Buying Guide

Off-Grid Water Pumping Design Considerations

Intro to Water Pumps

Water pumps are used to transfer water from one point to another by converting mechanical energy into pressure (head). Electrical energy typically drives the mechanical pump, whether from the grid, solar direct, batteries or an inverter. There are various things to keep in mind when selecting a pump and designing a system. Here we'll discuss the multiple types of pumps, the application requirements which will define suitable pumps, and the overall concepts for powering the pump in a sustainable manner.

What are the different types of pumps?

There are two basic types of water pumps—centrifugal pumps and positive displacement pumps. Centrifugal pumps use rotating impellers and rotational (or centrifugal) force to fling the water around and out of the pump. Positive displacement pumps deliver flow using mechanical contraction of a volume. To picture this in action, imagine crushing a water bottle or a piston moving through a cylinder.

What are the basics of a centrifugal pump?

Centrifugal pumps (jet pumps) are often seen in high flow rate and low head applications. Common uses are irrigation, reservoir transfer, pool pumping, lake aeration, etc. For the most part these pumps are minimally affected by small debris and sediment and they can be used with low viscosity fluids. They can be manufactured as surface pump or submersible pump solutions. Due to the nature of these pumps, they offer minimal-to-no suction lift, thus they must be primed for surface pump applications. Also, if the suction head of a surface pump solution is too low, clavation can accrue on the impeller which will damage the pump.

What are the basics of a positive displacement pump?

Positive displacement pumps (rotary pumps or diagram pumps) are often used for lower flow rate applications where high pressure or head is required. Mostly this involves deep well or reservoir transfer applications with high elevation change where centrifugal pumps fail to adequately deliver. These pumps are very efficient and can often remove unwanted air from the intake lines, meaning they don't usually need to be primed for surface pump applications. In most cases, tight tolerances between wear surfaces inside the pump make it necessary for these pumps to have clean

How do I figure out which pump to go with?

The use of a pump—whether it's for well pumping, irrigation, household supply, cattle watering, pool pumping, etc.— is generally known. However, the considerations that will define which pump to go with and what's necessary to power the pump can be more complicated. The most common driving factors for system design are going to be desired flow rate—or volume of water needed per day—and the system's total dynamic head. Both are needed to determine pump suitability and the required amount of energy/power, as well as the method for delivering this power effectively and sustainably.

How do I determine desired flow rate?

When trying to determine flow rate you're usually going to have some sort of limit or goal. For a residential household pressure system, it's typical to have a requirement of around 6-12 gallons per minute. For other applications, like pumping from a well into a cistern or storage tank, your goal could be limited to the well's flow rate, the size of the tank or expected daily consumption. A household daily consumption could be anywhere from 50-100 gallons per day, per person. So, a household of four people could consume something like 200-400 gallons per day. If you're setting up a cattle watering system and pumping into a tank or open reservoir, each animal could consume anywhere from 10-20 gallons per day. So, 50 head of cattle could consume anywhere from 500-1000 gallons per day. If you're putting a drip irrigation system together, you'll want to calculate the sum of drip irrigation flow. With a gravity-feed system, you can multiply that by the necessary plant/tree saturation time to get a total required amount of water daily needed to full the cistern. The calculations for determining total water volume requirements are generally quite easy but knowing how much water you need to produce is very important with the following considerations.

The duration of pumping time is the next aspect of system design. This can be a tough concept to nail down initially. There are various circumstances that will define the pumping period. The simplest to imagine is a basic pressure system, where the pump may be powered 24/7 but will only cycle based on demand. These applications require a pump flow rate equal to the required house flow rate of about 6-12 GPM. Solar-direct pumping is another option. For these systems the water is often pumped to a storage reservoir over a period of time (while the sun is out). Typical pump time is going to be defined by the sun hours for that given location. If the location receives six hours (or 360 minutes) of usable sun and you need to achieve about 1000 gallons per day, then you would need a pump that can achieve about three GPM. In some cases, it may be required to extend the pumping time beyond sun hours In this case, it would be necessary to use batteries. Regardless of how you do it, the total volume of water divided by the allowed pumping time will result in the necessary flow rate, often defined in gallons per minute (GPM).

How do I determine total dynamic head?

The calculations for total dynamic head can get very technical and can be overwhelming. We're going to make this very simple and conceptual but it may not address all situations. First let's define head. Head simply means height and it's essentially a measurement in feet (or other relevant units) above a reference point (usually the pump). Total dynamic head is essentially the sum of elevation head, friction head, and pressure head. It determines how high the pump needs to push the liquid above itself to get to the final destination (point of use or point of storage). Water likes to flow downhill, so to push it uphill energy must be exerted on the water. Once the water is up there, it's captured, often in a reservoir or held pressure state. At this point, it's maintaining an amount of potential energy.

