How to Conduct a Sanitary Survey of Small Water Systems

A Learner's Guide

Designed to Assist in the Delivery of a Sanitary Survey Training Course

2003 Edition

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Contents

Introduction

> *"Using need-to-know criteria and delivered by professional technical instructors, a competency based training course is a training approach to bringing and maintaining nationwide consistency in the conduct of a sanitary survey of a small water system."*
>
> Ken Hay, EPA Educational Specialist.

A sound sanitary survey program is an essential element of an effective state drinking water program. Sanitary surveys fundamental to helping the state drinking water program better understand how a system is operating and ensure that the water system is providing safe water and protecting public health.

Learning Objectives

By the end of this chapter, learners should be able:

- To evaluate their own background and experiences and identify subjects to learn more about during the training.
- To define "sanitary survey" and explain the purpose of a sanitary survey of a small water system.
- To explain that the focus of the training is the identification of conditions or deficiencies that may cause public health risks in a typical small water system.

Course Description

Purpose of this Training Guide

This sanitary survey training course is designed for field staff who inspect and evaluate small water systems for sanitary deficiencies and compliance with the Safe Drinking Water Act (SDWA). Its purpose is to apply basic scientific information and a working knowledge of the operation, maintenance, management, and technology of a small water system to identify sanitary deficiencies. **Sanitary deficiencies** are defects in a water system's infrastructure, design, operation, maintenance, or management that cause, or may cause, interruptions to the "multiple barrier" protection system and adversely affect the system's ability to produce, reliably and in adequate quantities, safe drinking water. Most community water systems must correct sanitary deficiencies determined to be "significant deficiencies."

Need-to-Know Criteria

The training is designed to present the activities of a sanitary survey and identify the questions to ask and the conditions to look for. This Guide addresses each of the eight elements of a sanitary survey as defined in the *EPA/State Joint Guidance on Sanitary Surveys*, December 1995. (A separate chapter covers cross-connections because they are of concern in both treatment and distribution systems.) In addition, the training discusses the process for conducting a sanitary survey; familiarizes the learner with security concerns; reviews applicable federal drinking water regulations; and explains the relationship between federal and state regulations. The chapters of this Guide, and the activities the learner will be able to do after working through them, are presented below.

- **Organizing the Sanitary Survey** - Prepare for, conduct, and perform follow-up activities for a sanitary survey.
- **Regulations** - Explain the applicability of federal regulations that apply to water systems and their relationship to state regulations.
- **Water Sources** - Evaluate water supply sources and intake structure to determine proper source protection.
- **Storage Facilities** - Evaluate the adequacy, reliability, and safety of finished water storage.
- **Treatment Processes** - Evaluate treatment processes, facilities, components, and techniques and related chemical addition and handling.
- **Distribution System** - Evaluate the adequacy, reliability, and safety of the system for distributing water to consumers.
- **Cross-Connections** - Identify cross-connections and evaluate the cross-connection control program.
- **Pumps and Pumping Facilities** - Identify proper operation and maintenance of water system pumps and pumping facilities.
- **Monitoring, Reporting and Data Verification** - Review monitoring data for source and finished water quality for bacteriological, physical, chemical and radiological properties and, as required, perform and evaluate results of field analyses.
- **Management** - Evaluate the effect of management practices on the reliability of the system and review the qualifications of system personnel.

Length of Training

This basic training lasts 3 1/2 days and focuses on the information an inspector needs to know in order to recognize and identify conditions or practices that may contribute to a sanitary risk. The training can also be taught as a 2-day session focusing either on sanitary surveys of ground water systems or surface water systems. It can also be adapted to address state-specific needs such as a state's standard sanitary survey form and significant deficiencies, or sanitary surveys of non-community systems. In each case the training presents the opportunity to discuss what sanitary deficiencies are, where they are most likely to occur, and how to recognize or anticipate them.

Approach

The training combines classroom presentations and discussion with site visits to ground water and surface water systems. The field exercises conducted during the site visits provide opportunities for hands-on application of classroom information to identify actual problematic conditions (i.e., sanitary deficiencies) that may contribute to a public health or "sanitary" risk. Guided team discussions after the field exercise clarify the reasons the deficiencies present public health risks and identify potential corrective actions that might be taken to eliminate the risks.

Field Exercise

Participants are divided into teams and conduct a sanitary survey during the on-site field exercises. Summaries of team findings are presented for discussion by participants. Participants should be punctual and dress appropriately for field exercises and for possible inclement weather.

Training Materials

Instruction is supplemented with this Learners Guide, two Field Guides (ground water and surface water), and audiovisual training materials. Unless otherwise noted, the standards and rates mentioned throughout the guide have been taken from the publications "Technologies for Upgrading Existing or Designing New Drinking Water Treatment Facilities," U.S. EPA Office of Drinking Water Center for Research Information, Cincinnati, OH 45268 (EPA/625 4-89/023) and "Recommended Standards for Water Works," 1997, Health Education Services, Health Research Inc., P.O. Box 7126, Albany, N.Y. 12224 (518) 439-7286. A list of additional references is provided in the appendices along with a list of training films and video tapes.

Entering Competencies of Participants

Essential Background

Participants who have a working knowledge of the vocabulary associated with water systems and an understanding of how water systems work will benefit from the competency-based sanitary survey training. Basic knowledge of small water systems is essential. Participants will be encouraged to interact with one another, share experiences and case histories, enter into team exercises and discussions, ask questions, and contribute answers and solutions to problems as they are presented.

Definition of Sanitary Survey

Definition

A sanitary survey is defined in 40 CFR 141.2 as "an on-site review of the water source (identifying sources of contamination using results of source water assessments where available), facilities, equipment, operation, and maintenance and monitoring compliance of a public water system for the purpose of evaluating the adequacy of such sources, facilities, equipment, operation, and maintenance for producing and distributing safe drinking water." In addition, an assessment of management practices is included in this Guide.

Classes of Surveys

Sanitary surveys may be Class I or Class II:

- A Class I sanitary survey is a comprehensive on-site evaluation of all water system components and operation and maintenance procedures. The state should conduct Class I sanitary surveys for all community water systems no less frequently than once every three years and for non-community systems at least once every five years. All Class I sanitary surveys should address sources; treatment; distribution; finished water storage; pumping facilities and controls; monitoring, reporting, and data verification; system management and operation; and operator compliance with state requirements.
- A Class II sanitary survey is a limited on-site survey, conducted on an as-needed basis. The survey may include, but is not limited to, specific water system component inspections, operations and maintenance procedure inspections, investigatory (complaint-related) inspections, Class I follow-up inspections, or inspections conducted as a result of a compliance problem and/or enforcement related action. A Class II Survey is not a substitute for a Class I Survey.

Rationale for Conducting Sanitary Surveys

Compliance Driven

The sanitary survey is compliance driven. The SDWA regulations are designed to prevent the development of conditions and practices that contribute to sanitary deficiencies. The National Primary Drinking Water Regulations (40 CFR Part 141) require that sanitary surveys be conducted at public water systems at least every 3 to 5 years, depending on the type of system and size. Consequently, compliance is a very good indication of a system's ability to reliably produce an adequate supply of safe drinking water. The sanitary survey inspector should be concerned whether long-term compliance is likely, or whether compliance is precarious and possibly subject to a high degree of risk that could impair water quality or quantity and jeopardize public health.

Personnel to Conduct Survey

Who Conducts Sanitary Surveys

Sanitary surveys must be conducted by competent personnel who have experience and knowledge of the design, operation, maintenance, and management of small water systems. These individuals must be qualified to assess problems and make sound decisions using hydrological, hydraulic, mechanical, and other basic engineering and management knowledge.

1 Organizing the Sanitary Survey

To conduct an effective and efficient sanitary survey, the inspector must organize and plan the entire effort. Many critical steps are required, beginning with the first phone call to arrange the on-site inspection and ending with the sustainable correction of sanitary defects. The sanitary survey process has three stages:

- Preparation, including background research.
- On-site inspection.
- Follow-up activities to ensure that sanitary deficiencies are corrected

The sanitary survey process should be viewed as a cooperative partnership between the primacy agency and the water purveyor since both share the goal of providing safe drinking water to the public.

Learning Objectives

By the end of this chapter, learners should be able:

- To give an overview of activities that occur before, during, and after a sanitary survey of a small water system.
- To determine with whom to communicate and how to communicate before, during, and after an on-site inspection.
- To identify a purpose for speaking with each of the contacts identified. Explain what types of information should be communicated and in what form.
- To explain the activities to be accomplished during the preparation phase and the importance of each activity.
- To plan a schedule for the sanitary survey, estimating the time required for each activity.
- To evaluate sample forms and discuss field notes as tools to assist in conducting the survey.
- To identify personal protective equipment and safety precautions for inspectors during an on-site inspection.
- To identify field test equipment for inspectors, and explain the importance of a preventive maintenance program for field equipment.
- To explain the functions of a sanitary survey report and technical assistance.

Preparation

Planning

Estimate Time Required. In planning the sanitary survey, the inspector needs to estimate the time required in order to manage his time well. The estimate should include time prior to, during, and after the on-site inspection. Although the time required will vary with the complexity of the water system and the experience of the inspector, a good rule of thumb is 2 hours in the office for every hour in the field.

Research

Review Files. Prior to each survey, the inspector should review available information for at least the past 5 years concerning the system to be surveyed. The review will help the inspector to become fully briefed on the system's history and condition.

Often, if the inspector is familiar with the system's history, it is easier to understand remarks made during the on-site inspection concerning previous letters or conversations that may otherwise be taken out of context, misstated, or misunderstood.

Knowledge of the system's past conveys to the water system personnel the inspector's professionalism and concern for the system. The end result will be better, more accurate, and useful information concerning the operation and facilities. The inspector should obtain as much of the following information about the water system as possible before the sanitary survey inspection. This information should be available from the primacy agency's electronic database and hard-copy files. Otherwise, the information and data may be obtained during the inspection.

- Prior sanitary survey reports.
- Correspondence with the state.
- Compliance monitoring results.
- The system's consumer confidence report.
- Records of enforcement actions or warnings of potential actions.
- Plans on file (e.g., source protection, monitoring, emergency or contingency plans, cross-connection control, capital improvement).

Regulations and Standards to Consider

The inspector should also review and consider the following materials prior to the inspection:

- 40 CFR Part 141 - National Primary Drinking Water Regulations, as adopted by the state.
- Additional state regulations.
- State engineering and construction standards.
- EPA's proposed ground water rule.
- Capacity development guidance.
- Minimum operator certification requirements.

Contacts

Phone and Write

The inspector must contact the water system owner to explain the purpose of the sanitary survey; schedule a meeting location, date, and time when key personnel will be available; and discuss any preparations the water system staff need to make for the sanitary survey.

Telephone contact followed by a short follow-up notification letter is recommended. The letter should reiterate the content of the phone conversation. It should also provide instructions for requesting changes to the schedule. This is also a good opportunity to emphasize the reasons for performing the survey and to inform water system personnel of specific information they will need to provide. This contact should give system personnel sufficient time to respond to the notice.

It is essential that the inspector contact the person directly responsible for the overall management of the system (e.g., CEO, mayor, water commissioner, utility manager) in order to obtain cooperation, gather information, coordinate with other departments or agencies, and transmit the results of the evaluation. Prior to the on-site inspection, the inspector should contact the people identified in the table below.

Contact	*Purpose*
Water System Owner	▪ Obtain cooperation ▪ Establish survey dates ▪ Explain purpose of survey ▪ Request that necessary information be available ▪ Coordinate gaining entry to site ▪ Ensure presence of all necessary operational personnel during survey
Other Regulatory Agencies	▪ Ensure cooperation and coordination ▪ Obtain information pertinent to system

Changing the Schedule. If the schedule must be changed, the inspector should change it as early as possible. The survey must never be postponed or canceled without prior notification of the water system's representatives.

Organizing Equipment

Field Test Equipment

Check Your Equipment. Prior to the on-site inspection, sanitary survey inspectors should ensure that field equipment is in good repair. Preventive maintenance is essential for all types of equipment. Equipment that is broken, dirty, in disrepair, out of calibration, or otherwise improperly maintained will not provide accurate, dependable, or reproducible data. For best results, follow the manufacturer's specifications for preventive maintenance.

Check Standards. Of equal importance are standards for the field test equipment. The inspector should check expiration dates and keep up with and use current standard testing methods and calibration procedures.

Recommended Equipment. Recommended types of field test equipment include, but are not limited to, the following:

- Portable pH meter (digital, not analog).
- Residual chlorine test kit (hand held colorimeter or portable spectrophotometer).
- Camera with automatic time stamp.
- Binoculars.
- Flashlight.

Personal Protective Equipment and Safety Precautions

Inspector Safety. Another aspect of the sanitary survey is safety. This is a concern for the field inspector as well as for the operating staff of the system. Safety hazards include:

- Electrical shock
- Exposure to chemicals
- Drowning
- Entering confined spaces
- High-intensity noise
- Sprains and strains due to lifting
- Slips, trips, and falls

Safety Equipment. Prior to the on-site inspection, the sanitary survey inspector should ensure that personal protective equipment is available. We acknowledge that many state agencies do not provide this equipment, however, the inspector may wish to provide some of the equipment and ensure that items such as respirators are available at the site. The most frequently used equipment and the necessity of each is as follows:

- **Safety hats** – Provide protection from falling objects and overhead obstructions in pipe galleries. They can also be used as a means of identification.
- **Goggles** – Provide eye protection from chemicals and flying objects. They may need to be supplemented by full face shield when working around some chemicals.
- **Gloves** – Provide protection against injuries from chemicals and equipment. Rubberized materials are preferred over leather or cloth gloves.
- **Steel-toed safety shoes** – Provide protection from falling objects.
- **Respirators** – Protect the wearer from inhaling dust, Hanta virus, organic vapors, and other chemicals. This equipment is used where the atmosphere is not oxygen-deficient.
- **Self-contained breathing apparatus** – Provides protection in oxygen-deficient atmospheres (e.g., confined spaces).

General Recommendations for On-site Inspections

Keep Purpose in Mind

In conducting the on-site inspection, it is important for the inspector to remember the purpose of the survey. The inspector is to perform an on-site review of the water source, facilities, equipment, operation, maintenance, and management for the production and distribution of safe drinking water. **The inspector should not let the sanitary survey become an exercise in filling in the blanks on a particular form.** An inspector needs to concentrate on identifying potential or existing problems and evaluating their risks.

Be Punctual – Work With the Water System Staff

In performing the on-site survey, the first step is to be punctual so that system personnel are not waiting for the inspector. A successful survey requires representatives of the water system to participate in the sanitary survey process. Individuals in charge of management, operation, and maintenance should be involved during the on-site inspection. Besides providing the inspector with critical information, this will allow the inspector and staff members to interact and develop a mutual understanding of the purpose of the survey and confidence in each other's abilities. Once this trust has been developed, the staff may be more willing to be open about the operations and problems of the system.

Use Forms and Field Notes

Field notes, diagrams, and completed inspection forms are critical to the sanitary survey process. A properly designed form can facilitate and simplify the conduct of the sanitary survey. A field inspection form is a data management tool. It can serve as a systematic guide during the survey and ensure completeness so that critical data or other information are not overlooked. A good form anticipates questions and affords the inspector the opportunity to focus on answers and responses and to record observations without the distraction of planning the next question.

In most cases, it is good to use a standard form to help the inspector cover all points of the system. **It is important to remember that filling out a form is not the primary function of the survey.** The inspector should understand why each question is being asked. The judicious use of the form, however, will provide uniformity of inspections, ensure completeness of the inspection, facilitate recordkeeping, document observations, and allow follow-up inspection by another inspector.

Communications During the On-site Visit

Contacts During the Survey

During the inspection, the inspector should work with the owner of the water system and the operational personnel.

When meeting with the system owner, the inspector should:

- Obtain information pertinent to system
- Explain use of survey results
- Explain recommended actions
- Explain what action will result from survey

When communicating with the operational personnel, the inspector should:

- Obtain information pertinent to system
- Explain recommended action

Relationship with Operator

Establishing a good relationship with the operational personnel is important to the success of the survey. The operator of the small water system occupies a unique position in the water supply industry. In most cases, the operator is responsible for all aspects of the system from operation of the plant to budgeting for equipment. In small systems, he may also be responsible for other services in the community (e.g., wastewater treatment, road repair). Consequently, the operator may have a basic working knowledge of his water system and processes, but not necessarily knowledge of the regulatory requirements.

Sequence of Activities

The on-site inspection should be carried out in a systematic fashion. The sequence should include the following steps:

- Initial briefing
- Background review
- Management assessment
- Facility walk-through
- Inspector's assimilation of findings
- Debriefing

The details of each activity follow.

Initial Briefing

The purpose of the initial briefing with water system personnel is to explain the purpose of the sanitary survey and describe the sequence of activities to be completed during the on-site inspection. This is also an opportunity for the inspector and water system personnel to discuss concerns that are not directly related to the inspection (e.g., proposed regulations or activities of the primacy agency). Management, operations, and maintenance staff should be represented at this briefing.

Background Review

This session also involves personnel representing management, operations, and maintenance of the water system. During this phase, the inspector should review previous sanitary survey reports and discuss actions taken by the water system on any sanitary deficiencies that were identified. Also, basic information should be obtained or verified, including but not limited to number and classification of service connections, daily production peaks and averages, a flow diagram and description of the major facilities, and a log of customer complaints.

Management Assessment

Although the owners and managers are the primary focus of this session, the operations and maintenance personnel should also participate. During this phase, the inspector will assess the adequacy of programs and procedures including SDWA compliance sampling, source protection, cross-connection control, contingency plans, corrosion control, safety, training, distribution system flushing and pressure testing, financial management, capital improvement, maintenance of records, preventive maintenance, and standard operating procedures. The inspector will also assess how the utility deals with customer complaints and whether staffing is adequate. Finally, the inspector should review the operating records (from in-house monitoring) in preparation for the next phase of the on-site inspection.

Facility Walk-Through

It is imperative to the successful outcome of a sanitary survey that the individuals responsible for operation and maintenance (O&M) participate in this phase. The inspector should begin at the water source and work through the system (following the "water stream") including the distribution system and the pumping and storage facilities. At each step in the process the inspector should conduct visual observations and ask the O&M staff specific questions about the process, equipment, and O&M strategies employed. The manner in which questions are posed to the operators should not be suggestive in nature. For example, an accurate answer is more likely to be obtained when asking, "How do you determine when to backwash a filter?" rather than, "You always backwash the filter prior to an increase in filtered water turbidity, right?" Another rule of thumb is never assume anything. Even if the inspector thinks that he knows the answer to a particular question, he should ask it anyway. The answer will build on the inspector's assessment of the operator's knowledge and may lead to an additional series of questions regarding the system.

NOTE: The inspector should not attempt to adjust or operate any of the plant equipment.

Inspector's Assimilation of Findings

At this stage, the inspector should work alone to complete the survey form and identify and prioritize the sanitary deficiencies that he noted. Top priority should be given to the sanitary deficiencies that are determined to pose an imminent threat to public health. This is the time when the inspector should, if necessary, seek advice from peers or supervisors in the primacy agency office with regard to findings and actions to be taken. The inspector also should use this time to prepare for the debriefing.

Debriefing

Prior to leaving the site, the inspector should meet again with the individuals who attended the initial meeting and brief them on the sanitary deficiencies that were identified, in order of priority. The inspector should explain what action will result from the survey and advise the water system representatives that a report of findings and recommendations will be prepared and provided to them. The report will include a list of any significant deficiencies, which will require system follow-up. All important issues should be covered in the debriefing so there are no surprises in the final written report.

Caution: As the inspector, your recommendations may be to "fix something," but you are not required to specify exactly how to fix it. If you are in doubt, it may be better to return to the office and discuss your findings before you make specific recommendations and priorities.

Follow-up

Summary of Activities

Briefly, the activities during this period are:

- Finalize documentation and prioritization of all sanitary deficiencies that were identified during the on-site investigation.
- Complete the formal sanitary survey report, including options for correcting the sanitary deficiencies and sources of technical assistance. Also identify any differences between the findings in the written report and the oral debriefing.
- Notify appropriate organizations of the results.
- Follow up on questions asked by water utility personnel.

The Sanitary Survey Report

Importance of Report

The sanitary survey report is an important component of a sanitary survey.

The survey report is an important tool for tracking compliance with the Safe Drinking Water Act and for evaluating a system's compliance strategy. Perhaps more important, it provides a record that will support enforcement actions and allow future inspectors to track progress. It also provides information much needed during emergenices and when technical assistance providers are on site. It is the inspector's responsibility to the water system and to the public to provide an accurate and detailed description of improper operation or other system deficiencies in a sanitary survey report.

Along with the verbal communication that occurs during a sanitary survey, the written report can be used to motivate corrective actions. This motivation can be generated by the professional nature of the report and an explanation of why the corrective actions in the report are necessary. If the sanitary survey inspector sends an accurate, detailed report in a timely manner, the water system personnel will, in most cases, perceive the survey, the inspector, and the inspector's organization as professional. This perception can foster confidence among system personnel and a willingness to cooperate in the correction of sanitary defects.

Official Notification

The sanitary survey report constitutes the official notification of the evaluation results. Undocumented verbal communication is not reliable. Important information, such as violations or required corrective actions, must be documented in the sanitary survey report. The completed report should reiterate the information presented to system personnel by the inspector at the end of the on-site evaluation. If the written evaluation is different from the oral debriefing, the inspector should inform the water system manager in advance.

The report itself can be as brief as a letter, if few deficiencies are found, but it must be as detailed as necessary to convey to the water utility what deficiencies exist and what must be done to correct them. However, by just listing the deficiencies, the inspector may not accomplish the objective of informing the system of a problem and seeking its correction. The inspector is often the water system manager or operator's only contact in discussing the technical operation of their facilities. It is sometimes incorrectly assumed that all managers or operators can understand the inspector's comments and technical references. Even if the system personnel understand what the inspector wants, it will be quite unlikely that corrective actions will be taken if they cannot understand the reason for doing them. The report should describe the problems in basic terms and explain the reasons they must be corrected. An explanation of how a problem adversely affects the system is more likely to motivate the system operator to correct it. The report should be sent "return receipt requested" to document receipt by the system.

Report Content

The report should contain:

- The date the survey was conducted and by whom.
- The names of those present during the survey, besides the inspector.
- A schematic of the system and, when possible, photographs of key components.
- A schematic of any treatment facilities showing locations of chemical injection.
- The survey findings and a discussion of any differences in the findings presented in the debriefing and the final report.
- A list of all significant deficiencies with specific recommendations for correction and with deadlines for completion.
- The inspector's signature.
- A listing of all other sanitary deficiencies, in order of priority, that should be addressed to enhance water system operations and safety.

Results of Documentation

No matter how professional the sanitary survey was, how involved or detailed the field aspects of the survey were, or how many deficiencies were pointed out verbally during the inspection, it is important that all finding be documented in writing so the system's owners and managers are made aware of deficiencies that require correction. In addition, if properly detailed documentation is not registered by the use of sanitary survey forms and a sanitary survey report, it will be very difficult to use any of the survey findings for enforcement purposes. Remember, when significant violations are found, a compliance schedule, consent agreement, administrative order, or litigation may be necessary to ensure prompt and proper correction.

Corrective Action

Options

To ensure that sanitary deficiencies are eliminated (at a minimum, the significant deficiencies), the sanitary survey inspector should provide the water utility with options, where applicable, for making improvements. Approaches to correcting sanitary deficiencies can include:

- Correction of problems by the water system staff, their consulting engineers, or contractors.
- Technical assistance to the water utility by a regulatory agency, organizations that specialize in training and technical assistance, or peers at other water systems.
- Technical assistance specifically for surface water systems.

A combination of any or all of these may be appropriate, based on the type and severity of the sanitary deficiencies.

In-House Corrective Action

At water systems with trained and competent staff, many items identified as sanitary deficiencies can be dealt with in house. A concern for the inspector in this case may be, "**How** did the system get into this condition, or **why** did the water utility manager or operator allow the system to get to this condition?" The inspector's recommendations should consider changes to management and operating procedures, as well as actions to correct specific deficiencies, in order to reduce the potential for continuing deficiencies. Once a problem is pointed out and explained to a competent and conscientious operator, he or she likely will deal with the problem immediately and with long-term compliance in mind.

Technical Assistance and Training

Water systems, especially publicly owned systems, usually are not out of compliance by choice. Most would like to be in compliance, but may need some assistance in determining the cause of their performance problems and in planning to correct the performance problems and achieve compliance. This assistance often takes the form of training and on-site, over-the-shoulder, system-specific technical assistance. The integration of training and technical assistance into the overall enforcement strategy has, in many states, proven to be the most effective method for achieving and maintaining compliance while promoting a partnership between the water system, the regulatory staff, and the training and technical assistance providers. Technical assistance, as it relates to sanitary surveys, means providing suggested approaches to analyzing and solving problems that contribute to sanitary deficiencies.

Sources of Technical Assistance

Technical assistance and training resources vary from state to state, can take many forms, and involve a variety of approaches. Many states have developed a means by which assistance can be provided to a water system either at its request or through a referral from a sanitary survey inspector. In most states, the state primacy agency provides some form of technical assistance either directly or through an agency grantee (a technical assistance provider). Often, field inspectors provide resource listings, referrals, and other forms of general technical assistance. Many states have a state environmental training center or other organization that can provide more specific technical assistance to explain and demonstrate exactly what to do to resolve problems. Private-sector consulting services are also available in most states.

Approach to Assistance

The information given during technical assistance or training is important. Unless the solution is obvious, technical assistance should be given only after the entire system has been surveyed. There are two reasons for this approach. First, the objective of the inspection is to evaluate the entire water system. If inspectors spend excess time trying to determine the causes of problems, they have changed their primary objective and may very well overlook a serious sanitary deficiency. Isolating the cause of a water system problem may be time-consuming and can be difficult without sampling and analytical support. Competent operators will have already evaluated and ruled out the more common causes of problems. The second reason for surveying the entire system is that there may be conditions contributing to problems throughout the system. Consequently, judgment should be reserved until the entire system has been reviewed.

Composite Correction Program

One form of technical assistance specifically for surface water systems is a comprehensive performance evaluation (CPE) of the treatment process to determine performance-limiting factors. The data and information generated by the CPE are used in the follow-on comprehensive technical assistance (CTA) program. The CPE identifies and prioritizes factors limiting plant performance, and the CTA attempts to correct each performance-limiting factor. This combined CPE/CTA approach is also known as a composite correction program (CCP). Implementation of the CCP is time-intensive and often requires daily on-site evaluations and over-the-shoulder technical assistance, as well as management of capital improvements.

The Use of Red Flags

The sanitary survey often generates the data and information that identify a treatment facility as a potential candidate for the CCP process. The sanitary survey looks at the same areas as the CPE (albeit to a lesser degree), but provides a more comprehensive overview of the entire water system, from the source to the point of distribution. Much of the information generated by the sanitary survey will be incorporated into the CPE. The areas and conditions where this integrated approach works well are highlighted throughout the text. Indicators or red flags that identify conditions in a plant that make it a good candidate for a CPE are listed below. (See also Chapter 6 – Water Treatment Processes)

- Hydraulic Loading
  - Hydraulic overload of unit processes.
  - Maximum hydraulic flow rate for short periods of time.
  - Rapid increases in plant flow.
- Chemical Feed
  - Calibration curves are not available for chemical feed pumps.
  - The operator cannot explain how chemicals, such as polymers, are diluted prior to application.
  - The operator cannot determine the chemical feed setting for various doses.
  - The operator does not adjust chemical feed rates for varying raw water quality conditions.
  - The operator cannot calculate chemical feed doses (e.g., cannot convert a desired mg/L dose to lb/day or mL/min to allow proper setting of the chemical feeder).

- Chemicals are used in combinations that have detrimental effects on plant performance. An example is the practice of feeding lime and alum at the same point without consideration of the optimum pH for alum coagulation.
- Chemical feed rates are not adjusted when plant flow rate changes.
- Chemical coagulants are not used when raw water turbidity is low (e.g., less than 0.5 to 1.0 NTU.)

■ Rapid Mix

- The rapid mixer is broken or intentionally taken out of service (e.g., to conserve power because "it does not improve performance").

■ Flocculation

- Variable-speed flocculation drives are not adjusted (e.g., they remain at the setting established when the plant was constructed).

■ Sedimentation

- Sludge is not routinley removed from sedimentation basins (e.g., routine sludge withdrawal is not practiced).

■ Filtration

- Individual filter performance is not monitored.
- Rapid increases in overall plant flow rate are made without consideration of filtered water quality. Filter performance after backwash is not monitored.
- Filters are removed from service without reducing plant flow rate, resulting in the total plant flow being directed to the remaining filters.
- There is no clear rationale to determine filter backwash frequency, duration, or flow rate.
- Filters are operated for excessive lengths of time between backwashings.
- Operators backwash filters only when effluent turbidity increases.
- Filters have significantly less media than specified, damage to underdrains or support gravels, or a significant accumulation of mudballs, and these conditions are unknown to the operating staff because the filters are not examined routinely.
- Obvious problems in backwash water distribution are observed during a backwash cycle.
- The purpose and function of the rate control device cannot be described.
- The flow controllers are not functioning properly.

■ Process Monitoring and Control

- Jar tests or other methods (e.g., streaming current monitor, zeta potential, or pilot filter) of coagulation control are not practiced.
- The operator does not understand how to prepare a jar test stock solution and to administer various chemical doses to the jars.
- The only testing conducted is raw water turbidity (daily) and finished water turbidity, as collected from a clearwell sample on a daily basis.
- Settled water turbidity is not measured routinely (e.g., minimum of once each shift).
- Individual filtered water quality is not monitored.
- There are no records available documenting performance of the individual sedimentation or filtration unit processes.

Limitations

Inspectors should temper any advice with a realistic assessment of their personal experience and knowledge of the problem. If erroneous information is provided, money, time, and credibility can be lost while the sanitary deficiency continues. Inspectors who have limited experience should refer problems to more experienced personnel. **Incorrect technical assistance that does not correct the problem can have ramifications ranging from loss of credibility to challenges to authority regarding corrective actions.**

2 Drinking Water Regulations

In addition to specifying Maximum Contaminant Levels (MCLs), the federal drinking water regulations address sampling location, frequency, recordkeeping, and other requirements that should be subject to compliance determinations during a sanitary survey. There may also be other requirements found in national safety standards, such as those promulgated by the Occupational Safety and Health Administration (OSHA), variances or exemptions, or enforcement orders that should be reviewed during a sanitary survey. In order to make these on-site compliance determinations, the inspector should be able to meet the following objectives.

Learning Objectives

By the end of this chapter, learners should be able:

- To define a sanitary survey as specified in EPA regulations and explain the comprehensive nature of sanitary surveys.
- To explain the importance of making an accurate determination of population served by the system and number of service connections.
- To determine if a water system is a public water system subject to EPA regulations adopted by the state.
- To determine if a public water system is properly classified (as community; non-transient, non-community; or transient, non-community).
- To explain the importance of and determine whether the system has made modifications to its sources, treatment, or distribution system without state approval.
- To describe the on-site compliance determinations that should be made for various provisions of the National Primary Drinking Water Regulations (NPDWRs) adopted by the state including siting; total coliform; surface water treatment; lead and copper; organic, inorganic and radiological contaminants; disinfectants and disinfection byproducts; reporting including the consumer confidence report; recordkeeping; and public notification.
- To determine whether the system is operating in accordance with the National Secondary Drinking Water Regulations (NSDWRs) as adopted by the state.
- To determine compliance with American National Standards Institute (ANSI) and National Sanitary Foundation (NSF) standards for direct and indirect additives.
- Examine compliance with other requirements such as OSHA regulations.
- To determine if the system is complying with conditions set forth in variances, exemptions, or compliance orders.

Data Collection

To efficiently determine a system's compliance with regulatory requirements, the inspector must rely on information that is available in the state primacy agency office, as well as that gathered in the field. Various reports, correspondence, engineering studies, and monitoring data are important sources of information for determining a system's compliance. They typically are available in the office for review and evaluation. Prior to an inspection, the inspector should review the following:

- Any violations of MCLs, treatment techniques, monitoring, or reporting.
- Current information on population served and number of service connections.
- State-approved coliform sample siting plan.
- State-approved locations for disinfection byproduct samples.
- Consistency with NSDWRs.
- Variances or exemptions that apply to the system.
- Compliance orders that apply to the system.
- Documentation of state approval for the installation of or changes to the system.

Regulations and Standards to Consider

The inspector should review the following regulations prior to the inspection:

- EPA or state primary and secondary drinking water regulations.
- State design standards or guidelines.
- ANSI/NSF standards.

Drinking Water Regulations

Basic Information

Safe Drinking Water Act of 1974. In recognition of potential public health risks associated with the nation's drinking water, Congress enacted the Safe Drinking Water Act (SDWA) in 1974. The Act was intended to ensure the delivery of safe drinking water by public water systems and to protect underground water sources from contamination.

1986 SDWA Amendments. In 1986, Amendments to SDWA were signed into law. They greatly expanded the number and type of contaminants to be regulated in drinking water and they strengthened EPA's enforcement authority. The passage of these Amendments was the result of heightened concern about the potential contamination of public water supplies by toxic chemicals and an increase in the number of waterborne disease outbreaks caused by microbiological contaminants. Congress was also concerned about the lack of speed with which EPA was developing regulation standards for drinking water.

1996 SDWA Amendments. In 1996, Congress again amended SDWA. The new law includes, for the first time, provisions for state revolving loan funds to improve water systems. It also requires EPA to base regulations on risk assessment and cost-benefit considerations. The statute requires EPA to identify the best treatment technologies for various sizes of systems, establish guidelines for operator certification, and provide monitoring relief for small systems. Source water protection and consumer confidence reports are part of the statute.

Code of Federal Regulations. Final EPA regulations are published (or "promulgated") in the *Federal Register*. Federal regulations are compiled annually and codified in the Code of Federal Regulations (CFR). EPA's regulations are found in Title 40 of the CFR (40 CFR). NPDWRs are incorporated or codified in 40 CFR Part 141, which is divided into subparts and sections for specific regulatory provisions. For example, coliform monitoring requirements are found in section 21 of Part 141 (40 CFR 141.21). The CFR is available from the Government Printing Office in Washington, D.C., and EPA's regulations can be accessed and downloaded from its Web site (www.epa.gov/epacfr40/chapt-I.info/chi-toc.htm). The EPA Drinking Water Hotline (1-800-426-4791) provides another easily accessible source of information on SDWA regulations.

National Primary Drinking Water Regulations (40 CFR Part 141). SDWA requires EPA to establish regulations for contaminants in drinking water that may have an adverse effect on the public health. These NPDWRs include MCLs or treatment techniques for more than 100 contaminants. Monitoring and testing procedures also are specified.

NPDWR Implementation. Congress intended that SDWA requirements be implemented primarily by the states. Therefore, SDWA requires EPA to define the requirements for allowing states to implement and enforce state regulations. State regulations must be at least as stringent as the federal regulations—and they can be more stringent. A state whose program has been approved by EPA is granted primary enforcement authority (“primacy”) for its drinking water program. Primacy requirements are codified in 40 CFR Part 142, National Primary Drinking Water Regulations Implementation. EPA may grant a state primary enforcement authority when the EPA Administrator determines that a state has met the following requirements:

- It has adopted drinking water regulations no less stringent than the NPDWR.
- Its definition of a public water system is consistent with the definition in SDWA.
- It has adequate enforcement authority and procedures.
- It maintains an inventory of public water systems.
- It has a systematic program for conducting sanitary surveys of public water systems, with priority given to systems not in compliance with the NPDWRs.
- It has a program to certify laboratories that will analyze water samples.
- It has a certified laboratory that will serve as its principal laboratory.
- It has a program to review the design and construction of new or modified systems.
- It has adequate recordkeeping and reporting requirements.
- It has an adequate plan to provide for safe drinking water in emergencies.
- Its variance and exemption requirements are as stringent as EPA’s (if the state chooses to allow variances or exemptions).

In primacy states (every state but Wyoming and the District of Columbia), state personnel derive their authority from state, rather than federal, drinking water regulations. **Therefore, whenever a federal regulation is cited in this document, the inspector needs to find and use the equivalent state regulation.**

National Secondary Drinking Water Regulations. EPA also sets National Secondary Drinking Water Regulations (NSDWRs), which are codified in 40 CFR Part 143. These regulations address drinking water contaminants that primarily affect the taste, odor, or color of drinking water. Such aesthetic considerations are a concern because if a system provides water that is unappealing to the senses, its users may seek alternative supplies, some of which may be unsanitary. In addition, there may be health implications at considerably higher concentrations of these contaminants. Although not federally enforceable, the secondary regulations are intended as guidelines for states and public water systems. Individual states may choose to adopt and enforce these secondary regulations.

Public Water Systems

Three important field determinations made during a sanitary survey are:

- How many people are served by the system.
- How many service connections the system has.
- Whether service is provided for at least 60 days a year.

This information determines whether a system meets the definition of a public water system in SDWA and whether it is subject to the NPDWRs.

Types of Systems. Although the NPDWRs apply to all public water systems, the regulations make a distinction between community and non-community systems. A further distinction is made between transient and non-transient, non-community systems.

Definition of a PWS. A public water system is a system for providing water for human consumption through pipes or other constructed conveyances which has at least 15 service connections or regularly serves at least 25 people at least 60 days a year. A system includes any collection, treatment, storage, and distribution facilities under control of the system operator and used primarily in connection with its operation and any collection or treatment facilities not under such control that are used primarily in connection with such a system.

Community Water Systems. Community water systems (CWSs) serve residential populations of at least 25 people or 15 service connections year-round. Users of community systems are likely to be exposed to any contaminants in the water supply over an extended time period, and are thus subject to both acute and chronic health effects.

Non-Community Water Systems.
Non-community water systems do not serve permanent residential populations. Non-community systems are either transient nor non-transient systems.

- **Non-transient, non-community** water systems (NTNCWSs) serve on a regular basis at least 25 of the same persons at least 6 months per year. Like community systems, these systems can expose users to drinking water contaminants over an extended time period (subjecting users to risks of both acute and chronic health effects). Schools, churches and factories that have their own water systems fall under this definition.

- **Transient, non-community** water systems (TNCWSs) serve short-term users. As a result, the users are exposed to any drinking water contaminants only briefly and are subject to experiencing acute health effects. Examples of TNCWSs are restaurants, gas stations, hotels, and campgrounds.

These distinctions, and others such as service population and water source, are important because EPA may regulate these systems differently. Population served determines sampling frequency in a number of regulations, such as the total coliform rule, lead and copper rule, inorganic chemicals rule, disinfectants and disinfection byproducts rule (D/DBPR), and the surface water treatment rule (SWTR). Most water system operators will know precisely how many individual service connections their systems have, but not necessarily the population served by the system. Some states will use a factor (i.e., estimated persons per connection) multiplied by the number of service connections to estimate population. During the survey, the inspector should determine if the state records on population and number of service connections are up-to-date. Further evaluation will be needed to determine if changes in population will affect the system's status relative to any SDWA requirement.

An inspector needs to know a system's characteristics to know whether the system is properly classified and, therefore, which regulations are applicable.

Sanitary Surveys and the Regulations

The regulations define a sanitary survey as follows:

> Sanitary survey means an on-site review of the water source, facilities, equipment, operation, and maintenance of a public water system for the purpose of evaluating the adequacy of such source, facilities, equipment, operation, and maintenance for producing and distributing safe drinking water. (40 CFR 141.2)

Clearly, the definition requires a comprehensive review of the entire water system from source to treatment to storage and distribution, including operation and maintenance of all the system's facilities. Following is a discussion of specific determinations the inspector should make for current SDWA rules.

Siting Requirements

Advance Notification. The regulation at 40 CFR 141.5 requires water systems to notify the state before a new water system is constructed or the capacity of an existing system is increased. The regulation also specifies that the system should avoid siting in areas subject to earthquakes, floods, and fires.

The inspector should be alert to any changes that have been made without state approval. Facilities, particularly wells that may be subject to flooding, should be evaluated. The inspector should recommend flood-proofing if facilities are located in flood plains.

Total Coliform Requirements

Sample Site Plan. The Total Coliform Rule (TCR) (40 CFR 141.21) requires a water system to have a written sample siting plan that is subject to state approval. The inspector should verify that the system has an approved plan and is using it. The inspector should also evaluate the plan to determine if it meets the requirements of the TCR. The rule requires collecting samples "which are representative of water throughout the distribution system." The rule also contains a table that shows the minimum number of samples required based on population served. In reviewing the sample siting plan, the inspector should note that more samples than the minimum may be required in order to be "representative." Some of the issues to be concerned with are short chlorine contact time (CT) to first customer, dead ends, long residence time in the system, multiple sources, storage tanks, areas of low pressure, biofilm, and cross-connections.

Survey Frequency. The TCR also contains specific requirements on the minimum frequency with which sanitary surveys must be conducted on systems that collect fewer than five samples per month (40 CFR 141.21(d)). This requirement is placed on the public water system, not the state. However, the sanitary surveys must be conducted by the state or a party approved by the state. Also, the state must review the results of each sanitary survey to determine whether the monitoring frequency is adequate and what additional measures, if any, the system needs to undertake to improve drinking water quality. More recent rules include special primacy requirements that establish minimum components for sanitary surveys and frequencies at which states must conduct them.

Type of System	Initial Survey	Subsequent Surveys
Community water system	June 29, 1994	5 years
Non-community water system	June 29, 1999	5 years
Non-community water system using only protected and disinfected ground water	June 29, 1999	5 years
Source: 40 CFR Part 141		

Sanitary surveys can also be used to allow the monitoring frequency for certain community systems serving fewer than 1,000 persons to be reduced to one coliform sample per quarter (40 CFR 141.21(a)(2)). They also can be used as a basis for reduced monitoring for certain non-community systems (40 CFR 141.21(a)(3)).

Variances. Variances may be granted from the total coliform MCL if a system can demonstrate to the state that a violation is due to persistent regrowth in the distribution system, rather than from a treatment lapse, a treatment deficiency, or a problem in the operation or maintenance of the distribution system (40 CFR 141.4(b)).

Surface Water Treatment Rule

General Requirements. Subpart H of 40 CFR Part 141 (Filtration and Disinfection) contains requirements for the filtration and disinfection of surface water supplies and ground water supplies under the direct influence of surface water (defined as "subpart H systems"). The treatment technique requirements consist of installing and properly operating water treatment processes that achieve 99.9 percent removal and/or inactivation of *Giardia* and 99.99 percent removal and/or inactivation of viruses. Water systems have two ways of complying with the SWTR requirements. They can meet all the filtration avoidance criteria in 40 CFR 141.71 and provide 99.9 percent *Giardia* and 99.99 percent virus inactivation by disinfection, or they can provide both filtration and disinfection that, in combination, meet the removal/inactivation requirements for *Giardia* and viruses.

Ground Water Under the Direct Influence of Surface Water. As noted above, systems that use ground water sources under the direct influence of surface water are subject to the SWTR and, therefore, are included in the definition of subpart H systems. The state determination for direct influence is based on site-specific measurements of water quality (such as the occurrence of insects, algae, or pathogens such as *Giardia lamblia* or *Cryptosporidium*) or documentation of well construction characteristics and geology with field evaluation. A source subject to flooding, or the alteration of a stream course bringing it closer to a well, might result in a change in water quality. During the survey, the inspector should evaluate any conditions that might cause the state to alter its determination that a ground water source is not influenced by surface water.

No Recontamination. Water cannot be subject to recontamination by surface water after treatment, for example, by using open, uncovered finished water storage subject to runoff. During a sanitary survey, the inspector should verify that treated water is not subject to recontamination by surface water.

First Customer. The removal and/or inactivation requirements must be met before or at the first customer. In many cases, the first customer is the treatment plant itself. In some cases, a new first customer may be added to the system. The inspector should identify the first customer and ensure that the requirements for removal and/or inactivation are being met there.

Entry Point Residual. The disinfectant residual entering the system residuals cannot be less than 0.2 mg/L for more than 4 hours and must be monitored continuously. The only exception is systems that do not provide filtration and serve fewer than 3,300 persons; they may take grab samples at specified frequencies in lieu of continuous monitoring (40 CFR 141.74(b)(5)).

System Size by Population	Grab Samples per Day
<500	1
501-1,000	2
1,001-2,500	3
2,501-3,300	4

Residual in the Distribution System. The residual must be detectable in 95 percent of the samples taken in the system. Samples should be taken at the same time and place as coliform samples. Systems may also use a heterotrophic plate count (HPC) to determine compliance. During the sanitary survey, the inspector should verify that all conditions for disinfection are being met. The inspector should determine that residuals are measured at the proper locations throughout the distribution system. Testing techniques should also conform to the rule.

Qualified Personnel. The SWTR requires that each system subject to it be operated by qualified personnel. Compliance with the state's operator certification program will meet this requirement and, therefore, should be verified during the survey.

Unfiltered Systems Requirements. To avoid filtration, a subpart H system must meet stringent **source water quality conditions** and **site-specific conditions** designed to ensure safe drinking water.

- **Source Quality Conditions**. To meet the avoidance criteria, unfiltered systems must monitor raw source water immediately before the first point of disinfection and have a fecal coliform concentration of less than or equal to 20/100 mL, or a total coliform concentration of less than or equal to 100/100 mL in at least 90 percent of all measurements over the previous 6 months. Also, the turbidity of the source water cannot exceed 5 NTU at the same sampling point (with some exceptions).

- **Site-Specific Conditions**. In addition to the source water quality conditions, systems meeting the filtration avoidance criteria must:

  - Comply with disinfection requirements that:

    - Ensure 3 log *Giardia lamblia* and 4 log virus inactivation. (CT [concentration of residual multiplied times contact time] values are specified in the rule and must be met at the first customer.)
    - Provide redundancy of components or automatic shut-off when the residual is <0.2 mg/L.
    - Ensure a residual of 0.2 mg/L entering the distribution system.
    - Provide a detectable residual in the distribution system when measured at the same time and place coliform samples are collected.

  - Maintain a watershed control program that minimizes the potential for contamination by *Giardia lamblia*, viruses, *Cryptosporidium,* and other pathogens.

  - Be subject to an annual on-site inspection. On-site inspections for systems subject to the filtration avoidance criteria are similar to sanitary surveys and may be accomplished during sanitary surveys. Items to be reviewed include:

- Effectiveness of watershed control.
- Condition of intake.
- Facilities and operation and maintenance (O&M) of disinfection.
- Operating records.
- Effectiveness of disinfection.
- Needed improvements.
- Waterborne disease outbreaks.
- Compliance with MCLs for total coliform and Stage 1 disinfectants and disinfection byproducts.

- Maintain compliance with the Total Coliform Rule and the Disinfectants/ Disinfection Byproducts Rule.

During the sanitary survey, the inspector should review the system's data on raw water quality and its source water protection program. The inspector also should check the available CT for compliance.

Filtered System Requirements. The requirements that systems which use filtration must meet are described below.

- **Filtration Requirements.** Systems that are unable to comply with all criteria to avoid filtration must meet the 3 log *Giardia lamblia* and 4 log virus inactivation and/or removal requirements by using both an appropriate filtration technology and disinfection. Compliance with the treatment technique requirements of the SWTR is measured against turbidity performance criteria specific to the type of filtration in use (subject to state approval) and adequate CT to inactivate the remaining *Giardia lamblia* and viruses.

- **Turbidity Requirements**. Minimum turbidity performance criteria are established in the SWTR for the various filtration methods. Regardless of the filtration method, however, the turbidity level of filtered water must never exceed 5 Nephelometric Turbidity Units (NTU).

- **Conventional and Direct Filtration**. Filtered water turbidity must be less than or equal to 0.5 NTU in 95 percent of the measurements taken every month. At the state's discretion, levels less than or equal to 1 NTU may be permitted in 95 percent of the measurements on a case-by-case basis. If levels greater than 0.5 NTU are permitted in the system being inspected, the inspector should verify that the system is in compliance with any conditions placed on it by the state, such as redundant disinfection facilities. Note that since January 1, 2001, subpart H systems serving at least 10,000 people are subject to enhanced filtration and disinfection requirements in 40 CFR 141.170 to 175. Smaller subpart H systems (those serving fewer than 10,000 persons) have been subject to very similar requirements since January 12, 2002. For conventional and direct filtration plants, the above reference performance criteria (i.e., 0.5 NTU and 5 NTU) will be reduced to 0.3 NTU and 1 NTU.

- **Slow Sand Filtration**. Filtered water turbidity must be less than or equal to 1 NTU in 95 percent of the measurements taken every month. A state may allow a higher level of turbidity if it determines that there is no significant interference with disinfection at the higher turbidity level. The turbidity of slow sand filter effluent must never exceed 5 NTU. The inspector should verify that these conditions are being met if the state allows the system to exceed 1 NTU.

- **Diatomaceous Earth Filtration**. Filtered water turbidity must be less than or equal to 1 NTU in 95 percent of the measurements for each month. The turbidity level of representative samples may at no time exceed 5 NTU.

- **Other Filtration Technologies**. Alternative technologies must be shown to be capable of consistently achieving 99.9 percent and 99.99 percent removal and/or inactivation of *Giardia lamblia* cysts and viruses, respectively. Systems that can make this demonstration are required by the original SWTR to comply with the turbidity performance requirements for slow sand filtration. Since January 1, 2001, subpart H systems serving at least 10,000 persons must demonstrate to the state that alternative technologies are capable of 99 percent *Cryptosporidium*, 99.9 percent *Giardia lamblia*, and 99.99 percent virus removal and/or inactivation. For systems that can make this demonstration, the state will establish turbidity performance criteria at a level that ensures adequate cyst removal.

- **Turbidity Measurements**. The inspector should verify that the required turbidity measurements are being made, that the results are accurate and reliable, that sampling frequency, locations, and analytical procedures are appropriate, and that the turbidity readings comply with the SWTR requirements. The inspector should check for compliance with CT requirements and make sure the system operator is properly doing the daily calculations.

- **Operation and Maintenance**. The inspector should verify that the required filtration and disinfection facilities are in place and are properly operated and maintained.

Interim Enhanced Surface Water Treatment Rule (IESWTR)

At 40 CFR Part 141, subpart P, Enhanced Filtration and Disinfection (40 CFR 141.170-.175), are additional requirements for subpart H systems that serve 10,000 or more persons. These requirements took effect January 1, 2001, and are primarily to address public health risks from *Cryptosporidium.* They include:

- More stringent turbidity limits for combined filter effluent from conventional and direct filtration plants.

- Continuous monitoring of individual filter effluent in conventional and direct filtration plants.

- Follow-up actions for exceeding "trigger" turbidity levels in two consecutive measurements taken 15 minutes apart at an individual filter for conventional and direct filtration plants.

- Requirements for all filtered systems to remove 99 percent (2 log) *Cryptosporidium* cysts.

- Disinfection profiling and benchmarking requirements for systems with elevated levels of disinfection byproducts.

- Measures to control *Cryptosporidium* in the watersheds of unfiltered systems meeting the criteria for avoiding filtration.

In addition, 40 CFR Part 142 now requires states to describe how they will provide sanitary surveys for subpart H systems that include all eight essential elements on a frequency of at least once every 3 years for community systems and every 5 years for non-community systems. Community subpart H systems whose performance is determined by the state to be outstanding may have sanitary surveys conducted at intervals of up to 5 years.

Inspectors should check to see if systems that are required to prepare disinfection profiles have done so. The system's disinfection benchmark should be calculated and any planned changes in disinfection practices should be discussed. Also, the inspector must, in the sanitary survey report, designate any sanitary deficiencies deemed by the state to be "significant" deficiencies. Inspector follow-up is then necessary to ensure the system responds in writing and addresses the significant deficiencies.

Long Term 1 Enhanced Surface Water Treatment Rule (LT1 ESWTR)

EPA promulgated this rule on January 12, 2002. The rule applies requirements similar to those of the IESWTR to systems that use surface water or ground water under the direct influence of surface water and serve fewer than 10,000 persons.

Filter Backwash Recycling Rule (FBRR)

EPA promulgated this rule (40 CFR 141.76) on June 8, 2001.

The inspector should determine whether direct and conventional filtration plants recycle spent filter backwash water, sludge thickener supernatant, or liquids from dewatering processes. Plants that recycle regulated flows must bring them back to the head of the plant (after June 1, 2003) or to an alternative location approved by the state. The state will also determine if treatment or equalization of the recycle stream is necessary. The inspector should also make sure the plant is in compliance with FBRR monitoring and reporting requirements.

Lead and Copper Rule

Under 40 CFR 141.80 to 91, community and non-transient, non-community water systems must collect first-draw samples from strategically located service connections and have them analyzed for lead and copper. If the levels of lead or copper exceed action levels (0.015 mg/L for lead and 1.3 mg/L for copper) in more than 10 percent of the required samples, corrective action must be taken.

The inspector should verify that the system has taken the required first-draw samples. It is particularly important with small systems to make sure they are sampling at appropriate locations and times. Small schools, for example, often sample at the beginning of the school year or from taps that have not been used for weeks; they exceed action levels because of the excessive time water was in the line.

When action levels have been exceeded, the inspector must ensure that the appropriate follow-up corrective actions including treatment, when necessary, have been taken.

Stage 1 Disinfectants and Disinfection Byproducts (D/DBPs)

Community and non-transient, non-community systems that chemically disinfect their water must meet the requirements of 40 CFR Part 141, subpart L, Disinfectant Residuals, Disinfection Byproducts, and Disinfection Byproduct Precursors. Portions of subpart L also apply to transient, non-community systems that use chlorine dioxide. Components of subpart L that inspectors must be aware of include:

- MCLs for disinfection by-products including TTHMs, haloacetic acids (HAA5), bromate and chlorite.
- Maximum residual disinfectant levels (MRDLs) for chlorine, chloramines, and chlorine dioxide.
- Monitoring plan requirements.
- Enhanced coagulation and enhanced softening requirements to address DBP precursors for subpart H systems that have conventional or softening plants.

It should be noted that each system affected by this rule must develop and implement a monitoring plan. The system must then maintain the monitoring plan and make it available for inspection by the state and general public (systems serving more than 3,300 persons must submit their plans to the state). The inspector should review the monitoring plan while on site to ensure that monitoring is in accordance with the rule.

Inorganic and Organic Chemicals

Monitoring requirements for inorganic and organic chemicals are contained in 40 CFR 141.23 and 40 CFR 141.24, respectively. For both groups of contaminants, samples are required at the entry points to the distribution system. Inspectors should verify that all sources are appropriately monitored at the entry point. It is important to note that transient, non-community systems are required to monitor for nitrate and nitrite.

