MAINTENANCE AND INSTRUMENTATION

Like any other business, a water system spends a great deal of money on infrastructure and capital improvements. These expenses include piping, storage and all of the mechanical equipment required to produce, treat, and deliver water. A maintenance program is essential to insuring that the mechanical components of the system stay in good working order and provide the longest possible service life. A preventive maintenance schedule should be utilized to make sure that each piece of equipment gets the proper attention. Most preventive maintenance consists of inspecting, cleaning, and lubricating the equipment. The equipment operators can usually complete these tasks. Specially trained personnel that possess the necessary mechanical skills should handle major maintenance, including component replacement and overhaul.

PUMP MAINTENANCE

The most common piece of equipment in a water system is the centrifugal pump. There are several maintenance procedures that must be performed periodically for any centrifugal pump. Pump packing wears out, bearings must be lubricated or replaced, mechanical seals need replacing, couplings must be maintained, and motor and pump shafts must be aligned. These procedures are not difficult to learn. Some of the procedures may require the use of a few special tools. Once an operator understands the basic procedures and has a chance to put the theories into practice, it doesn't take long to become proficient at each task.

PUMP PACKING

Pump packing is one of the biggest problem areas for operators in charge of pump maintenance. Poor maintenance of pump packing is responsible for more pump damage than any other maintenance item. Improperly maintained packing can cause several problems including:

DAMAGE CAUSED BY PACKING FAILURE

- Loss of prime or suction due to an air leak
- Shaft and sleeve damage
- Water contamination of bearings
- Flooding of pump stations

There are many different types of pump packing available for use in today's pumps. The most common type of packing comes in a square braided stock. There are a number of different kinds of braided packing. It can be manufactured from jute, asbestos, nylon, Teflon or other synthetics. It can be lubricated with graphite, grease, or other synthetic lubricants such as Teflon. Prices for packing range from several dollars a pound for graphite-impregnated jute to hundreds of dollars a pound for pure Teflon and other synthetics.

A rule of thumb is to buy the most expensive packing that you can afford, provided that you are taking care of the rest of the pump properly. If scored or damaged shaft sleeves and out of round or bent shafts are not going to be repaired, use the cheapest packing you can get. Expensive packing will not last any longer than the cheap stuff if the sleeve is scored or the shaft is bent. If the rest of the pump is properly cared for, the more expensive types of packing will last several times longer than the cheap packing and will usually pay for itself with a longer life.

REMOVING OLD PACKING

It's time to replace the packing when there is no more adjustment left in the packing gland and there is too much leakage from the stuffing box. When this occurs, <u>all</u> of the packing rings must be replaced. Adding an additional ring or just replacing one or two rings will only lead to premature packing failure and damage to the shaft and sleeve. Use the following procedure to remove the old packing:

1. Tag the pump in the "OFF" position and lock it out so that it can’t be accidentally restarted.

2. Isolate the pump by closing the suction and discharge valves.

3. Drain the pump by opening the drain cock or removing the drain plug in the bottom of the volute.

4. Remove the packing gland. If it is not split for removal from the shaft, it should be tied off so that it is out of the way.

5. Remove the packing rings with a packing puller (corkscrew on the end of flexible T-handle) taking care not to score the shaft sleeve.

6. Measure the distance to the lantern ring and then remove it with the packing puller. It may take a puller on each side of the lantern ring to pull it out without getting it cocked sideways. If the lantern ring is split, it can be removed from the shaft. If you're not sure the lantern ring was in the right placed to begin with, measure the distance from the face of the stuffing box to the seal water port or refer to the vendor's engineering drawing of the stuffing box for the correct position.

7. Remove the remaining packing rings and clean the stuffing box and shaft.

8. Disconnect, inspect, and clean the seal water line and seal water port.

9. Inspect the shaft or shaft sleeve. If it is scored or grooved, the pump should be dismantled and the shaft dressed or repaired by a machine shop.

