WHITE PAPER

Vertical Turbine Pump Selection for Potable Water Applications

Design Considerations to Meet NSF Requirements

Systems that are destined to carry potable water have a big responsibility to deliver water from the source to the end user without introducing contaminants. Consequently, potable water applications carry an extra level of consideration when choosing vertical turbine pumps (VTPs). Because the liquid that flows through the pumps is meant for human consumption, they must meet stringent standards for public health protection.

Common vertical turbine pump potable water applications are municipal residential distribution, hospital water systems, purification plants, and bottled water plants. Each application carries its own special considerations, in addition to the requirements of the related NSF standards.

NSF standards impact all aspects of pump selection from materials of construction to pump design. These are in addition to ensuring a cost-effective and reliable pump. This guide outlines the relevant NSF standard, parameters for selecting an efficient pump, and how they relate to various pump material and engineering decisions.

NSF Standards

The National Sanitation Foundation (NSF) is an accrediting body that sets standards for public health and safety. This independent organization tests, inspects, and certifies products to ensure they meet established standards. NSF standards apply to a wide range of products, including food, water, and consumer goods. These standards encompass not just the consumable products themselves, but also the equipment on which they are processed.

In order to become NSF certified, a company that manufactures pumps for potable water applications must complete a rigorous review of its materials and manufacturing facilities. To maintain the certification, it must submit to annual testing that verifies continued compliance.

The standard that applies to pump manufacturing is NSF/ANSI 61. It is written specifically for drinking water system components and establishes minimum levels of impurities and chemicals which can leach into drinking water from the equipment used in drinking water systems. This standard covers everything the water touches on its journey from ground to water glass–storage tanks, pipes, hoses, valves and fittings, and any coating or filter materials. In pumps, this standard applies to all the 'wetted parts', or those that come in contact with the pumped liquid.

How these regulations impact pump selection is discussed in more detail under Material Selection.

Figure 1: Only NSF Certified vendors may display the NSF logo on their marketing and technical materials.

Obtaining official NSF certification is a difficult, time-consuming and expensive process. Beware of any suppliers who state they are 'compliant with NSF standards'. The NSF is not testing their materials or processes and you have only the manufacturer's word that its products meet the standards. When it comes to public safety, it's best not to take that gamble.

Additionally, many municipalities are bound by specifications that require vendors to be fully certified, not just compliant. Starting a project with a vendor who is only 'compliant' may necessitate time and money lost in switching to a 'certified' vendor. It's best to start with identifying an NSF Certified pump vendor from the beginning. NSF Certified vendors are granted the use of the official NSF logo (Figure 1).

Understanding Selection Parameters

All centrifugal pumps, regardless of application, are selected based on the supply system's flow and pressure. Because a single pump can cover a wide range of flow and pressure, there are often several bowl sizes and models that can meet the conditions. Care should be taken to choose a pump that not just fits in the range but also offers the most efficient operation.

This necessitates an understanding of pump curves, a curve's marked Best Efficiency Point (BEP), and Net Positive Suction Head of the pump.

Using Curves for Bowl Size and Model Selection

One of the first selections in building a pump is determining the bowl size. This is done by comparing the applications' required flow and pressure performance parameters with the available pump models' curves to determine which will meet the system's operating conditions.

The range of a pump's performance is typically given in the form of a pump curve which shows the volume of liquid a pump can move given various pressure conditions. Pump manufacturers build curves through performance testing.

