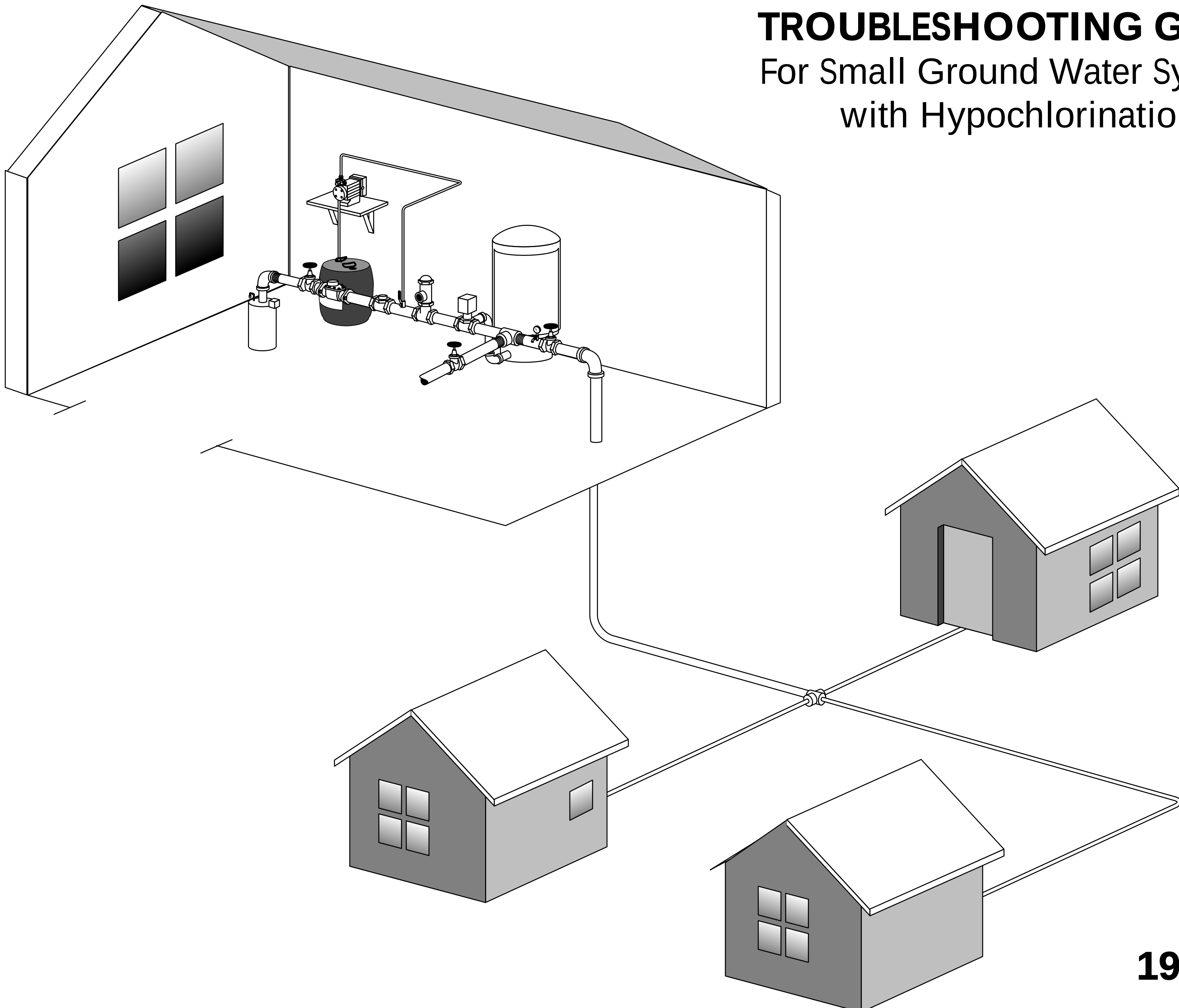
TROUBLESHOOTING GUIDE

For Small Ground Water Systems with Hypochlorination



1999

Developed under EPA Training Grant 825-583-01
Copyright Provisions Apply

Notice

Preface

The objective of this Troubleshooting Guide is to enable an individual to apply a systematic troubleshooting process to solve or correct operational problems of a small ground water system with disinfection using hypochlorination. At no time should the troubleshooter undertake troubleshooting activities for which they are untrained or involve unsafe practices. The troubleshooting process presented in this Guide begins with the simplest, and often the easiest to correct, and continues to the more complex without endangering the troubleshooter or the users of the water system. The troubleshooting steps allow the troubleshooter to assess an operational problem to the point that it can either be easily corrected or requires a technical specialist, e.g. electrician, well specialist, etc. The Guide also encourages the user to contact their state, county, or local drinking water office for water systems for information, technical assistance and advice when responding to a water system problem.

Forward

This Troubleshooting Guide was developed by the UF/TREEO Center in partial fulfillment of a grant number 825-583-01 from the U.S. Environmental Protection Agency-Office of Ground Water & Drinking Water, Kenneth M. "Ken" Hay, EPA project officer.

Acknowledgments

Specific recognition is due to the individuals who were involved in the development and implementation of this troubleshooting guide. See Appendix for the names of the project director, project coordinator, graphics/publication team and the authors of this guide.

Table of Contents

Troubleshooting Distribution Systems

Cross-Connections

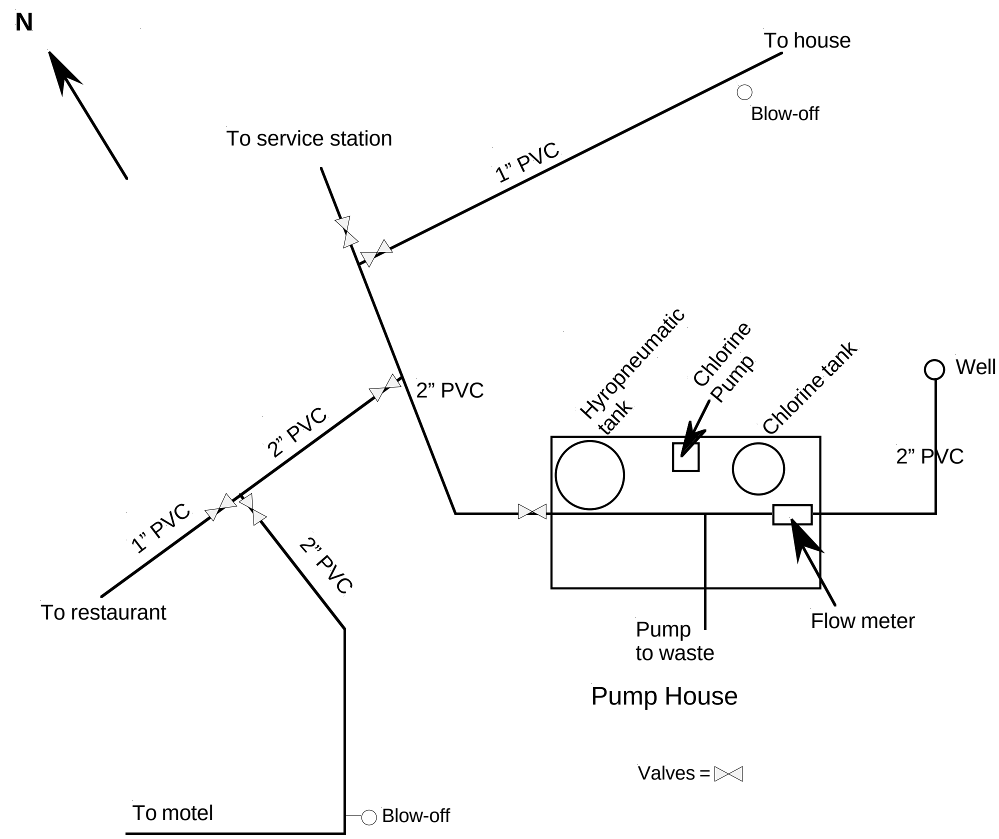
Sampling & Monitoring

Appendix

Organization

Introduction

This Troubleshooting Guide (TSG) is designed for operators of small and very small drinking water systems using wells, hypochlorination, hydropneumatic pressure tanks and small distribution systems.



Note: The drawing above is an example of a water system description and drawing. Use it as a guide in preparing a drawing of your water system.

This TSG is to be used by individuals who have the responsibility to respond to drinking water system problems such as cloudy water, low pressure, no water, taste and odors, etc. Operators of drinking (potable) water systems have a significant responsibility to provide safe drinking water in compliance with the Safe Drinking Water Act (SDWA). This responsibility includes responding to drinking water problems quickly to prevent the delivery of water which is not safe to drink (non-potable).

The information in this TSG is in agreement with the Safe Drinking Water Act (SDWA) and the Amendments of 1986 and 1996 in effect as of January 1, 1999.

Organizing the Troubleshooting Process

All problems with water systems must be treated as serious health risks and require immediate correction. In order to respond quickly and effecitvely to a water system problem requires that certain basic information be readily available. Completing the Water System Technical Information Form at the end of this chapter will compile the information on your system necessary for troubleshooting problems and responding to emergencies.

Resources

In addition to basic information on your system, you need a list of emergency and technical assistance resources. The second form at the end of this chapter provides an Emergency & Technical Assistance Resource Listing.

The individual from the State, County, or Local Drinking Water Office, who inspects your system is a very important local resource. This individual should be notified whenever you have problems with your water system or when you are thinking of making changes or expanding any part of your water system.

Other resources include neighboring water system operators, especially those with system similar to yours, and your state environmental training center, as well as state and national associations. A list of references and resources are provided in Appendix 1.

There are eight Technical Chapters which provide basic information and labeled drawings to assist in describing and troubleshooting small water system problems. Each Technical Chapter also has a glossary of technical terms. The 8 chapters are:

1. Organization
2. Wells
3. Pumps

4. Disinfection (with hypochlorination)
5. Hydropneumatic Pressure Tanks
6. Distribution System
7. Cross Connection Control
8. Sampling & Monitoring

A Troubleshooting Table follows each Technical Chapter. The Troubleshooting Table provides a listing of common water system problems and complaints. For each problem there is step-by-step guidance on how to troubleshoot the possible cause of the problem and the possible corrective actions to take.

Problem	Possible Cause	Possible Solution

The troubleshooting process begins with the simplest possible cause and solution and continues with the more complex possible causes, troubleshooting techniques and possible solutions.

The troubleshooting guidance takes you to the point that a technical specialist or professional is required. When in doubt call in a professional. Correction of some problems may require professional service such as a master electrician, pump specialist, well driller, etc.

Caution: Troubleshooting water system problems may involve exposure to electrical, mechanical, chemical, and confined space hazards as well as slips, trips and falls and other unsafe conditions. Do not attempt to take corrective steps unless you are knowledgeable and familiar with the equipment, systems and activities involved.

Troubleshooting

In troubleshooting a problem information is critical. You are encouraged to set up a file of information on your water system to include manufacturer's literature, drawings of the distribution system piping, sampling plan, etc. The third form at the end of this Technical Chapter, Water System Description & Drawing, is provided for your convenience.

Maintaining records of basic information on a regular basis is helpful to troubleshooting water system problems, e.g. a log of customer complaints can assist in pinpointing the location of a problem and may also help in recognizing the development of a problem.

Take time to review what you know about the problem:

1. What is the nature of the problem? No water, low pressure, color, etc.

2. Has this problem occurred before?

3. What conditions seem to contribute to the problem?

4. Where does the problem or complaint occur?

Next it is important to follow a logical series of steps working from the simplest to the most complex.

For example, in troubleshooting a water pump that has stopped running, start with the power supply first; Has the circuit breaker tripped? Is the outlet working? as opposed to immediately concluding that the pump motor has to be replaced.

Follow the steps in the Troubleshooting Table conducting the troubleshooting process as described and in the sequence presented. You may find that you have to use more than one Troubleshooting Table to identify the cause of a water system problem and take the appropriate corrective action.

It is also important to follow through after troubleshooting, e.g. if the circuit breaker tripped and you have reset the breaker and the system is back on line, you also need to determine why the circuit breaker tripped. This may require an electrician.

In conclusion, remember troubleshooting requires skills and knowledge. As operator of the water system you should be prepared to quickly troubleshoot problems with the water system. This requires access to information and knowing where and what to look for during the troubleshooting process. Finally, if you are not familiar with the troubleshooting process call in an expert, such as a well specialist, electrician, etc. as appropriate.

Water System Technical Information Form

Please complete the following to make this TSG specific to your system:

Water System Components				
Source (s)	Well No. 1	Well No. 2	Well No. 3	Well No. 4
Location				
Depth				
Water Pump; Submersible or Turbine				
Manufacturer				
Horsepower				
Capacity in gpm				
Date and Nature of Last Service				
Chemical Feed Pump				
Manufacturer				
Horsepower				
Capacity in gpm				
Date and Nature of Last Service				
Electrical Controls				
Water Pump				
Hypochlorinator				
Hydropneumatic Tank				
Hydropneumatic Pressure Tank				
Manufacturer				
Size				
Pressure Settings				
Other				

Emergency & Technical Assistance Resources Listing

Please complete the following to make this TSG specific to your system:

	Water System Services			
PWS Number				
	Company	Name	Address	Phone No.
Public Water System (PWS)				
1. Medical Emergencies				
2. State or County Drinking Water Program Representative				
3. Approved Laboratory Service				
4. Electrician				
5. Water System Specialist				
6. Water Pump Service				
7. Chlorine Pump Service				
8. Hypochlorination Supplies				
9. Trenching/Excavation Equipment Service				
10. Plumber				
11. Hydropneumatic Tank Service				
12. Well Driller				
13. Power Supply Service				
14. State Environmental Training Center				
15. State Affiliate, National Rural Water Association				
16. State Affiliate, Rural Community Assistance Project				
17. Other				

Water System Description & Drawing

Line Drawing of Source/Distribution System

Draw your water system on the following page. The drawing on page 1-1 is an example of how the drawing of your system might look. Orient your drawing so the top of the page is North and use roads, buildings, etc. as reference points. Include the following information on your drawing:

1. Well(s)
2. Transmission Line(s)
3. Hypochlorinator(s)
4. Hydropneumatic Pressure Tank
5. Distribution System
    A. piping, valves & blow-offs for lines from:well to disinfection & hydropneumatic tank, and hydropneumatic tank to distribution system
    B. mains
    C. laterals
    D. service connections
    E. valves
    F. blowoffs

Draw your water system here.

North

Glossary of Terms

Blowoffs	A controlled outlet on a pipe line, tank, or conduit that is used to discharge water or accumulations of material carried by the water.
Disinfection	The process used to control disease causing organisms.
Hydropneumatic Pressure Tank	A small, usually less than 1000 gallon, tank used by a hydropneumatic system. The tank contains water and air, typically 1/3 air to 2/3 water.
Hypochlorination	The addition of hypochlorites, such as sodium hypochlorite (bleach) or calcium hypochlorite to water or wastewater to be treated. Hypochlorite is used where chlorine requirements are small or where chlorine gas may pose a hazard.
Hypochlorinators	Hypochlorinators are devices that are used to feed calcium, sodium, or lithium hypochlorite as the disinfecting agent.
Laterals	Small water distribution systems lines. Individual services are normally connected to laterals.
Mains	The larger water lines in a water distribution system. Typically mains have very few service connections.
Non-potable	Water that is not safe to drink.
Potable Water	Water satisfactory and safe for drinking purposes from the standpoint of its chemical, physical, and biological characteristics and in compliance with the Safe Drinking Water Act.
Safe Drinking Water Act	The federal law that authorizes and requires EPA and state health agencies to monitor drinking water quality.
Service Connections	The connection to an individual home of business
State, County or Local Drinking Water Office	The agency with designated regulatory power under the Safe Drinking Water Act (SDWA).
Transmission lines	The piping from the water source, e.g. well, to the point of disinfection and storage.
Troubleshooting	A systematic process of assessing the problem and determining the most probable cause of the problem.
Valves	Any device for controlling the flow of a liquid.

Troubleshooting Wells

Introduction

The purpose of this chapter is to provide background information about wells; types of wells, construction and main components, and the common problems associated with wells, their likely causes, and ways to proceed with their correction. (First, however, it is important to discuss how well problems can affect the health and safety of a community.)

Small system operators usually learn of well problems when complaints are received about no water or low pressure, or the water smells, tastes, or looks bad. Whatever the problem, the operator is responsible for identifying the cause of the problem and for correcting it as soon as possible. The lack of a safe and adequate water supply requires an immediate response. Public health officials regard the lack of a safe and adequate water supply for more than 24 hours as a serious health hazard. The lack of an adequate and safe supply of water means the users are unable to wash, flush away bodily wastes, or safely prepare food and beverages. When tap water is discolored, or has a disagreeable taste or odor, users may reject it and may obtain drinking water from a source that is unsafe.

Background Information

Well Types

To reach the ground waters beneath the earth's surface, a well must be constructed to reach the desired water-bearing level. These structures may be dug, driven, bored, jetted, or drilled depending on the geological formations through which they must pass and the depth to which they must reach.

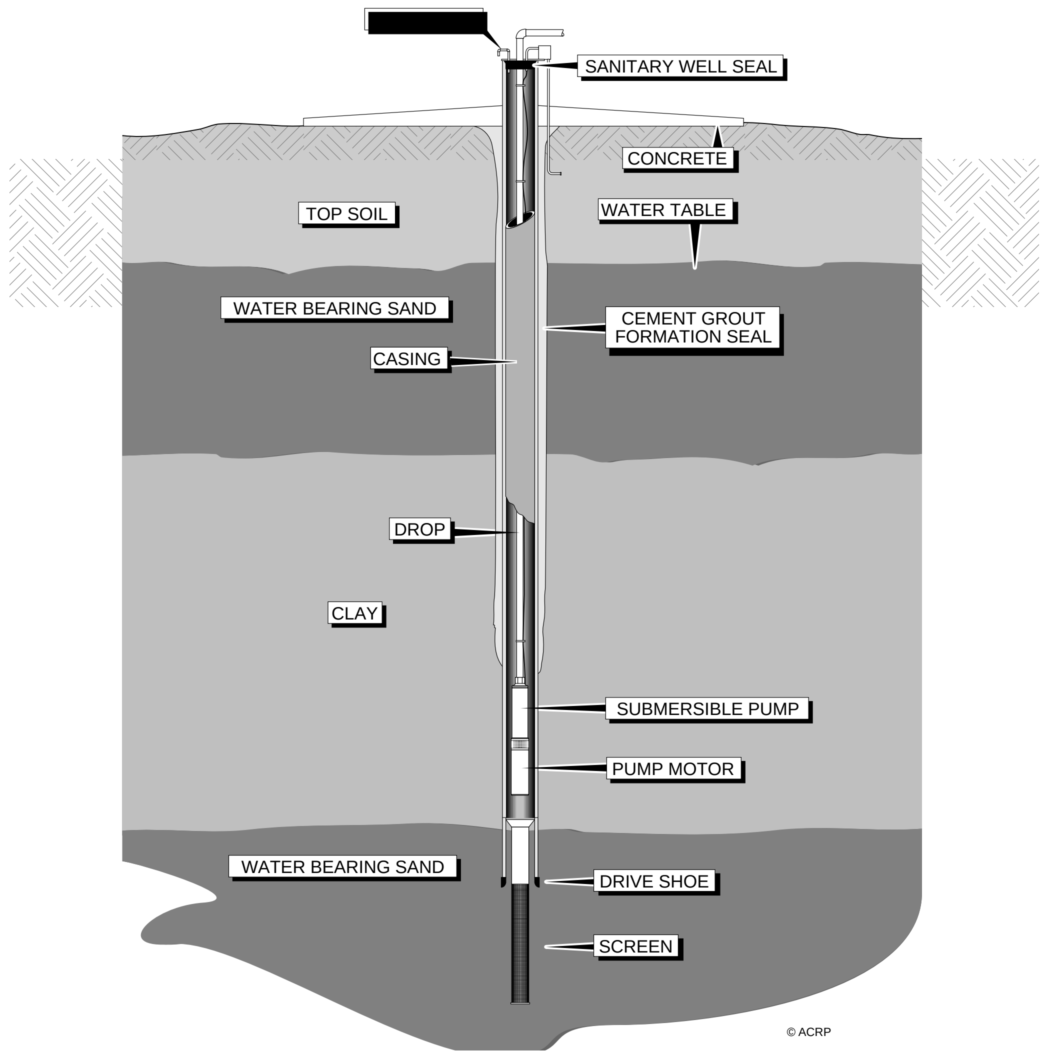
Sinking Methods

Dug, driven, bored, and jetted wells are usually confined to relatively soft soils overlaying rock and to shallow depths normally less than 50 feet (15 meters). Wells using these sinking methods should not be constructed for use as public water sources unless specifically approved by the state regulatory agency. Drilled wells are preferred for potable water supplies and can be used in both soft and hard soil and in rock and may be sunk to depths of several hundred or more feet.

