CHAPTER 3. WELLS

(Lesson 4 of 4 Lessons)

3.6 OPERATOR RESPONSIBILITY AND RECORDKEEPING

3.60 Health and Safety

Properly designed and constructed well pumping stations should produce water in sufficient quantity and quality to meet the needs of the entire community. If the pumping stations fail to do so, the fault can often be traced to poor operation or neglect. The health and safety of the water users depends on good operation.

3.61 Operator Responsibility

All operators have the responsibility to exercise due care and diligence to protect the water sources under their surveillance; to effectively operate and maintain the water production facilities; and to take corrective action as necessary to ensure that safe and potable water in adequate quantities and pressure is continuously supplied to the water users in the community.

When an area with residences on private wells connects to a public water supply distribution system, the private wells should be disconnected from each residential water system. Otherwise, each residence must install an approved cross-connection control device between the residential and public water supply system.

3.62 Knowledge of the Water Production Facilities

All operators should have a working knowledge of all of the component parts of a well pumping station and completely understand the role each individual part performs in the overall operation of the facility.

3.63 Routine Facility Servicing

The frequency of routine service calls to a well pumping facility usually depends on the nature and importance of the pumping facility and the availability of personnel. In small utility operations, the manager may also perform the duties of operator, meter reader, and maintenance personnel. In large utility operations, a full-time staff of qualified operators is usually available, including personnel trained in removing and replacing pumping equipment and electrical components.

Regardless of the size of the water utility, the pumping stations must be checked often enough to ensure that the facility components are receiving proper servicing, that routine maintenance functions are performed, that the plant is operational and capable of producing safe water, and that the security of the plant is intact.

The frequency of service calls for small utility operations may be two or three per week, while a large utility may check their facilities daily including weekends and holidays.

3.64 What to Look For

Look, listen, and feel. When the operator enters the pumping facility, a complete visual inspection of the facility should be made, including listening for any unusual noises and feeling for vibrations on pieces of equipment such as motors and pumps.

3.65 Forms

Some type of inspection form should be available for the operator to record pertinent data relative to the operation of the pumping facility. Various types of forms have been developed based on the individual preferences of the utility and the characteristics of the facility. Figure 3.30 is an example of a typical form that could be used by the average water utility.

A monthly operational record should be maintained for each well pumping facility. This record should be filled out each time the operator visits the well pumping facility, either for routine service or for other purposes.

The items of information to record will vary depending on the type of installation, but generally speaking the following items are necessary:

1. Date and time of service visit.
2. Water production meter reading.

DATE	TIME	METER READING IN GALLONS	WATER PRODUCTION IN GALLONS	DISCHARGE PRESSURE	AIR LEVEL IN TANK	LUBE OIL ADDED	STANDING WATER LEVEL	OPERATOR	REMARKS
31									
30									
29									
28									
27									
26									
25									
24									
23									
22									
21									
20									
19									
18									
17									
16									
15									
14									
13									
12									
11									
10									
9									
8									
7									
6									
5									
4									
3									
2									
1									
LAST DAY OF PREVIOUS MONTH									
TOTAL									

Fig. 3.30 Pumping facility inspection form

3. Electric power meter reading. (Optional.)
4. Amount of lineshaft oil added.
5. Oil level if motor is equipped with motor bearing oil reservoir.
6. Greasing frequency.
7. Air level in pressure tank.
8. Water level in storage tank if well pumps directly to tank.
9. Status of chlorination equipment, including feed rate and amount of chlorine used. (Scales or graduated solution tank required.)
10. Standing water level in well. (Recommend monthly, but could be performed quarterly.)
11. Water level in well before and after pumping and well yield.
12. General operation and appearance of facility. Note any unusual conditions or observations such as noise, vibration, and signs of vandalism.

3.66 Records

In previous sections, we have discussed the importance of maintaining good records. We cannot overstress that recordkeeping is an extremely important part of any water purveyor's operation. Often, recordkeeping for the small water system operator is minimal at best. The operator must realize that there is no substitute for good records.

Due to the variety and size of the various types of water utilities, it is difficult to set forth a specific guideline as to what type of records should be maintained. At a minimum, recordkeeping should cover the following areas of operation:

1. *NEW CONSTRUCTION RECORDS*

   New water facilities added to the system (wells, pumps, boosters, storage tanks, water mains, chlorination equipment) should be adequately recorded on an as-built (record) drawing showing type and location of facilities installed.

   For well pumping stations, this should also include copies of the well drillers' report, well log, pump suppliers' equipment sheet with performance curves, construction details of the pump base and related appurtenances, motor specifications, pump controls, wiring diagrams, parts list, and operating instructions.

2. *EQUIPMENT RECORDS*

   Individual equipment items should have the manufacturers' specifications and literature available for review along with any warranty documents.

3. *REPAIRS AND MODIFICATIONS*

   Records of repairs and modifications to well pumping facilities should be accurately maintained with a drawing showing what work was done.

Many states require that well drillers file a "Water Well Drillers' Report" upon completion of the well. The well owner receives a copy of this report. If the well driller is accurate in filling out this report, then it could be a very important document for the well owner's file. Figure 3.31 is a copy of a report required in California by the State Department of Water Resources.

Figures 3.32 and 3.33 are examples of forms used for recording pump information.

Figure 3.34 is a self-inspection form that could be used by the operator as a starting point toward maintaining adequate records.

The length of time that records must be kept from a legal standpoint is generally considered to be seven years. However, records pertaining to wells, equipment, water production, and other pertinent data should be kept longer than seven years.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 140.

3.6A What might cause a properly designed and constructed well pumping station to fail to produce water in sufficient quantity and quality to meet the needs of the entire community?

3.6B What should an operator do when entering a pumping facility for an inspection?

3.6C Recordkeeping should cover what areas of operation?

3.7 SAND IN WELL WATER SYSTEMS

3.70 Sources of Sand

Nearly all wells produce a certain amount of sand. Every reasonable effort should be made to prevent sand particles from entering the distribution system.

Wells drilled in *ALLUVIAL*[42] formations where the water-bearing aquifers consist of numerous layers of sand and gravel deposits are susceptible to sand production. In many localities, formations of sand and gravel are the only water-bearing formations of sufficient yield available to a community. Properly designed and constructed wells can be drilled in these types of formations that produce high yields while at the same time are virtually sand free. A carefully designed gravel envelope well, with selected louvers or well screen, supported by an engineered

[42] *Alluvial* (uh-LOO-vee-ul). Relating to mud or sand deposited by flowing water. Alluvial deposits may occur after a heavy rainstorm.

ORIGINAL
File with DWR

Notice of Intent No.___
Local Permit No. or Date___

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
WATER WELL DRILLERS REPORT

Do not fill in
No. 104475
State Well No.___
Other Well No.___

(1) OWNER: Name___
Address___
City___ Zip___

(2) LOCATION OF WELL (See instructions):
County___ Owner's Well Number___
Well address if different from above___
Township___ Range___ Section___
Distance from cities, roads, railroads, fences, etc.___

WELL LOCATION SKETCH

(3) TYPE OF WORK:
New Well ☐ Deepening ☐
Reconstruction ☐
Reconditioning ☐
Horizontal Well ☐
Destruction ☐ (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:
Domestic ☐
Irrigation ☐
Industrial ☐
Test Well ☐
Stock ☐
Municipal ☐
Other ☐

(5) EQUIPMENT:
Rotary ☐ Reverse ☐
Cable ☐ Air ☐
Other ☐ Bucket ☐

(6) GRAVEL PACK:
Yes ☐ No ☐ Size___
Diameter of bore___
Packed from___ to___ ft.

(7) CASING INSTALLED:
Steel ☐ Plastic ☐ Concrete ☐

From ft.	To ft.	Dia. in.	Gage or Wall

(8) PERFORATIONS:
Type of perforation or size of screen

From ft.	To ft.	Slot size

(9) WELL SEAL:
Was surface sanitary seal provided? Yes ☐ No ☐ If yes, to depth___ft.
Were strata sealed against pollution? Yes ☐ No ☐ Interval___ft.
Method of sealing___

(10) WATER LEVELS:
Depth of first water, if known___ft.
Standing level after well completion___ft.

