

# Improve Process Control With Rotary Positive Displacement Pumps

BY INCLUDING PD PUMPS IN THE CONFIGURATION OF THEIR FLUID-TRANSFER SYSTEMS, USERS CAN EFFICIENTLY AND RELIABLY CAPITALIZE ON THE POTENTIAL TO ACHIEVE OPERATIONAL EXCELLENCE

*By Michael Moore*



Rotary positive displacement (PD) pumps installed in a process pumping system. Shown are Blackmer® S Series screw pumps.

## Introduction

Rotary positive displacement (PD) pump technology, when properly configured and operated, gives users improved control of their processes while increasing throughput and reducing waste. In many instances, pumping processes can be simplified and/or consolidated to the point where they will reduce the amount of equipment needed to minimize associated operating expenses (OPEX), while at the same time freeing up space for repurposing.

This white paper will provide relevant and practical guidance to users and illustrate how they can effectively configure their pumping systems by using rotary PD pump technology. The mechanical and electrical control and instrumentation needs for single and multi-pump systems will be considered. With this groundwork laid, normal startup and planned and unplanned shutdown scenarios

will be explained. Throughout these two segments the unique benefits of rotary PD pumps will be highlighted, compared to the operation of reciprocating PD and centrifugal pumps.

## Working Principles Of PD Pump Technology

Rotary PD pumps are volumetric, fluid-handling machines that deliver a nearly continuous, useful flow rate when their internal pumping components are actuated by relative rotary motion via the input connection between the driver and the pump shaft. These components operate inside a close-fitting casing to ensure minimal internal recirculation or slip in the pumping chamber, thereby achieving high volumetric efficiency.

Unlike reciprocating PD pumps, rotary PD pumps require no inlet or outlet valves to isolate the pumping chamber

during operation as there is always a mechanical restriction separating the downstream and upstream systems. With the pumping components being actuated by constant, rotary motion rather than linear, the generation of seismic forces from fluid pulsations during the suction and discharge strokes of a reciprocating pump can be avoided. To mitigate this phenomena that is native to reciprocating PD pumps, users are required to pour large mass-supporting foundations, as well as use pulsation dampeners mounted before and after the reciprocating pump in the process piping. These extra requirements add to overall system complexity, footprint and capital expense (CAPEX), and are not required when operating rotary PD pumps.

As volumetric pumping devices, PD machines passively convey the fluid volume from inlet to outlet without developing internal pressure, unlike a centrifugal pump. Any differential pressure observed between the PD pump inlet and outlet is merely a function of the downstream system's resistance to the induced flow. In the event of changing downstream friction losses, the PD pump will continue to maintain a near constant output flow rate and will only require more or less input torque to overcome changes in process backpressure. If excessive flow restrictions exist, care needs to be taken that the driver does not stall due to torque overload or the pump is mechanically overloaded due to overpressurization. For this reason, the pump and/or downstream process system must be equipped with a pressure-limiting device.

Like all pumps, a rotary PD pump's point of operation is determined by the intersection point between its individual pump performance curve and the system curve of the process (see Figure 1).

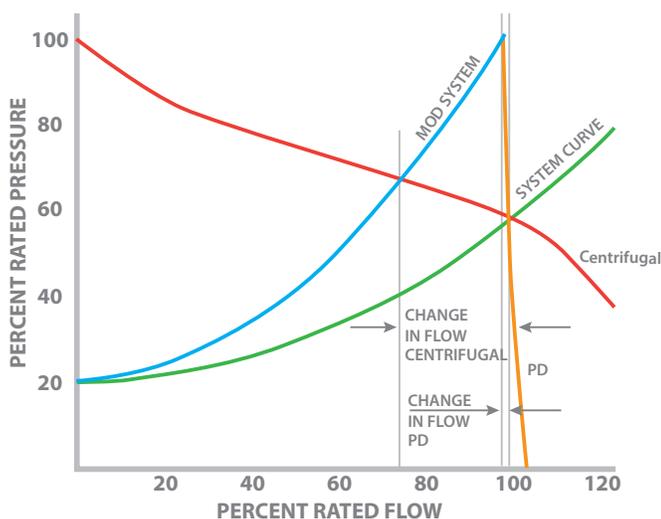


Figure 1

The system curve is comprised of three process elements:

