WHITEPAPER

How to Pick a Centrifugal Pump

By JMP Equipment Company and RL Deppmann Company

WHITEPAPER

Pump selection isn't just about capacity and price. An engineer must consider many factors before choosing a pump for a project and client. First and foremost engineers must determine the client's priorities, which will invariably include some degree of all of the following:

- Installed cost
- Efficiency/operating costs
- Pump life expectancy and reliability
- Ease of service and maintenance
- Saving floor space
- Seismic concerns if any exist
- Local parts availability and vendor support

The engineer is tasked with choosing a pump not only fits the system but aligns with how the individual client prioritizes each of the above concerns. Some decisions will be fairly intuitive. For instance, even a moderately experienced engineer understands that a property developer is highly motivated to conserve equipment floor space, as square footage equals profit. On the other hand, life expectancy and reliability are likely top priorities for an elementary school.

In this white paper we will cover all aspects of pump selection so that engineers can confidently make the best decisions for their specific client.

Frames to Seals: Choosing the Right Structural and Mechanical Components

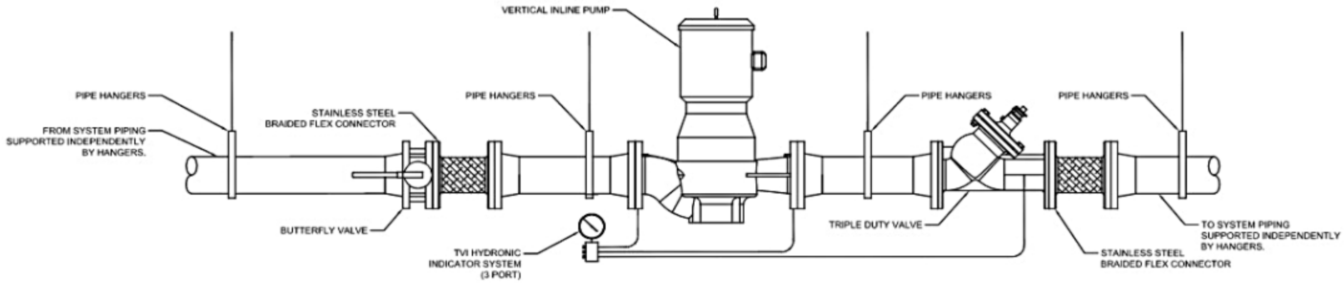
Base-mounted or Inline?

One of the first decisions an engineer must make when selecting a pump is whether to use a base-mounted or inline pump.

Based-mounted pumps have all their components (pump, motor, and bearing assembly) mounted on a common base that is installed on a concrete foundation at the jobsite. They are available in a wide range of configurations (end-suction pumps, double suction, with or without couplers, etc.) and offer more stability. This makes them preferable whenever the installation in an error that is prone to seismic events.

Inline pumps are traditionally mounted in the piping line and the weight of the pump is supported by the pipe and/or pipe hangers. They may be installed horizontally or vertically and therefore offer more flexibility in certain applications.

In-line pumps are not suitable when seismic activity is a concern because they are at greater risk for what is known as an overturning moment (OTM). An OTM is the point at which a specific rotational force becomes great enough to cause an object to tip over or overturn. Obviously, inline pumps don't tip over, but seismic forces can magnify their rotational movement, resulting in a *twisting effect* on the piping and placing higher than acceptable stress on the pump flange and bolts.

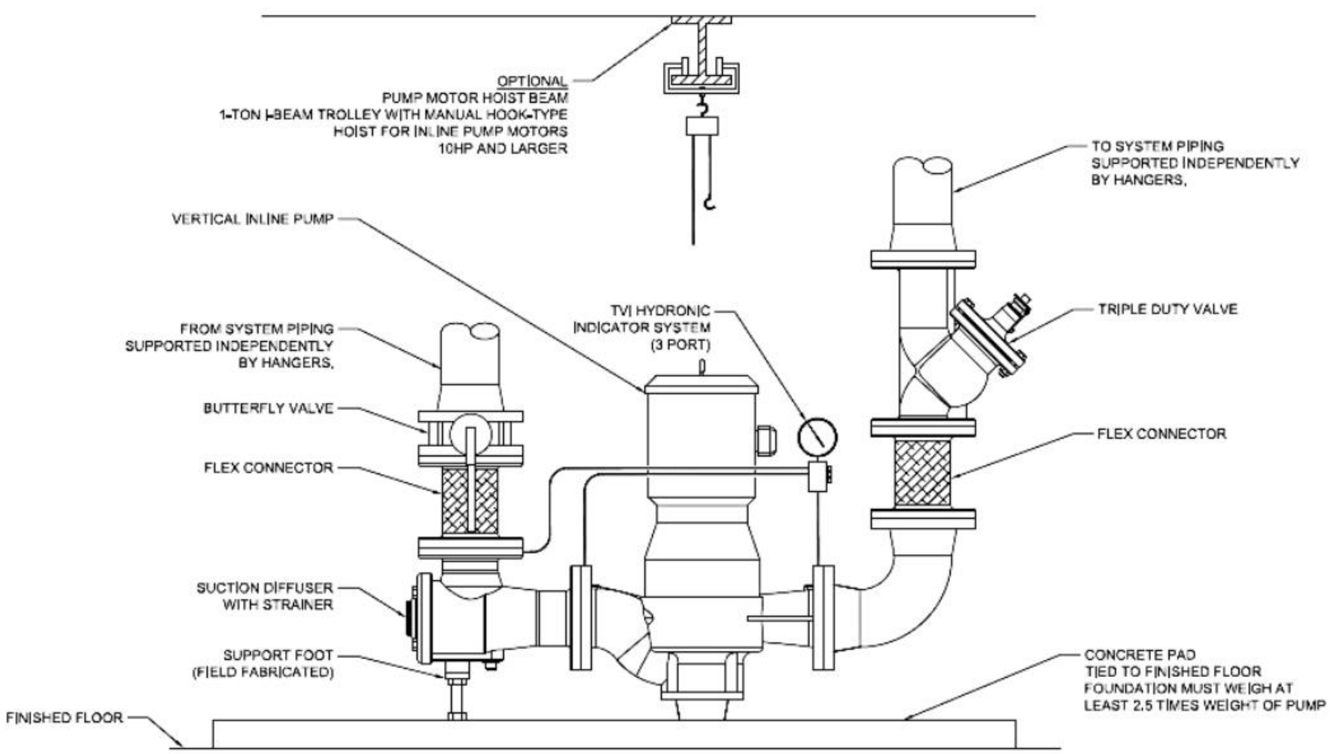


Inline Pump Pipe Supported Detail

If seismic stability is not an overriding concern, space will likely dictate your choice of pump frame.

