

DISTRIBUTION BASICS

CONTINUING EDUCATION

PROFESSIONAL DEVELOPMENT COURSE

1st Edition



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We require the final exam to be proctored.

Do not solely depend on TLC's Approval list for it may be outdated.

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This training course is based upon a form of induction training, made of topical and technical precepts. The training topics are made up of “micro-content” or “precepts”—or small chunks of information that can be easily digested. These bite-size pieces of technical information are considered to be one of the most effective ways of teaching people new information because it helps the mind retain knowledge easier. Micro-learning or precept-based training doesn’t rely on the student to process a large amount of information before breaking it down. Our method includes short modules with clearly defined learning goals for each section. This method allows a student to hone in on a particular skill, then given the opportunity to exhibit their knowledge in the final assessment.



Normal duties for a distribution worker include:

Working in unsafe trenches, dangerous road conditions and operating a tamper to compact the soil to be able to support heavy traffic.

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Responsibility

This course contains EPA's federal rule requirements. Please be aware that each state implements drinking water/wastewater/safety regulations may be more stringent than EPA's or OSHA's regulations. Check with your state environmental agency for more information. You are solely responsible in ensuring that you abide with your jurisdiction or agency's rules and regulations.

Important Information about this Manual

Disclaimer

This manual has been prepared to assist employees in the general awareness of the water distribution system and groundwater production system, complex pumping ideas, dangerous excavation techniques, water regulatory sampling and dealing with often-complex procedures and requirements for safely handling hazardous and toxic materials. The scope of the material is quite large, requiring a major effort to bring it under control. Employee health and safety, as well as that of the public, depend upon careful application of federal and state regulations and safe working procedures.

This manual will cover general laws, regulations, required procedures and work rules relating to water distribution and sampling. It should be noted, however, that the federal and state regulations are an ongoing process and subject to change over time. For this reason, a list of resources and hyperlinks is provided to assist in obtaining the most up-to-date information on various subjects. You can find these on our website or in this manual.

This manual is a guidance document for employees who are involved with water distribution, water quality and pollution control. It is not designed to meet the full requirements of the United States Environmental Protection Agency (EPA) or the Department of Labor-Occupational Safety and Health Administration (OSHA) rules and regulations. This course manual will provide general guidance and should not be used as a preliminary basis for developing general water/wastewater sampling plans or water distribution safety plans or procedures. This document is not a detailed water/wastewater textbook or a comprehensive source book on water/wastewater/safety rules and regulations.

Technical Learning College makes no warranty, guarantee or representation as to the absolute correctness or appropriateness of the information in this manual and assumes no responsibility in connection with the implementation of this information. It cannot be assumed that this manual contains all measures and concepts required for specific conditions or circumstances. This document should be used for guidance and is not considered a legal document. Individuals who are responsible for water distribution, production and/or sampling and the health and safety of workers at hazardous waste sites should obtain and comply with the most recent federal, state, and local regulations relevant to these sites and are urged to consult with OSHA, the EPA and other appropriate federal, state and local agencies.



Remember, Chlorine gas or Cl₂ will cause olfactory fatigue, if not death.

Technical Learning College's Scope and Function

Welcome to the Program,

Technical Learning College (TLC) offers affordable continuing education for today's working professionals who need to maintain licenses or certifications. TLC holds several different governmental agency approvals for granting of continuing education credit.

TLC's delivery method of continuing education can include traditional types of classroom lectures and distance-based courses or independent study. TLC's distance based or independent study courses are offered in a print- based format and you are welcome to examine this material on your computer with no obligation. We will beat any other training competitor's price for the same CEU material or classroom training.

Our courses are designed to be flexible and for you do finish the material on your leisure. Students can also receive course materials through the mail. The CEU course or e-manual will contain all your lessons, activities and assignments. All of TLC's CEU courses allow students to submit assignments using e-mail or fax, or by postal mail. (See the course description for more information.)

Students have direct contact with their instructor—primarily by e-mail or telephone. TLC's CEU courses may use such technologies as the World Wide Web, e-mail, CD-ROMs, videotapes and hard copies. (See the course description.) Make sure you have access to the necessary equipment before enrolling, i.e., printer, Microsoft Word and/or Adobe Acrobat Reader. Some courses may require proctored closed-book exams depending upon your state or employer requirements.

Flexible Learning

At TLC, there are no scheduled online sessions or passwords you need contend with, nor are you required to participate in learning teams or groups designed for the "typical" younger campus based student. You will work at your own pace, completing assignments in time frames that work best for you. TLC's method of flexible individualized instruction is designed to provide each student the guidance and support needed for successful course completion.

Course Structure

TLC's online courses combine the best of online delivery and traditional university textbooks. You can easily find the course syllabus, course content, assignments, and the post-exam (Assignment). This student friendly course design allows you the most flexibility in choosing when and where you will study.

Classroom of One

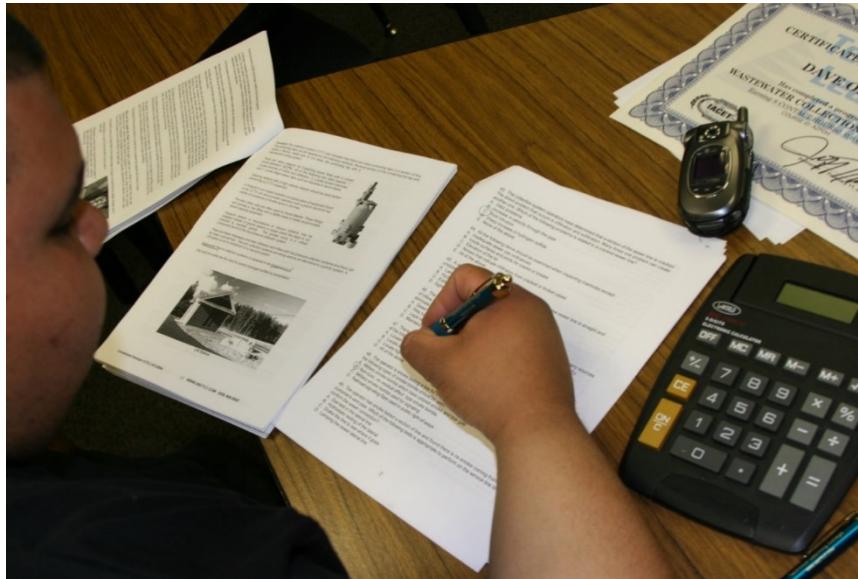
TLC offers you the best of both worlds. You learn on your own terms, on your own time, but you are never on your own. Once enrolled, you will be assigned a personal Student Service Representative who works with you on an individualized basis throughout your program of study. Course specific faculty members are assigned at the beginning of each course providing the academic support you need to successfully complete each course.

No Data Mining Policy

Unlike most online training providers, we do not use passwords or will upload intrusive data mining software onto your computer. We do not use any type of artificial intelligence in our program. Nor will we sell you any other product or sell your data to others as with many of our competitors. Unlike our training competitors, we have a telephone and we humanly answer.

Satisfaction Guaranteed

We have many years of experience, dealing with thousands of students. We assure you, our customer satisfaction is second to none. This is one reason we have taught more than 20,000 students.



We welcome you to do the electronic version of the assignment and submit the answer key and registration to us either by fax or e-mail. If you need this assignment graded and a certificate of completion within a 48-hour turn around, prepare to pay an additional rush charge of \$50.

We welcome you to complete the assignment in Word.

Once we grade it, we will mail a certificate of completion to you. Call us if you need any help.

Contact Numbers
Telephone (866) 557-1746
Fax (928) 468-0675
Email Info@tlch2o.com

Course Description

Distribution Basics CEU Training Course

Review of water distribution systems and related treatment fundamentals. This course will cover the basic requirements of the Safe Drinking Water Act and general water distribution principles. You will not need any other materials for this course. Task Analysis and Training Needs Assessments have been conducted to determine or set Needs-To-Know for this course. The following is a listing of some of those who have conducted extensive valid studies from which TLC has based this program upon: the Environmental Protection Agency (EPA), the Arizona Department of Environmental Quality (ADEQ), the Texas Commission of Environmental Quality (TCEQ) and the American Boards of Certification (ABC).

Final Examination for Credit

Opportunity to pass the final comprehensive examination is limited to three attempts per course enrollment.

Course Procedures for Registration and Support

All of Technical Learning College's correspondence courses have complete registration and support services offered. Delivery of services will include, e-mail, web site, telephone, fax and mail support. TLC will attempt immediate and prompt service. When a student registers for a distance or correspondence course, he/she is assigned a start date and an end date.

It is the student's responsibility to note dates for assignments and keep up with the course work. If a student falls behind, he/she must contact TLC and request an end date extension in order to complete the course. It is the prerogative of TLC to decide whether to grant the request.

Instructions for Written Assignments

The Distribution Basics CEU training course uses a multiple choice answer key. If you should need any assistance, please email all concerns and the final test to: info@tlch2o.com. You may write your answers or type out your own answer key.

TLC would prefer that you utilize the answer key found on the TLC website under Assignments and e-mail the answer key to TLC, but it is not required. You may also fax the answer key. Please call us a couple hours later to ensure we received your information.

You can write your answers in this manual or type out your own answer key. TLC would prefer that you type out and e-mail the final exam to TLC, but it is not required. There is a Second Edition of this course available. 40 PDHs, 4 CEUs, 40 Contact Hours for \$200.00. Check with your State for course acceptance.

Feedback Mechanism (examination procedures)

Each student will receive a feedback form as part of their study packet. You will be able to find this form in the front section of the assignment.

Security and Integrity

All students are required to do their own work. All lesson sheets and final exams are not returned to the student to discourage sharing of answers. Any fraud or deceit and the student will forfeit all fees and the appropriate agency will be notified.

Grading Criteria

TLC will offer the student either pass/fail or a standard letter grading assignment. If TLC is not notified, you will only receive a pass/fail notice.

Required Texts

The Distribution Basics CEU training course will not require any other materials. This course comes complete. No other materials are needed.

Recordkeeping and Reporting Practices

TLC will keep all student records for a minimum of seven years. It is the student's responsibility to give the completion certificate to the appropriate agencies. We will send the required information to Texas, Indiana and Pennsylvania for your certificate renewals.

ADA Compliance

TLC will make reasonable accommodations for persons with documented disabilities. Students should notify TLC and their instructors of any special needs.

Course content may vary from this outline to meet the needs of this particular group.

You will have 90 days from receipt of this manual to complete it in order to receive your Continuing Education Units (**CEUs**) or Professional Development Hours (**PDHs**). A score of 70% or better is necessary to pass this course.

Educational Mission

The educational mission of TLC is:

To provide TLC students with comprehensive and ongoing training in the theory and skills needed for the environmental education field,

To provide TLC students with opportunities to apply and understand the theory and skills needed for operator certification,

To provide opportunities for TLC students to learn and practice environmental educational skills with members of the community for the purpose of sharing diverse perspectives and experience,

To provide a forum in which students can exchange experiences and ideas related to environmental education,

To provide a forum for the collection and dissemination of current information related to environmental education, and to maintain an environment that nurtures academic and personal growth.

Please include your name and address on your exam.

Objective: *To train distribution operators in the safe and effective maintenance and operation of various water distribution systems and related daily operations.*

New Water Service Installation ACP Main



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Safe Drinking Water Act (SDWA) Summary

On August 6, 1996, President Clinton signed the Reauthorization of the Safe Drinking Water Act, bringing a successful conclusion to years of work on the part of water professionals and a broad range of public interest groups throughout the nation.

This new Law strikes a balance among federal, state, local, urban, rural, large and small water systems in a manner that improves the protection of public health and brings reason and good science to the regulatory process.

The major elements of the new Law include:

- The law updates the standard-setting process by focusing regulations on contaminants known to pose greater public health risks.
- It replaces the current law's demand for 25 new standards every three years with a new process based on occurrence, relative risk and cost-benefit considerations.
- It also requires the EPA to select at least five new candidate contaminants to consider for regulation every five years.
- The EPA is directed to require public water systems to provide customers with annual "**Consumer Confidence Reports**" in newspapers and by direct mail.
- The reports must list levels of regulated contaminants along with Maximum Contaminant Levels (**MCLs**) and Maximum Contaminant Level Goals (**MCLGs**), along with plainly worded definitions of both.
- The reports must also include a plainly worded statement of the health concerns for any contaminants for which there has been a violation, describe the utility's sources of drinking water and provide data on unregulated contaminants for which monitoring is required, including Cryptosporidium and radon.
- The EPA must establish a toll-free hot line customers can call to get additional information.
- The EPA is required to publish guidelines for states to develop water source assessment programs that delineate protection areas and assess contamination risks.
- The EPA is required to identify technologies that are affordable for small systems to comply with drinking water regulations.
- Technical assistance funds and Small System Technical Assistance Centers are authorized to meet the training and technical needs of small systems.
- States are authorized to grant variances for compliance with drinking water regulations for systems serving 3,300 or fewer persons.
- The EPA is required to publish certification guidelines for operators of community and nontransient noncommunity public water systems.
- States that do not have operator certification programs that meet the requirements of the guidelines will lose 20 percent of their SRLF grant.
- A source water petition program for voluntary, incentive-based partnerships among public water systems and others to reduce contamination in source water is authorized.
- The law establishes a new State Revolving Loan Fund (**SRLF**) of \$1 billion per year to provide loans to public water systems to comply with the new SDWA.
- It also requires States to allocate 15 percent of the SRLF to systems serving 10,000 or fewer people unless no eligible projects are available for loans.

- It also allows states to jointly administer SDWA and Clean Water Act loan programs and transfer up to 33 percent between the two accounts.
- States must ensure that all new systems have compliance capacity and that all current systems maintain capacity, or lose 20 percent of their SRLF grant.

Although the EPA will continue to provide policy, regulations and guidance, state governments will now have more regulatory flexibility allowing for improved communication between water providers and their local regulators.

Increased collaboration will result in solutions that work better and are more fully supported by the regulated community.

States that have a source water assessment program may adopt alternative monitoring requirements to provide permanent monitoring relief for public water systems in accordance with EPA guidance.



A special camera that is used to record the condition of a groundwater well.

Assignment Highlights

An Ion is best described as an electrically charged atom.

If the desired result of cleaning large pipes is to remove slime and light scale without disturbing heavier encrustation, the best choice for cleaning would be a *Pig*.

Depending upon your area, most water providers have the responsibility of the water service line up to the customer's side of the water meter; but the SDWA states the responsibility is to the last free flowing tap.

Safe Drinking Water Act of 1974

(PL 93-523) as amended by:

- The Safe Drinking Water Act Amendments of 1986
- National Primary Drinking Water Regulations, 40 CFR 141
- National Interim Primary Drinking Water Regulations Implementation, 40 CFR 142
- National Secondary Drinking Water Regulations, 40 CFR 143

This is the primary Federal legislation protecting drinking water supplied by public water systems (those serving more than 25 people). The Environmental Protection Agency (**EPA**) is the lead agency and is mandated to set standards for drinking water. The EPA establishes national standards of which the states are responsible for enforcing.

The act provides for the establishment of primary regulations for the protection of the public health and secondary regulations relating to the taste, odor, and appearance of drinking water. Primary drinking water regulations, by definition, include either a maximum contaminant level (**MCL**) or, when a MCL is not economically or technologically feasible, a prescribed treatment technique which would prevent adverse health effects to humans. An MCL is the permissible level of a contaminant in water that is delivered to any user of a public water system. Primary and secondary drinking water regulations are stated in 40 CFR 141 and 143, respectively.

As amended in 1986, the EPA is required to set maximum contaminant levels for 83 contaminants deemed harmful to humans (with specific deadlines). It also has authority over groundwater. Water agencies are required to monitor water to ensure it meets standards.

National Drinking Water Regulations

The Act instructs the EPA on how to select contaminants for regulation and specifies how the EPA must establish national primary drinking water regulations once a contaminant has been selected (Section 1412). As of late 1996, the EPA had promulgated 84 drinking water regulations.

Contaminant Selection

P.L. 104-182 establishes a new process for the EPA to select contaminants for regulatory consideration based on occurrence, health effects, and meaningful opportunity for health risk reduction.

By February 1998 and every 5 years thereafter, the EPA must publish a list of contaminants that may warrant regulation. Starting in 2001, and every 5 years thereafter, the EPA must determine whether or not to regulate at least 5 of the listed contaminants. The Act directs the EPA to evaluate contaminants that present the greatest health concern and to regulate contaminants that occur at concentration levels and frequencies of public health concern.

The law also includes a schedule for the EPA to complete regulations for disinfectants and disinfection byproducts (**D/DBPs**) and **Cryptosporidium** (a waterborne pathogen).

Standard Setting

Developing national drinking water regulations is a two-part process. For each contaminant that the EPA has determined merits regulation, the EPA must set a non-enforceable maximum contaminant level goal (**MCLG**) at a level at which no known or anticipated adverse health effects occur and which allows an adequate margin of safety.

The EPA must then set an enforceable standard, a maximum contaminant level (**MCL**), as close to the MCLG as is "**feasible**" using best technology, treatment techniques, or other means available (taking costs into consideration).

Standards are generally based on technologies that are affordable for large communities; however, under P.L. 104-182, each regulation establishing an MCL must list any technologies, treatment techniques or other means that comply with the MCL and that are affordable for three categories of small public water systems.

The 1996 Amendments authorize the EPA to set a standard at other than the feasible level if the feasible level would lead to an increase in health risks by increasing the concentration of other contaminants or by interfering with the treatment processes used to comply with other SDWA regulations. In such cases, the standard or treatment techniques must minimize the overall health risk. Also, when proposing a regulation, the EPA must now publish a determination as to whether or not the benefits of the standard justify the costs.

If the EPA determines that the benefits do not justify the costs, the EPA may, with certain exceptions, promulgate a standard that maximizes health risk reduction benefits at a cost that is justified by the benefits.

Risk Assessment

P.L. 104-182 adds risk assessment and communication provisions to SDWA. When developing regulations, the EPA is now required to: (1) use the best available, peer-reviewed science and supporting studies and data; and (2) make publicly available a risk assessment document that discusses estimated risks, uncertainties, and studies used in the assessment.

When proposing drinking water regulations, the EPA must publish a health risk reduction and cost analysis.

The law permits the EPA to promulgate an interim standard without first preparing a benefit-cost analysis or making a determination as to whether the benefits of a regulation would justify the costs if the EPA determines that a contaminant presents an urgent threat to public health.

New regulations generally become effective 3 years after promulgation. Up to 2 additional years may be allowed if the EPA (or a state in the case of an individual system) determines the time is needed for capital improvements. Section 1412 includes specific provisions for arsenic, sulfate and radon.

The law authorizes states to grant Systems variances from a regulation if raw water quality prevents meeting the standards despite application of best technology (Section 1415). A new provision authorizes small system variances based on best affordable technology.

States may grant these variances to systems serving 3,300 or fewer persons if the system cannot afford to comply (through treatment, an alternative water source, or restructuring) and the variance ensures adequate protection of public health; states may grant variances to systems serving between 3,300 and 10,000 persons with EPA approval. To receive a small system variance, the system must install a variance technology identified by the EPA. The variance technology need not meet the MCL, but must protect public health. The EPA must identify variance technologies for existing regulations. Variances are not available for microbial contaminants.

The Act also provides for exemptions if a regulation cannot be met for other compelling reasons (including costs) and if the system was in operation before the effective date of a standard or treatment requirement (Section 1416). An exemption is intended to give a public water system more time to comply with a regulation and can be issued only if it will not result in an unreasonable health risk. Small systems may receive exemptions for up to 9 years.

State Primacy

The primary enforcement responsibility for public water systems lies with the States, provided they adopt regulations as stringent as the national requirements, adopt authority for administrative penalties, develop adequate procedures for enforcement, maintain records, and create a plan for providing emergency water supplies (Section 1413).

Currently, 55 of 57 states and territories have primacy authority. P.L. 104-182 authorizes \$100 million annually for the EPA to make grants to states to carry out the public water system supervision program.

States may also use a portion of their SRF grant for this purpose (Section 1443).

Whenever the EPA finds that a public water system in a state with primary enforcement authority does not comply with regulations, the Agency must notify the state and the system and provide assistance to bring the system into compliance. If the state fails to commence enforcement action within 30 days after the notification, the EPA is authorized to issue an administrative order or commence a civil action.

Nonprimacy State

In a nonprimacy state, the EPA must notify an elected local official (if any has jurisdiction over the water system) before commencing an enforcement action against the system (Section 1414).

Primacy states may establish alternative monitoring requirements to provide interim monitoring relief for systems serving 10,000 or fewer persons for most contaminants, if a contaminant is not detected in the first quarterly sample.

States with approved source water protection programs may adopt alternative monitoring requirements to provide permanent monitoring relief to qualified systems for chemical contaminants (Section 1418).

P.L. 104-182 requires states to adopt programs for training and certifying operators of community and nontransient noncommunity systems. The EPA must publish guidelines specifying minimum standards for operator certification by February 1999.

Two years thereafter, the EPA must withhold 20% of a state's SRF grant unless the state has an operator certification program (Section 1419).

States are also required to establish capacity development programs based on EPA guidance. State programs must include: 1) legal authority to ensure that new systems have the technical, financial, and managerial capacity to meet SDWA requirements; and 2) a strategy to assist existing systems that are experiencing difficulties to come into compliance.

Back in FY2001, the EPA withheld a portion of SRF grants from states that do not have compliance development strategies (Section 1420).

Underground Injection Control

Another provision of the Act requires the EPA to promulgate regulations for state underground injection control (**UIC**) programs to protect underground sources of drinking water.

These regulations contain minimum requirements for the underground injection of wastes in five well classes to protect underground sources of drinking water and to require that a state prohibit, by December 1977, any underground injection that was not authorized by state permit (Section 1421).

Ground Water Protection Grant Programs

The Act contains three additional ground water protection programs. Added in 1986, Section 1427 established procedures for demonstration programs to develop, implement, and assess critical aquifer protection areas already designated by the Administrator as sole source aquifers. Section 1428, also added in 1986, and established an elective state program for protecting wellhead areas around public water system wells.

If a state established a wellhead protection program by 1989, and the EPA approved the state's program, then the EPA may award grants covering between 50% and 90% of the costs of implementing the program.

Section 1429, added by P.L. 104-182, authorizes the EPA to make 50% grants to states to develop programs to ensure coordinated and comprehensive protection of ground water within the states. Appropriations for these three programs and for LYIC state program grants are authorized through FY2003.

Source Water Protection Programs

P.L. 104-182 broadens the pollution prevention focus of the Act to embrace surface water as well as ground water protection. New Section 1453 directs the EPA to publish guidance for states to implement source water assessment programs that delineate boundaries of assessment areas from which systems receive their water, and identify the origins of contaminants in delineated areas to determine systems' susceptibility to contamination.

States with approved assessment programs may adopt alternative monitoring requirements to provide systems with monitoring relief under Section 1418.

New Section 1454 authorizes a source water petition program based on voluntary partnerships between state and local governments. States may establish a program under which a community water system or local government may submit a source water quality partnership petition to the state requesting assistance in developing a voluntary partnership to: (1) reduce the presence of contaminants in drinking water; (2) receive financial or technical assistance; and (3) develop a long-term source water protection strategy.

This section authorizes \$5 million each year for grants to states to support petition programs.

Also, states may use up to 10% of their annual SRF capitalization grant for the source water assessment activities or for the petition program.

State Revolving Funds

Section 1452, added by P.L. 104-182, authorizes a State Revolving Loan Fund (**SRF**) program to help systems finance improvements needed to comply with drinking water regulations. The law authorizes the EPA to make grants to states to capitalize SDWA SRFs, which states then use to make loans to public water systems. States must match 20% of the federal grant.

Grants will be allotted to states using the formula for distributing state PWSS grants through FY1997; then, grants will be allotted based on a needs survey. Each state will receive at least 1% of funds. The District of Columbia will receive 1% of funds as well. A state may transfer up to 33% of the grant to the Clean Water Act (**CWA**) SRF, or an equivalent amount from the CWA SRF to the SDWA SRF.

Drinking water SRFs may be used to provide loan and grant assistance for expenditures that the EPA has determined will facilitate compliance or significantly further the Act's health protection objectives. States must make available 15% of their annual allotment for loan assistance to systems that serve 10,000 or fewer persons.

States may use up to 30% of their SRF grant to provide grants or forgive loan principle to help economically disadvantaged communities.

Also, states may use a portion of funds for technical assistance, source water protection and capacity development programs, and for operator certification.

The law authorized appropriations of \$599 million for FY1994 and \$1 billion per year for FY1995 through FY2003 for SRF capitalization grants.

The EPA is required to reserve from annual SRF appropriations: 0.33% for financial assistance to several Trusts and Territories; \$10 million for health effects research on drinking water contaminants; \$2 million (starting in FY1998) for the costs of monitoring for unregulated contaminants; and up to 2% for technical assistance. EPA may use 1.5% of funds each year for making grants to Indian Tribes and Alaska Native Villages.



Other Provisions

Public water systems must notify customers of violations with potential for serious health effects within 24 hours. Systems must also issue to customers annual reports on contaminants detected in their drinking water (Section 1414).

Section 1417 requires any pipe, solder, or flux used in the installation or repair of public water systems or of plumbing in residential or nonresidential facilities providing drinking water to be "**lead free**" (as defined in the Act). As of August 1998, it will be unlawful to sell pipes, plumbing fittings or fixtures that are not "**lead free**" or to sell solder or flux that is not lead free (unless it is properly labeled); with the exception of pipes used in manufacturing or industrial processing. P.L. 104-182 sets limits on the amount of lead that may leach from new plumbing fixtures, and allows one year for a voluntary standard to be established before requiring the EPA to take regulatory action.

The Administrator has emergency powers to issue orders and commence civil action if a contaminant likely to enter a public drinking water supply system poses a substantial threat to public health and state or local officials have not taken adequate action (Section 1431).

If a chemical necessary for water treatment is not reasonably available, the Administrator can issue a "**certification of need**," in which case the President can order an allocation of the chemical to those needing it (Section 1441).

The EPA is provided authority to conduct research, studies, and demonstrations related to the causes, treatment, control, and prevention of diseases resulting from contaminants in water. The Agency is directed to provide technical assistance to the states and municipalities in administering their public water system regulatory responsibilities. The law authorizes, annually, \$15 million for technical assistance to small systems and Indian Tribes, and \$25 million for health effects research (Section 1442). P.L. 104-182 authorizes additional appropriations for drinking water research, not to exceed \$26.6 million annually.

The Administrator may make grants to develop and demonstrate new technologies for providing safe drinking water and to investigate health implications involved in the reclamation/reuse of waste waters (Section 1444).

Also, suppliers of water who may be subject to regulation under the Act are required to establish and maintain records, monitor, and provide any information that the Administrator requires to carry out the requirements of the Act (Section 1445).

The Administrator may also enter and inspect the property of water suppliers to enable him/her to carry out the purposes of the Act. Failure to comply with these provisions may result in criminal penalties. The Act established a National Drinking Water Advisory Council, composed of 15 members (with at least 2 representing rural systems), to advise, consult, and make recommendations to the Administrator on activities and policies derived from the Act (Section 1446).

National Security

Any federal agency having jurisdiction over federally owned and maintained public water systems must comply with all federal, state and local drinking water requirements as well as any underground injection control programs (Section 1447). The Act provides for waivers in the interest of national security.

Procedures for judicial review are outlined (Section 1448), and provision for citizens' civil actions is made (Section 1449). Citizen suits may be brought against any person or agency allegedly in violation of provisions of the Act, or against the Administrator for alleged failure to perform any action or duty which is not discretionary.

The EPA may use the new estrogenic substances screening program created in the Food Quality Protection Act of 1996 (P.L. 104-170) to provide for testing of substances that may be found in drinking water if the Administrator determines that a substantial population may be exposed to such substances (Section 1457).

The EPA is directed to conduct drinking water studies involving subpopulations at greater risk and biological mechanisms, and studies to support several rules including those addressing D/DBPs and **Cryptosporidium**.

The Act includes a provision amending the Federal Food, Drug, and Cosmetic Act, generally requiring the Secretary of Health and Human Services to issue bottled drinking water standards for contaminants regulated under the Safe Drinking Water Act.

Other provisions of P.L. 104-182 authorize water and wastewater grants for colonies and Alaska rural and native villages, and authorize the transfer of the Washington (D.C.) Aqueduct to a regional authority.

The 1996 Amendments also authorize a \$50 million per year grant program for additional infrastructure and watershed protection projects; the conference report lists, and directs the EPA to give priority consideration to 24 such projects.



Removing the well casing from a groundwater well.



Butterfly Valve



Large Gate Valve

42 USC Part A - SDWA Definitions

TITLE 42 - THE PUBLIC HEALTH AND WELFARE
CHAPTER 6A - PUBLIC HEALTH SERVICE
SUBCHAPTER XII - SAFETY OF PUBLIC WATER SYSTEMS
Part A - Definitions

Part A - Definitions

42 USC Sec. 300f

01/05/99

TITLE 42 - THE PUBLIC HEALTH AND WELFARE
CHAPTER 6A - PUBLIC HEALTH SERVICE
SUBCHAPTER XII - SAFETY OF PUBLIC WATER SYSTEMS
Part A - Definitions

Sec. 300f. Definitions

For purposes of this subchapter:

- (1) The term ''primary drinking water regulation'' means a regulation which -
 - (A) applies to public water systems;
 - (B) specifies contaminants which, in the judgment of the Administrator, may have any adverse effect on the health of persons;
 - (C) specifies for each such contaminant either -
 - (i) a maximum contaminant level, if, in the judgment of the Administrator, it is economically and technologically feasible to ascertain the level of such contaminant in water in public water systems, or
 - (ii) if, in the judgment of the Administrator, it is not economically or technologically feasible to so ascertain the level of such contaminant, each treatment technique known to the Administrator which leads to a reduction in the level of such contaminant sufficient to satisfy the requirements of section 300g-1 of this title; and
 - (D) contains criteria and procedures to assure a supply of drinking water which dependably complies with such maximum contaminant levels; including accepted methods for quality control and testing procedures to insure compliance with such levels and to insure proper operation and maintenance of the system, and requirements as to (i) the minimum quality of water which may be taken into the system and (ii) siting for new facilities for public water systems.

At any time after promulgation of a regulation referred to in this paragraph, the Administrator may add equally effective quality control and testing procedures by guidance published in the Federal Register. Such procedures shall be treated as an alternative for public water systems to the quality control and testing procedures listed in the regulation.

- (2) The term ''secondary drinking water regulation'' which applies to public water systems and which specifies the maximum

contaminant levels which, in the judgment of the Administrator, are requisite to protect the public welfare. Such regulations may apply to any contaminant in drinking water (A) which may adversely affect the odor or appearance of such water and consequently may cause a substantial number of the persons served by the public water system providing such water to discontinue its use, or (B) which may otherwise adversely affect the public welfare. Such regulations may vary accordingly to geographic and other circumstances.

(3) The term "'maximum contaminant level'" means the maximum permissible level of a contaminant in water which is delivered to any user of a public water system.

(4) Public water system. -

(A) In general. - The term "'public water system'" means a system for the provision to the public of water for human consumption through pipes or other constructed conveyances, if such system has at least fifteen service connections or regularly serves at least twenty-five individuals. Such term includes (i) any collection, treatment, storage, and distribution facilities under control of the operator of such system and used primarily in connection with such system, and (ii) any collection or pretreatment storage facilities not under such control which are used primarily in connection with such system.

(B) Connections. -

(i) In general. - For purposes of subparagraph (A), a connection to a system that delivers water by a constructed conveyance other than a pipe shall not be considered a connection, if -

(I) the water is used exclusively for purposes other than residential uses (consisting of drinking, bathing, and cooking, or other similar uses);

(II) the Administrator or the State (in the case of a State exercising primary enforcement responsibility for public water systems) determines that alternative water to achieve the equivalent level of public health protection provided by the applicable national primary drinking water regulation is provided for residential or similar uses for drinking and cooking; or

(III) the Administrator or the State (in the case of a State exercising primary enforcement responsibility for public water systems) determines that the water provided for residential or similar uses for drinking, cooking, and bathing is centrally treated or treated at the point of entry by the provider, a pass-through entity, or the user to achieve the equivalent level of protection provided by the applicable national primary drinking water regulations.

(iii) Irrigation districts. - An irrigation district in existence prior to May 18, 1994, that provides primarily agricultural service through a piped water system with only incidental residential or similar use shall not be considered to be a public water system if the system or the residential or similar users of the system comply with subclause (II) or (III) of clause (i).

(C) Transition period. - A water supplier that would be a public water system only as a result of modifications made to this paragraph by the Safe Drinking Water Act Amendments of

1996 shall not be considered a public water system for purposes of the Act until the date that is two years after August 6, 1996. If a water supplier does not serve 15 service connections (as defined in subparagraphs (A) and (B)) or 25 people at any time after the conclusion of the 2-year period, the water supplier shall not be considered a public water system.

(5) The term "supplier of water" means any person who owns or operates a public water system.

(6) The term "contaminant" means any physical, chemical, biological, or radiological substance or matter in water.

(7) The term "Administrator" means the Administrator of the Environmental Protection Agency.

(8) The term "Agency" means the Environmental Protection Agency.

(9) The term "Council" means the National Drinking Water Advisory Council established under section 300j-5 of this title.

(10) The term "municipality" means a city, town, or other public body created by or pursuant to State law, or an Indian Tribe.

(11) The term "Federal agency" means any department, agency, or instrumentality of the United States.

(12) The term "person" means an individual, corporation, company, association, partnership, State, municipality, or Federal agency (and includes officers, employees, and agents of any corporation, company, association, State, municipality, or Federal agency).

(13)(A) Except as provided in subparagraph (B), the term "State" includes, in addition to the several States, only the District of Columbia, Guam, the Commonwealth of Puerto Rico, the Northern Mariana Islands, the Virgin Islands, American Samoa, and the Trust Territory of the Pacific Islands.

(B) For purposes of section 300j-12 of this title, the term "State" means each of the 50 States, the District of Columbia, and the Commonwealth of Puerto Rico.

(14) The term "Indian Tribe" means any Indian tribe having a Federally recognized governing body carrying out substantial governmental duties and powers over any area. For purposes of section 300j-12 of this title, the term includes any Native village (as defined in section 1602(c) of title 43).

(15) Community water system. - The term "community water system" means a public water system that -

(A) serves at least 15 service connections used by year-round residents of the area served by the system; or

(B) regularly serves at least 25 year-round residents.

(16) Noncommunity water system. - The term "noncommunity water system" means a public water system that is not a community water system.

The Safe Drinking Water Act Amendments of 1996, referred to in par. (4)(C), is Pub. L. 104-182, Aug. 6, 1996, 110 Stat. 1613. For complete classification of this Act to the Code, see Short Title of 1996 Amendment note set out under section 201 of this title and Tables.



Broken Water Service



Broken Water Main

National Primary Drinking Water Regulations

Inorganic Chemicals	MCLG ¹ (mg/L) ⁴	MCL ² or TT ³ (mg/L) ⁴	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Antimony	0.006	0.006	Increase in blood cholesterol; decrease in blood glucose	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder
Arsenic	none ⁵	0.010	Skin damage; circulatory system problems; increased risk of cancer	Discharge from semiconductor manufacturing; petroleum refining; wood preservatives; animal feed additives; herbicides; erosion of natural deposits
Asbestos (fiber >10 micrometers)	7 million fibers per Liter	7 MFL	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits
Barium	2	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
Beryllium	0.004	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries
Cadmium	0.005	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints
Chromium (total)	0.1	0.1	Some people who use water containing chromium well in excess of the MCL over many years could experience allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits
Copper	1.3	Action Level=1.3; TT ⁶	Short term exposure: Gastrointestinal distress. Long term exposure: Liver or kidney damage. Those with Wilson's Disease should consult their personal doctor if their water systems exceed the copper action level.	Corrosion of household plumbing systems; erosion of natural deposits; leaching from wood preservatives
Cyanide (as free cyanide)	0.2	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories
Fluoride	4.0	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth.	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories
Lead	zero	Action Level=0.015; TT ⁶	Infants and children: Delays in physical or mental development. Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits

Inorganic Mercury	0.002	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and cropland
Nitrate (measured as Nitrogen)	10	10	"Blue baby syndrome" in infants under six months - life threatening without immediate medical attention. Symptoms: Infant looks blue and has shortness of breath.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Nitrite (measured as Nitrogen)	1	1	"Blue baby syndrome" in infants under six months - life threatening without immediate medical attention. Symptoms: Infant looks blue and has shortness of breath.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Selenium	0.05	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines
Thallium	0.0005	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and pharmaceutical companies

Organic Chemicals	MCLG ¹ (mg/L) ⁴	MCL ² or TT ³ (mg/L) ⁴	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Acrylamide	zero	TT ²	Nervous system or blood problems; increased risk of cancer	Added to water during sewage/wastewater treatment
Alachlor	zero	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops
Atrazine	0.003	0.003	Cardiovascular system problems; reproductive difficulties	Runoff from herbicide used on row crops
Benzene	zero	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills
Benzo(a)pyrene	zero	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines
Carbofuran	0.04	0.04	Problems with blood or nervous system; reproductive difficulties.	Leaching of soil fumigant used on rice and alfalfa
Carbon tetrachloride	zero	.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities
Chlordane	zero	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide
Chlorobenzene	0.1	0.1	Liver or kidney problems	Discharger from chemical and agricultural chemical factories
2,4-D	0.07	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops
Dalapon	0.2	0.2	Minor kidney changes	Runoff from herbicide used on rights of way

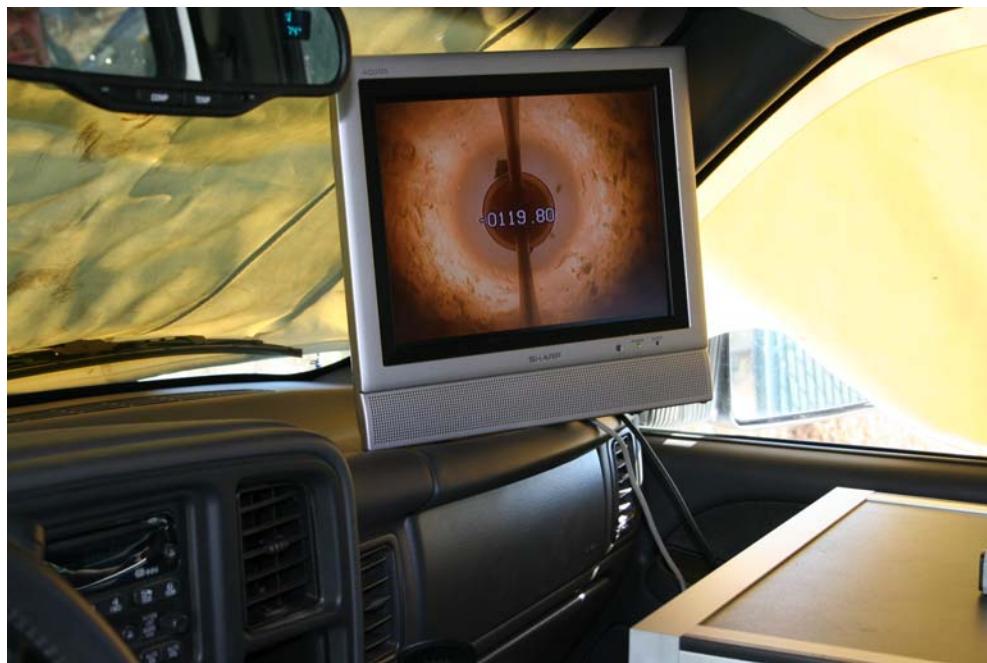
1,2-Dibromo-3-chloropropane (DBCP)	zero	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards
o-Dichlorobenzene	0.6	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories
p-Dichlorobenzene	0.075	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories
1,2-Dichloroethane	zero	0.005	Increased risk of cancer	Discharge from industrial chemical factories
1-1-Dichloroethylene	0.007	0.007	Liver problems	Discharge from industrial chemical factories
cis-1, 2-Dichloroethylene	0.07	0.07	Liver problems	Discharge from industrial chemical factories
trans-1,2-Dichloroethylene	0.1	0.1	Liver problems	Discharge from industrial chemical factories
Dichloromethane	zero	0.005	Liver problems; increased risk of cancer	Discharge from pharmaceutical and chemical factories
1,2-Dichloropropane	zero	0.005	Increased risk of cancer	Discharge from industrial chemical factories
Di(2-ethylhexyl)adipate	0.4	0.4	General toxic effects or reproductive difficulties	Leaching from PVC plumbing systems; discharge from chemical factories
Di(2-ethylhexyl)phthalate	zero	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories
Dinoseb	0.007	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables
Dioxin (2,3,7,8-TCDD)	zero	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories
Diquat	0.02	0.02	Cataracts	Runoff from herbicide use
Endothall	0.1	0.1	Stomach and intestinal problems	Runoff from herbicide use
Endrin	0.002	0.002	Nervous system effects	Residue of banned insecticide
Epichlorohydrin	zero	TT ⁷	Stomach problems; reproductive difficulties; increased risk of cancer	Discharge from industrial chemical factories; added to water during treatment process
Ethylbenzene	0.7	0.7	Liver or kidney problems	Discharge from petroleum refineries
Ethelyne dibromide	zero	0.00005	Stomach problems; reproductive difficulties; increased risk of cancer	Discharge from petroleum refineries
Glyphosate	0.7	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use
Heptachlor	zero	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide
Heptachlor epoxide	zero	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor
Hexachlorobenzene	zero	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories
Hexachlorocyclopentadiene	0.05	0.05	Kidney or stomach problems	Discharge from chemical factories
Lindane	0.0002	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens
Methoxychlor	0.04	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock
Oxamyl (Vydate)	0.2	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes

Polychlorinated biphenyls (PCBs)	zero	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals
Pentachlorophenol	zero	0.001	Liver or kidney problems; increased risk of cancer	Discharge from wood preserving factories
Picloram	0.5	0.5	Liver problems	Herbicide runoff
Simazine	0.004	0.004	Problems with blood	Herbicide runoff
Styrene	0.1	0.1	Liver, kidney, and circulatory problems	Discharge from rubber and plastic factories; leaching from landfills
Tetrachloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners
Toluene	1	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories
Total Trihalomethanes (TTHMs)	none ⁵	0.10	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection
Toxaphene	zero	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle
2,4,5-TP (Silvex)	0.05	0.05	Liver problems	Residue of banned herbicide
1,2,4-Trichlorobenzene	0.07	0.07	Changes in adrenal glands	Discharge from textile finishing factories
1,1,1-Trichloroethane	0.20	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories
1,1,2-Trichloroethane	0.003	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories
Trichloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from petroleum refineries
Vinyl chloride	zero	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories
Xylenes (total)	10	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories

Radionuclides	MCLG ¹ (mg/L) ⁴	MCL ² or TT ³ (mg/L) ⁴	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Beta particles and photon emitters	none ⁵	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits
Gross alpha particle activity	none ⁵	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits
Radium 226 and Radium 228 (combined)	none ⁵	5 pCi/L	Increased risk of cancer	Erosion of natural deposits
Microorganisms	MCLG ¹ (mg/L) ⁴	MCL ² or TT ³ (mg/L) ⁴	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
<i>Giardia lamblia</i>	zero	TT ⁸	Giardiasis, a gastroenteric disease	Human and animal fecal waste
Heterotrophic plate count	N/A	TT ⁸	HPC has no health effects, but can indicate how effective treatment is at controlling microorganisms.	n/a
<i>Legionella</i>	zero	TT ⁸	Legionnaire's Disease, commonly known as pneumonia	Found naturally in water; multiplies in heating systems
Total Coliforms (including fecal coliform and <i>E. Coli</i>)	zero	5.0% ⁹	Used as an indicator that other potentially harmful bacteria may be present ¹⁰	Human and animal fecal waste
Turbidity	N/A	TT ⁸	Turbidity has no health effects but can interfere with disinfection and provide a medium for microbial growth. It may indicate the presence of microbes.	Soil runoff
Viruses (enteric)	zero	TT ⁸	Gastroenteric disease	Human and animal fecal waste



Normal well crew, an Electrician, Distribution Foreman and Hydrogeologist working together to provide quality groundwater.



Video screen of a well scan. This picture is from inside a truck cab. Technology today is crazy.

National Secondary Drinking Water Regulations

National Secondary Drinking Water Regulations (**NSDWRs**) or secondary standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water.

The EPA recommends secondary standards to water systems, but does not require systems to comply. However, states may choose to adopt them as enforceable standards.

Contaminant	Secondary Standard
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L
Corrosivity	noncorrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5-8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L

Notes

¹ Maximum Contaminant Level Goal (MCLG) - The maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health effect of persons would occur, and which allows for an adequate margin of safety. MCLGs are non-enforceable public health goals.

² Maximum Contaminant Level (MCL) - The maximum permissible level of a contaminant in water which is delivered to any user of a public water system. MCLs are enforceable standards. The margins of safety in MCLGs ensure that exceeding the MCL slightly does not pose significant risk to public health.

³ Treatment Technique - An enforceable procedure or level of technical performance which public water systems must follow to ensure control of a contaminant.

⁴ Units are in milligrams per Liter (mg/L) unless otherwise noted.

⁵ MCLGs were not established before the 1986 Amendments to the Safe Drinking Water Act. Therefore, there is no MCLG for this contaminant.

⁶ Lead and copper are regulated in a Treatment Technique which requires systems to take tap water samples at sites with lead pipes or copper pipes that have lead solder and/or are served by lead service lines. The action level, which triggers water systems into taking treatment steps if exceeded in more than 10% of tap water samples, for copper is 1.3 mg/L, and for lead is 0.015mg/L.

⁷ Each water system must certify, in writing, to the state (using third-party or manufacturer's certification) that when acrylamide and epichlorohydrin are used in drinking water systems, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows:

- **Acrylamide** = 0.05% dosed at 1 mg/L (or equivalent)
- **Epichlorohydrin** = 0.01% dosed at 20 mg/L (or equivalent)

⁸ The Surface Water Treatment Rule requires systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- **Giardia lamblia**: 99.9% killed/inactivated
Viruses: 99.99% killed/inactivated
- **Legionella**: No limit, but EPA believes that if *Giardia* and viruses are inactivated, *Legionella* will also be controlled.
- **Turbidity**: At no time can turbidity (cloudiness of water) go above 5 nephelometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month.
- **HPC**: NO more than 500 bacterial colonies per milliliter.

⁹ No more than 5.0% samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive). Every sample that has total coliforms must be analyzed for fecal coliforms. There cannot be any fecal coliforms.

¹⁰ Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human animal wastes. Microbes in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms.

New EPA Rules

Arsenic

Arsenic is a chemical that occurs naturally in the earth's crust. When rocks, minerals, and soil erode, they release arsenic into water supplies. When people either drink this water or eat animals and plants that drink it, they are exposed to arsenic. In the U.S., eating and drinking are the most common ways that people are exposed to arsenic, although it can also come from industrial sources. Studies have linked long-term exposure of arsenic in drinking water to a variety of cancers in humans.

To protect human health, an EPA standard limits the amount of arsenic in drinking water. In January 2001, the EPA revised the standard from 50 parts per billion (**ppb**), ordering that it fall to 10 ppb by 2006. After adopting 10ppb as the new standard for arsenic in drinking water, the EPA decided to review the decision to ensure that the final standard was based on sound science and accurate estimates of costs and benefits. In October 2001, the EPA decided to move forward with implementing the 10ppb standard for arsenic in drinking water.

More information on the rulemaking process and the costs and benefits of setting the arsenic limit in drinking water at 10ppb can be found in TLC's Arsenic CEU Course or at www.epa.gov/safewater/arsenic.html.

ICR

The EPA has collected data required by the Information Collection Rule (**ICR**) to support future regulation of microbial contaminants, disinfectants, and disinfection byproducts. The rule is intended to provide the EPA with information on chemical byproducts that form when disinfectants used for microbial control react with chemicals already present in source water (disinfection byproducts (**DBPs**)); disease-causing microorganisms (pathogens), including Cryptosporidium; and engineering data to control these contaminants.

Drinking water microbial and disinfection byproduct information collected for the ICR is now available on the EPA's Envirofacts Warehouse website.

Disinfection Byproduct Regulations

In December 1998, the EPA established the Stage 1 Disinfectants/Disinfection Byproducts Rule that requires public water systems to use treatment measures to reduce the formation of disinfection byproducts and to meet the following specific standards:

Total trihalomethanes (TTHM)	80 parts per billion (ppb)
Haloacetic acids (HAA5)	60 ppb
Bromate	10 ppb
Chlorite	1.0 parts per million (ppm)

Currently trihalomethanes are regulated at a maximum allowable annual average level of 100 parts per billion for water systems serving over 10,000 people under the Total Trihalomethane Rule finalized by the EPA in 1979. The Stage 1 Disinfectant/Disinfection Byproduct Rule standards became effective for trihalomethanes and other disinfection byproducts listed above back in December 2001 for large surface water public water systems. These standards became effective in December 2003 for small surface water and all ground water public water systems.

Disinfection byproducts are formed when disinfectants used in water treatment plants react with bromide and/or natural organic matter (i.e., decaying vegetation) present in the source water. Different disinfectants produce different types or amounts of disinfection byproducts. Disinfection byproducts for which regulations have been established have been identified in drinking water, including trihalomethanes, haloacetic acids, bromate, and chlorite.

Trihalomethanes (THM) are a group of four chemicals that are formed along with other disinfection byproducts when chlorine or other disinfectants used to control microbial contaminants in drinking water react with naturally occurring organic and inorganic matter in water. The trihalomethanes are chloroform, bromodichloromethane, dibromochloromethane, and bromoform. The EPA has published the Stage 1 Disinfectants/Disinfection Byproducts Rule to regulate total trihalomethanes (**TTHM**) at a maximum allowable annual average level of 80 parts per billion. This standard will replace the current standard of a maximum allowable annual average level of 100 parts per billion in December 2001 for large surface water public water systems. The standard became effective in December 2003 for small surface water and all ground water systems.

Haloacetic Acids (HAA5) are a group of chemicals that are formed along with other disinfection byproducts when chlorine or other disinfectants used to control microbial contaminants in drinking water react with naturally occurring organic and inorganic matter in water. The regulated haloacetic acids, known as HAA5, are: monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid. The EPA has published the Stage 1 Disinfectants/Disinfection Byproducts Rule to regulate HAA5 at 60 parts per billion annual average. This standard will become effective for large surface water public water systems in December 2001 and for small surface water and all ground water public water systems in December 2003.

Bromate is a chemical that is formed when ozone used to disinfect drinking water reacts with naturally occurring bromide found in source water. The EPA has established the Stage 1 Disinfectants/Disinfection Byproducts Rule to regulate bromate at annual average of 10 parts per billion in drinking water. This standard became effective for large public water systems in December 2001 and for small surface water and all ground public water systems in December 2003.

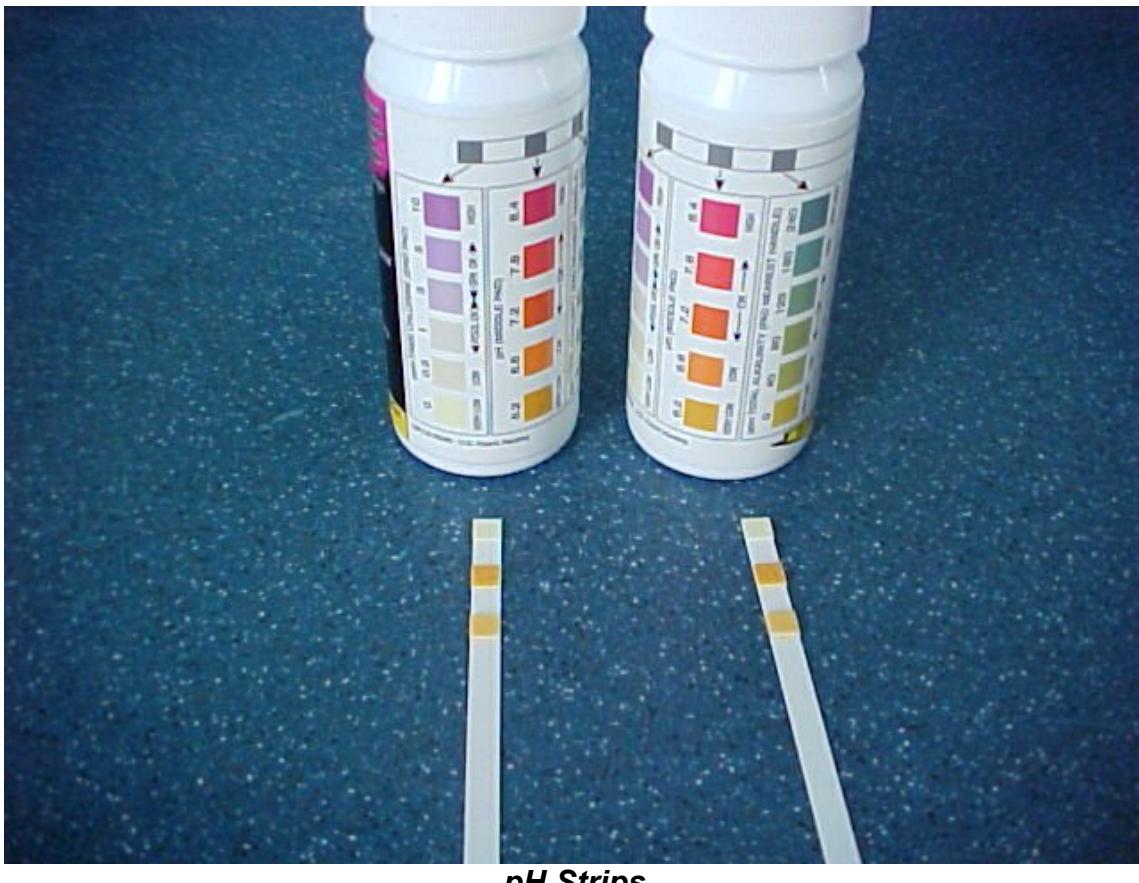
Chlorite is a byproduct formed when chlorine dioxide is used to disinfect water. The EPA has published the Stage 1 Disinfectants/Disinfection Byproducts Rule to regulate chlorite at a monthly average level of 1 part per million in drinking water.

This standard became effective for large surface water public water systems in December 2001 and for small surface water and all ground water public water systems in December 2003.

Microbial Regulations

One of the key regulations developed and implemented by the United States Environmental Protection Agency (**USEPA**) to counter pathogens in drinking water is the Surface Water Treatment Rule.

Among its provisions, the rule requires that a public water system, using surface water (or ground water under the direct influence of surface water) as its source, have sufficient treatment to reduce the source water concentration of **Giardia** and viruses by at least 99.9% and 99.99%, respectively. The Surface Water Treatment Rule specifies treatment criteria to assure that these performance requirements are met; they include turbidity limits, disinfectant residual and disinfectant contact time conditions.



pH is on a scale from 0-14.

7 is considered neutral and acid is on the 0 to 7 side and the base is 7-14.

pH is known as the Power of Hydroxyl Ion activity.



Common Sample bottles, Radiochems, VOCs, (Volatile Organic Compounds), TTHMs, Total Trihalomethanes), Nitrate, Nitrite .

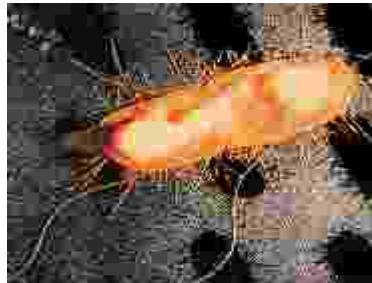
Most of these sample bottles will come with the preservative already inside the bottle.

Some bottles will come with a separate preservative (acid) for the field preservation.

Slowly add the acid or other preservative to the water sample; not water to the acid or preservative.



Bac-T Sample Bottle, often referred to as a Standard Sample, 100 mls. Notice the white powder inside the bottle. That is Sodium Thiosulfate, a de-chlorination agent. Be careful not to wash-out this chemical while sampling. Notice the custody seal on the bottle.