- The static head difference of the fluid surface levels between the supply and delivery points
- The required backpressure at the delivery point
- All friction losses through the interconnected process piping

For a rotary pump, which is a constant-flow machine, the performance curve resembles a nearly vertical line when its rated flow is plotted against rated pressure, whereas a centrifugal pump's performance curve will show a constant rise to shutoff from the intersection point, and a constant decline in rated pressure capabilities as the flow rate extends beyond this point. In the event of a change in the system, the delivered capacity of the centrifugal pump, unless controlled otherwise, will either naturally increase or decrease. To ensure reliability, the operating limits of the centrifugal pump should be restricted to a range close to the Best Efficiency Point (BEP) with a net positive suction head (NPSH) margin.

Conversely, the strength of the rotary PD pump as a fluid-handling solution is that any system changes will have a negligible effect on pump capacity. Furthermore, since a rotary PD pump is a volumetric machine that creates a constant flow rate at a given speed (and only needs one NPSH requirement) its performance is not governed by these criteria, which simplifies its application and reliable use.

Since the flow rate of a rotary PD pump is directly proportional to the pump speed, the machine, when controlled by an adjustable-speed drive, gives the operator the ability to dispatch differing volume rates to various interconnected points throughout the production facility. Utilizing a single, fluid-handling technology in a multi-purpose manner like this makes the most out of the CAPEX cost, eliminates the need for multiple application/product-specific pump trains, and empowers the operator to take control of the operation without the need for fluid recycling or pump throttling, which are required for centrifugal pumps even with adjustable-speed control.

This extreme flexibility in variable-speed operation (oftentimes a greater than 10:1 turndown ratio) is due to the inherent differences in volumetric versus kinetic (centrifugal) pump operation. Typically, the turndown ratio of a centrifugal pump is limited to a 3:1 ratio. This limit is due to the reduction in the pressure-development capabilities of a centrifugal pump as its speed is reduced. The affinity laws that govern this type of rotodynamic machine state that the total developed pressure of the centrifugal pump will be reduced by the square of the ratio of the shaft's speed change.

Looking at Figure 2, and considering the starting position of the system's head curve, a centrifugal pump's turndown speed will be initially governed by the BEP's low-flow case and ultimately by the point at which the pump's developed pressure is unable to positively discharge into the system. In theory, for rotary PD pumps, the maximum turndown ratio is really only limited by the operating condition at which the theoretical displacement of the pump is nearly equivalent to the internal recirculation or slip of product from discharge back to suction.

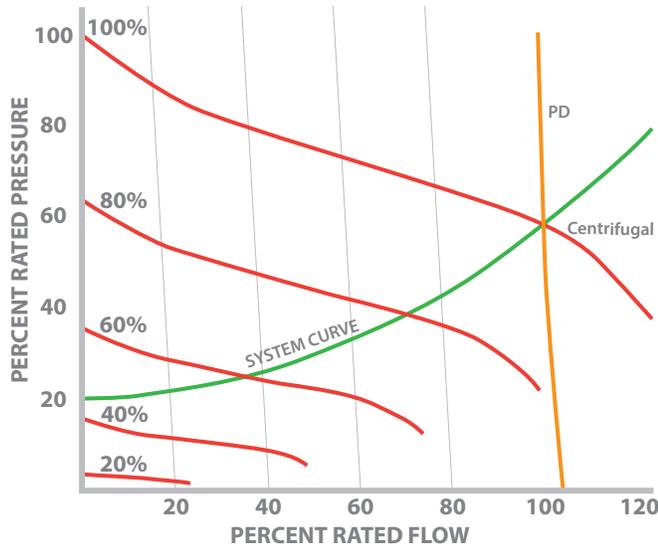
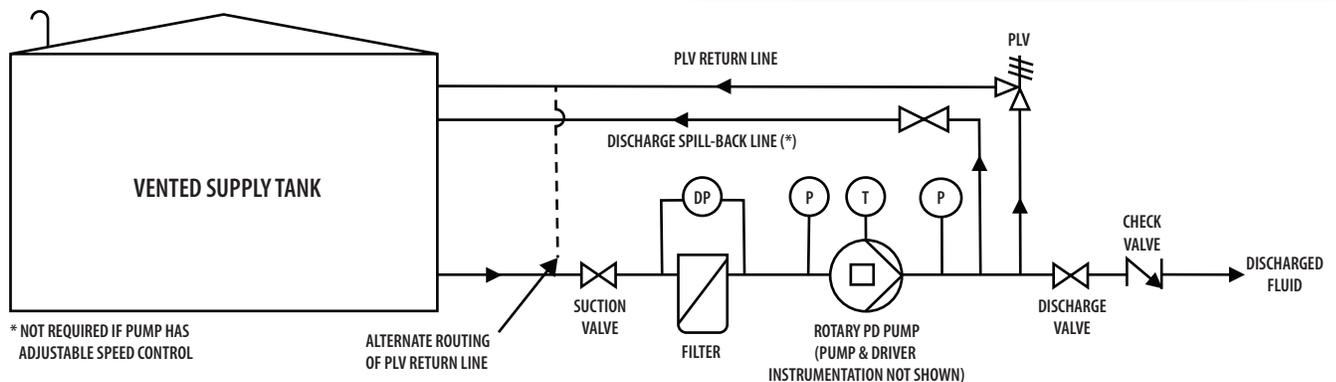


