The Basics of Pump Startup

It is frequently asked for pump startup commissioning advice and procedures—and from experience I begrudgingly predict that what most folks are actually looking for is the abridged CliffsNotes version. I typically start asking specific questions about the pump and the application, but the conversation quickly falters and fades to sports.

The Basics

There are a few basic steps no matter the pump type or application that it will cover, and then will also address the often-overlooked details (common mistakes) that can deliver both people and equipment into pump purgatory. For the purposes of this column, this article is speaking only for centrifugal pumps and, unless otherwise noted, the pumps are not self-priming. Many of these tips and comments are for initial startups (commissioning evolutions), but will also deftly apply to the pump you start up every Monday morning.

Whenever you have scheduled to supervise a pump startup, you immediately remind to yourself of one of old and trusty mnemonic devices. This one is borrowed from the medical profession and in Latin is "primum non nocere" or in English, "first, do no harm."

There is several witnessed some expensive startup mistakes that could have easily been avoided if only the operator had simply read and observed a few key points in the instruction book.

Let's start with a few basic steps that are true regardless of the pump type, model and application.

1. You have read and understand the instruction manual and the local facility operating procedure manual.
2. Every centrifugal pump must be primed, vented and full of liquid before it is started. The pump you are about to start must be properly vented and primed.
3. The suction valve must be fully open.

4. The discharge valve may be closed, partially open or fully open; it depends on several factors that are explained later in same article.
5. The bearings for both the pump and driver must have proper lubrication—oil at the proper level and/or validation check for the presence of grease. For oil mist applications, you must verify that the generator is in operation.
6. Pump packing and/or mechanical seal must be adjusted and/or set properly.
7. The driver must be accurately aligned to the pump.
8. A full system lineup procedure (valve positions) shall be completed.
9. Do you have permission to start the pump (lock out/tag out procedures addressed)?
10. Start the pump and subsequently fully open the discharge valve.
11. Observe the discharge pressure gauge rise to the proper pressure and the flow meter display the correct flow rate.

Sounds pretty simple so far, but it is not really as simple. In the words of author Stephen Covey ("Seven Habits of Highly Effective People"), you must "start with the end in mind." Before starting the pump, did you first envision a smooth operating pump that was producing the proper flow and head while operating at the best efficiency point (BEP) with no problems? If you did, then you missed a few steps in the previous startup procedure.

All too often we will find ourselves at the pump, not properly prepared for the initial startup and accompanied by an impatient operations supervisor pushing to "just start it up." The issue here is that in reality there is a long list of items that should have been accomplished and/or checked before this high drama startup moment arrives. Pumps are expensive, and you can easily waste all of the cost and more in the one second it takes to push the start button.

Another troublesome issue frequently observe is that the person with the least amount of operating experience is selected as the supervisor for the startup. The person is selected for several reasons, which are unofficial but nevertheless realistic, including: the startup is on third shift or a weekend or a holiday; the building is not heated; the building is not cooled; there is no building and the weather is miserable; the site is remote; and finally, the fatal assumption that a formal education means you surely had a class on pump startup somewhere in the past.

The discussion will limit to the "things" that are required and or recommended prior to startup. The more complicated the pump and the system, the more steps and checks required.

Regarding proper pump selection, there are also countless numbers of decisions and action steps that should have taken place long before this critical moment we call startup (alternate title: “Things You Should Have Done Prior to or During Installation”).

Examples of these basics that should have been done earlier are foundation design, grouting, elimination of pipe strain, ensuring sufficient net positive suction head (NPSH) margin, pipe size and system geometry, materials choices, system hydro test, system instrumentation, submergence calculations and auxiliary systems.

ANSI Pumps

American National Standards Institute (ANSI) pumps are some of the most ubiquitous pump types in the world. Consequently, some more important things will be addressed that are important for this group.

ANSI pumps include adjustable impeller clearance settings. There are basically two styles that are the opposite of each other, but regardless of the style they must be adjusted to the proper clearance prior to startup. The mechanical seal will also need to be adjusted and set. Note: It is imperative to set the seal after the impeller clearance is set or the setting/adjustment will change.

The direction of rotation on ANSI pumps is extremely important because if the pump is rotated in the wrong direction, the impeller will immediately “expand” (unscrews from the shaft) into the casing and cause expensive damage to the casing, impeller, shaft, bearings and mechanical seal. For this reason, these pumps are typically shipped without the coupling installed. It is essential to perform the driver rotation check prior to the coupling installation. Skipping this step is unfortunately a common problem.

