Selecting the Right Bearings to Improve Vertical Turbine Pump Reliability

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Introduction

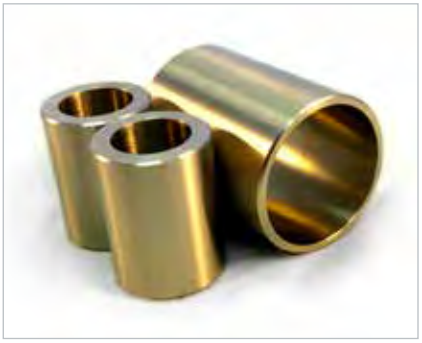
Vertical Turbine Pumps (VTPs) are available in a variety of configurations and are used for a number of different applications such as flood control, cooling water, waste water and drinking water supply. One of the biggest contributors to pump failures are issues involving the pump bearings. The type of water that lubricates the bearing as it is pumped varies considerably from application to application. Additionally, the amount of abrasives in the pumped water can vary significantly in different regions whereby the amount of abrasives can drastically effect bearing life. It is therefore critical to select the appropriate bearing material for the service as bearing life is influenced by the media being pumped.

The VTP bearings found in the bowl and column assemblies are one of the most critical components of any pump. Bearings not only support the shaft; they also reduce friction on the pump's moving parts.

Common Bearing Materials Used in VTPs

A) Bronze

- The most popular bearing used in VTPs as it is readily available, easy to machine and easy to install
- Bronze has poor abrasion resistance and is malleable and can deform under impact, which can translate into increased shaft clearances. Bronze is not recommended for dry starts and requires oil or grease which can contaminate pumped water
- Bronze is seven times heavier than non-metallic bearings, making installation of large sizes difficult
- Due to lead content, most bronze bearings are not approved for drinking water
- Bronze can be expensive in large sizes



Bronze Bearings

B) Rubber

- Rubber is too soft to install directly into a pump housing and requires a metallic or phenolic carrier to install into the housing
- It offers good abrasion resistance and accepts some vibration and shock loading
- Rubber has a high coefficient of friction, thus dry starts are not recommended. Some manufacturers try to address this by applying a thin layer of Teflon® to the ID of the bearing. Teflon® has a low coefficient of friction but very poor abrasion resistance so if the pump is running in abrasive water, the Teflon® will wear away and the bearing will lose its dry start capabilities
- Rubber has lower mechanical strength so longer bearing lengths are recommended. Shorter bearings allow abrasives to pass through a bearing quicker and allows water to cool the bearing faster, which can translate into longer bearing life
- Rebuilding a pump is difficult with rubber bearings. During the rebuild process the housing and shaft are usually machined and now require a non-standard size. The wall of the metal shell of the bearing is thin to begin with and rubber is difficult to machine so a non-standard size must be ordered. This can lead to long lead times and extra costs
- Rubber is bonded into the shell. There are numerous cases of the bond breaking causing catastrophic failures

Due to its low mechanical strength, rubber bearings are typically bonded into a metallic carrier. Poor bonding can result in the bearing working its way out of the carrier.

C) Carbon graphite

- Has good dry running capabilities and temperature resistance
- Carbon graphite offers very poor abrasion resistance
- Bearings are brittle and can fracture during installation or from thermal shock

Cracking of carbon bearings

D) Teflon®

- Teflon® has excellent dry run capabilities and chemical strength
- Teflon® bearings have poor abrasion resistance
- Due to its low mechanical strength, Teflon® bearings cannot be retained by traditional press fit methods

Abrasive wear on Teflon® bearings

E) Thermoset Laminate

- Thermoset Laminates are used in some applications due to their low costs
- There are many manufacturers and grades of this type of bearing so physical properties can vary depending on the manufacturer. Most are made with cotton or glass cloth layers impregnated with thermosetting resins
- These materials also have poor abrasion resistance and dry run capabilities. As with rubber, some manufacturers try to enhance dry running capabilities by applying a thin layer of Teflon® to the wear surface. This Teflon® layer does not last long in abrasive conditions
- Machining of thermoset laminates can pose health issues due to fine resin dust being generated during the process. Special breathing apparatus is required
- During the machining process, some surface cords may become exposed and lead to significant surface swell which can reduce running clearance causing the pump to bind up