Figure 2

## Configuring A Rotary PD Pump System

The basic mechanical process layout of a “single” operating rotary PD pump (see Figure 3) is not altogether dissimilar to that of a single operating centrifugal pump. The suction header design from the supply vessel to the pump, as well as the discharge header layout from the pump to the downstream delivery point, should follow the recommended practices of the Hydraulic Institute. To guard against long-term abrasive wear, the suction header should be fitted with a filter unit, with an appropriately sized filter mesh or basket with perforations, to prevent undesirable particles from entering the pump and travelling into the process.

Figure 3



\* NOT REQUIRED IF PUMP HAS ADJUSTABLE SPEED CONTROL

ALTERNATE ROUTING OF PLV RETURN LINE

INSTRUMENTATION NOT SHOWN

## Screw Pumps Can Be A First-Choice PD Pump

As mentioned, rotary positive displacement (PD) pumps can oftentimes be a more efficient and reliable alternative to centrifugal pumps in fluid-handling applications. Within the rotary PD pump realm, however, screw-pump technology has begun to gain ground as a first-choice solution.

The pumping principle of screw pumps is one of the world's oldest, dating back to invention of the technology in 300 B.C., which is attributed to the Greek scientist Archimedes. The pumping principle is simple: two or more screws intermesh to move fluids through a system. As the fluid enters the pump, it is pushed toward the discharge by the increased pressure that is created by the rotating screws.

The most significant benefit of screw pumps is that they are able to produce the highest flow rates of any type of PD pump. This capability makes them an outstanding choice for applications that require the high-volume transfer of hard-to-move or excessively viscous fluids. Typical screw-pump flow rates can range from 50 to 15,000 gallons per minute (189-56,780 l/min) with pressure ranges from 50 to 4,500 psi (3 to 310 bar).

Acknowledging the potential for growth in such important industrial markets as oil and gas, chemical-processing and liquid terminals, all of which require the high-volume transfer of fluids with varying viscosities, Blackmer®, Grand Rapids, MI, USA, a leading developer of pumps and compressors for industrial use, and a product brand of PSG®, Oakbrook Terrace, IL, USA, a Dover company, has created the S Series Screw Pump product line.

This pump family consists of three S Series models – Twin Screw With Timing Gear (WTG), Twin Screw With Non-Timing Gear (NTG) and Triple Screw.

The Twin Screw (WTG) pumps have external bearings and a timing-gear transmission, which produces double-suction, self-priming operation with no metal-to-metal contact between the pump's internal components. The Twin Screw (WTG) pumps achieve the highest flow rates of any rotary PD pump, even at varying backpressures and viscosity levels.

Twin Screw (NTG) have a single-suction design where the axial pressure on the hydraulic components is compensated by a balance piston with some metal contact existing between the screws and the casing bore. This design enables Twin Screw (NTG) pumps to transfer lubricating fluids with higher viscosities at medium or high temperatures.