(11) WELL TESTS:
Was well test made? Yes ☐ No ☐ If yes, by whom?___
Type of test Pump ☐ Bailer ☐ Air lift ☐
Depth to water at start of test___ft. At end of test___ft
Discharge___gal/min after___hours Water temperature___
Chemical analysis made? Yes ☐ No ☐ If yes, by whom?___
Was electric log made? Yes ☐ No ☐ If yes, attach copy to this report

(12) WELL LOG: Total depth___ft. Depth of completed well___ft.
from ft. to ft. Formation (Describe by color, character, size or material)

Work started___19___ Completed___19___

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

SIGNED___
(Well Driller)
NAME___
(Person, firm, or corporation) (Typed or printed)
Address___
City___ Zip___
License No.___ Date of this report___

DWR 188 (REV. 7-76) IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

CONFIDENTIAL
NOT FOR PUBLIC USE
WATER CODE SEC. 13752

Fig. 3.31 Water well drillers' report
(Permission of California Department of Water Resources)

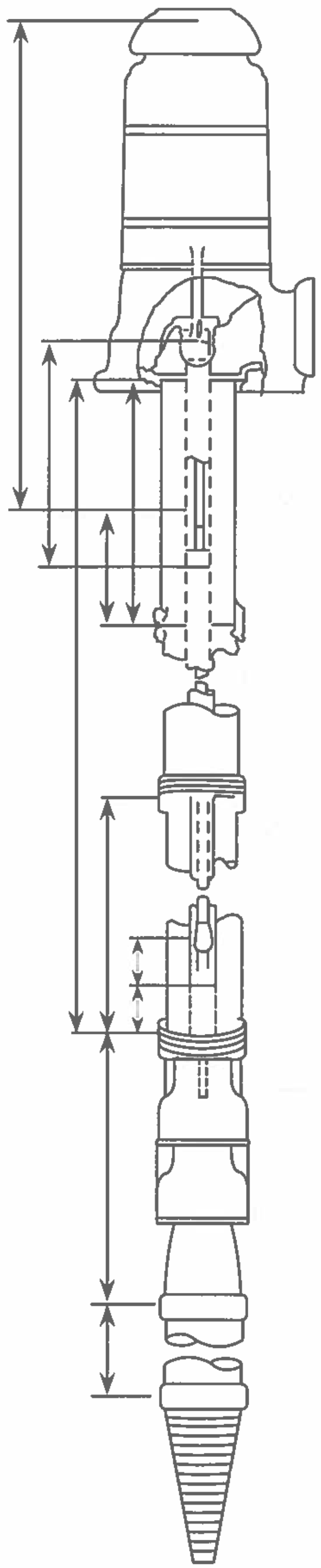
SAMPLE RECORD OF PUMP INFORMATION

Owner ___
Pump purchased from ___
Pump installed by ___
Well Number ___ Date pump installed ___
Pump: Make ___ Type ___
Model ___ Serial No. ___
Pump performance curve number ___
Bowl diameter ___ Capacity ___ Total head ___
Number of bowls ___ Depth of setting ___
Column diameter ___ Shaft diameter ___ Length ___
Length of strainer or tailpipe ___ Length of airline ___
Motor: Make ___ Type ___
Model ___ Serial No. ___
Horsepower ___ RPM ___
Voltage ___ Phase ___ Cycles ___

REPAIR RECORD

Date	Type of Repairs	Repairs made by

Fig. 3.32 Sample record of pump information



Well No. ____________
Location ____________

MOTOR Cat. No. ____________ Date ____________
Serial ________ Frame ________ Thr Brg. ________ Oil Cap. ____
City Inv. No. ______ Mfg. ____ HP ____ Rad. Brg. ____ Oil Cap. ____
Voltage ________ MPM ________ Make ________ Type ________
Type of Shaft ________ Weatherproof Yes ____
No____ Drive Nut Thd. ____

HEAD Cat. No. ____________
Mfg. ________ City Inv. No. ________ Serial No. ________
Col. Size ________ Max. Col. Size________ Col. Bolt Cir ________
Disch. Size ____________ Disch. Bolt Cir. ____________
Tension Nut Type ____________ Thd. ____________

COLUMN
Diameter ____________ Type of Thread ____________

TUBE
Inside Dia. ____________ Type of Thread ____________

SHAFT
Outside Dia. ____________ Type of Thread ____________

BOWLS Cat. No. ____________
Mfg. ____________ Size or Type ________ No. Stages ____
Serial No. ____________ Impeller O.D. ____________
Performance Curve No. ____________ Pump Level ____
Draw Down ________ Capacity ________ GPM at ________

SUCTION
Diameter ____________ Type of Thread________
Adapter ____________ X ____________

STRAINER
Size ____________

AIR LINE
Length ____________

MISCELLANEOUS
Well Dia. ________ Sounding Depth ________ S.W.L. ____
Spiders At ____________ Joints

REMARKS ____________

Pulled By ____________ Installed By ____________

Fig. 3.33 Sample record of well pump
(Source: City of Phoenix, AZ)

WELL INSPECTION FORM

System: ____________ IBM No. ________

Source of Information: ____________

Evaluated By: ____________ Date: ________

Item or Component	Well No.	Well No.	Well No.	Well No.
Site fenced				
Lot paved				
Size of lot				
Nearest property line				
Wastewater disposal				
Nearest abandoned well				
Flood hazard, describe				
Year well drilled				
Cable tool				
Gravel envelope				
Hard rock or other				
Casing size and depth				
Conductor size and depth				
Sanitary grout seal, depth				
Perforations, depth, type				
Pedestal height				
Pump base sealed				
Slab around pump base, type				
Pump in pit, special construction				
Well casing vent, approved type				
Air-vac relief valve, approved type				
Well head seal, approved type				
Gravel tube, approved type				

Fig. 3.34 Well inspection form

Item or Component	Well No.	Well No.	Well No.	Well No.
Sampling tap, approved type				
Type of meter				
Type pump, HP				
Pump capacity, GPM				
Pump setting				
Lubrication, oil or water				
Power, electric or gas				
Auxiliary power, gearhead/generator				
Pump control				
Pressure range, psi				
Frequency of use				
Pump discharges to -				
Pressure tank, capacity				
Pressure relief valve				
Pressure tank drains to -				
Air release valve discharge				
Air charger, approved type				
Housing type				
Floor material				
Housekeeping				
Chemicals fed at well				
Chemical application point				
Well records maintained				
Pump efficiency tests				
Well log				
Water level measured				

Fig. 3.34 Well inspection form (continued)

filter pack, should operate many years without producing any significant quantities of sand. However, the typical perforated casing or open-bottom well that has penetrated water-bearing sand formations is likely to produce sand. Some wells produce sand from the very beginning while others may be in use for some length of time before it is evident that the quantity of sand produced by the well is causing problems.

3.71 Problems Associated with Sand

The abrasive action of sand can damage well pumping facilities, consumers' fixtures and appliances, water meters, and precision equipment. In addition, sand can accumulate in the mains in the distribution system, thereby reducing their carrying capacity and increasing friction loss. Sand can also be carried into the consumers' premises with resultant complaints. Excessive sand production from a well could create cavities in the water-bearing formations and result in the eventual collapse of unstable overlying strata (layer of soil) and damage to the well. Tests have demonstrated that it is the sand particles larger than 200 mesh (74 microns) that cause the most trouble. Almost all sand contained in well water is this size or coarser.

Several methods are available to the well system operator to reduce sand production to an acceptable level. One method is to install a sand separator designed to remove the objectionable sand and other solids from the well water. Another method would be to pump the well at various rates of flow to determine if a lower rate of flow would reduce the amount of sand to an acceptable level. Many times, a small change in water production will make a large change in sand production. In addition, if the system hydraulics permit, the well or wells producing objectionable amounts of sand could be operated on a continuous basis by either raising the cutoff pressure or, preferably, by controlling the operation of the well pump by means of a time clock. An alternative, and perhaps less desirable, approach would be to keep the sand-producing well in an emergency or standby mode. This can be done by setting the cut-in (start) and cutoff (stop) pressure 10 pounds (psi) below the other pumps in the system.