Examples of thermoset laminates

F) Thermoplastics

- There are many manufacturers of thermoplastic materials using different materials
- Nylon thermoplastics have high moisture absorption and poor abrasion resistance
- Acetal's abrasion resistance is worse than nylon and it has poor impact resistance.
- Some thermoplastics offer good abrasion resistance and these will be discussed later in this paper
- PPS (commonly called Ryton) has good chemical resistance and thermal properties but poor abrasion resistance. It is brittle and can crack due to shock or vibration. It can be expensive. Due to its chlorine resistance, it is often used as a bearing for applications in water parks and aquariums.
- Engineered thermoplastic such as Vespel and PEEK are used in many pump applications but are overkill for water-lubricated pumps. More appropriate applications for these materials would be in harsh chemicals or high temperatures

Examples of different thermoplastics

Continues on next page

- PEEK has high temperature capabilities combined with good chemical and steam resistance as well as thermal and hydrolytic stability. Most bearing grades are reinforced with carbon fiber and/or graphite making it difficult to process and machine. PEEK is expensive and has poor abrasion resistance. The high pricing is due to their high resin costs and limited number of molds available
- PFA is a Thermoplastic Fluoropolymer similar to Teflon®. It has good chemical resistance and low water absorption as well as good thermal capabilities
- Vespel CR-6100 is a carbon reinforced PFA with a high cost and has poor abrasion resistance. Common pump applications for this material would be harsh chemicals and high temperatures. The high pricing is due to their high resin costs and limited number of molds available
- AR-1 is another expensive filled PFA which also has poor abrasion resistance and is limited in applications to 37.8°C (100°F). Figure 1. AR-1 has limited molds available. The tube stock available to machine bearings has heavier wall thicknesses than are ideal for the application causing more machining and the waste of expensive material resulting in higher costs and longer lead times

Figure 1 - Vertical Turbine Pump Bearing Materials

Material	Maximum Suspended Solids	Remarks
Bronze	10 - 50 ppm	Poor dry running, especially alloys with low lead content.
Carbon Graphite	0 - 10 ppm	Self-lubricating. Corrosion resistant.
Teflon®	0 - 10 ppm	Self-lubricating. Corrosion resistant.
Vespel®	0 - 10 ppm	Self-lubricating. Corrosion resistant.
Rubber	50 - 200 ppm	Good with abrasive. Poor dry running
Hardened Metal	50 - 200 ppm	Expensive alternate for abrasives. Normally poor dry running.

Common Causes of Bearing Failure

Abrasion resistance and dry start capabilities are the prime causes of bearing failure and most of the bearing materials mentioned previously might be good with one of these issues but seldom are good at handling both.

Abrasive Wear

Abrasive wear occurs due to sand, grit, or other particulates that are suspended in the water being pumped. These particulates can abrade the bearing ID and shaft OD causing significant damage. Due to the growth of the world's population, water is now being pumped in many regions of the world where the level of abrasives in the water is very high. Also due to rising ocean levels many cities located along the coast have been installing flood control pumps, many of which are pumping abrasive water.

Pump manufacturers have addressed this by isolating the key wear components from the process water primarily through enclosing tubes or upgrading materials.

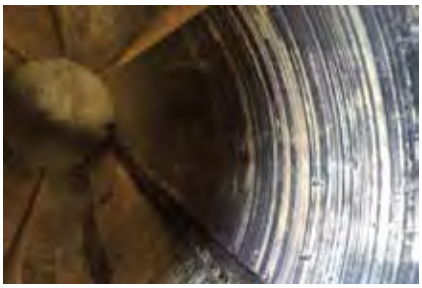
Enclosing tubes isolate the bearing and shaft from the process water. The bearings and shaft inside the tube are typically lubricated with oil. The system is now sealed from the abrasives. The biggest drawback to this approach is additional cost.

Upgraded materials are typically a combination of harder shaft materials and softer bearings such as rubber which handle abrasives better. The problem with this approach is that when there is a requirement for a dry start, rubber bearings can burn up from frictional heat created with little to no lubricant.