Drilled Wells

Drilled wells can be constructed in all instances where driven, jetted, dug and bored wells are constructed. The larger diameter of a drilled well, compared with a driven or jetted well, allows the use of larger pumping equipment that can develop the full capacity of the aquifer.

Well Components



Most Cannot be seen

There are various components of a well, many of which cannot be observed by the operator. Some of the more important ones follow:

Casing

Well casing is installed in wells to prevent the collapse of the walls of the bore hole, to prevent pollutants (either surface or subsurface) from entering the water source and to provide a column of stored water and a support housing for the pump mechanisms and pipes. The top of the casing should be extended above the ground level around the well so that it will not be flooded.

Grout

Cement grout is used to fill the annular open space left around the outside of the well casing during construction to prevent undesirable water and contamination from entering the well.

Screens

Screens are installed at the intake point of the well to hold back unstable aquifer material and permit free flow of water into the well. The well screen should be of good quality (corrosion-resistant, hydraulically efficient, and with good structural properties).

Sanitary Seal

Well head covers or seals are used at the top of the casing or pipe sleeve connections to prevent contaminated water or other material from entering the well. A variety of covers and seals are available to meet the variety of conditions encountered, but the principles and the objective of excluding contamination are the same.

Pitless Units

Pitless units are used to eliminate the need for a well pit. Because of the flooding and pollution hazards involved, a well pit to house the pumping equipment or to permit accessibility to the top of the well is not recommended. Some states prohibit its use. These units vary in design but generally include a special fitting designed for placement on the side of the well casing. The well discharge piping is screw-threaded into the fitting, providing a tight seal. The pitless system permits the connection of the well piping to the casing underground below frost depth and, at the same time, provides for good accessibility to the well casing for repairs without excavation.

Pump

A submersible pump is normally used to lift water from inside the well casing to the ground surface. In most small systems with minimal treatment of the raw water, the pump also delivers the water to the point of application of chemical treatment, such as chlorination, and then into the storage and distribution system. This is accomplished without exposing the pumped water to the atmosphere. The reader is referred to Chapter 2. Pumps for more details about well pumps and troubleshooting well pump problems.

Troubleshooting Well Problems

Experience has shown that many well problems are related to electricity. Well pumps require electricity to run, and when the electrical supply is interrupted, so is the water supply. What this tells us is that lack of water in the system, or low pressure complaints probably means that electricity is not reaching the well pump. See the Troubleshooting Table that lists this problem and others, and identifies corrective actions.

Troubleshooting Table for Wells

Problem	Possible Cause	Possible Solution
1. Well pump will not start.	1A. Circuit breaker or overload relay tripped.	1A. Reset breaker or manual overload relay.
	1B. Fuse(s) burned out.	1B. Check for cause and correct, replace fuse(s).
	1C. No power to switch box.	1C. Check incoming power supply. Contact power company.
	1D. Short, broken or loose wire.	1D. Check for shorts and correct, tighten terminals, replace broken wires.
	1E. Low voltage.	1E. Check incoming line voltage. Contact power company if low.
	1F. Defective motor.	1F. Contact electrical contractor.
	1G. Defective pressure switch.	1G. Check voltage of incoming electric supply with pressure switch closed. Contact power company if voltage low. Perform maintenance on switch if voltage normal.
2. Well pump will not shut off.	2A. Defective pressure switch.	2A. Check switch for proper operation. Replace switch.
	2B. Cut-off pressure setting too high.	2B. Adjust setting.
	2C. Float switch or pressure transducer not functioning.	2C. Check and replace components or cable as needed.

Problem	Possible Cause	Possible Solution
3. Well pump starts and stops too frequently (excessive cycle rate).	3A. Pressure switch settings too close.	3A. Adjust settings.
	3B. Pump foot valve leaking.	3B. Check for **backflow**. Contact well contractor.
	3C. Water-logged hydropneumatic tank.	3C. Check air volume. Add air if needed. If persistent, check air compressor, relief valve, air lines and connections, and repair if needed.
4. Sand sediment is present in the water.	4A. Problems with well screen or gravel envelope.	4A. Contact well contractor.
5. Well pump operates with reduced flow.	5A. Valve on discharge partially closed or line clogged.	5A. Open valve, unclog discharge line.
	5B. Well is over-pumped.	5B. Check **static water level** and compare to past readings. If significantly lower, notify well contractor.
	5C. Well screen clogged.	5C. Contact well contractor.
6. Well house flooded without recent precipitation.	6A. **Check valve** not operating properly.	6A. Repair or replace check valve.
	6B. Leakage occurring in discharge piping or valves.	6B. Inspect and repair/replace as necessary.

Problem	Possible Cause	Possible Solution
7. Red or black water complaints.	7A. Water contains excessive **iron** (red-brown) and/or **manganese** (black water).	7A. Test for iron and manganese at well. If levels exceed 0.3 mg/L iron or 0.005 mg/L manganese, contact regulatory agency, TA provider or water treatment contractor.
	7B. Complainant's hot water needs maintenance.	7B. Check hot water heater and flush if needed.
8. Raw water appears **turbid** or a light tan color following rainfall.	8A. Surface water entering or **influencing** well.	8A. Check well for openings that allow surface water to enter. Check area for **sinkholes**, **fractures**, or other physical evidence of surface water **intrusion** Check water **turbidity**. Notify regulatory agency if >0.5 **NTU**. Check raw water for coliform **bacteria**. Notify regulatory agency immediately if positive.
9. **Coliform** tests are positive.	9A. Sample is invalid.	9A. Check sampling technique, sampling container, and sampling location and tap.
	9B. **Sanitary protection** of well has been **breached.**	9B. Notify regulatory agency immediately and re-sample for re-testing.

Glossary of Terms

Atmosphere	The gases that surround the earth.
Backflow	A reverse flow condition, created by a difference in water pressures, which causes non-potable water to flow into a potable water system.
Bacteria	Living organisms, microscopic in size, which consist of single cell. Most bacterial utilize organic matter for their food and produce waste produces as the result of their life processes.
Breached	A failure of the well seal, well casing, or well casing grouting.
Check Valve	A special valve with a disc or flap which has a hinge on one edge so that it opens in the direction of normal flow and is forced shut when flows attempt to go in the reverse or opposite direction of normal flows.
Chlorination	The application of chlorine to water, sewage, or industrial wastes, generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results.
Coliform Bacteria	The Coliform group of bacteria is a bacterial indicator of contamination. This group has as one of its primary habitats the intestinal tract of human beings. Coliforms also may be found in the intestinal tract of warm-blooded animals, and in plants, soil, air and the aquatic environment.
Column	The pillar of water inside of the well casing.
Contamination	The introduction into water of toxic materials, bacteria, or other deleterious agents that make the water unfit for its intended use.
Corrosion-resistant	Metal that is not easily corroded by water.
Excavation	Any man-made cavity or depression in the earth's surface, including its sides, walls, or faces, formed by earth removal and producing unsupported earth conditions by reason of the excavation.
Fitting	A pipe component used to connect two or more pieces of pipe of piping appurtenances.
Fractures	A crack or opening in the surface of the earth.
Free Flow	Unrestricted flow of water.
Housing	An area, the casing, that encloses and protects the pump.
Hydraulically Efficient	Piping material with low headloss.

Influencing	Changing the quality of the water in the well.
Intrusion	The flow of surface water into the well.
Iron	This metal causes a rust stain and metallic taste when present in water in concentrations above 0.3 mg/L.
Manganese	This metal causes black stains and objectionable taste when present in water in concentrations above 0.05 mg/L.
NTU	The units of measure of turbidity, Nephelometric Turbidity Units, the measurement as mead with a nephelometric turbidimeter.
Pollutants	Organic or inorganic material that deteriorates the quality of the water.
Sanitary protection	Any means of ensuring that unsanitary or unclean conditions that can result in non edible or nonpotable conditions.
Sinkholes	In geology, a hole extending downward from the surface to an underground cavern or cavity, formed in a variety of ways but commonly by surface water passing downward and dissolving the rock, or an undertrained depression of the land surface, so caused.
Sleeve Connections	The process of placing one pipe, tightly, over another.
State Regulatory Agency	The state agency with regulatory power of the safe drinking water act.
Static water level	The level of water in the well when the well pump is not pumping, i.e. the level of ground water when no water is being removed.
Structural properties	The physical characteristics of a material, e.g. the structural properties of cast iron pipe are that it is very strong but brittle.
Submerged	Below or underneath the surface of the water
Submersible	Designed to be used below the surface of the water, e.g. a submersible pump is located beneath the surface of the water in the well.
Submersible pump	Vertical turbine pumps that are designed so the pump and motor may be submersed in water.
Turbid	Unclear or murky because of stirred-up sediments.
Turbidity	A condition in water caused by the presence of suspended matter, resulting in the scattering and absorption of light rays.
Well pit	A below ground-level structure or vault in which a well is located.

Well Pumps

Background

Pumping equipment can be considered the single most important and vulnerable component in all water supply system. This includes water systems that range in size from single family dwellings that are served by one well, to large water systems that serve metropolitan areas and incorporate many water sources.

In small water systems, the role of pumping equipment is extremely critical. Because these systems are frequently constructed without back-up pumps, a single pump could fail and cause most or all customers to be without water for an extended period of time. Additionally, small systems that utilize hydropneumatic tanks have very little stored water and therefore a pump failure can result in customers being completely out of water within a matter of minutes.

It is therefore important for all operators of water systems, especially small systems, to be familiar with basic troubleshooting techniques for water pumps in order to reduce the frequency of system failures.

In most small water systems, the only water supply pumps consist of those used for withdrawing water from wells. Well pumps in use today consist of centrifugal type pumps. Detailed information on the operating characteristics of centrifugal pumps can be found in the following publications:

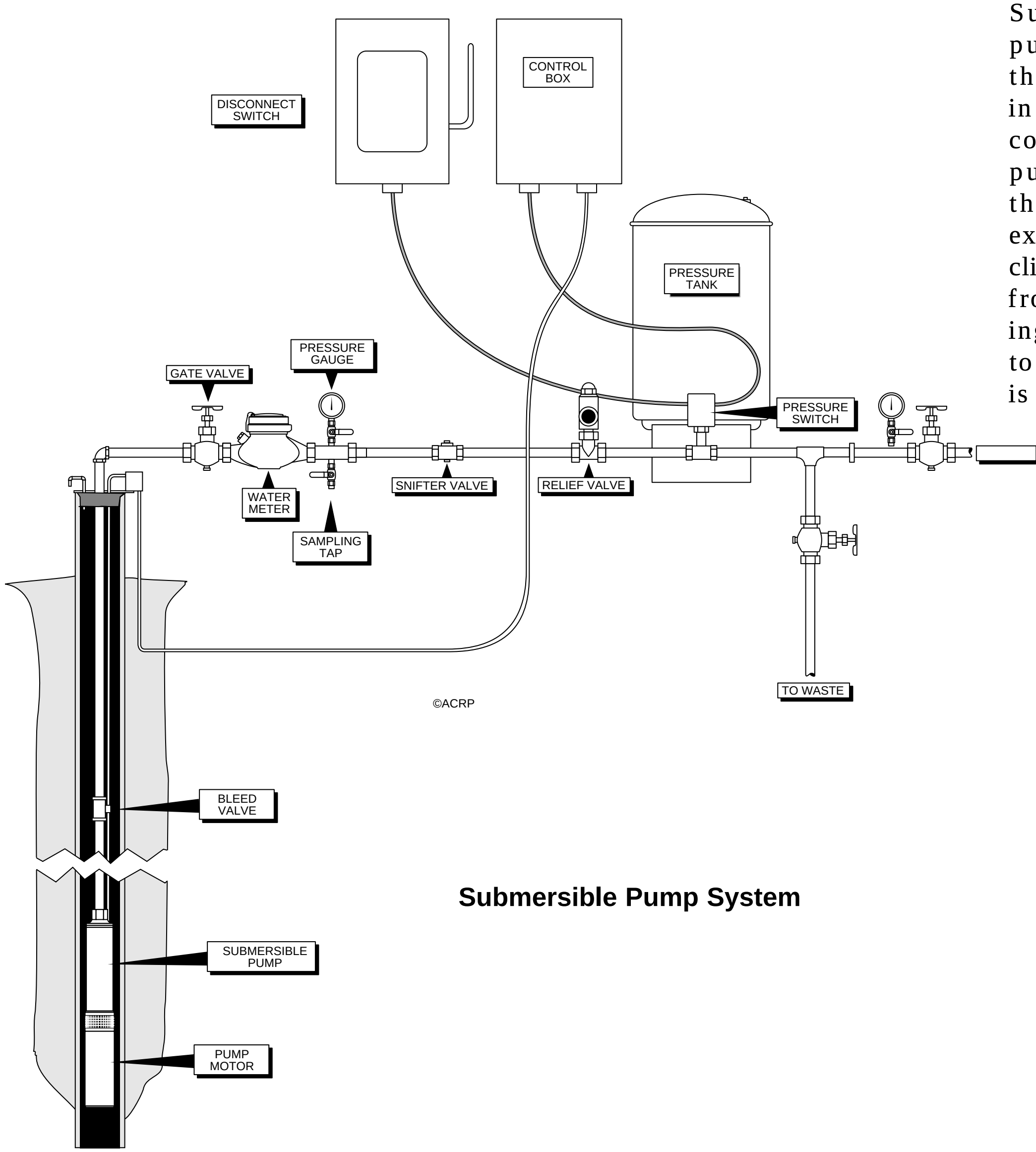
<u>“Pumps and Pumping”</u> ACR Publications, Albany, Oregon (541) 928-6199

<u>“Small Water System O&M”</u> California State University-Sacramento (916) 278-6142

There are three common centrifugal pump applications utilized for water production wells. They are

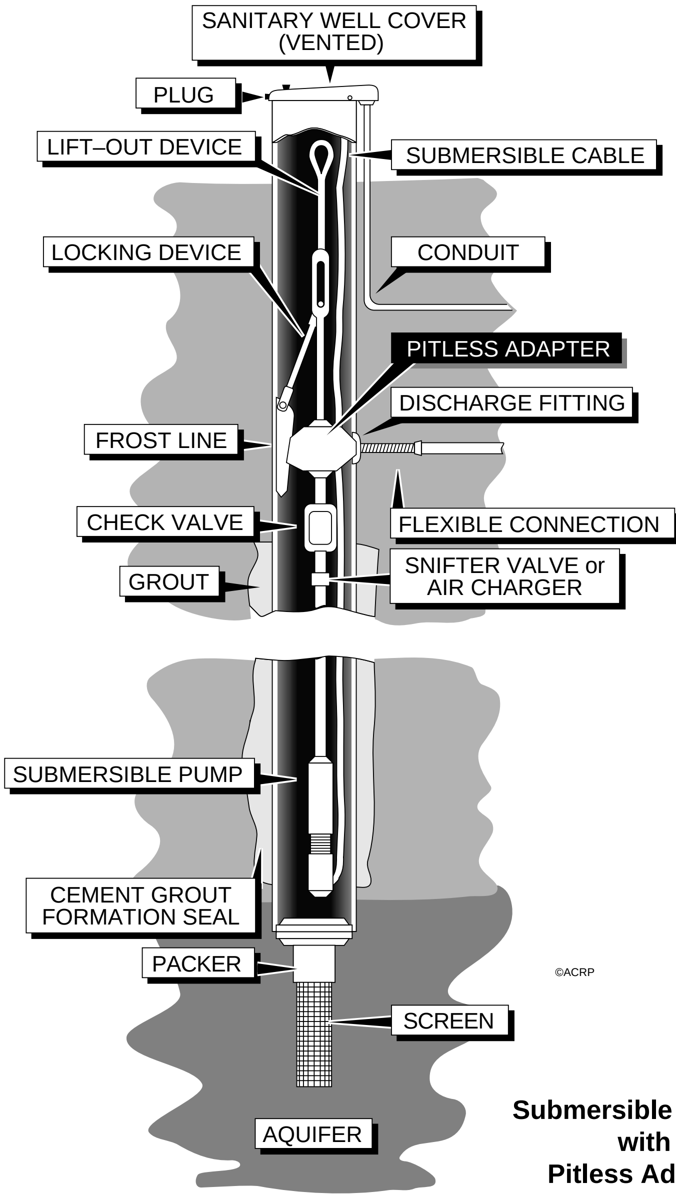
1) Submersible Pumps
2) Line-shaft Pumps
3) Jet Pumps

Submersible Pump Systems

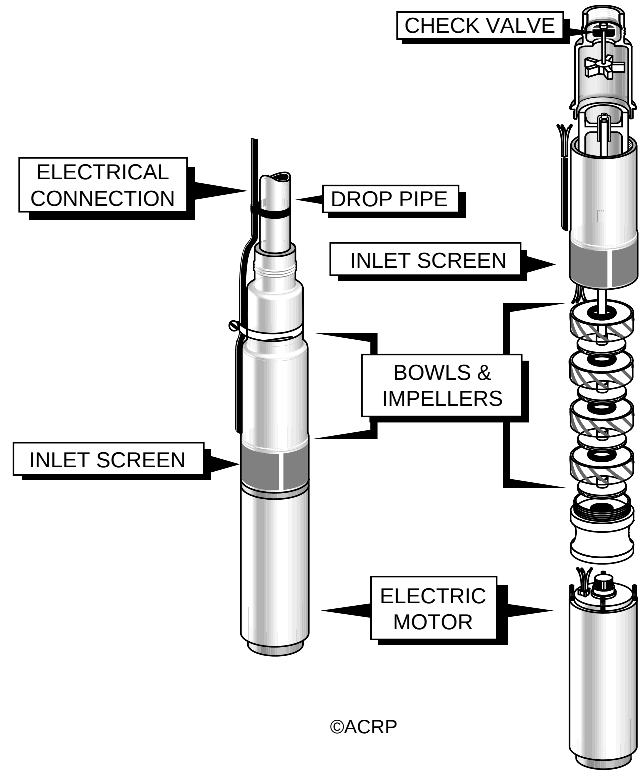


Submersible Pump System

Submersible pump units consist of a centrifugal pump with an electrical motor close-coupled to the pump. The entire unit is sealed and positioned in the well casing below the water level in a well. A column (discharge) pipe is connected to the pump, and serves as a conduit to move water from the pump to the surface. An electrical power cable extends down to the submersible motor. In cold climates, if the column pipe extends above the frost line, the pipe must be protected from freezing by a heated enclosure (building). An alternative to this is a pitless adapter where the column pipe is buried below the frost line.