The Triple Screw can handle clean lubricating fluids without solid content across a wide range of viscosities, temperatures and pressures. They are designed with a male drive spindle, two female secondary spindles and a case that contains the screws, which allows the fluid to move smoothly and continuously in an axial direction from suction to discharge. This method of operation delivers smooth, constant product flow with low noise and high levels of energy efficiency.

If the rotary PD pump is operated by a constant-speed motor, and there is excess design capacity included in the specified flow rate, a discharge spill-back line to the suction supply reservoir should be included in the system. If the rotary PD pump is operated by means of an adjustable-speed drive then this circuit is not required, which may partly justify the cost of the adjustable-speed drive. In either case, a pressure-limiting valve is needed to guard against overpressurizing the pump. Direct-mounted pressure-limiting valves are intended to protect the pump only, but if the valve is fitted into the discharge header downstream of the pump and piped back to an atmospheric tank, or piped well upstream of the pump, it will safeguard the pump and the downstream process.

From an electrical standpoint, rotary PD pumps, as constant-torque machines (and contrasted to centrifugal pumps, which are variable-torque machines), must have the driver sized to handle the pump's full torque range. Typically, with electric motor drives, constant-speed motors will be specified. Where other types of drives are used, the pump's speed-torque curve must be provided to the manufacturer to confirm that the drive system can satisfy the pump's full torque requirements, including pressure-limiting valve activation and accumulation input power requirements.

Recommended instrumentation is divided into two groups: process-related and pump set-related. To monitor the PD pump's process, and to assist in trending the load, the differential pressure should be tracked across the suction-filter assembly, as well as the pump's suction pressure, pump casing temperature and discharge pressure. Depending on the criticality of the service, manual gauges or devices with visual displays can be used, or electronic switches or transmitters with pre-determined alarm and/or shutdown set points may be selected. In the latter case, these signals can be used as permissives to start that guard against improper pump-set operation.

The second grouping of instrumentation will provide condition-monitoring support for the pump and driver and may include auxiliary lube or seal systems. Once again, the level of instrumentation required should be appropriate to the criticality of the service and the overall capital/replacement cost of the equipment. Typically, temperature and vibration measurements are captured for the pump and driver using either single-point or multi-function devices. Windings temperatures for the electric

motor may be also captured to monitor the integrity of the motor stator.

Similarly, these devices and their corresponding signals will be used as permissives to start, as well as triggers for alarm and shutdown to avert equipment failures. Inputs from this instrumentation, when combined with a programmable logic controller (PLC) in an adjustable-speed drive, can be used to preprogram repetitive operations, which will enable a single operator to oversee multiple duties in a work-cell format. Where needed, the operator could also selectively over-speed a unit in order to recover lost volumetric performance due to a viscosity reduction or internal pump wear.

For processes using "multiple" rotary PD pumps, the pump sets are generally configured in a parallel arrangement (see Figure 4). This is achievable through the hydraulic capabilities of rotary PD technology that allow the management of differential pressures that would exceed the capabilities of a single-stage centrifugal pump. This layout eliminates the need to operate pumps in series, which subjects the downstream unit(s) to the discharge pressure of the upstream unit(s). To achieve a common shaft-sealing

