An Introduction to Water System Pump Operation and Maintenance

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J. Paul Guyer, P.E., R.A., Fellow ASCE, Fellow AEI

Continuing Education and Development, Inc.
9 Greyridge Farm Court
Stony Point, NY 10980

P: (877) 322-5800
F: (877) 322-4774

info@cedengineering.com

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J. Paul Guyer, P.E., R.A.

Paul Guyer is a registered civil engineer, mechanical engineer, fire protection engineer and architect with 35 years of experience designing buildings and related infrastructure. For an additional 9 years he was a principal staff advisor to the California Legislature on capital outlay and infrastructure issues. He is a graduate of Stanford University and has held numerous national, state and local offices with the American Society of Civil Engineers, Architectural Engineering Institute and National Society of Professional Engineers.

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1. INTRODUCTION. This discussion covers the operation and maintenance of pumps used in water supply and treatment facilities. It also covers the motors, engines, and accessories (together called pump drivers) that provide the mechanical source of energy to pumps.

2. PUMPS. Velocity pumps and positive-displacement pumps are the two categories of pumps commonly used in water supply operations. Velocity pumps, which include centrifugal and vertical turbine pumps, are used for most distribution system applications. Positive-displacement pumps, which include rotary and reciprocating pumps, are most commonly used in water treatment plants for chemical metering and pumping sludge. Detailed descriptions of the pump types commonly used in water supply systems, along with applications, operating characteristics, and a listing of general advantages and disadvantages, are discussed here. Table 1 lists maximum capacity and discharge head values for several general pump types.

Pump Type	Maximum Capacity gpm	(Lps)	Maximum Discharge Head feet of water	(kg/sq cm)
Air lift	3,000	(190)	700	(21)
Centrifugal				
Axial flow (propeller)	200,000+	(12,600)	50	(2)
Diffuser	700	(45)	1,000	(30)
Mixed flow	250,000+	(15,800)	100	(3)
Regenerative turbine	100	(6)	600	(18)
Vertical turbine	30,000	(1,890)	>1,500	(45)
Volute	40,000	(2,500)	500	(15)
Ejector (jet)	50	(3)	150	(5)
Progressive cavity (helical rotor)	1,200	(75)	2,300	(70)
Reciprocating displacement				
Diaphragm	300	(20)	800	(25)
Piston	300	(20)	800	(25)
Plunger	300	(20)	800	(2)
Rotary displacement	55	(3)	1,000	(30)

Table 1

Comparison of Pump Discharge and Head

3. OPERATION OF PUMPS. Operate all mechanical equipment, including pumps, in accordance with the manufacturer's instructions.

3.1 GENERAL OPERATING INSTRUCTIONS FOR CENTRIFUGAL PUMPS. A quick reference checklist for starting and stopping centrifugal pumps is provided below (Table 2). Procedures may vary for different pump types and pump applications. Know what to expect when the equipment starts.

3.2 TROUBLESHOOTING CENTRIFUGAL PUMPS. Symptoms and possible causes of operating difficulties are listed in Table 3. See also Table 10, a troubleshooting checklist for vertical turbine well pumps, which are a class of centrifugal pumps.

3.2.1 CAVITATION PROBLEMS. Cavitation is one of the most serious operational problems with centrifugal pumps. Cavitation occurs when cavities or bubbles of vapor form in the liquid. The bubbles collapse against the impeller, making a sound as though there are rocks in the pump. If left uncorrected, cavitation will seriously damage the pump.

3.2.2 CAUSES OF CAVITATION. Conditions that typically cause cavitation include operating the pump with an excessive suction lift or an insufficiently submerged suction inlet. Cavitation develops when normal pump operating conditions have been exceeded. Noise, vibration, impeller erosion, and reduction in total head and efficiency result from cavitation. Cavitation in a centrifugal pump may be caused by any of the following:

a) The impeller vane is traveling at higher revolutions per minutes (rpm) than the liquid.

b) Suction is restricted. (Note: Do not throttle the suction of a centrifugal pump.)

c) The required net positive suction head (NPSH) is equal to or greater than the available NPSH.

d) The specific pump speed is too high for the operating conditions.

e) The liquid temperature is too high for the suction conditions.

Inspection	Action
Prestart Checks	
Valves	Open the valve in the cooling liquid supply to the bearing, if the bearings are liquid cooled.
	Open the valve in the flushing water supply to the stuffing boxes, if so equipped.
	Open the valve in the sealing liquid supply to the stuffing boxes or mechanical seals, if so equipped.
	Open or close the discharge valves according to the manufacturer's manual.
Rotors	Check the rotor to see that it is free. You should be able to turn the rotor shaft by hand. Do not start the pump until any difficulty is corrected.
	Prime centrifugal pumps before startup. The equipment will not pump water unless air in the pump and suction piping is replaced with water. In addition, the rotating element may seize from a lack of lubrication.
	Use one of the following methods to prime the pump, depending on operating conditions: positive suction head (1) or negative suction head (2).
Starting the Pump	Always start the pump according to the manufacturer's manual.
Equipment area	Ensure that all personnel are clear of dangerous areas.
Valves	For pumps started with discharge valves closed, open valves slowly after pump approaches operating speed. Do not operate the pump with a closed discharge valve.

Table 2

Routine Operations Check List for Centrifugal Pumps

Inspection	Action
Stuffing boxes and Packing	Observe leakage from the stuffing boxes and adjust the sealing liquid valve for proper flow to ensure packing lubrication. For new packing, allow pump to run for 10 to 15 minutes before tightening the stuffing box gland. Gradually tighten the stuffing box gland until leakage slows to a constant drip.
Pump and driver	Check the general mechanical operation of the pump and driver. Ensure that working parts are free to move without damage.
Stopping the Pump	Always review instructions for disconnecting and securing drive and rotating equipment.
Valves	As a rule, there is a check valve in the discharge line close to the pump. In such cases, shut down the pump by stopping the driver according to the manufacturer's manual.
	Then close all valves, except the check valve, in this order: discharge, suction, pump cooling water supply, and other connections leading to the pump or system.
	In some instances, however, the use of a check valve is not feasible because the sudden closing of the valve under high discharge pressure might create pressure surges or water hammer. In such cases, close the discharge valve slowly to avoid water hammer.
Monitoring Operations	
Unusual sounds	Learn to recognize the normal sounds and conditions of a properly run pump. Listen to the sounds of the pump on regular inspection tours and investigate any abnormal sounds at once.

Table 2 (continued)

Routine Operations Check List for Centrifugal Pumps

Inspection	Action
Bearings	Check bearing temperature and lubrication. Where petroleum-based lubricants are used, follow the manufacturer's manual and do not over lubricate.
Suction and discharge readings	Check these readings and compare with "normal" valves. Make sure valves are set as required. Check shaft packing. Check discharge rate. Check driving equipment.

Table 2 (continued)

Routine Operations Check List for Centrifugal Pumps

(1) Positive Suction Head. When the intake (suction) side of the pump is under pressure, use the following priming sequence:

a. Open all suction valves to allow water to enter the suction pipe and pump casing.

b. Open all vents located on the highest point of the pump casing to allow trapped air to be released. (Note: The pump is properly primed when water flows from all open vents in a steady stream.)

(2) Negative Suction Head. Two priming methods are available for a negative suction head condition; i.e., when the pump lifts water to the intake (suction lift).

a. Vacuum Pump or Ejection Method. When steam, high-pressure water, or compressed air is available, prime the pump by attaching an ejector to the highest point in the pump casing for evacuating the air from the suction piping and casing. A vacuum may be substituted for the above equipment. Start the ejector or vacuum pump to exhaust the air from the pump casing and suction pipe. When water discharges from the ejector or vacuum pump, start the centrifugal pump, but continue priming until the centrifugal pump has reached operating speed.

b. Priming a Pump with a Foot Valve. A foot valve is used at the lowest point on the suction pipe. The foot valve retains water in the suction pipe and pump casing after the pump has been initially primed. To prime, open the suction valve, if one is installed. Open the vent valves at the highest points on the pump casing. Fill the pump and suction line from an independent water supply. Allow to fill until a steady steam flows from the vent valves.

