Vertical Pump Troubleshooting Guide

The Heart of Your Process

The Importance of Troubleshooting

Your Sulzer vertical pump was built to meet the operating conditions and specifications provided at the time it was ordered and built in the factory. When correctly installed and operated, the pump will deliver many years of satisfactory service. Your specific pump life can vary depending upon many such factors as the specific application, liquid pumped, temperature, operating speed, number of starting and stops, and many other operating conditions.

As with all machines, there comes a time in its life when trouble signs start to show. Identifying and correcting the trouble before a serious breakdown occurs is vitally important. In most industrial, municipal and agricultural applications, the pump is a critical element. A pump breakdown can bring the whole process to a halt and cause costly downtime. That is why it is so important to become familiar with proper pump performance, closely monitor pump operation, and correct problems quickly as possible.

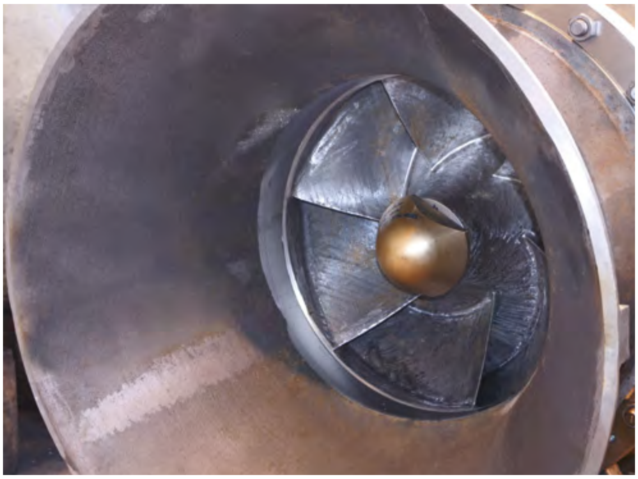
Each pump develops its own characteristic patterns of sound and vibration. Once you establish what is "normal" for your pump, be alert to changes in these day-to-day patterns that could mean trouble. Increased or erratic vibration of the driver is often the first symptom of an impending breakdown. Other danger signs include reduced speed, decreased flow rate, excessive leakage, and strange noises.

Further symptoms may become evident if you pull and disassemble the pump. Watch for unevenly worn parts, bent shafts, loose impellers, and signs of corrosion or abrasion.

The Purpose of this Troubleshooting Guide is Threefold:

1. To help you understand how your vertical pump works.
2. To help you spot problems in pump operation and identify probable causes.
3. To suggest possible solutions to the problems.

We cannot cover all pump problems in a volume this size. However, the following pages are a good overview of the problems commonly encountered. Sulzer Pumps hopes this guide will help you keep your vertical pumps running properly and return disabled pumps to service quickly in the event you do encounter problems.



Safety Precautions

Warning: Working on or around your pump equipment can be dangerous and not following common sense safety practices can lead to severe damage to equipment, permanent personal injury or death. Remember, there is no substitute for safety. Always exercise extreme caution when working or inspecting your pump and motor.

Personnel must be protected at all times from rotating shafts and couplings. All screens and protective devices furnished with the pump, driver and related equipment must be installed prior to pump start-up and must remain in place during operation. If protective devices are not furnished, then the user must provide safety equipment conforming to the regulations, codes, and statues applicable to the operating site.

Contents

Checkpoints for Initial Start-up of a Vertical Pump

Initial start-up means starting a pump for very first time after it is installed, connected and wired at its location. There are some steps required to ensure correct rotation of the pump impellers BEFORE the pump is coupled with the motor and adjusted for lift. The following describes a typical procedure for hollow-shaft or solid-shaft electric motors after the pump is set and grouted in place, motor drive installed and wired but not yet connected with pump.

1. Check the hold-down bolts on the motor, baseplate and discharge flange. Check all lubrication systems. Adjust the seal or packing box gland; gland nuts should be finger-tight at start-up.
2. Make sure the pump has sufficient fluid in the sump or supply lines. Make sure all suction valves are fully open on barrel-type pumps. Do not run any pump without fluid.
3. Verify correct wiring and rotation of motor shaft:
   a. For vertical hollow-shaft motor driven pumps, ensure the top shaft nut (adjusting nut) and gib key are removed and the motor is not coupled to the pump. The pump shaft can turn freely from the pump motor. As an added precaution on a one (1) head shaft assembly it is advisable to remove the motor drive clutch plate to ensure that it does not 'gall' or seize to the head shaft when the motor is 'bumped'. If a two (2) piece head shaft is supplied it is advised not to install the upper head shaft until after the motor has been 'bumped' for rotational verification. Prior to removal of the motor drive clutch plate for any reason, it is recommended to 'match mark' the component at the original location to ensure correct re-installation as this is a balanced component.

Mechanical seals must be adjusted per the manufacturer's instructions after impeller adjustments have been completed.

Closed Impellers			
Bowl Size		**Impeller Lift**	
mm	**inch**	**mm**	**inch**
Up to 230	Up to 9	3	0.125
255 - 355	10 - 14	6	0.250
380 - 610	15 - 24	9.5	0.375
635 - 915	25 - 36	12.5	0.500
Over 1015	Over 40	16	0.625
Mixed Flow and Semi-Open Impellers			
Bowl Size		**Impeller Lift**	
mm	**inch**	**mm**	**inch**
150 - 330	6 - 13	0.38 - 0.51	0.015 - 0.020
355 - 610	14 - 24	0.51 - 0.76	0.020 - 0.030
635 - 915	25 - 36	0.76 - 1.30	0.030 - 0.050
Over 1016	Over 40	1.30 - 1.90	0.050 - 0.075
JD Dynaline Pumps			
Bowl Size		**Impeller Lift**	
mm	**inch**	**mm**	**inch**
200 - 230	8 - 9	0.40	0.016
280 - 330	11 - 13	4.75	0.187
400 - 760	16 - 30	6.35	0.250
915 - 1015	36 - 40	7.87	0.310
1220	48	9.40	0.370

   At this opportunity with the drive clutch plate removed, note if the head shaft is centered within the the motor hollow shaft. If not, a misalignment has likely occurred during installation and should be investigated and corrected at this time.
   b. For vertical solid-shaft motors, ensure the pump to motor pump coupling is not connected and the pump shaft can turn feely from the pump motor.
   c. Ensure all tools, equipment and personnel are clear and away from all rotating components.
   d. Verify rotation and correct wiring of motor by flick starting the motor. It is not necessary or desirable to energize the motor for longer than ¼ of a second or permit the motor to run to full speed.
   e. As the motor shaft begins to slow from the very brief connection with its power source, observe the motor shaft rotation. The rotation should match the direction arrow of the pump nameplate. If this does not match, a qualified electrician will need to change the leads on the motor connection and the process above repeated.
4. When rotation is verified correct, reconnect the pump and motor, and adjust the impellers (see instruction on adjustment).
5. Start the pump and check amperage on the motor. Run the pump long enough to determine that no unusual noise or vibration is present and that the mechanical seal or packing box is functioning properly.

Vertical Pump Impeller Adjustment

Improper impeller adjustment will cause unnecessary wear, reduction of capacity and pressure, and motor overload problems. Impellers set too low will drag on the pump bowls and wear both the impeller skirts and bowl castings, eventually destroying them. Impellers set too high can drag on the upper bowl case. Both situations cause high horsepower loading that frequently trips the motor overload relays. If drag is severe, shafts can snap before overloads trip.

Improper impeller settings can also create vibration and cause premature bearing wear and failure. The following instructions must be followed to avoid these problems.

Vertical pumps are provided with either a hollow-shaft (VHS) or a solid-shaft (VSS) drive. On the VHS drive, the impeller adjusting nut is situated above the motor drive coupling. On the VSS drive, the adjusting nut is a component of the flanged motor/pump coupling.

Vertical Turbine Pump Adjustment

Initial Adjustment

Install the 'gib key' in the drive clutch plate & rotate the component to align with the head shaft keyway. Ensure the 'gib key' is a good slide fit in the keyway.

After correct impeller adjustment, turn the adjusting nut to the nearest hole in the motor drive clutch plate and install the locking set screws.