Coliform bacteria are common in the environment and are generally not harmful. However, the presence of these bacteria in drinking water is usually a result of a problem with the treatment system or the pipes which distribute water, and indicates that the water may be contaminated with germs that can cause disease.

Yellow indicates Coliform bacteria, fluoresce indicates fecal bacteria.

Water Distribution Systems

Your heart and lungs play a vital role in keeping you alive. If you don't take care of your body and how your blood circulates you will die. Our body works very similar to the water system we operate.

Our lungs clean the blood exchanging carbon dioxide with oxygen; our water treatment plant treats the water by taking impurities out. Our heart pumps the blood to our lungs and out to other vital organs; our water pump stations deliver the water to our systems and to the customers.

What happens if our arteries become clogged and damaged or we lose circulation? The blood flow will no longer make its way back to the lungs or the lungs will no longer be able to send the purified blood to the vital organs. The same can happen if we have problems with our water transmission lines or distribution lines.

Water Treatment Basics

Water is a powerful solvent that is capable of dissolving almost everything it comes in contact with. For instance, water can pick up harmless minerals from the earth, such as calcium, magnesium, carbonates and sulfates. These give the water a pleasing taste as well as beneficial health qualities.

This is also because water utilities across the country have in place effective processes to remove contaminants that cause waterborne diseases. The most commonly used processes include filtration, flocculation and sedimentation, and disinfection.

Flocculation/Sedimentation

The flocculation process coagulates (joins together) particles with alum and metal salts so that they settle out of the water as sediment. Sedimentation is simply a gravity process that removes flocculated particles from the water.

Filtration

Filtration removes remaining particles from the water supply. Those particles may include silt, natural organic matter, iron and manganese, and microorganisms. Filtration clarifies water and improves the effectiveness of disinfection.

Disinfection (Chlorination, ozonation)

Water is then disinfected to ensure that dangerous microbes are killed. Chlorine-based disinfectants or ozone are used because they are very effective. Chlorine-based disinfectants also provide residual protection against biological contamination in the water distribution system. This is a critical step to assure our water is safe all the way to the consumer's tap.

Groundwater and Wells

A well can be easily contaminated if it is not properly constructed or if toxic materials are released into the well. Toxic material spilled or dumped near a well can leach into the aquifer and contaminate the groundwater drawn from that well.

Safe practices around wells should include applying disinfectant in or around a well casing during cleaning or disinfection.

Contaminated Wells

Contaminated wells used for drinking water are especially dangerous. Wells can be tested to see what chemicals may be in the well and if they are present in dangerous quantities.

Groundwater is withdrawn from wells to provide water for everything from drinking water for the home and business to water to irrigate crops to industrial processing water. When water is pumped from the ground, the dynamics of groundwater flow change in response to this withdrawal.

Groundwater flows slowly through water-bearing formations (aquifers) at different rates. In some places, where groundwater has dissolved limestone to form caverns and large openings, its rate of flow can be relatively fast, but this is exceptional.



Well with a mineral oil sealed vertical turbine pump

Aquifer

Many terms are used to describe the nature and extent of the groundwater resource. The level below which all the spaces are filled with water is called the **water table**.

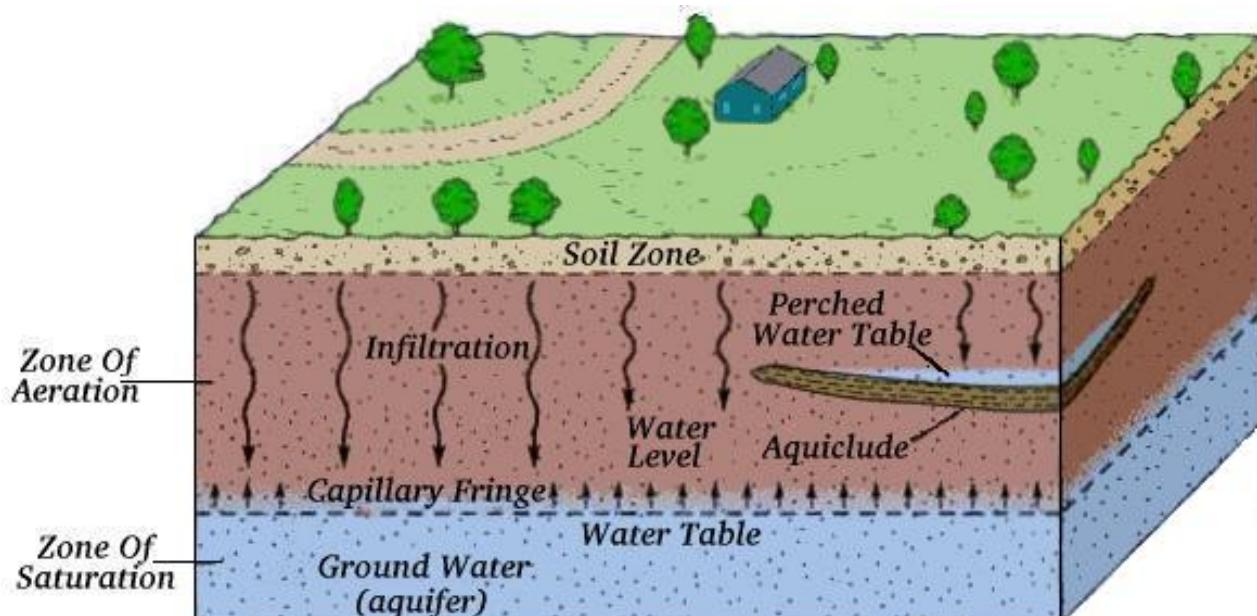
Above the water table lies the **unsaturated zone**. Here the spaces in the rock and soil contain both air and water. Water in this zone is called **soil moisture**. The entire region below the water table is called the **saturated zone** and water in this saturated zone is called **groundwater**.

Fractured aquifers are rocks in which the groundwater moves through cracks, joints or fractures in otherwise solid rock.

Examples of fractured aquifers include granite and basalt. Limestones are often fractured aquifers, but here the cracks and fractures may be enlarged by solution, forming large channels or even caverns.

Limestone terrain where solution has been very active is termed **karst**. Porous media such as sandstone may become so highly cemented or recrystallized that all of the original space is filled. In this case, the rock is no longer a porous medium. However, if it contains cracks it can still act as a fractured aquifer.

Most of the aquifers of importance to us are unconsolidated porous media such as sand and gravel. Some very porous materials are not permeable. Clay, for instance, has many spaces between its grains, but the spaces are not large enough to permit free movement of water.



Groundwater usually flows downhill with the slope of the water table. Like surface water, groundwater flows toward, and eventually drains into, streams, rivers, lakes and the oceans.

Groundwater flow in the aquifers underlying surface drainage basins, however, does not always mirror the flow of water on the surface.

Therefore, groundwater may move in different directions below the ground than the water flowing on the surface.



Vertical Turbine Well

Unconfined aquifers are those that are bounded by the water table. Some aquifers, however, lie beneath layers of impermeable materials. These are called **confined aquifers**, or sometimes **artesian aquifers**.

A well in such an aquifer is called an *artesian well*. The water in these wells rises higher than the top of the aquifer because of confining pressure. If the water level rises above the ground surface a **flowing artesian well** occurs.

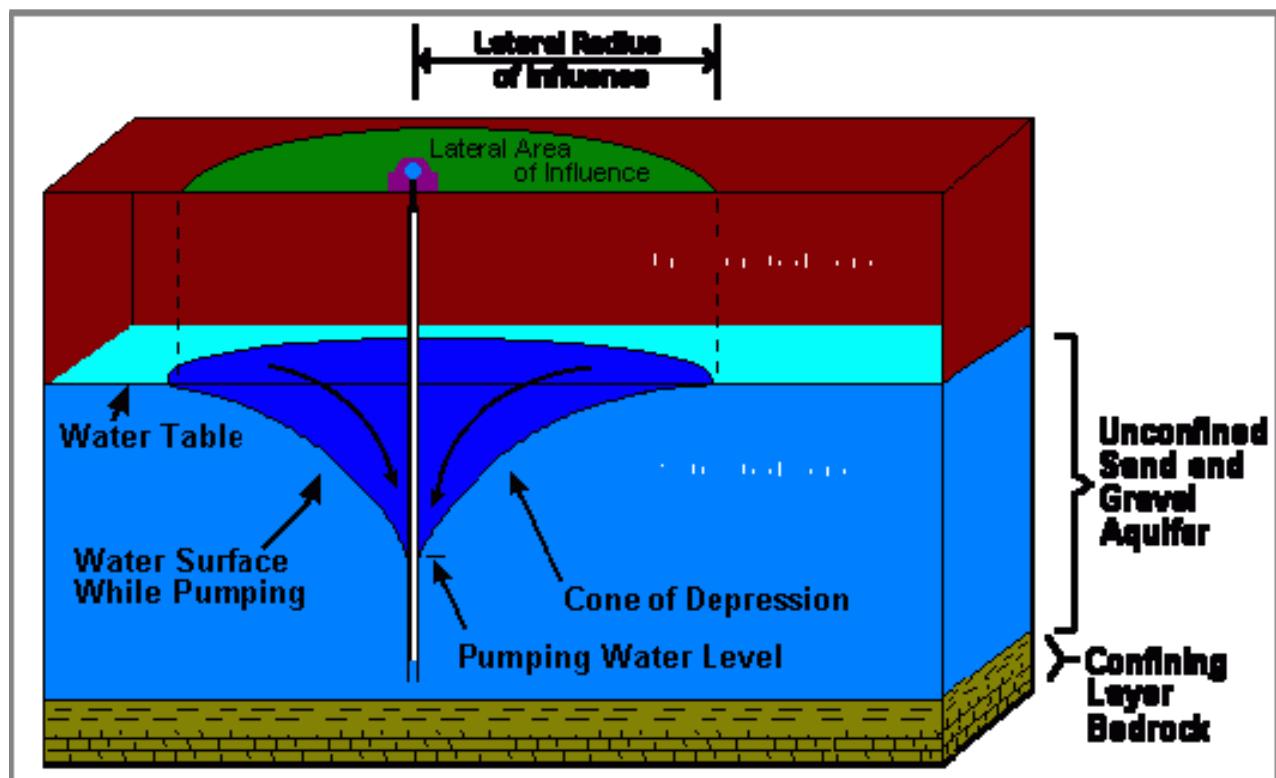
The **piezometric surface** is the level to which the water in an artesian aquifer will rise.

Cone of Depression

When pumping begins, water begins to flow towards the well in contrast to the natural direction of groundwater movement. The water level in the well falls below the water table in the surrounding aquifer.

As a result, water begins to move from the aquifer into the well. As pumping continues, the water level in the well continues to increase until the rate of flow into the well equals the rate of withdrawal from pumping. The movement of water from an aquifer into a well results in the formation of a cone of depression.

The cone of depression describes a three-dimensional inverted cone surrounding the well that represents the volume of water removed as a result of pumping. Drawdown is the vertical drop in the height between the water level in the well prior to pumping and the water level in the well during pumping.





Large Water Storage Tank

When a well is installed in an unconfined aquifer, water moves from the aquifer into the well through small holes or slits in the well casing or, in some types of wells, through the open bottom of the well. The level of the water in the well is the same as the water level in the aquifer. Groundwater continues to flow through and around the well in one direction in response to gravity.



Top of a storage reservoir

Water Use or Demand

Water system demand comes from a number of sources including residential, commercial, industrial and public consumers as well as some unavoidable loss and waste. If fire protection is desired, that could also represent a rather significant (although not continuous) demand upon the system.

The combination of storage reservoirs and distribution lines must be capable of meeting consumers' needs for quality, quantity and pressure at all times.

The quantity of water used in any community varies from 50 to 500 gallons per person per day. A common design assumption is to use from 100 to 150 gallons per person per day for average domestic use.

The maximum daily use is approximately 2 to 3 times the average daily use. Maximum daily use is usually encountered during the summer months and can vary widely depending on irrigation practices.

Water Pressure

For ordinary domestic use, water pressure should be between 25 and 45 psi. A minimum of 60 psi at a fire hydrant is usually adequate, since that allows for up to 20 psi pressure drop in fire hoses. In commercial and industrial districts, it may be common to have 75 psi or higher. 20 psi is considered the minimum required at any point in the water system, so that backflow and infiltration is prevented.

Pressure is provided by the direct force of the water (such as water from a pump), or by the height of the water (such as a storage reservoir). 2.31 feet of water is equal to 1 psi, or 1 foot of water is equal to about a half a pound (.433 pounds to be exact).

Storage and Distribution

The cost of supplying water to the users of any water system includes the installation of storage and distribution facilities. Also, there are on-going maintenance costs associated with cleaning, repairing and replacing these facilities.

The distribution system must also protect water quality between the source and the customer's tap. Proper construction is important in maintaining system integrity. Care must be taken that no foreign material is introduced into the system during pipe laying operations. Pipe ends should be covered at the end of the work day or during interruptions of construction.

All pipes, joints and fittings should be pressure tested and disinfected with a 5% chlorine solution such as household bleach before backfilling.

It is also important that all materials in contact with potable water meet the requirements of the National Sanitation Foundation (**NSF**) or American Water Works Association (**AWWA**) or have equivalent third-party certification. This includes solders (must be lead-free), pipes, joining and sealing materials, and protective coatings.

Water Storage Facilities

Water storage facilities and tanks vary in size, shape, and application. There are different types that are used in the water distribution systems, such as stand pipes, elevated tanks and reservoirs, hydropneumatic tanks and surge tanks. These tanks serve multiple purposes in the distribution system. Just the name alone can give you an idea of its purpose.

- **SURGE tanks**
- **RESERVOIRS**
- **ELEVATED tanks** *Water towers and Standpipes*

Surge Tanks

What really causes water main breaks - **ENERGY** - when released in a confined space, such as a water distribution system. Shock waves are created when hydrants, valves, or pumps are opened and closed quickly, trapping the kinetic energy of moving water within the confined space of a piping system. These shock waves can create a turbulence that travels at the speed of sound, seeking a point of release. The release the surge usually finds is an elevated tank, but the surge doesn't always find this release quickly enough. Something has to give, and oftentimes, it's your pipe fittings. Distribution operators are aware of this phenomenon! It's called **WATER HAMMER**.

This banging can be heard as water hammer. Try it at home - turn on your tap, then turn it off very quickly. You should hear a bang, and maybe even several. If you turn the tap off more slowly, it should stay quiet, as the liquid in the pipes slows down more gradually.

A **Surge tank** should not be used for water storage. The goal of the water tower or stand pipe is to store water high in the air, where it has lots of gravitational potential energy. This stored energy can be converted to pressure potential energy or kinetic energy for delivery to homes. Since height is everything, building a cylindrical water tower is inefficient. Most of the water is then near the ground. By making the tower wider near the top, it puts most of its water high up.

According to the manual, the minimum absolute pressure is 20 psi & 35 psi is the minimum working pressure recommended in the distribution system to maintain safe conditions.



Storage Reservoirs

Storage reservoirs allow the system to meet the fluctuations in demand described earlier. It is recommended that the volume of storage be equal to from one to three days of the system's average daily use. It is also recommended that storage reservoirs be located at a high enough elevation to allow the water to flow by gravity to the distribution system.

This, coupled with restricted usage on the part of the consumers, should provide an uninterrupted water supply in the event of pump failure, loss of power or an acute contamination event or cross-connection.

Also, if applicable, some storage for fire protection should be provided. Reservoirs are also used as detention basins to provide the required chlorine contact time necessary to ensure adequate disinfection.

As such, the contact time in a reservoir is greatly improved when the reservoir is constructed with a separate inlet and outlet pipe, preferably located on opposite sides of the reservoir and at different levels.

Also, baffles inside the reservoir (walls, curtains, or spirals) increase the contact time by preventing the water from leaving the reservoir too quickly (known as "**short-circuiting**").

Steel Reservoirs

Steel reservoirs or tanks generally have lower construction and installation costs than concrete, but require more maintenance. To protect against corrosion, the exterior should be kept cleaned and painted. Interiors of steel reservoirs are commonly coated with an epoxy or enamel-type finish.

Some coal-tar linings used in the past have apparently degraded over time and are implicated in the release of small amounts of solvents into the stored water.

Steel reservoirs are usually welded or bolted together and are manufactured in a variety of sizes. Small steel reservoirs can be manufactured off-site and then trucked and lifted into place.

Steel tanks should be inspected once a year and repainted every 5-7 years. Steel tanks should also have cathodic protection and be screened to keep birds and insects out.

The maintenance program for reservoir tanks should call for annual draining for a complete inspection of the interior. Cleaning and disinfection prior to placing the reservoir or tank back in service is necessary.

Disinfection by chlorine can be accomplished by one of three methods:

- 1. Fill the tank or reservoir with a 25 mg/l chlorine solution and leave it for 24 hours.**
- 2. Fill the reservoir with a 50 mg/l chlorine solution and leave it for 3 hours.**
- 3. Spray or brush on a 200 mg/l chlorine solution and allow it to remain for 3 hours.**

The chlorinated water shall be disposed of in a manner that will not have an adverse effect on the environment. Check with your state environmental, health or drinking water section.



150 pound chlorine gas cylinder. Always tag the empty cylinder and store upright. Bottom, this is a dry chlorine tablet or HTH feeder.



Disinfection of Reservoirs

The distribution system is the piping that delivers water to service connections.

There are several types of piping material that can be used.

Each has its advantages and disadvantages.

The pipe material must have adequate strength to withstand external loads from backfill, traffic and earth movement, high burst strength to withstand high water pressure, smooth interior surfaces, corrosion resistant exteriors and tight joints.

A number of linings are also used to extend the life of the pipe and improve flow characteristics:

Reservoir size (gals.) Gallons of 5% bleach to add to achieve a 25ppm chlorine dose

1,000	.5
2,000	1
3,000	1.5
4,000	2
5,000	2.5
10,000	5
20,000	10
30,000	15
40,000	20
50,000	25

Reservoir size (gals.) Amount (in pounds of dry weight) of 65% strength dry chlorine powder (HTH) to add to achieve a 25ppm dose.

10,000	3.5
20,000	6.5
30,000	10
40,000	13
50,000	16
100,000	32
200,000	64
300,000	100
400,000	130
500,000	160

Waterborne Pathogens

Bacteria, viruses and protozoan that cause disease are known as pathogens. Most pathogens are generally associated with diseases that cause intestinal illness and affect people in a relatively short amount of time, generally a few days to two weeks. They can cause illness through exposure to small quantities of contaminated water or food or from direct contact with infected people or animals.

How Diseases are Transmitted

Pathogens that may cause waterborne outbreaks through drinking water have one thing in common: they are spread by the fecal-oral or feces-to-mouth route. Pathogens may get into water and spread when infected humans or animals pass the bacteria, viruses and protozoa in their stool. For another person to become infected, he or she must take that pathogen in through the mouth.

Waterborne pathogens are different from other types of pathogens such as the viruses that cause influenza (the flu) or the bacteria that cause tuberculosis. Influenza virus and tuberculosis bacteria are spread by secretions that are coughed or sneezed into the air by an infected person. Human or animal wastes in watersheds, failing septic systems, failing sewage treatment plants or cross-connections of water lines with sewage lines provide the potential for contaminating water with pathogens. The water may not appear to be contaminated because the feces has been broken up, dispersed and diluted into microscopic particles. These particles, containing pathogens, may remain in the water and be passed to humans or animals unless adequately treated.

Only proper treatment will ensure eliminating the spread of disease. In addition to water, other methods exist for spreading pathogens by the fecal-oral route. The foodborne route is one of the more common methods. A frequent source is a food handler who does not wash his hands after a bowel movement and then handles food with “**unclean**” hands. The individual who eats feces-contaminated food may become infected and ill. It is interesting to note the majority of foodborne diseases occur in the home, not restaurants.

Day care centers are another common source for spreading pathogens by the fecal-oral route. Here, infected children in diapers may get feces on their fingers, then put their fingers in a friend’s mouth or handle toys that other children put into their mouths. The general public and some of the medical community usually refer to diarrhea symptoms as “**stomach flu**.” Technically, influenza is an upper respiratory illness and rarely has diarrhea associated with it; therefore, stomach flu is a misleading description for foodborne or waterborne illnesses, yet is accepted by the general public. So the next time you get the stomach flu, you may want to think twice about what you’ve digested within the past few days.

Chain of Transmission

Water is contaminated with feces. This contamination may be of human or animal origin. The feces must contain pathogens (disease-causing bacteria, viruses or protozoa). If the human or animal source is not infected with a pathogen, no disease will result.

The pathogens must survive in the water. This depends on the temperature of the water and the length of time the pathogens are in the water. Some pathogens will survive for only a short time in water, others, such as Giardia or Cryptosporidium, may survive for months. The pathogens in the water must enter the water system's intake and in numbers sufficient to infect people. The water is either not treated or inadequately treated for the pathogens present. A susceptible person must drink the water that contains the pathogen. Illness (disease) will occur.

This chain lists the events that must occur for the transmission of disease via drinking water. By breaking the chain at any point, the transmission of disease will be prevented.

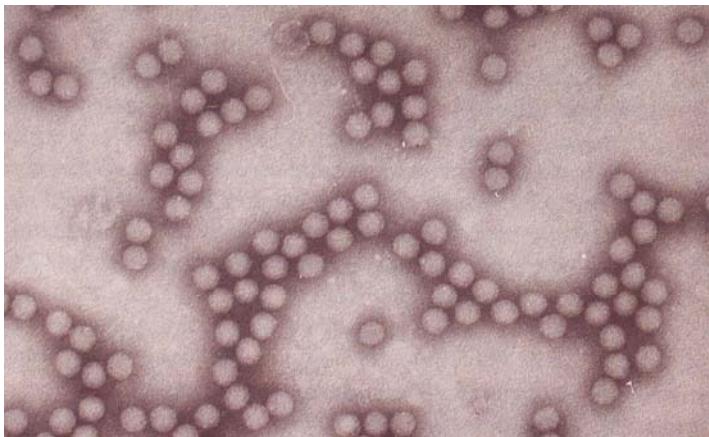
Bacterial Diseases

Campylobacteriosis is the most common diarrhea illness caused by bacteria. Symptoms include abdominal pain, malaise, fever, nausea and vomiting; and they usually begin three to five days after exposure. The illness is frequently over within two to five days and usually lasts no more than 10 days. Campylobacteriosis outbreaks have most often been associated with food, especially chicken and unpasteurized milk as well as unchlorinated water. These organisms are also an important cause of "**travelers' diarrhea**." Medical treatment generally is not prescribed for campylobacteriosis because recovery is usually rapid. Cholera, Legionellosis, salmonellosis, shigellosis, and yersiniosis, are other bacterial diseases that can be transmitted through water. All bacteria in water are readily killed or inactivated with chlorine or other disinfectants.

Viral-Caused Diseases

Hepatitis A is an example of a common viral disease that may be transmitted through water. The onset is usually abrupt with fever, malaise, loss of appetite, nausea and abdominal discomfort, followed within a few days by jaundice. The disease varies in severity from a mild illness lasting one to two weeks, to a severely disabling disease lasting several months (rare).

The incubation period is 15-50 days and averages 28-30 days. Hepatitis A outbreaks have been related to fecally contaminated water; food contaminated by infected food handlers, including sandwiches and salads that are not cooked or are handled after cooking; and raw or undercooked mollusks harvested from contaminated waters. Aseptic meningitis, polio and viral gastroenteritis (Norwalk agent) are other viral diseases that can be transmitted through water. Most viruses in drinking water can be inactivated by chlorine or other disinfectants.

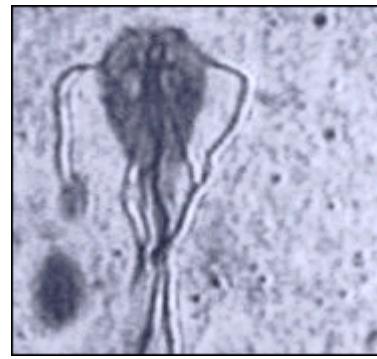


Protozoan Caused Diseases

Protozoan pathogens are larger than bacteria and viruses but still microscopic. They invade and inhabit the gastrointestinal tract. Some parasites enter the environment in a dormant form, with a protective cell wall, called a “**cyst**.” The cyst can survive in the environment for long periods of time and is extremely resistant to conventional disinfectants such as chlorine. Effective filtration treatment is therefore critical to removing these organisms from water sources.

Giardiasis

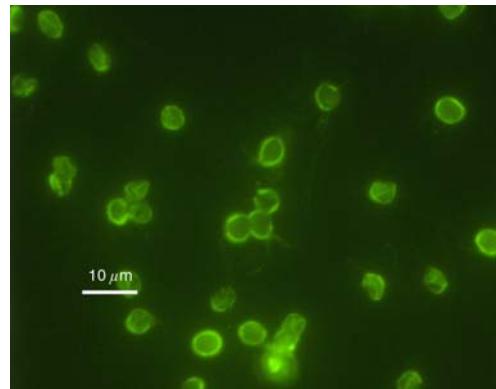
Giardiasis is a commonly reported protozoan-caused disease. It has also been referred to as “**backpacker’s disease**” and “**beaver fever**” because of the many cases reported among hikers and others who consume untreated surface water. Symptoms include chronic diarrhea, abdominal cramps, bloating, frequent loose and pale greasy stools, fatigue and weight loss. The incubation period is 5-25 days or longer, with an average of 7-10 days. Many infections are asymptomatic (no symptoms). Giardiasis occurs worldwide. Waterborne outbreaks in the United States occur most often in communities receiving their drinking water from streams or rivers without adequate disinfection or a filtration system.



The organism, *Giardia lamblia*, has been responsible for more community-wide outbreaks of disease in the U.S. than any other pathogen. Drugs are available for treatment but these are not 100% effective.

Cryptosporidiosis

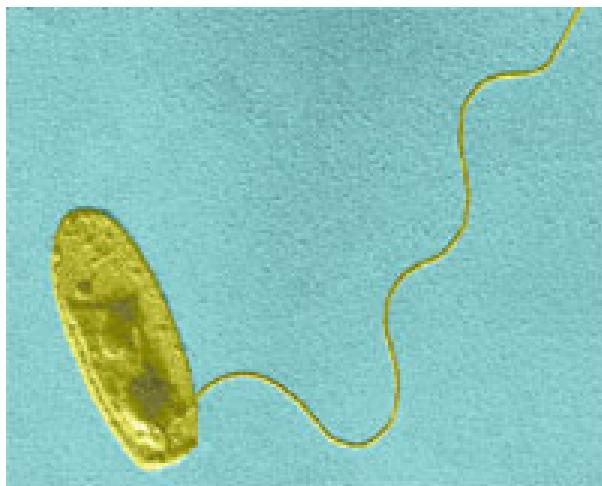
Cryptosporidiosis is an example of a protozoan disease that is common worldwide but was only recently recognized as causing human disease. The major symptom in humans is diarrhea, which may be profuse and watery. The diarrhea is associated with cramping abdominal pain. General malaise, fever, anorexia, nausea and vomiting occur less often. Symptoms usually come and go, and end in fewer than 30 days in most cases. The incubation period is 1-12 days, with an average of about seven days. *Cryptosporidium* organisms have been identified in human fecal specimens from more than 50 countries on six continents. The mode of transmission is fecal-oral, either by person-to-person or animal-to-person. There is no specific treatment for *Cryptosporidium* infections.



All of these diseases, with the exception of hepatitis A, have one symptom in common: diarrhea. They also have the same mode of transmission, fecal-oral, whether through person-to-person or animal-to-person contact and the same routes of transmission, being either foodborne or waterborne. Although most pathogens cause mild, self-limiting disease, on occasion, they can cause serious, even life threatening illness. Particularly vulnerable are persons with weak immune systems such as those with HIV infections or cancer.

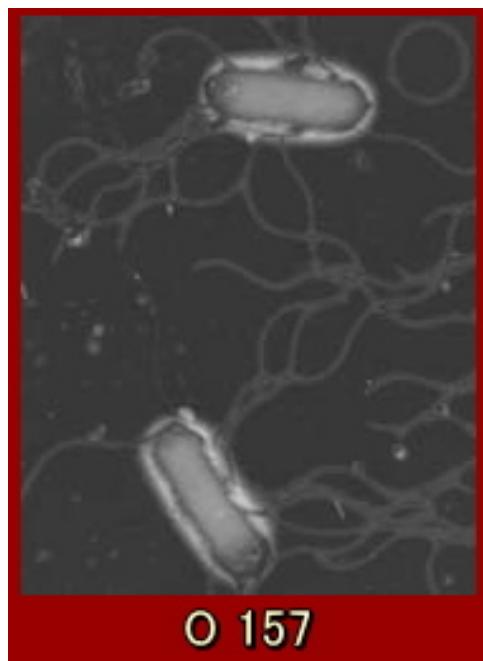
By understanding the nature of waterborne diseases, the importance of properly constructed, operated and maintained public water systems becomes obvious. While water treatment cannot achieve sterile water (no microorganisms), the goal of treatment must clearly be to produce drinking water that is as pathogen-free as possible at all times.

For those who operate water systems with inadequate source protection or treatment facilities, the potential risk of a waterborne disease outbreak is real. For those operating systems that currently provide adequate source protection and treatment, operating and maintaining the system at a high level on a continuing basis is critical to prevent disease.



**Legionella, left and Cryptosporidium,
right hand side.**

E Coli →



Waterborne Diseases

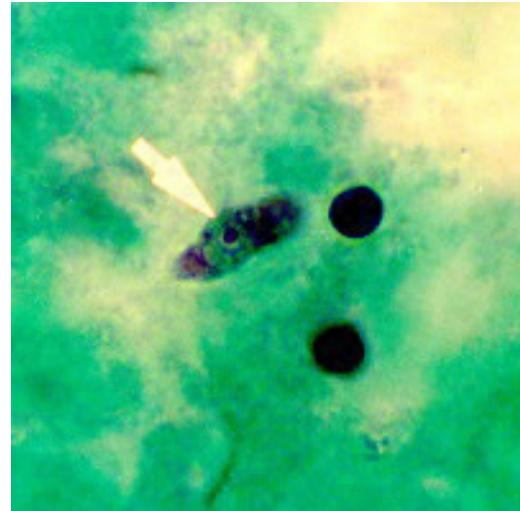
Name	Causative organism	Source of organism	Disease
Viral gastroenteritis	Rotavirus (mostly in young children)	Human feces; Diarrhea or vomiting	
Norwalk-like viruses	Human feces; also, shellfish; lives in polluted waters;	Diarrhea and vomiting	
Salmonellosis	Salmonella (bacterium)	Animal or human feces.	Diarrhea or vomiting
Gastroenteritis	Escherichia coli-- E. coli O1 57:H7 (bacterium); Other <i>E. coli</i> organisms; Human feces; symptoms vary with type caused		
Typhoid	Salmonella typhi (bacterium)	Human feces, urine; Inflamed intestine, enlarged spleen, high temperature— sometimes fatal.	
Shigellosis	Shigella (bacterium)	Human feces.	Diarrhea
Cholera	Vibrio choleras (bacterium)	Human feces; also, shellfish; lives in many coastal waters; Vomiting, severe diarrhea, rapid dehydration, mineral loss —high mortality.	
Hepatitis A	virus	Human feces; shellfish grown in polluted waters; Yellowed skin, enlarged liver, fever, vomiting, weight loss, abdominal pain — low mortality, lasts up to four months.	
Amebiasis	Entamoeba histolytica (protozoan)	Human feces; Mild diarrhea, dysentery, extra intestinal infection	
Giardiasis	Giardia lamblia (protozoan)	Animal or human feces. Diarrhea, cramps, nausea, and general weakness — lasts one week to months.	
Cryptosporidiosis	Cryptosporidium parvum (protozoan)	Animal or human feces. Diarrhea, stomach pain — lasts days to weeks.	

Health Stream Article - Issue 28 December 2002

Naegleria Deaths In Arizona

Residents of the Arizona towns of Peoria and Glendale have been shocked by the deaths of two five-year old boys from amoebic meningitis caused by *Naegleria fowleri*. The source of the infections has not been positively established but suspicion has fallen on a small unchlorinated ground water supply operated by a private company.

This supply was taken off-line on 3 November, a boil water notice was issued and 6,000 consumers were warned not to use unboiled tap water for drinking, cooking or bathing. Schools and restaurants in the suspect area were also closed, and residents were advised to drain and clean spas and hyperchlorinate swimming pools. Supply to the affected area was switched to a chlorinated surface water source, and a flushing program with hyperchlorinated water was carried out to remove possible contamination from the water distribution system.



One of the victims lived in Peoria and the other in the neighboring town of Glendale, some four miles away. They attended separate schools, however the Glendale boy frequently visited his grandparents' home a few blocks from the other boy's residence in Peoria. Both boys became ill on 9 October and died a few days later on 12 and 13 October respectively. Health authorities then began investigating possible common sources of *Naegleria* exposure including drinking water, pools, bathtubs, spas and fountains.

About 100,000 of Peoria's 120,000 residents receive chlorinated drinking water from the municipal supply. This supply is predominantly drawn from surface water sources, but is supplemented by groundwater in times of high demand. As Arizona state law prevents counties from supplying water to areas outside the incorporated municipal zones, the remaining 20,000 residents in the rapidly growing town are served by private water companies which mainly rely on groundwater sources. Some of these companies chlorinate their groundwater supplies and some do not.

The suspect water supply is drawn from a deep aquifer and is not routinely chlorinated, although periodic chlorination has been used after new connections, line breaks or incidents that might allow ingress of microbial contamination.

Tests by the Centers for Disease Control and Prevention have detected *N. fowleri* in three samples:

- one pre-chlorination water sample from a municipal well that was routinely chlorinated**
- one tank water sample from the suspect unchlorinated groundwater system**
- the refrigerator filter from the home of the grandparents of one of the boys**

The chlorinated well is believed unlikely to be the source of infection as chlorination is effective in killing *N. fowleri*. *Naegleria fowleri* is a free living amoeba which is common in the environment and grows optimally at temperatures of 35 to 45 degrees C. Exposure to the organism is believed to be relatively common, but infections resulting in illness are rare. The disease was first described in 1965 by Dr Malcolm Fowler, an Australian pathologist, who identified the amoeba in a patient who had died from meningitis.

Most reported cases of *N. fowleri* meningitis are associated with swimming in natural surface freshwater bodies, and infection occurs through introduction of the organism into the nasal cavities. Cases are often reported to be associated with jumping or falling into the water, providing conditions where water is forced into the nose at pressure. The amoeba may then penetrate the cribiform plate, a semiporous barrier, and spread to the meninges (the membrane surrounding the brain) and often to the brain tissue itself. The cribiform plate is more permeable in children, making them more susceptible to infection than adults.

People with immune deficiencies may also be more prone to infection. The incubation period is usually 2 to 5 days, and the infection cannot be transmitted from person to person. In early studies, transmission by contaminated dust was suspected as an infection route but this has since been discounted as the organism does not survive desiccation. *N. fowleri* meningitis causes non-specific symptoms such as fever, drowsiness, confusion, vomiting, irritability, high pitched crying and convulsions. Similar symptoms also occur in viral and bacterial forms of meningitis which are much more common than the amoebic form. Most cases of *N. fowleri* meningitis are fatal, with only four survivors known among about 100 cases in the US since 1965. Cases of disease have also been associated with swimming pools where disinfection levels were inadequate, and inhalation of tap water from surface water supplies that have been subject to high temperatures.

The involvement of tap water supplies was first documented in South Australia, where a number of cases occurred in the 1960s and 70s in several towns served by unchlorinated surface water delivered through long above-ground pipelines. About half of the cases in the state did not have a recent history of freshwater swimming, but had intra-nasal exposure to tap water through inhaling or squirting water into the nose.

Investigators found *N. fowleri* in the water supply pipelines, and concluded that the high water temperatures reached in summer provided a suitable environment for growth of the organism. Tap water may also have been the primary source of infections attributed to swimming pools in these towns. The incidence of disease was greatly reduced by introduction of reliable chlorination facilities along the above-ground pipelines and introduction of chloramination in the 1980s led to virtual elimination of *N. fowleri* from the water supplies. Cases of disease have also been recorded in Western Australia, Queensland and New South Wales, and *N. fowleri* has been detected in water supplies in each of these states as well as the Northern Territory. Prior to the incidents in Peoria, *N. fowleri* infections had not been reported to be associated with groundwater supplies. However as the organism may be found in moist soil, it is feasible that the amoeba may penetrate poorly constructed bores or be introduced by occasional contamination events. Warm water conditions and the absence of free chlorine may then allow it to proliferate in the system. Local health authorities in Arizona are continuing their investigation into the two deaths with assistance from CDC personnel. Plans are also underway to install a continuous chlorination plant on the groundwater supply, and some residents have called for the municipality to purchase the private water company and take over its operations.

* Lanthanides

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
90	91	92	93	94	95	96	97	98	99	100	101	102	103
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Legend - click to find out more...

H - gas	Li - solid	Br - liquid	Tc - synthetic
Non-Metals	Transition Metals	Rare Earth Metals	Halogens
Alkali Metals	Alkali Earth Metals	Other Metals	Inert Elements

How is the Periodic Table Organized?

The periodic table is organized with eight principal vertical columns called groups and seven horizontal rows called periods. (The groups are numbered I to VIII from left to right, and the periods are numbered 1 to 7 from top to bottom.) All the metals are grouped together on the left side of the periodic table, and all the nonmetals are grouped together on the right side of the periodic table. Semimetals are found in between the metals and nonmetals.

What are the eight groups of the Periodic Table?

- ✓ **Group I: Alkali Metals - Li, Na, K, Rb, Cs, Fr**
 - known as alkali metals
 - most reactive of the metals
 - react with all nonmetals except the noble gases
 - contain typical physical properties of metals (ex. shiny solids and good conductors of heat and electricity) softer than most familiar metals; can be cut with a knife
 - ✓ **Group II: Alkaline Earth Metals-Be, Mg, Ca, Sr, Ba, Ra**
 - known as alkaline earth metals
 - react with nonmetals, but more slowly than the Group I metals
 - solids at room temperature
 - have typical metallic properties

- ✓ harder than the Group I metals
- ✓ higher melting points than the Group I metals
- ✓ **Group III: B, Al, Ga, In, Tl**
boron is a semimetal; all the others are metals
- ✓ **Group IV: C, Si, Ge, Sn, Pb**
carbon is a nonmetal; silicon and germanium are semimetals; tin and lead are metals
- ✓ **Group V: N, P, As, Sb, Bi**
nitrogen and phosphorus are nonmetals; arsenic and antimony are semimetals; bismuth is a metal
- ✓ **Group VI: O, S, Se, Te, Po**
oxygen, sulfur, and selenium are nonmetals; tellurium and polonium are semimetals
- ✓ **Group VII: Halogens-F, Cl, Br, I, At**
very reactive nonmetals
- ✓ **Group VIII: Noble Gases-He, Ne, Ar, Kr, Xe, Rn**
very unreactive

How do the properties of metals and nonmetals differ?

Properties of Metals

Solids at room temperature

Conduct heat very well

Have electrical conductivities that increase with decreasing temperature

Have a high flexibility and a shiny metallic luster

Are malleable-can be beaten out into sheets or foils

Are ductile-can be pulled into thin wires without breaking

Emit electrons when they are exposed to radiation of sufficiently high energy or when They are heated (known as photoelectric effect and thermionic effect)

Properties of Nonmetals

May be gases, liquids, or solids at room temperature

Poor conductors of heat

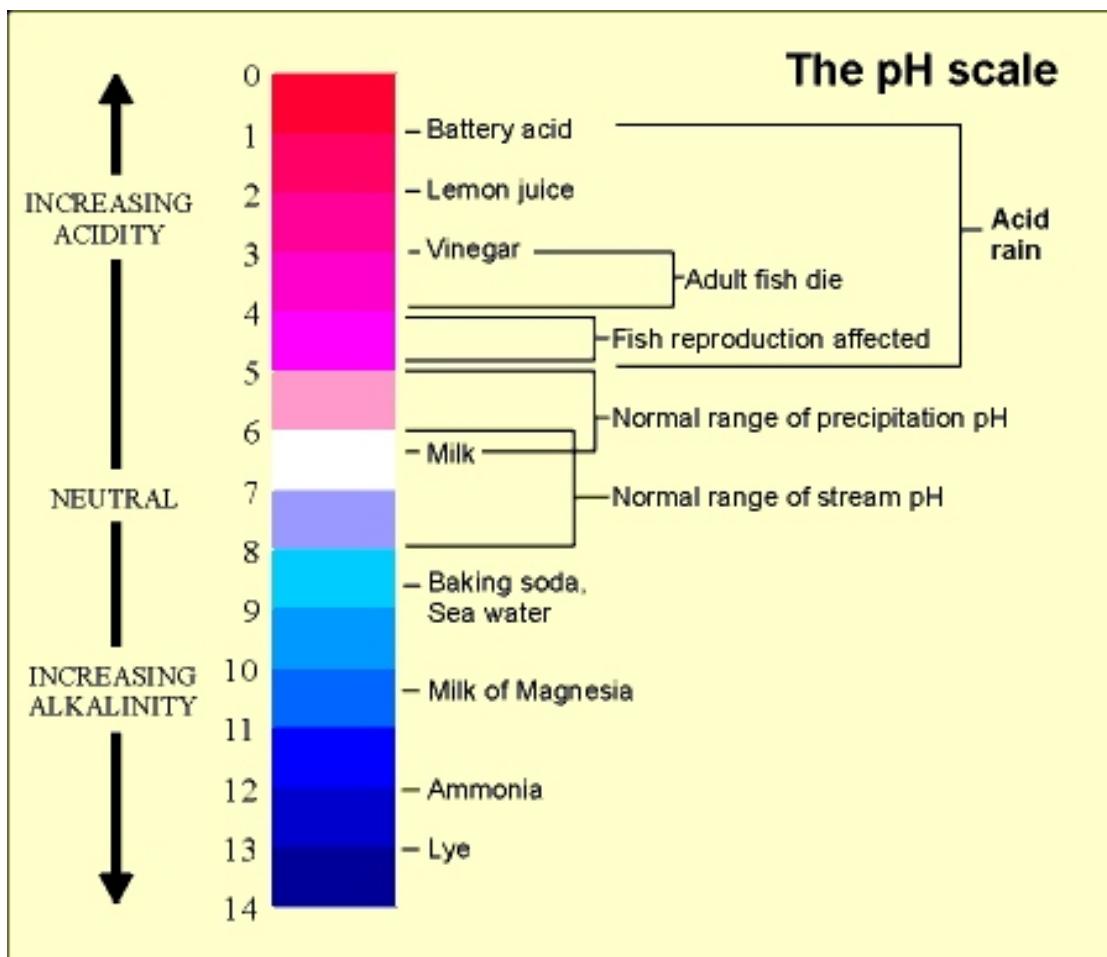
Are insulators-very poor conductors of electricity

Do not have a high reflectivity or a shiny metallic appearance

In solid form generally brittle and fracture easily under stress

Do not exhibit photoelectric or thermionic effects

The pH Scale



pH: A measure of the acidity of water. The pH scale runs from 0 to 14 with 7 being the mid point or neutral. A pH of less than 7 is on the acid side of the scale with 0 as the point of greatest acid activity. A pH of more than 7 is on the basic (alkaline) side of the scale with 14 as the point of greatest basic activity.

pH = (Power of Hydroxyl Ion Activity).

The acidity of a water sample is measured on a pH scale. This scale ranges from **0** (maximum acidity) to **14** (maximum alkalinity). The middle of the scale, **7**, represents the neutral point. The acidity increases from neutral toward **0**.

Because the scale is logarithmic, a difference of one pH unit represents a tenfold change. For example, the acidity of a sample with a pH of **5** is ten times greater than that of a sample with a pH of **6**. A difference of 2 units, from **6** to **4**, would mean that the acidity is one hundred times greater, and so on.

Normal rain has a pH of **5.6** – slightly acidic because of the carbon dioxide picked up in the earth's atmosphere by the rain.



Various water sample bottles and chain-of-custody form



Modern Water Treatment Disinfectants

Many water suppliers add a disinfectant to drinking water to kill germs such as giardia and e coli. Especially after heavy rainstorms, your water system may add more disinfectant to guarantee that these germs are killed.

Chlorine. Some people who use drinking water containing chlorine well in excess of the EPA's standard could experience irritating effects to their eyes and nose. Some people who drink water containing chlorine well in excess of the EPA's standard could experience stomach discomfort.

Chloramine. Some people who use drinking water containing chloramines well in excess of the EPA's standard could experience irritating effects to their eyes and nose. Some people who drink water containing chloramines well in excess of EPA's standard could experience stomach discomfort or anemia.

Chlorine Dioxide. Some infants and young children who drink water containing chlorine dioxide in excess of the EPA's standard could experience nervous system effects. Similar effects may occur in fetuses of pregnant women who drink water containing chlorine dioxide in excess of EPA's standard. Some people may experience anemia.

Disinfectant alternatives will include Ozone, and Ultraviolet light. You will see an increase of these technologies in the near future.

Disinfection Byproducts (DBPS)

Disinfection byproducts form when disinfectants added to drinking water to kill germs react with naturally-occurring organic matter in water.

Total Trihalomethanes. Some people who drink water containing trihalomethanes in excess of the EPA's standard over many years may experience problems with their liver, kidneys, or central nervous systems, and may have an increased risk of getting cancer.

Haloacetic Acids. Some people who drink water containing haloacetic acids in excess of the EPA's standard over many years may have an increased risk of getting cancer.

Bromate. Some people who drink water containing bromate in excess of EPA's standard over many years may have an increased risk of getting cancer.

Chlorite. Some infants and young children who drink water containing chlorite in excess of the EPA's standard could experience nervous system effects. Similar effects may occur in fetuses of pregnant women who drink water containing chlorite in excess of EPA's standard. Some people may experience anemia.



Ozone generator and Oxygen storage tank



Bacteriological Monitoring

Most waterborne disease and illnesses have been related to the microbiological quality of drinking water. The routine microbiological analysis of your water is for coliform bacteria. The coliform bacteria group is used as an indicator organism to determine the biological quality of your water.

The presence of an indicator or pathogenic bacteria in your drinking water is an important health concern. Indicator bacteria signal possible fecal contamination and therefore, the potential presence of pathogens. They are used to monitor for pathogens because of the difficulties in determining the presence of specific disease-causing microorganisms.

Indicator bacteria are usually harmless, occur in high densities in their natural environment and are easily cultured in relatively simple bacteriological media. Indicators in common use today for routine monitoring of drinking water include total coliforms, fecal coliforms and *Escherichia coli* (*E. coli*).

Bacteria Sampling

Water samples for bacteria tests must always be collected in a sterile container. Take the sample from an inside faucet with the aerator removed. Sterilize by spraying a 5% Clorox or alcohol solution or flaming the end of the tap with disposable butane lighter.

Run the water for five minutes to clear the water lines and bring in fresh water. Do not touch or contaminate the inside of the bottle or cap. Carefully open the sample container and hold the outside of the cap. Fill the container and replace the top.

Refrigerate the sample and transport it to the testing laboratory within six hours (in an ice chest). Many labs will not accept bacteria samples on Friday so check the lab's schedule. Mailing bacteria samples is not recommended because laboratory analysis results are not as reliable.

Iron bacteria forms an obvious slime on the inside of pipes and fixtures. A water test is not needed for identification. Check for a reddish-brown slime inside a toilet tank or where water stands for several days.

Bac-T Sample Bottle, often referred to as a Standard Sample, 100 mls, Notice the white powder inside the bottle. That is Sodium Thiosulfate, a de-chlorination agent. Be careful not to wash-out this chemical while sampling. Notice the custody seal on the bottle.

Coliform bacteria are common in the environment and are generally not harmful. However, the presence of these bacteria in drinking water is usually a result of a problem with the treatment system or the pipes which distribute water, and indicates that the water may be contaminated with germs that can cause disease.

Laboratory Procedures

The laboratory may perform the total coliform analysis in one of four methods approved by the U.S. EPA and your local environmental or health division.

Methods

The MMO-MUG test, a product marketed as Colilert, is the most common. The sample results will be reported by the laboratories as simply coliforms present or absent. If coliforms are present, the laboratory will analyze the sample further to determine if these are fecal coliforms or E. coli and report their presence or absence.

Types of Water Samples

It is important to properly identify the type of sample you are collecting. Please indicate in the space provided on the laboratory form the type of sample.

The three (3) types of samples are:

1. **Routine:** Samples collected on a routine basis to monitor for contamination. Collection should be in accordance with an approved sampling plan.
2. **Repeat:** Samples collected following a '**coliform present**' routine sample. The number of repeat samples to be collected is based on the number of routine samples you normally collect.
3. **Special:** Samples collected for other reasons.

Examples would be a sample collected after repairs to the system and before it is placed back into operation or a sample collected at a wellhead prior to a disinfection injection point.

Routine Coliform Sampling

The number of routine samples and frequency of collection for community public water systems is shown in Table 3-1 below.

Noncommunity and nontransient noncommunity public water systems will sample at the same frequency as a like sized community public water system if:

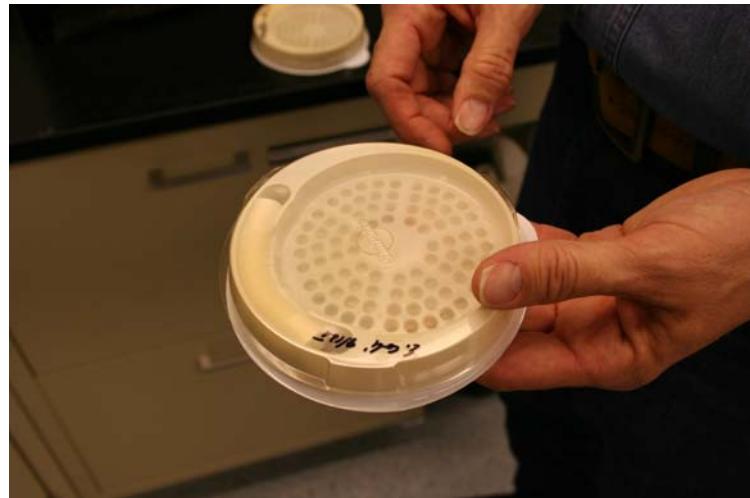
1. It has more than 1,000 daily population and has ground water as a source, or
2. It serves 25 or more daily population and utilizes surface water as a source or ground water under the direct influence of surface water as its source.

Noncommunity and nontransient, noncommunity water systems with less than 1,000 daily population and groundwater as a source will sample on a quarterly basis.



Table 3.1 No. of Samples per System Population*Persons served - Samples per month*

up to 1,000	1
1,001-2,500	2
2,501-3,300	3
3,301 to 4,100	4
4,101 to 4,900	5
4,901 to 5,800	6
5,801 to 6,700	7
6,701 to 7,600	8
7,601 to 8,500	9
8,501 to 12,900	10
12,901 to 17,200	15
17,201 to 21,500	20
21,501 to 25,000	25
25,001 to 33,000	30
33,001 to 41,000	40
41,001 to 50,000	50
50,001 to 59,000	60
59,001 to 70,000	70
70,001 to 83,000	80
83,001 to 96,000	90
96,001 to 130,000	100
130,001 to 220,000	120
220,001 to 320,000	150
320,001 to 450,000	180
450,001 to 600,000	210
600,001 to 780,000	240



Repeat Sampling

Repeat sampling replaces the old check sampling with a more comprehensive procedure to try to identify problem areas in the system. Whenever a routine sample is total coliform or fecal coliform present a set of repeat samples must be collected within 24 hours after being notified by the laboratory. The follow-up for repeat sampling is:

1. If only one routine sample per month or quarter is required, four (4) repeat samples must be collected.
2. For systems collecting two (2) or more routine samples per month, three (3) repeat samples must be collected.
3. Repeat samples must be collected from:
 - a. The original sampling location of the coliform present sample.
 - b. Within five (5) service connections upstream from the original sampling location.
 - c. Within five (5) service connections downstream from the original sampling location.
 - d. Elsewhere in the distribution system or at the wellhead, if necessary.
4. If the system has only one service connection, the repeat samples must be collected from the same sampling location over a four-day period or on the same day.
5. All repeat samples are included in the MCL compliance calculation.
6. If a system which normally collects fewer than five (5) routine samples per month has a coliform present sample, it must collect five (5) routine samples the following month or quarter regardless of whether an MCL violation occurred or if repeat sampling was coliform absent.

Positive or Coliform Present Results

What do you do when your sample is positive or coliform is present?

When you are notified of a positive test result you need to contact either the Drinking Water Program or your local county health department within 24 hours or by the next business day after the results are reported to you. The Drinking Water Program contracts with many of the local health departments to provide assistance to water systems.

After you have contacted an agency for assistance you will be instructed as to the proper repeat sampling procedures and possible corrective measures for solving the problem. It is very important to initiate the repeat sampling immediately as the corrective measures will be based on those results.

Some examples of typical corrective measures to coliform problems are:

1. Shock chlorination of a ground water well. The recommended dose of 5% household bleach is 2 cups per 100 gallons of water in the well. This should be done anytime the bell is opened for repair (pump replacement, etc.). If you plan to shock the entire system, calculate the total gallonage of storage and distribution.
2. Conduct routine distribution line flushing. Install blowoffs on all dead end lines.
3. Conduct a cross connection program to identify all connections with non-potable water sources. Eliminate all of these connections or provide approved backflow prevention devices.
4. Upgrade the wellhead area to meet current construction standards as set your state environmental or health agency.
5. If you continuously chlorinate, review your operation and be sure to maintain a detectable residual (0.2 mg/l free chlorine) at all times in the distribution system.
6. Perform routine cleaning of the storage system.

This list provides some basic operation and maintenance procedures that could help eliminate potential bacteriological problems, check with your state drinking water section or health department for further instructions.

Maximum Contaminant Levels (MCLs)



State and federal laws establish standards for drinking water quality. Under normal circumstances when these standards are being met, the water is safe to drink with no threat to human health. These standards are known as maximum contaminant levels (**MCL**). When a particular contaminant exceeds its MCL a potential health threat may occur. The MCLs are based on extensive research on toxicological properties of the contaminants, risk assessments and factors, short term (acute) exposure and long term (chronic)

exposure. You conduct the monitoring to make sure your water is in compliance with the MCL. There are two types of MCL violations for coliform bacteria. The first is for total coliform; the second is an acute risk to health violation characterized by the confirmed presence of fecal coliform or E.coli.

Heterotrophic Plate Count HPC

Heterotrophic Plate Count (**HPC**) --- formerly known as the standard plate count, is a procedure for estimating the number of live heterotrophic bacteria and measuring changes during water treatment and distribution in water or in swimming pools. Colonies may arise from pairs, chains, clusters, or single cells, all of which are included in the term "**colony-forming units**" (**CFU**).

Method:

There are three methods for standard plate count:

1. Pour Plate Method

The colonies produced are relatively small and compact, showing less tendency to encroach on each other than those produced by surface growth. On the other hand, submerged colonies often are slower growing and are difficult to transfer.



2. Spread Plate Method

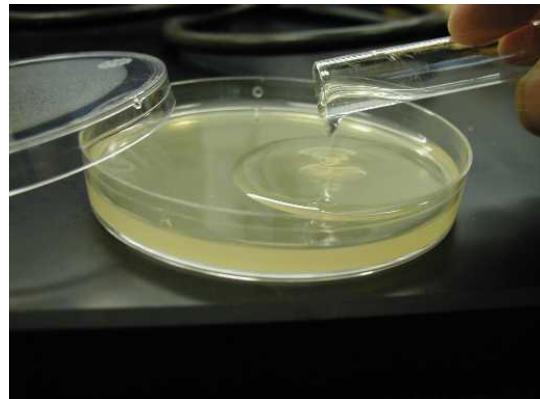
All colonies are on the agar surface where they can be distinguished readily from particles and bubbles. Colonies can be transferred quickly, and colony morphology easily can be discerned and compared to published descriptions.

3. Membrane Filter Method

This method permits testing large volumes of volume of low-turbidity water and is the method of choice for low-count waters.