REPACKING THE PUMP

Before new rings are cut, it is important to determine the size and number of packing rings that are needed for the stuffing box. This information should be available in the vendor's engineering drawings. If these drawings are not available, measurements of the stuffing box and shaft can be used to make the determination. The correct packing size is determined using the following procedure:

1. Measure the inside diameter of the stuffing box and the outside diameter of the shaft.

2. Subtract the shaft diameter from the stuffing box diameter.

3. Divide the difference by two. (See illustration on page 12-5)

The correct number of rings can be determined using the following procedure:

1. Measure the depth of the stuffing box.

2. Divide the depth of the stuffing box by the size of the packing to get the total number of rings.

3. Subtract one from this total if a lantern ring is used in the stuffing box.

Once the size and number of rings has been determined, the new packing can be cut and installed. Great care should be taken to keep the packing material clean and free from dirt. Packing spools should be stored in plastic bags to prevent contamination. Dirt and grit in the packing rings will lead to serious shaft and sleeve damage. The two most important aspects of cutting packing rings involves cutting them the right length and cutting them so the ends will butt together squarely. Cutting rings the same length with ends that butt together squarely can be accomplished using the following procedure:

1. Cut the packing to the proper length and shape using a very sharp knife or carton cutter. Wrap the packing material around the shaft, an old sleeve, or even a piece of hardwood turned to the proper diameter. Cut all of the rings at once with the packing on the shaft to insure that the ends will butt together squarely.

2. Wrap each ring of packing around the shaft and seat it in the stuffing box completely before adding the next ring. Open the ring by twisting it instead of pulling the ends apart. A light coat of grease on the outside of the ring will make it much easier to push into the stuffing box. Stagger the joints of the rings so that they are 90 degrees apart. Make sure the lantern ring lines up with the seal water port when it is installed.

3. Install the packing gland. Make sure the gland tightened down evenly. It is usually made out of cast material and will break easily if it gets in a bind.

ADJUSTING THE PACKING GLAND

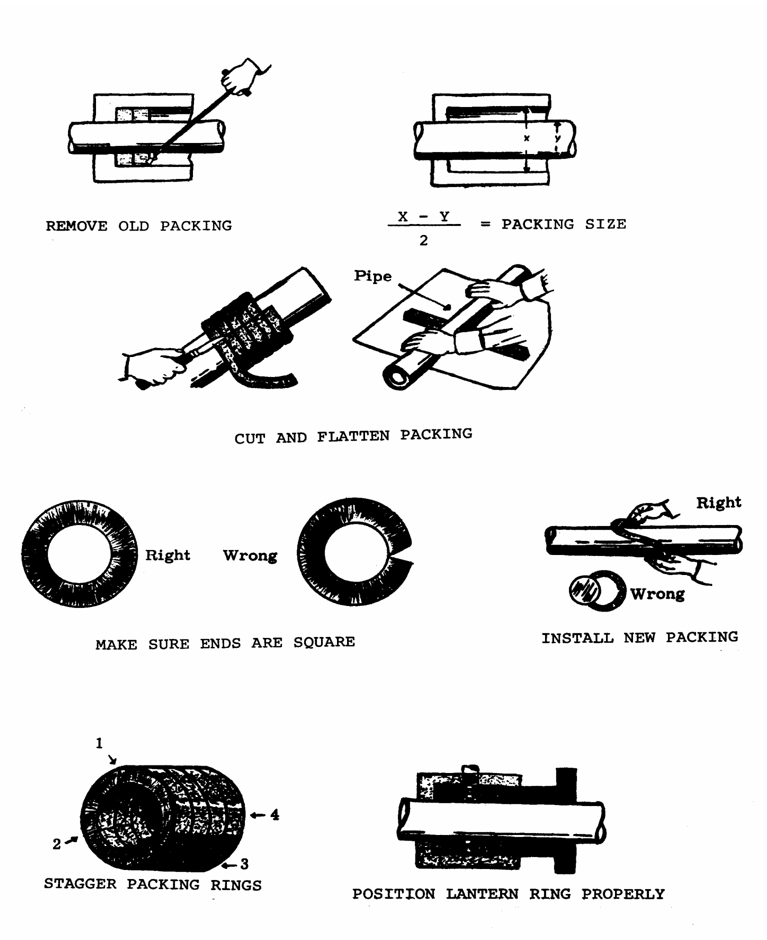
The final adjustment of the packing gland is made while the pump is running. The pump can be restarted once the locks and tags have been removed, the discharge and suction valves are completely opened, and the pump has been primed. More packing jobs have been ruined by improper gland adjustment than any other single reason. Adjust the packing gland using the following procedure:

1. Tighten the gland one half turn a time on each side until it just begins to put pressure on the packing.

2. Start the pump and tighten the gland until the flow of water is reduced just enough to prevent flooding the drain line. Allow the pump to run for at least five minutes while the packing rings seat. Never allow the packing to get hot during this "breaking in" period. If the packing heats up and lubricant is seen oozing from the gland, the packing is already ruined and should be removed and replaced immediately.