Priming the Pump

Often misunderstood, or simply overlooked, the pump must be primed prior to startup. Even a self-priming pump must be primed the first time. The brief definition of primed means that all the air and non-condensable gases are removed from the pump and suction line and that only liquid is present in the system. If the pump is in a flooded system, the process of priming is easy. A flooded system simply means that the source of liquid is at an elevation above the pump impeller centerline—gravity is your friend in the priming process. To remove the air and non-condensable gases, you still must vent them outside of the system. Most systems will include a vent line with a valve or a removable plug to facilitate this. If there is no means of venting, you will need to be creative, and those methods are perhaps the subject of a future column.

Venting Tips

You cannot properly vent a running pump. The heavier liquid will be expelled while the lighter air/gas and will stay in the middle of the pump, often trapped in the eye of the impeller and/or the stuffing box/seal chamber. Think centrifuge principles of operation and realize water is almost 800 times heavier than air. Improper venting explains that squealing noise you will hear on startup that goes away after a minute and immediately before the mechanical seal starts to leak because it ran dry. Most seal chambers/stuffing boxes should be separately vented prior to startup. Pumps with throat bushings (restrictive) bushings in the stuffing box will present specific challenges to vent. Some designs, specific seal flush systems and some accessories will allow this evolution to occur automatically. Don’t assume your system has the special design.

Vertical pumps present their own special requirements for venting. Because the stuffing box is at the high point, you need to take extra precautions in these cases.

A pump that has a centerline discharge nozzle will typically lend itself to automatic venting, but not necessarily the stuffing box or seal chamber. Pumps that are horizontal split case or have a tangential discharge will require that the casing be vented by some other means. No matter the pump type, the air still needs somewhere to go, so be sure it has a place to go. Magic is not an acceptable response.

Pump Is Not Flooded

When the liquid source is below the centerline of the impeller (lift situation) you will need to vent and prime the pump in some other manner. The three main methods are:

1. The use of a foot valve (type of check valve) at the suction end of the pipe. You can fill the suction line with liquid and the foot valve will hold it in the line until the pump is started.
2. The use of an external means of drawing a vacuum on the suction line. This can be accomplished with a vacuum pump and ejector or an auxiliary pump—typically a positive displacement pump.
3. The use of a priming tank or chamber.

Additional Tips

Foot valves are notorious for failing or jamming at the worst time in either the full-open or full-closed position. You may not realize that it is not working when it fails in a partial position.

Any air in the suction line still needs somewhere to go (otherwise it is trapped), and the pump will not be able to compress it. You will require some type of vent line or automatic air relief valve. If there is a downstream check valve, the pump will not be able to create sufficient pressure to lift and open the check valve.

Self-priming pumps or pumps that are primed from another source will need to have lubrication to the mechanical seal during the startup and priming process. Many self-primers handle this issue with a design that uses an oil-filled seal chamber. Of course, the pump is not necessarily shipped with oil in that chamber, and you need to add it prior to startup. Other pumps will require an external source of lubrication and or independent seal flush system.

Self-primer pumps in operating mode will not leak liquid out of the suction line or the seal chamber because those areas are typically under some vacuum, but do realize that air will leak in.

Keep a record the data: bearing temperatures, flow, pressure (head), amps, voltage, frequency, vibrations and ambient conditions.

Other Considerations

In no particular order, here is a list of other checks and action steps that are frequently overlooked when starting the pump.

Safety always has to be first and the prime directive. Please realize you could be working with pressurized systems that can be very hot, contain acid and start automatically. You are also standing next to rotating equipment that will unforgivably reach out, grab you and pull you in.

Wherever you are starting the equipment there is almost a 99 percent chance that the owner has some procedures that must be followed.

The most frequent oversight is that the operating manual is cast aside and a long list of incorrect assumptions is formed that includes things that the factory must have done—but they did not. You must understand that no industrial pump is "plug and play."

A simple check is to rotate the pump by hand. The pump should turn freely with no binding/rubbing. Large pumps may require added torque due to inertia that you can overcome with a strap wrench (be careful how and where the wrench is applied to preclude shaft damage).

Rotating by hand should be done after the lubrication is addressed, but before the seal is set. Also, it is much easier before the coupling is assembled.

It is implicit that the unit system must be locked out and tagged out.

Never rotate the pump under power without completing a rotational direction check on the uncoupled driver first. It is recommended to look at documentation. Incorrect rotation is probably the second most frequent mistake will happen.

Unfortunately, new systems typically have abundant dirt and debris in the lines from construction. It is prudent to install a temporary commissioning strainer on the suction line. The strainer must have a cross-sectional area to allow proper flow and not create NPSH margin issues. The strainer must have some means of measuring the differential pressure across itself, otherwise you won't know when it is clogged.

Pump systems with long and empty discharge lines will present issues for initial startup; as the line is filling with liquid, there is little to no resistance for the pump and so it will “run out” (to the right) on the curve. You can introduce temporary faux resistance by closing partially on the discharge valve. There is also the increased risk of water hammer and associated damage when the system does fill.