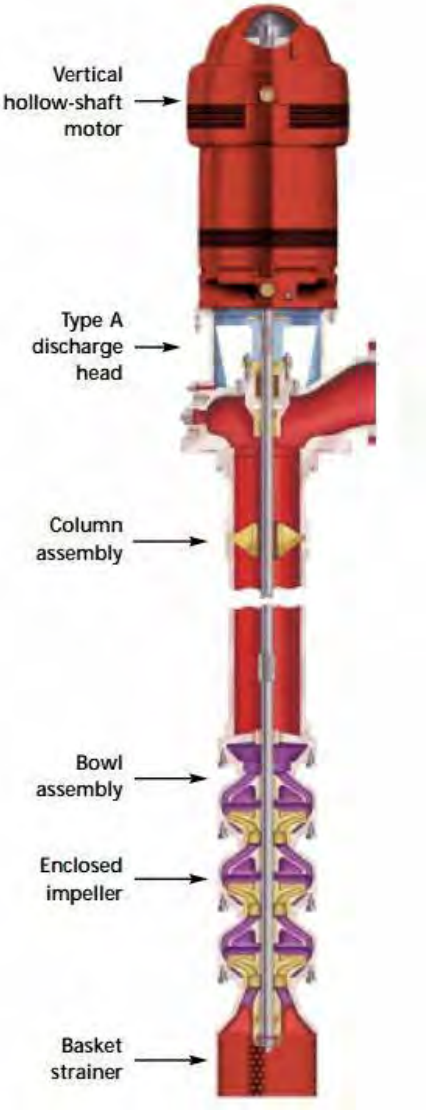
Dry Starts

Most VTPs consist of long shafts and multiple line shaft bearings in order to pump water from the source. In many cases it takes 10-60 seconds for the pumped water to flow up the pump through the bearings to the pump outlet. Flood control pumps are often required to start before the flooding occurs, necessitating dry starts.

As discussed previously, materials such as bronze, rubber, and most phenolic bearings cannot handle running dry for this amount of time due to their low friction properties. To address this problem, oil-lubrication or a water flush is required to lubricate the bearings until process water is flowing. The addition of lubrication or water flush systems adds additional costs for pump operation. You also run the risk of contaminating the process water with oil.



Abrasive wear on metal, select a grade with a higher hardness rating.



Typical vertical turbine pump profile

Thordon Bearing Materials
A More Reliable Solution for Vertical Turbine Pumps

Figure 2 - Thordon Material Selection Guide for Pump Bearing Materials

Level of Abrasives	Particle Size Diameter (µm)	Total Suspended Solids (mg/L)	Recommended Thordon Grade
Clean	< 50	< 200	ThorPlas / SXL
Slightly Abrasive	50 - 80	100 - 300	SXL
Moderately Abrasive	80 - 100	300 - 500	Composite
Heavily Abrasive	> 100	> 500	Composite

Note: Care should be taken to ensure the grade selected is also chemically compatible with pump media.