Symptom	Possible Cause
Pump does not deliver water.	Pump not primed. Pump or suction pipe not completely filled with water.
	Suction lift too high.
	Air pocket in suction line.
	Inlet of suction pipe insufficiently submerged.
	Suction valve not open or partially open.
	Discharge valve not open.
	Speed too low.
	Wrong direction of rotation.
	Total head of system higher than design head of pump.
	Parallel operation of pumps unsuitable for existing conditions.
	Foreign matter in impeller.
Insufficient capacity delivered.	Pump or suction pipe not completely filled with water.
	Suction lift too high.
	Excessive amount of air or gas in water.
	Air pocket in suction line.
	Air leaks into suction line.
	Air leaks into pump through stuffing boxes.
	Foot valve too small.
	Foot valve partially clogged.
	Inlet of suction pipe insufficiently submerged.

Table 3

Troubleshooting Checklist for Centrifugal Pumps

Symptom	Possible Cause
	Suspension valve only partially open. Discharge valve only partially open. Speed too low. Total head of system higher than design head of pump. Parallel operation of pumps unsuitable for such operation. Foreign matter in impeller. Wearing rings worn. Impeller damaged. Casing gasket defective, permitting internal leakage.
Insufficient pressure developed.	Excessive amount of air or gas in water. Speed too low. Wrong direction of rotation. Total head of system higher than design head of pump. Parallel operation of pumps unsuitable for existing conditions. Wearing rings worn. Impeller damaged. Casing gasket defective, permitting internal leakage.
Pump loses prime after starting.	Pump or suction pipe not completely filled with water. Suction lift too high. Excessive amount of air or gas in water. Air pocket in suction line. Air leaks into suction line.

Table 3 (continued)

Troubleshooting Checklist for Centrifugal Pumps

Symptom	Possible Cause
	Air leaks into pump through stuffing boxes.
	Inlet of suction pipe insufficiently submerged.
	Water-seal pipe plugged.
	Seal cage improperly located in stuffing box, preventing sealing fluid from entering space to form the seal.
Pump requires excessive power.	Speed too high. Wrong direction of rotation.
	Total head of system higher than design head of pump.
	Total head of system lower than pump design head.
	Foreign matter in impeller existing conditions.
	Misalignment.
	Shaft bent.
	Rotating part rubbing on stationary part.
	Wearing rings worn.
	Packing improperly installed.
	Incorrect type of packing for operating conditions.
	Gland too tight resulting in no flow of liquid to lubricate packing.
Stuffing box leaks excessively.	Seal cage improperly located in stuffing box, preventing sealing fluid entering space to form the seal.
	Misalignment.
	Shaft bent.
	Shaft or shaft sleeves worn or scored at the packing.
	Packing improperly installed.

Table 3 (continued)

Troubleshooting Checklist for Centrifugal Pumps

Symptom	Possible Cause
Packing has short life.	Incorrect type of packing for operating conditions. Shaft running off center because of worn bearings or misalignment. Rotor out of balance, resulting in vibration. Gland too tight, resulting in no flow of liquid to lubricate packing. Excessive clearance at bottom of stuffing box between shaft and casing, causing packing to be forced into pump interior. Dirt or grit in sealing liquid, leading to scoring of shaft or shaft sleeve. Water-seal pipe plugged. Seal cage improperly located in stuffing box, preventing sealing fluid from entering space to form the seal. Misalignment. Shaft bent. Bearings worn. Shaft or shaft sleeves worn or scored at the packing. Packing improperly installed. Incorrect type of packing for operating conditions. Shaft running off center because of worn bearings or misalignment. Rotor out of balance, resulting in vibration. Gland too tight, resulting in no flow of liquid to lubricate packing.

Table 3 (continued)

Troubleshooting Checklist for Centrifugal Pumps

Symptom	Possible Cause
Pump vibrates or is noisy.	Failure to provide cooling liquid to water-cooled stuffing boxes. Excessive clearance at bottom of stuffing box between shaft and casing, causing packing to be forced into pump interior. Dirt or grit in sealing liquid, leading to scoring of shaft or shaft sleeve. Pump or suction pipe not completely filled with water. Suction lift too high. Foot valve too small. Foot valve partially clogged. Inlet of suction pipe insufficiently submerged. Operation at very low capacity. Foreign matter in impeller. Misalignment. Foundations not rigid. Shaft bent. Rotating part rubbing on stationary part. Bearings worn. Impeller damaged. Shaft running off center because of worn bearings or misalignment. Rotor out of balance, resulting in vibration. Dirt or grit in sealing liquid, leading to scoring of shaft or shaft sleeve.

Table 3 (continued)

Troubleshooting Checklist for Centrifugal Pumps

Symptom	Possible Cause
Bearings have short life.	Excessive grease or oil in antifriction-bearing housing, or lack of cooling, causing excessive bearing temperature.
	Lack of lubrication.
	Improper installation of antifriction bearings (damage during assembly, incorrect assembly of stacked bearings, use of unmatched bearings as a pair, etc.).
	Dirt getting into bearings.
	Rusting of bearings because of water getting into housing.
	Excessive cooling of water-cooled bearing resulting in condensation in the bearing housing of moisture from the atmosphere.
	Misalignment.
	Shaft bent.
	Rotating part rubbing on stationary part.
	Bearings worn.
	Shaft running off center because of worn bearings or misalignment.
	Rotor out of balance, resulting in vibration.
	Excessive thrust caused by a mechanical failure inside the pump or by the failure of the hydraulic balancing device, if any.
	Excessive grease or oil in antifriction-bearing housing or lack of cooling, causing excessive bearing temperature.
	Lack of lubrication.

Table 3 (continued)

Troubleshooting Checklist for Centrifugal Pumps

Symptom	Possible Cause
Pump overheats and seizes.	Improper installation of antifriction bearings (damage during assembly, incorrect assembly of stacked bearings, use of unmatched bearings as a pair, etc.). Dirt getting into bearings. Rusting of bearings because of water getting into housing. Excessive cooling of water-cooled bearing, resulting in condensation in the bearing housing of moisture from the temperature. Pump not primed. Operation at very low capacity. Parallel operation of pumps unsuitable for existing conditions. Misalignment. Rotating part rubbing on stationary part. Bearings worn. Shaft running off center because of worn bearings or misalignment. Rotor out of balance, resulting in vibration. Excessive thrust caused by a mechanical failure inside the pump or by the failure of the hydraulic balancing device, if any. Lack of lubrication.

Table 3 (continued)

Troubleshooting Checklist for Centrifugal Pumps

3.3 OPERATING INSTRUCTIONS FOR EJECTOR (JET) PUMPS. Jet pumps are a type of centrifugal pump. Because of their relatively low efficiency, they are rarely used for public water systems. However, jet pumps are inexpensive and require little maintenance and may be used on wells supplying very small, low-demand systems. (Note: All operating rules and troubleshooting checks that apply to centrifugal pumps apply to ejector pumps.) Start the pump and adjust the manual back pressure valve until the correct operating cycle is achieved. Do not change the adjustment after the pump is operating. If pump discharge decreases, check troubleshooting guides for centrifugal pumps. Also inspect the ejector nozzle and throat for deposits and check nozzle submergence.

3.4 OPERATING INSTRUCTIONS FOR PROGRESSIVE CAVITY PUMPS. Progressive or helical-rotor pumps are positive displacement pumps and not subject to the same problems as centrifugal pumps. Operate according to the manufacturer's instructions. (Caution: Do not run dry.) Common operating problems encountered with progressive cavity pumps and possible causes are given in Table 4.

3.5 OPERATING INSTRUCTIONS FOR ROTARY- AND RECIPROCATING-DISPLACEMENT PUMPS.

3.5.1 PRESTART. Rotary- and reciprocating-displacement pumps do not usually require priming. However, when priming is necessary, follow priming procedures for centrifugal pumps.

3.5.2 STARTING AND OPERATING. Always start and operate rotary- and reciprocating-displacement pumps with both suction and discharge valves open to prevent motor overload and pump damage.

Symptom	Possible Cause
No water is delivered.	Broken or disconnected shaft. Excessive discharge head. Plugged or nonsubmerged suction.
Pump does not deliver rated capacity.	Speed too low. Suction lift excessive. Suction partially plugged. Mechanical defect.
Pressure is too low.	Discharge head too high. Speed too low. Pressure relief valve set too low. Mechanical defect.
Pump stops after starting to operate.	Bent column shaft. Clogged suction.

Table 4

Troubleshooting Checklist for Progressive-Cavity Pumps

3.5.3 OPERATING PRECAUTIONS.

a) Rotary- and reciprocating-displacement pumps depend on clearances for efficiency. Keep grit or other abrasive material out of the liquid being pumped to prevent excessive wear and rapid loss of efficiency and self-priming ability.

b) A pressure-relief valve that discharges back to the suction side of the pump is usually provided on the outlet piping. Adjust this valve for a relief pressure that does not overload the motor. Make sure the check valves seat properly at normal pressures. Otherwise, loss of efficiency and priming ability result.

c) Use the manufacturer's manuals to develop a checklist for the particular rotary- or reciprocating-displacement pump being used.