Rotate the shaft slowly by hand to ensure there is no rubbing or drag present.

Rotate the adjusting nut until the rotation assembly turns without dragging. Then continue to rotate the adjusting nut until the vertical clearances obtained are slightly higher than those listed in the table.

Use an ammeter to check the preliminary setting, and make sure that the impellers are not dragging and the motor is not overloaded.

Do not attempt to run the pump with the impellers dragging! Permanent damage will result!

Final Adjustment

After the system is operational, the impellers can be reset to recommended clearances.

Adjust closed impellers in accordance with the manufacturer's instructions or use the table on the previous page as a guide.

Semi-open and mixed flow impellers should be adjusted to operate at the minimum allowable clearance without dragging when in operation. An ammeter is necessary to obtain this fine adjustment and to determine that the motor is not overloaded. With semi-open impellers, dragging will occur at shutoff if the impellers are set properly at the condition point.

Clearances shown in the table on the previous page are general guidelines and apply to pumps with a 23 m or 50 ft maximum setting. The clearances in your pump might be different due to differences in operating temperature, materials of construction, applicable specifications, such as API-610 or other requirements. Refer to the manufacturer's operating instructions for deeper settings.

Propeller Pump Adjustment

1. Use a suitable wrench and raise the shaft by turning the adjusting nut until the propeller breaks free. At this point, the rotating assembly will turn easily, usually by hand.
2. Raise the shaft until the propeller is in the full up position. Measure this distance.
3. Lower the propeller one-half of the measured distance.
4. Turn the adjusting nut to the nearest hole in the motor clutch and install the lock screws.

JD Pump Adjustment

The JD "Dynaline" range was designed as a high pressure can pump. Because of this the settings are very short and operators should use the dimensions in the separate table.

Always refer to settings on the pump nameplate and/or installation, operation and maintenance manual which are specific to the application and serial number.

Trouble Indicators and Possible Causes

Insufficient Pressure

1. Speed too slow (check voltage)
2. Improper impeller adjustment
3. Impeller loose
4. Impeller plugged
5. Wear rings worn
6. Entrained air in pump
7. Leaking column joints or bowl castings
8. Wrong rotation

No Liquid Delivered

1. Pump suction broken (water level below bell inlet)
2. Suction valve closed
3. Impeller plugged
4. Strainer clogged
5. Wrong rotation
6. Shaft broken or unscrewed
7. Impeller loose

Vibration

1. Motor imbalance - electrical
2. Motor bearings not properly seated
3. Motor drive coupling out of balance
4. Misalignment of pump, castings, discharge head, column or bowls
5. Discharge head misaligned by improper mounting or pipe strain
6. Bent shafting
7. Worn pump bearings
8. Clogged impeller or foreign material in pump
9. Improper impeller adjustment
10. Vortex problems in sump
11. Resonance - system frequency at or near pump speed

Insufficient Capacity

1. Speed too slow
2. Improper impeller trim
3. Impeller loose
4. Impeller or bowl partially plugged
5. Leaking joints
6. Strainer partially clogged
7. Suction valve throttled
8. Low water level
9. Wrong rotation

Using Too Much Power

1. Speed too high
2. Improper impeller adjustment
3. Improper impeller trim
4. Pump out of alignment or shaft bent
5. Lubricating oil too heavy
6. Pumping sand, silt or foreign material

Abnormal Noise

1. Motor noise
2. Pump bearings running dry
3. Broken column bearing retainers
4. Broken shaft or shaft enclosing tube
5. Impellers dragging on bowl case
6. Cavitation due to low submergence or operation beyond maximum capacity rating
7. Foreign material in pump

Wear Analysis: Vertical Turbine Pumps

Trouble Source	Probable Cause	Remedy
Uneven wear on bearings, uniform wear on shafts.	Pump non-rotating parts misaligned.	Check mounting and discharge pipe connection and check for dirt between column joints. Correct misalignment, replace bearings, and repair or replace shaft.
Uniform wear on bearings and shafts.	Abrasive action.	Replace parts. Consider changing materials or means of lubrication.
Uniform wear on bearings, uneven wear on shafts.	Shaft run-out caused by bent shafts, shafts not butted in couplings, dirt or grease between shafts.	1. Straighten shaft or replace, clean and assemble correctly. 2. Face parallel and concentric.
Wear on impeller skirts and/or bowl seal ring.	1. Abrasive action or excess bearing wear allowing impeller skirts to function as bearing journal. 2. Impellers set too high.	1. Install new bearings and wear rings. Upgrade material if abrasion occurring. 2. Re-ring and adjust impellers correctly.
Impeller seal ring end wear.	Improper impeller adjustment. Impeller running on bottom.	Install "L"-shaped bowl wear rings. Adjust impeller setting per manufacturer's recommendations.
Wear on bowl vanes.	Abrasive action.	Coat bowls, upgrade material, or rubber line.
Wear on suction bell vanes.	Cavitation due to recirculation.	Correct condition or upgrade material to extend life.
Impeller Wear		
Exit vanes and shrouds.	Abrasive action.	Replace impeller if excessive. Consider coating or upgrading material.
Pitting on entrance vanes of impeller.	Cavitation.	Correct condition or upgrade material to extend life. See section on Cavitation.
Pitting on impellers and bowl casing.	Corrosion, erosion, or recirculation.	Investigate cost of different materials versus frequency of replacements. See section on Corrosion.
Bearings Failures		
Bearing wear.	Abrasive action.	Convert to fresh water flushing on bearings; or use pressure-grease or oil lubrication; or use bearings made of harder material.
Bearing seized or galling on shaft.	Running dry without lubrication.	Check lubrication, look for plugged suction or evidence of flashing.
Bearing failure or bearing seized.	High temperature failure.	Check pump manufacturer for bearing temperature limits. Generally: Bronze - 175 °F / 80 °C maximum in water Synthetics - 125 °F / 50 °C Carbon - 300 °F / 150 °C Rubber - 125 °F / 50 °C
Excessive shaft wear.	Rubber bearings will swell in hydrocarbon, H_2S and high temperature.	Change bearing material.
Bearings Failures		
Bent shaft.	Mishandling in transit or assembly.	Check straightness. Correct to 0.005 in/ft (0.13 mm/300 mm) total runout or replace.
Shaft coupling unscrewed.	Pump started in reverse rotation.	Shafts may be bent. Check shafts and couplings. Correct rotation.
Shaft coupling elongated (necked down).	1. Motor started while pump is running in reverse. 2. Corrosion. 3. Pipe wrench fatigue on reused couplings. 4. Power being applied to shafts that are not butted in coupling.	1. Look for faulty check valve. Could also be momentary power failure or improper starting timers. 2. Replace couplings. 3. Replace couplings. 4. Check for galling on shaft ends.
Broken shaft.	1. Can be caused by same reasons listed for coupling elongation. 2. Can also be caused by bearings seized due to lack of lubrication. 3. Foreign material locking impellers or galling wear rings. 4. Metal fatigue due to vibration. 5. Improper impeller adjustment or continuous upthrust conditions, causing impeller to drag.	1.Look for faulty check valve, momentary power failure or improper starting timers. 2. Same as above for bearing seizure. 3. Add strainers or screens. 4. Check alignment of pump components to eliminate vibration. 5. See sections on Impeller Adjustment and Upthrusting.
Impeller loose on shaft (rarely occurs).	1. Repeated shock load by surge in discharge line (could knock top impeller loose). 2. Foreign material jamming impeller. 3. Differential expansion due to temperature. 4. Improper parts machining and assembly. 5. Torsional loading on submersible pumps.	1. Refit impeller. 2. Usually will break shaft or trip overloads before impeller comes loose. 3. Change to material with the same expansion factor. 4. Repair and refit. 5. Overcome by adding keyway to collet mounting.

Packing Boxes

A packing box is a device used to seal off the pressure of the pumped liquid and minimize leakage.
For illustration purposes, a simple packing box designed for six rings of lubricated/braided packing will be used. High-pressure, by-pass type packing boxes have two lantern rings, one at the bottom of the box and one in the middle.

