By NAZMUL ZAMAN

There is much to understand when studying a life cycle cost comparison for paper stock pumps

CONSIDER THE TOTAL COST

It is a best practice to consider the total cost of ownership or the life cycle cost of a pump. The major components included in the cost of ownership are the initial cost, installation cost, operating cost and maintenance cost. One sub-segment of the life cycle cost is associated with the cost of sealing the pump. This white paper will identify the costs associated with sealing a pump, different sealing methods, and will compare their respective costs during the pump's life cycle.

A sealing method is required for most pumps except for magnetically driven pumps and canned rotor pumps. A sealing method must be incorporated to seal between the rotating shaft and the static stuffing box cover in order to prevent pressurized liquid from escaping.

Option 1: Packing: Packing is the original method of sealing a pump. The compressible fiber is formed to stuff the annular space between the stuffing box cover and the shaft. Packing requires lubrication and cooling to prevent excess heat generation by friction. It is normally recommended by the pump manufacturer to flush the packing with water and let it leak at a rate of 50 to 60 drops per minute. Packing requires a constant supply of clean water and periodic attention of an operator.

Options 2 and 3: Single and double mechanical seals: Mechanical seals are another method of sealing a pump; special attention is needed to seal a paper stock pump. A regular single seal will most likely fail in a paper stock environment without a clean water flush, which provides a clean environment and lubrication between the seal faces. A carbon or Teflon throat bushing is used at the bottom of the stuffing

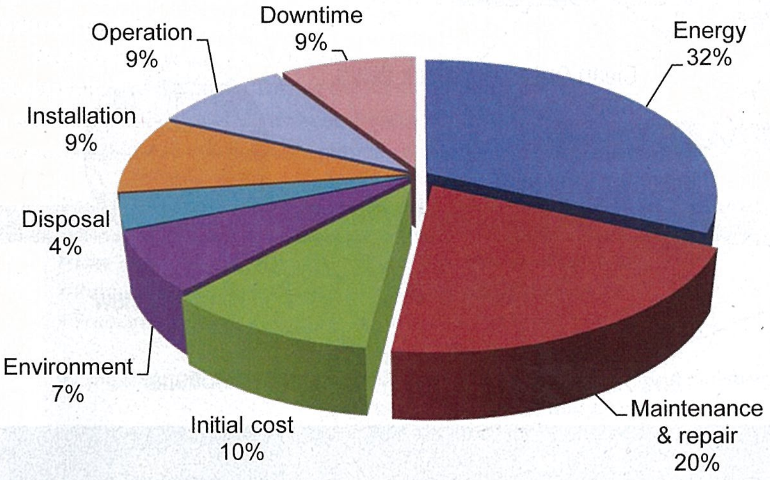

Fig. 1 - **Respective life cycle costs of a pump: Top 10 Global Chemical Manufacturer, FY 2006**

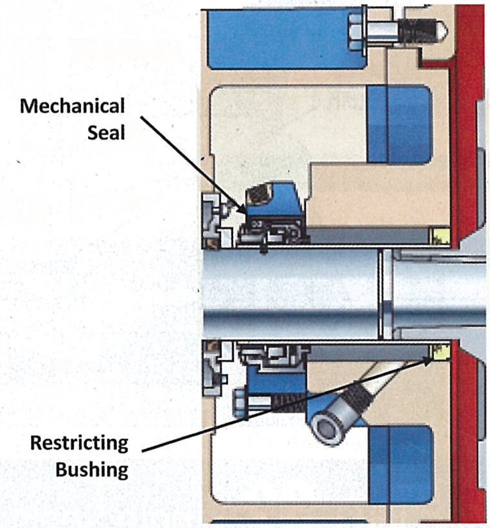

Fig. 2 - **Single mechanical seal with restrictive bushing**

box cover in order to prevent stock fiber from entering the seal chamber. A throat bushing alone will not prevent the fiber from reentering the seal chamber. A good rule of thumb is to maintain a flush water flow rate that provides a 15-ft/sec velocity across the throat bushing in order to keep stock fiber or other solids from migrating into the seal chamber.

Theoretically, a 3-in. seal requires about 2.45 gal/min of water to maintain 15 ft/sec velocity through the bushing clearance. Some seal manufacturers recommend using 1 gal/min per inch of seal size as a rule of thumb. Other seal manufacturers have invented special throat bushings with spiral internal grooves to remove solids from the seal chamber. They also claim that the flush water requirement can be drastically reduced by using such bushings. One example is the SpiralTrac™ by EnviroSeal.