Waivers for Volatile Organic Chemicals, Inorganic Chemicals, and Synthetic Organic Chemicals. Waivers from monitoring requirements can be obtained based on knowledge of previous use of a contaminant including transport, storage, or disposal. If use is unknown, waivers can be based on sources of contamination resistance and wellhead or watershed protection. These factors should be evaluated during a sanitary survey to determine if conditions have changed that would cause the state to reconsider a waiver previously granted or to grant a new waiver.

- Asbestos monitoring, unless a waiver is received, must be done at a tap served by asbestos cement pipe. This should be verified.
- Reduced monitoring for inorganic chemicals is based on factors that can affect contaminant concentrations. These include:
  - Changes in ground water pumping rates.
  - Changes in the system’s configuration,
  - Changes in the system’s operating.procedures.
  - Changes in stream flow or characteristics.

During a sanitary survey, the inspector should determine that no changes have occurred that would cause the state to reconsider a waiver or reduced monitoring.

- A state may grant a waiver from monitoring for organic chemicals based on a system's vulnerability to contamination.

Radiological Contaminants

- Community water systems are required to sample for radiological contaminants. Compliance with radiological monitoring requirements should be checked by the inspector while on site or when reviewing the system's files prior to the sanitary survey.

Direct and Indirect Additives

Contaminants Not Regulated. During a sanitary survey, it is important to be alert to contaminants other than those that are regulated under the national primary or secondary regulations. Of particular concern are contaminants that may be added during the process of collecting, treating, storing, or distributing drinking water.

Treatment, Chemicals, and Coatings. Treatments, chemicals, and coatings in contact with drinking water must be certified as meeting certain industry consensus standards for water contact or treatment. The certification itself can be made by an agency acceptable to the state to test and certify that products meet the standard.

NSF Standard 60. The National Sanitation Foundation (NSF) is the organization responsible for developing Standard 60, which covers direct additives to drinking water. Examples of direct additives include water treatment chemicals such as chlorine, polymers, orthophosphates, coagulants and aids, fluoride compounds, copper sulfate, and corrosion control chemicals.

40 CFR 141.111. EPA regulations place limits on two contaminants that may be contained in organic polymers used in coagulation and filtration. The water system must annually certify to the state in writing that the dose and monomer level do not exceed the following:

- Acrylamide, 0.05 percent dosed at 1 ppm.
- Epichlorohydrin, 0.01 percent dosed at 20 ppm.

During a survey, the inspector should determine that the system is complying with these requirements.

NSF Standard 61. NSF Standard 61 covers indirect additives. This category of additives includes products that come into contact with drinking water or into contact with treatment chemicals, such as filter media, coatings, liners, solvents, gaskets, welding materials, pipes, fittings, valves, chlorinators, and separation membranes. Products certified as meeting NSF Standard 60 or 61 can be identified by markings on them or their packaging. Lists of certified products are available from the certifying agencies.

State Requirements. Although there are no federal regulations requiring that additives used must meet NSF Standards 60 and 61, many states have or will adopt such requirements. In any event, an inspector should determine during a sanitary survey whether the system is using approved additives and is aware of the additives certification program.

Operator Certification

EPA guidelines specify minimum standards for the certification and recertification of operators of community and non-transient, non-community public water systems. All states have requirements that meet the EPA guidelines. The inspector should always check to make sure each system is in compliance with the state requirements.

Consumer Confidence Report Rule

Since October 1999, and every July 1 thereafter, community water systems must issue to their customers annual drinking water quality reports called consumer confidence reports (CCRs). The report must include required source water information, health information, detected contaminants and violations incurred. The systems must submit to the primacy agency copies of the annual CCR and a certification that the CCR was distributed to customers with information that is correct and consistent with monitoring data.

Because submitted CCRs are subject to annual review by the primacy agency, sanitary survey efforts should be limited to verifying whether copies of the CCRs are kept on file by the system for at least 5 years.

Recordkeeping

There are a number of general recordkeeping requirements specified in 40 CFR 141.33. In addition, the SWTR (40 CFR 141.75) and the Lead and Copper Rule (40 CFR 141.91) have specific requirements.

The inspector should verify the availability of these records at the water system during a sanitary survey.

Other Records. In addition to records required by federal regulation, the water system should maintain a variety of other records to ensure the continual proper operation and maintenance of the system. These include monitoring plans for disinfectants and disinfection byproducts; disinfection profiles; maps of the system; as-built plans; and water quality data from source, treatment, and distribution. The availability and security of these records should be evaluated during a sanitary survey.

Records to Keep	Retention Period
Bacteriological analysis	5 years
Chemical analysis	10 years
Actions to correct violations	3 years
Sanitary survey reports	10 years
Variance or exemption	5 years
Turbidity results	10 years
All lead and copper data	12 years

Data Integrity. SDWA and its regulations require self-monitoring and self-reporting by water systems to show compliance with the regulations. The consequences of non-compliance can be severe (e.g., compliance orders and penalties). Errors in information reported to the state can result from ignorance of proper testing procedures and instruments that are out of calibration. Data falsification is rare, but serious. During a survey the inspector should be alert to intentional or unintentional errors in data.

Variances, Exemptions, and Orders

Variances, exemptions, and compliance orders will contain provisions requiring the public water system to comply with certain conditions. (For example, a compliance order will normally include a schedule.) A sanitary survey can be used to determine a system's progress in complying with these conditions. Sanitary surveys can also be used to determine, case by case, the need for, and the possible conditions that may be set forth in, a variance, exemption, or order.

Field Compliance Questions/Sanitary Deficiencies

1. **Is the information in the state files on population served and number of service connections accurate?**

2. **Is the information on the status of the system correct (i.e., is it large enough to be a public water system, and is its classification as CWS, TNCWS, or NTNCWS correct)?**

3. **Is the system in compliance with various provisions of the NPDWRs, including siting of facilities, coliform monitoring, filtration and disinfection, lead and copper corrosion control, organic and inorganic contaminants, and direct and indirect additives?**

4. **Has the system modified its source, treatment process, chemicals used, or distribution system without state approval?**

5. **Is the system using chemicals and coatings approved by ANSI/NSF or another third party?**

6. **Is the system staffed by qualified operators?**

7. **Are appropriate records maintained?**

8. **Is the system complying with conditions set forth in any waivers, variances, exemptions, or orders?**

9. Does the system have a written monitoring plan for disinfectants and disinfection byproducts?

10. Was the system required to prepare a disinfection profile and, if so, is it available for review?

Sanitary Surveys and Capacity Development

The 1996 SDWA Amendments require states to develop two programs: One is to ensure that new community water systems and new non-transient, non-community water systems have adequate capacity before they can operate. The other must provide a strategy to help existing public water systems achieve and maintain capacity. Sanitary surveys can be used to assess capacity at existing systems.

Water system capacity (not to be confused with production capacity as measured in units of water) is the ability to plan for, achieve, and maintain compliance with applicable drinking water standards. For a system to have capacity, adequate capability is required in three distinct, but interrelated, areas:

- **Technical.** The essential elements of technical capacity are source water adequacy, infrastructure adequacy, and technical knowledge. These can be assessed when reviewing the following sanitary survey elements: source, treatment, distribution, storage, pumps, monitoring and reporting, management and operations, and operator certification.

- **Managerial**. The essential elements of managerial capacity are ownership accountability, staffing and organization, and effective external linkages. These can be assessed when reviewing the monitoring and reporting, management and operations, and operator certification elements of a sanitary survey.

- **Financial**. The essential elements of financial capacity are revenue sufficiency, fiscal management and controls, and credit worthiness. Like technical capacity, evidence of financial capacity can be found in all elements of a sanitary survey.

In assessing capacity as part of a sanitary survey, it is important to recognize the relationship between sanitary surveys and capacity development:

- Both attempt to identify deficiencies that may jeopardize a system's ability to deliver an adequate quantity or quality of water to consumers.

- Both require follow-up to accurately assess and remedy a system's problems.

- Both address technical, management and financial issues.

The last point is especially significant. If you are conducting thorough sanitary surveys, you are probably already addressing many of the issues that would be raised in a capacity development assessment. The addition of a few questions–most likely on managerial and financial issues–may be necessary. Chapter 10 of this Guide provides some additional questions related to managerial and financial capacity.

A state may use the sanitary survey to screen systems regarding capacity, since some inspectors will not feel comfortable discussing managerial or financial issues. However, basic questions can be asked to assess whether more detailed follow-up by other state personnel is warranted.

As you conduct a sanitary survey, be aware that many of the questions you ask address capacity. Think about the information in terms of capacity, and you will have taken the few additional steps required to complete a capacity assessment at the same time as your sanitary survey.

3 Water Sources

The source of water for a public water system is the first area of concern in the multiple-barrier approach to preventing waterborne disease. Inspectors should determine the safety, adequacy, and reliability of the source during a sanitary survey.

Learning Objectives

By the end of this chapter, learners should be able:

- To evaluate the safety, adequacy, and reliability in terms of quantity and quality of ground and surface water sources.
- To evaluate the adequacy of source water protection.
- To review the key components of water sources for ground and surface supplies.
- To identify the key data required to determine potential sanitary deficiencies.
- To recognize sanitary deficiencies associated with facilities, operations, maintenance, management, and contingency planning.
- To identify improper well construction and equipment installation.
- To evaluate the adequacy of surface water intakes and appurtenances.
- To evaluate adequacy of spring and roof catchment facilities, operation, and maintenance.
- To evaluate the adequacy of transmission facilities.
- To determine compliance with federal, state, and local regulations.

Data Collection

Generally, enough data should be collected so the inspector can evaluate the safety, adequacy, and reliability of the water source being surveyed. For example, raw water quality data aid in evaluating the safety of the source; high raw turbidity or coliform counts may indicate problems with source quality and may aid in regulatory compliance determination. Information about safe yield and system demand is important in evaluating the adequacy of the system to meet the demands for water placed on it. Data that should be collected are included in the following narrative and sanitary survey questions.

Regulations and Standards to Consider

Most of the regulatory requirements for public water systems focus on the quality of water entering the distribution system. However, source water type and quality are a major part of the Surface Water Treatment Rule, the Interim Enhanced Surface Water Treatment Rule and the Stage 1 Disinfectant/Disinfection By-products Rule. Compliance with the Ground Water Rule, Long-Term 1 and Long-Term 2 Enhanced Surface Water Treatment Rules, and Stage 2 Disinfectant/ Disinfection By-product Rule will also depend on source quality and type. See Chapter 2 of this Guide for more information on these rules.

Water Sources

Quantity of Water

Importance of Evaluating. The inspector should evaluate the capability of the system to meet the demands placed on all of its components. Demands exceeding available treatment capacity can cause inadequately treated water to enter the distribution system. Similarly, inadequate flow or pressure in the system can result when demand exceeds the capacity of the source of supply, transmission lines, pumps, distribution system piping, or storage facilities. Inadequate flow or pressure affects the consumers' use of the water supply, hinders fire fighting capabilities, and creates opportunities for non-potable liquids to enter the system through cross-connections. Prolonged interruptions in water service represent a public health hazard.

Estimating Demand. Most States have guides for estimating the average daily demand, maximum daily demand, and probable maximum momentary demand for various types of establishments (non-community systems) and community systems. These guides may be useful for evaluating small system demands. The values shown may vary throughout the nation, and the inspector is advised to review local information on similar water systems serving similar size establishments and communities. State and local requirements may vary. Additional allowance should be made for uses such as frequent lawn watering, swimming pool maintenance, industrial and commercial process water, cooling water, and fire fighting.

It is also very important for the inspector to recognize the relationship between source water quantity and storage. For example, when bulk storage is provided the sources have to be capable of providing at least the maximum daily demand. Storage facilities can provide water during periods of high demand and can fill during periods of low demand. On the other hand, hydropneumatic tanks are essentially designed to maintain acceptable pressures while limiting the cycling of pumps. Hydropneumatic tanks are the only storage provided for most very small systems, so the source and source water pumping must be capable of meeting the system's much higher maximum momentary demand. The inspector should be prepared to make reasonably accurate estimates of probable water demands for a wide variety of types and sizes of community and non-community public water systems.

Sanitary Deficiencies – Quantity

1. **What is the total design production capacity?**

   Comparing this figure with metered or estimated demand figures allows the inspector to determine if source capacity is adequate.

2. **What is the present average daily production?**

   Comparing this figure with values for other, similar systems on a per capita basis may point out problems within the system. An evaluation of average daily production trends also may indicate problems. For example, if consumption is higher than in similarly sized systems, or if production trends are increasing without an accompanying population or use increase, excessive leakage within the distribution system may be indicated.

3. **What is the maximum daily production?**

   This figure should be compared with the design capacity of the various major system components. Operating records from the maximum demand day can be reviewed to determine the performance of the source, treatment, storage, and distribution system under stressful conditions.

4. **Is the safe yield sufficient to meet current and future demands?**

   Capital improvements may be necessary if average daily production approaches or exceeds the design capacity of major system components (e.g., the safe yields of the sources of supply or the raw water pumping and transmission, treatment, finished water pumping, storage, and additional sources).

5. **Is the quantity of the source adequate?**

   To answer this question, the inspector should determine if the source is adequate for current as well as future demands. The source should be able to continuously meet the demands of the water system, the demands of which will vary based on the system type, size, climatic conditions, and storage facilities used. Decreasing trends in quantity are also important to note. Operating records should provide this information, but when operating records are not available the inspector must be prepared to make reasonable estimates.

6. If permits are required, is the facility operating within the limits? Are permits available?

Some States require systems to have operating permits or to operate within the constraints of water rights laws. In addition, systems that discharge waste streams to ground or surface water may be required to have discharge permits (e.g., National Pollutant Discharge Elimination System [NPDES] permits).

7. Does the system have an operational master meter?

Without an operational and calibrated master meter, it is difficult for the utility to accurately monitor production. Some small systems meter the hours their pumps run. With this information the inspector can use pump curves to estimate production.

8. How many service connections are there?

This figure gives the inspector an idea of the size of the system in terms of number of homes and businesses served by the system. It should not include connections for vacant lots.

9. Are service connections metered?

This allows a water balance to be made. There is also a correlation between metered service and water conservation. If the system is metered, the per capita consumption is usually lower than if the system is not metered.

10. Does the system have interconnections with neighboring systems or a contingency plan for water outages?

It is important that the system have a plan to deal with water outages so it can quickly correct their causes. Interconnections should be made with only approved sources. Also, emergency supplies should be made available during extended outages or to meet emergencies.

11. Does the system have redundant sources?

Many States require community water systems supplied by ground water to have at least two supply sources in case one is lost.

12. Are there any abandoned, unused, or auxiliary sources?

Surface supplies that are physically connected to the water system may contaminate finished water. Abandoned sources should be physically disconnected. Abandoned or unused wells should be sealed properly to prevent contamination of the aquifer.

Quality of Water

Proximity to Contamination

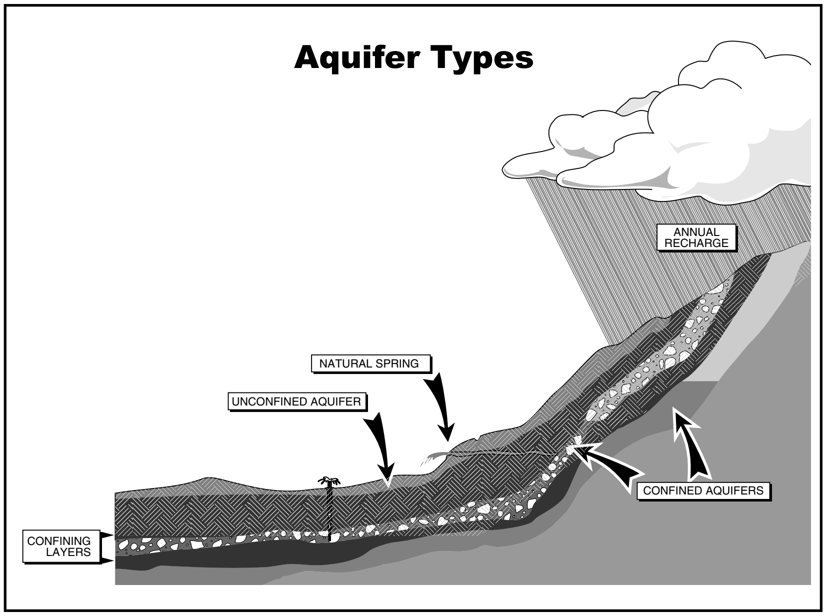
The likelihood of contamination is increased by the proximity of the water source to, for example, sewers, septic tank waste disposal, construction projects, animal pastures, chemically treated agricultural land, and chemical storage areas (such as highway deicing salt or petroleum products). Other sources of contamination are natural, such as runoff from high flooding; iron, manganese, or other chemicals in soil and rock formations; and decomposing organic matter.

Substances that Alter Quality

Substances that alter the quality of water as it moves over or below the surface of the earth may be classified as organic, inorganic, biological, or radiological.

Sources of Impurities

The impurities in natural waters depend largely on the circumstances of the source and its history. Water destined to become ground water picks up impurities, including possible contaminants, as it seeps through soil and rock. Potential pollution sources include leaking sanitary sewers, septic systems, waste disposal sites, and accidental discharges. Uptake of minerals by water is common. The natural straining of water as it moves through soil and aquifer material can remove some particulates and, combined with a relatively long retention period in the ground, often aids in removing and inactivating microorganisms. A long retention time can, however, create problems. Purging contaminated ground water can require much time and money.

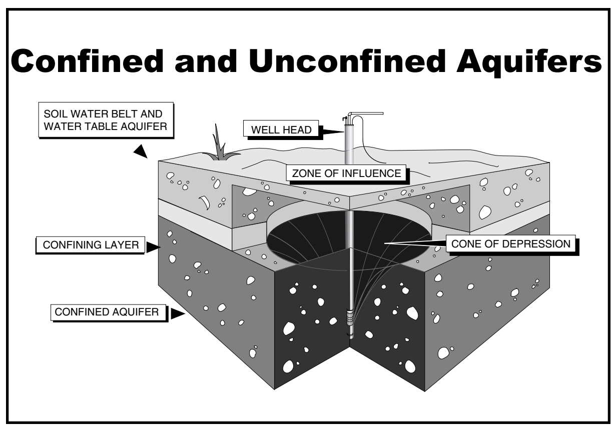


Ground Water

Small Utilities - Main Source. Ground water is the principal source of water for small systems. It is readily available in most areas of the country in sufficient quantities to meet the needs of small water systems. Ground water generally has a more consistent and better microbiological quality than surface water, having undergone considerable natural purification through straining and prolonged storage. However, a number of ground water systems have suffered source water contamination due to improper chemical storage and waste disposal. Ground water tends to require little treatment prior to use, while surface water usually requires rather extensive treatment to remove or inactivate bacteria, *Giardia*, *Cryptosporidium*, and viruses.

Aquifer Classification. Aquifers are classified as confined (or artesian) aquifers or unconfined (or water-table) aquifers. The distinction between the two is important in terms of the vulnerability of the aquifer to man-made contamination. In a confined aquifer, the water is sandwiched between an upper and a lower layer of impermeable material called an aquiclude. Clay, the most frequently encountered aquiclude, forms a natural barrier to the upward or downward migration of ground water. This barrier restricts the downward movement of contaminants from the surface into the confined aquifer, protecting the wells and springs that draw water from it. Aquicludes also restrict migration of contaminants from other aquifers above or below the confined aquifer. Because of the protection provided to confined aquifers, their water is considered to be relatively invulnerable to contamination.

Contamination of Unconfined Aquifers. An unconfined aquifer rests on an aquiclude and has no confining layer above it. As a result, percolation of precipitation and infiltration of surface water from streams, lakes, and reservoirs carries water and contaminants from the surface into the aquifer. Unconfined aquifers are, therefore, considered to be comparatively vulnerable to contamination.

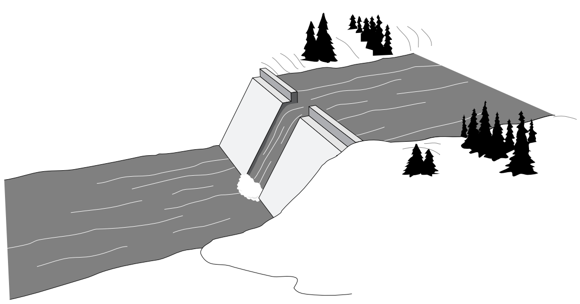


Surface Water

Quality. Because surface water is subject to contamination by both man and nature, and because its quality can vary considerably over time, a relatively high degree of treatment is required to ensure surface water's safety on a continuous basis. Surface water treatment is generally more sophisticated than ground water treatment, requires more diligent operation and maintenance, and results in higher costs.

Impoundments. On occasion, a small water system will rely on surface water as its source because of the poor quality or lack of local ground water. Other factors being equal, impoundments such as natural lakes, ponds, or reservoirs are preferable to streams because the quality of the water is usually less variable.

Surface Water Impoundment



Sanitary Deficiencies – Quality

1. **Does the system monitor raw water quality?**

   Most drinking water regulatory monitoring requirements relate to treated water, that is water in the treatment process, at the entry point to the distribution system, or in the distribution system. Water systems should have an appropriate raw water quality monitoring program to track changes in quality with particular attention to periods of high runoff, drought, and other stressful conditions.

2. **Is the source adequate in quality?**

   A review of monitoring records should answer this question. As with quantity, any trends of decreasing quality should be noted.

3. **Is the system using the highest quality source available?**

   Because water quality monitoring and testing do not measure all potential contaminants, a system should use the highest quality source available, based on its knowledge of water quality and potential sources of contamination.

4. **Is there a trend of decreasing raw water quality that would suggest the need for a new source or changes in treatment in the future?**

   Inspectors should review water quality trends in raw and finished water to determine if the system should consider seeking new sources or adding or changing treatment.

5. **Does monitoring of raw water quality indicate an immediate, significant sanitary deficiency?**

   In the case of a ground water source, for example, does the occurrence of coliform-positive samples suggest a sanitary defect is in the well that requires immediate attention.

Source Protection

The inspector should evaluate the system's efforts to protect its water source. The basic principles of source protection apply regardless of whether a system has a ground water supply or surface water supply. In general, systems should follow these steps in this evaluation:

1. Select a planning team.

2. Define the wellhead protection area or the watershed area.

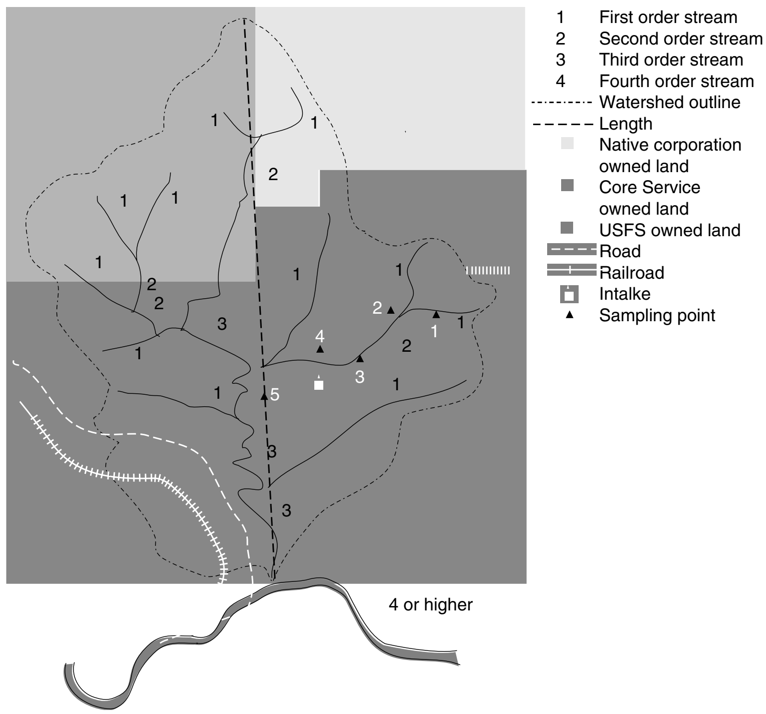
3. Identify actual or potential sources of contamination in the defined area.

4. Implement measures to control sources of contamination.

5. Plan for the future and develop a contingency plan.

During the sanitary survey, the inspector should determine the adequacy of the system's source water protection program. Are sufficient resources being devoted to this effort? Does the system have an actual program? Is the program active? Was a program discontinued because the system was unable to implement important tasks such as identifying or controlling sources of contamination?

Source Water Protection Map



Sanitary Deficiencies – Source Protection

1. Is the watershed or aquifer-recharge area protected?

Recharge Zone Activity. What is the nature of the area? Does the system have a wellhead or watershed protection program? The nature of activities in the well's recharge zone or in the watershed and the degree to which they are controlled can influence the quality of the water source. This is especially true if the aquifer is unconfined.

Wellhead Protection Program. An effective way for systems to protect well source recharge areas from contamination is to develop and implement wellhead protection (WHP) plans. A system's WHP plan should follow EPA's effective five-step process for wellhead protection presented on page 3-5.

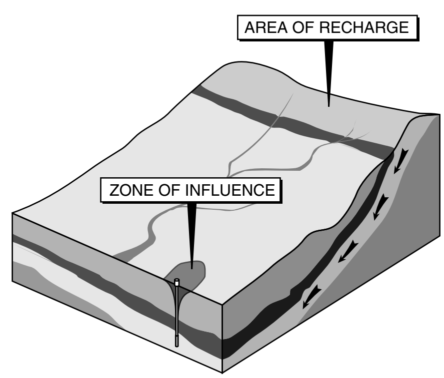
The SDWA Amendments of 1986 required states to develop a wellhead protection program for all public water system wells. On a system-specific basis, this involves delineating the wellhead protection area, inventorying the potential sources of contamination, managing the wellhead protection area, and planning for contingencies.

Components of a Program. Measures that can be used to protect the source include ownership of the recharge area and zoning ordinances or regulations that prohibit certain land uses within the recharge area. The inspector should determine if recharge area protection, such as a wellhead protection plan, is in place and should evaluate its effectiveness.

2. What is the size of the protected area and who owns it?

To reduce the extent of contamination of their watersheds, many utilities have chosen to purchase a portion of them. Another method is to restrict activities through zoning and ordinances.

Recharge Area



3. **What is the nature of the protection area?**

   Is the protection area industrial, agricultural, forest, or residential? As previously noted, activities in the watershed will affect the water quality of runoff. The potential for spills from industrial activities, herbicides and pesticides from agricultural land uses, organics from plant decay, and animal-borne diseases are a few problems associated with land use in a watershed.

4. **How is the area controlled?**

   This question enables the inspector to evaluate the effectiveness of watershed control measures. Ownership with restricted access is the most stringent measure, but it is also the most costly. If ordinances are used, the inspector should determine how they are enforced.

5. **Has management had the area surveyed?**

   If the utility has had a survey conducted, the inspector may be able to answer many of the above questions by referring to it. The fact that a utility has conducted such a survey indicates it is concerned about protecting its water supplies.

6. **Is there an emergency spill response plan?**

   Some industries (e.g., petroleum) are required to have emergency spill plans. The utility should identify potential spill sites and develop contingency plans to deal with any spills. However, because a plan is only paper, the utility must identify the necessary equipment and personnel. In addition, coordination among relevant agencies (fire, police, water utility) must be worked out and rehearsed prior to any emergency.

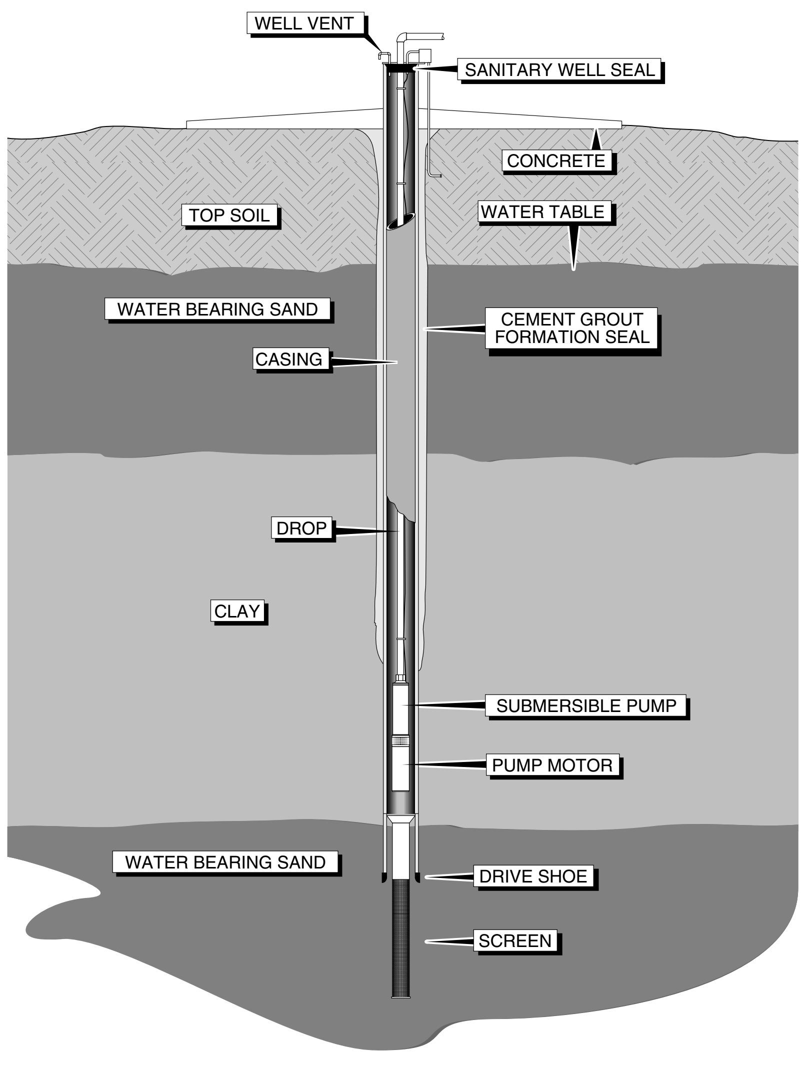
Wells – Specific Sanitary Deficiencies

Well Components

Many well components cannot be seen. Some of the more important components are described below.

Casing. A well casing prevents the collapse of the bore hole, keeps surface and subsurface pollutants from entering the water source, provides a column

Components of a Drinking Water Well



of stored water for positive well pump suction head, and houses the pump and its discharge pipe.

Grout. Cement or bentonite clay grout is frequently used during construction to fill the annular open space left around the outside of the well casing. This grout prevents surface water and shallow ground water from entering the well, and it prevents water from moving between aquifers.

Screens. Screens are installed at a well's intake point to hold back unstable aquifer material and permit the free flow of water into the well. The well screen should be of good quality (e.g., good structural properties, corrosion resistant, and hydraulically efficient). Where formation conditions are suitable, many small systems use perforated or slotted casings in lieu of screens.

Sanitary Seal. Wellhead covers or seals at the top of the casing or pipe sleeve connections prevent contaminated water and other material from entering the well. Several types of covers and seals are available to meet the variety of conditions encountered, but the principles and objectives of allowing free movement of air while excluding contamination are the same.

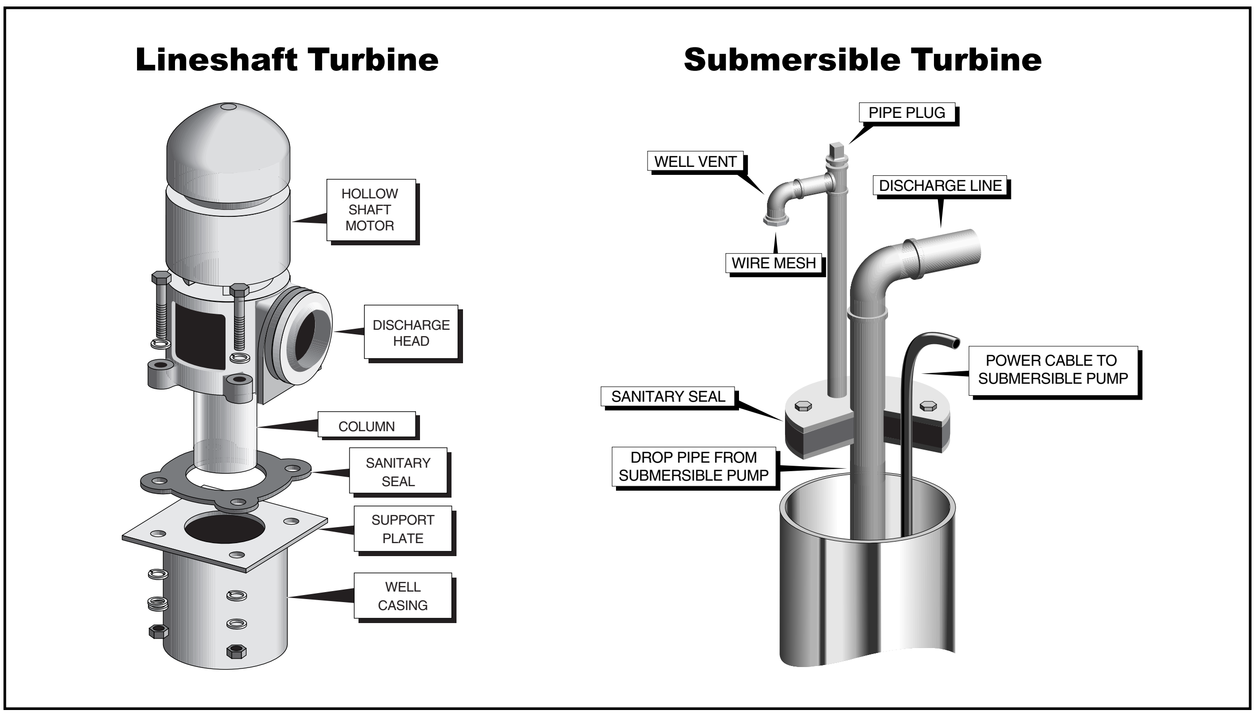
Pitless Units. Pitless adapters eliminate the need for a well pit. A well pit to house the pumping equipment or allow access to the top of the well casing is not recommended because the pits can flood, introduce pollution hazards, and present confined space entry risks. Some states prohibit the use of pits. A pitless adapter generally includes 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 allows the well piping to be connected to the casing underground below frost depth and, at the same time, provides good accessibility to the well pump and drop pipe for repairs without excavation.

Sanitary Deficiencies Related to Wells[1]

1. Is the well in a confined or unconfined aquifer?

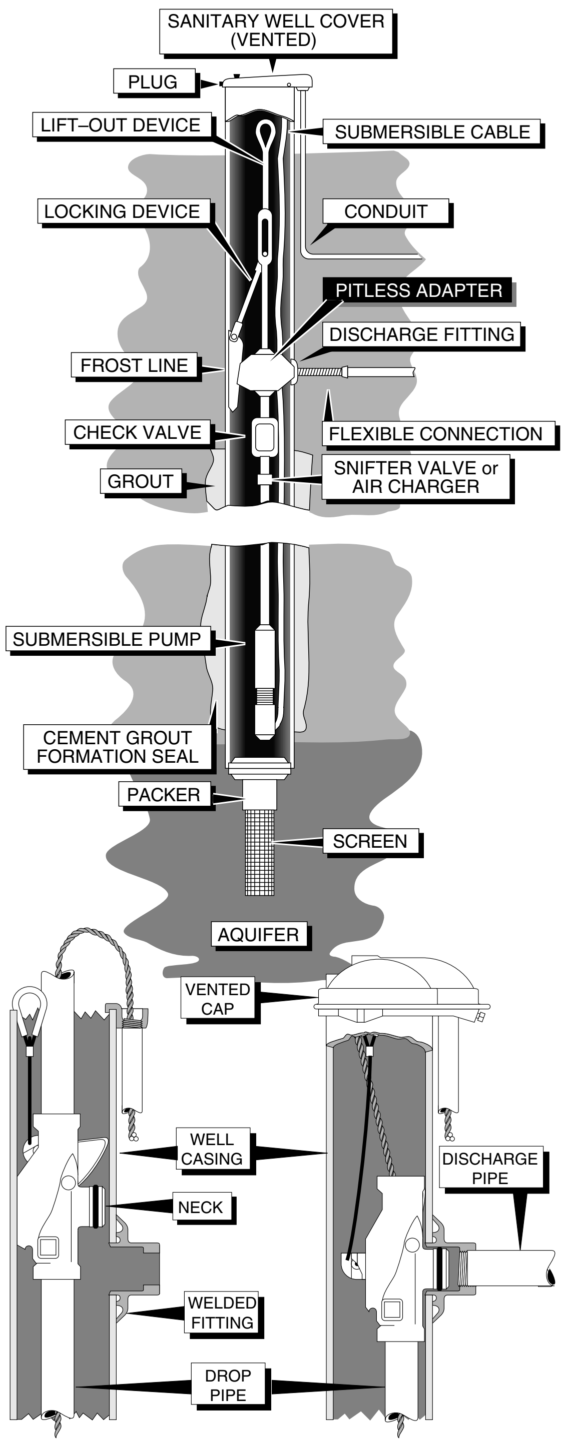
This information is important in evaluating the source's vulnerability to contamination. The name of the aquifer and its type can usually be obtained from the operator or from well drilling records. Well logs made during well drilling can indicate whether there is one or more confining layers above the well screen.

[1] The student may want to consider viewing the NETA video *Sanitary Survey Inspection; Before You Begin . . . WELLS* prior to reading this section.



The presence of significant thicknesses of clay material indicates that a confining layer separates the well screen from the ground surface and, therefore, the well is likely to be in a confined aquifer. The log also includes additional useful information.

Pitless Adapters



Other sources of information about the type of aquifer a well is in includes the state's geological survey agency and the U.S. Geological Survey. These agencies frequently maintain reports on wells and aquifers across the state.

2. **Is the site subject to flooding?**

Surface water should be kept from entering a well. Runoff in the immediate area should be drained away from the well site. At the least, any openings in the well casing should be located at least 3 feet above the 1 percent chance (i.e., 100-year) flood elevation.

Flood Insurance Rate Maps (FIRMs) can be obtained from the Federal Emergency Management Agency's National Flood Insurance Program. FIRMs show the base flood elevation in a given area. Information on flooding and site drainage may be obtained from the owner/operator, visual inspection, and flood-stage records. Any openings in the well casing should be located at least 3 feet above the the 100-year flood elevation.

3. **Is the well located near any immediate or potential sources of pollution?**

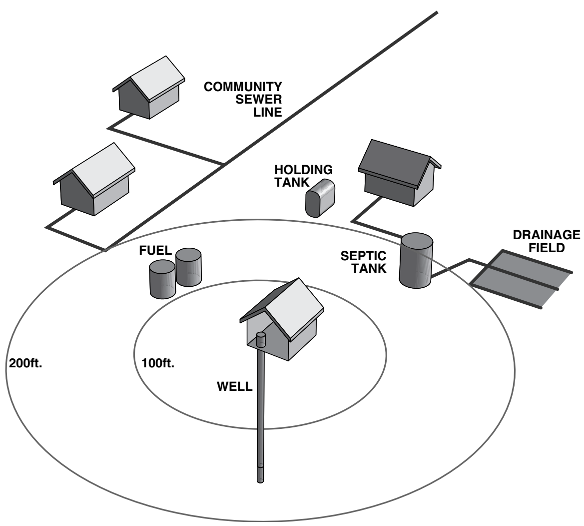
The appropriate state regulatory agency should be consulted for its policy concerning well location, particularly the minimum protective distances between the well and sources of existing or potential pollution. The table on the next page provides examples of typical minimum distances. These distances are based on general experience and are not guarantees of freedom from contamination. The table makes no distinction between unconfined and confined aquifers, although confined aquifers are typically much better protected. The water purveyor should provide even greater protection where possible. The table applies to properly constructed wells with the protective casing set to a depth of at least 20 feet below the ground surface. Other types of wells require special considerations.

Sample Minimum Distances Between Wells and Pollution Sources

Source	Feet from Well	Remarks
Watertight Sewers	50	Consult the state regulatory agency for special local requirements.
Other Sewers	100	
Septic Tanks	100	
Sewage Field, Bed, or Pit	200	
Animal Pens and Yards	200	

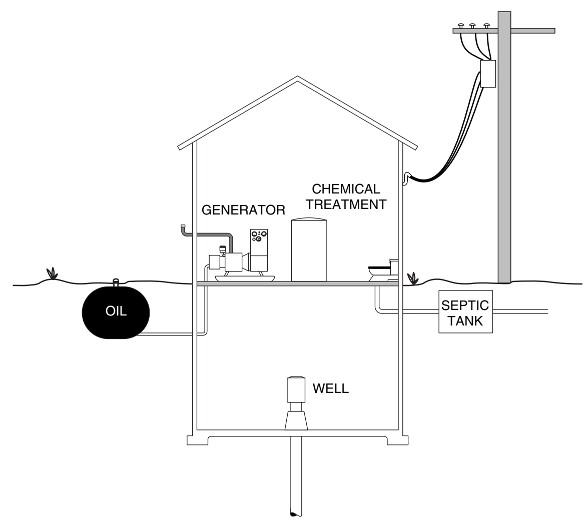
Source: *Small Water Systems Serving the Public,* Chapter 5.

Sample Minimum Distances from Well to Pollution Sources



Look for Other Sources. During the field inspection, inspectors should also be alert for potential sources of contamination other than those listed above. Fuel and chemical storage facilities and transmission lines are important sources to evaluate. Pollution from these sources can travel much farther than pollution from the sources in the table and illustration above. On-site water treatment chemical storage and fuel tanks should be investigated as well as off-site sources. Also, spills and highway runoff that contain petroleum products or deicing salt can contaminate shallower wells nearby.

Potential Contamination Sources



4. How Deep Is the Well?

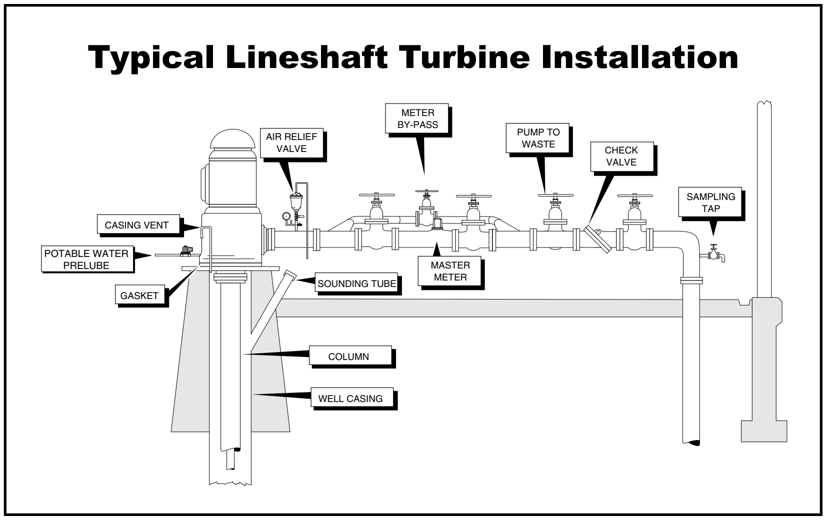
The greater the depth of the aquifer used, the less chance there is that surface contamination will degrade water quality. Deeper aquifers generally have a more consistent quality of water.

5. Is drawdown measured?

Drawdown is the difference between static water levels and pumping water levels. Measuring drawdown is important because changes in static water level or drawdown can indicate problems in the aquifer (declining water levels) or pump. Such changes also can indicate well encrustation. The operator should be regularly measuring drawdown and recording the results.

6. What is the depth of the casing?

The casing must be strong enough to resist the pressures exerted by the surrounding formation and corrosion by soil and water environments. The casing must be long enough to provide a channel from the aquifer to the surface through unstable formations and through zones of actual or potential contamination. The casing should extend above potential levels of flooding and should be protected from flood water contamination and damage. In unconsolidated soils, the casing should extend at least 5 feet (1.5 meters) below the estimated maximum expected drawdown level. In consolidated rock formations, the casing should extend 5 feet into firm bedrock and be sealed into place. The system should be able to provide this information.



7. What is the depth of grouting?

Specific grouting requirements for a well depend on surface conditions, especially the location of pollution sources, and subsurface geologic and hydrologic conditions. To achieve the desired protection against contamination, the annular space must be sealed to whatever depth is necessary, but in no case less than 20 feet.

8. Does the casing extend at least 18 inches above the floor or ground?

This provides protection against surface runoff or drainage problems. Eighteen inches is recommended when there is no potential for flooding.

9. Is the well properly sealed?

Wellhead covers or sanitary seals at the top of the casing or pipe sleeve connections prevent contaminated water and other material from entering the well. Well covers and pump platforms should be elevated above the adjacent finished ground level and sloped to drain away from the well casing.

10. Does the well vent terminate 18 inches above the ground or floor, or 3 feet above maximum flood level with return bend facing downward and screened?

This is necessary to keep water (from water-cooled bearings, for example), dust, insects, and animals out of the well casing.

11. Does the well have a suitable smooth-nozzle raw-water sampling tap?

This is important when raw water samples need to be collected. A threaded tap can introduce contaminants.

12. Are check valves, blow-off valves, and water meters maintained and operated properly?

Valves should be maintained and operated to prevent contaminants from entering the well.

13. Is the upper termination of the well protected?

The upper termination of the well should be either housed or fenced to protect it from vandalism and vehicle damage. The area should be sloped away from the well to prevent surface water from draining toward the casing.

14. Is lightning protection provided?

Lightning surges can develop in power lines during thunderstorms. Such surges can damage pump motors, resulting in loss of water supply and costly repairs. To protect against this, lightning arresters can be installed where electrical service lines are connected to service entrance cables, or at the motor control box. Multi-ground arrangements can be used to protect the entire pump and well against damage.

15. Is the pump intake located below maximum drawdown?

Locating the pump intake below maximum drawdown prevents the pump from running dry and protects against the pumping of contamination from upper portions of the water table.

16. Are foot valves and check valves accessible for cleaning?

As with above-ground valves, these valves must be maintained in an operating manner to prevent the backflow of distribution system water into the well.

Surface Sources – Sanitary Deficiencies

Special Considerations

Surface sources used by small water supply systems require consideration of additional factors not usually associated with ground water sources. When small streams, open ponds, lakes, or open reservoirs are used as sources of water supply, the danger of contamination and spread of intestinal diseases such as cholera, typhoid fever, *cryptosporidiosis*, *giardiasis* and dysentery are generally increased. Clear water is not always safe, and the old saying that running water purifies itself to drinking water quality within a stated distance is not true.

Unsafe Unless Treated

The physical, chemical, and bacteriological contamination of surface water make it necessary to regard such sources of supply as unsafe for domestic use unless reliable treatment, including filtration and disinfection, is provided. The treatment of surface water to ensure a constant, safe supply requires diligent attention to operation and maintenance by the owner of the system. Principal sources of surface water that may be developed are controlled catchments, ponds or lakes, surface streams, and irrigation canals. Except for irrigation canals, where flows depend on irrigation activity, these sources derive water from direct precipitation over the drainage area.

Value and Use

The value of a pond or lake as a source is its ability to store water during wet periods for use during periods of little or no percipitation. A pond should be capable of storing at least 1 year's supply of water. It must be of sufficient capacity to meet water supply demands during periods of low rainfall with an additional allowance for seepage and evaporation losses. The drainage area (watershed) should be large enough to catch enough water to fill the pond or lake during wet seasons.

Reduce Contamination

To minimize the possibility of chance contamination, the watershed should be:

- A fenced area that is clean and has controlled vegetation.
- Free from barns, septic tanks, privies, and soil absorption fields.
- Protected from erosion and drainage from livestock areas.

Reservoirs

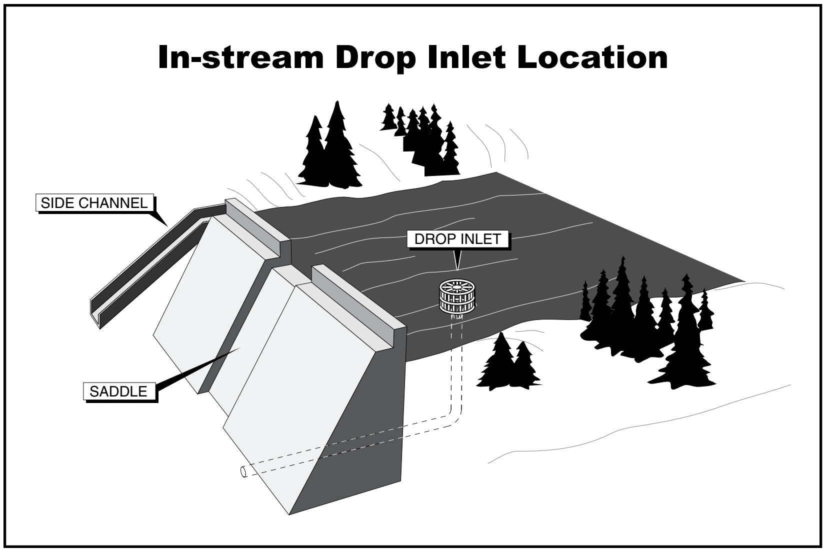
Reservoirs such as dam impoundments offer several advantages:

- Raw water reserve.
- Settling.
- Best quality raw water with multiple intakes.

Streams and Rivers

Impact on Treatment

Streams that receive runoff from large uncontrolled watersheds may be the only sources of water supply. The physical, chemical, and bacteriological quality of surface water varies and may impose unusually or abnormally high loads on the treatment facilities.



Use with Streams and Lakes

Galleries may be considered where porous soil formations adjoin a stream or lake so that the water can be intercepted underground to take advantage of natural filtration. Any gallery access structures should be located above the level of severe flooding.

Components

A typical installation generally involves the construction of an under-drained, sand filter trench parallel to the stream bed and about 10 feet from the high-water mark. The sand filter is usually located in a trench at least 30 inches wide and about 10 feet deep, sufficient to intercept the water table. At the bottom of the trench, perforated or open joint tile is laid in a bed of gravel about 12 inches thick, with about 4 inches of graded gravel over the tile to support the sand. The embedded tile is covered with at least 24 inches of clean, coarse sand, and the remainder of the trench is backfilled with fairly impervious material. The collection tile drains to a watertight, concrete chamber from which water may flow to the distribution system by gravity or pump, whichever is appropriate.

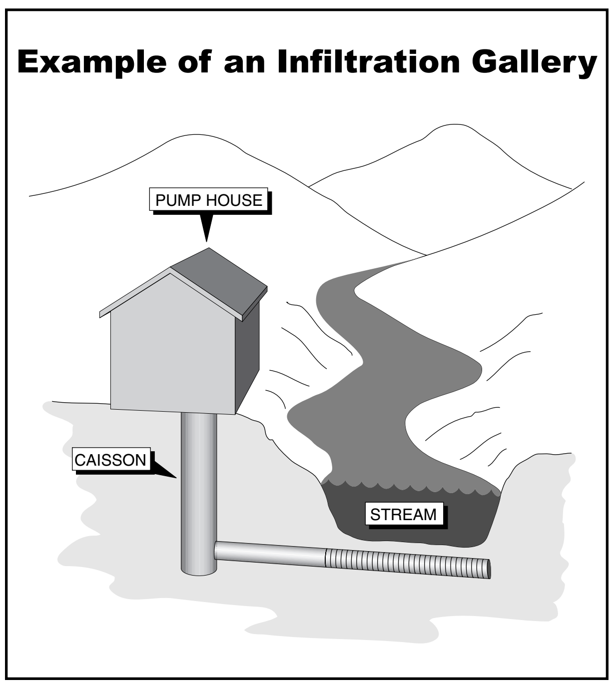
Intake Location

Stream intakes should be located upstream from wastewater discharges, storm drains, and other sources of contamination. If possible, water should be pumped when the silt load is low. A low-water stage usually means that the temperature of the water is higher than normal and the water is of poorest chemical quality. Maximum silt loads, however, occur during maximum runoff. High-water stages shortly after storms are usually the most favorable for diverting or pumping water to storage. These conditions vary and should be considered for the particular stream. Obviously, many systems have no raw water storage facilities and have to meet daily demands with run-of-the-river water quality.

Infiltration Galleries

Use and Location

Recreational or other developments in the mountains may have access to a headwater mountain stream where the watershed is generally heavily forested and uninhabited by human beings. After periods of heavy rainfall or spring thaws, however, debris and turbidity may cause problems at the water intake and will materially increase the required degree of treatment. If the conditions are suitable, this problem can be avoided by constructing the intake in an underground chamber (infiltration gallery) along the shore of the stream or lake.



Chlorination is required for all surface water sources and adequate contact time must be provided to meet the requirements of the Surface Water Treatment Rule (SWTR). Filtration is also required of all surface water systems that are unable to meet the SWTR's criteria for avoiding filtration.

Modified Gallery

Where soil formations adjoining a stream are unfavorable for the location of an infiltration gallery, the debris and turbidity occasionally encountered in a mountain stream may be controlled by constructing a modified infiltration gallery in the stream bed.

Using a Dam

If there is no natural pool in the stream bed, a dam is usually constructed across the stream to form a pool. The filter is installed in the pool by laying perforated pipe in a bed of graded gravel, which is then covered by at least 24 inches of clean, coarse sand. About 24 inches of free board should be allowed between the surface of the sand and the surface water level. The collection lines may terminate in a watertight, concrete basin located adjacent to the upstream face of the dam from which the water is diverted to chlorination and treatment facilities.

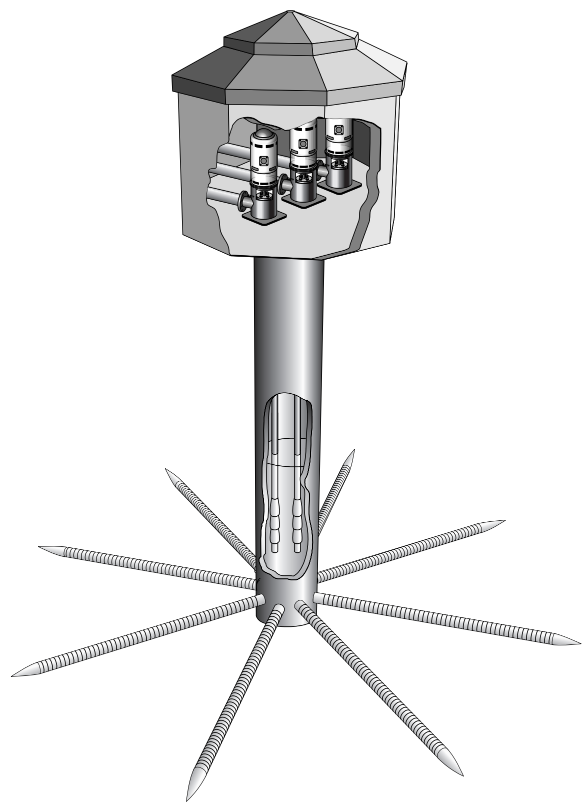
Ranney Well Collector

Ranney well collectors are located in the flood plain to draw water from a river bed water table.