1. Push the packing to the bottom of the box. Seat the bottom ring carefully by tamping; it must seat on the face of the throttle bearing as well as against the shaft and the bore. Repeat this operation with each ring, making sure to stagger the joints 90 degrees.
2. If a lantern ring is used, be sure it is properly positioned so that it is in line with the drilling in the packing box.
3. Position the gland, checking for squareness to make sure it is not cocked in the box. Allow at least 3.18 mm/0.125 inch for the gland entrance. Make sure the gland nuts are only finger-tight.
4. It is critical to permit enough leakage to keep the packing box running cool. Check for overheating. If the pump runs hot and leakage begins to choke off, stop the pump and permit it to cool down. Again, make sure the gland nuts are only finger-tight.
   Warning: The danger of excessive tightening on the gland nuts will result in inadequate leakage and lubrication, causing the packing to burn and damage to the shaft and sleeves.
5. Allow the pump to run approximately 15 minutes and, if the leakage rate is more than desirable, tighten the gland nuts. The packing adjustment is made only with the pump running. Before making another adjustment, allow the packing to equalize against the increased pressure and permit leakage to decrease gradually to a steady rate. Pump packing must always leak slightly. Exercise extreme caution when adjusting packing and keep any loose clothing or long hair a safe distance from rotating shaft.
   New packing will run a little warmer for the first few hours until the packing has burnished in. Again, do not overtighten the gland nuts. The resulting inadequate leakage and lubrication not only burns the packing, it damages the shafts and sleeves.
6. A good practice is to have cooling water available when running in (breaking in) the packing.

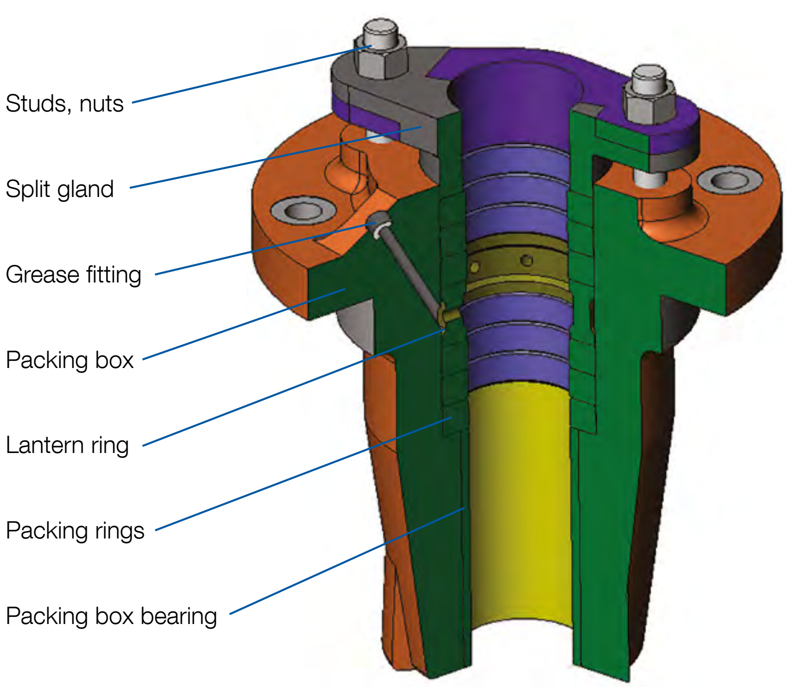
Packing Failure

What causes packing to fail prematurely? Some of the common causes are improper finishes, incorrect clearances, wrong selection of packing, faulty installation and maintenance, abrasive or corrosive conditions, insufficient lubrication, and leakage.

Abrasives in the fluids being pumped can be kept out of the packing box by using a flushing system. There are, however, other sources of abrasives such as scale in the pipe solids that might be left when water evaporates. These are just as damaging as abrasives in the fluid itself.

Eliminating pressure differentials as much as possible is another way to prolonging packing life, since leakage is directly proportional to pressure differences. One common way of accomplishing this is to use a throttle bearing below the packing and bleed off pressure through a bypass line.

Shaft run-out also causes packing difficulties. Run-out can be the result of a bent shaft, a shaft which flexes at high speeds, misalignment, an imbalanced motor coupling, or worn bearings.



NOTE: When repacking a packing box, be sure to clean out the old packing, including the packing below the lantern ring. Packing box is provided with a provision for a grease fitting but greasing is at the discretion of the operator. Standard packing provided by Sulzer only requires product lubrication.

Mechanical Seal Maintenance and Troubleshooting

A mechanical seal is another device designed to seal off the pressure of the pumped liquid and eliminate leakage. Considering the many variables encountered in mechanical seal applications, we suggest you contact your local mechanical seal service representative for assistance if you have problems. We highly recommend that all mechanical seal installations be backed up with a spare mechanical seal kit. There are also special seal cartridge designs which permit removing a complete cartridge and replacing it with a new one. The old cartridge can be repaired and placed back on the shelf, ready for use.

Checklist for Identifying Causes of Seal Failure

Sypmton	Probable Cause	Remedy
Seal leaks steadily.	Faces not flat.	Check for incorrect dimensions.
	Blistered carbon graphite seal faces.	1. Check for gland plate distortion due to over-torquing of gland bolts. 2. Improve cooling flush line, if overheated. 3. Check gland gasket for proper compression. 4. Clean out any foreign particles between seal faces. Re-lap faces, if necessary. 5. Check for cracks and chips at seal faces during installation. 6. Replace primary and mating rings, if damaged.
	Secondary seals nicked or scratched during installation.	Replace secondary seals.
	Worn out or damaged ‘O’-rings.	Check for proper seals with seal manufacturer.
	Compression set of secondary seals (hard and brittle).	Check for proper lead-in on chamfers, burrs, etc.
	Chemical attack (soft and sticky).	Check seal manufacturer for alternative materials.
	Spring failure.	Replace parts.
	Erosion damage of hardware and/or corrosion of drive mechanism.	Check seal manufacturer for alternative materials.
Carbon dust accumulating on outside of gland ring.	Inadequate amount of liquid to lubricate seal faces.	1. Flush line may be needed (if not in use). 2. Enlarge flush line and/or orifices in gland plate.
	Liquid film evaporating between seal faces.	Check for proper seal design with seal manufacturer if pressure in mechanical seal box is excessively high.
Seal squeals during operation.	Inadequate amount of liquid to lubricate seal faces.	1. Flush line may be needed (if not in use). 2. Enlarge flush line and/or orifices in gland plate.
Seal leaks intermittently.	See causes listed under “Seal leaks steadily”.	1. Refer to list under “Seal leaks steadily”. 2. Check for squareness of mechanical seal box to shaft. 3. Align shaft, impeller and bearing to prevent shaft vibration and/or distortion of gland plate and/or mating ring.
Short seal life.	Abrasive particles in fluid.	1. Prevent abrasives from accumulating at seal faces. 2. Flush line may be needed (if not in use). Use abrasive separator or filter.
	Seal running too hot.	1. Increase cooling of seal faces (for example, by increasing flush line flow). 2. Check for obstructed flow in cooling lines.
	Equipment mechanically misaligned.	Align properly. Check for rubbing of seal on shaft.

Thrust in Vertical Turbine Pumps

An understanding of the forces causing thrust on a vertical turbine pump impeller is necessary to obtain satisfactory operating life and to diagnose pump troubles.

The forces causing thrust on a vertical turbine pump are shown in Figure 1. Since the predominant hydraulic force in a vertical pump is downward, the vertical motors used with these pumps are designed for continuous downthrust operation. In addition to the downthrust force, there is also a counter force commonly known as upthrust. In the normal operating range of a pump, the upthrust is small compared to the downthrust. However, when a given size pump is run at very high capacity, the upthrust can overcome the downthrust, especially on close-coupled vertical pumps.

Figure 2 shows a typical thrust curve on a vertical pump. The pump downthrust is high at low flows, decreases to a zero thrust point at a capacity generally 30% higher than pump peak efficiency, and changes to upthrust beyond that point.