Material:

- i) Apparatus
 - Glass rod
 - Erlenmeyer flask
 - Graduated Cylinder
 - Pipet
 - Petri dish
 - Incubator
- ii) Reagent and sample
 - Reagent-grade water
 - Nutrient agar
 - Sample



Procedure*:

1. Boil mixture of nutrient agar and nutrient broth for 15 minutes, and then cool for about 20 minutes.
2. Pour approximately 15 ml of medium in each Petri dish, let medium solidify.
3. Pipette 0.1 ml of each dilution onto surface of pre-dried plate, starting with the highest dilution.
4. Distribute inoculum over surface of the medium using a sterile bent glass rod.
5. Incubate plates at 35°C for 48h.
6. Count all colonies on selected plates promptly after incubation; consider only plates having 30 to 300 colonies in determining the plate count.

*Duplicate samples

Computing and Reporting:

Compute bacterial count per milliliter by the following equation:

CFU/ml = colonies counted / actual volume of sample in dish a) If there is no plate with 30 to 300 colonies, and one or more plates have more than 300 colonies, use the plate(s) having a count nearest 300 colonies.

b) If plates from all dilutions of any sample have no colony, report the count as less than 1/actual volume of sample in dish estimated CFU/ml.

c) Avoid creating fictitious precision and accuracy when computing CFU by recording only the first two left-hand digits.

Heterotrophic Plate Count

(Spread Plate Method)

Heterotrophic organisms utilize organic compounds as their carbon source (food or substrate). In contrast, autotrophic organisms use inorganic carbon sources. The Heterotrophic Plate Count provides a technique to quantify the bacteriological activity of a sample. The R2A agar provides a medium that will support a large variety of heterotrophic bacteria. After an incubation period, a bacteriological colony count provides an estimate of the concentration of heterotrophs in the sample of interest.

Laboratory Equipment:

100 x 15 Petri Dishes

Turntable

Glass Rods: Bend fire polished glass rod 45 degrees about 40 mm from one end. Sterilize before using.

Pipet: Glass, 1.1 mL. Sterilize before using.

Quebec Colony Counter

Hand Tally Counter

Reagents:

1) R2A Agar: Dissolve and dilute 0.5 g of yeast extract, 0.5 g of proteose peptone No. 3, 0.5 g of casamino acids, 0.5 g of glucose, 0.5 g of soluble starch, 0.3 g of dipotassium hydrogen phosphate, 0.05 g of magnesium sulfate heptahydrate, 0.3 g of sodium pyruvate, 15.0 g of agar to 1 L. Adjust pH to 7.2 with dipotassium hydrogen phosphate **before adding agar**. Heat to dissolve agar and sterilize at 121 C for 15 minutes.

2) Ethanol: As needed for flame sterilization.

Preparation of Spread Plates:

Immediately after agar sterilization, pour 15 mL of R2A agar into sterile 100 x 15 Petri dishes; let agar solidify. Pre-dry plates inverted so that there is a 2 to 3 g water loss overnight with the lids on. Use pre-dried plates immediately or store up to two weeks in sealed plastic bags at 4 degrees C.

Sample Preparation:

Mark each plate with sample type, dilution, date and any other information before sample application. Prepare at least duplicate plates for each volume of sample or dilution examined. Thoroughly mix all samples by rapidly making about 25 complete up-and-down movements.

Sample Application:

Uncover pre-dried agar plate. Minimize time plate remains uncovered. Pipet 0.1 or 0.5 mL sample onto surface of pre-dried agar plate.

Record volume of sample used. Using a sterile bent glass rod, distribute the sample over surface of the medium by rotating the dish by hand on a turntable. Let the sample be absorbed completely into the medium before incubating. Put cover back on Petri dish and invert for duration of incubation time. Incubate at 28°C for 7 days. Remove Petri dishes from incubator for counting.

Counting and Recording:

After incubation period, promptly count all colonies on the plates. To count, uncover plate and place on Quebec colony counter. Use hand tally counter to maintain count. Count all colonies on the plate, regardless of size. Compute bacterial count per milliliter by the following equation:

$$\text{CFU/mL} = \frac{\text{colonies counted}}{\text{actual volume of sample in dish, mL}}$$

To report counts on a plate with no colonies, report the count as less than one (<1) divided by the sample volume put on that plate (remember to account for any dilution of that sample).

If plates of all dilutions for a sample have no colonies, report the count as less than one (<1) divided by the largest sample volume used. Example: if 0.1 mL of a 100:1 and 10000:1 dilution of a sample both turned up with no colonies formed, the reported result would be <1 divided by the largest sample volume 0.001 mL (0.1 mL divided by 100). The final reported result for the sample is <1000 CFU per mL.

Assignment:

1. Report the number of colony forming units (**CFU**) found on each plate.
2. Calculate the CFU per mL for each plate.
3. The aim of diluting samples is to produce a plate having 30 to 300 colonies, which plates meet these criteria. If no sample produces a plate with a count in this range, use the plate(s) with a count closest to 300. Based on these criteria, use your calculated results to report the CFU per mL for each sample.

In the conclusion of your lab report, comment on your final results for each sample type as well as the quality of your application of this analysis technique. Feel free to justify your comments using statistical analysis. Also, comment on the general accuracy of this analytical technique and the factors that affect its accuracy and or applicability.

Data Table for Samples

Sample ID	Volume of Sample, mL	Colonies Counted per plate

Total Coliforms

This MCL is based on the presence of total coliforms and compliance is on a monthly or quarterly basis, depending on your water system type and state rule. For systems which collect fewer than 40 samples per month, no more than one sample per month may be positive. In other words, the second positive result (repeat or routine) in a month or quarter results in an MCL violation.

For systems which collect 40 or more samples per month, no more than five (5) percent may be Positive, check with your State drinking water section or health department for further instructions.

Acute Risk to Health (Fecal coliforms and E.coli)

An acute risk to human health violation occurs if either one of the following happens:

1. A routine analysis shows total coliform present and is followed by a repeat analysis which indicates fecal coliform or E. coli present.
2. A routine analysis shows total and fecal coliform or E. coli present and is followed by a repeat analysis which indicates total coliform present. An acute health risk violation requires the water system to provide public notice via radio and television stations in the area. This type of contamination can pose an immediate threat to human health and notice must be given as soon as possible but no later than 72 hours after notification from your laboratory of the test results.

Certain language may be mandatory for both these violations and is included in your state drinking water rule.

Public Notice

A public notice is required to be issued by a water system whenever it fails to comply with an applicable MCL or treatment technique or fails to comply with the requirements of any scheduled variance or permit. This will inform users when there is a problem with the system and give them information.

A public notice is also required whenever a water system fails to comply with its monitoring and/or reporting requirements or testing procedure. Each public notice must contain certain information, be issued properly and in a timely manner and contain certain mandatory language.

The timing and place of posting of the public notice depends on whether an acute risk is present to users. Check with your state drinking water section or health department for further instructions.

The following are acute violations:

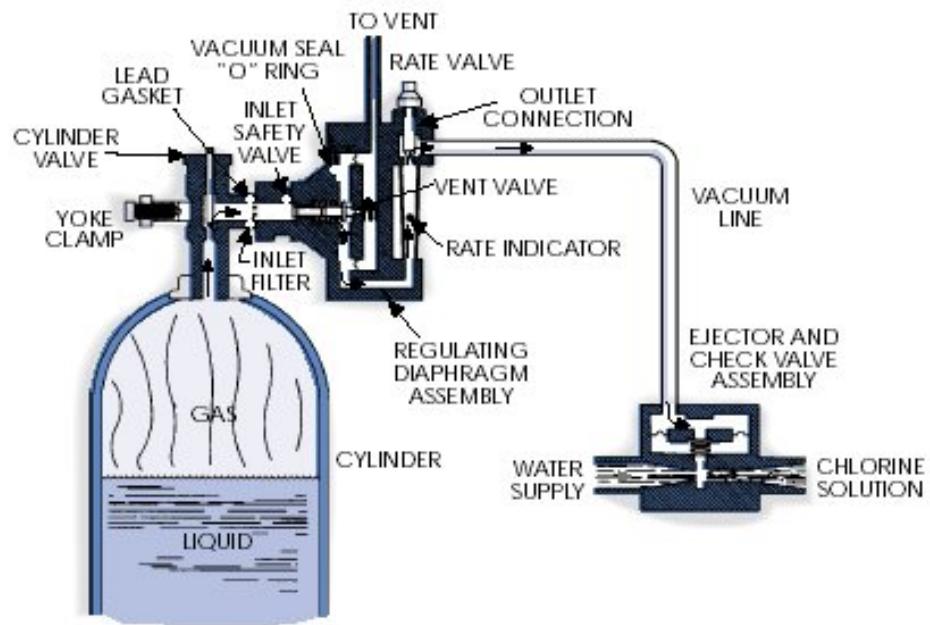
1. Violation of the MCL for nitrate.
2. Any violation of the MCL for total coliforms, when fecal coliforms or E. coli are present in the distribution system.
3. Any outbreak of waterborne disease, as defined by the rules.

Chlorine Section



1 Ton Cl₂ containers.

Cylinder-Mounted Chlorinator

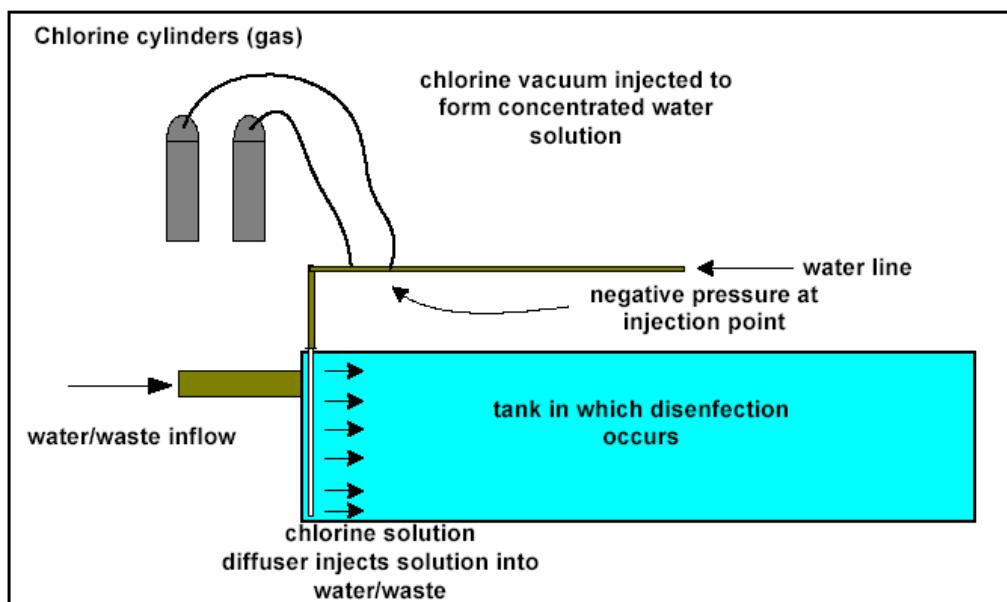


150 pound Cylinders

Chlorine Gas

Background: Chlorine gas is a pulmonary irritant with intermediate water solubility that causes acute damage in the upper and lower respiratory tract. Chlorine gas was first used as a chemical weapon at Ypres, France in 1915. Of the 70,552 American soldiers poisoned with various gasses in World War I, 1843 were exposed to chlorine gas. Approximately 10.5 million tons and over 1 million containers of chlorine are shipped in the U.S. each year.

Chlorine is the most common chemical used to disinfect water and wastewater. It is added as a gas to most large installations. At very small facilities sodium hypochlorite (bleach) is added as a powder (tablets).



Chlorine is a yellowish-green gas at standard temperature and pressure. It is extremely reactive with most elements. Because its density is greater than that of air, the gas settles low to the ground. It is a respiratory irritant, and it burns the skin. Just a few breaths of it are fatal. Cl₂ gas does not occur naturally, although Chlorine can be found in a number of compounds.

Atomic Number: 17

Standard State: gas at 298K

Melting Point: 171.6K (-101.5 C)

Boiling Point: 239.11K (-34.04 C)

Density: N/A

Molar Volume: 17.39 cm³

Electronegativity: 3.16 Pauling Units

Crystal Structure: The Diatomic Chlorine molecules arrange themselves in an orthorhombic structure.

Pathophysiology

Chlorine is a greenish-yellow, noncombustible gas at room temperature and atmospheric pressure. The intermediate water solubility of chlorine accounts for its effect on the upper airway and the lower respiratory tract. Exposure to chlorine gas may be prolonged because its moderate water solubility may not cause upper airway symptoms for several minutes. In addition, the density of the gas is greater than that of air, causing it to remain near ground level and increasing exposure time.

The odor threshold for chlorine is approximately 0.3-0.5 parts per million (ppm); however, distinguishing toxic air levels from permissible air levels may be difficult until irritative symptoms are present.

Mechanism of Activity

The mechanisms of the above biological activity are poorly understood and the predominant anatomic site of injury may vary, depending on the chemical species produced. Cellular injury is believed to result from the oxidation of functional groups in cell components, from reactions with tissue water to form hypochlorous and hydrochloric acid, and from the generation of free oxygen radicals. Although the idea that chlorine causes direct tissue damage by generating free oxygen radicals was once accepted, this idea is now controversial.



The cylinders on the right contain chlorine gas. The gas comes out of the cylinder through a gas regulator. The cylinders are on a scale that operators use to measure the amount used each day. The chains are used to prevent the tanks from falling over.

Chlorine gas is stored in vented rooms that have panic bar equipped doors. Operators have the equipment necessary to reduce the impact of a gas leak, but rely on trained emergency response teams to contain leaks.

Solubility Effects

Hydrochloric acid is highly soluble in water. The predominant targets of the acid are the epithelia of the ocular conjunctivae and upper respiratory mucus membranes.

Hypochlorous acid is also highly water soluble with an injury pattern similar to hydrochloric acid.

Hypochlorous acid may account for the toxicity of elemental chlorine and hydrochloric acid to the human body.

Early Response to Chlorine Gas

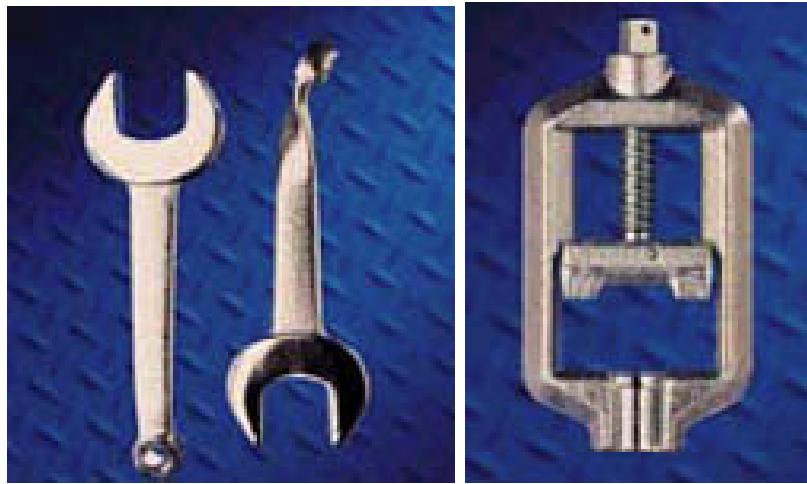
Chlorine gas, when mixed with ammonia, reacts to form chloramine gas. In the presence of water, chloramines decompose to ammonia and hypochlorous acid or hydrochloric acid. The early response to chlorine exposure depends on the (1) concentration of chlorine gas, (2) duration of exposure, (3) water content of the tissues exposed, and (4) individual susceptibility.

Immediate Effects

The immediate effects of chlorine gas toxicity include acute inflammation of the conjunctivae, nose, pharynx, larynx, trachea, and bronchi. Irritation of the airway mucosa leads to local edema secondary to active arterial and capillary hyperemia. Plasma exudation results in filling the alveoli with edema fluid, resulting in pulmonary congestion.

Pathological Findings

Pathologic findings are nonspecific. They include severe pulmonary edema, pneumonia, hyaline membrane formation, multiple pulmonary thromboses, and ulcerative tracheobronchitis. The hallmark of pulmonary injury associated with chlorine toxicity is pulmonary edema, manifested as hypoxia. Noncardiogenic pulmonary edema is thought to occur when there is a loss of pulmonary capillary integrity.



Chlorine Cylinder Wrenches and Yoke Connector



Notice the corrosive effect of Cl₂ gas on these wrenches. Just a little of this gas will eat the enamel right off your teeth.

Using DPD Method for Chlorine Residuals

N, N – diethyl-p-phenylenediamine, only super nerds know this name.



Small portable chlorine measuring kit. The redder the mixture the “hotter” or stronger the chlorine in solution.

Measuring Chlorine Residual

Chlorine residual is the amount of chlorine remaining in water that can be used for disinfection. A convenient, simple and inexpensive way to measure chlorine residual is to use a small portable kit with pre-measured packets of chemicals that are added to water. (Make sure you buy a test kit using the **DPD method**, and not the outdated orthotolodine method.)

Chlorine test kits are very useful in adjusting the chlorine dose you apply. You can measure what chlorine levels are being found in your system (especially at the far ends).

Free chlorine residuals need to be checked and recorded daily. These results should be kept on file for a health or regulatory agency inspection during a regular field visit.

The most accurate method for determining chlorine residuals is to use the laboratory amperometric titration method.

Chemical Equations, Oxidation States and Balancing of Equations

Before we break down Chlorine and other chemicals, let's start with this review of basic chemical equations.

Beginning

The common chemical equation could be A + B \rightarrow C + D. This is chemical A + chemical B, the two reacting chemicals will go to products C + D etc.

Oxidation

The term "oxidation" originally meant a reaction in which oxygen combines chemically with another substance, but its usage has long been broadened to include any reaction in which electrons are transferred.

Oxidation and reduction always occur simultaneously (redox reactions), and the substance which gains electrons is termed the oxidizing agent. For example, cupric ion is the oxidizing agent in the reaction: Fe (metal) + Cu⁺⁺ \rightarrow Fe⁺⁺ + Cu (metal); here, two electrons (negative charges) are transferred from the iron atom to the copper atom; thus the iron becomes positively charged (is oxidized) by loss of two electrons while the copper receives the two electrons and becomes neutral (is reduced).

Electrons may also be displaced within the molecule without being completely transferred away from it. Such partial loss of electrons likewise constitutes oxidation in its broader sense and leads to the application of the term to a large number of processes which at first sight might not be considered to be oxidation. Reaction of a hydrocarbon with a halogen, for example, CH₄ + 2 Cl \rightarrow CH₃Cl + HCl, involves partial oxidation of the methane; halogen addition to a double bond is regarded as an oxidation.

Dehydrogenation is also a form of oxidation, when two hydrogen atoms, each having one electron, are removed from a hydrogen-containing organic compound by a catalytic reaction with air or oxygen, as in oxidation of alcohol to aldehyde.

Oxidation Number

The number of electrons that must be added to or subtracted from an atom in a combined state to convert it to the elemental form; i.e., in barium chloride (BaCl₂) the oxidation number of barium is +2 and of chlorine is -1. Many elements can exist in more than one oxidation state.

Now, let us look at some common ions. An ion is the reactive state of the chemical, and is dependent on its place within the periodic table.

Have a look at the "periodic table of the elements". It is arranged in columns of elements, there are 18 columns. You can see column one, H, Li, Na, K etc. These all become ions as H⁺, Li⁺, K⁺, etc. The next column, column 2, Be, Mg, Ca etc. become ions Be²⁺, Mg²⁺, Ca²⁺, etc. Column 18, He, Ne, Ar, Kr are inert gases. Column 17, F, Cl, Br, I, ionize to a negative F⁻, Cl⁻, Br⁻, I⁻, etc.

What you now need to do is memorize is the table of common ions, both positive ions and negative ions.

Table of Common Ions

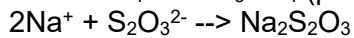
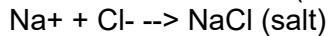
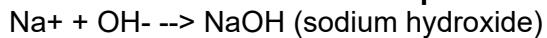
Positive Ions

Valency 1		Valency 2		Valency 3	
lithium	Li^+	magnesium	Mg^{2+}	aluminum	Al^{3+}
sodium	Na^+	calcium	Ca^{2+}	iron III	Fe^{3+}
potassium	K^+	strontium	Sr^{2+}	chromium	Cr^{3+}
silver	Ag^+	barium	Ba^{2+}		
hydronium	H_3O^+	copper II	Cu^{2+}		
(or hydrogen)	H^+	lead II	Pb^{2+}		
ammonium	NH_4^+	zinc	Zn^{2+}		
copper I	Cu^+	manganese II	Mn^{2+}		
mercury I	Hg^+	iron II	Fe^{2+}		
		tin II	Sn^{2+}		

Negative Ions

Valency 1		Valency 2		Valency 3	
fluoride	F^-	oxide	O^{2-}	phosphate	PO_4^{3-}
chloride	Cl^-	sulfide	S^{2-}		
bromide	Br^-	carbonate	CO_3^{2-}		
iodide	I^-	sulfate	SO_4^{2-}		
hydroxide	OH^-	sulfite	SO_3^{2-}		
nitrate	NO_3^-	dichromate	Cr_2O_7^-		
bicarbonate	HCO_3^-	chromate	CrO_4^{2-}		
bisulphate	HSO_4^-	oxalate	$\text{C}_2\text{O}_4^{2-}$		
nitrite	NO_2^-	thiosulfate	$\text{S}_2\text{O}_3^{2-}$		
chlorate	ClO_3^-	tetrathionate	$\text{S}_4\text{O}_6^{2-}$		
permanganate	MnO_4^-	monohydrogen phosphate	HPO_4^{2-}		
hypochlorite	OCl^-				
dihydrogen phosphate	H_2PO_4^-				

Positive ions will react with negative ions, and vice versa. This is the start of our chemical reactions. For example:



You will see from these examples, that if an ion of one (+), reacts with an ion of one (-) then the equation is balanced. However, an ion like PO_4^{3-} phosphate will require an ion of 3+ or an ion of one (+) (but needs three of these) to neutralize the 3- charge on the phosphate. So, what you are doing is balancing the charges (+) or (-) to make them zero, or cancel each other out.

For example, aluminum exists in its ionic state as Al^{3+} , it will react with many negatively charged ions, examples: Cl^- , OH^- , SO_4^{2-} , PO_4^{3-} .

Let us do these examples and balance them.



How did we work this out?

Al^{3+} has three positives (3+)

Cl^- has one negative (-)

It will require **3 negative charges** to cancel out the **3 positive charges** on the aluminum (Al^{3+}).

When the **left hand side** of the equation is written, to balance the number of chlorine's (Cl^-) required, the number 3 is placed in front of the ion concerned, in this case Cl^- , becomes 3Cl^- .

On the **right hand side** of the equation, where the ions have become a compound (a chemical compound), the number is transferred to after the relevant ion, Cl_3 .

Another example:



Let me give you an easy way of balancing:

Al is 3+

SO_4 is 2-

Simply transpose the number of positives (or negatives) for each ion, to the other ion, by placing this value of one ion, in front of the other ion. That is, Al^{3+} the 3 goes in front of the SO_4^{2-} as 3SO_4^{2-} , and SO_4^{2-} , the 2 goes in front of the Al^{3+} to become 2Al^{3+} . Then on the **right hand side** of the equation, this same number (now in front of each ion on the **left side** of the equation), is placed after each "ion" entity.

Let us again look at:

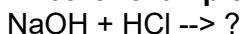


Put the three from the Al in front of the SO_4^{2-} and the 2 from the SO_4^{2-} in front of the Al^{3+} .

Equation becomes:

$2\text{Al}^{3+} + 3\text{SO}_4^{2-} \rightarrow \text{Al}_2(\text{SO}_4)_3$. You simply place the valency of one ion, as a whole number, in front of the other ion, and vice versa. **Remember** to encase the SO_4 in brackets. **Why?** Because we are dealing with the sulfate ion, SO_4^{2-} , and it is this ion that is 2- charged (not just the O_4), so we have to ensure that the "ion" is bracketed. Now to check, the 2 times $3^+ = 6^+$, and 3 times $2^- = 6^-$. We have equal amounts of positive ions, and equal amounts of negative ions.

Another example:



Na is Na^+ , OH is OH^- , so this gave us NaOH. Originally the one positive canceled the one negative.

HCl is $\text{H}^+ + \text{Cl}^-$, this gave us HCl.

Reaction is going to be the Na^+ reacting with a negatively charged ion. This will have to be the chlorine, Cl^- , because at the moment the Na^+ is tied to the OH^- . **So:** $\text{Na}^+ + \text{Cl}^- \rightarrow \text{NaCl}$

The H^+ from the HCl will react with a negative (-) ion this will be the OH^- from the NaOH.

So: $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$ (water).

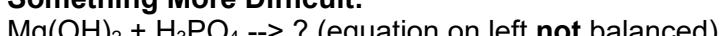
The complete reaction can be written:

$\text{NaOH} + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O}$. We have **equal amounts** of all atoms **each side** of the equation, so the equation is **balanced**.

or



Something More Difficult:

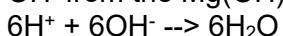


$\text{Mg}^{2+} 2\text{OH}^- + 3\text{H}^+\text{PO}_4^{3-} \rightarrow ?$ (equation on left **not balanced**), so let us rewrite the equation in **ionic form**.

The Mg^{2+} **needs to react with a negatively charged ion**, this will be the PO_4^{3-} , **so:** $3\text{Mg}^{2+} + 2\text{PO}_4^{3-} \rightarrow \text{Mg}_3(\text{PO}_4)_2$

(**Remember** the **swapping** of the positive or negative charges on the ions in the **left side** of the equation, and placing it in front of each ion, and then placing this number after each ion on the **right side** of the equation)

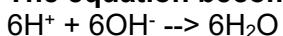
What is left is the H^+ from the H_3PO_4 and this will react with a negative ion, we only have the OH^- from the $\text{Mg}(\text{OH})_2$ left for it to react with.



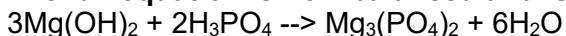
Where did I get the 6 from? When I balanced the Mg^{2+} with the PO_4^{3-} , the equation became $3\text{Mg}^{2+} + 2\text{PO}_4^{3-} \rightarrow \text{Mg}_3(\text{PO}_4)_2$

Therefore, I must have required $3\text{Mg}(\text{OH})_2$ to begin with, and $2\text{H}_3\text{PO}_4$, (because we originally had $(\text{OH})_2$ attached to the Mg, and H_3 attached to the PO_4 . I therefore have 2H_3 reacting with $3(\text{OH})_2$. We have to write this, on the **left side** of the equation, as $6\text{H}^+ + 6\text{OH}^-$ because we need it in ionic form.

The equation becomes:



The full equation is now balanced and is:

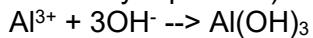


I have purposely split the equation into segments of reactions. This is showing you which ions are reacting with each other. Once you get the idea of equations you will not need this step.

The balancing of equations is simple. You need to learn the valency of the common ions (see tables). The rest is pure mathematics--you are balancing valency charges, positives versus negatives. You have to have the **same number of negatives or positives** on each side of the equation, and the **same number of ions or atoms** on each side of the equation.

If one ion, example Al^{3+} , (3 positive charges) reacts with another ion, example OH^- (one negative ion) then we require 2 more negatively charged ions (in this case OH^-) to counteract the 3 positive charges the Al^{3+} contains.

Take my earlier hint, place the 3 from the Al^{3+} in front of the OH^- , now reads 3OH^- , place the 1 from the hydroxyl OH^- in front of the Al^{3+} , now stays the same, Al^{3+} (the 1 is **never** written in chemistry equations).



The 3 is simply written in front of the OH^- , a recognized ion, there are no brackets placed around the OH^- . On the right hand side of the equation, all numbers in front of each ion on the left hand side of the equation are placed after each same ion on the right side of the equation. Brackets are used in the right side of the equation because the result is a compound. Brackets are also used for compounds (reactants) in the left side of equations, as in $3\text{Mg}(\text{OH})_2 + 2\text{H}_3\text{PO}_4 \rightarrow ?$



Conductivity, temperature and pH measuring equipment.



Hard to tell, but these are one ton cylinders. Notice the five gallon bucket of motor oil in the bottom picture. Also notice that this picture is the only eye wash station that we found during our inspection of 10 different facilities. Do you have an eye wash and emergency shower?

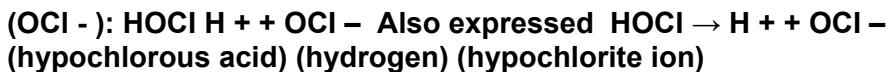


Chemistry of Chlorination

Chlorine can be added as sodium hypochlorite, calcium hypochlorite or chlorine gas. When any of these is added to water, chemical reactions occur as these equations show:



All three forms of chlorine produce hypochlorous acid (HOCl) when added to water. Hypochlorous acid is a weak acid but a strong disinfecting agent. The amount of hypochlorous acid depends on the pH and temperature of the water. Under normal water conditions, hypochlorous acid will also chemically react and break down into a hypochlorite ion.



The hypochlorite ion is a much weaker disinfecting agent than hypochlorous acid, about 100 times less effective.

Let's now look at how pH and temperature affect the ratio of hypochlorous acid to hypochlorite ions. As the temperature is decreased, the ratio of hypochlorous acid increases. Temperature plays a small part in the acid ratio. Although the ratio of hypochlorous acid is greater at lower temperatures, pathogenic organisms are actually harder to kill. All other things being equal, higher water temperatures and a lower pH are more conducive to chlorine disinfection.

Types of Residual

If water were pure, the measured amount of chlorine in the water should be the same as the amount added. But water is not 100% pure. There are always other substances (interfering agents) such as iron, manganese, turbidity, etc., which will combine chemically with the chlorine.

This is called the **chlorine demand**. Naturally, once chlorine molecules are combined with these interfering agents they are not capable of disinfection. It is free chlorine that is much more effective as a disinfecting agent.

So let's look now at how free, total and combined chlorine are related. When a chlorine residual test is taken, either a total or a free chlorine residual can be read.

Total residual is all chlorine that is available for disinfection.

Total chlorine residual = free + combined chlorine residual.

Free chlorine residual is a much stronger disinfecting agent. Therefore, most water regulating agencies will require that your daily chlorine residual readings be of free chlorine residual.

Break-point chlorination is where the chlorine demand has been satisfied, any additional chlorine will be considered **free chlorine**.

Residual Concentration/Contact Time (CT) Requirements

Disinfection to eliminate fecal and coliform bacteria may not be sufficient to adequately reduce pathogens such as Giardia or viruses to desired levels. Use of the "**CT**" disinfection concept is recommended to demonstrate satisfactory treatment, since monitoring for very low levels of pathogens in treated water is analytically very difficult.

The CT concept, as developed by the United States Environmental Protection Agency (Federal Register, 40 CFR, Parts 141 and 142, June 29, 1989), uses the combination of disinfectant residual concentration (mg/L) and the effective disinfection contact time (in minutes) to measure effective pathogen reduction. The residual is measured at the end of the process, and the contact time used is the T10 of the process unit (time for 10% of the water to pass).

CT = Concentration (mg/L) x Time (minutes)

The effective reduction in pathogens can be calculated by reference to standard tables of required CTs.



**500 pound container and 150 pound cylinders. The 1/2 ton is on a scale.
Cylinders stand up right and containers on their sides.**

Required Giardia/Virus Reduction

All surface water treatment systems shall ensure a minimum reduction in pathogen levels: 1 3-log reduction in Giardia; and 1 4-log reduction in viruses. These requirements are based on unpolluted raw water sources with Giardia levels of = 1 cyst/100 L, and a finished water goal of 1 cyst/100,000 L (equivalent to 1 in 10,000 risk of infection per person per year). Higher raw water contamination levels may require greater removals as shown on Table 4.1.

**TABLE 4.1
LEVEL OF GIARDIA REDUCTION**

Raw Water Giardia Levels*

Recommended Giardia Log Reduction

< 1 cyst/100 L 3-log

1 cyst/100 L - 10 cysts/100 L 3-log - 4-log

10 cysts/100 L - 100 cysts/100 L 4-log - 5-log

> 100 cysts/100 L > 5-log

*Use geometric means of data to determine raw water Giardia levels for compliance.

Required CT Value

Required CT values are dependent on pH, residual concentration, temperature and the disinfectant used. The tables attached to Appendices A and B shall be used to determine the required CT.

Calculation and Reporting of CT Data

Disinfection CT values shall be calculated daily using either the maximum hourly flow and the disinfectant residual at the same time, or by using the lowest CT value if it is calculated more frequently. Actual CT values are then compared to required CT values. Results shall be reported as a reduction Ratio, along with the appropriate pH, temperature, and disinfectant residual. The reduction Ratio must be greater than 1.0 to be acceptable. Users may also calculate and record actual log reductions. **Reduction Ratio = CT actual ÷ CT required.**



Chlorine (DDBP)

Today, most of our drinking water supplies are free of the micro-organisms — viruses, bacteria and protozoa — that cause serious and life-threatening diseases, such as cholera and typhoid fever. This is largely due to the introduction of water treatment, particularly chlorination, at the turn of the century.

Living cells react with chlorine and reduce its concentration while they die. Their organic matter and other substances that are present convert to chlorinated derivatives, some of which are effective killing agents. Chlorine present as Cl, HOCl, and OCl⁻ is called **free available chlorine**, and that which is bound but still effective is **combined chlorine**. A particularly important group of compounds with combined chlorine is the chloramines formed by reactions with ammonia.

One especially important feature of disinfection using chlorine is the ease of overdosing to create a "residual" concentration. There is a constant danger that safe water leaving the treatment plant may become contaminated later. There may be breaks in water mains, loss of pressure that permits an inward leak, or plumbing errors. This residual concentration of chlorine provides some degree of protection right to the water faucet. With free available chlorine, a typical residual is from 0.1 to 0.5 ppm. Because chlorinated organic compounds are less effective, a typical residual is 2 ppm for combined chlorine.

There will be no chlorine residual unless there is an excess over the amount that reacts with the organic matter present. However, reaction kinetics complicates interpretation of chlorination data. The correct excess is obtained in a method called "**Break Point Chlorination**".

Chlorine by-products

Chlorination by-products are the chemicals formed when the chlorine used to kill disease-causing micro-organisms reacts with naturally occurring organic matter (e.g., decay products of vegetation) in the water. The most common chlorination by-products found in U.S. drinking water supplies are the trihalomethanes (**THMs**).

The Principal Trihalomethanes are:

Chloroform, bromodichloromethane, chlorodibromomethane and bromoform. Other less common chlorination by-products includes the haloacetic acids and haloacetonitriles. The amount of THMs formed in drinking water can be influenced by a number of factors, including the season and the source of the water. For example, THM concentrations are generally lower in winter than in summer, because concentrations of natural organic matter are lower and less chlorine is required to disinfect at colder temperatures. THM levels are also low when wells or large lakes are used as the drinking water source, because organic matter concentrations are generally low in these sources. The opposite — high organic matter concentrations and high THM levels — is true when rivers or other surface waters are used as the source of the drinking water.

Health Effects

Laboratory animals exposed to very high levels of THMs have shown increased incidences of cancer. Also, several studies of cancer incidence in human populations have reported associations between long-term exposure to high levels of chlorination by-products and an increased risk of certain types of cancer.

For instance, a recent study conducted in the Great Lakes basin reported an increased risk of bladder and possibly colon cancer in people who drank chlorinated surface water for 35 years or more.

Possible relationships between exposure to high levels of THMs and adverse reproductive effects in humans have also been examined recently. In a California study, pregnant women who consumed large amounts of tap water containing elevated levels of THMs were found to have an increased risk of spontaneous abortion.

The available studies on health effects do not provide conclusive proof of a relationship between exposure to THMs and cancer or reproductive effects, but indicate the need for further research to confirm their results and to assess the potential health effects of chlorination by-products other than THMs.



Chlorine storage room, notice the vents at the bottom and top. The bottom vent will allow the gas to ventilate because Cl₂ gas is heavier than air.

Risks and Benefits of Chlorine

Current evidence indicates that the benefits of chlorinating our drinking water — reduced incidence of water-borne diseases — are much greater than the risks of health effects from THMs.

Although other disinfectants are available, chlorine continues to be the choice of water treatment experts. When used with modern water filtration practices, chlorine is effective against virtually all infective agents — bacteria, viruses and protozoa. It is easy to apply and most importantly, small amounts of chlorine remain in the water and continue to disinfect throughout the distribution system. This ensures that the water remains free of microbial contamination on its journey from the treatment plant to the consumer's tap.

A number of cities use ozone to disinfect their source water and to reduce THM formation. Although ozone is a highly effective disinfectant, it breaks down quickly, so that small amounts of chlorine or other disinfectants must be added to the water to ensure continued disinfection as the water is piped to the consumer's tap. Modifying water treatment facilities to use ozone can be expensive, and ozone treatment can create other undesirable by-products that may be harmful to health if they are not controlled (e.g., bromate).

Examples of other disinfectants include chloramines and chlorine dioxide. Chloramines are weaker disinfectants than chlorine, especially against viruses and protozoa; however, they are very persistent and, as such, can be useful for preventing re-growth of microbial pathogens in drinking water distribution systems.

Chlorine dioxide can be an effective disinfectant, but it forms chlorate and chlorite, compounds whose toxicity has not yet been fully determined. Assessments of the health risks from these and other chlorine-based disinfectants and chlorination by-products are currently under way.

In general, the preferred method of controlling chlorination by-products is removal of the naturally occurring organic matter from the source water so it cannot react with the chlorine to form by-products. THM levels may also be reduced through the replacement of chlorine with alternative disinfectants.

A third option is removal of the by-products by adsorption on activated carbon beds. It is extremely important that water treatment plants ensure that methods used to control chlorination by-products do not compromise the effectiveness of water disinfection.



Chlorine Piping



A water softener may be needed when your source water is too hard for successful Chlorination using HTH.



Chlorinator Parts

- A. Ejector
- B. Check Valve Assembly
- C. Rate Valve
- D. Diaphragm Assembly
- E. Interconnection Manifold
- F. Rotometer Tube and Float
- G. Pressure Gauge
- H. Gas Supply



Chlorine measurement devices or Rotometers



Safety Information: There is a fusible plug on every chlorine tank. This metal plug will melt at 158° to 165° F. This is to prevent a build-up of excessive pressure and the possibility of cylinder rupture due to fire or high temperatures.

Chlorination Equipment Requirements

For all water treatment facilities, chlorine gas under pressure shall not be permitted outside the chlorine room. The chlorine room is the room where chlorine gas cylinders and/or ton containers are stored. Vacuum regulators shall also be located inside the chlorine room. The chlorinator, which is the mechanical gas proportioning equipment, may or may not be located inside the chlorine room.

For new and upgraded facilities, from the chlorine room, chlorine gas vacuum lines should be run as close to the point of solution application as possible. Injectors should be located to minimize the length of pressurized chlorine solution lines. A gas pressure relief system shall be included in the gas vacuum line between the vacuum regulator(s) and the chlorinator(s) to ensure that pressurized chlorine gas does not enter the gas vacuum lines leaving the chlorine room.

The gas pressure relief system shall vent pressurized gas to the atmosphere at a location that is not hazardous to plant personnel; the vent lines should be run in such a manner that moisture collecting traps are avoided. The vacuum regulating valve(s) shall have positive shutdown in the event of a break in the downstream vacuum lines.

As an alternative to chlorine gas, it is permissible to use hypochlorite with positive displacement pumping. Anti-siphon valves shall be incorporated in the pump heads or in the discharge piping.

Capacity

The chlorinator shall have the capacity to dose enough chlorine to overcome the demand and maintain the required concentration of the "**free**" or "**combined**" chlorine.

Methods of Control

A chlorine feed system shall be automatic proportional controlled, or automatic residual controlled, or compound loop controlled. In the automatic proportional controlled system, the equipment adjusts the chlorine feed rate automatically in accordance with the flow changes to provide a constant pre-established dosage for all rates of flow. In the automatic residual controlled system, the chlorine feeder is used in conjunction with a chlorine residual analyzer which controls the feed rate of the chlorine feeders to maintain a particular residual in the treated water.

In the compound loop control system, the feed rate of the chlorinator is controlled by a flow proportional signal and a residual analyzer signal to maintain particular chlorine residual in the water.

Manual chlorine feed systems may be installed for groundwater systems with constant flow rate.

Standby Provision

As a safeguard against malfunction and/or shut-down, standby chlorination equipment having the capacity to replace the largest unit shall be provided. For uninterrupted chlorination, gas chlorinators shall be equipped with an automatic changeover system. In addition, spare parts shall be available for all chlorinators.

Weigh Scales

Scales for weighing cylinders shall be provided at all plants using chlorine gas to permit an accurate reading of total daily weight of chlorine used. At large plants, scales of the recording and indicating type are recommended. As a minimum, a platform scale shall be provided. Scales shall be of corrosion-resistant material.

Securing Cylinders

All chlorine cylinders shall be securely positioned to safeguard against movement. Tag the cylinder "**Empty**" and store upright and chained. Ton containers may not be stacked.

Chlorine Leak Detection

Automatic chlorine leak detection and related alarm equipment shall be installed at all water treatment plants using chlorine gas. Leak detection shall be provided for the chlorine rooms. Chlorine leak detection equipment should be connected to a remote audible and visual alarm system and checked on a regular basis to verify proper operation.

Leak detection equipment shall not automatically activate the chlorine room ventilation system in such a manner as to discharge chlorine gas. During an emergency if the chlorine room is unoccupied, the chlorine gas leakage shall be contained within the chlorine room itself in order to facilitate a proper method of clean-up. Consideration should also be given to the provision of caustic soda solution reaction tanks for absorbing the contents of leaking one-ton cylinders where such cylinders are in use.

Chlorine leak detection equipment may not be required for very small chlorine rooms with an exterior door (e.g., floor area less than 3m²). You can use a spray solution of Ammonia or a rag soaked with Ammonia to detect a small Cl₂ leak. If there is a leak, the ammonia will create a white colored smoke.

Safety Equipment

The facility shall be provided with personnel safety equipment to include the following: Respiratory equipment, safety shower, eyewash, gloves; eye protection, protective clothing, cylinder and/or ton repair kits.

Respiratory equipment shall be provided which has been approved under the Occupational Health and Safety Act, General Safety Regulation - Selection of Respiratory Protective Equipment. Equipment shall be in close proximity to the access door(s) of the chlorine room.

Chlorine Room Design Requirements

Where gas chlorination is practiced, the gas cylinders and/or the ton containers up to the vacuum regulators shall be housed in a gas-tight, well illuminated, and corrosion resistant and mechanically ventilated enclosure. The chlorinator may or may not be located inside the chlorine room. The chlorine room shall be located at the ground floor level.

Ventilation

Gas chlorine rooms shall have entirely separate exhaust ventilation systems capable of delivering one (1) complete air change per minute during periods of chlorine room occupancy only - there shall be no continuous ventilation. The air outlet from the room shall be 150 mm above the floor and the point of discharge located to preclude contamination of air inlets to buildings or areas used by people. The vents to the outside shall have insect screens.

Air inlets should be louvered near the ceiling, the air being of such temperature as to not adversely affect the chlorination equipment.

Separate switches for fans and lights shall be outside the room at all entrance or viewing points, and a clear wire-reinforced glass window shall be installed in such a manner as to allow the operator to inspect from the outside of the room.

Heating

Chlorine rooms shall have separate heating systems, if a forced air system is used to heat the building. Hot water heating system for the building will negate the need for a separate heating system for the chlorine room. The heat should be controlled at approximately 15°C. Cylinders or containers shall be protected to ensure that the chlorine maintains its gaseous state when entering the chlorinator.

Access

All access to the chlorine room shall only be from the exterior of the building. Visual inspection of the chlorination equipment from inside may be provided by the installation of glass window(s) in the walls of the chlorine room. Windows should be at least 0.20 m² in area, and be made of clear wire reinforced glass. There should also be a 'panic bar' on the inside of the chlorine room door for emergency exit.

Storage of Chlorine Cylinders

If necessary, a separate storage room may be provided to simply store the chlorine gas cylinders, with no connection to the line. The chlorine cylinder storage room shall have access either to the chlorine room or from the plant exterior, and be arranged to prevent the uncontrolled release of spilled gas. Chlorine gas storage room shall have provision for ventilation at thirty air changes per hour. Viewing glass windows and panic button on the inside of door should also be provided. In very large facilities, entry into the chlorine rooms may be through a vestibule from outside.

Scrubbers

For facilities located within residential or densely populated areas, consideration shall be given to provide scrubbers for the chlorine room.



Proper signage is necessary outside the Cl2 building

Alternate Disinfectants

Chloramine

Chloramine is a very weak disinfectant for Giardia and virus reduction. It is recommended that it be used in conjunction with a stronger disinfectant. It is best utilized as a stable distribution system disinfectant.

In the production of chloramines, the ammonia residuals in the finished water, when fed in excess of stoichiometric amount needed, should be limited to inhibit growth of nitrifying bacteria.

Chlorine Dioxide

Chlorine dioxide may be used for either taste and odor control or as a pre-disinfectant. Total residual oxidants (including chlorine dioxide and chlorite, but excluding chlorate) shall not exceed 0.30 mg/L during normal operation or 0.50 mg/L (including chlorine dioxide, chlorite and chlorate) during periods of extreme variations in the raw water supply.

Chlorine dioxide provides good Giardia and virus protection but its use is limited by the restriction on the maximum residual of 0.5 mg/L ClO₂/chlorite/chlorate allowed in finished water. This limits usable residuals of chlorine dioxide at the end of a process unit to less than 0.5 mg/L.

Where chlorine dioxide is approved for use as an oxidant, the preferred method of generation is to entrain chlorine gas into a packed reaction chamber with a 25% aqueous solution of sodium chlorite (NaClO₂).

Warning: Dry sodium chlorite is explosive and can cause fires in feed equipment if leaking solutions or spills are allowed to dry out.

Ozone

Ozone is a very effective disinfectant for both Giardia and viruses. Ozone CT values must be determined for the ozone basin alone; an accurate T10 value must be obtained for the contact chamber, residual levels measured through the chamber and an average ozone residual calculated.

Ozone does not provide a system residual and should be used as a primary disinfectant only in conjunction with free and/or combined chlorine.

Ozone does not produce chlorinated byproducts (such as trihalomethanes) but it may cause an increase in such byproduct formation if it is fed ahead of free chlorine; ozone may also produce its own oxygenated byproducts such as aldehydes, ketones or carboxylic acids. Any installed ozonation system must include adequate ozone leak detection alarm systems, and an ozone off-gas destruction system.

Ozone may also be used as an oxidant for removal of taste and odor or may be applied as a pre-disinfectant.

Amperometric Titration

The chlorination of water supplies and polluted waters serves primarily to destroy or deactivate disease-producing microorganisms. A secondary benefit, particularly in treating drinking water, is the overall improvement in water quality resulting from the reaction of chlorine with ammonia, iron, manganese, sulfide, and some organic substances.

Chlorination may produce adverse effects. Taste and odor characteristics of phenols and other organic compounds present in a water supply may be intensified. Potentially carcinogenic chloro-organic compounds such as chloroform may be formed.

Combined chlorine formed on chlorination of ammonia- or amine-bearing waters adversely affects some aquatic life. To fulfill the primary purpose of chlorination and to minimize any adverse effects, it is essential that proper testing procedures be used with a foreknowledge of the limitations of the analytical determination.

Chlorine applied to water in its molecular or hypochlorite form initially undergoes hydrolysis to form free chlorine consisting of aqueous molecular chlorine, hypochlorous acid, and hypochlorite ion. The relative proportion of these free chlorine forms is pH- and temperature-dependent. At the pH of most waters, hypochlorous acid and hypochlorite ion will predominate. Free chlorine reacts readily with ammonia and certain nitrogenous compounds to form combined chlorine. With ammonia, chlorine reacts to form the chloramines: monochloramine, dichloramine, and nitrogen trichloride.

The presence and concentrations of these combined forms depend chiefly on pH, temperature, initial chlorine-to-nitrogen ratio, absolute chlorine demand, and reaction time. Both free and combined chlorine may be present simultaneously. Combined chlorine in water supplies may be formed in the treatment of raw waters containing ammonia or by the addition of ammonia or ammonium salts. Chlorinated wastewater effluents, as well as certain chlorinated industrial effluents, normally contain only combined chlorine. Historically the principal analytical problem has been to distinguish between free and combined forms of chlorine.



Hach's AutoCAT 9000™ Automatic Titrator is the newest solution to hit the disinfection industry – a comprehensive, bench top chlorine-measurement system that does it all: calibration, titration, calculation, real-time graphs, graphic print output, even electrode cleaning.

More a laboratory assistant than an instrument, the AutoCAT 9000 gives you: High throughput: performs the titration and calculates concentration, all automatically:

- Forward titration: USEPA-accepted methods for free and total chlorine and chlorine dioxide with chlorite
- Back titration: USEPA-accepted method for total chlorine in wastewater
- Accurate, yet convenient, the easiest way to complete ppb-level amperometric titration

If you're dechlorinating, modifying your current disinfectant delivery, changing over to another chlorine species, or adjusting disinfection processes to meet new regulations, this is the workhorse system that yields the fast, accurate residual readings you need.

Chlorine Exposure Limits

This information is necessary to pass your certification exam.

*** OSHA PEL 1 PPM - IDLH 10 PPM and Fatal Exposure Limit 1,000 PPM**

The current Occupational Safety and Health Administration (**OSHA**) permissible exposure limit (**PEL**) for chlorine is 1 ppm (3 milligrams per cubic meter (mg/m³)) as a ceiling limit. A worker's exposure to chlorine shall at no time exceed this ceiling level. * **IDLH 10 PPM**

Physical and chemical properties of chlorine: A yellowish green, nonflammable and liquefied gas with an unpleasant and irritating smell. Can be readily compressed into a clear, amber-colored liquid, a noncombustible gas, and a strong oxidizer. Solid Chlorine is about 1.5 times heavier than water and gaseous chlorine is about 2.5 times heavier than air. Atomic number of chlorine is 17. Cl is the elemental symbol and Cl₂ is the chemical formula.

Monochloramine, dichloramine, and trichloramine are also known as Combined Available Chlorine. Cl₂ + NH₄.

HOCl and OCl⁻; the **OCL-** is the hypochlorite ion and the both of these two species are known as free available chlorine, they are the two main chemical species formed by chlorine in water and they known by collectively as hypochlorous acid and the hypochlorite ion. When chlorine gas is added to water, it rapidly hydrolyzes. The chemical equations best describes this reaction is **Cl₂ + H₂O → H⁺ + Cl⁻ + HOCl**. Hypochlorous acid is the most germicidal of the chlorine compounds with the possible exception of chlorine dioxide.

Yoke-type connectors should be used on a chlorine cylinder's valve assuming that the threads on the valve may be worn.

The connection from a chlorine cylinder to a chlorinator should be replaced by using a new, approved gasket on the connector. Always follow your manufacturer's instructions.

On a 1 ton container, the chlorine pressure reducing valve should be located downstream of the evaporator when using an evaporator. This is the liquid chlorine supply line and it is going to be made into chlorine gas.

In water treatment, chlorine is added to the effluent before the contact chamber (before the clear well) for complete mixing. One reason for not adding it directly to the chamber is that the chamber has very little mixing due to low velocities.



Here are several safety precautions when using chlorine gas: in addition to protective clothing and goggles, chlorine gas should be used only in a well ventilated area so that any leaking gas cannot concentrate. Emergency procedures in the case of a large uncontrolled chlorine leak: notify local emergency response team, warn and evacuate people in adjacent areas, and be sure that no one enters the leak area without adequate self-contained breathing equipment.

Here are several symptoms of chlorine exposure: burning of eyes, nose, and mouth; coughing, sneezing, choking; nausea and vomiting; headaches and dizziness; fatal pulmonary edema, pneumonia, and skin blisters. A little Cl² will corrode the teeth and then progress to throat cancer.

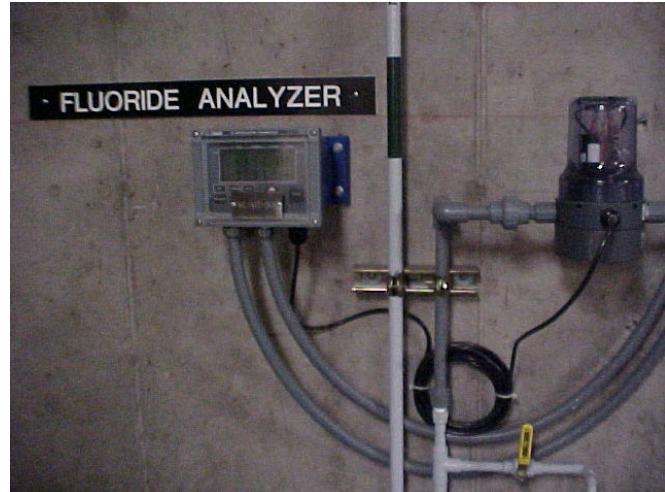
Approved method for storing a 150 - 200 pound chlorine cylinder: Secure each cylinder in an upright position, attach the protective bonnet over the valve and firmly secure each cylinder. Never store near heat. Always store the empty in an upright, secure position with proper signage.

Fluoride

Some water providers will add fluoride to the water to help prevent cavities in children. Too much fluoride will mottle the teeth.

Chemical Feed

The equipment used for feeding the fluoride to water shall be accurately calibrated before being placed in operation, and at all times shall be capable of maintaining a rate of feed within 5% of the rate at which the machine is set.



The following chemical feed practices apply:

1. Where a dry feeder of the volumetric or gravimetric type is used, a suitable weighing mechanism shall be provided to check the daily amount of chemical feed.
2. Hoppers should be designed to hold a 24 hour supply of the fluoride compound and designed such that the dust hazard to operators is minimized.
3. Vacuum dust filters shall be installed with the hoppers to prevent dust from rising into the room when the hopper is filled.
4. Dissolving chambers are required for use with dry feeders, and the dissolving chambers shall be designed such that at the required rate of feed of the chemical the solution strength will not be greater than 1/4 of that of a saturated solution at the temperature of the dissolving water. The construction material of the dissolving chamber and associated piping shall be compatible with the fluoride solution to be fed.
5. Solution feeders shall be of the positive displacement type and constructed of material compatible with the fluoride solution being fed.
6. The weight of the daily amount of fluoride fed to water shall be accurately determined.
7. Feeders shall be provided with anti-siphon valves on the discharge side. Wherever possible, positive anti-siphon breakers other than valves shall be provided.
8. A "**day tank**" capable of holding a 24 hour supply of solution should be provided.
9. All equipment shall be sized such that it will be operated in the 20 to 80 percent range of the scale, and be capable of feeding over the entire pumpage range of the plant.
10. Alarm signals are recommended to detect faulty operation of equipment.
11. The fluoride solution should be added to the water supply at a point where the fluoride will not be removed by any following treatment processes and where it will be mixed with the water. It is undesirable to inject the fluoride compound or solution directly on-line unless there are provisions for adequate mixing.

Metering

Metering of the total water to be fluoridated shall be provided, and the operation of the feeding equipment is to be controlled.

Control of the feed rate shall be automatic/ proportional controlled, whereby the fluoride feed rate is automatically adjusted in accordance with the flow changes to provide a constant pre-established dosage for all rates of flow, or (2) automatic/ residual controlled, whereby a continuous automatic fluoride analyzer determines the residual fluoride level and adjusts the rate of feed accordingly, or compound loop controlled, whereby the feed rate is controlled by a flow proportional signal and residual analyzer signal to maintain a constant residual.

Alternate Compounds

Any one of the following fluoride compounds may be used:

- 1. Hydrofluosilicic acid,**
- 2. Sodium fluoride, or,**
- 3. Sodium silicofluoride.**

Other fluoride compounds may be used if approved by the EPA.

Chemical Storage and Ventilation

The fluoride chemicals shall be stored separately from other chemicals, and the storage area shall be marked "**FLUORIDE CHEMICALS ONLY**". The storage area should be in close proximity to the feeder, kept relatively dry, and provided with pallets, if using bagged chemical, to allow circulation of air and to keep the containers off the floor.