3. After five minutes, adjust the packing slowly until the leakage is reduced to the desired level. The appropriate amount of leakage will vary with the size of the pump and type of packing, but a general rule of thumb is 20-60 drips per minute. Tighten the gland and check the water temperature periodically. When the water turns lukewarm there is not enough flow to cool the packing properly.

   Loosen the packing gland just enough to cool the water back down to room temperature. The packing gland will probably need to be checked again as the packing rings get properly seated. This may have to be done several times over the next 24 hours of run time.



BEARING MAINTENANCE

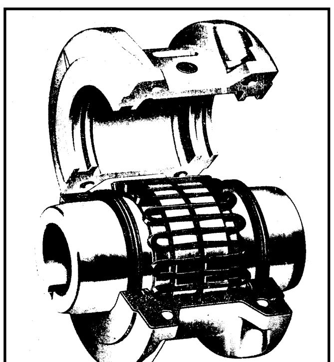
Proper bearing lubrication is a critical part of getting the designed life out of pump and motor bearings. As strange as it may sound, more bearings have failed from over-lubrication than from lack of lubrication. In fact, some bearings never require lubrication and may fail if they are greased. Shielded and sealed bearings come factory-lubricated and have sufficient lubricant to last the life of the bearing. Shielded bearings have a metal skirt that is attached to the outer race. It covers the rollers but doesn't touch the inner race. Sealed bearings have a rubber skirt that does touch the inner race. Bearings that do require periodic grease lubrication use a surprisingly small amount of grease when compared to the bearing housing size. A properly greased bearing will have a bearing housing that is never more than 25-30% full. The grease is responsible for lubricating and cooling the bearing.

Grease that is inside the bearing will get hot as the bearing heats up. When the grease gets hot it becomes more fluid and is thrown out of the bearing and onto the wall of the bearing housing, where it cools. Grease that is outside the bearing is drawn into the race, where it again heats up and is thrown out. This process keeps the bearing lubricated and removes heat from the bearing. If the bearing housing is full of grease there is no way for the hot grease to get out of the bearing. The lubricant inside the bearing overheats and breaks down. Bearings overheat and fail when this happens.

As bearings heat up and cool down, the races and rollers expand and contract. Bearings are temperature stabilized to about 250^{0}F. This means they will assume their original dimensions as long as the temperature does not rise above 250^{0}F. This is the reason small electric motors should not operate above 220^{o}F or 105^{0}C. Lubrication schedules for low-speed (under 2500 rpm) anti-friction bearing applications are based on the operating temperature of the bearing. Always refer to the vendor recommendations for the proper lubricant and lubrication frequency.

COUPLINGS

Couplings connect the motor shaft to the pump shaft. The exception to this would be a close-coupled pump. A close-coupled pump will have the impeller mounted directly to the motor shaft. Couplings can be rubber or steel. Steel couplings are most commonly gear-type or grid couplings.



Flexible Grid Coupling

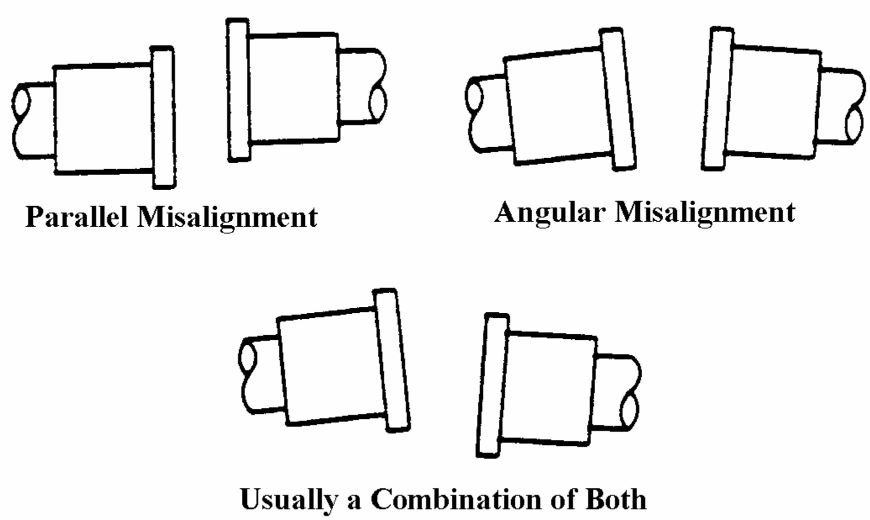
Couplings are mounted and removed by pressing or heating the coupling. They should never be mounted using a hammer. The halves of the coupling should be separated by a gap large enough to accept the thermal expansion as the shaft and motor heat up. Couplings flex as the two shafts spin. This movement generates friction and heat in the coupling and requires grease lubrication. The main problem with lubrication in a coupling is centrifugation. As the coupling spins, it tries to throw the grease out of the housing.