If sand production from a well cannot be controlled by the methods described, then rehabilitation of the well or eventual abandonment may be necessary.

Many water utilities have adopted new well specifications that define a sand-free well as one having a sand content of fewer than five milligrams per liter. This is measured by a properly located Rossum sand tester when it is surged and pumped at 1,000 gallons per minute (63 liters/sec). An alternative to this specification would be a sand content of fewer than five milligrams per liter for a 10-minute period after the well pump starts.

3.72 Flushing Mains[43]

Numerous factors must be considered when a flushing program is established, such as hydraulic gradient from the sources of supply, size of the mains within the distribution system, location of the main line valves, location of the flushing outlets, and the ability to dispose of large quantities of water in a short period of time.

Generally speaking, the majority of sand complaints are usually associated with smaller mains and deadend lines. Repeated flushing of small diameter mains may be ineffective and costly. Sand problems associated with small mains may originate from the larger mains supplying them; unless the larger mains are adequately flushed, sand complaints are likely to continue from consumers served by the small mains.

Available data suggest that flushing velocities should be at least five feet per second (1.5 m/sec) or higher, and the total volume of water flushed should be 10 times the volume of the main. Velocities in this range are more readily obtainable in smaller mains, but may be difficult to achieve in larger mains unless special flushing outlets are provided.

The flushing guidelines shown in Table 3.9 are for each 1,000 feet (300 m) of water main and are based on a velocity of five feet per second (1.5 m/sec).

TABLE 3.9 FLUSHING GUIDELINES

Main Size, Inches	Flow, GPM	Flushing Time, Minutes	Volume of Water to Dispose of, Gallons
4	220	30	6,000
6	450	30	13,500
8	775	30	23,250
10	1,225	30	36,750
12	1,750	30	52,500

Flushing techniques and procedures should be tailored to the characteristics of the distribution system. In order to obtain the desired velocity of five feet per second (1.5 m/sec) or more, it may be necessary to alter the normal water flow to a problem area by closing off selected valves and concentrating the flow in a given section of main. If the sand problem area is extensive, flushing should start on the source side of the problem area and progress toward the extremities of the distribution system.

Several minutes of flushing may be required before there is any noticeable amount of sand, but once sand is observed, the flushing operation should continue as long as sand is evident, even if the time period exceeds the 30 minute criterion shown in column three of the guideline (Table 3.9). In other words, do not shut off a flushing outlet if any significant amount of sand is present unless there is danger of flooding property. Where it is not possible to dispose of the entire quantity of water needed, it is more effective to flush at the required velocity for a shorter period of time than it is to reduce the velocity.

[43] See Chapter 5, "Distribution System Operation and Maintenance," in *WATER DISTRIBUTION SYSTEM OPERATION AND MAINTENANCE* for additional information on how to flush water mains.

3.73 Test for Sand, Volumetric Method

Numerous devices are available for collecting sand samples, such as settling basins, filtration units, and centrifugal separators. The most frequently used device is the centrifugal sand separator, which is designed for continuous sampling.

The centrifugal sand sampler most often used for evaluating new wells and monitoring existing wells is the Rossum sampler developed in the early 1950s by John R. Rossum, Engineer of Sanitation for the California Water Service Company. Rossum's work on the quantitative measurement of sand and his theoretical and experimental investigations of hydraulic transportation of sand through water mains have become a standard in the water utility field. The Rossum sand sampler is illustrated in Figure 3.35.

The sampler is usually installed on the discharge piping from the well pump. Samples taken immediately downstream from valves, meters, and other fittings that create turbulence are representative if the water velocity is five feet per second (1.5 m/sec) or more. The water enters the sampler tangentially (along the outside edge), and the entrained sand, thrown to the outside by centrifugal force, falls into the graduated tube. The sand-free water flows out through an orifice (opening) in the top of the unit. Flow through the unit is maintained by a flow control valve rated at 0.5 gallon per minute (0.03 liter/sec). Periodically, the graduated tube is checked and the volume of sand recorded, along with the time period the pump has operated. With this information, it is possible to compute the average sand concentration based on the flow through the tester.

Studies conducted by Rossum have shown that the sand concentration is considerably greater when a well is first started than it is after a period of continuous operation. This effect is illustrated in Figure 3.36.

The sand tester is a valuable tool. The tester is used to determine if new wells meet the contract specifications for sand volume. When used as a daily operational tool, any increase in sand production can be readily detected and remedial steps taken before any significant amount of sand enters the distribution system.

3.74 Acceptable Concentrations

Studies have been made that suggest that permissible concentration of sand production from a well should not exceed 0.3 cubic foot per million gallons of water (2.2 cubic centimeters of sand per cubic meter of water) pumped. Sand concentrations above this value will almost always result in sanded meters and consumer complaints. Ideally, the sand concentration should not exceed 0.1 cubic foot per million gallons of water (0.7 cubic centimeter of sand per cubic meter of water).

