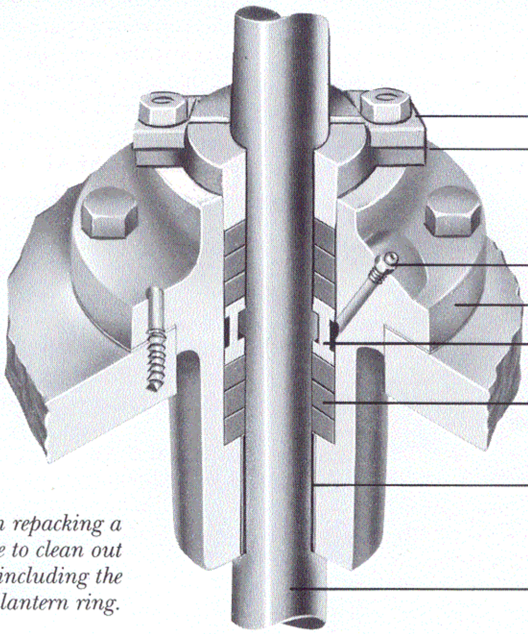
WEAR ANALYSIS: VERTICAL TURBINE PUMPS

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 runout 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 occuring. 2. Re-ring and adjust impellers correctly.
Impeller end seal 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 casting.	Corrosion, erosion, or recirculation.	Investigate cost of different materials versus frequency of replacements. See section on Corrosion.
Bearing 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 degrees F maximum in water. *Synthetics*—125 degrees F. *Carbon*—300 degrees F. *Rubber*—125 degrees F.
Excessive shaft wear.	Rubber bearings will swell in hydrocarbon, H_2S, and high temperature.	Change bearing material.
Shaft and Couplings Bent shaft.	Mishandling in transit or assembly.	Check straightness. Correct to .0005 in./ft. 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



NOTE: When repacking a packing box, be sure to clean out the old packing, including the packing below the lantern ring.

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 packing boxes have two lantern rings, one at the bottom of the box and one in the middle.

1. It is recommended that grease or oil be applied to each ring. 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 ⅛-inch for the gland entrance. Make sure the gland nuts are finger-tight.
4. It is critical to permit enough leakage to keep the stuffing 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.

   The danger of excessive tightening on the gland nuts should be mentioned once again. The resulting inadequate leakage and lubrication not only burns the packing, but damages the shafts 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.**

   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 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 of 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 runout also causes packing difficulties. Runout can be the result of a bent shaft, a shaft which flexes at high speeds, misalignment, an imbalanced motor coupling, or worn bearings.

MECHANICAL SEAL MAINTENANCE & TROUBLESHOOTING

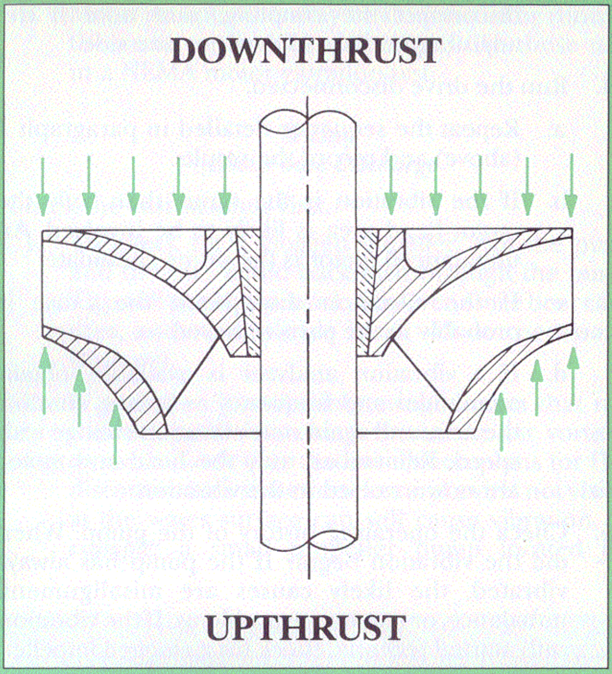
A mechanical seal is another device designed to seal off the pressure of the pumped liquid and eliminate leakage. Considering the many variables encountered in mechanical seal applications, we suggest you contact your local mechanical seal service representative for assistance if you have problems. We 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

Symptoms	Probable Cause	Remedy
Seal leaks steadily.	Faces not flat.	Check for incorrect installation 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 alternate materials.
	Spring failure.	Replace parts.
	Erosion damage of hardware and/or corrosion of drive mechanism.	Check seal manufacturer for alternate materials.
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.
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 stuffing box is excessively high.
Seal leaks intermittently.	See causes listed under "Seal leaks steadily."	1. Refer to list under "Seal leaks steadily". 2. Check for squareness of stuffing 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 continuously 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.

Momentary Upthrust During Startup

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 hollowshaft (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 hollowshaft motors must be bolted to the rotor housing to prevent the motor drive coupling and pump rotating assembly from lifting due to starting upthrust.

Startup 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 troubles will be encountered if the vertical shaft movement is limited to .015 inch.

NOTE: Vertical pumps with column settings over 100 feet generally do not encounter upthrusting during startup because the weight of rotating elements and lineshaft is sufficient to overcome the upthrust forces.

TYPICAL THRUST CURVE

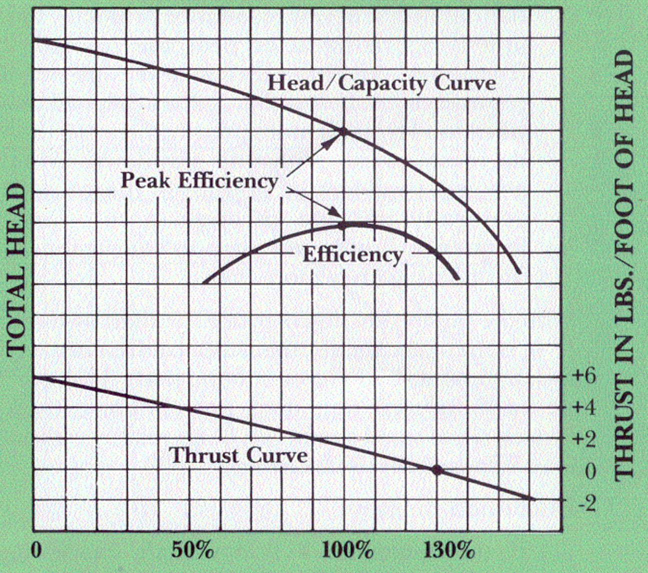


FIG. #2

VIBRATION

General

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 vibration 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 amplitudes on the motor and head in line and 90-degree 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. If not, misalignment has likely occurred due to mismachining, a bent shaft, a bad fit between the motor and pump, excessive pipe strain on the head, or conduit strain on the motor.
   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 (above) 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 or base. Carefully observing and analyzing 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 solve 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 increases, change the bolt hole.