Invariably engineers are starved for mechanical space, which makes the idea of a suspended inline pump attractive. This is a reasonable strategy assuming the pump and motor are small enough to be supported by the pipe and that the pump isn't installed in a space hard or even dangerous to access. Piping supports must be designed for the extra weight of the pump and accessories (e.g. the triple duty check and balance valve).

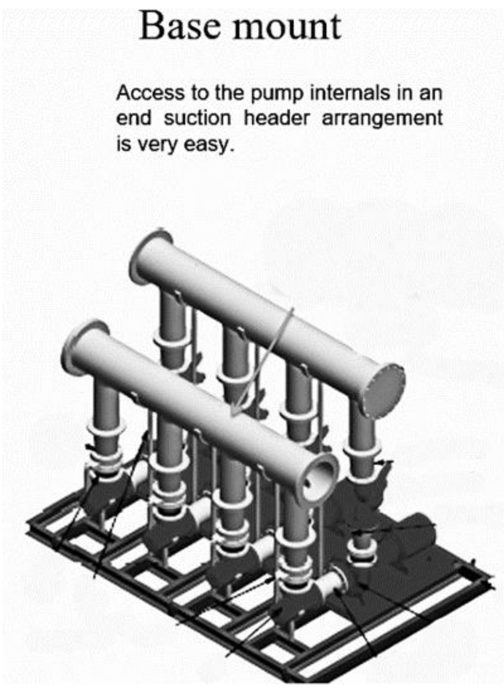
Also, keep in mind that horsepower has a dramatic impact on the weight of a pump motor and therefore the support structure that may be required for an inline pump. If an inline pump is 15 HP or more it should be installed on the floor if possible.



If an inline pump is installed on the floor it must be installed with a suction diffuser or long radius elbow and 5 pipe diameters of straight pipe and discharge elbow, all of which will increase the amount of floor space required.

In these cases an end-suction or vertical double suction base mounted pump may actually take up less floor space. An end-suction base mounted pump eliminates the need for the discharge elbow; a vertical split case double suction pump eliminates both the discharge elbow and suction diffuser. Plus, either base-mounted pump can be serviced without necessarily having to remove the motor.

If two or more pumps are to be piped and installed in parallel, base-mounted provide better access for service:

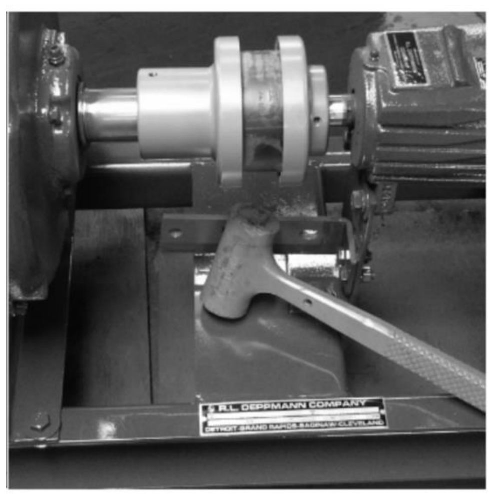


Close, Split, or Flexible Coupled?

Pump couplings connect the pump to the motor for the efficient transfer of power and accommodate for misalignment, making it easier to service the pump. Hydronic HVAC pumps typically have one of the following types of couplers:

Split Couplers - The sole purpose of the split coupling is to connect a standard frame motor to the pump end. Split couplers can make the pump easier to service but notice that the coupling is made of steel and doesn't

provide any flexion. If the motor shaft starts to vibrate due to motor bearing wear, the vibration and movement will be transferred directly to the pump. If the pump end starts to vibrate due to cavitation, age, etc., the vibration will be directly transferred to the motor bearings and shaft.



Flexible Couplers - Flexible couplers are most often used on base-mounted pumps. They are typically made of a rubber material sandwiched between two metal hubs. The flexion of the rubber insert helps protect motor bearings from pump borne damage and protects the pump from motor borne damage. This is important with the non-constant torque associated with

HVAC pumps and variable-speed systems. A flexible coupler also helps compensate for various types of misalignment that occur during typical operation.

Flexible couplers act as a sacrificial fuse that breaks to protect the motor bearings and the pump shaft. (It is much less expensive to replace a flexible coupler than a shaft or bearing!)

Closed Coupled or Direct Coupled HVAC Pumps - Pumps that do not have couplers are referred to as close coupled pumps. These pumps have a single shaft that extends from the motor to the pump body through an opening in the cover plate. The mechanical seal, shaft sleeve, and impeller are all mounted on the motor shaft. There is no bearing assembly in the pump section, so the motor bearings must absorb all of the torsional load. This means the bearings have to be large, which makes the motors somewhat special and less readily available.

CLOSE-COUPLED PUMP

Close-coupled pumps often take up less floor space but they can be tricky to service because the motor must be removed for seal changing and maintenance. An overhead gantry and crane may be required to lift the motor away from the pump if the motor is large or there is not enough horizontal space to remove the motor.

One advantage of closed coupled pumps is they do not need to be aligned. This can be helpful if you have a high speed (3600 rpm) application where the alignment tolerances are tight.

While there are pros and cons to all of the above pump configurations, base-mounted, flexible-coupled pumps are generally preferred, unless the specific application precludes them as an option (e.g. there is not sufficient floor space for a base-mounted pump).

Single or Double Suction Pump?

Double suction pumps have an impeller that is designed to draw flow through it from both sides. This design eliminates the axial forces on the impeller and allows higher flows than a single suction. As a result, double suction pumps are also less vulnerable to wear and tear caused by axial thrust. Since water enters both sides of a double suction impeller, one side effectively cancels out the axial thrust of the other – assuming the flow is even on both sides. But since that is not always the case, double suction pumps have inboard and outboard bearings to absorb some of this load.

Double suction pump can be twice the cost of a comparable single suction design. However they have longer lifecycles, as much as 30 years.

We typically recommend a double suction pumps for HVAC applications that or above 2,000 GPM and above or if the pipe size is eight inches or greater.

