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

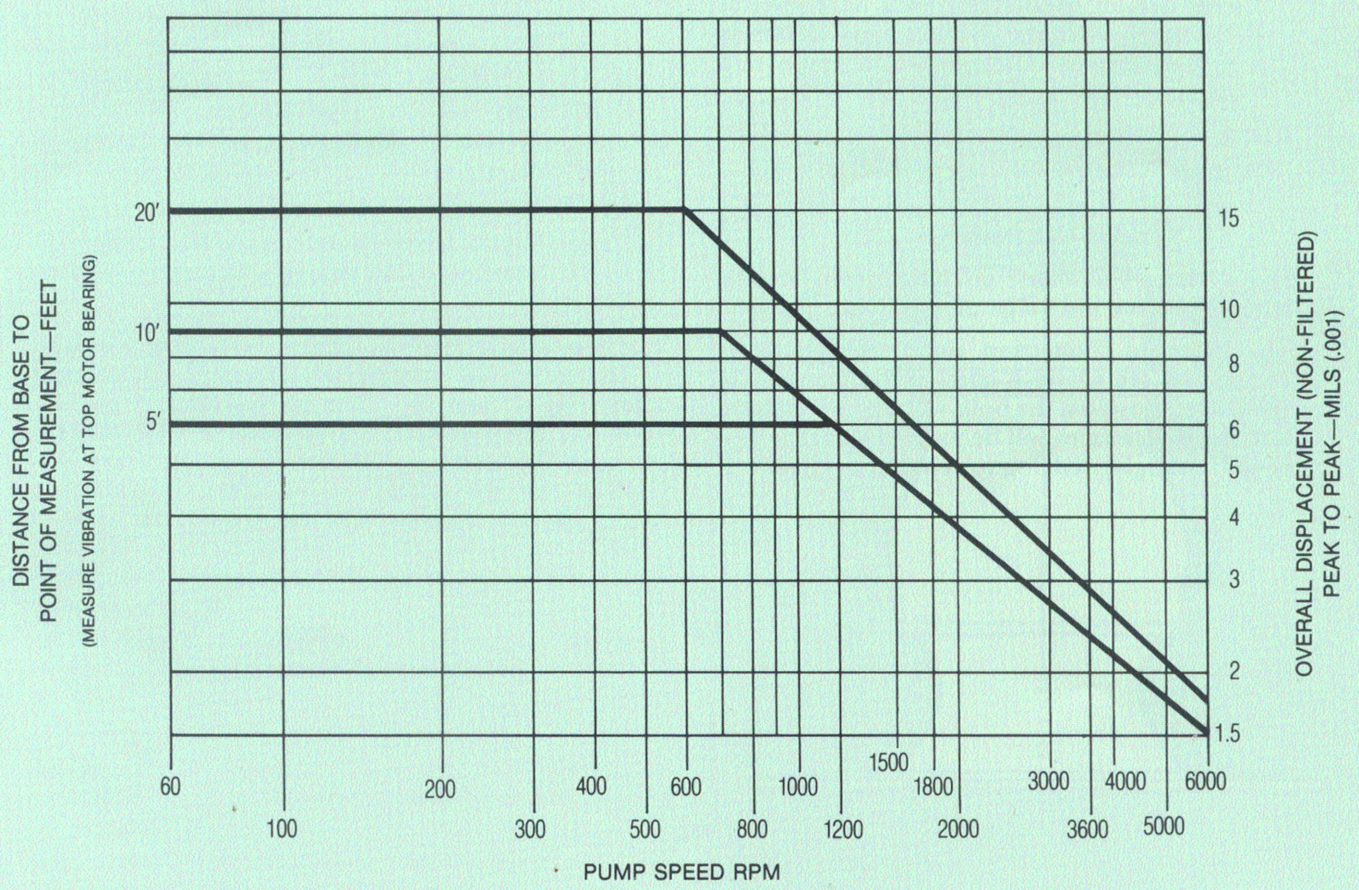
Check the easiest items first.

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 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.

c. Continue checking for misalignment as you disassemble the pump.



ACCEPTABLE FIELD VIBRATION LIMITS FOR VERTICAL PUMPS—CLEAR LIQUIDS

Courtesy Hydraulic Institute Standards

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 .060 inches parallel. Slip in the gasket and tighten the bolts evenly, using a "180 degrees apart" tightening pattern. 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.

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.