Continuous Upthrust

Continuous operation in upthrust can damage the pump:

1. Lineshafts bend and buckle due to compression load. Vibration and rapid bearing wear result.
2. Mechanical seals leak due to shaft vibration and/or excessive upward axial movement of the shaft.
3. Impellers rub on the tops of bowls.
4. Driver radial bearings undergo upthrust loads and fail rapidly.
5. Driver thrust bearings fail since they can take thrust in only one direction.
6. The motor rotor rubs against the stator, causing electrical and mechanical damage.
7. Ultimate destruction of the motor and/or pump may occur due to one or a combination of the above causes.

No pump should be operated at a capacity greater than 130% of the full diameter peak efficiency capacity, unless specifically designed for continuous operation in high capacity ranges. Contact the factory for proper modifications to the pump and driver to meet this requirement.

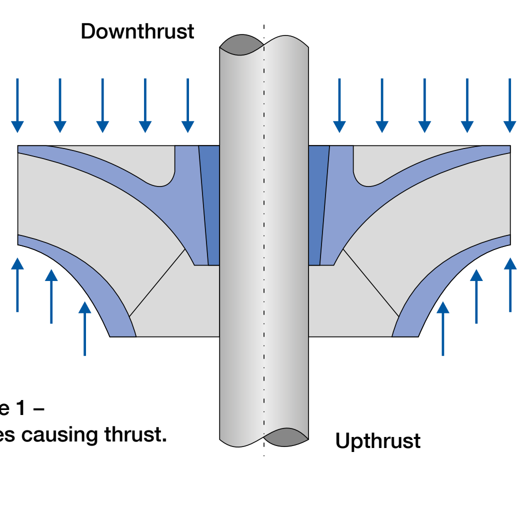
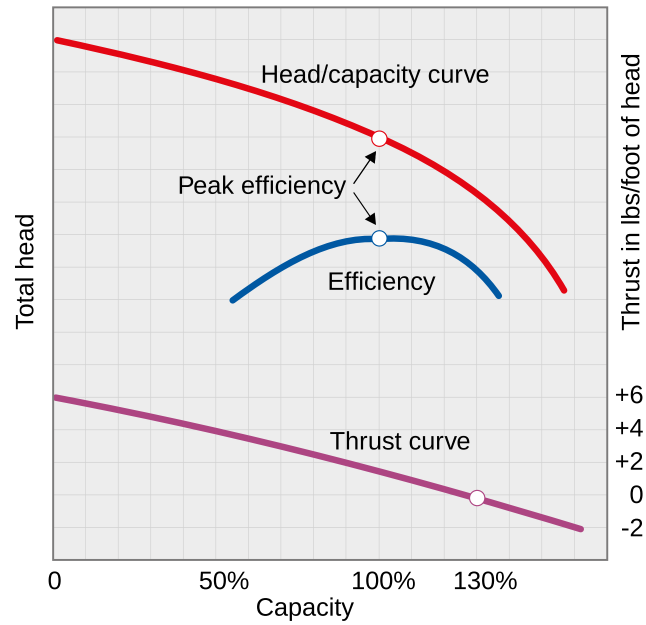


Figure 1 – Forces causing thrust.

Figure 2 – Typical thrust curve.



Momentary Upthrust During Start-up

When a pump is first started, it is likely to operate at a high capacity while the motor gets up to speed. In most installations, however, the head builds up immediately so that the upthrust is only momentary.

To prevent upward motion of the rotating parts, both vertical hollow-shaft (VHS) and vertical solid-shaft (VSS) motors are normally supplied to handle momentary upthrust equal to 30% of the downthrust capacity. The top drive coupling on vertical hollow-shaft motors must be bolted to the rotor housing to prevent the motor drive coupling and pump rotating assembly from lifting due to starting upthrust.

Start-up Problems

Starting upthrust problems can also cause mechanical seal malfunction. This occurs when the shaft moves upward too much, changing the fine adjustment between the stationary face and the rotating face of the seal. The ability of the seal to accommodate vertical movement of the shaft varies with each seal design. However, as a general rule, no seal trouble will be encountered if the vertical shaft movement is limited to 0.38 mm/0.015 inch.

NOTE: Vertical pumps with column settings over 30 m/100 ft generally do not encounter upthrusting during start-up because the weight of rotating elements and lineshaft is sufficient to overcome the upthrust forces.

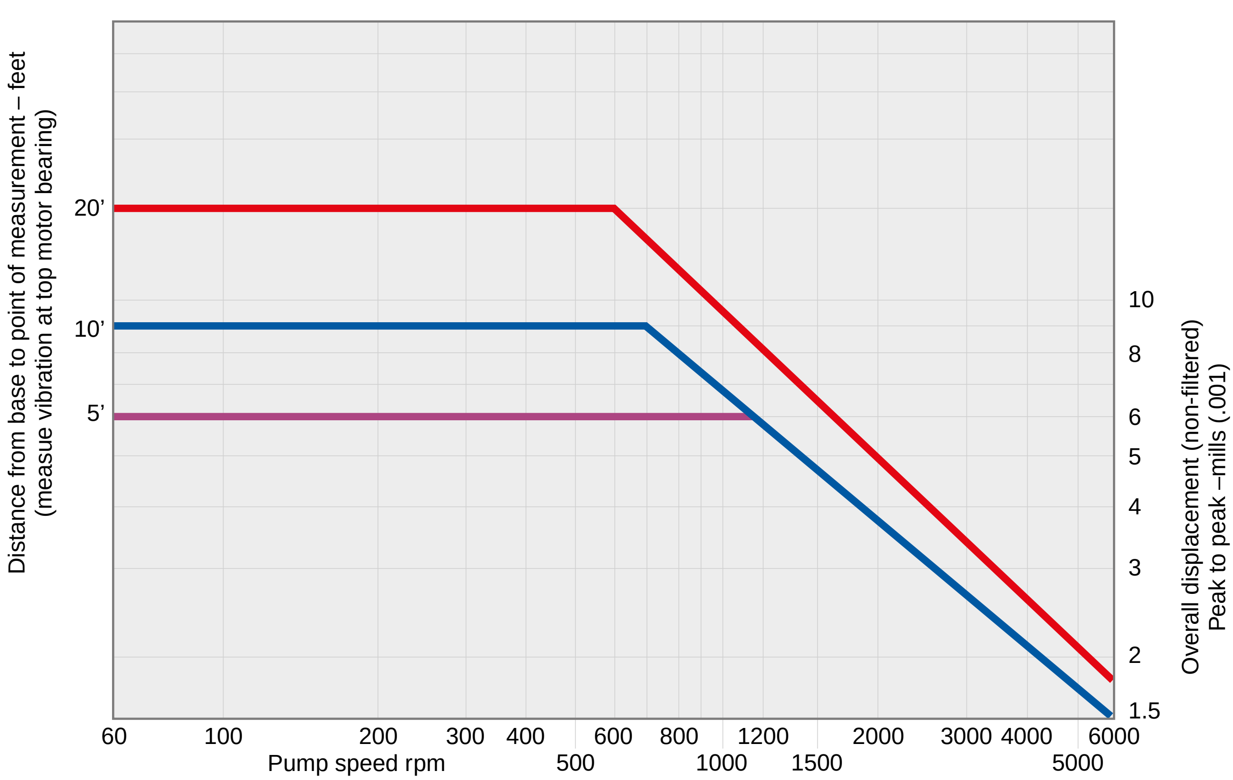
Vibration

Almost all vertical pump vibration problems are reported as a vibrating motor regardless of the type of vibration. This occurs because the head and motor are the only parts observed by the user, and since the motor top is at the extremity, it exhibits the largest vibration amplitude. Vibrations below the pump base are seldom noted, nor do they seem damaging to the equipment. Normally on vertical pumps, below base and above base vibrations are isolated from each other by their stiff base configurations.
If a running pump is vibrating, feel by hand the motor, head, piping and base to determine the maximum amplitudes, including their locations and slopes from maximum to nil. Usually the maximum is at the top of the motor, with amplitudes decreasing to near zero either at the head or motor base. Sometimes a discharge pipe is vibrating more than the pump. Picturing the high amplitude locations and how the pump is vibrating aids in understanding the causes.

If a vibration analyzer is available, determine amplitude on the motor and head in line and 90 degrees to discharge (motor top and bottom, head top and bottom).

