replace the float if it is sun rotted.
13. The system is prepared for winter and won't need any work until the water needs to be started up in the spring.

Troubleshooting

This pump/electrical system is pretty simple and there aren't all that many things that typically go wrong. The first task is often to decide if it's an electrical or mechanical issue. If the pump motor won't come on at all, you need to establish whether there's power at the pump's contactor and whether the contactor is being actuated by the sprinkler controller's 24 VAC signal. If the latter is not true, make sure that there's water in the cistern so that the float switch is closed. I usually do this by visually seeing where the water level is and then pushing the float switch down into the water. I'll hear the contactor open when the float switch is in a position that indicates there's not enough water in the cistern.

If that part is OK and I've verified the circuit breaker is on (I verify the power is on by turning on a light in the outbuilding that contains the circuit breaker panel), then I take the cover off the rain-tight box and use my DMM to verify there's AC voltage at the contactor's terminals. If there's voltage at both sets of the contacts when the contactor is actuated, then the problem is in the wiring to the motor or the motor itself. I pop off the metal cover to the electrical connections at the motor and measure the voltage on the hot and neutral lines. If there's no voltage, then the problem is in the wiring. If there is and the pump won't run, then there's something wrong with the motor.

These pumps typically have ceramic seals that are quite reliable. However, they will be damaged rather quickly if you run the pump with no water in it. You can run the pump up to around 5 minutes without damaging the seal if the pump is filled with water but not pumping. However, if the pump is going to pump, it should start pumping in much less time than that -- my pump takes a maximum of 30 seconds to develop full output after water starts to dribble out of an output hose bib.

Symptom	Cause	Fix
Pump won't start -- blows circuit breaker	The pump's motor shaft is locked somehow. This can be caused by the impeller welding to the diffuser, a foreign object inside the pump, or the motor's bearings catastrophically failing.	Take the pump apart to inspect the interior (usually involves removing 4 bolts and 3 screws). The impeller should turn freely with the diffuser removed.
Pump runs but doesn't develop flow	♦ Pump not primed ♦ Trying to lift water too far	♦ Prime the pump ♦ Change to a pump capable of the needed lift
Pump runs but doesn't develop full flow	♦ Collapsed flexible PVC hose[5] ♦ Suction line is clogged ♦ Air leak in suction ♦ Filter element is clogged	♦ Replace flexible hose ♦ Clean suction line ♦ Find and fix air leak ♦ Clean filter element
Pump runs intermittently	♦ Controller not working properly ♦ Water level in cistern varying	♦ Fix controller ♦ Stabilize water supply or adjust float switch
Pump leaks around seal	♦ Seal is damaged	♦ Replace seal
Pump won't maintain prime	♦ Foot valve is not sealing ♦ Leak in suction plumbing	♦ See if some contamination is blocking the foot valve from closing. If not, replace the seal or the foot valve. ♦ Fix leak.

Miscellaneous Tips

These are things that occur to me in no particular order.

As a pump's plumbing is assembled, disassembled, and reassembled, it can develop small leaks over time. For the short steel nipples that thread into the pump (a common leakage point), it is recommended that you only reuse a nipple once or twice before replacing it.

For steel to steel or cast iron threaded pipe joints, I have used numerous types of Teflon tape and pipe joint compounds over the decades. I do not care for Teflon tape except for threaded PVC fittings. For metal to metal threaded joints, I have come to prefer Tite-Seal #3 pipe joint compound, as I've had the best joints with this material.

If you need to use Teflon tape, stay away from places like Lowes and Home Depot -- they sell low-grade consumer junk. Go to a plumbing supply house or buy the yellow Teflon tape intended for natural gas piping. While it's more expensive than the junk, you'll feel it's worth it the first time you have to fix a crummy joint that leaks.