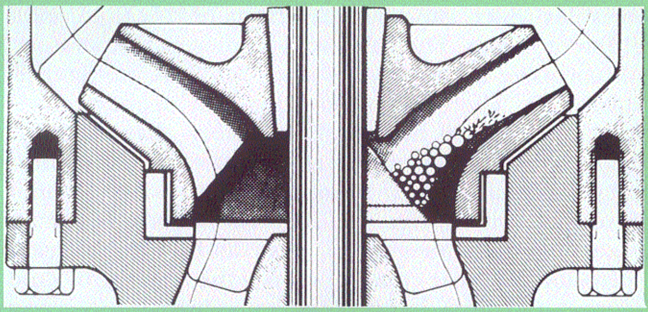
The natural frequency of an installed pump varies with the foundation and piping, which create a system resonance.

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 crackling 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.

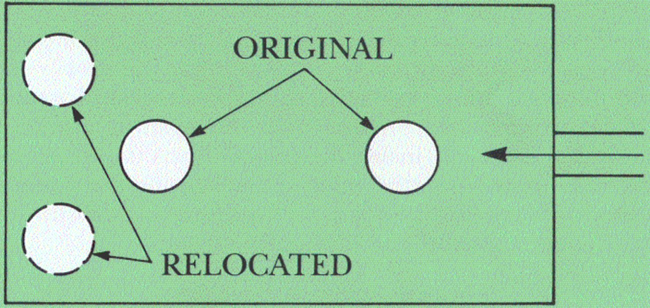
Contact a Johnston service center for assistance in evaluating your system NPSH and recommended solutions. Frequently Johnston low NPSH impeller assemblies can be furnished to fit your existing vertical pumps.

Vortexing

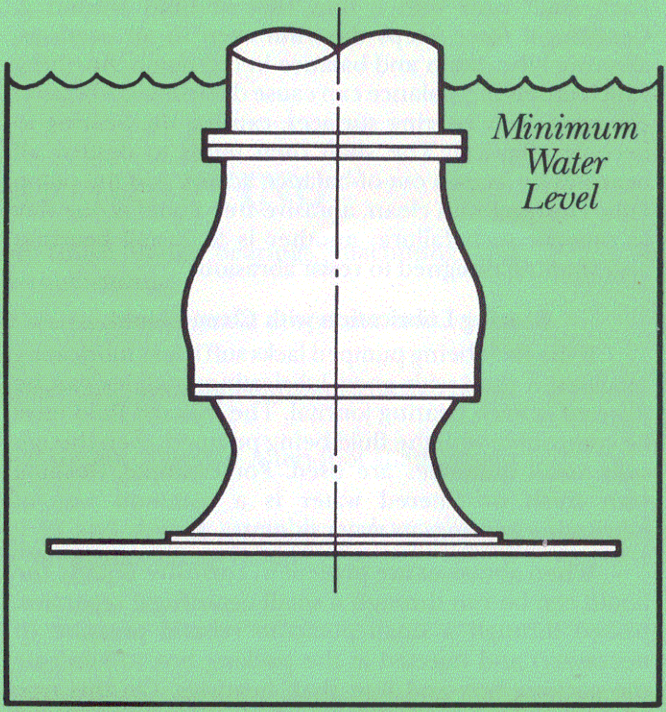
"Something is wrong with the pump! It's sucking in slugs of air." This remark is frequently made when vortices form in flow patterns, causing loud rumbling noises.

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.

Relocate pumps at back wall, as indicated by dashed lines



PUMPS RELOCATED



SUCTION UMBRELLA ADDED

CORROSION, ABRASION AND EROSION

Definitions

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 Bearings

A vertical pump uses sleeve bearings inside a bearing retainer for proper line shaft 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 line shaft bearings. On this type of system, the line shaft is installed within an enclosed tube, and the flushing liquid lubricates each line shaft 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 rifle 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 degrees F, the story changes at 90 degrees F. Other chemicals in seawater can cause difficulty, especially if their presence is not known. Around oil docks, drilling rigs, etc., sulfides might be present; even small quantities of sulfides could 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 Johnston Pump service center maintains detailed records and analyses 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 degrees F) require *special clearances.* All clearances shown are diametrical in inches.