1. Slow down the pump. If it is an electric drive just shut it off; if it is an engine drive, throttle it down. Be aware of how the vibration changes with speed.
   a. If the vibration reduces gradually, it is a sign that unbalance, misalignment, or bent shafting is the cause.
   b. If the vibration decreases immediately with the electrical power shutoff, the cause is electrical imbalance in the motor.
   c. If the vibration disappears with only a small speed change, then the cause is probably a natural frequency or resonance problem. The unit is operating at or near the resonance frequency. If the vibration is due to a resonance just below the operating speed, the vibration level will momentarily increase, then decrease quickly with unit slowdown. When a pump shudders in slowdown, the cause is generally passage through a resonance frequency. But do not jump to conclusions at this point; gather more data.
2. With the pump shut down, rotate the shaft by hand. If it is hard to rotate, the suspected causes are misalignment, bad fit, or a bent shaft. However, an easily rotated unit does not eliminate these causes, since small shafts can bend readily without load imposed on the bearings.
3. Disconnect the drive.
   a. If the motor is a hollow-shaft, mark the position, remove the drive coupling, and note if the head shaft is centered within the motor's hollow shaft. If not, misalignment has likely occurred due to mismatching, a bent shaft, a bad fit between the motor and pump, excessive pipe strain on the head, or conduit strain on the motor.

Acceptable field vibration limits for vertical pumps – clear liquids



   b. On a solid-shaft motor, mark the position, disconnect the coupling, and note if the adjusting nut leans heavily to one side.
4. Run the drive disconnected.
   a. Repeat the sequence detailed in paragraph 1 and record the results.
   b. If the vibration is the same, then only the motor-head area is likely to be involved. An unbalanced motor is the prime candidate.
   c. If the vibration disappears, the cause is probably in the parts removed.
   d. If a vibration analyzer is available, obtain amplitudes and frequency as before, shut off the unit and again note vibration change with speed. Remember, only the head and motor are now involved in the vibration.
5. Check the operating history of the pump. When did the vibration begin? If the pump has always vibrated, the likely causes are misalignment, unbalance, or resonance problems. If the vibration only started recently, check for a clogged impeller, worn bearings, worn rings, or a change in the piping base. Carefully observing and analysing the operational and physical clues will usually reveal the cause. Even if you are not able to pinpoint the cause, the data you collect will help a qualified pump engineer to address the problem and suggest corrective action.

Vibration Correction

Vibration correction should not be attempted without a manufacturer's representative present.

Electric Motor

1. If you encounter "loose iron" or rotor eccentricity, contact the motor manufacturer and do not attempt repairs yourself.
2. Unbalance in the motor drive coupling.
   a. Rotate the drive coupling on the hollow-shaft and run the motor with the pump connected. Change locations until the minimum vibration point is located.
   b. Field balance the hollow-shaft for light balancing only, by trial and error adding washers under drive bolts. Start in line with a hollow-shaft key and add a washer. If the vibration is less, you are in the right plane. Add more weight until it is smooth running or the vibration increases. If the vibration increase, change the bolt hole.
   c. Using a vibration analyzer or balancer, weight may be added to or removed from the motor bearing shaft housing or the fan assembly until a proper balance is achieved.
   d. Motor acceptability may be shop tested by running the motor on a thick rubber pad like those used in a NEMA motor vibration test.

Pump
Above-base Discharge

Check the easiest items first.

1. To check for a clogged impeller, run the pump and then let liquid backflush through the pump. This will not always work, however, since beer cans, tires and other pliable items will not necessarily flush out.
2. If you hear "metal hammering" noises that may indicate cavitation, check the intake for vortexes or swirls. Look over the installation plans for flow discontinuities since vortexes and swirls not visible at the water surface can still cause vibration. An example; a small propeller pump located just beyond a sharp step down in the sump floor in the suction approach of some large pumps. The small pump would run fine alone, but start the big pumps - and the small pump would lose performance and begin vibrating.
3. Look for off-center shaft conditions in housings, beginning with the motor.
   a. Vertical hollow-shaft motor: Turn off the power and remove the drive coupling. If the shaft is not in the center of the motor's hollow shaft, rotate the shaft 180 degrees. A bent shaft will follow rotation. Misalignment will cause the shaft to continue leaning in the same direction.
   b. Vertical solid-shaft motor: Turn off the power and disconnect the motor/pump coupling. Take indicator readings on both the motor and pump shafts to determine if the cause is bent shafting or misalignment. Indicate to the shafts, not the couplings.
   c. Continue checking for misalignment as you disassemble the pump.

4. Piping strain: Suction and discharge piping must be independently supported so that they do not impose a load on the discharge head. Any stress transmitted to the pump may cause misalignment and subsequent damage to the pump.
   a. Unbolt the discharge flange and see where it goes. If the flange is in the correct position, all bolts will slip out by hand and you will be able to remove the gasket only by loosening the pump base bolts and wedging the assembly slightly apart.
   b. To correct the assembly, leave the base bolts loose and bring the flanges together to about 1.52 mm/0.060 inch parallel. Slip in the gasket and tighten the bolts evenly, using a "180 degrees apart" tightening process. Then tighten the base bolts.
   c. Recheck the pump alignment.
5. Observe wear patterns.
   a. If the bearing is worn on one side and the shaft is worn evenly, the pump housing is misaligned.
   b. If the shaft is worn on one side and bearing wear is even, then check for a bent shaft or misalignment of the rotating parts. Debris or grease between shaft ends can cause misalignment.
6. Check for debris in pump housing joints which can cause misalignment.

Below-base Discharge

Pumps with a below-base discharge often become misaligned when the discharge pipe is being attached.

1. On a flanged connection, unbolt the discharge flange and see where it goes. If the flange is in the correct position, the bolts will slip out by hand and the flange faces will be parallel and together, requiring slight wedging to remove the gasket. If necessary, realign the assembly as directed for above-base discharge (see paragraph 4b above).
2. On flexible or semi-flexible joints, like those on bellows or Dresser-type couplings, use an indicator to measure movement from the rest position to running operation. If there is more than three mils of deflection per foot down from the pump base, a tie-bar arrangement should be added: if a tie-bar is already being used, it should be adjusted (see below). This procedure varies depending on the shaft size and pump construction, so if in doubt, contact the pump manufacturer.
3. Tie-bar adjustment: With the pump running, tighten or loosen one tie-bar slightly and check the result with a vibration meter on the pump motor. If improvement occurs, move to a lower amplitude and continue adjusting, alternating from side to side. Keep the sides relatively even with each move to a lower amplitude.
4. The lowest amplitude vibration indicates the least vibrational force, and so is the straightest shaft position. If correcting the discharge alignment does not lessen the vibration sufficiently, continue troubleshooting according to the guidelines in the section on above-base discharge pumps.
5. On product lubricated pumps, a connection is provided at the pedestal for installation of an air relief valve as the upper portion of discharge elbow must be vented to allow fluid to reach packing.

Resonance

All equipment has a natural frequency at which it will vibrate. Resonance vibration occurs when a pump is operated at a speed corresponding to this natural frequency.

The natural frequency of an installed pump varies with the foundation and piping, which create a system resonance. Correction of vibration due to resonance requires a change in the spring rate or mass of the system to stiffen or weaken the pump or structures. A qualified pump vibration engineer can determine solutions based on data obtained from field investigations.