In the curve example below (Figure 2), the X axis marks flow in gallons per minute (gpm). The Y axis marks pressure, expressed in feet of head. Each curved shape on the graph represents the marked bowl size's operating range. The upper line of the curve indicates the operation of that model at its maximum impeller diameter. The lower curve indicates the operation of that model at its minimum impeller diameter. (Impeller trimming allows a pump

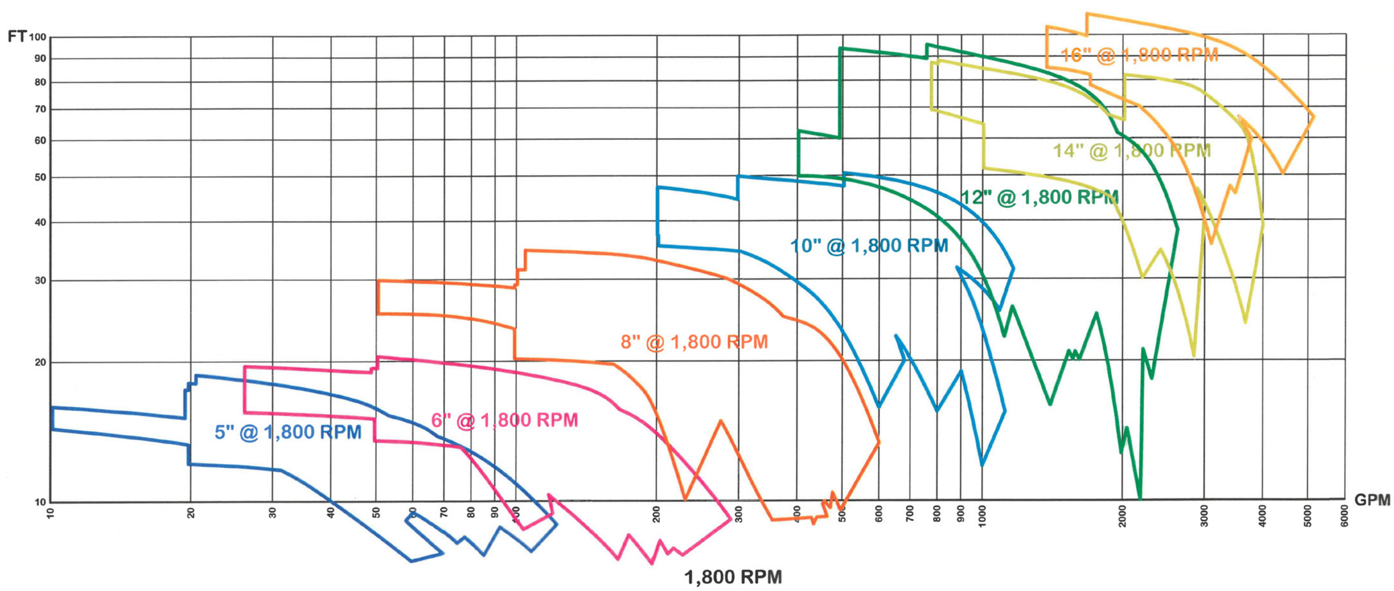

Figure 2: A vertical turbine pump curve for a range of bowl sizes at 1800 rpm

model's performance range to be fine-tuned to its intended application's performance parameters.) The entire area inside the curved shape represents operating conditions that a pump model can meet.

Referencing Figure 2 again, the green lines on the curve represent the operating conditions for a 12" bowl. Every flow/pressure combo that falls inside that green outline is technically within the operating range of that 12" bowl pump. In some cases, the ranges overlap, as in the 12" and 14" bowls. If operating conditions are in that overlap area, say 1,500 gpm at 60 feet of head, then technically either a 12" or 14" bowl pump model would work for those parameters. In practice, one is a better choice; to determine which one that is, the Best Efficiency Points of the two pump curves should be compared. Best Efficiency Point is explained in more detail below.

Looking at each of the outlines, you can also see that as bowl size increases, so does the amount of flow and pressure it can achieve. A 5" bowl tops out at about 300 gpm (at 10 feet of head), and just over 20 feet of head (at 50 gpm). The 16" bowl can reach over 5,000 gpm (at just under 70 feet of head), and more than 100 feet of head (at flows of about 1,750 gpm).

Pump curves are always based on the performance of a single stage (bowl plus impeller assembly) pump. Flow is a function of bowl size and pump model. No matter how many stages are added, the flow range of a given model remains static. Pressure is more adaptable. If an application's pressure requirements are higher than that shown on the curve, the amount of pressure the pump can handle can be increased by adding additional stages. Each stage increases the pressure range by the same amount of pressure as the original single stage.