The external clean liquid flush to a single seal is often referred as the CPI Plan 7332 or simply the Flush Plan 32. A simple Plan 32 consists of a flow-regulating valve, Y-strainer and piping. It may also include optional pressure and temperature gauges, a flow indicator, a shut off valve, and a check valve.

Double mechanical seals are also successfully used in sealing paper stock pumps. A double mechanical seal consists of two single seals mounted back to back. Pressurized barrier fluid is required for the double seal arrangement, therefore Flush Plan 54 or Plan 53 are used in conjunction with a double seal.

Flush Plan 54 includes piping and fittings to provide barrier fluid to the double mechanical seal. It may also include the combination of a flow meter, flow or pressure control valves, and a flow indicator. Flush Plan 54 is the responsibility of the customer.

Plan 53, normally the responsibility of the pump manufacturer, consists of a pressurized reservoir that usually contains a fluid such as Glycol, heat transfer fluid or vegetable oil. However, none of these fluids are allowed in paper stock applications as they can contaminate an entire batch of pulp if the inner seal fails. Using plain water as a barrier fluid might also be prohibited in geographical locations where the ambient temperature can reach below freezing.

Option 4: Dynamic seals: Dynamic seals are another means of sealing without flush water. Hydrodynamic sealing, or dynamic seals, were developed in the 1940s by the leading pump manufacturers of the day. It is a zero flush sealing method for paper stock pumps that is now preferred by many customers.

In a hydrodynamic sealing method, an expeller or repeller is installed behind the impeller inside the cavity of a modified stuffing box cover, and normally separated by a backplate. During the pump operation the pumping action of the expeller reduces the pressure at the stuffing box cover. Depending on the suction pressure, the centrifugal action of the expeller can create a slight vacuum and draw a small amount of air into the expeller cavity. As the air fills the cavity, the pumping action is reduced and equilibrium between the liquid and air phase is established.

Hydrodynamic sealing is only possible during the operation of the pump. During the idle condition, a secondary sealing method must be incorporated to prevent leakage from the static pressure of the suction head. Typical secondary sealing may include diaphragm seal, check-seal, lip-seal, or three rings of self-lubricating packing.

A dynamic seal eliminates the need for external flush water, but it is very limited in sealing higher suc-

Plan 32 requires a constant supply of pressurized water.