4. PUMP MAINTENANCE. Information contained in the following paragraphs is general and is not intended to replace maintenance procedures provided by the equipment manufacturer.

4.1 MAINTENANCE PROCEDURES FOR CENTRIFUGAL PUMPS. The following paragraphs describe general maintenance procedures for all types of horizontal and vertical centrifugal pumps. For details of procedures that apply specifically to volute, diffuser, regenerative-turbine, split-case, and multistage design, consult the manufacturer's manuals.

4.1.1 LUBRICATION. Manufacturer's manuals cover lubrication frequency for special cases, but the following generally applies. (Caution: Do not lubricate totally enclosed equipment or insufficiently guarded equipment while it is moving.)

a) To avoid errors, establish a marking system to make sure that the proper lubricant is used. Make sure the same product symbol and identifying color are marked on lubricant containers, lubricant applicators, and at locations near lubrication points.

b) Never over lubricate. Over lubrication causes antifriction bearings to overheat and may damage the grease seals. Over lubrication may also damage electric motor windings.

c) For simplified operation, provide the same type of grease gun fitting (zerk) at all points using the same type of grease. The fewer the types of grease are used, the fewer grease guns are required, and the less likelihood of improper grease being used.

d) Table 5 provides a general lubrication schedule for centrifugal type pumps. When hand oilers are used to lubricate the shaft bearings, check the settings daily and adjust them according to Table 6.

4.1.2 PACKING. Selection of packing is usually done in accordance with the manufacturer's recommendations or assistance. For pumping water, packing types include non-reinforced woven or braided cotton asbestos, semi-metallic plastic, or a combination of the two. If you require the manufacturer's assistance to select packing, supply detailed information to the manufacturer on the following items:

a) Description of liquid handled: percentage concentration, temperature and impurities

b) Amount of abrasive present

c) Stuffing box dimensions (depth of box, outside diameter, and shaft or sleeve diameter)

d) Stuffing box pressure and temperature

e) Shaft speeds

f) Sealing cage (lantern gland) location and width

g) Shaft or seal material and hardness

Lubrication Point	Action Required	Frequency (1)
Antifriction bearing	Check temperature (with thermometer); if running hot, bearing is probably over lubricated; remove excess lubricant.	M
	Drain lubricant; flush lubricant wells and bearings with kerosene; add clean fresh lubricant.	Q
Ball-thrust bearing	Add fresh grease to grease cups, but do not attempt to keep grease from coming out around the collar seal.	M
	Change the grease in the grease cup if the pump operates more than 50 times a day; otherwise, change yearly.	Q
Bearing housing	Check oil level in oil housing; do not add oil with pump running; remove oil vent plug when adding oil.	D
	Open housing; flush with kerosene; add clean fresh lubricant.	Q
Enclosed shaft-type bearing	Check oil cup; add lubricant as necessary.	W

Table 5

Lubrication Schedule for Centrifugal-Type Pumps

Lubrication Point	Action Required	Frequency (1)
Grease-sealed packing gland	Check spring-loaded grease cup; refill as necessary; adjust spring tension to maintain grease discharge through packing at approximately 1 ounce per day.	D
Guide bearing	Add grease through fittings provided.	M
Sealing water system	Check packing gland assembly; adjust packing if excessive seal-water leakage is noticed, allow 60 drops per minute with pump running.	D
	Check stuffing box for free movement of gland.	SA
Hand oiler	According to Table 15.	Each shift
Solenoid oiler	Check that leads are connected; check needle valve for clogging; adjust for 2 to 4 drops per minute; refill container as necessary.	D
Sleeve bearing	Check bearing temperature; if too hot, add lubricant.	M
	Drain lubricant; wash wells and bearing with kerosene.	Q
Universal joint coupling	Lubricate couplings and slip splines with fresh grease.	SA

(1) D-Daily; W-Weekly; M-Monthly; Q-Quarterly;
SA-Semiannually.

Table 5 (continued)

Lubrication Schedule for Centrifugal-Type Pumps

Pump Operation Schedule (times per day)	Pump Running Time (minutes)	Oiler Rate
Maximum of 2	Not over 5 (a)	1 drop/15 min
3 to 12	Not over 5 (a)	1 drop/4 min
12 to 50	Not over 5 (a)	1 drop/2 min
More than 50		2 to 4 drops/min

(a) Pump running times in excess of 5 minutes will require increased oiling rates.

Table 6

Hand Oiler Adjustment

4.1.3 SEALING WATER SYSTEMS. Make the daily checks for the sealing water system that are listed in Table 5. If the leakage cannot be adjusted properly, repack the stuffing box according to Table 7. Each year, disassemble the sealing water lines and valves to make sure that the water passages are open.

4.1.4 ROTARY SEALS. If a pump has seals that do not have the conventional follower and pliable, replaceable packing, consult the manufacturer's manual.

4.1.5 SHAFTS AND SHAFT SLEEVES. Each year, when the pump is dismantled, examine the shaft carefully at the impeller hub, under the shaft sleeves, and at the bearings.

a) Shafts. The shaft may be damaged by rusting or pitting caused by leakage along the shaft at the impeller or shaft sleeves. If antifriction bearings are improperly fitted to the pump shaft, the inner race rotates on the pump shaft and damages the shaft. Excessive thermal stresses or corrosion may loosen the impeller on the shaft and subject the keyway to shock. Replace any shaft that is bent or distorted. After the shaft has been replaced, check it for possible runout. The maximum allowable is 0.002 inches (51 microns [μ]).

b) Shaft Sleeves. Inspect shaft sleeves each year. They are subject to wear and may require replacement, depending on the severity of service. When the sleeve has become appreciably worn, the packing cannot be adjusted to prevent leakage and the sleeve should be replaced. Otherwise, excessively grooved or scored sleeves will pare and score new packing as soon as it is inserted into the stuffing box.

c) Bearings. Inspect the bearings and add lubricant according to the procedures described in Table 8.

4.1.6 WEARING OR SEALING RINGS. Each year, inspect the wearing or sealing rings that seal the discharge water from suction water in rotating pumps. These are not perfect seals and do allow some leakage. Do not allow this leakage to become excessive because of worn rings, or the pump efficiency will be impaired.

a) Proper wearing ring clearance is very important. In the straight-type wearing ring (the most common type) the diametrical clearance need not be less than 0.025 inch (0.64 mm) and should not be greater than 0.050 inch (1.25 mm).

b) In the L-shaped type, the clearance in the space parallel to the shaft should be the same as for the straight-type. The clearance in the space at the right angle to the shaft is governed by the end-play tolerances in the bearing.

c) For specification information on the L-shape and labyrinth-type rings, consult the manufacturer’s manual.

See Figure 1 for the types of wearing or sealing rings.

Inspection/ Procedure	Action	Frequency (1),(2)
Inspect stuffing box	Ensure that stuffing box glands are moving freely and that gland bolts and nuts are oiled.	SA
	Check for excessive leakage that cannot be reduced by gland adjustment; if found, proceed according to the steps below:	
Remove old packing	a) Remove old packing and clean box. If the box has a seal cage, make sure it is located opposite the sealing liquid inlet.	V
	b) Use packing recommended by manufacturer.	
	c) Measure the depth of box and sealing liquid inlet tap. Place enough rings of packing in the bottom of the box that seal cage is in proper position once packing is compressed. Do not try to pack a pump by renewing only the last three or four rings.	
Check packing ring joints	a) Make sure the packing ring joints are staggered.	V
Add new packing	a) Cut the packing so that the joints are square after the packing is bent around the shaft. Packing should be cut about 1/16 inch longer than measured to be sure that the outside diameter of the ring hugs the stuffing box wall rather than the sleeve. Use care in cutting the rings.	V
	b) Except as detailed below, use the follower gland and a few convenient equal-length spacers to compress each ring firmly into place before inserting the next ring.	