Before the pump is started you should know what flow and pressure to expect on the instrumentation and, oh yes, you need instrumentation. Also, know ahead of time what will be the expected amp reading, frequency (if using a variable frequency drive [VFD]) and perhaps the watt or power readings. It is aways advisable to carry own strobe-tachometer, vibration probe and infrared digital thermometer in the event the facility does not have this type of equipment. (Note: You will typically need permission and many facilities will not allow the use of personal equipment.)

Prior to starting the pump ask, is the mechanical seal support system online? This is especially important on API seal pipe plans 21/23/32/41/52/53/54/and 62.

For pumps that use packing in the stuffing box, check to ensure if there should be a flush line and, if so, is it connected to a clean water source? Also check for adequate pressure (flow) to the stuffing box. It is good practice to turn the flush water on prior to opening the suction and discharge valves on the pump. Check with the pump and/or packing supplier for the proper packing leakage rates that will vary with the liquid temperature and its other physical properties, shaft speed and size.

If you can’t find a reliable answer for your application, go with 10 drops per minute per inch of shaft diameter. You may go with a more liberal 30 to 55 drops per minute regardless of diameter on the initial break-in period.

Make the gland adjustments in small increments, meaning one “flat” per adjustment on each gland nut, and space the adjustments out over 15 to 30 minute increments. The key to proper packing adjustment is patience. Consult with the “Fluid Sealing Association Technical Manual 4th Edition Compression Packing” for more.

You should use all of your senses when starting pumps or any equipment. Look for sparks, smoke and things rubbing that should not be—such as an improperly set bearing isolator or flinger. Listen for the popping of vapor bubbles in the impeller or a squealing mechanical seal that is starving for lubrication. Smell that? Packing is not supposed to smoke. Can you feel the deck and/or the pipe vibrate because the pump is coming off the base due to imbalance or cavitation? Know that you are not at Disney

World on an E Coupon—this is the real world with expensive equipment that can crash, burn and hurt you and/or others.

Always minimize the time the pump will be operating at or near minimum flow areas (left side of the curve). Just as important is to not allow the pump to operate at the far right of the curve.

Avoid thermal shock issues if you are pumping something that is hot (above 200 F to 300 F, 93 C to 149 C)—warm-up procedures should be followed prior to startup. Large pumps will likely have minimum and maximum allowable rates of heat up and cool down. Many multistage pumps will require a warm-up procedure that also requires slow rotation on turning gear (aka, jacking gear) for some specified length of time or preordained temperature differential. Remove the pump from turning gear prior to startup. The valve lineup procedure will also include balance drum, warm-up and bypass lines.

Bearing temperatures (or the oil temperature) should be closely monitored on startup. Do not use your hand to feel for the temperature as it is not a precise method and, more importantly, most people will feel a bearing housing at 120 F (49 C) and think that it is really hot. It is not uncommon for bearing or oil temperature to approach 175 F or 180 F (80 C or 82 C). The important parameter to watch is the rate of change in temperature. Fast climbing temperatures are a red flag, and it is suggested shutting the unit down and investigating the root cause. Where the temperature is measured is also important; a thermocouple inserted in the bearing is more indicative and timely than bearing oil sump or return path temperatures.

Frequent motor starts often occur during commissioning processes. Be aware of the allowable number of motor starts per unit of time for your motor—refer to National Electrical Manufacturers Association (NEMA) and/or the manufacturer for specifics. Typically the larger the motor and the fewer number of poles will result in a reduced number of starts allowed.

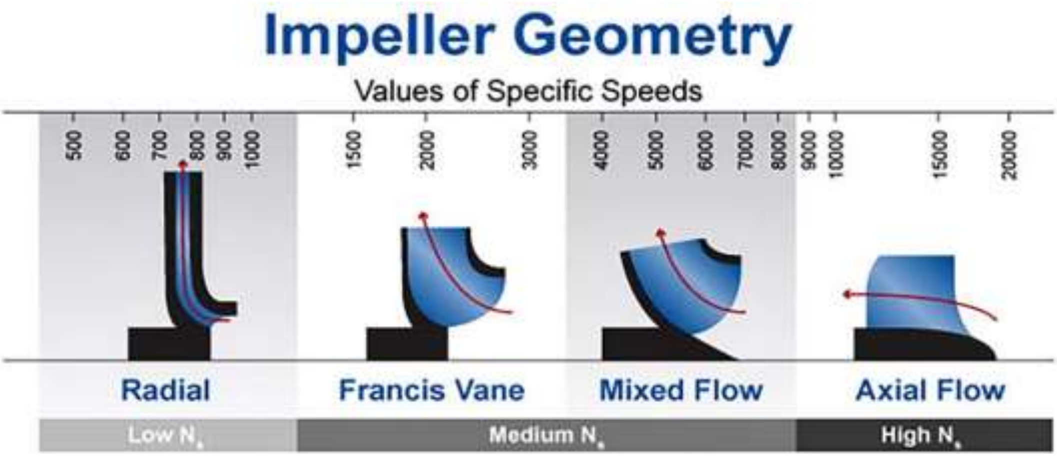

IMAGE 1: Values of specific speeds for different impeller types

Discharge Valve Position

It is very common doubt: Should the discharge valve be open or closed when the pump is started? Answer is it depends, but regardless, the suction valve better be open. First things first—if you are a visitor to a client facility, you should never supersede their operating procedures.