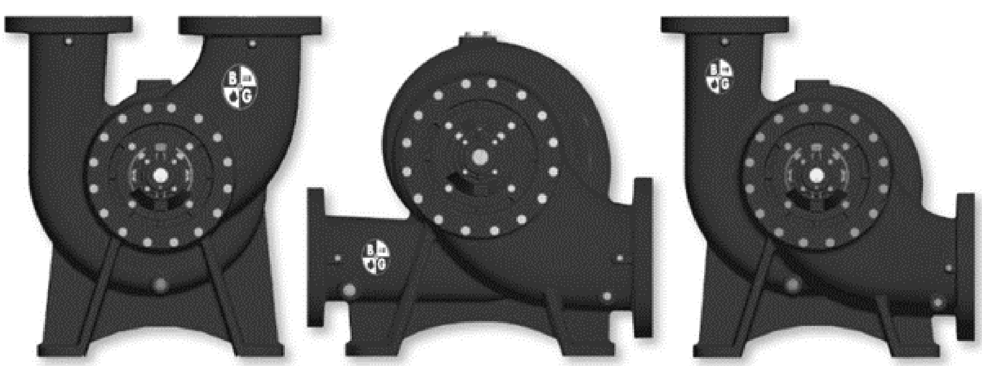
When selecting a double suction pump it is advisable to (1) choose a pump with the shortest shaft span possible to minimize shaft deflections, and (2) specify base-mounted pumps with flexible couplers as they generally require less maintenance and are easier to service.

There are three types of double suctions pumps:

Horizontal Split Case – These pumps have a “clam shell” type volute that is split horizontally. The top part of the volute is bolted to the bottom. Because the pump is split horizontally, there is significantly more service time and rigging required to lift the heavy top of the pump.

HORIZONTAL SPLIT CASE DOUBLE SUCTION PUMP

Vertical Split Case – These pumps are split vertically with a removable cover plate at the end-suction that can be removed to service the bearings or pump shaft. They are available in three different configurations which gives owners more options for saving space.



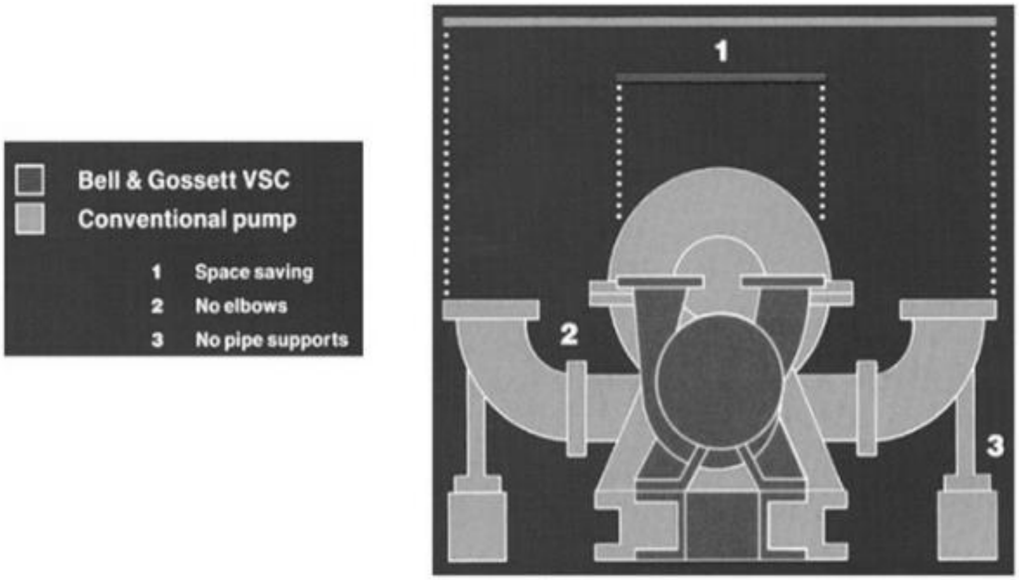
CONFIGURATIONS OF VERTICAL SPLIT CASE PUMPS

Double Suction Inline – These pumps can be quite large and are typically used when the piping flange size is over 12 inches. Double suction inline pumps have bushings (no moving parts) instead of bearings, which must be changed whenever the pump seal is serviced because they are susceptible to wear and tear. To perform this service the motor must be lifted off the top to for access to the bushings and seal.

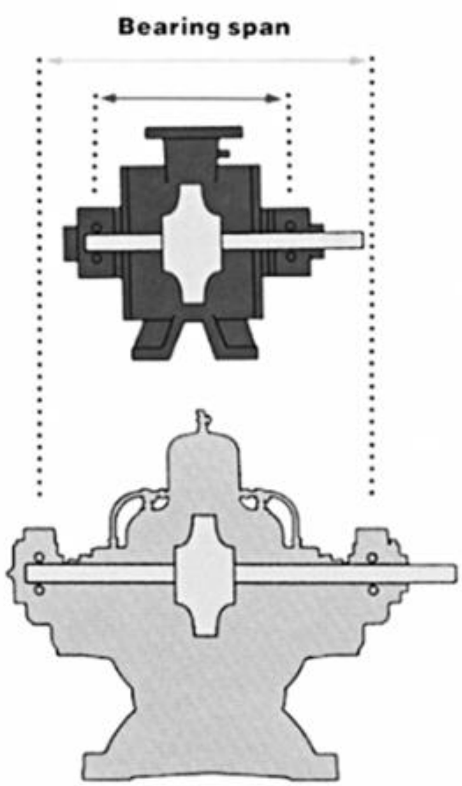
VERTICAL INLINE DOUBLE SUCTION PUMP

So when would one want to specify a vertical split case pump over a horizontal?

All other things being equal, a very good case can be made for choosing a vertical over a horizontal split case pump. First, vertically split case pumps usually take up substantially less space, depending on the orientation of the pipe connections. Assuming the suction and discharge piping can be vertical, it's easy to see from the following diagram why this is so:



Second, the shorter distance between the bearings on a vertical split case pump helps reduce shaft deflection and helps lengthen the life of the pump:



Internally Or Externally Flushed Mechanical Seals?

Even though mechanical seals play a huge roll in the functionality of an HVAC pump, many specifiers have only a very general idea of how they work.

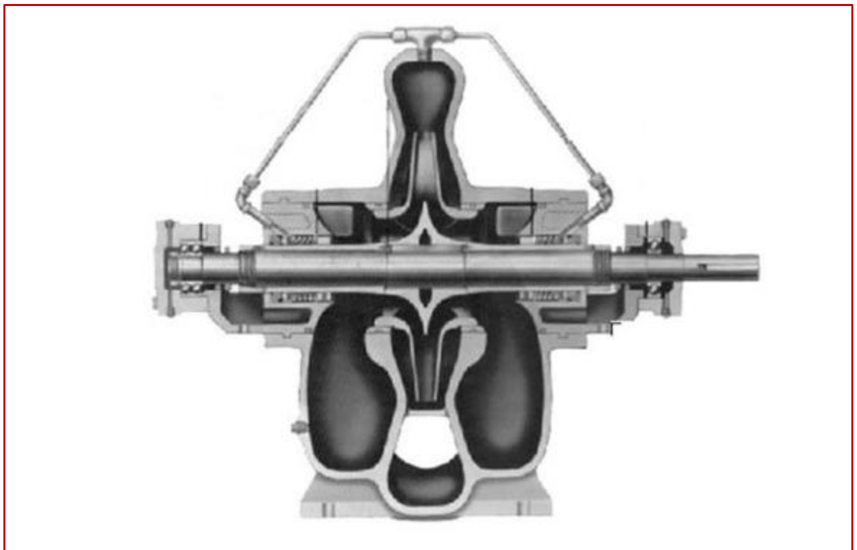
Today, mechanical seals are the standard in HVAC pumps and have long since replaced old "stuffing box" style seals that were once the source of much leakage, corrosion and maintenance. Mechanical seals do not leak; rather they have an integral spring that provides the pressure against two highly polished faces to reliably seal the pump. Even pumps with old style pump volutes designed with exterior stuffing boxes have long since been retrofitted to accept mechanical seals. That's why today there are two types of mechanical pump seals – those designed for older style with an external flushing line and those with an internal flushing style. Externally flushed seals, however, should be avoided.