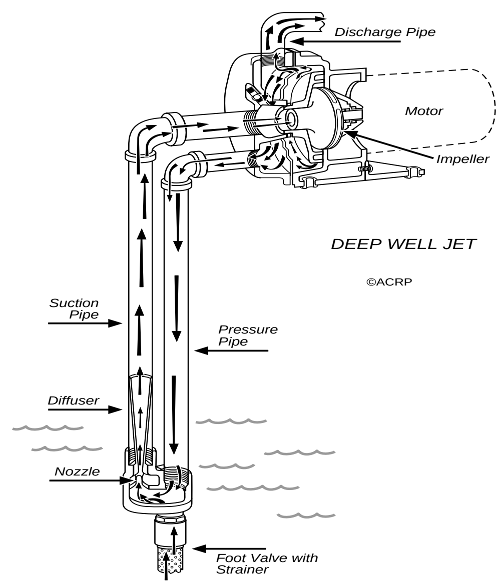
Submersible Turbine with Pitless Adapter



Submersible Turbine Pump

Jet Pumps

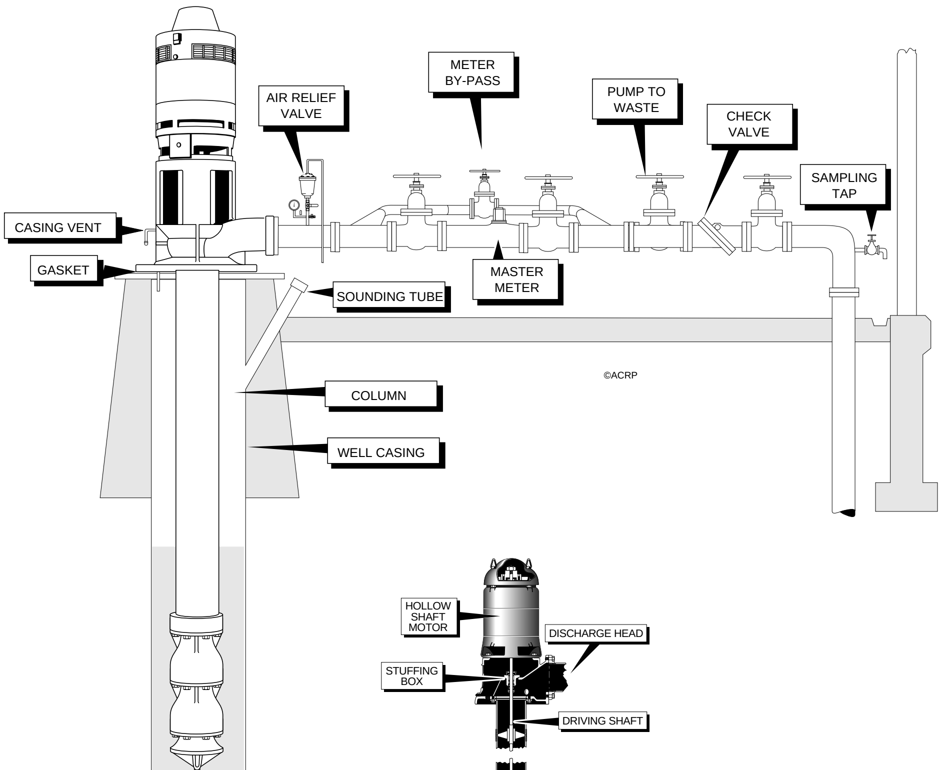
Jet pumps incorporate a centrifugal pump and a venturi. A motor and pump are usually close-couples and mounted horizontally above the ground surface. The centrifugal pump circulates water through the venturi. This action creates a vacuum on an intake pipe which extends below the water level in the well. These pumps are limited in the height that they can lift water. A jet pump will loose “prime” (water flow) when the groundwater table drops or the suction side of the pump develops air leaks.

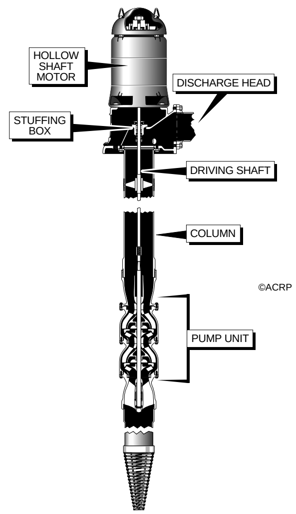


Conversion to Submersible Pump

In recent years, many small water systems have replaced line-shaft and jet pumps with submersible pumps. This is due to the high maintenance costs associated with line shaft pumps and the poor of reliability of jet pumps. The technology for submersible pumps has rapidly evolved making them more compact, reliable, capable of producing a high volume of water, and capable of lifting water from deep wells to elevated storage tanks. Many submersible pumps are energy efficient, and economical when compared to the other alternatives.

Line- Shaft Pump Systems





Lineshaft Turbine Pump and Motor

Line-shaft pumps units consist of a motor mounted on a pedestal above the ground level. The motor is connected to the pump with several sections of line shaft (drive shaft) that extend to below the water level in the well. The line shaft is secured inside the column pipe with bearings. Water from the pump is discharged through the column pipe to the surface. The discharged water comes into direct contact with the line shaft. The line shaft bearings must be lubricated. Older models were equipped with oil lubricated bearings, however nearly all of these systems in use today have converted to water lubricated bearings in order to eliminate the possibility of a bearing seal failure and oil being leaked into the water supply. In cold climates, the motors and discharge piping must be protected against freezing. These buildings must be of sufficient size to allow easy access for inspections and maintenance, and must be kept free of dust and moisture to avoid clogging of cooling vents on fan-cooled motors.

Maintenance of Submersible Pumps and Motors

Because submersible pumps are located inside the well casing, in order to perform maintenance on them requires that they be removed from the well. Operators do not typically perform this maintenance. Rather, a well driller or well service company is hired to perform maintenance and repairs as needed. It is highly recommended that an annual inspection be performed by the well professional to insure that the system is adequate and reliable. The operator should however perform regular inspections to insure that sanitary and safe conditions are maintained, and that the pump is working properly and not reducing in capacity. During the inspection the operator should check and record the following:

- discharge pressure
- discharge flow rate and total gallons pumped
- operating hours
- presence of sand, air, or lubricant in the water
- any unusual noise or vibration
- water leaking from pipe or fittings
- exposed or chafing wires
- corrosion
- insure that there are no openings in the sanitary seal (at the top of the casing) that would allow the entrance of contaminates
- general housekeeping around the well and well station.

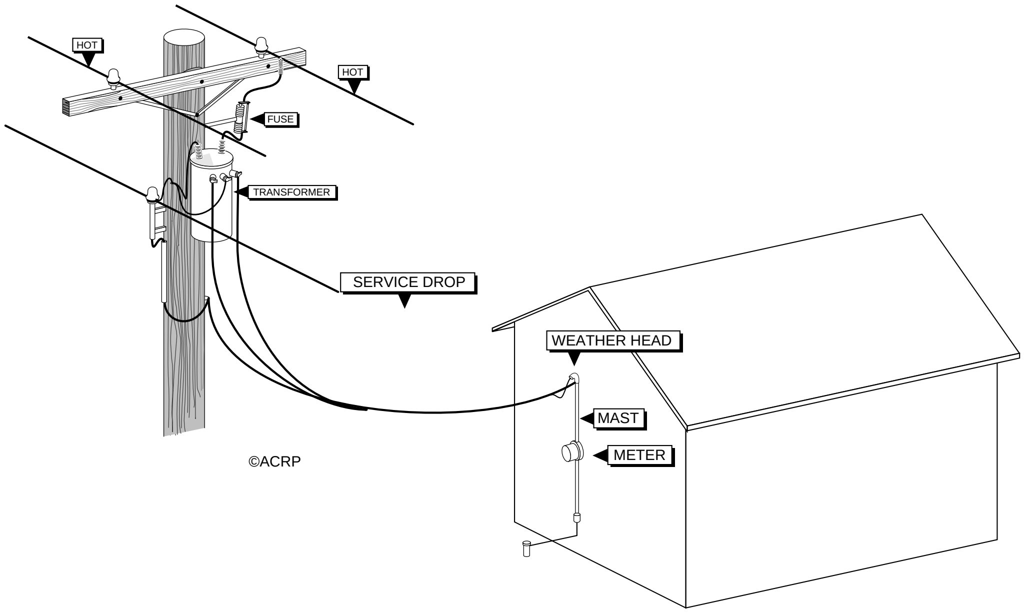
The annual inspection performed by the well driller/well service company should include at a minimum:

- measurement of the well draw-down (difference between the static water level and pumping level)
- pumping rate and total dynamic head
- quantity of sand in the water
- presence of iron or sulfur reducing bacteria
- basic analysis of the raw (untreated) water quality including coliform, iron and manganese, hardness, pH, and turbidity. (Note: other tests my be required by the local regulatory agency.)

• general condition of the well. This may include a video inspection of the well when the pump is removed for maintenance or replacement.

Other Components

In addition to the pump and motor components, well pumping systems include electrical components to; provide power to the motor, control the on/off cycles, provide fail-safe devices and failure alarms. Additionally, there are piping and appurtenances that control and measure water flow and pressure. These items are discussed in more detail below:



Power Supply

The incoming power supply can consist of voltages ranging from 120 to 480 and single or three phase. The pump motor must correspond to the incoming power unless transformers are provided. In addition to the electrical cables (which should be enclosed in conduit), the electrical power supply consists the following components;

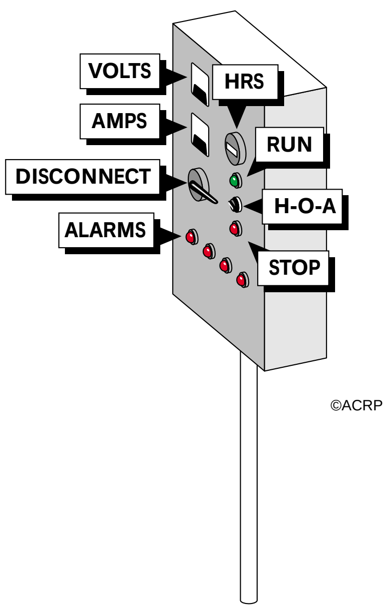
Electric Meter

This is usually owned and maintained by the electric utility and should not be tampered with.

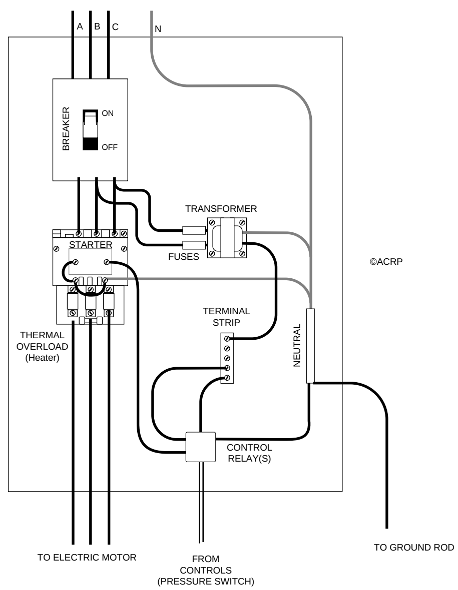
Motor Control / Disconnect System

This may include one or several separate cabinets. Inside these cabinets are

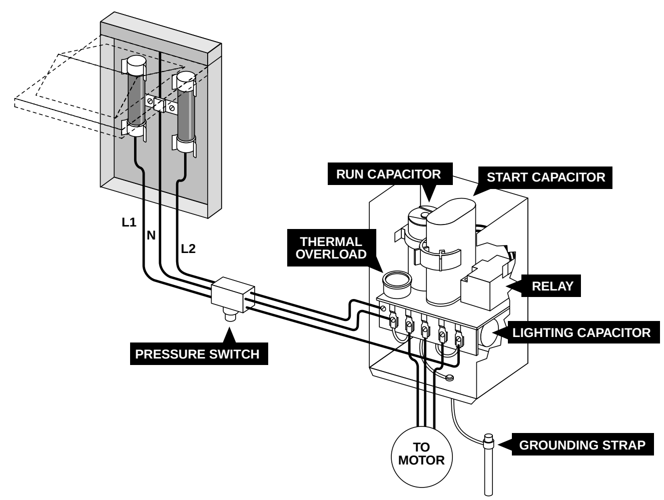
- disconnect bar (main switch) operable from outside the panel.
- fuse panel
- electrical contactor (starter)
- circuit breakers
- overload relays with reset switches
- transformers



Exterior of Electrical Control Panel



Interior of 3-phase
Electricl Control Panel



Single phase
Electricl Control Panel

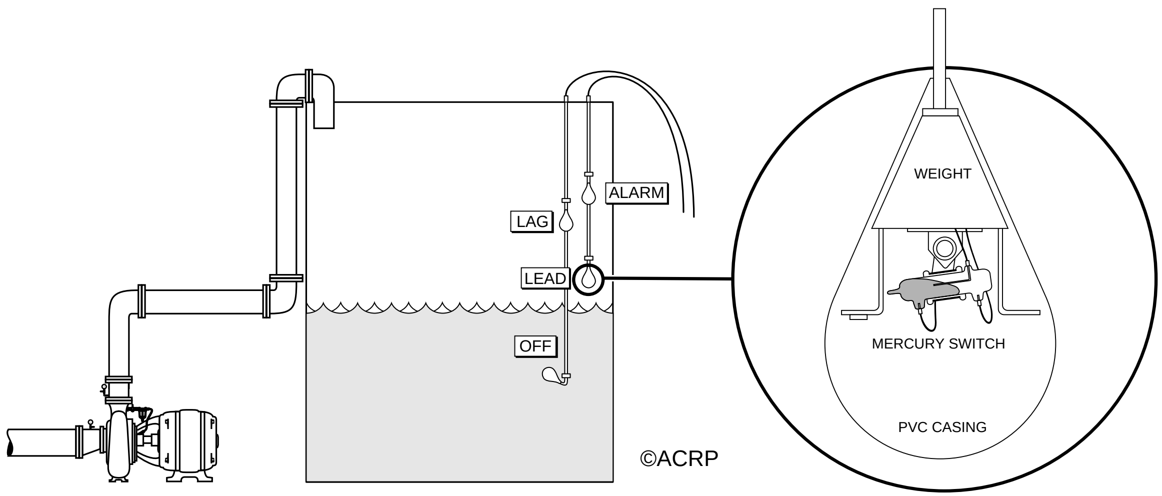
• low voltage pump control systems

• Hand/Off/Automatic switch

• elapsed running time meter

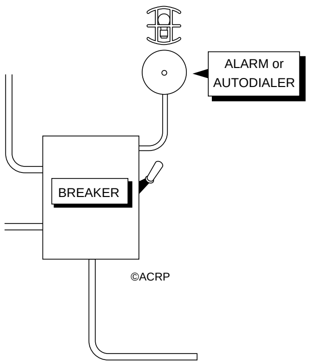
This is the heart of the electrical system for the pump motor and consists of very delicate and potentially hazardous components. The electrical panels should be weatherproof and remain securely closed at all times. If a panel is located in the outdoors it should be locked to prevent vandals from entering the panels and operating the disconnect arm (main switch). A discussion on maintenance to electrical systems is provided below.

Instrumentation & Controls



Water supply systems should be equipped with monitoring devices and controls that automatically start and stop the well pumps in order to maintain pressure in the water distribution system. The pump sequence should be set to maintain a range of between about 40 and 70 psi throughout the system. This is usually controlled by mercury type switches that are sometimes set inside gravity storage tanks to sense the water level or more commonly tied into small water lines connected to hydropneumatic tanks or the distribution system. These controls can be adjusted, but this should only be done by trained and qualified specialists.

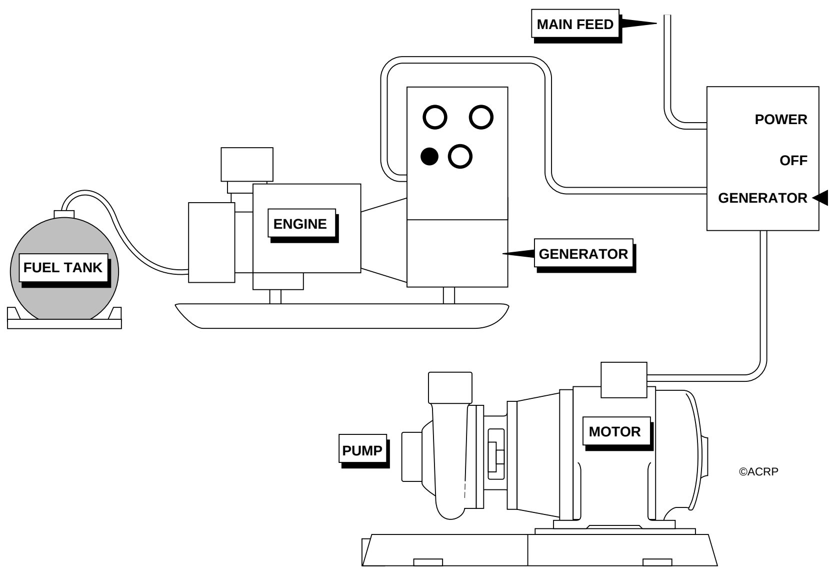
Fail Safe Systems and Alarms



Systems should be provided that prevent the overfeed of chemicals in the event of a pump failure as well as alarms to alert the operator in the event of a system failure, such as pump failure, or low water pressure. Occasionally, these fail safe systems will engage in the event of a power surge, particularly during thunderstorms. When this occurs, operators may have to respond to the well pump stations to reset overload relays and breakers in order to re-energize the automatic control system and maintain adequate water pressure. The alarm system must be designed such that the operations staff is notified of a failure by telephone (eg an “autodialer”) or visible/audible alarm. A schedule should be established so that there is always someone on call to respond to failure alarms. As stated previously, in many small water systems the time between a pump failure and critically low water pressure can be only a matter of minutes.

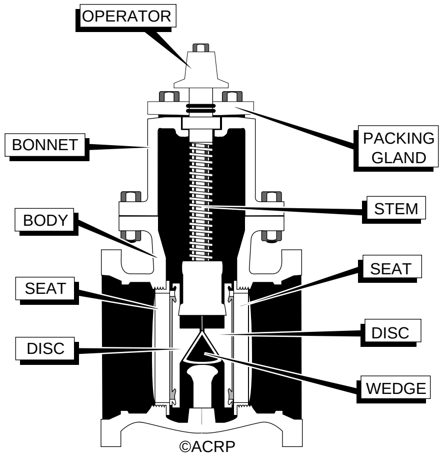
Auxiliary (Stand by) Power Systems

Many well pumping systems are also equipped with back-up generators in the event of a failure of the primary electrical supply. At least weekly, the generator should be exercised

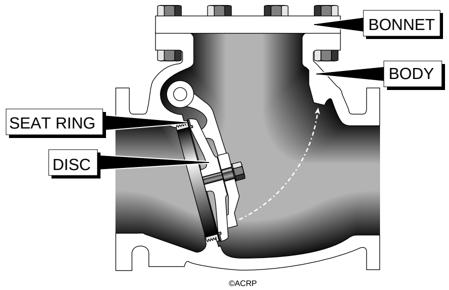


and made to operate the well pump and other electrical systems at the well station. The operator should record engine and generator gauge readings. Stand-by power systems should receive regular preventive maintenance by a qualified service technician.

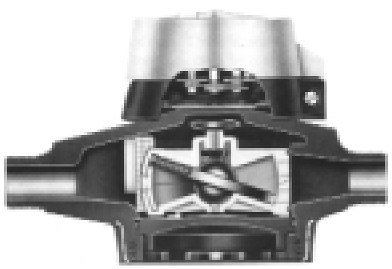
Piping and Appurtenances



Gate Valve



Swing Check Valve



Water Meter

Piping and appurtenances associated with a well pump station may include;

- gate valves
- check valves
- pressure gauges
- sample taps
- water meters
- pressure relief valves

Valves should be exercised approximately every 6 months to insure that they will function when needed. Check valves and pressure relief valves (depending on the type) may require specialized preventive maintenance. Pressure gauge and flow meter readings should be recorded regularly. During routine inspection of the well station, the operator should check to make sure that all of these appurtenances are functioning properly and that there are no signs of leaks or water hammers (surges of pressure).

Maintenance and Repair Resources

In order to insure that the customers receive a consistent supply of water, every water utility, large and small, must have a preventive maintenance program as well as an inventory of tools and materials for maintenance and repairs. The amount of maintenance performed and inventory maintained "in-house" depends on the size, complexity, and staffing at the water utility. Most small water systems utilize staff to perform light repairs and preventive maintenance such as lubrications, cleaning, and pipe repairs. Operators of small systems must recognize that occasionally the services of trained specialists are needed to perform more complex maintenance tasks. For this, small water utilities should maintain a list of competent and reliable resources that can be called upon when needed. For pumping systems, this may include:

- well driller/well service company
- pump/motor manufacturer's representative for parts and service
- electrical contractor experienced in industrial controls
- master plumber
- factory authorized service representative for auxiliary power supply equipment.
- O&M related technical assistance resources such as the state environmental training center, rural water association, and other water system operators in the local area.

All water systems should maintain:

- a library of O&M manuals from the manufacturers of pumps, motors, and control systems.
- as-built plans and specifications for wells and associated equipment
- common replacement items such as fuses, light bulbs, relays, and lubricants

Maintenance to Electrical Systems

ONLY Qualified electricians and operators specifically trained in electrical troubleshooting and maintenance should be permitted to work on electrical equipment. Untrained personnel risk the possibility of electrocution, serious damage to electrical components, and/or excessively low or high pressure in the distribution system. Spare fuses and overload relays should be kept in stock and must be of the proper type and size as recommended by the manufacturer. Bypassing a fuse or installing an incorrect capacity fuse could cause the motor to burn out or even an electrical fire. Qualified electrical specialists experienced in industrial controls systems should be hired to perform preventive maintenance and repairs. Operator who are not trained in this should limit activities to what can be performed from outside the panel. This includes resetting breakers and relays and making sure that the panels are secure. In addition to being available to respond to emergencies, the electrical/controls specialist should be brought in at least annually to perform the following;

- amperage and voltage measurements
- inspection and cleaning of the electrical cabinets
- inspection of all power supply and control components
- tightening of all connections

Troubleshooting Well Pump Problems

It is the responsibility of the operator to perform basic troubleshooting of problems in well pumping systems. The operator has to decide, based on his/her own training and capability when a problem requires assistance from a supervisor, another operator, or an outside expert. Operators should not hesitate to seek assistance if they are uncomfortable with a particular problem or situation. Remember, the goal is to provide a safe and consistent supply of water and this cannot always be accomplished by one or two individuals who have a multitude of other responsibilities. Corrective action should only be performed by individuals who are trained and skilled in that particular area, as not doing so could result in personal injury or serious damage to the water system equipment.