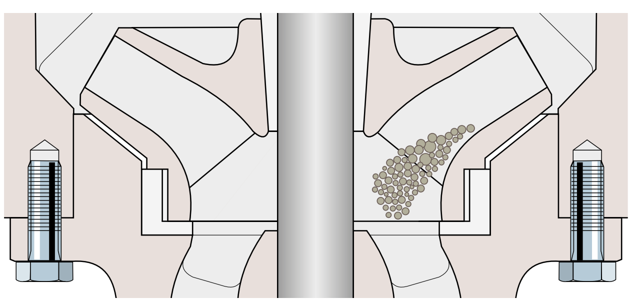
Cavitation and Vortexing

Cavitation

Cavitation occurs when the absolute pressure of a moving liquid is reduced to a value equal to (or below) the vapor pressure of the liquid. Small vacuum pockets or bubbles form, then collapse in the area where pressure increases in the impeller. The collapse of these vapor pockets is so rapid that it makes a rumbling or cracking noise - like rocks passing through the pump. The forces in the collapse are generally high enough to cause minute pockets of fatigue on metal surfaces adjacent to bubbles. This action may be progressive and under severe conditions can cause serious pitting damage on the metal subject to cavitation attack.
Cavitation takes place along the impeller vane tips and vane surfaces, as shown in the cross-section. Cavitation can cause the following problems:

1. Reduced pump capacity
2. Erratic power consumption
3. Noisy operation
4. Damage to impeller
5. Pitted suction inlet vanes and impaired casting strength

Note: The same type of damage can result from recirculation caused by operating the pump away from the best efficiency point (BEP).



How to Prevent Cavitation in Existing Installations

Cavitation can be avoided by providing sufficient net positive suction head (NPSH) for the pump. However, this may be an expensive correction in the field. An alternate solution is to reduce the NPSH requirement of the pump by one of the following methods:

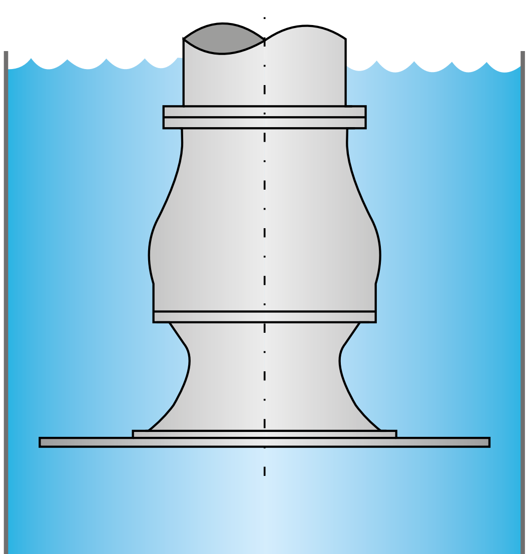
1. Evaluate system head conditions, NPSH available, and, if possible, reduce pump capacity.
2. Change pump impellers to obtain low NPSH design.
3. Replace the pump bowl assembly with a different model capable of operating with the system NPSH available.

Contact a Sulzer Pumps Service Center for assistance in evaluating your system NPSH and recommended solutions. Frequently, Sulzer Pumps low NPSH impeller assemblies can be furnished to fit your existing vertical pumps.

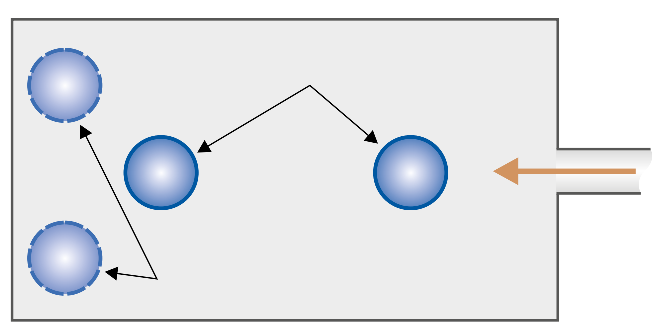
Vortexing

“Something is wrong with the pump! It’s sucking in slugs of air”. This remark is frequently made when vortices form in flow patterns, causing loud rumbling noises.
A vortex is a whirlpool caused by a combination of factors such as sump design, inlet velocity, direction and flow, submergence, and the position of the bowl assembly in the sump. Air entering the pump through these vortices causes noise and vibration, but not cavitation. Various methods can be used to prevent vortices. These include using suction umbrellas, lowering the inlet velocities in the sump, increasing submergence and relocating pumps.

Suction umbrella added.



Relocate pumps at back wall, as indicated by dashed lines.



Corrosion, Abrasion and Erosion

Corrosion means “eating away by degrees by chemical action”. Abrasion is “the process of rubbing or wearing away by friction”. A pump’s performance can be reduced and eventually destroyed by corrosion or abrasion - or a combination of the two, commonly called erosion, which means “a gradual wearing away”.

Corrosion Alone

When metallic corrosion alone is adversely affecting pump performance, the solution is to select material which will corrode very slowly when in contact with the fluid being pumped. Protective coatings can also reduce corrosion in some applications.

Corrosion and Abrasion Working Together

Great difficulties arise when corrosion and abrasion are both present. All metals rely on a thin oxide film or “skin” to protect them against corrosive chemical agents in fluids. If a corrosive fluid contains hard abrasives - even in small amounts - then abrasion will eventually wipe away the protective skin and the metal will corrode, forming a new skin. As long as the abrasives are harder than the corroded skin, this process of wear and corrosion will continue until the metal is eroded away. Fluid velocity inside the pump affects this erosive cycle. Lowering internal velocity - by slowing the pump speed or oversizing the pump for the design conditions - will reduce abrasion and slow down erosion.

Abrasive Action at the Bearings

A vertical pump uses sleeve bearings inside a bearing retainer for proper lineshaft support. The straightness of this shafting is the secret of long vertical pump life. Each shaft runs with a thin film of fluid around it. Centrifugal force keeps this film even in all bearings, assuring lubrication and balance in the pump. Anything which upsets this balance can cause difficulties. Abrasion can wipe away bearing surfaces, causing the bearing to become elliptical. The shaft then tends to destroy all bearings by its own out-of-balance action, and the pump fails. Flushing with clean, abrasive-free liquid is one way to prevent such failure; another is to install bearings and shafting designed to resist abrasion.

Bearing Lubrication with Clean Liquid

If the fluid being pumped lacks sufficient lubricating qualities, a fluid with good lubricating qualities can be injected at each bearing journal. The injected fluid must be compatible with the fluid being pumped, even though only small quantities are used. For example, flushing with fresh or filtered water is a common way of lubricating bearings in water pumps.

When abrasives are present in corrosive liquids, the liquid can be run through a small centrifugal separator, passed through a small pump to rebuild pressure (if necessary) and injected at the packing box to lubricate the packing box and lineshaft bearings. On this type of system the lineshaft is installed within an enclosing tube and the flushing liquid lubricates each lineshaft bearing.

The bowl assembly bearings can be lubricated by running a line to the tail bearing (suction bearing) on single-stage units. On multi-stage pumps, the impeller shaft is gun-drilled, and holes are bored at each bearing location to introduce clean liquid to each bearing. The flushing liquid should be introduced at ten psi higher pressure than the maximum discharge pressure at the pump bowls.

Seawater Corrosion

One of the most difficult corrosive fluids to handle and understand is seawater. This is because of several variables which can alter the effects of this fluid upon different metals. The first consideration is temperature. All corrosive fluids become more active as the temperature rises. Therefore, where cast iron might be used successfully at 30˚F / -1˚C , the story changes at 90˚F / 32˚C . Other chemicals in seawater can cause difficulty, especially if their presence is not known. Around oil docks, drilling rigs, etc, sulphides might be present; even small quantities of sulphides would greatly increase corrosion. Another consideration is the quantity of sand present. Offshore installations are subject to tides and wave action which constantly change the sand content of the water, making system analysis very difficult. The electrolytic action of dissimilar metals in the presence of the seawater must also be taken into account.

The best defense is your own experience on any given unit. Good records are a necessity. Each pump should be checked for vibration and amperage periodically. This information, along with the shutoff head, should be noted in the permanent record. Any changes should be cause for investigation. Any repairs should be noted with complete description of parts used, materials and condition of the parts being replaced. With this type of record, it is possible to keep track of improvements in performance and to be aware of what materials or actions brought them about. Without such information, it is impossible to be certain that a solution is correct for a particular application and expensive parts could be lost. Defending against corrosion is a never-ceasing battle to extend the life of equipment. Your Sulzer Pumps Service Center maintains detailed records and analysis on pump repairs to determine changes that will improve pump operating life.

Wear Ring and Bearing Clearances

The following are average clearances for bronze bearings and bronze or cast iron wear rings. Special materials, stainless steel wear rings, and high-temperature liquids (above 180˚F / 82˚C) require special clearances. All clearances shown are diametrical. These values are not applicable to Dynaline (type JD) bowls.