Transmission Lines

Raw-water transmission lines occasionally serve customers on the way to the treatment plant. In such instances, point-of-entry or point-of-use treatment must be provided to ensure adequate protection of public health and compliance with the SWTR's requirements.

Ranney Well



Sanitary Deficiencies Related to Surface Sources

1. **Is any treatment provided in the reservoir?**

   The addition of any chemicals to the reservoir should be noted. Of particular concern is ensuring that only approved chemicals are used, that they are properly applied, and that there are no discharges of treated water that will cause violations of the Clean Water Act.

2. **Is the area around the intake restricted for a radius of 200 feet?**

   Restricting contact sports (e.g., swimming and water skiing) and the use of power boats near the intake is important. These restrictions will help reduce the coliform and organic pollution of the intake water.

3. **Are there any pollution sources near the intakes?**

   Sources of pollution such as wastewater discharges, feed lots, marinas, and boat-launching ramps should be identified. If the use of the reservoir is not restricted, the impacts of these activities should be minimized as much as possible by keeping them away from the intakes.

4. **Are multiple intakes at different levels used?**

   Because of fluctuating water surface elevation and variable water quality, intakes must be provided at different depths. Seasonal turnover of the reservoir, algae blooms, and thermal stratification can cause water quality problems. These concerns apply to deep reservoirs. Streams and shallow reservoirs generally are not subject to stratification.

5. **Is the highest quality water being drawn?**

   The operator should perform monitoring tests to determine the water quality at various depths in order to draw the best quality water. The operator should be asked how the intake level is selected, what tests are performed, and at what frequency. Suggested tests are algae counts, dissolved oxygen, metals, and nitrogen values.

6. **How often are intakes inspected?**

   As with all components, maintenance must be periodically performed on the intake structure. Removal of debris and inspection of intake screen integrity will prevent damage to piping valves and pumps. This is particularly important during winter due to the danger of ice buildup.

7. **What conditions cause fluctuations in water quality?**

   Conditions such as stratification, algae blooms, ice formation, on-shore winds, and changing currents may adversely change water quality. Conditions creating such problems should be noted, along with the measures taken to mitigate them.

8. **Has the dam been inspected for safety (if applicable)?**

   Dams should be routinely inspected to avoid conditions that may endanger their integrity. Many states require such inspections. If inspections are not required, operators should be encouraged to look for such things as erosion, sinkholes, burrowing animals, and trees growing in the dam face.

Springs – Specific Sanitary Deficiencies

Capture Ground Water

To properly develop a spring as a source of supply, the natural flow of ground water must be captured below the ground surface in a way that does not contaminate the water. Springs are subject to contamination by wastewater disposal systems, animal wastes, and surface drainage. They are also susceptible to seasonal flow variations, and their yield may be reduced by the pumping of nearby wells.

Types of Springs

Springs may be gravity or artesian. **Gravity springs** occur where a water-bearing stratum overlays an impermeable stratum and outcrops to the surface. The water permeates at the point where the impermeable stratum outcrops. They also occur where the ground surface intersects the water table. This type of spring is particularly sensitive to seasonal fluctuations in ground water storage and frequently dwindles or disappears during dry periods. Gravity springs are characteristically low-yielding sources, but when properly developed they may be satisfactory for small water systems.

Artesian springs discharge from openings in the confining layers of artesian aquifers. They may occur where the confining formation over the artesian aquifer is ruptured by a fault. Artesian springs are usually more dependable than gravity springs, but they are particularly sensitive to the pumping of wells developed in the same aquifer. As a consequence, artesian springs may be dried up by nearby well pumping.

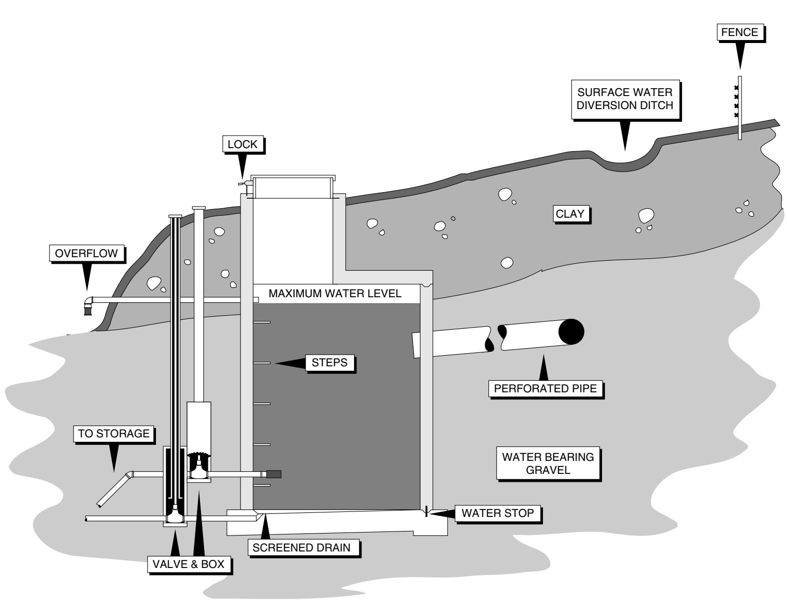
Criteria for Selection

Important criteria for spring sources include selection of a spring with acceptable water quality, development to the required quantity of water, and sanitary protection of the spring collection system. The measures taken to develop a spring must be tailored to the prevailing geological conditions.

Spring Source Collection System

Perforated Pipe. Spring flow is intercepted by a system of perforated pipes driven into the water-bearing stratum or laid in gravel-packed trenches. The flow is directed into a storage tank. As an alternative, a watertight concrete collection chamber is constructed with openings in the bottom, a side wall, or both to intercept the flow. This chamber may also serve as the storage tank. Where possible, the walls of the collection chamber should extend to bedrock or to the impervious stratum. The watertight walls should extend at least 2 feet above the finished ground to prevent surface water from entering. An overlapping (shoe-box) cover will prevent the entrance of debris.

Example of a Spring Collection System



Spring Box. The spring box is usually constructed in place out of reinforced concrete. It is designed to intercept as much of the spring as possible. When a spring is located on a hillside, the downhill wall and sides are extended downward to bedrock or impervious soil to ensure that the structure will hold back water to maintain the desired level in the chamber. Supplementary cutoff walls of concrete or impermeable clay may be used to assist in controlling the water table near the tank. The lower portion of the uphill wall of the tank must have an open construction to allow water to move in freely while the aquifer material is held back. Back filling with graded gravel helps restrict the movement of aquifer material.

At the completion of construction the area around the spring box should be covered with an impermeable material (clay or membrane). It should be sloped away to prevent surface water from entering the collection system.

The Spring Box Cover. The spring box cover should be cast in place to ensure a good fit. Is should be of a "shoe box" type framed at least 4 inches, and preferably 6 inches, above the surface of the roof at the manhole opening. The opening should be fitted with a hinged, lockable, watertight cover that extends down the frame at least 2 inches. When the spring box is covered, the manhole should be elevated 24 to 36 inches above the covering sod.

Drain Pipe. A drain pipe with an exterior valve should be placed close to a wall of the spring box at the floor level to allow draining. The end of the pipe should extend far enough to allow free discharge to the ground surface, away from the spring box. The discharge end of the pipe should be screened to prevent nesting by animals and insects.

Overflow. The overflow is usually placed slightly below the maximum water level elevation. The overflow should be screened and have free discharge to a drain apron of rock to prevent soil erosion at the point of overflow.

Intake to System. The supply intake should be located about 6 inches above the floor and should be screened. Care should be taken to ensure good bond between pipes and the concrete structure.

Sanitary Deficiencies Related to Springs

1. Is the recharge area protected?

Activities in the recharge area and the degree to which they are controlled can affect the quality of the water source.

2. What is the nature of the recharge area?

Is it industrial, agricultural, forested, or residential? Different types of activities potentially subject the water source to pollutants from land uses, spills, and runoff.

3. Is the site subject to flooding?

The introduction of surface water into a spring should be avoided and runoff should be drained away from the spring.

4. Is the supply intake adequate?

The supply intake should be screened and located 6 inches above the chamber floor in order to reduce the withdrawal of sludge that may build up in the chamber.

5. Is the site adequately protected?

The following precautionary measures will help ensure spring water of consistently high quality:

- A surface drainage ditch should be located uphill from the source to intercept surface water runoff and carry it away from the source. Springs close to agriculturally developed land treated by pesticides and herbicides may be particularly susceptible to contamination.

- Site fencing, locked covers, and warning signs should be used to provide protection from stray livestock and from tampering.

6. Is the spring box properly constructed?

The spring box should be watertight to prevent the inflow of undesirable water. The spring box cover should be overlapping, impervious, and lockable. The drain should have an exterior valve, and the exterior end should be screened. The overflow should have a downward turned, screened free discharge to a drain apron to prevent soil erosion. This information may be obtained by inspecting the spring box.

7. What conditions cause changes to the quality of the water?

A marked increase in turbidity or flow after a rainstorm is a good indication that surface runoff is reaching the spring.

Roof Catchments

It is a common practice in various locations to use roof catchments to collect rain water. While the quality and quantity of rain water may be questionable at times, it may be the only reliable source of water available to a small community or an individual. The quality of water is affected by the type of roofing material, its age, and the amount of debris collected on the roof.

Collection

Rain water is collected in a roof gutter and directed to one or more downspouts. The flow is directed into a storage tank.

Diversion Box

The first water that runs off the roof usually contains the maximum amount of debris and bird droppings. This material is prevented from flowing into the storage tank by the diversion box.

The Tank

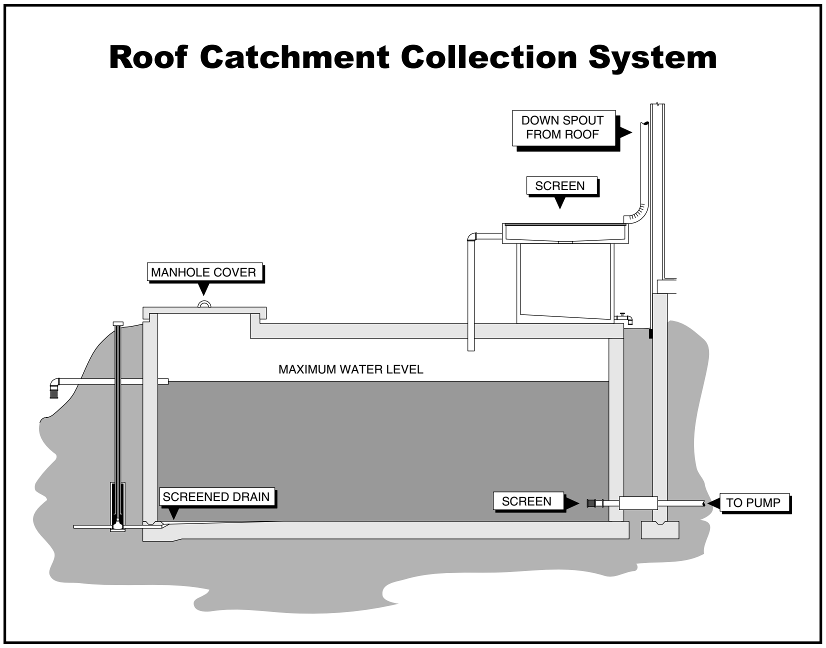
The tank is usually constructed of plastic, concrete, wood, or metal.

The Tank Cover

The tank's manhole cover should be cast in place to ensure a good fit. Is should be of a “shoe box” type framed at least 4 inches, and preferably 6 inches, above the surface of the roof at the manhole opening. The opening should be fitted with a hinged, lockable, watertight cover that extends down the frame at least 2 inches.

Drainpipe

A drainpipe with an exterior valve should be placed close to a wall of the tank at the floor level to permit draining. The end of the pipe should extend far enough to allow free discharge to the ground surface, away from the tank. The discharge end of



the pipe should be screened to prevent nesting by animals and insects.

Overflow

The overflow is usually placed slightly below the maximum water level elevation. It should be screened and have free discharge to a drain apron of rock to prevent erosion at the overflow point.

Intake to System

The supply intake should be located about 6 inches above the floor and should be screened. Care should be taken to ensure a good bond between pipes and the concrete structure.

Sanitary Deficiencies Related to Roof Catchments

1. **What is the condition of the roof?**

   Old roofs, especially roofs made of galvanized metal, can contribute to high concentrations of contaminants.

2. **Is there a diversion box?**

   This is a key to reducing contamination.

3. **What is the condition of the gutter system?**

   The gutters should be in good repair and protected from excessive debris.

4. **Is the collection chamber properly constructed?**

   The tank cover should be lockable. The drain should have an exterior valve, and the exterior end should be screened. The overflow should have a downward turned, screened free discharge to a drain apron to prevent soil erosion. This information may be obtained by inspecting the collection chamber.

5. **Is the supply intake adequate?**

   The supply intake should be located 6 inches above the chamber floor and screened. This location reduces the withdrawal of the sludge that may build up in the chamber. In addition, the roof area and gutter system must be sized to allow an adequate collection of water. The collection quantity is based on rainfall frequency and amount, roof area, and gutter capacity.

6. **Is the roof catchment system cross-connected to another public water system?**

   Many homes and apartment buildings that have roof catchment systems are also connected to the distribution system of a public water system. In these cases the public water system should always be provided with backflow protection.

Transmission – Specific Sanitary Deficiencies

Importance of Transmission

Transmission of raw water from the source of supply to the treatment facility is a vital component of a public water supply system. Transmission facilities from the treatment plant to the distribution system are equally important.

Deficiencies

A bypass around a treatment plant by a transmission line, for example, is an important sanitary deficiency that could allow raw water to enter the distribution system. During a sanitary survey the inspector should evaluate the ability of transmission facilities to provide an adequate and continuous supply of safe drinking water.

Sanitary Deficiencies – Transmission System

1. **Are transmission facilities in place that can bypass a treatment plant?**

   The inspector should carefully evaluate piping in and around the treatment plant to ensure that the plant is not being bypassed. Closed valves are insufficient to prevent raw water from bypassing treatment. It is not uncommon for bypasses to be installed during construction and then not removed when the plant is brought on line.

2. **Are there any customers on the raw water transmission lines?**

   Customers who use water from the raw water transmission lines are not receiving potable water. They should be disconnected or provided with appropriate treatment.

3. **What are the age and condition of the transmission lines?**

   Old transmission lines may be subject to catastrophic failures that could result in a water system being completely without water. The inspector should evaluate the potential for such failures.

4. **Are there redundant transmission facilities?**

   Would failure of a single transmission line leave a system without water? The inspector should evaluate this potential and recommend additional transmission lines if needed.

5. **Are transmission lines vulnerable to disasters or terrorism?**

   Transmission lines in earthquake-prone areas or that cross streams or rivers are subject to failures that could render the water system without an adequate supply of water. Inspectors should evaluate how disaster-proof a facility is and how the system would respond to a potential disaster.

   Transmission lines are also points at which contaminants could be deliberately injected in an effort to affect a large portion of the service population.

4 Water Supply Pumps and Pumping Facilities

Pumps and pumping facilities are essential, yet vulnerable, components in nearly all water systems. Improper design, operation, or maintenance of pump systems can pose serious sanitary deficiencies, including a complete loss of the water supply. To assess the safety, adequacy, and reliability of the entire water system, the inspector must include water supply pumps and pumping facilities as an integral part of the sanitary survey.

Learning Objectives

By the end of this chapter, learners will be able:

- To list the regulatory standards that apply and key data required to conduct a sanitary survey of a pumping facility.
- To identify various types of water supply pumps, their appropriate uses, and their associated components.
- To recognize sanitary deficiencies and serious safety hazards associated with physical facilities including the pumping station, pumping equipment, appurtenances, and stand-by power systems.
- To recognize sanitary deficiencies and serious safety hazards associated with procedures and practices including management, operations, and maintenance of the pumping facilities.
- To determine if a pumping facility is safe, adequate, and reliable.

Data Collection

If available in the files at the inspector's office, the following data should be reviewed prior to conducting the on-site inspection of a pumping facility:

- Operating records provided by the water utility.
- The utility's construction, operation, and maintenance specifications.

If this information is not available in advance, it should be collected during the inspection. Once in the field, during the initial interview with the operator, the inspector should develop a list of the pumps in the system to Ensure that they all are evaluated during the sanitary survey.

Regulations and Standards to Consider

Prior to the inspection, the following regulations should be reviewed and considered by the inspector as part of the sanitary survey:

- State design standards for pumping systems
- ANSI/NSF standards 60 and 61
- Chapter 2 of this Guide

Water Supply Pumps and Pumping Facilities

Basic Information

Introduction. There are several types of pumps and applications in water systems. Pumps that are used to transport water through the system are either "variable displacement" or "centrifugal" pumps. Other applications such as chemical feed, sludge removal, sampling, and air compression require “positive displacement” pumps. This chapter covers the prime movers of water. The other pumping applications are addressed in subsequent chapters.

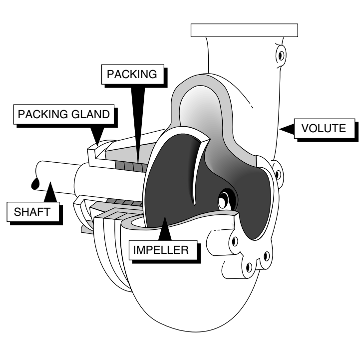
During the sanitary survey, the inspector must be able to identify pumps by type to assess whether they are being used appropriately. Each category of pump has its own operating characteristics and appropriate set of applications. There are multiple types of pumps in each category.

Variable Displacement Pumps, Applications, and Components

Variable Displacement Described. Variable displacement pumps are used in high-volume applications where an even flow rate is required (e.g., transporting water through the treatment and distribution systems). Their discharge rate varies with the head (i.e., as the lift or head increases, the pump output decreases). These pumps are not self priming. Consequently, they depend on a positive suction head, or an air-tight seal on the intake side of the pump if the level of the water to be pumped is below the pump impeller. The most common class of variable displacement pump is the centrifugal pump.

Centrifugal Pump. A centrifugal pump has a rotating impeller mounted on a shaft turned by the power source. The rotating impeller increases the velocity of the water and discharges it into a surrounding casing (volute) designed to slow its flow and convert the velocity to pressure.

Centrifugal Pump

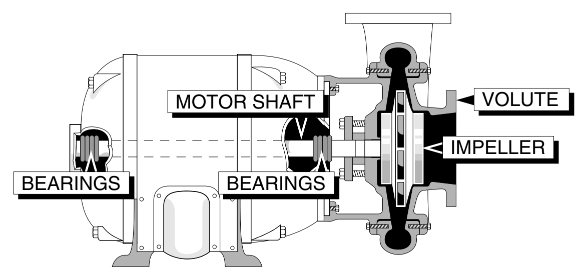


Centrifugal pumps equipped with one impeller are classified as single-stage and pumps containing two or more impellers are classified as multi-stage. Multi-stage pumps are capable of pumping against greater discharge heads, but do not increase the volume of flow.

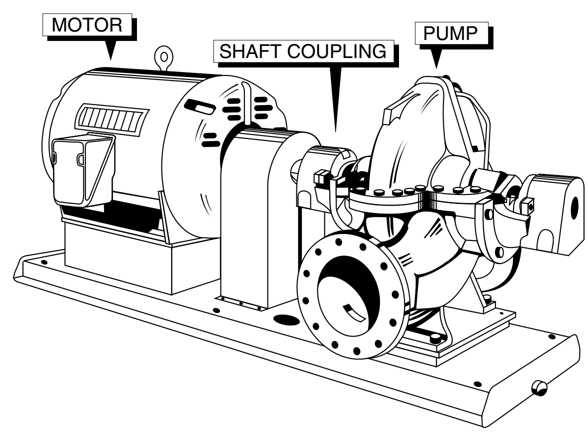
Applications in a Water System. Several types of centrifugal pumps are used in water systems for a wide variety of applications. The most common applications are:

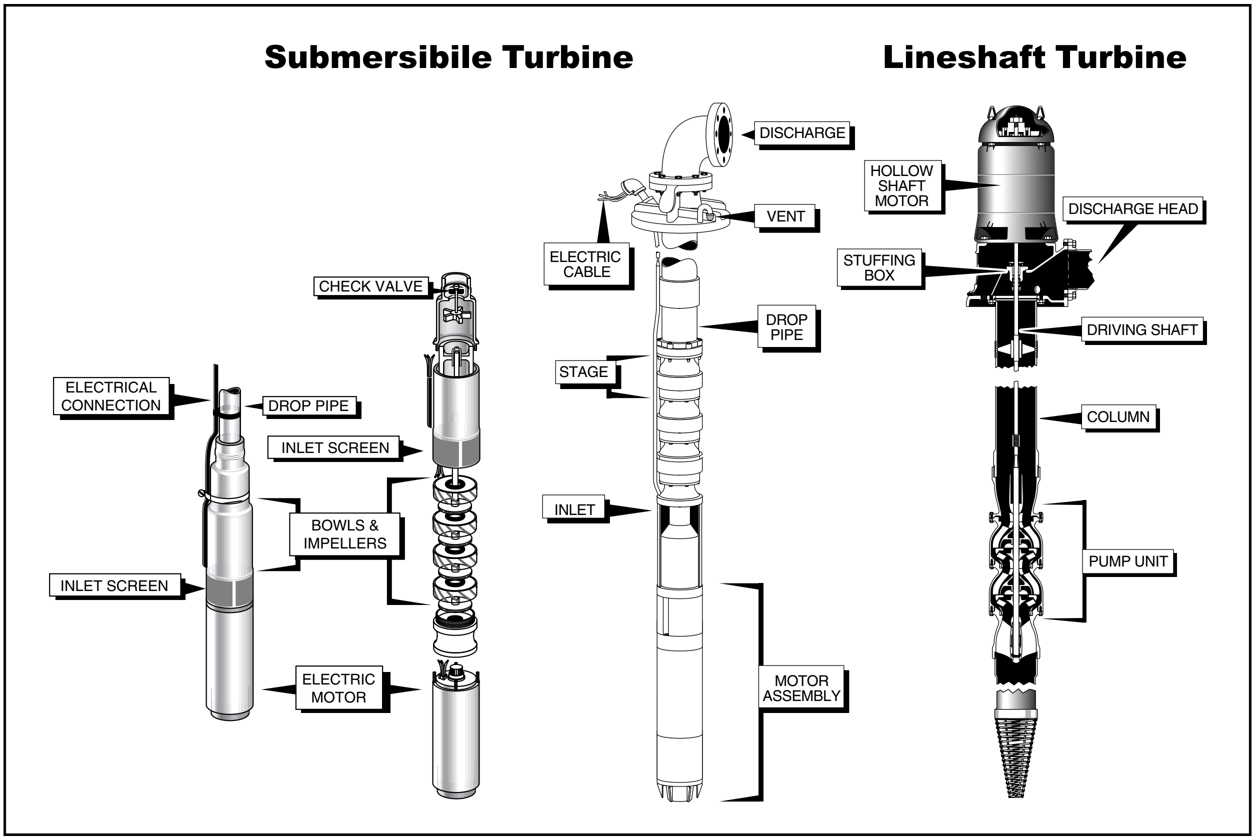
- Well pumps (vertical turbine and submersible).
- Gas chlorine system and vacuum booster pumps.
- Backwash water pumps.
- Raw water pumps.
- Finished water pumps (high lift).
- Booster pumps in distribution system.

Horizontal – Close Coupled



Horizontal – Split Case





Sanitary Deficiencies for the Pumping Station and Well House.

The inspector should evaluate the facilities that house pumping systems. These facilities include well houses, booster stations, and raw and finished water pumping stations. The questions that the inspector should ask include the following:

1. Is security adequate?

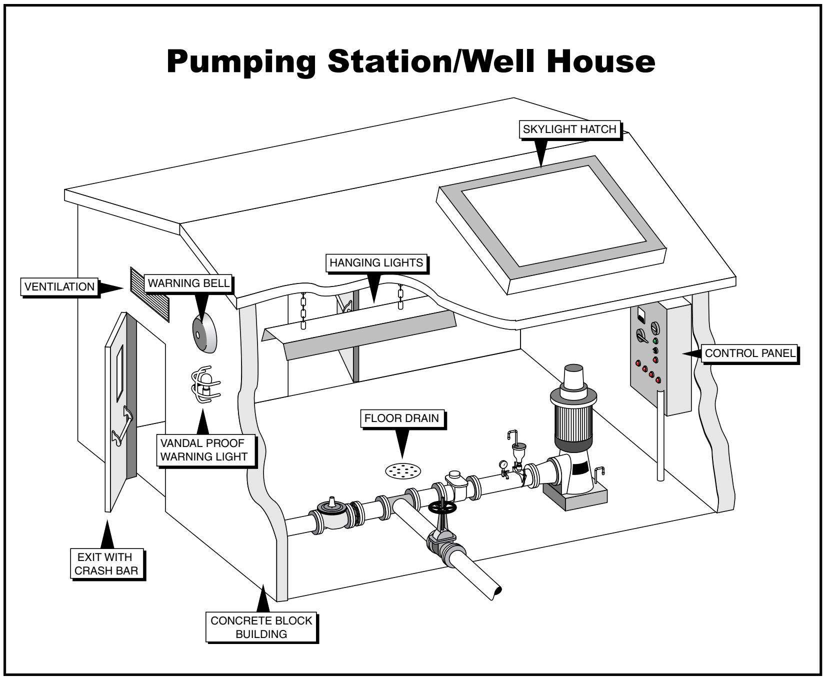
Pumping facilities should be protected against vandalism and unauthorized entry. The perimeter of the property should be fenced in and the building's doors and windows should be locked. Check around the outside of the building for electrical panels, switches, and valves. Make sure that they cannot be accessed by the public. Also, drain and vent openings in the building should be screened to prevent animals from entering.

2. Are the building and equipment protected from flooding?

The pumping station should be at least 3 feet above the highest flood level, and surface runoff should drain away from it. Pumping stations should have adequate drains to protect the pumping equipment from flooding if a pipe breaks inside the facility. Compartments that are below grade, such as wet wells and dry pits, should be sealed to prevent the entry of undesirable water, either through the walls or from surface runoff. Dry pits should include a sump and sump pump. Check to make sure that electrical controls and motors are not subject to flooding.

3. What is the structural condition of the building?

Check the condition of the walls, roof, windows, and doors to make sure that rain cannot enter the building. Concrete floors and masonry walls should be checked for cracks. Cracks around pump piping indicate water hammer conditions when pumps are started and stopped. This can result in pressure surges that cause breaks in the distribution system.



4. **Are heating, ventilation, and lighting adequate?**

Where appropriate, the building should be heated to prevent pipes from freezing. Ventilation should be provided in all climates to reduce heat, moisture, and corrosion. The interior of the building should have permanent lighting to facilitate inspections and maintenance at night.

5. **Can equipment be accessed and removed from the building for maintenance?**

Check to see that there is access to the equipment for inspection and maintenance. In addition, there should be a way to remove large equipment from the building. For example, a well house should have a removable access hatch in the roof directly over the well. This will make it easier to use a crane to remove mechanical equipment.

6. **Is the building orderly and clean?**

The order and cleanliness of the pumping facility should be observed. Dirt can combine with lubricants and reduce bearing life. Also, dirt and moisture will form an insulating coating on motor windings and can cause the motor to burn out. Poor housekeeping is in most cases a sign of poor operation and maintenance (O&M). Do not, however, automatically assume that an orderly and clean room indicates good O&M practices are followed.

7. **Is the pumping station also used for storage?**

The pumping equipment room should not be used to store hazardous, flammable, or corrosive materials. Chemicals (including water treatment chemicals such as chlorine, hypochlorite, fluoride, and sodium hydroxide) should be stored in and fed from a room that is separate from the pumping equipment and electrical controls. (For more information on chemical feed and storage, see Chapter 6, Water Treatment Processes.)

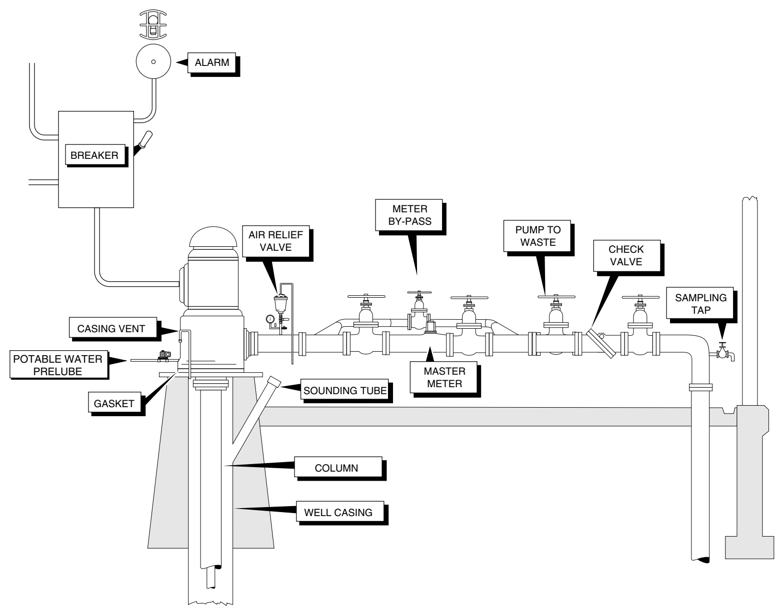
8. **Is safety equipment adequate?**

Check to see that the water system has identified all confined spaces and they are properly vented. The operator should activate the vent fans and test the atmosphere prior to entry. ***All OSHA confined-space entry procedures should be followed.*** Access ladders should be firmly anchored. Each pumping station should be equipped with a fire extinguisher that, at a minimum, is rated for class B (flammable liquids) and class C (electrical equipment) fires.

Sanitary Deficiencies for Pumping Equipment and Appurtenances

As the inspector, you should evaluate the pumping equipment and appurtenances. This includes pumps, motors, drives, valves, piping, meters, gauges, electrical controls, and alarm systems.

Lineshaft Turbine Pump Station



Pumps and Motors

1. **What are the number (including reserves), location, and type of pumps?**

   There should be at least two equal pumping units for each application—except in the case of well pumps where another complete well system provides suitable back-up. The system may use pumps for various reasons, and type of pump should be matched to the application. For example, centrifugal (variable displacement) pumps should not be used to feed liquid chemicals when precise delivery is required against a variable head. Talking to the operator and reviewing plant schematics can provide this information.

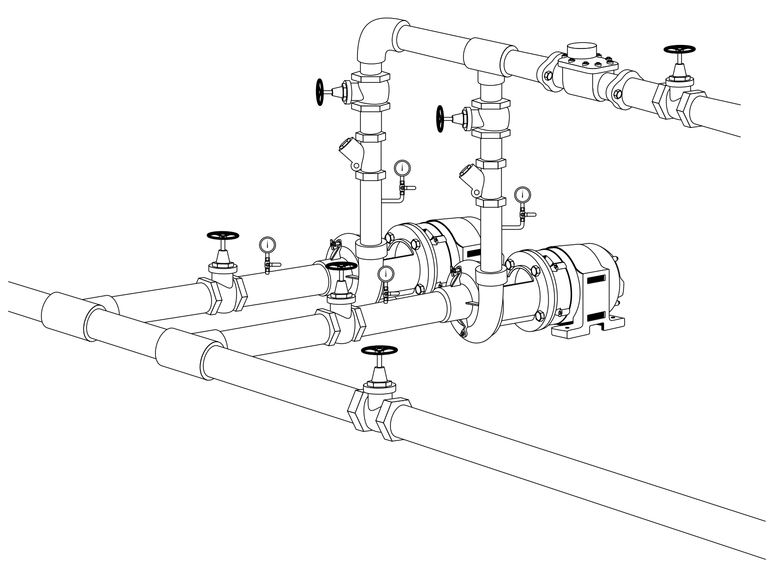
2. **Is the actual capacity of the pumping facility adequate to meet the demand?**

   Pumps should have ample capacity to supply enough water to meet peak demands. The required reserve capacity for pumps may vary from state to state, but a rule of thumb for a water supply/multiple unit/constant speed pump application is: *With the largest pump out of service, the average daily demand should be supplied by the remaining available pumps within a maximum combined pumping time of 18 hours*. A review of pump system operating records should provide this information.

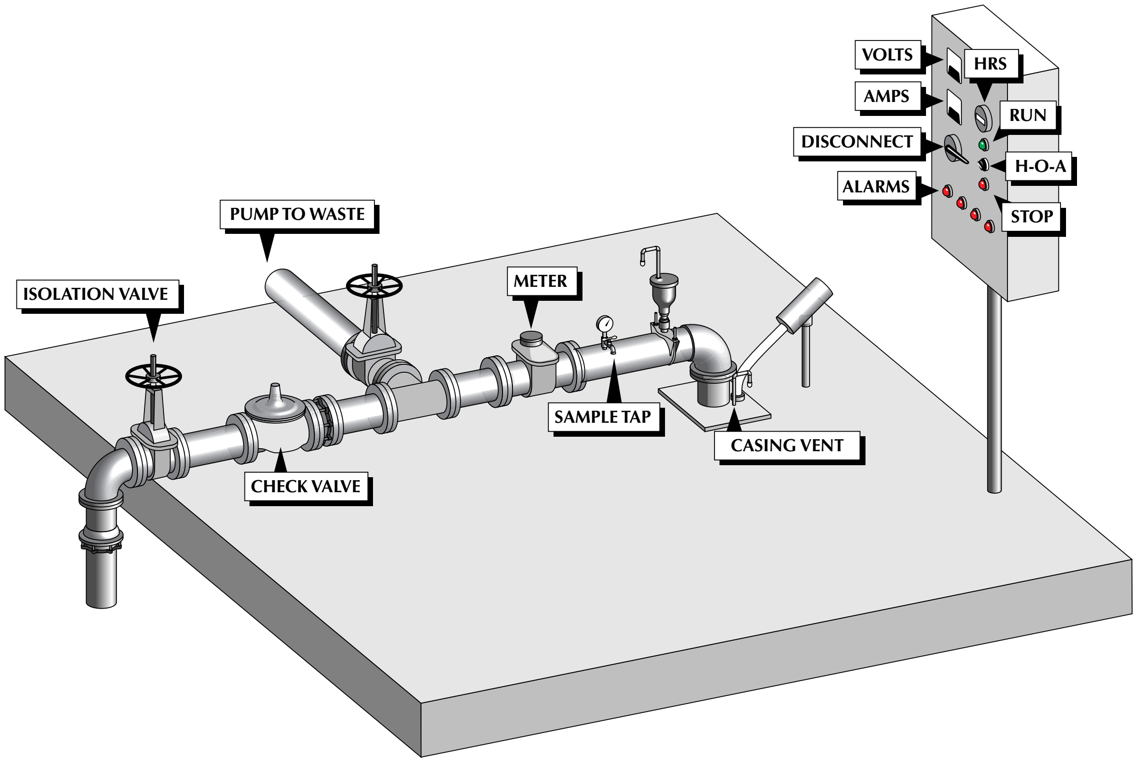
3. **When and how are pump capacities determined?**

   The inspector should determine the results of any pump tests and when each pump was last rated. The inspector should also verify that the

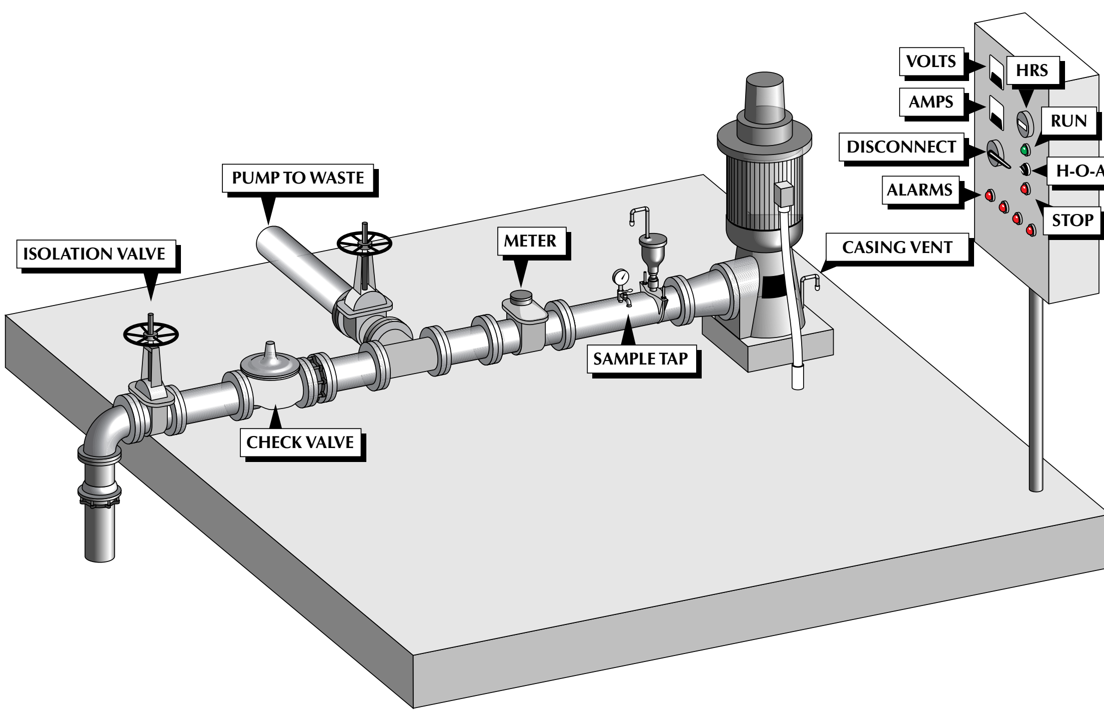
Booster Pump Station



Submersible Turbine Pumping Station



Lineshaft Turbine Pumping Station



method used was correct. This is particularly important when elapsed-time meters (pumping time) are used to estimate water production. For example, 10 years ago the pump may have operated at an average of 8 hours per day. Now the same pump averages 12 hours per day. The question is: Is the increase in running time due to an increase in water demand or a change in operational strategy, or has pump output capacity been reduced because of an increase in operating head or mechanical wear? This can be verified only with a functioning flow meter and pressure gauge and suitable operating records. Upon reviewing pump testing and operating records, the inspector should determine if duplicate pumps are equally productive.

4. What is the condition of the equipment?

All units operable? All pumps should be operable. A serious sanitary deficiency exists, for example, if only one of two raw water pumps is functional. The inspector should inquire about the strategy by which pumps are operated. Ask how often backup units are exercised. If there will be ***no*** disruption to the operation, the inspector should ask the operator to run each unit, one at a time, to observe it. While each pump is operating, the inspector should examine the state of repair by looking and listening for excessive noise, vibration, heat, odors, and leaking water or lubricant. The inspector should also look for signs of moisture and dirt around motor cooling inlets.

Excessive noise, vibration, heat or odors? While running, the pump and motor should have a smooth sound and should not be excessively hot. Excessive noise, vibration, and heat indicate serious problems such as bearing failure, shaft misalignment, pump cavitation, impeller wear, or motor breakdown. Heat and the smell of ozone or burning insulation can indicate many problems including motor winding failure, poor power supply, excessive current draw, loose connections, and motor control system deficiencies. Any one of the items cited above is an indicator that immediate maintenance is required.

Leaking water? A pump stuffing box requires a constant drip of water through the packing gland, not an excessive spray. Leaking water can produce moisture around the motor, unsafe conditions around the pump room, and a pathway for contaminants to enter the water supply if vacuum conditions occur at the stuffing box when the pump is shut down.

Dirt and grime? The inspector should look for signs of dirt around the motor cooling fins and air intake ports. Dirt and grime can inhibit the flow of air necessary to cool the motor windings.

Leaking lubricant? Pumps and motors should not be over lubricated because bearing failure and motor burnout can result. Signs of improper or excessive lubrication are grease pushing out of bearing seals and grease or oil accumulating around the pump and motor.

5. Are the correct types of lubricant used?

ANSI/NSF-approved lubricants should be used where contact is made with the water supply (i.e., stuffing box, oil-lubricated well shaft bearings, check valves). It is not necessary to use ANSI/NSF-approved lubricants on components that do not come into direct contact with the water supply (i.e., motor bearings, shaft, and external pump bearings). All lubricants should be used according to the manufacturer's recommendations.

6. Are the frequency and amount of lubrication adequate?

The inspector should observe the level and appearance of oil in pump and motor lubricant reservoirs to determine if adequate attention is being paid to lubrication. Oil that has a milky appearance has become contaminated with moisture. In the case of well pumps, the type and amount of lubrication are particularly important. Some vertical turbine pumping systems are designed with oil-lubricated shaft bearings. If the sealing tube surrounding one of these bearings fails, oil will enter the water supply. The inspector should find out how much oil is added regularly by the operator and compare this to the amount used when the equipment was new. A significant increase in oil addition is a sure sign of a broken seal.

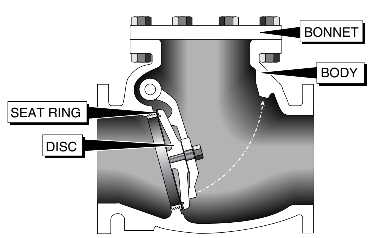
An indication that greased bearings are not being lubricated properly is unbroken painted surfaces covering the grease fittings and exit port plugs. A schedule for lubrication should be part of a preventive maintenance program.

Appurtenances

1. Are the pumping systems equipped with:

Check valves? On centrifugal pump systems, each pump should have an operating check valve. When observing the operation of each pumping unit during the sanitary survey, the inspector should pay particular attention to the check valve during the start-up and shut-down periods.

Swing Check Valve



The check valve should not slam open or shut. If it does, pressure surge or water hammer conditions could be occurring in the distribution system, resulting in breaks in the mains or service lines. When the pump is not running, the drive shaft should not spin backwards. Backspin is an indicator that the check valve is not functioning and, in some cases, could lead to the impeller actually spinning off of the drive shaft.

Isolation valves? Each pump should have an isolation valve on the discharge line. In systems where the intake water level is above the pump impeller (an application known as "flooded suction" or "suction head"), an isolation valve is also required on the intake side of each pump.

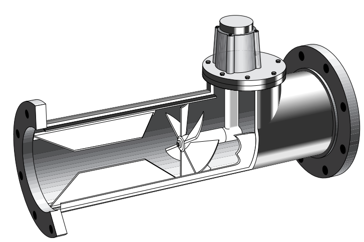
O Y & S Gate Valve

Isolation valves facilitate removing the pump for main-tenance. Simply because a valve is present does not mean that it is working. The inspector should ask the operator how frequently the valves are exercised and should request the opening and closing of one or more isolation valves.

Pressure gauges? Each pump should have a discharge pressure gauge so that actual operating head conditions can be measured. A pressure gauge and flow meter are critical for determining pump capacity and detecting changes in operating conditions. In addition to a discharge pressure gauge, distribution system booster pumps should also be equipped with compound gauges on the intake side of the pumps. Compound gauges measure positive and negative pressures. The pressure on the intake side of distribution booster pumps should not be allowed to fall below 20 psi because lower pressures can cause backflow problems in the distribution system upstream of the booster pump.

Flow meter? The inspector should note if the pump is metered and if the meter is functioning properly. Besides providing a more accurate accounting of water being pumped, a meter can help the operator detect changes in the system and take corrective action before a serious problem develops. Flow meters should be equipped with totalizers to record the total amount of water pumped over a given time period.

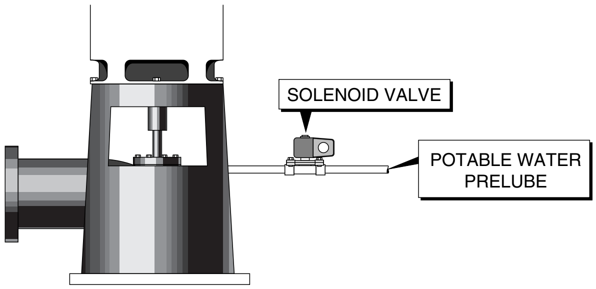
Turbine Flow Meter



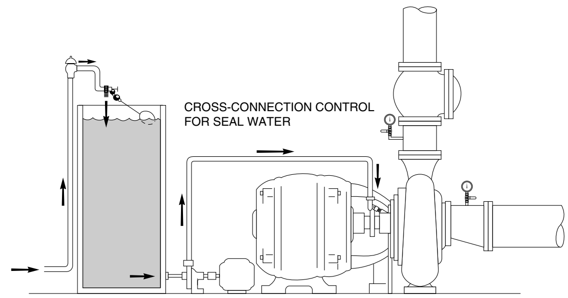
Blow-off line? Pumping systems, especially well pumps and raw water pumping systems, should be fitted with isolation valves and piping to direct the discharge to the open air and not into the water supply line. Blow-off lines facilitate flushing the immediate water source and testing the pump.

Air/vacuum relief valve? To prevent air from entering the distribution system at startup and to prevent vacuum and possible collapse of the

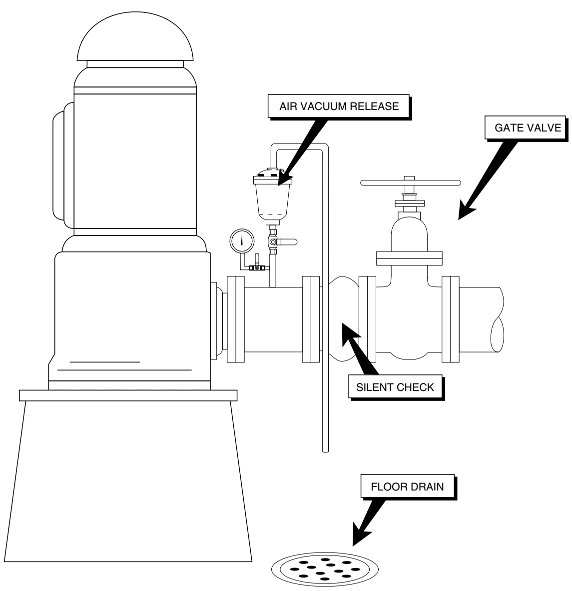
Prelube for Water Lubricated Bearings



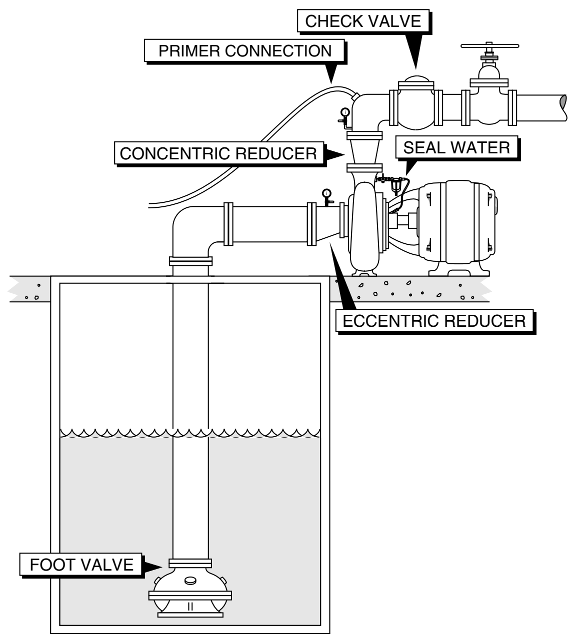
Raw Water Pump Seal Water System



Air/Vacuum Release Discharge Line

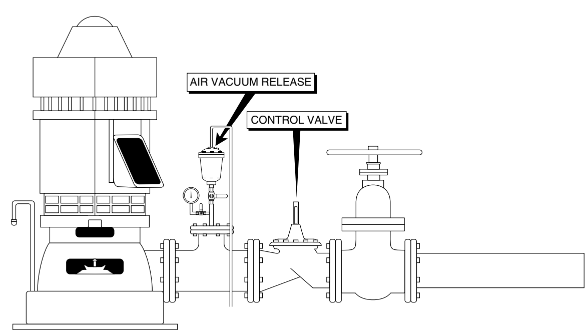


Prime Line – Suction Lift Pump



column pipe during shutdown, well pumping systems should be equipped with a foot valve (submersible well pumps) or air/vacuum relief units (vertical turbine well pumps). The inspector should determine whether the relief valve closes properly following startup and opens properly following shutdown. The discharge pipe on the relief valve should be turned downward, screened, and terminated with a suitable air-gap.

Lineshaft Turbine with Air Release Valve



2. Are there any cross connections present?

Cross connections can be found in:

- Water lubricated bearing systems
- Pump seal water lubrication systems
- Air/vacuum release discharge lines
- Priming lines for suction-lift pumps

In each case, if the source water for these systems is treated water, the potential for backflow exists. These systems must be adequately protected with an air-gap or approved backflow prevention device. A thorough description of cross-connections and examples are provided in Chapter 8.

Controls

1. Is the motor control system adequately designed and reliable?

Automatic systems are widely used to control pumping cycles. The inspector should evaluate the control system and determine if it is suitable for the application, if it is functioning properly, and if it is equipped with resets and a manual override switch. Pumps that supply water to the distribution system should be controlled automatically based on the pressure in the system. An example of unsuitable application of a control system is finished water pumps that are controlled by time clocks alone. In this case, the pumps would not supply additional water if demand is unusually high, for example if a main breaks or firefighters must tie into a hydrant. This could result in low pressure or a total loss of supply. The inspector should ask the operator how frequently, if ever, he or she resets the motor controls or operates the pumps manually in order to maintain the system pressure.

A hydropneumatic system typically uses a simple pressure switch to cycle pumps off and on. The inspector should check to see that the system is operating properly and should make sure there is no shut-off valve between the pressure switch and the pump. If a valve is closed between the pressure switch and the pump, the system will call for water and the pump will become damaged by pumping against a closed valve.

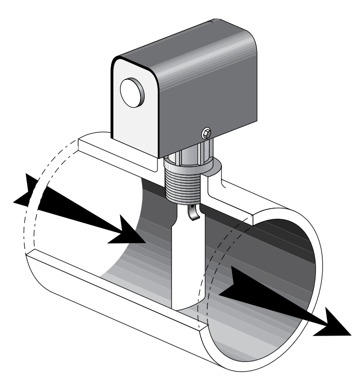
2. Is the pump system equipped with an adequate failure alarm system?

The pump control system should be equipped with failure alarms. If the pump fails to start, or stops for any reason other than normal shut-down on the automatic cycle, an alarm system should activate to notify the operator that the system has failed. The type of alarm should also be considered. Many pumping stations are equipped with a flashing light or a horn situated outside the building and activated when the system fails. This type of alarm depends on someone actually seeing the light or hearing the horn and calling the water system operator. It is not, of course, fool proof. A more dependable alarm system is one connected to a telephone line and programmed to automatically dial a series of telephone numbers until the problem is corrected.

3. Does the auxiliary equipment have fail-safe devices?

The control sequence for equipment that operates in conjunction with the main pump and motor should be evaluated. For example, the electrical supply to a chemical feeder that activates automatically with the water pump motor should be equipped with an automatic shut-down device in case the pump fails to produce water for any reason. This can be done by installing a “low-flow” or “low-pressure” cut-out switch between the pump and the check valve. This device must sense water flow or pressure in order to energize the chemical feeder. The absence of such a device has in many cases led to a significant overfeed of chemical.

Low-Flow Switch



4. Are controls equipped with elapsed time meters (ETMs)?

Motor control systems should be equipped with an ETM for each pump. An ETM is similar to an automobile odometer and registers the cumulative running time of the pump motors. This information can be used by the operator to schedule maintenance, estimate pump output, and compare duty cycles and efficiency of equal pumping units.

5. Are controls adequately protected?

The inspector should take note of the general condition of the control devices and check that the equipment is enclosed in protective cabinets. Control enclosures that are outside buildings should be closed tightly and have a NEMA 4X rating (weatherproof). Control switches such as hand, off, or automatic switches, disconnects, and resets should not be accessible to the public.

6. Are control systems adequately maintained?

The control systems should be included in the water system's preventive maintenance program. Maintenance of these systems requires a particular expertise in industrial controls. The operator should be thoroughly trained in this area, or should have an expert available to respond to system malfunctions.

Safety

1. Do rotating and electrical equipment have protective guards?

The inspector should be concerned with safety as well as with the sanitary aspects of the equipment. Check to see that belts, gears, rotating shafts, and electrical wiring are properly shielded to prevent injury.

[Note: While conducting the sanitary survey, the inspector should not wear loose clothing or a necktie.]

Sanitary Deficiencies – Auxiliary Power

The inspector should evaluate the need for auxiliary power and, if provided, should evaluate the design, condition, and O&M of auxiliary power units (APUs).

1. Is auxiliary power needed and, if so, is it provided?

Auxiliary power may be necessary for the continuous operation of a water system. It is especially critical if outages are frequent or if a system has limited capacity for storing finished water. The inspector should ascertain the frequency and duration of previous power outages and what effect power outages have had on the water supply. State design guidelines should also be consulted when determining the need for auxiliary power.