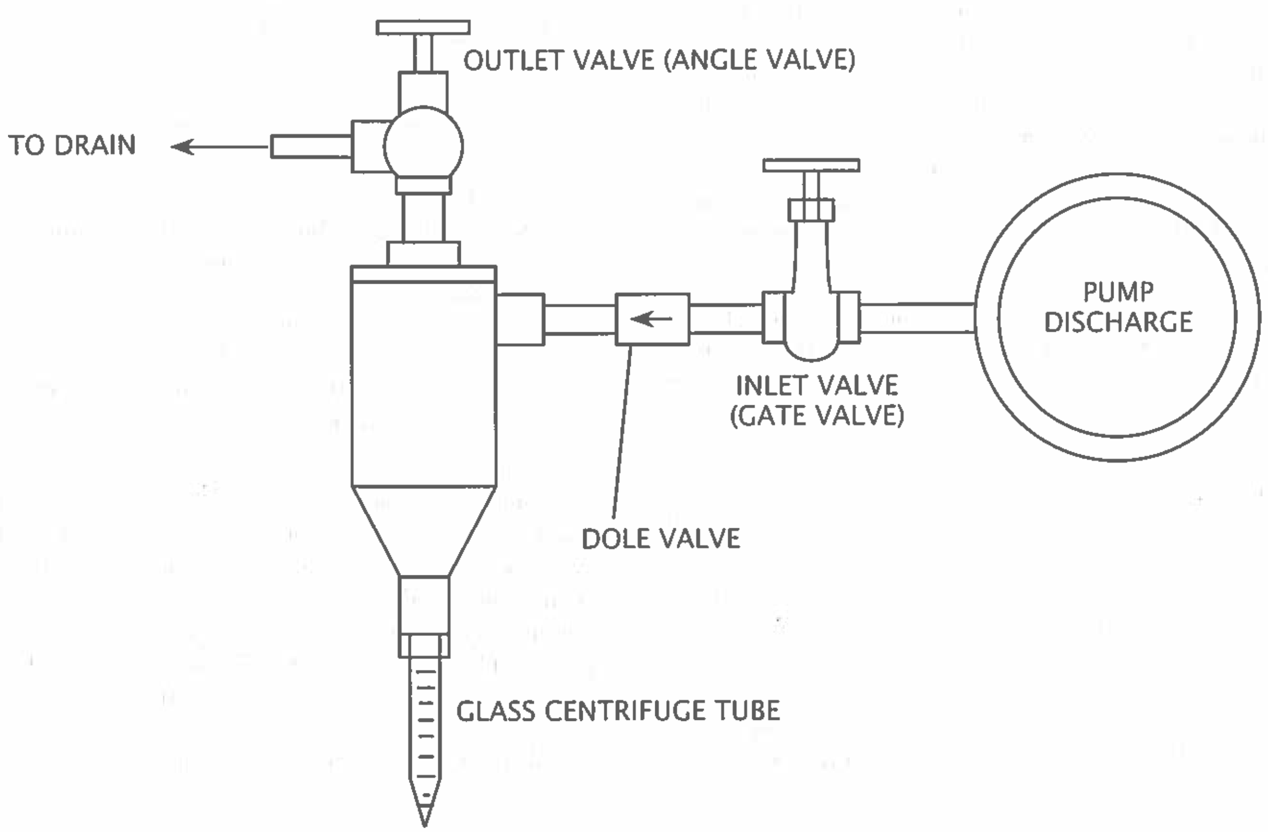


Fig. 3.35 Rossum sand sampler

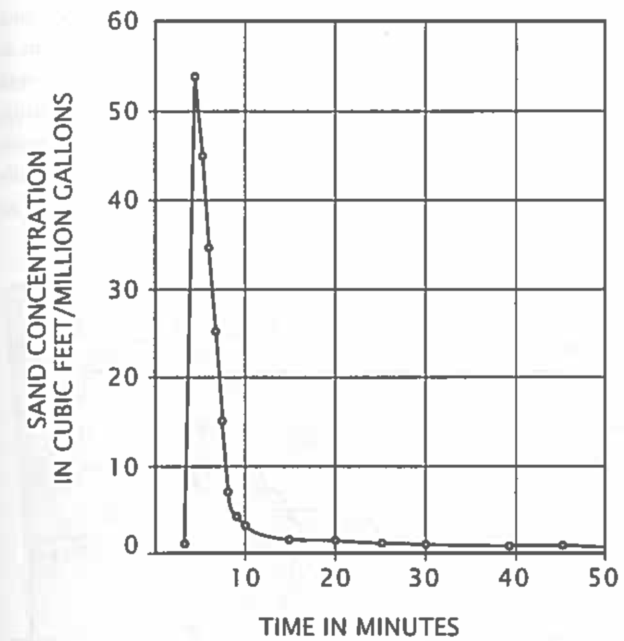


Fig. 3.36 Sand concentration at start of pumping

3.75 Responding to Complaints

Respond to a sand complaint by obtaining the name, address, and phone number of the person calling. Try to determine the source of the sand (well, main) and how many other people have similar problems. Take corrective action such as removing sand at the well, flushing the mains, or relocating the consumer's tap at or near the top of the main.

Detailed records should be maintained showing the date and location of sand complaints, including estimated concentrations. From this record, you can establish a routine flushing program to flush these problem areas before sand builds up to a nuisance level.

When flushing is necessary, notify consumers in the immediate area not to use water during this flushing period. Heavy concentrations of sand in suspension could be drawn into the consumers' premises causing malfunction of appliances, fixture damage, plugging of lawn sprinklers, and numerous other problems leading to additional complaints and callbacks.

Sand complaints may be isolated to only one or two residences in a block. This condition can occur if the consumer's service lateral is tapped into the side of the main near a fitting or valve, which creates turbulence. This type of situation can generally be corrected by relocating the tap at or near the top of the main.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 140.

3.7A How can a well in a sand formation be constructed so that it will be almost sand free?

3.7B What problems are associated with sand in well water?

3.7C The majority of sand complaints concern what part of the distribution system?

3.7D How long should a flushing operation be continued?

3.7E What is the permissible concentration of sand in water from a well?

3.8 ELECTRICAL SUPPLY AND CONTROLS

3.80 Purpose of Electrical Supply and Controls

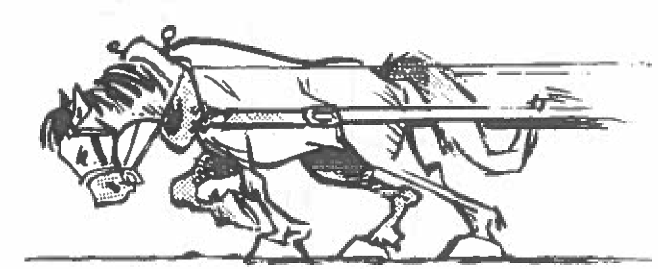
"Control," reduced to its basic definition, is the influence over the action of a device resulting from the measurement and decision of another device or control.

Many options are available for electrical and electronic control of well production. These range from a simple manual start/stop system to automated facilities complete with recorded drawdown and water quality analysis. In this section, we will limit our discussion to the most common and useful types of controls and automation.

3.81 Electrical Supply

3.810 Electricity

Electricity is normally supplied as an alternating current (AC) at 120, 240, or 480 volts. The voltage is considered the driving force and quite often the amount of voltage available depends on the location of the well installation and the ability of the utility company to provide power. The voltage required is related to the size (motor horsepower) of the pump; larger motors require higher voltages. High horsepower (HP) motors may require large surges of power at start-up.



3.811 Motor Starters

Motor starters are basically controls for starting and stopping motors used with large pumps. Upon receiving a signal to start, current is fed into the motor causing the pump to run. Starters can be direct, across-the-line types or what is referred to as step starters. In step starters, power to the motor is increased slowly (in steps) allowing the pump to come up to speed gradually. This prevents pump damage and disturbances along electrical lines. A typical across-the-line starter arrangement for a 3-phase pump is shown in Figure 3.37.

3.812 Auxiliary Power

Auxiliary power is an important consideration to many water districts. If a water supply system depends on wells and hydropneumatic pressure tanks for both supply and storage, a power

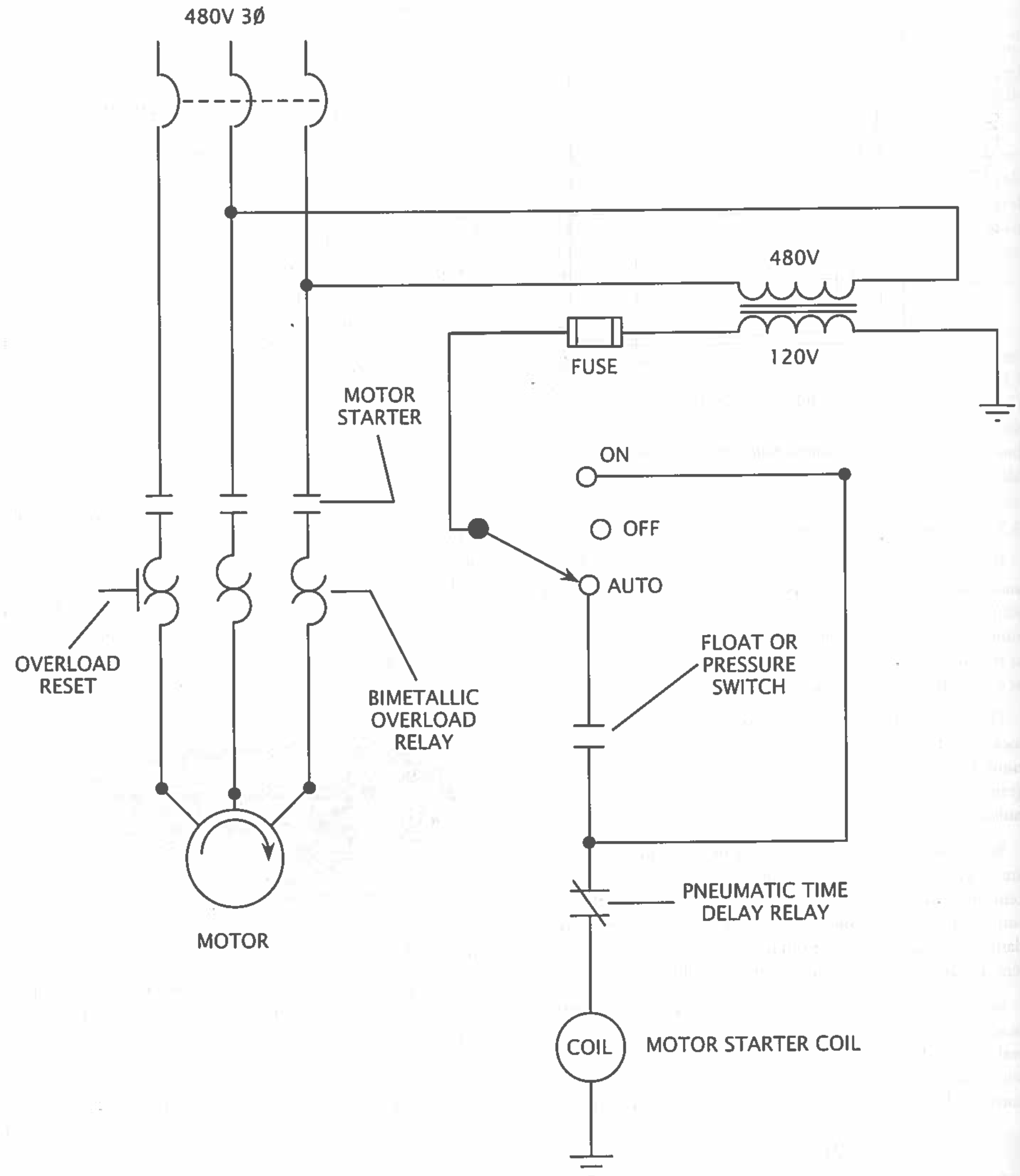


Fig. 3.37 Schematic of typical 3-phase pump control starter circuit

outage could create very severe water shortages. Auxiliary power is not difficult to provide at well sites, but it is expensive. These systems can be installed to start and stop automatically and are quite dependable. A typical gasoline-driven engine generator is shown in Figure 3.38. There are numerous manufacturers of diesel or gasoline-powered generators and they can be obtained in almost any size.