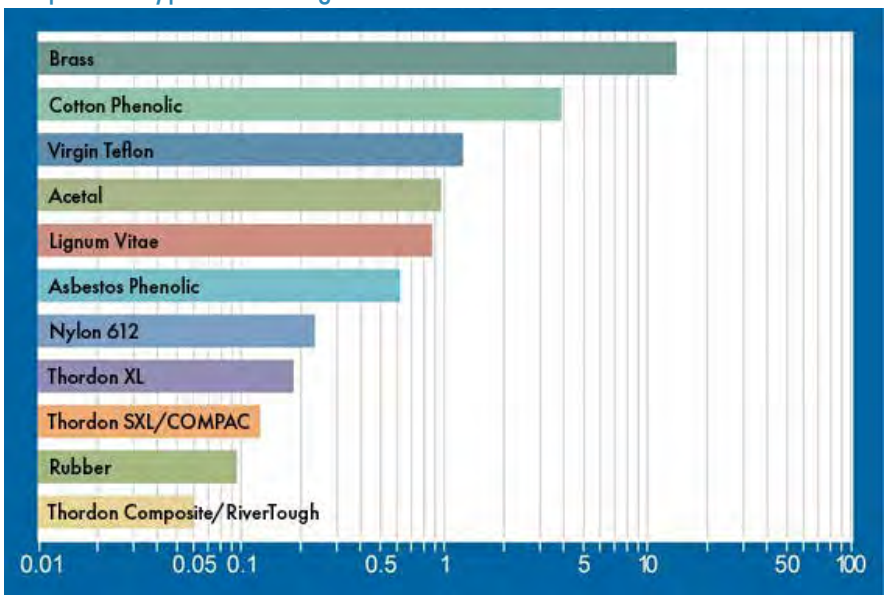
Thordon SXL

High Abrasion Resistance and Dry Start Capability

Thordon SXL has been used successfully as pump bearings for over 30 years and is approved by most pump manufacturers. It has a coefficient of friction that is lower than most VTP bearings. Low friction bearings operate longer with less wear and decrease start up torque requirements. This also translates into excellent dry start capabilities of 30 seconds or longer.

One of the key advantages of SXL is its excellent abrasion resistance. Graph 1 was conducted by an independent test. The results in Graph 2 were conducted by Thordon.

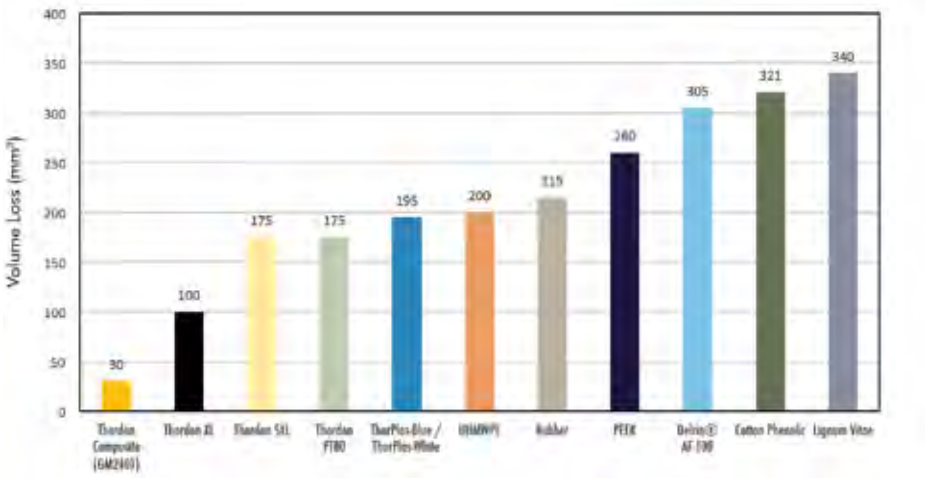
Graph 1 - Typical Bearing Abrasive Wear Rates



Projected Bearing Wear by Volume (cc/24 Hours)
(Independent Testing at University of Cincinnati, USA)

Graph 2 - Typical Bearing Abrasive Wear Rates

Rotary Drum Abrasion Test (ASTM D 5963-96)

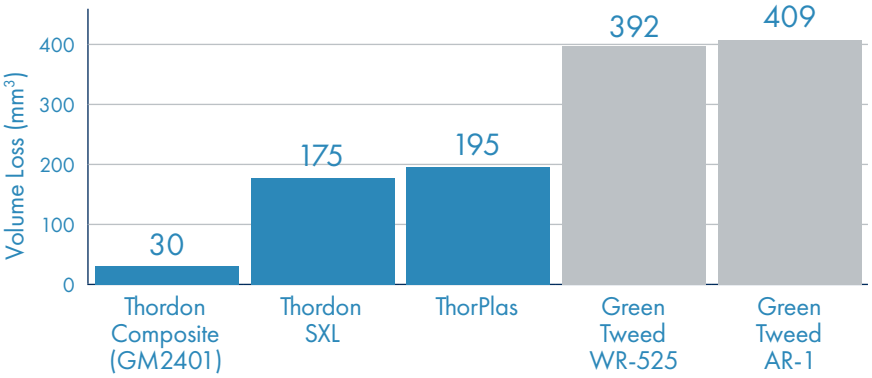


Projected Bearing Wear by Volume (cc/24 Hours)
(Testing done by Thordon)

Thordon's R&D Department performed a rotary drum abrasion test based on ASTM 05963. Although this abrasion testing method does not simulate all the abrasive and frictional conditions found in actual service, it offers a very standard and well-accepted method for relative comparison of abrasion resistance for different polymer materials. Graph 3 below, shows the comparative results obtained in our controlled laboratory for Greene Tweed materials against Thordon's most common pump bearing products.