Table 7

Guide for Stuffing Box Inspection

Inspection/ Procedure	Action	Frequency (1),(2)
	c) Stagger the joints, and make sure that the lantern ring is centered under the water supply connection.	
	d) After the last piece of packing has been placed, tighten the follower gland nuts until finger tight.	
Woven or braided packing	a) Dip each ring of packing in oil before adding it to the stuffing box.	
	b) Woven or braided packing does not have to be added one ring at a time. Fill the box half full. Then draw the rings up snug by taking up on the packing sleeves and gland. Release the follower, add the remainder of the packing, and draw up snug. Then back off the gland until finger tight.	
Plastic or metal packing	a) Plastic and metallic packing must be compressed individually. Dip each ring in oil, insert in the stuffing box, and draw up tight by split-packing rings and gland. Hand turn the shaft a few times to gloss the packing.	
	b) Always use metallic or jacketed rings next to the bottom of the box, bushings, seal cages, or glands because non-jacketed plastic rings will squeeze into the clearances provided at these locations.	
Combustion-type packing	a) Follow instructions supplied by the manufacturer when using combustion-type packing.	

Table 7 (continued)

Guide for Stuffing Box Inspection

Inspection/ Procedure	Action	Frequency (1),(2)
Position lantern rings	a) If a lantern ring is used, be sure it is positioned correctly; if grease sealing is used, be sure the lantern ring is filled with grease before the remaining rings are put in place.	V
Run-in new packing	a) New packing has to be run-in.	V
	b) Start the pump with the stuffing box gland quite loose. Allow the pump to run 10 to 15 minutes.	
	c) Gradually tighten the stuffing box gland until leakage is reduced to a constant drip. Packing that is too tight in the box causes undue friction, creates heat, glazes the packing, and may score the shaft sleeves. Packing must remain soft and pliable.	
	d) Use drip leakage to ensure proper lubrication throughout the packing box.	
Inspect packing gland	If the stuffing box leaks too much, tighten the gland. If this does not help, remove the packing and inspect the shaft sleeve	W

(1) W-Weekly; SA-Semiannually; V-Variable, as conditions may indicate.

(2) The frequencies shown are suggested frequencies that may be modified by local command, as individual installation conditions warrant.

Table 7 (continued)

Guide for Stuffing Box Inspection

4.1.7 IMPELLER. Each year, remove the rotating element and inspect it thoroughly for wear (see Paragraph 6.5.1.10 for dismantling procedures).

a) Remove any deposits or scaling.

b) Check for erosion and cavitation effects. Cavitation causes severe pitting and a spongy appearance in the metal.

c) If cavitation effects are severe, some changes in pump design or use may be necessary. Report the matter to the supervisor.

Inspection	Action	Frequency (1),(2)
Antifriction bearings Check bearing temperature	Check with a standard thermometer. Antifriction bearings that are running too hot probably have too much lubricant.	M
Change lubricant	Change lubricant according to Table 14). If lubricant change does not prevent overheating, disassemble and inspect the bearing. If nothing appears to be wrong, check the pump and motor alignment.	Q
Check clearances	During the quarterly lubrication change, check the clearances. Recommended clearance is 0.002 inch (51 µ), plus 0.001 inch (25 µ) for each inch (25 mm) of the shaft-journal diameter.	Q
Check bearing condition	Each year, when the pump is dismantled, check the condition of the bearings and the bearing race; replace as necessary. The preferred method in general use for mounting a bearing on a pump shaft is to heat the bearing to expand the inner race and shrink it on the shaft. The bearing is heated in an oil bath or electric oven to a uniform temperature of 200° to 250°F (93° to 121°C). When heated, it should be quickly mounted on the shaft. An alternate method uses force exerted by an arbor press or hammer blows. In forcing a bearing onto a shaft, be sure that the race is never cocked during the operation. The bearing position on the shaft should be pressed firmly against the shaft shoulder. Check with a feeler gage.	A

Table 8

Maintenance Checklist for Bearings

Inspection	Action	Frequency (1),(2)
Sleeve bearings	Check with a standard thermometer. Sleeve bearings that are running too hot probably have too much lubricant.	M
Change lubricant	Change lubricant according to Table 14). If lubricant change does not solve the overheating problem, disassemble and inspect the bearing. If the bearing is in good condition, check the pump and motor alignment.	Q
Check clearances	During the quarterly lubrication change, check the clearances. Normal clearance is 0.002 inch (51 μ), plus 0.001 inch (25 μ) for each inch (25 mm) of the shaft-journal diameter.	Q
	Make sure that the oil rings are free to turn with the shaft. Repair or replace oil rings when necessary.	
Check bearing condition	Each year, when the pump is dismantled, check the condition of the bearings and the bearing race; replace as necessary. Sleeve bearings are usually split-type and can be easily removed and installed. Rotation of the bearing is prevented by a pin in the top half of the bearing housing.	A

(1) M-Monthly; Q-Quarterly; A-Annually.

(2) The frequencies shown are suggested frequencies that may be modified by local command, as individual installation conditions warrant.

Table 8 (continued)

Maintenance Checklist for Bearings

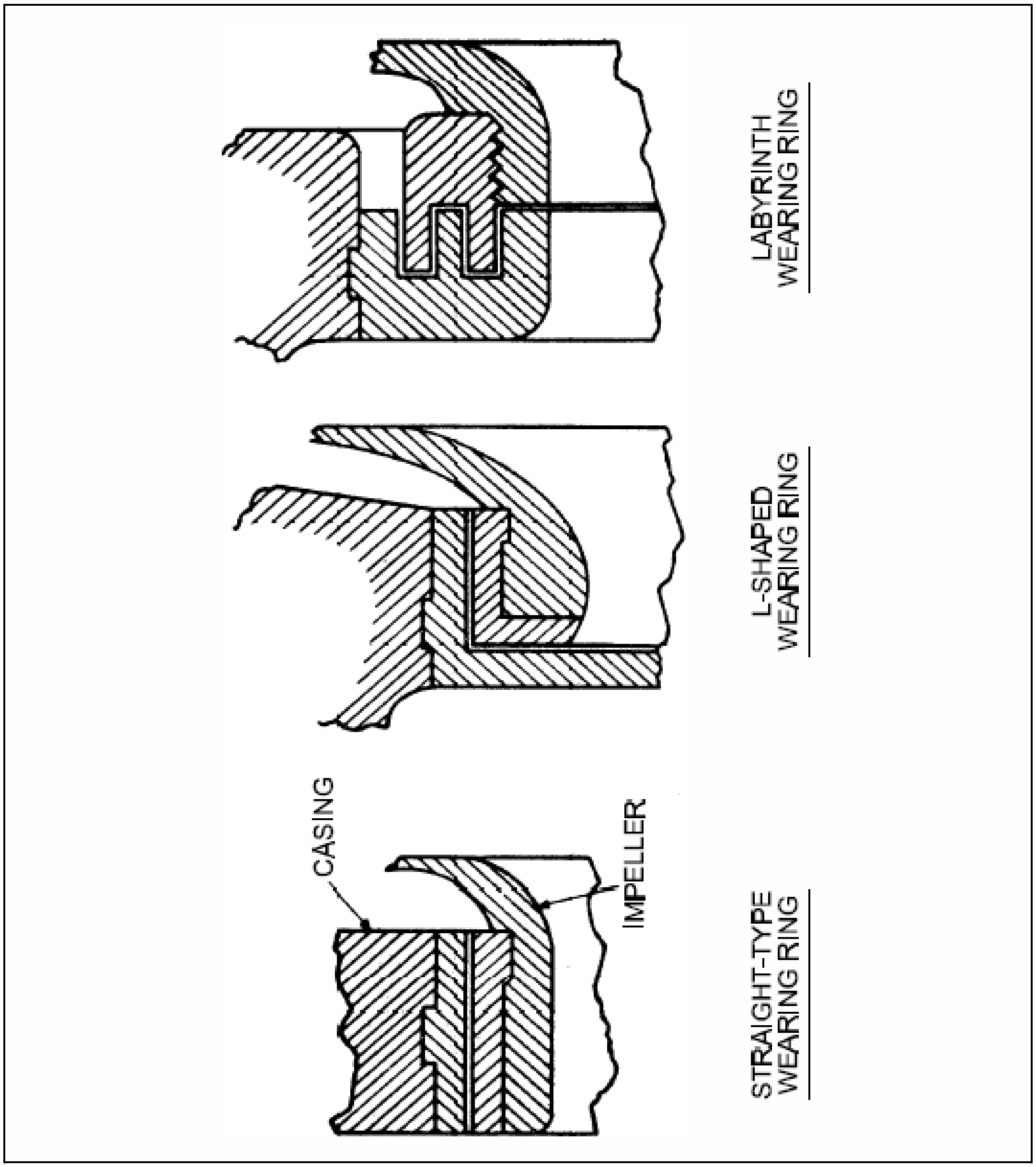

Figure 1

Types of Wearing (Seal) Ring

4.1.8 CASING MAINTENANCE. Keep the waterways clean and clear of rust. When the unit is dismantled, clean and paint the waterway with a suitable paint that will adhere firmly to the metal. A routine program of cleaning and repainting helps prevent complete erosion of the protective coat before replacement.