For example, a given application's operating conditions are 1,000 gpm at 120 feet of head. A pump model is identified that delivers 1,000 gpm, but only up to 60 feet of head. An additional stage can be added to expand the pressure range. The new two stage pump is now suitable for pressures up to 120 feet of head. If the original pressure requirement had been 180 feet of head, a third stage could be added to take the pump's operating range up to 180 feet of head, and so on.

In the example above, the flow remains static at 1,000 gpm, no matter how many stages are added and how much the pressure range is increased. Theoretically, the operating pressure could be increased infinitely by continuing to add stages, but you would be limited by physical space and material constraints. The internal components-seals, bearings, cast parts-each have their own pressure ratings that limit how much pressure that particular part can withstand. Consequently, a pump's pressure can't exceed the pressure rating of its lowest rated part.

Once potential models/bowl sizes have been identified, the selection is then narrowed by evaluating how efficiently the options meet the performance conditions, as described below under Best Efficiency Point.

Best Efficiency Point

The testing that establishes the pump curve also determines the efficiency for each model pump. This includes the point at which it operates most efficiently. This point is called the Best Efficiency Point (BEP).

At the BEP, the least amount of fluid is bypassed back to the low- pressure (or suction) side of the pump. The pump runs the smoothest at this point, the flow is the cleanest moving through the pump, and there is minimal axial loading on the pump bearings.

During normal operation, a good rule of thumb is that a vertical turbine pump should always be operated between 60% and 90% of the BEP. There is more room to operate a pump at a lower range (down to 60%) than to max out its operation (up past 90%). The reason for this range is based on the physics of the design. Operation in this zone assures the highest efficiencies and the most reliable operation, with the lowest bearing loads, turbulence and vibration.

A manufacturer's stated BEP is a fixed point at a fixed operating condition. In practice, pumps seldom operate under the same controlled conditions as a performance test. There are almost inevitably variations in pressure on pump systems.

With a pump selected just at BEP, these fluctuations in the flow can result in operation well outside the pump's BEP. From BEP, it only takes movement of 20% to go too far out on the curve, creating the potential for cavitation and increased axial loads.

Selecting a pump that will typically operate at 85% of BEP allows for these system fluctuations. It enables variances of up to 20% on either side of the BEP, without moving out of the acceptable 60-90% window.

The following vertical turbine pump curve (Figure 3) shows the operating range area with shading to indicate the most efficient conditions within that 60%-90% window.

The sweet spot is the area in green just to either side of the 85% of BEP target. As the shading passes from yellow to orange to red at the outer reaches of that 60-90% window, the pump operation becomes more unstable.

As previously noted, pumps are less forgiving of operation in excess of BEP. Note the short distance past BEP before the pump would enter into the red zone of non-optimal and potentially problematic operation.

NPSH

A final consideration in designing an efficient pump is understanding Net Positive Suction Head (NPSH). NPSH is a measurement of liquid pressure at the suction intake of the pump. Two different aspects of NPSH need to be determined to make this calculation: NPSHr (required) and NPSHa (available).

NPSHr is the amount of net positive suction that the system needs to deliver to the pump in order for it to operate properly. This requirement is directly dictated by the pump design. NPSHa is the amount of net positive suction that the system can deliver to the pump. The available amount of net positive suction is calculated based on several factors-atmospheric and vapor pressure, suction lift, and friction.

If a system's NPSHa is lower than the pump's NPSHr, the suction system will not perform properly, resulting in cavitation and damage to pump. Understanding how the two work in tandem allows engineering of a pump design with an NPSHr that aligns with the system's NPSHa. Conversely if other factors dictate a pump design with an incompatible NPSHr, the suction system may be modified, changing the NPSHa to meet a given pump design's NPSHr.