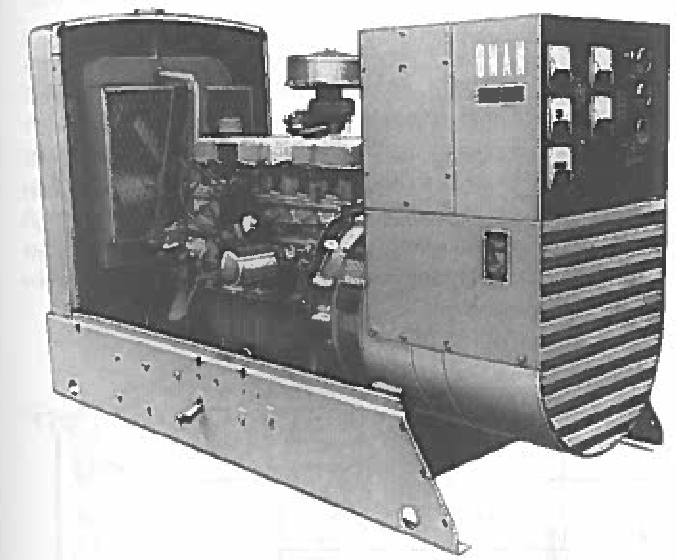


Fig. 3.38 Gasoline-powered auxiliary power generator
(Photo courtesy of Onan Corporation, Minneapolis, MN)

The manufacturers of auxiliary generators also produce automated control packages, but the most commonly used control device is a time delay starter. If a power failure occurs, a relay will sense the loss of power and drop out. A timer then measures a definite time delay that power is off and, after a predetermined period, the auxiliary engine is activated. Shutdown usually occurs in the same manner.

Although we are not going to describe auxiliary power systems in detail here, they should be an important consideration for any water district. These systems can be a real asset under very adverse conditions.

3.82 Pump Controls

3.820 Types of Controls

There are three major types of pump controls: (1) ON/OFF, (2) proportional, and (3) derivative (sometimes called "reset" or "rate"). Electrical controls fall mostly into the first category. ON/OFF, the simplest form, consists of a measured variable such as the level in a pond, or the pressure in a tank, which upon falling to some preset level, closes a switch contact. This engages a motor, which drives a pump to increase the level until it reaches a preset cutoff point. For most applications, the use of the simple ON/OFF set of controls is quite acceptable, and it has the advantages of being low in cost, having few parts, and performing reliably.

As drinking water regulations become more stringent, some form of proportional control will be needed. Proportional control provides more corrective effort as the measured variable gets farther from the *SET POINT*.[44] In the case of the reservoir level, this might mean that as the level gets low, and then lower, several additional pumps may be called upon to pump into it. As the level approaches the desired level, the extra pumps are turned off and, eventually, as it arrives at the set point, all pumps stop. Figure 3.39 shows the typical start/stop arrangement for both ON/OFF and proportional control systems.

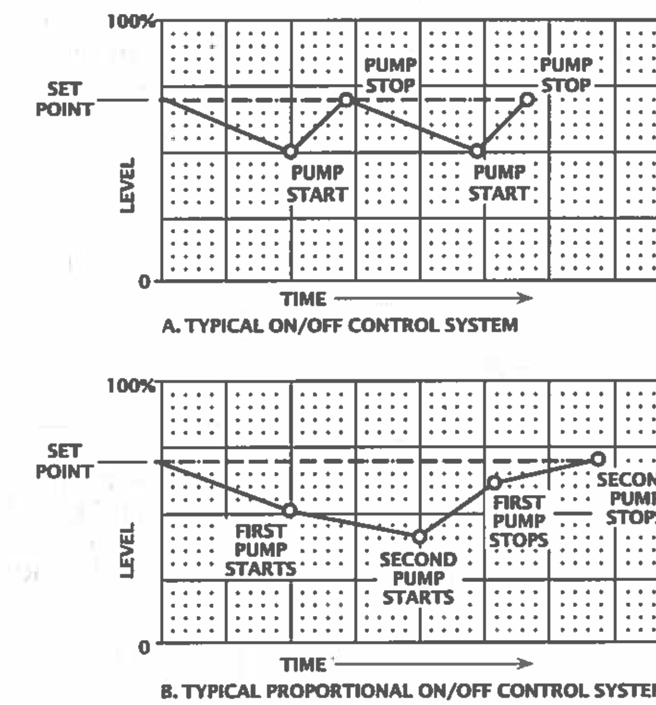


Fig. 3.39 Typical pump start/stop control systems

The derivative or rate controls are used to maintain water levels or pressures within very close tolerances. This type of control is normally coupled with variable-speed motor drives. As the need arises, the controller can cause the pump to increase or decrease its speed to keep water levels or pressures within closely confined limits. Unless the system is highly sophisticated or is restricted by critical operating guidelines, rate controls are seldom used.

3.821 Control Systems

Control systems vary but practically all pumping facilities have some kind of automatic start/stop arrangement. Various

[44] *Set Point.* The position at which the control or controller is set. This is the same as the desired value of the process variable. For example, a thermostat is set to maintain a desired temperature.

pump start/stop sequences are associated with one or more of the following: pressure, water level, time sequences, heat protection, backspin protection, flow, and water quality. The control system is quite often coupled with recordings of flow, bearing temperatures, pressure, water levels, and alarms. The two most common pump control elements are pressure and water level.

3.822 Pressure

Pressure is a necessary element of a water system and can easily be monitored at various locations in the system. The most common such pressure regulation system is that associated with hydropneumatic tanks. As a pressure reduction is sensed, a signal is sent to the pumps to start. The subsequent pump start-up pushes water into the system, which results in an increase in pressure. Once the desired pressure is reached and sustained for a predetermined length of time, a signal is sent to the pump, ordering a shutdown. High- or low-pressure cutoffs (signals to shut off the pumps if pressure is too high or too low) are common safety features built into the system. These are often coupled with alarms that alert the operator to unusual conditions at the pump. High pressure might indicate valve failure or blockage in the discharge lines. Low pressure would be an indicator of excessive water use or a broken water line. In either case, the automatic pressure controls provide a mechanism for shutting down the pumps until the problem is located and corrected.

3.823 Water Level

The most frequently used pump control system is the water level controller in reservoirs and storage tanks. A sensor measures the water level and signals the pump to start or stop. As the water level is lowered in the tank, the pump is instructed to start. Once the tank has filled, the pump is ordered to stop. A typical pump control system from a reservoir is shown in Figure 3.40. However, well pump starts/stops can also be controlled by the water level in a well.