In the following section, a guide is provided that is intended to assist operators of small water systems to troubleshoot basic problem with well pump systems.

Troubleshooting Table for Submersible Well Pump Systems

Problem	Possible Cause	Possible Solution
1. Pump will not start.	1A. No power to switch box.	1A. Check position of main electrical disconnect arm (main switch) and insure that it is in the up (energized) position. If main power supply is interrupted, auxiliary power system (generator) should be started.
	1B. Circuit breaker or overload relay tripped.	1B. Reset breaker or overload relay. If pump does not start within a few minutes, start motor by turning the "Hand/Off/Automatic Switch" to the HAND (manual) position for approximately 2 to 5 minutes (do not over pressurize the distribution system). If motor runs, return the HOA switch to the AUTO position. Notify supervisor. If motor does not run, see other probable causes below.
	1C. Fuses burned out.	1C. Check for cause and replace fuses with correct type and size fuses. Make sure to pull down (de-energize) the main electrical disconnect arm (main switch) before opening the panel and replacing the fuses.

Problem	Possible Cause	Possible Solution
1. Pump will not start.	1D. Defective pressure switch or automatic control system.	1D. Turn the "Hand/Off/Automatic Switch" to the HAND (manual) position for a short period. If pump starts, the problem is in the automatic control system. Notify supervisor or electrician experienced with industrial controls to repair automatic control system. Pump can be operated in manual position in order to supply water, however the operator must monitor the discharge pressure (pressure on the distribution system) and insure that the normal working pressure is not exceeded.
	1E. All of the above checked and pump will still not run.	1E. Notify supervisor, or electrician experienced with industrial controls.
2. Pump will not shut off.	2A. Defective pressure switch or automatic control system. High pressure cut-off switch may need to be adjusted.	2A. Turn the "Hand/Off/Automatic Switch" to the OFF position. If pump stops, the problem is in the automatic control system. Notify supervisor, or electrician experienced with industrial controls to repair automatic control system. Pump can be operated in manual position in order to supply water, however the operator must monitor the discharge pressure (pressure on the distribution system) and insure that the normal working pressure is not exceeded. The pump should not be left in the OFF position, long enough to allow a the distribution system pressure to drop below the normal minimum working pressure.

Problem	Possible Cause	Possible Solution
3. Pump starts too frequently.	3A. Leaking foot valve or check valve.	3A. During the OFF cycle, listen for water running back into the well and check the water flow meter to see if it is running backward. If there is a swing-type check valve in the discharge pipe in the well station it may be stuck in the open position. With the well pump running (on), try manually lifting lowering the operating arm on the check valve. With the well pump off, slowly and gently push the operating arm to the closed position. If the problem persists, notify supervisor, or well service company.
	3B. Water logged hydropneumatic tank.	3B. See troubleshooting guide for hydropneumatic tanks.
	3C. Defective pressure switch or automatic control system. High or Low pressure cut-off switches may need to be adjusted.	3C. Notify supervisor or electrician experienced with industrial controls.
4. Fuses blow, circuit breaker or overload relays trip when pump is in operation.	4A. Insufficient discharge head causing a high amperage (electrical current) draw.	4A. Check water flow meter to see if the discharge rate is much higher than normal and the discharge pressure gauge to see if the pressure is lower than normal. If so, the water system could be out of water (no pressure) and/or there could be a very large leak in discharge line or in the distribution system. At the well station, with the pump running, try throttling back on the discharge gate valve until the pressure reached the normal operating pressure. DO NOT close the valve completely or operate the pump for an extended period time against a throttled valve. Immediately Notify the supervisor.

Problem	Possible Cause	Possible Solution
4. Fuses blow, circuit breaker or overload relays trip when pump is in operation. (continued)	4B. Incorrect voltage, excessive heat in control panel, motor overloaded, incorrect fuses, breakers, or overload relays.	4B. Notify supervisor or electrician experienced with industrial controls.
5. Pump will not deliver normal amount of water.	5A. Discharge valve partially closed.	5A. Fully open discharge valve and see if pump rate increases. Make sure pump does not break suction.
	5B. Pump breaking suction, water level in well near or below pump intake. Air may be present in water drawn from sample tap.	5B. Partially throttle discharge valve. The discharge rate may actually decrease, but the water level in the well should rise and the pump should no longer break suction. Notify supervisor or well service company.
	5C. Pump worn, hydraulic problems, intake plugging.	5C. Notify supervisor or well service company.
6. Sand is present in the water.	6A. Problems with well screen or gravel envelope.	6A. Partially throttle discharge valve until sand reduces or disappears. Notify supervisor or well service company.
7. Air is present in the water.	7A. If there is a check valve between the well pump and the hydropneumatic tank, and air is present on the well side of the check valve, then the pump may be breaking suction. In this case the water level in well is near or below the pump intake.	6B. Partially throttle discharge valve. Notify supervisor or well service company.

Problem	Possible Cause	Possible Solution
7. Air is present in the water.	7B. If there is a check valve between the well pump and the hydropneumatic tank, and air is present only on the hydropneumatic tank side of the check valve and in the distribution system, then air from hydropneumatic may be tank entering water.	7B. See troubleshooting guide for hydropneumatic tanks.
8. Auxiliary Power System (generator) will not activate during loss of power supply.	8A. Automatic transfer switch (ATS) is not functioning.	8A. Manually start the auxiliary power system.
	8B. No fuel.	8B. Check fuel and add if necessary.
	8C. Dead battery.	8C. Jump-start or charge battery.
	8D. Mechanical problem with engine/ generator.	8D. Notify supervisor or auxiliary power system service company.

Glossary of Terms

Amperage	The measurement of electron flow.
Appurtenances	Components such as hydrants, valves, tees, elbows, etc. that allow the water main to operate but are not considered part of the water main structure.
Back-up Pumps	Pumps used when the main pump fails or is taken off line for maintenance.
Bearings	Anti-friction device containing a surface that does not severely damage the shaft.
Capacity	The volume, usually expressed in gpm, that a pump will produce.
Check Valve	A special valve with a disc or flap which has a hinge on one edge so that it opens in the direction of normal flow and is forced shut when flows attempt to go in the reverse or opposite direction of normal flows.
Circuit Breaker	A device used to protect wiring from burning as a result of over-current. Serves the same function as a fuse.
Close-coupled	The process where the pump shaft and motor shaft are the same.
Coliform Bacteria	The Coliform group of bacteria is a bacterial indicator of contamination. This group has as one of its primary habitats the intestinal tract of human beings. Coliforms also may be found in the intestinal tract of warm-blooded animals, and in plants, soil, air and the aquatic environment.
Column Pipe	The pipe leading from the pump to the well head.
Contaminates	Toxic material, microorganisms, or other deleterious agents that make water unfit for its intended use.
Cooling Vents	Openings on the ends of a motor.
Disconnect Bar	A means of disconnecting the power from the control panel.
Draw Down	The difference between the static water level and the pumping level.
Elapsed Running Time Meter	A meter that records the total amount of time, usually in hours, that a device is operating.
Electric Contactor	An electrically operated switch, usually electromagnetic, that when closed allows power to be applied to an electric motor.
Energy Efficient	A pump and motor that has few electrical or mechanical losses.

Fail-safe Devices	Any device that either shuts down or prevents the start of a pump when there is a drop or loss of pressure, flow or level.
Failure Alarms	An electrical device that sends a signal, rings a bell, or turns on a light to alter the operator of a problem.
Fan-cooled Motors	Electric motors that use an internal fan for cooling the stator and rotor.
Frost Line	The lower depth of frost penetration.
Fuse Panel	An electrical panel that contains the fuses for the system.
Gate Valves	A valve in which the closing element consists of a disk which slides over the opening or cross-sectional area through which water passes, and fits tightly against it.
Gravity Storage Tanks	Water storage tanks that provide system pressure by gravity.
Hand / off / automatic switch	A three position switch that allows the operator to select between hand operations, off, and automatic operations.
Hardness	A characteristic of water, caused primarily by calcium and magnesium ions. Harness causes deposits and scale to form on pipes and fixtures.
In-house	The use of personnel already on the payroll.
Iron	A metallic element number 26. This metal causes a rust stain and metallic taste when present in water in concentrations above 0.3 mg/L.
Iron or Sulfur Reducing Bacteria	Bacteria that use iron or sulfur as an energy source.
Jet Pumps	A pump utilizing the Venturi effect to move water.
Line-shaft Pumps	A type of vertical turbine. With this type of vertical turbine, the motor is mounted above the ground and the pump unit is mounted below the water surface. A column extends from the pump to a discharge head that is mounted above the ground just below the motor. A shaft extends on a straight line from the center of the motor to the pump. The pump may be mounted a few feet away from the motor or several hundred feet away.
Low Voltage Pump Control Systems	A control system that uses low DC voltage, usually 24 volts DC.
Manganese	This metal causes black stains and taste when present in water in concentrations above 0.05 mg/L
Mercury Type Switches	A float or pressure switch that uses mercury contained in a capsule along with two electrodes. When switch is rotated the mercury flow either onto the electrodes or away from the electrodes making or breaking contact.

Oil Lubricated Bearings	Bearings on the vertical shaft of a line-shaft turbine that require oil in order to operate properly. The oil is provided by a drip system located on the side of the pump discharge head.
Overload Relays with Reset Switches	A device designed for overload protection of electric motors. The device is heat sensitive and is placed in the power circuit with an electrical connection to the control circuit.
Pedestal	A concrete structure holding the well casing and supporting the discharge head and pump motor.
pH	An expression of the intensity of the basic or acidic strength of a water.
Pitless Adapter	A device installed in the upper portion of the well casing that allows the pump discharge line to exit the casing below the frost line.
Power Surge	Typically a sudden drop or rise in voltage.
Pressure Gauges	A mechanical device used to register system pressure.
Pressure Relief Valve	A valve that opens automatically to ample area when the pressure reaches an assigned limit, to relieve the stress on a pipeline.
Preventive Maintenance Program	The process identifying, scheduling, and performing predictable operations and maintenance tasks.
Prime	The process of maintaining water in the volute case of a pump.
Raw (untreated) Water	Water that has not been treated and is not considered safe to drink.
Sample Taps	A point in the discharge piping used to obtain water quality samples.
Sanitary	Protected from contamination.
Sanitary Seal	A watertight seal on top of the well casing or between a lineshaft turbine and the well casing, that prevents water or other liquid from entering the well under normal or flooding conditions.
Single or Three Phase Power	Single phase - Two sources of power 120° out of phase with each other. Three phase - Three sources of power that are 120° out of phase with each other.
Stored Water	The volume of water stored in the distribution system.
Submersible Pumps	End-suction, close-coupled pumps that are designed so that the pump and motor may be submersed in water.
Suction Side	The water inlet side of a centrifugal pump.
System Failures	The inability of the system to operate.

Total Dynamic Head	(TDH) - The sum of all the energy needed to move water from one elevation to another. Includes static head, velocity head, and headloss due to friction.
Transformers	Electrical device used to step up or step down voltage.
Turbidity	A condition in water caused by the presence of suspended matter, resulting in the scattering and absorption of light rays.
Vacuum	A pressure below atmospheric.
Venturi	A device used to create a vacuum. The vacuum is created by transferring pressure head to velocity head.
Visible / audible alarm	An alarm system that produces a sound or operates a light.
Voltage	The measurement of the emf between two points.
Water Hammer	A sudden increase in water pressure caused by a quick reduction or stopping of flow.
Water Lubricated Bearings	Bearings on the vertical shaft of a line-shaft turbine that require water in order to operate properly. The water is provided by a drip system located on the side of the pump discharge head.
Water Meters	Devices used to measure the volume of water in gallons or cubic feet.
Well Casing	Metal or plastic pipe used to support the bore hole from caving in.

Disinfection with Hypochlorination

Introduction

Many failures to meet the requirements of the SDWA are related to inadequate disinfection. Disinfection is the process of destroying a large portion of microorganisms in drinking water, with the probability that pathogenic (disease causing) bacteria are killed in the process. This chapter looks at disinfection, types of chlorine, chlorine in water, dosages, and monitoring chlorine residual.

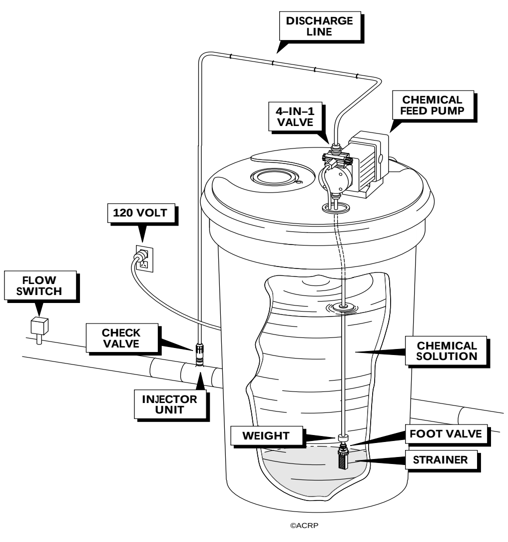
Background

The most common disinfection method used by water systems in the US is chlorination. Chlorine may be added to drinking water as a gas or liquid. The liquid form or hypochlorination system is most common for small water systems and therefore is the focus of this guide.

Hypochlorination Feed Systems

The typical hypochlorination system consists of a chemical feed pump, a solution of sodium or calcium hypochlorite, and the appropriate electrical and flow control systems.

See diagram below:

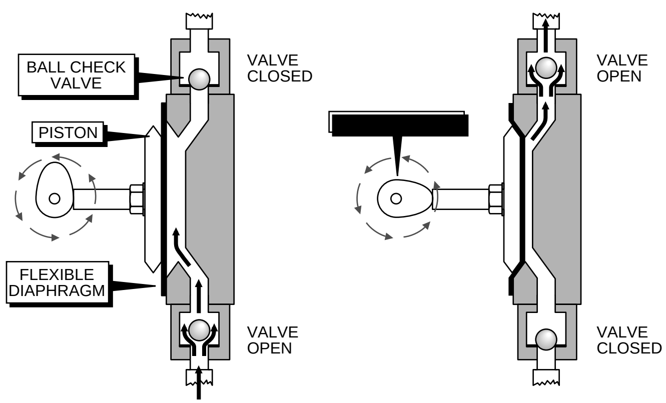


Hypochlorination systems have become very reliable and safe, however proper techniques should be used in handling these materials to prevent injuries from splashes, spills, or inhaling fumes. This would include the use of protective clothing such as rubber gloves, face or eye shields, and an apron. Many small water systems have hypochlorination over chlorine gas due to safety concerns, as well as new regulations concerning safety,training, and environmental issues. Although hypochlorination systems are safer than gas, OSHA requires hypochlorites be listed in the Hazardous Materials inventory and written procedures for handling, using, and responding to spills.

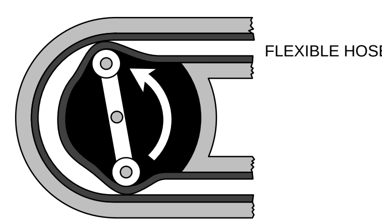
Sodium hypochlorite provides the least handling hazard to the operator. It may be fed directly from the container that it is delivered in, or can be diluted in a solution tank if desired. It is available in concentrations from 5% to 15% but can lose effectiveness if stored for periods in excess of 30 days. This chemical should be properly stored in a covered container, out of direct sunlight and away from the electrical control systems associated with the operation of the chemical feed pump.

Calcium hypochlorite is a powder with a chlorine concentration generally in the range of 65%. The powder is mixed with water and fed with the same type of chemical feed pump used for the sodium hypochlorite. Providing a consistent feed rate with calcium hypochlorite can be difficult due to the amount of inert material in this product that can clog chemical feed pump. To prevent chemical feed pump clogging, it may be better to mix the hypochlorite powder with water in one tank, and then transfer the well mixed solution to another tank where it would be pumped into the raw water. By using this approach, the operator could leave the undissolved inert material, that could cause clogging problems, in the bottom of the mixing tank and not exposed to the chemical feed pump. The calcium hypochlorite should be stored in a cool, dry environment.

DIAPHRAGM PUMP



PERISTALTIC PUMP



©ACRP

Chemical feed pumps like the ones pictured one the previous page are typical for feeding liquid hypochlorite in small water systems. The pump on the left has a diaphragm which is controlled by speed and stroke. The stroke determines the amount of hypochlorite to be injected and the speed control determines how often that amount is injected. The lower speed settings may allow several gallons of water to pass before another dose of hypochlorite is injected. The speed and stroke should be adjusted in combination. If both speed and stroke have to be operated at the highest settings to achieve the desired chlorine residual, consider installing an additional chemical feed pump.The pump on the right is a peristaltic pump. The peristaltic pump utilizes a flexible hose and two rollers attached a rotating shaft. As the shaft turns the rollers role along the hose, compressing it and forcing the liquid forward. In all cases, a backup pump or at the very least the spare parts should be on hand in the event of a chemical feed pump failure.

CAUTION: Allowing petroleum products such as oils, grease, etc., or moisture to be placed in a calcium hypochlorite container may cause spontaneous combustion and explosion.

Chlorine Dosage & Residual

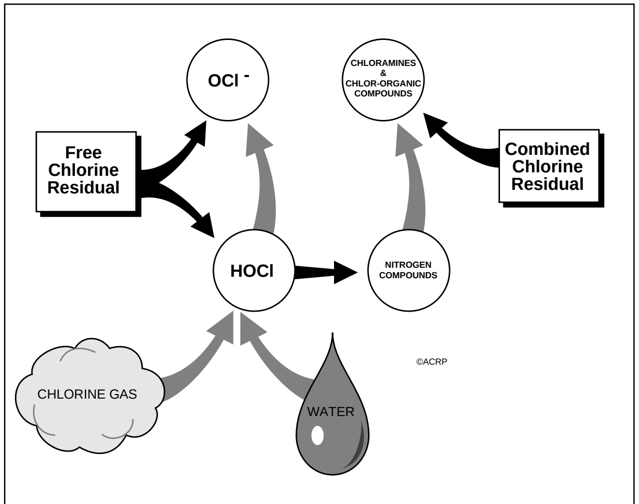
The total amount of chlorine fed into a volume of water by the chlorine feed equipment is referred to as dosage and is calculated in milligram per liter (mg/L). Chlorine is a very active chemical oxidizing agent. When injected into water, it combines readily with certain inorganic substances that are oxidizable (e.g., hydrogen sulfide, ferrous iron, nitrate, etc.) and with organic impurities including microorganisms and nitrogen compounds (e.g. animal wastes, ammonia from fertilizers, etc.). These reactions consume some of the chlorine. The amount of chlorine added is called the chlorine dose. The amount of chlorine consumed is called chlorine demand. The amount of chlorine remaining is the call Chlorine Residual. This can be written as the following equation:

Chlorine Demand = Chlorine Dose - Chlorine Residual

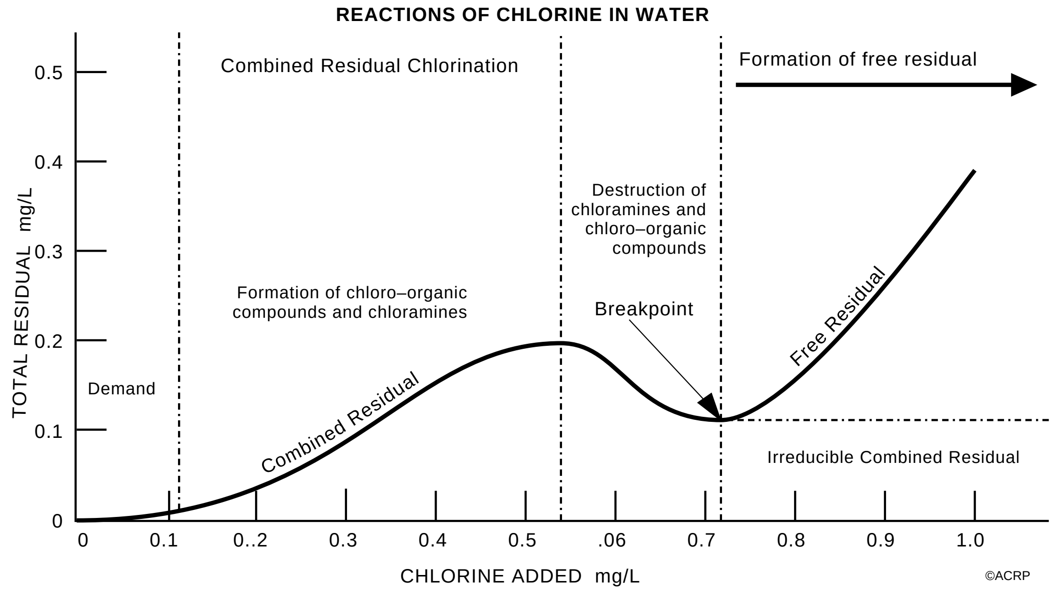
Chlorine Reaction in Water

Regardless of the form of chlorine used (hypochlorites or chlorine gas), the reaction in water is basically the same. The chlorine mixed with water will produce hypochlorous acid and hypochlorite ion and the measurement of these compounds is called free chlorine residual. If organic or inorganic compounds are available in the water, particularly nitrogen compounds, the hypochlorous acid will combine with these compounds to produce chloramines and/or chloro-organic compounds. The measurement of the presence of these compounds is called combined chlorine residual. Free chlorine has proven to be a more effective disinfectant than combined chlorine compounds. The measurement of both the free and combined chlorine residuals is called total residual.