2. What type of auxiliary power is provided and how is it activated?

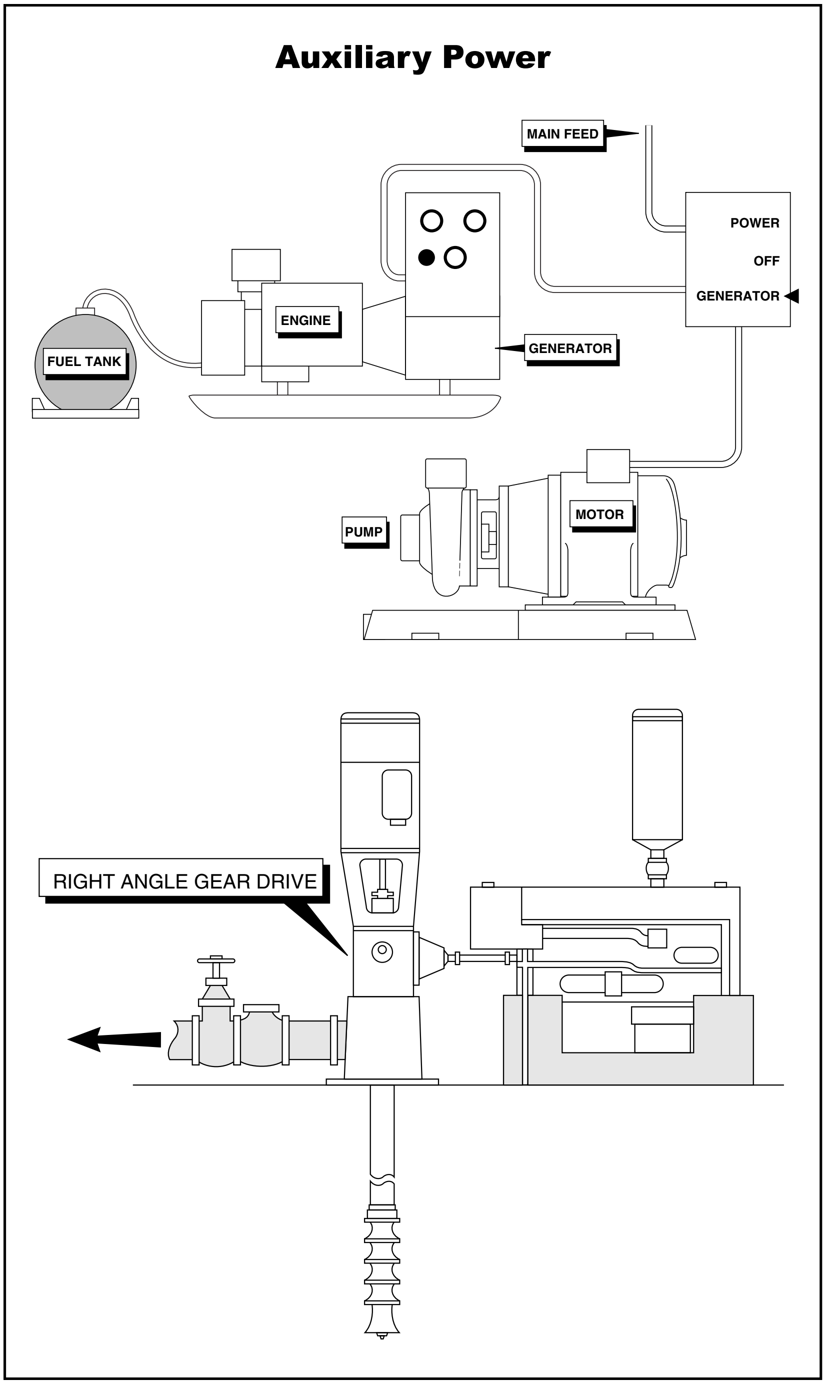
Emergency power may be provided by an auxiliary generator that is driven by diesel or gasoline engines, or by engines that are directly connected to the pump drive shaft by a right-angle drive mechanism. Activation of the APU should be automatic upon the loss of primary power. There should be an "automatic transfer switch" that will transfer the current load to the auxiliary power unit. Upon loss of power, the operator should not be required to manually start the APU and transfer the load, although the system should allow manual operation.

3. Does the auxiliary power unit supply ALL electrical systems at the pumping station?

In addition to the pump motor, the APU should operate all electrical functions in the pumping station, including lights, heat, ventilation, automatic controls, and—most important—any chemical feed systems that are connected. This is a problem with mechanically driven (right-angle drive) type systems operate only the pump during primary-power outages; consequently, untreated or partially treated water is pumped to the distribution system.

4. Where is the fuel tank located?

Is the fuel tank for the APU buried underground? If so, is there a risk of fuel leaking into the water supply? If the fuel tank is above ground, it should be mounted inside a spill containment vessel.



5. Is the auxiliary power unit exercised and tested regularly and properly?

The inspector should ascertain how and how often the APU is exercised and tested. The system should be exercised at least once a week, with an operator in attendance. If the APU is exercised automatically without an operator in attendance, there is no way to monitor the system's performance and no way to detect small problems before they escalate. Furthermore, these systems should be exercised under a load. The APU should be used as the source of power for the pumping facility during the exercise period. This procedure ensures that all functions of the APU are tested and working properly. Records should be kept of APU exercising, and these records should include engine and generator gauge readings.

6. Is the auxiliary power unit secure and maintained in good condition?

The inspector should check to see that the APU is included in the preventive maintenance program. Regular maintenance should be performed according to the manufacturer's recommendations. The inspector should visually check the general condition of the unit for signs of leaking fluids or lubricants. If the APU is outside, it should be enclosed. Vent openings and openings around piping should be screened to prevent the entrance of animals. The APU should not be accessible to the public.

7. Are there any cross-connections between the auxiliary power system and potable water?

Some APU engines use potable water for cooling. The inspector should determine how the engine is cooled. If potable water is used, the coolant should not return to the potable system, and the connection between the water supply and the engine should be protected by an air-gap or approved backflow-prevention device.

Sanitary Deficiencies – Operation and Maintenance

Equipment-specific O&M concerns were addressed previously in this chapter. During the sanitary survey, the inspector should also assess the overall O&M approach as it relates to the pumping systems from a programmatic standpoint.

1. Are the number and skill level of the staff adequate for operating and maintaining the pumping facilities?

The management and operations staff should be assessed according to the recommendations provided in Chapter 10. Individuals who are responsible for maintaining pumping systems should be trained in troubleshooting them and in maintaining electrical and mechanical systems. If no one on the staff is competent in these areas, maintenance should be performed by contractors.

2. Are adequate operational records maintained for pumping facilities?

The system should maintain, at a minimum, the following operating records for each pumping unit:

- Suction and discharge pressures
- Operating hours
- Flow meter readings
- Amperage and voltage readings.

3. Are written standard operating procedures available and followed?

Written operational instructions should be provided so that all operators follow the same procedures. This may be as complex as a comprehensive operations manual, or as simple as a one-page list of instructions. Written procedures should cover items such as daily operations and inspections (including a checklist), start-up and shutdown procedures, and responses to equipment failure and other emergencies. They should include contingency plans).

4. Is there an established and documented preventive maintenance (PM) program?

Improper maintenance can lead to system failures and sanitary deficiencies. A written PM program should be established and followed for each piece of equipment in the pumping facility. The programs should be based on manufacturers' recommended maintenance tasks, and records should be kept of maintenance as it is performed. In general, smaller water systems need much less sophisticated PM programs, however, all water systems should have a program in place, even if it is very basic. The inspector should determine if specific components of a PM program exist and ask to see PM records. Critical components of a PM program include:

- **Equipment Inventory**: A record that includes data plate information such as model and serial numbers, manufacturer's ratings, and performance specifications.

- **Manufacturers' Technical Literature**: Provided with new equipment by its manufacturer, this includes O&M specifications, schematics, and spare parts lists.

- **Written PM Tasks and Schedule**: A written list of PM tasks (from the O&M manuals), a schedule, and instructions for performing these tasks. This can be part of a computer program, or in smaller systems, can simply be recorded on index cards.

- **Records of Maintenance Performed**: In small systems, this can be recorded on index cards. The inspector should look for recent dates and make spot comparisons to the task schedule.

- **List of Technical Resources**: This should include manufacturers' representatives for service and parts, local specialists for instrumentation maintenance, electrical and mechanical repair specialists, and construction contractors.

- **Tools**: The operator should have a complete set of tools for performing basic maintenance.

- **Spare Parts Inventory**: Critical and frequently replaced parts for pumping equipment should be included in the water system's inventory. Materials that are not maintained in stock should be readily available from local suppliers or factory authorized representatives.

5 Storage Facilities

Finished water storage facilities play a vital role in providing a safe, adequate, and reliable supply of water. Schools, hospitals, nursing homes, factories, and home owners all depend on a consistent, dependable supply of safe water. Failure to maintain the structural and sanitary integrity of storage facilities can lead directly to the loss of property, illness, and death.

Learning Objectives

- Identify key data needed regarding design, maintenance, and operation of storage facilities in order to determine their adequacy and reliability.
- Review the major components of ground, elevated, and hydropneumatic finished water storage facilities.
- Evaluate operator safety practices and equipment in relationship to storage facilities.
- Recognize sanitary deficiencies related to the capacity, physical condition, and operation of storage systems such as inadequate volume or pressure, contamination by animals and insects, corrosion, metal fatigue, and vandalism.

Data Collection

To evaluate water storage for sanitary deficiencies, the inspector should gather the following information:

- Type and volume of the storage facilities.
- The results of the last inspection.
- Maximum and minimum pressures at high and low elevations in the system.
- Maximum and minimum pressures in each pressure zone.
- Documentation of state approval for changes to or installation of the tanks.
- Number of pressure zones are the system.
- Verification of the presence of a hydraulic model of the system.
- The type of chlorine residual testing method being used.

Regulations and Standards to Consider

The inspector should consider and review the following information prior to inspection:

- 40 CFR 1926.146 - Confined space entry.
- The American Water Works Association (AWWA) standard for the type of piping materials used in the system.
- AWWA C-652-92 - Disinfection of water storage facilities.
- System construction standards.

[1]The student may want to consider viewing the video entitled Sanitary Survey Inspection; Before You Begin . . . STORAGE FACILITIES prior to reading this section. To order, see www.epa.gov/safewater/dwa/orderform.pdf.

- State construction standards.

Storage Facilities

Basic Information

Purpose of Storage. The purpose of storage is to ensure that safe water is always available for normal situations and emergencies.

Clearwell. Finished water storage often begins at the treatment facility in a structure known as a clearwell. Outside the distribution system, storage tanks are normally elevated on steel legs or built on hills to provide water pressure. A very small system will often use a pressurized tank known as a hydropneumatic tank to provide pressure and limit the cycling frequency of pumps.

Adequate Volume and Pressure. Water systems must be able to provide safe water at all times at adequate volumes with sufficient pressure (normally not less than 35 psi at any point in the system). Low pressure, inadequate volumes, and contaminated water from storage facilities are a result of poor design, construction, operation or maintenance.

Varying Demand for Water. Demand for water in a distribution system changes significantly throughout each day. As it varies, a properly operated finished water storage facility acts as a reserve, or buffer, which prevents sudden changes in water pressure in the system. Below is an example of varying water demands during one day. An average daily demand of 80,000 gallons per day equals 56 gpm. However, an average gpm is very misleading. As shown in the table below, the demand varies greatly between the low at 3 a.m. and the high during a small house fire at 3 p.m.

Example of Water Use		
System Population		800 persons
Average daily per capita usage		100 gallons
800 x 100 = 80,000 gallons per day, Average Daily Demand (ADD)		
100,000 gallon elevated storage (tower)		
Two pumps supply the system and fill the tower		
Pump #1	85 gpm	122,400 gpd
Pump #2	120 gpm	172,800 gpd
Note: gpm = gallons per minute; gpd = gallons per day		

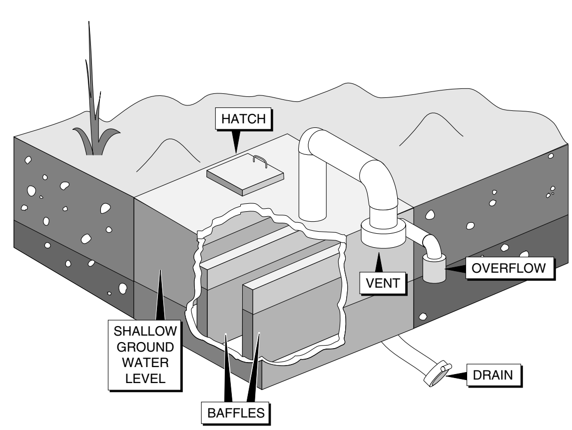
Time of Day	Average Demand	Demand
3 a.m.	Low	30 gpm
7 a.m.	Showers, Dishes	56 gpm
3 p.m.	House Fire	750 - 1,000 gpm

Pumps Alone Insufficient. Although either pump is capable of pumping the required 80,000 gpd based on 24 hours, neither is capable of keeping up with the day's peak demands. The water stored in the tower makes up the difference. In addition, the demand for water varies from day to day and from one season to the next.

Clearwell

Clearwells are often in-ground tanks from which water is pumped to storage and distribution after treatment including disinfection. The effectiveness of chemical disinfectants, such as chlorine, depends on the concentration of the disinfectant and the contact time the organisms are exposed to the disinfectant. Contact time (CT)is usually achieved

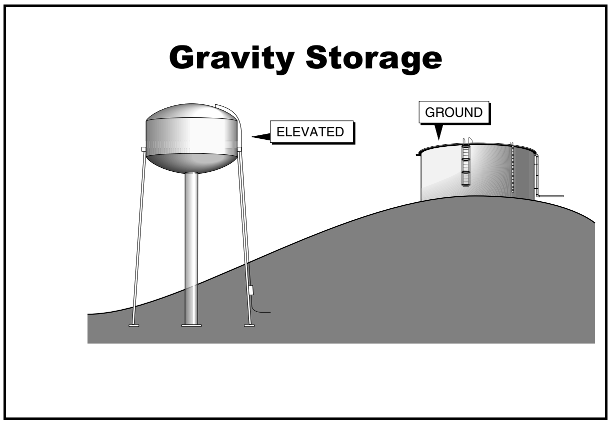
Clearwell



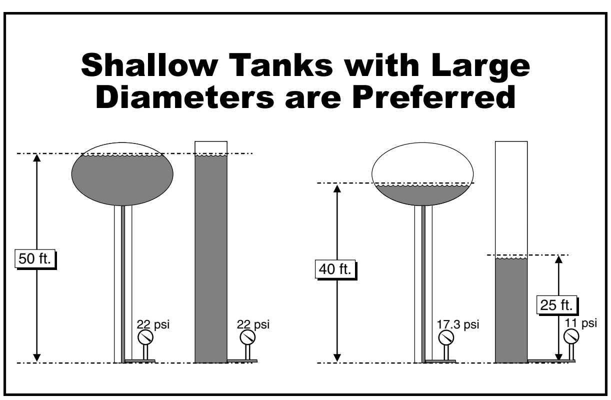
in the clearwell, often with baffling, to ensure adequate CT (CT in mg-min./L = contact time in minutes X disinfectant residual in mg/L). See Chapter 6 for a more complete explanation of CT.

Gravity Storage

[Note: Many of the following items apply to clearwells as well as to storage in the distribution system. Gravity storage facilities (tanks) must be elevated to maintain sufficient pressure to all customers within the service area. This elevation may be accomplished by mounting the tank on structural supports above ground or by erecting the tank on a hill.]



Large-Diameter Tanks Preferred. When gravity storage is used, the pressure at the head of the distribution system fluctuates with the water level in the tank. Shallow, large-diameter storage tanks are preferred over deep, small-diameter tanks because the larger diameter tanks have more water per foot of drawdown and are thus less prone to pressure fluctuations.



Materials. Storage tanks are most commonly constructed of steel or reinforced concrete. Prefabricated standpipes and elevated tanks are readily available in a wide range of capacities. Prestressed concrete tanks are common for ground level and underground applications; they are quite popular because they require less maintenance than steel tanks.

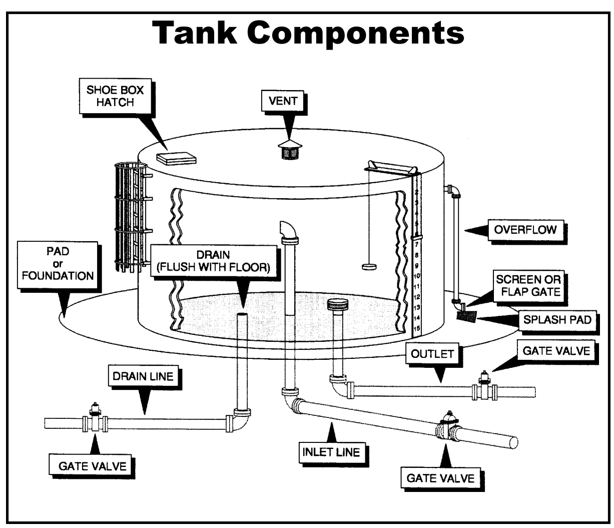
Components. In addition to the basic tank, storage facilities (for both elevated tanks and clearwells) include some or all of the following components:

- **Cover or Roof.** Keeps out rain and foreign matter (e.g., birds, bird droppings, leaves). The roof and sidewalls must not have any gap where they join.

- **Air Vent (screened).** Gravity tanks must "breathe" as the tank is filled and emptied. A plugged vent can result in structural damage to the tank from either a vacuum or an excess pressure condition. A screen is essential to keep out birds, bugs, and mammals.

  Note: A globe-shaped device known as a "finial ball," which is a combination vent and roof ladder support, was popular on old riveted tanks and generally was constructed without any kind of protection from rain, birds, or bugs. These vents and others that are poorly designed should be replaced or modified in a manner that accommodates air movement while protecting water quality.

- **Overflow Pipe (screened).** Prevents excessive pressure and structural damage to the tank and distribution system if supply



pumps fail to shut off. A screen or a close-fitting flapper gate is required on the overflow to keep out birds, bugs, and mammals.

- **Inlet and Outlet Piping.** Connects to the distribution system for filling and discharging the tank.
- **Drain Pipe.** Empties the storage facility (not into the distribution system).
- **Isolation Valve.** Isolates the tank from the distribution system.
- **Access Hatch.** Facilitates inspection and maintenance of the tank.
- **Cathodic Protection Plate.** Provides access to cathodic protection rods.
- **Ladders and Walkways.** Facilitate inspection and maintenance of interior and exterior. Internal catwalks should have a solid floor with raised edges to keep dirt out of the water.
- **Fence Enclosure.** Provides security and safety.
- **Staff Gauge with Float.** Measures water level in the tank.
- **Ultrasonic Sensor.** Measures water level in the tank.
- **Pressure Gauge.** Measures head pressure. The head pressure can be used to calculate the level of water in the tank.
- **Control System.** Maintains water levels in the tank.
- **Altitude Valve.** Prevents a tank at a lower elevation from overflowing while allowing a tank at a higher elevation to fill.
- **Valve Pit.** Contains altitude valve, isolation valve, and drain valves.
- **Alarm System.** Detects unacceptable low and high water levels and sends signal to operators.

Advantages of Gravity Storage

A gravity storage system offers several advantages over other (e.g., hydropneumatic) systems:

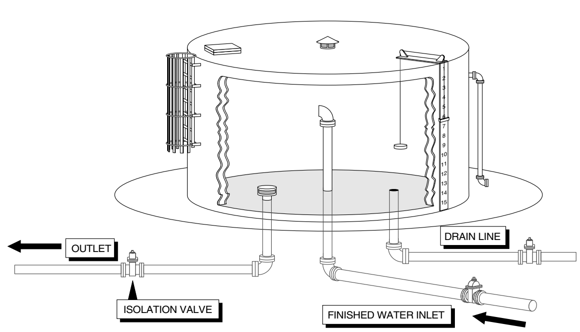
- Greater flexibility to meet peak demands with less variation in pressure.
- Storage for fire-fighting use.
- One to five days of storage to meet needs.
- Use of lower capacity wells (well not required to meet peak demand by itself).
- Sizing of pumps to take better advantage of electric load factors (able to pump during discount hours).
- Reduced on-and-off cycling of pumps.

Storage Filling Requirements. When gravity storage is employed, it is recommended that the pumping system be capable of supplying the average daily demand (ADD) in 18 hours without the use of the largest pump. Using our previous example:

ADD: 80,000 gallons per day
Large Pump: 120 gpm (not part of determination)
Small Pump: 85 gpm (91,800 gallons in 18 hours)

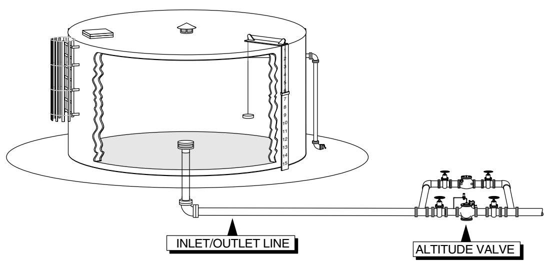
Two Methods of Filling and Using Storage. Water supplies may pump directly to a gravity storage tank from which water flows on demand to the points of use. This method is called **direct pumping.** It can be designed to provide chlorine contact time for disinfection.

Direct Pumping



Water may also be pumped into the distribution system several miles from the tank, with the tank riding or **floating** on the system.

Tank Floating on the System



Sanitary Deficiencies for Gravity Storage

1. **Is the storage system designed for direct pumping or floating on the distribution system?**

   Direct pumping systems offer an advantage over floating systems in that the storage tank provides additional chlorine contact time. Direct pumping systems tend to have higher fluctuations in head pressure than floating systems. In floating systems, treated water is sent directly to the customer through the distribution system. A sanitary risk is presented if disinfection at the treatment facility is inadequate.

2. **Is the storage capacity adequate?**

   The total storage capacity for gravity storage systems should be equal to one to five days of average daily demand. There should be reserve capacity in the storage tank to allow for extreme conditions such as power outages in which case the pumps would be unavailable unless standby power is supplied. Utilities that lack adequate storage run the risk of losing system pressure.

3. **Is the storage over-designed?**

   Conversely, storage facilities that are extremely over-designed run the risk of producing water that has objectionable taste and odors. Chlorine residuals can be lost by failing to use and replace water on a regular basis, and disinfection byproducts can be produced if water is kept in storage for a long time. In addition, ice buildup can be a threat to the tank.

4. **Is the pumping capacity adequate?**

   The pumping capacity must be designed to supply water for both normal peak demand and potential fire demand while preventing the excessive loss of head pressure in the tank. (Most small systems are not designed to meet fire demands.)

5. **Is the elevation of the tank sufficient to maintain distribution pressure throughout the system?**

   The water tank should be sized properly and located sufficiently above the distribution system to produce minimum operating pressures of 35 psi (about 81 feet of head); operating pressures of 40-60 psi (92 to 139 feet of head) are preferred.

6. **Is there a need for separate pressure zones?**

   Pressures should not be allowed to exceed 100 psi (231 feet of head). In communities that have varying topography, customers in the higher elevations could experience low water pressure if the gravity storage system is not designed with separate pressure zones.

   The inspector must not assume that because storage capacity is well designed it is actually being used. During the sanitary survey, the inspector should evaluate the operational strategy of the storage system.

7. **Does the operator understand the controls that regulate tank water levels?**

   The operator should understand the functions of the water level control systems and should be capable of making minor adjustments. There should be a record that documents the control pressures and elevation for each phase of the pumping cycle, including the pressures at which the alarms are activated.

The operator of a system that has altitude valves and multiple tanks must be capable of taking pressure and water-level readings and adjusting the valves to control tank levels.

8. Are there adequate minimum rise and fall distances?

To maintain an adequate volume of water and an even distribution system pressure, the supply pump automatic controls should keep to a minimum the distance the water inside the tank rises and falls. The rise and fall should be sufficient, however, to prevent excessive pump cycles during hours of peak usage. The water in the tank should be allowed to rise as close as possible to the overflow pipe before the supply pumps stop. The maximum water level, however, should not be so close to the overflow pipe that overflows actually occur during automatic operation.

9. Are control systems reliable and properly protected?

Determine if the controls are suitable for the application and are functioning properly. Each storage facility should be equipped with a manual override and an alarm system to warn of pump failures and low water levels. The inspector should note the general condition of the control devices and wiring. Check to see that they are adequately protected from lightning and other outside elements.

10. Is the water level indicator accurate?

Every storage tank should have a reliable means of measuring the water level. If properly maintained, a float and staff gauge is the most reliable level indicator.

Pressure gauges are acceptable for determining the water level, but occasional visual checks should be made inside the tank to verify the pressure gauge accuracy. (**NOTE:** 1 psi = 2.31 ft.; 1 ft. = 0.433 psi.)

11. Is there a maintenance program?

Maintaining control systems requires particular expertise in industrial controls. The operator should be thoroughly trained in this area, or should have an expert readily available to respond in case of a system malfunction.

Direct Contamination Concerns

The inspection items below are extremely important to the health and well being of everyone in the water system.

1. Is all treated water storage covered?

Finished-water storage tanks must be covered to prevent airborne contamination, e.g., from birds, insects, mammals, and algae. Covers must be watertight, made of permanent material, and constructed to drain freely and prevent contaminants from entering the stored water. The surface of the storage tank cover should not be used for any purpose that may result in contamination of the stored water. The roof-to-sidewall joint must be sealed.

2. Are overflow pipes:

- **Terminated 12 to 24 inches above a splash pad**?

All overflows and drain lines from a storage facility should discharge freely into a drainage inlet structure or onto a splash pad. When a drainage structure is not available, the splash pad should be designed to prevent erosion and undermining of the tank supports or foundation. The discharge pipe should terminate 12 to 24 inches above the inlet structure or splash pad. Overflows must never be plumbed directly to any sewer or storm line.

- **Screened?**

All overflow pipes should have removable #24 mesh screens to prevent the entrance of birds, insects, rodents, and contaminating materials.

3. Are air vents:

- **Turned down or covered to protect the tank's contents from rain?**

Roof vents should terminate in a downward inverted U or have a cover to exclude rain and wind-blown debris. They must be designed to exclude birds and animals and should exclude insects and dust as much as possible consistent with effective venting. Finial ball designs and venting through open areas between the roof and sidewall are of particular concern.

- **Terminated at a minimum of three pipe diameters above the surface of storage tank roof?**

A properly constructed vent terminates three pipe diameters above the roof, which helps to prevent dried bird droppings from being inhaled or blown into the vent. For ground-level structures, the vent should terminate in an inverted U with the opening 24 to 36 inches above the roof or sod.

- **Screened?**

A #4 mesh screen will prevent birds from entering the tank, but this large mesh screen will not keep out insects, feathers, pieces of grass, and other foreign material. A #24 mesh screen is necessary to control insects. Fine-mesh screens can become clogged, and clogged vents have led to imploded tanks. While fine-mesh screens are necessary to keep the water clean, they must be designed to "give way," or fail, to protect the tank from collapsing if a vacuum occurs.

4. Are the cathodic protection access plates watertight?

Access plates that are not sealed to a watertight condition allow bird droppings to wash directly into the drinking water.

5. Is the top access hatch designed correctly and does it close tight?

The hatch opening should have raised side walls not less than 4 inches tall. The lid or cover should drop down over the side walls at least 2 inches. The lid must seal tight to prevent dust, dried bird droppings, and feathers from being inhaled or blown into the hatch opening. Improperly fitted hatch covers are a common problem, but many can be made acceptable with minor modifications.

6. Are access hatches locked?

Access hatches should be closed with a solid watertight cover and a sturdy locking device. It is not unusual for the wind to lift open an unlocked cover. Padlocks are often cut off and individuals then swim or throw things in the storage facilities.

7. Is there a roof penetration for a water level indicator cable?

This penetration for the cable allows bird droppings to wash into the storage facility unless it is covered and designed to cause rain water to flow away from the cable opening.

8. Are there other roof penetrations?

Roof penetrations for water lines, chlorine lines, and electrical devices are all opportunities for contamination if they are not kept watertight.

9. Are there sewer lines within 50 feet of an in-ground storage tank?

Any sewer lines within 50 feet of a storage facility, such as a clearwell with a floor below ground level, should be constructed of extra-heavy or service-weight cast iron pipe with tested, watertight joints. No sewer lines should be closer than 10 feet to the tank.

10. Are there cracks in the walls or covers of the in-ground concrete storage tanks?

Cracks in the tank can allow ground or surface water into the tank.

11. Is there protection from flooding?

If the drain line is likely to be submerged by flood water, a watertight blind flange should be provided to prevent backflow of contaminated water into the storage facility. All storage facilities should be protected against flood waters. The structure and its related parts should be watertight. The ground above an underground tank should be graded to drain surface water away from the tank and to prevent surface water from pooling near it. Underground drainage should discharge away from the structure.

12. Can the tank be isolated from the system?

A utility should be able to take its tanks out of service for inspection and maintenance without shutting down the entire system. This can usually be accomplished if gate valves and a drain pipe have been provided. The operator should exercise valves regularly to ensure their integrity.

13. Is the site protected against vandalism?

The storage site should be fenced and locked to prevent unauthorized entry. Ladders to the tops of storage tanks should terminate 10 feet above the ground to deter unauthorized climbing. Many ladders have a section that "telescopes" up into the cage. In such cases, the ladder and access hatch to the ladder cage should be locked.

14. Are the interior surface coatings approved?

Coatings that are in contact with water should be approved by the National Sanitation Foundation (NSF). Unapproved coatings can create problems due to organic and inorganic contamination of stored water.

Coatings should be applied to a water tank by certified professionals and in accordance with AWWA Standard D 102-78: Painting Steel Water Storage Tanks.

15. Are volatile organic chemicals (VOCs) sampled after painting?

Whenever a tank is painted, the proper curing time should be allowed. Before the tank is placed back into service, the tank should be flushed, disinfected, and filled with water. Samples should be taken and analyzed for coliform and VOCs.

[Note: Causes of coating failure. Coatings can fail for several reasons, including improper surface preparation, application, and curing; use of the wrong type of coating; removal by ice or other environmental exposure; and lack of maintenance.]

The rise and fall of water in the tank can affect corrosion. Exposed metal surfaces that are submerged and then exposed to air (oxygen) will corrode at an increased rate. Cathodic protection (corrosion control devices) may be provided for metal storage tanks. These devices should be inspected and maintained annually by factory-authorized service representatives.

16. Is the tank protected against icing?

When temperatures fall below zero for several days, ice may form in underground and elevated storage tanks. In underground tanks, ice formation is usually limited to surface ice. In elevated tanks, icing may be more severe; thick accumulations on sidewalls have been observed. Serious damage to walls and structures may result. Tanks have blown their tops due to the pressures that result; in less severe cases, the cathodic protection and tank interiors may be damaged.

Tanks should not be allowed to remain idle if freezing is a problem. Heaters, circulators, or bubblers may need to be used in tanks. Insulation around standpipes should be provided in very cold climates.

17. Are there indications that the tank may not be structurally sound?

The inspector should base the answer to this question on visual observation of washouts, signs of foundation failure, cracking or spalding concrete, tank leakage, buckling of steel, slack in support rods, corrosion, and signs of other problems.

18. Is the tank protected against corrosion?

The inspector should determine the corrosivity of the water. The system should take steps during water treatment to correct for corrosive properties. Corrosive water can seriously damage a steel storage tank if the protective coating is not completely intact.

19. What is the frequency of general inspection and cleaning?

Storage tanks should be on the operator's daily inspection list. During the daily visits, the operator should check the water level in the tank (with a visual indicator or pressure gauge), the functioning of the controls, the condition of the overflow pipe, and security. For facilities with easy access to the roof, the vent and hatch should also be inspected. The exterior and interior of the tank should be inspected annually by qualified personnel.

20. How and how often are the storage tank's structure and coating inspected?

In addition to the annual inspection, a thorough structural and coating inspection should be carried out approximately every 5 years. This inspection should be performed by personnel certified by the National Association of Corrosion Engineers (NACE) and done according to AWWA D101-53: Inspecting and Repairing Steel Water Tanks, Standpipes, Reservoirs, and Elevated Tanks for Water Storage.

21. Are storage tanks disinfected following interior maintenance?

Reservoirs and elevated tanks on the distribution system must be disinfected before being put into service and after extensive repairs or cleaning.

Disinfection should be done according to AWWA C652-92: Disinfection of Water Storage Facilities.

22. Are there procedures to sustain the water supply when the storage tank is out of service for maintenance?

Prior to removing the tank from service for maintenance, the water utility staff should coordinate and practice procedures for sustaining the distribution system pressure. This can be relatively simple in systems that are equipped with adequate back-up storage facilities. A small system that has only one storage tank or limited reserve storage would require a more complex means of maintaining the water supply. This could include operating high-service pumps manually and positioning fire hydrant relief valves at various locations within the distribution system.

Temporary measures should be established, tested, and practiced thoroughly before the storage tank is actually removed from service for maintenance. All water system customers and the fire department should be notified well in advance so that conservation and alternative plans can be made to decrease stress on the water system. When necessary, high-consumption customers should be notified and asked to conserve voluntarily.

23. Are emergency procedures established?

The inspector should learn about the procedure to detect and respond to low tank levels (low pressure) and determine if the program is adequate. A resource list should be available that contains information on where to obtain essential storage repair materials and services in the event of an emergency. An alternative source of water should be available.

24. Are safety precautions followed?

There are climbing and atmospheric hazards associated with water storage tanks. Ladders should be in good condition and secure. The inspector should determine whether safety gear is available for climbing and for entry into confined spaces.

25. If the tank is wooden, is it operated in a manner to minimize an increase in bacterial count?

The most effective operating method for a wooden reservoir includes maintaining a chlorine residual of at least 1 mg/L, varying the water level in the tank a few feet each day, and never allowing the same water to stand in the tank longer than a few days.

Basic Information – Hydropneumatic Tanks

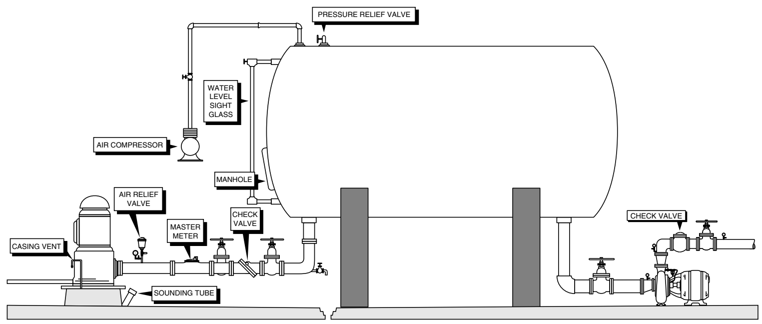
Hydropneumatic systems to maintain distribution system pressure are very common in small water systems (fewer than 150 living units). They are not considered adequate for fire fighting, however, and provide only enough storage to prevent excess cycling of the pumps. These systems combine the energy from a pump with the principle of compressed air pressure to force water into the distribution system. Understanding how the hydropneumatic system is susceptible to sanitary risk requires an understanding of basic system operation and the role of system components.

How They Operate

The system operates in the following manner:

- The water supply pump starts when the pressure drops to a predetermined level (cut-in pressure). The pumped water compresses and pressurizes a pocket of air (air volume) at the top of the pressure tank.
- When the pressure builds to a predetermined level (cut-out pressure), the pump stops and the compressed air expands as it forces the water into the distribution system in response to system demand.
- When the pressure falls to the "pump-on" level (often 35 to 40 psi), the pump starts again, and the cycle repeats. The cycle rate is the number of times the pump starts and stops in 1 hour and varies based on the system demand.

Hydropneumatic Tank System with Air Compressor

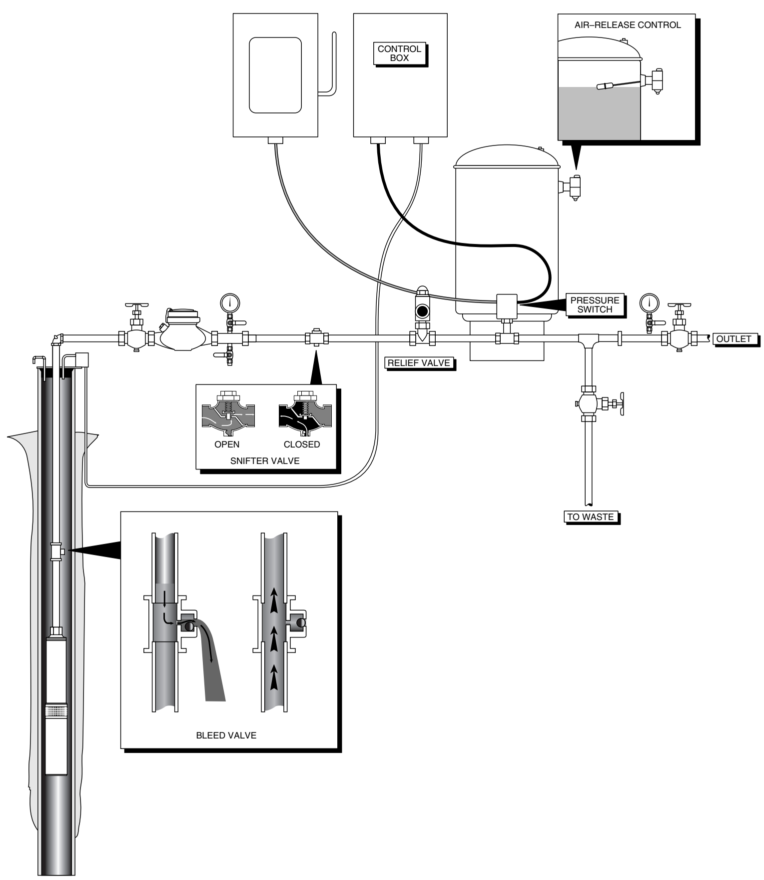


Components

A typical hydropneumatic system is made up of the following parts:

- **Steel Tank.** Stores water.
- **Air Volume Control.** Regulates air volume in the tank.
- **Relief Valve.** Prevents excessively high pressure.
- **Inlet and Outlet Piping.** Allows flow of water in and out of the system.
- **Sight Glass (tube).** Allows direct observation of air-to-water ratio, generally one-third air to two-thirds water.
- **Pressure Gauges.** Monitor pressure, generally a 100 psi gauge.

Submersible Turbine and Hydropneumatic Tank (Typical for Home or Very Small System)



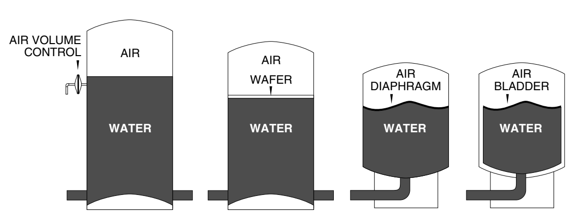
- **Pump and Motor Controls.** Control cut-in and cut-out points.
- **High and Low Water Levels.** Regulate water level in tank.
- **Low Pressure or Flow Controls.** Maintain balance between water and air pressure.
- **Air Compressor.** Forces additional air into tank to increase pressure (prepressurization).
- **Master Flow Meter.** Measures quantity of water pumped.
- **Cycle Counter.** Counts number of pump cycles.
- **Elapsed Time Meter.** Records hours of operation.

Different Styles of Pressure Tanks

Most hydropneumatic systems differ only in the kind of pressure storage tank used. Primary differences in tanks include:

- Size.
- Orientation (horizontal or vertical).
- Methods of separating water and air.

Styles of Pressure Tanks



All these factors may contribute to the degree of vulnerability to sanitary deficiencies. The three kinds of tanks are described below:

- **Conventional Tank**
  - Air cushion in direct contact with water; air volume controls necessary.
  - Capacity ranges from a few to several thousand gallons.
  - Vertical or horizontal placement.
  - Outlet located near bottom of tank. Combined inlet-outlet or inlet-outlet separated on opposite sides of tank to provide chlorine contact time.
  - Air volume control located at the water/air interface of tank; provisions available for prepressurizing.
- **Floating Wafer Tank**
  - Floating wafer (rigid floats or flexible rubber or plastic) separates water and air, **but** separation not complete; some loss of air is expected, requiring occasional recharging.
  - Vertical placement limits tank capacity.
  - Inlet and outlet combined at bottom of tank.
  - Internal air check valve to prevent premature loss of air due to electric outage or excess water demand.
- **Tank with a Flexible Separator**
  - Separator fastened around inside of tank for complete separation of air and water, either flexible diaphragm or bag type.
  - Vertical placement limits tank capacity.
  - Supercharged at factory or on site to pressures just below pump starting pressure.

Sanitary Deficiencies of Hydropneumatic Storage Tanks

1. Is tank capacity adequate?

There are several formulas for determining required tank capacity. Two methods, A and B, are presented below. In selecting and evaluating the tank, capacity must be matched to the system’s peak demand. Engineering records, which should be available at the facility, list pump capacity, cut-in, and cut-out pressures. Operating records show current peak demand and whether peak demand has changed since the tank was installed, which could require a change in tank size.

[Note: To ensure against over stressing facilities at peak demand, system operators must know the pumping capacity and peak demand rates.]

The inspector should be especially concerned about the adequacy of supply capacity and tank size in communities that have substantially increased their service population without upgrading the water system.

A. Tank Capacity Formula

Tank capacity = at least 10 times the capacity of the well's largest pump, and

The well pumps = at least 10 times the average daily consumption rate.

B. Alternative "Rule of Thumb"

The capacity of the wells and pumps must be at least equal to the peak instantaneous demand.

The active storage volume of the hydropneumatic tanks must be sufficient to limit pump cycling to manufacturer's and industry recommendations.

Maximum cycling frequency must be determined for the largest pump when demand is one-half the capacity of the largest pump or combination of pumps operated by the same pressure switch.

2. Does low pressure "pump-on" level maintain adequate distribution system pressure?

Maintaining adequate pressure is especially important to keep the water flowing from storage facilities to serviced areas. Because the pump and source have to be capable of meeting the system's maximum momentary water demands, the potential for low pressure situations and backflow or backsiphonage is substantially increased. To prevent backflow and backsiphonage, minimum pressure must be maintained at all times. Too little pressure can cause the water flow to reverse, allowing water from a polluted source to enter potable, stored water. Low pressure can indicate improper connections, or cross connections, made from storage to serviced facilities. Too much pressure, on the other hand, can strain system components, cause high leakage rates, and force air out with water.

System pressures (Pounds per square inch)

- Optimum Working Pressure: 60-80 psi.
- Minimum Working Pressure: 35 psi.
- Maximum Pressure at Service Connections: 100 psi.
- Minimum Pressure Under Fire Flow Conditions: 20 psi.

Check for hazards. Inspectors should check engineering records to assess potential backflow hazards in the water of facilities served by the system. They also should consult operating records to see whether pressure is adequate and they should determine whether and how often breakdowns and pressure losses occur.

3. Are instruments and controls adequate and operational? Are they used and maintained?

Proper operation and maintenance of the storage system is also essential. Failure to adjust gauges and controls properly can lead to inadequate pressure or inadequate supplies of water. And tanks equipped with air compressors may be polluted by airborne or waterborne foreign matter. Careful installation and maintenance of air filters and cross-connection control devices can prevent the entry of foreign material into the hydropneumatic system.

Components to be Checked. To ensure proper operation and maintenance of the system, the following components must be routinely checked and adjusted for changes in the peak demand:

- Air volume control

- Relief valves
- Motor controls
- High and low water level controls
- Low pressure flow controls
- Air compressor and controls

Check Records. Frequently, controls are not adjusted after the system arrives from the factory. Operating records should report the original calibration and whether peak demand has changed.

4. What are the cycle rate and air-to-water ratio?

Cycle rate. The water supply pump should not cycle frequently (10 to 15 cycles per hour is acceptable). Frequent or constant operation of the pump indicates a "waterlogged" tank, improper settings on the pressure controls, or system demand that is close to exceeding the supply pump capacity.

Air-to-water ratio. The air-to-water ratio in conventional hydropneumatic tanks should be approximately one-third air to two-thirds water at "pump off" pressure. If the air volume is too high, the tank could lose water before the pump starts, which would send air into the distribution system.

5. Are the tank and controls properly protected?

The tank should be located in a secure building or surrounded by a fence to protect it from vandalism. The controls should be housed in a waterproof and secure structure, but must be easily accessible for maintenance. Lightning protection should be included.

6. Are emergency procedures established?

Pump failure—in either a low- or high-pressure situation—should be detected by the control system which activates an alarm. Some alarm systems consist of a light or horn at the facility. This type of alarm is not as reliable as an automatic telephone dialer alarm, which can be programmed to call several numbers until a response is obtained.

7. Are there back-up systems?

Many water systems, especially small ones, do not have redundant equipment. Inadequately maintained hydropneumatic systems are extremely prone to malfunction, and pressure is usually lost before the problem can be corrected. The sanitary deficiencies of pressure loss due to equipment failure are substantially reduced if back-up systems are provided. Provisions for an emergency source of safe water should be established.

Service contract. The utility should have a service contract with an industrial controls technician for maintenance and trouble-shooting.

CAUTION: Hydropneumatic tanks are pressure vessels. A pressure of 50 psi is equivalent to 3.5 tons per square foot of tank surface area**. DO NOT TAP ON THE TANKS!**

8. Are the interior and exterior surfaces in good condition?

The interior and exterior should be in good physical condition. The inspector should check for signs of coating failure and corrosion. The inspector most likely will not be able to examine the interior surfaces, but should emphasize to the operator the importance of regular inspections.

By reviewing maintenance records, the inspector may determine if inspections are being performed. Some states require all pressure vessels to undergo regular hydrostatic testing. The tank should not be buried.

9. Are tank supports adequate and structurally sound?

The tank should be properly and permanently supported. An inadequately supported tank may shift and damage the piping connections.

10. Is the recharge air free of pollutants such as oil from an air compressor?

Air compressors can introduce lubrication oil as an aerosol into the hydropneumatic pressure tank.

11. What is the physical condition of the outside hatch?

An outside access hatch that is in poor physical condition can compromise the integrity of the pressure vessel, causing safety and sanitary deficiencies.

12. Are the pump and source capable of meeting the system's maximum momentary demand?

The system's maximum momentary demand can occur when the hydropneumatic tank has exhausted its stored water (at the "pump-on" pressure), therefore, the system can lose pressure if the pump and source cannot meet peak demands.

6 Water Treatment Processes

The sanitary survey inspector must thoroughly evaluate all water treatment processes to ensure the production of a safe, adequate, and reliable supply of water for consumers. The water treatment plant is the primary barrier against unsafe water, and any malfunction in the treatment process could result in water quality problems. The inspector must evaluate the operation, maintenance, and management of the water treatment plant to identify any existing or potential sanitary deficiencies.

Learning Objectives

By the end of this chapter, learners should be able:

- To identify key data items required to evaluate sanitary survey risks at water treatment plants such as turbidity, pH, alkalinity, Stage 1 DBP Rule monitoring plans, disinfection profiles, and chlorine residuals.

- To review key components of water treatment processes such as chemical feed systems, coagulation, flocculation, and sedimentation processes, filtration systems, and disinfection.

- To recognize sanitary deficiencies of the water treatment processes as they relate to the physical facilities, operation and maintenance, and management. Issues may include inadequate treatment, inadequate application of water treatment concepts to process control, hydraulic surges, poor maintenance procedures, staffing and funding deficiencies, and cross-connections.

- To identify safety issues that affect the operations staff, and could affect the facility's ability to perform effectively. Safety issues may include chemical handling, chemical storage, and confined spaces.

- To review regulatory issues that are appropriate to each specific process to determine their relationship to sanitary deficiencies.

Data Collection

The inspector needs to obtain as much of the following information about the water system as possible before the sanitary survey inspection. Information and data not obtained during the investigation must be obtained during the inspection.

Treatment Processes Information

- Schematic of complete treatment facilities showing the type of treatment processes used and application points of all chemicals.

Chemicals Used in Treatment Process Information and Data

- Specific chemicals used and purpose of addition.

- Quantity added.

- Application points.

Chemical Feed Equipment and Storage Information and Data

- Type of feed system in operation (i.e., liquid, gas, solid).

- Condition of equipment.

- Calibration procedures.
- Redundancy for all systems.
- Safe and adequate chemical storage.

Process Control Data

- Type and frequency of testing throughout treatment process.
- On-line monitoring equipment available and operable.
- Data recording procedures.

Physical Facilities Information

- Buildings and rooms where treatment processes are located; adequacy of accessibility, safety, and overall maintenance.
- Operation, maintenance and design of treatment units such as rapid mixers, flocculators, clarifiers, and filters.

Regulations and Standards to Consider

The inspector needs to consider and review the following information prior to the inspection:

- Chapter 2 of this Guide.
- Specific regulations that apply to the facility.
- Past inspection reports to identify previous compliance problems.

Water Treatment Processes

Basic Information

Purpose of Water Treatment. The purpose of water treatment is to condition, modify, or remove undesirable impurities or pathogens in order to provide water that is safe, palatable, and acceptable to consumers. National standards for some of the impurities that are considered important to the health of consumers are set under the federal Safe Drinking Water Act (specified in 40 CFR Part 141 with maximum contaminant levels [MCLs] and treatment techniques). If the levels of contaminants present exceed the established MCLs, the water must be treated to reduce the levels. Techniques are specified in the regulations when MCLs are not appropriate for public health protection.

Secondary standards for some impurities that affect the aesthetic qualities of water are found in 40 CFR Part 143. These standards are not enforceable by the federal government, but states may choose to adopt and enforce them. Treatment or modification of the water to comply with secondary standards is highly recommended because consumers may seek out unsafe sources if the drinking water supplied by the public system has an undesirable appearance, taste, or odor.

Treatment Processes

Some of the common treatment processes for surface and ground water are discussed below.

Pretreatment. Pretreatment is a physical, chemical, or mechanical process that removes some impurities or alters some of the objectionable characteristics of water (such as taste and odor, iron and manganese, organics, or hardness) before it is treated further. On occasion, chemical addition to alter the water quality is the only treatment technique used. This technique may include corrosion control, iron and manganese sequestering, disinfection, and fluoridation.

Coagulation and Flocculation. Coagulation and flocculation are chemical and physical processes to improve the particulate and colloid-reduction efficiency of subsequent settling or filtration processes. Coagulation involves feeding chemicals to destabilize the similar charges on suspended particles, allowing them to coalesce and thereby begin to form floc. Flocculation, which partly overlaps the coagulation, requires gentle mixing of destabilized particles to form floc that can be removed by settling or filtering.

Sedimentation. Sedimentation follows coagulation and flocculation. In sedimentation, the velocity of the water is reduced to allow the flocculated particles to settle out and be removed before filtration.

Filtration. Filtration is the passage of water through a porous filtering medium, such as sand, anthracite, or other granular material, to remove most of the remaining destabilized particulate impurities and floc.

Disinfection. Disinfection is the process of destroying pathogenic organisms using chlorine, certain chlorine compounds, or other means.

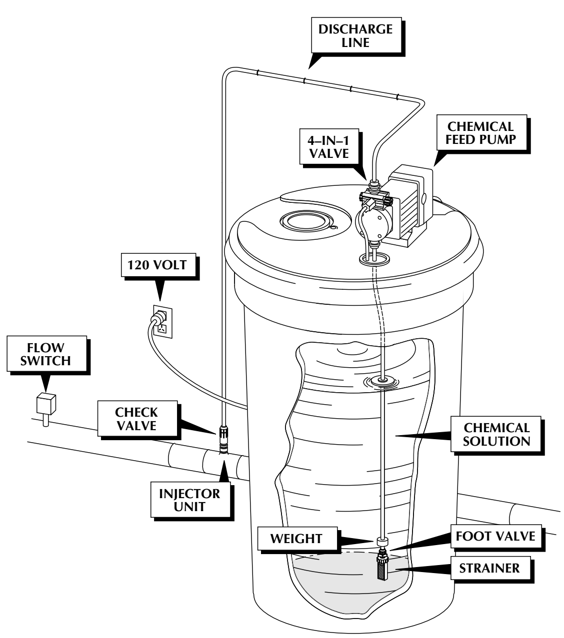
Chemical Feed Systems

Chemical feed systems are common to all types of treatment plants. They may be used to feed treatment chemicals such as coagulants, and oxidants into the water. They may also be used to feed corrosion inhibitors, pH adjustment chemicals, chemicals for taste and odor control, disinfectants, and fluoride. Types of chemical feed systems include liquid feed pumps and dry feeders.

Liquid feed pumps. These systems are very simple, as illustrated in the drawing below. The system is made up of these basic components:

- Tank to hold the chemical solution.
- Chemical feed pump.

Liquid Feed Pump (Hypochorinator)



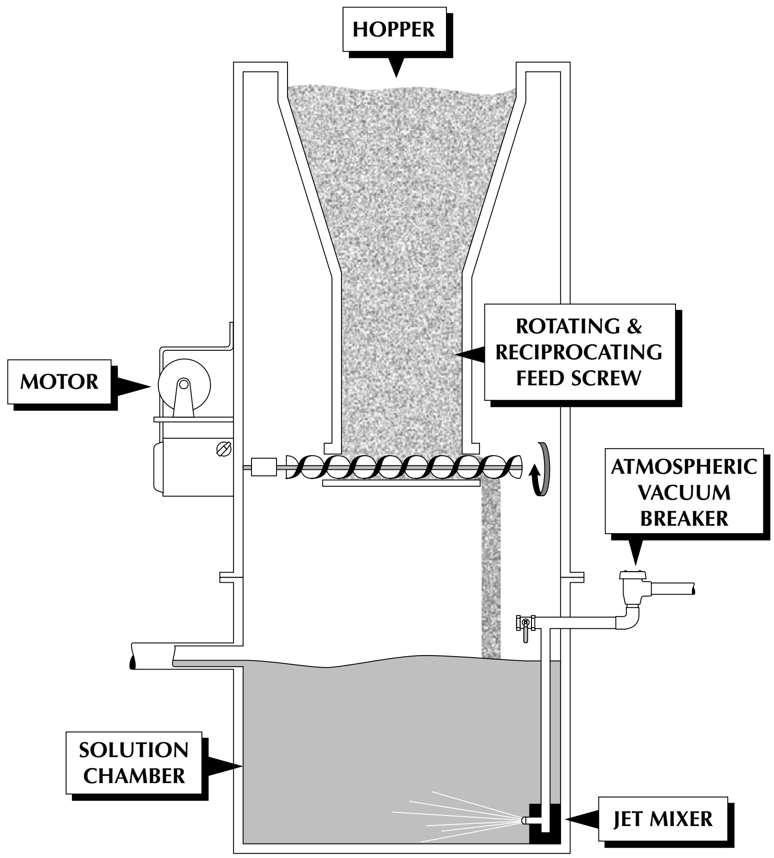
- Injection valve with check valve.
- Electrical control system with fail safe flow switch.
- Chemical storage area.
- **Dry Feeders (Volumetric).** In these feeders, the feed rate is based on the volume of chemical rather than weight. Volumetric feeders can achieve acceptable performance for materials with stable density and uniformity, particularly at low feed rates.
- **Dry Feeders (Gravimetric).** This type of system feeds dry chemicals based on actual weight. Consequently, it is more accurate than other types of dry feeders and better able to achieve the desired dose rates.