For instance, suction piping diameter impacts how much friction the system generates. So increasing piping diameter on the system will raise NPSHa, while decreasing the diameter will lower NPSHa. This change is due to the amount of piping friction losses prior to pump suction.

NPSHa of the intended system should always be calculated and compared to a proposed pump models' NPSHr prior to finalizing a selection.

Design Choices

Material Selection

When it comes to wetted component materials that meet the NSF/ANSI61 standard, there are two main choices: Scotchkote™134 and Stainless Steel (typically 316). Wetted components include the interior of the column and bowls, the shaft, and the impellers. Each has its own benefits and drawbacks.

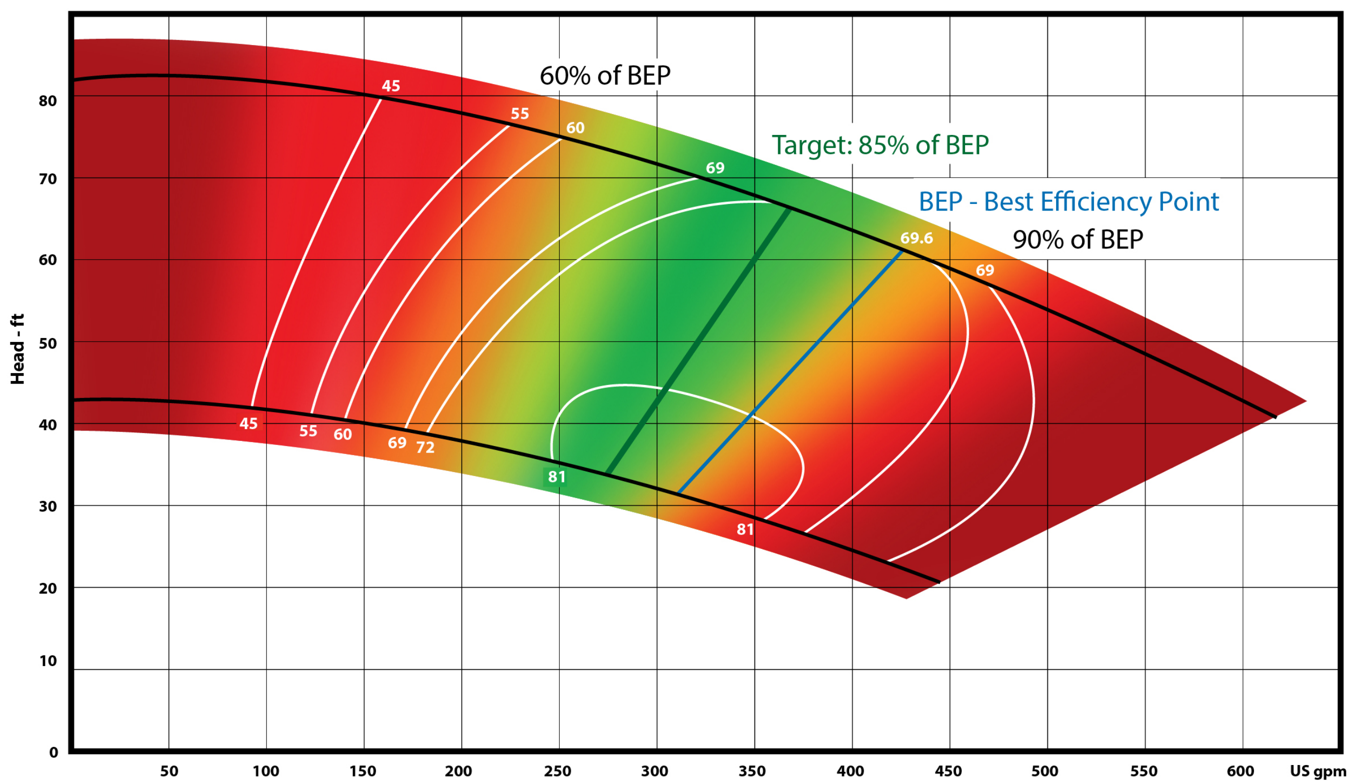

Figure 3: A vertical turbine pump curve for a range of bowl sizes at 1800 rpm

Scotchkote, 3M's™ Fusion-Bonded Epoxy Coating, is applied to more affordable metals such as cast iron. The heat bonded epoxy creates a protective barrier that is impervious to leaching of impurities and protects the components from corrosion.