Free Residual Chlorine + Combined Residual Chlorine = Total Chlorine Residual



xChlorine Reactions with Water



Breakpoint Chlorination Curve

If there are organic and inorganic compounds in the water, then enough chlorine has to be added to complete the reactions with these compounds before an adequate free residual can be produced. This process is called breakpoint chlorination.

There may be times when chlorine taste and odor complaints become a problem in the distribution system. This problem is generally related to high combined residuals and inadequate free residual. The solution to this problem may be to increase the chlorine dose rate to get past the breakpoint. As a rule of thumb, the free residual should be at least 85% of the total residual in order to prevent chlorine taste and odor problems and insure an adequate free residual for effective disinfection.

A sudden increase in combined chlorine may signify the presence of organic contaminants such as dirt and debris. The sudden presence of organic material may result from a line break, loss of pressure or unprotected cross connection such as lawn irrigation, etc.

Chlorine Residual Testing

The test kit used for chlorine residual testing must be an EPA approved kit. This can be verified by checking with the local state regulatory staff. The test kits are provided with detailed instructions on proper procedures for running both free and total chlorine residual tests. It is also important to insure that all chemicals used in the testing procedure are used before the posted expiration date shown on the chemical packages.

Troubleshooting Table for Hypochlorination Problems

Problem	Possible Cause	Possible Solution
1. Chemical feed pump won't run.	1A. No power.	1A. Check to see if plug is securely in place. Insure that there is power to the outlet and control systems.
	1B. Electrical problem with signal from well pump or flow sensor.	1B. Check pump motor starter. Bypass flow sensor to determine if pump will operate manually.
	1C. Motor failure.	1C. Check manufacturer's information.
2. Low chlorine residual at POE.	2A. Improper procedure for running chlorine residual test or expired chemical reagents.	2A Check expiration date on **chemical reagents**. Check test procedure as described in test kit manual. Speed or stroke setting too low.
	2B. Pump not feeding an adequate quantity of chlorine.	2B. Damaged **diaphragm** or suction leak.
	2C. Change in raw water quality.	2C. Test raw water for constituents that may cause increased chlorine demand. (i.e. iron, manganese, etc.)
	2D. Pump **air bound**.	2D. Check foot valve.
	2E. Chlorine supply tank empty.	2E. Fill supply tank.
	2F. Reduced effectiveness of chlorine solution.	2F. Check date that chlorine was received. Sodium hypochlorite solution may lose effectiveness after 30 days. If that is the case, the feed rate must be increased to obtain the desired residual.

Problem	Possible Cause	Possible Solution
2. Low chlorine residual at POE. (continued)	2G. Damaged suction or discharge lines. (cracks or crimps)	2G. Clean or repair lines with problems.
	2H. Connection at point of **injection** clogged or leaking.	2H. Flush line and connection with mild acid such as **acetic** or **muriatic**. Replace any damaged parts that may be leaking.
3. Chemical feed pump won't prime.	3A. Speed and stroke setting inadequate.	3A. Check manufacturers recommendations for proper settings to prime pump.
	3B. Suction lift too high due to feed pump relocation.	3B. Check maximum suction lift for pump and relocate as necessary.
	3C. Discharge pressure too high. (see Chapter 3 Pumps)	3C. Check well pump discharge pressure. Check pressure rating on chemical feed pump.
	3D. Suction fitting clogged.	3D. Clean or replace screen.
	3E. Trapped air in suction line.	3E. Insure all fittings are tight.
	3F. Suction line not submerged in solution.	3F. Add chlorine solution to supply tank.
4. Loss of prime.	4A. Solution tank empty.	4A. Fill tank.
	4B. Air leaks in suction fittings.	4B. Check for cracked fittings.
	4C. Foot valve not in vertical position.	4C. Adjust foot valve to proper position.
	4D. Air trapped in suction tubing.	4D. Check connections and fittings.

Problem	Possible Cause	Possible Solution
5. Excessive chlorine residual at POE.	5A. Pump speed or stroke setting too high.	5A. Verify dose rate and calibrate pump to get desired dose.
	5B. Siphoning from solution tank.	5B. Insure that 4 in 1 anti-siphon valve on chemical feed pump is operating properly.
	5C. Low well pump discharge pressure.	5C. Insure well pump discharge pressure is at least 25psi. (see Chapter 3 Pumps)

Glossary of Terms

Air bound	The result of the loss of prime in a centrifugal pump.
Acetic Acid	A mild acid, often associated with vinegar, which can be used to clean chemical feed lines and valves.
Bacteria	Living organisms, microscopic in size, which consist of single cell. Most bacterial utilize organic matter for their food and produce waste produces as the result of their life processes.
Calculated	The process of determining a mathematical result.
Calibrate	The process of determining the rate that a pump produces.
Chemical Oxidizing Agent	Chemicals which are very reactive, such as chlorine, which combine readily with both organic and inorganic compounds by adding a oxygen, eg ferrous iron has two oxygens and will stay in solution, but if an oxidizing agent such as chlorine is added, an oxygen is added to the ferrous iron to create ferric iron with three oxygens and comes out of solution as a reddish-brown sediment.
Chemical Reagents	Most test kits used to test for chemicals such as chlorine use other chemicals as part of the testing process, these chemicals which are provided with the test kit are known as chemical reagents.
Consistent Feed Rate	A feed rate that does not vary from hour to hour or day to day.
Diaphragm	A flexible device, usually circular, that is used by a chemical feed pump to move fluid.
Discharge Pressure	The pressure in the system to which the chemical feed pump is pumping.
Disinfectant	A chemical that destroys pathogenic microorganisms.
Disinfection	The process used to control pathogenic organisms.
Environment	The soundings material, and spiritual influences which affect the growth, development and existence of a living being.
EPA	Environmental Protection Agency - The federal agency charged with protecting the quality of water and air in the United States.
Foot Valve	A one-way valve placed at the entrance of a suction line which is opened by the flow of water. The purpose of the valve is to prevent reverse flow.

Inert Material	Material that will not react chemically.
Injection	The point at which chlorine is added to the system.
Inorganic Substances	Chemical substances of mineral origin.
Microorganisms	Minute organisms, either plant or animal, invisible or barely visible to the naked eye.
Muriatic Acid	A 5% of less solution of hydrochloric acid.
Organic Impurities	Chemical substances of animal or vegetable origin, made basically of carbon structure.
OSHA	Occupational Safety and Health Administration, The federal agency responsible for the development and enforcement of employee safety and health regulations.
Oxidizable	Chemicals which will react with oxidizers such as chlorine to produce compounds with additional oxygen.
Pathogenic	Disease producing organisms.
Prime Pump	The process of causing the pump to pump fluid.
Reactions	The chemical interaction between two or more materials.
Siphoning	The transferring of a liquid from an upper level to a lower level by means of suction created by the weight of the liquid as it flows from to the lower level.
Spontaneous combustion	To ignite or become flammable a material without an outside source of heat.
Stroke	The amount of vertical movement of the pump diaphragm.
Submerged	Below or underneath the surface of the water
Suction Lift	A pumping condition where the eye of the impeller of the pump is above the surface of the water that the pump is pumping from.
Vertical	Perpendicular or upright, the opposite of horizontal.

Hydropneumatic Tanks

Introduction

Hydropneumatic tanks are important to the protection of the well pump and adequate pressure in the distribution system.

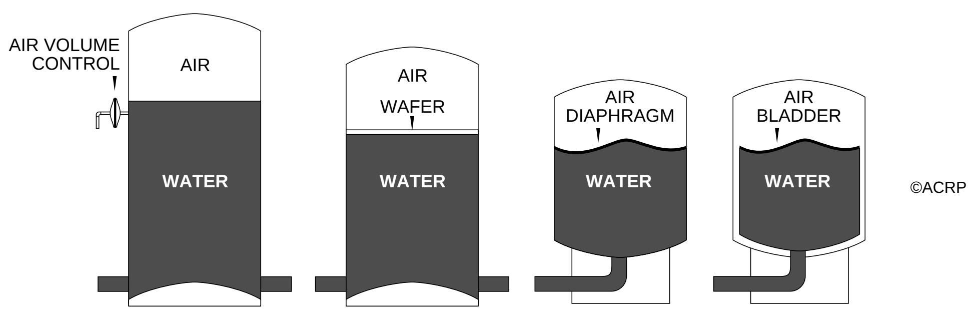
Background

Hydropneumatic tanks (or pressure tanks) are very common in small water systems that use wells to supply drinking water. The hydropneumatic system combines the energy from a pump (usually the well pump) with the principle of air pressure to force water into the distribution system. These tanks are installed between the well pump and distribution system and are intended to:

• Maintain an adequate and relatively even pressure in the distribution system

• Reduce the number of times the well pump turns on and off

Hydropneumatic tanks are usually not large enough to provide any water storage or to supply water for fire fighting. Consequently, hydropneumatic tanks are used primarily for residential water supply. The requirements for hydropneumatic tank sizing vary from state to state and therefore the water system operator should consult the state regulatory authority if there is a question about the adequacy of a particular tank. Because the volume of stored water is minimal, operational failures that occur with hydropneumatic tank systems can result in the water system customers being completely out of water within a matter of minutes. It is therefore important for all operators of these systems to be familiar with basic troubleshooting steps to identify and correct problems with the water system.

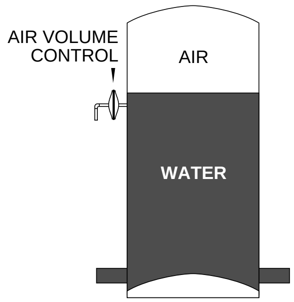


Types of Hydropneumatic Tanks

While the number and size of hydropneumatic tanks may vary widely from system to system, there are four basic styles of tanks. Depending on the type and size, these tanks can be installed vertically or horizontally. The general differences between the four styles (shown below) involve the method of separating the air and the water inside the tank. Operators should be familiar with the type of tank(s) in their system.

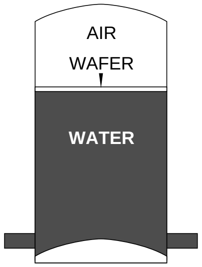
1. Conventional Tank:

The air cushion is in direct contact with the water. Because air can dissolve in the water, an air volume controller is necessary as well as an air compressor system.



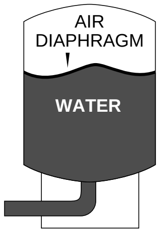
2. Floating Wafer Tank:

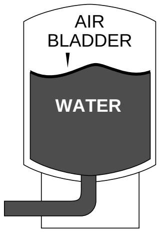
There is a floating wafer (usually constructed of a ridged material, flexible rubber, or plastic) that separates the air and water. This wafer, however, does not completely separate the air and water, and therefore some dissolving of air is expected. These tanks require occasional recharging with air.



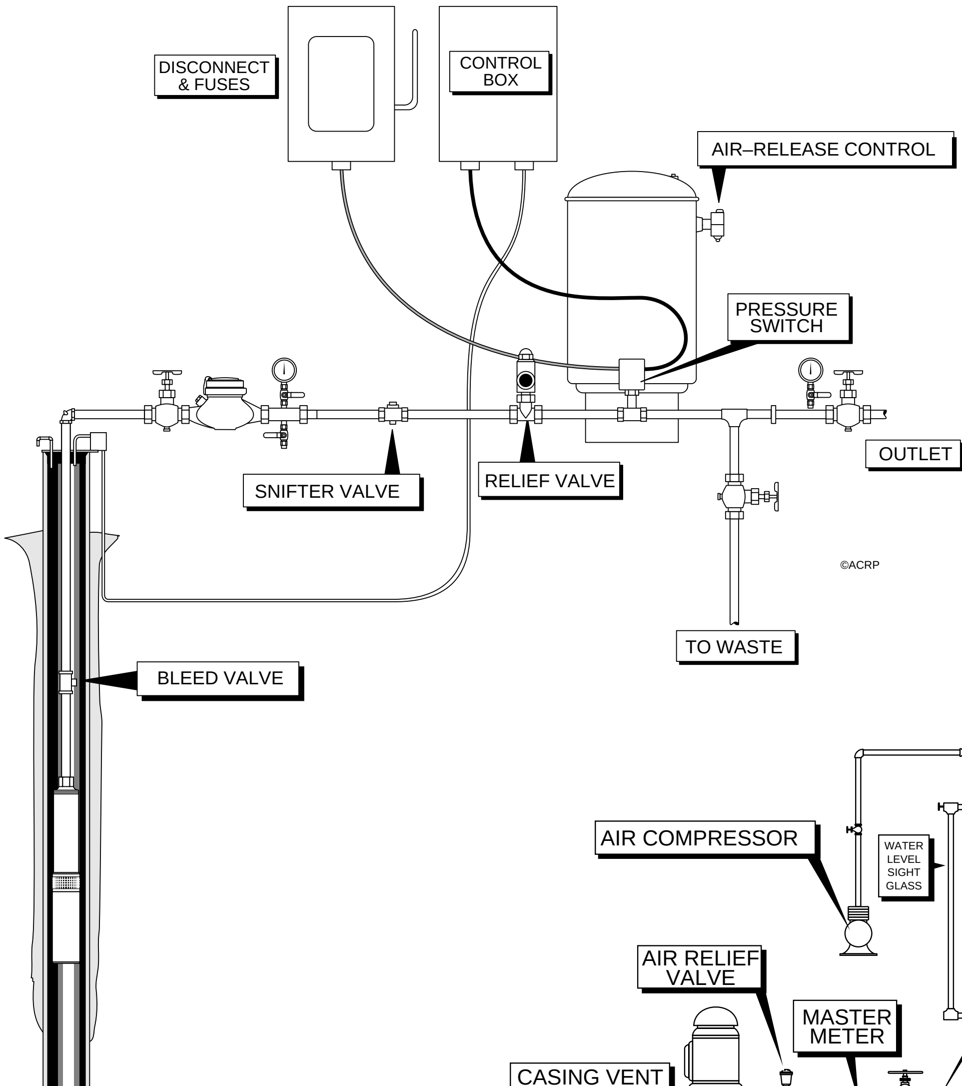
3. Tanks with Flexible Separator:

These tanks provide a complete separation of the air and water. A separator is fastened around the inside of the tank (diaphragm type) or a bag is provided for containing the air (air bladder). These units may be charged with air at the factory, however most are fitted with an air valve (similar to a tire), which the operator can use to adjust the pressure inside the tank. Care must be taken when adding air to these tanks in order to avoid over-pressurization and a possible rupture of the separator. Manufacturer's literature must be consulted before adding air to these tanks and the procedure should be performed only by qualified personnel.

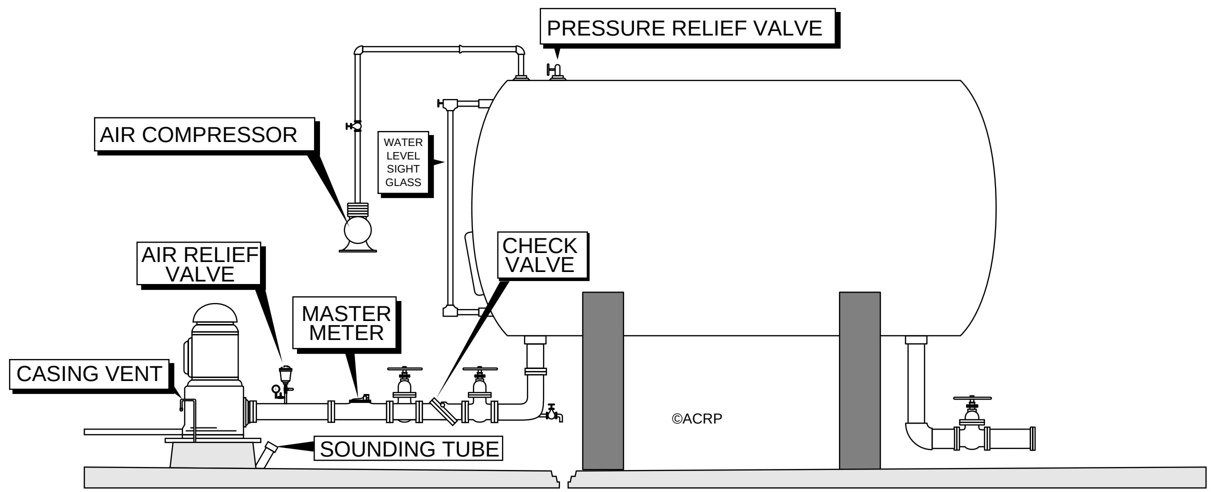




Small System Hydropneumatic tank piping



Hydropneumatic tank with air compressor



Components

The following is a list of the major components of a hydropneumatic tank system and the purpose for each:

Component	Purpose
Steel Tank	Stores water and air. Pressurized vessel. Some states require periodic hydrostatic testing and certification. (Check with state regulatory agency)
Tank Supports	Attaches the tank to the floor or ground and insures that the tank will not tip over and break a main water supply line.
Air Volume Controller	Regulates air volume in tank (controls compressor)
Air Compressor	Supplies air to the tank to maintain air cushion. Unit should be “oil free” type or be fitted with filters to prevent oil from entering the water.
Pressure Relief Valve	Prevents excessively high pressure in the tank. Generally 100 psi maximum.
Inlet/Outlet Piping	Allows flow of water in and out of tank. Both should be fitted with gate valves and inlet pipe should be fitted with a check valve.
Sight Glass (Tube)	Allows direct observation of “air-to-water ratio.” Generally the ratio should be 1 to 2, ie: 1/3 air to 2/3 water.
Pressure Gauges	For monitoring pressure inside the tank and on the distribution system.
Pump/Motor Controls	Controls “cut-in” (start) and “cut-out” (stop) cycles of the well pump.
High/Low Pressure Controls	Regulates the pump/motor controls based on pre-set cut-in and cut-out points. These are adjustable but adjustments should be performed only by qualified personnel. The settings should generally provide a minimum of 40 psi and a maximum of 70 psi throughout the distribution system. The pressure should never be allowed to drop to below 20 psi. Alarms should be provided to notify the operator in the event of a system failure (low water pressure)
High/Low Water Level Controls	Regulates water level in the tank.
Master Water Flow Meter	Measures quantity of water pumped.
Cycle Counter	Records number of pump cycles. Should be limited to a maximum of 10-15 cycles per hour. Cycles can adjusted by high/low pressure controls.
Elapsed Time Meter	Records total hours of water supply pump operation.

Note: Some hydropneumatic tank systems may not have all of the major components listed.

Hydropneumatic tank systems operate in the following manner:

1. The well pump starts when the pressure drops to a predetermined low pressure (cut-in pressure.) Pumping water into the tank pressurizes a pocket of air (air volume) inside the top of the hydropneumatic tank. The cut-in pressure should normally not be less than 40 psi, however it may have to be higher to maintain a reasonable working pressure at the end or at higher elevations in the distribution system. At no time should the water pressure be allowed to drop below 20 psi anywhere in the distribution system.
2. When the pressure builds up to a pre-determined high pressure (cut-out pressure), the well pump stops and the compressed air inside the tank forces the water into the distribution system. The cut-out pressure should normally not be more than 70 psi. Excessively high pressures can damage distribution system piping and plumbing inside homes.
3. As water is consumed from the distribution system, the pressure inside the tank drops. When the pressure drops to the cut-in point, the water supply pump starts again. The “cycle rate” is the number of times the water supply pump starts and stops in one hour, 10 - 15 cycles per hour.