Record of Performance

Accurate daily records shall be kept. These records shall include:

1. The daily reading of the water meter which controls the fluoridation equipment or that which determines the amount of water to which the fluoride is added.
2. The daily volume of water fluoridated.
3. The daily weight of fluoride compound in the feeder.
4. The daily weight of fluoride compound in stock.
5. The daily weight of the fluoride compound fed to the water.
6. The fluoride content of the raw and fluoridated water determined by laboratory analysis, with the frequency of measurement as follows:
 - (i) treated water being analyzed continuously or once daily, and
 - (ii) raw water being analyzed at least once a week.

Sampling

In keeping the fluoride records, the following sampling procedures are required:

1. A sample of raw water and a sample of treated water shall be forwarded to an approved independent laboratory for fluoride analysis once a month.
2. On new installations or during start-ups of existing installations, weekly samples of raw and treated water for a period of not less than four consecutive weeks.
3. In addition to the reports required, the EPA may require other information that is deemed necessary.

Fluoride Safety

The following safety procedures shall be maintained:

1. All equipment shall be maintained at a high standard of efficiency, and all areas and appliances shall be kept clean and free of dust. Wet or damp cleaning methods shall be employed wherever practicable.
2. Personal protective equipment shall be used during the clean-up, and appropriate covers shall be maintained over all fluoride solutions.
3. At all installations, safety features are to be considered and the necessary controls built into the installation to prevent an overdose of fluoride in the water. This shall be done either by use of day tanks or containers, anti-siphon devices, over-riding flow switches, sizing of pump and feeders, determining the length and duration of impulses, or other similar safety devices.
4. Safety features shall also be provided to prevent spills and overflows.
5. Individual dust respirators, chemical safety face shields, rubber gloves, and protective clothing shall be worn by all personnel when handling or being exposed to the fluoride dust.
6. Chemical respirators, rubber gloves, boots, chemical safety goggles and acid proof aprons shall be worn where acids are handled.
7. After use, all equipment shall be thoroughly cleaned and stored in an area free of fluoride dusts. Rubber articles shall be washed in water, and hands shall be washed after the equipment is stored.
8. All protective devices, whether for routine or emergency use, shall be inspected periodically and maintained in good operating condition.

Repair and Maintenance

Upon notifying the appropriate local board of health, a fluoridation program may be discontinued when necessary to repair or replace equipment, but shall be placed in operation immediately after the repair or replacement is complete. Records shall be maintained and submitted during the period that the equipment is not in operation.





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Water Quality

What's That Stuff in the Tap Water?

by Jameel Rahman and Gary A. Burlingame

Jameel Rahman is a retired analytical chemist supervisor for the Materials Testing Laboratory at the Philadelphia Water Department, where Gary A. Burlingame is the supervisor of water quality and research. Contact Burlingame at gary.burlingame@phila.gov or (215) 685-1417.

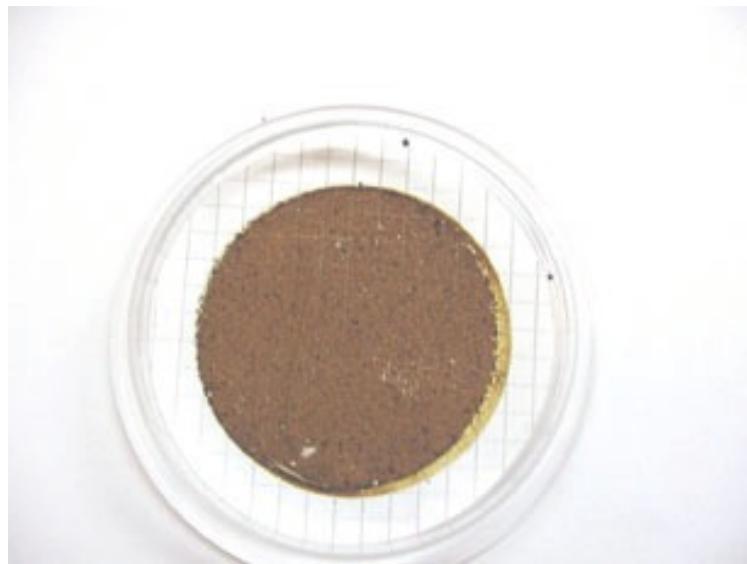
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Almost every water utility employee responsible for solving customer problems has fielded a complaint about particles in a bathtub or faucet aerator. Although particles can come from cold or hot water systems, household plumbing, water distribution systems, and water treatment, the water supplier—at least in customers' eyes—is usually “*guilty until proven innocent*.”

The Philadelphia Water Department has standardized procedures in place that can identify offending materials and help pinpoint their source.

Collecting and Identifying Particulates

Typically, the suspended matter customers complain about is particulate in form. The most important step in solving a particulate complaint is to collect as much suspect material as possible, making sure it represents the customer's actual concern. Sometimes enough material for analysis can be collected from faucet aerators. A container may be left with the customer for sample collection during normal tap use. Particulates can also accumulate in the toilet tank.



Particulate matter can be extracted from water samples by using nitrocellulose membrane filters. A $0.45\text{ }\mu\text{m}$ filter can be used if the water's colloidal matter doesn't clog the filter before enough particulate material is collected for analysis. Enough particulate matter can usually be captured with a water sample of approximately 250 mL. When samples have low turbidity, larger volumes will need to be filtered.

←Granular Rust

Under a microscope, examine the particulate matter captured on a filter. Use a zoom microscope with at least 40 \times , preferably 75 \times , magnification to identify matter on the membrane filter disk, which can be stored in a plexiglas Petri dish. For optimum observation, illuminate the particulates from above with a fiber-optic light.

Some particulates can be identified by their appearance and, sometimes, by touching them with a sharp needle and observing their physical properties, such as softness, stickiness, or solubility in a solvent. Particulates can be quantified as few, several, or numerous. If particulates cannot be identified by their appearance, perform simple chemical tests on the filter. A characteristic evolution of a gas, such as carbon dioxide from scale particulates or marble, can be observed under the microscope. Color formed by chemical reactions can be seen by the unaided eye. If these tests still fail to identify the debris, or further delineation is required, use infrared spectroscopy (IR).

Visual Identification

Sand particulates have a characteristic vitreous appearance and irregular shape with smooth facets. They can be colorful but usually appear translucent to whitish.

Mica particulates have a characteristic platelet shape and shine under reflected light. You will need to understand the common soil minerals in your area to identify them.

Man-made fibers, found in all colors and with a characteristic wrinkled strip shape, are present in single strands, have significant length, and often are visible to the unaided eye. Usually, fibers are not present in large numbers — at most, 10 per filter. Fibers used in apparel are round, but fibers found in water typically have a strip shape, indicating a common source, such as pump packing.

Glass chips are transparent, may have smooth facets with sharp edges, and may be colorful.

Relatively large amounts of similar particulates often indicate a problem within a plumbing system. Usually the source of such particulates is disintegrating plastic, a rubber gasket, or a corroding component of the plumbing system.

Heat Identification

Activated carbon particulates are black and usually coated with debris. They can show porosity but appear dull compared to anthracite particulates, which display a shiny luster under reflected light. Pick up a few particulates on the tip of a wetted platinum wire and burn them in the blue part of a Bunsen burner flame. AC particulates will burn instantaneously with a glitter and no visible smoke or residue.

Disintegrated plastic particulates are usually white, large, and may be present in large numbers. Pick up a few particulates and burn them in a Bunsen burner flame. Plastic burns with a smoke. With fine-tipped tweezers, remove sufficient particulates from the disk and further identify them by IR. Most often they are polypropylene plastic.

Disintegrated rubber gasket particulates are usually black, relatively large, and do not smear the filter disk with black when a drop of toluene is applied. If pressed with a needle, they flex. Remove a few particulates and burn them; rubber burns with a black smoke. Identify them further by IR.

Often these particulates are ethylene-propylene-diene monomer, used in gaskets.

Acid Identification

Rust particulates are usually abundant and are easy to identify with their typically brown and rough irregular shapes. Large particulates may have yellow and black streaks or inclusions, while fine rust particulates form a uniform brown film on the filter disk. To confirm rust, add a drop of (1+1) hydrochloric acid (500 mL of 11.5N hydrochloric acid [**HCl**] solution plus 500 mL of distilled water) to the filter. Yellow staining indicates the presence of ferric chloride. Add a drop of 2 percent solution of potassium thiocyanate on the yellow area where HCl was added. Brick-red staining confirms the presence of potassium ferrithiocyanate.



Large Rust Particles

Lead solder particulates are gray and may have a whitish coating, are usually brittle, and can be easily pulverized. Often, they are relatively large in size compared to most other particulates on the filter disk. If lead particulates are suspected, add a drop of pH 2.8 tartrate-buffer solution followed by a drop of 0.2 percent solution of freshly prepared sodium rhodizonate. If the particulates turn scarlet red, lead solder is present.

Prepare a pH 2.8 buffer solution by dissolving 1.9 g of sodium bitartrate and 1.5 g of tartaric acid in 100 mL of distilled water. To prepare the sodium rhodizonate reagent, dissolve 0.2 g of rhodizonic acid disodium salt in 100 mL of distilled water.

Patina is hydrated basic copper carbonate and has a greenish color. These irregularly shaped particulates result from corrosion of copper and copper alloys. To confirm their presence, add a drop of (1+1) HCl from a Pasture pipette. If tiny bubbles of carbon dioxide form under the microscope, the presence of patina is indicated. Remove a few particulates and place them in the cavity of a spot-test plate. Add a drop of (1+1) HCl followed by a drop of ammonia.

Appearance of a blue precipitate or blue color confirms the presence of patina particulates. Rust particulates will interfere with this test if it is performed on the rust-coated filter.

Calcium carbonate can develop as a white scale through evaporation of hard water or can occur as a particulate of limestone or calcite. Scales can form in water heaters.

Limestone can come from water treatment processes. Add a drop of HCl (1+1) on the particulates and observe the evolution of carbon dioxide under the microscope. The brisk evolution of gas confirms the presence of carbonates.

Solvent Identification

Asphalt pipe-coating compounds are black. To differentiate between various black particulates, add a drop of toluene or chloroform to the filter disk under the microscope. If the disk becomes smeared with black around the particulates, the particulates are classified as pipe-coating of an asphaltic nature. Anthracite, activated carbon, and rubber particulates are insoluble in the solvents used.

Anthracite particulates appear shiny compared with other black particulates and do not smear the filter disk if a drop of toluene is applied. These particulates can be removed from the filter disk and burned in a crucible; they will leave a solid residue.

Grease particulates are black and may be shiny. They are usually present as tiny heaps on the filter disk because of their softness and hydrophobic nature. They are soft and sticky when touched with a needle and can be smeared easily on the disk. Add a drop of toluene; grease will dissolve and a black color will spread around the particulates.

Let the toluene evaporate or use an oven to expedite drying. Touch the particulates with a needle in the area where toluene was added; they should no longer be sticky and may behave like a black powder. All greases may not behave this way, but their stickiness and extreme softness differentiates them from other black particulates.

Infrared Spectroscopy

When particulates cannot be completely identified by the above means, use IR to identify organic and inorganic materials. Inorganic compounds include calcium carbonate, calcium sulfate, barium sulfate, lead carbonate, metal oxides, silicates, or phosphates. Visually, and with the aid of heat, you might suspect a particulate is plastic in nature, but various types of plastics can occur in water systems, including polypropylene, polyvinyl chloride, and polyethylene. IR can differentiate between plastic materials.

Atoms in a molecule are in constant motion, changing bond angles by bending and bond lengths by stretching. Among these motions only certain vibrations absorb infrared radiation of specific energy. When portions of electromagnetic radiation are absorbed by such vibrations, an IR absorption band spectrum appears, which an infrared spectrometer records.

Each compound has a unique infrared absorption spectrum, and various compounds can be identified by comparing absorption band positions in the IR spectrum of an unknown compound to band positions of known compounds.

Particulates are removed with fine-tipped tweezers one by one from the filter disk and transferred to a small vial for dissolving in a solvent or to a small agate mortar for grinding and mixing with KBr for making a potassium bromide (KBr) pellet.

The usually brittle plastic fragments can be powdered easily, and 10 mg of sample is all that is commonly needed to produce a good infrared absorption spectrum. Inorganic materials are identified by IR scanning of the KBr pellet of the sample alone; organic materials are identified by scanning a pellet or a film of the sample cast on a KBr plate.



Zeolite Particles from a Water Softener

Most plastics are readily soluble in hot o-dichlorobenzene; try dissolving the sample in this solvent first. If soluble, cast a film of the sample on a KBr plate and scan it. If the sample is insoluble, evaporate the solvent completely and transfer the particulates to an agate mortar, make a KBr pellet, and scan the pellet. After obtaining a reasonably strong infrared spectrogram, the sample is identified by manual means or a computer search of a commercially available online IR library.

Standard Chemical Analyses

Chemical analyses available in most full-service water testing laboratories can be used to identify particulates when sufficient material is available. For example, hydrated aluminum oxide can occur as white slurry and be analyzed by inductively coupled plasma emission spectrometry after dissolving in mineral acids.

Similarly, granules of lead solder can also be analyzed by wet chemical or instrumental methods. After a sample is dissolved in a mineral acid, it can be analyzed for various elements by atomic absorption spectrophotometry. A variety of materials, including iron oxides, manganese dioxides, aluminum oxides, calcium carbonates, and copper and silicate particulates, can be identified by common chemical analyses.

During the late 1990s, customers in Philadelphia and across the country complained about white particulates clogging faucet aerators. Infrared spectroscopy revealed the particulates to be polypropylene, a plastic not used in the distribution system. The only common source for this plastic was found to be the dip tubes in residential gas hot-water heaters (see *Opflow*, December 1998).

Eventually, the dip-tube manufacturer admitted to changing materials to a less-durable plastic, prompting water heater manufacturers to give rebates to customers for dip-tube replacements. When this issue made the TV news, Philadelphia was in a good position to explain the situation to customers because our procedure was already in place for testing and characterizing particulates.



Dip Tube Particles

Table 1. Potential sources for particulate matter found in tap water

	From Customer Plumbing	From Water Supplier Piping
Particulate		
Activated carbon fines		X
Asphaltic lining fragments		X
Backfill sand		X
Calcium carbonate scale	X	X
Cast iron rust		X
Cement lining fragments		X
Copper fragments	X	
Glass chips		X
Greases and lubricants	X	X
Lead fragments	X	
Manganese dioxide deposits		X
Man-made fibers		X
On-site treatment device media		X
Plastic fragments	X	
Rubber gasket fragments	X	X
Soil minerals, mica		X

Table 2. Suspended matter classified by size

Soluble	< 0.45 µm
Colloidal	< 1.0 µm but > 0.45 µm
Particulate	> 1.0 µm

End of article by Jameel Rahman and Gary A. Burlingame

Granular Activated Carbon / Powdered Activated Carbon

Along with aeration, granular activated carbon (**GAC**) and powdered activated carbon (**PAC**) are suitable treatments for removal of organic contaminants such as VOCs, solvents, PCBs, herbicides and pesticides.

Activated carbon is carbon that has been exposed to very high temperature, creating a vast network of pores with a very large internal surface area; one gram of activated carbon has a surface area equivalent to that of a football field. It removes contaminants through adsorption, a process in which dissolved contaminants adhere to the surface of the carbon particles.

GAC can be used as a replacement for existing media (such as sand) in a conventional filter or it can be used in a separate contactor such as a vertical steel pressure vessel used to hold the activated carbon bed.

After a period of a few months or years, depending on the concentration of the contaminants, the surface of the pores in the GAC can no longer adsorb contaminants and the carbon must be replaced. Several operational and maintenance factors affect the performance of granular activated carbon.

Contaminants in the water can occupy adsorption sites, whether or not they are targeted for removal. Also, adsorbed contaminants can be replaced by other contaminants with which GAC has a greater affinity so their presence might interfere with removal of contaminants of concern.

A significant drop in the contaminant level in influent water can cause a GAC filter to desorb, or slough off, adsorbed contaminants, because GAC is essentially an equilibrium process. As a result, raw water with frequently changing contaminant levels can result in treated water of unpredictable quality.

Bacterial growth on the carbon is another potential problem. Excessive bacterial growth may cause clogging and higher bacterial counts in the treated water. The disinfection process must be carefully monitored in order to avoid this problem.

Powdered activated carbon consists of finely ground particles and exhibits the same adsorptive properties as the granular form. PAC is normally applied to the water in a slurry and then filtered out. The addition of PAC can improve the organic removal effectiveness of conventional treatment processes and also remove tastes and odors.

Advantages of PAC are that it can be used on a short-term or emergency basis with conventional treatment, creates no headloss, does not encourage microbial growth and has relatively small capital costs.

The main disadvantage is that some contaminants require large doses of PAC for removal. It is also somewhat ineffective in removing natural organic matter due to the competition from other contaminants for surface adsorption and the limited contact time between the water and the carbon.

Corrosion Control

Corrosion is the deterioration of a substance by chemical action. Lead, cadmium, zinc, copper and iron might be found in water when metals in water distribution systems corrode. Drinking water contaminated with certain metals (such as lead and cadmium) can harm human health.

Corrosion also reduces the useful life of water distribution systems and can promote the growth of microorganisms, resulting in disagreeable tastes, odors, slimes and further corrosion. Because it is widespread and highly toxic, lead is the corrosion product of greatest concern.

The EPA has banned the use of lead solders, fluxes and pipes in the installation or repair of any public water system. In the past, solder used in plumbing has been 50% tin and 50% lead. Using lead-free solders, such as silver-tin and antimony-tin is a key factor in lead corrosion control.

The highest level of lead in consumers' tap water will be found in water that has been standing in the pipes after periods of nonuse (overnight or longer). This is because standing water tends to leach lead or copper out of the metals in the distribution system more readily than does moving water.

Therefore, the simplest short-term or immediate measure that can be taken to reduce exposure to lead in drinking water is to let the water run for two to three minutes before each use. Also, drinking water should not be taken from the hot water tap, as hot water tends to leach lead more readily than cold.

Long-term measures for addressing lead and other corrosion by-products include pH and alkalinity adjustment; corrosion inhibitors; coatings and linings; and cathodic protection, all discussed below.

Cathodic Protection

Cathodic protection protects steel from corrosion, which is the natural electrochemical process that results in the deterioration of a material because of its reaction with its environment. Cathodic protection is an electrical system used for the prevention of rust, corrosion, and pitting of metal surfaces which are in contact with water or soil. E.M.F. is a crazy term is used to express the electrical pressure available to cause a flow of current when an electric circuit is closed.

Metallic structures, components and equipment exposed to aqueous environments, soil or seawater can be subject to corrosive attack and accelerated deterioration. Therefore, it is often necessary to utilize either impressed current or sacrificial anode cathodic protection (**CP**) in combination with coatings as a means of suppressing the natural degradation phenomenon to provide a long and useful service life. However, if proper considerations are not given, problems can arise which can produce unexpected, premature failure.

There are Two Types of Cathodic Protection:

- Ø Sacrificial Anodes (Galvanic Systems)
- Ü Impressed (Induced) Current Systems

How Does Cathodic Protection Work?

Sacrificial anodes are pieces of metal more electrically active than the steel piping system. Because these anodes are more active, the corrosive current will exit from them rather than the piping system. Thus, the system is protected while the attached anode is "**sacrificed**".

Sacrificial anodes can be attached to existing piping system or coated steel for a pre-engineered Cathodic protection system.

An asphalt coating is not considered a suitable dielectric coating.

Depleted anodes must be replaced for continued Cathodic protection of the system.

Impressed or Induced Current Systems

An impressed current Cathodic protection system consists of anodes, cathodes, a rectifier and the soil. The rectifier converts the alternating current to direct current. The direct current is then sent through an insulated copper wire to anodes that are buried in the soil near the piping system.

Typical anode materials are ceramic, high silicon cast iron, or graphite. Ceramic anodes are not consumed, whereas high silicon cast iron and graphite anodes partially dissolve each year and must be replaced over time.

The direct current then flows from the anode through the soil to the piping system, which acts as the cathode, and back to the rectifier through another insulated copper wire.

As a result of the electrochemical properties of the impressed current Cathodic protection system, corrosion takes place only at the anodes and not at the piping system. Depleted anodes must be replaced for continued Cathodic protection of the piping system.

Sacrificial Anode System

In this system, a metal or alloy reacting more vigorously than that corroding specimen, acts as an anode and the corroding structure as a whole is rendered Cathodic. These anodes are made of materials such as magnesium, aluminum or zinc which are anodic with respect to the protected structure. The sacrificial anodes are connected directly to the structure.

Advantages

1. Needs no external power source.
2. Does not involve maintenance work.
3. If carefully designed it can render protection for anticipated period.
4. Installation is simple.
5. Does not involve expensive accessories like rectifier unit, etc.
6. Economical for small structures.

Disadvantages

1. The driving voltage is small and therefore the anodes have to be fitted close to the structure or on the structure, thereby increasing the weight or load on the structure.
2. The anodes have to be distributed all over the structure (as throwing power is lower) and therefore have design limitations in certain applications.
3. Once designed and installed, protection current cannot be altered or increased as may be needed in case of cathode area extension (unprotected) or foreign structure interference (physical contact).

Impressed Current System

The impressed current anode system, on the other hand, has several advantages over the sacrificial anode systems. In this system the protection current is "**Forced**" through the environment to the structure (cathode) by means of an external D.C. source. Obviously we need some material to function as anodes. It can be high silicon chromium cast iron anodes, graphite anodes or lead silver alloy anodes.

Advantages

1. Since the driving voltage is large, this system offers freedom of installation design and location.
2. Fewer anodes can protect large structures.
3. Variations in protection current requirements can be adjusted to some extent (to be incorporated at design stage).

Disadvantages

1. Shut down of D.C. supply for a long times allows structure to corrode again.
2. Reversal of anode cathode connection at D.C. source will be harmful as structure will dissolve anodic
3. Needs trained staff for maintenance of units and for monitoring
4. Initial investments are higher and can pay off only in long run and economic only for large structures
5. Power cost must be incorporated in all economic considerations.
6. Possibility of overprotection should be avoided as it will affect the life of the paint.
7. Any foreign structure coming within this field will cause an interference problem.

Alkalinity and pH Adjustment

Adjusting pH and alkalinity is the most common corrosion control method because it is simple and inexpensive. pH is a measure of the concentration of hydrogen ions present in water; alkalinity is a measure of water's ability to neutralize acids.

Generally, water pH less than 6.5 is associated with uniform corrosion, while pH between 6.5 and 8.0 can be associated with pitting corrosion. Some studies have suggested that systems using only pH to control corrosion should maintain a pH of at least 9.0 to reduce the availability of hydrogen ions as electron receptors. However, pH is not the only factor in the corrosion equation; carbonate and alkalinity levels affect corrosion as well.

Generally, an increase in pH and alkalinity can decrease corrosion rates and help form a protective layer of scale on corrodible pipe material. Chemicals commonly used for pH and alkalinity adjustment are hydrated lime (CaOH_2 or calcium hydroxide), caustic soda (NaOH or sodium hydroxide), soda ash (Na_2CO_3 or sodium carbonate), and sodium bicarbonate (NaHCO_3 , essentially baking soda).

Care must be taken, however, to maintain pH at a level that will control corrosion but not conflict with optimum pH levels for disinfection and control of disinfection by-products.

Corrosion Inhibitors

Inhibitors reduce corrosion by forming protective coatings on pipes. The most common corrosion inhibitors are inorganic phosphates, sodium silicates and mixtures of phosphates and silicates. These chemicals have proven successful in reducing corrosion in many water systems.

The phosphates used as corrosion inhibitors include polyphosphates, orthophosphates, glassy phosphates and bimetallic phosphates. In some cases, zinc is added in conjunction with orthophosphates or polyphosphates.

Glassy phosphates, such as sodium hexametaphosphate, effectively reduce iron corrosion at dosages of 20 to 40 mg/l.

Glassy phosphate has an appearance of broken glass and can cut the operator. Sodium silicates have been used for over 50 years to inhibit corrosion. The effectiveness depends on the water pH and carbonate concentration.

Sodium silicates are particularly effective for systems with high water velocities, low hardness, low alkalinity and a pH of less than 8.4.

Typical coating maintenance doses range from 2 to 12 mg/l. They offer advantages in hot water systems because of their chemical stability. For this reason, they are often used in boilers of steam heating systems.



A 36 inch water main that blew out and destroyed an entire building.

Water System Design and Valves

System design depends on the area where you live. You may be a flatlander, like in Texas, and the services could be spread out for miles. You may live in the Rocky Mountain area and have many fluctuating elevations. Some areas may only serve residents on a part-time basis and water will sit for long periods of time, while other areas may have a combination of peaks and valleys with short and long distances of service. Before you design the system you need to ask yourself some basic questions.

1. ***What is the source of water?***
2. ***What is the population?***
3. ***What kind of storage will I need for high demand and emergencies?***
4. ***How will the pressure be maintained?***

System Elements

The elements of a water distribution system include distribution mains, arterial mains, storage reservoirs, and system accessories. These elements and accessories are described as follows:

DISTRIBUTION MAINS Distribution mains are the pipelines that make up the distribution system. Their function is to carry water from the water source or treatment works to users.

ARTERIAL MAINS Arterial mains are distribution mains of large size. They are interconnected with smaller distribution mains to form a complete gridiron system.

STORAGE RESERVOIRS Storage reservoirs are structures used to store water. They also equalize the supply or pressure in the distribution system. A common example of a storage reservoir is an aboveground water storage tank. The purpose of a hydropneumatic tank is to provide air for the water system.



The inside of a booster pump station, notice the PRV and air relief valve.

Commonly found system accessories include the following:

Booster stations are used to increase water pressure from storage tanks for low-pressure mains.

Valves control the flow of water in the distribution system by isolating areas for repair or by regulating system flow or pressure.



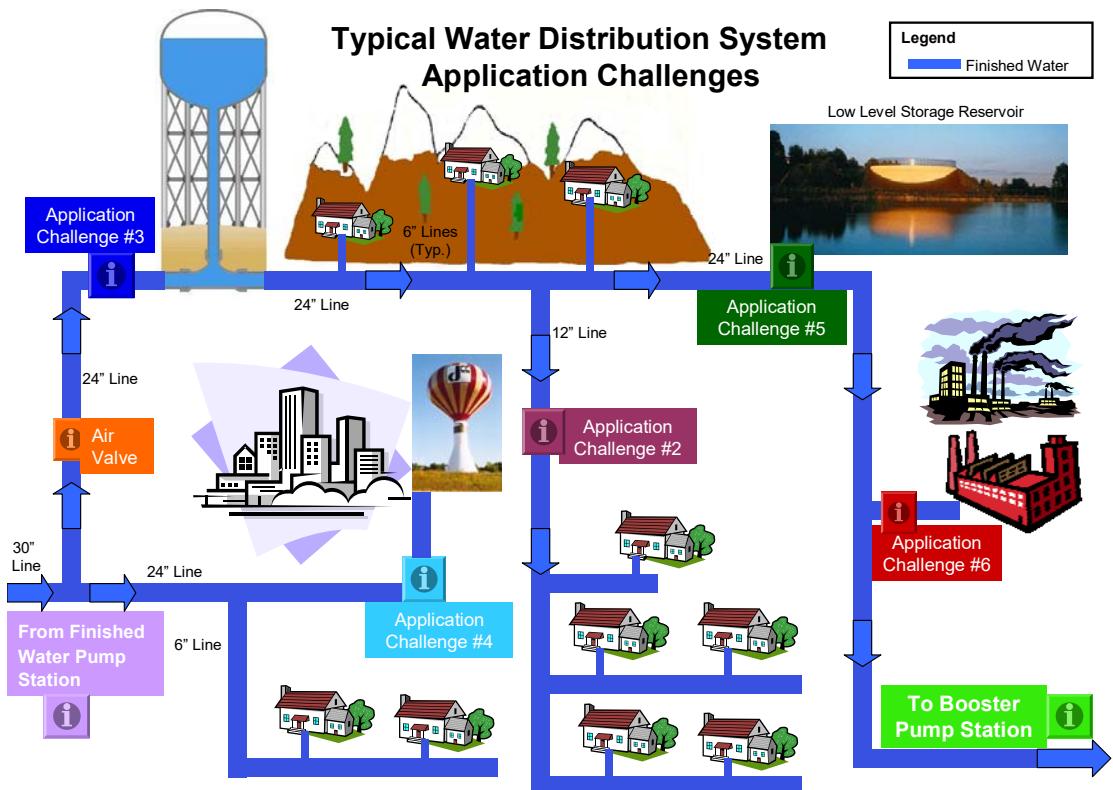
Two different styles of Gate Valves

Top picture is valve ready for a valve replacement.

Bottom picture is OS&Y commonly found on fire lines.

(Outside Screw and Yoke) As the gate is lifted or opened, the stem will rise.

Gate valves should be used in the distribution system for main line isolation.



Distribution System Layouts

There are three general ways systems are laid out to deliver water (picture your quarter section layouts). They include:

- Tree systems
- Loop or Grid systems
- Dead-end systems - **Taste and odor problems.**

Tree System

Older water systems frequently were expanded without planning and developed into a treelike system. This consists of a single main that decreases in size as it leaves the source and progresses through the area originally served. Smaller pipelines branch off the main and divide again, much like the trunk and branches of a tree. A treelike system is not desirable because the size of the old main limits the expansion of the system needed to meet increasing demands. In addition, there are many dead ends in the system where water remains for long periods, causing undesirable tastes and odors in nearby service lines.

The most reliable means to provide water for fire fighting is by designing redundancy into the system. There are several advantages gained by laying out water mains in a loop or grid, with feeder and distributor mains interconnecting at roadway intersections and other regular intervals.



How do you like this nightmare? A weak spot in a 54 inch water main blew out and destroyed an entire street. Are you ready for such an event?

Distribution Valves

The purpose of installing shutoff valves in water mains at various locations within the distribution system is to allow sections of the system to be taken out of service for repairs or maintenance without significantly curtailing service over large areas.

Valves should be installed at intervals not greater than 5,000 feet in long supply lines and 1,500 feet in main distribution loops or feeders. All branch mains connecting to feeder mains or feeder loops should have valves installed as close to the feeders as practical. In this way, branch mains can be taken out of service without interrupting the supply to other locations.

In the areas of greatest water demand or when the dependability of the distribution system is particularly important, valve spacing of 500 feet maybe appropriate.

At intersections of distribution mains, the number of valves required is normally one less than the number of radiating mains. The valve omitted from the line is usually the one that principally supplies flow to the intersection. Shutoff valves should be installed in standardized locations (that is, the northeast corner of intersections or a certain distance from the center line of streets), so they can be easily found in emergencies. All buried small- and medium-sized valves should be installed in valve boxes. For large shutoff valves (about 30 inches in diameter and larger), it may be necessary to surround the valve operator or entire valve within a vault or manhole to allow repair or replacement.

Classification of Valves

There are two major classifications of water valves: **Rotary** and **Linear**. Linear is a fancy word for up and down or blade movement.

Gate Valve Linear Valve Our primary Linear valve

The most common valve in the distribution system. Primary used for main line shut downs. Should be exercised on annual basis.

Gate valves are used when a straight-line flow of fluid and minimum flow restriction are needed. Gate valves are so-named because the part that either stops or allows flow through the valve acts somewhat like a gate. The gate is usually wedge-shaped. When the valve is wide open the gate is fully drawn up into the valve bonnet. This leaves an opening for flow through the valve the same size as the pipe in which the valve is installed.

Therefore, there is little pressure drop or flow restriction through the valve. Gate valves are not suitable for throttling purposes. The control of flow is difficult because of the valve's design, and the flow of fluid slapping against a partially open gate can cause extensive damage to the valve. Except as specifically authorized, gate valves should not be used for throttling.



I always liked to listen to the valve key when shutting down a gate valve. You will easily hear it sing as you shut the water off or leak by. It is very easy to create a water hammer with opening or closing a Gate valve. Always take your time when operating a gate valve or any valve. I know that most of you will not listen to me and you will end up breaking plastic water services and customer's water lines at first. Next, you'll move up to water main breaks. We like to blame the Fire Department or Street Sweepers for water hammers, and they should be blamed, but most water hammers are created by water personnel. Yes, I said it. A great example is watching a rookie shut down or open a fire hydrant. These young rookies like to turn the hydrant on or off as fast as possible, like the firemen do. Pretty soon, the hydrant starts chattering and pumping. The ground feels like an earthquake and the rookie pretends that nothing is happening. We've all done this and if you haven't, you've probably never worked in the field.

Problems

Valve Jammed Open

Dr. Durbin recommends that opened valves should not be jammed-tight on the backseat.

Always back the valve-off a quarter turn from the fully opened position.

Note that motor operated valves coast inevitably to the backseat by tripping on a limit switch. Valve should not be back seated on torque.

Valve Jammed Closed

Variations in the temperature and/or pressure of the working fluid are often the cause of a valve failing to open.

Thermal binding can occur in high temperature situations depending on the seat and wedge material, length of exposure and closing torque applied. Thermal binding can cause galling on the valve sealing surfaces as well as on the guides.

A valve can lock in the closed position when high pressure enters the cavity and has no way to escape. This is known as over-pressurization.

If Excessive Torque is Needed to Work the Valve

Variations in the temperature and/or pressure of the working fluid are often the cause of a valve failing to open.

Thermal binding can occur in high temperature situations depending on the seat and wedge material, length of exposure and closing torque applied. Thermal binding can cause galling on the valve sealing surfaces as well as on the guides.

A valve can lock in the closed position when high pressure enters the cavity and has no way to escape. This is known as over-pressurization. We will cover this in a later section.

Single direction sealing gate valves have a nameplate on the side of the valve that has a relief hole or pressure equalizer. This should be the high pressure side when the valve is closed.



Here is a nasty 4 inch broken gate valve with serious tuberculation. The valve is broken in the closed position. The rust particles are very sharp and can easily cut the water service worker. The flange bolts or Tee bolts were cut off to replace this valve. The rubber gasket will leave a black ink-like stain on your clothes and in the water line as well. You will see lots of nasty stuff in the top portion of a valve. Some engineers or big shots refer to this area of the valve as the "angular space". If they really knew that this space contained nasty particles or debris and sediment they would never visit your Yard or facility again. One practice that I am not sure about is the common procedure of only removing the bonnet or removing the guts of a closed valve. I guess that sometimes this practice is necessary, but I don't like removing the guts and packing of cement and a redwood plug in the stem hole, but it happens. Dr. Durbin's advice: This is very difficult because of mud and water lines that are under pressure, but be super careful of rust particles cutting your skin. Get in line at the Doctor's or Health Provider's facility and get all of your shots, especially Tetanus and Hepatitis. I know some of you will fight this suggestion but the facts are that you will probably be infected with something nasty while working on the distribution system. Biofilms are the result of a complex interaction among microorganisms. The organisms form Microcolonies and secrete extracellular material that makes them highly resistant to biocides.



Notice the corrosion inside this cast iron main.

This corrosion is caused by chemical changes produced by electricity or electrolysis. We call this type of corrosion tuberculation. It is a protective crust of corrosion products that have built up over a pit caused by the loss of metal due to corrosion or electrolysis. This type of corrosion will decrease the C-Factor and the carrying capacity in a pipe. Crenothrix bacteria or Red-Iron bacteria will live in the bioslime in this type of tuberculation. Now for dealing with this nasty stuff there are two methods: 1) the fast method, super chlorinate and flush for ever. Or, 2) replace the line with a nice plastic water main. It is up to your Supervisor, but remember the nasty in the water. No one that knows about it will ever drink water from the house service.

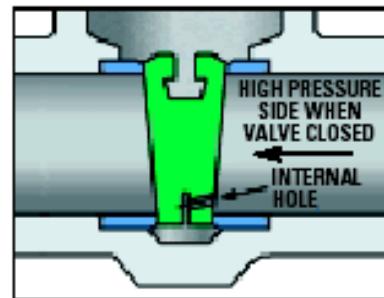


Gate valve storage procedures: Always store a gate valve with the gate up or opened. Not like in the above picture. Sunlight will give the rubbers a good shot of Vitamin D and a sunburn that will destroy the rubbers. I like to keep the valves covered and clean. I know that some of you don't care because these valves are so damn heavy and bother-some. Get over it and quit making \$800.00 bird nests. We are professionals and must remember the final outcome. We provide drinking water to the public. Don't ever let me catch you doing this, or I'll throw you under the bus.

Knife Gate Valve

Always follow standard safety procedures when working on a valve. Install the valve so that the arrows on both sides of the body are in the direction of positive pressure differential.

The preferred orientation is with the stem vertical and the handwheel pointing up. The opposite orientation is not recommended, because fiber and dirt can build-up in the bonnet.



Common Rotary Valves

Globe Valve Rotary Valve

Are primarily used for flow regulation, and work similar to a faucet. Rare to find in most distribution systems but can be found at treatment plants. Always follow standard safety procedures when working on a valve.

Most Globes have compact OS & Y type, bolted bonnet, rising stem, with renewable seating valves. A Check Valve spring loaded disc resulting with most advanced design features provides the ultimate in dependable, economical flow control.

Globe valves should usually be installed with the inlet below the valve seat. For severe throttling service, the valve may be installed so that the flow enters over the top of the seat and goes down through it. Note that in this arrangement, the packings will be constantly pressurized. If the valve is to be installed near throttling service, verify with an outside contractor or a skilled valve technician. Globe valves per se are not suitable for throttling service.



Various Globe Valves

The valve should be welded onto the line with the disc in the fully closed position. Leaving it even partially open can cause distortion and leaking. Allow time for the weld to cool before operating the valve the first time in the pipeline.

The preferred orientation of a globe valve is upright. The valve may be installed in other orientations, but any deviation from vertical is a compromise. Installation upside down is not recommended because it can cause dirt to accumulate in the bonnet.



Globe Valve Problems and Solutions

If the valve stem is improperly lubricated or damaged: disassemble the valve and inspect the stem. Acceptable deviation from theoretical centerline created by joining center points of the ends of the stem is 0.005"/ft of stem. Inspect the threads for any visible signs of damage. Small grooves less than 0.005" can be polished with an Emory cloth. Contact specialized services or an outside contractor if run-out is unacceptable or large grooves are discovered on the surface of the stem.

If the valve packing compression is too tight: Verify the packing bolt torque and adjust if necessary.

Foreign debris is trapped on threads and/or in the packing area: This is a common problem when valves are installed outdoors in sandy areas and area not cleaned before operating.

Always inspect threads and packing area for particle obstructions, even seemingly small amounts of sand trapped on the drive can completely stop large valves from cycling. The valve may stop abruptly when a cycle is attempted. With the line pressure removed from the valve, disconnect the actuator, gear operator or handwheel and inspect the drive nut, stem, bearings and yoke bushing. Contaminated parts should be cleaned with a lint-free cloth using alcohol, varsol or equivalent. All parts should be re-lubricated before re-assemble. If the valves are installed outdoors in a sandy area, it may be desirable to cover the valves with jackets.

If the valve components are faulty or damaged: If you suspect that the valve components are damaged or faulty contact specialized services or an outside contractor.

If the valve 's handwheel is too small: Increasing the size of the handwheel will reduce the amount of torque required to operate the valve. If a larger handwheel is installed, the person operating the valve must be careful not to over-torque the valve when closing it.

Ball or Corporation Stop Rotary Valve Small Valves 2 inch and smaller

Most commonly found on customer or water meters. All small backflow assemblies will have two Ball valves. It is the valve that is either fully on or fully off. It is the valve that you use to test the abilities of a water service rookie. The best trick is to remove the ball from the Ball valve and have a rookie *Jump a Stop*. The Corp is usually found at the water main on a saddle. Some people say that the purpose of the Corp is to regulate the service. I don't like that explanation. No one likes to dig up the street to regulate the service and Ball valves are only to be used fully on or fully off.



Most ball valves are the quick-acting type. They require only a 90-degree turn to either completely open or close the valve. However, many are operated by planetary gears. This type of gearing allows the use of a relatively small handwheel and operating force to operate a fairly large valve. Always follow standard safety procedures when working on a valve.

The gearing does, however, increase the operating time for the valve. Some ball valves also contain a swing check located within the ball to give the valve a check valve feature. The brass ball valve is often used for house appliance and industry appliance, the size range is 1/4"-4". Brass or zinc is common for body, brass or iron for stem, brass or iron for ball, aluminum, stainless steel, or iron for handle including a Teflon seal in the ball housing. Flush the pipeline before installing the valve. Debris allowed to remain in the pipeline (such as weld spatters, welding rods, bricks, tools, etc.) can damage the valve. After installation, cycle the valve a minimum of three times and re-torque bolts as required. Ensure that the valve is in the open position and the inside of the body bore of the valve body/body end is coated with a suitable spatter guard.



Bird's eyed view of the stainless steel ball.



Removing the ball is very difficult. I think they use a robot to tighten the rear nut just to keep you from removing it. I recommend that you always use pipe dope or Teflon tape when installing a Stop. I know a lot of you think that brass or bronze will make up the slack, but pipe dope, Teflon dope or tape makes a nicer job and makes for an easier removal.

Butterfly Valve Rotary Valve

Usually a huge water valve found in both treatment plants and throughout the distribution system. If the valve is not broken, it is relatively easy to operate. It is usually accompanied by a Gate valve used as a by-pass to prevent water hammer. When I was a Valve man, it seemed that every Bypass valve was broken closed when near a Butterfly valve.

These are rotary types of valves usually found on large transmission lines. They may also have an additional valve beside it known as a "**bypass**" to prevent a water hammer.

Some of these valves can require 300-600 turns to open or close. Most Valvemen or the politically correct term Valve Operators will use a machine to open or close a Butterfly Valve, the machine will count the turns required to open or close the valve.

Butterfly valves should be installed with the valve shaft horizontal or inclined from vertical. Always follow standard safety procedures when working on a valve.

The valve should be mounted in the preferred direction, with the "HP" marking. Thermal insulation of the valve body is recommended for operating temperatures above 392°F (200°C).



The valve should be installed in the closed position to ensure that the laminated seal in the disc is not damaged during installation.

If the pipe is lined, make sure that the valve disc does not contact the pipe lining during the opening stroke. Contact with lining can damage the valve disc.



54-inch Butterfly valve on a huge transmission line. Nice job, but no shoring or valve blocking. Don't let me catch you doing this, or I'll throw you in the back of the bus.

GA Industries Inc.
MANUFACTURERS OF

GOLDEN ANDERSON VALVES

FEATURES & ADVANTAGES

AWWA C504, CLASS 150B, BUTTERFLY VALVES

BODY
Heavy duty cast iron furnished standard, with ductile iron available as an extra cost option. Flanged Valves are faced and drilled per ANSI B16.1, Class 125. Mechanical Joint Valves are machined per ANSI/AWWA C111/A21.11. Wafer Valves are machined to fit between ANSI B16.1, Class 125 flanges.

SHAFT
Corrosion resistant stainless steel per ASTM A276 Type 304 furnished standard or type 316 furnished as an extra cost option. One piece design on valves sizes 3" to 8" and two piece design 10" and up. Shafts are sized to meet AWWA C504 for Class 150B Butterfly Valves.

BEARINGS
(Upper and Lower)
Fiberglass reinforced nylon bearings are low friction, self-lubricating and provide exceptionally long life.

DISC
Corrosion resistant ASTM A276, Type 316 stainless steel sizes 3", 4" and 6". High strength ASTM-A536, 65-45-12, ductile iron with a 316 stainless steel edge per AWWA C504 and a thin epoxy coating on sizes 8" and up. Streamlined lens shaped disc provides minimum headloss. Discs are attached to shafts with 316 stainless steel tapered dowel pins.

SHAFT SEALS
(Upper and Lower)
Buna-N (Nitrile) Chevron V packing is self adjusting and provides exceptionally long life.

RESILIENT BODY SEAT
Standard Material is Buna-N (Nitrile) Rubber, permanently bonded to the iron body and tested per AWWA Standard C504.

SELF CENTERING DISC-NO ADJUSTMENT NECESSARY
Flats molded into the vulcanized rubber seat ring provide positive alignment flats on the disc to provide positive centering of the disc in the body. Accurate centering of the disc in the body assures maximum seat life.

AWWA STANDARD C-504 BUTTERFLY VALVES



ELANGED WITH WORM GEAR ACTUATOR & HANDWHEEL

WAVER WITH 10 POSITION LEVER

M.J. WITH TRAVELING NUT ACTUATOR & 2" SQ. NUT

Bulletin BF150-2

GA Industries Inc.
MANUFACTURERS OF

GOLDEN ANDERSON VALVES

ACTUATION METHODS



- Standard Handwheel
- Chainwheel Operated
- Square Nut
- Pneumatic
- Electric

Butterfly Valve Problems

A butterfly valve may have jerky operation for the following reasons:

If the packing is too tight: Loosen the packing torque until it is only hand tight. Tighten to the required level and then cycle the valve. Re-tighten, if required. CAUTION: Always follow safety instructions when operating on valve.

If the shaft seals are dirty or worn out: Clean or replace components, as per assembly-disassembly procedure. CAUTION: Always follow safety instructions when operating on valve.

If the shaft is bent or warped: The shaft must be replaced. Remove valve from service and contact an outside contractor or your expert fix it person.

If the actuator/shaft adaptor is misaligned: Remove the actuator mounting and realign.

If the valve has a pneumatic actuator, the air supply may be inadequate: Increase the air supply pressure to standard operating level. Any combination of the following may prevent the valve shaft from rotating.

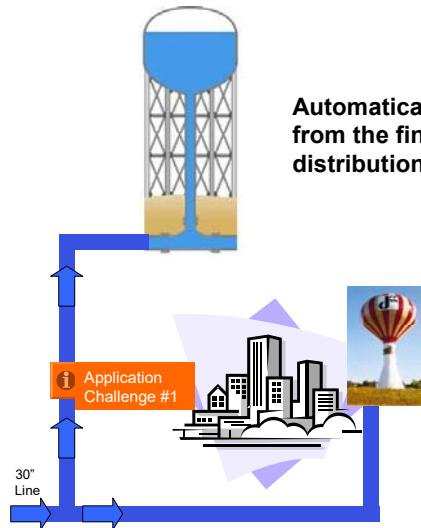
If the actuator is not working: Replace or repair the actuator as required. Please contact specialized services or an outside contractor for assistance.

If the valve is packed with debris: Cycle the valve and then flush to remove debris. A full cleaning may be required if flushing the valve does not improve valve shaft rotation. Flush or clean valve to remove the debris.



A broken 54-inch Butterfly and a worker inside the water main preparing the interior surface. Notice, this is a Permit Required Confined Space. A Hot work permit is also required. Don't let me catch you without a permit, or I'll drive over you with my bus or Harley or both.

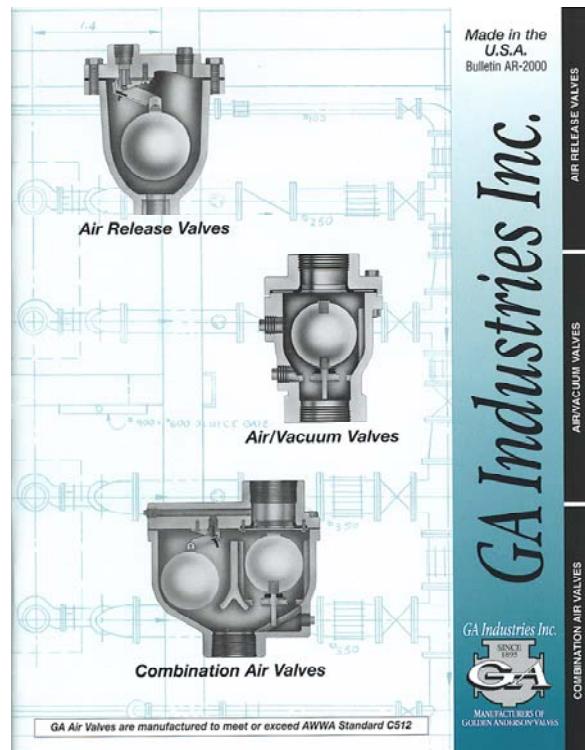
Water Distribution System Application Challenge #1



Automatically improve the pumping efficiency from the finished water pump station to the distribution system in a long pipeline..



Proposed Solution: Automatic Air Valves



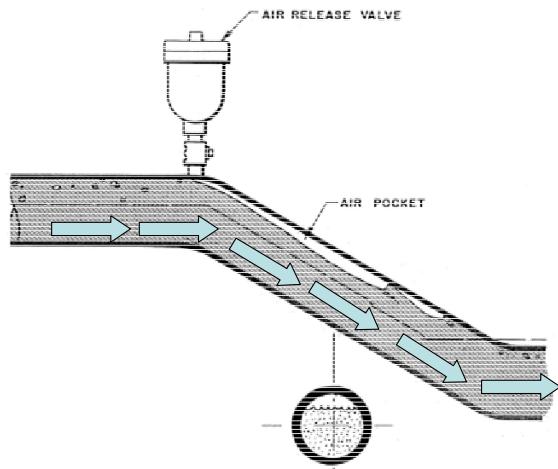
Why use automatic air valves?

- Increase flow capacity
- Reduce pumping costs (less electricity)
- Lessen the effect of water hammer.
- Prevent vacuum damage, such as pipeline collapse, seal failure, contamination and cross connection.
- Keep the lines full to reduce corrosion of the pipe.



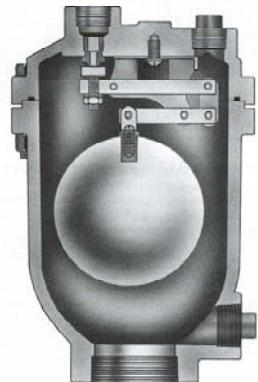
Air pockets reduce the cross sectional area of the pipe available to transmit the fluid, similar to partially closed valves. The velocity will increase at all air pockets and therefore the system head loss also increases.

The flow in the pipeline will push the air pocket down the pipe. The location of air valves should be at the point of the anticipated air pocket during flowing conditions.





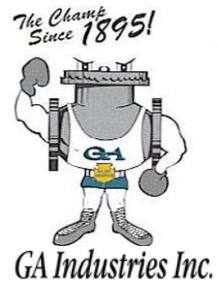
AIR RELEASE VALVES



- Opens under pressure to releases small amounts of entrained air which have come out of solution and accumulated in the valve. The air displaces the liquid lowering the float and opening the valve. The air is released and the water bousys the float to the closed position sealing the valve.
- Small outlet orifice (usually measured in fractions of an inch) normally sized to release air at a rate equivalent to 2% of the liquid flow.
- Locate at high points and at $\frac{1}{4}$ to $\frac{1}{2}$ mile intervals along long lengths of pipe.

COMBINATION AIR VALVES

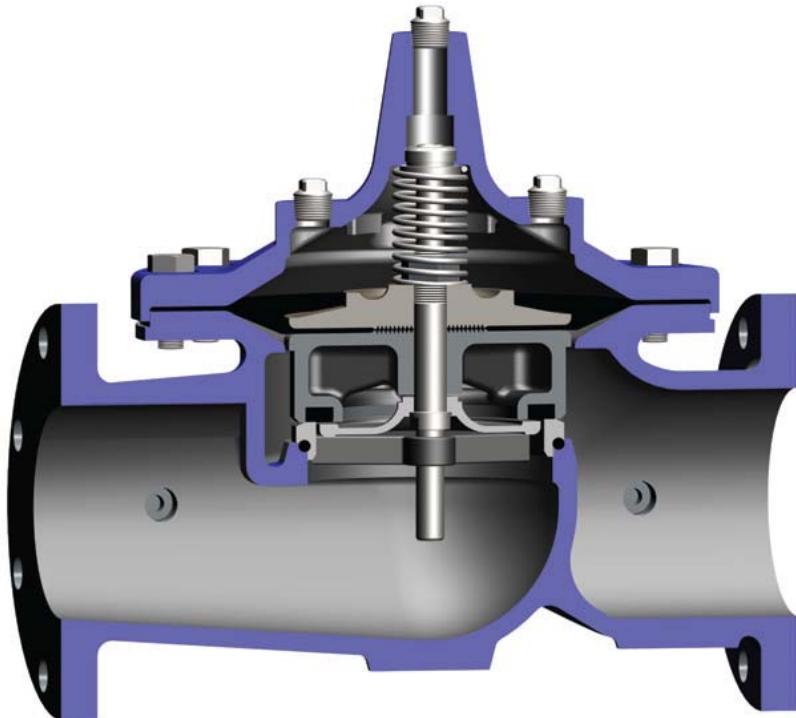
Performs functions of both the small orifice air release and large orifice air/vacuum valve



Pressure Reducing Valves Rotary Valve

How do Pressure Relief Valves Operate?

Most pressure relief valves consist of a main valve and pilot control system. The basic main Cla-Val valve is called a Hytrol Valve.



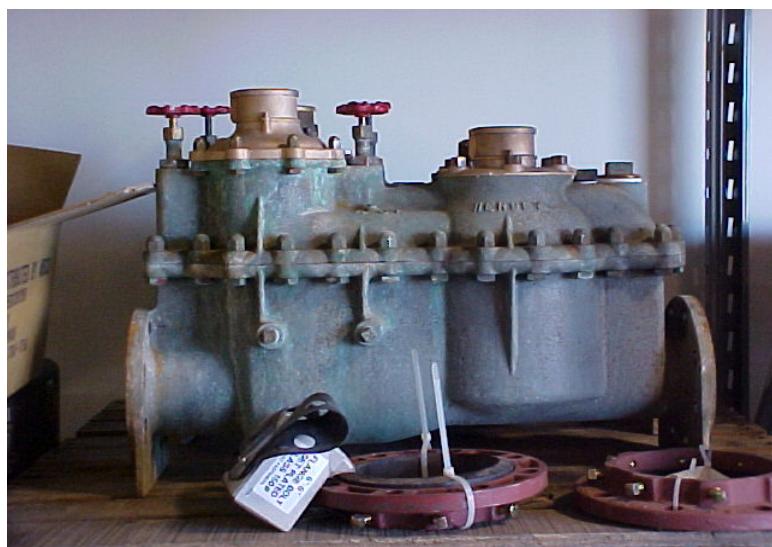
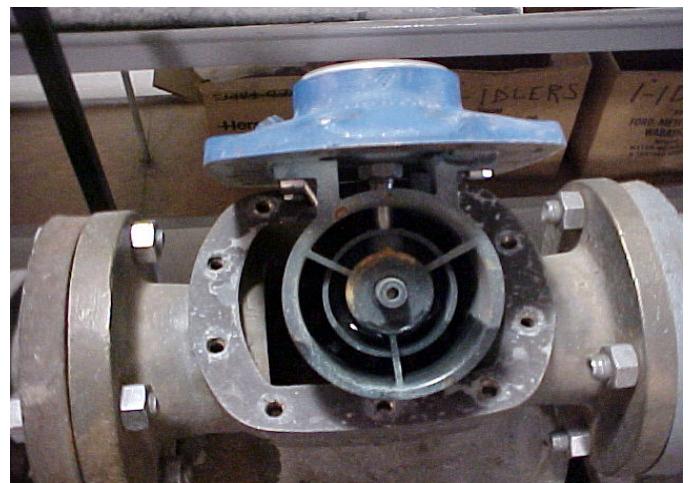
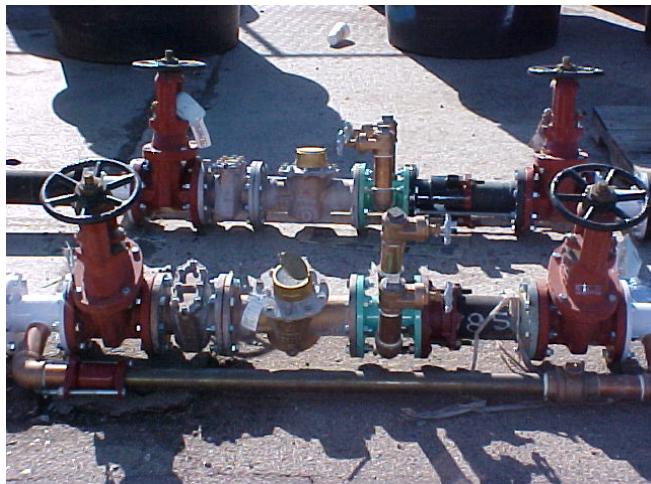
When no pressure is in the valve, the spring and the weight of the diaphragm assembly hold the valve closed.