Couplings should be inspected periodically. The housing should be removed and the old grease removed using a solvent. Care must be taken not to get solvent in the bearings or seals. Broken or worn teeth and wear or pits on the grids are indicators that the coupling should be replaced. Gear-type housings are usually cast material. The housing bolts must be tightened carefully in a crossing pattern to avoid cracking the assembly. Vibration occurs in a coupling when it is misaligned.

MOTOR ALIGNMENT

Maintenance of electrical equipment and chemical feed systems is important in order to reduce downtime and maintain proper process control in water system facilities. One of the most important parts of equipment maintenance involves aligning the motor to the driven equipment.

If the pump and motor shafts are not aligned properly, the result will be vibration and subsequent damage to the pump coupling, mechanical seals, and the pump and motor bearings. Misalignment can be angular or parallel (offset). Angular misalignment means that the motor is crooked when it lines up with the pump shaft. Parallel misalignment means that the shafts are in a straight line but one of them is off center. Misalignment can also be in the horizontal plane, requiring a side-to-side movement of the motor. It can also be in the vertical plane, requiring raising the motor with shims. This means that measurements must be taken at the top, bottom, and both sides of the coupling.



Types of Misalignment

A crude check of the misalignment can be done using a straight edge and feeler gauge on the coupling halves. A dial indicator or laser system can be used to more accurately gauge the amount of offset or angularity. These methods are capable of precise measurements down to 0.001”.

ELECTRIC MOTORS

Very few operators do electrical repairs or trouble shooting because this is a highly specialized field and unqualified operators can seriously injure themselves or damage costly equipment. For these reasons the operator must be familiar with electricity, know the hazards, and recognize his own limitations when working with electrical equipment. Most water systems use a commercial electrician for major problems. However, the operator should be able to explain how the equipment is supposed to work and what it is doing or not doing when it fails. Electric motors are used to convert electrical energy into mechanical energy. A motor generally consists of a stator, rotor, end bells, and windings. The rotor has an extending shaft, which allows a machine to be coupled to it. Most large motors will be three phase motors rated from 220 or 4160 volts.

Electrical terms like watts and volts have counterparts in fluid hydraulics. Voltage is similar to the hydraulic term pressure. Hydraulic pressure is measured in psi and electrical pressure is measured in volts. The electrical equivalent of friction loss is resistance or ohms. Hydraulic flow is measured in gpm and electrical current flow in measured in amps. Hydraulic horsepower is determined by multiplying flow by the pressure. The electrical equivalent of horsepower is watts. Watts are determined by multiplying amps by the voltage.

Vertical turbine pumps have hollow core motors. The shaft slides into the rotor. Impeller clearance is adjusted by raising and lowering the shaft. This is accomplished by tightening or loosening the adjusting nut or thrust nut on the top of the motor.

PHASES

The term "phase" applies to alternating current (AC) systems and describes how many external winding connections are available from a generator, transformer, or motor for actual load connections. Motors are either single-phase or three-phase.

SINGLE PHASE MOTORS

Single-phase motors are normally operated on 110-220 volt AC single-phase systems. A straight single-phase winding has no starting torque so it must incorporate some other means of spinning the shaft. A single-phase motor requires a special start circuit within the motor to make sure it runs in the right direction. Several different types of starter windings are available in these motors. Single-phase power leads will have three wires, like a three-prong extension cord. The third wire is the neutral or ground.