Operation and Maintenance of Chemical Feed

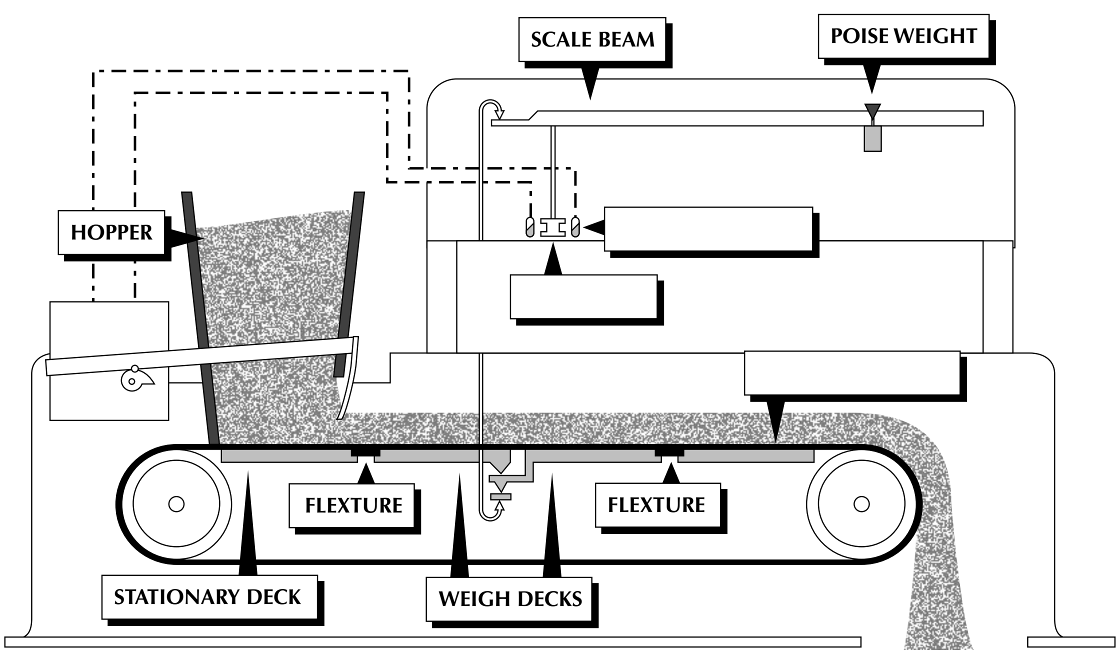
The proper operation and maintenance of chemical feed systems is critical to the overall performance of the treatment plant. For example, a conventional surface water plant cannot consistently achieve optimum performance unless its chemical feed systems are functioning properly. Issues to be addressed by inspectors for all chemical feed systems include:

- Adequate maintenance, including a preventive maintenance (PM) program, spare parts for critical component and components that need regular replacement, and repair budgeting.
- Back-up units for redundancy, particularly for critical processes such as coagulation and disinfection.
- Physical condition of buildings and areas where feed equipment is being housed.
- Storage of chemicals, including the segregation of incompatible chemicals that should not be stored together. For example, storing powdered activated carbon (PAC) and potassium permanganate ($KMnO_4$) in the same area could result in explosion or fire hazards. Chemicals should not be stored

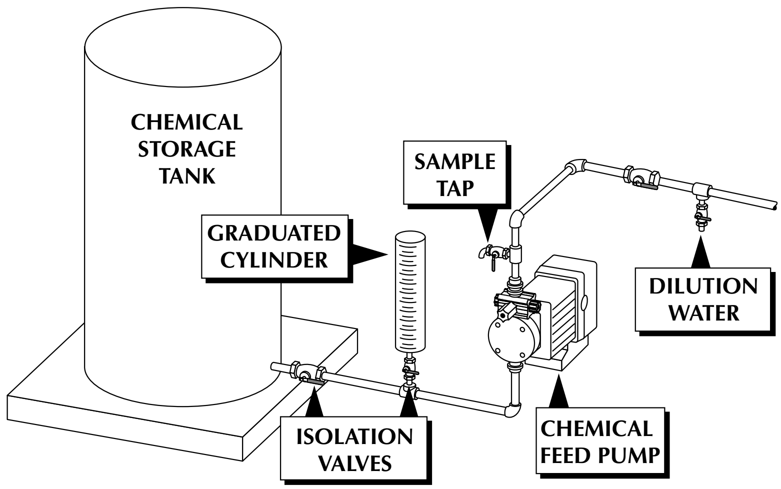
Volumetric Dry Feeder



Belt Gravimetric Dry Feeder



Chemical Feed System



where they could contaminate the system's water supply in the event of a spill.

- A hazardous communication program in place, to deal with the handling of all chemicals.
- Containment of chemical spills and the location of proper drains in chemical areas.
- Safety in terms of the handling and feeding of chemicals and the availability and proper use of safety equipment such as chemical goggles and respiratory protection.
- Calibration of all chemical feed systems as a regular operational procedure.

Sanitary Deficiencies – Chemical Feed Systems

1. What chemicals are used?

The inspector should determine what chemicals are used, if they are approved for water treatment, and if they are applied properly. The operator should be aware of possible adverse effects of adding the chemicals, such as the development of trihalomethanes (THMs) as a result of pre-chlorination.

2. What is the amount of chemicals used?

The amount of chemicals used should be based on testing. The operator should be able to explain how the dosage is determined (such as by jar testing, pH measurement, or streaming current detectors) and the frequency with which this determination is made. The chemicals should be approved for use in potable waters by ANSI/NSF or other acceptable federal or state standards.

3. Where is each chemical applied?

The inspector should note the application points and evaluate them in light of the purpose of the chemical addition. Chemicals may counteract each other if not applied in the proper sequence. For example, PAC will remove chlorine if it is fed downstream of the chlorine injection point. This situation often unintentionally wastes chlorine and PAC. Similarly, sequestering agents fed to control iron or manganese must be added ahead of chlorine because the chlorine will oxidize the dissolved metals and render the sequestering chemicals useless. Insoluble calcium fluoride may precipitate out of the water if fluoride compounds and lime are added in close proximity to each other, another possible result of inappropriate application points. Chemical addition should not result in a cross-connection. Certain chemicals, such as corrosion inhibitors or fluoride, will generally be applied at the end of the treatment process.

As a general rule, the inspector should know the application points and feed rates of all the chemicals used in the system's treatment plants. The inspector must understand the purpose of the chemicals in order to evaluate the feed locations and rates. Therefore, the inspector will often need to perform, either before or after the survey, some research on the chemicals used by the system.

4. Does the system have adequate monitoring and testing procedures?

Systems should monitor for the chemicals added as well as for the chemicals to be removed. This monitoring requires following standard testing procedures and using properly calibrated and maintained monitoring and testing equipment. The system should have adequate facilities to undertake monitoring and testing.

5. What is the condition of the chemical feed equipment?

The equipment must be functional and properly maintained. For example, with dry chemical feeders the inspector should watch for problems with "bridging" of the chemical in the hopper. Liquid feeder lines should be checked to see that they are not clogged. There should be chemical feeder redundancy.

Chemical feed pump diaphragm foot valves, injection valves, and control valves should be replaced at least once a year. The suction and discharge piping should be inspected for discoloration and clogging. When clear plastic lines turn opaque, they should be replaced. The inspector should determine if there is a preventative maintenance program in place and should examine PM and repair records. The chemical addition program is vital to ensure proper treatment and cannot be interrupted due to equipment malfunction. Therefore, the operator should have adequate spare parts or redundant equipment.

6. Is the chemical feed equipment calibrated?

The equipment should be calibrated each time a new batch of chemicals is used. The feed equipment feed rate should be checked at least daily.

Ideally, the operator should calibrate chemical feed pumps at least annually. An alternative method is to use a graduated cylinder to verify the feed rate weekly or monthly.

7. Are instrumentation and controls for the process adequate, operational, and used?

Controlling processes is difficult when instrumentation such as flow meters, turbidimeters, and chlorine residual analyzers are not functional or properly calibrated. The inspector should observe the controls and ask the operator about calibration checks and how process control decisions are made based on the results of the measurements. The instrumentation is useless if the operator does not know the significance of the measurement.

8. Is chemical storage adequate and safe?

A minimum of a 30-day supply of chemicals is recommended. Level indicators, overflow protection, and spill containment should be provided for liquid chemical storage. This is particularly important to prevent contamination of the aquifer by tanks located near a well. Chemicals stored in the same area should be compatible. For example, petroleum-based oils and lubricants must not be stored near oxidizers such as $KMnO_4$ because of fire and explosion hazards. Chemicals must be stored in a manner that precludes a spill from entering the water being treated or the raw water source.

PAC storage areas need to be dry and equipped with an explosion-proof electrical system. Make sure that sodium fluoride is stored in a separate area and not with any other chemicals. Sodium fluoride is very corrosive and a poison.

Check on access to the chemical storage. If access is difficult, the operator may not be diligent in transferring chemicals from storage to use.

9. Do daily operating records reflect chemical dosages and total quantities used?

It is extremely critical that the operator monitor daily chemical use and dose rates. Overfeeding chemicals can be as detrimental as under-dosing. Monitoring feed rates is key to the optimized performance of any chemical feed system.

10. Is the chemical feed system tied to flow (i.e., flow paced)?

The chemical feed pump can be paced with the flow by a 4 to 20 mA signal from a flow recorder, or the system may be tied directly to a pump so the feeder is activated each time the pump is operated and there is flow in the line.

When the chemical feeder is tied to a pump, it is very important that some type of flow sensor be used as a fail safe. The chemical feeder should not be allowed to come on until there is flow in the pipe. Without flow control, a pump motor starter may engage but not start the pump. If the signal that engages the starter also starts the chemical feed system, highly concentrated chemicals can be fed into the line and received by a customer.

11. Is there an operating 4-in-1 valve or equivalent on each feed pump?

This valve reduces the possibility of siphoning all of the chemical into the system and protects the pump from damage due to shutdown of the discharge piping. Ask the operator to show you how it works.

12. Is there a hazardous chemicals protection and communication program in place?

The utility needs to have an inventory of all hazardous chemicals, a Material Safety Data Sheet (MSDS) for each chemical, and written procedures for using, transporting, and handling these chemicals. The utility also should have an emergency response plan in the event of a spill of hazardous chemicals.

13. Is there appropriate safety equipment (e.g., cartridge respirator for calcium hypochlorite) and personal protective equipment (PPE) (e.g., goggles and gloves) available and in use? Have operators been trained to use the safety equipment?

The PPE should be in good condition; respirators must be clean and stored in a sealed bag. PPE should be readily available in the location where it will be used. **Facility management is responsible for training all personnel in the use of safety equipment.** Ask for documentation that this training has occurred during the past 12 months.

When respiratory protection is required, the utility must have a written respiratory protection program. This program includes a fit test of the device and training in selection, use, and care of the device. In addition, the program requires annual physical exams of all personnel required to use the devices.

Cartridges on cartridge respirators must be changed at least every 6 months. All respirators must be inspected monthly.

14. Is the building as clean and dry as possible?

Keeping the interior of the building clean and dry reduces the opportunity for spills of liquid or powdered chemicals to react with water, increasing corrosion in the building. When calcium hypochlorite mixes with water, chlorine gas escapes into the atmosphere. This gas will increase the rate of corrosion and deterioration in the facility.

Treatment Processes

Disinfection

Introduction. Disinfection is the process of destroying a large portion of the microorganisms in water, with the probability that all pathogenic bacteria and viruses are inactivated in the process. Many failures to meet drinking water standards are directly related to inadequate disinfection. In addition, chlorine, the most widely used disinfectant, is a hazardous chemical and can cause severe health problems or death for the operator and the public. The inspector must determine if the disinfection system is adequate and reliable. This will help ensure that the water is safe to drink.

Disinfection Methods. Chlorination is the most common disinfection method used by water systems in the United States. While chlorine is the most common, there is a general trend in the industry to experiment with other disinfection systems such as:

- Ozone
- Ultraviolet (UV) light

- Chlorine dioxide
- Chloramination

While these methods are used in some systems, both ozone and UV require the addition of chlorine to meet the residual requirements of the Surface Water Treatment Rule (SWTR), 40 CFR 141.73. Because chlorine is the primary method of disinfection, only this equipment will be discussed in this lesson.

Dosages and Residuals

Review of Terms. The standard term for the concentration of chlorine in water is milligrams per liter (mg/L). The concentration of chlorine gas in the atmosphere is measured in parts per million (ppm).

Dosage. The total amount of chlorine fed into a volume of water by the chlorinator is the **dosage**. This value should be calculated daily in mg/L. Operators are more likely to record the dosage as pounds or gallons per day. While the number of pounds or gallons used per day is important, it is not the dosage but the feed rate.

Demand. 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, nitrate, and ferrous iron), organic impurities including microorganisms, and organic nitrogen compounds such as protein and amino acids. These reactions consume or use some of the chlorine. The amount used is called the **chlorine demand**. Because the reaction time between chlorine and most organic compounds is long (hours to days), the demand is based on time. That is, the measurable demand at the end of 20 minutes is less than the measurable demand at the end of one hour of contact.

Residual. Residual is the amount of chlorine present in the water after a specified period of time. It is measured in mg/L.

Chlorine demand (mg/L) = Chlorine Dose (mg/L) - Chlorine Residual (mg/L)

Chlorine and Water. Regardless of the form of chlorination–chlorine gas or hypochlorites–the reaction in water is basically the same. Chlorine mixed with water will produce two general compounds, HOCl (hypochlorous acid) and OCl (hypochlorite ion). The measurement of these compounds is called **free chlorine residual**. If organic or inorganic compounds, especially nitrogen compounds, are available, the HOCl will combine with them to produce chloramines or chloro-organic compounds. The measurement of the presence of these compounds in water is called **combined chlorine residuals**.

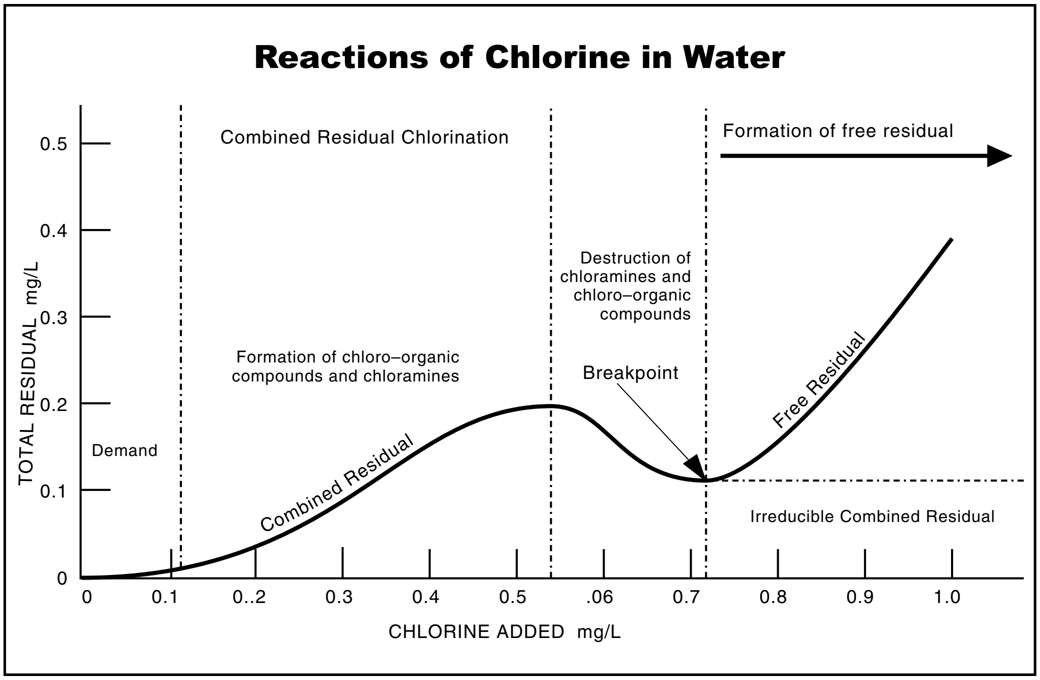
Germicidal Effectiveness. It is commonly agreed that a free chlorine residual of HOCl and OCl is much more effective as a disinfectant than a combined chlorine residual.

Breakpoint Chlorination. To produce a free chlorine residual, enough chlorine must be added to destroy the nitrogen compounds. This process is called **breakpoint chlorination**. While this process destroys most of the nitrogen compounds, it does not destroy all of them. Those that remain combine with the chlorine to produce what is called the **irreducible combined residual**.

Free + Combined = Total. For many systems, this results in a residual in the distribution system that includes free and combined residuals. The measurement of both of these residuals is called **total chlorine residual**. The combined residuals are the primary contributors to taste and odor problems in a system. The table below shows the threshold of odor of various residuals. It is apparent that free chlorine and monochloramine are likely to produce fewer taste and odor complaints.

Compound	Threshold of Odor
Free HOCl	20 mg/L
Monochloramine	5 mg/L
Dichloroamine	0.8 mg/L
Nitrogen trichloride	0.02 mg/L

Taste and Odor Considerations. As can be seen from the table above, taste and odor complaints result primarily from combined residuals that form after enough chlorine has formed to produce dichloramines and nitrogen trichloride. If the system operates with a free chlorine residual but receives chlorine taste and odor complaints, the inspector should suggest that the operator measure both free and total residuals. As a rule of thumb, if



the free chlorine residual is less than 85 percent of the total, the odor and taste problem is a result of combined residuals. This problem may be resolved in two ways:

- Remove the precursors that cause the combined residuals.
- Increase the chlorine dosage. There may be an insufficient quantity of chlorine (pound for pound with the organics) to oxidize the organic compounds sufficiently to avoid the problem.

When a system uses chloramines as a residual disinfectant, the operator must pay close attention to the chlorine-ammonia feed ratio to ensure that the residual is monochloramine.

Stage 1 Disinfectants and Disinfection Byproducts (DBP) Rule. Two considerations for the sanitary survey inspector from the Stage 1 DBP Rule should be the development of disinfection byproducts (i.e., total trihalomethanes [TTHMs] and haloacetic acids [HAA5]) and maximum residual disinfectant levels (MRDLs). Production of disinfection byproducts such as TTHMs and HAA5 can, in most cases, be dramatically reduced by discontinuing prechlorination at a surface water treatment plant. However, prechlorination may have a significant impact on the coagulation process and the disin-fection benchmark. Therefore, the inspector should not suggest that prechlorination be discon-tinued without fully under-standing the system's specific situation. Review the Stage 1 DBP Rule for information on maximum allowable residual disinfectants, MCLs for disinfection byproducts, and treatment technique requirements (i.e., enhanced coagulation and enhanced softening).

Sanitary Deficiencies – Disinfection Dosages and Residuals

1. **Can the operator answer basic questions about the disinfection process, including what is done, and when and why it is done?**

   An operator's lack of knowledge of the process and equipment indicates that equipment failure or process effectiveness may not be resolved in a timely manner. **Management is responsible for ensuring that operators are well trained in the use and maintenance of disinfection equipment.** Lack of knowledge of this key process can be considered a significant sanitary deficiency.

2. **Have there been any interruptions in disinfection? If so, why?**

   If disinfection is provided because the system uses a surface water source or has had a bacteriological problem, then interruption of service is a significant consideration. Interruptions often occur when a chemical feed pump fails or during cylinder changes when only one cylinder at a time is connected to the system.

3. Is a proper residual entering the distribution system at all times?

The SWTR requires that a residual of 0.2 mg/L be present at the entry point to the distribution system. This residual must occur after sufficient contact time to meet the SWTR's inactivation requirements. Some states may require a higher residual at the entry point to the system. In addition, the inspector should verify where this point is in the system and that the residual is measured at this point at least daily.

If the system adds ammonia to create choramines, the residual will be a combined chlorine residual and should generally be considerably higher than 0.2 mg/L. Although this is state-specific, the most common requirement is 2.0 mg/L.

4. What disinfectant residual is maintained?

The SWTR requires that a trace of chlorine residual be maintained at all coliform sampling points in the system, but some states may require a higher value. The inspector should verify that chlorine testing sites are representative of the system and thus provide sufficient information to ensure that a trace is available at all points and that MRDLs of the Stage 1 DBPR are not exceeded. The inspector may wish to measure residuals at points of high residence time.

In addition to verifying that there is a proper residual, the inspector should determine whether the equipment and testing methods are adequate. See the Distribution and Monitoring chapters (7 and 9, respectively) for more details on testing.

5. Is the contact time between the point of disinfection and the first customer adequate?

The contact time is the interval in minutes (T) that elapses between the time when chlorine is added to the water and the time when that same slug of water passes by the sampling point. A certain minimum period of time, depending on disinfectant residual concentration (C), water temperature, and other factors, is required for completion of the disinfection process. The requirements for contact time (T) and disinfectant residual concentration (C) depend on the pH, temperature, and flow rate of the water.

In general, the contact period for ground water systems should be adequate to ensure inactivation of 4 log viruses under peak demand flow conditions. The contact period for surface water systems must be adequate to ensure compliance with the requirements of the SWTR. More time may be desirable under unfavorable conditions, such as when the raw water has high levels of microbial contamination.

To determine if disinfection is adequate to remove and inactivate viruses and *Giardia* cysts, the SWTR requires unfiltered systems to determine CT values and show they are adequate to ensure inactivation of 4 log viruses and 3 log *Giardia lamblia*. CT is measured in milligram-minutes per Liter (mg-min/L) and is calculated as shown in the following equation.

Disinfectant residual concentration in mg/L (C) X contact time in minutes (T) = CT in mg-min/L

Filtered systems must show that filtration and disinfection combined provide the required 3 and 4 log inactivation or removal of *Giardia* and viruses. More complete information on the requirements and methods for determining CT values is provided in the SWTR and SWTR Guidance Manual.

6. Are the temperature and pH of the water at the point of chlorine application measured and recorded daily?

The CT value required for proper inactivation of *Giardia* and viruses depends on the pH and temperature of the water. Therefore, the SWTR requires operators to take these two measurements daily and calculate CT at peak hourly flow. The pH must be measured with a meter, not with litmus paper or a color comparitor, and the temperature must be measured with a calibrated thermometer.

Hypochlorination Systems

Facilities

Introduction. Modern hypochlorination systems are very reliable and effective. With the implementation of new regulations regarding chlorine, many small and medium-size facilities have switched to this safe, easy method of disinfecting water. The primary disadvantage of hypochlorniation systems is their higher annual operating costs compared to gas systems. However, as a result of new safety and environmental regulations, the cost of using chlorine gas has continued to rise, making hypochlorination systems more desirable. Water systems must list hypochlorites in their hazardous materials inventories, and they must have written procedures for handling hypochlorites, using them, and responding to spills. This is an OSHA requirement.

Sodium Hypochlorite Considerations. Of all the chlorine disinfection products, sodium hypochlorite presents the least handling hazard to the operator. Sodium hypochlorite is available in concentrations from 5 percent to 15 percent. It carries a UN number of 1791 and is classified by DOT as a corrosive with a hazard classification of 8. Personal protective equipment for handling sodium hypochlorite includes chemical goggles and gloves.

Calcium Hypochlorite Considerations. Calcium hypochlorite is a powder containing chlorine in concentrations up to 67 percent. It is usually mixed with water to form a 1 percent to 3 percent solution, which is fed into the water system. Calcium hypochlorite can be difficult to dissolve in hard water (above 125 mg/L total hardness). It has a UN number of 1748 and is classified by DOT as an oxidizer with a hazard classification of 5.1. The dust from calcium hypochlorite powder or tablets contains chlorine in concentrations up to 67 percent. Therefore, the required personal protective equipment for handling includes a cartridge respirator for chlorine with a dust filter, chemical goggles, and gloves.

Sanitary Deficiency – Hypochlorination Systems

Facilities

[Note: The sanitary deficiencies related to Chemical Feed Systems and Disinfection - Dosages and Residuals earlier in this chapter should also be applied to this section.]

1. **What kind of hypochlorite is used (e.g., calcium, sodium, or others)?**

   Sodium hypochlorite is vulnerable to a significant loss of available chlorine over time. The deterioration of sodium hypochlorite solutions is more rapid with increasing concentrations and increasing temperatures. Thus, the inspector should ask how much chemical is on hand and how old it is. The table below shows the half life deterioration of sodium hypochlorite. This information can be used by systems to determine the concentration of solution that best fits their needs.

Sodium Hypochlorite Half Life (Days)				
Percent	Temperature			
	212° F	140° F	77° F	59° F
10.0	0.079	3.5	220	800
5.0	0.25	13.0	790	5,000
2.5	0.63	28.0	1,800	
0.5	2.5	100.0	6,000	

   Sodium hypochlorite is a corrosive liquid. It should not be stored with dry chemicals or other liquids with which it can react, such as petroleum products.

   Calcium hypochlorite has a long life, but feed equipment requires greater maintenance than when sodium hypochlorite is used. The calcium hypochlorite solution contains a great deal of abrasive material that deteriorates the chemical feed pump suction and discharge valves.

   Calcium hypochlorite is a fairly reactive oxidizer that should not be stored with other chemicals with which it can react. **Under no conditions should petroleum products be**

stored with calcium hypochlorite. The reaction between chlorine and petroleum products is quick and violent.

2. **Is the solution tank covered to minimize corrosive vapors?**

   If the tank is not covered, chlorine gas will escape into the room and deteriorate the equipment.

3. **Is there adequate spill containment?**

   A double tank or containment area must be installed around all chemical storage tanks. A spill of 10 gallons of hypochlorite or 100 pounds of dry calcium hypochlorite is a reportable incident under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).

4. **Are safe practices followed during chemical handling and mixing?**

   Observe operator PPE and the space where chemicals are stored and used. If PPE does not appear to have been used, or the space is not clean, the inspector can assume that safe practices are not being followed.

Gas Chlorination Systems

Gas Systems

A wide variety of gas systems is produced by various manufacturers. The inspector need not be familiar with all of these systems. All chlorinators manufactured in the United States are vacuum operated. This is a basic safety feature. The systems used by small water utilities fall into one of three general categories:

- Pressure systems
- Remote vacuum systems
- Cylinder-mounted systems

The easiest way to tell a remote vacuum system from a pressure system is to look at the line from the cylinder to the chlorinator. If the line is metal, the system uses gas under pressure between the cylinder and the chlorinator. If the line is plastic, the water system uses a remote vacuum system; gas is under a vacuum between the cylinder and the chlorinator.

Facility

The drawing on the next page shows the key points of a small gas-chlorine facility that meets current OSHA and Uniform Building Code requirements. In general, these include:

- Containment of the chlorine, should there be a release or leak.
- Air treatment system so that the exiting air does not exceed 50 percent of the Permissible Exposure Level (15 ppm is 50 percent).
- Gas leak alarm system.
- Crash bars on doors.
- Negative pressure in the room when the air treatment system is operating.
- Overhead sprinkler system with a 20-minute capacity.
- Containment of the air treatment system and sprinkler water.
- Emergency power for the air treatment system.
- Booster pump to provide pressure to the injector.
- Scales to weigh the cylinders.

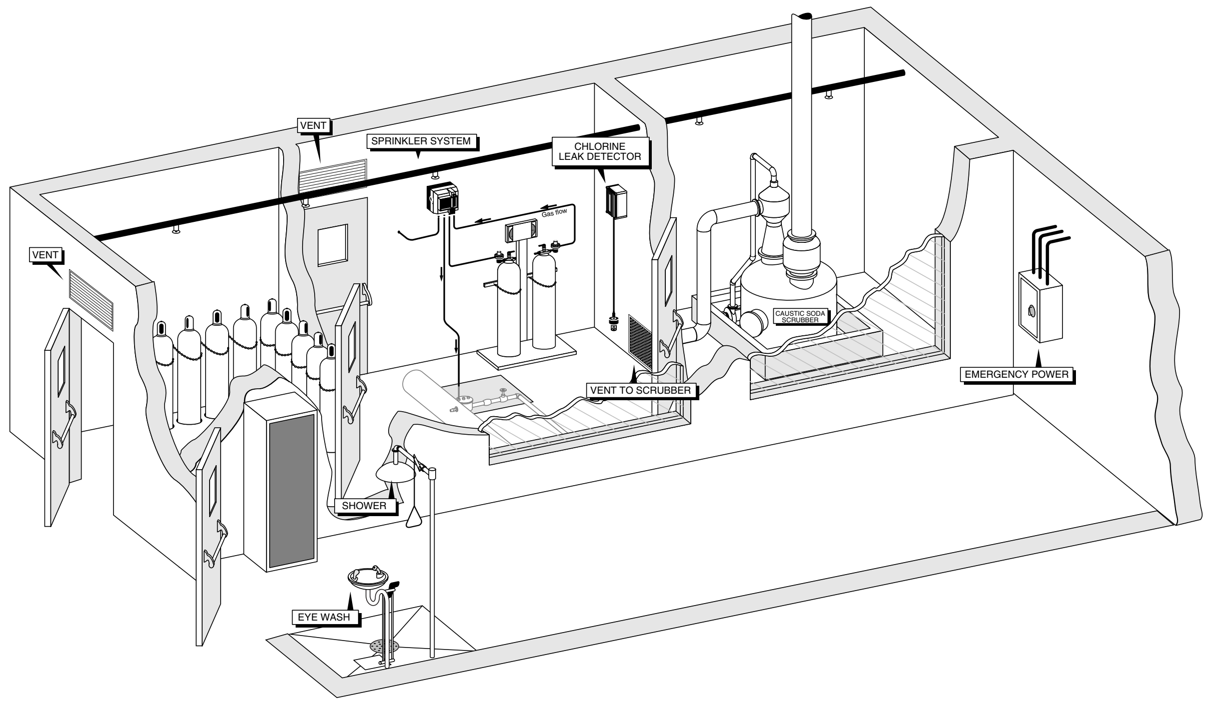
Gas Containers

Gas chlorine is provided in 100-pound and 150-pound cylinders, 1-ton containers, and tank cars. (These values are the net weight of liquid chlorine in the container.) Most small systems use 100- and 150-pound cylinders.

Hazard Assessment

Gas chlorine is classified as a poison gas and an inhalation hazard by OSHA, EPA, and DOT. The UN number for chlorine gas is 1017, and the DOT classification hazard number is 2.3 (poison gas).

Chlorine Gas Treatment Room



[Note: Gas chlorine has been reclassified. As a result, different regulations apply to gas chlorine.]

Safety Consideration

The inspector must focus on the adequacy and reliability of the chlorination system to provide disinfection. However, the threat of injury or illness to the operator caused by the chlorination system means a review of the major safety considerations for gas chlorination systems is advisable.

Sanitary Deficiencies – Gas Chlorination Systems

Facility

[Note: The sanitary deficiencies related to Chemical Feed Systems and Disinfection - Dosages and Residuals earlier in this chapter should also be applied to this section.]

1. **How are leaks detected? At what detection concentration are automatic detectors set and have they been tested recently?**

   Automatic detectors should be tested at least monthly. This test can be done by placing a small pan of bleach under the air intake and adding some vinegar.

   Many operators set the detection level at the high end of the range, although it should be set at the low end (1 ppm). Although this situation may not constitute a sanitary deficiency, it does not comply with current OSHA recommendations.

2. **Is the sensor tube for the automatic detector near the floor level? Is the tube screened?**

   Look at the leak detector. Because chlorine gas is heavier than air, the intake should not be more than 12 inches from the floor. Some new detectors use solid state sensors, which must be replaced each year.

3. Is the chlorination equipment properly contained?

To meet current Uniform Fire Code requirements, the room that houses the chlorination equipment must be designed to fully contain a chlorine release or leak.

One common deficiency of these rooms are floor drains. They often are connected to other parts of the facility and should be sealed when not being used for floor cleaning.

4. Is the chlorination room vented at floor level with an adequate make-up air supply coming from the ceiling across the room? Is the vent switch located outside by the door? Does the system store chlorine gas in quantities sufficient to be covered by the Uniform Fire Code?

The air exhaust and intake systems must be designed to provide a slight negative pressure in the chlorine room when the air ventilation system is operating. A switch on the outside of the door allows the operator to turn on the air handling system prior to entry. The ventilation system may be wired to come on automatically when the door is opened or when the light is turned on.

Systems which have chlorine gas in quantities that are covered by the Uniform Fire Code must be equipped with scrubbing devices that will keep chlorine concentrations below 10 ppm[1] in discharges of contaminated air.

Many organizations have classified chlorine rooms as confined spaces. **[Note: Do not enter if you are not sure that the air handling system is operating properly.]**

5. Does the door in the chlorination room open out and have a panic bar and a window?

The panic bar and outward-opening door are OSHA requirements and not a direct sanitary deficiency. The window allows the operator to observe the conditions in the chlorine room without entry, thus reducing exposure to hazardous conditions.

6. Are there any cross-connections in the chlorine feed make-up water or injection points?

A common cross-connection problem in chlorination facilities is a drinking water connection to the injector and the make-up water for hypochlorination systems. There must be a physical separation or an acceptable backflow preventer between the drinking water system and the feed water to the injector.

An atmospheric vacuum breaker must be installed on make-up water lines. A pressure vacuum breaker must be used if there is a shut-off valve on the discharge end of the make-up water line, such as a nozzle on the end of the hose.

7. Is there an alarm tied to interruptions in the chlorine feed?

Low system vacuum and low cylinder pressure are the two most common alarm systems. If there is an alarm system, does it work? Does the system shut down the flow of water, or just initiate an alarm?

8. Does the system use automation, pace with flow, chlorine residual analyzer, or other system to adjust feed rates? Does it work?

It is common to find automatic equipment that does not work. Determine whether the system provides adequate residual during high flows and whether the residuals are higher during low flows. Failure of the system to follow the flow conditions is a significant sanitary deficiency.

9. Is there more than one cylinder, and are they equipped with a manifold and an automatic switch-over to avoid running out of chlorine?

The inspector should determine whether the switch-over devices work. If there is only one cylinder, determine if the operator shuts off water flow when the cylinder is changed. If not, the disinfection is interrupted.

[1]*Handbook of Chlorination and Alternative Disinfectants*, Fourth Edition, G.C. White.

10. Are the cylinders on a working scale?

A scale must be used to determine the amount of chlorine used each day. To calculate dosage and signal the amount of chlorine remaining in the cylinders, scales must be maintained and calibrated.

11. Are the tanks in use a quarter turn open with a wrench in place for quick turnoff?

Full feed of 40 pounds per day can be obtained from a cylinder by opening the valve one-quarter of a turn. Opening the valve more is not necessary. By opening it only one-quarter of a turn and leaving the wrench in place, the operator can quickly shut down the cylinder if there is a release.

12. Are all cylinders properly marked and restrained to prevent falling?

Cylinders should be marked and stored in a manner that clearly indicates which cylinders are full and which are empty.

All cylinders must be restrained two-thirds of the way from the bottom with a chain that prevents falling. In an earthquake zone, they must also be restrained at or near the bottom.

13. Does the facility transport gas chlorine cylinders? If so, are the requirements of 49 CFR parts 171 and 172 followed?

Remember, this is not a direct sanitary deficiency. However, cylinders that are transported must be secured in two locations, and the vehicle must have DOT placards on all sides. The driver must have a Commercial Drivers License (CDL) with a hazardous material rider. In addition, these regulations require specific training and other transportation considerations.

14. Is the proper concentration of ammonia available to test for leaks?

Use a concentrated ammonia solution containing 28 to 30 percent ammonia as NH_3 (this is the same as 58 percent ammonium hydroxide or, HN_4OH, commercial 26^0 Baume). Household ammonia is not strong enough to reliably indicate a chlorine leak.

15. Are there adequate leak containment provisions?

The Uniform Building Code requires the air treatment system and fire sprinkler water to be totally contained.

16. Are safe practices followed during cylinder changes and maintenance?

The key here is training. Has the utility provided detailed training on handling and changing cylinders? This training should be documented and practiced at least yearly.

Check to see if there is a written standard operating procedure (SOP) for changing cylinders. If not, there is no assurance that the staff is using a safe procedure, and it is not the inspector's job to have them change a cylinder in order to determine if the procedure is safe.

17. How many individuals are present when the chlorine cylinders are changed?

Industry standards call for two people, one to change the cylinder and one to watch. If this is not possible, switching to hypochlorination may be a safer option.

18. What type of respiratory protection is used?

When respiratory protection is required, the utility must provide a written respiratory protection program. This program includes a fit test of the device and training in its selection, use, and care. In addition, the program requires annual physical exams of all personnel required to use the devices.

Cartridges on cartridge respirators must be changed every 6 months. All respirators must be inspected each month.

The current thinking on self-contained breathing apparatuses (SCBAs) is to limit their use to emergency response crews and to have operators use an emergency escape mask, either cartridge or self-contained. (Many small systems depend on the local fire department because of the risks associated with chlorine gas and on-going training requirements to maintain proficiency.) To use a SCBA in a hazardous atmosphere requires a minimum of three people, two with SCBAs and total containment suits and one observer. **In addition, the personnel must be trained in hazardous material response.**

19. Is there an emergency plan, and when was it last practiced?

The facility must have a written emergency evacuation plan and should practice implementing the plan at least annually. This is an OSHA requirement.

20. What is the operating condition of the chlorinator?

Gas chlorinators should be disassembled, cleaned, and rebuilt each year. The rotameter can provide a clue as to the frequency of cleaning. If it is coated on the inside with a heavy green or blackish film, the machine is past due for cleaning.

In addition, general appearance can also be a key. Check preventative maintenance and repair records and determine whether preventative maintenance is routinely performed. Some indicators of problems for gas chlorination are valves, piping, and fittings that are damaged, badly corroded, or loose; no gas flow to the chlorinator; and frost on tank, valves or piping.

21. Is redundant equipment available, and are there adequate spare parts?

Disinfection must be continuous. Therefore, stand-by equipment of sufficient capacity to replace the largest unit is recommended. If stand-by equipment is not available, flow to the water system should be stopped and critical spare parts should be on hand for immediate replacement. At a minimum, the system must have spare diaphragms and a set of lead gaskets.

22. Are the appropriate lighting, guards, and railings in place? Are there other safety concerns, such as electrical hazards?

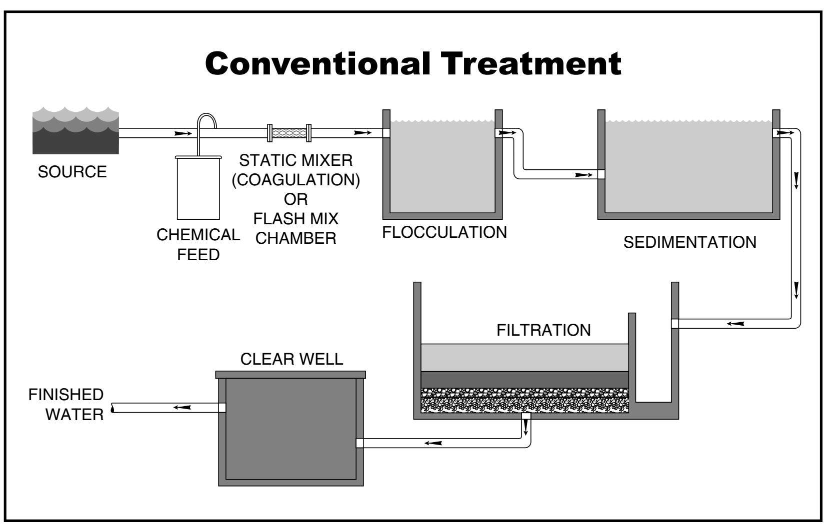
All electrical fixtures in a chlorine room should be NEMA 4X (corrosion resistant).

[Note: These general sanitary deficiencies on chemical feed systems are applicable to all feed systems used for any and all chemicals employed in the treatment process.]

Turbidity Removal

Purpose of Treatment

According to the SWTR, all community and non-community public water systems that use a surface water source or a ground water source under the direct influence of surface water must meet certain criteria for the removal or inactivation of *Giardia* cysts and of viruses. For surface water systems required to filter, the removal of turbidity by one of the treatment processes is a key step in complying with these requirements. In recent years, outbreaks caused by *Cryptosporidium* in the United States have prompted recommendations from EPA and the American Water Works Association (AWWA) to achieve turbidity removals well beyond the levels required by the SWTR's performance standards as measured in the combined filter effluent. This goal encourages direct and conventional filtration plants to be optimized to achieve maximum turbidity removal efficiency and to keep the effluent from each individual filter below 0.1 NTU at all times.

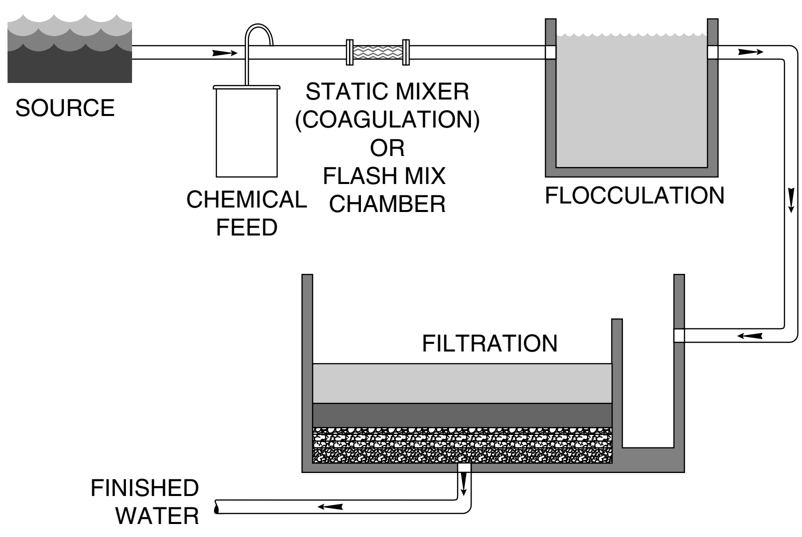


Treatment Processes

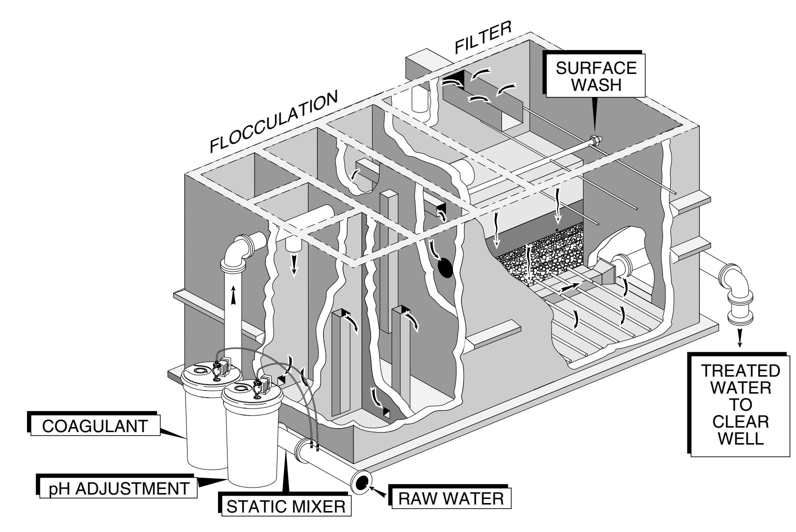
Conventional Treatment. The most widely used technology for removing turbidity and microbial contaminants from surface water supplies includes coagulation, flocculation, and sedimentation, followed by filtration. Conventional treatment plants typically use aluminum or iron compounds in the coagulation processes, but polymers may also be used to enhance coagulation and filtration. Generally, gravity filters with sand, dual, or mixed media filters are used. The filtration rates may be from 2 gpm/ft^2 with sand as the single medium up to 6 gpm/ft^2 for dual and mixed media filters**.**

Direct Filtration. This process is similar to conventional treatment, except sedimentation is omitted. Direct filtration generally consists of coagulation, flocculation, and filtration using dual or mixed-media filters. A variation of this process, which may be called "in-line filtration," includes only filters preceded by chemical coagulant application and mixing. Direct filtration is best suited to systems that have high quality and seasonally consistent influent supplies. The influent generally should have turbidity of no more than 10 NTU and color of less than 30 units.

Direct Filtration



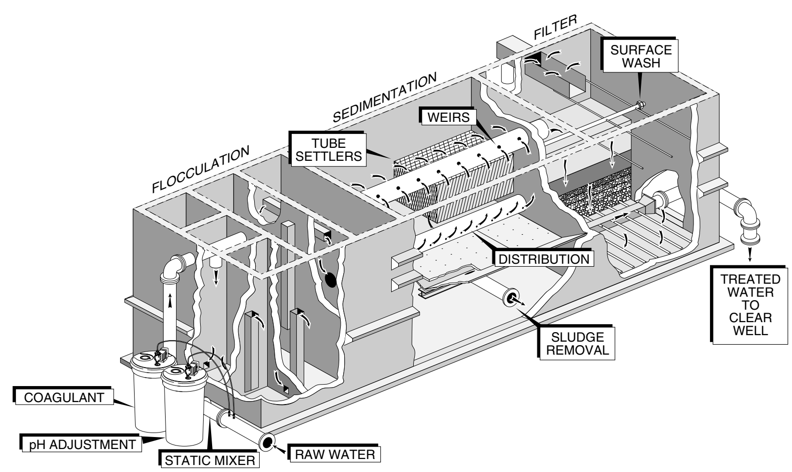
Direct Filtration Package Plant



Packaged Filtration. This technology generally includes the processes found in a conventional treatment plant. The unit processes are combined in a package by an equipment supplier and can be delivered to a site where a simple hook up of pipes is all that is necessary to provide treatment. Package filtration may be cost effective for small communities but, contrary to some literature, requires skilled operators to achieve consistent performance. This is particularly true when the raw water is susceptible to rapid changes in quality.

Each of the three treatment processes discussed above depends on the operators successfully providing coagulation and flocculation of the particles in the raw water. As discussed earlier, coagulation and flocculation are chemical and physical processes to improve the particulate and colloid reduction efficiency of subsequent settling or filtration processes. Coagulation involves feeding chemicals to destabilize the similar charges on suspended particles, allowing them to coalesce and thereby begin to form floc. This process is very

Conventional Treatment Package Plant



difficult to control with surface waters of changing turbidity, temperature, alkalinity, and color. Flocculation, which partly overlaps the coagulation process, requires gentle mixing of destabilized particles to form floc that can settle, or be filtered, ou, of the water. The inspector must be able to determine if the operators are using proper process control procedures to ensure removal of turbidity and associated pathogens. A careful review of the system's operating records and logs will help make such determinations.

Sanitary Deficiencies - Conventional Treatment

Coagulation - Rapid Mix

[Note: The sanitary deficiencies related to chemical feed systems earlier in this chapter should also be applied to this section.]

1. **Is a coagulant used at all times the plant is in operation?**

   The inspector should ask if a coagulant is always added when the plant is in operation. If a coagulant is not being added, the state primacy agency should be notified immediately because it may want to issue a boil water notice. The inspector should check that there are redundant pumps for the primary coagulant and polymers and that spare parts are available. In answering the questions below, the inspector should observe the operator's level of skill and understanding.

2. **What type and combination of coagulants are being used?**

   Alum or ferric salts are used as primary coagulants. The effectiveness of alum decreases when pH exceeds 8.0. Low molecular weight cationic polymers are also used as primary coagulants. Typically used with raw water that is low in turbidity, they are more applicable to direct filtration. Polyaluminum chloride combines alum and polymer so the operator adds only one chemical. Nonionic and anionic polymers are used as coagulant, flocculent, filter, and backwash-water aids.

3. **For what purpose is each coagulant chemical used?**

   The operator should be able to fully explain the purpose of each coagulant chemical and why it is injected at a particular point. For example, "This low molecular weight polymer which is injected immediately downstream of rapid mix is used as a coagulant aid, and this high molecular weight polymer is added at a bend in the pipe prior to the filters as a filter aid." Is the plant adding too many coagulant chemicals?

4. **How is the dosage of each coagulant chemical determined?**

   The inspector should determine whether the operator uses a streaming current monitor, jar tests, pilot studies or combinations of such tests to determine dosage. Ask the operator to show you how to make up stock solutions for jar tests for both alum and polymers, how to run and dose a jar test, how to calculate mL/min from mg/L, how to calibrate the feed pump, and how to prepare the proper dilution for day tanks. An operator unable to perform these routine operations likely does not have the advanced skill needed to run rapid sand filtration. Typical filter aid dosages range from 0.02 to 0.1 mg/L, and backwash water dosages range from 0.1 to 0.15 mg/L. Since polymers typically neutralize the charges on particles, it is easy to overdose.

5. **Is there a process control plan for coagulation addition?**

   What type of process control plan has been developed to control chemical dosages during routine and emergency levels of raw water turbidity or other water quality problems? Does the system have shortened filter runs due to filter-clogging algae, and what is done to control this and other special problems? Does the system respond to changes in raw water quality with changes in process control in order to keep the quality of finished water high?

6. **Is the rapid mix process adequate?**

   The rapid mix process is a critical part of the coagulation process. Mixing can be accomplished by several means, such as mechanical units, diffusers, in-line mixers, and baffles. The inspector should note the type of mixer and determine if the mixing equipment is functioning properly for all flows and all ranges of coagulant. Inadequate mixing can severely affect the performance of downstream processes, particularly when raw water quality is deteriorating.

Flocculation

1. **Is the flocculation process adequate?**

   Problems with short circuiting in the flocculation basin should be noted. The inspector should observe if there is good floc formation at the effluent end of the flocculation basin prior to entry into the sedimentation basin. The best floc size may range from approximately 0.1 mm to 3.0 mm, depending on the characteristics of the treatment plant. The paddles of mechanical flocculators should be in place and turning properly.

Sedimentation

1. **Is the sedimentation process adequate?**

   The inspector should describe the sedimentation process (e.g., tube settlers, lamealla plates) and note problems with short circuiting or excessive turbulence.

   For upflow-solids-contact clarifiers, the mixer must remain in operation to keep the blanket in suspension when the unit is shut down.

   There should be little or no carryover of floc from the sedimentation basin to the filters. As a rule of thumb, the coagulation, flocculation, and sedimentation processes are functioning properly if the turbidity of the effluent of the sedimentation basin is monitored every 4 hours and measures less than 2 NTU. The inspector may want to calculate the surface overflow rate under peak flow conditions and compare the calculated value with the state's design standards. The inspector should determine if sludge removal is adequately addressed in the plant's operational procedures. Those procedures should include removal of sludge from the sedimentation basins and ultimate sludge disposal from the treatment plant.

Filtration

1. **Is the filtration process performing adequately?**

   The primary purpose of filtration is to remove suspended solids. Filter performance can be measured by the reduction in turbidity through each filter. The inspector should be concerned with the turbidity removal characteristics of each filter in service.

2. **Is there adequate pre-treatment?**

   The quality of water entering the filters must be monitored to ensure that the filter is performing according to design guidelines. The filtration process, regardless of type, cannot perform effectively if the influent's characteristics are unacceptable. **[Note: This condition is also critical in systems such as slow sand, diatomaceous earth (DE), and membrane filtration.]**

3. Are there rapid fluctuations in the flow through the filter?

Rapid changes in flow can cause breakthrough. The inspector should record causes of rapid flow fluctuations, e.g., operation procedures, recycling of backwash water, or a cycling rate control valve.

4. What control and assessments are used to evaluate the performance of each filter?

The inspector should determine what methods are used, such as continuous turbidity and other monitoring, to evaluate performance, including raw and settled water turbidity, pH, alkalinity, and hardness. Also determine the frequency of the evaluations. Systems covered by the IESWT Rule and LT1 must continuously monitor the turbidity of each individual filter and keep a record of the measurements taken at 15 minute intervals. The inspector should request those records and inspect them to make sure the filters are operating properly and that the system has not exceeded triggers which would require follow-up action.

5. Are instrumentation and controls for the process adequate, operational, and in service?

Because turbidimeters must be extremely accurate, they should be calibrated (secondary and primary standards) regularly according to manufacturer's recommendations. Head loss through the filter is also important to filter operation, as is the use of rate of flow controllers. The instruments for these measurements and controls should be functioning properly. The inspector should determine if proper filtration and backwash rates are used where applicable. If the filter-to-waste option is available at the plant, the inspector should ensure that it is used properly and that testing is done to check the adequacy of the procedure. The operator should be able to explain the significance of the readings obtained from the instrumentation at the facility.

6. Are the filters and related equipment operated properly and in good repair?

Is there sand in the clearwell indicating underdrain failure or severe media problems? Are backwash pumps operated at too low a rate, leading to mudballs and short-circuiting, or at too high a rate, which will wash the media out of the filter. Is the surface wash operated to break up the mat on top of the filter? Is the media checked for the accumulation of mud on the surface and mudballs within the media? Is the top layer of sand manually cleaned regularly if mud accumulation is a problem? Is the media expansion during backwash adequate at all water temperatures? Is the backwash rate increased and decreased slowly to avoid damaging the filter? Is the media probed to check for adequate media depth and to find uneven gravel levels or dead spots where damage to the underdrain is not allowing bed expansion? During operation, are there depressions, cracking, or other indications of short-circuiting in the media? Is there filter-to-waste capability and is it used? Does the system have a maintenance plan for the filter and all related appurtenances?

Pressure filters are a special concern due to the difficulty of opening the bolted hatch for inspection and assessment; the inspector should ask when the hatch was last opened and the filter inspected for the above items.

7. What initiates a backwash, and is there an SOP in place?

Backwashing may be initiated due to head loss, time, or effluent turbidity. It is important that all the operators of a system use the same criteria. In addition, the system should have a written standard operating procedure for backwashing and for returning the filter to service to ensure that all staff do these tasks in the same way.

The inspector should check how backwash water is disposed of to ensure compliance with state and federal regulations and to determine its impact on the treatment process. Research shows that recycling backwash water may concentrate *Giardia* cysts, *Cryptosporidium* oocysts, and disinfection byproducts. Equalization or treatment of backwash water and other recycle streams prior to their injection at the plant headworks helps minimize these risks. The inspector should check to ensure the system's compliance with the Filter Backwash Recycling Rule.

The inspector needs to have the operator backwash a filter during the sanitary survey, if feasible, in order to determine the existence of any of the conditions noted above. The inspector should also examine preventative maintenance and repair records.

8. **If the plant is a conventional plant, is it meeting the disinfection byproduct precursor removal requirements of the Stage 1 Disinfectants/Disinfection Byproducts Rule?**

   The inspector should review the system's operating records and quarterly reports to the state to make sure adequate TOC is being removed in compliance with the Stage 1 DBP Rule. The inspector should request a copy of the system's State 1 DBP Rule monitoring plan and review it as well.

9. **Was the system required to prepare a disinfection profile? Is the profile available for review?**

   The inspector should review the system's disinfection profile on site and check to ensure that adequate CT is available to meet the removal/inactivation requirements of the SWTR. Any planned or potential changes in disinfection practices should be discussed.

Slow Sand Filtration

This process consists of a single medium of fine sand approximately three to four feet deep. The medium is not backwashed as it is in a rapid sand filter; instead, it is cleaned manually by removing the surface of filtration medium.

Slow sand filters operate in the range of 0.03-0.10 gpm/ft^2, and therefore require extensive land area. These filtration systems may be appropriate for small communities, but must include adequate (physical, not chemical) pre-treatment. They are not suitable for raw water with high turbidities and rapidly changing quality. These filters are operated under continuous submerged conditions. They function using biological mechanisms (schmutzdecke) and physical-chemical mechanisms.