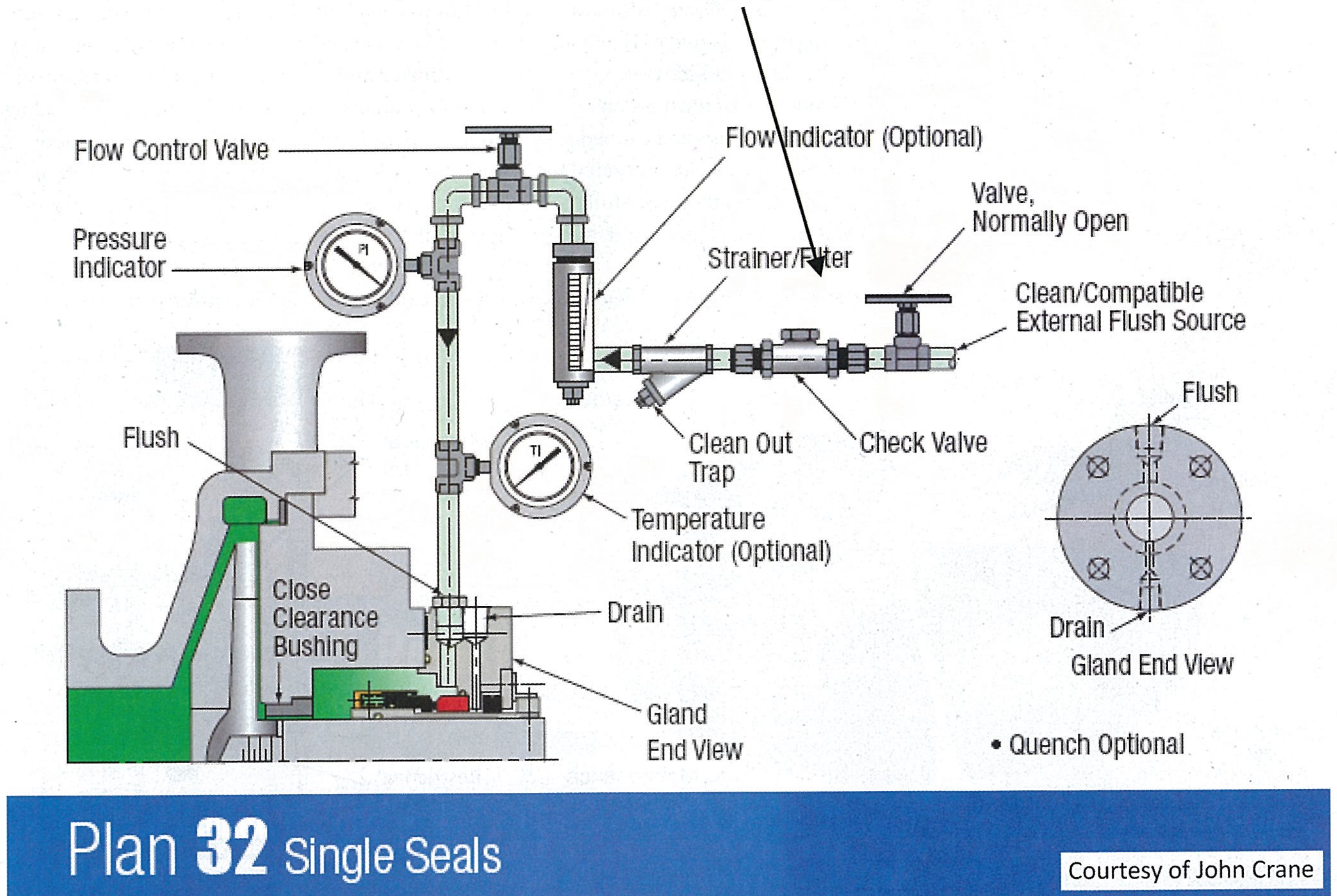

Fig. 3 - **Plan 32 single seals**

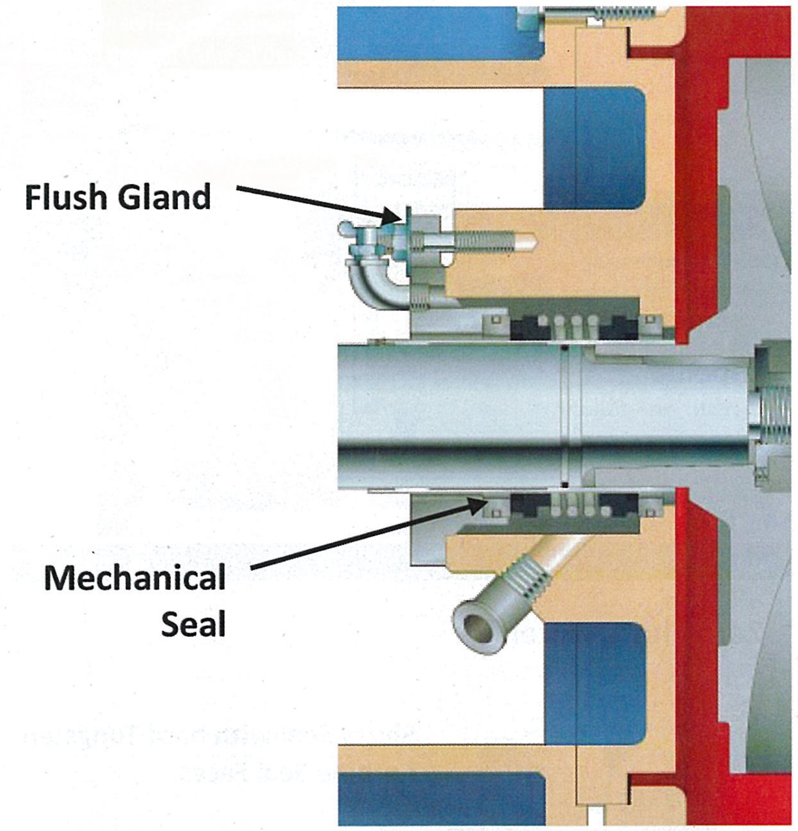

Fig. 4 - **Double mechanical seal in standard box**

Table 1 - **Reliability issues with flush water**

Plan 32	Plan 53—Pressurized air	Plan 54
• Pump is remotely located • Freezing problems • Clogging problems.	• Pump is remotely located • Limitation of types of barrier fluid (only water can be used) • Compressed air often contains moisture which can freeze and block air supply • Fluctuation of air pressure • If the seal chamber pressure is higher than supply air pressure, a pressurized nitrogen bottle will be required.	• Pump is remotely located • Freezing problems • Clogging problems • The barrier water outlet from double seal normally goes to the drain. Any water that goes in the drain also has to be treated before discharging to nature (river or lake).