Often a small box can be connected to an existing pilot PRV valve to control the main Pressure Reducing Valve on the pipe network. This single box contains both the control electronics and an integral data logger to save the cost and space of having both a controller and a separate data logger. There are basically two types of PRV controllers, either time based (to reduce the pipe pressure at low demand times, e.g. at night) or flow modulated (which can realize leakage savings throughout the day and night by adjusting the pressure according to the demand, to prevent excessive pressure at any time of the day or night).



Close up picture of the blow out on the 54-inch. Nasty for sure. Can you go without your large production water line for an extended period? Well, you better think about this type of problem coming to your system. I personally like pulling those hedgehogs or rocket-shaped boring machines out of the main. Of course the contractor is already in Mexico by the time most water companies find the problem.

**Water Meters record the flow of water in a part of the distribution system.
Bypass, Compound, Turbine or Propeller meters.**



Water Meters

It is important to account for the water produced and supplied. A master meter should be installed on each source, with service meters placed at each point of use. These should be read and recorded periodically. Totals from the master meters should be compared to totals from the service meters to compute the amount of water lost in the distribution system. This information is important in locating and eliminating leaks and unauthorized taps.

Losses of 10 to 20 percent are not uncommon in many distribution systems. Also, it has been shown that a system which is not metered is likely to have a water usage up to three times as great as a metered system. Un-metered water users tend to water freely and have little incentive to repair plumbing leaks.



Computerized handheld meter reader "station"



Water Theft (*Unaccounted for Water*)

Commonly found methods and devices. Notice diversion with the semi-truck and dial removal. Get used to seeing everyone stealing water. Even rich people are bad.



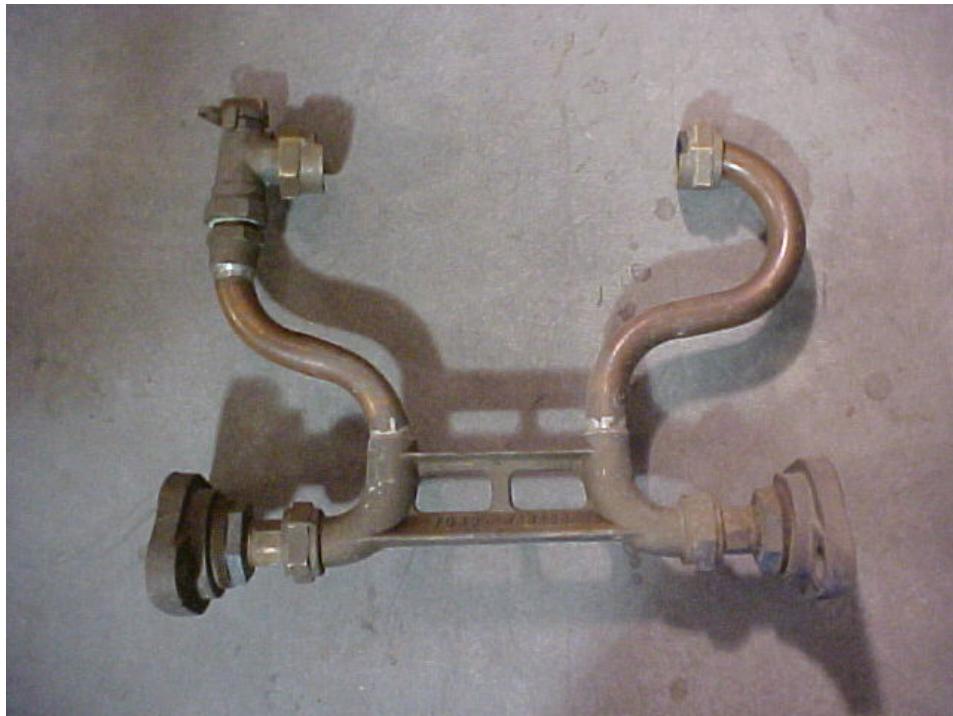
Meter Shop

Equipment used for meter calibration. Most meters will read lower than normal, never higher. All meters will create “**head loss**” on the water service except for a “**Magnetic Meter**”. The large tanks are used to measure the water in gallons that is used to calibrate or check the water meter.

Most water utilities will charge the customer a fee to check the accuracy of the meter.



Service connections are used to connect individual buildings or other plumbing systems to the distribution system mains.



Water Meter Re-setter, riser or sometimes referred to as a copper yoke.

The purpose of a "Copper Yoke" on a water service line connection is to secure pipe for a water meter installation.



Common distribution fittings. Single check, Poly Pig, 1-inch repair clamp, 4-inch full circle clamp, T- Bolt and a corp. and saddle



Ductile pipe Cement-lined iron pipe



Flex Coupling used to join pipes or to “cut-in a valve”



Four-Way Pipe cutting tool used for iron pipe

Recent Backflow Situations

Oregon 1993

Water from a drainage pond, used for lawn irrigation, is pumped into the potable water supply of a housing development.

California 1994

A defective backflow device in the water system of the County Courthouse apparently caused a sodium nitrate contamination that sent 19 people to the hospital.

New York 1994

An 8-inch reduced pressure principle backflow assembly in the basement of a hospital discharged under backpressure conditions, dumping 100,000 gallons of water into the basement.

Nebraska 1994

While working on a chiller unit of an air conditioning system at a nursing home, a hole in the coil apparently allowed Freon to enter the circulating water and from there into the city water system.

California 1994

The blue tinted water in a pond at an amusement park backflowed into the city water system and caused colored water to flow from homeowner's faucets.

California 1994

A film company shooting a commercial for television accidentally introduced a chemical into the potable water system.

Iowa 1994

A backflow of water from the Capitol Building chilled water system contaminated potable water with Freon.

Indiana 1994

A water main break caused a drop in water pressure, allowing anti-freeze from an air conditioning unit to backsiphon into the potable water supply.

Washington 1994

An Ethylene Glycol cooling system was illegally connected to the domestic water supply at a veterinarian hospital.

Ohio 1994

An ice machine connected to a sewer sickened dozens of people attending a convention.



Various Reduced Pressure Principle Backflow Assemblies.



This dude was covered with 3 foot high grass. The grass was thriving because the RP was leaking. No one noticed, not even the customer that was used to paying an additional \$150 each month for the leak. Remember, every drop counts, find and stop all leaks. Any leak makes the Distribution Section look bad.

Backflow Prevention and Cross-Connection Principles

Atmospheric Pressure

The atmosphere is the entire mass of air that surrounds the earth. While it extends upward for about 500 miles, the section of primary interest is the portion that rests on the earth's surface and extends upward for about 7 1/2 miles. This layer is called the troposphere.

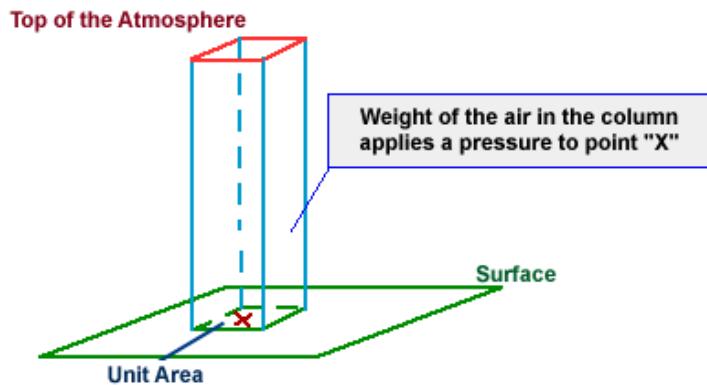
If a column of air 1-inch square extending all the way to the "top" of the atmosphere could be weighed, this column of air would weigh approximately 14.7 pounds at sea level. Thus, atmospheric pressure at sea level is approximately 14.7 psi.

As one ascends, the atmospheric pressure decreases by approximately 1.0 psi for every 2,343 feet. However, below sea level, in excavations and depressions, atmospheric pressure increases. Pressures under water differ from those under air only because the weight of the water must be added to the pressure of the air.

Atmospheric pressure can be measured by any of several methods. The common laboratory method uses the mercury column barometer. The height of the mercury column serves as an indicator of atmospheric pressure. At sea level and at a temperature of 0° Celsius (C), the height of the mercury column is approximately 30 inches, or 76 centimeters. This represents a pressure of approximately 14.7 psi. The 30-inch column is used as a reference standard.

Another device used to measure atmospheric pressure is the aneroid barometer. The aneroid barometer uses the change in shape of an evacuated metal cell to measure variations in atmospheric pressure. The thin metal of the aneroid cell moves in or out with the variation of pressure on its external surface. This movement is transmitted through a system of levers to a pointer, which indicates the pressure.

The atmospheric pressure does not vary uniformly with altitude. Its changes are more rapid. Atmospheric pressure is defined as the force per unit area exerted against a surface by the weight of the air above that surface. In the diagram below, the pressure at point "X" increases as the weight of the air above it increases. The same can be said about decreasing pressure, where the pressure at point "X" decreases if the weight of the air above it also decreases.



Pressure may be referred to using an absolute scale, pounds per square inch absolute (psia), or gauge scale, (psig). Absolute pressure and gage pressure are related. Absolute pressure is equal to gage pressure plus the atmospheric pressure. At sea level, the atmospheric pressure is 14.7 psai.

Absolute pressure is the total pressure. Gauge pressure is simply the pressure read on the gauge. If there is no pressure on the gauge other than atmospheric, the gauge will read zero. Then the absolute pressure would be equal to 14.7 psi, which is the atmospheric pressure.

Vacuum

The term **vacuum** indicates that the absolute pressure is less than the atmospheric pressure and that the gauge pressure is negative. A complete or total vacuum would mean a pressure of 0 psia or -14.7 psig.

Since it is impossible to produce a total vacuum, the term vacuum, as used in this document, will mean all degrees of partial vacuum.

In a partial vacuum, the pressure would range from slightly less than 14.7 psia (0 psig) to slightly greater than 0 psia (-14.7 psig).

Backsiphonage results from atmospheric pressure exerted on a liquid forcing it toward a supply system that is under a vacuum.

Water Pressure

The weight of a cubic foot of water is 62.4 pounds per square foot. The base can be subdivided into 144-square inches with each subdivision being subjected to a pressure of 0.433 psig.

Suppose you placed another cubic foot of water on top of the first cubic foot. The pressure on the top surface of the first cube which was originally atmospheric, or 0 psig, would now be 0.4333 psig as a result of the additional cubic foot of water. The pressure of the base of the first cubic foot would be increased by the same amount of 0.866 psig or two times the original pressure.

Hydraulics

The word **hydraulics** is based on the Greek word for water, and originally covered the study of the physical behavior of water at rest and in motion. Use has broadened its meaning to include the behavior of all liquids, although it is primarily concerned with the motion of liquids. Hydraulics includes the manner in which liquids act in tanks and pipes, deals with their properties, and explores ways to take advantage of these properties.

Hydraulics is a branch of engineering concerned mainly with moving liquids. The term is applied commonly to the study of the mechanical properties of water, other liquids, and even gases when the effects of compressibility are small.

Hydraulics can be divided into two areas, hydrostatics and hydrokinetics. Hydrostatics, the consideration of liquids at rest, involves problems of buoyancy and flotation, pressure on dams and submerged devices, and hydraulic presses.

Hydrodynamics

The relative incompressibility of liquids is one of its basic principles.

Hydrodynamics, the study of liquids in motion, is concerned with such matters as friction and turbulence generated in pipes by flowing liquids, the flow of water over weirs and through nozzles, and the use of hydraulic pressure in machinery.

Development of Hydraulics

Although the modern development of hydraulics is comparatively recent, the ancients were familiar with many hydraulic principles and their applications. The Egyptians and the ancient people of Persia, India, and China conveyed water along channels for irrigation and domestic purposes, using dams and sluice gates to control the flow. The ancient Cretans had an elaborate plumbing system. Archimedes studied the laws of floating and submerged bodies. The Romans constructed aqueducts to carry water to their cities.

After the breakup of the ancient world, there were few new developments for many centuries. Then, over a comparatively short period, beginning near the end of the seventeenth century, Italian physicist, Evangelista Torricelle, French physicist, Edme Mariotte, and later, Daniel Bernoulli conducted experiments to study the elements of force in the discharge of water through small openings in the sides of tanks and through short pipes. During the same period, Blaise Pascal, a French scientist, discovered the fundamental law for the science of hydraulics. Pascal's law states that increase in pressure on the surface of a confined fluid is transmitted undiminished throughout the confining vessel or system.

For Pascal's law to be made effective for practical applications, it was necessary to have a piston that "**fit exactly**." It was not until the latter part of the eighteenth century that methods were found to make these snugly fitted parts required in hydraulic systems.

This was accomplished by the invention of machines that were used to cut and shape the necessary closely fitted parts and, particularly, by the development of gaskets and packings. Since that time, components such as valves, pumps, actuating cylinders, and motors have been developed and refined to make hydraulics one of the leading methods of transmitting power.

Liquids are almost incompressible. For example, if a pressure of 100 pounds per square inch (**psi**) is applied to a given volume of water that is at atmospheric pressure, the volume will decrease by only 0.03 percent. It would take a force of approximately 32 tons to reduce its volume by 10 percent; however, when this force is removed, the water immediately returns to its original volume. Other liquids behave in about the same manner as water.

Another characteristic of a liquid is the tendency to keep its free surface level. If the surface is not level, liquids will flow in the direction which will tend to *make* the surface level.

Liquids at Rest

In studying fluids at rest, we are concerned with the transmission of force and the factors which affect the forces in liquids. Additionally, pressure in and on liquids and factors affecting pressure are of great importance.

Pressure and Force

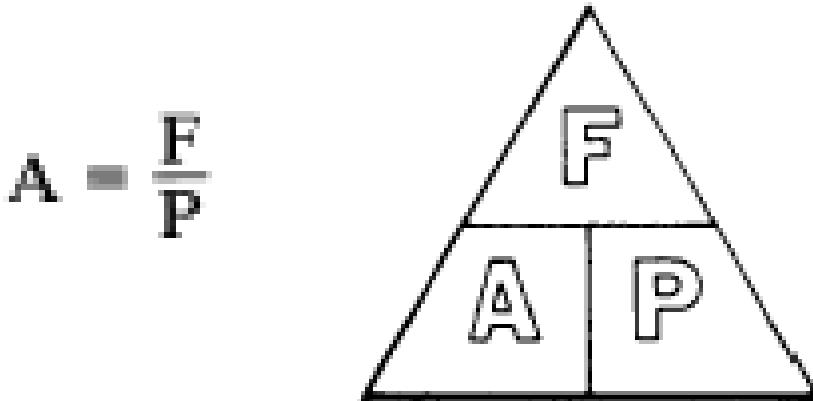
Pressure is the force that pushes water through pipes. Water pressure determines the flow of water from the tap. If pressure is not sufficient then the flow can reduce to a trickle and it will take a long time to fill a kettle or a cistern.

The terms **force** and **pressure** are used extensively in the study of fluid power. It is essential that we distinguish between the terms. Force means a total push or pull. It is the push or pull exerted against the total area of a particular surface and is expressed in pounds or grams.

Pressure means the amount of push or pull (force) applied to each unit area of the surface and is expressed in pounds per square inch (lb/in²) or grams per square centimeter (gm/cm²). Pressure maybe exerted in one direction, in several directions, or in all directions.

Computing Force, Pressure, and Area

A formula is used in computing force, pressure, and area in fluid power systems. In this formula, P refers to pressure, F indicates force, and A represents area. Force equals pressure times area. Thus, the formula is written



Pascal's Law

The foundation of modern hydraulics was established when Pascal discovered that pressure in a fluid acts equally in all directions. This pressure acts at right angles to the containing surfaces. If some type of pressure gauge, with an exposed face, is placed beneath the surface of a liquid at a specific depth and pointed in different directions, the pressure will read the same. Thus, we can say that pressure in a liquid is independent of direction.

Pressure due to the weight of a liquid, at any level, depends on the depth of the fluid from the surface. If the exposed faces of the pressure gauges are moved closer to the surface of the liquid, the indicated pressure will be less. When the depth is doubled, the indicated pressure is doubled. Thus the pressure in a liquid is directly proportional to the depth.

Consider a container with vertical sides that is 1 foot long and 1 foot wide. Let it be filled with water 1 foot deep, providing 1 cubic foot of water. 1 cubic foot of water weighs 62.4 pounds. Using this information and the equation, $P = F/A$, we can calculate the pressure on the bottom of the container.

Since there are 144 square inches in 1 square foot, this can be stated as follows: the weight of a column of water 1 foot high, having a cross-sectional area of 1 square inch, is 0.433 pound. If the depth of the column is tripled, the weight of the column will be 3×0.433 , or 1.299 pounds, and the pressure at the bottom will be 1.299 lb/in² (psi), since pressure equals the force divided by the area.

Thus, the pressure at any depth in a liquid is equal to the weight of the column of liquid at that depth divided by the cross-sectional area of the column at that depth. The volume of a liquid that produces the pressure is referred to as the fluid head of the liquid. The pressure of a liquid due to its fluid head is also dependent on the density of the liquid.

Gravity

Gravity is one of the four forces of nature. The strength of the gravitational force between two objects depends on their masses. The more massive the objects are, the stronger the gravitational attraction.

When you pour water out of a container, the earth's gravity pulls the water towards the ground. The same thing happens when you put two buckets of water, with a tube between them, at two different heights. You must work to start the flow of water from one bucket to the other, but then gravity takes over and the process will continue on its own.

Gravity, applied forces, and atmospheric pressure are static factors that apply equally to fluids at rest or in motion, while inertia and friction are dynamic factors that apply only to fluids in motion. The mathematical sum of gravity, applied force, and atmospheric pressure is the static pressure obtained at any one point in a fluid at any given time.

Static Pressure

Static pressure exists in addition to any dynamic factors that may also be present at the same time.

Pascal's law states that a pressure set up in a fluid acts equally in all directions and at right angles to the containing surfaces. This covers the situation only for fluids at rest or practically at rest. It is true only for the factors making up static head.

Obviously, when velocity becomes a factor it must have a direction, and as previously explained, the force related to the velocity must also have a direction, so that Pascal's law alone does not apply to the dynamic factors of fluid power.

The dynamic factors of inertia and friction are related to the static factors. Velocity head and friction head are obtained at the expense of static head. However, a portion of the velocity head can always be reconverted to static head. Force, which can be produced by pressure or head when dealing with fluids, is necessary to start a body moving if it is at rest, and is present in some form when the motion of the body is arrested. Therefore, whenever a fluid is given velocity, some part of its original static head is used to impart this velocity, which then exists as velocity head.



Cooling Tower
A common location of a cross-connection

Volume and Velocity of Flow

The volume of a liquid passing a point in a given time is known as its **volume of flow** or flow rate. The volume of flow is usually expressed in gallons per minute (gpm) and is associated with relative pressures of the liquid, such as 5 gpm at 40 psi. The **velocity of flow** or velocity of the fluid is defined as the average speed at which the fluid moves past a given point. It is usually expressed in feet per second (fps) or feet per minute (fpm). Velocity of flow is an important consideration in sizing the hydraulic lines.

Volume and velocity of flow are often considered together. With other conditions unaltered—that is, with volume of input unchanged—the velocity of flow increases as the cross section or size of the pipe decreases, and the velocity of flow decreases as the cross section increases. For example, the velocity of flow is slow at wide parts of a stream and rapid at narrow parts, yet the volume of water passing each part of the stream is the same.

Bernoulli's Principle.

Bernoulli's principle thus says that a rise (fall) in pressure in a flowing fluid must always be accompanied by a decrease (increase) in the speed, and conversely, an increase (decrease) in the speed of the fluid results in a decrease (increase) in the pressure. This is at the heart of a number of everyday phenomena. As a very trivial example, Bernoulli's principle is responsible for the fact that a shower curtain gets ``**sucked inwards**'' when the water is first turned on. What happens is that the increased water/air velocity inside the curtain (relative to the still air on the other side) causes a pressure drop. The pressure difference between the outside and inside causes a net force on the shower curtain which sucks it inward.

A more useful example is provided by the functioning of a perfume bottle: squeezing the bulb over the fluid creates a low pressure area due to the higher speed of the air, which subsequently draws the fluid up. This is illustrated in the following figure on the next page.

Bernoulli's Principle also tells us why windows tend to explode, rather than implode in hurricanes. The very high speed of the air just outside the window causes the pressure just outside to be much less than the pressure inside, where the air is still.

The difference in force pushes the windows outward, and hence explode. If you know that a hurricane is coming. It is therefore better to open as many windows as possible, to equalize the pressure inside and out. Another example of Bernoulli's principle at work is in the lift of aircraft wings and the motion of "**curve balls**" in baseball.

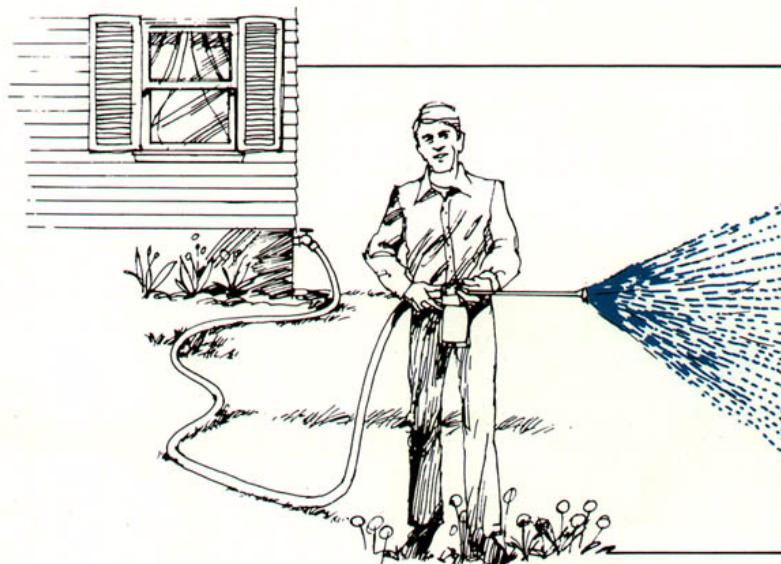
In both cases the design is such as to create a speed differential of the flowing air past the object on the top and the bottom - for aircraft wings this comes from the movement of the flaps, and for the baseball it is the presence of ridges. Such a speed differential leads to a pressure difference between the top and bottom of the object, resulting in a net force being exerted, either upwards or downwards.

Properties of Water

Specific gravity of water at 60°F = 1.00

Weight per gallon is based on 7.48052 gallons per cubic foot.

Action of a spray atomizer

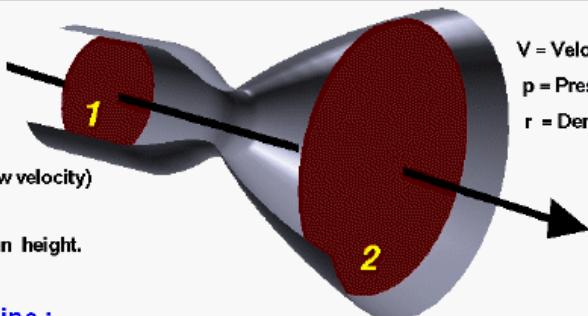


Bernoulli's Equation

Glenn
Research
Center

Restrictions :

- Inviscid
- Steady
- Incompressible (low velocity)
- No heat addition.
- Negligible change in height.



Along a streamline :

$$\text{static pressure} + \text{dynamic pressure} = \text{total pressure}$$

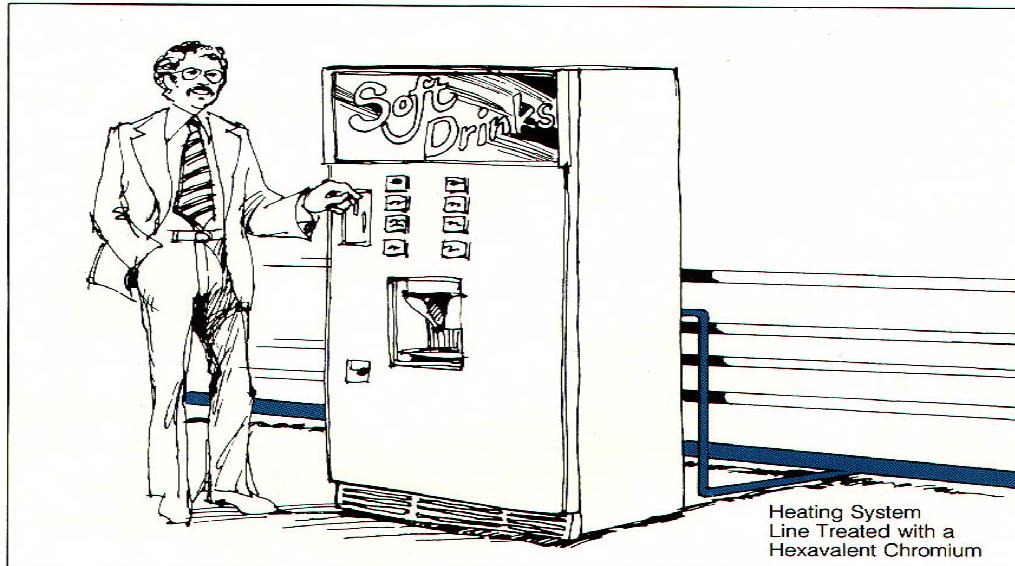
$$p_s + \frac{rV^2}{2} = p_t$$

$$(p_s + \frac{rV^2}{2})_1 = (p_s + \frac{rV^2}{2})_2$$

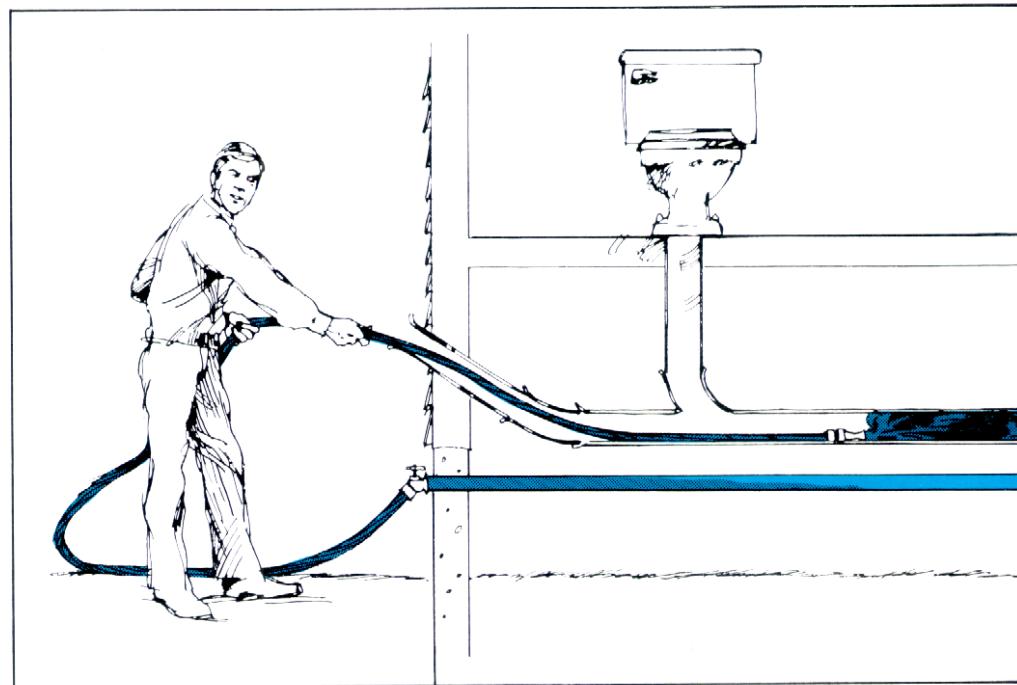
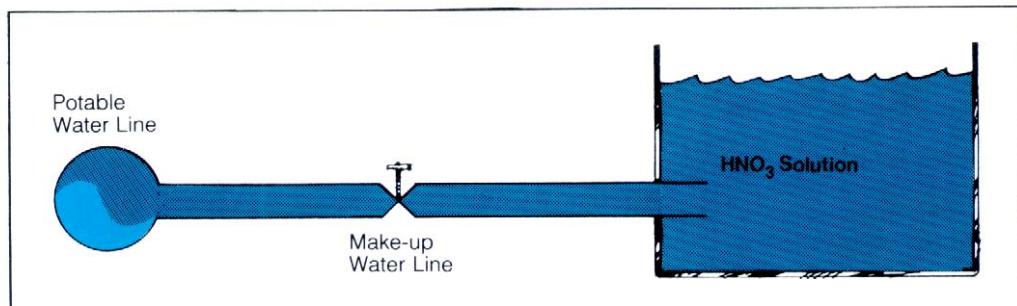
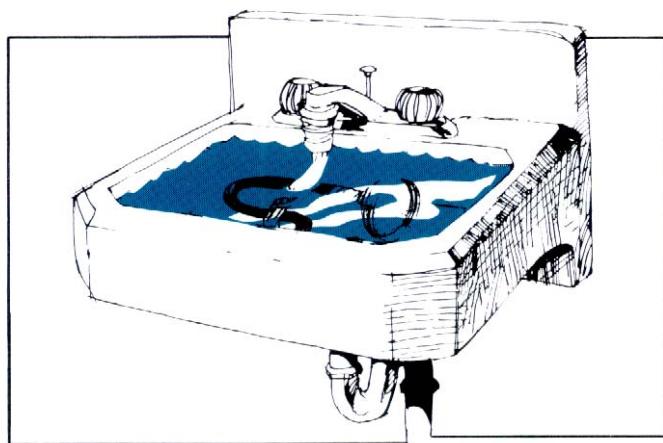
Cross-Connection Terms

Cross-connection

A cross-connection is any temporary or permanent connection between a public water system or consumer's potable (i.e., drinking) water system and any source or system containing nonpotable water or other substances. An example is the piping between a public water system or consumer's potable water system and an auxiliary water system, cooling system, or irrigation system.



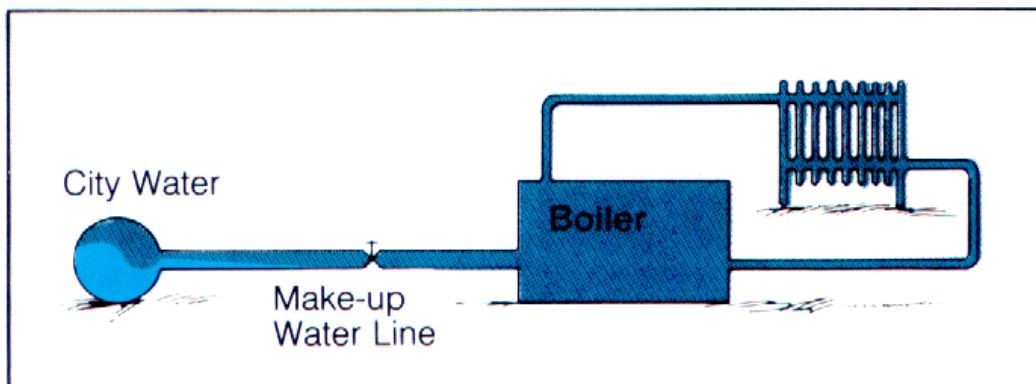
Commonly Found Cross-Connections



Backflow

Backflow is the undesirable reversal of flow of nonpotable water or other substances through a cross-connection and into the piping of a public water system or consumer's potable water system. There are two types of backflow--**backpressure** and **backsiphonage**.

Backsiphonage

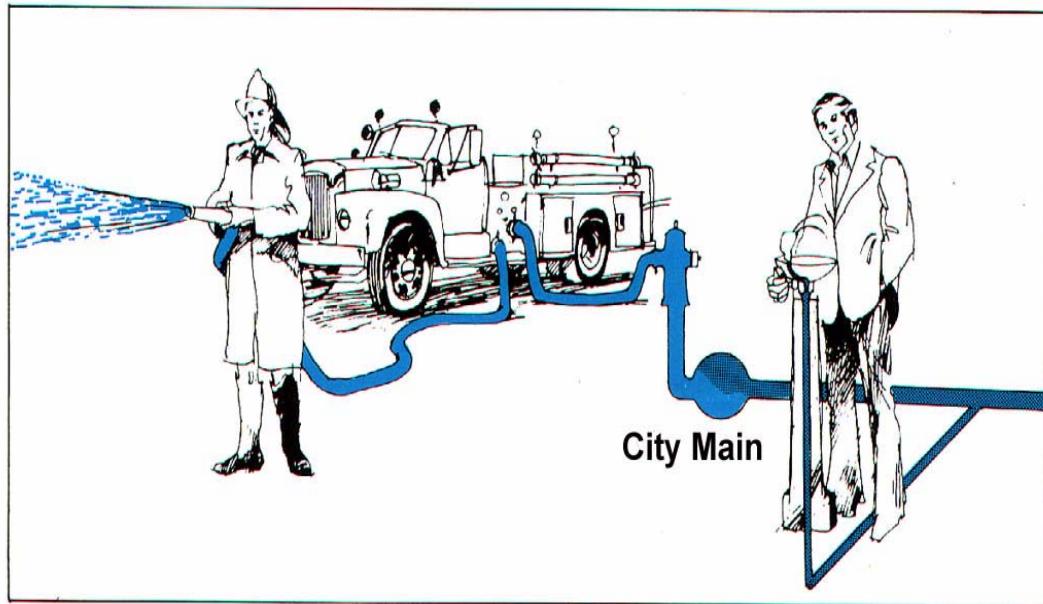


Backpressure Example

Backsiphonage

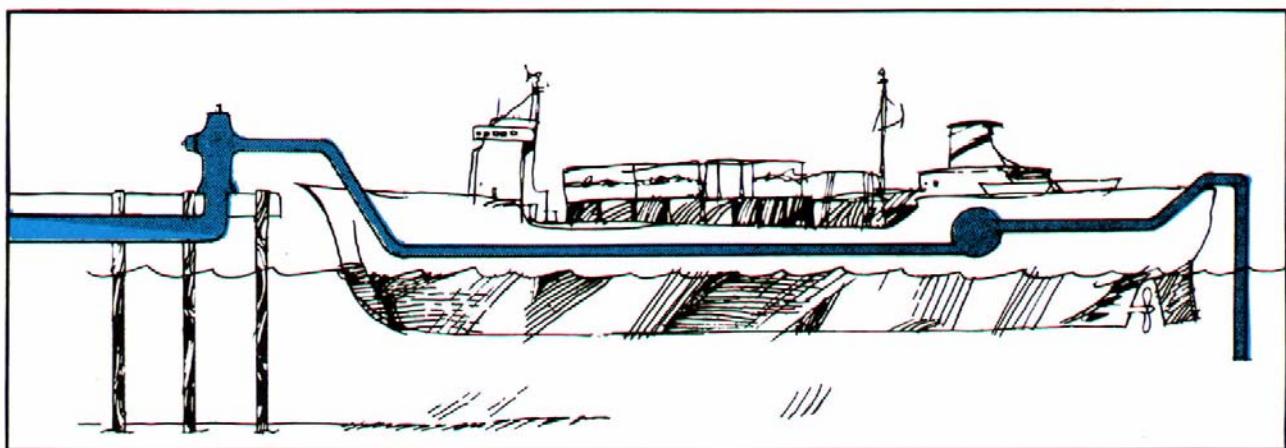
Backsiphonage is backflow caused by a negative pressure (i.e., a vacuum or partial vacuum) in a public water system or consumer's potable water system. The effect is similar to drinking water through a straw.

Backsiphonage can occur when there is a stoppage of water supply due to nearby fire fighting, a break in a water main, etc.



Backpressure Examples:

Booster pumps, pressure vessels

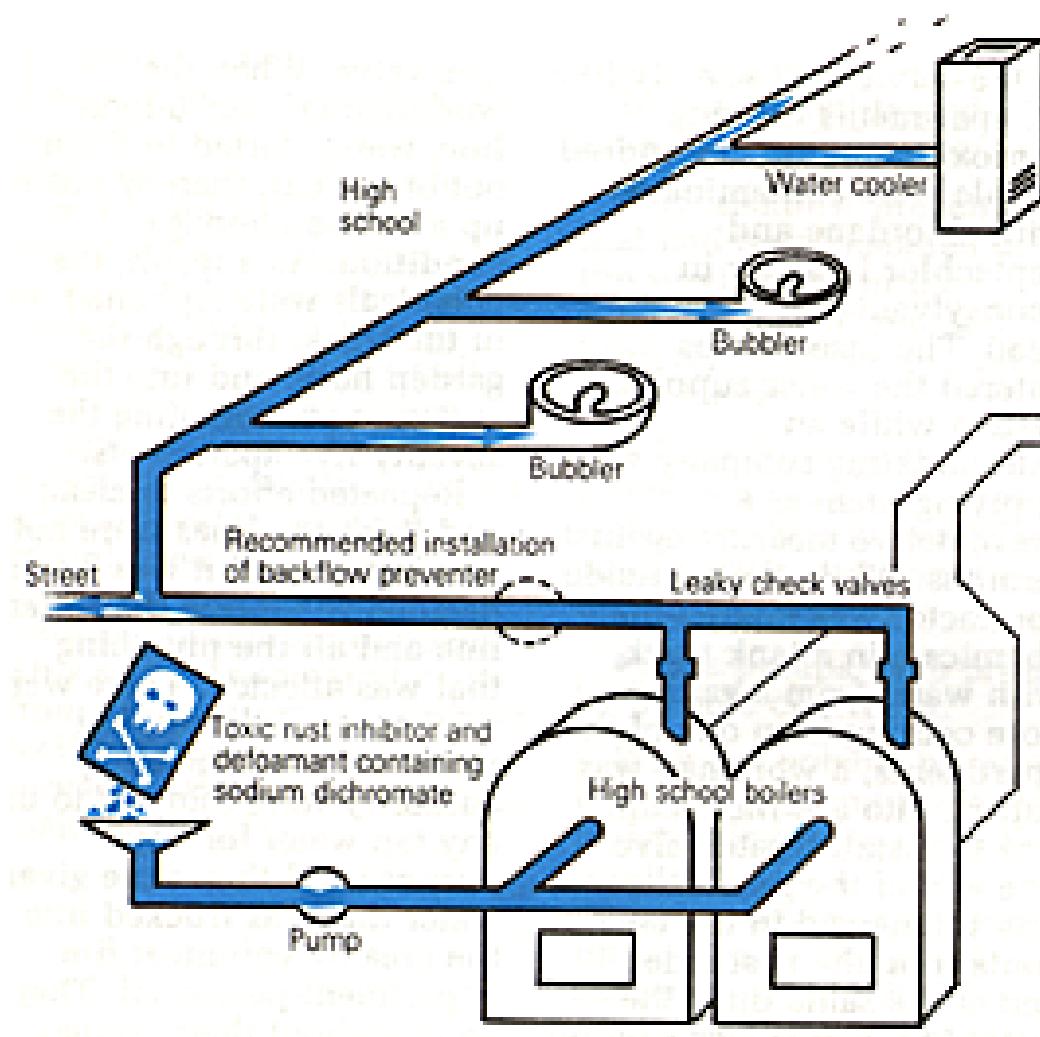


Backpressure

Backpressure is backflow caused by a downstream pressure that is greater than the upstream or supply pressure in a public water system or consumer's potable water system.

Backpressure (i.e., downstream pressure that is greater than the potable water supply pressure) can result from an increase in downstream pressure, a reduction in the potable water supply pressure, or a combination of both. Increases in downstream pressure can be created by pumps, temperature increases in boilers, elevation, etc.

Reductions in potable water supply pressure occur whenever the amount of water being used exceeds the amount of water being supplied, such as during water line flushing, fire fighting, or breaks in water mains.



Backflow Responsibility

The Public Water Purveyor

The primary responsibility of the water purveyor is to develop and maintain a program to prevent or control contamination from water sources of lesser quality or other contamination sources from entering into the public water system.

Under the provisions of the Safe Drinking Water Act of 1974, (**SDWA**) and current Groundwater Protection rules the Federal Government through the EPA, (Environmental Protection Agency), set national standards of safe drinking water. The separate states are responsible for the enforcement of these standards as well as the supervision of public water systems and the sources of drinking water.

The water purveyor or supplier is held responsible for compliance to the provisions of the Safe Drinking Water Act, to provide a warranty that water quality by their operation is in conformance with EPA standards at the source, and is delivered to the customer without the quality being compromised as its delivery through the distribution system.

This is specified in the Code of Federal Regulations (Volume 40, Paragraph 141.2 Section c):

Maximum contaminant level, means the permissible level of a contaminant in water which is delivered to the free flowing outlet of the ultimate user of a public water system, except in the case of turbidity where the maximum permissible level is measured at the point of entry (**POE**) to the distribution system.

Contaminants added to the water under circumstances controlled by the user, except those resulting from corrosion of piping and plumbing caused by water quality, are excluded from this definition.

The Water Consumer

Has the responsibility to prevent contaminants from entering into the public water system by way of their individual plumbing system, and retain the expenses of installation, maintenance, and testing of the approved backflow prevention assemblies installed on their individual water service line.

The Certified General Backflow Tester

Has the responsibility to test, maintain, inspect, repair, and report/notify on approved backflow prevention assemblies as authorized by the persons that have jurisdiction over those assemblies.

Why do water suppliers need to control cross-connections and protect their public water systems against backflow?

Backflow into a public water system can pollute or contaminate the water in that system (i.e., backflow into a public water system can make the water in that system unusable or unsafe to drink), and each water supplier has a responsibility to provide water that is usable and safe to drink under all foreseeable circumstances. Furthermore, consumers generally have absolute faith that water delivered to them through a public water system is always safe to drink. For these reasons, each water supplier must take reasonable precautions to protect its public water system against backflow.

What should water suppliers do to control cross-connections and protect their public water systems against backflow?

Water suppliers usually do not have the authority or capability to repeatedly inspect every consumer's premises for cross-connections and backflow protection. Alternatively, each water supplier should ensure that a proper backflow preventer is installed and maintained at the water service connection to each system or premises that poses a significant hazard to the public water system.

Generally, this would include the water service connection to each dedicated fire protection system or irrigation piping system and the water service connection to each of the following types of premises:

- (1) Premises with an auxiliary or reclaimed water system.
- (2) Industrial, medical, laboratory, marine or other facilities where objectionable substances are handled in a way that could cause pollution or contamination of the public water system.
- (3) Premises exempt from the State Plumbing Code and premises where an internal backflow preventer required under the State Plumbing Code is not properly installed or maintained.
- (4) Classified or restricted facilities.
- (5) Tall buildings.

Each water supplier should also ensure that a proper backflow preventer is installed and maintained at each water loading station owned or operated by the water supplier.

What is a Backflow Preventer?

A backflow preventer is a means or mechanism to prevent backflow. The basic means of preventing backflow is an air gap, which either eliminates a cross-connection or provides a barrier to backflow. The basic mechanism for preventing backflow is a mechanical backflow preventer, which provides a physical barrier to backflow.

The principal types of mechanical backflow preventer are the reduced-pressure principle assembly, the pressure vacuum breaker assembly, and the double check valve assembly.

A secondary type of mechanical backflow preventer is the residential dual check valve.

Degrees of Hazards (HAZARD RATINGS)

High, Contaminant
or
Low, Pollutinal

Two Methods of Protection

Containment Protection, Secondary Protection

This approach utilizes a minimum of backflow devices and isolates the customer from the water main. It virtually insulates the customer from potentially contaminating or polluting the public water supply system.

Containment protection does not protect the customer within his own building, it does effectively remove him from the possibility public water supply contamination.

Containment protection is usually a backflow prevention device as close as possible to the customer's water meter and is often referred to as "**Secondary Protection**". This type of backflow protection is excellent for water purveyors and is the least expense to the water customer but does not protect the occupants of the building.

Internal Protection, Primary Protection

The water purveyor may elect to protect his customers on a domestic internal protective basis and/or "**fixture outlet protective basis.**" In this case, cross-connection-control devices (backflow preventors) are placed at internal hazard locations and at all locations where cross-connections may exist including the "**last free flowing outlet.**"

This type of protection entails extensive cross-connection survey work usually performed by a plumbing inspector or a Cross-Connection Specialist.

In a large water supply system, internal protection in itself is virtually impossible to achieve and police due to the quantity of systems involved, the complexity of the plumbing systems inherent in many industrial sites, and the fact that many plumbing changes are made within commercial establishments that do not get the plumbing department's approval or require that the water department inspects when the work is completed.

Internal protection is the most expensive and best type of backflow protection for both the water purveyor and the customer alike, but it is very difficult to maintain.

In order for the purveyor to provide maximum protection of the water distribution system, consideration should be given to requiring the owner of the premises to provide at his own expense, adequate proof that his internal water supply system complies with the local or state plumbing codes.

In addition, he may be required to install, test, and maintain all backflow protection assemblies.

Types of Backflow Prevention Methods and Assemblies

Approved Air Gap Separation (AG)

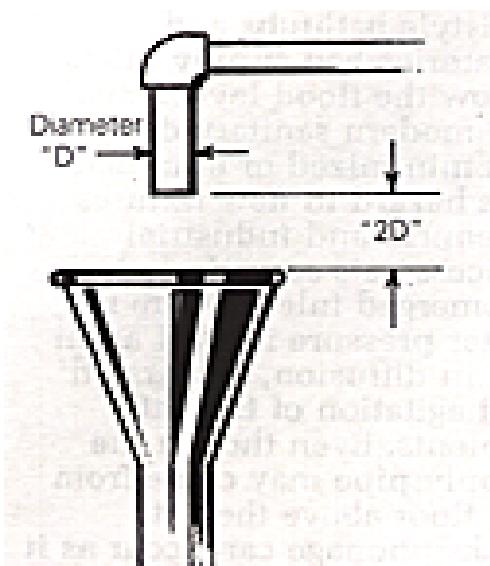
An approved air gap is a physical separation between the free flowing discharge end of a potable water supply pipeline, and the overflow rim of an open or non pressure receiving vessel. These separations must be vertically orientated a distance of at least twice the inside diameter of the inlet pipe, but never less than one inch.

An obstruction around or near an air gap may restrict the flow of air into the outlet pipe and nullify the effectiveness of the air gap to prevent backsiphonage. When the air flow is restricted, such as the case of an air gap located near a wall, the air gap separation must be increased. Also, within a building where the air pressure is artificially increased above atmospheric, such as a sports stadium with a flexible roof kept in place by air blowers, the air gap separation must be

increased.



Which of these ice machine drains are approved air gaps?



Notice the larger pipe is an approved air gap,

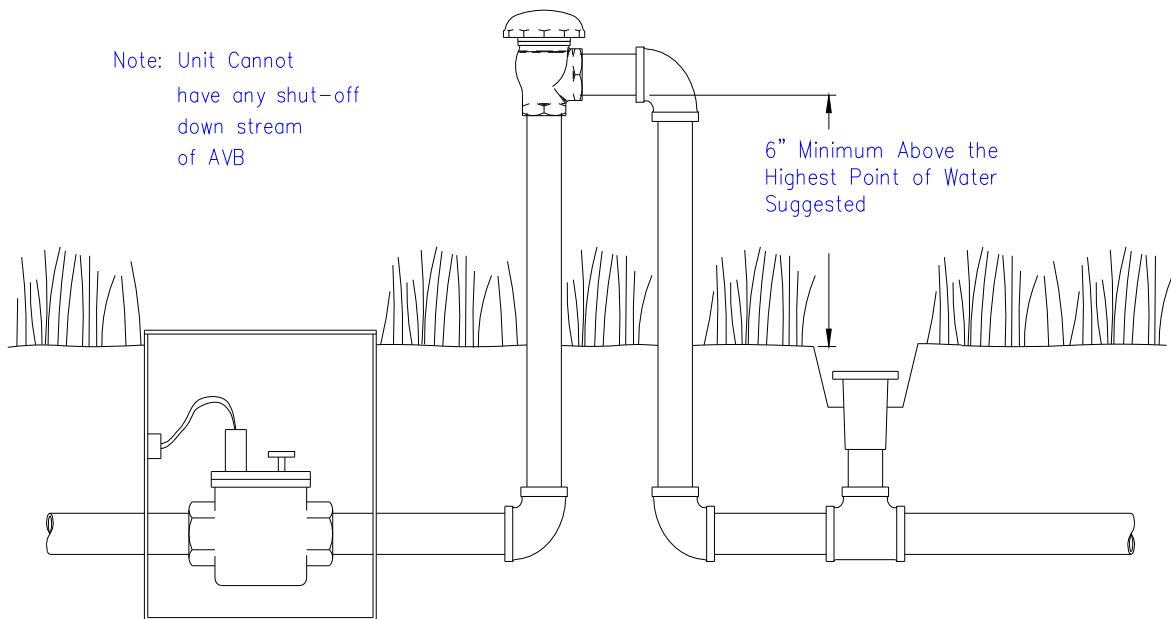
but what about the smaller drain in the rear **Atmospheric Vacuum Breaker (AVB)**

The Atmospheric Vacuum Breaker contains a float check (poppet), a check seat, and an air inlet port. The device allows air to enter the water line when the line pressure is reduced to a gauge pressure of zero or below. The air inlet valve is not internally loaded. To prevent the air inlet from sticking closed, the device must not be installed on the pressure side of a shutoff valve, or wherever it may be under constant pressure more than 12 hours during a 24-hour period.

Atmospheric vacuum breakers are designed to prevent backflow caused by backsiphonage only from low health hazards.

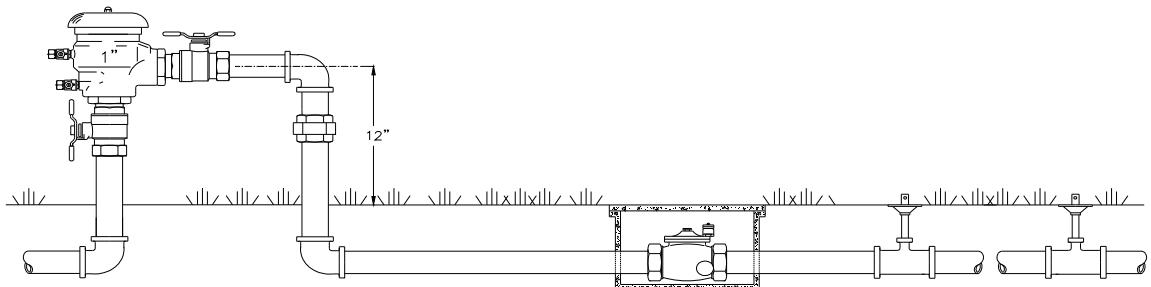
Atmospheric Vacuum Breaker Uses: Irrigation systems, commercial dishwasher and laundry equipment, chemical tanks and laboratory sinks (backsiphonage only, nonpressurized connections)

(Note: hazard relates to the water purveyor's risk assessment; plumbing codes may allow AVB for high hazard fixture isolation).



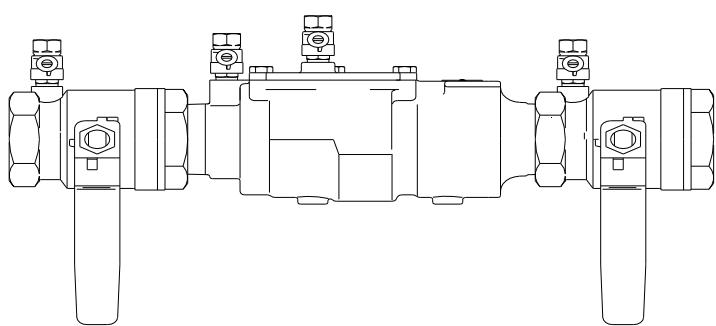
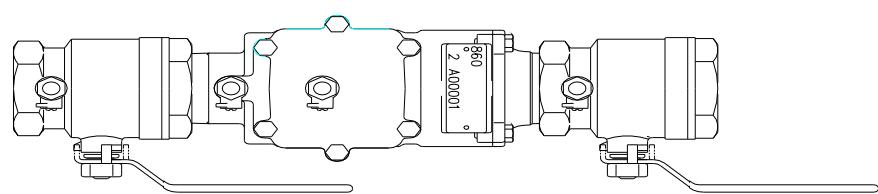
Pressure Vacuum Breaker Assembly (PVB)

The Pressure Vacuum Breaker Assembly consists of a spring loaded check valve, an independently operating air inlet valve, two resilient seated shutoff valves, and two properly located resilient seated test cocks. It shall be installed as a unit as shipped by the manufacturer. The air inlet valve is internally loaded to the open position, normally by means of a spring, allowing installation of the assembly on the pressure side of a shutoff valve.



Double Check Valve Assembly (DC)

The Double Check Valve Assembly consists of two internally loaded check valves, either spring loaded or internally weighted, two resilient seated full ported shutoff valves, and four properly located resilient seated test cocks. This assembly shall be installed as a unit as shipped by the manufacturer. The double check valve assembly is designed to prevent backflow caused by backpressure and backsiphonage from low health hazards. Low pressure at the inlet and high pressure at the outlet conditions would make the Double Check or Reduced Pressure backflow preventer operate to prevent backflow.



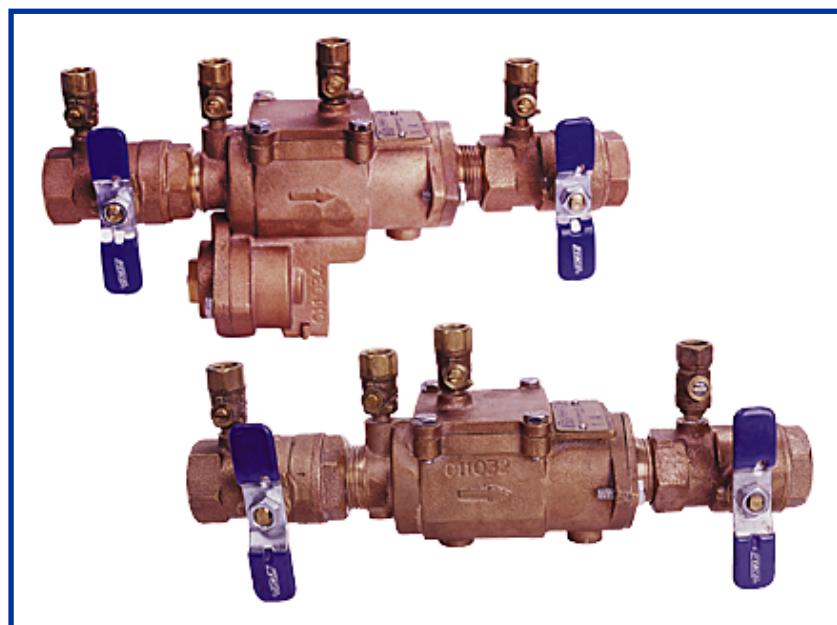
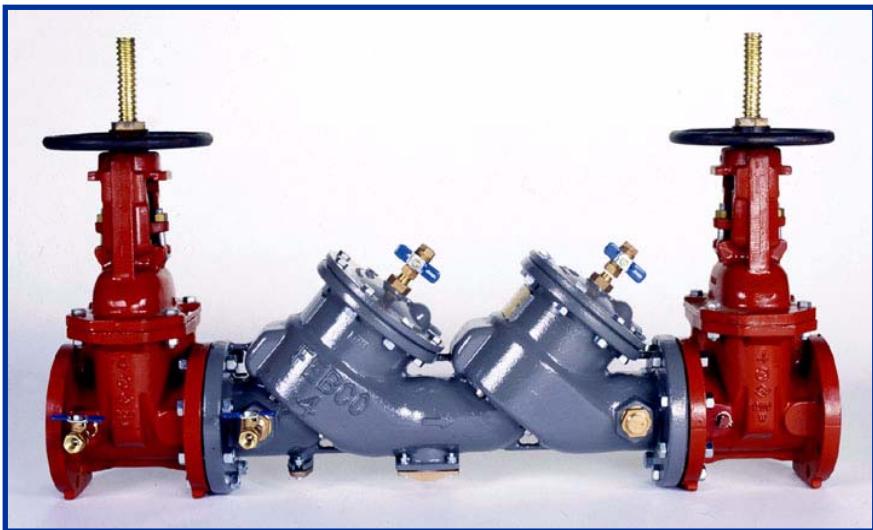
Reduced Pressure Backflow Assembly (RP)

The reduced pressure principle backflow assembly consists of two independently acting spring loaded check valves separated by a spring loaded differential pressure relief valve, two resilient seated full ported shutoff valves, and four properly located resilient seated test cocks. This assembly shall be installed as a unit shipped by the manufacturer.