Externally flushed seals operate similarly to other mechanical seals but are designed to be installed in the dry space of the volute, just like older style packed seals. Thus, they require external lubrication to prevent overheating from friction between the shaft and rotating and stationary seal parts. This lubrication is provided by capillary type tubes that route water from the discharge of the pump to the mechanical seal. There are three downsides to this design:

(1) The first concern is simply the size of the flushing line. These are normally ¼” or 3/8” copper tubing. If the water quality starts to build up sediment in the lines or there is field damage to the lines, there will be a restriction to the flow rate which will reduce the seal life.

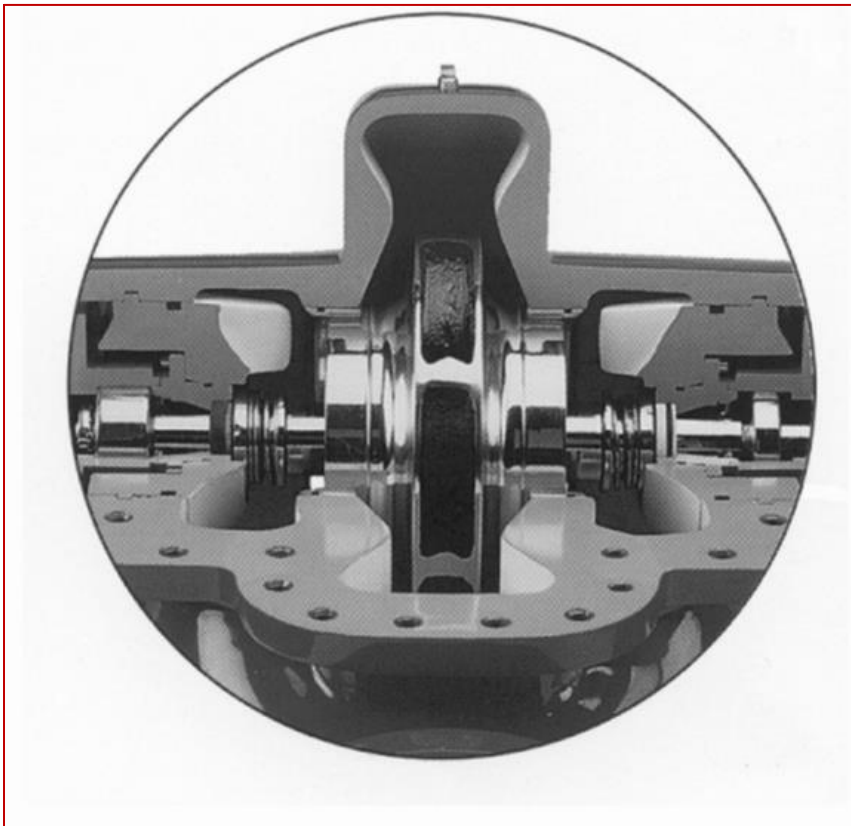
(2) The seal faces are highly polished surfaces and any grit that gets between the faces can etch these surfaces, causing premature seal failure and/or leaks.

(3) The third concern has to do with the amount of water being flushed across the seal to reduce the heat build-up caused by friction. The amount of flow is subject to the pressure difference between the inlet and outlet and the pipe friction loss. The manufacturer designed the pipe size and flow rate to match what is needed for the pump. But what happens when we put a variable speed drive on the pump? The suction pressure in a closed system remains fairly constant but the discharge pressure drops. The flow varies as the square root of the difference and the flow drops. This may not be much of an issue in a chilled water system but could reduce seal life in a heating system.



EXTERNALLY FLUSHED MECHANICAL SEAL ON SPLIT-CASE DOUBLE SUCTION PUMP.

Just like externally flushed mechanical seals, internally flushed mechanical seals prevent water from escaping the pump casing while also allowing the pump shaft to spin freely. However, the design is more sophisticated and more reliable.



INTERNALLY FLUSHED SEALS ON A HORIZONTAL SPLIT-CASE PUMP

Internally flushed mechanical seals are located closer to the impeller of the pump, in an area that is filled with water upon start-up. They are actually submerged in the system water and are exposed to about 25% of the pump flow. This eliminates the need for any exterior lubrication and tubing, and the higher velocity of the water surrounding the seal provides better flushing, increasing the seal life.

While pumps designed for externally flushed seals are still available today, we recommend you specify and demand pumps with internally flushed mechanical seals for hydronic HVAC systems, whether the pump is part of a brand new installation or is a replacement for an existing pump with an external seal.

Mechanical Seal Components and Materials

Mechanical seals are simple devices. There are metal parts including a spring, a stationary seat, and a rotating seat (also called the primary ring) and there are elastomers parts.

Water is the most common heat transfer fluid used in HVAC pump applications; glycol-based fluids are the second most common. In either case, the fluid in these applications contain very little particulate and are typically well below 225°F. Given these “easy service” conditions, the majority of seals used in HVAC applications are “carbon-ceramic.”

Carbon-ceramic seals have stainless steel metals, BUNA elastomers, a 99.5% pure aluminum oxide ceramic stationary seal face, and a carbon rotating face. These seals work well with the temperatures mentioned above and a pH neutral range of 7.0-9.0. They can handle up to 400 ppm of dissolved solids and 20 ppm of undissolved solids which satisfies most system requirements. However, there are certain circumstances when a different type of material for the mechanical seal should be specified. These include:

Systems with high pH levels. Most HVAC applications maintain a pH from 7.0 to 9.0. Once in a while the pH is too high for the carbon-ceramic seal material. The main issue may be located in the chemical treatment portion of your specification. There are specifications that call for the pH to be maintained at levels in the 9.0-11.0 range. If your specification calls for this range, the pump seal material specification should be changed to EPR/Carbon/Tungsten Carbide (TC) or EPR/Silicon Carbide (SiC) /Silicon Carbide (SiC). We recommend the EPR/SiC/SiC material since that seal can handle pH up to 12.5 which gives some “wiggle room.”