Overall cost for Scotchkoted pumps is generally less than the cost of Stainless construction. However, sending the components out to be coated adds to pump manufacturing lead time. An additional drawback of Scotchkoting is durability and lifetime maintenance. If the coating becomes chipped, it will be vulnerable to rust and could potentially allow leaching of impurities higher than the levels allowed by NSF61.

From one small chip, rust can travel under the coating and compromise the entire pump. To remedy any wear, the pump must be fully disassembled, sandblasted to remove the original coating and any corrosion, then recoated. This can be a very time-consuming process that increases maintenance downtime and cost.

Stainless Steel has traditionally been considered a pricey premium option. In recent years, as Stainless material costs have equalized with other materials, it is becoming a more competitive option, especially in light of its advantages relative to Scotchkoted pumps. Stainless parts are typically available off the shelf, cutting as much as two weeks off the pump lead time over parts sent out for coating. Stainless is naturally corrosion and rust resistant; chips carry no risk of rusting. Finally, because Stainless is a harder material than cast iron, Stainless parts generally withstand friction and wear better.

Sealing Method

In addition to the initial and lifetime costs of NSF-compliant materials outlined above, there are other vertical turbine pump design considerations that can affect ongoing maintenance costs. Choice of sealing method is a key decision where selection can significantly impact initial cost versus lifetime cost.

The sealing method is meant to minimize the leakage that naturally occurs around the shaft opening during normal pump operation. Excessive leakage can cause loss of valuable process fluids (in this case, clean potable water), as well as wet hazardous plant conditions. The three sealing method options are packing, mechanical seals and self-seal column designs.

The packing box, or stuffing box, is a chamber filled with fibrous material designed to slow down, but not eliminate, leakage. While it has the lowest initial cost, it's the least perfect of the three options. As the packing and shaft wear, the packing requires frequent maintenance in the form of compression adjustment to control the leakage rate. Too much compression causes serious wear on the shaft and increases the amount of leakage.

Improperly managed packing could damage the shaft enough to require shaft replacement, at significant cost. Additionally, packing material naturally degrades over time, compromising its integrity and requiring potentially costly downtime while it is replaced. Ongoing maintenance and potential for costly repairs, while failing to completely stem leakage, makes packing the least attractive option.

Mechanical seals were designed to overcome the shortcomings of packing box designs. A mechanical seal consists of two primary rings of extremely smooth material– one rotates with the shaft and the second remains stationary with the pump. A thin film of process fluid lubricates these faces. The seal is engineered to leak this lubricating fluid to the atmosphere, ideally so slowly that it evaporates rather than collects.

If the two faces of the seal become mis-aligned, worn, or damaged, more process fluid than intended escapes from the shaft opening and collects in noticeable leaks. Vibration from shaft movement, air entrainment, cavitation, solids, or improper operation (such as running a seal dry) can all cause seal damage.

When a seal starts to fail and leak excessively, the pump must be taken out of service for seal replacement. Even under ideal operating conditions, regular wear dictates that mechanical seals be replaced regularly, which can be a matter of every few months or every few years, depending on system operation.

In potable water applications, some of the mechanical seal drawbacks are less apparent. The engineered leakage tends to evaporate quickly, as intended. Also, as potable water should be free of any solids, there's no danger of any contaminants working their way between the seal faces and causing damage. Potable water represents the ideal operating conditions for a mechanical seal, making it more likely to perform as designed. While more expensive than a packing box, predictable routine maintenance requirements make mechanical seals a viable choice for balancing initial cost and lifetime cost.