THREE PHASE MOTORS

Three-phase systems refer to the fact that there are three sets of windings in the motor and three legs of power coming in from the distribution system. This type of motor is used where loads become larger than single-phase circuits can handle. With three legs to carry power, more amps can be delivered to the motor. Three phase motors are the most common types used in water and wastewater systems.

Squirrel cage induction motors are widely used because of its simple construction and relative low maintenance requirements. The windings are stationary and are built into the frame of the motor. The power supply is connected to the windings in the stator, which creates a rotating magnetic field. The rotor is made up of bars arranged in the shape of a cylinder and joined to form a "squirrel cage." Squirrel cage induction motors make up approximately 90% of all motors used in industry today.

A megger is a device that is used to determine the condition of the insulation in the motor windings of a squirrel cage motor. It produces a very high voltage used to check for potential weaknesses in the insulation. Vertical turbine line shaft pumps will often have a hollow core or hollow shaft motor. The rotor is hollow and the motor shaft can slide up and down to allow adjustment of impeller clearance. This is called a lateral adjustment. The shaft is raised and lowered using the top nut, known as the thrust nut or adjusting nut.

Three-phase motors do not use a start circuit. The direction of rotation is determined by how the three leads are wired to the motor. If any two of the leads are switched, the motor rotation will be reversed.

SINGLE PHASING

Anytime a lead becomes grounded, a dead short develops, or one set of the contacts opens in a three-phase motor, single phasing will result. When this occurs, the speed of the motor will drop and it will begin to overheat. The single phase will draw too many amps and it will quickly burn up. When single phasing occurs while the motor is not running, it simply will not start up again. Special circuit protection is available that will shut the motor off if single phasing occurs.

CIRCUIT PROTECTION

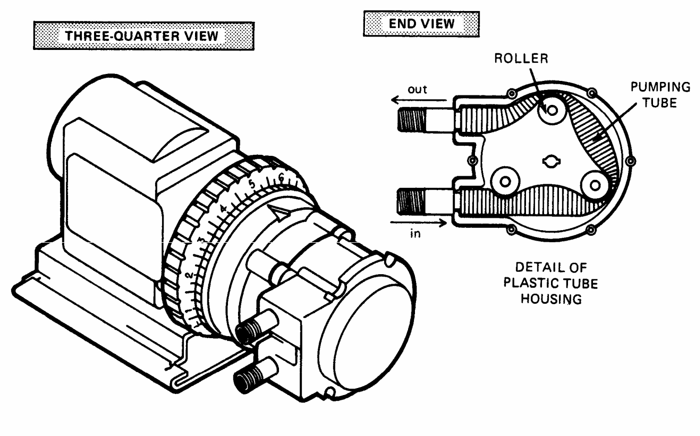
Motors need to be protected from power surges and overloads. Fuses and circuit breakers are designed to open the circuit when the current load threatens to damage the motor. Fuses are generally sized at 120-150% of motor capacity. Circuit breakers can be reset when they trip, instead of being replaced like a fuse. Circuit breakers can react faster than fuses and are usually sized closer to the current rating of the motor. They are normally found on single phase 110 or 220 volt motors.

CHEMICAL FEED SYSTEMS

Chemical feeders are necessary to assure that the proper amount of each chemical is added to the water on a continuous basis. Each feeder must have a storage bin, a device that feeds the chemical into a solution tank where it is dissolved, and a delivery system to add the chemical at the proper point in the treatment process. Chemical feeders are either gravimetric or volumetric. Gravimetric feeders usually have a conveyor that uses a set of scales to maintain a constant weight of material on the belt. They are not used in water treatment much because most treatment chemicals are corrosive and will damage the scale mechanism. Volumetric feeders are the most common. The most common type of volumetric feeder is the positive displacement diaphragm pump.