Higher solids levels. Solids, otherwise known as dirt, are another area of concern for mechanical seals. If the system is dirty or has silica in the water, you may find that you need the EPR/SiC/SiC seal. The standard Buna/Carbon/Ceramic seal in HVAC systems cannot handle any silica or other solids. The silicon carbide seal can handle 60 times the dissolved solids content and double the undissolved solids content with 20 ppm silica content thrown in for good measure.

So, why not just always specify EPR/SiC/SiC seals? The answer is cost and lead time. This seal will cost three times as much as the standard seal and because it is considered non-standard it may take longer to get.

Improperly mixed glycols. In HVAC systems you want a properly mixed glycol-based heat transfer fluid that has the correct inhibitors for the application. If you use automotive antifreeze in HVAC systems, the silica based inhibitors will create a gel in the coils that blocks heat transfer and flow. That is, if the seals don't leak first!

We commonly see Dowtherm® SR-1 and Dowfrost™ HD heat transfer fluids used for these type of applications. These products are made for use in our industry but should be mixed according to the manufacturer's instructions. Dow recommends they be pre-mixed with deionized water before filling the system. If you simply mix these product with city or well water the calcium and magnesium in water will mix with inhibitors and cause a particulate that exceeds the ppm of normal seals.

Occasionally contractors will put the glycol-based fluid in the system, fill it with water and then turn on the pump to "mix" the solution in the piping system. This subjects the pump seals to shots of up to 100% ethylene or propylene glycol which is well beyond the maximum recommended amounts for even silicon carbide seals.

Our experience is that the standard carbon ceramic seal work fine with properly mixed glycol products designed for our industry. However, brands vary in their quality and make-up so we cannot say that carbon-ceramic seals are appropriate for all glycol mixtures. These fluids do carry a higher pH than water, so we recommend specifying a glycol seal if there is any question.

What You Need To Know About Pump Motor Speed

RPM in the HVAC/Pluming Worlds

How does RPM (revolutions per minute) impact pump operation? And what RPM is best suited for hydronic applications?

A pump's RPM or "synchronous speed" is determined by the number of magnetic poles in the motor winding as they interact with alternating current power. Magnetic fields are induced in the stator, the part of the motor with copper windings. The rotor (the part with the shaft) has an opposite magnetic field. As the magnetic field is changed in the stator, the rotor moves. Think of playing with two magnets of opposite polarity. You can move one magnet with the other without the magnets ever touching. The number of "magnetic" poles in the rotor will determine its speed.

Pumps used for hydronic HVAC or plumbing applications have the following RPMs:

- Two pole, 60 Hz motors that run at 3600 rpm

- Four pole, 60 Hz motors that run at 1800 rpm

- Six pole, 60 Hz that run at 1200 rpm

Perhaps you've noticed that the speed listed on the nameplate of the motor is slightly less speed than stated above. The industry may call a motor 1800 RPM or 1750 RPM and the nameplate might read 1770 RPM or 1765 RPM. These are all the same in our world. The reason can be stated simply or made very complex. The simple reason is that the magnets in the motor spin faster than the shaft due to bearing friction and torque or load. This difference is called "slip."

In the past, motors had lower efficiencies than the premium efficiency motors of today, so you will see older motors and older pump curves at slower speeds such as 1750 or 1735, while today the motor may be run at 1770 or 1780 RPM. The EPAct Energy Policy Act premium efficiency regulation increased the minimum efficiency which reduced the friction in the motor and increased the rated speed of the shaft. Different people in the HVAC world may refer to a motor as 3500, 3600, 3550, or 3565 RPM but for practical purposes they are all the same.

Electronically commutated motors (ECM) for HVAC centrifugal pumps are also an option for smaller pumps. ECM motors are variable speed and extremely efficient. Typically, the larger motors we normally use in the industry are induction motors that use an alternating current (AC) to produce a magnetic field as described above. This process produces heat which reduces efficiency. However, ECM motors utilize permanent magnets and since we are not having to produce a magnetic field, the efficiency of the ECM motor is higher than an induction motor.

The challenge with ECM motors is size. The maximum ECM horsepower available today is around 5 HP. For this reason, ECM motors are normally only available on smaller pumps for smaller applications. They are very prevalent in fractional horsepower pumps and fans. Unless we are willing to install and operate multiple pumps in series and in parallel, we are limited to using induction motors for larger applications.

Over Speeding HVAC Pumps & Motors

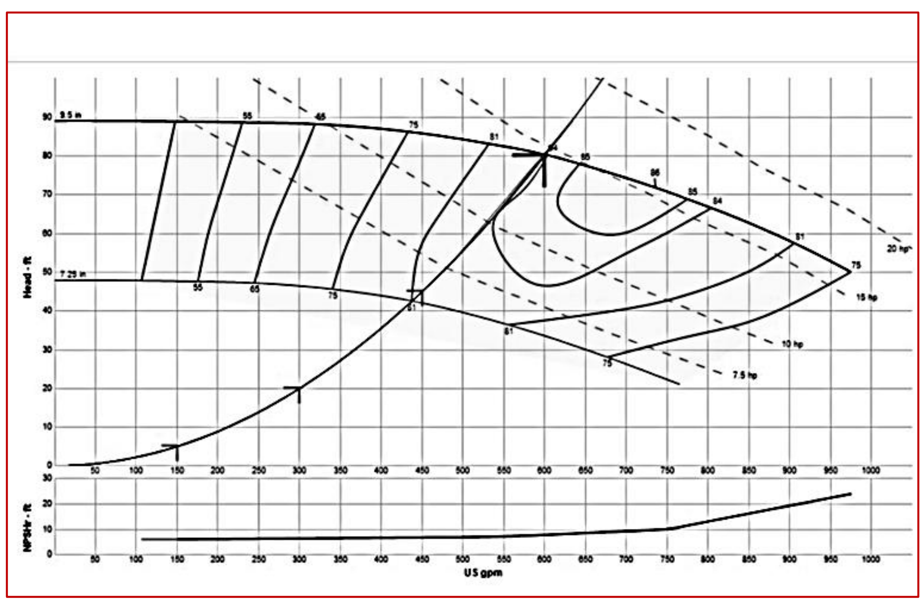
Sometimes it makes sense to select a pump with a little extra capacity as a safety factor. One way to do this is to operate the pump above the its rated RPM speed by using a variable frequency drive.