Maintenance

The well pump and pump control systems are important components of the hydropneumatic tank system. Maintenance to these systems is discussed in greater detail in Chapter 2 of this guide. As with the pumps and controls, the hydropneumatic tank should be included in an overall preventive maintenance program for the water system. It is important to remember that these tanks are under high pressure. Never strike these tanks with hard objects such as hammers, as serious damage and personal injury could occur. Follow proper lock-out/tag-out procedures when taking these tanks out of service for maintenance, including isolating the water supply and distribution systems from the tank with gate valves and slowly bleeding the air from the tank. Maintenance should only be performed by qualified technicians.

Periodic Inspections

Regular inspections should be carried out by the system operators. During the inspections the operator should, at a minimum, check and record the following:

Routine Inspection - Hydropneumatic Tanks

- Pressure fluctuation during a cycle (actual cut-in and cut-out pressures)
- Number of pump cycles per hour
- Leaks around water piping, the tank, and fittings
- Leaking air from the compressor, air lines, or tank
- **Air-to-water ratio** (water level in the tank) by visually checking the sight tube
- Presence of sediment in the tank by visually checking the sight tube
- Condition of paint on the exterior of the tanks and signs of corrosion
- If oil lubricated compressor:

  ✓ any oil leaking from the compressor

  ✓ oil separators on the air discharge line

  ✓ presence of oil in the water (usually gives the water a milky appearance)
- Air compressor intake air filters
- Control systems and alarms to insure that they are operating properly and protected from moisture and corrosion
- Condition of tank supports to insure that the tanks are adequately secured to the floor

Because hydropneumatic tanks are constructed of steel they are subject to corrosion, especially inside the tanks where air and water may come into direct contact. This can result in weakening of the structure. Some states require periodic “hydrostatic testing” and certification of larger tanks to insure that these tanks are structurally sound. Operators should check with their state regulatory agency regarding the local requirements for hydrostatic testing. Approximately every five to ten years, the interior of large hydropneumatic tanks should be inspected by a specialist in steel tank structure and coating (paint). This inspection should consider the condition of the tank as well as what type of maintenance should be performed on the tank to increase its useful life. For small hydropneumatic tanks, when they become corroded, the most cost effective option is usually to replace them with new units.

Maintenance and Repair Resources

As stated previously, certain maintenance should be performed only by qualified technicians. The water system operator should have a list of contractors and material suppliers that are reliable and thoroughly familiar with hydropneumatic tank systems. This list should include the following information for hydropneumatic tanks:

Water System Service Providers

- Well driller / service company
- Local manufacturers representative for the hydropneumatic tank(s)
- Steel tank structural and coating (paint) specialists
- Electrical contractor experienced in industrial controls
- **O&M** related technical assistance resources such as the state environmental training center, rural water association, and other water system operators in the area.

All water systems should maintain the following information and records for hydropneumatic tanks:

Manuals, Plans, Records & Spare Parts for Hydropneumatic Tanks

- O&M manuals from the manufacturers of the hydropneumatic tank(s)
- **As-built** plans and **specifications** for the tank(s) and associated equipment
- A record of **preventive and corrective maintenance** performed
- A record of inspections performed on tanks including; hydrostatic, structural, and coating
- Common replacement items such as air compressor filters, and a spare pressure relief valve

Hydropneumatic Tanks Out of Service for Maintenance - Effects on the Water Supply

Whenever a tank must be taken out of service for maintenance, the operator should insure that the water pressure is maintained by other back-up tanks in the system. If this is not possible, customers should be given as much advance notice as possible, maintenance should be conducted during periods of low water demand, and the maintenance should be conducted as quickly as possible to reduce the time without water service.

Troubleshooting Hydropneumatic Tank Problems

It is the responsibility of the operator to perform basic troubleshooting of problems in hydropneumatic tank systems. The operator has to decide, based on his/her own training and capability when a problem requires assistance from another operator or an outside expert. Operators should not hesitate to seek assistance if they are uncomfortable with a particular problem or situation. Remember, the goal is to provide a safe and consistent supply of water and this cannot always be accomplished by one or two individuals who may have many other responsibilities. Corrective action should only be performed by individuals who are trained and skilled in that particular area. Corrective actions by unskilled individuals could result in personal injury or serious damage to the water system equipment.

The following troubleshooting table is provided to assist operators of small water systems to troubleshoot basic problem with hydropneumatic tanks. It must be recognized that problems occurring in hydropneumatic tanks could also be related to the well, water supply pump and controls, and the distribution system, therefore other troubleshooting tables included in this manual should be consulted in addition to the troubleshooting table for hydropneumatic tanks.

Troubleshooting Table for Hydropneumatic Tanks

Problem	Possible Cause	Possible Solution
1. Well pump will not start.	1A. Circuit breaker or overload relay tripped.	1A. Reset breaker or manual overload relay.
	1B. Fuse(s) burned out.	1B. Check for cause and correct, replace fuse(s).
	1C. No power to switch box.	1C. Check incoming power supply. Contact power company.
	1D. Short, broken or loose wire.	1D. Check for shorts and correct, tighten terminals, replace broken wires.
	1E. Low voltage.	1E. Check incoming line voltage. Contact power company if low.
	1F. Defective motor.	1F. Contact electrical contractor.
	1G. Defective pressure switch.	1G. Check voltage of incoming electric supply with pressure switch closed. Contact power company if voltage low. Perform maintenance on switch if voltage normal.
2. Well pump will not shut off.	2A. Defective pressure switch. 2B. Cut-off pressure setting too high. 2C. Float switch or pressure transducer not functioning.	Refer to troubleshooting table on “Pumps.” Note: If the water supply pump is running constantly, excessive pressures can develop in the hydropneumatic tank and distribution system. The tank should be equipped with a pressure relief valve that opens at approximately 100 psi. This may protect the tank from damage but it is possible that the distribution system could be damaged if pressures exceed normal working pressures. Check for leaks throughout the service area. Notify electrician experienced with industrial controls.

Problem	Possible Cause	Possible Solution
3. Well pump starts and stops too frequently (Excessive cycle rate).	3A. Leaking foot valve or check valve.	3A. Contact well specialist.
	3B. Defective pressure switch or automatic control system. High or Low pressure cut-off switches may need to be adjusted.	3B. Contact well specialist or electrician.
	3C. Excessive water use or major leak in water distribution system.	3C. Locate and repair leak.
	3D. Water-logged hydropneumatic tank.	3D. Check air-to-water ratio from sight tube (if provided). If the tube is completely filled with water or if the water level exceeds 2/3 of the volume of the tank, then air will have to be introduced into the tank. Check tank and air system for leaks. The optimum air-to-water ratio in the hydropneumatic tank should be 2/3 water to 1/3 air. If the problem persists or if there is no sight tube, notify water system specialist.
	3E. Air-logged hydropneumatic tank.	3E. Check air-to-water ratio from sight tube (if provided). If the tube is completely filled with air or if the water level is less than 1/2 of the volume of the tank, then air will have to bled from the tank. The optimum air-to-water ratio should be 2/3 water to 1/3 air. If the problem persists or if there is no sight tube, notify water system specialist.
4. Sand / sediment is present in the water.	4A. Problems with well screen or gravel envelope.	4A. Contact well contractor.

Problem	Possible Cause	Possible Solution
4. Sand / sediment is present in the water. (continued)	4B. If there is iron or manganese in the well water and it is not removed before the hydropneumatic tank, and the air in the hydropneumatic tank comes into direct contact with the water in the tank, then the iron and manganese could be oxidizing and settling in the tank. Also, sediment could be present in the distribution system.	4B. Check air-to-water ratio from sight tube (if provided). If the tube is completely filled with air or if the water level is less than 1/2 of the volume of the tank, then air will have to bled from the tank. The optimum air-to-water ratio should be 2/3 water to 1/3 air. If the problem persists or if there is no sight tube, notify water system specialist. If there is a physical separation between the air and water in the tank, then the separator could have broken. Notify water system specialist.
5. Air is present in the water.	5A. If there is a check valve between the well pump and the hydropneumatic tank, and air is present on the well side of the check valve, then the pump may be breaking suction. In this case, the water level in well is near or below the pump intake.	5A. Partially throttle discharge valve. Notify supervisor or well service company.
	5B. If there is a check valve between the well pump and the hydropneumatic tank, and air is present only on the hydropneumatic tank side of the check valve and in the distribution system, then air from hydropneumatic may be tank entering water.	5B. Improve removal of iron and manganese. If the hydropneumatic tank is equipped with a drain, open the drain valve and discharge the sediment to waste.
6. Oil is present in the water.	6A. Oil leaking from air compressor.	6A. Check the oil separator on the discharge side to the air compressor. Notify water system specialist. Consider replacing the unit with a non-oil lubricated type unit.

Problem	Possible Cause	Possible Solution
7. Dirt and or bacteria present in the water.	7A. Inadequate disinfection.	7A. Refer to troubleshooting table on "hypochlorinators."
	7B. Intake filters on air compressor broken or dirty.	7B. Replace filter. Also review troubleshooting table on "hypochlorinators." Notify water system specialist.
8. Excessively high distribution system pressure (greater than 70 psi).	8A. Automatic pressure controls needs adjustment or cut-out sequence is not functioning.	8A. See Problem Item #2 in this troubleshooting table.
9. Excessively low distribution system pressure (normal working pressure below 40 psi or occasional pressures below 20 psi during peak usage).	9A. Automatic pressure controls needs adjustment or cut-in sequence is not functioning.	9A. Refer to troubleshooting guide Chapter 3 "Pumps." Notify supervisor.
10. Corrosion present onoutside of tank.	10A. Inadequate protective coating (paint).	10A. Clean area with a wire brush. Prime and paint the surface with . Do not chip rust from the tank unless it is drained and out of service. If chipping is required, contact a tank corrosion specialist. The tank may not be structurally sound and re-pressurizing could cause further damage or personal injury. Note: 50 psi exerts a pressure of 3.5 tons per square foot! Never paint the tank interior without first consulting the state regulatory authority.
11. Tank is unstable and can be easily be moved, or tank is supported by the piping.	11A. Tank supports are inadequate.	11A. Provide suitable and permanent supports so the tank can not be moved and the piping is not supporting the weight of the tank. This may require taking the system out of service while these repairs are made. Never try to move a tank that is pressurized. Notify your water system specialist.

Glossary of Terms

Air Bladder	A flexible container located inside of a hydropneumatic tank to hold air.
Air Compressor	A device that compresses air and increases pressure.
Air Cushion	The volume of air inside a hydropneumatic tank.
Air Volume Controller	A device that regulates the volume of air in a hydropneumatic tank.
Air-to-Water Ratio	The relationship between the amount of air and the amount of water in a hydropneumatic tank.
As-built Plans	Drawings such as blue-prints that show the actual components and their relationships.
Back-up Tanks	Tanks that are used to temporally replace tanks that fail or are taken out of service for maintenance.
Corrective Maintenance	The process of replacing worn components or rebuilding equipment based on inspections.
Cut-in Pressure	The low pressure of the system where the system pump will start.
Cut-out Pressure	The high pressure of the system where the pump will stop.
Cycle Counter	An electrical device that records the number of times a pump operates, ie: comes on and shuts off.
Cycle Rate	The frequency that a pump operates per day or hour.
Diaphragm	A flexible device, usually circular, that is used by a chemical feed pump to pump a liquid solution.
Distribution System	A system of pipes, valves, and related components by which a water supply is distributed to consumers. The term applies particularly to the network or pipelines in the streets in a domestic water system.
Elapsed Time Meter	An electrical device that records the amount of time a device operates, usually in hours.
Floating Wafer	A plastic circular device placed in a hydropneumatic tank to separate the air from the water.
Gate Valves	A valve in which the closing element consists of a disk which slides over the opening (or cross-sectional area through which water passes) and fits tightly against it.
Hydropneumatic Tanks	A small, less than 1,000 gallon, tank used by a hydropneumatic system. The tank contains air and water, typically in a 1:2 air to water, ie: 1/3 air to 2/3 water.

Hydrostatic Testing	A pressure test used to verify the integrity of the tank.
Low Water Demand	The days or hours with the lowest water use.
Master Water Flow Meter	A meter that measures the total volume of water used by the system.
O&M	Operation and Maintenance.
Pressure Gauges	A mechanical device used to register system pressure.
Pressure Relief Valve	A valve that opens automatically to relieve the stress on a pipeline when the pressure reaches an assigned limit.
Preventive Maintenance	The process of preventing or reducing failure of equipment by performing routine and non-routine scheduled maintenance.
psi	Pounds per square inch.
Recharging	The process of introducing air into a hydropneumatic tank.
Sight glass	A glass tube which connects the top half of a container to the lower half and serves to show the level of liquid in the container.
Specifications	The detail description of materials, and/or practices and procedures to be used in constructing a water system project.
State Regulatory Agency	The state agency with the regulatory authority to enforce the Safe Drinking Water Act.

Troubleshooting Distribution Systems

Introduction

Many failures to meet the requirements of the safe drinking water standards are directly related to poor operating and maintenance procedures for distribution systems and development of sanitary risks or defects in the system.

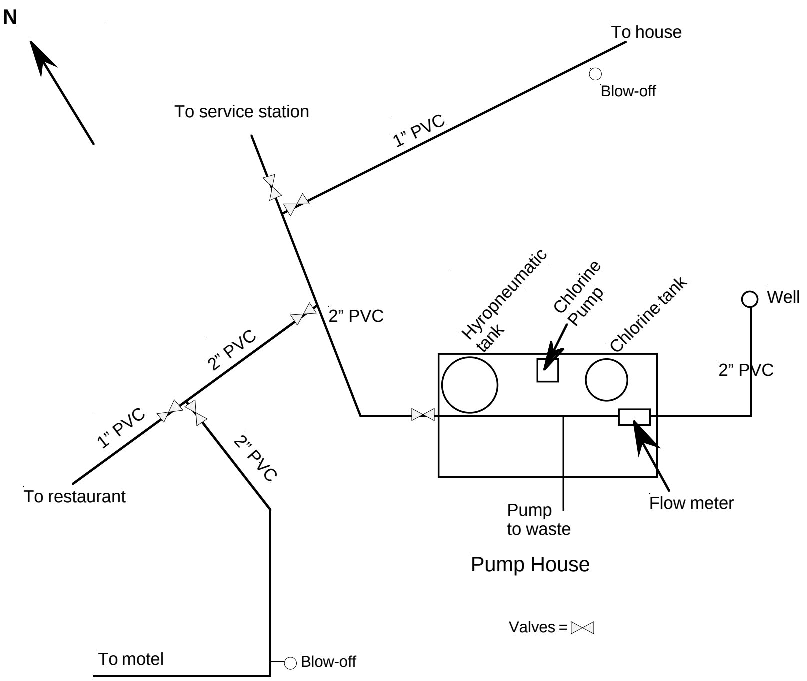
Components of the Distribution System

Troubleshooting water system problems requires information. In the case of distribution system problems it is critical to have a map of the distribution system. Even a hand drawn map is helpful in identifying where distribution system piping, valves, hydrants, and blowoffs are located. The following drawing is a good example of a distribution system map.

Pipes

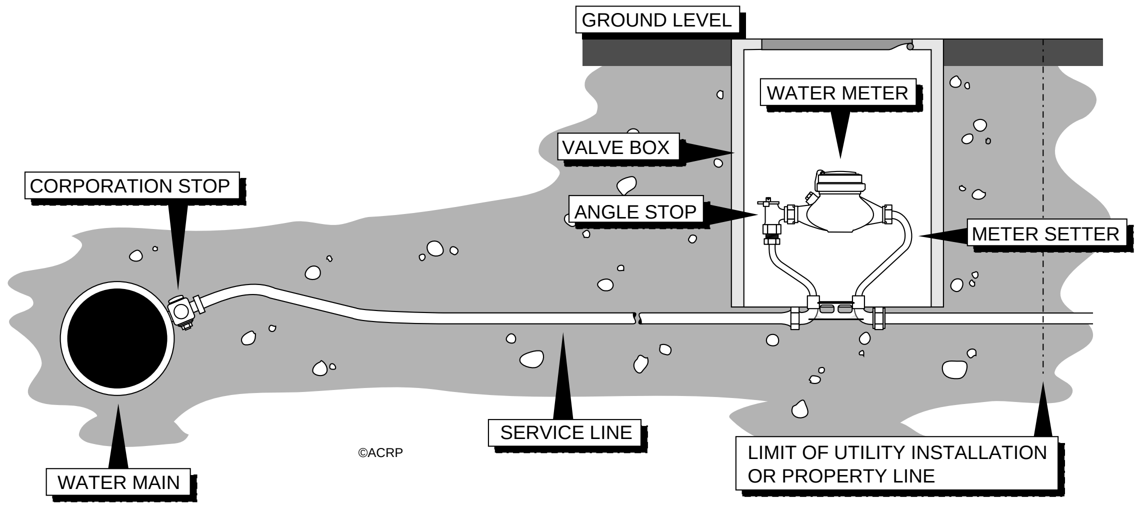
Distribution pipes include

- street water mains,
- service lines
- blow-off lines and
- mains connecting
- hydrants
- storage and
- pumping systems to the system.



Service Lines

Service lines, those that connect services to the meter, or up to the distribution main when meters are not installed, are usually the responsibility of the owner, not the water utility.



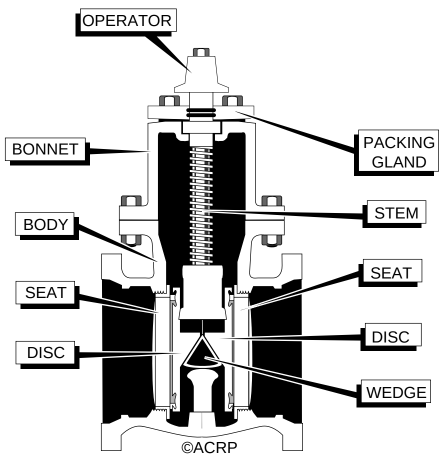
Pipes have been made of galvanized steel, cast iron, ductile iron, lead, copper, brass, steel, asbestos cement, and plastics including polyvinyl chloride (PVC), polybutylene and polyethylene (PE). Each type of material has its own characteristics, advantages and disadvantages. For the operator who is responsible for troubleshooting the distribution system, it is most important to know what types of materials are used in the system and where. Particularly in small systems, there may be more than one pipe material type in the system.

Problems occur when pipes leak and break. These problems are difficult to trouble shoot when the location of the pipes is not known. Also, some pipe materials may allow contaminants from the pipe to be dissolved in the water flowing or standing in them. In these cases, contaminants leached from the pipe material can cause water that contains tastes, odors, and regulated contaminants to be delivered to the system's customers. One effective way to minimize the possibility of contamination from pipe materials is to use pipe that has been certified as meeting standards established by the National Sanitation Foundation (NSF) and the American Society for Testing and Materials (ASTM) for use with potable water.

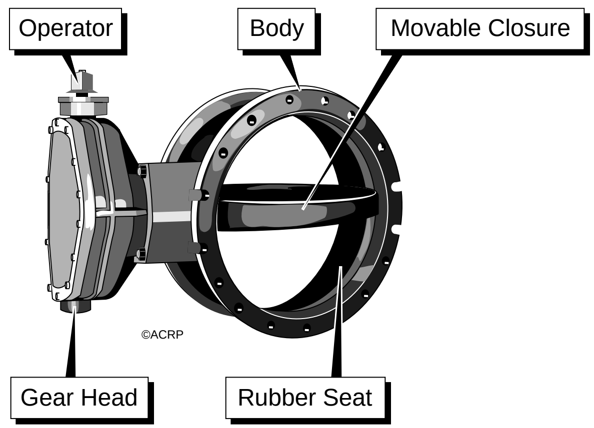
Repairing leaks and breaks in a distribution system require both an inventory of spare parts, valves, repair clamps, etc. as well trenching and excavation services. The operator is responsible for maintaining a basic inventory and developing a list of local service providers.