BOWL SIZE	STANDARD WEAR RING CLEARANCE	SPECIAL WEAR RING CLEARANCE	BEARING CLEARANCE	STANDARD SHAFT SIZE
4"		None	.006	¾
6"	.012-.014	.016-.018	.007	1
7"	.012	.016	.008	1 3/16
8"	.013	.016-.017	.008	1 3/16
10"	.013-.015	.017-.018	.008	1½
12"	.015	.017-.018	.009	1 11/16
14"	.015	.018-.020	.010	1 15/16
16"	.018	.020-.022	.011	2 3/16
18"	.018	.022	.011	2 3/16
20"	.018	.022-.024	.012	2 7/16
22"	.018	.022	.012	2 11/16
24"	.026	.030	.012	2 7/16
25"	.026	.030	.012	2 15/16
27"	.026	.030	.012	3 3/16
28"	.026	.030	.012	3 3/16
30"	.032	.036	.012	3 ¼
32"	.032	.030	.012	3 7/16
33"	.032	.036	.012	3 7/16
36"	.032	.036	.012	4
42"	.034	.039	.012	4½
48"	.034	.039	.012	4½
56"	.036	.041	.015	5
64"	.036	.041	.015	5½

VERTICAL PUMP SHAFTING

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

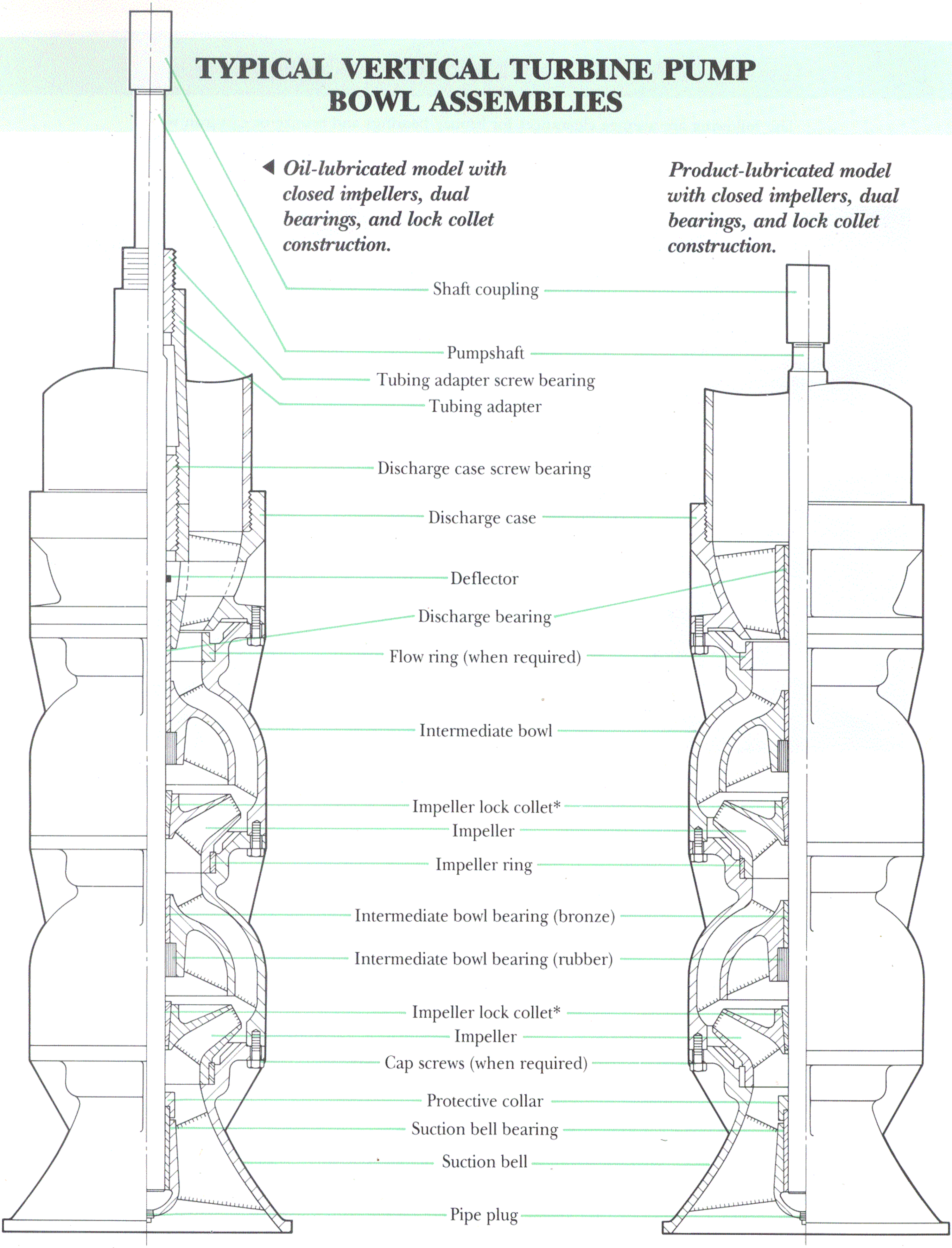
Vertical pump shafting materials are carefully selected for physical properties and micro-finish to operate under sleeve bearings.

Shaft threads must be machined parallel and concentric, and shaft ends must be machined and faced perfectly square.