Sanitary Deficiencies - Slow Sand Filtration

1. **What pre-treatment is used, if any?**

   Because chemical pre-treatment with a coagulant is not needed and not recommended due to filter clogging, what pre-treatment, if any, is used? Is a screen, chlorine, or a roughing filter (coarser sand) used prior to slow sand?

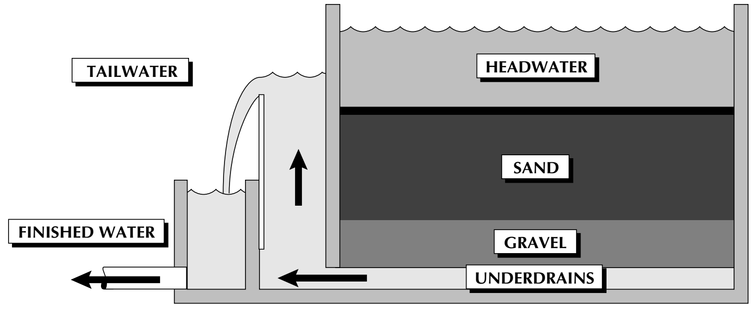
2. **What method is used to clean the slow sand filters?**

   What is the average and worst case time between cleaning the filters? Is cleaning accomplished by scraping (the most common method) or by harrowing (low backwash rate while turning the medium)? What is the sand depth? New sand should be added when the depth approaches 24 inches.

3. **Are there redundant slow sand filters?**

   Slow sand filters perform poorly for 1 or 2 days, and sometimes up to 2 weeks, after being cleaned. Therefore, it is essential that the facility have redundant units with a filter-to-waste cycle to allow the filter to build up a biological mat. Filters can be returned to service sooner when the harrowing technique of

Slow Sand Filter and Schmutzdecke



cleaning is used. Slow sand depends on microbes, and their worst enemy is the lack of moisture. The inspector should ask if the filter is ever left unsubmerged and, if so, for how long.

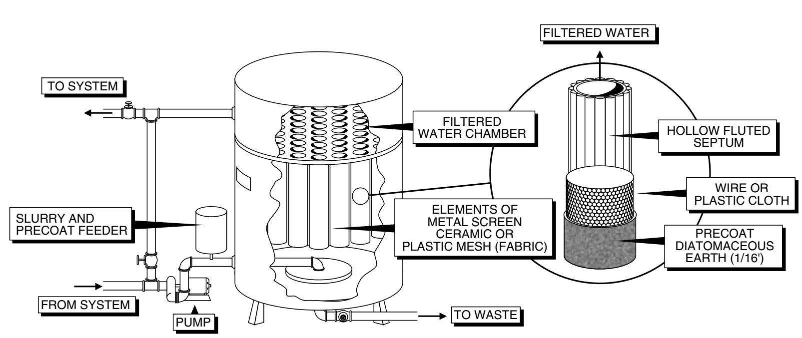
4. **Is the slow sand filter covered and light-free?**

   Slow sand filters should be enclosed in a building so they can be cleaned and so ice buildup during the winter can be avoided. The housing should also be light free to eliminate algae growth.

Diatomaceous Earth (DE) Filtration

DE filtration, also known as precoat or diatomite filtration, is appropriate for direct treatment of surface waters to remove relatively low levels of turbidity and microorganisms. Diatomite filters consist of a layer of DE (about 1/8-inch thick) supported on a septum or filter element. Septa may be placed in pressure vessels or operated under a vacuum in open vessels. Units are generally designed for a filtration rate of 1 gpm/ft^2.

Diatomaceous Earth Filtration



Sanitary Deficiencies – Diatomaceous Earth Filtration

1. **What levels of precoat and continuous body feed are added?**

   The minimum amount of filter precoat should be 0.2 lb/ft^2, and the minimum thickness of precoat should be 0.5 cm to enhance cyst removal. DE filters do not need a filter-to-waste cycle because of the precoat process. What amount of precoat is used?

   Continuous body feed is required because the filter cake is subject to cracking. Also, if there is no body feed there will be a rapid increase in headloss due to buildup on the surface. What dosage is used for body feed and is it continuously added? Can the operator verify the dosages?

2. **Is the flow interrupted?**

   Interruptions of flow cause the filter cake to fall off the septum, allowing pathogens to pass through the DE filter. (For this reason, DE is not a recommended technology for on/off operation.) Is the precoating reapplied any time flow is interrupted at this facility?

3. **When is backwashing initiated?**

   The rate of body feed and size of the media are critical for determining the length of the filter run. Filter runs typically range from 2 to 4 days. Shorter runs minimize filtered water taste and odor problems arising from the decomposition of organic matter trapped in the filter. DE is effective for removing algae, but if prechlorination is used, increased taste and odor can be expected. The inspector should determine whether this facility has taste and odor problems that are attributable to long filter runs or prechlorination? How often is the septum inspected and cleaned (~100 filter runs)? How is the spent filter cake disposed of?

Bag and Cartridge Filtration

Bag and cartridge filters use filter elements (ceramic, paper, or fiber) with pore sizes as small as 0.2 μm. This pore size may be suitable for producing potable water from raw water supplies containing moderate levels of turbidity, algae, and microbiological contaminants. The advantage to small systems of these microporous filters is that no chemicals, other than the disinfectant, are required. The use of this type of filtration should be limited to low-turbidity waters (<5.0 NTU) because of susceptibility to rapid headloss buildup. Many installations address this problem by installing sand or dual media pressure filters, without coagulation, for pre-treatment.

Sanitary Deficiencies - Bag and Cartridge Filtration

1. What type of pre-treatment is used?

Bag and cartridge filters can be used on raw water of any quality depending on the degree of pre-treatment that is provided. The inspector should describe the pre-treatment that is used at the facility and whether the bag and cartridges are used as the primary treatment or to provide an extra level of physical removal to ensure public health protection (for example, filters added after a poorly performing conventional treatment plant).

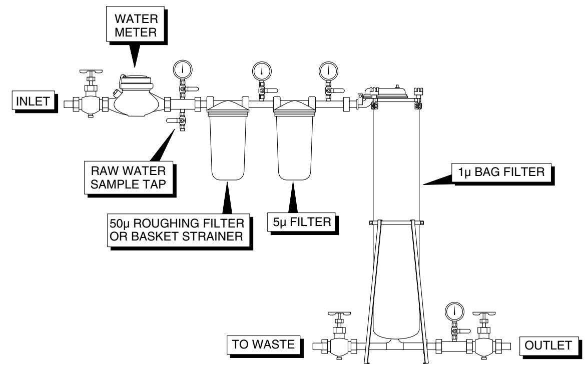
2. What is the micron rating for the final unit?

There should be at least two stages of filtration, the first using a 10 micron or larger pore size and the second using a 1 to 5 micron pore size. The inspector should verify through the labeling on spent filters or manufacturers' invoices that the second filter has not been replaced by one with a larger pore size because the filter runs were too short. If the pore size of the second filter is not in the 1 to 5 micron range, pathogens can pass through the filter, resulting in a serious public health concern.

3. What are the average and the shortest times between filter replacements?

Depending on site-specific conditions, these filters show excellent to poor turbidity reductions when used with turbid raw water of less than 10 NTU. Some bags will last only a few hours when turbidity exceeds 1 NTU. The inspector should ask the operator what seasonal site-specific conditions may shorten filter runs. The inspector should also ask whether the facility can meet the turbidity standard for finished water at all times. Is bag replacement so frequent that upgrades to the pre-treatment are justified? The inspector should make sure the system never operates without the filter cartridges or bags in place. Some small systems have been known to remove them when turbidity necessitates frequent change out.

Bag and Cartridge Filtration

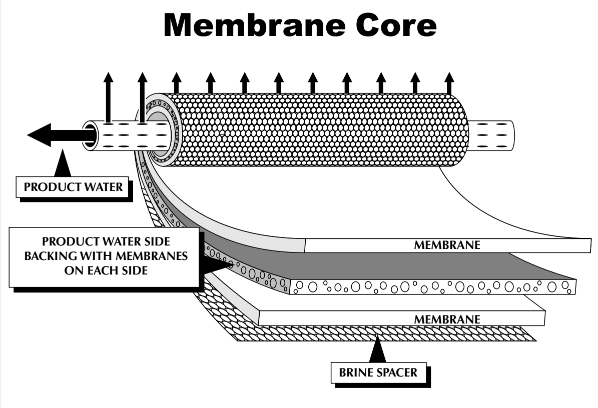


4. Is there a manufacturer's challenge for *Giardia* removal for the filter and housing being used?

To optimize filter run time, operators may have experimented with different filters from various manufacturers. Different filters may not be compatible with the original housing, jeopardizing the seal and allowing pathogens to pass through the filter. The inspector should check that the housing and filter currently being used are the same ones that were used in any challenge study that is on record at the plant. If they are not the same, the inspector should bring this to the attention of the state, which may want to perform a new challenge study. Otherwise, are there any filter integrity tests required by the state and have they been performed?

Membrane Filtration

The membrane filtration process involves passing water at high pressure through a thin membrane of hollow-fiber or spiral-wound composite sheets. Microfiltration can remove bacteria, *Giardia*, and some viruses. Membrane filtration may be attractive for small systems because of its small size and because it does not require chemical coagulants. Periodic chemical cleaning is required and the resulting product requires proper disposal. Membranes can be grouped into the four categories described below. The selection of a membrane is based on site specific treatment goals (for example, inorganics removal, natural organic matter removal, particulate removal or pathogen removal).



The advantage of membranes is that filter quality is achieved regardless of changes in turbidity, microorganism burden, algae blooms, pH, temperature, or operator interaction. Instead of compromising the quality of finished water, membrane systems lose operational performance, such as increasing pressure differentials across the membrane and shortening of the time between cleanings. The necessary level of operator skill is classified as basic, except for reverse osmosis, which is classified as high because of the high level of pre-treatment needed. Fouling and scaling of the membranes are the main concerns, especially for high-pressure membranes.

Reverse Osmosis (RO). RO uses high pressure to remove salts from brackish water and seawater. It excludes particles less than 0.001 microns in size. RO is an absolute barrier for cysts, bacteria, and viruses. Because it is used for very specific water quality problems, RO is discussed in more detail under Speciality Treatments in this chapter.

Nanofiltration (NF). NF is also called membrane softening and low pressure RO. It is effective in the removal of calcium and magnesium ions (multivalent cations or hardness). NF is the most efficient membrane for removing natural organic matter to control disinfection byproducts (DBPs). It excludes molecules larger than 0.001 microns, the organic compound range, and is an absolute barrier for cysts, bacteria, and viruses.

Ultrafiltration (UF). UF uses low-pressure membranes to remove natural organic matter and particulates. UF excludes molecules larger than 0.01 microns, the molecular/macromolecular range, and is an absolute barrier to cysts. It provides partial removal of bacteria and viruses.

Microfiltration (MF). MF uses low-pressure membranes to remove particulates and suspended solids. MF excludes molecules larger than 0.1 microns, the macromolecular/microparticle range. It is an absolute barrier to cysts and provides partial removal of bacteria and viruses.

Sanitary Deficiencies - Membranes

[Note: The sanitary deficiencies related to chemical feed systems earlier in this chapter should also be applied to this section.]

1. What type of membrane is used, and what is its intended purpose?

The inspector needs to identify which of the above categories of membranes is being used and why it was selected. For example, NF may have been chosen to remove the organic compounds that are precursors to DBPs.

2. What type of pre-treatment is used?

A 500-micron screen is usually the only pre-treatment needed for MF. For RO and NF systems to operate economically, suspended solids, microorganisms, and colloids have to be removed before these technologies can effectively remove dissolved contaminants. MF is the best pre-treatment for RO and NF. The inspector should describe what pre-treatment is performed prior to the final membrane.

3. What safeguards exist to warn operators of membrane failure?

Membranes provide a very effective barrier to pathogens, depending on which membrane is used. However, membranes are only a single barrier. If that barrier fails, pathogens are not removed by any other means. Some membranes have TDS meters, others have automatic membrane integrity tests to determine the integrity of the membrane; an integral module will exhibit little, if any, decay over the test period. The inspector should discuss what type of membrane integrity test is used and what is done if the test shows the membrane is failing.

Are redundant units available in case one of the units fails, is being cleaned, or is undergoing membrane replacement?

4. **What are the fouling rate and life of the membranes?**

   Fouling can be controlled by pH adjustments and the degree of pre-treatment provided. The smaller the pore size of the membrane, the greater the concerns about fouling. For MF, pH adjustments are not needed since MF does not remove uncomplexed dissolved ions. Generally, a silt density index of less than 1.0 means that the fouling potential is low. The inspector should describe the fouling problems that the facility experiences and how they affect membrane life.

5. **What is the percentage recovery and what technique is used for backwash?**

   The inspector should determine the percentage recovery (the percentage of raw water that actually makes it through the membrane) for the membranes used at the facility. For example, the recovery for MF is approximately 90 percent. The inspector should also discuss how backwashing is accomplished (for example, gas backwash), how often it is performed, and how the raw water quality affects the volume required. For example, the backwash volume for MF is approximately 6 percent for low turbidity water and up to 12 percent for high turbidity water.

6. **What is the frequency of cleaning and disposal of cleaning fluids and brines?**

   How often do the membranes require cleaning? The inspector should describe what chemicals are used and how the system disposes of them. Several methods are available to dispose of the brine: sanitary sewers, surface water streams, lagoons or holding ponds, land application, and recycling back to the headworks. How is the brine disposed of at this facility? The inspector should check to see that the brine is properly disposed of. Some contaminants, if present in high concentrations in the raw water, may create a brine that is a hazardous waste.

7. **What is the condition of the plant, gauges and appurtenances?**

   Membrane plants are mechanically complex and have many automatic valves and many more connections that require o-rings to achieve a tight water seal. The inspector should determine whether all the valves are operating properly and whether there are leakage problems throughout the piping network.

Corrosion Control

Corrosion causes the deterioration of pipe materials. It generally occurs in drinking water distribution systems by the principle mechanism of dissolution. The dissolution of pipe materials occurs when favorable water chemistry and physical conditions combine.

Need for Treatment. Altering water quality characteristics through treatment can extensively reduce some forms of corrosion activity, but may have less significant effects on others. Many public water systems must implement optimal corrosion control treatment to meet the lead and copper action levels established by the federal Lead and Copper Rule.

Corrosion Control Treatment. Corrosion control treatment is principally intended to inhibit dissolution. The objective is to alter the water quality so that the chemical reactions between the water supply and the pipe materials favor the formation of a protective layer on the interior of the pipe walls. Corrosion control treatment attempts to reduce the contact between the pipe and the water by creating a film that is:

- Present throughout the distribution and home plumbing systems.
- Relatively impermeable.
- Resistant to abrupt changes in velocity.
- Less soluble than the pipe material.

Corrosion control technologies can be characterized by two general approaches to inhibiting lead and copper dissolution:

- Precipitation of insoluble compounds on the pipe wall as a result of adjusting the water chemistry.

- Passivation[2] of the pipe material itself through the formation of less soluble metal compounds (carbonates or phosphates) that adhere to the pipe wall.

In general, the available corrosion treatment technologies are precipitation by calcium hardness adjustment and passivation by pH/alkalinity adjustment or the addition of a corrosion inhibitor.

Sanitary Deficiencies – Corrosion Control

[Note: The sanitary deficiencies related to chemical feed systems earlier in this chapter should also be applied to this section.]

1. **What are the results of current lead and copper sampling?**

   Depending on whether the lead or copper action levels were exceeded, the results may indicate different corrosion control strategies.

2. **What are the characteristics of the water entering and leaving the treatment plant?**

   The operator should be able to provide test data that indicate the chemical characteristics of the water entering and leaving the treatment plant. These data should be the basis for developing an appropriate corrosion control program and for demonstrating that the chemicals being applied are accomplishing the desired goals.

3. **What sampling is conducted in the distribution system as part of the corrosion control program?**

   Appropriate sampling in the distribution system must be done to ensure the desired results and to prevent problems possibly associated with overfeeding chemicals. For example, excessive feeding of a phosphate inhibitor could encourage the growth of undesirable biological slimes in the distribution system piping.

4. **Is the test equipment to monitor the data appropriate and in good working order?**

   Since pH is generally a critical parameter in corrosion control, the test equipment must be accurate and properly calibrated.

Iron and Manganese Removal

Iron (Fe) and manganese (Mn), which comprise approximately 5 percent and 0.1 percent, respectively, of the earth's crust, are found widely distributed in surface and ground waters in nearly all geographic areas.

Fe and Mn in Surface Water. Iron and manganese may be present in surface water due to their dissolution from the associated geologic formations or from the decomposition of organic materials. Nearly all of the available methods for iron and manganese removal, except ion exchange, rely on the oxidation of the soluble forms to insoluble forms along with or followed by clarification or filtration to remove the resulting precipitates. Therefore, the processes discussed in the section on surface water treatment (pre-treatment, chemical addition, coagulation, flocculation, sedimentation, and filtration) will generally be adequate to deal with iron and manganese problems in surface water.

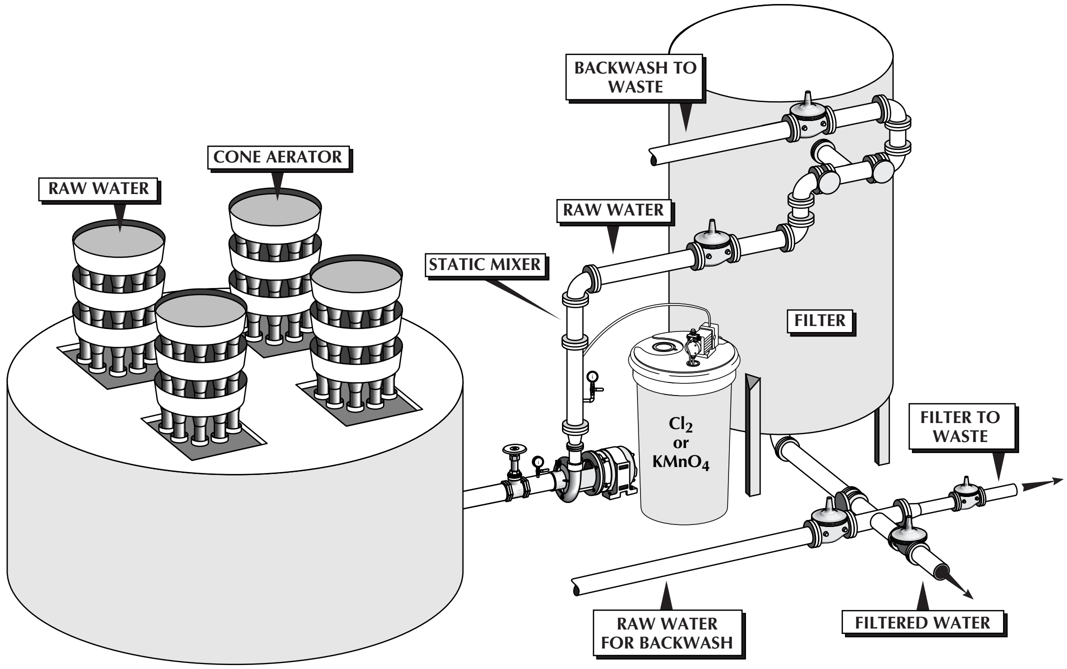
Fe and Mn in Ground Water. In ground water, iron and manganese are found particularly in the ground water drawn from underground formations of shale, sandstone, and alluvial deposits. Iron in ground water is normally in the range of a few hundredths to about 25 mg/L, with the majority of wells drawing water in which the Fe concentration is less than 5 mg/L. Manganese is usually present in ground water in a concentration less than 1 mg/L, although in some places manganese levels have been significantly higher.

Treatment Processes. Processes for removing iron and manganese from ground water will generally be one of the following:

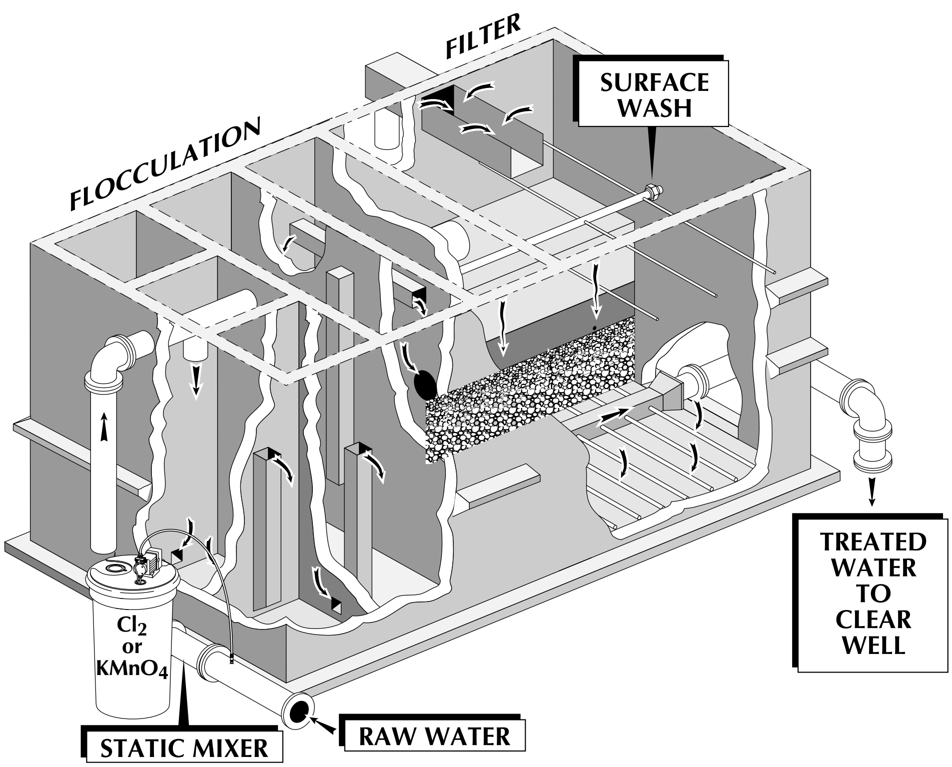
- Oxidation (aeration, chlorination, or potassium permanganate) followed by filtration.

[2]Passivation is a generic term referring to the process whereby a surface becomes covered with a dense protective layer that serves to protect the surface from corrosion.

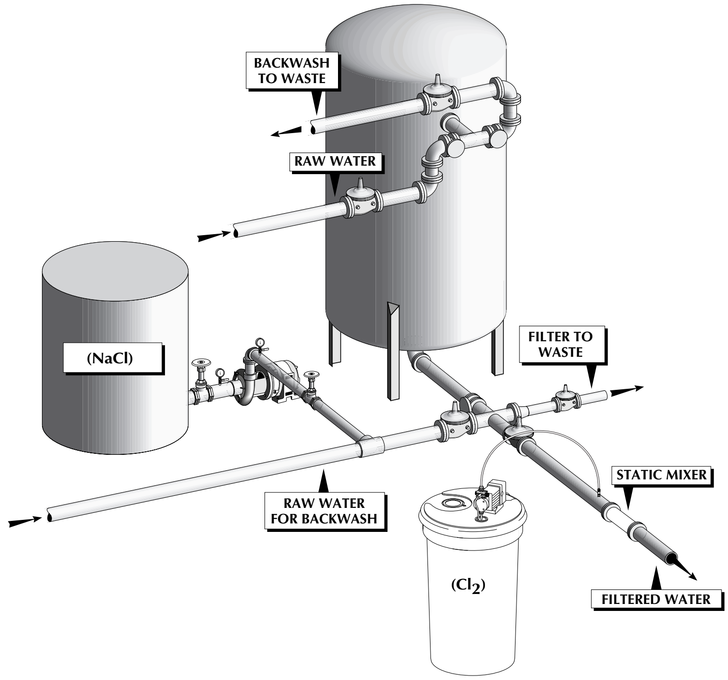
Aeration – Filtration



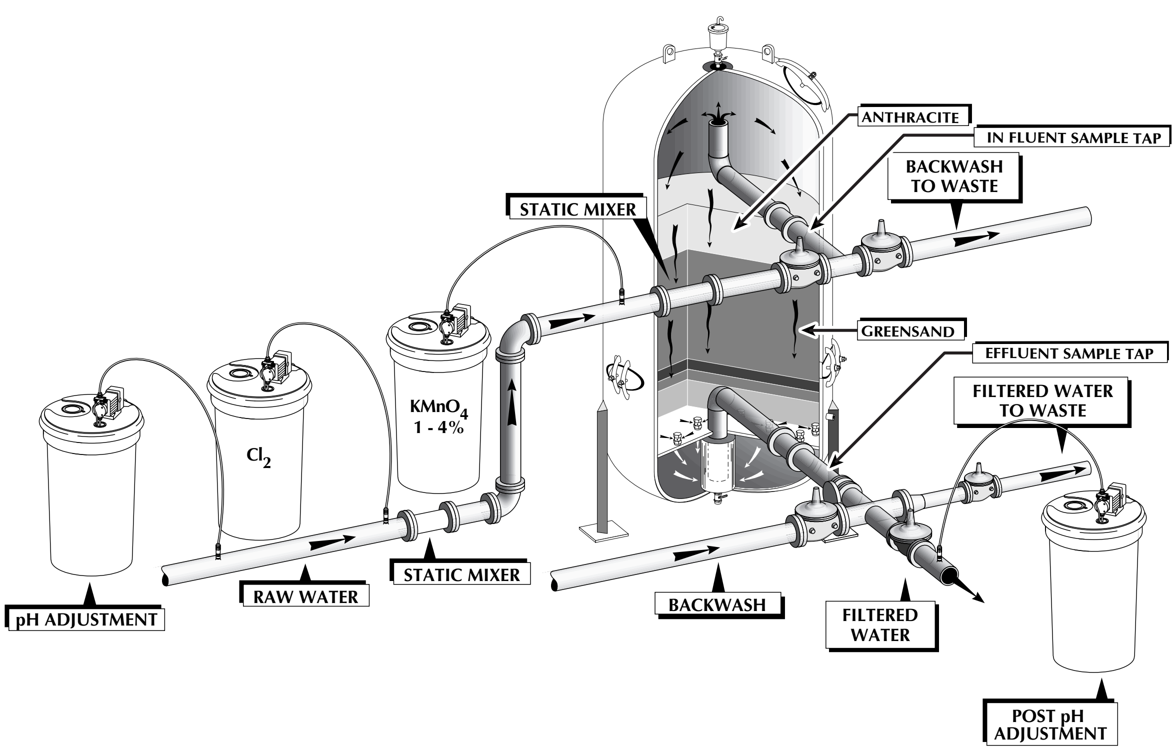
Chlorine Oxidation – Filtration

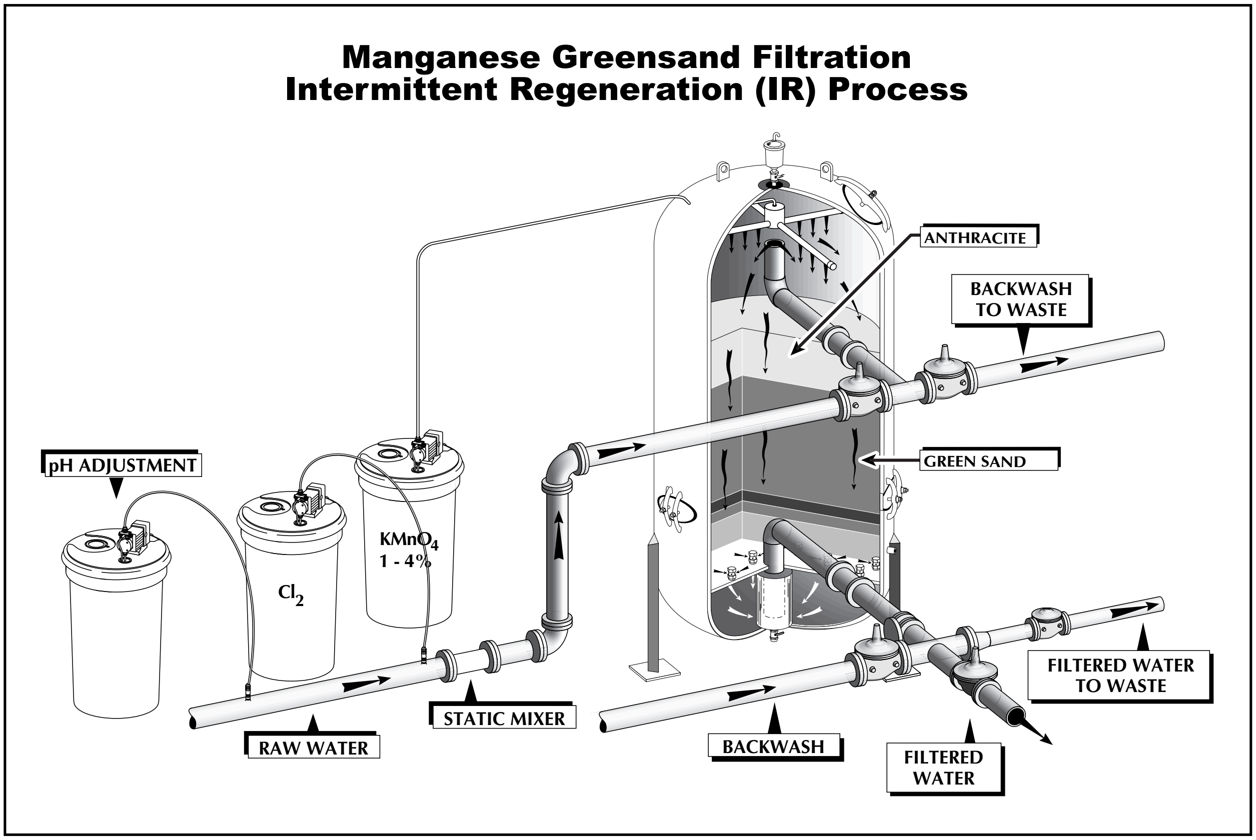


Ion Exchange



Manganese Greensand Filtration Continuous Regeneration (CR) Process





- Oxidation, clarification, and filtration.
- Ion exchange.
- Manganese greensand filtration.

Application. The applicability of each of the above processes and the sequence of chemical addition depends on the raw water quality and plant capacity at each water treatment facility. For specific information on the design and operation of each of these processes, consult the suggested references at the end of this Guide.

Sanitary Deficiencies – Iron and Manganese Removal

[Note: The sanitary deficiencies related to chemical feed systems earlier in this chapter should also be applied to this section.]

1. What treatment process is used?

A number of processes, as well as variations on some of the standard processes, are available for iron and manganese removal. The operator should be able to describe the process used and why the plant is operating in that particular mode.

2. Is the process performing adequately based on visual observation?

The inspector should examine the filtered water to determine if any color is evident. Discolored finished water could indicate iron or manganese breakthrough or an overdose of potassium permanganate, which could result in water with a pink color.

3. What chemicals are used and in what amounts?

In a manganese greensand filtration plant, the operator may be using some combination of chlorine, potassium permanganate, and a chemical for pH adjustment (caustic soda, soda ash, or lime). The quantity of each chemical is critical to consistent plant performance.

4. Where are the chemicals applied?

The sequence of chemical addition in a manganese greensand filtration plant will greatly influence the effectiveness of the system in removing iron and manganese. The inspector should determine whether the plant is being operated in the CR (continuous regeneration) mode or IR (intermittent regeneration) mode and should determine the justification for the mode being used. Generally, the CR mode is applied where iron removal is the main objective, with or without the presence of manganese. The IR mode is used when the water contains all or mostly manganese, with lesser quantities of iron.

When polyphosphate is used to sequester lower concentrations of the metals, the inspector should check to be sure the sequestering agent has sufficient time and mixing prior to chlorine addition.

Organics Removal

A number of methods including granular activated carbon, powdered activated carbon, aeration, and enhanced coagulation are commonly used to remove organic substances from drinking water.

Carbon Absorption

Carbon absorption is primarily used to reduce organics that contribute to taste and odor and to reduce organics that contribute to THM formation, some of which may be carcinogenic.
The two forms of activated carbon used in the water works industry are powdered activated carbon (PAC) and granular activated carbon (GAC).

PAC. Powdered activated carbon is less than 0.1 mm in diameter. One gram of PAC contains 500 to 600 square meters of surface area. PAC weighs approximately 20 to 45 pounds per cubic foot (0.32 - 0.72 g/cm^3).

- **Use:** PAC is primarily used to remove taste and odor caused by organic compounds. It can also be used to aid flocculation. Because of its high density, PAC helps to form the nuclei of the floc particles.

- **Feeding:** PAC is commonly delivered to the site in 5-pound bags. It can be fed dry or as a slurry. The most common method of application is the use of special dry chemical feeders where it is mixed into a slurry containing approximately 1 pound per gallon. This solution is then fed to the plant flow. Because PAC can be fed from a chemical feeder, it is more effective than GAC when the concentration of the organics varies. However, the PAC addition must be followed by filtration to remove the carbon before it enters the distribution system.

- **Handling:** PAC requires special handling and storage. Because PAC produces large amounts of fine powder, it is highly combustible and explosive.

- **Contact Time:** The ability of PAC to do its job is based on contact time and concentration. The most important of these, however, is contact time. Because PAC absorbs chlorine, it loses its effectiveness if fed in after the introduction of chlorine.

- **Effectiveness:** For best results in reducing taste and odor and in absorbing the precursors to THMs, PAC should be fed into the raw water at the front end of the plant prior to the introduction of Cl_2, with a lesser dosage fed just prior to filtration.

GAC. Granular activated carbon ranges from 1.2 to 1.6 mm in diameter. One gram of GAC contains 650 to 1,150 square meters of surface area. GAC weighs approximately 26 to 30 pounds per cubic foot (0.42 -0.48 g/cm^3).

- **Use:** GAC is primarily used to remove organic compounds, which may be associated with taste and odor production, and to prevent the formation of THMs when the concentration of the organics is constant. It also can be used to remove disinfection byproducts after they are formed and to remove VOCs and SOCs. GAC does not require post-treatment filtration.

- **Bag Sizes:** GAC is delivered to the site in 60-pound bags or in bulk. It is used as a filter medium or placed in columns called contactors.

- **Filter Placement:** When placed in a filter, GAC should be at least 24 inches deep. The placement of GAC in a typical filter can enhance turbidity removal. A common filtration rate for a GAC filter is 2 gpm/ft^2. Life expectancy of GAC filters ranges from up to 3 years for taste and odor removal to as little as 1 month for THM removal. Due to GAC's lower specific gravity, backwashing procedures must be changed when GAC is placed in filters.

- **Contactor Beds:** GAC contactors are composed of beds of GAC at least 3 feet deep. The beds are often placed in parallel operation so that one can be replaced while the second is being used. Alternatively, columns may be placed in series so that the contaminant is entirely contained within the downstream column after the lead column has been saturated. When the activated carbon is replaced in the upstream column, the flow is reversed so it goes through the freshest column last. This arrangement helps maximize the use of carbon.

  GAC contactors are used when the life expectancy of the GAC is only a few months. It is easier to change the GAC than to change a filter bed. GAC contactors are commonly placed in the system after filtration. GAC contactors are commonly sized based on empty bed-contact time and regeneration frequency.

Sanitary Deficiencies – Organics Removal

[Note: The sanitary deficiencies related to chemical feed systems earlier in the chapter should also be applied to this section.]

Activated Carbon

1. Why is activated carbon used?

There should be some documentation of the need, such as an engineering study or a management decision. The reasons could include taste and odor, THM, or the removal of organics. In any case, there needs to be a defined reason for the use of activated carbon.

2. Which process is being used?

Is the PAC or GAC process used? It is important to remember that PAC is most effective when the concentrations of the contaminants vary.

3. What testing is performed to determine the effectiveness of the activated carbon?

The testing should be directly associated with the defined need for activated carbon. Small systems may not be testing for THMs. However, if the presence of THMs is what caused them to use activated carbon, they should test for its effectiveness. Often, GAC beds are placed in the filter to solve a problem and then forgotten. Thus, they can become ineffective without the operator knowing it.

If PAC is being fed:

1. Have they had any problems with black water?

PAC will pass through some filter media, especially pressure filters.

2. How often are the feeders calibrated?

Chemical feeders feeding PAC should be calibrated with each new batch of PAC. The feed rate should be checked by measuring the output daily.

3. Do the operators have proper safety equipment?

They should have dust masks, sealed safety glasses, and shower facilities.

4. Is the PAC stored properly?

PAC is an explosive dust. Storage must include an explosion-proof electrical system and adequate ventilation.

When GAC is added to a filter:

1. Is the backwash adequate?

Check for the presence of mud balls, filter surface cracking, or compaction.

2. What is the depth of the GAC?

Since it is lighter than most other media, GAC can easily be washed away during the backwash process. The inspector should also check to see that the carbon is replaced on a schedule that ensures proper treatment.

When GAC contactors are used, what is the empty-bed contact time and regeneration or replacement frequency?

Aeration

Aeration is a process by which air and water are brought into intimate contact with each other for the purpose of transferring volatile substances to or from the water. This process is primarily found at ground water facilities. Aeration may be used to:

- Reduce volatile organic compounds, radon gas, and taste and odor-producing compounds such as hydrogen sulfide.
- Oxidize organic and inorganic chemicals such as iron, manganese, and organic matter.

Packed Tower Aeration. There are many types of aeration devices. Of the aeration options available, packed towers are becoming widely used to reduce trace concentrations of VOCs. The object is to contact a small volume of organic-contaminated water with a large volume of contaminant-free air. The tower is filled with packing material. A common material is a plastic ball about the size of a ping pong ball.

- **Water and Air Flow.** Water is pumped to the top of the tower and allowed to fall over the balls. Air is pumped under pressure into the bottom of the tower. The water flows downward, and the air flows upward. Thus, this arrangement is commonly referred to as countercurrent tower aeration. The packing material creates very fine droplets of water in the downward flow. This aids in diffusing dissolved gases into the upward flow of air.
- **Air-to-Water Relationship.** The air-to-water relationship typically ranges from 20 to 1 to 50 to 1 (air to water, volume to volume).
- **Problems.** There are two major problems associated with this process: contamination of the water from contaminated air and violation of air quality standards in the vicinity of the tower. (The output from the tower contains a high VOC level.)

Sanitary Deficiencies – Aeration

1. What type of aeration system is used?

Different types of units (cascade, tray, mechanical, packed tower, spray) are used, depending on the purpose of treatment. The operator should be able to explain the reason for the type of system in place.

2. What parameters are monitored to evaluate the performance of the process?

The efficiency of the tower should be evaluated routinely. Failure to do so is an indication that the tower may not be performing as designed. The frequency with which evaluations of tower efficiency are made must meet local and state requirements for the facility. Inspectors should check the frequency against their own communications about this problem. Parameters typically monitored include pH, moisture, VOCs, odor, and color. When an aeration tower is also used to reduce odor and taste, methane may be released. If this is the case, there should be a systematic monitoring program to determine the level of methane in the area.

3. What types of contaminants are in the vicinity that could be pulled into the air supply?

If the air intake is next to the chlorine room, lime storage area, or in a dusty environment, the water supply may become contaminated.

4. What types of operational problems has the facility experienced that could contribute to poor performance of the aeration device?

Typical problems include plugged nozzles on the air system, algae and other biological growth on the media, failure of the air blower, and breaking up of the floc, which causes high floc carry-over onto the filters.

5. **After treatment in the aerator, is the effluent disinfected adequately before it is introduced into the water distribution system?**

   Contamination by wind-borne pollutants and biological growth in the packing material requires diligent post-treatment disinfection.

6. **What is the condition of the aerator, both inside and out?**

   If the aerator is not accessible for close examination, the inspector should review the maintenance records to determine the status of the equipment.

Water Softening

Purpose. The primary purpose of water softening is to reduce the content of dissolved minerals, particularly calcium and magnesium, in order to minimize the tendency of scale to form. Softening hard water may provide additional benefits, such as:

- Biological growth control.
- Enhancement of use for boiler feed and cooling processes.
- Removal of many trace inorganics.
- Organics (i.e., disinfection byproducts precursor) removal.

Description	Hardness (mg/L of $CaCO_3$)
Soft	0 - 75
Moderate	75 - 150
Hard	150 - 300
Very Hard	Above 300

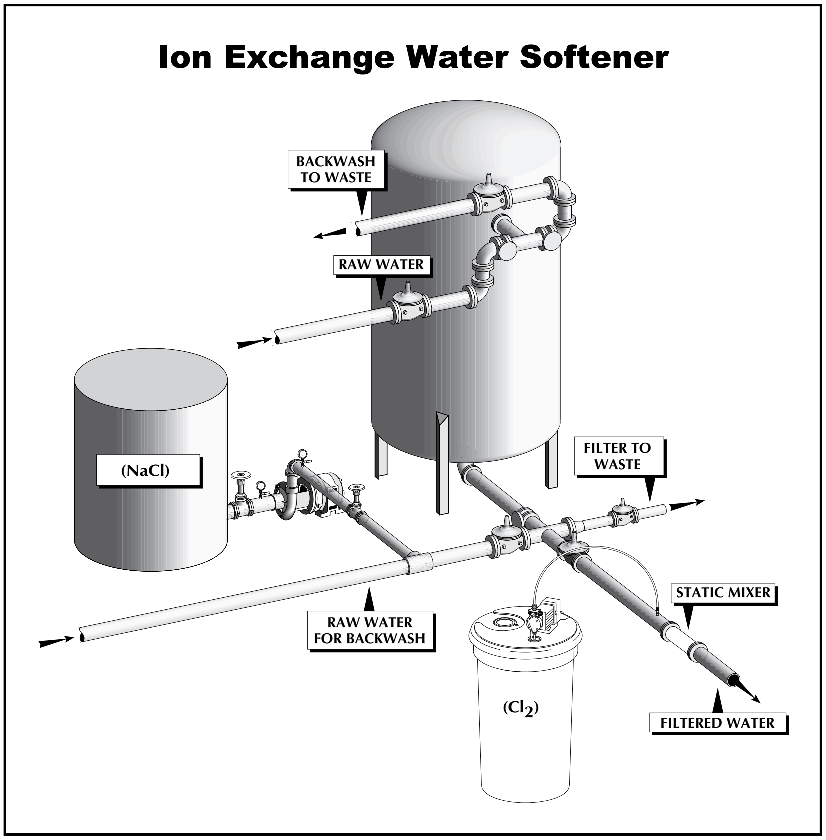
Softening water may also have the following negative results:

- The plant effluent pH of a lime soda softening facility is usually about 8.9. At pH 7.5, only one-half of the chlorine residual is hypochlorous acid. At pH 8.9 it is down to approximately 10 percent. This means that the disinfection capabilities are reduced.

Definitions Pertaining to Softening	
Hardness	A characteristic of water caused by divalent metallic cations, mainly calcium and magnesium, but also strontium, ferrous iron, and manganous ions. These cations are typically associated with anions such as bicarbonate, carbonate, sulfate, chloride, and nitrate.
Calcium Hardness	Hardness caused by calcium ions (Ca^{2+}).
Magnesium Hardness	Hardness caused by magnesium ions (Mg^{2+}).
Total Hardness	The sum of the hardness caused by calcium and magnesium.
Carbonate Hardness	Hardness caused by the divalent metallic cations and the alkalinity present in the water, up to the level of the total hardness.
Non-Carbonate Hardness	That portion of the hardness in excess of an amount equal to the alkalinity.
Alkalinity	The buffering capacity of water to retard the change of pH; the result of carbonate, bicarbonate, hydroxide, and occasional bicarbonate, silicate, and phosphate; commonly expressed as an equivalent concentration of calcium carbonate.
Calcium Carbonate ($CaCO_3$) Equivalent	An expression of the concentration of specified constituents in water in terms of their equivalent value of calcium carbonate.

- The water may become aggressive, thus corroding metal pipes.
- Disposal of the sludge is a problem.
- THM levels may increase due to elevation of the pH.

Softening Processes



There are two common softening techniques: lime soda and ion exchange. Selecting a process is based on a number of factors associated with operating costs, operating effectiveness, and construction costs.

Lime Soda Softening. There are three common lime soda softening processes: conventional, excess lime, and split treatment.

Conventional
Removing Carbonate Hardness. The lime soda process is used to remove the carbonate hardness by precipitation. When magnesium hardness is high, excess lime can be fed to raise the pH and cause the precipitation of magnesium hydroxide. To reduce the pH and make the water more stable, the flow is treated with carbon dioxide in a process called recarbonation. The amount of lime required depends on the concentration of the hardness and the type of hardness (calcium or magnesium). The conventional lime soda process is used when there is only a small amount of magnesium hardness and excess lime is used when magnesium hardness must also be reduced.

Removing Noncarbonate Hardness. In this process, soda ash is added following excess lime softening. This second step is effective in removing noncarbonate hardness, but is not commonly used because of the additional treatment units and associated capital costs.

Split Treatment Process. The split treatment process is an adaption of the excess lime process. A portion of the water is treated and added back into the untreated water to dilute it to the desired level of hardness. This process reduces the amount of chemical required to soften the water and thus reduces operating costs.

Ion Exchange Softening. Ion exchange softeners are primarily used in small ground water facilities and in individual homes. They are composed of a pressurized vessel resembling a pressure filter. The vessel is primarily filled with a resin like the filter bed. The resin holds an excess of sodium ions. These sodium ions are exchanged for calcium and magnesium ions in the plant flow. Once all of the sodium ions have been used, the resin is regenerated with a brine solution and the excess calcium and magnesium are removed. The hardness of the effluent of this type of facility is zero or near zero. Common ion exchange resins include synthetic zeolites and organic polymers (polystyrene resins).

Any water to be treated using the ion exchange process must be relatively free of particulate matter in order to prevent plugging the medium and subsequent operational problems. Iron, manganese, or other heavy metals, if present at high levels, may cause problems with ion exchange resins by binding permanently to the medium, thereby reducing the exchange capacity over time. One problem in the operation of an ion exchange system is the disposal of spent brine from the regeneration of the medium. Severe limits may be in place relating to the proper discharge of this high salinity water.

Sanitary Deficiencies – Softening

[Note: The sanitary deficiencies related to chemical feed systems earlier in this chapter should also be applied to this section.]

Lime Soda Process

1. **What are the treatment goals?**

   The staff should have finished water quality targets for parameters such as pH, alkalinity, and hardness. It is important that these targets are clear to all staff in order to obtain optimum plant performance.

2. **Is the facility performing adequate process control testing?**

   Testing at each stage of the process should include at least the following process control tests:

   - Alkalinity.
   - Hardness.
   - pH - carbon dioxide.

3. **Is the facility tracking the chemicals used?**

   This process involves the use of a number of chemicals that may have conflicting functions and must be monitored carefully. For example, too high a finished pH could cause disinfection or disinfection byproduct problems.

4. **Is the facility meeting the TOC removal requirements (if applicable) of the Stage 1 DBP Rule?**

   Surface water systems that employ lime softening must meet step 1 TOC removal requirements. The inspector should check the system's operating records and state reports to make sure the system is in compliance.

Ion Exchange

1. **What are the treatment goals?**

   This treatment process can reduce water hardness to a very low level. This may result in aggressive water quality that could contribute to lead and copper problems in the distribution system. The operators must understand the implications of their treatment goals in light of other possible problems.

2. **What is the condition of the equipment?**

   The condition of the media is important and must be monitored to ensure that fouling, which will eventually affect the efficiency of the process, is not occurring. Also, the overall condition of the filter units and valves is important to proper operation.

3. **What is the operators' knowledge of the softening process?**

   Because softening chemistry is typically more complicated than other treatment processes, it is normally not well understood. Operators need to understand the softening process in order to handle problems when they arise. **Chemistry training is available, and management is responsibile for providing this training to the operators.**

Specialty Treatment

Reverse Osmosis

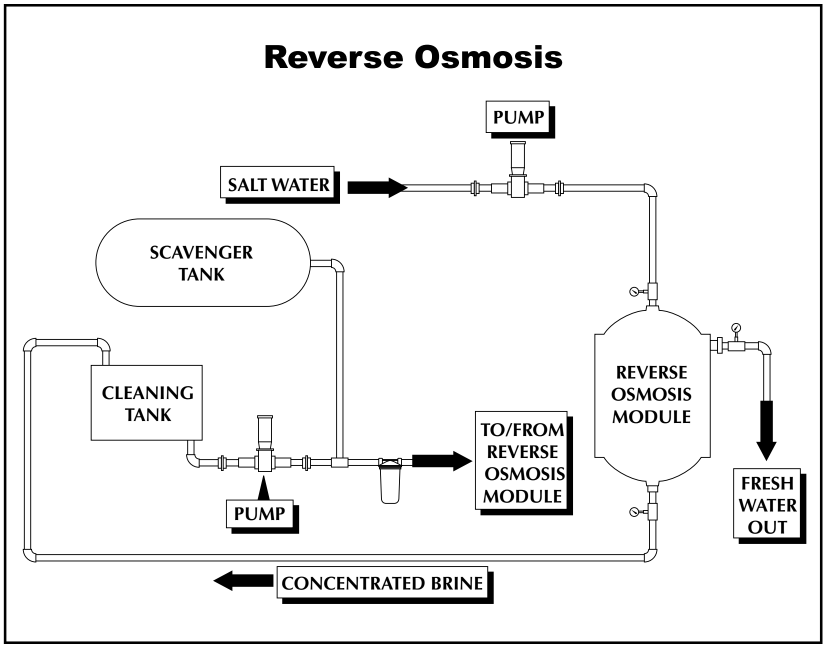
Principle of Reverse Osmosis

The Use. Reverse osmosis (RO) is used to demineralize salt water, brackish water, and water with concentrations of total dissolved solids (TDS)from 100 to 8,000 mg/L. Its removal (rejection) efficiency varies from a high of 90 percent on most TDS constituents to a low of 40 percent for mercury.

The Process of Osmosis. When a solution that has a high TDS concentration is separated from a solution of low TDS by a semipermeable membrane, fluid will flow from the dilute solution to the concentrated solution. This process is called osmosis. The pressure caused by the difference in concentration of the two fluids is called **osmotic pressure.**

The Reverse Osmosis Process. Placing pressure on the concentrated solution will force the fluid backward through the membrane. The membrane removes (rejects) the TDS in the concentrated solution, thus producing fresh water from brackish water. This process is called **reverse osmosis.**

Equipment



A typical RO facility is composed of the following components.

- **Pump.** A high pressure pump (350 to 500 psi).

- **Membrane.** The membrane is commonly made of cellulose acetate. There are three common types of membranes:

  - Spiral wound.
  - Pressure vessel.
  - Hollow fiber.

  These membranes are typically 100F thick. One side of the membrane has a dense layer approximately 0.2F thick that is used to reject the minerals. The remainder of the membrane is a spongy, porous mass.

- **Acid Feed.** An acid feed pump is used to control the pH of the feed water. Sulfuric acid is commonly used. It is normal for the feed water to be adjusted to a pH of 5.5. This low pH reduces the natural destruction of the membrane (called hydrolysis) and retards the buildup of calcium carbonate scale on the membrane.

- **Scale Inhibitor Feeder.** While pH adjustment will control calcium carbonate scale, it has little effect on calcium sulfate. To control calcium sulfate, a polyphosphate is commonly fed. Typically, sodium hexametaphosphate (SHMP) at dosages of 2 to 5 mg/L is used.

- **Chlorinator.** A chlorinator is used to provide a 1 to 2 mg/L residual through the unit in order to reduce bacterial growth in the membrane.

- **Cleaning Tank, Pump, and Solution.** Typical cleaning solutions include citric acid, sodium tripolyphosphate, B13, Triton X-100, and EDTA.

Performance

The primary advantage of the RO process is that it rejects a high percentage of dissolved solids from the raw water. The rejection allows contaminated, brackish, and saline water to be desalted for potable use. Problems associated with RO plants include:

- High initial and operating costs.

- Need for pre-treatment of turbid raw water with acid and other chemicals to prevent fouling of the membranes by slimes, suspended solids, iron, manganese, and precipitates of calcium carbonate and magnesium hydroxide.

- Need to stabilize finished water with pH adjustment chemicals to prevent corrosion in the distribution system.

- Disposal of reject waste stream.

Sanitary Deficiencies – Reverse Osmosis

[Note: The sanitary deficiencies related to chemical feed systems earlier in this chapter should also be applied to this section.]

1. **What performance testing is being done?**

   The facility should be testing for TDS, pH, temperature, turbidity, and alkalinity.

2. **What operational data is the system collecting?**

   The operator needs to observe, record, and respond to pressure pump suction, discharge pressure, and RO unit pressure differences between feed and product water. The difference between feed and product water pressures over time is a key to determining scale and biological buildup on the membrane.

3. **What chemicals are being fed and at what dosages?**

   Typical scale inhibitor feed rates are 1 to 2 mg/L. Chlorine residual should be between 1 and 2 mg/L. The facility should calculate feed rates and dosages for the feed acid, scale inhibitor, chlorine, and cleaning solutions.

4. **Are the operators adequately protected?**

   Because these units require the feeding of chlorine and various acids, operators will need rubber gloves, eye protection, breathing protection, rubber aprons to be worn when mixing or pouring the acids, and a safety shower in case of accidents or spills.

5. **Are all automatic controls in operation?**

   RO facilities have various shut-down alarms and automatic systems to control the facility. Because of the high pressures and the presence of acids, this equipment tends to fail frequently. All automatic equipment, safety shutdowns, and alarms must be in working order.

6. **If RO-treated water is blended with untreated water, how is the blending ratio determined and is the final water satisfactory?**

Fluoridation

Background. Drinking water systems add fluoride to their water in order to reduce dental cavities in their customers. Fluoridation is a controversial practice. The inspector's responsibility is to focus on the sanitary risk of the fluoridation system in the same way that he or she focuses on the sanitary risk of any chemical feed system in a public water supply.

Concerns. During the past few years, 2 customers of public water systems have died as a result of a fluoride overdose. In addition, the Centers for Disease Control and Prevention has collected information on 7 fluoride overfeed incidents between 1976 and 1992. These incidents resulted in 314 reported illnesses and 2 deaths. The incident rate over a 16-year period is less than 1 event per 1,000 systems that add fluoride. However few these incidents, their conjunction with considerations about operator safety make it imperative that any fluoridation facilities be part of the sanitary survey. This section is divided into four parts:

- General application of the fluoridation processes.
- Use of fluoride saturators (sodium fluoride).
- Use of sodium silicofluoride (dry feeder fluoride).
- Use of hydrofluorosilic acid (fluoride acid feed).

General Application

Definition. Fluoridation is the addition of fluoride to a water supply in order to obtain an optimum fluoride concentration in drinking water.