Valves

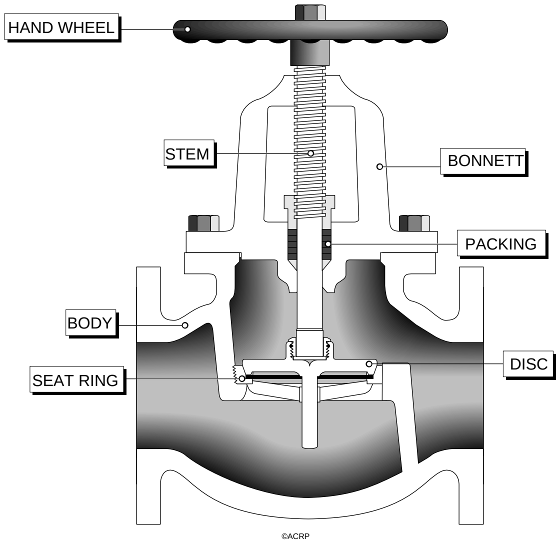
Valves most commonly used in small systems include isolation valves, blow-off and flushing valves, hydrants, pressure-reducing valves, and air or vacuum relief valves. The majority of isolation, blow-off and flushing valves are gate valves, butterfly valves and globe valves.



Gate Valve

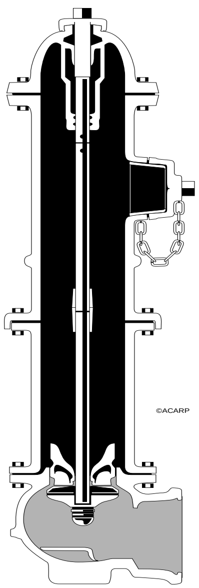


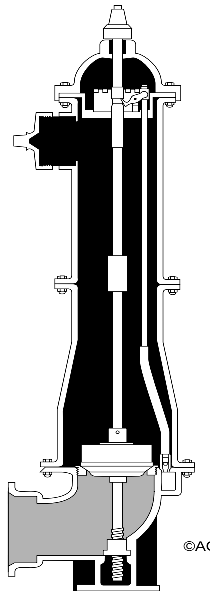
Butterfly Valve

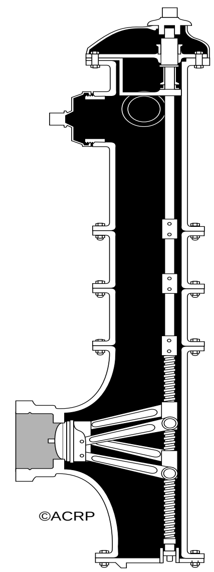


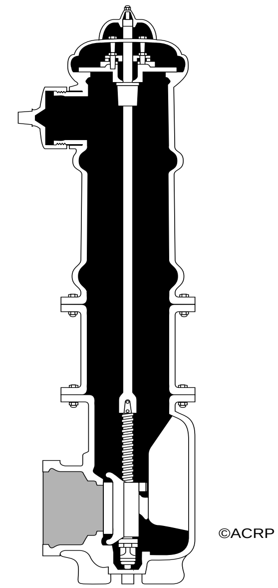
Globe Valve

Hydrants, pressure-reducing, and air or vacuum release valves are specialized for each use.









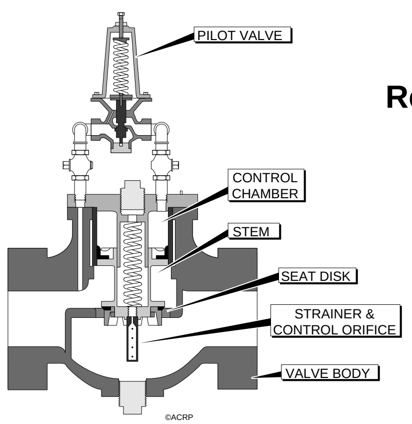
Compression Hydrants

Opens against flow

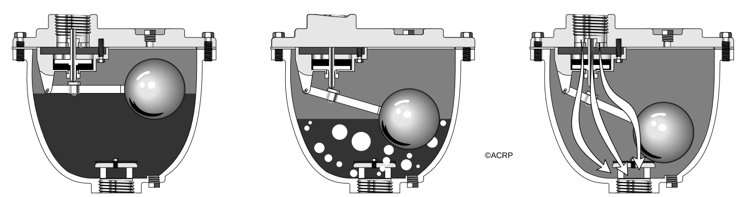
Opens with flow

Toggle Hydrant

Slide Gate Hydrant



Pressure-Reducing Valve



Air Release Valves

Problems with valves occur when they leak or become stuck in the open or closed position. It is important to exercise each valve annually, i.e. fully close and open each valve. Troubleshooting these problems in small systems requires updated, as-built plans of the system.

Flushing

Flushing is a common corrective action for distribution system problems. Flushing requires both an adequate flow and velocity to effectively clean the distribution system piping. The direction for flushing must be unidirectional, i.e. flow in one direction always from clean sections to dirty sections. An effective flushing program requires careful planning.

Meters

An important part of troubleshooting distribution problems is to determine if water is being lost due to leaks. Measuring water pumped and water used by the service connections requires meters at all wells and all hook-ups. Calculating the amount of water lost by subtracting the amount of water used from the amount of water pumped is called a “water audit.” An acceptable water loss due to leaks is 15% or less. Meters must be read regularly, maintained, calibrated, and replaced periodically. Meters may also benefit from flushing.

Troubleshooting Table for Distribution Systems

Problem	Possible Cause	Possible Solution
1. Dirty water complaints	1A. Localized accumulations of debris, solids/**particulates** in distribution mains	1A. Collect and **preserve** samples for **analysis** if needed Isolate affected part of main and flush
	1B. Cross connection between water system and another system carrying non-potable water.	1B. Collect and preserve samples for analysis if needed Conduct survey of system for cross connections. Contact regulatory agency.
2. Red water complaints	2A. Iron content of water from source is high. Iron precipitates in mains and accumulates.	2A. Collect and test water samples from water source and location of complaints for iron. If high at both sites, contact regulatory agency, TA provider, consulting engineer or water conditioning company for assistance with iron removal treatment.
	2B. Cast iron, ductile iron, or steel mains are corroding causing "rust" in the water.	2B. Collect and analyze samples for iron and corrosion parameters. Contact state regulatory agency, TA provider, consulting engineer or water conditioning company for assistance with corrosion control treatment.
3. No or low water pressure	3A. Source of supply, storage or pumping station interrupted.	3A. Check source, storage and pumping stations. Correct or repair as needed.

Problem	Possible Cause	Possible Solution
3. No or low water pressure. (continued)	3B. System cannot supply **demands.**	3B. Check to see if demands are unusually high. If so, try to reduce demand. Contact regulatory agency, TA provider or consulting engineer.
	3C. Service line, meter or connections shut-off or clogged with debris.	3C. Investigate and open or unclog service.
	3D. Broken or leaking distribution pipes.	3D. Locate and repair break or leak.
	3E. Valve in system closed or broken.	3E. Check and open closed isolation and pressure-reducing valves. Repair or contact contractor if valves are broken.
4. Excessive water **usage**.	4A. More connections have been added to the system.	4A. Compare increase in usage over time with new connections added over same period. If correlation evident take action to curtail demand or increase **capacity** if needed. Contact regulatory agency, TA provider or consulting engineer.
	4B. Excessive leakage (>15% of production) is occurring, meters are not installed or not registering properly.	4B. Conduct a water audit to determine the cause. If leakage, contact regulatory agency, and consulting engineer or leak detection contractor.
	4C. Illegal connections have been made.	4C. Conduct survey to identify connections.

Glossary of Terms

Analysis	The process of determining the concentration of a material in water.
Blow-off Lines	Lines and valves used to flush a water distribution system.
Capacity	The volume, usually expressed in gpm, that a pump will produce.
Demand	When related to chlorine, the amount of chlorine neutralized by iron, manganese, algae, and microorganisms in a specified period of time.
Inventory	The purchase and storage of spare parts.
Particulate	Small solids.
Preserve	A process of protecting a sample from deterioration by cooling or the addition of chemi-cals.
Service lines	The smaller diameter piping which take off from the street mains and delivers water to the individual hook-ups.
Street water mains	The larger diameter piping which carries the water through out the distribution system and from which smaller piping takes off water for final delivery to the individual hook-ups.
Usage	The amount used, e.g. the number of gallon of water used per hook up.

Cross Connections

Introduction

Cross connections in a drinking water system can be deadly. Safe drinking water can become unsafe when drinking (potable) water lines are cross connected to an undrinkable (nonpotable) liquid such as an undiluted sodium hypochlorite solution, hose bib with hose immersed in a bucket of soapy water or swimming pool, etc.

Background

Cross connections are easy to create and can be in place for a long time without notice until the right set of conditions occur. Cross connections usually become active when the water system loses pressure, such as would occur with a break in a distribution line or a water pump failure.

The most typical example of a cross connection is the common garden hose. This indirect cross connection occurs when one end of a hose is attached to an unprotected hose bib/faucet and the other end of the hose is in the hypochlorite solution tank. If the water system pressure drops due to a waterline break, the undiluted hypochlorite solution can be pulled back (backsiphoned) into the distribution system piping. This is backsiphon backflow in which the contaminate enters the system as the result of a vacuum created by a negative pressure in the sytstem and the flow of water backwards to meet the demand for water at the waterline break.

Backflow can also occur when there is a backpressure such as a boiler heating system for hot water and/or heat. The Boiler pressure can exceed the water system pressure and cause backpressure backflow. This can result in boiler heating water, often containing chemicals such as antiscalants, to be pushed into the distribution system.

Cross connections can contribute to all kinds of water quality and health problems:

• cloudy or turbid water,

• positive coliform tests,

• color,

• introduction of concentrated chemicals such as hypochlorite solution

The first step in controlling cross connections is to identify the cross connections. You may want to have someone with experience in cross connections to come in and assist you. Resources include your local state drinking water office, state environmental training center or other technical assistance provider. Trace the flow of water and look for any connections between potable and non-potable liquids. Color coding, labeling, and flow direction arrows on pipes can be very helpful in determining which pipes are carrying potable water and which are not and the direction of flow. The following are the most typical examples of where cross connections occur:

Typical Cross Connections in Small Water Systems

1. Garden hose attached to an unprotected hose bib and immersed in nonpotable liquid
2. Garden hose attached to a hose bib with an atmospheric vacuum breaker but with a spray shutoff valve on the other end
3. Make-up water for the hypochlorination feed/solution tank
4. Chemical feed pump without 4 in 1 valve
5. Boilers such as heating units
6. Many hand-held pesticide or herbicide applicators
7. In-ground lawn irrigation systems
8. Connections with un-approved, abandoned or non-potable water wells

The second step in controlling cross connections is to correct the problem. The following are the traditional approaches to controlling cross connections:

1. Air gap - The most effective backflow prevention is an air gap. The air gap from the outlet fixture to the flood rim of the receiving container must be twice the diameter of the outlet fixture figure 1. A good example is the design of modern sinks which have the end of the faucet terminating well above the flood rim of the sink. Another typical example is the following drawing of the make-up water hook up to add potable water to a dilution tank for feeding sodium hypochlorite.

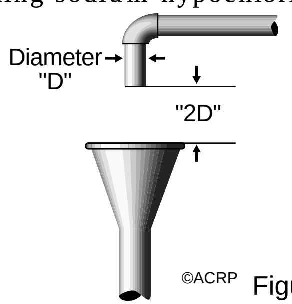


Figure 1

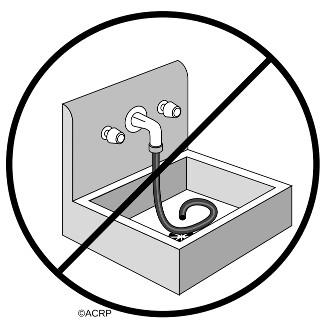
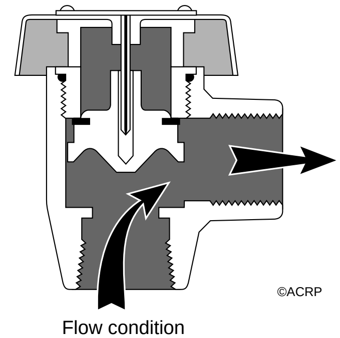


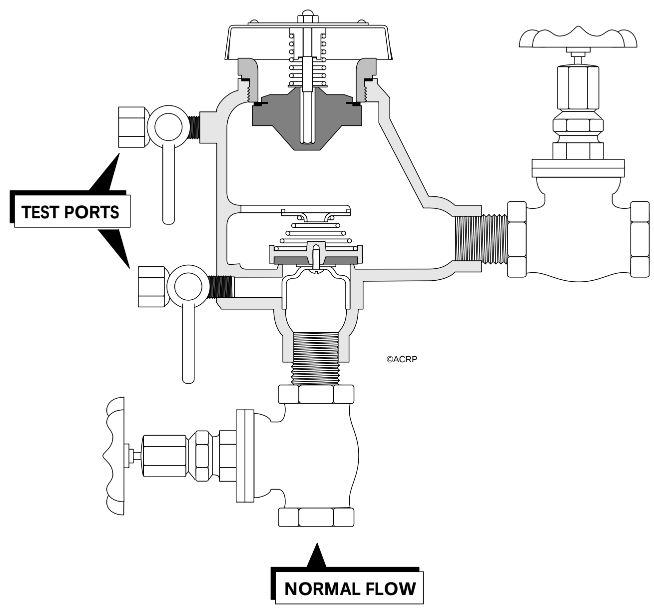
Figure 2

An air gap may not always be possible. The following devices or assemblies are alternatives to the air gap.

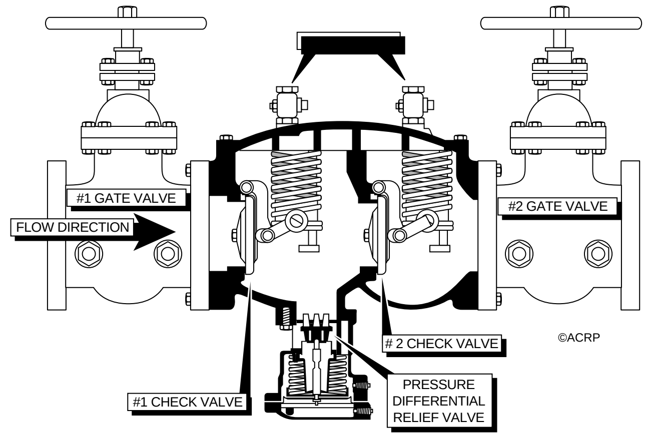
2. Atmospheric Vacuum Breaker (AVB) - An inexpensive device that is activated when the supply line develops negative pressure and prevents back-siphonage. An atmospheric vacuum breaker will not prevent backpressure backflow. The device must be installed six inches above the highest outlet and there can be no downstream shutoffs which would keep the AVB under continuous pressure. For example, a hose bib with a vacuum breaker will prevent back-siphonage backflow unless there is a downstream shut off valve such as a hose spray nozzle. This downstream shutoff puts the AVB under continuos pressure which interferes with the operation of the device.



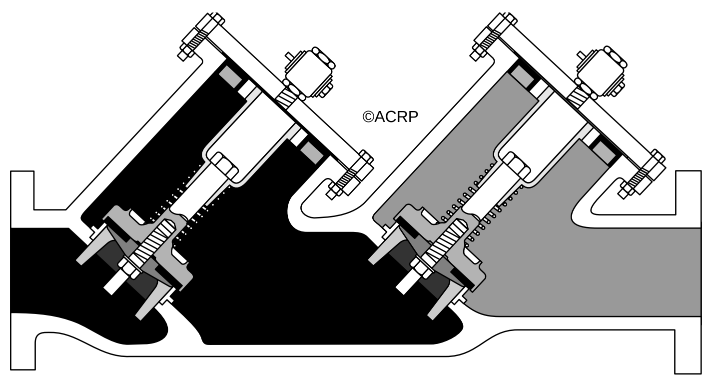
3. Pressure-type Vacuum Beaker (PVB) - This device is similar to the AVB except the PVB can be held under continuos pressure and will operate when a drop in water system pressure occurs. PVB’s are spring loaded and consequently can become inoperable due to corrosion and sediments. PVB's must be installed a minimum of 12 inches above the highest outlet



4. Reduced Pressure Zone Backflow Preventer (RPZ) - This device is for the highest hazards and must be properly maintained and tested annually. This device consists of two spring loaded pressure-reducing check valves with a pressure regulated relief valve located between the two check valves. Periodic discharge of water from the center valve indicates that the valve has responded to a drop in water system pressure. A continuous discharge of water from the relief port may indicate malfunctioning of one or both of the check valves or relief valve. Under no circumstances should the relief port be plugged because the device depends on an open port for effective operation. RPZ's must be protected from freezing and vandals.



5. Double-check valve assembly - Useful for low and intermediate hazard levels and must be inspected annually. Homemade double-checks such as two single checks hooked up in series are not an acceptable substitute.



NOTE: It is important to note that not all states accept or approve all of the devices described above. Check with your local state drinking water office to determine the specific requirements and approved devices for you system.

You should also determine what caused the conditions which activated the cross connection. It might be as simple as an excessively high demand for water due to unusual usage in one part of the distribution system or a tripped breaker switch for the water pump causing a drop in system pressure.

Your local state drinking water office can help you find resources for cross connection surveys as well as installing, maintaining and testing of appropriate backflow prevention devices.

The following Troubleshooting Table presents typical problems which cross connections contribute to. Remember that with cross connections it is important to not only identify and control the cross connection but to determine what caused the conditions which activated the cross connection.

Troubleshooting Table for Cross Connection

Problem	Possible Cause	Possible Solution
1. Sudsy or soapy water.	1A. Hose connected to an unprotected hose bib with the other end in a bucket or sink of soapy water.	1A. Equip all hose bibs with an AVP.
3. Positive Coliform.	2A. Hose connected to an unprotected hose bib with the other end lying on the floor of the pump house, on the ground in the car wash area, in the wading or swimming pool or other nonpotable liquid.	2A. Equip all hose bibs with an AVP.
	2B. Unprotected potable water line feeding a lawn irrigation system.	2B. Install a backflow preventer on the potable water line feeding the irrigation system.
	2C. Submerged inlet, e.g. faucet submerged.	2C. Relocate faucet above flood level.
3. Coloring in the water (unusual colors such as bright blue).	3A. Backflow from toilet.	3A. Get help. Bring in someone who understands cross connections to evaluate your system.
4. Organic odors.	4A. Handheld pesticide/herbicide applicator attached to unprotected hose.	4A. Don't use these devices

Glossary of Terms

Flood Rim	The upper level of a tank or container. When filed above this point water will run out of the container.
Outlet Fixture	A device such as a faucet which controls the flow of water from a point of use.
Sediments	The mineral or organic matter that settles to the bottom of a liquid.
Terminating	The end of something, e.g. the well casing terminates above ground.

Sampling & Monitoring

Introduction

Coliform bacteria and chlorine residual are the only routine sampling and monitoring requirements for small ground water systems with chlorination. The coliform bacteriological sampling is governed by the Total Coliform Rule (TCR) of the SDWA. Although there is presently no requirement for chlorination of groundwater systems under the SDWA, state regulations will usually require chlorine residual monitoring of those systems that do chlorinate the water.

Background

TCR

The TCR requires all Public Water Systems (PWS) to monitor their distribution system for coliform bacteria according to the written sample siting plan for that system. The sample siting plan identifies sampling frequency and locations throughout the distribution system that are selected to be representative of conditions in the entire system. Coliform contamination can occur anywhere in the system, possibly due to problems such as; low pressure conditions, line breaks, or well contamination, and therefore routine monitoring is required. A copy of the sample siting plan for the system should be kept on file and accessible to all who are involved in the sampling for the water system.