I prefer to use steel threaded unions wherever possible. However, in the last plumbing work I did (changing the suction line to 2"), the PVC threaded unions were 60% cheaper than the steel ones, so that's what I used. When I can use steel threaded unions, I always put Permatex antisieze compound on the metal-to-metal threads, as this helps greatly with assembling and disassembling these unions. For PVC unions, I put waterproof silicone grease on the threads. In addition, you'll probably want to have a spud wrench to put on the big hex of the threaded union. A 14" pipe wrench will fit the small hex on 1.5" and smaller threaded unions.

Have the suction line to the pump at a slight slope so that no air pockets can form in the line.

Exposed PVC piping may sun rot in the sunlight. One fix is to buy some window shade material (or

5 Flexible PVC hose makes it easier to install a pump, but the stuff will sun rot and eventually collapse unless you protect it from the sun.

other suitable fabric) and cut pieces to wrap around the pipe (hold in place with tie wraps[6]). Painting the pipe is another option. You can also use duct tape for a quick fix, but it will rot out after a couple of years. Over the years I've also built small rectangular covers from scrap cedar fence slats (these work well and are no cost).

Putting flexible PVC piping in the suction or discharge sides of the plumbing can prove convenient, as things don't need to be aligned perfectly. However, if you leave this flexible pipe in the sun, it can sun rot and collapse on the suction side -- the pump will run, but not anywhere near its rated capacity.

Beware of voltage drops in long electrical wiring runs. While voltages can typically vary ±10% from nameplate values and still be in spec, a motor runs more efficiently and cooler at or slightly above the rated voltage. If you have a long run of wire, consider installing an autotransformer to boost the voltage.

The manuals say to turn PVC to steel threaded connections hand-tight, then tighten with a wrench half a turn. I've not found this sufficient, as I often have to tighten things more than that to get a joint that doesn't leak.

Be careful with longer runs of unsupported PVC piping, especially if you need to tighten fittings with pipe wrenches. It's not that hard to break a fitting on an unsupported pipe with pipe wrenches. Fortunately, it's straightforward to add supports that eliminate this problem.

The pump's circuit breaker should be a GFI type because you're dealing with AC voltages around water.

To protect the pump, piping, filter, and electrical components from the elements, I built a small "house" that covers the pump. It was built with some left-over plywood from a project. This was meant to be temporary, but, surprisingly, it has lasted for 25 years (it got a couple coats of paint a few years ago and I also put on some surplus roof shingles from when we did our roof). I cut a number of 1" holes in it and cut a large hole near the end of the motor to improve circulation and keep things a bit cooler (the screen keeps the cats out of the box). The exhaust of the motor is too hot to touch on a hot summer day when the motor has been running a while.

6 Use outdoor-rated tie wraps; otherwise, they'll sun rot too.

Pipe tools

For virtually all of my plumbing work, I use two 14" pipe wrenches. These work on pipe up to 2" size (2.38 inch outside diameter). For 1/2" and smaller pipe, I'll often use a little 7" pipe wrench, which gets into tighter places. If I was buying myself some new pipe wrenches, I'd make sure they were aluminum, as I'd appreciate the lighter weight.

I also have some large Channellock groove-joint pliers that are useful for grabbing big things up to 3.6" in diameter. However, these do not hold well enough for turning the larger pipe sizes like 1.5" and 2". But they work well for e.g. grabbing and holding the large PVC threaded unions to help assemble or disassemble them. If I were to do things over again, I'd buy some large Knipex Cobra pliers instead, as I like them much better than the Channellock design.

If you've never heard of Knipex before, you should learn about their pliers. The two most important pliers I have are a Knipex 180 mm Cobra pliers and a 180 mm Pliers Wrench. These are expensive, but they're well-made and should last you the rest of your life if you take care of them. Whenever I have a fix-it task around the house, these two pliers are always in my toolbox.

For working with large hex nuts like on 1.5" and 2" threaded unions, you'll want a spud wrench. My Ridgid spud wrench opens up to 2-5/8 inches and works well for all the plumbing work I've needed to do. Reed Manufacturing also makes spud wrenches (Reed calls them "smooth jaw wrenches"; the RSPUD model looks very similar to the Ridgid spud wrench). A big 100-year old monkey wrench works fine too.