4.1.9 PUMP SHUTDOWN. When a pump is shut down for an extended period, or for overhaul inspection and maintenance, the following procedures apply:

a) Shut off all valves on suction discharge, waterseal and priming lines. Drain the pump completely by removing the vent and drain plugs until the water has run off. This operation protects against corrosion, sedimentation and freezing.

b) Disconnect the switch to the motor and remove the fuses.

c) Drain the bearing housing. If the shutdown is to be followed by an inactive period, purge all the old grease. Otherwise, refill with fresh grease. If an overhaul is scheduled, do not refill the oil or grease receptacles until the pump is reassembled.

4.1.10 OVERHAUL PROCEDURES. The frequency of complete overhaul depends on the hours of pump operation, the severity of service conditions, the construction material of the pump, and the care the pump receives during its operation. If the pump is not operated continuously, opening the pump for inspection is not necessary unless there is definite evidence that the capacity has fallen off excessively, or if there is an indication of trouble inside the pump or in the bearings. In general, it is a good practice to dismantle pumps in a relatively continuous operation once a year. Because pump designs and construction vary from model to model, and from one manufacturer to another, there is no set of specific procedures for dismantling and reassembling. Rules (a) through (d) below are basic. For detailed procedures, consult the manufacturer's manual.

a) Use extreme care in dismantling the pump to avoid damaging internal parts. For convenience in reassembly, lay out all parts in the order they are removed. Protect all machined faces against metal-to-metal contact and corrosion. Do not remove ball bearings unless absolutely necessary.

b) While the pump is dismantled, examine the foot valve and check valve to make sure they are seating and functioning properly.

c) To assemble the pump, reverse the dismantling procedure. Follow the manufacturer's manual explicitly.

d) Check the pump and motor alignment after reassembly.

4.2 ROTARY-DISPLACEMENT PUMPS. There are numerous types of rotary displacement pumps and, therefore, it is not possible to set up detailed maintenance procedures that apply to all types. Establish individual maintenance procedures according to the manufacturer's manual. Using the manual, set up procedures similar to those presented for a centrifugal-type pump. At annual intervals, disassemble the pumps and clean both exterior and interior surfaces.

4.2.1 CLEARANCES. Check clearances for tolerances listed in the manufacturer's manual.

4.2.2 PACKING. Check the packing assembly and repack as needed.

4.2.3 BEARINGS AND ALIGNMENT. Check the bearings and the alignment of the pump and motor.

4.2.4 CHECKLIST ITEMS. Check that all items are included in the checklist previously determined from the manufacturer's manual and the listings for centrifugal-type pumps.

4.2.5 PAINTING. Paint exterior surfaces and interior surfaces subject to rust with a suitable underwater paint or effective protective coating.

4.3 RECIPROCATING-DISPLACEMENT PUMPS. There are three types of reciprocating pumps: plunger, piston and diaphragm. Consult the manufacturer's manual for each individual pump.

4.3.1 CALCULATIONS. Calculate the delivery of piston and plunger pumps every year. The decrease in percent delivery from the volumetric displacement per pump stroke is termed "slippage." Excessive slippages indicate the need for maintenance and possible repair.

a) Volumetric Displacement: Compute the volumetric displacement by multiplying the piston or plunger area by the length of stroke. Make proper allowance for double-action pumps.

b) Delivery: Calculate the percent delivery from a comparison of the measured delivery per stroke and the computed volumetric displacement per stroke. If delivery is less than 90 percent of the volumetric displacement, check the valves, pistons and packing for leakage. Make any necessary replacements to maintain the desired efficiency.

4.3.2 PUMP INSPECTION. Dismantle the pump and inspect thoroughly each year according to the following schedule:

a) Remove and examine all valves, valves seats and springs. Reface valves and valve seats as necessary and replace worn or defective parts.

b) Remove all old packing and repack.

c) Check the pump and driver alignment.

d) Check the plunger or rod for scoring or grooving.

e) Clean the interior and exterior surfaces. Paint the interior with suitable underwater paint or protective coating. Paint the exterior.

4.4 SLUDGE PUMPS. Two types of sludge pumps, reciprocating and progressive cavity, are discussed here. Maintain centrifugal-type sludge pumps according to the procedures previously presented for centrifugal-type pumps. Modify the procedures listed to conform to manufacturers' manuals. For lubrication requirements of all sludge pumps, consult the manufacturer's manual.

4.4.1 PACKING PROCEDURES FOR RECIPROCATING SLUDGE PUMPS

a) Daily, or more frequently if necessary, check the sight-feed oil cup, if one is provided for lubrication between the plunger and the stuffing box. Add a squirt of oil around the plunger as often as necessary.

b) At varying intervals, renew the packing when no take-up is left on the packing-gland bolts.

(1) Remove the old packing and clean the cylinder and piston walls. Place new packing in the cylinder and tamp each ring into place. Be sure that the packing ring joints are staggered.
(2) To break the packing, run the pump for a few minutes with the sludge line closed and the valve covers open.
(3) Turn down the gland nuts, no more than is necessary, to keep sludge from getting past the packing. Be sure all packing-gland nuts are tightened uniformly. When chevron-type packing is used, make sure that the nuts holding the packing gland are only finger tight to prevent ruining the packing and scoring the plunger.

c) Check the packing-gland adjustment each week to make sure that the gland is just tight enough to keep sludge from leaking through the gland, making sure that the piston walls are not being scored. Before operating a pump, especially after it has been standing idle, loosen all nuts on the packing gland.

4.4.2 BEARINGS AND GEAR TRANSMISSION FOR RECIPROCATING SLUDGE PUMPS

a) Daily (or once per shift), lubricate the bearings and the gear transmissions with a grease gun. If the pump runs continuously, grease more often than once a shift.

b) Check the gear transmission each month and keep it filled to the proper level with the proper oil. Open the drain to eliminate accumulated moisture.

c) Change the oil every 3 months to prevent excessive emulsification.

4.4.3 SHEAR PINS IN RECIPROCATING SLUDGE PUMPS

a) Check the shear-pin adjustment each week. Set the eccentric by placing a shear pin through the proper hole in eccentric flanges to give the required stroke. Tighten the hexagonal nuts on the eccentric flanges just enough to take the spring out of the lock washers.

b) If shear pins fail, check for a solid object lodged under the piston, a clogged discharge line, or a stuck or wedged valve.

c) When a shear pin fails, the eccentric moves to the neutral position and prevents damage to the pump. Remove the cause of failure and insert a new shear pin.

4.4.4 BALL VALVES IN RECIPROCATING SLUDGE PUMPS. Every 3 months, replace all valve balls that are worn small enough to jam into the valve chamber. A decrease in diameter of 1/2 inch (13 mm) is sufficient to cause this difficulty. Check the valve chamber gaskets and replace them when necessary.

4.4.5 ECCENTRICS IN RECIPROCATING SLUDGE PUMPS. Each year, remove the brass shims from the eccentric strap to take up the babbitt bearing. After removing the shims, operate the pump for 1 hour and check the eccentric to be sure it is not running hot.

4.4.6 PROGRESSIVE-CAVITY SLUDGE PUMPS. Follow these maintenance procedures for screw-type sludge pumps:

4.4.6.1 SEALS. When grease seals are used instead of water seals, check the grease pressure in the seals daily.

4.4.6.2 BEARINGS. Lubricate the sludge pump through the grease connections on the bearing housing each week. Flush out the bearing housing each year. Then refill with new grease.

4.4.6.3 PACKING GLANDS. Check the packing glands for leakage each week.

a) For water seals, allow about 60 drops of leakage per minute when the pump is running.

b) If leakage is high, tighten the two gland nuts evenly a few turns, but do not draw the glands too tight. After adjusting the gland, turn the shaft by hand to make sure that it turns freely.