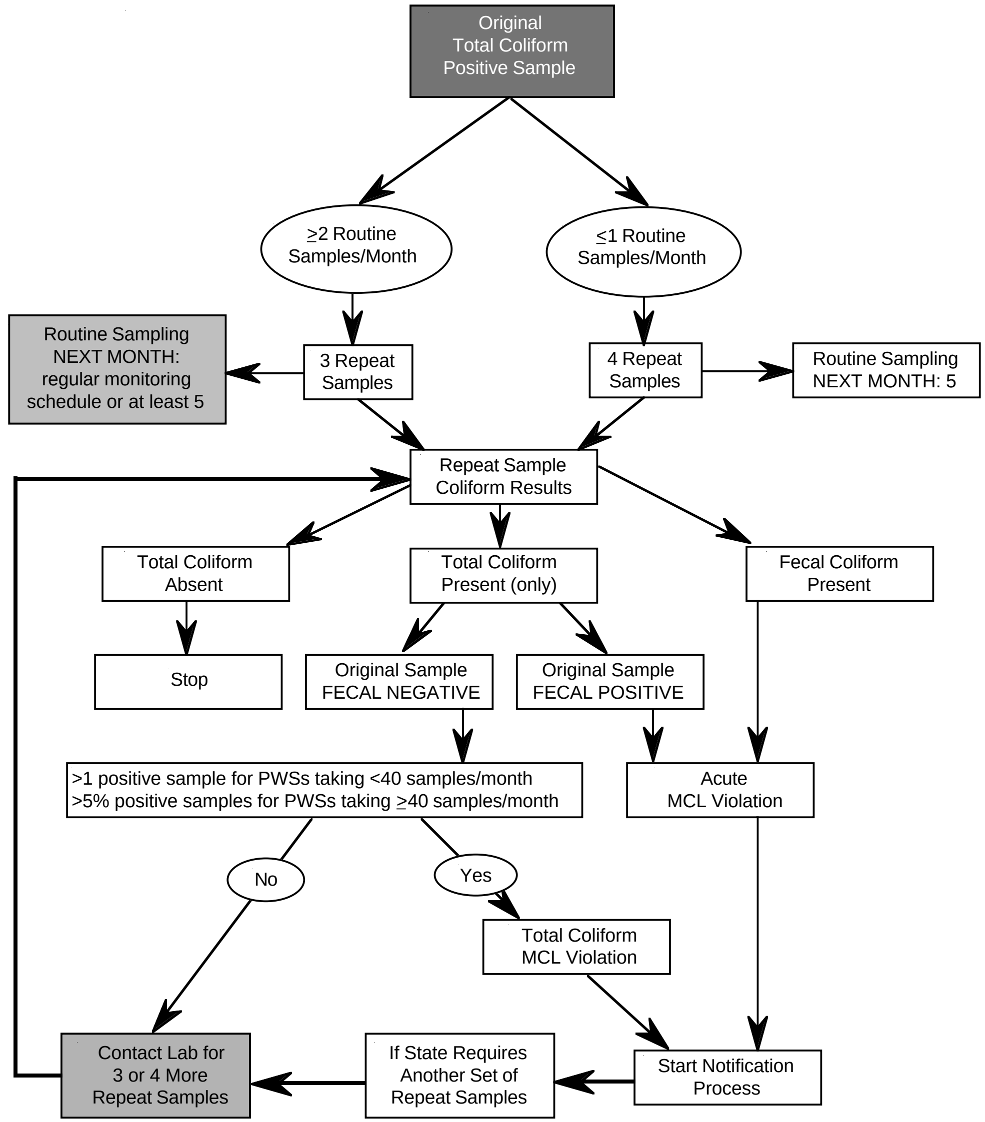
Number of Monthly Samples

The number of samples to be collected monthly depends on the size of the system. The TCR specifies the minimum number of coliform samples collected but it may be necessary to take more then the minimum number in order to provide adequate monitoring. This is especially true if the system consists of multiple sources, pressure zones, booster pumps, long transmission lines, or extensive distribution system piping. Since timely detection of coliform contamination is the purpose of the sample siting plan, sample sites should be selected to represent the varying conditions that exist in the distribution system. The sample siting plan should be updated as changes are made in the water system, especially the distribution system.

Sampling Procedures

The sample siting plan must be followed and all operating staff must be clear on how to follow the sampling plan. In order to properly implement the sample siting plan, staff must be aware of how often sampling must be done, the proper procedures and sampling containers to be used for collecting the samples, and the proper procedures for identification, storage and transport of the samples to an approved laboratory. In addition, proper procedures must be followed for repeat sampling whenever a routine sample result is positive for total coliform. The following diagram outlines the requirements for responding to a positive Total Coliform sample.

Total Coliform Action Response Require



Source: University of Iowa Hygienic Laboratory Symposium, 1991

Each water system should have specific procedures for TCR sampling to address the issues described. The sample siting plan and sampling procedures must be readily available to all operations personnel at the facility. In order to prevent obtaining inaccurate sample results that could cause compliance problems, it is critical that the operator be aware of some key issues relating to the collection and transport of the total coliform samples.

TotalColiformRule TCRSamplingConsiderations
Samples must be collected in sterile containers provided by the approved laboratory that will be doing the colifor analysis.
All sample containers should be labeled with the date, time, and location of sample collection as well as the sigr of the person who collected the sample.
Use only clean sample taps. If cleanliness is questionable, apply a solution of sodium hypochlorite to the surface the tap before collecting the sample.
The sample should be taken from a smooth nosed cold water tap if possible.
Aerators, strainers, and hose attachments should be removed before collecting a sample.
Samples should not be taken from: Leaky taps that allow water to flow from around the stem and over the outside of the faucet. Swivel faucets. Houses with home treatment units. Taps with nonremovable aerators, strainers, or hose attachments.
The spout of the sampling tap should face the ground so that water cannot stand in the spout when the tap is t off.
Prior to collecting the sample, open the tap fully and flush to clear the service line.
Reduce the flow enough to prevent splashing, open and fill the sample container without rinsing, leaving a 1 incl space in the container.
If sample will be in transport to the laboratory for more than 1 hour, use an iced cooler to maintain sample temp of 4 degrees C. Do not submerse the tops of the sample containers.
Samples can be held for up to 6 hours before analysis if kept refrigerated.
It may be necessary to mail the sample to a lab if the PWS is in a remote location. Insulation and mailing is acc as long as the time from collection to analysis is less that 24 hours and a chain of custody is maintained.

All of the information described above, relating to the TCR requirements, is readily available from local, state, and federal regulatory agencies. Include your state's monitoring requirements and policies on file with your sample siting plan. There are a number of operator guidance manuals available describing the detailed requirements and procedures necessary to comply with the TCR. It is the operators responsibility to obtain the necessary information to insure compliance.

Chlorine Residual Monitoring

Although the SDWA does not presently require chlorination of all groundwater systems, many small water systems may be chlorinating for a variety of reasons. Some states require chlorination of groundwater systems above a specified population served, others may require it when a system has had bacteriological problems or other water quality problems. In the future, the SDWA may require disinfection of groundwater systems that are considered susceptible to bacteriological contamination as part of the new Ground Water Rule.

If a system is chlorinating at the well, the operator will generally attempt to maintain at least a detectable free chlorine residual at the far ends of the distribution system. In particular, dead end lines are usually a problem area and should be checked for a residual. In order to accomplish this, it may be necessary to maintain a much higher residual at the point of entry (POE) to the distribution system. Therefore, it is important to monitor the chlorine residual at several points in the system in order to properly control the dose rate and maintain the desired residual at the most critical locations. Developing a comprehensive set of data on chlorine residual levels at various points in the distribution system will assist the operator in early detection of problems and possibly help avoid a serious water quality problem.

Normally in a ground water system, the free and total chlorine residuals are very close to the same number. As a rule of thumb, the free residual should be at least 85 % of the total residual. Additional discussion of the relationship between the free and total chlorine residual can be found in Chapter 4 on Hypochorination in this guide. The inability to maintain the free residual at 85% of the total chlorine residual throughout the distribution system can result in water quality problems such as chlorine taste and odor and possibly positive coliform results. The problem of chlorine taste and odor is generally related to high combined residual and the solution may be to increase the chlorine dose rate to get past the breakpoint so that an adequate free residual can be maintained. A comprehensive sampling and monitoring program for both free and total chlorine residual is critical in providing the highest quality water to the public.

Troubleshooting Table for Sampling & Monitoring

Problem	Possible Cause	Possible Solution
1. Positive Total Coliform.	1A. Improper sampling technique.	1A/ Check distribution system for low pressure conditions, possibly due to line breaks or excessive flows, that may result in a backflow problem.
	1B. Contamination entering distribution system.	1B. Insure that all staff are properly trained in sampling and transport procedures as described in the TCR.
	1C. Inadequate chlorine residual at the sampling site.	1C. Check the operation of the chlorination feed system. Refer to issues described in the chapters on pumps and hypochlorination systems. Insure that residual test is being performed properly.
	1D. Growth of **biofilm** in the distribution system.	1D. Thoroughly flush effected areas of the distribution system. **Superchlorination** may be necessary in severe cases.
2. Chlorine taste and odor.	2A. High total chlorine residual and low free residual.	2A. The free residual should be at least 85% of the total residual. Increase the chlorine dose rate to get past the breakpoint in order to destroy some of the combined residual that causes taste and odor problems. Additional system flushing may also be required.

Problem	Possible Cause	Possible Solution
3. Inability to maintain an adequate free chlorine residual at the furthest points of the distribution system or at dead end lines.	3A. Inadequate chlorine dose at treatment plant.	3A. Increase chlorine feed rate at point of application.
	3B. Problems with chlorine feed equipment.	3B. Check operation of chlorination equipment.
	3C. Ineffective distribution system flushing program.	3C. Review distribution system flushing program and implement improvements to address areas of inadequate chlorine residual.
	3D. Growth of biofilm in the distribution system.	3D. Increase flushing in area of biofilm problem.

Glossary of Terms

Bacteriological Sampling	The process of collecting samples for testing for Coliform bacterial.
Biofilm	An organic slime that grows on the inside of a pipe.
Booster Pumps	A pump installed on a pipeline to raise the pressure of the water on the discharge side of the pump.
Chlorinate	The process of adding chlorine to water.
Chlorine Residual	The amount of chlorine left in solution after a period of time. For instance with new water lines, the reaction time is 24 hours. The residual is usually expressed in mg/L.
Cross Connection	Any physical arrangement whereby a potable water supply is connected, directly or indirectly, with an non-potable or unapproved water supply or system.
Dead-end Lines	The end of a water main which is not connected to other parts of the distribution system by means of a connecting loop.
Detection	The process of identifying the presence or absence of coliform bacteria.
Dose Rate	The rate in mg/L that chlorine or other chemicals are added to water.
Groundwater	Subsurface water occupying a saturated geological formation from which wells and springs are fed.
Implement	To carry into effect.
Monitoring Requirements	The type and frequency of sampling and testing the water quality.
Multiple Sources	More than one source of water.
Point of Entry (POE)	The point at which water enters the distribution system.
Pressure Zones	An area embraced within the distribution system of a domestic or municipal water supply, in which the pressure in the mains in maintained within certain specified limits.
Public Water Systems	Water systems designed to deliver water to more than one home or family.
Superchlorination	Chlorination wherein the doses are deliberately selected to produce free or combined residuals so large as to require dechlorination.
Total Coliform Rule	A rule of SDWA requiring water systems to monitor for coliform bacteria on a monthly basis.
Transmission lines	The piping from the water source, e.g. well, to the point of disinfection and storage.

Appendix

Acknowledgements

Project Director

Dr. William Engel, CET, Director; Training, Research and Education for Environmental Occupations Center (TREEO Center), University of Florida, Gainesville, Florida

EPA Project Officer

Kenneth “Ken” Hay, Education/Training Specialist; Office of Ground and Drinking Water, United States Environmental Protection Agency; Washington, DC

Project Coordinator

Andrew A. Holtan, CET, President; International Studies & Training Institute; Whiteford, Maryland

Graphics & Publication

Everett E. “Skeet” Arasmith, CET, President; Arasmith Consulting Resources, Albany, Oregon
Kevin Zentz, Illustrator; Arasmith Consulting Resources, Albany, Oregon

Authors

The following individuals developed the material presented in this Troubleshooting Guide:

Doug Abbott, CET, President; Abbott & Associates, Columbia, Maryland

Lenny Gold, President; Gold and Associates, Easton, Maryland

William Parrish, Water Systems Specialist, Cockeysville, Maryland

Suggested References

1. At America's Service - Karl Albrecht
   Available from: Dow Jones-Irwin
   Homewood, Illinois 60430

2. AWWA B600-78: Standard for Powdered Activated Carbon
   Available from: AWWA
   6666 W. Quincy Avenue
   Denver, CO 80235

3. AWWA B604-74: Standard for Granular Activated Carbon
   Available from: AWWA
   6666 W. Quincy Avenue
   Denver, CO 80235

4. Basic Science Concepts and Applications Reference Handbook
   Available from: AWWA
   6666 W. Quincy Avenue
   Denver, CO 80235

5. Construction of Distribution Systems
   Available from: ACR Publications
   1298 Elm St. SW
   Albany, OR 97321
   541-928-6199
   800-433-8150
   Fax - 541-926-3478
   www.acrp.com

6. Distribution Systems
   Available from: AWWA
   6666 W. Quincy Avenue
   Denver, CO 80235

7. Electrical Fundamentals for Water and Wastewater
   Available from: ACR Publications
   1298 Elm St. SW
   Albany, OR 97321
   541-928-6199

   800-433-8150
   Fax - 541-926-3478
   www.acrp.com

8. Environmental Engineering and Sanitation — by Joseph A. Salvato
   Available from: John Wiley & Sons, Inc.
   Somerset, NJ 08873

9. How to Conduct a Sanitary Survey Procedures Manual
   Available from: New Mexico Health and Environmental
   Department Environmental
   Improvement Division
   P.0. Box 968
   Santa Fe, NM 87504-0968

10. Introduction to Small Water Systems
   Available from: ACR Publications
   1298 Elm St. SW
   Albany, OR 97321
   541-928-6199
   800-433-8150
   Fax - 541-926-3478
   www.acrp.com

11. Introduction to Utility Management
   Available from: ACR Publications
   1298 Elm St. SW
   Albany, OR 97321
   541-928-6199
   800-433-8150
   Fax - 541-926-3478
   www.acrp.com

12. Introduction to Water Distribution, Volume III
    Available from: AWWA
    6666 W. Quincy Avenue
    Denver, CO 80235

13. Introduction to Water Treatment, Volume II
    Available from: AWWA
    6666 W. Quincy Avenue
    Denver, CO 80235

14. Introduction to Water Quality Analysis, Volume IV
    Available from: AWWA
    6666 W. Quincy Avenue
    Denver, CO 80235

15. Introduction to Water Sources Transmission, Volume I
    Available from: AWWA
    6666 W. Quincy Avenue
    Denver, CO 80235

16. Maintenance Management
    Available from: AWWA
    6666 W. Quincy Avenue
    Denver, CO 80235

17. Manual of Individual Water Supply Systems
    Available from: Superintendent of Documents
    U.S. Government Printing Office
    Washington, D.C. 20402
    Stock No. 055-000-00229-1

18. A Manual of Instruction for Water Treatment Plant Operators
    Available from: Health Education Services, Inc.
    P.O. Box 7126
    Albany, NY 12224
    518-439-7286

19. Manual of Treatment Techniques for Meeting the Interim Primary Drinking Water Regulation; EPA 600/8-77-005
    Available from: 0RD Publications
    USEPA-CERI
    26 West St. Clair Street
    Cincinnati, OH 45268

20. Manual of Water Utility Operations
    Available from: Texas Water Utilities Association
    6521 Burnet Lane
    Austin, TX 78757

21. National Primary Drinking Water Regulations
    Available from: Superintendent of Documents
    U.S. Government Printing Office
    Washington, DC 20402
    Stock No. 055-000-00157-0

22. National Secondary Drinking Water Regulations
    Available from: Environmental Protection Agency
    Office of Water Supply
    Washington, D.C. 20460

23. Occurrence and Removal of VOC's from Drinking Water
    Available from: AWWA
    6666 W. Quincy Avenue
    Denver, CO 80235

24. O & M of Chlorination Systems
    Available from: ACR Publications
    1298 Elm St. SW
    Albany, OR 97321
    541-928-6199
    800-433-8150
    Fax - 541-926-3478
    www.acrp.com

25. Opflow— Volume 12, No. 5, May 1986
Available from: AWWA
6666 W. Quincy Avenue
Denver, CO 80235 EPA-570/9/76-OOO

26. Planning for an Individual Water System
Available from: American Association for Vocational
Instructional Materials
Engineering Center
Athens, GA 30602

27. Pumps and Pumping
Available from: ACR Publications
1298 Elm St. SW
Albany, OR 97321
541-928-6199
800-433-8150
Fax - 541-926-3478
www.acrp.com

28. Recommended Standards for Water Works (Ten States Standards)
Available from: Health Education Services, Inc.
P.O. Box 7126
Albany, NY 12224
518-439-7286

29. Small Water System Operation & Maintenance
Available from: Department of Civil Engineering
California State University, Sacramento
6000 J Street
Sacramento, CA 95810

30. Standards for the Disinfection of Pipe
Available from: AWWA
6666 W. Quincy Avenue
Denver, CO 80235

31. The Safe Drinking Water Act Handbook for Water System Operators
Available from: AWWA
6666 W. Quincy Avenue
Denver, CO 80235

32. Thriving on Chaos Tom Peters
Available from: Alfred A. Knopf
New York, NY

33. Water Distribution System Operation & Maintenance
Available from: Department of Civil Engineering
California State University, Sacramento
6000 J Street
Sacramento, CA 95810
916-278-6142

34. Water Systems Handbook
Available from: Water Systems Council
221 North LaSalle Street
Chicago, IL 60601

35. Water Treatment Plant Design, prepared jointly by the American Water Works Association, Conference of State Sanitary Engineers, and American Society of Civil Engineers
Available from: Data Processing Department, AWWA
6666 W. Quincy Avenue
Denver, CO 80235

36. Water Treatment Plant Operations, Volume I
Available from: Department of Civil Engineering
California State University, Sacramento
6000 J Street
Sacramento, CA 95810
916-278-6142

37. Water Treatment Plant Operations, Volume II
Available from: Department of Civil Engineering
California State University, Sacramento
6000 J Street
Sacramento, CA 95810
916-278-6142

38. Water Quality and Treatment: A Handbook of Public Water Supplies; American Water Works Association, Third Edition, McGraw-Hill, 1971.
Available from: Data Processing Department, AWWA
6666 W. Quincy Avenue
Denver, CO 80235
Order No. 10008

Audio-Visual Training Materials

Films

1. Safe Handling of Chlorine
   Available from: AWWA - Technical Library
   6666 W. Quincy Avenue
   Denver, CO 80235
   (Phone: 303-794-7711)
2. Anybody Can Do It (Price: $200)
   Available from: EPIC Productions
   7630 Wood Hollow 237
   Austin, TX 78731
3. Safe Handling of Chlorine
   Available from: AWWA - Technical Library
   6666 W. Quincy Avenue
   Denver, CO 80235
   (303) 794-7711
4. Working Together for Safe Water
   University of Southern California Foundation for Cross- Connection Control and Hydraulic Research (Price: $200 for 16 mm film)
   Available from: Foundation for Cross-Connection Control and Hydraulic Research, University of Southern California
   KAP-200 University Park MC-2531
   Los Angeles, CA 90089-2531

Slides/Tapes

1. Sanitary Surveys - Before you Begin.. Wells
2. Sanitary Surveys - Before you Begin.. Cross Connections
3. Sanitary Surveys - Before you Begin.. Storage
4. Sanitary Surveys - Before you Begin.. Hypochlorintion and Groundwater
   Available from: NETA
   3020 East Camelback Road, Suite 399
   Phoenix, AZ 85016-442
   (602) 956-6099
5. Water Regulation Compliance Training
6. Introduction to the Safe Drinking Water Act and the Lead Contamination Control Act”
7. Surface Water Treatment Rule
8. Total Coliform Rule
9. Operator Training for the Total Coliform Rule
10. Transient Non-community Water System Regulations
11. Lead and Copper Regulations
12. Operator Training for the Lead and Copper Regulations
13. Inorganic and Organic Chemical Rules
14. Compliance and Enforcement
15. Safe Handling of Water Treatment Chemicals
    Available from: AWWA - Technical Library
    6666 W. Quincy Avenue Denver, CO 80235
    (Phone: 303-794-7711)
16. Handbook on National Primary and Secondary Regulations
    Available from: NETA
    3020 East Camelback Road, Suite 399
    Phoenix, AZ 85016-4421
    (602) 956-6099

17. Working Together for a Safe Water (VHS video - $80)
    Available from: Foundation for Cross-Connection Control and Hydraulic Research
    University of Southern California, KAP-200
    University Park MC-253
    Los Angeles, CA 90089-2531
    (Phone: 213-740-2032)

18. Anybody Can Do It (VHS video - $200)
    Available from: EPIC Productions
    7630 Wood Hollow 237
    Austin, TX 78731
    (Phone: 512-345-2563)

19. "Cross-Connections: The Unseen Hazards
    Available from: EPIC Productions
    7630 Wood Hollow 237
    Austin, TX 78731
    (Phone: 512-345-2563)

20. Water, Water Everywhere
    Available from: (to borrow) Los Alamos National Library,
    Film Library (Linda Coller), Mail Stop P364
    Los Alamos, NM 87545
    (Phone: 505-667-4446)
    (to purchase) Los Alamos National Library,
    IS Twelve, Mail Stop D415
    Los Alamos, NM 87545
    (Phone: 505-667-5161)