During normal operation, the pressure between the two check valves, referred to as the zone of reduced pressure, is maintained at a lower pressure than the supply pressure. If either check valve leaks, the differential pressure relief valve maintains a differential pressure of at least two (2) psi between the supply pressure, and the zone between the two check valves, by discharging water to atmosphere. The reduced pressure backflow assembly is designed to prevent backflow caused by backpressure and backsiphonage from low to high health hazards.

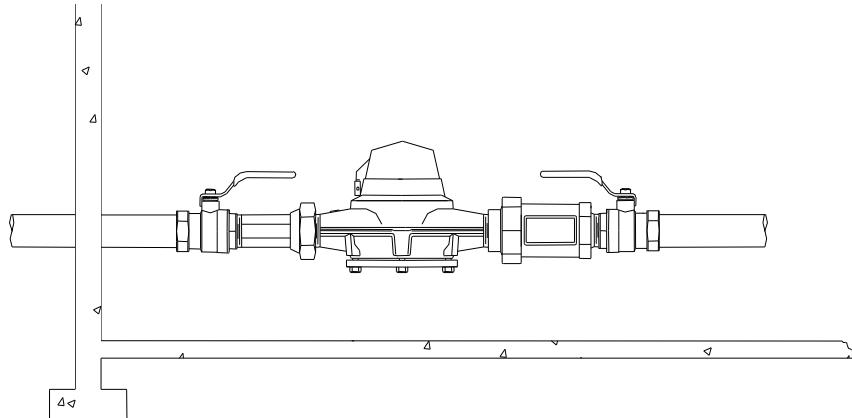


Different Styles of RPs



Residential Dual Check Valve (rdc)

An RDC is similar to a DC in that it is a mechanical backflow preventer consisting of two independently acting, spring-loaded check valves. However, it usually does not include shutoff valves, may or may not be equipped with test cocks or ports, and is generally less reliable than a DC. An RDC is effective against backpressure backflow and backsiphonage but should be used to isolate only nonhealth hazards and is intended for use only in water service connections to single-family homes. Below, a typical Dual Check installation at the water meter and model is a Febco 810.



Why do Backflow Preventers Have to be Tested Periodically?

Mechanical backflow preventers have internal seals, springs, and moving parts that are subject to fouling, wear, or fatigue. Also, mechanical backflow preventers and air gaps can be bypassed. Therefore, all backflow preventers have to be tested periodically to ensure that they are functioning properly. A visual check of air gaps is sufficient, but mechanical backflow preventers have to be tested with properly calibrated gauge equipment.

Backflow prevention devices must be tested annually to ensure that they work properly. It is usually the responsibility of the property owner to have this test done and to make sure that a copy of the test report is sent to the Public Works Department or Water Purveyor. If a device is not tested annually, Public Works or the Water Purveyor will notify the property owner asking them to comply. If the property owner does not voluntarily test their device, the City may be forced to turn off water service to that property. State law requires the City to discontinue water service until testing is complete.



Leaky RP

Fireline Backflow Assemblies



Reduced Pressure Backflow Assembly on a fireline

Types of Pipes Used in the Distribution Field

Several types of pipe are used in water distribution systems, but only the most common types used by operators will be discussed. These piping materials include copper, plastic, galvanized steel, and cast iron. Some of the main characteristics of pipes made from these materials are presented below.

Plastic Pipe (PVC)

Plastic pipe has seen extensive use in current construction. Available in different lengths and sizes, it is lighter than steel or copper and requires no special tools to install. Plastic pipe has several advantages over metal pipe: it is flexible; it has superior resistance to rupture from freezing; it has complete resistance to corrosion; and, in addition, it can be installed aboveground or below ground.

One of the most versatile plastic and polyvinyl resin pipes is the polyvinyl chloride (**PVC**). PVC pipes are made of tough, strong thermoplastic material that has an excellent combination of physical and chemical properties. Its chemical resistance and design strength make it an excellent material for application in various mechanical systems.

Sometimes polyvinyl chloride is further chlorinated to obtain a stiffer design, a higher level of impact resistance, and a greater resistance to extremes of temperature. A CPVC pipe (a chlorinated blend of PVC) can be used not only in cold-water systems, but also in hot-water systems with temperatures up to 210°F. Economy and ease of installation make plastic pipe popular for use in either water distribution and supply systems or sewer drainage systems.



Various types and sizes of coupons or tap cut-outs. You will want to date and collect these cut-outs to determine the condition of the pipe or measure the corrosion.

Plastic Pipe (PVC)

This is currently the most common type of pipe used in distribution systems. It is available in diameters of 1/2" and larger, and in lengths of 10', 20', and 40'. A main advantage is its light weight, allowing for easy installation. A disadvantage is its inability to withstand shock loads. Since it is non-metallic, a tracer wire must be installed with the PVC water main so that it can be located after burial.

The National Sanitation Foundation (**NSF**) currently lists most brands of PVC pipe as being acceptable for potable water use. This information should be stamped on the outside of the pipe, along with working pressure and temperature, diameter and pipe manufacturer.

PVC pipe will have the highest C Factor of all the above pipes. The higher the **C factor** the smoother the pipe.

Cast Iron (CIP)

This is another type of piping material that has been in use for a long time. It is found in diameters from 3" to 48". Advantages of this material are its long life, durability and ability to withstand working pressures up to 350 psi. Disadvantages include the fact that it is heavy, difficult to install and does not withstand shock loading. Although it is not currently the material of choice, there is still a lot of it in the ground.

Ductile Iron Pipe (DIP)

This was developed to overcome the breakage problems associated with cast iron pipe. It can be purchased in 4" to 45" diameters and lengths of 18' to 20'. Its main advantage is that it is nearly indestructible by internal or external pressures. It is manufactured by injecting magnesium into molten cast iron. It is sometimes protected from highly corrosive soils by wrapping the pipe in plastic sheeting prior to installation. This practice can greatly extend the life of this type of pipe.

Steel Pipe

This pipe is often used in water treatment plants and pump stations. It is available in various diameters and in 20' or 21' lengths. Its main advantage is the ability to form it into a variety of shapes. It also exhibits good yielding and shock resistance. It has a smooth interior surface and can withstand pressures up to 250 psi. A disadvantage is that it is easily corroded by both soil and water. To reduce corrosion problems, steel pipe is usually galvanized or dipped in coal-tar enamel and wrapped with coal-tar impregnated felt. At present, however, coal-tar products are undergoing scrutiny from a health standpoint and it is recommended that the appropriate regulatory agencies be contacted prior to use of this material.

Asbestos Cement Pipe (ACP)

This pipe is manufactured from Portland cement, long fibrous asbestos and silica. It is available in diameters from 3" to 36" and in 13' lengths. Its main advantages are its ability to withstand corrosion and its excellent hydraulic flow characteristics due to its smoothness. A major disadvantage is that it is brittle and is easily broken during construction or by shock loading. There is some concern regarding the possible release of asbestos fibers in corrosive water and there has been much debate over the health effects of ingested asbestos. Of greater certainty, however, is the danger posed by inhalation of asbestos fibers.

Asbestos is considered a hazardous material, and precautionary measures must be taken to protect water utility workers when cutting, tapping or otherwise handling this type of pipe.

Galvanized Pipe

Galvanized pipe is commonly used for the water distributing pipes inside a building to supply hot and cold water to the fixtures. This type of pipe is manufactured in 21-ft lengths. It is **galvanized** (coated with zinc) both inside and outside at the factory to resist corrosion. Pipe sizes are based on nominal INSIDE diameters. Inside diameters vary with the thickness of the pipe. Outside diameters remain constant so that pipe can be threaded for standard fittings.

Copper

Copper is one of the most widely used materials for tubing. This is because it does not rust and is highly resistant to any accumulation of scale particles in the pipe. This tubing is available in three different types: **K, L, and M**.

K has the thickest walls, and M, the thinnest walls, with L's thickness in between the other two. The thin walls of copper tubing are soldered to copper fittings. Soldering allows all the tubing and fittings to be set in place before the joints are finished. Generally, faster installation will be the result.

Type K copper tubing is available in either rigid (hard temper) or flexible (soft temper) and is primarily used for underground service in the water distribution systems.

Soft temper tubing is available in 40- or 60-ft coils, while hard temper tubing comes in 12- and 20-ft straight lengths. Type L copper tubing is also available in either hard or soft temper and either in coils or in straight lengths. The soft temper tubing is often used as replacement plumbing because of the tube's flexibility, which allows easier installation.

Type L copper tubing is widely used in water distribution systems.

Type M copper tubing is made in hard temper only and is available in straight lengths of 12 and 20 ft. It has a thin wall and is used for branch supplies where water pressure is low, but it is **NOT** used for mains and risers. It is also used for chilled water systems, for exposed lines in hot-water heating systems, and for drainage piping.



Copper Crimpers

Asbestos Cement Pipe (ACP)

Notice that the pipe has been illegally cut with a powersaw blade. Please check with OSHA on details on handling this common water pipe. ACP will not corrode like metal pipe but will become slow and stained by iron over time.

It is easily cracked by heavy loads, but easily repaired with a clamp.

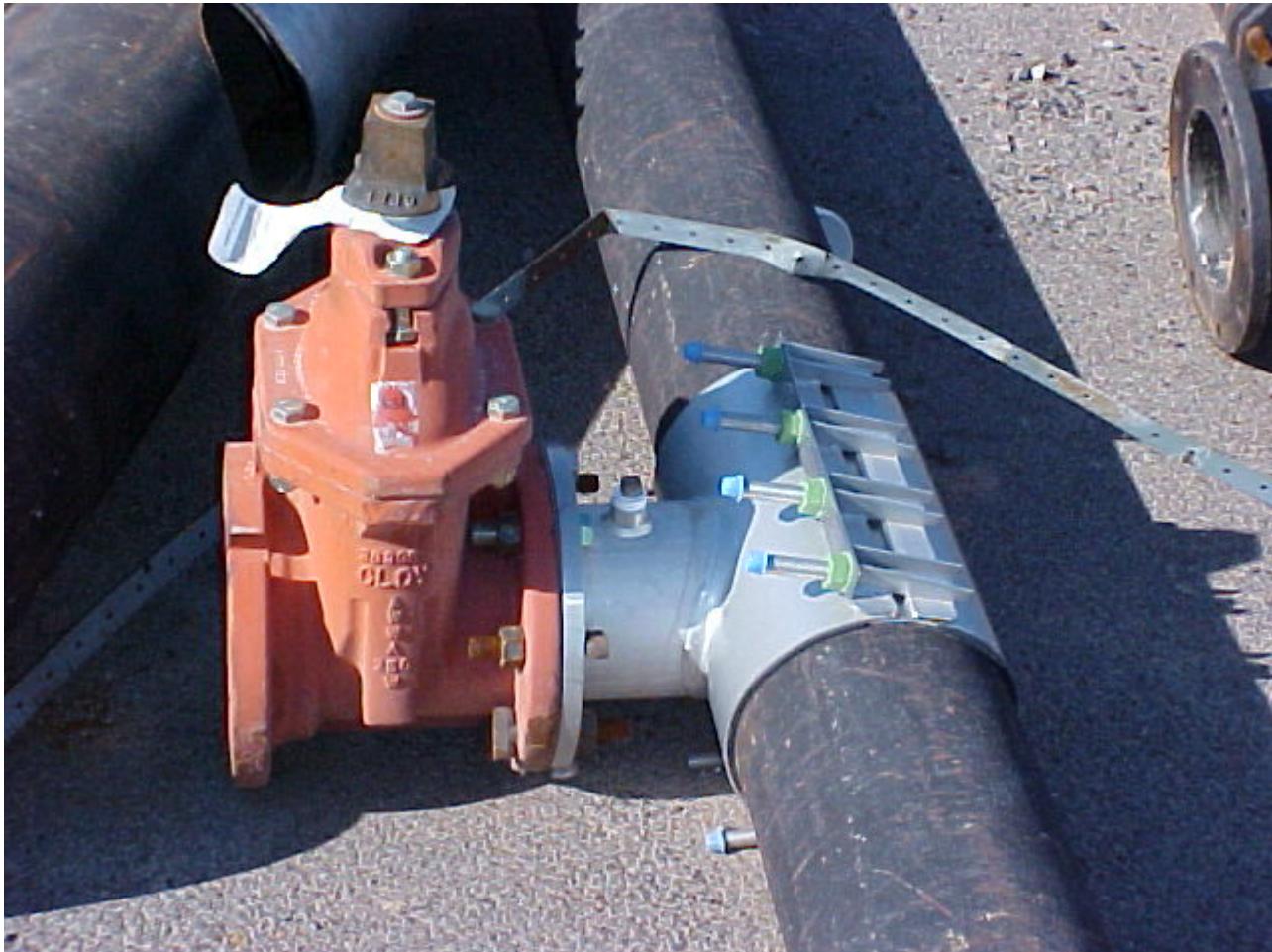


Joints and Fittings

Fittings vary according to the type of piping material used. The major types commonly used in water service include elbows, tees, unions, couplings, caps, plugs, nipples, reducers, and adapters.

Besides bell-and-spigot joints, cast-iron water pipes and fittings are made with either flanged, mechanical, or screwed joints. The screwed joints are used only on small-diameter pipe.

Tapping Sleeve



A Gate Valve is used to isolate sections of water mains. Not to be used to throttle or regulate the flow. A Globe valve should be used to regulate the flow. Be sure to chlorinate or disinfect all distribute part such as valves.

Customers are not inconvenienced by having their water turned off is one of the reason we utilize pressure taps or hot taps. Some of you are lucky to punch a hole with a ball-peen hammer.

Caps

A pipe cap is a fitting with a female (inside) thread. It is used like a plug, except that the pipe cap screws on the male thread of a pipe or nipple.

Couplings

The three common types of couplings are straight coupling, reducer, and eccentric reducer. The **STRAIGHT COUPLING** is for joining two lengths of pipe in a straight run that do not require additional fittings. A run is that portion of a pipe or fitting continuing in a straight line in the direction of flow.

A **REDUCER** is used to join two pipes of different sizes. The **ECCENTRIC REDUCER** (also called a **BELL REDUCER**) has two female (inside) threads of different sizes with centers so designed that when they are joined, the two pieces of pipe will not be in line with each other, but they can be installed to provide optimum drainage of the line.

Elbows (OR ELLS) 90° AND 45°

These fittings (fig. 8-5, close to middle of figure) are used to change the direction of the pipe either 90 or 45 degrees. **REGULAR** elbows have female threads at both outlets. **STREET** elbows change the direction of a pipe in a close space where it would be impossible or impractical to use an elbow and nipple.

Both 45 and 90-degree street elbows are available with one female and one male threaded end. The **REDUCING** elbow is similar to the 90-degree elbow except that one opening is smaller than the other is.

Nipples

A nipple is a short length of pipe (12 in. or less) with a male thread on each end. It is used for extension from a fitting. At times, you may use the **DIELECTRIC** or **INSULATING TYPE** of fittings. These fittings connect underground tanks or hot-water tanks. They are also used when joining pipes of dissimilar metals. These nipples help slow down corrosion that starts inside the pipe and works to the outside of the pipe. Do not heat or solder dielectric fittings; you may melt the plastic coating on them. Zinc is a coating on the outside and inside of pipes to slow corrosion. This process is called "**galvanization**".

Tees

A tee is used for connecting pipes of different diameters or for changing the direction of pipe runs. A common type of pipe tee is the **STRAIGHT** tee, which has a straight-through portion and a 90-degree takeoff on one side.



Notice the type of pipe connection device.
This is known as a "Restraining Flange".

All three openings of the straight tee are of the same size. Another common type is the **REDUCING** tee, similar to the straight tee just described, except that one of the threaded openings is of a different size than the other.

Unions

There are two types of pipe unions. The **GROUND JOINT UNION** consists of three pieces, and the **FLANGE UNION** is made in two parts. Both types are used for joining two pipes together and are designed so that they can be disconnected easily joined, the two pieces of pipe will not be in line with each other, but they can be installed to provide optimum drainage of the line.



Soldering pipe, there are several types of copper pipe. Soft and rigid, K-Green, L-Blue, M-Red, and DWV-yellow. You can no longer use lead solder for potable water. Most distribution workers are not allowed to solder pipe but instead utilize compression style fittings.

Water Main Installation Procedures

Installation of new or replacement pipe sections should be in accordance with good construction practices. The line must be buried a minimum of 30" below the ground surface to prevent freezing. The line must be bedded and backfilled properly insuring protection from weather and surface loadings.

Also, thrust blocking (**Kickers**) at all bends, tees, and valves is essential to hold the pipe in place and prevent separation of line sections. Thrust blocking is not necessary if the pipe is welded.

Disinfection of new installations or repaired sections is required prior to placing them in service. This can be accomplished by filling the line with a 25 mg/l free chlorine solution and allowing it to stand for 24 hours. Valves and fittings used in the waterworks industry are made of cast iron, steel, brass, stainless and fiberglass.

Enough gate valves should be placed throughout the system to enable problem areas (leaks, etc.) to be isolated and repaired with minimal service disruption.

Air relief valves should be installed at high points in the system. Valves should be installed with valve boxes and covers.

Regardless of the type of pipe installed, certain maintenance routines should be performed on the distribution system to maintain water quality and optimal service. These programs should be scheduled and performed on a regular basis.

Flushing at blowoffs on dead end lines and at fire hydrants throughout the system should be done at least twice per year. Flushing is needed to remove stagnant water in dead ends and to remove accumulated sediment that results from turbidity, iron, manganese, etc.

This should also help minimize customer complaints of water quality. Flushing should always be done from the source to the ends of the system. Affected customers should be notified of this process in advance. To do an adequate job of flushing, the flow should reach a velocity of at least 2.5 feet per second, known as the "**minimum cleansing velocity**" of the system (at hydrant locations).

These tests are important to determine the adequacy of the distribution system in transmitting water, particularly during days of peak demand. Also, these tests can help determine if pipe capacity is decreasing over time due to internal corrosion or deposits. Pressure tests should be done at various locations in the distribution system several times per year. This helps to monitor the performance of the system and alert the operator to problems such as leaks or internal deposits. It is sometimes advantageous to have certain points in the system continuously monitored to provide a constant evaluation of the system.

Fire hydrants which are classified as "**dry-barrel**" are used in areas where freezing may occur.

Water Softening

Water softening is a method of removing from water the minerals that make it hard. Hard water does not dissolve soap readily. It forms scale in pipes, boilers, and other equipment in which it is used.

The principal methods of softening water are the lime soda process and the ion exchange process.

In the **lime soda process**, soda ash and lime are added to the water in amounts determined by chemical tests. These chemicals combine with the calcium and magnesium in the water to make insoluble compounds that settle to the bottom of the water tank.

In the **ion exchange process**, the water filters through minerals called **zeolites**. As the water passes through the filter, the sodium ions in the zeolite are exchanged for the calcium and magnesium ions in the water, and the water is softened. After household softeners become exhausted, a strong solution of **sodium chloride** (salt) is passed through the filter to replace the sodium that has been lost. The use of two exchange materials makes it possible to remove both metal and acid ions from water. Some cities and towns, however, prohibit or restrict the use of ion exchange equipment on drinking water, pending the results of studies on how people are affected by the consumption of the added sodium in softened water.

Calcium and magnesium in water create hard water, and high levels can clog pipes. The best way to soften water is to use a water softener unit connected into the water supply line. You may want to consider installing a separate faucet for unsoftened water for drinking and cooking. Water softening units also remove iron.

The containers hold the resin for the de-ionization.



Softens Household Water

The most common way to soften household water is to use a water softener. Softeners may also be safely used to remove up to about 5 milligrams per liter of dissolved iron if the water softener is rated for that amount of iron removal. Softeners are automatic, semi-automatic, or manual. Each type is available in several sizes and is rated on the amount of hardness it can remove before regeneration is necessary.

Using a softener to remove iron in naturally soft water is not advised, a green-sand filter is a better method. When the resin is filled to capacity, it must be recharged. Fully automatic softeners regenerate on a preset schedule and return to service automatically. Regeneration is usually started by a preset time clock, some units are started by water use meters or hardness detectors. Semi automatic softeners have automatic controls for everything except for the start of regeneration. Manual units require manual operation of one or more valves to control back washing, brining and rinsing. In many areas, there are companies that provide a water softening service. For a monthly fee the company installs a softener unit and replaces it periodically with a freshly charged unit.

The principle behind water softening is really just simple chemistry. A water softener contains resin beads which hold electrically charged ions. When hard water passes through the softener, calcium and magnesium ions are attracted to the charged resin beads. It's the resulting removal of calcium and magnesium ions that produces "**soft water**."

When the resin beads in your softener become saturated with calcium and magnesium ions, they need to be recharged. Sodium ions from the water softening salt reactivate the resin beads so they can continue to do their job. Without sufficient softening salt, your water softener is less efficient. As a rule, you should check your water softener once a week to be sure the salt level is always at least one quarter full.



Resin Beads with small stones from a nearby groundwater well.

Mechanical Water Treatment Softeners

Mechanical water treatment softening units can be permanently installed into the plumbing system to continuously remove calcium and magnesium.

Water treatment softeners operate on the ion exchange process. In this process, water passes through a media bed, usually sulfonated polystyrene beads.

The beads are supersaturated with sodium. The ion exchange process takes place as hard water passes through the softening material. The hardness minerals attach themselves to the resin beads while sodium on the resin beads is released simultaneously into the water.

When the resin becomes saturated with calcium and magnesium, it must be recharged. The recharging is done by passing a salt (**brine**) solution through the resin. The sodium replaces the calcium and magnesium which are discharged in the waste water.

Hard water treated with an ion exchange water softener has sodium added. According to the Water Quality Association (**WQA**), the ion exchange softening process adds sodium at the rate of about 8 mg/liter for each grain of hardness removed per gallon of water.

For example, if the water has a hardness of 10 grains per gallon, it will contain about 80 mg/liter of sodium after being softened in an ion exchange water softener if all hardness minerals are removed.

Because of the sodium content of softened water, some individuals may be advised by their physician not to install water softeners, to soften only hot water or to bypass the water softener with a cold water line to provide unsoftened water for drinking and cooking, usually to a separate faucet at the kitchen sink.

Mechanically softened water is not recommended for watering plants, lawns, and gardens due to its sodium content.



**The container behind the salt pallet is a high concentration of salt and water.
(Brine)**



Here is a nice little trap for a small car or two. Believe it or not, there are two men inside this excavation and the ladders are nice and dry outside the hole. Never, ever, work without shoring or ladders. Never work outside the shield either. Always wear your hard hat and never pick your ear. This is a certain death trap.



What you need to know about Water Filters.

Water filters generally come in two forms. Portable ion exchange water filters, and reverse osmosis water filters. Both are used for "**point of use**" drinking water, that is, to filter out harmful or unwanted particles before the water is used for human consumption.

Reverse Osmosis works by forcing the water through a semi-permeable membrane that stops certain particles from passing through.

Portable water filters work using a cartridge containing activated carbon and ion exchange resin. The carbon absorbs and helps reduce the levels of chlorine and chlorine compounds, as well as pesticides, color and other organic substances. This improves taste and appearance. The ion exchange resin works to reduce temporary hardness.

Activated Carbon Filtration



Activated carbon has been used for many years to solve water problems. In the beginning, its use was more art than science. Today, however, we understand more about what activated carbon can remove and how it removes impurities.

Activated carbon quickly and effectively removes chlorine from water.

The presence of organic matter in water can cause color, taste and odor complaints. Activated carbon adsorbs organic matter in its extensive network of pores. The adsorption process takes time, so service rates should be limited to 5 gpm/ft (12m/hr) or less for these applications.

SOC

Synthetic organic chemicals (**SOC**) include all man-made organics, some of which are volatile organic compounds (**VOC**). Activated carbon can substantially reduce many VOCs such as benzene, trichloroethane and carbon tetrachloride.

Activated carbon also removes SOCs such as Alachlor, EDB and toluene. The EPA is establishing limits for these chemicals in public drinking water supplies.

Before recommending treatment, water suspected of containing any of these and other substances must be analyzed to determine their concentrations and whether they exceed EPA standards.

Activated carbon beds compact with use so they may need occasional backwashing, however, backwash carbon as little as possible to prevent loss of the fragile material. Also, contaminant-laden carbon may migrate toward the bottom of the bed during backwash and reduce filter performance. When operating carbon on turbid water supplies, remove suspended particles with a depth filter before treating it with activated carbon. A carbon filter typically backwashes at 10 gpm/ft (25 m/hr) for about 10 minutes, followed by a 5 minute downflow rinse.

Over a period of several months to two years, the carbon's adsorption capacity diminishes. The exhausted carbon bed should be replaced with fresh carbon. The old carbon should be hauled to an approved disposal facility.



Membrane Filtration Processes

In 1748, the French physicist Nollet first noted that water would diffuse through a pig bladder membrane into alcohol. This was the discovery of osmosis, a process in which water from a dilute solution will naturally pass through a porous membrane into a concentrate solution. Over the years, scientists have attempted to develop membrane that would be useful in industrial processes, but it wasn't until the late 1950s that membranes were produced that could be used for what is known as reverse osmosis. In reverse osmosis, water is forced to move through a membrane from a concentrate solution to a dilute solution.

Since that time, continual improvements and new developments have been made in membrane technology, resulting in ever-increasing uses in many industries. In potable water treatment, membranes have been used for desalination, removal of dissolved inorganic and organic chemicals, water softening, and removal of the fine solids.

In particular, membrane technology enables some water systems having contaminated water sources to meet new, more stringent regulations. In some cases, it can also allow secondary sources, such as brackish groundwater, to be used. There is great potential for the continuing wide use of membrane filtration processes in potable water treatment, especially as technology is improved and cost are reduced.

Description of Membrane Filtration Processes

In the simplest membrane processes, water is forced through a porous membrane under pressure while suspended solid, large molecules or ions are held back or rejected.

Types of Membrane Filtration Processes

The two general classes of membrane processes, based on the driving force used to make the process work, are:

- Pressure-driven processes
- Electric-driven processes

Pressure-Driven Processes

The four general membrane processes that operate by applying pressure to the raw water are:

- Microfiltration
- Ultratiltration
- Nanofiltration
- Reverse Osmosis



Microfiltration

Microfiltration (**MF**) is a process in which water is forced under pressure through a porous membrane. Membranes with a pore size of 0.45 mm are normally used; this size is relatively large compared with the other membrane filtration processes.

This process has not been generally applicable to drinking water treatment because it either does not remove substances that require removal from potable water, or the problem substances can be removed more economically using other processes. The current primary use of MF is by industries to remove very fine particles from process water, such as in electronic manufacturing. In addition, the process has also been used as a pretreatment for other membrane processes. In particular, RO membranes are susceptible to clogging or binding unless the water being processed is already quite clean.

However, in recent years, microfiltration has been proposed as a filtering method for particles resulting from the direct filtration process. Traditionally, this direct filtration process has used the injection of coagulants such as alum or polymers into the raw water stream to remove turbidity such as clay or silts. The formed particles were then removed by rapid sand filters. The suggested their use to improve filtering efficiency, especially for small particles that could contain bacterial and protozoan life.

Ultrafiltration

Ultrafiltration (**UF**) is a process that uses a membrane with a pore size generally below 0.1 m. The smaller pore size is designed to remove colloids and substances that have larger molecules, which are called high-molecular-weight materials.

UF membranes can be designed to pass material that weigh less than or equal to a certain molecular weight. This weight is called the molecular weight cutoff (**MWC**) of the membrane. Although UF does not generally work well for removal of salt or dissolved solids, it can be used effectively for removal of most organic chemicals.

Nanofiltration

Nanofiltration (**NF**) is a process using a membrane that will reject even smaller molecules than UF. The process has been used primarily for water softening and reduction of total dissolved solids (**TDS**). NF operates with less pressure than reverse osmosis and is still able to remove a significant proportion of inorganic and organic molecules. This capability will undoubtedly increase the use of NF for potable water treatment.

Reverse Osmosis

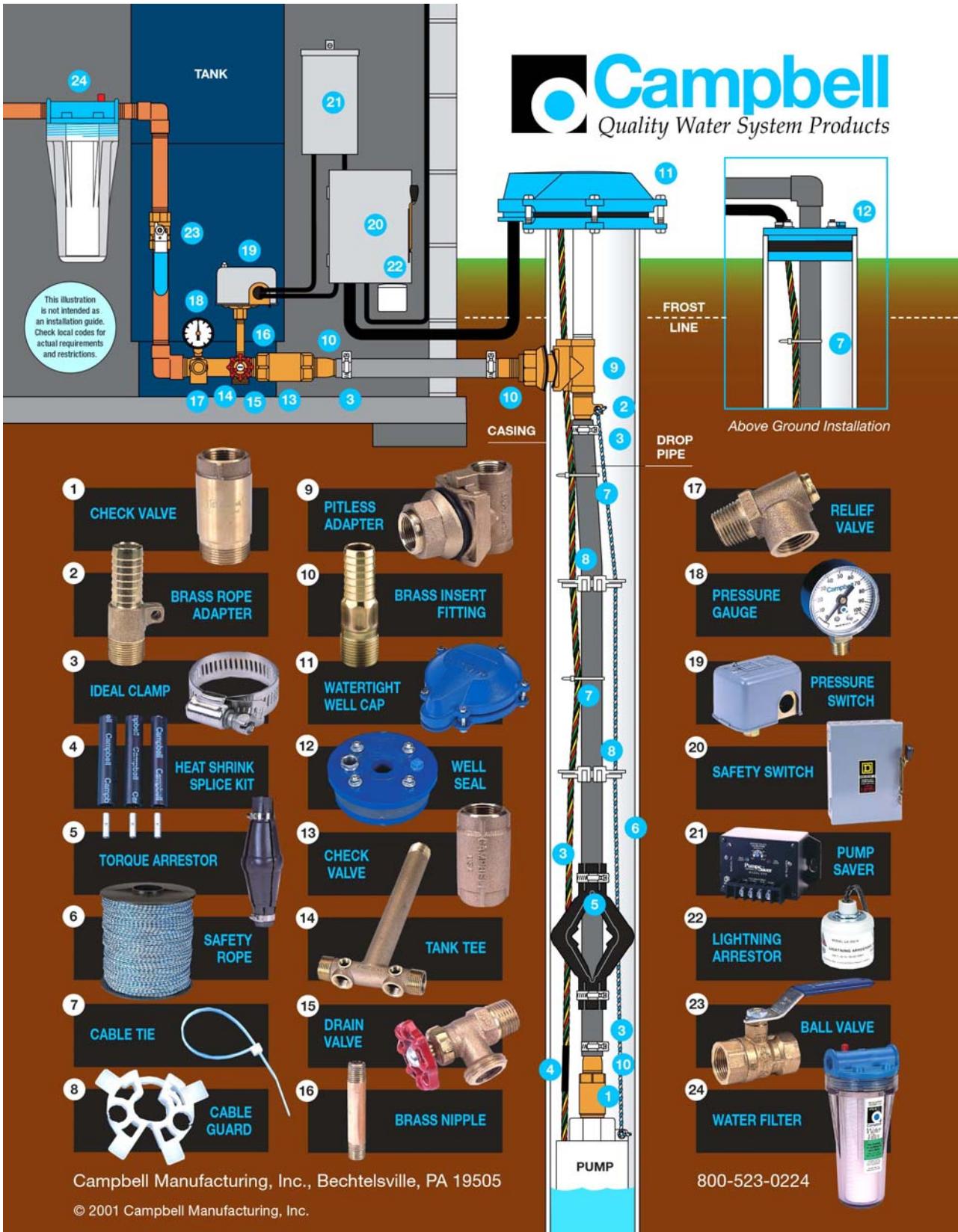
Reverse Osmosis (**RO**) is a membrane process that has the highest rejection capability of all the membrane processes. These RO membranes have very low MWC pore size that can reject ions at very high rates, including chloride and sodium.

Water from this process is very pure due to the high reject rates. The process has been used primarily in the water industry for desalination of seawater because the capital and operating costs are competitive with other processes for this service. The RO also works on most organic chemicals, and radionuclides and microorganisms.

Pump and Motor Operation Section

Pump Objectives

- ★ **What is a pump?**
- ★ **Identify different types of pumps and related parts.**
- ★ **Identify the main purpose of a motor starter.**
- ★ **Describe the main use of AC and DC motors in the plant.**
- ★ **Describe the operations of level sensor controls.**
- ★ **Identify and describe the most commonly used pumps.**
- ★ **Identify the suction and discharge valving.**
- ★ **Distinguish between discharge head, total head, suction head, and suction lift.**
- ★ **Describe information to be obtained from pump performance graphs.**
- ★ **Identify types of couplings, bearings, seals and other pump components.**
- ★ **Describe the importance of alignment of coupling.**
- ★ **Indicate when packing seals need to be replaced.**
- ★ **Describe cavitation.**
- ★ **Describe water hammer.**
- ★ **State the basic principles of positive displacement pumps.**



Pump Definitions (*Larger Glossary in the rear of this manual*)

Fluid: Any substance that can be pumped, such as oil, water, refrigerant, or even air.

Gasket: Flat material that is compressed between two flanges to form a seal.

Gland follower: A bushing used to compress the packing in the stuffing box and to control leakoff.

Gland sealing line: A line that directs sealing fluid to the stuffing box.

Horizontal pumps: Pumps in which the Center line of the shaft is horizontal.

Impeller: The part of the pump that increases the speed of the fluid being handled.

Inboard: The end of the pump closest to the motor.

Inter-stage diaphragm: A barrier that separates stages of a multi-stage pump.

Key: A rectangular piece of metal that prevents the impeller from rotating on the shaft.

Keyway: The area on the shaft that accepts the key.

Kinetic energy: Energy associated with motion.

Lantern ring: A metal ring located between rings of packing that distributes gland sealing fluid.

Leak-off: Fluid that leaks from the stuffing box.

Mechanical seal: A mechanical device that seals the pump stuffing box.

Mixed flow pump: A pump that uses both axial-flow and radial-flow components in one Impeller.

Multi-stage pumps: Pumps with more than one impeller.

Outboard: The end of the pump farthest from the motor.

Packing: Soft, pliable material that seals the stuffing box.

Positive displacement pumps: Pumps that move fluids by physically displacing the fluid inside the pump.

Radial bearings: Bearings that prevent shaft movement in any direction outward from the center line of the pump.

Radial flow: Flow at 90° to the center line of the shaft.

Retaining nut: A nut that keeps the part in place.

Rotor: The rotating parts, usually including the impeller, shaft, bearing housings and all other parts between the bearing housing and the impeller.

Score: To cause lines, grooves or scratches.

Shaft: A cylindrical bar that transmits power from the driver to the pump impeller.

Shaft sleeve: A replaceable tubular covering on the shaft.

Shroud: The metal covering over the vanes of an impeller.

Slop drain: The drain from the area that collects leak-off from the stuffing box.

Slurry: A thick viscous fluid, usually containing small particles.

Stages: Impellers in a multi-stage pump.

Stethoscope: A metal device that can amplify and pinpoint pump sounds.

Strainer: A device that retains solid pieces while letting liquids through.

Stuffing box: The area of the pump where the shaft penetrates the casing.

Suction: The place where fluid enters the pump.

Suction eye: The place where fluid enters the pump impeller.

Throat bushing: A bushing at the bottom of the stuffing box that prevents packing from being pushed out of the stuffing box into the suction eye of the impeller.

Thrust: Force, usually along the center line of the pump.

Thrust bearings: Bearings that prevent shaft movement back and forth in the same direction as the center line of the shaft.

Troubleshooting: Locating a problem.

Vanес: The parts of the impeller that push and increase the speed of the fluid in the pump.

Vertical pumps: Pumps in which the center line of the shaft runs vertically.

Volute: The part of the pump that changes the speed of the fluid into pressure.

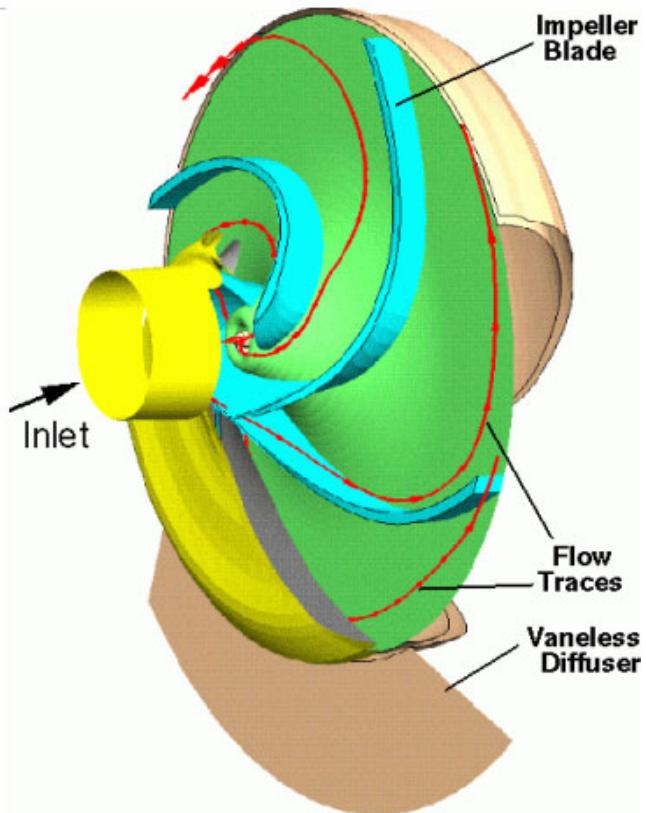
Wearing rings: Replaceable rings on the impeller or the casing that wear as the pump operates.

Basic Water Pump

The water pumps in distribution systems are centrifugal pumps. These pumps work by spinning water around in a circle inside a cylindrical pump housing. The pump makes the water spin by pushing it with an impeller. The blades of this impeller project outward from an axle like the arms of a turnstile and, as the impeller spins, the water spins with it. As the water spins, the pressure near the outer edge of the pump housing becomes much higher than near the center of the impeller.

There are many ways to understand this rise in pressure, and here are two:

First, you can view the water between the impeller blades as an object traveling in a circle. Objects do not naturally travel in a circle--they need an inward force to cause them to accelerate inward as they spin. Without such an inward force, an object will travel in a straight line and will not complete the circle. In a centrifugal pump, that inward force is provided by high-pressure water near the outer edge of the pump housing. The water at the edge of the pump pushes inward on the water between the impeller blades and makes it possible for that water to travel in a circle. The water pressure at the edge of the turning impeller rises until it is able to keep water circling with the impeller blades.



You can also view the water as an incompressible fluid, one that obeys Bernoulli's equation in the appropriate contexts. As water drifts outward between the impeller blades of the pump, it must move faster and faster because its circular path is getting larger and larger. The impeller blades work on the water so it moves faster and faster. By the time the water has reached the outer edge of the impeller, it is moving quite fast. However, when the water leaves the impeller and arrives at the outer edge of the cylindrical pump housing, it slows down.

Here is where Bernoulli's equation figures in. As the water slows down and its kinetic energy decreases, that water's pressure potential energy increases (**to conserve energy**). Thus, the slowing is accompanied by a pressure rise. That is why the water pressure at the outer edge of the pump housing is higher than the water pressure near the center of the impeller.

When water is actively flowing through the pump, arriving through a hole near the center of the impeller and leaving through a hole near the outer edge of the pump housing, the pressure rise between center and edge of the pump is not as large.

Vertical Turbine Pump



**Large Diameter Submersible Pump,
Motor and Column Pipe**

**Larger check valve installed on
submersible pump to prevent water
hammer (notice motor shaft splines).**

Types of Water Well Pumps

The most common type of water well pumps used for municipal and domestic water supplies are **variable displacement** pumps. A variable displacement pump will produce at different rates relative to the amount of pressure or lift the pump is working against. **Centrifugal** pumps are variable displacement pumps that are by far used the most. The water production well industry almost exclusively uses **Turbine** pumps, which are a type of centrifugal pump. Gauges are often used with pumps so that pumping efficiency can be determined.

The turbine pump utilizes **impellers** enclosed in single or multiple **bowl**s or stages to lift water by **centrifugal force**. The impellers may be of either a **semi-open** or **closed type**. Impellers are rotated by the **pump motor**, which provides the horsepower needed to overcome the pumping head. A more thorough discussion of how these and other pumps work is presented in the pump section of this course. The size and number of stages, horsepower of the motor, and pumping head are the key components relating to the pump's lifting capacity.

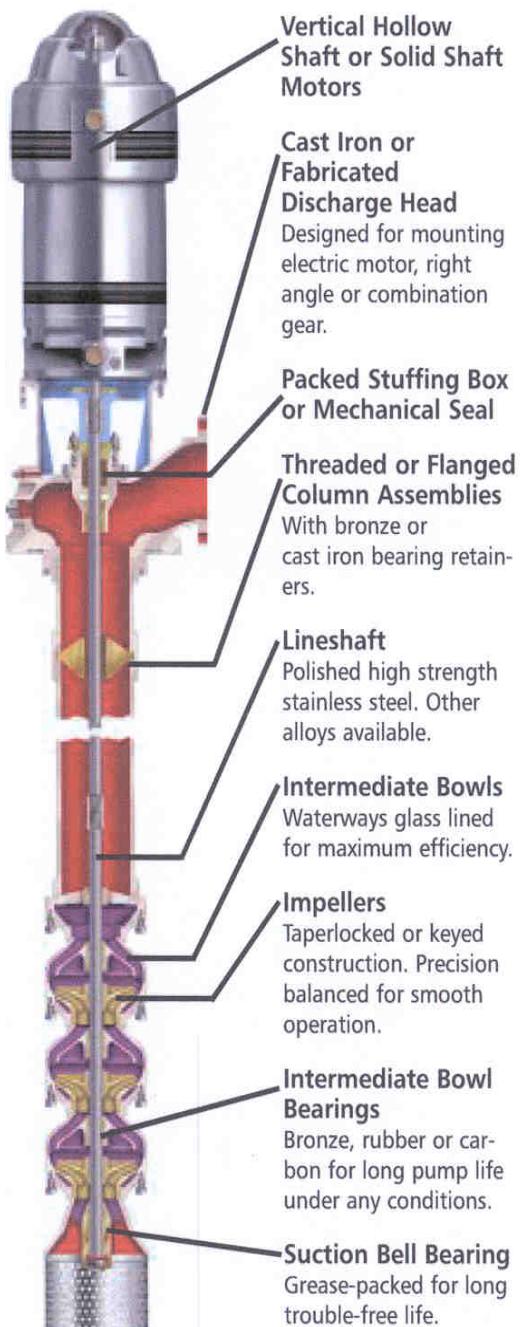
Vertical turbine pumps are commonly used in groundwater wells. These pumps are driven by a shaft rotated by a motor on the surface. The shaft turns the impellers within the pump housing while the water moves up the column. This type of pumping system is also called a **line-shaft turbine**. The rotating shaft in a line shaft turbine is actually housed within the column pipe that delivers the water to the surface. The size of the column, impeller, and bowls are selected based on the desired pumping rate and lift requirements.

Column pipe sections can be threaded or coupled together while the drive shaft is coupled and suspended within the column by **spider bearings**. The spider bearings provide both a seal at the column pipe joints and keep the shaft aligned within the column. The water passing through the column pipe serves as the lubricant for the bearings. Some vertical turbines are lubricated by oil rather than water. These pumps are essentially the same as water lubricated units only the drive shaft is enclosed within an **oil tube**.

Food grade oil is supplied to the tube through a gravity feed system during operation. The oil tube is suspended within the column by **spider flanges** while the line shaft is supported within the oil tube by **brass or redwood bearings**. A continuous supply of oil lubricates the drive shaft as it proceeds downward through the oil tube. A small hole located at the top of the pump bowl unit allows excess oil to enter the well. This results in the formation of an oil film on the water surface within oil-lubricated wells. Careful operation of oil lubricated turbines is needed to ensure that the pumping levels do not drop enough to allow oil to enter the pump.

Both water and oil lubricated turbine pump units can be driven by electric or fuel powered motors. Most installations use an electric motor that is connected to the drive shaft by a keyway and nut. However, where electricity is not readily available, fuel powered engines may be connected to the drive shaft by a right angle drive gear. Also, both oil and water lubricated systems will have a strainer attached to the intake to prevent sediment from entering the pump. When the line shaft turbine is turned off water will flow back down the column, turning the impellers in a reverse direction. A pump and shaft can easily be broken if the motor were to turn on during this process. This is why a **time delay** or **ratchet** assembly is often installed on these motors to either prevent the motor from turning on before reverse rotation stops or simply not allow it to reverse at all.

Common Elements of Vertical Turbines



Vertical Turbine

Pump Being Removed →

(notice line shaft)



Closed Pump Impeller→



Submersible Pumps

Submersible pumps are, in essence, very similar to turbine pumps. They both use impellers rotated by a shaft within the bowls to pump water. However, the **pump portion is directly connected to the motor**. The pump shaft has a keyway in which the splined motor end shaft inserts. The motor is bolted to the pump housing. The pump intake is located between the motor and the pump and is normally screened to prevent sediment from entering the pump and damaging the impellers.

The efficient **cooling of submersible motors is very important** so these types of pumps are often installed such that flow through the well screen can occur upwards past the motor and into the intake. If the motor end is inserted below the screened interval or below all productive portions of the aquifer it will not be cooled, resulting in premature motor failure. Some pumps may have **pump shrouds** installed on them to force all the water to move past the motor to prevent overheating.

The shroud is a piece of pipe that attaches to the pump housing with an open end below the motor. As with turbine pumps the size of the bowls and impellers, number of stages, and horsepower of the motor are adjusted to achieve the desired production rate within the limitations of the pumping head.



**Insertion of
motor spline
into pump
keyway**



←Cut away of a small submersible pump

The picture below illustrates the components that are common to all pump assemblies.

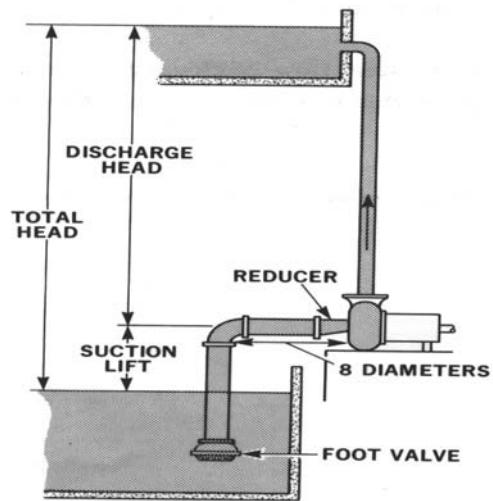
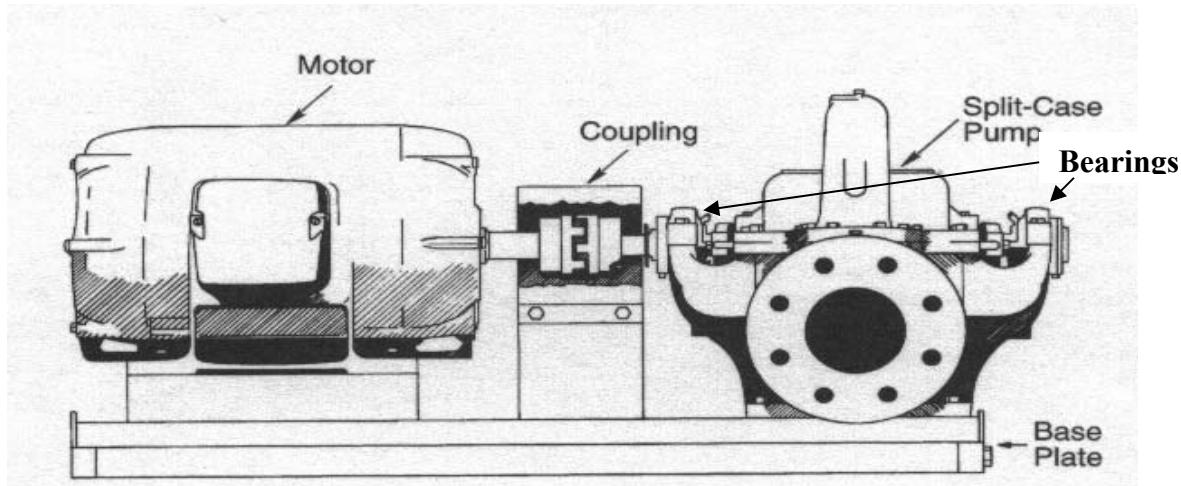


Illustration A

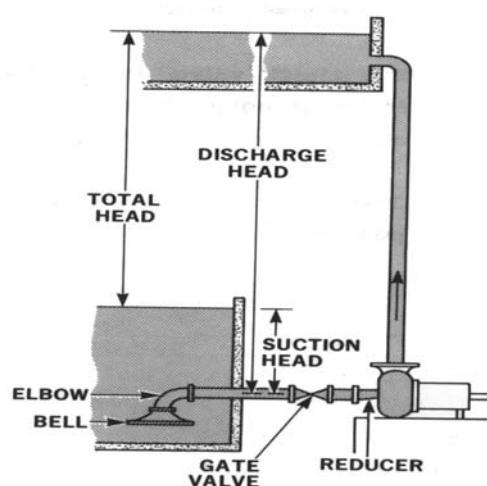


Illustration B

General Pumping Fundamentals

Here are the important points to consider about suction piping when the liquid being pumped is below the level of the pump.

- First, the term suction lift is when the level of water to be pumped is below the centerline of the pump. Sometimes suction lift is also referred to as '**negative suction head**'.
- The ability of the pump to lift water is the result of a partial vacuum created at the center of the pump.
- This works similar to sucking soda from a straw. As you gently suck on a straw, you are creating a vacuum or a pressure differential. Less pressure is exerted on the liquid inside the straw, so that the greater pressure is exerted on the liquid around the outside of the straw causing the liquid in the straw to move up. By sucking on the straw this allows atmospheric pressure to move the liquid.
- Look at the diagram illustrated as "**A**". The foot valve is located at the end of the suction pipe of a pump. It opens to allow water to enter the suction side, but closes to prevent water from passing back out of the bottom end.
- The suction side of pipe should be one diameter larger than the pump inlet. The required eccentric reducer should be turned so that the top is flat and the bottom tapered.

Notice in illustration "**B**" that the liquid is above the level of the pump. Sometimes this is referred to as 'flooded suction' or 'suction head' situations.

Points to Note are:

If an elbow and bell are used, they should be at least one pipe diameter from the tank bottom and side.

This type of suction piping must have a gate valve which can be used to prevent the flow when the pump has to be removed.

In the illustrations you can see in both cases the discharge head is from the centerline of the pump to the level of the discharge water. The total head is the difference between the two liquid levels.

Motor, Coupling, and Bearings

We will now refer to the motor, coupling, and bearings. The power source of the pump is usually an electric motor. The motor is connected by a coupling to the pump shaft. The purpose of the bearings are to hold the shaft firmly in place, yet allow it to rotate. The bearing house supports the bearings and provides a reservoir for the lubricant. An impeller is connected to the shaft.

The pump assembly can be a vertical or horizontal set up; the components for both are basically the same.

Motors

The purpose of this discussion on pump motors is to identify and describe the main types of motors, starters, enclosures and motor controls, as well as to provide you with some basic maintenance and troubleshooting information.

Although pumps could be driven by diesel or gasoline engines, pumps driven by electric motors are commonly used in our industry.

There are two general categories of electric motors:

- D-C motors, or direct current
- A-C motors, or alternating current

You can expect most motors at facilities to be A-C type.

D-C Motors

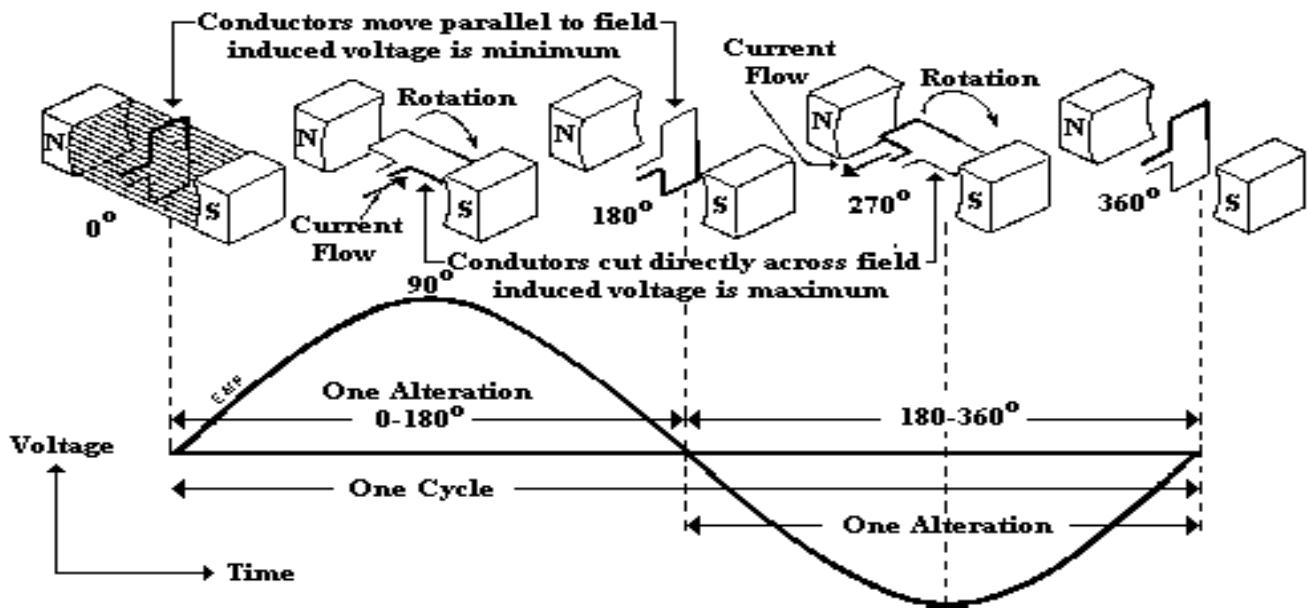
The important characteristic of the D-C motor is that its speed will vary with the amount of current used. There are many different kinds of D-C motors, depending on how they are wound and on their speed/torque characteristics.

A-C Motors

There are a number of different types of alternating current motors, such as synchronous and induction, wound rotor and squirrel cage.

The synchronous type of A-C motor requires complex control equipment, since they use a combination of A-C and D-C. This also means that the synchronous type of A-C motor is used in large horsepower sizes, usually above 250 HP.

The induction type motor uses only alternating current. The squirrel cage motor provides a relatively constant speed and the wound rotor type could be used as a variable speed motor.



Define the following:

Voltage:

EMF:

Power:

Current:

Resistance:

Conductor:

Phase:

Single phase:

Three phase:

Hertz:

Motor Starters

All electric motors, except very small ones such as chemical feed pumps, are equipped with starters, either full voltage or reduced voltage. This is because motors draw a much higher current when they are starting and gaining speed. The purpose of the reduced voltage starter is to prevent the load from coming on until the amperage is low enough.

How do you think keeping the discharge valve closed on a centrifugal pump could reduce the start up load?

Motor Enclosures

Depending on the application, motors may need special protection. Some motors are referred to as open motors. They allow air to pass through to remove heat generated when current passes through the windings. Other motors use specific enclosures for special environments or safety protection.

Can you think of any locations within your facility that requires special enclosures?

Two types of totally enclosed motors commonly used are:

- ↳ **TENV**, or totally enclosed non-ventilated motor
- ↳ **TEFC**, or totally enclosed fan cooled motor



Totally enclosed motors include dust-proof, water-proof and explosion-proof motors. An explosion proof enclosure must be provided on any motor where dangerous gases might accumulate.

Motor Controls

All pump motors are provided with some method of control, typically a combination of manual and automatic. Manual pump controls can be located at the central control panel at the pump or at the suction or discharge points of the liquid being pumped.