4.5 WELL PUMPS. Well-pump types are centrifugal pumps, reciprocating (piston or plunger) pumps, and jet (ejector) pumps.

4.5.1 CENTRIFUGAL WELL PUMPS. The turbine well pump is the most widely used type of well pump. Use the maintenance items listed for the centrifugal-type pumps and the manufacturer's manual to develop maintenance charts for turbine well pumps. In addition, check the following items:

4.5.1.1 TYPES OF LUBRICATION

a) Oil-Lubricated Pump and Bearings. Make sure that the oil tubing and lubricators are filled each day. Check the solenoid oilers for proper operation and see that they are filled. Check the oil level in the sight gauge lubricator for underwater bearings. Make sure that the oil feed is at an average rate of 3 to 4 drops per minute.

b) Water-Lubricated Pump and Bearings. This type of design requires lubrication with clear water. Daily, make sure that the pre-lubrication tank is full when the pump is in use.

(1) When filling the tank by a pump, be sure to close the tank-filling valve when the tank is full. Open the lubrication valve to allow water to reach the bearings.
(2) If the bearings are lubricated from the main pressure, close the lubricating valve after the pump is started.
(3) If the pump operates automatically and has a lubrication-delayed solenoid valve, wait 1 minute before checking the lubricating valve for proper operation. Check the operation of the solenoid valve and check the packing for excessive leakage.
(4) Check the pre-lubrication control on pumps that have safety controls to prevent starting before lubrication water is turned on. Make sure that this water flows to the bearings when the equipment is supposed to function.
(5) Check the time-delay relay for proper functioning and compare with the manufacturer’s recommendation.
(6) Clean and lubricate the guides and linkages.

4.5.1.2 IMPELLER ADJUSTMENT. Every 3 months, check the impeller for maximum efficiency setting and adjust if necessary. On hollow-shaft motors, the adjustment nut is on the top of the motor. Consult the manufacturer’s manual for the detailed adjustment procedure.

4.5.1.3 IMPELLER FITTING. When the pump is pulled for inspection, note signs of pitting or wear on the impellers.

a) Cavitation. Pitting in the lower stages may be from cavitation.

b) Sand Erosion. Sand in the water erodes the impellers. If sand is the cause of difficulty, check the well screen and replace if necessary. Where the erosion effect is appreciable, repair or replace impellers that are not likely to last until the next inspection.

c) Clearances. Repair or replace impellers, as necessary, to maintain the close clearance required for pump efficiency. See the manufacturer's manual regarding pump clearances and efficiencies.

d) Bowls and Waterways. When the pump is pulled for inspection, inspect the bowls and water passage for pitting, wear, and corrosion.

e) Overhaul Procedures:

(1) Frequency. As with the centrifugal pumps, the frequency of complete overhaul depends on the hours of operation, severity of operation, etc. Generally, however, a pump in continuous operation should be pulled for inspection and overhaul annually. Perform the overhaul under experienced supervision and in strict accordance with the manufacturer's manual. Overhaul the pump if any of the following conditions exist, regardless of the scheduled frequency of maintenance:

a. The pump shaft does not turn freely because parts below the pump head are binding;
b. The pump shows excessive vibration; or
c. A performance test shows a decrease of 25 percent in capacity under normal head and speed conditions.

(2) Clearances. When a pump is pulled, check the diametrical clearance of each bearing ring to make sure it is between 0.025 and 0.050 inch (0.64 and 1.25 mm). Allow a maximum diametrical clearance of 0.025 inch (0.64 mm) on oil lubricated bearings. Maximum allowable clearances for water-lubricated cutless rubber bearings are 0.040 inch (1.0 mm) for shaft diameters up to 1.5 inches (40 mm), and 0.070 inch (1.8 mm) for shaft diameters between 1.5 to 4 inches (40 to 100 mm).

(3) Dismantling and Reassembly. Follow the same procedures listed for centrifugal-type pumps.

(4) Alignment. Check the pump and motor alignment each year.

(5) Painting. Annually, or when the pump is pulled, paint all iron parts with a good grade of underwater paint or effective protective coating on the exterior of the pump and, if possible, on the interior parts subject to rust. Apply the paint only to surfaces that are clean and dry. Do not paint the data plate.

4.5.2 RECIPROCATING WELL PUMPS

4.5.2.1 GENERAL INFORMATION. Use the manufacturer's manual to develop checklists for each reciprocating well pump.

4.5.2.2 DELIVERY. Measure the pump output twice a year for a known number of strokes. Delivery per stroke should be at least 90 percent of the volumetric displacement of the pump (plunger area times the stroke length). When the pump delivery drops to 50 percent or less, or when the pump delivery is between 50 and 90 percent but less than the installed water requirements, remove the pump from the well and check the valves and cup leathers. Before removing the pump, consult the manufacturer's method for picking up the foot valve and for additional maintenance procedures.

4.5.2.3 OVERHAUL PROCEDURES. Inspect the pump jack for wear each year. Replace worn bearings and parts. Check the packing assembly and repack as necessary. If the pump delivery is satisfactory, do not overhaul the pump parts in the well. Paint the exterior of the pump as necessary.

4.5.3 EJECTOR PUMPS

4.5.3.1 CENTRIFUGAL PUMP. Maintain the centrifugal pump portion of the system according to the maintenance items listed for centrifugal pumps.

4.5.3.2 EJECTOR ASSEMBLY. Each year, or as directed by the utilities manager, remove the ejector, the foot valve, and the screen from the well. Examine all parts for wear and corrosion and repair or replace any defective parts. Paint the exterior of the pump. If practical, paint the interior iron with a good grade of underwater paint or effective protective coating meeting ANSI/NSF Standard 61.

4.5.4 STARTING A NEW WELL PUMP. Table 9 lists startup procedures for vertical turbine well pumps. While plant operators will not generally be responsible for performing these startup procedures, they may be charged with overseeing the contractors performing the installation. Also, it is preferable that plant operators are familiar with the startup tasks. Figure 2 shows the necessary water-level checks. If problems occur, refer to the troubleshooting checklist provided in Table 10.

5. PUMP DRIVERS. Pump drivers provide the mechanical source of energy to pumps. The driver is usually an electric motor, gasoline or diesel engine.

5.1 ELECTRIC MOTORS. Electric motors are the most common drive used in most water systems. Proper operation of an electric motor requires that the operator be able to recognize the normal sounds and conditions of a properly running motor. In general, investigate any change in the sound or operating condition detected during the regular inspection. Table 11 includes a list of routine operating checks for electric motors.

5.1.1 MAINTENANCE. As a rule, the electrical shop is responsible for routine maintenance of electrical motors. Under some circumstances, the responsibility for cleaning and servicing antifriction bearings may be delegated to the operator.

5.1.2 GASOLINE AND DIESEL ENGINES. Gasoline and diesel engines are commonly used for emergency, standby and portable pumping units. The operator is usually responsible for performing operating checks. Table 12 lists items to check before, during, and after starting gasoline and diesel engines. Use this checklist as a general guide only. Obtain specific details from the manufacturer's manual for each unit and perform any additional services specified in the manual. In addition to the checks listed in Table 12, perform the following tasks:

5.1.2.1 UNIT READINESS CHECKS. Operate all emergency and standby units at full load for the time specified by the equipment manufacturer. One hour each week is often recommended to ensure unit readiness.

5.1.2.2 ROUTINE MAINTENANCE. Operators are generally responsible for operating checks and routine maintenance.

Inspection	Action
Prestart Inspection	
Well	Disinfect according to par. 4.5.2.5.
Pump equipment	
	Check alignment.
Valve and piping system	Check for proper operation. Check for leaks. Set valves so water pumped at startup does not feed into distribution system until bacteriological quality has been tested and clearance received.
Bearings	Pre-lubricate bearings on water-lubricated, line-shaft pumps with settings of more than 50 feet.
Electrical connections	Make sure that all electrical connections are correct and that terminals are tight.
Instrumentation	Make sure all instrumentation is hooked up according to the manufacturer's instructions.
Startup Inspection	
Pump	Start pump. Check immediately for evidence of malfunction or excessive heat or vibration. Check operating power input.
Motor	Check for malfunction or excessive heat or vibration. Check rotation direction of motor. Check water or oil lubrication system
Instrumentation	Observe how quickly motor comes up to operating speed; check final operation speed.
Bearings	Check for excessive heat or vibration.

Table 9
Startup Checklist for Vertical Turbine Well Pumps

Inspection	Action
Post-Startup Inspection	
Well	Check for abrasive material (sand pumping) or the presence of gas within the well.
Water level	Make immediate check of water level and record data for future reference. Perform pumping and recovery water-level checks as shown in Figure 6.
Pressure tests	Check pump pressure and flow output. Determine the corresponding pumping level in the well. Compute the field head (1) and compare it to the pump curve supplied by the manufacturer (2).
Water quality	After pumping for 24 hours, collect a water sample for microbiological analysis to ensure water is free from disease-causing organisms.