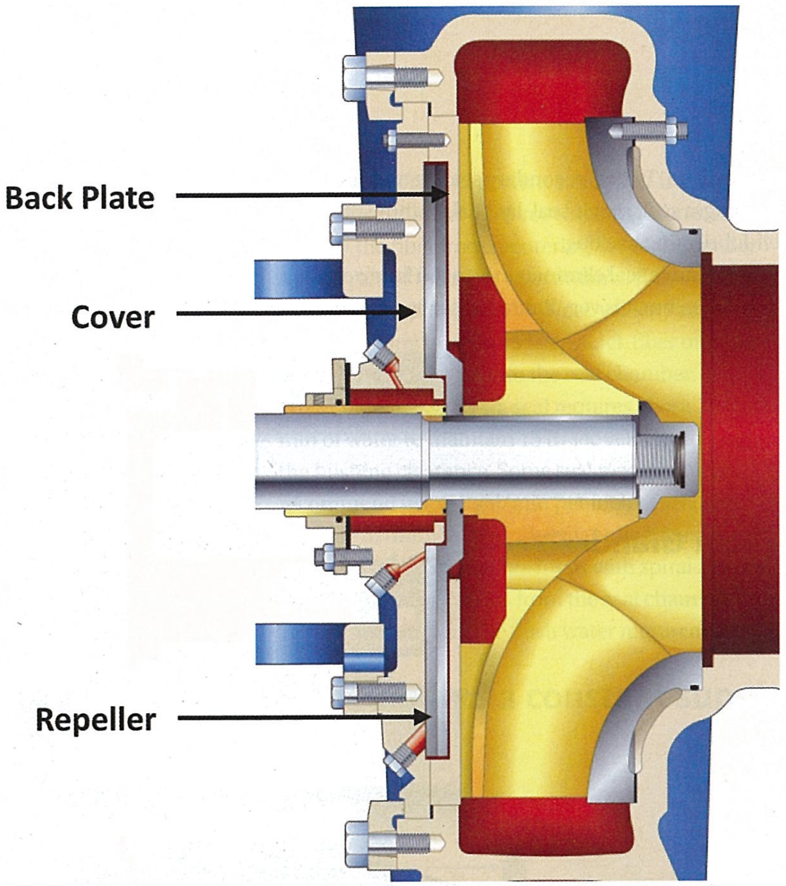

Fig. 5- **Dynamic seals**

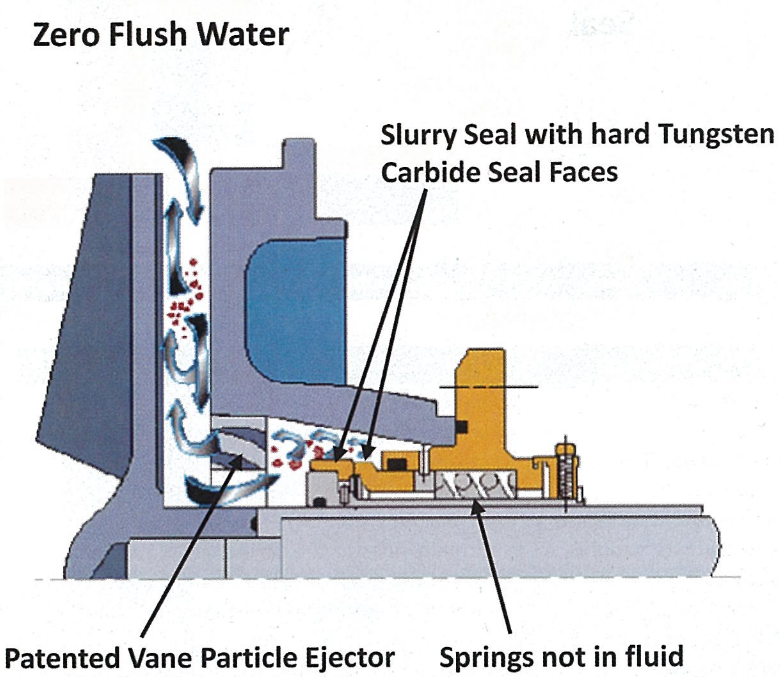

Fig. 6 - **No-flush mechanical seal vane particle ejector ring**

tion pressure. It becomes impractical when the pump speed is too low or driven by a variable frequency drive (VFD). A standby or idle pump with a dynamic seal may dewater and dry between the small clearances. A water flush may be required during a restart of the pump. Hence a pump with a dynamic seal may not be considered completely flushless. Issues with flush water line clogging and freezing remain a concern. In addition, since the expeller is like a small impeller, it absorbs power and therefore increases operating costs.

Option 5: No-flush mechanical seal vane particle ejector ring: In the early 1990s, ITT Goulds Pumps developed a TaperBore™ PLUS seal chamber with Vane Particle Ejector (VPE™ ring). The VPE ring is a set of static vanes against the rotating shaft. The static vanes of the VPE ring induce the fluid from the seal chamber and eliminate solid particles, vapor and air bubbles from it. The process also refurbishes the seal chamber with clean liquid.

With the success of the VPE ring in chemical and general industry applications, in 1999 ITT Goulds Pumps initiated tests of the VPE ring in a paper stock application. A 500-hour test was performed on an end-suction pump in Goulds Pumps' R&D paper stock test loop.

The pump was fitted with a slurry seal with tungsten carbide faces and a VPE ring. The test included simulation of a mill outage by shutting down the pump during the weekend and turning it on Monday morning. There was no visual leakage at any point of the test. The seal was disassembled and under a thorough analysis the seal revealed no signs of abnormal wear.

Eight years ago, one pump in the field pumping 5% paper stock was retrofitted with a slurry seal (John Crane 5870) and the VPE ring. A few years later, several pumps were converted with the same sealing arrangement. The original pump is still running after eight years. The pumps that were retrofitted later have now been running for six years. (The six-year average is not due to the mean time between failures (MTBF); most of the conversions are not older than six years.)