Graph 3 - Comparative Dry Abrasive Wear

Rotary Drum Abrasion Test (ASTM D 5963-96)



SXL has higher mechanical strength than rubber bearings and does not require a metal carrier or shell as long as the pump housing is straight with no reliefs. Greater mechanical strength allows SXL to operate at half the length of a rubber bearing, allowing abrasives and cooling water to flow through the bearing quicker, translating into longer life.

Another advantage of not requiring a bearing carrier is cost and delivery, especially on nonstandard pump sizes or rebuilds. During a rebuild the housing and shaft are usually machined. A larger OD and smaller ID on the replacement bearings are required. This may cause delayed deliveries on rubber bearings. SXL pre-grooved stock is available, and it is easily machined by Thordon or on site for a quick turnaround.

SXL exhibits an excellent blend of resilience and stiffness. The modulus of resistance is many times that of bronze. SXL absorbs impact or shock loads without permanent deformation and exhibits a compression modulus and damping capability nearly five times that of rubber.

SXL is easily machined with standard tools and easily installed by a press fit with dry ice or liquid nitrogen. A sizing program is available to take the guesswork out of the installation process.

GM2401/Composite

One of the Best Bearing Choices for Highly Abrasive Media

Documented data from US Mississippi River workboat and pump operators shows typical Thordon Composite bearing wear rates of 0.075mm to 0.100mm (0.003"-0.004") in 6000 to 7000 hours of annual use. This wear rate is typically half that of rubber bearings. Two excellent examples of GM2401 longevity are Peach Bottom Nuclear Station and Jacksonville Electric Authority in the U.S. In both of these installations GM2401 has been running in abrasive water for over 20 years. Case studies for both installations are included at the end of the paper.

GM2401 has increased stiffness and resilience compared to rubber which results in easier alignment and less edge loading. It can also be supplied with an L/D ratio of 3:1, which facilitates lower friction and cost savings from its shorter length than rubber.

ThorPlas-Blue Thermoplastic

ThorPlas-Blue has higher abrasion resistance than most pump bearings plus dry start capabilities. ThorPlas has an enhanced temperature rating of 80°C (176°F) and chemical resistance properties to most hydrocarbons, weak acids, and bases. Developed as a maintenance-free alternative to replace greased bronze bearings, this proprietary engineered thermoplastic bearing is capable of dynamic operating pressures up to 45 MPa (6527 psi). ThorPlas-Blue has a water absorption percentage of less than 0.15 which is lower than most non-metallic bearings, making it an ideal choice for pumps where low shaft clearances are required. ThorPlas-Blue is easy to machine and install and is readily available in either finished bearings or tube stock.

ThorPlas-White Thermoplastic

ThorPlas-White has all of the same properties as ThorPlas-Blue, but also has NSF and WRAS approval for potable water.

A pump bearing selection guide is included in Figure 3.