The final choice, a self-sealing column, is the only one of the three that completely prevents any process fluid

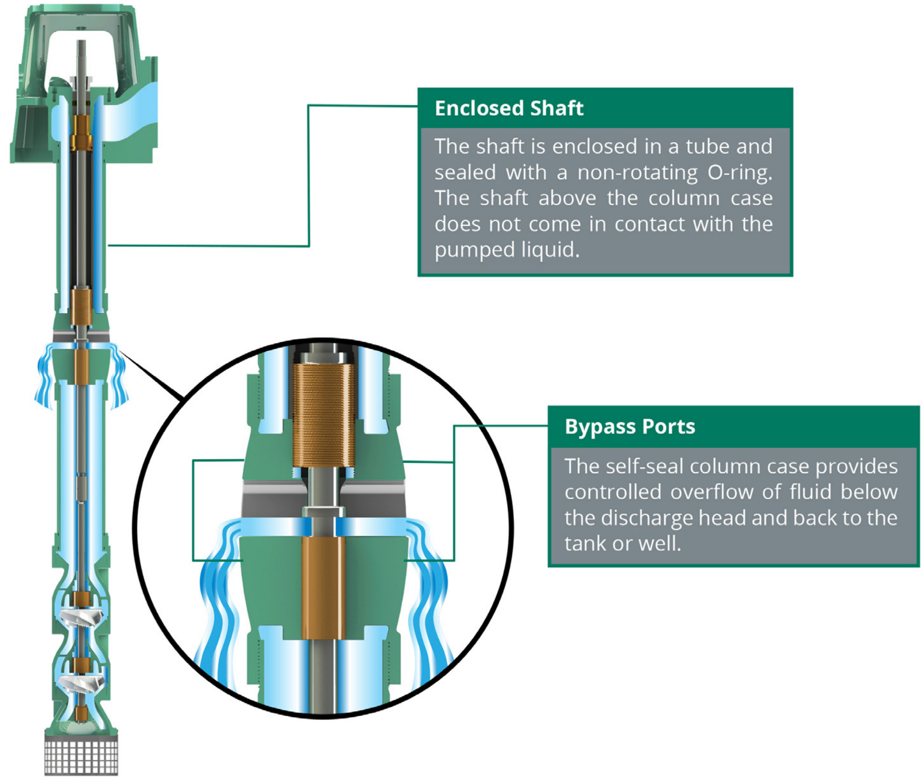

Figure 4: Typical self seal column operation in vertical turbine pump eliminates leaks

from escaping the pump. A seal-free pump first reduces any leakage to a minimal amount. Secondly, it collects and contains any leakage within the system and returns it to the process. This method prevents hazardous puddles from creating dangerous plant conditions and eliminates the loss of process fluid (in this case, potable water, an increasingly precious resource).

Figure 4 illustrates how the self-seal design works. The shaft above the self-seal case is enclosed in a tube isolated from the fluid. A non-rotating O-ring seals this shaft-enclosing tube. As the pumped solution passes up through the lower column assembly, it enters the self-seal column case, located below the discharge head.

The self-seal column case throttles the fluid pressure, diverting liquid away from the shaft-enclosing tube. A minimal amount of fluid flows past the lower bushing into the self-seal case. A stainless steel slinger in the self-seal column case directs this fluid to the pump's bypass ports which funnels any liquid back to the tank or well. From the self-seal case upward, the shaft is enclosed in a dry tube away from the fluid, making it impossible for leaks to occur at the point the shaft passes out of the discharge head.

While there is a higher upfront cost for a self-seal design, lifetime cost is typically low. There is no risk of failure damaging other parts of the pump, necessitating costly repairs. Normal greasing is the only regular preventative maintenance required.

Conclusion

Proper pump selection has critical implications for public health and safety in potable water applications. These needs also have to be balanced against the reality of budget and maintenance resource concerns. Efficiency, materials selection and design features can all impact both the initial pump cost and the costs over the lifetime of the pump. An NSF Certified pump manufacturer is deeply familiar with all of these factors and can guide you through the selections that result in a safe, compliant, and cost-effective pump.