To compare the economics of each sealing method a thorough lifecycle cost of all sealing methods was calculated and graphed to present a visual comparison.

LIFE CYCLE COST CALCULATION METHODS

- Sealing costs are calculated for an end-suction pump with single seal and 3-in. sleeve OD.
- Pump operates 24 hr/day, 7 days per week.
- Life of the pump is 20 years.
- Cumulative cost or life cycle is defined as the total expenses related to sealing the pump for the 20-year estimated life. This includes the initial cost of the sealing device, and its operational costs including power consumption and the cost of flush water. It also includes the replacement cost of the sealing device, any periodic maintenance costs, and the cost of any spares directly related to the sealing method.
- A spreadsheet was created to calculate the costs.
- A simple series was assumed without calculating the Net Present Value of the costs.
- 70% efficiency was assumed for the plant water (seal water) pump to calculate power consumption for producing 80 PSI flush water.

Table 2 - **Life cycle cost assumptions**

	Packing	3-inch single cartridge seal with silicon carbide faces, carbon restricting bushing and Plan 32	3-inch split seal with 316SS special bushing, internal groove and Plan 32	Dynamic seal	TaperBore™ PLUS seal chamber with VPE™ ring and John Crane 5870 cartridge seal—no flush
Initial cost	Packing—$80 Sleeve—$866 Lantern ring—$174 TOTAL—$1,090	$1,675	Single cartridge with split mechanical seal and silicon carbide faces—$2,848 Special 316SS restricting bushing with internal grooves—$1,200 TOTAL—$4,048	Dynamic seal—$5,611 Sleeve—$1,281 Diaphragm—$63 Expeller—$4,250 TOTAL—$11,205	Slurry seal—$3,162 VPE ring—$705 TOTAL—$3,867
Replacement interval	Packing—6 months Sleeve and lantern ing—1 year	2 years	4 years	5 years	6 years
Replacement labor—hours	Packing—1 Sleeve and lantern ring—4	4	4	None (Replaced during major overhauls)	4
Sealing water—gallons per minute*	.5	2	.25	None	None
Seal drag**	None	.38 HP at 1,750 rpm	.38 HP at 1,750 rpm	1.4 HP at 1,750 rpm	.38 HP at 1,750 rpm

*U.S. Environmental Protection Agency
**Seal Drag is the additional horsepower needed to turn the shaft against the closing force of the mechanical seal faces.