Figure 3 - Material Selection Guide for Pumps

	Thordon Grades				
Parameter	Thordon XL	Thordon SXL	Thordon Composite (GM2401)	ThorPlas-Blue	ThorPlas-White
Description	Elastomeric Polymer Alloy	Elastomeric Polymer Alloy	Elastomeric Polymer Alloy	Engineered Thermoplastic	Engineered Thermoplastic
Temperature Limit	60°C (140°F)	60°C (140°F)	60°C (140°F)	80°C (176°F)	80°C (176°F)
Suitable for Dry Start-up	NO	YES**	NO	YES**	YES**
Resistance to Acids	Limited	Limited	Limited	Limited	Good
Resistance to Alkalies	Limited	Limited	Limited	Limited	Fair
Suitable for Hydrocarbons	YES	YES	YES	YES	YES
Abrasion Resistance	Good	Very Good	Excellent	Acceptable	Acceptable
Shaft Sleeve Material	Bronze, Stainless Steel	Bronze, Stainless Steel	Ni-Cr-B Recommended	Bronze, Stainless Steel	Bronze, Stainless Steel
Lubrication	Water, Seawater, Most Fluids (pH 5-10)	Water, Seawater, Most Fluids (pH 5-10)	Water, Seawater, Most Fluids (pH 5-10)	Water, Seawater, Most Fluids (pH 3-11)	Potable Water
Remarks	Good balance between abrasion resistance and medium level of friction.	Lowest friction. Suitable for dry start-up. Good abrasion resistance.	For use in highly abrasive operating environments.	Good for low abrasion applications and for use at temperatures and in chemical solutions unsuitable for Thordon elastomers.	NSF International Certification for NSF/ANSI 61 Drinking Water System Components. Accepted Material by CFIA. WRAS Material Approval
Appearance					

*** For dry start-up times longer than 30 seconds, please contact Thordon Engineering for grade selection.*

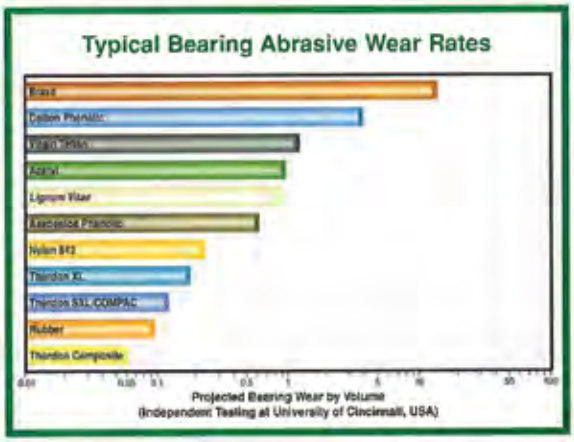
Case Studies

THORDON SOLUTION TO ABRASIVE-MEDIUM PUMP PROBLEMS

Sleeve bearings in vertical, medium lubricated pumps are a frequent source of problems. Poor shaft support, dry starts, high friction and rapid wear in abrasive services are some of the more common problems encountered. One of the common solutions to some of these problems is the addition of a sealed tube around the shaft with either a fresh water flush or oil/grease lubrication. This approach has a high initial cost and a continuing expense in the supply of fresh water or oil/grease and also has the potential for contamination of the medium being pumped. Jacksonville Electric Authority (JEA) of Florida has solved their abrasive wear problem by installing Thordon bearings.

Jacksonville Electric Authority has been using Thordon bearings in their riverfront circulating water pumps since 1996. "Over the past 3½ years, Thordon steel-backed GM2401 (Composite) bearings have held up well under brackish, high silt, river water application on 500HP vertical shaft circulating water pumps at Northside Station," stated John Kang, Director of Maintenance at JEA. John said, "In one incident, one of the pumps ran with minimal seal water for 24 to 48 hours due to a clogged seal water strainer. Past experience with a different bearing material would have been catastrophic." John added, "This pump continues to operate with no deviations in vibration which is the primary indicator of pump bearing wear. We have also had excellent follow-up and professional service during the past three years of material evaluation from Thordon's Florida Distributor, Coppedge Marine."

JEA has initiated a complete inventory switch to Thordon Composite from cutless bearings for all circulating pumps. John added, "We believe that Thordon GM2401's superior material characteristics over cutless rubber enables it to be more resilient and resistant to silt and sand impregnation resulting in longer wear and stable pump operation."



THORDON

GM2401 SHOWS NO VISIBLE SIGNS OF WEAR IN DIRTY WATER PUMP APPLICATION

When the engineers at Peach Bottom Atomic Station (Pennsylvania, USA) needed to improve the facility's river water circulation system, they were faced with two options: a costly upgrade of the water filtration system by installing new corrosion-free piping to protect the current bearings; or, a much less expensive upgrade of the Bingham pumps by replacing the bearings with Thordon GM2401. They choose the latter. Two years after installation, an inspection has revealed no visible signs of bearing wear, despite the dirty water conditions.