(1) Field head is computed as follows: calculate the static and dynamic head losses being overcome by the pump. The total field head equals (a) the friction losses in the pump column and through the pump discharge elbow to the location of the pressure gage on the pump plus (b) the vertical distance from the pumping level in the well to the pressure gage plus (c) the pressure gage reading converted to feet of head.

(2) The manufacturer's pump curve should be a combined curve showing a composite assembly rating for multistage pumps, not a single-bowl-assembly curve used for a single-stage pump.

Table 9 (continued)

Startup Checklist for Vertical Turbine Well Pumps

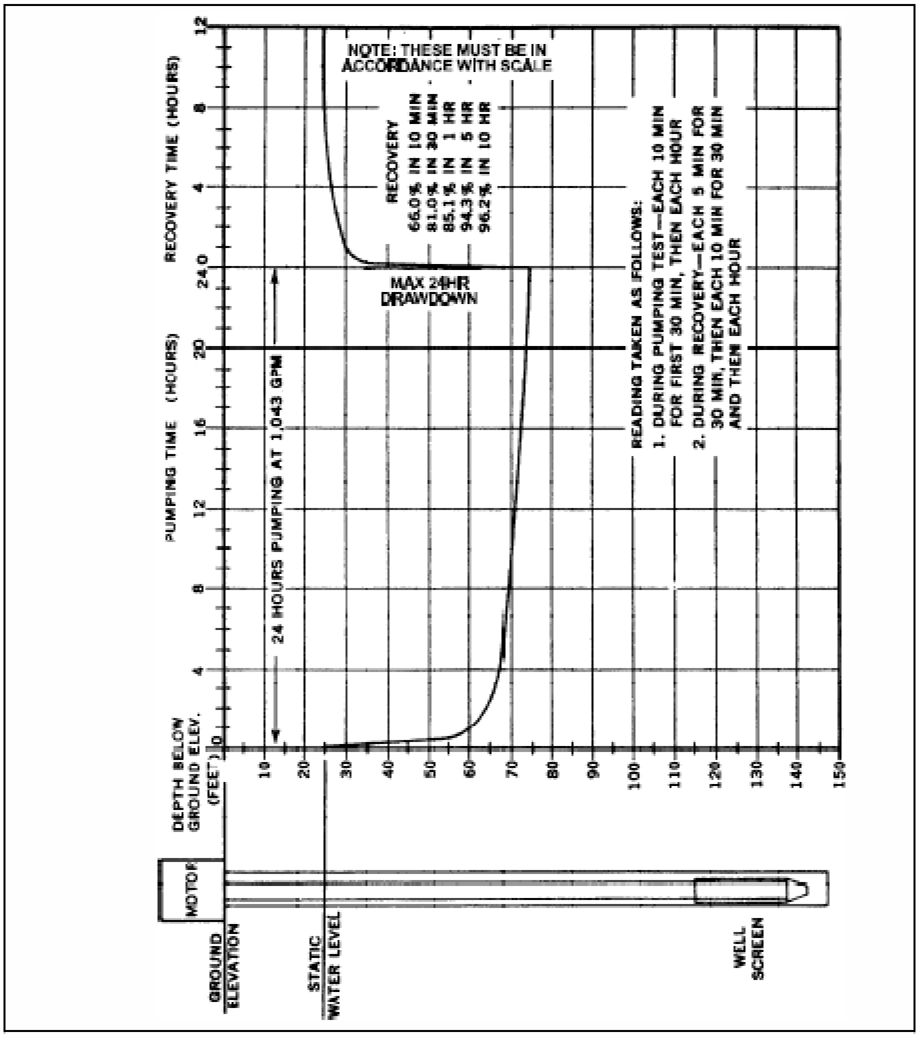

Figure 2

Typical well pumping and recovery test

Symptom	Cause of Trouble	Remedy
Pump fails to start.	Bearing friction	Check tube tension nut for tightness; check for bent shaft and proper anchoring; check oil.
	Corrosion products or biological growth	Check, particularly on out-of-service pumps. Where necessary, flush with acid, chlorine, and/or hexametaphosphate.
	Fuses burned out	Check voltages at each phase of motor terminals.
	Impeller locked	Check for sand; raise or lower impeller; backwash. Pull pump if necessary. Also check impeller adjustment; raise impeller to allow shaft to stretch for hydraulic thrust.
	Faulty driver	Disconnect from pump and check starting.
	Power not available	Check circuit breaker, fuse, and starter.
	Overload relay trip	Reset.
	Trash in casing	Check. If necessary, pull pump and clean.
	Low voltage	Check.
	Well cave-in	Check; pull pump; repair well.
Pump does not deliver water.	Pump not primed	Check for proper pump submergence. Vent well to atmosphere to eliminate vacuum at pump suction.
	Discharge head too high	Check for closed discharge valves or stuck check valves.

Table 10

Troubleshooting Checklist for Vertical Turbine Well Pumps

Symptom	Cause of Trouble	Remedy
	Pump parts failure	Check for broken shaft, broken bowl assembly, loose impellers, and loose column-pipe joints.
	Wrong direction of rotation	Check for switched power leads.
	Speed too low	Check power supply voltage and frequency. Check for bearing friction and impeller corrosion or obstruction.
	Suction clogged	Backwash or use chemical treatment to clean.
	Operating water level low	Check static level and drawdown. Lower pump, clean screen, and decrease pumping rate.
	Low speed	Check power supply voltage and frequency; check for excessive bearing friction and impeller corrosion or obstruction.
	Low water level in well	Check well vent. Check pump inlet for turbulence, vortexing, or eddies. Check well screen for sand, rust, or biological growth.
	Faulty instruments	Correct instrument readings.
Pump requires excessive power.	Impeller rub	Check adjustment of impeller height.
	Wrong lubricant	Compare manufacturer's instructions with lubricant being used.
	Misalignment	Check for tight bearings; check for pump and casing vibration.

Table 10 (continued)

Troubleshooting Checklist for Vertical Turbine Well Pumps

Symptom	Cause of Trouble	Remedy
Pump vibrates excessively.	Packing too tight	Check for proper leakage to provide shaft lubrication.
	Pump selection wrong	Check capacity rating, etc.
	Wrong direction of rotation	Check power leads.
	Excessive speed	Check power frequency and voltage; check gear ratios.
	Air entering pump	Check on over-pumping and water level drawdown; check leaks in well vent.
	Bearing trouble	Check for sand in water. Check lubricant (oil and grease) for proper grade.
	Rough operation	Check disconnected motor. Check for sand in impeller or bowl. Check for wear in rotating parts.

Table 10 (continued)

Troubleshooting Checklist for Vertical Turbine Well Pumps

Inspection	Action
Motor	Keep the motor free from dirt or moisture. Keep the operating space free from articles that may obstruct air circulation. Check the bearings for oil leakage.
Unusual Conditions Unusual noises in operation Motor fails to start or to come up to speed normally Motor or bearings feel or smell hot Continuous or excessive sparking at commutator Hot commutator Blackened commutator Sparking at brushes Fine dust under couplings with rubber buffers or pins Smoke, charred insulation, or solder whiskers extending from armature Excessive hum Regular clicking Rapid knocking Chattering brush Vibration	Check regularly for these unusual conditions. Report any irregularities to the plant superintendent for correction by the electrical shop.

Table 11

Routine operations checklist for electric motors

Inspection	Action
Prestart Checks	
Motor	Check equipment for signs of tampering or leaks.
Fire extinguisher	Ensure extinguisher is in working order.
Gages	Check all fuel, oil, and water levels.
Accessories and drives	Inspect according to manufacturer's instructions.
Battery	Check for cracks and leaks.
Air breather	Make sure breather is free of obstruction.
Startup/Warmup Checks	
Choke or primer	Check for proper operation.
Engine	Test warmup time and efficiency.
Indicator lights	Ensure oil gage or indicator lights are in working order.
Other instruments	Check that ammeter, tachometer, fuel gage, voltmeter, and temperature gage are working.
Operating Checks	
Clutch	Ensure clutch is working properly.
Transmission and engine/controls	Check for unusual sounds, vibration, overheating, etc.
Instruments	Check that all instruments are registering readings.
Post-Shutdown Checks	
Gages	Check fuel, oil, and water levels.