- The chart was created using Years of Operation as the horizontal axis and Cumulative Cost as the vertical axis.

It is important to be open minded about these cost assumptions. Costs can vary according to pump size, manufacturer and customer discount levels. In addition, the cost of water and utilities may vary from country to country, state to state and plant to plant. However, the relative trends revealed by this analysis provide an accurate guideline.

CONCLUSIONS

- Over a 20-year period of operation, running a single seal with throat bushing and Plan 32 is the most expensive sealing method.
- Next in cumulative cost is for single split with SpiralTrac™ and Plan 32.
- Although packing shows low initial cost and lower operating cost, packing requires constant attention by mill personnel. It leaks continually and causes wet flooring around the pump.
- Initial cost of dynamic seal is higher. Dynamic seal also consumes higher power. But the 20-year life cycle cost is actually lower than single seal and packing. However, there are limitations on suction pressure with dynamic seal, especially when the pump is driven by VFD or at lower speed.
- TaperBore™ PLUS Seal chamber with VPE ring and John Crane 5870 Cartridge Seal requires moderate initial investment, but the 20-year life cycle cost is lower than the other sealing methods

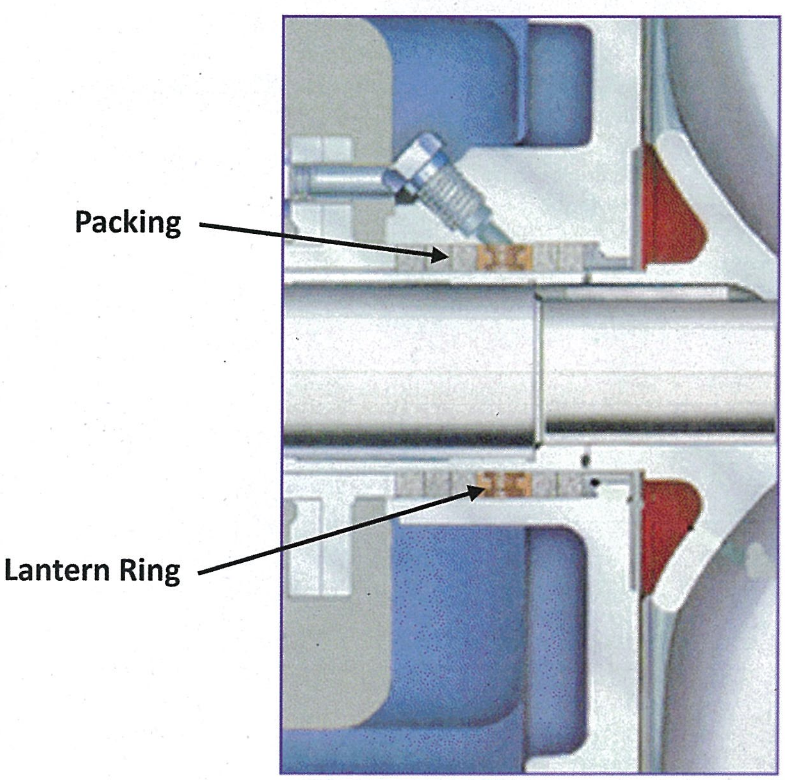

Fig. 7 - **Stuffing box with packing**

TaperBore™ PLUS Seal chamber with VPE ring and John Crane 5870 cartridge seal advantages:

- 20-year life cycle cost is lowest among the other sealing methods
- Lower initial investment than dynamic seal
- High P-V (Pressure-Velocity) Limit. Can handle much higher suction pressure
- No flush water requirement
- No instrument air or nitrogen bottle requirement
- Pump can be remotely located without worry
- No freezing or clogging issues related to flush water
- Much lower power consumption than dynamic seal, resulting in higher overall pump efficiency
- No secondary sealing. No lip seal or elastomeric diaphragm seal

Regardless of the variation in initial cost for each sealing method, power and water costs, and use of any flush, will increase the cost of sealing in the long run. That is the ultimate finding of this exercise.

1. SpiralTrac™ is a trademark of EnviroSeal.
2. TaperBore™PLUS is a trademark of ITT Goulds Pumps.
3. VPE™ is a trademark of ITT Goulds Pumps. **PPI**

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