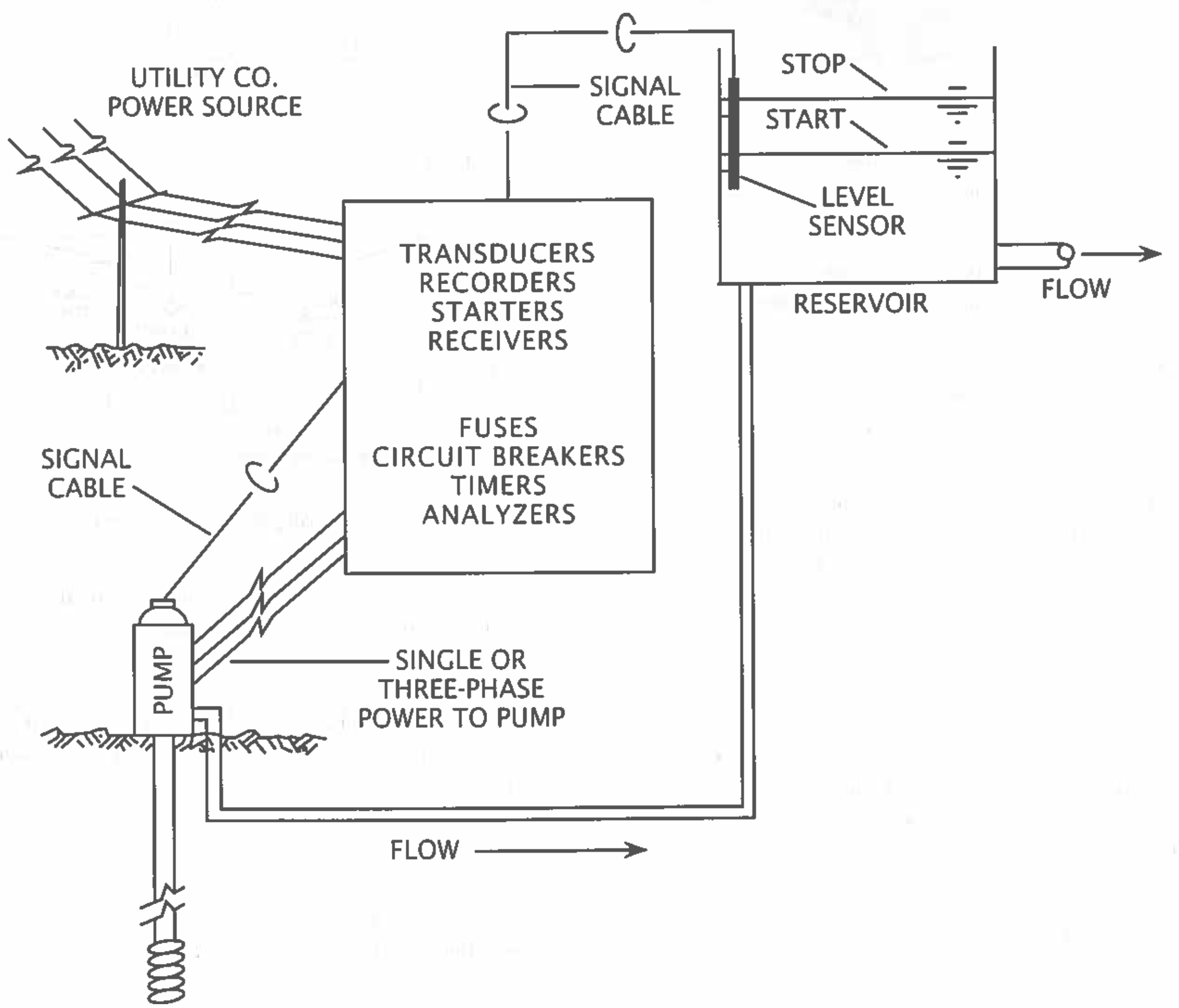
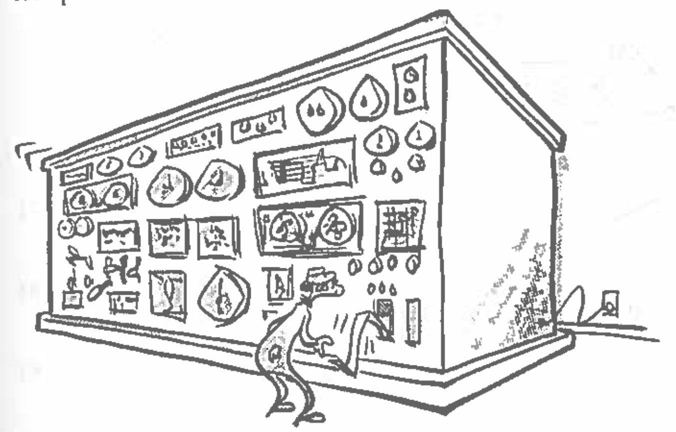


Fig. 3.40 Typical pump control system

In the case of wells, water level operation would only be implemented in the case of low-yield wells that had to be protected from overdraft. Damage to the pumps can occur if the water level is allowed to be drawn below the pump bowls. If low water level appears to be a real problem associated with a particular well, then some provision for low level shutdown must be made.

Other items that are often monitored or controlled automatically at pump installations are excessive power demand by the pump, bearing heat on the motor or pump, turbidity measurements, and flow. Backspin protection[45] is provided for with time delays built into the automatic controls. High head or high volume pumps are sometimes shut down through the use of automatic pump control valves. The total number and combination of controls of pumps is extremely large but automation can provide a high measure of reliability along with lower cost for operation and maintenance.