Bowl size		Standard wear ring clearance		Special wear ring clearance		Bearing clearance		Standard shaft size
mm	inch	mm	inch	mm	inch	mm	inch	inch
100	4”				0.006	0.15	3/4	3/4
150	6”	0.31-0.36	0.012-0.014	0.41 -0.46	0.016-0.018	0.18	0.007	1 1/4
200	8”	0.31	0.012	0.41	0.016	0.2	0.008	1 1/4
255	10”	0.33	0.013	0.41 -0.43	0.016-0.017	0.2	0.008	1 1/2
305	12”	0.33-0.38	0.013-0.015	0.43 -0.46	0.017-0.018	0.2	0.008	1 11/16
355	14”	0.38	0.015	0.43 -0.46	0.017-0.018	0.23	0.009	1 15/16
405	16”	0.38	0.015	0.46 -0.56	0.018-0.022	0.25	0.010	1 1/4
460	18”	0.46	0.018	0.51 -0.56	0.020-0.022	0.28	0.011	2 1/4
510	20”	0.46	0.018	0.56	0.022	0.28	0.011	2 7/16
560	22”	0.46	0.018	0.56 -0.61	0.022-0.024	0.31	0.012	2 11/16
610	24”	0.66	0.026	0.56	0.022	0.31	0.012	2 7/16
635	25”	0.66	0.026	0.76	0.030	0.31	0.012	2 15/16
685	27”	0.66	0.026	0.76	0.030	0.31	0.012	3 1/4
710	28”	0.66	0.026	0.76	0.030	0.31	0.012	3 1/4
760	30”	0.81	0.032	0.91	0.036	0.31	0.012	3 1/4
810	32”	0.81	0.032	0.76	0.030	0.31	0.012	3 7/16
840	33”	0.81	0.032	0.91	0.036	0.31	0.012	3 7/16
915	36”	0.81	0.032	0.91	0.036	0.31	0.012	4
1065	42”	0.86	0.034	0.99	0.039	0.31	0.012	4 1/2
1220	48”	0.86	0.034	0.99	0.039	0.31	0.012	4 1/2
1420	56”	0.91	0.036	1.04	0.041	0.38	0.015	5
1625	64”	0.91	0.036	1.04	0.041	0.38	0.015	5 1/2

Vertical Pump Shafting

Proper selection of shaft materials, shaft finish under bearings, machining and straightening are vital functions of vertical pump manufacturing.

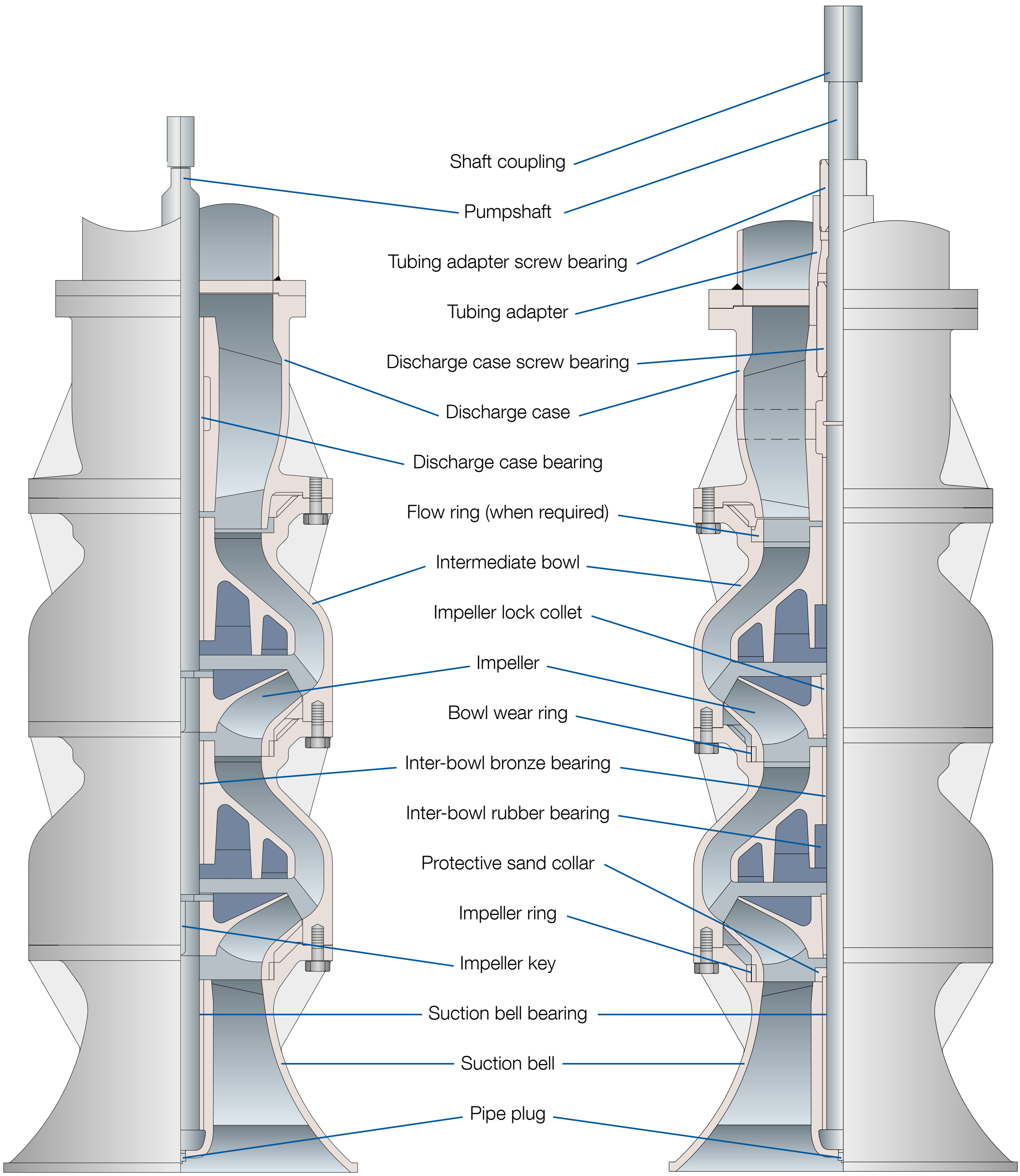
Vertical pump shafting materials are carefully selected for physical properties and micro-finish to operate under sleeve bearings.

Shaft threads must be machined parallel and concentric, and shaft ends must be machined and faced perfectly square. It is recommended to machine a recess/counter bore on the shaft ends, approx 50% of the shaft diameter x 0.031 in or 0.794 mm deep to ensure the shaft are perfectly square and make full contact during installation. Finished machined shafts are best stored in the vertical position on a slight angle I.e. ‘A’ frame shaped shaft rack prior to assembly in the pump. The shaft end centers must also be properly machined to remove any raised area that would prevent proper face-to-face contact between mating shafts.

Shafts must be straightened to 0.13 mm per 305 mm or 0.0005 in/ft in total runout. Example: A ten-foot shaft cannot exceed 0.005 in total runout.

Finally, careful handling of all shafting prior to and during assembly and installation is necessary to avoid bent shafting which will cause premature pump failure.