Chemicals. There are three chemicals used in the application of fluoride to drinking water:

- Sodium fluoride, a powder.
- Hydrofluorosilicic acid, a liquid.
- Sodium silicofluoride, a powder.

The most common chemical used in small systems is sodium fluoride.

Hazards. Handling fluoride chemicals, especially powders, can have a **long-term health effect** on the operator. Fluoride is a medical poison and will accumulate in the body. Thus, it is important that the safety hazards associated with handling this chemical be addressed by the inspector.

Optimum Concentration. The optimum concentration recommended by the U.S. Public Health Service is 0.7 to 1.2 mg/L. Most states base their optimum concentration on the ambient temperature; they assume that as the ambient temperature increases so does the volume of water consumed. However, the concentration almost always remains within the stated range. One exception is Alaska, where the recommended range is 1.1 to 1.7 mg/L. The lower end of the range was selected in the belief that at least 1.0 mg/L is required for fluoride to provide the needed protection. The upper end of the range was selected to remain below the secondary MCL. Other states may have similar criteria. When a nontransient noncommunity system (i.e., typically a rural school) adds fluoride, it may be appropriate to feed the chemical at a higher rate if students will be drinking water at home that contains low concentrations of fluoride. **The inspector is responsible for being familiar with local and state regulations on fluoride.**

Reaction. Fluoride in a sodium fluoride solution is fairly stable, so there will be little noticeable difference between the dosage and the residual. The notable exception is calcium. Fluoride will react with calcium, reducing the fluoride residual. This is most noticeable when the concentration of calcium in the exceeds 75 mg/L.

MCL. Fluoride is one of two chemicals that has both a primary and a secondary MCL. (The other is copper.) The primary MCL is 4.0 mg/L, and the secondary MCL is 2.0 mg/L. At concentrations above 4.0 mg/L fluoride will cause skeletal fluorosis. At a concentration of 2.0 mg/L fluoride will cause dental fluorosis.

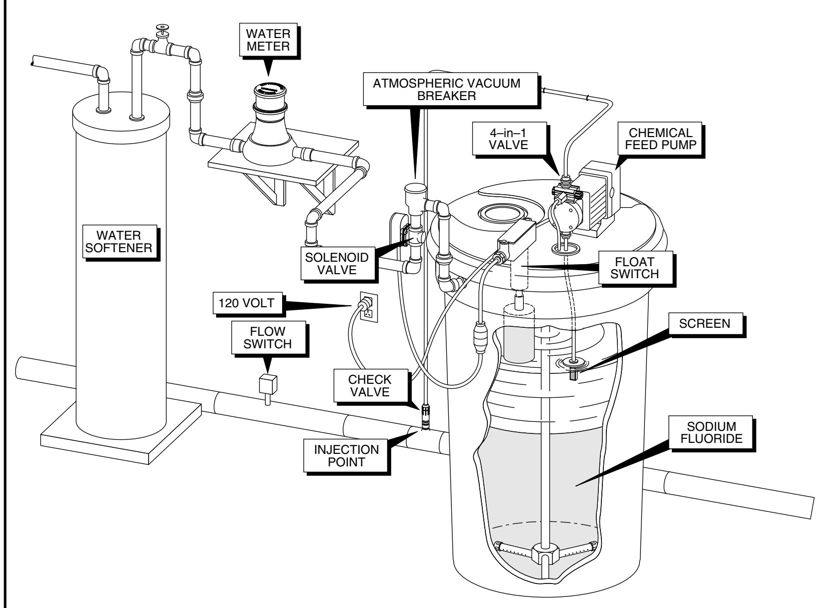
Fluoride Saturator System

Introduction. Up-flow and down-flow saturators are used to feed sodium fluoride. Up-flow saturators are the most common method in small systems. They produce a very stable fluoride solution containing 4.0 percent sodium fluoride and 1.73 percent fluoride ion.

Equipment. Saturator systems are very simple, as can be seen in the drawing below. The system is made up of these basic components:

- Saturator tank connected at its top to a water supply and equipped with a manifold at its bottom.
- Float switch used to maintain the water level in the saturator.
- Water inlet system, which contains a water meter, solenoid valve, vacuum breaker, and a softener if the feed water is relatively hard.
- Chemical feed pump.
- Electrical system including fail-safe controls.

Fluoride Saturator



Sodium Fluoride Considerations. Sodium fluoride carries a UN number of 1690 and is classified by DOT as a poison with a hazard classification of 6.1. **Fluoride dust represents a significant health risk to the operator, so proper PPE is critical to operator health.**

Operation. Sodium fluoride is placed in the bottom of the saturator tank, then the tank is filled with water and allowed to stand for 2 hours. At the end of this time the solution contains concentrations of 4.0 percent sodium fluoride and a 1.73 percent fluoride ion. As fluoride is fed, the water level in the saturator drops. When the water drops 3 to 4 inches, the float switch opens the solenoid valve. The valve's opening sends water down through the distributor and up through the fluoride crystals, maintaining the level in the tank and preventing the solution's concentrations from changing significantly.

The only way to determine the amount of fluoride fed each day is from the water meter readings on the make-up water.

Fail-Safe. The chemical feed pump must be connected electrically so that fluoride can be fed only when there is a flow in the water line.

Corrosion. Sodium fluoride leaks are annoying and the sodium fluoride is somewhat corrosive, but not dangerous.

Dry Feeder Fluoride System

Introduction. Volumetric and gravimetric dry feeders are used to feed sodium silicofluoride or sodium fluoride crystals. Due to its lower cost, however, sodium silicofluoride is most commonly used. Dry feeder systems are usually used where system flows exceed 1 million gallons per day. **[Note: See the chemical feed system section of this chapter for drawings and descriptions of volumetric and gravimetric dry chemical feeders.]**

Sodium Silicofluoride Considerations. Sodium silicofluoride carries a UN number of 1690 and is classified by DOT as a poison with a hazard classification of 6.1. Because the fluoride dust represents a significant health risk to the operator, proper PPE is critical to protecting operator health.

Operation. Dry chemical is metered into the solution tank based on water system flow. The feed rate can be adjusted using a 4 to 20 mA signal from a flow meter. The solution is either fed by gravity to the clearwell or fed into a pressure system by a chemical feed pump.

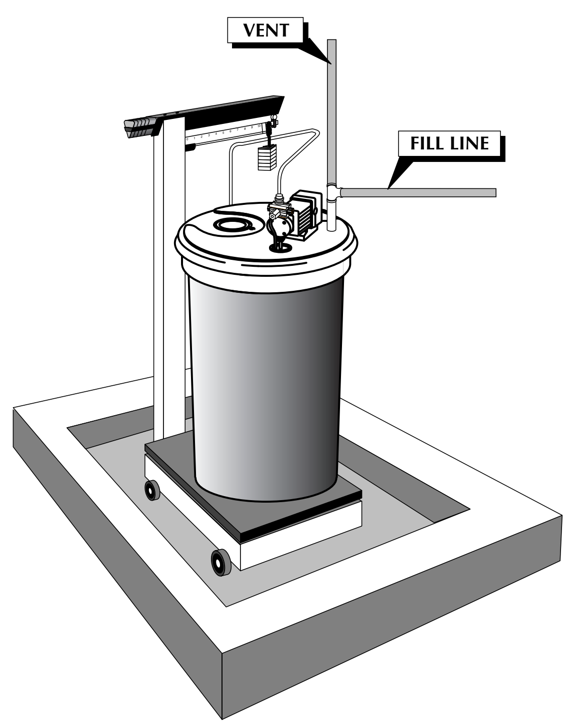
Fluoride Acid Feed System

Introduction. Acid feed systems are one of the simplest fluoride feed systems used. They feed hydrofluorosilicic acid directly from a shipping container into the water system flow.

Equipment. An acid feed system is made up of these basic components:

- Set of scales to determine the quantity of chemical feed.
- Chemical feed pump system.
- Electrical system including fail safe controls.
- Spill containment.

Fluoride Acid Feed System



Hydrofluorosilicic Acid Considerations. Hydrofluorosilicic acid carries a UN number of 1778 and is classified by DOT as corrosive, with a hazard classification of 8. Because it represents a significant health risk to the operator, proper PPE is critical to operator health.

Operation. An acid feed system uses a chemical feed pump with an anti-siphon valve to pump concentrated acid directly into the system flow. The only way to determine the amount of fluoride fed each day is by weighing the solution.

Fail-Safe. The chemical feed pump must be connected electrically so that fluoride can be fed only when there is a flow in the water line.

Corrosion. Hydrofluorosilicic acid leaks are an annoyance and very corrosive.

Sanitary Deficiencies – Fluoridation

1. **Can the operator answer basic questions about the fluoridation process, including what is done, when, and why?**

   An operator's lack of knowledge about the process and equipment is an indication that failures of equipment or the effectiveness of the process may not be resolved in a timely manner. **Management is responsible for ensuring that operators are well trained in the use and maintenance of fluoridation equipment.** Lack of knowledge of this key process can be considered a significant sanitary deficiency.

2. **Is there a proper concentration of fluoride in the distribution system at all times?**

   An optimum residual must be maintained for fluoride to be effective. Generally, this residual is 0.7 to 1.2 mg/L. Most states base the residual on the ambient temperature of the area. They assume that more water is consumed as the temperature increases. However, it is also true that water consumption increases in areas where the winter temperature is below freezing. Some states, such as Alaska, set 1.1 to 1.7 mg/L as the optimum range. Higher concentrations also may be appropriate for rural schools.

3. **Are fluoride concentrations tested in the system daily?**

   A key way to prevent overfeeding of fluoride is to test its concentration in the system. The fact that there are primary and secondary MCLs for fluoride also indicates that a prudent operator would perform this test daily. In addition, any natural fluoride in the raw water must be tested daily because the concentration may vary from day to day, requiring adjustments of the feed system.

4. **Does the fluoride concentration vary from day to day?**

   The variation should not be more than 0.2 mg/L. If there is a change, check to see that the tests are conducted correctly, at the same time of day, and under the same conditions. For example, are pumps on or off? What is the concentration of fluoride in the raw water?

5. **Is the testing performed correctly?**

   There are three common procedures for testing fluoride: the SPADNS method, the ALIZARIN-VISUAL test, and the specific ion probe method. Most small systems use either the ALIZARIN-VISUAL or the SPADNS method. These methods are prone to interference from aluminum and polyphosphates, respectively. The inspector should verify that the operator knows the proper test procedure and that the chemicals are not past their expiration date. There are numerous reports of false fluoride readings based on out-of-date chemicals. The operator should also regularly send samples to a certified laboratory to double-check the on-site measurements.

6. **When was the testing instrument last calibrated?**

   Both color tests should be performed against a standard that is part of the routine test procedure. The inspector should determine whether the operator is performing this portion of the test. If a specific ion probe is used, the inspector should check to see how it is used and how often it is replaced.

7. Is there a water meter on the inlet line when using a saturator?

The amount of fluoride solution fed each day can be determined only by reading the water meter on the dilution tank inlet water supply. The inspector should determine whether this reading is recorded each day and whether the total amount of water used is calculated each day.

8. How often is the saturator tank cleaned?

The fluoride saturator should be disassembled and cleaned once a year. The crystals should be removed and new crystals installed. This annual cleaning and crystal replacement will help maintain the stability of the fluoride solution.

9. What is the level of fluoride crystals in the tank?

With a normal saturator using a 50-gallon tank, the crystal level should not be allowed to drop below 10 inches in height.

10. What method is used to dispose of old fluoride crystals?

The proper method is mixing the fluoride crystals with an equal amount of lime in a metal bucket and allowing the solution to stand for 24 hours. The reaction will generate heat, which will result in a solid block of non-reactive material.

11. Is there a scale for weighing the solution tank for a liquid acid system?

The amount of acid fed each day can be determined only by daily weighing of the solution tank. The inspector should check to see that this reading is recorded each day and that the total amount of fluoride used is calculated each day.

12. How often are the scales calibrated?

Because the dosage rate can be determined only by weight, the scales should be calibrated once each year.

13. Is the electrical system wired with a fail-safe?

When the fluoride feed system is tied to a system pump, it is very important that some type of flow-sensing device be used as a fail-safe. The fluoride feed pump should not be allowed to come on until there is a flow in the pipe. Without a fail-safe flow detection system, a pump motor starter may engage but not start the pump. If the signal that engaged the pump starter also starts the fluoride feed pump, a highly concentrated fluoride solution can be fed into the line and be received by a customer. The lack of this type of system is thought to be responsible for at least one overdose death.

7 Distribution Systems

The sanitary survey inspection must evaluate the water distribution system to determine if it can provide a safe, adequate, and reliable supply of water.[1] Distribution system piping and appurtenances have contributed to the deterioration of water quality. In addition, construction and repair techniques expose personnel and customers to a wide variety of hazards. The inspector must evaluate each of the operation, maintenance, and management practices that influences the distribution system in order to evaluate the sanitary deficiencies. To perform this evaluation, the inspector should be able to meet the following objectives.

Learning Objectives

By the end of this chapter, learners should be able:

- To identify data collection requirements necessary for evaluation of sanitary deficiencies of a water distribution system.
- To review the major components of a water distribution system including pipes, valves, meters, meter vaults, fire hydrants, thrust blocks, and anchors.
- To describe how the type of material and selection standards of water distribution system components can affect system reliability or water quality.
- To identify the standards used to select water distribution system components, and describe how these standards protect public health and the reliability of the distribution system.
- To identify factors that contribute to reduction in water quality in a distribution system.
- To identify the information that should be included on water distribution system blueprints.
- To describe the proper monitoring of a water distribution system.
- To identify operation and maintenance tasks, such as flushing, necessary to maintain the integrity of the water distribution system.
- To describe the safety practices that should be in place to protect the operator and public during distribution system operation, construction, and repair.
- To describe the proper methods, based on American Water Works Association (AWWA) standards, for disinfecting new and repaired water distribution system lines and appurtenances.
- To identify design and operational constraints that have a negative effect on the water quality in a water distribution system.
- To identify design and operational constraints that have a negative effect on the reliability of a water distribution system.
- To identify construction techniques that can be a positive influence on distribution system integrity.

[1] The student may want to consider viewing the video *Sanitary Survey Inspection; Before You Begin . . . DISTRIBUTION* prior to reading this section. To order, see www.epa.gov/safewater/dwa/orderform.pdf.

Data Collection

To evaluate and assess a water distribution system for sanitary deficiencies, the inspector should gather the following data:

- Type and quantity of piping materials.
- Age and condition of piping materials.
- Standards used for the construction of the system.
- Maximum and minimum pressures at high and low elevations in the system.
- Maximum and minimum pressures in each pressure zone.
- Documentation of state approval for changes to or installation of the system.
- Staffing for construction (i.e., in-house staff or by contractors).
- Number of pressure zones in the system.
- Method used to separate pressure zones.
- Hydraulic model of the system.
- Chlorine residual testing technique used.
- Method used to notify the utility when there is a main break.
- Routine maintenance tasks performed by outside contractors.
- 24-hour call-out procedure.

Regulations and Standards to Consider

The inspector should consider and review the following information prior to an inspection:

- 29 CFR 1926. 650 - Competent person - excavation safety.
- 29 CFR 1926. 146 - Confined space entry.
- MUTCD - Manual on uniform traffic control devices.
- AWWA C-601 - Disinfection of water lines.
- The AWWA standard for the type of piping materials used in the system.
- System construction standards.
- State construction standards.
- 40 CFR 141. 73 - chlorine residual requirements.
- 40 CFR 141. 86 - Lead and Copper Rule.

Distribution Systems

Basic Information

Introduction. Many failures to meet the requirements of the drinking water standards are directly related to poor operating and maintenance of distribution systems or to sanitary deficiencies in the system. Some contributing causes of poor water quality are:

- Insufficient treatment at the point of production.
- Cross-connections.
- Improperly protected distribution system storage.
- Inadequate main disinfection and unsatisfactory main construction, including improper joint-packing.
- Close proximity of sewers to water mains.
- Improperly constructed, maintained, or located blow-off, vacuum, and air-relief valves.
- Negative pressures in the distribution system.

Components of the Distribution System

Introduction. A typical water distribution system may contain the following components:

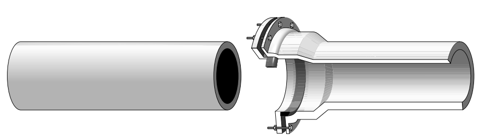
- Main lines.

- Service lines and service meters.
- In-line valves.
- Blow-offs.
- Air relief, air release, and combination air vacuum valves.
- Pressure reducing valves (PRVs).
- Fire hydrants.

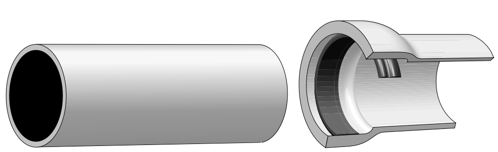
Main Lines. Typical main line materials include:

- Gray cast iron (CIP).
- Ductile cast iron (DCIP).
- Asbestos cement (AC).
- Steel.
- Polyvinyl chloride (PVC–pressure and class pipe, also called C-900).
- Wood.
- High-density polyethylene (HDPE).

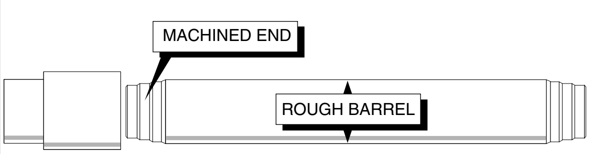
Gray Cast Iron Pipe (CIP)



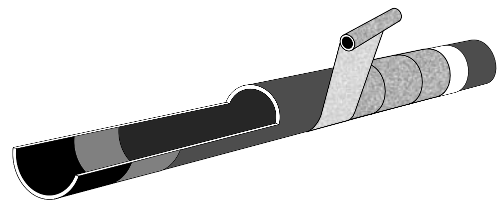
Ductile Cast Iron Pipe (DCIP)



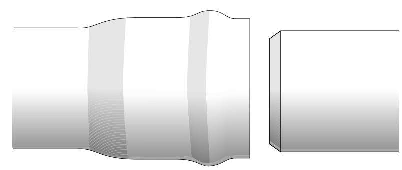
Asbestos Cement (AC) Pipe



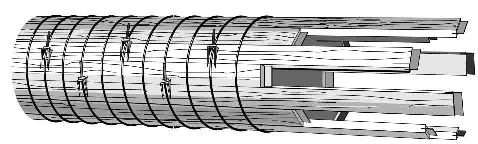
Steel Pipe



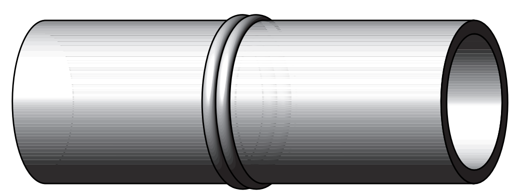
PVC Pipe



Wood Pipe



HDPE Pipe



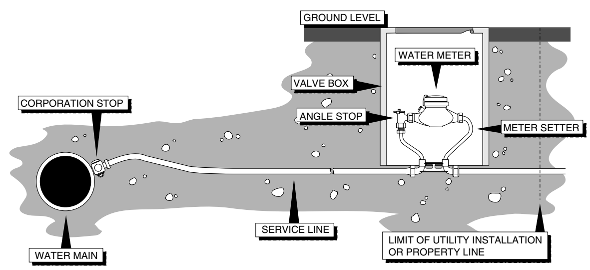
Services Lines. Typical service lines materials include:

- Galvanized steel
- Copper
- HDPE
- PVC
- Lead

Service Meters. There are two points where meters are used in distribution systems:

- The introduction to a pressure zone
- The customer's connection

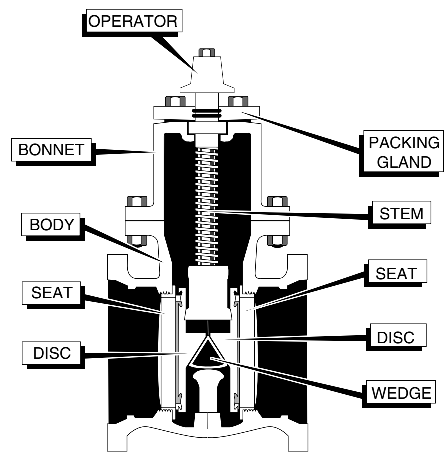
Service Meter Installation



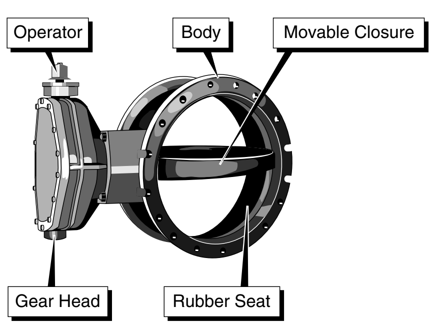
These meters are used to determine the amount of water sold. They also are used to determine unaccounted-for water and to identify leaks.

In-Line Valves. Gate and butterfly valves are the two most common in-line valves used in a distribution system. They are used to isolate portions of the system during repairs.

Gate Valve



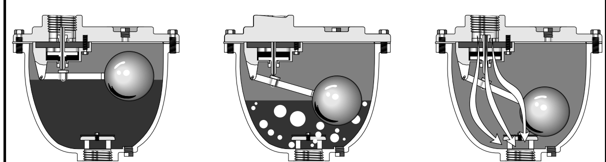
Butterfly Valve



Blow-offs. Blow-offs are gate, butterfly, or globe valves installed at the end of dead-end lines or in other locations. Blow-offs are used in flushing the distribution system.

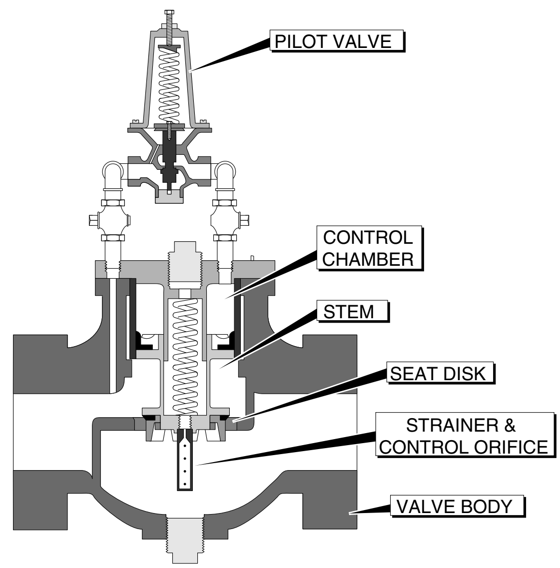
Air valves. Air relief, air release, and combination air vacuum valves are used to remove air that accumulates in the distribution system and to relieve a vacuum caused by line flushing, line breaks, or other high-flow conditions. Accumulated air can cause system pressure and flow variations. Vacuums can contribute to the failure of a pipe joint and intrusion of contaminated ground water into the system.

Air Release Valves



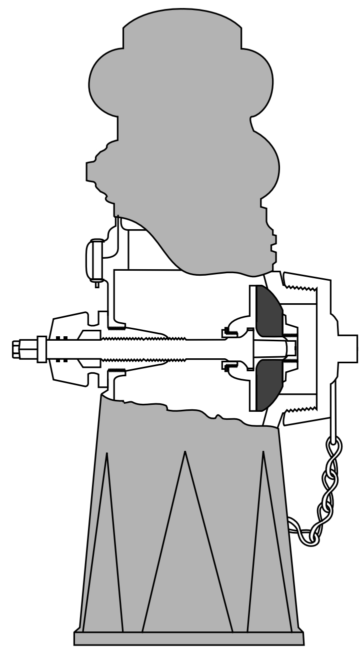
Pressure Control. Pressure-reducing valves are globe valves used to reduce or maintain the pressure in a specific zone of the distribution system.

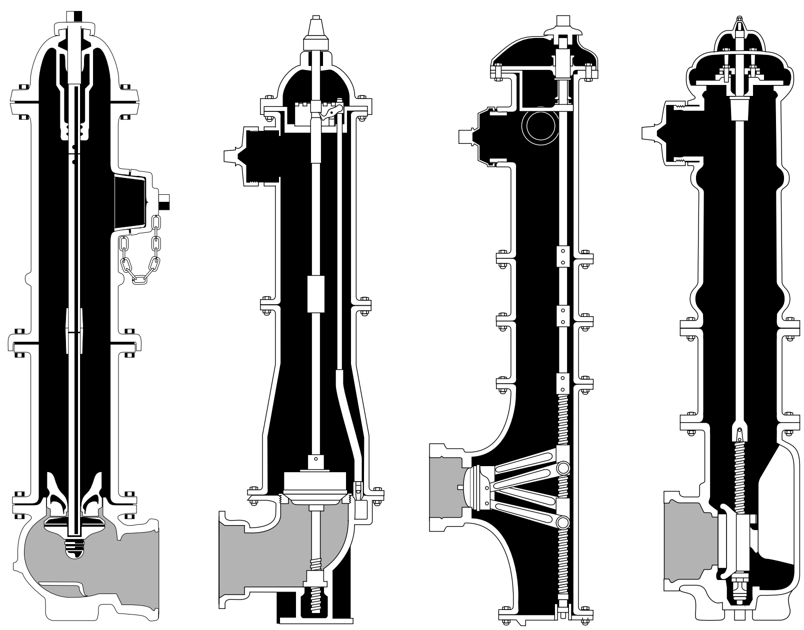
Pressure Reducing Valve



Fire Hydrants. Two general styles of fire hydrants are used in the United States: wet barrel and dry barrel. There are four types of dry barrel hydrants, as shown below: two compression types, toggle, and slide gate. Besides fire suppression, fire hydrants are used to provide water for construction, sewer line flushing, and flushing the distribution system piping.

Construction Considerations. To prevent the joints of fittings and other appurtenances from shifting and allowing the joint to leak, restrained joints or thrust blocks are installed at all changes in direction and at the end of dead-end lines.





Sanitary Deficiencies for Distribution Systems

Piping Materials

1. **Does the system contain any thin-wall PVC pipe?**

   This material has a 2.5:1 burst ratio and will often fail more frequently than class C-900 pipe. In addition, this material must be installed with hand-tamped backfill to prevent failure from external loads.

2. **Does the system contain any grey cast-iron pipe?**

   Grey cast-iron pipe is prone to failure from sudden internal or external shock loads.

3. **Does the system contain any wood pipe?**

   Wood pipe is easily contaminated and, once contaminated, is nearly impossible to disinfect.

4. **Is HDPE pipe used for main lines or service connections?**

   Petroleum products will travel through HDPE and other polyethylene and polybutylene piping material and into the water system. This can occur if the lines are adjacent to a leaking underground fuel storage tank or if fuel is spilled on the ground above the line.

5. Does the system contain any steel pipe that is more than 35 years old?

In most locations, steel pipe is given a design life of 35 years. If the ground is wet or the soil is aggressive, the pipe may deteriorate in less time. Leaks in steel pipe are normally in the form of pin holes. If there is a high velocity through the pipe, then contaminated ground water may be drawn in through these same pin holes.

6. Does the system contain any solvent-weld PVC pipe larger than 2 inches in diameter?

Large-diameter solvent-weld PVC pipe has a higher failure rate than push-on joint pipe. This is due to the expansion and contraction of the pipe caused by temperature changes during construction or operation.

7. Are there any lead goosenecks still in place and being used for service connections? If yes, how many? Are there plans to remove these? If yes, by what date?

Lead goose necks have been identified as one of the major contributors to high lead levels in finished water.

Material Standard

1. What standards are used to select materials?

The distribution system components should be selected to meet current standards including NSF 61 for indirect additives. The corrosive effects of finished water on metal pipe used for service lines are considered, together with possible toxicological effects on consumers, resulting from dissolution of the metals. Only NSF-approved plastic pipe should be used, when plastic pipe is acceptable. Caulking materials should not support pathogenic bacteria and should be free of tar or greasy substances. Joint-packing materials should meet the latest AWWA specifications.

2. Are all materials used in the system manufactured according to AWWA standards?

The AWWA standard is a “buyer beware” standard. It is the purchaser’s responsibility to require the manufacturer or supplier to provide proof that the material meets these standards. AWWA does not test material, and it does not have standards on all construction materials or all sizes of mains.

3. Are all materials ANSI/NSF certified?

See qualification in question 1.

4. Is there a set of construction standards used by the utility?

Failure to use construction standards often complicates the installation of piping, valves, and hydrants that are of different brands, types, and materials. This contributes to increased materials inventory costs and maintenance worker training. For a small utility, this increased cost may mean that all appropriate training and repair materials will not be on hand. In addition, lack of construction standards may contribute to poor quality construction, which results in premature failure of materials.

5. Does the system have its own construction standards, or has it adopted some from another agency?

Many small utilities borrow construction standards from a larger local community. While this can work, the standards often do not fit the needs of the community. This can cause contractors and staff to ignore the standards. The result is the same as not having a standard.

6. Do the construction standards meet state requirements?

Because some states do not review construction standards, the utility may have adopted standards that violate existing state standards. Assuming the state standards were developed to provide the minimum degree of reliability to the system, the utility’s standards should be consistent with, and at least as protective as, the state requirements.

7. Are in-house staff and contractors required to use the same standards?

In many locations, staff construction methods may vary from those used by contractors. The lack of consistency in construction methods and in the standardization of materials leads to maintenance problems and slows repairs during emergencies.

8. Are standards actually followed?

Take a look at the set of standards and compare them to blueprints and materials in storage. If the system is not following its own standards, the actual construction techniques are suspect. Thus, the system may not be reliable.

Water Quality

1. Is there any point in the system where pressure drops below 20 psi during peak demand or fire response?

Pressures below 20 psi are considered to represent a sanitary deficiency. At pressures this low, or even negative, it is possible for contaminated ground water to enter through leaks. Also, a backflow condition could occur due to backpressure. The system must be designed to supply adequate quantities of water under ample pressure and operated to prevent, as far as possible, conditions leading to the occurrence of negative pressure. Steps to prevent negative pressure include minimizing unplanned shutdowns, providing adequate supply capacity, correcting undersized conditions, and properly selecting and locating booster pumps to prevent the occurrence of a negative head in piping subject to suction. Continuity of service and maintenance of adequate pressure throughout a public water supply system are essential to prevent backsiphonage. The inspector should determine if complaints about inadequate pressure have been registered and if there is a program to periodically monitor pressures throughout the system.

2. If the valves are in a vault, can the operator observe pressures without entering the vault? If the valves are in a confined space, does the operator have and use gas monitoring equipment and follow a confined space entry procedure?

Vaults are typically confined spaces. **Do not enter**. If the operator must enter the space and does not use a proper confined space entry procedure, this is a sanitary deficiency. Injury or illness that keeps the operator from performing required duties reduces the system's reliability.

3. If there is a vault, is there a sign identifying it as a confined space?

All confined spaces must be labeled with a red, white, and black injury-prevention tag.

4. If there are pressure zones controlled by automatic pressure reducing valves (PRVs), do the PRVs work properly?

Check upstream and downstream pressures. (The absence of pressure gauges above and below the PRV is considered a sanitary deficiency because the operator is unable to determine if the PRV is working properly.) If the upstream and downstream pressures are the same, have the operator open a fire hydrant downstream and observe the reaction of the pressure across the valve.

5. If there are PRVs, can the operator describe how they work and what they do?

The operator's lack of knowledge about key components of the system is a sanitary deficiency. Such a lack makes it unlikely that any problems which arise will be solved in a timely manner. Failure of a PRV can cause high downstream pressures that can lead to the failure of main lines and services.

6. How would the utility be notified if a PRV fails?

The failure of the PRV to reduce pressure can cause a main or service line to break. Low pressures can result in backflow from backpressure or backsiphonage. The longer a failure goes undetected, and the longer the delay in fixing it, the greater the possibility of contaminating the system.

7. Is the system designed with dead-end lines?

Areas of stagnant water in a distribution system may result in bacteriological regrowth, red water, or customer complaints. These areas should be flushed routinely, and long-range plans for connection should be put into place if they are feasible. Records should be kept of complaints and corrective actions taken.

8. Are there several low places in the piping system?

Low areas in the piping system can accumulate silt and organic material that can reduce chlorine residual, grow bacteria, and cause odor and taste problems. Question 7, above, explains for how to correct the problem.

9. Do reservoirs turn over at least once every 14 days?

Water held in a reservoir for more than 14 days can become stagnant, causing taste and odor complaints, a reduction in chlorine residuals, and an increase in bacteriological activity.

10. If there is a hydraulic model, has it been compared to actual conditions? When was it last updated? Does it show any low-pressure conditions?

Hydraulic models help the manager identify low-pressure points and areas of inadequate supply. While the lack of a hydraulic model is not considered a sanitary deficiency, it can be if there are low-pressure problems that have not been addressed by use of a model or other specific method. A model that has not been calibrated against actual system data is of little value.

11. Are backflow prevention devices installed and tested at each commercial site where backflow could cause a reduction in water quality?

This issue is discussed in depth in the cross-connection chapter. These devices are necessary to prevent contamination of the system.

12. Does the discharge piping on all air valves extend a proper distance above ground and flood level?

One source of contamination is surface water that enters the distribution system through air valves.

13. Are distribution system problem areas identified on a system map?

A map or other record keeping system for system problems is a good indicator of management support for solving system problems. If the utility is not using a map or other system to record system problems, are they aware of their problems? Lack of awareness means that the problems will not be resolved in a timely manner.

Maps, Drawings and Planning

1. Are as-built drawings available?

As-built drawings are scaled drawings that show the actual locations of all constructed facilities. The lack of as-built drawings makes it difficult for the staff to perform proper repairs in a timely manner.

2. How often are maps updated?

Drawings and as-builts that are not updated at least once each year do not reflect current conditions. Inaccurate data can cause the staff to obtain the wrong materials and thus delay a repair. If this happens too many times, the staff may stop using the drawings.

3. Do maps and as-builts contain the proper information?

Maps and as-builts should contain the following information, or the information must be available in some form of asset data base: pipe size, date of installation, pipe material, line valve and blow-off locations, hydrant locations, storage tank locations, and interconnections to other systems.

4. Is there a master plan showing proposed construction and replacement lines?

To provide adequate and reliable service now and in the future, system changes and additions should be based on a master plan. If this plan does not exist, the utility commonly responds to developers' needs. This can cause the system to expand lines to areas that cannot be served with adequate pressure.

Distribution System Monitoring

1. Are chlorine residuals tested in the system as required?

The Surface Water Treatment Rule (SWTR) requires residuals to be measured at the same time and place as coliform samples are collected. Many states require daily monitoring of disinfectant residuals in the distribution system. The maintenance of a chlorine residual is the last line of defense against waterborne disease. This is one of the key quality control items in the operation of a water system.

2. Is the residual at least 0.2 mg/L prior to the first customer?

This is a SWTR requirement. It assumes that this residual is available after contact time (CT) requirements have been met.

3. Is a trace of residual maintained at coliform sampling points?

This is a SWTR requirement. It is good operational practice to keep a measurable residual at all points in the distribution system. If any point in the system does not have a chlorine residual, the water quality is suspect.

4. Are there an adequate number of residual sampling sites, and do they provide a representative sample of system conditions?

Sampling points should be established so the utility can monitor disinfectant residuals in the entire system. Small systems may be able to rotate through a number of sample sites to get an overall picture of disinfectant residuals.

5. Is the correct reagent used for testing free residual?

Check the reagents. Many times operators accidentally use reagents for total chlorine residual when using free chlorine as a secondary disinfectant.

6. Are operators waiting the correct length of time before reading the residual?

Some kits require the test for DPD to be completed within 1 minute of adding the reagent for free chlorine and within 3 to 5 minutes for total chlorine. In general, the manufacturer's instructions should be followed when using field test kits.

7. When was the testing instrument last calibrated?

Color wheels have a life of about 1 year. In addition, spectrophotometers can give false data. The spectrophotometer should be checked against a color wheel once a quarter, or when the operator suspects the accuracy of the data.

8. Is system pressure monitored at high and low elevations? Is this information recorded?

To obtain representative data, system pressure must be measured at high and low elevations. In addition, data should be recorded using blue ink. See Water Quality question 1, above, for more information on low-pressure problems.

9. Are customers' water quality complaints recorded?

Many states require utilities to record the nature and response to all water quality complaints. With the 1996 Amendments to the Safe Drinking Water Act requiring that customers be given water quality information in the Consumer Confidence Report, this is no longer just good operations and customer relations. By recording and analyzing customer complaints, a manager can prevent problems, or address them before they get out of hand. Many customers are very sensitive to changes in water quality, and a positive response to customer problems is a good management practice.

10. What is the percentage of unaccounted-for water?

A high quantity of unaccounted-for water, above 15 percent, is an indication of either inaccurate meters or excessive leakage. Inaccurate meters result in a utility not being paid for all the water that is consumed, reducing income and making it more difficult to maintain the system. Holes in pipelines and bad pipe joints are potential entry points for contaminated ground water.

System Operation and Maintenance

1. What is the frequency of main breaks?

The best number is zero, however, main breaks are one of the normal problems in a water system. If the breaks are frequent, there may be a problem with the integrity of the piping material. (Frequency depends on area and type of piping material.) Each main break opens the system to contamination, and frequent breaks increase the potential for introducing waterborne pathogens into the system.

Most breaks are due to leaks, not age. The leaks undermine the pipe, causing it to fail under the weight of the overburden. To prevent main breaks, a routine leak detection program should be conducted and a record of distribution system repairs should be kept. This record should identify the location and type of repair, repair device or length of replacement pipe, and general condition of the line.

2. Are the breaks primarily in one area? What type of pipe is involved?

If management has this type of information, it is an indication that they are attempting to address problems before they become critical. This information should be compared with the master plan to ensure that they are in agreement. The lack of this information may be considered a lack of response by management to the system's deteriorating conditions.

3. Is there a line flushing program? Is a systematic unidirectional process used? Are records maintained of frequency, location, and amount of time required?

The whole system should be flushed once or twice a year to clear sediment in the lines. The flushing should be well planned and carried out, preferably beginning at points near the water plant and storage facility and moving to the outer ends of the system. A minimum velocity of 2.5 fps must be maintained during the flushing. This can be done only cutting off portions of the distribution system with isolation valves so the direction of the water flow is known and comes from a single line. A pitometer should be used to measure flow at questionable areas of the distribution system when the flushing begins.

4. Is there a valve inspection and exercising program and are records maintained?

Every valve in a system should be inspected and exercised annually. This should include completely closing, opening, and re-closing until the valve seats properly. Leaking or damaged valves should be scheduled for repair. A record of valve maintenance and operation, including the number and direction of turns to closure, should be kept.

5. Is there a fire hydrant flushing program separate from the line flushing program?

Fire hydrant leads can be a source of water quality deterioration. The water can become stagnant, consuming chlorine, causing odor and taste problems, and increasing bacteriological counts. Annual flushing can prevent this problem.

6. Does the utility have a backhoe? If not, how long would it take a contractor or rental company to provide one if needed? Can this equipment be obtained late at night?

The lack of equipment such as a backhoe can prevent the staff from making repairs in a timely manner. The longer a portion of the system is shut down at a reduced pressure, the greater the opportunity for contamination.

7. How often are pressure readings taken in the distribution system? Are they representative of the system?

A program to read pressures may be conducted in conjunction with the fire department to determine adequacy of fire flow. A record of pressures and flows throughout the system may help to identify problems. If the programs are conducted during the day and at night, they will indicate hydraulic efficiency under common requirements.

8. Are adequate repair materials on hand?

If repair materials are not available, how many hours would it take to obtain these materials at 2:00 a.m? The minimum materials include two full-circle repair bands for each pipe size, two cast-iron couplings for each pipe size, two cast-iron pipe joint repair bands, and one length of each size of pipe.

9. Are there written procedures for isolating portions of the system and repairing mains?

Written emergency response procedures improve the water system's reliability. In a small system, they provide a way to handle unexpected problems when the regular operator is not available. They also give the operator a means of dealing more effectively with non-routine tasks.

10. Does the utility maintain an updated list of critical customers?

Reducing water pressure, shutting off service, or reducing water quality can severely affect some customers, including hospitals, clinics, photo developers, and users of special medical equipment. It is important for customer support and for the reduction of liability to maintain a list of these customers and to notify them of changes in the system that could adversely affect them.

11. Does the utility have a corrosion control program?

The utility should have a program to evaluate corrosion and the effectiveness of a program to control contaminants such as lead and to minimize red water complaints. A record of complaints and the corrective actions should be kept.

Safety Considerations

1. Does the utility use proper safety procedures for handling line disinfection chemicals?

This is an Occupational Safety and Health Administration (OSHA) requirement. It includes using proper personal protection equipment (chlorine and dust filter respirator for calcium hypochlorite, gloves and chemical goggles for sodium hypochlorite). There must be a written procedure for transporting and handling chlorine. This procedure should be referenced in the hazard communication program list of non-routine tasks.

2. Is there a trained, competent person on the staff?

This is an OSHA requirement.

3. Does the competent person evaluate soil and work site hazards at each excavation?

This is an OSHA requirement.

4. Are excavation hazard evaluations documented?

This is an OSHA requirement.

5. Does the utility have and use cave-in protection equipment?

Cave-in protection equipment must be used in any trench more than 5 feet deep (4 feet deep in some states). The competent person must know how to select the correct protection system based on soil testing results.

6. **Does the utility have and does it use proper traffic control equipment?**

According to the MUTCD, all temporary signs must be orange and black and at least 36 inches X 36 inches. Stop and go paddles must be at least 18 inches. Cones must be at least 18 inches tall, and each work site must have at least 13.

7. **Have all field workers been trained in the use of traffic control equipment?**

Failure to provide training is one of the most common safety violations.

8. **Do all employees who operate industrial trucks have a Commercial Drivers License?**

This is a U.S. Department of Transportation requirement.

Disinfection Procedures

1. **What disinfection procedure is used for new lines?**

The procedure outlined in the AWWA Standard for Disinfecting Water Mains (C651-99) should be followed (25 mg/L of chlorine not to drop below 10 mg/L after 24 hours). The inspector should ask the operator what procedures are used. The final determining factor should be that new mains should demonstrate negative bacteriological results prior to being placed into service.

2. **Does this procedure meet the AWWA C-651 Standard?**

Three methods are described in C-651; the least reliable is the use of chlorine tablets.

3. **What disinfection procedure is used during repairs of broken lines?**

It is common industry practice to disinfect all repair parts and any contaminated line with sodium hypochlorite. (If proper disinfection practices have been followed, in most cases repaired mains may be returned to service prior to determining the bacteriological quality of the water because the sanitary risks of loss of service and cross connections are likely greater than that of bacterial contamination.)

Design and Operational Constraints on Water Quality

1. **Are water lines looped, or are there dead ends?**

Dead-end lines can lead to reductions in water quality. Where a pipe is dead ended for future expansion, it is desirable to provide some type of temporary loop or to flush the line frequently.

2. **Are there any bottlenecks in the piping system (a small diameter pipe connected on both ends by large diameter pipe)?**

Bottlenecks cause high velocities, which can cause a Venturi effect, drawing contaminated water into the system through leaks in the bottleneck.

3. **Are blow-offs connected to sanitary or storm sewers, or do they exit below flood level in ditches or streams?**

Blow-off connections to sewers or sewer manholes are a direct cross-connection and are prohibited.

Design and Operational Constraints on Reliability

1. **Is the system interconnected with any other water systems?**

An interconnection to a second water system may provide an alternative source in the case of drought, contamination of the primary source, or similar emergency.

2. **Does the system have adequate valves?**

The system should have enough isolation and blow-off valves to make necessary repairs without undue interruption of service over any appreciable area.

Construction Considerations

1. Are concrete thrust blocks or restraining fittings used at all elbows, tees, and dead ends?

Concrete thrust blocks must be used to restrain all fittings, elbows, tees, and dead ends.

2. Are proper bedding and backfill procedures used with new or repaired pipes?

Bedding and backfill protect pipes from external damage. With PVC, they also support pipe walls and protect them from deflecting and thus breaking longitudinally.

3. Are pressure or leak tests performed on all new pipe construction?

Pressure tests check the integrity of the piping material. Leak tests check the integrity of the pipe joints.

4. Are cast-iron and steel pipe protected from external corrosion?

Placing poly bags over cast-iron pipe is the best way to protect it from external corrosion and thus extend its life. Steel pipe is protected with any one of many external coatings.

8 Cross-Connections

Cross-connections in water systems are a significant sanitary risk that threaten drinking water quality and public health.[1] During a sanitary survey, the inspector must first evaluate the adequacy of the system's cross-connection control program. Second, the inspector should identify cross-connections that are owned or controlled by the water system in the treatment facility and in the distribution system. To perform these evaluations, the inspector should be able to meet the following objectives.

Learning Objectives

By the end of this chapter, learners should be able:

- To define the term cross-connection and recognize common cross-connections.
- To differentiate between the two types of backflow that can occur due to cross-connections: backpressure and backsiphonage.
- To determine if adequate pressure is maintained in the distribution system.
- To identify devices to prevent contamination, explain their operation, and determine if they are installed properly.
- To evaluate the water system's cross-connection control program and its implementation.
- To identify unprotected cross-connections within the water system, including those in a treatment facility, pumping station, or distribution system.
- To determine if the appropriate backflow prevention devices are used, properly tested, and maintained depending on the degree of hazard.

Data Collection

To evaluate the system's compliance status, the inspector should review the following information:

- System's written cross-connection control program.
- Number and type of backflow preventers in the system.
- Frequency of testing of backflow preventers.
- Qualifications of persons authorized to test devices.
- Number of plans for new building construction that are reviewed.

Regulations and Standards to Consider

The inspector should consider or review the following information prior to the inspection:

- State regulatory requirements for cross-connections.

[1] The student may want to consider viewing the video *Sanitary Survey Inspection; Before You Begin . . . CROSS-CONNECTIONS* prior to reading this section. To order, see www.epa.gov/safewater/dwa/orderform.pdf.

- EPA's Cross-Connection Control Manual.
- AWWA's Manual of Cross-Connection Control, M-14.
- *Manual of Cross-Connection Control*, Foundation for Cross-Connection Control, University of Southern California.

Cross-Connections

Basic Information

Cross-Connection Defined. To prevent contamination of its water, a system must make sure that service connections are properly made and continually monitored for cross-connection hazards. **A cross-connection is an actual or potential physical connection or arrangement between otherwise separate potable water piping systems and any contaminant that allows water to flow between the two systems.** Hazards occur when a contaminant flows toward the potable supply. Unless controlled, cross-connections can result in contaminated water replacing potable water at various sites within a water system. There is a potential for the contamination to spread throughout the distribution system, endangering the health of the entire community.

Plumbing Defects. Plumbing defects can occur in any part of a water system, and cross-connection hazards can occur where outside water pressure can exceed potable water pressure. Cross-connections must be prevented or controlled at all service sites. The water treatment plant is often the site of a number of cross-connections.

Types of Cross-Connections. A cross-connection link can be made either as a pipe-to-pipe connection, in which potable and contaminated water pipes are linked without proper control valves, or as a pipe-to-water connection, in which the outlet from a potable water supply is submerged in contaminated water. Cross-connections are usually made unintentionally or because their hazards are not recognized or are underestimated.

Backpressure and Backsiphonage. The two major types of cross-connection hazards, backpressure backflow and backsiphonage backflow, are distinguished by their origins. **Backpressure** backflow refers to the flow of contaminated water toward a potable supply when the contaminated water's pressure is greater than the potable water's pressure. **Backsiphonage** backflow results from negative pressure (a vacuum) in the distribution pipes of a potable water supply. Contaminated water is sucked up toward the potable supply.

Control of Cross-Connections. Successful control of cross-connection hazards depends not only on inspecting for cross-connections by a water system and by water users, but also on an enforceable cross-connection control program. If a community subscribes to a modern plumbing code, such as the National Plumbing Code, its provisions will govern backflow and cross-connections. However, the water system must obtain authority to conduct a community inspection program through an ordinance or other means and carry out a comprehensive program.

Components of Water System's Cross-Connection Control Program

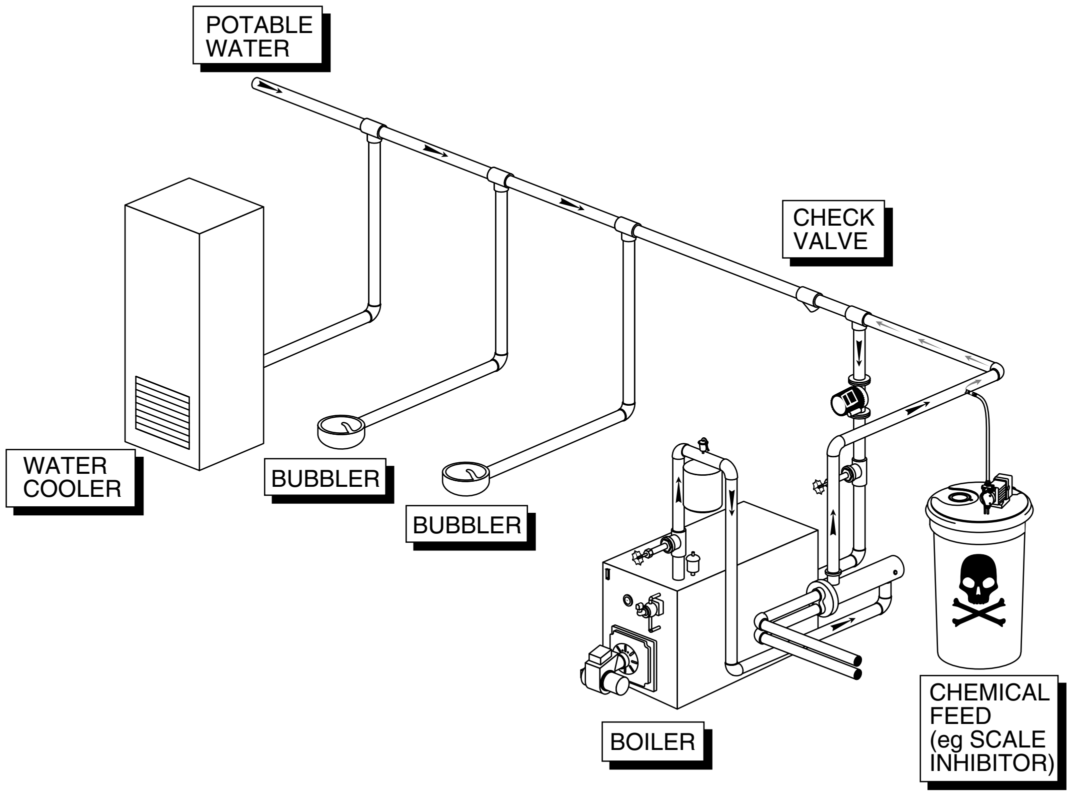
A cross-connection control program should have these basic components:

- Ordinance or other authority to establish a program.
- Technical provisions to eliminate cross-connections.
- Right of entry and inspection of existing facilities served by the system.
- Backflow prevention device testing, repair and recordkeeping.
- Certification of backflow prevention device testing personnel.
- Review of new construction plans to ensure no cross-connections are present.
- Penalty provisions for violations.