There are a number of ways in which automatic control of a pump motor can be regulated:

- ☛ Pressure and vacuum sensors
- ☛ Preset time intervals
- ☛ Flow sensors
- ☛ Level sensors

Two typical level sensors are the float sensor and the bubble regulator. The float sensor is pear shaped and hangs in the wet well. As the height increases the float tilts and the mercury in the glass tube flows toward the end of the tube that has two wires attached to it. When the mercury covers the wires, it closes the circuit.

A low pressure air supply is allowed to escape from a bubbler pipe in the wet well. The back-pressure on the air supply will vary with the liquid level over the pipe. Sensitive air pressure switches will detect this change and use this information to control pump operation.

Motor Maintenance

Motors should be kept clean, free of moisture, and lubricated properly. Dirt, dust, and grime will plug the ventilating spaces and can actually form an insulating layer over the metal surface of the motor.

What condition would occur if the ventilation becomes blocked?

List step-by-step ways that you would perform cleaning the motor in the space provided below.

Moisture

Moisture harms the insulation on the windings to the point where they may no longer provide the required insulation for the voltage applied to the motor. In addition, moisture on windings tends to absorb acid and alkali fumes, causing damage to both insulation and metals. To reduce problems caused by moisture, the most suitable motor enclosure for the existing environment will normally be used. It is recommended to run stand by motors to dry up any condensation which accumulates in the motor.

Motor Lubrication

Friction will cause wear in all moving parts, and lubrication is needed to reduce this friction. It is very important that all your manufacturer's lubrications are strictly followed. You have to be careful not to add too much grease or oil, this could cause more friction and generate heat.

To grease the motor bearings, this is the usual approach:

1. Remove the protective plugs and caps from the grease inlet and relief holes.
2. Pump grease in until fresh grease starts coming from the relief hole.

If fresh grease does not come out of the relief hole, this could mean that the grease has been pumped into the motor windings. The motor must then be taken apart and cleaned by a qualified service representative.

To change the oil in an oil lubricated motor, this is the usual approach:

1. Remove all plugs and let the oil drain.
2. Check for metal shearing.
3. Replace the oil drain.
4. Add new oil until it is up to the oil level plug.
5. Replace the oil level and filter plugs.

Never mix oils, since the additives of different oils, when combined, can cause breakdown of the oil.

Couplings

The pump coupling serves two main purposes:

- It couples or joins the two shafts together to transfer the rotation from motor to impeller.
- It compensates for small amounts of misalignment between the pump and the motor.

Remember that any coupling is a device in motion. If you have a 4-inch diameter coupling rotating at 1800 rpm, its outer surface is traveling about 20 mph. With that in mind, can you think of safety considerations?

There are three commonly used types of couplings: ***rigid, flexible, and V-belts.***

Rigid Coupling

Rigid couplings are most commonly used on vertically mounted pumps. The rigid coupling is usually specially keyed or constructed for joining the coupling to the motor shaft and the pump shaft. There are two types of rigid couplings: the flanged coupling, and the split coupling.

Another type of coupling is the flexible coupling. The flexible coupling provides the ability to compensate for small shaft misalignments.

Shafts should be aligned as close as possible regardless. The greater the misalignment, the shorter the life of the coupling. Bearing wear and life are also affected by misalignment.



Example of a flexible flanged coupling

Alignment of Flexible and Rigid Couplings

Both flexible and rigid couplings must be carefully aligned before they are connected.

Mis-alignment will cause excessive heat and vibration, as well as bearing wear. Usually the noise from the coupling will warn you of shaft misalignment problems.

Three types of shaft alignment problems are shown in the pictures below:



ANGULAR MISALIGNMENT



ANGULAR AND PARALLEL



PARALLEL MISALIGNMENT

Different couplings will require different alignment procedures. We will look at the general procedures for aligning shafts.

1. Place the coupling on each shaft.
2. Arrange the units so they appear to be aligned. Place shims under the legs of one of the units to raise it.
3. Check the run-out or difference between the driver and driven unit by rotating the shafts by hand.
4. Turn both units so that the maximum run-out is on top.

Now you can check the units for both parallel and angular alignment. Many techniques are used such as, straight edge, Needle deflection (dial indicators), calipers, tapered wedges, and laser alignment.

V-belt Drives

V-belt drives connect the pump to the motor. A pulley is mounted on the pump and motor shaft. One or more belts are used to connect the two pulleys. Sometimes a separately mounted third pulley is used. This idler pulley is located off centerline between the two pulleys, just enough to allow tensioning of the belts by moving the idler pulley. An advantage of driving a pump with belts is that various speed ratios can be achieved between the motor and the pump.

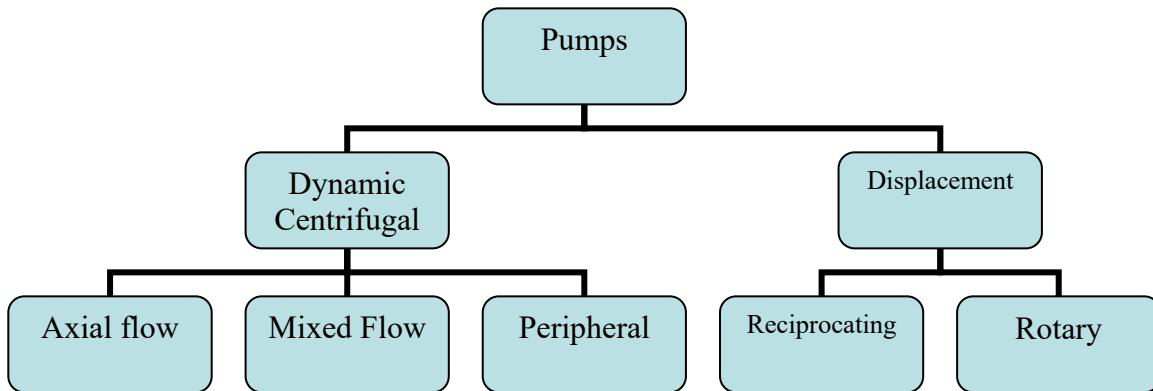
Shaft Bearings

There are three types of bearings commonly used, ball bearings, roller bearings, and sleeve bearings. Regardless of the particular type of bearings used within a system; whether it is ball bearings, a sleeve bearing, or a roller bearing, the bearings are designed to carry the loads imposed on the shaft.

Bearings must be lubricated. Without proper lubrication, bearings will overheat and seize. Proper lubrication means using the correct type and the correct amount of lubrication. Similar to motor bearings, shaft bearings can be lubricated either by oil or by grease.

Pump Categories

Pumps may be classified on the basis of the application they serve. All pumps may be divided into two major categories: (1) dynamic, in which energy is continuously added to increase the fluid velocities within the machine, and (2) displacement, in which the energy is periodically added by application of force.



Centrifugal pumps may be classified in several ways. For example, they may be either **SINGLE STAGE** or **MULTI-STAGE**. A single-stage pump has only one impeller. A multi-stage pump has two or more impellers housed together in one casing.



Multi-stage bowls

As a rule, each impeller acts separately, discharging to the suction of the next stage impeller. This arrangement is called series staging. Centrifugal pumps are also classified as **HORIZONTAL** or **VERTICAL**, depending upon the position of the pump shaft.

The impellers used on centrifugal pumps may be classified as **SINGLE SUCTION** or **DOUBLE SUCTION**. The single-suction impeller allows liquid to enter the eye from one side only. The double-suction impeller allows liquid to enter the eye from two directions. Impellers are also classified as **CLOSED** or **OPEN**.

Impellers

Closed impellers have side walls that extend from the eye to the outer edge of the vane tips. Open impellers do not have these side walls. Some small pumps with single-suction impellers have only a casing wearing ring and no impeller ring. In this type of pump, the casing wearing ring is fitted into the end plate.

Recirculation lines are installed on some centrifugal pumps to prevent the pumps from overheating and becoming vapor bound in case the discharge is entirely shut off or the flow of fluid is stopped for extended periods. Seal piping is installed to cool the shaft and the packing, to lubricate the packing, and to seal the rotating joint between the shaft and the packing against air leakage. A lantern ring spacer is inserted between the rings of the packing in the stuffing box.



Seal piping leads the liquid from the discharge side of the pump to the annular space formed by the lantern ring. The web of the ring is perforated so that the water can flow in either direction along the shaft (between the shaft and the packing). Water flinger rings are fitted on the shaft between the packing gland and the pump bearing housing. These flingers prevent water from the stuffing box from flowing along the shaft and entering the bearing housing.

Leakage

During pump operation, a certain amount of leakage around the shafts and casings normally takes place. This leakage must be controlled for two reasons: (1) to prevent excessive fluid loss from the pump, and (2) to prevent air from entering the area where the pump suction pressure is below atmospheric pressure. The amount of leakage that can occur without limiting pump efficiency determines the type of shaft sealing selected. Shaft sealing systems are found in every pump. They can vary from simple packing to complicated sealing systems.

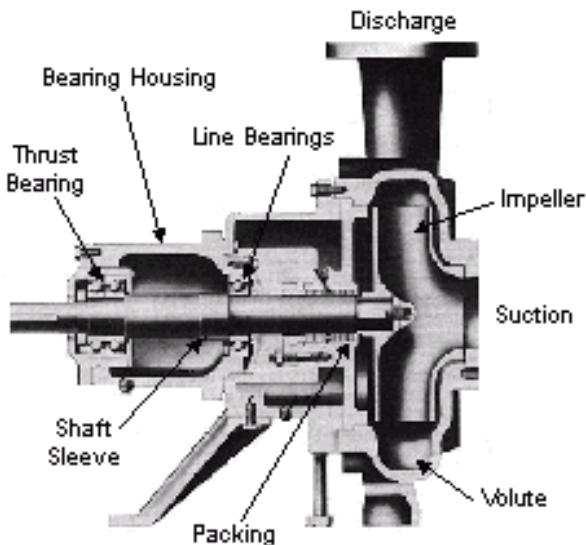
Packing is the most common and oldest method of sealing. Leakage is checked by the compression of packing rings that causes the rings to deform and seal around the pump shaft and casing. The packing is lubricated by liquid moving through a lantern ring in the center of the packing. The sealing slows down the rate of leakage. It does not stop it completely since a certain amount of leakage is necessary during operation. Mechanical seals are rapidly replacing conventional packing on centrifugal pumps.

Some of the reasons for the use of mechanical seals are as follows:

1. Leaking causes bearing failure by contaminating the oil with water. This is a major problem in engine-mounted water pumps.
2. Properly installed mechanical seals eliminate leakoff on idle (vertical) pumps. This design prevents the leak (water) from bypassing the water flinger and entering the lower bearings. Leakoff causes two types of seal leakage:
 - a. Water contamination of the engine lubrication oil.
 - b. Loss of treated fresh water that causes scale buildup in the cooling system.

Centrifugal pumps are versatile and have many uses. This type of pump is commonly used to pump all types of water and wastewater flows including thin sludge.

We will now look at the components of the centrifugal pump.



As the impeller rotates, it sucks the liquid into the center of the pump and throws it out under pressure through the outlet. The casing that houses the impeller is referred to as the volute, and the impeller fits on the shaft inside. The volute has an inlet and outlet that carries the water as shown above.

How can we prevent the water from leaking along the shaft?

A special seal is used to prevent liquid leaking out along the shaft. There are two types of seals commonly used:

- **Packing seal**
- **Mechanical seal**

Should packing have leakage?

Packing Seals

Lantern rings are used to supply clean water along the shaft. This helps to prevent grit and air from reaching the area. Another component is the slinger ring. The slinger ring is an important part of the pump because it is used to protect the bearings.

Mechanical Seals

Mechanical seals are commonly used to reduce leakage around the pump shaft. There are many types of mechanical seals.

Similar to the packing seal, clean water is fed at a pressure greater than that of the liquid being pumped. There is little or no leakage through the mechanical seal. The wearing surface must be kept extremely clean. Even fingerprints on the wearing surface can introduce enough dirt to cause problems.



What care should be taken when storing mechanical seals?

Wear Rings

Not all pumps have wear rings. However, when they are included, they are usually replaceable. Wear rings can be located on the suction side and head side of the volute. Wear rings could be made of the same metal but a different alloy. The wear ring on the head side is usually a harder alloy.

It's called a "**WEAR RING**" and what would be the purpose?

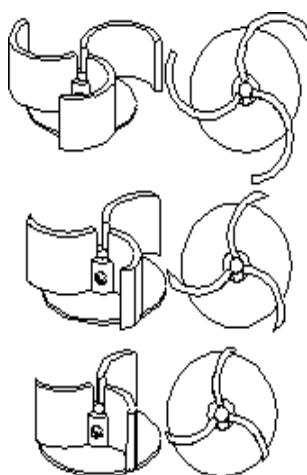
Pump Casing

There are many variations of centrifugal pumps. The most common type is an end suction pump. Another type of pump used is the split case. There are many variations of split case such as, two-stage, single suction, and double suction. Most of these pumps are horizontal.

There are variations of vertical centrifugal pumps. The line shaft turbine is really a multistage centrifugal pump.

Impeller

In most centrifugal pumps, the impeller looks like a number of cupped vanes on blades mounted on a disc or shaft. Notice in the picture below how the vanes of the impeller force the water into the outlet of the pipe.



As the water is being thrown out of the pump, this means you can run centrifugal pumps with the discharged valve closed for a **SHORT** period of time. Remember, the motor sends energy along the shaft and if the water is in the volute too long it will heat up and create steam. Not good!

Impellers are designed in various ways. We will look at:

- Closed impellers
- Semi-open impellers
- Opened impellers, and
- Recessed impellers

The impellers all cause a flow from the eye of the impeller to the outside of the impeller. These impellers cause what is called **radial flow**, and they can be referred to as radial flow impellers.

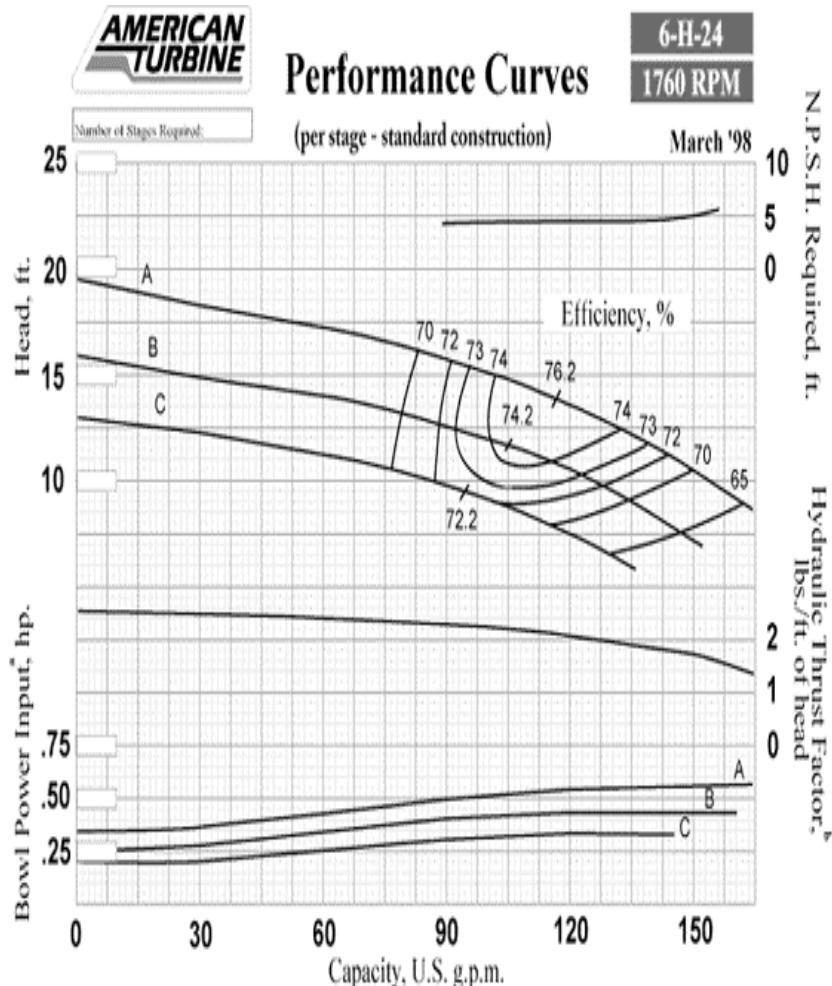
The **critical distance** of the impeller and how it is installed in the casing will determine if it is high volume / low pressure or the type of liquid that could be pumped.

An **Axial flow** impeller looks like a propeller and creates a flow that is parallel to the shaft.

Pump Performance and Curves

Lets looks at the big picture. Before you make that purchase of the pump and motor you need to know the basics such as:

- Total dynamic head, the travel distance
- Capacity, how much water you need to provide
- Efficiency, help determine the impeller size
- HP, how many squirrels you need
- RPM, how fast the squirrels run



Positive Displacement Pumps

There are many types of positive displacement pumps.

We will look at:

- ➔ Plunger pumps
- ➔ Diaphragm pumps
- ➔ Progressing cavity pumps, and
- ➔ Screw pumps

What kind of mechanical device do you think is used to provide this positive displacement in the:

Plunger pump?

Diaphragm pump?

In the same way, the progressing cavity and the screw are two other types of mechanical action that can be used to provide movement of the liquid through the pump.

Plunger Pump

The plunger pump is a positive displacement pump that uses a plunger or piston to force liquid from the suction side to the discharge side of the pump. It is used for heavy sludge. The movement of the plunger or piston inside the pump creates pressure inside the pump, so you have to be careful that this kind of pump is never operated against any closed discharge valve.

All discharge valves must be open before the pump is started, to prevent any fast build-up of pressure that could damage the pump.

Diaphragm Pumps

In this type of pump, a diaphragm provides the mechanical action used to force liquid from the suction to the discharge side of the pump. The advantage the diaphragm has over the plunger is that the diaphragm pump does not come in contact with moving metal. This can be important when pumping abrasive or corrosive materials.

There are three main types of diaphragm pumps available:

- ↳ Diaphragm sludge pump
- ↳ Chemical metering or proportional pump
- ↳ Air-powered double-diaphragm pump

Progressing Cavity Pumps

In this type of pump, components referred to as a rotor and an elastic stator provide the mechanical action used to force liquid from the suction to the discharge side of the pump.

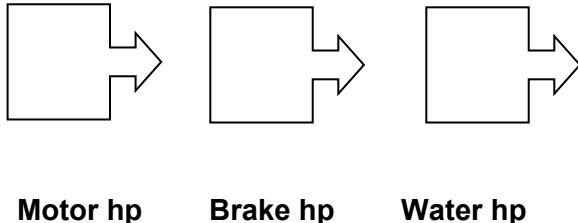
Progressing cavity pumps are used to pump material very high in solids content. The progressive cavity pump must never be run dry, because the friction between the rotor and stator will quickly damage the pump.

Screw Pumps

In this type of pump, a large screw provides the mechanical action to move the liquid from the suction to the discharge side of the pump. Here are some typical characteristics of screw pumps:

- Most screw pumps rotate in the 30 to 60 rpm range, although some screw pumps are faster.
- The slope of the screw is normally either 30° or 38°.
- The maximum lift for the larger diameter pumps is about 30 feet. The smaller diameter pumps have lower lift capabilities.

Motor and Pump Calculations



Horsepower

Work involves the operation of force over a specific distance. The rate of doing work is called power.

The rate in which a horse could work was determined to be about 550 ft-lbs/sec or 33,000 ft-lbs/min.

1 hp = 33,000 ft-lbs/min

Motor Horsepower (mhp)

1 hp = 746 watts or .746 Kilowatts

MHP refers to the horsepower supplied in the form of electrical current. The efficiency of most motors range from 80-95%. (manufacturers will list efficiency %)

Brake Horsepower (bhp)

$$\text{Brake hp} = \frac{\text{Water hp}}{\text{Pump Efficiency}}$$

BHP refers to the horsepower supplied to the pump from the motor. As the power moves through the pump, additional horsepower is lost, resulting from slippage and friction of the shaft and other factors.

Water Horsepower

$$\text{Water hp} = \frac{(\text{flow gpm})(\text{total hd})}{3960}$$

Water horsepower refers to the actual horse power available to pump the water.

Horsepower and Specific Gravity

The specific gravity of a liquid is an indication of its density or weight compared to water. The difference in specific gravity, include it when calculating ft-lbs/min pumping requirements.

$$\frac{(\text{ft})(\text{lbs/min})(\text{sp.gr.})}{33,000 \text{ ft-lbs/min/hp}} = \text{whp}$$

MHP and Kilowatt Requirements

$$1 \text{ hp} = 0.746 \text{ kW} \quad \text{or} \quad \frac{(\text{hp}) (746 \text{ watts/hp})}{1000 \text{ watts/kW}}$$

Well Calculations

1. Well drawdown

Drawdown ft = Pumping water level, ft - Static water level, ft

2. Well yield

$$\text{Well yield, gpm} = \frac{\text{Flow, gallons}}{\text{Duration of test, min}}$$

3. Specific yield

$$\text{Specific yield, gpm/ft} = \frac{\text{Well yield, gpm}}{\text{Drawdown, ft}}$$

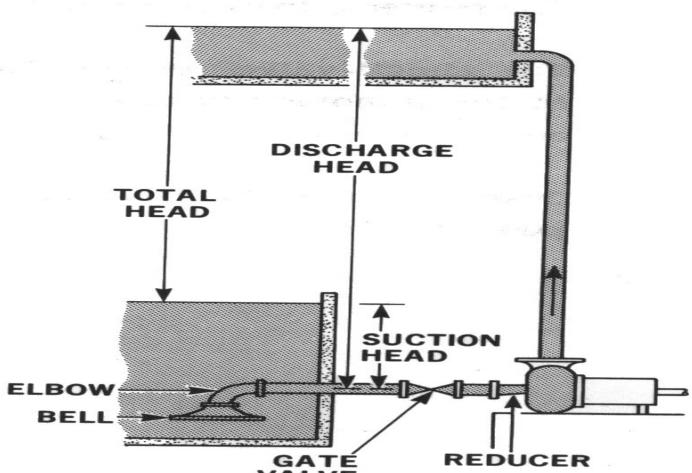
4. Deep well turbine pump calculations

Discharge head, ft = (pressure measured)
(2.31 ft/psi)

Field head, ft = pumping water + discharge head, ft

Bowl head, ft = field head + column friction

1 psi = 2.31 feet of head 1 foot of head = .433 psi



Example 1

A centrifugal pump is located at an elevation of 722 ft. This pump is used to move water from reservoir **A** to reservoir **B**. The water level in reservoir **A** is 742 ft and the water level in reservoir **B** is 927 ft. Based on these conditions answer the following questions:

- 1. If the pump is not running and pressure gauges are installed on the suction and discharge lines, what pressures would the gauges read?**

Suction side:

Discharge side:

- 2. How can you tell if this is a suction head condition?**

- 3. Calculate the following head measurements:**

SSH:

SDH:

TSH:

- 4. Convert the pressure gauge readings to feet:**

6 psi:

48 psi:

110 psi:

- 5. Calculate the following head in feet to psi:**

20 ft:

205 ft:

185 ft:

Pump Troubleshooting Section

As an Operator, some of the operating troubles you may encounter with centrifugal pumps, together with the probable causes, are discussed in the following paragraphs.

If a centrifugal pump **DOES NOT DELIVER ANY LIQUID**, the trouble may be caused by (1) insufficient priming; (2) insufficient speed of the pump; (3) excessive discharge pressure, such as might be caused by a partially closed valve or some other obstruction in the discharge line; (4) excessive suction lift; (5) clogged impeller passages; (6) the wrong direction of rotation (this may occur after motor overhaul); (7) clogged suction screen (if used); (8) ruptured suction line; or (9) loss of suction pressure.

If a centrifugal pump delivers some liquid but operates at **INSUFFICIENT CAPACITY**, the trouble may be caused by (1) air leakage into the suction line; (2) air leakage into the stuffing boxes in pumps operating at less than atmospheric pressure; (3) insufficient pump speed; (4) excessive suction lift; (5) insufficient liquid on the suction side; (6) clogged impeller passages; (7) excessive discharge pressure; or (8) mechanical defects, such as worn wearing rings, impellers, stuffing box packing, or sleeves.

If a pump **DOES NOT DEVELOP DESIGN DISCHARGE PRESSURE**, the trouble may be caused by (1) insufficient pump speed; (2) air or gas in the liquid being pumped; (3) mechanical defects, such as worn wearing rings, impellers, stuffing box packing, or sleeves; or (4) reversed rotation of the impeller (3-phase electric motor-driven pumps).

If a pump **WORKS FOR A WHILE AND THEN FAILS TO DELIVER LIQUID**, the trouble may be caused by (1) air leakage into the suction line; (2) air leakage in the stuffing boxes; (3) clogged water seal passages; (4) insufficient liquid on the suction side; or (5) excessive heat in the liquid being pumped.

If a motor-driven centrifugal pump **DRAWS TOO MUCH POWER**, the trouble will probably be indicated by overheating of the motor. The basic causes may be (1) operation of the pump to excess capacity and insufficient discharge pressure; (2) too high viscosity or specific gravity of the liquid being pumped; or (3) misalignment, a bent shaft, excessively tight stuffing box packing, worn wearing rings, or other mechanical defects.

VIBRATION of a centrifugal pump is often caused by (1) misalignment; (2) a bent shaft; (3) a clogged, eroded, or otherwise unbalanced impeller; or (4) lack of rigidity in the foundation. Insufficient suction pressure may also cause vibration, as well as noisy operation and fluctuating discharge pressure, particularly in pumps that handle hot or volatile liquids.

If the pump fails to build up pressure when the discharge valve is opened and the pump comes up to normal operating speed, proceed as follows:

1. Shut the pump discharge valve.
2. Secure the pump.
3. Open all valves in the pump suction line.
4. Prime the pump (**fill casing with the liquid being pumped**) and be sure that all air is expelled through the air cocks on the pump casing.
5. Restart the pump. If the pump is electrically driven, be sure the pump is rotating in the correct direction.

6. Open the discharge valve to "load" the pump. If the discharge pressure is not normal when the pump is up to its proper speed, the suction line may be clogged, or an impeller may be broken. It is also possible that air is being drawn into the suction line or into the casing.

If any of these conditions exist, stop the pump and continue troubleshooting according to the technical manual for that unit.

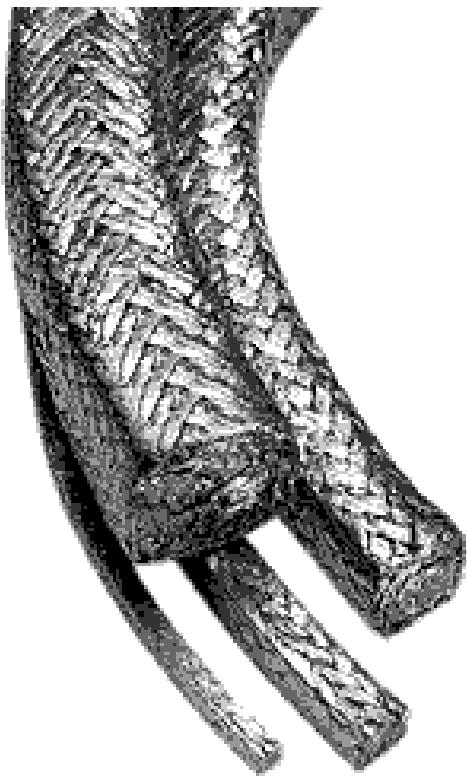
Maintenance of Centrifugal Pumps

When properly installed, maintained and operated, centrifugal pumps are usually trouble-free. Some of the most common corrective maintenance actions that you may be required to perform is discussed in the following sections.

Rewaxing-Lubrication of the pump packing is extremely important. The quickest way to wear out the packing is to forget to open the water piping to the seals or stuffing boxes. If the packing is allowed to dry out, it will score the shaft. When operating a centrifugal pump, be sure there is always a slight trickle of water coming out of the stuffing box or seal.

How often the packing in a centrifugal pump should be renewed depends on several factors, such as the type of pump, condition of the shaft sleeve and hours in use.

To ensure the longest possible service from pump packing, make certain the shaft or sleeve is smooth when the packing is removed from a gland. Rapid wear of the packing will be caused by roughness of the shaft sleeve (or shaft where no sleeve is installed). If the shaft is rough, it should be sent to the machine shop for a finishing cut to smooth the surface. If it is very rough, or has deep ridges in it, it will have to be renewed. It is absolutely necessary to use the correct packing. When replacing packing, be sure the packing fits uniformly around the stuffing box. If you have to flatten the packing with a hammer to make it fit, **YOU ARE NOT USING THE RIGHT SIZE.**



Pack the box loosely, and set up the packing gland lightly. Allow a liberal leak-off for stuffing boxes that operate above atmospheric pressure. Next, start the pump. Let it operate for about 30 minutes before you adjust the packing gland for the desired amount of leak-off.

This gives the packing time to run-in and swell. You may then begin to adjust the packing gland. Tighten the adjusting nuts one flat at a time. Wait about 30 minutes between adjustments. Be sure to tighten the same amount on both adjusting nuts. If you pull up the packing gland unevenly (or cocked), it will cause the packing to overheat and score the shaft sleeves.

Once you have the desired leak-off, check it regularly to make certain that sufficient flow is maintained.

Mechanical Seals

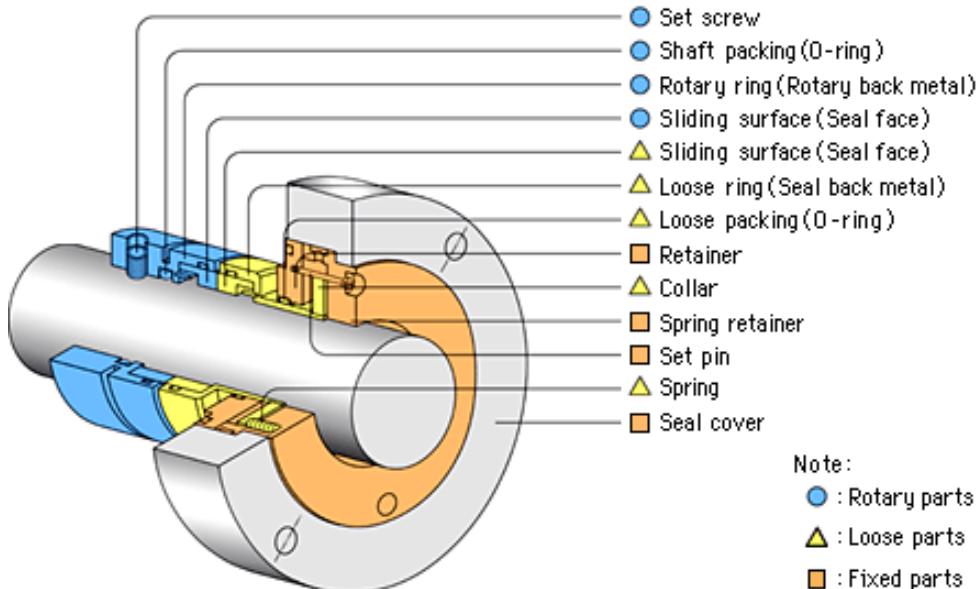
Mechanical seals are rapidly replacing conventional packing as the means of controlling leakage on rotary and positive-displacement pumps. Mechanical seals eliminate the problem of excessive stuffing box leakage, which causes failure of pump and motor bearings and motor windings.

Mechanical seals are ideal for pumps that operate in closed systems (such as fuel service and air-conditioning, chilled-water,

and various cooling systems). They not only conserve the fluid being pumped but also improve system operation. The type of material used for the seal faces will depend upon the service of the pump. Most water service pumps use a carbon material for one of the seal faces and ceramic (tungsten carbide) for the other. When the seals wear out, they are simply replaced.

You should replace a mechanical seal whenever the seal is removed from the shaft for any reason or whenever leakage causes undesirable effects on equipment or surrounding spaces. Do not touch a new seal on the sealing face because body acid and grease or dirt will cause the seal to pit prematurely and leak. Mechanical shaft seals are positioned on the shaft by stub or step sleeves. Mechanical shaft seals must not be positioned by setscrews. Shaft sleeves are chamfered (beveled) on outboard ends for easy mechanical seal mounting.

Mechanical shaft seals serve to ensure that position liquid pressure is supplied to the seal faces under all conditions of operation. They also ensure adequate circulation of the liquid at the seal faces to minimize the deposit of foreign matter on the seal parts.



Impellers





Two unsafe excavation examples. Top, notice the man in a 6-foot deep trench with no ladder or shoring and the placement of spoil. Bottom picture, utilities are marked after the excavation has begun, no hard hats, no ladders, no protective system, incorrect spoil placement.



Safety Section

Excavation & Trenching

This section outlines procedures and guidelines for the protection of employees working in and around excavations and trenches. This section requires compliance with OSHA Standards described in Subpart P (**CFR 1926.650**) for the construction industry.

Safety compliance is mandatory to ensure employee protection when working in or around excavations. The competent person(s) must be trained in accordance with the OSHA Excavation Standard, and all other programs that may apply (examples Hazard Communication, Confined Space, and Respiratory Protection), and must demonstrate a thorough understanding and knowledge of the programs and the hazards associated. All other employees working in and around the excavation must be trained in the recognition of hazards associated with trenching and excavating.



REFERENCES

- **29 CFR 1926.650, Subpart P - Excavations**
- **Excavation Equipment Manufacturer Safety Procedures**

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AJ ditch cave-in kills teen

Wall collapses on boy working in trench

By Rachel Ochoa
and Laura Trujillo
The Arizona Republic

A 17-year-old Chandler boy who was shoveling debris at the bottom of a sewer ditch was killed Saturday when a huge slab of dirt and rocks collapsed onto him, authorities said.

Joshua Holt Castro, a Dobson High School football player, was working without shoring or support in the 15- to 25-foot deep trench at an Apache Junction condominium complex when the avalanche buried him.

The Apache Junction Police Department is investigating the case and will look into the past performance of Galloway Construction, where Castro worked a part-time weekend job.



The Apache Junction Sewer District contracted with the construction company to hook up a new sewer line to the condos to city sewer lines, according to Lt. Brian Duncan, a police spokesman.

"It could have been prevented if proper shoring had been there and had competent personnel been on the scene," said Brian Wyatt, a spokesman for the Apache Junction Fire Department. He added that shoring is required while digging a trench.

Patrick Galloway, who owns the construction company and had just left the site before Castro was killed, could not be reached Saturday night. He spent much of Saturday talking with investigators.

OSHA is also investigating the death, which occurred just after noon, but officials wouldn't discuss the case Saturday.

It took Apache Junction and Mesa firefighters more than nine hours to retrieve the boy's body, buried under heavy rock and dirt just south of the Quail Creek Apartments Complex on North Idaho Road.

The only witness to the death was Galloway's 10-year-old son, Riley, and his 17-year-

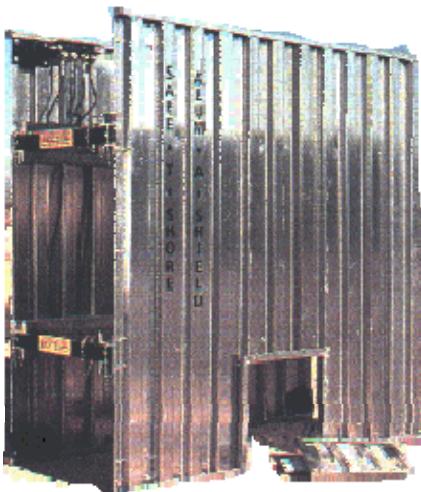


Firefighters work to recover the body of 17-year-old Joshua Holt Castro, who was killed Saturday afternoon when the trench he was digging collapsed, burying him under earth and rocks.

Randy Read/The Arizona Republic

— Please see CAVE-IN, Page B3

Every day you can easily find someone dying or getting injured in a trench. Don't be on the News tonight.



Trench Shield

Hazards

One of the reasons OSHA requires a competent person on-site during excavation & trenching are the numerous potential hazardous that may be encountered or created. Hazards include:

Electrocution

Gas Explosion

Entrapment

Struck by equipment

Suffocation

Hazard Controls

Before any work is performed and before any employees enter the excavation, a number of items must be checked and ensured:

- Before any excavation, underground installations must be determined. This can be accomplished by either contacting the local utility companies or the local "one-call" center for the area. All underground utility locations must be documented on the proper forms. All overhead hazards (**surface encumbrances**) that create a hazard to employees must be removed or supported to eliminate the hazard.
- If the excavation is to be over 20 feet deep, it must be designed by a registered professional engineer who is registered in the state where work will be performed.
- Adequate protective systems will be utilized to protect employees. This can be accomplished through sloping, shoring, or shielding.
- The worksite must be analyzed in order to design adequate protection systems and prevent cave-ins. There must also be an excavation safety plan developed to protect employees.
- Workers must be supplied with and wear any personal protective equipment deemed necessary to assure their protection.
- All spoil piles will be stored a minimum of **two (2) feet from** the sides of the excavation. The spoil pile must not block the safe means of egress.
- If a trench or excavation is 4 feet or deeper, stairways, ramps, or ladders will be used as a safe means of access and egress. For trenches, the employee must not have to travel any more than 25 feet of lateral travel to reach the stairway, ramp, or ladder.

- No employee will work in an excavation where water is accumulating unless adequate measures are used to protect the employees.
- A competent person will inspect all excavations and trenches daily, prior to employee exposure or entry, and after any rainfall, soil change, or any other time needed during the shift. The competent person must take prompt measures to eliminate any and all hazards.
- Excavations and trenches 4 feet or deeper that have the potential for toxic substances or hazardous atmospheres will be tested at least daily. If the atmosphere is inadequate, protective systems will be utilized.
- If work is in or around traffic, employees must be supplied with and wear orange reflective vests. Signs and barricades must be utilized to ensure the safety of employees, vehicular traffic, and pedestrians.

Competent Person Responsibilities

The OSHA Standards require that the competent person must be capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees, and have authorization to take prompt corrective measures to eliminate them and, if necessary, to stop the work.

A Competent Person is Required to:

- Have a complete understanding of the applicable safety standards and any other data provided.
- Assure the proper locations of underground installations or utilities, and that the proper utility companies have been contacted.
- Conduct soil classification tests and reclassify soil after any condition changes.
- Determine adequate protective systems (sloping, shoring, or shielding systems) for employee protection.
- Conduct all air monitoring for potential hazardous atmospheres.
- Conduct daily and periodic inspections of excavations and trenches.
- Approve design of structural ramps, if used.



Excavation Safety Plan

An excavation safety plan is required in written form. This plan is to be developed to the level necessary to ensure complete compliance with the OSHA Excavation Safety Standard and state and local safety standards.

Excavation safety plan factors:

- Utilization of the local one-call system.
- Determination of locations of all underground utilities.
- Consideration of confined space atmosphere potential.
- Proper soil protection systems and personal protective equipment and clothing.
- Determination of soil composition and classification.
- Determination of surface and subsurface water.
- Depth of excavation and length of time it will remain open.
- Proper adherence to all OSHA Standards, this excavation and trenching safety program, and any other coinciding safety programs.

Soil Classification and Identification

The OSHA Standards define soil classifications within the Simplified Soil Classification Systems, which consist of four categories: Stable rock, Type A, Type B, and Type C. Stability is greatest in stable rock and decreases through Type A and B to Type C, which is the least stable. Appendix A of the Standard provides soil mechanics terms and types of field tests used to determine soil classifications.

Stable rock is defined as natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed.

Type A soil is defined as:

- Cohesive soils with an unconfined compressive strength of 1.5 tons per square foot (**TSF**) or greater.
- Cemented soils like caliche and hardpan are considered Type A.

Soil is NOT Type A if:

- It is fissured.
- The soil is subject to vibration from heavy traffic, pile driving or similar effects.
- The soil has been previously disturbed.
- The material is subject to other factors that would require it to be classified as a less stable material.
- The exclusions for Type A most generally eliminate it from most construction situations.

Type B soil is defined as:

- Cohesive soil with an unconfined compressive strength greater than .5 TSF, but less than 1.5 TSF.
- Granular cohesion-less soil including angular gravel, silt, silt loam, and sandy loam.
- The soil has been previously disturbed except that soil classified as Type C soil.
- Soil that meets the unconfined compressive strength requirements of Type A soil, but is fissured or subject to vibration.
- Dry rock that is unstable.

Type C soil is defined as:

- Cohesive soil with an unconfined compressive strength of .5 TSF or less.
- Granular soils including gravel, sand and loamy sand.
- Submerged soil or soil from which water is freely seeping.
- Submerged rock that is not stable.

Soil Test & Identification

The competent person will classify the soil type in accordance with the definitions in Appendix A based on at least one visual and one manual analysis.

These tests should be run on freshly excavated samples from the excavation and are designed to determine stability based on a number of criteria: the cohesiveness, the presence of fissures, the presence and amount of water, the unconfined compressive strength, and the duration of exposure, undermining, and the presence of layering, prior excavation and vibration.

The cohesion tests are based on methods to determine the presence of clay. Clay, silt, and sand are size classifications, with clay being the smallest sized particles, silt intermediate and sand the largest. Clay minerals exhibit good cohesion and plasticity (can be molded). Sand exhibits no elasticity and virtually no cohesion unless surface wetting is present. The degree of cohesiveness and plasticity depend on the amounts of all three types and water.

When examining the soil, three questions must be asked: Is the sample granular or cohesive? Fissured or non-fissured? What is the unconfined compressive strength measured in TSF?

Methods of testing soils:

- Visual test: If the excavated soil is in clumps, it is cohesive. If it breaks up easily, not staying in clumps, it is granular.
- Wet manual test: Wet your fingers and work the soil between them. Clay is a slick paste when wet, meaning it is cohesive. If the clump falls apart in grains, it is granular.
- Dry strength test: Try to crumble the sample in your hands with your fingers. If it crumbles into grains, it is granular. Clay will not crumble into grains, only into smaller chunks.
- Pocket penetrometer test: This instrument is most accurate when soil is nearly saturated. This instrument will give unconfined compressive strength in tons per square foot. The spring-operated device uses a piston that is pushed into a coil up to a calibration groove. An indicator sleeve marks and retains the reading until it is read. The reading is calibrated in tons per square foot (**TSF**) or kilograms per cubic centimeter.



Pocket Penetrometer



Thumb Penetration Test: The competent person attempts to penetrate a fresh sample with thumb pressure. If the sample can be dented, but penetrated only with great effort, it is Type A. If it can be penetrated several inches and molded by light pressure, it is Type C. Type B can be penetrated with effort and molded.

Shearvane: Measures the approximate shear strength of saturated cohesive soils. The blades of the vane are pressed into a flat section of undisturbed soil, and the knob is turned slowly until soil failure. The dial is read directly when

using the standard vane. The results will be in tons per square foot or kilograms per cubic centimeter.

The competent person will perform several tests of the excavation to obtain consistent, supporting data along its depth and length. The soil is subject to change several times within the scope of an excavation and the moisture content will vary with weather and job conditions. The competent person must also determine the level of protection based on what conditions exist at the time of the test, and allow for changing conditions.

Excavation Protection Systems

The three basic protective systems for excavations and trenches are sloping and benching systems, shoring, and shields.

The protective systems shall have the capacity to resist without failure all loads that are intended or could reasonably be expected to be applied to or transmitted to the system. Every employee in an excavation shall be protected from cave-ins by an adequate protective system.

- Exceptions to using protective system:
- Excavations are made entirely in stable rock
- Excavations are less than 5 feet deep and declared safe by a competent person

Sloping and Benching Systems

There are four options for sloping:

- Slope to the angle required by the Standard for Type C, which is the most unstable soil type.
- The table provided in Appendix B of the Standard may be used to determine the maximum allowable angle (after determining the soil type).
- Tabulated data prepared by a registered professional engineer can be utilized.
- A registered professional engineer can design a sloping plan for a specific job.

Sloping and benching systems for excavations five (5) to twenty (20) feet in depth must be constructed under the instruction of a designated competent person.

Sloping and benching systems for excavations greater than twenty (20) feet must be designed and stamped by a registered professional engineer.

Sloping and benching specifications can be found in Appendix B of the OSHA Standard (Subpart P).

Shoring Systems

Shoring is another protective system or support system. Shoring utilizes a framework of vertical members (uprights), horizontal members (whales), and cross braces to support the sides of the excavation to prevent a cave-in. Metal hydraulic, mechanical or timber shoring are common examples.

The different examples of shoring are found in the OSHA Standard under these appendices:

APPENDIX C - Timber Shoring for Trenches

APPENDIX D - Aluminum Hydraulic Shoring for Trenches

APPENDIX E - Alternatives to Timber Shoring

Shield Systems (*Trench Boxes*)

Shielding is the third method of providing a safe workplace. Unlike sloping and shoring, shielding does not prevent a cave-in. Shields are designed to withstand the soil forces caused by a cave-in and protect the employees inside the structure. Most shields consist of two flat, parallel metal walls that are held apart by metal cross braces.

Shielding design and construction is not covered in the OSHA Standards. Shields must be certified in design by a registered professional engineer and must have either a registration plate on the shield or registration papers from the manufacturer on file at the jobsite office.

ANY REPAIRS OR MODIFICATIONS MUST BE APPROVED BY THE MANUFACTURER.



Safety Precautions for Shield Systems

- Shields must not have any lateral movement when installed.
- Employees will be protected from cave-ins when entering and exiting the shield (examples - ladder within the shield or a properly sloped ramp at the end).
- Employees are not allowed in the shield during installation, removal, or during any vertical movement.
- Shields can be 2 ft. above the bottom of an excavation if they are designed to resist loads at the full depth and if there are no indications of caving under or behind the shield.
- The shield must extend at least 18 inches above the point where proper sloping begins (the height of the shield must be greater than the depth of the excavation).
- The open end of the shield must be protected from the exposed excavation wall. The wall must be sloped, shored, or shielded. Engineer designed end plates can be mounted on the ends of the shield to prevent cave-ins.

Personal Protective Equipment

It is **OSHA** policy for you to wear a hard hat, safety glasses, and work boots on the jobsite. Because of the hazards involved with excavations, other personal protective equipment may be necessary, depending on the potential hazards present (examples: goggles, gloves, and respiratory equipment).

Inspection

Daily inspection of excavations, the adjacent areas and protective systems shall be made by the competent person for evidence of a situation that could result in a cave-in, indications of failure of protective systems, hazardous atmospheres or other hazardous conditions.

- All inspections shall be conducted by the competent person prior to the start of work and as needed throughout the shift.
- Inspections will be made after every rainstorm or any other increasing hazard.
- All documented inspections will be kept on file in the jobsite safety files and forwarded to the Safety Director weekly.
- A copy of the Daily Excavation Inspection form is located at the end of this program.

The competent person(s) must be trained in accordance with the OSHA Excavation Standard, and all other programs that may apply (examples Hazard Communication, Confined Space, and Respiratory Protection), and must demonstrate a thorough understanding and knowledge of the programs and the hazards associated.

All other employees working in and around the excavation must be trained in the recognition of hazards associated with trenching and excavating.

Safety Assignment Section Highlights

Upon entering a confined space, your gas meter indicates a reading of 17% O². The most appropriate course of action leave the space immediately, continuously ventilate the area and recheck the O² concentration. You need an O² level of 19.5 to 23.5.

A minimal shoring system should have stringers, cross braces and hangers

Climbing safety devices are commonly used on which of the following types of equipment?
Fixed ladders.

Control of hazardous energy: Before doing any work on any piece of electrical equipment, the operator should perform the following procedure on a piece of equipment: lock out and tag the equipment. (LOTO)

Critical operating information for pumps and motors can be quickly found on the equipment nameplate.

Safety authorities tell us that one out of ten injuries are the result of unsafe acts of either the person injured or someone else. Ignorance is used to describe the lack of experience or training, or a temporary condition that prevents the recognition of a hazard.

One-Call Center, Buried Utility Locates or Bluestakes

You are required to locate or call for proper buried utility locations before you dig or excavate. You will usually need a 48-hour notice before you excavate. Please check your local One-Call system.



Red-Electricity, Yellow-Gas, Blue-Water



Orange - Telephone & Fiber Optics

One Call Program

According to federal safety statistics, damage from unauthorized digging is the major cause of natural gas pipeline failures. To prevent excavation damage to all utilities, including pipelines, all 50 states have instituted "**One Call**" Programs. The programs provide telephone numbers for excavation contractors to call before excavation begins.

The One Call operator will notify a pipeline company of any planned excavation in the vicinity of its pipeline so that the company can flag the location of the pipeline and assign personnel to be present during excavation, if necessary.

In a related effort, a joint government-industry team has developed a public education program entitled "**Dig Safely**". The team involved representatives from the U.S. Department of Transportation, gas and liquid pipeline companies, distribution companies, excavators, the insurance industry, one-call systems and the telecommunications industry. This campaign provides information to the general public concerning underground utilities and the danger of unknowingly digging into buried lines and cables.

The program has posters, brochures and other printed materials available for use by interested organizations. For more information, contact www.digsafely.com.



Buried telephone cables

Confined Spaces are

- large enough to allow entry of any body part, and
- limited or restricted entry or exit, and
- not designed for continuous employee occupancy

Permit Required Confined Spaces are confined spaces that have any of the following

- potential hazardous atmosphere
- material inside that may engulf or trap you
- internal design that could trap or asphyxiate you
- any other serious safety or health hazard**

Entry Permits are required before you enter any
"Permit Required Confined Space"

Hazards include

- Fire & Explosion
- Engulfment
- Asphyxiation
- Entrapment
- Slips & Falls
- Electric Shock
- Noise & Vibration
- Chemical Exposure
- Toxic Atmospheres
- Thermal / Chemical Burns

Engineering Controls

- Ventilation
- Locked Access
- Lighting

Administrative Controls

- Controlled Access
- Hazard Assessments
- Entry Permits & Procedures
- Signs & Lockout Tagout
- Training

Smart Safety Rules

Know what you are getting into.

Know how to get out in an emergency.

Know the hazards & how they are controlled.

Only authorized & trained personnel may enter a Confined Space or act as an attendant.

No smoking in Confined Space or near entrance or exit area.

Attendant must be present at all times.

Constant visual or voice communication must be maintained between the attendant and entrants.

No bottom or side entry will be made, or work conducted, below the level any hanging material or material which could cause engulfment.

Air and oxygen Monitoring is required before entering a Permit-Required Confined Space.

Ventilation & oxygen monitoring is required when welding is performed.



Gas Meter



Service worker cutting abandoned utility conduit out of the way.

Distribution and Storage Section Summary

Safe entry into a confined space requires that all entrants wear a harness and safety line.

If an operator is working inside a storage tank and suddenly faints or has a serious problem, there should be two people outside standing by to remove the injured operator.

During an inspection of your water storage facility, you should inspect the Cathodic protection system including checking the anode's condition and the connections.

The concentration of polyphosphates that is used for corrosion control in storage tanks is typically 5 mg/L or less.

External corrosion of steel water storage facilities can be reduced with Zinc or aluminum coatings.

All storage facilities should be regularly sampled to determine the quality of water that enters and leaves the facility. One tool or piece of measuring equipment is the Jackson turbidimeter, which is a method to measure cloudiness in water.

The effects of water freezing in storage tanks can be minimized by alternating water levels in the tank.

Distribution system water quality can be adversely affected by improperly constructed or poorly located blowoffs of vacuum/air relief valves. Air relief valves in the distribution system lines must be placed in locations that cannot be flooded. This is to prevent water contamination. The common customer complaint of Milky Water or Entrained Air is sometimes solved by the installation of air relief valves. The venting of air is not a major concern when checking water levels in a storage tank. If the vent line on a ground level storage tank is closed or clogged up, a vacuum will develop in the tank may happen to the tank when the water level begins to lower.

If an overflow occurs on a storage tank, the operator should first check the altitude-control valve. Altitude-Control Valve is designed to, 1. Prevent overflows from the storage tank or reservoir, or 2. Maintain a constant water level as long as water pressure in the distribution system is adequate.

Pressure Regulation Valves control water pressure and operate by restricting flows. They are used to deliver water from a high pressure to a low-pressure system. The pressure downstream from the valve regulates the amount of flow. Usually, these valves are of the globe design and have a spring-loaded diaphragm that sets the size of the opening.

Backsiphonage is a condition in which the pressure in the distribution system is less than atmospheric pressure. In other words, something is "sucked" into the system because the main is under a vacuum.

The following are common pressure sensing devices: Helical Sensor, Bourdon Tube, and Bellows Sensor. The most frequent problem that affects a liquid pressure-sensing device is air accumulation at the sensor. A diaphragm element being used as a level sensor would be used in conjunction with a pressure sensor.

Inspection of magnetic flow meter instrumentation should include checking for corrosion or insulation deterioration.

Telemetering systems must often transmit more than one signal. You can use several types of systems including: Polling, Scanning and Multiplexing. Transmitting equipment requires installation where temperature will not exceed 130 degrees F.

The Strain Gauge is a common measuring device used for a variety of changes such as head. As the pressure in the system changes, the diaphragm expands which changes the length of the wire attached. This change of length of the wire changes the Resistance of the wire, which is then converted to head. Float mechanisms, diaphragm elements, bubbler tubes, and direct electronic sensors are common types of level sensors.

When the superintendent is inspecting the plans for a new ground water storage tank, the superintendent should pay attention to the outlet and inlet and be sure that they are on opposite sides of the tank.

Surge tanks can be used to control Water Hammer. A limitation of hydropneumatic tanks is that they do not provide much storage to meet peak demands during power outages and you have very limited time to do repairs on equipment.

The maximum momentary load placed on a water treatment plant, pumping station or distribution system is the Peak Demand.

When a pump receives a signal to start, a light will typically be illuminated on the control panel indicating that the pump is running. In order to be sure that the pump is actually pumping water, a Positive flow report-back signal should be installed on the control panel.

A vortex is a whirlpool in the water.

General Knowledge & Safety Information

One of the roles of a distribution system supervisor is to inform the operators of SOPs concerning public relations. This can be accomplished by regular informational staff meetings.

Sprains and strains are the most frequent type of accident(s) encountered by water distribution personnel.

If a thrust block of another utility is discovered in your path while excavating, you should not alter the existing thrust block in any way.

Right to Know Laws state that the employer has the responsibility to provide the employees with information about health hazards and chemical handling.

Uniforms and proper credentials aid meter readers and operators that work close to private property because they help readily identify personnel.

The Building Inspector is responsible for the enforcement of building regulations.

For a dead-end line of over 2,000 feet, the design criteria would dictate a minimum pipe diameter of 8 inches. The Hazen-Williams formula is used to determine pipe size.

The water utility has the responsibility for insuring that water contamination due to cross connections does not occur. Pesticide mixing tanks have one of the greatest potential hazards of contamination if a cross connection occurs. The most likely consequence if a backsiphonage condition causes a cross connection and pressure is then restored to the system is that the distribution system downstream of the cross connection will be contaminated.

Any equipment that utilizes water for cooling, lubrication, washing or as a solvent is always susceptible to Cross-connections.

When installing a vacuum breaker backflow device, the operator must make sure that it is 12 inches above the highest discharge outlet. A double check will stop backsiphonage and backpressure of low contamination threats.

The relief valve will open and drain if a pressure differential occurs between the two checks; this best describes the operation of a reduced pressure principal backflow assembly device.

An operator may place a screen before a backflow prevention assembly to prevent debris from fouling the assembly.

Water audits can be performed in order to account for the water in the system. A 24-hour measure of all the water entering the system should be the first step in a water audit.

When you are shutting a large valve, a bypass valve will reduce high pressure that can be present.

If the pH of water from a dead-end line begins to drop, it is most likely an indication that anaerobic conditions are present.

Negative pressure in parts of the system may occur during periods of high flow or a fire when the waterline's pressure has dropped drastically.

An Insertion Valve (Hydrostop) is used in the water distribution system to isolate sections of mains to permit the making of emergency repairs to be made without interruption of service to a large number of customers.

Breakpoint Chlorination is best described as chlorine is added until all microorganisms are killed and the organic and inorganic materials have been destroyed, satisfied or oxidized. Some of the effects of temperature on chlorine disinfection effectiveness in water is that low temperatures decrease the effect of chlorine disinfection and high temperatures will increase the activity and the activity of the bugs as well. Chlorine gas is easily detected because of the smell, but can also cause olfactory fatigue, which makes chlorine gas deadly. Olfactory fatigue means that you lose the ability to smell the odor.