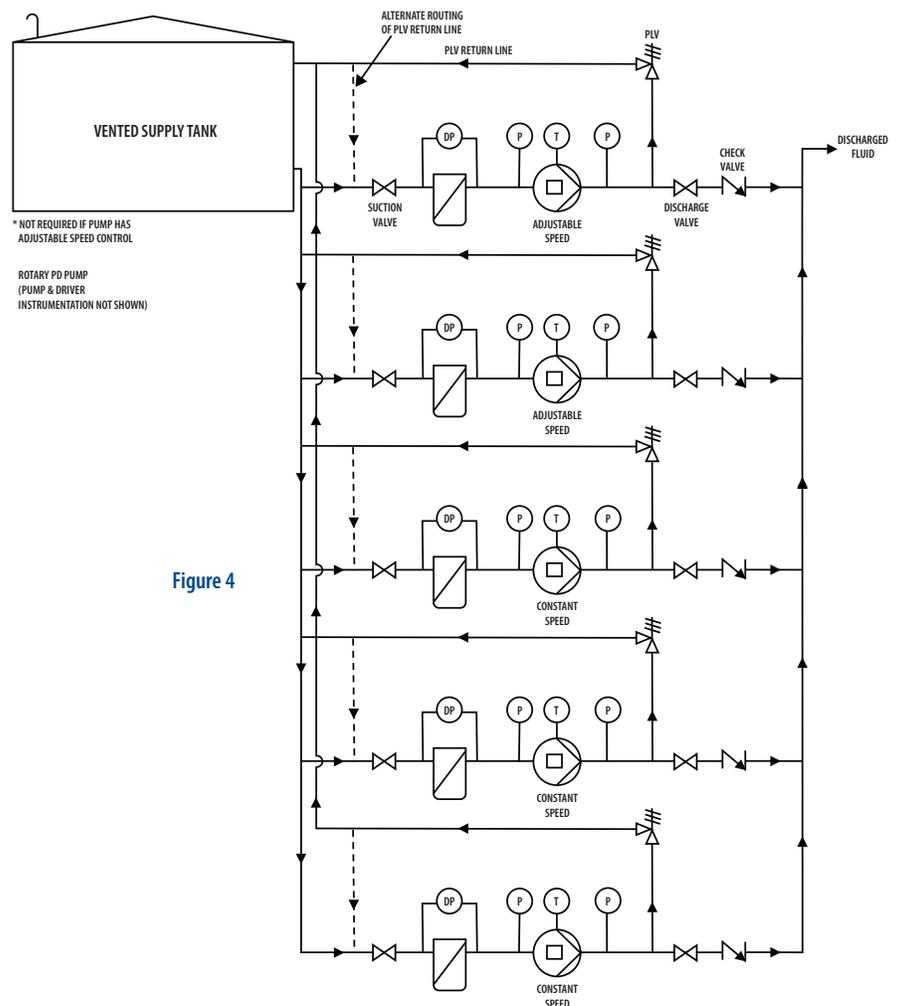


Figure 4

solution for all units a compromise between seal-face loading and allowable leakage rates is reached. This is not the case when the units are configured in parallel.

From an electrical perspective, it is desirable to employ a combination of constant-speed units and adjustable-speed electric motor units. This will afford optimum operational flexibility, built-in redundancy, extended driver life and will yield the best total cost of ownership. The adjustable-speed drive (plan for a minimum of two to have one installed as a backup) allows operations to perform a “soft start” of each constant-speed electric motor driver before switching each one to direct current. The reduced in-rush current and gradual motor load will extend the life of each motor.

When fully operating, the adjustable-speed pump set permits finite control of the overall flow rate without the need or expense of recycling excess process fluid. In the event of a power interruption and unplanned increase in fluid viscosity, the adjustable-speed unit(s) can be manually operated to safely allow the transfer of this medium within the pumping system’s NPSH and torque limits.

For multiple rotary PD pump systems, the instrumentation can also be PLC-programmed without direct operator involvement to trigger the automatic startup of additional pumps or shutdown of surplus pumps as fluid-handling requirements change, and to control the startup of a standby unit and shutdown of a problem unit.

## Operating A Rotary PD Pump System

The installation and pre-commissioning procedure of the rotary PD pump system should follow good industry practice, as well as the manufacturer’s recommendations in the Installation, Operation and Maintenance (IOM) manual. Critical aspects like pump-set lubrication, pump-train alignment, driver direction of rotation and shaft guarding should have been verified prior to proceeding to equipment startup.

Temporary strainers installed upstream of the pump are recommended when rotary PD pumps are first commissioned to guard against the ingress of foreign or tramp material during initial startup, which could damage the pump internals or seize the pump. These devices can be removed once the PD pump set has been in operation for approximately 50 hours.

With the above steps completed, operations can proceed to prime the suction line leading to the pump and the pump itself, ensuring that any air trapped in these areas has been

thoroughly vented. In the case of a flooded suction, where the supply-tank level is well above the pump-casing discharge connection, this can be easily achieved by opening the suction and discharge valves and allowing air in the system to be pushed through the suction line and the pump and released from a high-point vent.