Broken threaded plastic pipe fittings

For sprinkler connections, my wife and I have tried to standardize on using 3/4" threaded fittings, as this makes things easier to replace/fix when a sprinkler needs replacing. However, we occasionally have broken pipe in a threaded fitting and need to remove the broken piece. You can make or buy a tool to remove such broken things. The commercial tool is essentially a tapered left-hand 4-flute reamer that will grab the inside of schedule 40 or 80 pipe and allow you to unscrew a right-hand thread. This tool will pay for itself the first time you use it.

I once made myself one of these tools by grinding a suitable tapered pattern on a chunk of low carbon steel rectangular bar stock (I turn it with a wrench). But we have used the 1/2" and 3/4" broken thread removers so many times that they have easily paid for themselves, so I recommend you simply buy the needed tools. Almost any hardware store should have them.

Another approach, especially convenient for larger fittings when you can take them to the bench and hold them in a vise, is to use a diamond cold chisel and cut a groove in the plastic. Be careful not to cut into the threads of the mating fitting. When you've removed enough material, a punch can help you to get the broken threaded fitting out; it usually just falls out.

There are also internal pipe wrenches that may be suitable:

Unfortunately, these are usually sized to fit schedule 40 steel pipe and won't fit into a piece of schedule 80 plastic pipe, but you may be able to find a suitable internal pipe wrench at a plumbing specialty house. However, the tee-handled left-handed remover mentioned above works for both schedule 40 and 80 pipe, so I recommend it over these internal pipe wrenches.

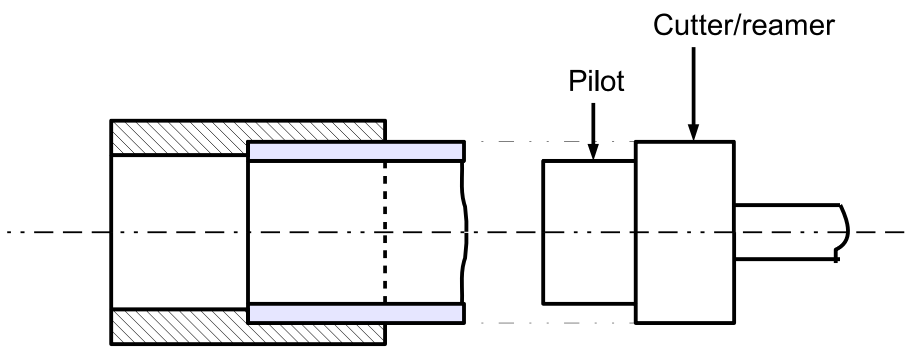
Reusing PVC fittings

You can reuse glued PVC joints if you can bore out the joint. Often, this isn't worth the effort, as it's quicker to just rebuild the plumbing using new parts. However when the replacement parts are expensive (like our 1.5" water filter -- the replacement is pushing $100) or it would be a lot of work to replace (e.g., digging up a bunch of buried line), it becomes more attractive to reuse parts if possible.

If you have a lathe, can get the parts to the lathe, and can hold them securely, it's straightforward to bore out the fitting, as PVC machines easily. I usually set the compound to a 1° or 2° taper to do the boring, as this lets the pipe enter the fitting more easily.

There are commercial tools available that can ream out glued joints so they can be reused. Here's one source: http://www.plumbingsupply.com/pvcsaver.html. Reed Manufacturing is another company that makes such things. Reed and Ridgid make commercial-grade stuff and it will last you a long time.

If you have a lathe, you can make a suitable tool from some drill rod (search the web using "PVC pipe reamer" for ideas). For a one-off project, something simple from threaded rod, nuts, and washers that are ground into cutting bits could be made. Here's the basic idea:



You'd want to put a small taper on the cutter/reamer to make it easier to assemble the pipe to the fitting. You may want to make the pilot replaceable, as the OD of the pipe is constant for a given size, but the ID varies depending on the schedule of the pipe.