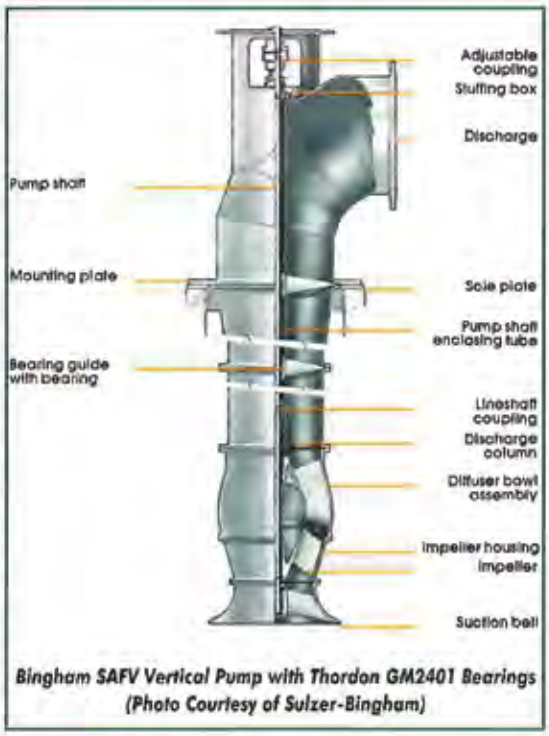
"Obviously, the Peach Bottom engineers are very pleased," says Larry Bohn, Sales Engineer for Fleetwood Industrial Products, the Thordon Bearings distributor in Pennsylvania. "They now expect to get several years out of the bearings before replacement is required."

Long life in abrasive conditions

Thordon GM2401 is a tough elastomeric polymer bearing material that was introduced by Thordon in 1974. In applications around the globe, the product has demonstrated incredible wear resistance in extremely abrasive environments when used in combination with a hard shaft surface. The bearing material has significantly outperformed rubber - often by a factor of two or more - in pump and propeller shaft bearing applications.

"We needed reliable, water-lubricated pump bearings that could stand the test of time in abrasive-laden water conditions," says Phillip Hennessy, Equipment Reliability Engineer for Exelon Nuclear, the operator of the station. "Thordon was the obvious choice."

Peach Bottom Atomic Power Station is situated on the Susquehanna River in York County, Pennsylvania, U.S.A. Peach Bottom has two boiling water reactors, which jointly produces over 2,300 megawatts. The station is co-owned by Public Service Electric & Gas of New Jersey and Exelon Corporation.



Bingham SAFV Vertical Pump with Thordon GM2401 Bearings (Photo Courtesy of Sulzer-Bingham)

River water is circulated throughout the facility and is used for cooling a variety of systems and components. Although Susquehanna waters are relatively clear on most days, rain and other weather conditions can stir up silt from the river bed. These particles remain suspended in the water and are highly abrasive.

A world of references

During plans to upgrade the river water circulation system, Peach Bottom engineers were enthusiastic - yet cautious - about a bearing material that claimed to perform well in dirty water. Replacing the pump bearings would be significantly less costly than replacing the piping. Yet, convincing evidence was required before Thordon GM2401 could be specified.

"That's where that staff at Thordon was very helpful," says Bohn. "The Peach Bottom people were definitely impressed by what we were telling them [about the bearing material], but they wanted to contact references before making a final decision."

Fortunately, references were not a problem.

Thordon GM2401 is installed in dozens of hydroelectric and pump systems worldwide. Numerous references were available involving applications that were just what the Peach Bottom engineers were looking for: large, vertical pump bearings operating in dirty river water and seawater. "Those references really helped us close the deal."

Peach Bottom is now another application of a long history of successes featuring Thordon GM2401. The bearings have been operating for approximately two years; running on 215 mm (8.5 in.) nickel-chrome-boron coated sleeves in the six Bingham pumps with a capacity of 250,000 GPM. Divers were recently sent into the river to inspect for bearing wear. They didn't find any. "In fact," says Hennessy, "they described the bearings using just one word: pristine."

THORDON