In applications where there is insufficient liquid level available, or the pump is operating in a suction-lift service, other means to prime the suction line and pump must be used. This consists of either manually filling these areas with liquid or installing a vacuum priming unit. As rotary PD pumps are virtually self-priming, once the pump internals have been partially wetted (assuming that a foot valve is fitted to the suction-drop pipe on services that take suction from a below-grade sump/tank) re-priming of the suction line is not normally required. This permits the rapid restarting of rotary PD pumps used in intermittent service, which cannot be accomplished with most centrifugal-style pumps.

For a primed, single-pump system (with all vent points closed on the process piping) startup is able to proceed if the following conditions have been satisfied:

1. Any supporting auxiliaries are fully operational before initiating driver start
2. The pump suction and discharge valves are open
3. The flow-return valve on the discharge spill-back line is properly preset
4. All instrumentation permissives to start are affirmative/positive

The constant-speed or adjustable-speed driver connected to the pump can now be started. If no pressure or low pressure is observed at the pump discharge the unit should be immediately stopped in order to troubleshoot the problem. If the pump is performing correctly, the unit should be operated in order to establish an overall condition-monitoring baseline. Special attention should be given to units that are controlled by an adjustable-speed drive to check for mechanical resonances that may be present in the system. In most cases, these particular reed frequencies can be avoided to prevent operating the pumping system at adverse frequencies. For multi-pump systems, follow the same basic startup procedure.

For the planned shutdown of a single-pump system the operator should trigger the stop sequence for the pump driver. A restart of the unit should not be attempted until

the unit has come to a complete stop. If the unit is to be taken out of service, the start control for the driver should be locked out and the suction and discharge valves should be closed to isolate the pump from the process. In the event of an unplanned shutdown, the restart of the unit should be delayed until the root cause of the interruption is understood.

For instances where there is a partial or complete flow obstruction downstream of the rotary PD pump, which causes the backpressure to increase, different actions can be taken based on the electrical and mechanical design of the pumping system.

For a constant-speed pump, the pressure-limiting valve or rupture disc will be activated, allowing a portion of the pump's flow rate to discharge back to the suction supply via a separate line. For a partial-flow obstruction, where the flow is routed back to the suction line just upstream of the pump, this may allow the rotary PD pump to continue operating for a short period if the restriction can be readily cleared. In cases where this is not possible, or the downstream network is fully blocked, the pumping unit will be shut down by a discharge pressure switch or transmitter. In cases where the pressure-relieving mechanism can discharge directly back to the suction supply tank, the rotary PD pump may be able to operate for a longer period of time and may not need to be shut down at all. In cases where there is a full discharge-line obstruction the pump will be shutdown.

For pumps that are operated by an adjustable-speed drive, the drive controller can be programmed to be the first line of defense against overpressurization by limiting the output torque that can be delivered by the drive. For partial line obstructions downstream of the pump, the pump's operating speed can be reduced, thereby limiting the friction loss/pressure drop/backpressure that the pump is exposed to. Iteratively, the pump speed can be decreased, which permits the pump to continue operating until the minimum driver-speed setting is reached. At this point, should the discharge pressure continue to rise the pressure-relief device and the instrumentation will become the second and third stages of

the overpressurization protocol. For multi-pump systems, the overpressurization strategy could employ one or both of the aforementioned methods depending on the driver type used, or a combination of the two.

## Conclusion

This white paper demonstrates that rotary PD pump technology, when properly configured and operated, affords the user innovative ways to realize improved control of their processes as compared to reciprocating PD pump and centrifugal pumps. Production throughput of fluids can be increased and CAPEX, OPEX and associated labor costs can be reduced.

Its operational versatility also enables operators to simplify their pumping processes, the amount of equipment that needs to be maintained and the associated installation footprint. Freed-up space can be repurposed for other facility needs. This relevant and practical guidance will help users and design engineers realize how pumping systems using rotary PD pumps can be effectively configured to realize measureable operational benefits. The challenge to the reader is to identify the ways that the capabilities of rotary PD pumping systems can enable them to achieve their vision of operational excellence.

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