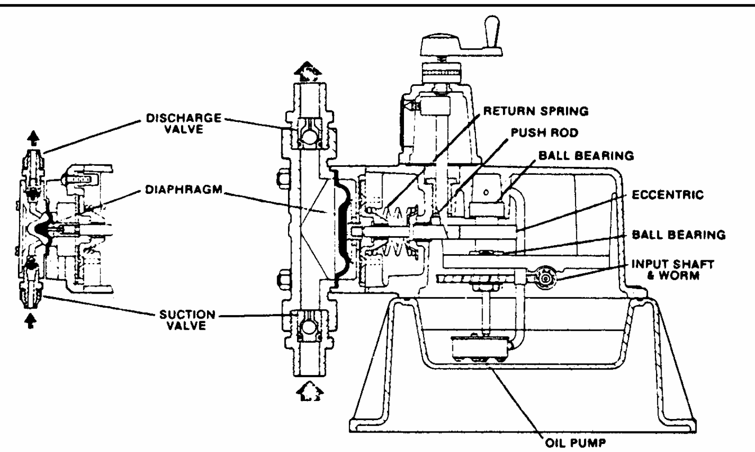
Volumetric dry chemical feeders must be calibrated. The first step is catching and weighing the feed chemical at different speeds and converting the weights to pounds-per-day. This data can be used to create a feed rate table for that particular feed machine. The feed chamber must be cleaned routinely in order to maintain accurate feed rates.

Chemical feed pumps are small positive displacement pumps. They are usually diaphragm pumps, but peristaltic pumps are becoming popular for very small systems. Peristaltic pumps consist of a circular pump head that contains a piece of flexible tubing and a roller assembly. As the pump motor turns the roller, fluid is squeezed out of the tube. These pumps can meter flows as low as 3-4 drips per minute (0.1-0.15 ml/min).



Peristaltic Pump

The diaphragm feed pump consists of a diaphragm driven pump chamber, and two check valves. The check valves, that provide the one-way flow through the pump, can get clogged with lime deposits. The strainer on the pump suction line should be located several inches above the bottom of the solution tank to prevent lime and grit from being drawn into the pump and fouling the check valves.

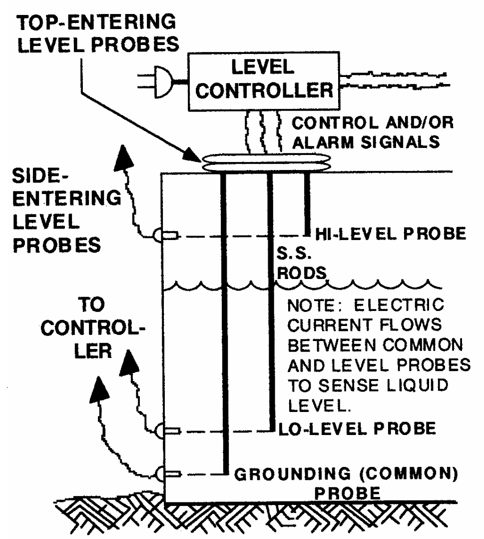


Diaphragm Pump

If the check valves get fouled, the pump will not pump any solution. Flushing the line with clean water or a weak acid, like vinegar, may also correct the problem. In severe cases the valves may have to be disassembled and cleaned. Always make sure the pump is primed before putting it back into service. It may also be advantageous to locate the pump so that it has a positive suction head.

PROCESS INSTRUMENTATION

There are two basic types of instrumentation in most mechanical processes. There are instruments that are digital in the sense that they are controlling processes that are either on/off or open/close types of operations. A pump start circuit can be controlled by a simple switch that turns the pump on or off when the water reaches a certain level in a tank. These systems use probes or mercury float switches to send signals to the pump.



Electrode Level Control System (Digital)

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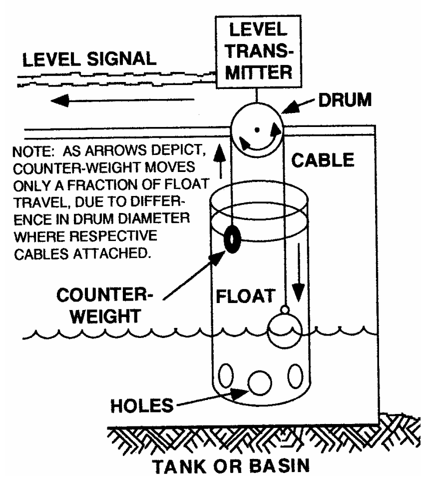
Float switch systems are used primarily in ground storage tanks. As the float rises or falls with the water level, high level or low level switches are tripped activating the pump control circuit. This type of level control will have to be checked on a regular basis to prevent malfunctions. Freezing during the winter is always a problem with float switches and electrodes due to damage caused as the water level (and the ice) rises and falls. Circulation of water inside the tank may help minimize ice buildup.