The pump affinity laws illustrate the dynamic relationship between flow, head, speed, and horsepower in a closed hydronic systems. One mantra frequently heard in our industry is, "twice the flow needs four times the head." The same is true for motor speed:

- Twice the motor speed gives twice the flow
- Twice the speed gives four times the head
- Twice the speed requires eight times the horsepower

How much you can over speed a pump may depends on the manufacturer. In general, Bell & Gossett recommends a maximum speed increase of 5%. There may be more increase available, but we recommend contacting the manufacturer to make sure there are no issues.

As an example, let's assume we have a closed chilled water system with a capacity of 600 GPM of water at 80 feet head. We've selected the below pump at 1770 RPM.



What happens if we want to increase the speed by 5% using a VFD set at 63 Hz? Using the affinity laws we come up with this:

FIRST AFFINITY LAW

$$\frac{GPM1}{GPM2} = \frac{RPM1}{RPM2} \qquad \frac{600}{630} = \frac{1770}{1858}$$

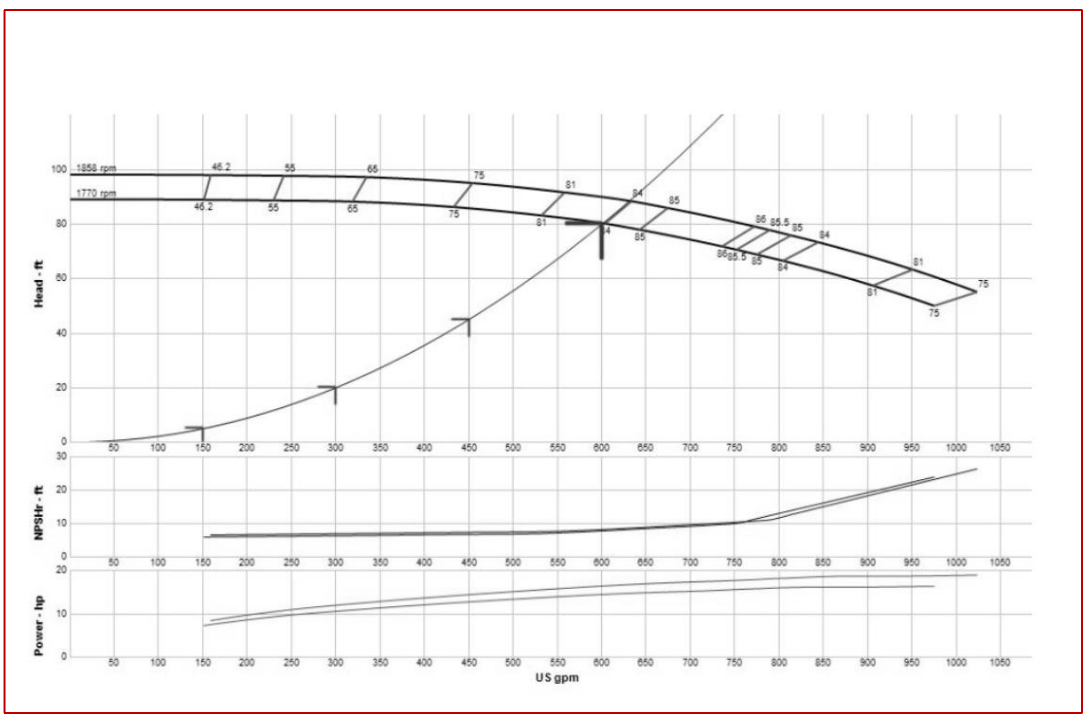
SECOND AFFINITY LAW

$$\left(\frac{RPM1}{RPM2}\right)^2 = \frac{HEAD1}{HEAD2} \qquad \left(\frac{1770}{1858}\right)^2 = \frac{80}{88}$$

THIRD AFFINITY LAW

$$\left(\frac{RPM1}{RPM2}\right)^3 = \frac{BHP1}{BHP2} \qquad \left(\frac{1770}{1858}\right)^3 = \frac{14.5}{16.8}$$

Based on this we would expect the potential capacity to be 630 GPM at 88 feet, but requiring 16.8 horsepower. Since the original selection would have a 20 HP motor to be non-overloading, the motor looks good. Here's what the curve looks like:



The selected pump is still non-overloading at 20 HP when running at a higher speed of 1858 RPM.

Limitations and Concerns

Before deciding to increase the pump speed, make sure that the drive and pump motor are rated for the higher amp draw caused by the increase horsepower. If the amp draw is larger than the rating of the drive, the breaker or fuse disconnect will trip.

Another issue is the pump and motor bearings. Often when a pump is available at a nominal 1800 RPM speed and also at 3600 RPM speed, the components inside the pump change. The change occurs because the work done by the pump could increase. The changes include larger bearings and shaft, and a different seal and coupler. When is this the case? There really is no fixed answer. It is imperative that you check with the pump manufacturer when considering over speeding a pump.

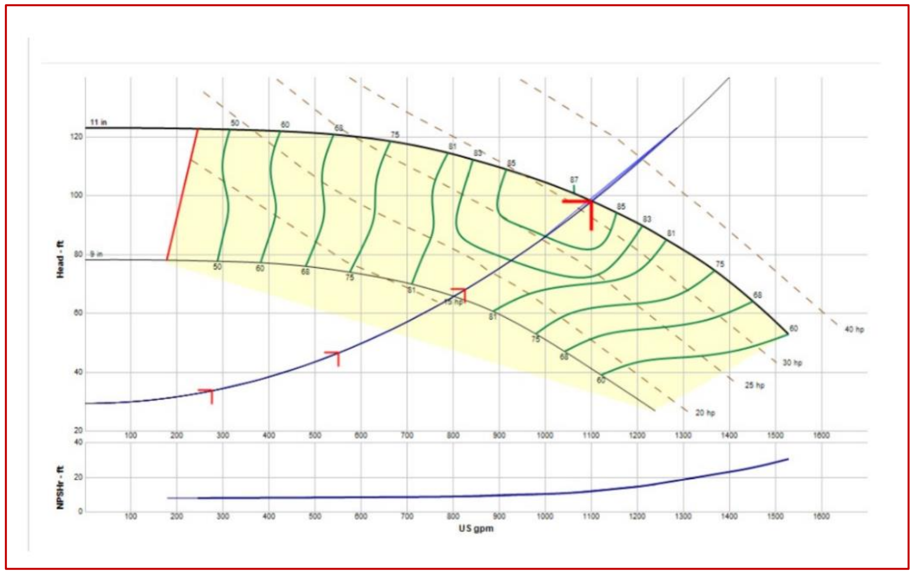
One last concern is the net positive suction head (NPSH) required by the pump. NPSH increases at a greater rate than the speed. If we over speed the pump by more than 5%, we should check the NPSH available (NPSHA). Once we have the NPSHA, a safety factor is applied since the exact NPSH varies slightly with manufacturing tolerances and also due to entrained air in the hydronic system. The example above is a low energy pump; the suggested safety factor is 1.3. As we change the speed of any pump, the energy of the pump may change and the suggested safety factor will also change.