Elevation head is the easiest to calculate and visualize. This is the vertical height change from where the water begins to where the water ends. It could be the elevation change from the top of a pond to a hilltop storage tank. For a well with submersible pump, the two heights would be the water level in the well and the height of the above-ground storage tank. The measured height in feet is the elevation head. Important note regarding this and wells—if the pump is placed in a well at 300 feet but the static water level (per the well specifications) is measured at 200 feet, the pump only has to pump 200 feet to the surface. The water is essentially already 100 feet over the top of the pump pushing down, so the pump only has to work on getting the water up that extra 200 feet.

Friction head is a component of head that accounts for the effective energy losses throughout the system. These losses are a result of the friction induced on the water by the pipe, joints, bend, values, and even filters. The primary contribution to friction head is the pipe and flow rate relationship. Imagine a scenario where a large flow rate is trying to get pushed through an undersized pipe. This would result in a significant amount of liquid in contact with the inside of the pipe and thus higher frictional losses. The alternative would be a much larger pipe, but this could be costly. Finding the perfect balance is very important. There are several calculators available that will help with calculating the frictional head loss. You simply plug in the desired flow rate, pipe type, pipe diameter and length. You can play around with various pipe sizes until you get a suitable solution. The result will offer the frictional head ,which can be added into the calculations for total dynamic head.

Pressure head is the additional head above atmospheric pressure needed or desired at the point of use. When pumping into a vented tank or reservoir, no additional pressure is needed because it's vented to atmosphere. Pressure head usually only pertains to pressurized systems, like household water supply. Typically, appliances throughout a home are happy with a pressure between 40-60PSI (pounds per square inch). You can convert this to pressure to feet of head by multiplying by 2.31. So, a system with an additional max pressure of 60 PSI would result in an additional pressure head requirement of about 140 feet of head.

Total dynamic head = elevation head + friction head loss + pressure head

At this point you should know your desired/required/limited flow rate and total dynamic head. These two values are instrumental in choosing an appropriate pump.

What are the differences between surface and submersible pumps?

Most applications are going to fall under two categories—either a surface pump or a submersible pump. Submersible pumps are installed under the surface of the water. They can be used in wells, ponds and tanks to pump water at high pressure/head or with high volume/flow rate. Submersible pumps have several advantages. They don't require priming, they stay cool in the water and they're less prone to freezing. They're also unaffected by suction lift limitations that must be considered with surface pumps. However, they tend to be more expensive and can be costly to install or maintain due to their limited access.

Surface pumps are often mounted on the surface of the water in a reservoir or shallow well. They can also be gravity fed and used to boost pressure or flow rate. All of the pump is exposed, so it's often easier to maintain but also affected by environmental conditions. The most significant limiting factor with surface pumps is suction lift. The maximum suction lift for a centrifugal pump (jet pump) is about 15 feet (at sea level), while the maximum suction lift for a positive displacement pump (rotary pumps or diagram pumps) is about 22-25 feet at sea level. Those can operate with higher suction lifts because they can often create stronger vacuums. Altitude significantly reduces the suction lift, as the lower pressure reduces the vapor pressure of the water. A rule of thumb is for every 1,000 feet above sea level you should subtract two feet from the sea level maximum suction lift. One way to improve this issue is to place the water pump as close to the liquid source as possible so it has less distance to suck the water up. This is not always possible and for such applications a submersible pump should be used.

What is cavitation?

For surface pumps, if the suction lift exceeds the liquid's physical limits, it's possible for the liquid within the pump to cavitate. Effectively, this means the vacuum on the suction side of the pump is lower than the vapor pressure of the water. The water under this state will instantaneously boil and thus expand—violently erupting in many tiny explosions. In other words, imagine lots of tiny air bubbles getting sucked up along with water on the intake side of the pump, and exploding inside the pump head. This happens at the point of lowest pressure, which is on the pump head. If this happens, it will cause permanent damage to the pump.

What are sustainable off-grid pumping systems?

Sustainable off-grid pumping systems typically fall under one of two categories—solar direct and battery-based. Solar direct applications are designed to take advantage of usable and immediate solar energy to directly pump the water. These pumping applications often include well-to-cistern, cattle watering, pond aeration, pool pumps and unregulated irrigation. Battery-based systems can consist of battery-direct or inverter-powered pumps. Both are often supplemented by solar power and/or a generator. Battery-based systems are often necessary for residential pressure systems, large irrigation projects or low flow rate pumps that need to continuously run to produce usable amounts of water. It's not uncommon to combine these two concepts effectively. Generally, it's much more cost effective to do solar-direct projects, using the sun to pump the water high up on a hill and then gravity feed the residence or irrigation system. If elevation isn't an option, you can use solar-direct to pump the water up to a cistern then a much smaller battery-powered booster pump to deliver the water to the pressure system. There are several ways to tackle powering these systems and it's often best to consult with an expert to get the final system designed to suit your application.