Next, let's look at the impeller. There are many things to consider, but the primary question to answer today is: What is the geometry of the impeller? From that shape it will determine the range of specific speed (Ns). For today's purpose, let's focus on the directional path of the liquid and specifically how it enters and exits the impeller. Ns is a predictive indicator for the shape of the curves for head, power and efficiency.

Low Ns

If the liquid enters the impeller on a path parallel with the shaft centerline and exits the impeller at an angle 90 degrees to the shaft centerline (at a right angle) then the impeller is in the low Ns range.

Medium Ns

If the liquid enters the impeller on a path parallel with the shaft centerline and exits somewhere close to a 45-degree angle, then the impeller is in a medium Ns range. These are mixed flow or Francis vane-type impellers.

High Ns

If the liquid enters the impeller on a path parallel with the shaft centerline and exits in a path parallel to the shaft centerline, this is a high Ns impeller. This axial flow type of impeller would look similar to a boat or airplane propeller.

Plan B

Don't know the NS of the impeller? Ask the equipment manufacturer.

For low NS pumps, the brake horsepower (BHP) required increases as you open the discharge valve and increase the flow rate; this is a direct relationship just as you would intuitively expect. For medium Ns pumps, the BHP curve and its maximum point moves back to the left some nominal amount. In the past, you may have not noticed this change. Axial flow pumps have a high Ns and the BHP is near its maximum point at the lower flow rates and actually reduces as the flow rate increases. Perhaps the opposite of what you would expect? Notice how the slope of the power graph also changes when the impeller design goes from low to high Ns.

Answering the Original Question

It is recommended that the discharge valve be closed on the startup of low Ns pumps and to be open on high Ns pumps. Note: This is a "thumb rule," and there are numerous caveats that can and will modify the answer. As follows:

1. If the low Ns pump is of any consequential size (flow, head and BHP), you may need to have the discharge valve slightly open to reduce the differential pressure (DP) across the valve. A high DP will prevent opening the valve and this step will minimize the effort to open the valve. Some systems will have a specific bypass line for this purpose. For pumps that have shafts with high shaft stiffness factors (L3/D4 is high), then you will want to keep the time operating on the left of curve as short as possible to ensure a longer seal and bearing life. Note that shaft stiffness factor values are counterintuitive and similar to golf scores. A high number is bad and a low number is good. Finally, note the curve shape; for example, curves that droop near shutoff can place the pump into a situation where it will hunt (oscillate). Consequently, you need to place the pump further out on the operating curve rather quickly.

2. Systems that have downstream pressure (from another source) with no check valves (or check valves that are leaking by) can force the pump to spin backwards when the discharge valve is open. Starting the pump while it is rotating backwards is an excellent method for breaking the shaft. Starting pumps that are in series or in parallel may often require procedures that are in too detailed.

3. If you are starting a pump that will operate in parallel with another pump(s), you need to consider check valve lift points and controlling instrumentation (proportional integral derivative [PID]). Also, when the first pump is started it can run out (far right) on its curve until the second (subsequent) pumps are started. This is too cumbersome to explain in this column.

4. Normally, high Ns pumps are started with the discharge valve open to reduce the electrical load and resultant stresses on the driver. In many cases the driver may not be adequately sized (on purpose) to handle the low flow power requirements and will trip offline.

Shutting Down

Normal procedures for shutting down pumps other than some high Ns types is to close the discharge valve first and then immediately secure the driver. This will mitigate unnecessary stress on the driver and, more importantly, it will reduce or entirely eliminate potential for water hammer issues.

For systems with variable speed drives there will probably be added steps and procedures. Care must be exercised as the driver frequency is turned down if the pump is being operating in parallel, and also due to minimum speed, check valve and system back pressure issues.

Final Pointers

Four last comments and tips to share:

Before you start the pump, know where and how to shut the unit down in case of an emergency.

During the startup evolution, never stand next to or in line with the motor fan or the coupling.

Have the phone number handy for your personal "phone-a-friend pump expert" for when things go wrong.

Always start with the end in mind.

Reference: Articles published in Pumps & Systems by Jim Elsey.