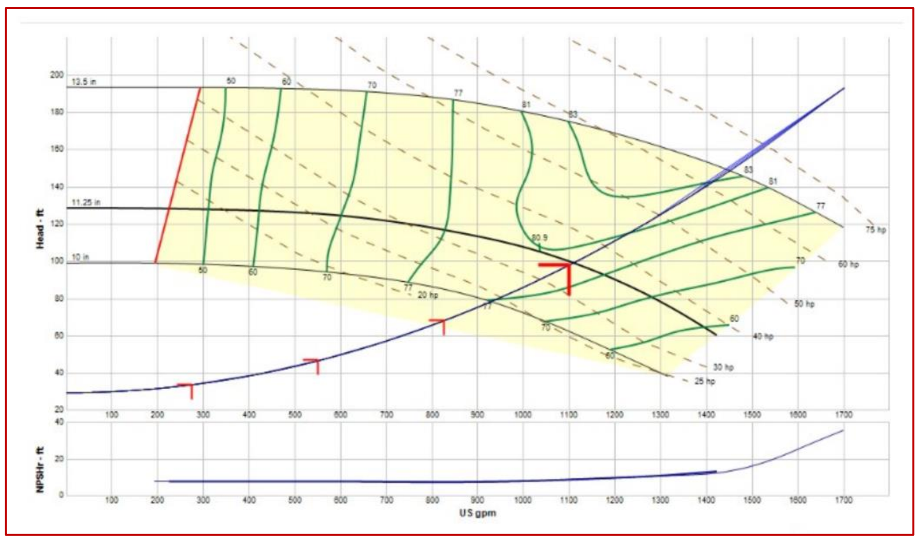
Over-Speeding an HVAC Pump with a VFD

Pump affinity laws, Btuh coil heat transfer calculations, and ASHRAE flow tolerance recommendations all tell us that a slight miss on the pump head may result in only a minor difference in the pumping system's ability to satisfy load. Still, no one wants the owner to receive a balance report indicating a shortage of flow compared to the schedule.

There are many specifications that instruct pump selection at less than the maximum impeller so the designer has "room to move" if needed. These "hand-me-down" statements often create confusion and flawed pump selections. In addition, by not selecting a pump at or close to the maximum impeller published, you give up the possible best efficiency point (BEP) of the pump. Over speeding a pump with a VFD allows engineers to safely take advantage of the efficiency associated with greater impeller diameters.

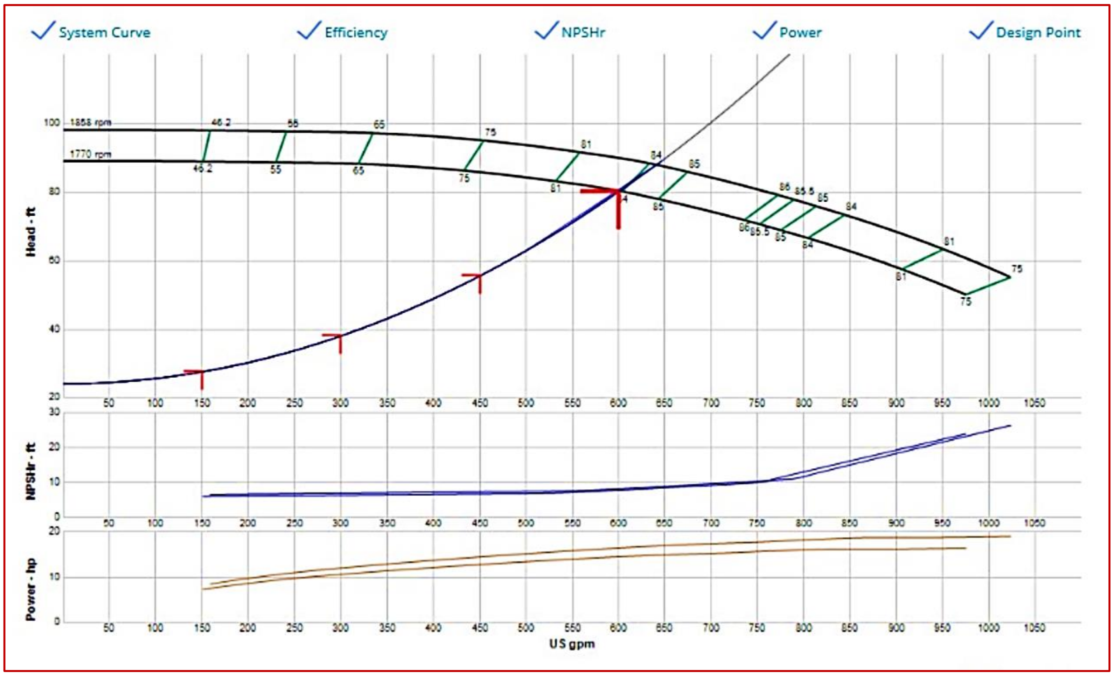
Look at the two selections below. The selection on the top is the better selection but many engineers would choose the one at the bottom so they can increase the impeller if they need to. But, there is more to the story….





If we need to increase the impeller so the flow rate increases by 5%, we will run out of horsepower and have to increase it from 40 HP to 50 HP.

What about the better curve on the bottom? If we increase the speed of the pump by 5% or up to 63 Hz, the 1510-5EB curve will now look like this:



The horsepower of the pump and the amp draw of the variable frequency drive (VFD) will be acceptable to operate this pump at 1860 RPM. This provides 10% additional head capacity for the future, while sustaining overall pump efficiency. We checked the horsepower and found it to be non-overloading all the way to 1450 GPM at the higher speed of 1860 RPM. This is a great pump selection!