Alarm sensors are also digital devices. They open a circuit and stop a piece of equipment when a preset alarm condition occurs. These protective devices can monitor temperatures, pressures, vibration and electrical conditions in the system and shutdown equipment when values are outside acceptable ranges.

The other type of instrumentation consists of analog devices. Analog instruments produce a value that can be displayed remotely. Pneumatic systems that use air bubblers and pressure transducers are analog devices that can be used to monitor water levels in storage tanks. Flow meters are another example of analog instrumentation.



Float System Level Controls (Analog)

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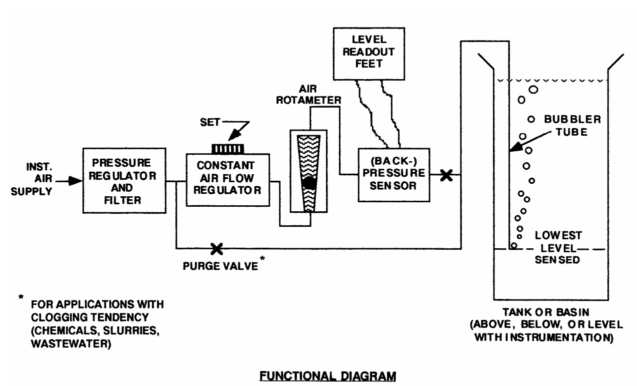
Float systems are usually located inside a conduit or stilling well. The stilling well keeps the float from becoming tangled on interior supports. It can also be heated with a low voltage heater element to protect the system from freezing. Bubbler systems and pressure transducers can be located outside the tank where they are easier to maintain and calibrate.



Bubbler System Level Controls (Analog)

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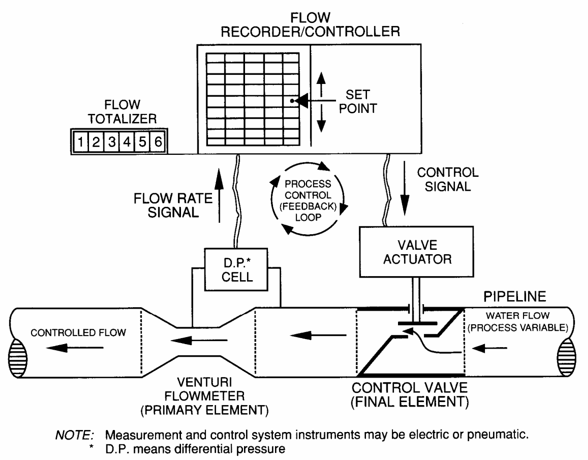
Treatment Plant Operation, Volume 2

Pressure sensing controls are normally located near the bottom of the storage tank. This type of control is activated by the amount of head pressure in the tank. As the pressure increases, a spring or metal band is expanded tripping a micro switch or a mercury switch that then activates the pump. The on and off levels on these switches are set by applying or decreasing the tension on the spring, or by setting manual control points on a dial for the mercury switch. These switches must be protected from freezing and extreme vibrations for proper operation. Pressure transmitters can also be used to control multiple wells or pumps and the signal can be converted into a tank level reading.

Other examples of analog instrumentation include flow controllers and chemical feed systems. A flow meter sends a flow signal to a recorder and a device controller. The controller changes the valve position (as seen below) or the speed of a variable speed pump.



Flow Control Instrumentation Loop

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INSTRUMENTATION LOOPS

Instrumentation is usually set up as either a "feed forward" or a "feedback" loop. An example of a feedback loop would be a venturi flow meter sending a signal to a control valve in order to maintain a set flow rate. The meter would be located downstream of the control valve and would feed a signal back upstream to the control valve. Another example of a feedback loop would be a chlorine analyzer changing the chlorine dosage based on a change in residual downstream of the chlorinator. It would be located downstream and feed the information back to the chlorinator.

Three things determine the rate at which an instrument makes a change in the process. One is the amount of change for each reading. This is referred to as the span. Another is how often readings are taken. This is called the rate. The third is the dead band. Dead band means that there is a range around the set point where no action is taken. For instance, a chemical feed instrument may be set to maintain a pH of 7.0. But the dead band may be set so that no action is taken until the pH rises to 7.2 or falls below 6.8. If the rate is too fast or the span too large, the process conditions may fluctuate as the instrumentation "hunts" for the set point.