Shafts must be straightened to .0005 in./ft. total runout. *Example:* A ten-foot shaft cannot exceed .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



◀ *Oil-lubricated model with closed impellers, dual bearings, and lock collet construction.*

Product-lubricated model with closed impellers, dual bearings, and lock collet construction.

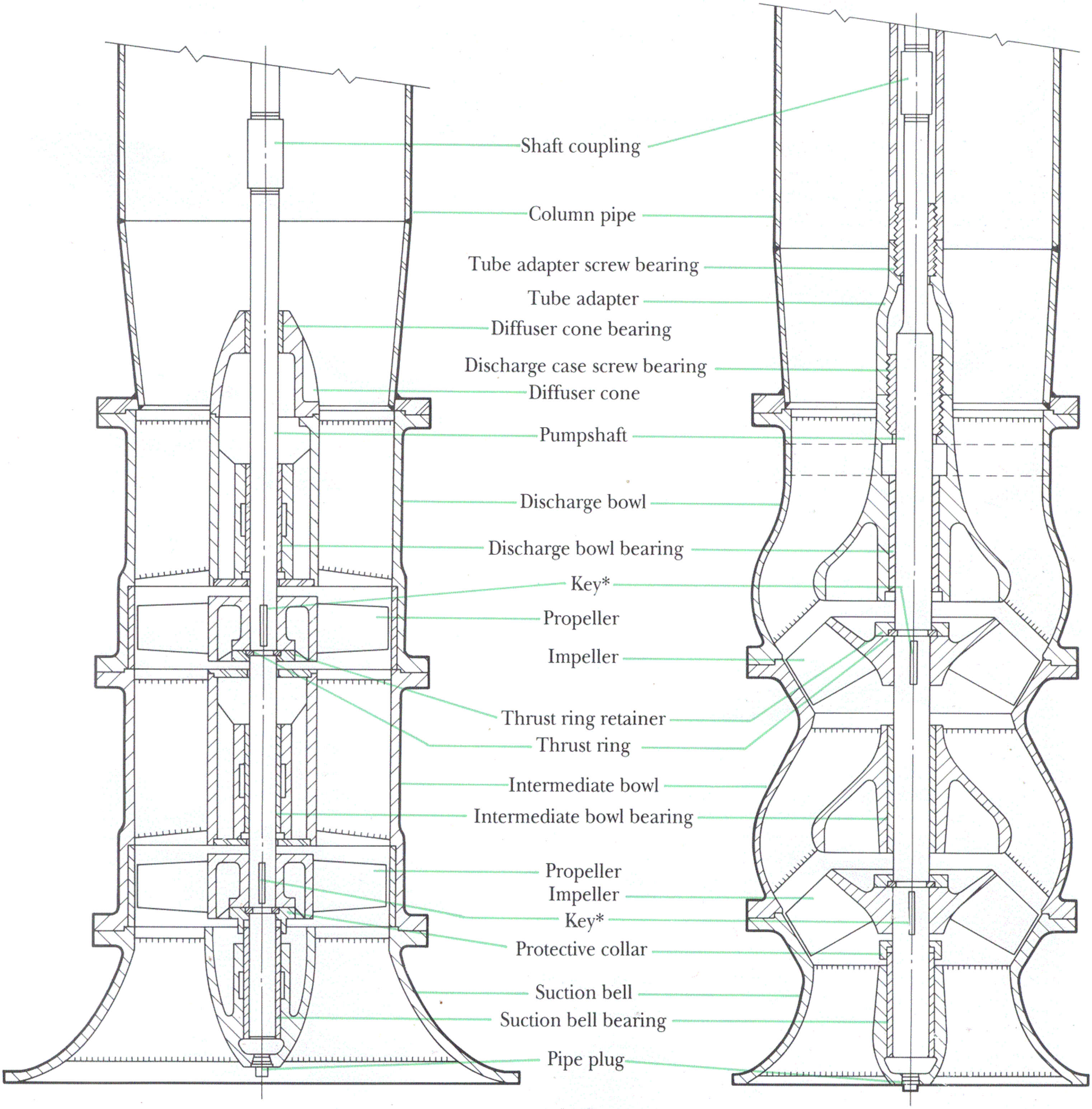
*Also available with keyed impeller mounting.

TYPICAL VERTICAL PROPELLER (AXIAL-FLOW) AND MIXED-FLOW PUMP BOWL ASSEMBLIES

LIKE DD#3 BUT OURS IS SINGLE STAGE

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

Oil-lubricated mixed-flow pump with thrust ring construction.



*Also available with lock collet impeller/propeller mounting.

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 unbalance
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. Unbalanced 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
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