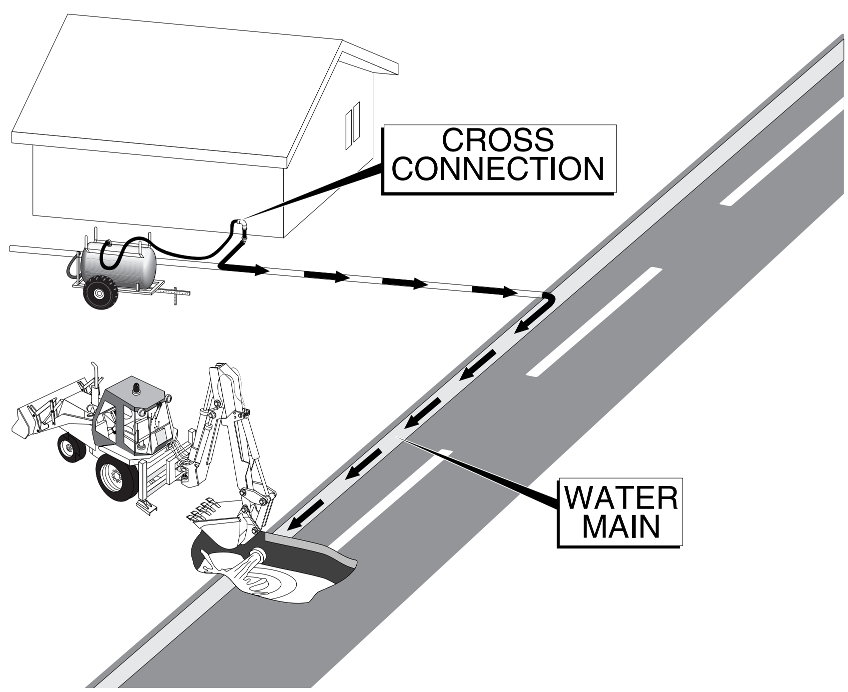
Protection Against Sanitary Deficiencies from Cross-Connections

Cross-connections at sites serviced by a water system can usually be controlled at the sites themselves. For example, a submerged water outlet in an apartment building could result in

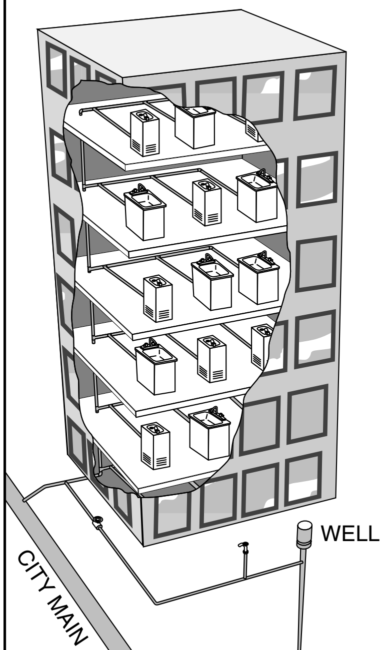
Backflow as a Result of Backpressure



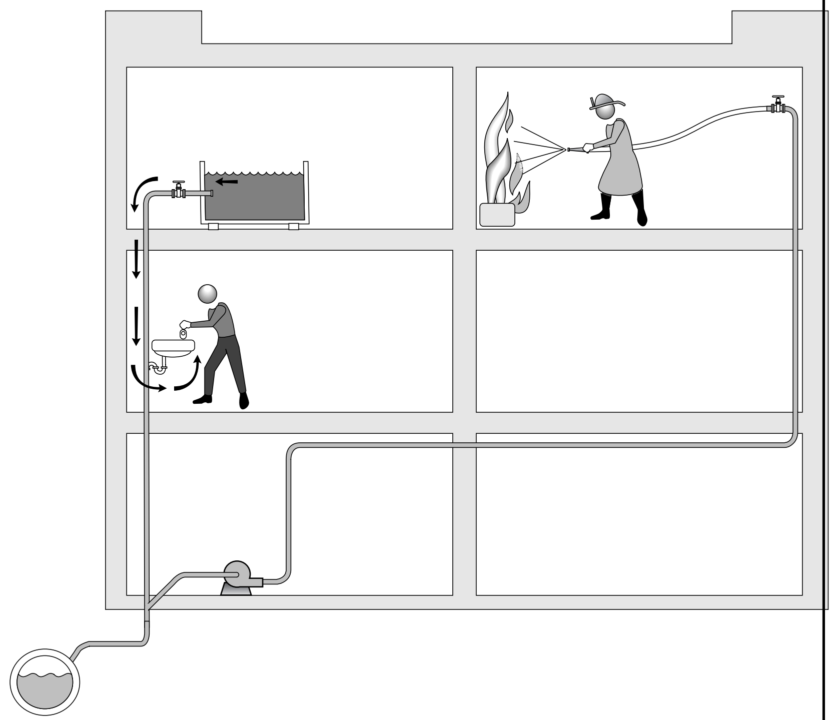
Backflow as a Result of Backsiphonage



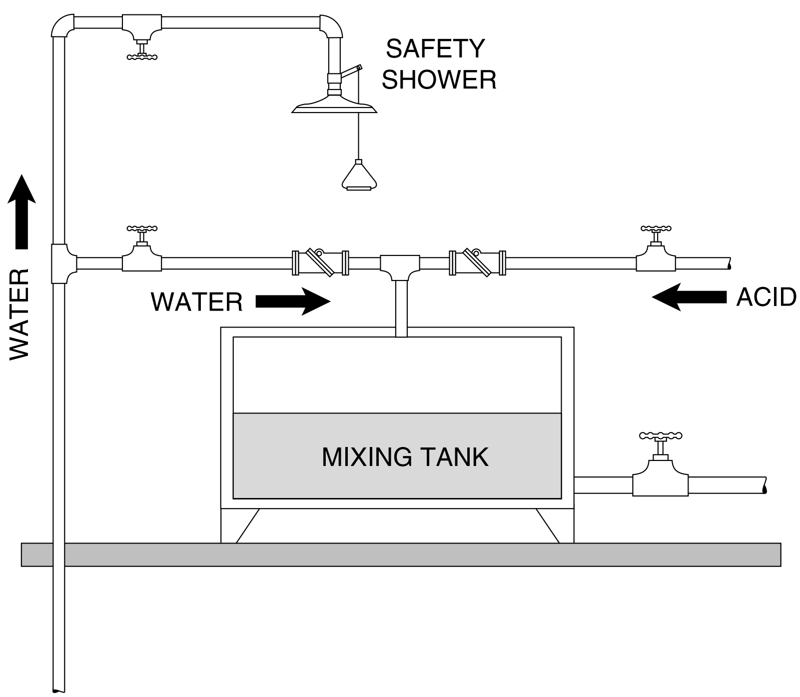
Backflow as a Result of Hydraulic Head



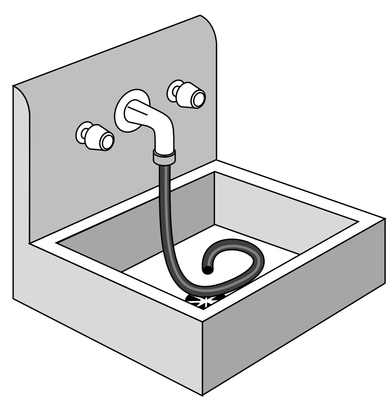
Backflow as a Result of Backsiphonage



Direct Cross Connection



Indirect Cross Connection

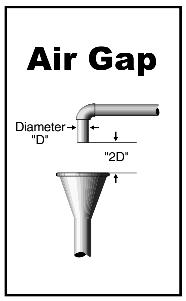


contamination of the water for the entire building (as well as threaten the water facility's supply) if the pressure of the contaminated water exceeds that of the potable water.

Pressure. An important aspect of reducing the threat from cross-connections is maintaining adequate pressure in the distribution system. States usually have a minimum pressure requirement of at least 20 psi under all conditions of flow in all portions of the system.

Devices. A number of devices are available to prevent cross-connections, including the following:

- **Air Gap.** To prevent a cross-connection hazard in the apartment example above, each fixture in the building should have a vertical air gap of twice the diameter of the pipe or fixture between its water outlet and its flow level rim. This will eliminate the physical cross-connection link and protect the building (and the municipal supply) against backflow. An air gap may also be made where the water service enters the building. This protects only the municipal supply, however, and not the building system.

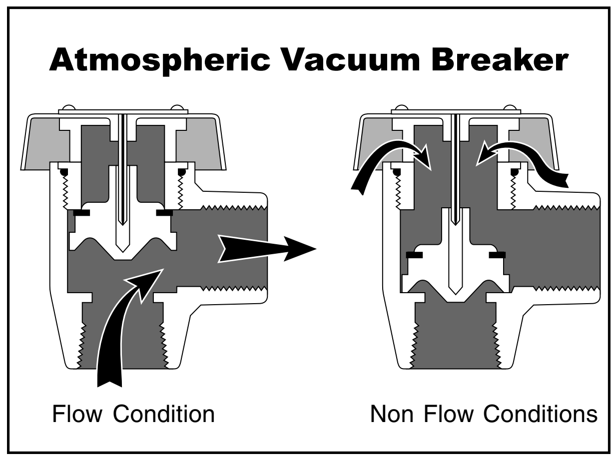


  Example: The faucet is at least two times the diameter above the highest level in a sink or tub.

- **Other Devices.** Other backflow prevention devices can be installed when an air gap cannot be made. They also provide backup when air gaps are made. Surge tanks in booster systems, color-coding, and labeling of pipes in dual water systems also help protect buildings against cross-connection backflow.

  Although state requirements may vary, it is generally agreed that backsiphonage can be prevented by installing vacuum breakers at water outlets where contaminated water is present (for example, at toilets and urinals equipped with flushometers, or at makeup water for a chemical solution tank). Vacuum breakers can also be used at hose bibs and in connection with in-ground lawn irrigation systems. They are not, however, effective against back pressure.

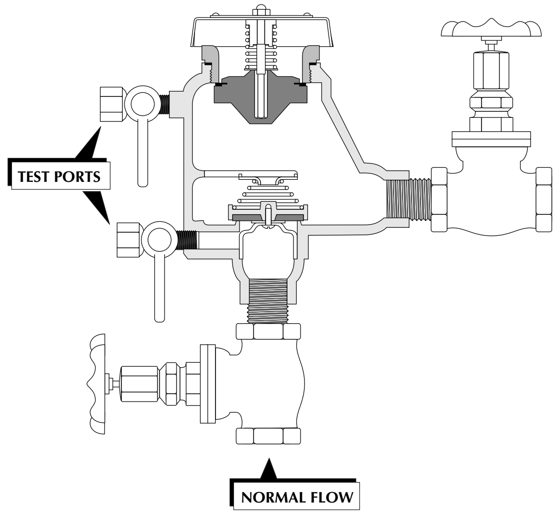
- **Atmospheric Vacuum Breaker.** An atmospheric vacuum breaker is activated by atmospheric pressure to block the water supply line when negative pressure develops in the line. This action admits air to the line and prevents backsiphonage. A vacuum breaker will not provide protection against backflow resulting from backpressure and should not be installed where backpressure may occur. Vacuum breakers must be installed a minimum of 6 inches above the highest outlet. Vacuum breakers are not suitable for continuous use because they may stick open. Therefore, they cannot have a valve on the downstream side, like a spray nozzle on a hose, that can shut water off.



- **Pressure Vacuum Breaker (PVB).** The PVB device is installed in pressurized systems and operates only when a vacuum occurs. It is usually spring loaded and should be specially designed to perform adequately after extended periods under pressure. This device is suitable for use when a high degree of hazard is present but only under backsiphonage conditions, for example, on irrigation systems. Pressure vacuum breakers must be installed a minimum of 12 inches above the highest outlet. They must be tested at least annually.

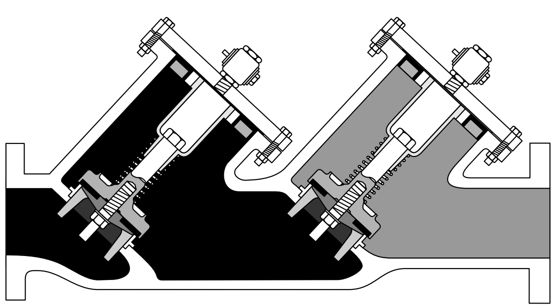
- **Double-Check Valve Assembly.** The double-check valve assembly is a reliable

Pressure Vacuum Breaker (PVB)



means of backflow protection from non-health hazards. For example, it can be used to protect the water supply against contaminants that would cause only aesthetic changes to water quality. As in the case of other backflow preventers, the double-check valve assembly should be inspected and tested annually. Homemade double check valve assemblies are not suitable because they cannot be tested for proper operation.

Double-Check Valve Assembly

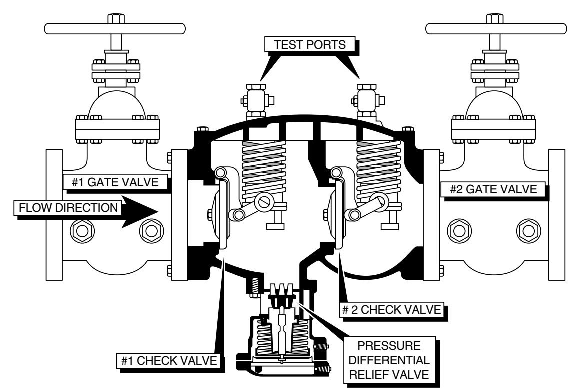


The double-check system has the advantage of a low head loss (maximum 10 psi). With the shut-off valves wide open, the two checks, when in an open position, offer little resistance to flow.

- **Reduced Pressure Zone Backflow Preventer (RPZ).** The RPZ device is the most reliable of the mechanical devices used to prevent backflow and can be used for both backpressure and backsiphonage. It should only be used for non-health or health hazards. RPZs are often used to provide protection on make-up water to boilers. This device consists of two independently loaded pressure-reducing check valves and a pressure-regulated relief valve located between them.

  Because all valves may leak as a result of wear or obstruction, the protection provided by the check valves is not considered sufficient. If some obstruction prevents a check valve from closing tightly, the leakage back into the central chamber would increase the pressure in this zone, the relief valve would open, and flow would be discharged to the atmosphere.

Reduced Pressure Zone Backflow Preventer (PRZ)



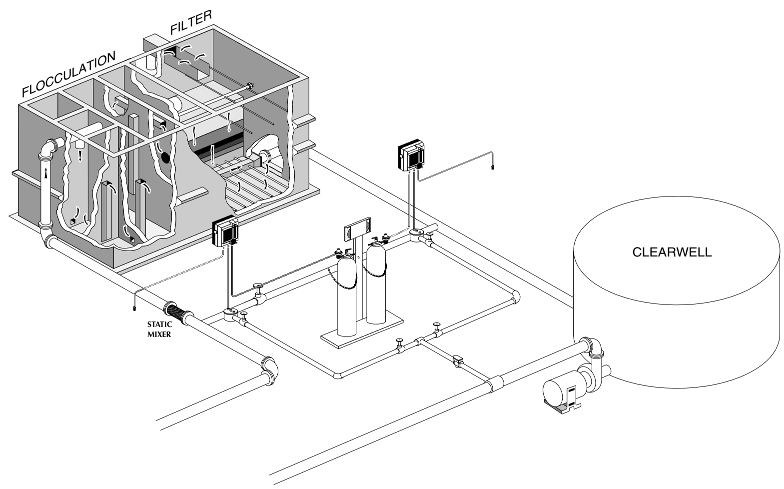
Malfunctioning of one or both of the check valves or the relief valve is indicated by a continuous discharge of water from the relief port; small amounts of water may be periodically discharged during normal operation. Under no circumstances should plugging of the relief port be allowed, because the device depends on an open port for safe operation.

Device Use and Maintenance

Testing Required. All types of backflow preventers should be tested at least annually to assure their proper function.

Certified Testers. Many states now require the certification of individuals who test backflow preventers. This is an important component of a system's cross-connection control program. Water systems may have their own employees certified, or allow private contractors to test devices.

Chlorine Split Feed



Cross-Connections Owned or Controlled by the Water System

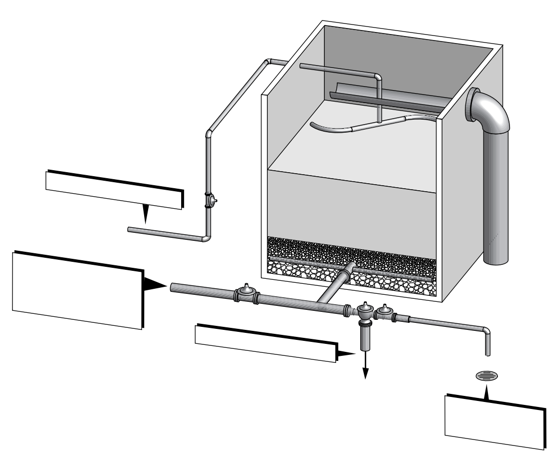
Requirements. In addition to the many cross-connections that may exist on the premises of a water system's customers, there can also be cross-connections that are owned or controlled by the system itself. These potential cross-connections should be subject to the same scrutiny as those that are privately owned.

Location of Cross-Connections. There can be cross-connections in water treatment plants, pumping stations, or in the distribution system that can pose a risk to water quality and public health. During a sanitary survey, the inspector should identify all cross-connections that are under the water system's control.

Water Treatment Plants. Water treatment plants can have a variety of potential cross-connections. The inspector should determine whether the following cross-connections exist. If they do exist, the water system should eliminate them with an air gap or, if that is not possible, the appropriate backflow-prevention device.

- Submerged inlets or water piped directly to chemical feed tanks.
- No antisiphon valves on chemical feeders.
- Hose bibs without vacuum breakers.
- Laboratory aspirators.
- Split chemical feeds to raw or partially treated water and finished water. Examples are pre- and post-chlorination or pre- and post-caustic addition for pH control.
- Surface wash on filters.
- Filter-to-waste piped directly to a drain.
- Drain or sewer traps with direct water injection.

Surface Wash Filter

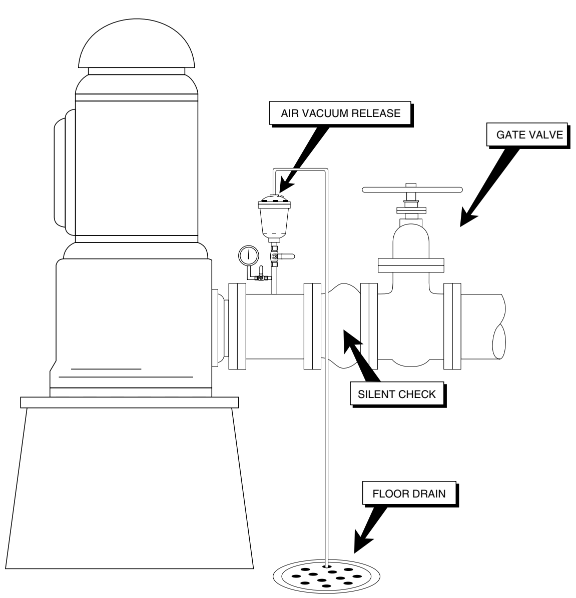


- Floor drains that allow water to be returned to the process stream.
- Lack of legends and color coding on pipes.
- Bypasses around backflow preventers.
- Feed water to boilers with chemical injection.
- Water loading stations for bulk water sales.

Pumping Stations. Pumping stations should also be inspected for cross-connections. Potential cross-connections include:

- Priming of raw water pumps with finished water.
- Air relief valves piped directly to a drain.
- Cooling water for an emergency generator submerged in a drain or returned to the potable supply.

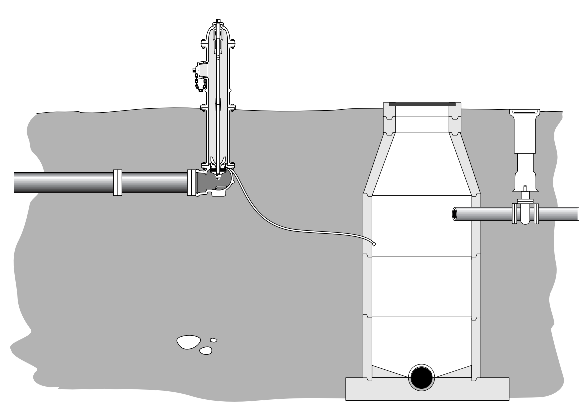
Air Relief Valve Incorrectly Piped Directly to Floor Drain



Distribution System. Many of the potential cross-connections in a distribution system cannot be seen. Therefore, the person responsible for the operation of the distribution system must be relied on to provide the appropriate answers relating to these cross-connections:

- Submerged blowoff in streams.
- Water mains passing through sewers.
- Connections to unapproved water systems or sources (i.e., fire systems or private wells).
- Submerged inlets in the water system's own meter testing equipment.
- Air relief valves in pits where their open ends may be submerged.
- Submerged relief ports from pressure-reducing valves.
- Overflows from storage tanks piped directly to storm drains or sewers.
- Direct connections to sewers for flushing either the water main or sewer.
- Hydrants with drain lines to sewers.
- Uncontrolled use of fire hydrants. (Contractors and others who use fire hydrants should only be allowed to do so when the flow is metered and the distribution system is protected against backflow with an RPZ.)
- Filling newly installed mains from fire hydrants for flushing and disinfection.

Hydrant Drain to Manhole



Sanitary Deficiencies and Cross-Connections

During a sanitary survey, the inspector should undertake two major activities related to cross-connections. The first is to evaluate the adequacy of the water system's cross-connection control program. The second is to look for cross-connections that may be owned or controlled by the water system. (These cross-connections may be in the water treatment plant, at pumping stations, or in the distribution system.) To perform these major activities, the inspector should determine the answers to a number of questions.

1. **Does the water system have a written cross-connection control program?**

   The inspector should determine if the system has a formal written program for controlling cross-connections. The program should be reviewed to determine if it has the following basic components:

   - Authority to establish a program.
   - Technical provisions.
   - Right of entry and inspections.
   - Device testing and repair.
   - Certified testers.
   - Plan review and inspection of new construction.
   - Penalties.

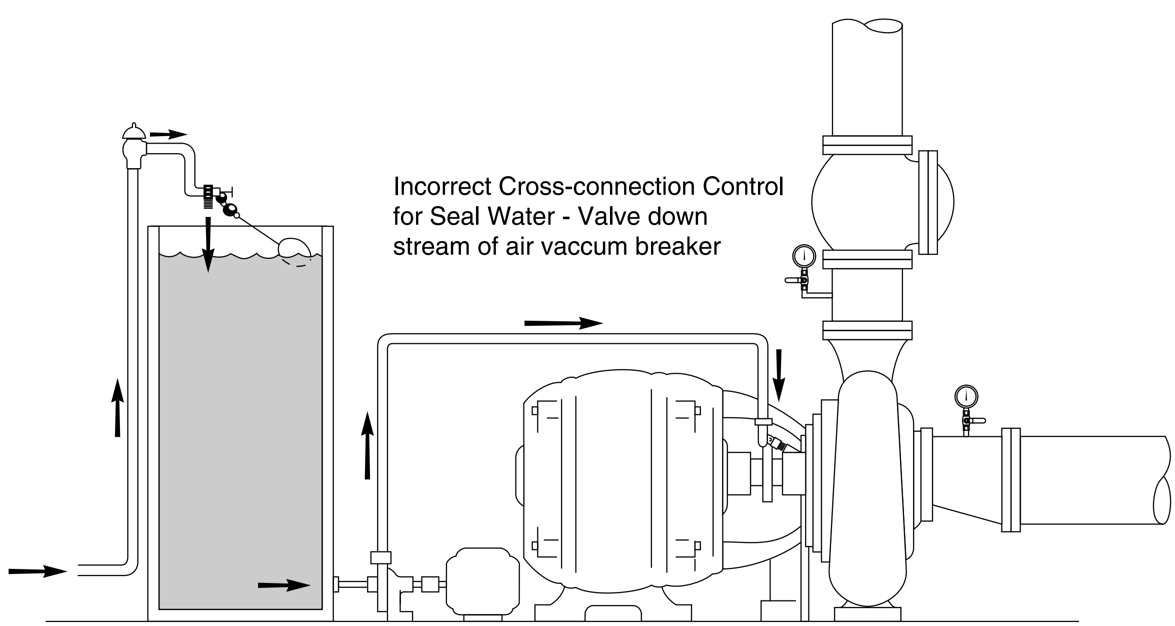
2. **Is the program active and effective in controlling cross-connections?**

   To determine if the program is being implemented effectively, the inspector can review its staffing and the records of the number of inspections that are conducted, the number of various devices installed in the system, and the number of tests that are performed.

3. **Are there cross-connections at the water treatment plant?**

   During a sanitary survey of a water treatment plant, the inspector should look for cross-connections. The likely locations of cross-connections are submerged inlets in chemical feed tanks, connections between potable water lines and process water, split chemical feeds in chlorination systems that pre- and post-

Example of Cross Connection Downstream of Air Vacuum Breaker



chlorinate, surface wash, and filter-to-waste connections to sewers. Also during the sanitary survey, the inspector should discuss with the plant operator the importance of eliminating cross-connections.

4. Does the system test backflow preventers at treatment plants and other facilities it owns?

The inspector should determine whether devices are tested at least yearly. Even a system that does not have an active cross-connection program needs to ensure the continued proper operation of its backflow preventers. Color coding and legends on piping also are useful in minimizing cross-connections and should be evaluated during the inspection.

5. Are there cross-connections in pumping stations?

While inspecting pumps and pumping stations, the inspector should identify any potential cross-connections. They can include raw water pumps that are primed with finished water, air relief valves piped directly to a drain, cooling water for emergency generators with submerged outlets, and cooling water that is returned to the potable system.

6. Are there cross-connections in the distribution system that the water system owns or controls?

To evaluate the presence of cross-connections in the distribution system, the inspector must speak with the person responsible for distribution system operations. In small systems, the entire system may be operated by one person. In larger systems, responsibility for treatment plant operation and distribution may be split. The inspector should question the operator carefully about distribution cross-connections. Examples of these are submerged blow-offs, direct connections to sewers, water mains in sewers, connections to unapproved systems, hydrant drain lines to sewers, and overflow from storage tanks piped directly to sewers or drains.

7. Does the water system have a program to control the use of fire hydrants?

The use of fire hydrants by non-water system personnel for filling tanks, cleaning sewers, or providing water for construction projects has the potential to create serious cross-connection hazards. The inspector should determine if the water system has a program to ensure that fire hydrants are not used for these purposes or, if they are used, that appropriate procedures are followed to prevent backflow. These procedures can include a permit system that requires the use of air gaps and backflow preventers.

9 Monitoring and Laboratory Testing

An important activity for water systems, monitoring is required to determine compliance, e.g., the presence of chlorine residuals, and to determine the effectiveness of the treatment process.[1]

Learning Objectives

By the end of this chapter, learners should be able to evaluate quality assurance in monitoring and laboratory testing. Specifically, they should be able:

- To identify responsibilities and requirements of water purveyors with respect to monitoring.
- To determine if in-house testing facilities, procedures, and equipment are adequate.
- To determine if test equipment is calibrated and maintained properly.
- To determine if reagents have an unexpired shelf life and are discarded appropriately after expiration date.
- To determine if the operator is performing tests properly.
- To determine if treatment adjustments are made based on laboratory results.
- To determine if certified laboratories are used when required.

Data Collection

To evaluate the system's compliance status, the inspector should review the following information:

- Any violations of MCLs, treatment techniques, monitoring, or reporting.
- Current information on population served and number of services.
- State-approved coliform sample siting plan.
- State-approved locations for THM samples.
- Variances or exemptions that apply to the system.
- Compliance with orders that apply to the system.
- Documentation of State approval for the installation of, or changes to, the system.

Regulations and Standards to Consider

The inspector should review the following information prior to the inspection:

- EPA or state primary and secondary drinking water regulations.
- State design standards or guidelines.
- ANSI/NSF standards.

[1] The student may want to consider viewing the video *Sanitary Survey Inspection; Before You Begin . . . SAMPLING AND MONITORING* prior to reading this section. To order, see www.epa.gov/safewater/dwa/orderform.pdf.

Monitoring and Laboratory Testing

Basic Information

Approved Laboratory. Monitoring requirements related to specific provisions of the Safe Drinking Water Act (SDWA) regulations are dealt with in Chapter 2, Regulations. Much of the required monitoring, with the exception of monitoring for turbidity and chlorine residual, must be performed by a certified laboratory, either the system's own laboratory or a contract laboratory.

In-House Monitoring. The operator must establish adequate in-house monitoring to properly evaluate the operation of the treatment system and develop an on-going process control program. The tests performed and the number of sample points used depend on the type of plant. The frequency of sampling depends on the raw water source, its variability in quality, and the importance of the parameter being tested. Below is an example of a comprehensive monitoring program for a conventional surface water treatment plant.

Sanitary Deficiencies for Monitoring and Laboratory Testing

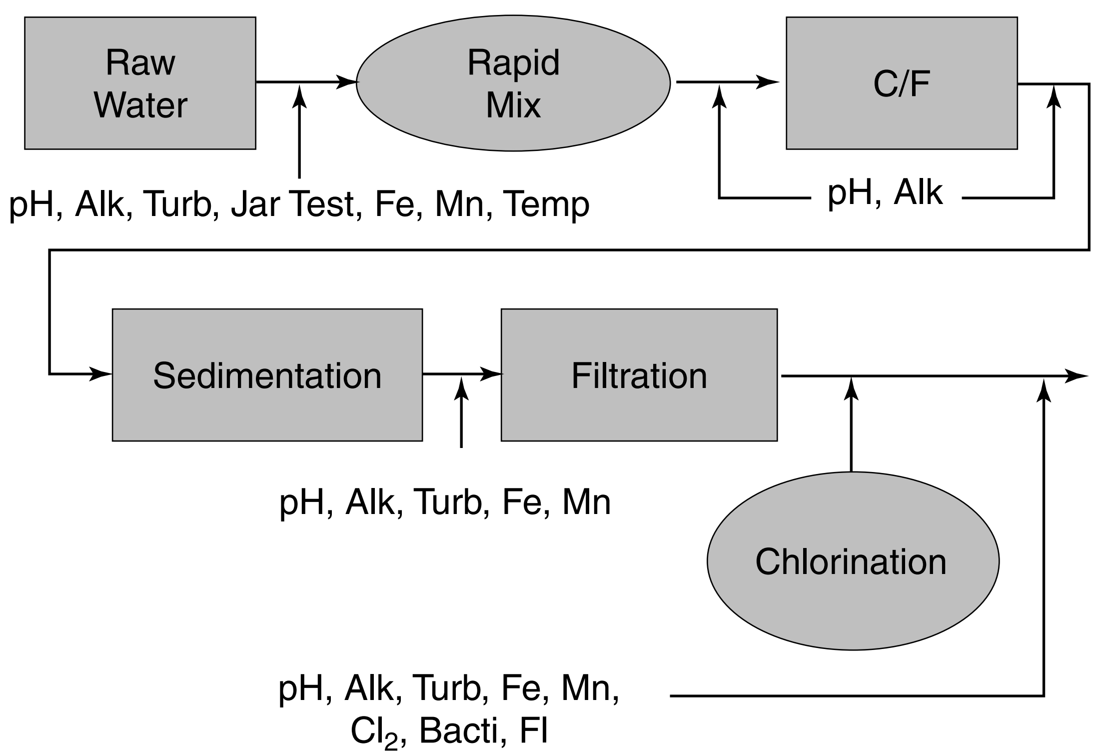
1. **Is adequate monitoring in place?**

   The operator should have an in-house monitoring program in place and should be performing the monitoring required to comply with all provisions of the SDWA.

2. **Is the operator following proper procedures?**

   The inspector may observe the operator's technique in collecting samples and performing analyses. The operator should follow correct procedures for calibrating the test equipment and for performing the test itself. For example, the operator must periodically check secondary turbidity standards against primary standards.

Example of a Comprehensive Monitoring Program for a Conventional Surface Water Treatment Plant



3. Are testing facilities and equipment adequate?

The owner must provide the operator with adequate test equipment to implement a comprehensive monitoring program. The inspector should verify that all test equipment used is working properly. The laboratory itself, in terms of space and environment, should be adequate for the test equipment being used. On-line monitoring equipment, such as turbidimeters, pH meters, and chlorine residual analyzers, must be checked and calibrated regularly to ensure accurate performance.

The inspector should ensure that only the correct chemical reagents for each application are being used with the test equipment. The reagent containers should be clearly marked with name of the reagent and the date of its preparation. Manufacturer-prepared reagents should be discarded when the expiration date is reached.

4. Are records of the monitoring program adequately maintained?

The results of the monitoring program should be maintained in an organized recordkeeping system.

5. Does the operator chart the results?

The operator should plot trends on graph paper or with a computer. This enables the operator to see the relationship in treatment changes. For example, as more chlorine is added, iron levels go down, or as lime is added, pH goes up.

6. Are treatment adjustments based on laboratory results?

The inspector should determine what action is taken based on the test results. The operator should understand the importance of the test results as they relate to the performance of the treatment plant.

7. Are certified laboratories used when required?

In some states, the results of some tests are not valid unless they are performed by a certified laboratory or certified laboratory technician.

10 Utility Management

The operation and maintenance (O&M) of any water system ultimately depends on management. Management is the process that provides funding and support (administrative, personnel, and purchasing) to ensure continued, reliable operation through adequate staffing, operating supplies, and equipment repair and replacement.

Learning Objectives

Upon successfully completing this chapter, learners should be able to evaluate the management of a small water supply system. Specifically, they should be able:

- To identify and evaluate key components of a water system's management organization.
- To identify the plans necessary for compliance and long-term capacity.
- To evaluate personnel staffing: numbers, skills, certification, training, and safety.
- To identify the key components necessary for reliable system operations.
- To evaluate in general terms the system's managerial and financial capacity for long-term reliability.

Data Collection

The inspector should obtain as much of the following information about the water system as possible before the sanitary survey inspection. If the inspector is unable to do so, however, the information and data may be obtained during the inspection.

- Previous sanitary survey reports.
- Correspondence.
- Compliance monitoring results.
- Compliance record.
- Plans on file (e.g., source protection, sampling, emergency and contingency, cross-connection control, and repair, replacement, future expansion).

Regulations and Standards to Consider

- Safe Drinking Water Act.
- Pertinent monitoring requirements.
- Applicable ground water disinfection requirements.
- Capacity development guidance.
- The system's Consumer Confidence Report.
- Minimum operator certification requirements.

Utility Management

Basic Information

The management of the water system does not, in itself, appear to represent a sanitary risk to the quality of the water. However, there are several aspects of management that will ultimately affect the overall capabilities of the system.

The management of a small system may be as small as a single individual serving as the operator and manager. Or, it may be a hierarchy of elected officials and municipal employees who approve budget requests, make purchases, and plan for infrastructure repairs and replacements to ensure the long-term adequate, reliable, and safe production, storage, and distribution of potable water. Make sure you are working with the most effective and responsible level of management.

Sanitary Deficiencies for Utility Management

In performing a sanitary survey, the following five areas of utility management contribute to sanitary deficiencies.

Organization. Management of a small water system often involves only one or two key individuals: the operator and the owner or elected official who is ultimately responsible for the system's O&M. One advantage of a small management team is the ability to identify the individual in charge and to provide information to that person. However, the workload may far exceed the staffing capabilities. More complicated management hierarchies improve individual workloads but also increase the opportunity for miscommunication and inadequate information collection and dissemination.

Whatever its form, management can have a profound effect on the reliability of a system. Managers must have a working knowledge of the compliance requirements that apply to their system. Staff must be empowered to make operating decisions and must be supported by management responsive to resource needs.

Information collection and management is also important. Activities range from tracking operating expenses and locating valves on a distribution map, to maintaining a record of breaks and repairs and a log of customer complaints. Information of this nature is critical for planning and budgeting for the next year, as well as the next decade.

Planning. Planning is often a challenge for many systems. The following plans are important to many public water systems:

- Source protection.
- Monitoring.
- Emergency or contingency.
- Distribution flushing.
- Operation and maintenance.
- Cross-connection control.

There are also safety programs with which the system must comply. Other equally critical plans include an annual budget and a 10-year capital improvement plan (CIP) to address repair, replacement, and future expansion.

Personnel. Personnel issues include adequate numbers of skilled operations staff, compliance with state certification requirements, training, and safety.

Operations. Management must first provide the facilities and equipment required to operate reliably and in compliance with all application regulations. Written standard operating procedures ensure reliability from one operator to the next.

Finance. Financing addresses the day-to-day operating budget, future repair and replacement, and future expansion. Conservation offers the opportunity to minimize demands on the system, protect source water quantity, reduce chemical and electrical costs, and promote the longevity of the system.

Reviewing these five areas will also help address the three elements of managerial capacity and the three elements of financial capacity.

Elements of Managerial Capacity	Elements of Financial Capacity
Ownership accountability	Revenue sufficiency
Staffing and organization	Fiscal controls
Effective external linkages	Credit worthiness

Although much of the information to address these issues can be collected during the sanitary survey, some aspects of managerial and financial capacity may not be evident from an inspection and a conversation with the operator. Fully assessing capacity in these areas may require a meeting with the water system's manager or governing authority and additional review of financial documents. The questions in this chapter should enable you to make at least a preliminary assessment of managerial and financial capacity.

Organization

Administration

1. Who owns the public water system?

The system representative should be able to tell you who owns the public water system and should be able to provide documentation of ownership.

2. Is there a formal organizational chart?

This chart can give the inspector a much clearer view of how the utility is organized and who is responsible for each portion of the utility. When there is no organizational chart, operators often may be unsure of whom to go to for decisions, what the normal lines of communications are, and what their job responsibilities are.

3. Does the operating staff have authority to make required operation, maintenance, or administrative decisions affecting the performance and reliability of the plant or system?

Determine if there are any established administrative policies that limit the decision-making authority of the operations staff and adversely affect plant performance. Examples include the lack of authority to adjust the chemical feed, hire an electrician, or purchase a critical piece of equipment, as well as the lack of support for training and insufficient plant funding.

4. Are administrators familiar with SDWA requirements and system needs?

Key managers should be familiar with the SDWA requirements that apply to their system. They should learn about system needs through plant visits and frequent discussions with operators. Lack of first-hand knowledge may result in poor plant performance, poor staff morale, and poor budget decisions, as well as limited support for system modifications.

5. Is there a formal and adequate planning process?

The lack of long-range plans for facility replacement, alternative sources of water, and emergency response can adversely affect the system's long-term performance. Planning is addressed later in a separate section of this guide.

Information Management

1. Does the utility manage its information?

Information management includes formal systems and written procedures for:

- Cataloging, sorting, and storing maps and as-built plans.
- Updating maps.
- Handling and tracking customer complaints.
- Handling and tracking line breaks, repairs, and replacements.
- Identifying, collecting, analyzing, and updating key operational and required monitoring data.
- Developing and maintaining standard operating policies and procedures.
- Developing and maintaining maintenance records.
- Developing and maintaining financial records.

The information listed above is essential to addressing existing problems and planning for future needs.

2. Does the utility track and identify typical operating parameters such as:

- Unaccounted-for water
- Cost per unit of production of water

When utilities track and share this type of information among operations personnel and the governing body, it is a good indication that the utility is focused on obtaining results and meeting customer needs.

This type of information justifies decisions and promotes compliance with SDWA and industry suggested practices for water conservation and quality.

3. **Does the utility track finances, operational data, and maintenance practices on a computer?**

   While a computer is not a requirement, it facilitates storage of data that can be presented to support management decisions.

Internal and External Communication

1. **Is there effective communication between key management staff, operations staff, and the state primacy agency?**

   Difficulties here can account for problems with the budget and personnel policy. They also can account for poor relations between management and staff and between the organization and the state enforcement agency. Inspectors should review previous correspondence to determine the responsiveness of the system and should ask questions to confirm observations.

2. **What is the level of cooperation between the system and other agencies and organizations?**

   To be successful, a utility needs to cooperate with associated utilities and enforcement agencies. Examples include cooperation with water conservation agencies, with one-call (Call Before You Dig) groups such as the APWA underground utility coordinating committee, and with county and state agencies involved in land-use planning and long-term water use, conservation, and water needs. This cooperation also involves active membership in professional groups such as AWWA and APWA. A second but also important area is cooperation between the utility and the state primacy agency. A history of poor relations may indicate that the utility has had difficulty complying with requirements.

3. **What is the level of cooperation between the system and the local fire department?**

   This is often difficult to determine directly. However, you may ask questions such as:

   - What role does the fire department play in inspecting fire hydrants, flushing fire hydrants, and determining the type and location of new fire hydrants?
   - What role does the fire department play in the system's emergency plan as a first responder for chemical spills or accidental releases?
   - What is the policy and procedure for notifying the fire department when a hydrant is out of service?
   - What is the notification procedure when the fire department uses a fire hydrant?
   - What is the role of the fire department in determining construction needs?

4. **Is there a customer complaint system and an ongoing public information program?**

   Lacking a system to keep track of and respond to customer complaints may indicate ineffective communication with customers. Not having an ongoing public information program, including a Consumer Confidence Report, may indicate that the system does not provide adequate information to its customers.

5. **Does the system have an adequate source of capital for operations, maintenance, and capital projects? Is the system eligible for, and has the system received, state or federal funding?**

   It is important for a system to have adequate returns or access to capital (from public or private sources) to repair or replace infrastructure and to address emergencies. Lack of access, or exhaustion of available funding, may indicate problems with the system's managerial and financial capabilities. However, systems should not borrow funds for normal O&M functions except in emergencies.

Federal and state funding programs generally provide lower interest rate loans to systems, in particular, smaller systems. Limited federal and state grant funding is also available, particularly for small, more rural systems. However, many of the programs have eligibility requirements and fund only certain types of systems and certain types or categories of projects. For example, some states have limited Drinking Water State Revolving Fund (DWSRF) loans to publicly owned systems. Also, DWSRF monies cannot be expended for monitoring, operation, and maintenance.

It is important that all systems, particularly small systems, establish a credit rating that will allow them access to funds if an emergency occurs or an unexpected cost arises. Financial institutions will look at the health of the system as measured through indicators, ratios, and ratings; previous credit records; and proof of assurance of repayment when determining whether a system is a good credit risk.

6. Is the staff active in industry and professional organizations?

Such participation is important because it improves the system's awareness of available external resources, new technology, and advances in the field.

Planning

1. Is an emergency or contingency plan available and workable?

The utility should have an emergency or contingency plan that outlines what actions will be taken and by whom. The emergency plan should meet the needs of the facility, the geographical area, and the nature of the likely emergencies. Conditions such as storms, floods, and major mechanical failures should be considered. The emergency plan should be updated annually, and larger facilities should practice implementation of the plan annually.

2. Are written, workable plans available for the areas listed below?

- Source protection.
- Sampling and monitoring.
- Emergency or contingency.
- Hazard communication plan (if required).
- Cross-connection control.
- Repair, replacement, and future expansion (capital improvement).
- Distribution system flushing program.

Personnel

Staffing

1. Are there sufficient personnel?

There should be enough personnel to provide for operation during evenings, weekends, vacations, and illness. The number of operators depends on the type and size of the treatment process. A good indication of the adequacy of personnel is if proper O&M procedures can be accomplished with little or no overtime.

2. Is the staff qualified?

The staff should have the appropriate aptitude, education, and level of certification to perform the job correctly.

Systems must comply with state requirements for certification. Proof of certification should be prominently displayed or otherwise made available to the inspector. Certification at the correct level is assumed to be one major measurement of staff qualifications.

3. Are personnel adequately trained?

To properly operate a system, personnel must be adequately trained. There should be an ongoing training program. Personnel can be trained in various ways, including in-house training conducted by more experienced personnel and state-sponsored training. Correspondence courses, such as *Water Treatment Plant Operation, Water Distribution System Operation and Maintenance*, and *Small Water System Operation and Maintenance* from California State University, Sacramento School of Engineering, and AWWA courses are also available. The inspector can solicit information from operators about process controls, maintenance requirements, and safety to help determine the adequacy of their training.

Safety Program

1. **Have the operators been adequately trained in safety procedures and equipment?**

   The safety of the operators and the inspector is of paramount importance. Injury to any of them can adversely affect the system. Although sanitary survey inspectors are not safety experts, conversations with the operators and managers of the system will enable the inspector to determine if a safety program is in place. Adequate safety training and safety equipment are essential. Management should be able to give the inspector a list of training activities and training attendance records. Proper safety equipment should be on site and adequately maintained. Examples of necessary equipment include, but are not limited to, self-contained breathing apparatus (SCBAs), chlorine cylinder repair kits, eye-wash stations, and fire extinguishers.

2. **Has the utility complied with OSHA safety requirements?**

   OSHA requirements include having a hazard communication program, lockout/tagout, and confined space entry training and procedures.

   The fact that Material Safety Data Sheets (MSDSs) are available and the operators know where they are can be taken by the inspector as some evidence of compliance with OSHA requirements. The inspector should determine if there is documentation of the required training in how to read the MSDSs, how to use hazardous materials, and how to handle emergencies associated with hazardous materials.

3. **Does the utility have a good safety record?**

   The inspector should review past safety records and determine the accident severity rate and the frequency rate for the previous 5 years. A poor safety record can be a good reflection of personnel problems, poorly maintained equipment, or lack of attention to safety by management. A poor safety record also can have a negative effect on water quality. It can reduce the number of personnel and the number of trained personnel available to handle normal conditions and to resolve problems.

Operations

Operating Procedures

1. **Is there an overall O&M manual for the facility?**

   In addition to the standard O&M manual, manufacturers' literature should be available for all pieces of equipment. All of this information, and the as-built plans of the facility, should be on site or readily available. Equipment cannot be properly maintained without adequate manuals and manufacturers' literature.

2. **Has a program of standard operating procedures (SOPs) been implemented at the facility?**

   Operations and management personnel should be queried about the availability of O&M manuals, manufacturers' literature, and SOPs. SOPs are essential to ensure consistent plant operations from one operator to the next.

Facilities and Equipment

1. **Is there sufficient storage for spare parts, equipment, vehicles, traffic control devices, and supplies?**

   The inspector should assess storage facilities for adequacy, housekeeping, and general appearance. The appearance of the facilities is often a reflection of the importance that management places on the people who work in the system.

2. **Are the facilities and equipment of the system adequate?**

   Inadequate facilities and equipment, such as undersized pumps, lack of redundancy, and poor maintenance, can interfere with the production of potable water. Buildings and structures must be sound and provide appropriate security. Equipment must be maintained according to manufacturers' specifications and should be properly sized for the job.

3. Are there adequate facilities for system personnel?

Such facilities include space for crew meetings, a lunch room, a rest room, and individual lockers. Check for adequacy and cleanliness.

Finance

In addition to looking specifically at a water system's finances, the inspector should be aware that other aspects of the sanitary survey can indicate the state of the system's finances and its financial capacity. For example, infrastructure deficiencies may be due not only to a lack of technical capability but to a lack of financial capacity as well. Without sufficient revenue, the system will not be able to cover the costs of source water protection, treatment, storage facility maintenance, and system upgrades.

1. Are the financing and budget satisfactory? What is the estimated income? What are the estimated expenses?

The system should have sufficient revenue for operation, maintenance, and future replacements. These funds should not be commingled with other accounts. The system should operate on its own revenues and should have a sinking fund for major equipment replacement.

An inability to answer the questions above indicates a lack of financial planning necessary for financial capacity. If answers are available, but they indicate that system revenues do not cover costs, the system lacks financial capacity. This lack may pose risks if insufficient funding results in an inability to maintain and upgrade the facility, pay appropriate salaries, or maintain sufficient stocks of spare parts, chemicals, or equipment.

2. Are funds focused in the correct direction?

Determine if the manner in which available funds are used causes problems in obtaining needed equipment or staff. In addition, determine if funds are spent on lower priority items while higher priority items are unfunded.

3. Are there sufficient funds for staff training?

AWWA recommends a training budget equal to 5 percent of the workers' salaries.

4. Are projected revenues consistent with projected growth?

If a system's revenue projections are not consistent with its projected growth–if revenue is not going to keep pace with system size–eventually there will be insufficient revenue to operate the system.

5. Does the system have formal accounting systems and written procedures for financial records?

If the system does not have formal systems and procedures for financial recordkeeping, it is likely that appropriate accounting and financial planning methods are not being followed.

6. Does the system have budget and expenditure control procedures?

Although it is important that water system staff have the authority to purchase supplies and equipment as they are needed, it is equally important that there be standard procedures for budget and expenditure control. A follow-up question might be to ask the representative what they do when they need to purchase something for the system. By discussing a real example, you might discover that the system representative was unsure of the terms used in the first question and the system does, in fact, have purchase order procedures and authorization requirements, and therefore procedures for budget and expenditure control.

7. What are the utility's debt service expenses?

If a system's debt service expenses are exceptionally high, the system either has a large level of debt, or it is paying a high interest rate on its debt. This situation could mean that the system has exhausted its access to capital, or it has a poor credit rating and is forced to pay higher interest when it borrows. In either case, high debt service expenses indicate a lack of financial capacity.

8. Does the system have a water conservation policy or program?

Water rates that promote conservation can yield savings. Conservation reduces the demand on the source, reduces chemical and electrical costs, and minimizes wear and tear on equipment such as pumps. In many cases a system can avoid the need for plant expansions by implementing an effective water conservation program.

Appendix A

Suggested References

1. **At America's Service - Karl Albrecht**
   Available from:
   Warner Books
   New York, NY 100020
   www.twbookmark.com

2. **AWWA B600-78: Standard for Powdered Activated Carbon**
   Available from:
   American Water Works Association (AWWA)
   6666 W. Quincy Avenue
   Denver, CO 80235
   (800) 926-7337
   Fax: (303) 347-0804
   www.awwa.org/bookstore

3. **AWWA B604-74: Standard for Granular Activated Carbon**
   Available from:
   AWWA
   6666 W. Quincy Avenue
   Denver, CO 80235
   (800) 926-7337
   Fax: (303) 347-0804
   www.awwa.org/bookstore

4. **Basic Science Concepts and Applications Reference Handbook**
   Available from:
   AWWA
   6666 W. Quincy Avenue
   Denver, CO 80235
   (800) 926-7337
   Fax: (303) 347-0804
   www.awwa.org/bookstore

5. **Chemistry of Water Treatment - Second Edition**
   Available from:
   Lewis Publishers, Inc.
   2000 Corporate Blvd, NW
   Boca Raton, FL 33431
   (800) 272-7737
   Fax: (407) 998-0555

6. **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

7. **Cross-Connection Control Manual**
   Available on line from:
   The U.S. Environmental Protection Agency
   www.epa.gov.safewater/crossconnection.html

8. **Distribution Systems**
   Available from:
   AWWA
   6666 W. Quincy Avenue
   Denver, CO 80235
   (800) 926-7337
   Fax: (303) 347-0804
   www.awwa.org/bookstore

9. **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

10. **Environmental Engineering and Sanitation, 4th Edition - by Joseph A. Salvato**
    Available from:
    John Wiley & Sons, Inc.
    1 Wiley Drive
    Somerset, NJ 08873
    (800) 225-5945
    Fax: (732) 302-2300
    www.wiley.com

11. **Guidance for Management of Distribution System and Operation and Maintenance**
    Available from:
    AWWARF
    6666 W. Quincy Avenue
    Denver, CO 80235
    (800) 926-7337
    Fax: (303) 347-0804
    www.awwa.org/bookstore

12. **Guidance Manual for Conducting Sanitary Surveys of Public Water Systems; Surface Water and Ground Water Under the Direct Influence**
    EPA Publication No. EPA 815-R-99-016
    www.epa.gov/safewater/mdbp/pdf/sansurv/sansurv.pdf

13. **Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water**
    Available from:
    AWWA
    6666 W. Quincy Avenue
    Denver, CO 80235
    (800) 926-7337
    Fax: (303) 347-0804
    www.awwa.org/bookstore

14. **Guidance Manual for Maintaining Distribution System Water Quality**
    Available from:
    AWWARF
    6666 W. Quincy Avenue
    Denver, CO 80235
    (800) 926-7337
    Fax: (303) 347-0804
    www.awwa.org/bookstore

15. **Integrated Design of Water Treatment Facilities - Second Edition**
    Available from:
    John Wiley & Sons, Inc.
    1 Wiley Drive
    Somerset, NJ 08873
    (800) 225-5945
    Fax: (732) 302-2300
    www.wiley.com

16. **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

17. **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

18. **Introduction to Water Distribution, Volume III**
    Available from:
    AWWA
    6666 W. Quincy Avenue
    Denver, CO 80235
    (800) 926-7337
    Fax: (303) 347-0804
    www.awwa.org/bookstore

19. Introduction to Water Treatment, Volume II
Available from:
AWWA
6666 W. Quincy Avenue
Denver, CO 80235
(800) 926-7337
Fax: (303) 347-0804
www.awwa.org/bookstore

20. Introduction to Water Quality Analysis, Volume IV
Available from:
AWWA
6666 W. Quincy Avenue
Denver, CO 80235
(800) 926-7337
Fax: (303) 347-0804
www.awwa.org/bookstore

21. Introduction to Water Sources Transmission, Volume 1
Available from:
AWWA
6666 W. Quincy Avenue
Denver, CO 80235
(800) 926-7337
Fax: (303) 347-0804
www.awwa.org/bookstore

22. Maintenance Management
Available from:
AWWA
6666 W. Quincy Avenue
Denver, CO 80235
(800) 926-7337
Fax: (303) 347-0804
www.awwa.org/bookstore

23. Manual of Individual Water Supply Systems
Available from:
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
(800) 553-6847
Fax: (703) 321-8547
Stock No. PB85-242279

24. 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
Fax: (518) 439-7022
www.hes.org

25. Manual of Treatment Techniques for Meeting the Interim Primary Drinking Water Regulation; EPA 600/8-77-005
Available from:
USEPA-NSCEPI
P.O. Box 42419
Cincinnati, OH 45242
(800) 490-9198
Fax: (513) 489-8695
www.epa.gov/ncepihom/ordering.htm

26. Manual of Water Utility Operations 8th Edition
Available from:
Texas Water Utilities Association
1106 Clayton Lane, Ste 101 East
Austin, TX 78723
(888) 367-8982
Fax: (512) 459-7124
www.twua.org/publications.htm

27. National Primary Drinking Water Regulations (40 CFR part 141)
Available on line from:
The U.S. Environmental Protection Agency
www.epa.gov/safewater/regs/cfr141.pdf

28. National Secondary Drinking Water Regulations (40 CFR part 143)
Available on line from:
The U.S. Environmental Protection Agency
www.epa.gov/safewater/regs/cfr143.pdf

29. Occurrence and Removal of VOC's from Drinking Water
Available from:
AWWA
6666 W. Quincy Avenue
Denver, CO 80235
(800) 926-7337
Fax: (303) 347-0804
www.awwa.org/bookstore

30. O&M of Chlorine Systems
Available from:
ACR Publications
1298 Elm St.
SW Albany, OR 97321
(541) 928-6199
(800) 433-8150
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31. Opflow, Volume 12, No. 5, May 1986
Available from:
AWWA
6666 W. Quincy Avenue
Denver, CO 80235
(800) 926-7337
Fax: (303) 347-0804
www.awwa.org/communications/opflow

32. Pathogen Intrusion into the Distribution System
Available from:
AWWARF
6666 W. Quincy Avenue
Denver, CO 80235
(800) 926-7337
Fax: (303) 347-0804
www.awwa.org/bookstore

33. Planning for an Individual Water System
Available from:
American Association for Vocational Instructional Materials
Engineering Center
220 Smithonia Road
Waterville, GA 30683
(800) 228-4689
Fax: (706) 742-7005
www.aavim.com

34. 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

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

36. Recommended Practice for Backflow Prevention and Cross-Connection Control
Available from:
AWWA
6666 W. Quincy Avenue
Denver, CO 80235
(800) 926-7337
Fax: (303) 347-0804
www.awwa.org/bookstore

37. Rehabilitation of Water Mains - Manual of Supply Practices - Second Edition
Available from:
AWWA
6666 W. Quincy Avenue
Denver, CO 80235
(800) 926-7337
Fax: (303) 347-0804
www.awwa.org/bookstore

38. Safe Drinking Water Advisor: A Compliance Assistance Resource (CD)
Available from:
AWWARF
6666 W. Quincy Avenue
Denver, CO 80235
(800) 926-7337
Fax: (303) 347-0804
www.awwa.org/bookstore

39. Small Water System Operation & Maintenance 4th Edition
Available from:
Office of Water Programs
California State University, Sacramento
6000 J Street
Sacramento, CA 95810
(916) 278-6142
Fax: (916) 278-5959
www.owp.csus.edu/OWPHome.html

40. **Standards for the Disinfection of Pipe**
Available from:
AWWA
6666 W. Quincy Avenue
Denver, CO 80235
(800) 926-7337
Fax: (303) 347-0804
www.awwa.org/bookstore

41. **The Safe Drinking Water Act Handbook for Water System Operators**
Available from:
AWWA
6666 W. Quincy Avenue
Denver, CO 80235
(800) 926-7337
Fax: (303) 347-0804
www.awwa.org/bookstore

42. **Water Distribution System Operation & Maintenance**
Available from:
Office of Water Programs
California State University, Sacramento
6000 J Street
Sacramento, CA 95810
(916) 278-6142
Fax: (916) 278-5959
www.owp.csus.edu/OWPHome.html

43. **Water Systems Handbook - Eleventh Edition**
Available from:
Water Systems Council
1101 30th Street, NW
Suite 500
Washington, DC 20007
(202) 625-4387
Fax: (202) 625-4363
www.watersystemscouncil.org

44. **Water Treatment Plant Design, Third Edition, 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
(800) 926-7337
Fax: (303) 347-0804
www.awwa.org/bookstore

ASCE Publications
1801 Alexander Bell Drive
Reston, VA 20191
(800) 548-2723
www.pubs.asce.org/pubshom1.html

45. **Water Treatment Plant Operations, Volume I - Fourth Edition**
Available from:
Office of Water Programs
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