Table 12

Operations Checklist for Gasoline and Diesel Engines

Inspection	Action
Instruments	Check indicators. Indicators should return to zero when engine is not running.
Battery and voltmeter	Check that battery has not run down and retains sufficient charge.
Accessories and belts	Check for signs of wear.
Electrical Wiring	Inspect wire integrity (no frayed or charred wires; no loose wires).
Air cleaner and breather caps	Look for obstructions or clogs.
Fuel filters	Be sure filters are not clogged or dirty. Change or clean as required or at regular intervals.
Engine controls	Controls should move freely. Check for binding, sticking, etc.
Leakage	Look for oil and coolant leaks.
Gear oil levels	Check level.

Table 12 (continued)

Operations Checklist for Gasoline and Diesel Engines

6. ACCESSORIES. Accessories include belt drives, gear drives, variable speed drives, and couplings that connect the driver to the pump.

6.1 BELT DRIVES. Two types of belts are used for belt drivers: V-belts and flat belts. Maintaining proper tension and alignment of belt drives ensures long life of belts and sheaves. Incorrect alignment causes poor operation and excessive belt wear. Inadequate tension reduces the belt grip and causes high belt loads, snapping, and unusual wear. Keep belts and sheaves clean and free of oil which deteriorates belts. Replace belts as soon as they become frayed, worn or cracked.

6.1.1 INSTALLING BELTS. Before installing belts, replace worn or damaged sheaves. Check alignment with a straight edge or string, and make the necessary corrections to keep the pulleys in line. Loosen the belt tensioning adjustment enough to remove and install belts without the use of force. Never use a screwdriver or other lever to force belts onto sheaves. Check multiple belts for matching size and length. It is not a good practice to replace only one V-belt on a multiple belt assembly. Instead, replace the complete set with a set of matching belts. After belts are installed, adjust the tension. Recheck the tension after 8 hours of operation.

6.1.2 CHECKING TENSION. Check belt tension each week and adjust, as required, to prevent slipping or excessive wear on the belts.

6.2 RIGHT-ANGLE GEAR DRIVES. O&M procedures for right-angle gear drives should follow manufacturer's recommendations. Immediately after starting a right-angle gear drive, remove the inspection plate and check for proper flow of lubricant. If there is no flow, stop the motion and check for mechanical defects. If no mechanical defect is found, it may be necessary to change the lubricant or drain and warm the old lubricant. Temperature or service conditions may require changing the lubricant type. To avoid detrimental effects of possible water-oil emulsion, drain the old oil and refill with fresh recommended lubricant quarterly, or about every 500 hours of operation, whichever is more frequent. The choice of lubricant depends on prevailing air temperatures and the manufacturer’s recommendations.

6.3 O&M FOR VARIABLE-SPEED DRIVES. Variable-speed drives are commonly used in water systems. Designs vary considerably from manufacturer to manufacturer. Therefore, consult the manufacturer’s manual to determine O&M requirements. Items common to most variable-speed drives are listed below.

6.3.1 CHECK FOR NORMAL OPERATION. Observe the drive each shift and note any abnormal conditions.

6.3.2 CLEAN DISCS. Remove grease, acid, and water from the disc face and thoroughly dry it. Use clear solvents that leave no residue.

6.3.3 CHECK SPEED-CHANGE MECHANISMS. Shift drive through the entire speed range to make sure that shafts and bearings are lubricated and discs move freely in a lateral direction on shafts.

6.3.4 CHECK V-BELT. Make sure the belt runs level and true. If one side rides high, a disc is sticking on the shaft because of insufficient lubrication or wrong lubricant application. In that case, stop the drive, remove the V-belt, and clean the disc and shaft thoroughly with kerosene until the disc moves freely.

6.3.5 CHECK LUBRICATION. Be sure to apply the lubricant at all force-feed lubrication fittings and grease cup fittings. Refer to the manufacturer’s manual for proper lubricants.

a) Once every 10 to 14 days, add two or three strokes of grease through the force-feed fittings at the end of the shifting screw and variable shaft to lubricate the bearings of movable discs. Shift the drive from one extreme speed to the other to thoroughly distribute the lubricant over the disc-hub bearings.

b) Every 60 days, add two or three shots of grease through the force-feed fittings that lubricate the frame bearings on the variable-speed shaft.

c) Every 60 days, add grease to grease the cup that lubricates the thrust bearings on the constant-speed shaft.

d) Every 60 days, add two or three strokes of grease through the force-feed fittings on motor-frame bearings. Do not use hard grease or grease that contains graphite.

e) Check the reducer oil level every 30 days and add oil when necessary. Drain and replace the oil according to the manufacturer's recommendations.

6.3.6 REMOVE UNIT FROM SERVICE. If the drive will not be operated for 30 days or more, shift the unit to minimum speed. This places the springs on the variable-speed shaft on minimum tension and relieves the belt of excessive pressure and tension.

6.4 COUPLINGS. Unless couplings between the driving and driven elements of a pump or any other piece of equipment are kept properly aligned, breaking or excessive wear occurs in the coupling, the driving machinery, or the driver. Worn or broken couplings, burned out bearings, sprung or broken shafts, and excessively worn or ruined gears are some of the damages caused by misalignment. To prevent outages and the expense of installing replacement parts, check the alignment of the equipment before damage occurs.

6.4.1 CHECKING COUPLING ALIGNMENT. Excessive bearing and motor temperatures caused by overload, noticeable vibration, or unusual noises may all be warnings of misalignment. Realign when necessary, using a straight edge and a thickness gauge or wedge. To ensure satisfactory operation, level up to within 0.005 inch (127 x 10-3 mm) as follows:

a) Remove coupling pins.

b) Rigidly tighten any driven equipment to its base. Slightly tighten the bolts holding the driver to its base.

c) To correct horizontal and vertical alignment, shift or shim the driver to bring the coupling halves into position so no light can be seen under a straight edge laid across them. Lay the straight edge in at quarter points of the circumference, holding a light in back of the straight edge to help ensure accuracy.

d) Check for angular misalignment with a thickness or feeler gauge inserted at the same four places to make sure that the space between the coupling halves is equal at all points.

e) If the equipment is properly aligned, coupling pins can be put in place easily (using only finger pressure). Do not hammer pins into place.

f) If the equipment is still misaligned, repeat the procedure.

6.4.2 LUBRICATION. Use lubrication procedures and lubricants as recommended.

7. RECORDKEEPING. Keep equipment and maintenance records for each pump and drive assembly. The method used is prescribed by local command. In general, records will contain entries for routine maintenance (lubrication, equipment checks, etc.), as well as scheduled overhauls and nonscheduled repairs. A description of the work done, the date, and the name of the person doing the work are minimum entries. Since a pump's condition is best evaluated by comparing its current performance to its original performance, a record of flow, pressure, pump speed, amperage, and other test data, determined immediately following installation, is recommended.

8. PUMP SAFETY. Specific hazards related to operating and servicing pumps include rotating equipment, lifting heavy machinery, using hand tools, working with electrical devices, and fires. Always stop machinery before it is cleaned, oiled or adjusted. Lock out the controlling switchgear before any work begins so that the machinery cannot be started by another person. Post a conspicuous tag on or over the control panel, giving notice that the equipment is under repair and should not be restarted. Also note the name of the person who locked out the equipment. (Caution: Remove guards for maintenance only when the machinery is not in operation.)

9. MOTOR AND ENGINE SAFETY. Follow special safety precautions when dealing with motors and engines. In addition to all the other safety concerns associated with water distribution (as discussed in other sections), be cautious around electrical devices and be aware of fire safety guidelines.

9.1 ELECTRICAL DEVICES

a) No safety tool can protect absolutely against electrical shock. Use plastic hard hats, rubber gloves, rubber floor mats, and insulated tools when working around electrical equipment. These insulating devices cannot guarantee protection, however, and no one using them should be lulled into a false sense of security.

b) Electrical shocks from sensors are possible in many facilities, such as pumping stations, because many instruments do not have a power switch disconnect. It is important to tag such an instrument with the number of its circuit breaker so that the breaker can be identified quickly. After the circuit breaker has been shut off, tag or lock the breaker so other personnel will not re-energize the circuit while repairs are being performed. Even after a circuit is disconnected, it is a good practice to check the circuit with a voltmeter to be certain that all electrical power has been removed. Make sure switches are locked open and properly tagged when personnel are working on equipment. Use fully enclosed, shockproof panels when possible. Such equipment should be provided with interlocks so that it cannot be opened while the power is on.

c) Use extreme care in working around transformer installations.