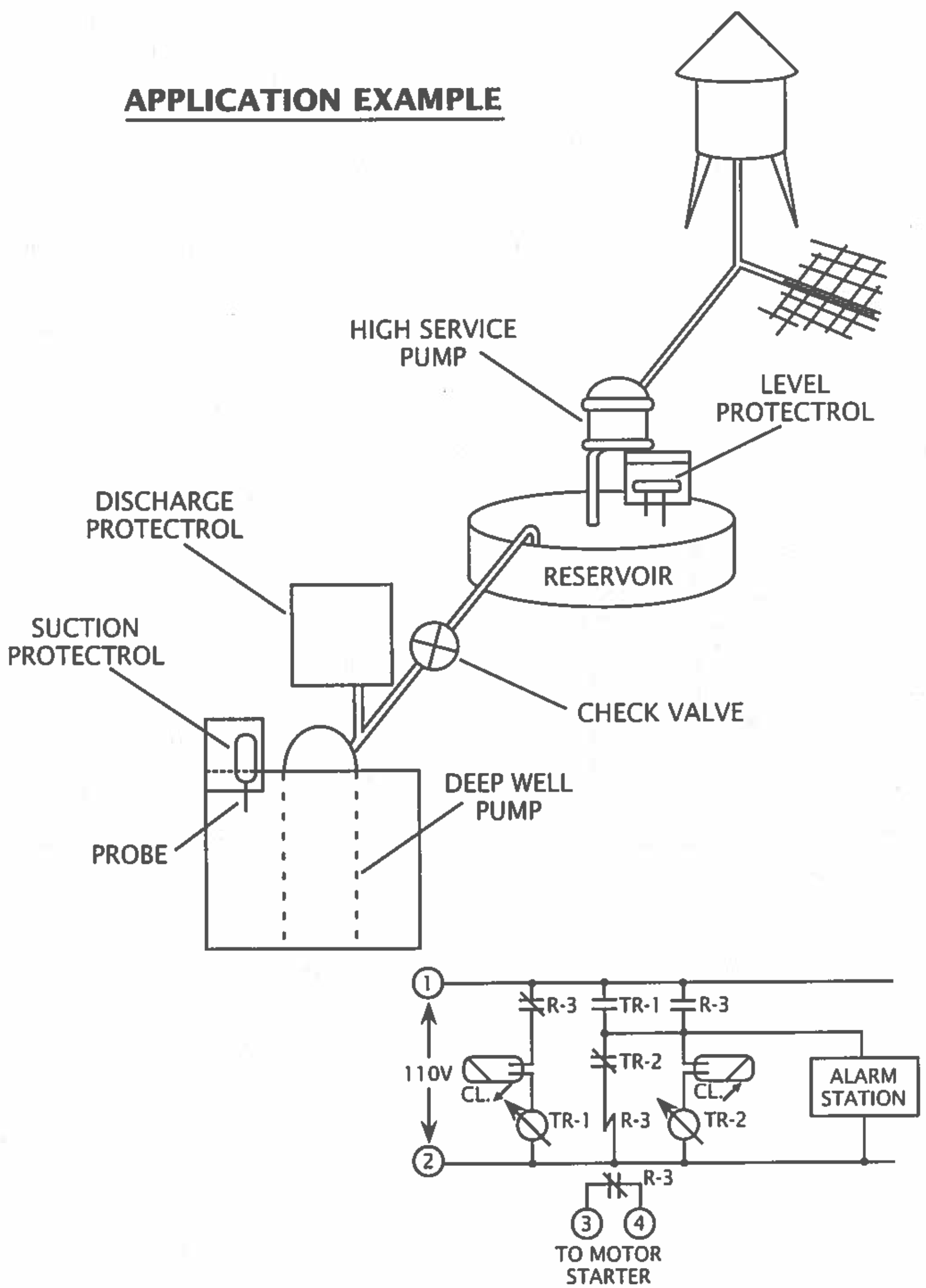
3.83 Equipment

Control equipment ranges from direct, connected units from tanks to pumps joined by signal wires, to units separated by several miles from the pumps, which transmit signals through telephone lines or by radio. Definitions of equipment commonly used in control systems are listed in Section 3.84. Figure 3.41 shows a typical pump control operation.

3.84 Common Electrical Control Definitions

1. *ALARM CONTACT.* A switch that operates when some preset low, high, or abnormal condition exists.
2. *ANALYZER.* A device that conducts a periodic or continuous measurement of turbidity or some factor such as chlorine or fluoride concentration. Analyzers operate by any of several methods including photocells, conductivity, or complex instrumentation.
3. *CONTACTOR.* An electric switch, usually magnetically operated.
4. *CONTROLLER.* A device that controls the starting, stopping, or operation of a device or piece of equipment.
5. *HEAT SENSOR.* A device that opens and closes a switch in response to changes in the temperature. This device might be a metal contact, or a thermocouple that generates a minute electric current proportional to the difference in heat, or a variable resistor whose value changes in response to changes in temperature. Also called a temperature sensor.
6. *INTERLOCK.* A physical device, equipment, or software routine that prevents an operation from beginning or changing function until some condition or set of conditions is fulfilled. An example would be a switch that prevents a piece of equipment from operating when a hazard exists.
7. *LEVEL CONTROL.* A float device (or pressure switch) that senses changes in a measured variable and opens or closes a switch in response to that change. In its simplest form, this control might be a floating ball connected mechanically to a switch or valve, such as is used to stop water flow into a toilet when the tank is full.
8. *MEASURED VARIABLE.* A factor (flow, temperature) that is sensed and quantified (reduced to a reading of some kind) by a primary element or sensor.
9. *PRESSURE CONTROL.* A switch that operates on changes in pressure. Usually this is a diaphragm pressing against a spring. When the force on the diaphragm overcomes the spring pressure, the switch is activated.
10. *PRIMARY ELEMENT.* A device that measures (senses) a physical condition or variable of interest. Floats and thermocouples are examples of primary elements. Also called a sensor.
11. *RECEIVER.* A device that indicates the result of a measurement, usually using either a fixed scale and movable indicator (pointer), such as a pressure gauge, or a moving chart with a movable pen like those used on a circular flow-recording chart. Also called an indicator.
12. *RECORDER.* A device that creates a permanent record, on a paper chart, magnetic tape, or in a computer, of the changes in a measured variable.
13. *SENSOR.* A device that measures (senses) a physical condition or variable of interest. Floats and thermocouples are examples of sensors. Also called a primary element.
14. *SET POINT.* The position at which the control or controller is set. This is the same as the desired value of the process variable. For example, a thermostat is set to maintain a desired temperature.
15. *SOLENOID* (SO-luh-noid). A magnetically operated mechanical device (electric coil). Solenoids can operate small valves or electric switches.

[45] If pump and motor are restarted while backspinning (water driving pump in reverse), the shaft may break causing expensive repairs. Provision must be made to prevent this from occurring.



Two pressure elements are manifolded and tapped directly into the suction main. If pressure falls to a danger point, the "cutout" element will close its switch, completing the circuit to the timer (TR-1), which begins to time out. If pressure remains low long enough for timer to time out, its contact will close, energizing the relay (R-3). A normally closed relay contact then opens, stopping the pump. When the pressure rises, the "restore" switch closes, energizing the second timer (TR-2). After it has timed out, its normally closed contact will open, de-energizing the relay, allowing the pump to restart if required by primary control.

Fig. 3.41 Typical pump control operation
(Permission of Automatic Control Company)

16. *STARTERS (MOTOR).* Devices used to start up large motors gradually to avoid severe mechanical shock to a driven machine and to prevent disturbance to the electrical lines (causing dimming and flickering of lights).

    NOTE: Most starters for small motors are "across-the-line," which means that they simply connect the motor terminals to the incoming line. Large motors would impose severe mechanical shock to the driven machine if started this way, as well as creating a severe disturbance to the electrical lines, causing dimming and flickering lights. Therefore, motors over 100 HP (75 kW) are usually started by reduced-voltage starters or two-step starters. The voltage reduction can be accomplished by the use of an auto-transformer with taps that provide 50 percent voltage until the motor and load are moving, then go to full voltage across-the-line. These can be operated manually, in response to a pair of switches, or automatically, in response to motor current or a definite time delay, which allows the assembly time to come up to speed.

17. *TIME LAG.* The time required for processes and control systems to respond to a signal or to reach a desired level.
18. *TIMER.* A device for automatically starting or stopping a machine or other device at a given time.
19. *TRANSDUCER.* A device that senses some varying condition measured by a primary sensor and converts it to an electrical or other signal for transmission to some other device (a receiver) for processing or decision making.

    NOTE: Flowmeters and heat sensors are examples of transducers.

20. *VARIABLE FREQUENCY DRIVE.* A control system that allows the frequency of the current applied to a motor to be varied. The motor is connected to a low-frequency source while standing still; the frequency is then increased gradually until the motor and pump (or other driven machine) are operating at the desired speed.

    NOTE: This system offers the additional advantage of continuous control of speed, in accord with some measurement.

3.85 Instrumentation

For additional information on controls and instrumentation, see *WATER TREATMENT PLANT OPERATION,* Volume II, Chapter 19, "Instrumentation and Control Systems," in this series of operator training manuals.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on pages 140 and 141.

3.8A The voltage required for a pump depends on what factors?

3.8B Why do large pumps need motor starters?

3.8C List the three major types of pump controls.

3.8D How does a proportional pump control work?

3.9 TROUBLESHOOTING

3.90 Need for Troubleshooting

Approximately 75 percent of well pump and control problems are associated with electricity. The well pump operator should have a good working knowledge of electric circuits and circuit testing instruments before attempting to service or troubleshoot the electric circuits and components commonly used in well pump operations. The operator should not undertake any electrically related troubleshooting or repair job until instructions have been received on how to do it properly and until the operator has been authorized to perform that job.

Small water utilities that do not have a knowledgeable operator or electrician on their staff should arrange with a local electrical firm or pump service company to perform this service.

3.91 Troubleshooting Guide

The "Troubleshooting Guide" on the following pages (Sections 3.910 to 3.916) is designed to assist the operator or service personnel in diagnosing and correcting the most common problems associated with well pumping facilities.

To Use the Guide:

1. Find the appropriate condition in the "Symptom" column or section.
2. Find the cause in the "Probable Cause" column.
3. Perform the "Corrective Action" listed in the third column. The remedy is listed briefly and the procedures may not be detailed enough to cover every possibility.

The operator should not proceed if there is any doubt as to what is meant or what course of action should be taken to correct a given problem.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 141.

3.9A What is the greatest cause of well pump and control problems?

3.9B If you are neither authorized nor qualified to perform electrical repairs, who should do it?

3.9C How would you correct a waterlogged tank?

3.9D What could cause a pump to draw too much power?