Instrumentation loops commonly operate with a 4-20 milliamp signal range. The instrument sends a signal between 4 and 20 milliamps to the controller. The controlling device will then convert the milliamp signal into a 0-100% value for the process variable. If a 4ma signal is sent, it represents a 0% or off condition. A 20ma signal represents a 100% condition. A signal between 4 and 20 milliamps is converted into the appropriate percentage variable by subtracting 4 from the signal and dividing the difference by the 16ma span of the signal. For example, an 8ma signal represents a 25% process value (8-4 =4 and 4/16 = 25%.) A 14.3ma signal represents a 64% value (14.3-4 = 10.3 and 10.3/16 = 64%.)

SCADA SYSTEMS

Many large and small systems are controlled by computerized SCADA systems. SCADA stands for Supervisory Control And Data Acquisition. The SCADA system is comprised of a central control computer and a number of satellite processors at pumping stations and wells or different processes at the water treatment plant. The satellite processors are known as Remote Terminal Units (RTU).) The central computer will contact each remote terminal unit by radio or telephone every 60-90 seconds. The RTU will upload any new data at its location to the central computer. The central computer will log the data for future access and decide if any new equipment actions should take place.

If new action is required, the central computer will issue a command to the RTU. The RTU will be responsible for initiating a startup or shutdown sequence for the equipment or change a control adjustment. The central computer cannot start pumps or open valves. It can only issue the supervisory command to the RTU. The other part of SCADA, the data acquisition part, includes logging each data point or process variable in a database. This information can be archived or accessed to evaluate system conditions or control responses for the control system.

Security issues for SCADA systems include the need to backup the database to a separate, secure had drive regularly. This is important because the data may be needed to reload and restart the system if it should crash. Access to the system must also be protected by passwords, encrypting data, and firewalls. Wireless systems that rely on radio transmission to relay data are more susceptible to security breaches than hardwired systems.

BASIC STUDY QUESTIONS

1. Why is a maintenance program important?
2. Why would a bearing that has just been lubricated run too hot?
3. What condition would indicate that the pump and motor might be misaligned?
4. What is the most common maintenance problem on a diaphragm or piston pump?

ADVANCED STUDY QUESTIONS

1. Which pump and motor parts may be damaged by misalignment?
2. Why should fuses be sized for more than the running load amps on the motor?
3. What type of meter measures a pressure drop across a restriction to determine the flow in a pipe?
4. Why would an instrument hunt for a control setpoint?
5. What does SCADA stand for?
6. Which type of telemeter system is most secure?
7. What is a 4-20ma signal used for?

BASIC SAMPLE TEST QUESTIONS

1. Packing must be allowed to drip in order to cool the stuffing box.

   A. True
   B. False

2. Which of these statements is true regarding changing pump packing?

   A. The joints should be staggered.
   B. All of the rings must be replaced.
   C. The lantern ring must be in line with the seal water port.
   D. All of the above

3. A coupling connects

   A. The lantern ring to the packing gland
   B. The impeller to the wear rings
   C. The motor to the pump
   D. The thermal overload to the starter

4. If any two leads on a 3-phase motor are switched:

   A. It will run faster
   B. It will overheat
   C. It will run in the opposite direction
   D. Nothing will happen

ADVANCED SAMPLE TEST QUESTIONS

1. Which of these devices is used to test the insulation of motor windings?

   A. Amp meter
   B. Volt meter
   C. Ohm meter
   D. Megger

2. When a motor single phases, what is the result?

   A. It will run cooler
   B. It will overheat
   C. It will use less energy
   D. It will stop running

3. Which of the following is not an analog instrument?

   A. Flow meter
   B. Level indicator
   C. High level probe
   D. pH meter

4. A pneumatic level sensing system uses:

   A. A float and tape
   B. Electrodes
   C. A bubbler and pressure transducer
   D. None of the above

5. Which of the following is a volumetric feeder?

   A. Reciprocating pump
   B. Peristaltic pump
   C. Auger
   D. All of the above

6. RTU stands for:

   A. Ready To Use
   B. Remote Terminal Unit
   C. Relay Technical Update
   D. Remote Training Unit