We also suggest removing all specification statements like, "85% of maximum impeller" or "capable of increasing the impeller by one diameter" or "pump selected for future larger impeller." Instead, consider adding this to your specification:

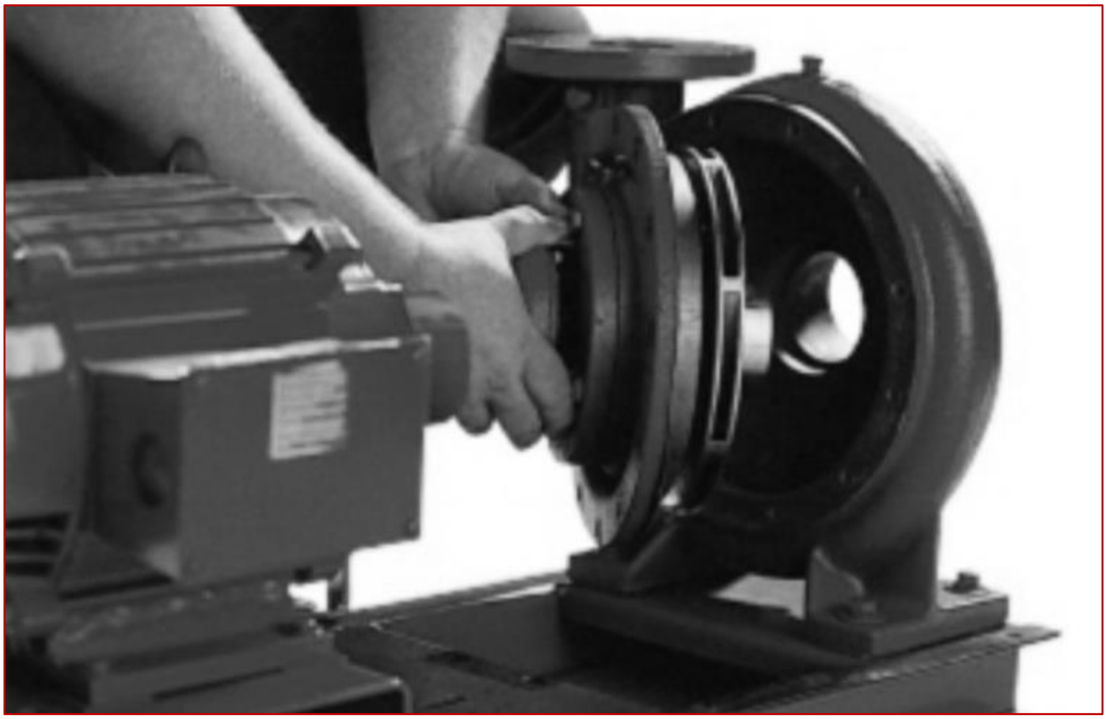
"Pump and motor shall have the ability to operate at 5% over the scheduled speed using a VFD without affecting the warranty or causing damage to the pump or motor."

Finally, make sure you have enough horsepower to operate the pump at the new speed. This could also impact frame size since changing an impeller might change the motor horsepower, the pump shaft size, the bearings, base and the pump dimensions.

Best Practices for Safety and Performance

There are several things an engineer can do to help ensure safe, efficient, and long lasting performance. Here is a useful list of best practices:

Specify Pumps with an OSHA Approved Coupler Guard. Coupler guards prevent dangling items (neckties, chains, etc.) from getting caught up in the coupler as the shaft is spinning. Such incidents can cause serious injury as well as lawsuits. State and Federal codes state that when a motor is flexibly-coupled to a pump shaft, there should be an OSHA-approved guard. Bell & Gossett provides OSHA-approved coupler guards as a standard feature on any pump it sells. That is not the case with every manufacturer so it is essential that you include this requirement in the specifications. Otherwise you get the old-style, U-shaped strip of sheet metal which is not OSHA approved.



*Look for Pumps with a True Back Pull-0ut Design***.** A pump with a true back-pullout design as shown below allows servicing the pump without moving the motor.

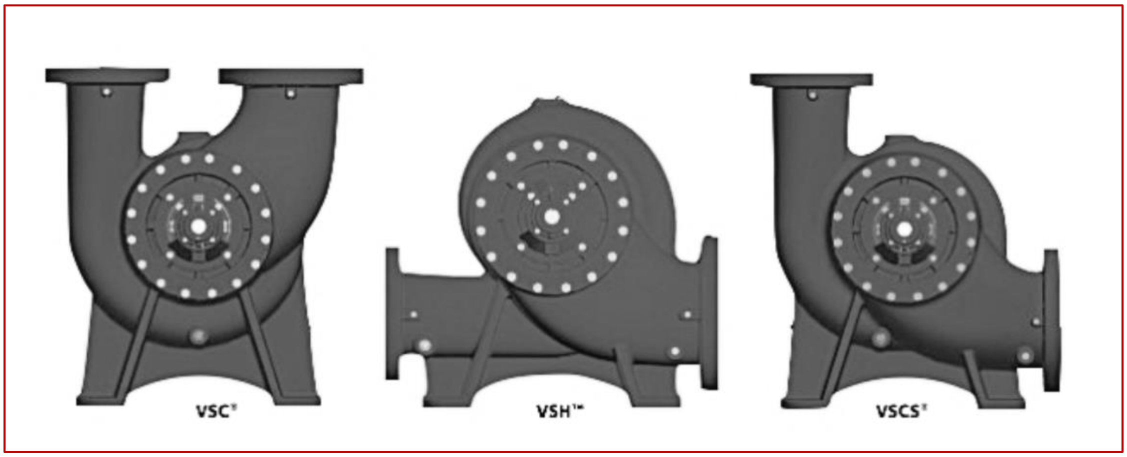
Select pumps with a Solid-foot Mounted Volute. Pumps with an integrally cast volute foot help you maintain pump alignment during maintenance. Also, since the piping can be quite heavy, this support keeps distortion from occurring which can lead to premature failure. This is especially important on hot water systems because of the continual pipe expansion.

Choose a Drop-out Spacer Coupling. This allows for removal of the bearing frame and rotational element without disturbing the pump alignment or electrical connections. Make sure the coupler type specified will operate without issue when used with a variable speed drive.

Consider Specifying a Trolley and Gantry for Inline Pumps. Remember, the motors for vertical inline pumps must be removed for servicing the pump bearings. Since these motors tend to be heavy, do your client a favor and include a "hoisting" mechanism so that the motor can be carefully lifted away from the pump for servicing. If this is not an option, make sure there is plenty of space around the pumps so a contractor can locate equipment to service the vertical inline pump.

Double Suction Pump Pipe Orientation. Avoid using an elbow that has a plane that is parallel to the pump shaft. Otherwise the flow will be severely non-uniform, creating fluctuating high pressures on one side of the impeller inlet, while starving the other side. This can also cause noisy operation and even damage due to cavitation. This needs to be a consideration when choosing between a base-mounted or vertical inline double suction pump. If the pump shaft is parallel to the elbow then a suction diffuser should be used.

- For double suction base-mounted pumps, depending on the piping arrangement, you can better orient the suction and discharge flanges in one of the following ways to eliminate an elbow: Horizontal discharge and horizontal suction (VSH)



- Vertical discharge with horizontal suction (VSCS)
- Vertical discharge and vertical suction if you have a Vertical split case pump (VSX)

Finally, the chart below is an excellent general reference for when to specify which type of pump.

As you will notice, all the pump types have flow ranges that are beyond what is actually optimal in terms of operating efficiency – sometimes well beyond. Ideally you want to stick with a pump type that will operate primarily within its optimal flow range (shown in red). This is not only improves efficiency, but also service life.