TROUBLESHOOTING GUIDE

Symptom	Probable Cause	Corrective Action
3.910 *Pump Will Not Start*	Circuit breaker or overload relay tripped, motor cold.	Reset breaker or reset manual overload relay.
	Fuses burned out.	Check for cause and correct, replace fuses.
	No power to switch box.	Confirm with multimeter by checking incoming power source, notify power company.
	Motor is hot and overload relay has tripped.	Allow motor to cool. Check supply voltage. If low, notify power company. If normal, reset overload relay, start motor, check amperage; if above normal, call electrician.
	Loose or broken wire, or short.	Tighten wiring terminal, replace any broken wires, check for shorts and correct.
	Low line voltage.	Check incoming power, use multimeter; if low, notify power company.
	Defective motor.	*MEG*[46] out motor; if bad, replace.
	Defective pressure switch.	With contact points closed, check for voltage through switch; if no voltage, replace switch; if low voltage, clean contact points; if full voltage, proceed to next item.
	Line to pressure switch is plugged or valve in line has accidentally been shut off.	Open valve if closed. Clean or replace line.
	Pump control valve malfunctioning.	Check limit switch for proper travel and contact. Adjust or replace as required.
	Defective time delay relay or pump start timer.	Check for voltage through relay or timer—replace as necessary—check for loose linkage.
	Float switch or transducer malfunctioning.	If pump is activated by float switch or pressure transducer on storage tank, check for incoming signal; if no signal, check out switch or transducer with multimeter. If OK, look for broken cable between storage tank and pump station.
3.911 *Pump Will Not Shut Off*	Defective pressure switch.	Points in switch stuck or mechanical linkage broken, replace switch.
	Line to pressure switch is plugged or valve in line has been accidentally shut off.	Open valve if closed. Clean or replace plugged line.
	Cutoff pressure setting too high.	Adjust setting.
	Pump control valve malfunctioning.	Check limit switch for proper travel and contact. Adjust or replaced as required.
	Float switch or transducer malfunctioning.	Defective incoming signal, check and replace components as required. Check cable.
	Defective timer in pump stop mode.	Check for voltage through pump stop timer, replace if defective.
3.912 *Pump Starts Too Frequently*	Pump switch cut-in and cutoff settings too close.	Adjust settings, maintain minimum 20 psi (138 kPa or 1.4 kg/sq cm) differential.
	Waterlogged tank.	Add air to tank. Check air charging system and air release valve. Also, check tank and connections for air leaks.
	Leaking foot valve.	Check for backflow into well; if excessive or if pump shaft is turning backward, correct problem as soon as possible.
	Time delay relay or pump start/stop timers are malfunctioning.	Check relay or timers for proper operation, replace defective components.

[46] *Meg.* (1) Abbreviation of MEGOHM. (2) A procedure used for checking the insulation resistance on motors, feeders, bus bar systems, grounds, and branch circuit wiring. Also see MEGGER.

TROUBLESHOOTING GUIDE *(continued)*

Symptom	Probable Cause	Corrective Action
3.913 *Fuses Blow, Circuit Breaker or Overload Relays Trip When Pump Is in Operation*	Switch box or control not properly vented, or in full-sun or dead-air location, overload relay may be tripping due to external heat.	Provide adequate ventilation (may require small fan). Provide shelter from sun. Paint box or panel with heat-reflective paint, preferably white.
	Incorrect voltage.	Check incoming power source. If not within prescribed limits, notify power company.
	Motor amperage incorrect or thermal relay components incorrectly sized.	Check motor running amperage, verify that thermal relay components are correctly sized to operating conditions. Repeated tripping will weaken units, replace if necessary.
	Motor overloaded and running very hot.	Modern motors are designed to run hot and if the hand can be held on the motor for 10 seconds without extreme discomfort, the temperature is not damaging. Motor current should not exceed *NAMEPLATE*[47] rating. Fifteen percent overload reduces motor life by 50 percent.
3.914 *Pump Will Not Deliver Normal Amount of Water*	Pump breaking suction.	Check water level to be certain water is above pump bowls when operating. If not, lower bowls.
	Pump impeller improperly adjusted.	Check adjustment and lower impellers (qualified personnel only).
	Rotation incorrect.	Check rotation.
	Impellers worn.	If well pumps sand, impeller could be excessively worn thus reducing amount of water pump can deliver. Evaluate and recondition pump bowls if required.
	Pump control valve malfunctioning.	Check limit switch for proper travel and contact. Adjust or replace as required.
	Impeller or bowls partially plugged.	Wash down pump by forcing water back through discharge pipe. Evaluate sand production from well.
	DRAWDOWN[48] more than anticipated.	Check pumping water level. Reduce production from pump or lower bowls.
	Pump motor speed too slow.	Check speed and compare with performance curves. Also, check lift and discharge pressure for power requirements.
3.915 *Pump Takes Too Much Power*	Impellers not properly adjusted.	Refer to manufacturer's bulletin for adjustment of open or closed impellers.
	Well is pumping sand.	Check water being pumped for presence of sand. Restrict discharge until water is clean. Care should be taken not to shut down pump if it is pumping very much sand.
	Crooked well, pump shaft binding.	Reshim between pump base and pump head to center shaft in motor quill. Never shim between pump head and motor.
	Worn bearings or bent shaft.	Check and replace as necessary.
3.916 *Excessive Operating Noise*	Motor bearings worn.	Replace as necessary.
	Bent line shaft or head shaft.	Check and replace, as necessary.
	Line shaft bearings not receiving oil.	Make sure there is oil in the oil reservoir and the oiler solenoid is opening. Check sight gauge drip rate, adjust drip feed oiler for 5 drops per minute plus 1 drop per minute for each 40 feet (12 m) of column.

[47] *Nameplate.* A durable, metal plate found on equipment that lists critical installation and operating conditions for the equipment.

[48] *Drawdown.* (1) The drop in the water table or level of water in the ground when water is being pumped from a well. (2) The amount of water used from a tank or reservoir. (3) The drop in the water level of a tank or reservoir.

3.10 ARITHMETIC ASSIGNMENT

Turn to the Appendix, "How to Solve Small Water System Arithmetic Problems," at the back of this manual and read the following sections:

1. A.2, "Areas"
2. A.3, "Volumes"
3. A.10, "Basic Conversion Factors (English System)"
4. A.11, "Basic Formulas"
5. A.12, "How to Use the Basic Formulas"

Check all of the arithmetic in Sections A.2, "Areas" (A.20, A.21, A.22, A.23, A.24, A.25, and A.26) and A.3, "Volumes" (A.30, A.31, A.32, A.33, and A.34) on an electronic pocket calculator. You should be able to get the same answers.

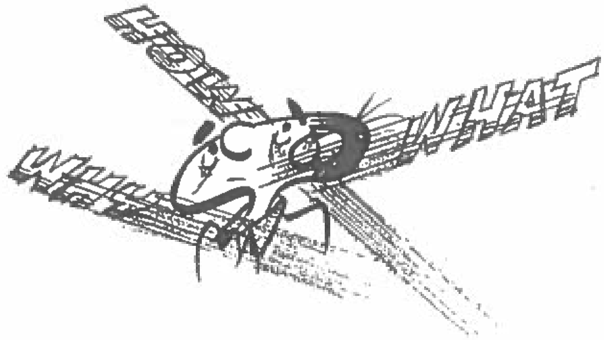
3.11 ADDITIONAL READING

TEXAS MANUAL, Chapter 13,* "Pumps and Measurement of Pumps."

* Depends on edition.

End of Lesson 4 of 4 Lessons on WELLS

Please answer the discussion and review questions next.



DISCUSSION AND REVIEW QUESTIONS

Chapter 3. WELLS

(Lesson 4 of 4 Lessons)

Write the answers to these questions in your notebook. The question numbering continues from Lesson 3.

22. What are the general responsibilities of operators of well systems?
23. How frequently should operators make routine service calls to a well pumping facility?
24. What procedures can be followed to reduce sand problems in wells drilled in sand formations?
25. How would you respond to a complaint by a consumer about sand in the water?
26. If a power failure occurs, how are auxiliary power generators started?
27. What are the advantages of ON/OFF pump controls?
28. Why do pumps have low-pressure cutoff controls?
29. What types of problems might an operator encounter when working with pumps?