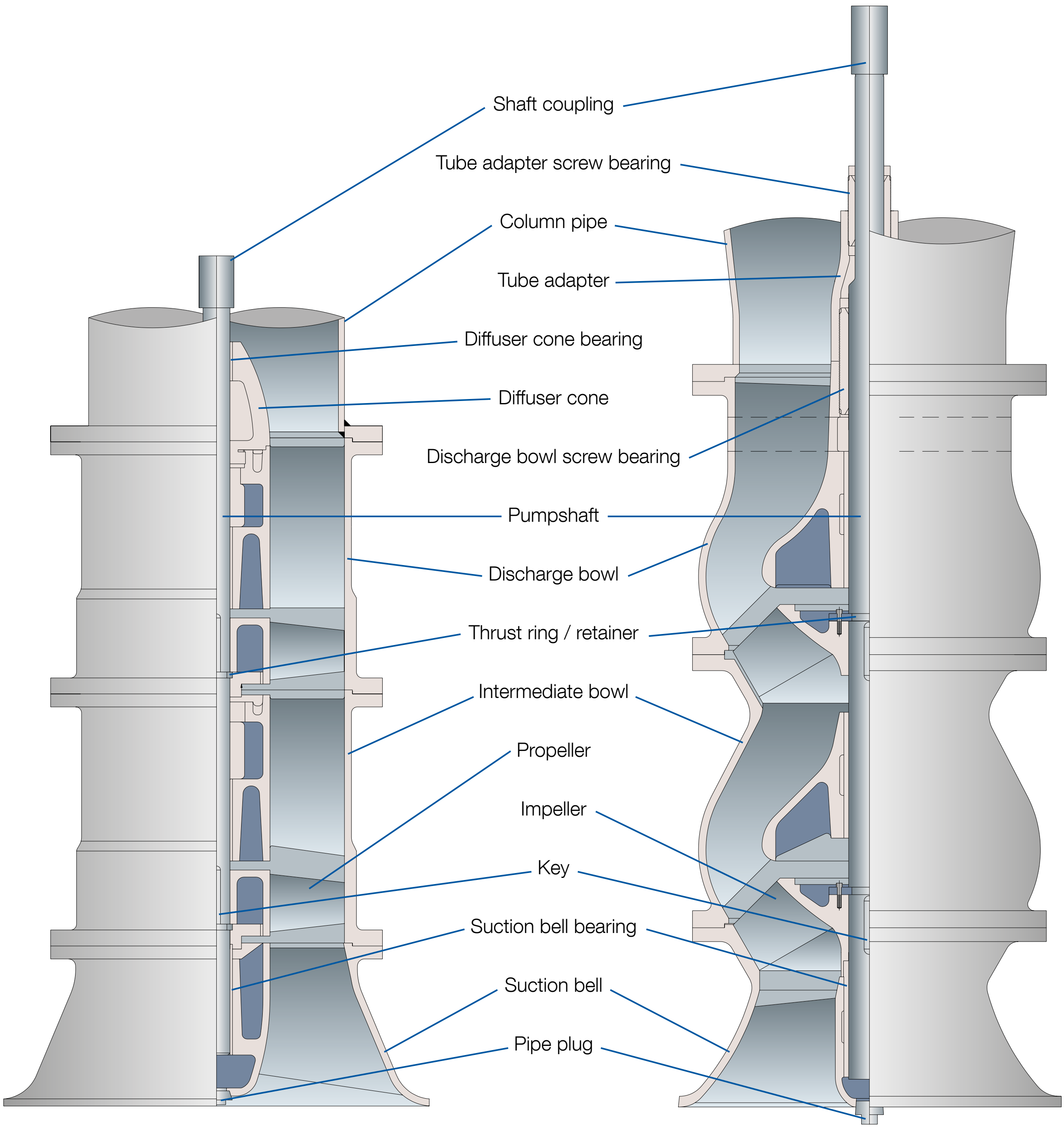
Typical Vertical Turbine Pump Bowl Assemblies



Product lubricated model
with closed impellers,
single bearings and
keyed impeller construction

Oil lubricated model
with closed impellers,
dual bearings and
lock collet construction

Typical Vertical Propeller (Axial-Flow) and Mixed-Flow Pump Bowl Assemblies



Product lubricated propeller (axial-flow) pump with thrust ring construction

Oil lubricated mixed-flow pump with thrust ring construction

Troubleshooting Vertical Induction Motors

While an electric motor is a reliable machine, lack of maintenance and defects in design, manufacturing, or workmanship can sometimes occur. None of the protective devices available will provide maintenance or solve built-in motor defects, so it is worthwhile to know when to suspect the motor. Fortunately, a motor will tend to exhibit some signs of distress prior to a complete and catastrophic failure, and while it does take experience to recognize many of these symptoms, the following summary of possible motor problems can help prevent failure.

Mechanical Failures and Probable Causes

Vibration

1. Excessive motor or pump imbalance
2. Misalignment or eccentricity of rotating parts
3. Open bars in motor rotor
4. Mounting unstable or uneven
5. Faulty bearings (improperly seated, pitted from long periods of idleness, fatigued)
6. Uneven motor air gap
7. Operation of spring-loaded spherical roller bearing motors with insufficient thrust load
8. Oil whip

Motor Noise

1. Worn bearings
2. Loose iron
3. Fan noise
4. Vibration
5. Bearing noise: Bearing noise is a normal phenomenon, but experience will tell when noise exceeds acceptable levels. Such excessive noise should be recognized as a symptom of impending bearing failure.

Motor Drive Coupling Problems

1. The most common complaint is failure of cap screws that hold the couplings. Motors are shipped with especially hardened cap screws which require proper values of torque when tightened to prevent shearing, but overtightening puts excessive stress on the cap screw fasteners. Replacement cap screws should be SAE Grade 5 or the equivalent.
2. Imbalanced drive coupling
   For additional technical assistance, please contact the motor manufacturer's representative or the nearest authorized motor service facility.

Oil Leaks

1. Over-filling – can also cause motor vibration and/or abnormal noise
2. Foaming because of improper oil
3. Leaks at fittings
4. Cracked castings (rare)

Motor Bearing Failures

1. Plate bearing failures: failure of oil film because of excessive thrust, rusting during storage, lack of cooling water.
2. Sleeve bearing failures: rusting during storage, improper lubricants.
3. Ball and roller bearing failure other than normal wear.
   a. Improper, contaminated or deteriorated lubricant
   b. Excessive loading
   c. False brinelling during storage
   d. Rusting
   e. Misalignment
4. Bearing overheating
   a. Over-greased
   b. Old grease
   c. Overloading
   d. Misalignment
5. High temperature breakdown of lubricating oil

Vertical Pump Service

Sulzer Pumps has the world's largest service organization devoted exclusively to troubleshooting and repairing all makes, models and sizes of vertical pumps.

Fully equipped Sulzer Pumps Service Centers are located in all major industrial areas all over the world. Each center is staffed by pump professionals who specialize in "Quick Turnaround Service" 24 hours a day.

We encourage you to visit the Sulzer Pumps Service Center nearest you. You will find overhead cranes, lathes, boring mills, radial drills, welding equipment and all the special machinery required for static and dynamic balancing, shaft straightening, parts resurfacing and coating.

You will also notice that each center carries a substantial inventory of spare parts. For regular customers, Sulzer Pump Service Centers even maintain special parts stocking programs. And all Sulzer Pumps' extensive inventory is tracked by a centralized computer system which speeds up parts location and shipment anywhere in the world.

If you need special parts manufactured – even for obsolete pumps, the Sulzer Pumps CSS (Customer Support Services) division can supply them.

Sulzer Pumps technicians do more than just repair pumps. They also analyze entire pumping systems to make sure pumps properly match media, flow, head and NPSH requirements. They are experts at rebuilding and upgrading pumps to meet changing needs. They will supervise pump start-up, help with your spare parts inventory and even conduct special training for your operating and maintenance people. Complete service contracts are also available. In short, Sulzer Pump Service Centers provide total vertical pump service.

Nuclear and Safety Related Service

Our Chattanooga, Tennessee Nuclear Service Division is solely dedicated to servicing the nuclear industry. This highly specialized facility meets all required standards to repair pumps in Class II and III service.

Our in-house nuclear capabilities include seismic analysis, design, fabrication, machining, modification, upgrading, repair/rebuild and performance testing. These services can be applied to all pumps regardless of manufacturer.

Our nuclear qualifications include many years nuclear experience; Appendix B to 10CFR Part 50; ANSI N45.2; ASME, Section III, Division 1, Class 2 and Class 3.

Worldwide Service

No matter where your pumps are located, you can rely on Sulzer Pumps' experienced trouble-shooters ready to go anywhere to handle emergencies with any vertical pump, regardless of make, model or size.

Skilled troubleshooting in the field, complete pump repair capabilities and unmatched expertise in vertical pumps – all reflect Sulzer Pumps' total commitment to providing the best vertical pump service available.

www.sulzer.com

E00669 (1) en 9.2012 (1,000), Copyright © Sulzer Pumps