When bumping slip joint pipe, the operator should use a recommended lubricant. Bacterial growth could occur if the wrong lubricant is used.

Climbing safety devices are commonly used on fixed ladders.

If the desired result of cleaning large pipes is to remove slime and light scale without disturbing heavier encrustation, the best choice for cleaning would be a *Pig*.

A nutating-disk water meter is categorized as a displacement type meter.

A Valve Intersection Map or Valve and Hydrant Map would most likely indicate specific information such as the number of turns necessary to open or close a valve.

Depending upon your area, but most the water provider has the responsibility of the water service line up to the customer's side of the water meter, the SDWA states the responsibility is to the last free flowing tap.

Peak demand on the distribution system is critical to the operation. Peak demand is defined as the maximum load placed on a water treatment plant and the distribution system as the maximum average load in one hour or less.

Normal operation conditions of a water treatment or distribution yard will include rainfall.

A minimal shoring system should have stringers, cross braces and hangers.

Control of hazardous energy:
Before doing any work on any piece of electrical equipment, the operator should perform the following procedure on a piece of equipment lock out and tag the equipment, LOTO.

Critical operating information for pumps and motors can be quickly found on the equipment nameplate.

Safety authorities tell us that one out of ten injuries are the result of unsafe acts of either the person injured or someone else. Ignorance is used to describe the lack of experience or training, or a temporary condition that prevents the recognition of a hazard.



Glossary

Excellent operator certification study tool.

0.2 mg/L: Should be the target value for the free chlorine residual in the distribution system.

10 ppm: The IDLH for Cl₂ gas according to the NIOSH manual.

Absence of Oxygen: The complete absence of oxygen in water described as Anaerobic.

Accuracy: How closely an instrument measures the true or actual value.

Acid and a Base is Mixed: When an acid and a base are mixed an explosive reaction occurs and decomposition products are created under certain conditions.

Acid Rain: A result of airborne pollutants.

Acid: Slowly add the acid to water while stirring. An operator should not mix acid and water or acid to a strong base.

Activated Charcoal: A treatment technique that is not included in the grading of a water facility.

Air Gap or Vacuum Breaker: A potable water line should be equipped with an air gap or vacuum breaker when connected to a chemical feeder for fluoride.

Air Gap: A physical separation space that is present between the discharge vessel and the receiving vessel, for an example, a kitchen faucet. Minimum 1 inch or twice the diameter whatever is greater.

Air Hood: The most suitable protection when working with a chemical that produces dangerous fumes.

Alternative Disinfectants: Disinfectants - other than chlorination (halogens) - used to treat water, e.g. ozone, ultraviolet radiation, chlorine dioxide, and chloramine. There is limited experience and scientific knowledge about the by-products and risks associated with the use of alternatives.

Aluminum Sulfate: The chemical name for Alum. The molecular formula of Alum is Al₂(SO₄)₃·14H₂O. It is a cationic polymer.

Ammonia: A chemical made with Nitrogen and Hydrogen and used with chlorine to disinfect water.

Most ammonia in water is present as the ammonium ion rather than as ammonia.

Anaerobic: An abnormal condition in which color and odor problems are most likely to occur.

Anaerobic conditions: When anaerobic conditions exist in either the metalimnion or hypolimnion of a stratified lake or reservoir, water quality problems may make the water unappealing for domestic use without costly water treatment procedures. Most of these problems are associated with Reduction in the stratified waters.

Aquifer: An underground geologic formation capable of storing significant amounts of water. Is a permeable layer of the subsurface that allows the movement of groundwater.

As: The chemical symbol of Arsenic.

Atom: The general definition of an ion is an atom with a positive or negative charge. Electron is the name of a negatively charged atomic particle.

Backflow 12 inches: The required distance above ground that a double check backflow or RP assembly needs to be installed.

Backflow or Cross-connection Failure: Might be the source of an organic substance causing taste and odor problems in a water distribution system.

Backflow Prevention: To stop or prevent the occurrence of, the unnatural act of reversing the normal direction of the flow of liquid, gases, or solid substances back in to the public potable (drinking) water supply. Continuous positive pressure in a distribution system is essential for preventing a backflow event. See Cross-connection control.

Backflow: A double check valve backflow assembly provides effective protection from both backpressure and backsiphonage of pollution only. Needs to be tested on an annual basis, needs to be installed 12 inches above the ground.

Backflow: The definition of '**backflow**' is a reverse flow condition that causes water or mixtures of water and other liquids, gases, or substances to flow back into the distribution system. To reverse the natural and normal directional flow of a liquid, gases, or solid substances back in to the public potable (drinking) water supply. This is normally an undesirable effect. The difference between a reduced pressure principle backflow device and a double check backflow device is that RP has a relief valve. 1 year is the maximum time period between having a backflow device tested by a certified backflow tester. An operator must ensure when installing a pressure vacuum breaker backflow device that it must be at least 12 inches above the highest downstream outlet. This is different than 12 inches above the ground. Backsiphonage condition usually causes reduced pressure or negative pressure on the service or

supply side. Equipment that utilizes water for cooling, lubrication, washing or as a solvent always susceptible to a cross-connection. Minimum water pressure must be maintained to ensure adequate customer service during peak flow periods. However minimum positive pressure must be maintained in mains to protect against backflow or backsiphonage from cross-connections.

Backsiphonage: A liquid substance that is carried over a higher point. It is the method by which the liquid substance may be forced by excess pressure over or into a higher point.

Back-up Disinfection units: If a chlorination system goes out of operation you are required to have back-up.

Backwash: A surface wash system should be activated prior to the start of the backwash.

Backwashing: Backwash the filters more frequently can be used to increase water production if an increase in raw water turbidity and coagulation feed rate creates additional loading on the filter.

Bacteria: Small, one-celled animals too small to be seen by the naked eye. Bacteria are found everywhere, including on and in the human body. Humans would be unable to live without the bacteria that inhabit the intestines and assist in digesting food. Only a small percentage of bacteria cause disease in normal, healthy humans. Iron bacteria is undesirable in a water distribution system because the bacteria may cause red water and slime. Examples include; Salmonella, Shigella, Bacillus, Vibrio Cholera and Cholera.

Battery: A source of direct current (**DC**) may be used for standby lighting in a water treatment facility. The electrical current used in a DC system may come from a battery.

Benching: A method of protecting employees from cave-ins by excavating the sides of an excavation to form one or a series of horizontal levels or steps, usually with vertical or near vertical surfaces between levels.

Breakpoint Chlorination: The process of chlorinating the water with significant quantities of chlorine to oxidize all contaminants and organic wastes and leave all remaining chlorine as free chlorine.

Bromine: This chemical disinfectant has been used only on a very limited scale for water treatment because of its handling difficulties. This chemical causes skin burns on contact, and a residual is difficult to obtain.

Bromine: Has a limited use for water treatment because of its handling difficulties. This is one of the chemical disinfectants (**HALOGEN**) that kills bacteria and algae.

Buffer: Chemical that resists pH change, e.g. sodium bicarbonate.

Bypass Valve: The name of a type of valve that reduces the differential pressure across a closed disk making the main valve easier to open and close.

Ca: The chemical symbol for calcium.

Cadmium: A contaminant that is usually not found naturally in water or in very small amounts.

Calcium Hardness: A measure of the calcium salts dissolved in water.

Calcium Ion: Divalent because it has a valence of +2.

Calcium, Magnesium, and Iron: Are the three elements that cause hardness in water.

CaOCl₂·4H₂O: The molecular formula of Calcium hypochlorite.

Capillary Fringe: The material immediately above the water table may contain water by capillary pressure in the small void spaces.

Carbon Dioxide Gas: The pH will decrease and alkalinity will change as measured by the Langelier index after pumping carbon dioxide gas into water.

Carbonate, Bicarbonate and Hydroxide: Chemicals that are responsible for the alkalinity of water.

Cathodic Protection: An operator should protect against corrosion of the anode and/or the cathode by painting the copper cathode.

Cathodic Protection: Cathodic protection interrupts corrosion by supplying an electrical current to overcome the corrosion-producing mechanism.

Cathodic Protection: Guards against stray current corrosion.

Caustic Soda: Also known as sodium hydroxide and is used to raise pH.

Ceiling Area: The specific gravity of ammonia gas is 0.60. If released, this gas will accumulate first at the ceiling area. Cl₂ gas will settle on the floor.

Centrifugal Force: That force when a ball is whirled on a string that pulls the ball outward. On a centrifugal pump, it is that force which throws water from a spinning impeller.

Centrifugal Pump: A pump consisting of an impeller fixed on a rotating shaft and enclosed in a casing, having an inlet and a discharge connection. The rotating impeller creates pressure in the liquid by the velocity derived from centrifugal force.

Check Valve: Allows water to flow in only one direction.

Chelation: A chemical process used to control scale formation in which a chelating agent "captures" scale-causing ions and holds them in solution.

Chemical Oxidizer: KMnO₄ is used for taste and odor control because it is a strong oxidizer which eliminates many organic compounds.

Chemical Reaction Rate: In general, when the temperature decreases, the chemical reaction rate also decreases. The opposite is true for when the temperature increases.

Chloramination: Treating drinking water by applying chlorine before or after ammonia. This creates a persistent disinfectant residual called chloramines.

Chloramines: A group of chlorine and ammonia compounds formed when chlorine combines with organic wastes in the water. Chloramines are not effective as disinfectants and are responsible for eye and skin irritation as well as strong chlorine odors (**also known as Combined Chlorine**).

Chlorination: The process in water treatment of adding chlorine (gas or solid hypochlorite) for purposes of disinfection.

Chlorine Demand: Amount of chlorine required to react on various water impurities before a residual is obtained. Also, means the amount of chlorine required to produce a free chlorine residual of 0.1 mg/l after a contact time of fifteen minutes as measured by iodometric method of a sample at a temperature of twenty degrees in conformance with Standard methods.

Chlorine Feeding: Chlorine may be delivered by vacuum-controlled solution feed chlorinators. The chlorine gas is controlled, metered, introduced into a stream of injector water and then conducted as a solution to the point of application.

Chlorine, Free: Chlorine available to kill bacteria or algae. The amount of chlorine available for sanitization after the chlorine demand has been met. Also known as chlorine residual.

Chlorine: A chemical used to disinfect water. Chlorine is extremely reactive, and when it comes in contact with microorganisms in water killing them. Chlorine is added to swimming pools to keep the water safe for swimming. Chlorine is available as solid tablets for swimming pools. Some public water system's drinking water treatment plants use chlorine in a gas form because of the large volumes required. Chlorine is very effective against algae, bacteria and viruses. Protozoa are resistant to chlorine because they have thick coats. Protozoa are removed from drinking water by filtration.

CL2 0.2 mg/L: If you are disinfecting to preserve water potability, the minimum concentration of free Cl2 residual in the distribution system.

CL2 10 mg/L: Small water storage tanks are commonly disinfected with a solution containing a Cl2 concentration of 50 mg/L. After 24 hours the minimum Cl2 concentration should be 10 mg/L.

CL2 A Fusible Plug: Considered a safety device on a Cl2 cylinder.

CL2 Chronic Exposure Corrosion of the Teeth: May occur due to chronic exposure to low concentrations of Cl2 gas. After long exposure, throat cancer will occur.

Cl2 Cylinder is Increased: If the temperature of a full Cl2 cylinder is increased by 50° F or 30° C, a rupture may occur.

Cl2 Demand: Cl2 combines with a wide variety of materials. These side reactions complicate the use of Cl2 for disinfecting purposes. Their demand for Cl2 must be satisfied before Cl2 becomes available to accomplish disinfection.

Cl2 Expands in Volume: Happens to Cl2 when the temperature of a Cl2 cylinder increases.

Cl2 Free Concentration: If you are disinfecting to preserve water potability, the minimum concentration of free chlorine residual in the distribution system should be 0.2 mg/l.

CL2 Gas Exposure: Chlorine gas causes suffocation, constriction of the chest, tightness in the throat, and edema of the lungs. As little as 2.5 mg per liter (approximately 0.085 percent by volume) in the atmosphere causes death in minutes, but less than 0.0001 percent by volume may be tolerated for several hours. Chlorine gas reacts with water producing a strongly oxidizing solution causing damage to the moist tissue lining the respiratory tract when the tissue is exposed to chlorine. The respiratory tract is rapidly irritated by exposure to 10-20 ppm of chlorine gas in air, causing acute discomfort that warns of the presence of the toxicant. Death is possible from asphyxia, shock, reflex spasm in the larynx, or massive pulmonary edema. Populations at special risk from chlorine exposure are individuals with pulmonary disease, breathing problems, bronchitis, or chronic lung conditions.

CL2 Gas IDLH: As soon as Cl2 gas enters the throat area, a victim will sense a sudden stricture in this area—nature's way of signaling to prevent passage of the gas to the lungs. The victim must attempt to get out of the area of the leak, proceeding upwind, and to take only very short breaths through the mouth. Normal breathing will cause coughing, which must be prevented if possible. Chlorine gas causes suffocation, constriction of the chest, tightness in the throat, and edema of the lungs. As little as 2.5 mg

per liter in the atmosphere causes death in minutes, but less than 0.01 percent by volume may be tolerated for several hours.

CL2 Gas Safety: Gas leak is the primary safety concern when using chlorine gas as opposed to calcium hypochlorite or sodium hypochlorite.

Cl2 Gas will Accumulate: If a Cl2 leak occurs, the Cl2 gas will accumulate on the floor.

CL2 Gaskets: Replace according to manufacturers recommendations should be done with the gaskets when making a new connection on a chlorine feed system.

CL2 General Statements: If an operator cannot open the valve on a Cl2 cylinder because it is too tight, first loosen the packing gland around the valve, and tap the valve gently with your hand.

The number 17 is the atomic number of Cl2. 200 mg/l is the generally acceptable concentration of Cl2 solution that should be prepared to wash the inside of a storage facility. A device that has a transparent tube with a tapered bore containing a ball and is often used to measure the rate of a gas or liquid is called a Rotameter. After Cl2 gas is manufactured, it primarily transported and packaged as a liquefied gas under pressure in steel containers. As soon as Cl2 gas enters the throat area, a victim will sense a sudden stricture in this area- Nature's way of signaling to prevent passage of the gas to the lungs. At this point, the victim must attempt to do two things: get out of the area of the leak, proceeding upwind, and to take only very short breaths through the mouth. Normal breathing will cause coughing, which must be prevented if possible. Before entering a Cl2 room to check on a leak don a self-contained breathing apparatus and check to see that the ventilation system is working. Be sure that no one enters the leak area without an adequate self-contained breathing apparatus. Breakpoint chlorination means adding Cl2 to the water until the Cl2 demand is satisfied. Chronic exposure to low concentrations of Cl2 gas may cause corrosion of the teeth. Cl2 combines with a wide variety of materials. These side reactions complicate the use of Cl2 for disinfecting purposes. Their demand for Cl2 must be satisfied before Cl2 becomes available to accomplish disinfection. Cl2 combines with water to form both hypochlorous and hydrochloric acids. Cl2 gas is highly corrosive in moist conditions. The only metals that are TOTALLY inert to moist Cl2 gas are Gold, Platinum, and Tantalum. Cl2 as with H2S gas produces olfactory fatigue. Cl2 gas reacts with water producing a strongly oxidizing solution causing damage to the moist tissue lining the respiratory tract when the tissue is exposed to Cl2. The respiratory tract is rapidly irritated by exposure to 10-20 ppm of Cl2 gas in air, causing acute discomfort that warns of the presence of the toxicant. Cl2 gas should only be used under a fume hood. Determine the ambient temperature in a Cl2 room by using a regular thermometer because ambient temperature is simply the air temperature of the room. Downstream from the point of post chlorination, the concentration of a free Cl2 residual should be 0.5 mg/L in a clear well or distribution reservoir. Even brief exposure to 1,000 ppm of Cl2 can be fatal. Free available Cl2 is very effective in killing bacteria. If an operator places water on a leaking Cl2 cylinder, corrosion will occur and the leak will get larger. Store an empty Cl2 cylinder upright, tagged as empty. The Cl2 storage ventilation equipment be checked on a daily basis. The CT values for disinfection are used to determine the disinfection efficiency based upon time and concentration of the disinfectant residual. The effectiveness of disinfection determined from the results of coliform testing. The first step when removing a hypochlorinator from service is to turn off the water supply pump. The fusible plug on a 150-pound Cl2 cylinder is designed to soften and melt at high temperatures. The physical and chemical properties of Cl2 are: A yellowish green, nonflammable and liquefied gas with an unpleasant and irritating smell. Can be readily compressed into a clear, amber colored liquid. A noncombustible gas, and a strong oxidizer, Cl2 is about 1.5 times heavier than water and gaseous Cl2 is about 2.5 times heavier than air. The purpose of an evaporator is to convert liquid Cl2 to gaseous Cl2 for use by gas chlorinators. The purpose of the bottom valve on a 1-ton Cl2 cylinder is to remove liquid Cl2. The purpose of the ejector on a hypochlorinator, is that the ejector draws in additional water for dilution of the hypochlorinate solution. The water temperature decreases from 70°F (21°C) to 40°F (4°C). Allow a longer contact time to maintain good disinfection of the water. When Cl2 is inhaled in high concentrations it causes emphysema and damage to the pulmonary blood vessels. When determining a Cl2 use rate, the scale or meter should be read at the same time each day. When hypochlorite is brought into contact with an organic material, the organic material decomposes releasing heat very rapidly. Where other factors are constant, the disinfecting action may be represented by: Kill = C x T.

Clear Well: A large underground storage facility sometimes made of concrete. A clear well or a plant storage reservoir is usually filled when demand is low.

ClO2: The molecular formula of Chlorine dioxide.

Coagulation: The best pH range for coagulation is between a pH of 5 and 7. Mixing is an important part of the coagulation process you want to complete the coagulation process as quickly as possible.

Coliform Bacteria: Are bacteria that are normally found in the intestines of warm-blooded animals. Coliform bacteria are present in high numbers in animal feces. They are an indicator of potential contamination of water. Adequate and appropriate disinfection effectively destroys coliform bacteria.

Coliform Testing: The effectiveness of disinfection is usually determined by Coliform bacteria testing. A positive sample is a bad thing and indicates that you have bacteria contamination.

Colloidal Suspensions: Because both iron and manganese react with dissolved oxygen to form insoluble compounds they are not found in high concentrations in waters containing dissolved oxygen except as colloidal suspensions of the oxide.

Colorimetric Measurement: A means of measuring and unknown chemical concentration in water by measuring a sample's color intensity.

Combined Chlorine: The reaction product of chlorine with ammonia or other pollutants, also known as chloramines.

Community Water System: A water system which supplies drinking water to 25 or more of the same people year-round in their residences.

Competent Person: One who is capable of identifying existing and predictable hazards in the surroundings or working conditions, which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

Compliance Cycle: A 9-calendar year time-frame during which a public water system is required to monitor. Each compliance cycle consists of 3 compliance periods.

Compliance Period: A 3-calendar year time-frame within a compliance cycle.

Composite Sample: Is a water sample that is a combination of a group of samples collected at various intervals during the day.

Condensation: The process called that changes water vapor to tiny droplets or ice crystals.

Contact Time, pH and Low Turbidity: Are factors which are important in providing good disinfection using chlorine.

Contact Time: If the water temperature decreases from 70 degrees F (21 degrees C) to 40 degrees F (4 degrees C). The operator needs to increase the detention time to maintain good disinfection of the water.

Contains the Element Carbon: Is a simple definition of an organic compound.

Contaminant: Any natural or man-made physical, chemical, biological, or radiological substance or matter in water, which is at a level that may have an adverse effect on public health, and which is known or anticipated to occur in public water systems.

Contamination: To make something bad; to pollute or infect something. To reduce the quality of the potable (drinking) water and create an actual hazard to the water supply by poisoning or through spread of diseases.

Control Taste and Odor Problems: KMnO⁴ Potassium permanganate is a strong oxidizer is commonly used to control taste and odor problems.

Copper: The chemical name for the symbol Cu.

Corrosion: The gradual decomposition or destruction of a material as it chemically reacts with water and is often referred to as corrosion. The removal of metal from copper, other metal surfaces and concrete surfaces in a destructive manner. Corrosion is caused by improperly balanced water or excessive water velocity through piping or heat exchangers.

Corrosivity: The Langelier Index measures corrosivity.

Coupon: Placed to measure corrosion damage in the water mains.

Cross-connection: A physical connection between a public water system and any source of water or other substance that may lead to contamination of the water provided by the public water system through backflow. Might be the source of an organic substance causing taste and odor problems in a water distribution system.

Cross-contamination: The mixing of two unlike qualities of water. For example, the mixing of good water with a polluting substance like a chemical substance.

Cryptosporidium: A disease-causing parasite, resistant to chlorine disinfection. It may be found in fecal matter or contaminated drinking water.

Diaphragm: Valves can be used to maintain a constant downstream pressure in a water distribution system, regardless of fluctuating demand. An integral component of these valves is a rubber diaphragm. Commonly found in a PRV.

Dangerous Chemicals: The most suitable protection when working with a chemical that produces dangerous fumes is to work under an air hood.

CWS: Community Water System.

Decibels: The unit of measurement for sound.

Decompose: To decay or rot.

Decomposition of Organic Material: The decomposition of organic material in water produces taste and odors.

Demineralization Process: Mineral concentration of the feed water is the most important consideration in the selection of a demineralization process. Acid feed is the most common method of scale control in a membrane demineralization treatment system.

Dental Caries Prevention in Children: Is the main reason that fluoride is added to a water supply.

Depolarization: The removal of hydrogen from a cathode.

Desiccant: When shutting down equipment which may be damaged by moisture, the unit may be protected by sealing it in a tight container. This container should contain a desiccant.

Detection Lag: The period of time between the moment of change in a chlorinator control system and the moment when the change is sensed by the chlorine residual indicator.

Detention Time: The minimum detention time range recommended for flocculation is 5 – 20 minutes for direct filtration and up to 30 minutes for conventional filtration.

Diatomaceous Earth: A fine silica material containing the skeletal remains of algae.

Direct Current: A source of direct current (**DC**) may be used for standby lighting in a water treatment facility. The electrical current used in a DC system may come from a battery.

Disinfect: To kill and inhibit growth of harmful bacterial and viruses in drinking water.

Disinfectant Residual: The CT values for disinfection are used to determine the disinfection efficiency based upon time and disinfectant residual.

Disinfection by-products (DBPs): The products created due to the reaction of chlorine with organic materials (e.g. leaves, soil) present in raw water during the water treatment process. The EPA has determined that these DBPs can cause cancer.

Disinfection: The treatment of water to inactivate, destroy, and/or remove pathogenic bacteria, viruses, protozoa, and other parasites. The effectiveness of disinfection determined by the results of coliform testing. Types of source water are required by law to treat water using filtration and disinfection are groundwater under the direct influence of surface water. Surface water sources.

Dissolved Oxygen: Can be added to zones within a lake or reservoir that would normally become anaerobic during periods of thermal stratification.

Distillation, Reverse Osmosis and Freezing: Processes can be used to remove minerals from the water.

Distribution 8 inches: The minimum pipe diameter for a dead end line exceeding 2,000 feet in length should be 8 inches.

Double Suction Pump: One advantage of a double suction pump is a reduction in the thrust load that the bearings must carry.

Dry Acid: A granular chemical used to lower pH and or total alkalinity.

E. Coli, Escherichia coli : A bacterium commonly found in the human intestine. For water quality analyses purposes, it is considered an indicator organism. These are considered evidence of water contamination. Indicator organisms may be accompanied by pathogens, but do not necessarily cause disease themselves.

Eccentric Valve: The plug on an eccentric valve contacts the valve seat when the valve is closed.

Effectiveness of Chlorination: The factors which influence the effectiveness of chlorination the most are pH, Turbidity and Temperature.

Effectiveness of the Chlorine Decreases: Will occur during disinfection in source water with excessive turbidity.

Electrical Problem: Moisture will cause the deterioration of oil in a transformer.

Electrical Resistance: Resistance of electrical equipment is affected by many variables including the thickness of the insulation and its total mass area.

Electrical: An operator using a voltage meter to test electrical equipment should first, make sure the main switch is off and the voltage tester is rated to handle the voltage expected in the circuit. If grease comes in contact with the winding of a motor the winding insulation may deteriorate. If the overload control on a motor has tripped and the motor has stopped running. An operator needs to wait for the

overload to cool, then tries to start the motor again. If the motor does not start, the operator should first check the fuse.

Electricity: Rubber may be used to prevent the flow of electricity through a wire.

Electron: The name of a negatively charged atomic particle.

Elementary Business Plan: Technical Capacity, Managerial Capacity, and Financial Capacity make up the elementary business plan. To become a new public water system, an owner shall file an elementary business plan for review and approval by the Department.

Emergency Response Team: Get out of the area and notify your local emergency response team is the first should be done first in case of a large uncontrolled chlorine leak.

Enhanced Coagulation: The process of joining together particles in water to help remove organic matter.

Enterovirus: A virus whose presence may indicate contaminated water; a virus that may infect the gastrointestinal tract of humans.

F: Is the chemical symbol of Fluorine.

Faucet with an Aerator: When collecting a water sample from a distribution system, a faucet with an aerator should not be used as a sample location.

Fecal Coliform: A group of bacteria that may indicate the presence of human or animal fecal matter in water.

Filtration: A series of processes that physically removes particles from water. A water treatment step used to remove turbidity, dissolved organics, odor, taste and color.

Filter Clogging: An inability to meet demand may occur when filters are clogging.

Filtration Methods: The conventional type of water treatment filtration method includes coagulation, flocculation, sedimentation, and filtration. Direct filtration method is similar to conventional except that the sedimentation step is omitted. Slow sand filtration process does not require pretreatment, has a flow of 0.1 gallons per minute per square foot of filter surface area, and is simple to operate and maintain. Diatomaceous earth method uses a thin layer of fine siliceous material on a porous plate. This type of filtration medium is only used for water with low turbidity. Sedimentation, adsorption, and biological action treatment methods are filtration processes that involves a number of interrelated removal mechanisms. Demineralization is primarily used to remove total dissolved solids from industrial wastewater, municipal water, and seawater.

Finished Water: Treated drinking water that meets minimum state and federal drinking water regulations.

Flocculation: The process of bringing together destabilized or coagulated particles to form larger masses that can be settled and/or filtered out of the water being treated.

Floc Shearing: Likely to happen to large floc particles when they reach the flocculation process.

Flocculation Basin: A compartmentalized basin with a reduction of speed in each compartment. This set-up or basin will give the best overall results.

Flood Rim: The point of an object where the water would run over the edge of something and begin to cause a flood.

Flow must be Measured: A recorder that measures flow is most likely to be located in a central location.

Fluoride Feeding System: Always review fluoride feeding system designs and specifications to determine whether locations for monitoring readouts and dosage controls are convenient to the operation center and easy to read and correct.

Fluoride: High levels of fluoride may stain the teeth of humans; this is called mottling. This chemical must not be overfed due to a possible exposure to a high concentration of the chemical. The most important safety considerations to know about fluoride chemicals is that all fluoride chemicals are extremely corrosive. These are the substances most commonly used to furnish fluoride ions to water: Sodium fluoride, Sodium silicofluoride and Hydrofluosilicic acid.

Flux: The term flux describes the rate of water flow through a semipermeable membrane. The water flux decreases through a semipermeable membrane when the mineral concentration of the water increases.

Formation of Tubercles: This condition is of the most concern regarding corrosive water effects on a water system. It is the creation of mounds of rust inside the water lines.

Free Chlorine Residual gives the best Disinfection: Is the reason for chlorinating past the breakpoint is to provide protection in case of backflow.

Free Chlorine Residual: Regardless of whether pre-chlorination is practiced or not, a free chlorine residual of at least 10 mg/L should be maintained in the clear well or distribution reservoir immediately downstream from the point of post-chlorination.

Free Chlorine: In disinfection, chlorine is used in the form of free chlorine or as hypochlorite ion.

Frequency must a Remote Operator inspect a Grade 1 or grade 2 Water Treatment Plant: Monthly or as necessary a remote operator inspect a grade 1 or grade 2 water treatment plant or distribution system that produces and distributes groundwater.

Gate Valve: The most common type of valve used in isolating a small or medium sized section of a distribution system and is the only linear valve used in water distribution. All the other valves are in the rotary classification.

Giardia Lamblia: A pathogenic parasite, which may be found in, contaminated water.

Giardiasis, Hepatitis, or Typhoid: Diseases that may be transmitted through the contamination of a water supply but not AIDS.

GIS - Graphic Information System: Detailed information about the physical locations of structures such as pipes, valves, and manholes within geographic areas with the use of satellites.

Globe Valve: The main difference between a globe valve and a gate valve is that a globe valve is designed as a controlling device.

Good Contact Time, pH and Low Turbidity: These are factors that are important in providing good disinfection when using chlorine.

Grab Sample: A type of sample that should be collected to analyze for coliform bacteria, pH and Temperature. A snap shot of a certain location and time.

Gt : Represents (Detention time) x (mixing intensity) in flocculation.

H₂SO₄: The molecular formula of Sulfuric acid.

Hard Water: Hard water causes a buildup of scale in household hot water heaters.

Hazards of Polymers: Slippery and difficult to clean-up are the most common hazards associated with the use of polymers in a water treatment plant.

Head: The measure of the pressure of water expressed in feet of height of water. 1 PSI = 2.31 feet of water or 1 foot of head equals about a half a pound of pressure or .433 PSI. There are various types of heads of water depending upon what is being measured. Static (water at rest) and Residual (water at flow conditions).

Head Loss: A negative effect that a water meter has on a service.

Headworks: The facility at the "head" of the water source where water is first treated and routed into the distribution system.

Health Advisory: An EPA document that provides guidance and information on contaminants that can affect human health and that may occur in drinking water, but which EPA does not currently regulate in drinking water.

Heat Damage to Air Compressor: An air compressor generates heat during the compression cycle. And is the most common type of damage caused by heat generated during operation.

Hertz: Is the term used to describe the frequency of cycles in an alternating current (AC) circuit.

Heterotrophic Plate Count Bacteria: A broad group of bacteria including non-pathogens, pathogens, and opportunistic pathogens; they may be an indicator of poor general biological quality of drinking water. Often referred to as **HPC**.

HF: The molecular formula of Hydrofluoric acid.

High Turbidity Causing an Increased Chlorine Demand: May occur or be caused by the inadequate disinfection of water.

Hydrochloric and Hypochlorous Acids: Are the compounds that are formed in water when chlorine gas is introduced.

Hydrogen Sulfide or Chlorine: These chemicals can cause olfactory fatigue.

Hydrophobic: Does not mix readily with water.

Hypochlorite and Organic Material: Heat and a possible fire may happen when hypochlorite is brought into contact with an organic material.

Hypochlorous and Hydrochloric Acids: Chlorine combines with water to form hypochlorous and hydrochloric acids, HOCL and HCL or free available chlorine.

If a facility is re-graded to a higher grade, how long does the facility have to hire or train an operator with the applicable class and grade?: 12 months.

Impeller: A rotating set of vanes designed to impart rotation to a mass fluid.

Impervious: Not allowing, or allowing only with great difficulty, the movement of water.

Infectious Pathogens/Microbes/Germs: Are considered disease-producing bacteria, viruses and other microorganisms.

Initial monitoring year: An initial monitoring year is the calendar year designated by the Department within a compliance period in which a public water system conducts initial monitoring at a point of entry.

Inorganic Contaminants: Mineral-based compounds such as metals, nitrates, and asbestos. These contaminants are naturally-occurring in some water, but can also get into water through farming, chemical manufacturing, and other human activities. The EPA has set legal limits on 15 inorganic contaminants.

Insoluble Compounds: Types of compounds cannot be dissolved. When iron or manganese reacts with dissolved oxygen (**DO**) insoluble compound are formed.

Intake Facilities: One of the more important considerations in the construction of intake facilities is the ease of operation and maintenance over the expected lifetime of the facility. Every intake structure must be constructed with consideration for operator safety and for cathodic protection.

Ion Exchange: Ion exchange is an effective treatment process used to remove iron and manganese in a water supply. The hardness of the source water affects the amount of water an ion exchange softener may treat before the bed requires regeneration.

Iron and Manganese: In water can be usually detected by observing the color of the inside walls of filters and the filter media. If the raw water is pre-chlorinated, there will be black stains on the walls below the water level and a black coating over the top portion of the sand filter bed. When significant levels of dissolved oxygen are present, iron and manganese exist in an oxidized state and normally precipitate into the reservoir bottom sediments. The presence of iron and manganese in water promote the growth of Iron bacteria. Only when a water sample has been acidified then you can perform the analysis beyond the 48 hour holding time. Iron and Manganese in water may be detected by observing the color of the filter media. Maintaining a free chlorine residual and regular flushing of water mains may control the growth of iron bacteria in a water distribution system.

Iron Bacteria: Perhaps the most troublesome consequence of iron and manganese in the water is they promote the growth of a group of microorganism known as Iron Bacteria.

Iron Fouling: You should look for an orange color on the resin and backwash water when checking an ion exchange unit for iron fouling

Iron: The elements iron and manganese are undesirable in water because they cause stains and promote the growth of iron bacteria.

Kill=C x T: Where other factors are constant, the disinfecting action may be represented by: Kill=C x T.

Kinetic Energy: The ability of an object to do work by virtue of its motion. The energy terms that are used to describe the operation of a pump are pressure and head.

Langelier Index: A measurement of Corrosivity. The water is becoming corrosive in the distribution system causing rusty water if the Langelier index indicates that the pH has decreased from the equilibrium point. Mathematically derived factor obtained from the values of calcium hardness, total alkalinity, and pH at a given temperature. A Langelier index of zero indicates perfect water balance (i.e., neither corroding nor scaling).

Leaching: A chemical reaction between water and metals that allows for removal of soluble materials.

Lead and Copper: Initial tap water monitoring for lead and copper must be conducted during 2 consecutive 6-month periods.

Lime Soda Softening: In a lime soda softening process, the pH of the water is raised to 11.0. In a lime softening process, excess lime is frequently added to remove Calcium and Magnesium Bicarbonate. The minimum hardness which can be achieved by the lime-soda ash process is 30 to 40 mg/L as calcium carbonate. The hardness due to noncarbonate hardness is most likely to determine the choice between lime softening and ion exchange to remove hardness.

Lime: A chemical that may be added to water to reduce the corrosivity. When an operator adds lime to water, Calcium and magnesium become less soluble.

Lines: Lines in the distribution system should be flushed on a regular basis. The flushing should be done at night and the water pressure in the distribution system must be at least 25 PSI.

LOTO: In a good lock-out/tag out program, if a piece of equipment is locked out, the key to the lock-out device the key should be held by the person who is working on the equipment. The tag is an identification device and the lock is a physical restraint.

Magnesium Hardness: Measure of the magnesium salts dissolved in water – it is not a factor in water balance.

Magnetic Starter: A type of motor starter should be used in an integrated circuit to control flow automatically.

Marble and Langelier Tests: Used to measure or determine the corrosiveness of a water source.

Maximum Contaminant Level Goal (MCLG): The level of a contaminant at which there would be no risk to human health. This goal is not always economically or technologically feasible, and the goal is not legally enforceable.

Maximum Contaminant Levels (MCLs): The maximum allowable level of a contaminant that federal or state regulations allow in a public water system. If the MCL is exceeded, the water system must treat the water so that it meets the MCL.

MCL for Turbidity: Turbidity is undesirable because it causes health hazards. An MCL for turbidity was established by the EPA because turbidity does not allow for proper disinfection.

Measure Corrosion Damage: A coupon is a strip of metal and is placed to measure corrosion damage in the distribution system in a water main.

Mechanical Seal: A mechanical device used to control leakage from the stuffing box of a pump. Usually made of two flat surfaces, one of which rotates on the shaft. The two flat surfaces are of such tolerances as to prevent the passage of water between them. Held in place with spring pressure.

Medium Water System: More than 3,300 persons and 50,000 or fewer persons.

Megger: Used to test the insulation resistance on a motor.

M-Endo Broth: The media shall be brought to the boiling point when preparing M-Endo broth to be used in the membrane filter test for total coliform.

Methane: Classified as an organic compound.

mg/L: Milligrams per liter.

Microbe, Microbial: Any minute, simple, single-celled form of life, especially one that causes disease.

Microbial Contaminants: Microscopic organisms present in untreated water that can cause waterborne diseases.

Microbiological: A type of analysis in which a composite sample unacceptable.

mL: milliliter

Moisture and Potassium Permanganate: The combination of moisture and potassium permanganate produces heat.

Moisture: If a material is hygroscopic it must be protected from water.

Motor 3600 rpms: The maximum synchronous speed of an electric motor that has a frequency of 60 Hz.

Motor Overload Control: The overload control on a motor has tripped and the motor has stopped running. An operator waits for the overload to cool, then tries to start the motor again. If the motor does not start, the operator should check first the Motor overload control.

Motor: If a motor is rated for 10 amps the overload relays that should be used are 10 to 11 amps. A possible cause for a mechanical noise coming from a motor is an unbalance of a rotating mechanical part. And a possible result of over-greasing a bearing is that there will be extreme friction in the bearing chamber.

Mottling: High levels of fluoride may stain the teeth of humans.

MSDS: A safety document an employer must provide to an operator upon request.

Mud Balls in Filter Media: A possible result of an ineffective or inadequate filter backwash.

Muriatic Acid: An acid used to reduce pH and alkalinity. Also used to remove stain and scale.

NaOCl: Is the molecular formula of Sodium hypochlorite.

NaOH: Is the molecular formula of Sodium hydroxide.

New Public Water System: Depending upon your state rule; Community water systems and non-transient non-community water systems that begin operations on or after October 1, 1999 must comply with Article 6, Capacity Development Requirements for a New Public Water System.

NH3: The molecular formula of Ammonia.

NH4+: The molecular formula of the Ammonium ion.

Nitrate and nitrite are prohibited: The Department will not grant a nitrate or nitrite waiver.

Nitrates: A dissolved form of nitrogen found in fertilizers and sewage by-products that may leach into groundwater and other water sources. Nitrates may also occur naturally in some waters. Over time, nitrates can accumulate in aquifers and contaminate groundwater.

Nitrogen and Phosphorus: Are pairs of elements and major plant nutrients that cause algae to grow.

NO3-: The molecular formula of the Nitrate ion.

Non-Carbonate Hardness: The portion of the total hardness in excess of the alkalinity.

Noncarbonate Ions: Water contains Noncarbonate ions if it cannot be softened to a desired level through the use of lime only.

Non-point source pollution: Air pollution may leave contaminants on highway surfaces. This nonpoint source pollution adversely impacts reservoir water and groundwater quality.

Non-Transient, Non-Community Water System: A water system which supplies water to 25 or more of the same people at least six months per year in places other than their residences. Some examples are schools, factories, office buildings, and hospitals which have their own water systems.

Normality: The number of equivalent weights of solute per liter of solution.

Notification and Safety of the Public: The most important concern to an owner/operator if a toxic substance contaminates a drinking water.

NTNCWS: Non-transient non-community water system.

NTU (nephelometric turbidity unit): A measure of the clarity or cloudiness of water.

O³: The molecular formula of ozone.

Oligotrophic: A reservoir that is nutrient-poor and contains little plant or animal life.

Organic Precursors: Natural or man-made compounds with chemical structures based upon carbon that, upon combination with chlorine, leading to trihalomethane formation.

Osmosis: The process by which water moves across a semi permeable membrane from a low concentration solute to a high concentration solute to satisfy the pressure differences caused by the solute.

Overrange Protection Devices: Mechanical dampers, snubbers and an air cushion chamber are examples of surging and overrange protection devices.

Oxidizing: The process of breaking down organic wastes into simpler elemental forms or by products. Also used to separate combined chlorine and convert it into free chlorine.

Oxygen Deficient Environment: Name one of the most dangerous threats to an operator upon entering a manhole.

Ozone does not provide a Residual in the Distribution System: One of the major drawbacks to using ozone as a disinfectant.

Ozone, Chlorine Dioxide or Chloramine O₃, ClO₂, or NH₄Cl₂: These chemicals may be used as alternative disinfectants.

PAC: A disadvantage of using PAC is it is very abrasive and requires careful maintenance of equipment. One precautions should be taken in storing PAC is that bags of carbon should not be stored near bags of HTH. Removes tastes and odors by adsorption only. Powered activated carbon frequently used for taste and odor control because PAC is non-specific and removes a broad range of compounds. Jar tests and threshold odor number testing determines the application rate for powdered activated carbon. Powdered activated carbon, or PAC, commonly used for in a water treatment plant for taste and odor control. Powdered activated carbon may be used with some success in removing the precursors of THMs

Packing: Material, usually of woven fiber, placed in rings around the shaft of a pump and used to control the leakage from the stuffing box.

Pathogens: Disease-causing pathogens; waterborne pathogens A pathogen is a bacterium, virus or parasite that causes or is capable of causing disease. Pathogens may contaminate water and cause waterborne disease.

Pb: The chemical symbol of Lead.

pCi/L: Picocuries per liter. A curie is the amount of radiation released by a set amount of a certain compound. A picocurie is one quadrillionth of a curie.

Peak Demand: The maximum momentary load placed on a water treatment plant, pumping station or distribution system.

Permeate: Water which has passed through the membrane of a reverse osmosis unit.

pH of Saturation: The ideal pH for perfect water balance in relation to a particular total alkalinity level and a particular calcium hardness level, at a particular temperature. The pH where the Langelier Index equals zero.

pH (Power of Hydroxyl Ion Activity): A measure of the acidity of water. The pH scale runs from 0 to 14 with 7 being the mid point or neutral. A pH of less than 7 is on the acid side of the scale with 0 as the point of greatest acid activity. A pH of more than 7 is on the basic (alkaline) side of the scale with 14 as the point of greatest basic activity. Alkalinity and pH tell an operator with regards to coagulation how to determine the best chemical coagulant to be used. The definition of an acidic solution is a solution that contains a significant number of H⁺ ions. An operator should calibrate the instrument with a known

buffer solution before using a pH meter. Rinse the electrodes with distilled water should be done with the electrodes after measuring the pH of a sample with a pH meter. pH Temperature and Chlorine dosage are the factors that influence the effectiveness of chlorination the most.

Phenolphthalein /Total Alkalinity: The relationship between the alkalinity constituent's bicarbonate, carbonate, and hydroxide can be based on the P and T alkalinity measurement.

Phosphate, Nitrate, and Organic Nitrogen: Nutrients in a domestic water supply reservoir may cause water quality problems if they occur in moderate or large quantities.

Pipeline Appurtenance: Pressure reducers, bends, valves, regulators (which are a type of valve), etc.

Pneumatic systems are not reliable over transmission lines greater than 1000 feet: Is the primary characteristic which limits the use of a pneumatic data transmission system.

Point of Entry: POE.

Pollution: The duration of exposure to the contaminant affects the dose of a toxic contaminant in a water supply.

Pollution: To make something unclean or impure. See Contaminated.

Polyphosphates: Chemicals that may be added to remove low levels of iron and manganese.

Potable: Good water which is safe for drinking or cooking purposes. **Non-Potable:** A liquid or water that is not approved for drinking.

Potential Energy: The energy that a body has by virtue of its position or state enabling it to do work.

PPM: Abbreviation for parts per million.

Pre-chlorination: The addition of chlorine to the water prior to any other plant treatment processes.

Perikinesis: The aggregation resulting from random thermal motion of fluid molecules.

Pressure Head: The height to which liquid can be raised by a given pressure.

Pressure Measurement: Bourdon tube, Bellows gauge and Diaphragm are commonly used to measure pressure in waterworks systems.

Pressure: A Bellows-type sensor reacts to a change in pressure.

Prevention: To take action; to stop something before it happens.

Proton, Neutron, Electron: The 3 fundamental particles of an atom.

Public Notification: An advisory that EPA requires a water system to distribute to affected consumers when the system has violated MCLs or other regulations. The notice advises consumers what precautions, if any, they should take to protect their health.

Public Water System (PWS): Any water system which provides water to at least 25 people for at least 60 days annually. There are more than 170,000 PWSs providing water from wells, rivers and other sources to about 250 million Americans. The others drink water from private wells. There are differing standards for PWSs of different sizes and types.

Pump 5,000 to 20,000 hours: The typical operating life of a mechanical seal.

Pump Discharge Valve Off: Never run a reciprocating pump or piston pump with the discharge closed.

Pump: A key and a tight fit is the common method used to secure an impeller to the shaft on double-suction pump. A mechanical seal is the best seal to use for a pump operating under high suction head conditions. A possible cause of a scored shaft sleeve is that the packing has broken down or the packing is too tight or over tightened. A reciprocating pump or piston pump should not be operated with the discharge valve in the closed position. An air compressor generates heat during the compression cycle. The most common type of damage caused by heat generated during operation is the lubricating oil tends to break down quickly requiring frequent replacement. Cavitation is caused by a suction line may be clogged or is above the water line. Centrifugal pumps do not generate suction unless the impeller is submerged in water. If a pump is located above the level of water a foot valve must be provided on the suction piping to hold the prime. Continuous leakage from a mechanical seal on a pump indicates that the mechanical seal needs to be replaced. One disadvantage of a centrifugal pump is that it is not self-priming. The main purpose of the wear rings in a centrifugal double suction pump is that the wear rings maintain a flow restriction between the impeller discharge and suction areas. The purpose of the foot valve on a pump is that it keeps the air relief opened. The viscosity decreases with most lubricants as the temperature increases. Two pumps of the same size can be operated alternately to equalize wear and distribute lubricant in bearings.

PWS: 3 types of public water systems. Community water system, non-transient non-community water system, transient non community water system.

Raw Water: Water that has not been treated in any way; it is generally considered to be unsafe to drink.

Recorder: A recorder that measures flow is most likely to be located anywhere in the plant where a flow must be measured and in a central location.

Reagent: A substance used in a chemical reaction to measure, detect, examine, or produce other substances

Red Water and Slime: Iron bacteria are undesirable in a water distribution system because of red water and slime complaints.

Relay Logic: The name of a popular method of automatically controlling a pump, valve, chemical feeder, and other devices.

Reservoir: An impoundment used to store water.

Residual Disinfection/Protection: A required level of disinfectant that remains in treated water to ensure disinfection protection and prevent recontamination throughout the distribution system (i.e., pipes).

Rotameter: The name of transparent tube with a tapered bore containing a ball is often used to measure the rate of flow of a gas or liquid.

Rules: The objective of a vulnerability assessment is to determine weakness in the distribution or water system.

Runoff: Surface water sources such as a river or lake are primarily the result of natural processes of runoff.

Safe Yield: A possible consequence when the "safe yield" of a well is exceeded and water continues to be pumped from a well is land subsidence around the well will occur.

Safety: 2 Feet: The distance from the edge of a hole must you place the spoil from an excavation.

Safety Statements: A supervisor should warn an operator about the presence of a confined space by clearly posting the appropriate signage at all entries to a confined space. Before beginning an excavation, an "Underground Service Alert" center should be contacted to assist in determining the location of all underground utilities in the work area. Corrosive-This type of chemical classification may weaken, burn, or destroy a person's skin or eyes and can be either acidic or basic. Ladders and climbing devices by inspected by a qualified individual once a year. The correct order for placing shoring equipment in a trench is starting at the top move to the bottom of the trench and reverse to remove it.

Salts are Absent: A strange characteristic that is unique to water vapor in the atmosphere.

Sample: The water that is analyzed for the presence of EPA-regulated drinking water contaminants. Depending on the regulation, the EPA requires water systems and states to take samples from source water, from water leaving the treatment facility, or from the taps of selected consumers.

Sand, Anthracite and Garnet: Mixed media filters are composed of these three materials.

Sanitary Survey: Persons trained in public health engineering and the epidemiology of waterborne diseases should conduct the sanitary survey. The importance of a detailed sanitary survey of a new water source can not be overemphasized. An on-site review of the water sources, facilities, equipment, operation, and maintenance of a public water systems for the purpose of evaluating the adequacy of the facilities for producing and distributing safe drinking water. The purpose of a non-regulatory sanitary survey is to identify possible biological and chemical pollutants which might affect a water supply.

Sanitizer: A disinfectant or chemical which disinfects (kills bacteria), kills algae and oxidizes organic matter.

Saturation Index: See Langlier's Index.

Saturator: A device which produces a fluoride solution for the fluoride process. Crystal-grade types of sodium fluoride should be fed with a saturator. Overfeeding must be prevented to protect public health when using a fluoridation system.

SCADA: A remote method of monitoring pumps and equipment. 130 degrees F is the maximum temperature that transmitting equipment is able to withstand. If the level controller may be set with too close a tolerance 45 could be the cause of a control system that is frequently turning a pump on and off.

Scale: Crust of calcium carbonate, the result of unbalanced water. Hard insoluble minerals deposited (usually calcium bicarbonate) which forms on pool and spa surfaces and clog filters, heaters and pumps. Scale is caused by high calcium hardness and/or high pH. The regular use of stain prevention chemicals can prevent scale.

Scroll and Basket: The two basic types of centrifuges used in water treatment.

Secondary Drinking Water Standards: Non-enforceable federal guidelines regarding cosmetic effects (such as tooth or skin discoloration) or aesthetic effects (such as taste, odor, or color) of drinking water.

Sectional Map: The name of a map that provides detailed drawings of the distribution system's zones. Sometimes we call these quarter-sections.

Sedimentation Basin: This location is where the thickest and greatest concentration of sludge will be found. Twice a year sedimentation tanks should be drained and cleaned if the sludge buildup interferes with the treatment process.

Sedimentation: The process of suspended solid particles settling out (going to the bottom of the vessel) in water.

Sensor: A float and cable system are commonly found instruments that may be used as a sensor to control the level of liquid in a tank or basin.

Shock: Also known as superchlorination or break point chlorination. Ridding a water of organic waste through oxidization by the addition of significant quantities of a halogen.

Shroud: The front and/or back of an impeller.

Single Phase Power: The type of power is used for lighting systems, small motors, appliances, portable power tools and in homes.

Sludge Basins: After cleaning sludge basins and before returning the tanks into service the tanks should be inspected, repaired if necessary, and disinfected.

Sludge Reduction: Organic polymers are used to reduce the quantity of sludge. If a plant produces a large volume of sludge, the sludge could be dewatered, thickened, or conditioned to decrease the volume of sludge. Turbidity of source water, dosage, and type of coagulant used are the most important factors which determine the amount of sludge produced in a treatment of water.

Small Water System: 3,300 or fewer persons.

SOC: A common way for a synthetic organic chemical such as dioxin to be introduced to a surface water supply is from an industrial discharge, agricultural drainage, or a spill.

Soda Ash: Chemical used to raise pH and total alkalinity (sodium carbonate). Chemical often used to soften water.

Sodium Bicarbonate: Commonly used to increase alkalinity of water and stabilize pH.

Sodium Bisulfate: Chemical used to lower pH and total alkalinity (dry acid).

Sodium Hydroxide: Also known as caustic soda, a by-product chlorine generation and often used to raise pH.

Softening Water: When the water has a low alkalinity it is advantageous to use soda ash instead of caustic soda for softening water.

Softening: The process that removes the ions which cause hardness in water.

Solar Drying Beds or Lagoons: Shallow, small-volume storage pond where sludge is concentrated and stored for an extended periods.

Solar Drying Beds, Centrifuges and Filter Presses: Are procedures used in the dewatering of sludge.

Solid, Liquid, Vapor: 3 forms of matter.

SPADNS: The lab reagent called SPADNS solution is used in performing the Fluoride test.

Split Flow Control System: This type of control system is to control the flow to each filter influent which is divided by a weir.

Spray Bottle of Ammonia: An operator should use ammonia to test for a chlorine leak around a valve or pipe. You will see white smoke if there is a leak.

Spring Pressure: Is what maintains contact between the two surfaces of a mechanical seal.

Standpipe: A water tank that is taller than it is wide. Should not be found in low point.

Stationing: The word stationing on a plan drawing refers to a representation of a location from a starting point or reference. A stoneline or benchmark.

Sterilized Glassware: The only type of glassware that should be used in testing for coliform bacteria.

Storage Tanks: Three types of water usage that determine the volume of a storage tank are fire suppression storage, equalization storage, and emergency storage. Equalization storage is the volume of water needed to supply the system for periods when demand exceeds supply. Generally, a water storage tank's interior coating (paint) protect the interior about 3-5 years.

Stuffing Box: That portion of the pump that houses the packing or mechanical seal.

Sulfate: Will readily dissolve in water to form an anion.

Sum of all the Atomic Weights of the Elements in a Molecule: Is the molecular weight of a compound.

Supernatant: The liquid layer which forms above the sludge in a settling basin.

Surface Water Sources: Surface water sources such as a river or lake are primarily the result of Runoff.

Surface Water: Water that is open to the atmosphere and subject to surface runoff; generally, lakes, streams, rivers.

Susceptibility Waiver: A waiver that is granted based upon the results of a vulnerability assessment.

Tapping Valve: The name of the valve that is specifically designed for connecting a new water main to an existing main that is under pressure.

Taste and Odor Problems in the Water: May happen if sludge and other debris are allowed to accumulate in a water treatment plant.

Taste and Odors: The primary purpose to use potassium permanganate in water treatment is to control taste and odors. Anaerobic water undesirable for drinking water purposes because of color and odor problems are more likely to occur under these conditions.

TCE, trichloroethylene: A solvent and degreaser used for many purposes; for example dry cleaning, it is a common groundwater contaminant.

TDS-Total Dissolved Solids: is an expression for the combined content of all inorganic and organic substances contained in a liquid which are present in a molecular, ionized or micro-granular (colloidal sol) suspended form. Generally the operational definition is that the solids (often abbreviated TDS) must be small enough to survive filtration through a sieve size of two micrometers. Total dissolved solids are normally only discussed for freshwater systems, since salinity comprises some of the ions constituting the definition of TDS. The principal application of TDS is in the study of water quality for streams, rivers and lakes, although TDS is generally considered not as a primary pollutant (e.g. it is not deemed to be associated with health effects), but it is rather used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of presence of a broad array of chemical contaminants.

TDS: Ion exchange is an effective treatment process used to remove iron and manganese in a water supply. This process is ideal as long as the water does not contain a large amount of TDS. When determining the total dissolved solids, a sample should be filtered before being poured into an evaporating dish and dried. Demineralization may be necessary in a treatment process if the water has a very high value Total Dissolved Solids.

Telemetering: The use of a transmission line with remote signaling to monitor a pumping station or motors. Can be used to accomplish accurate and reliable remote monitoring and control over a long distribution system.

Temperature: This test should be performed immediately in the field, a grab sample.

The rate decreases: In general, when the temperature decreases, the chemical reaction rate decreases also.

Thickening, Conditioning, and Dewatering: Are common processes that are utilized to reduce the volume of sludge.

Three-phase Motor: The incoming leads for a three-phase motor all have power.

Three-Phase Pumps: Large three-phase pumps employs the use of a magnetic starter.

Time for Turbidity Breakthrough and Maximum Head Loss: Are the two factors which determine whether or not a change in filter media size should be made.

Titration: Method of testing by adding a reagent of known strength to a water sample until a specific color change indicates the completion of the reaction.

Titration: The common method of standardization of a solution determination in the lab.

Total Alkalinity: A measure of the acid-neutralizing capacity of water that indicates its buffering ability, i.e. measure of its resistance to a change in pH. Generally, the higher the total alkalinity, the greater the resistance to pH change.

Total Dissolved Solids (TDS): The accumulated total of all solids that might be dissolved in water. See TDS.

Toxic substance contaminates a drinking water: Public Safety is the most important concern should an owner/operator allow a toxic substance to contaminate a drinking water.

Transient, Non-Community Water System: A water system which provides water in a place such as a gas station or campground where people do not remain for long periods of time. These systems do not have to test or treat their water for contaminants which pose long-term health risks because fewer than 25 people drink the water over a long period. They still must test their water for microbes and several chemicals. A Transient Non-community Water System: Is not required to sample for VOC's.

Treated Water: Disinfected and/or filtered water served to water system customers. It must meet or surpass all drinking water standards to be considered safe to drink.

Trihalomethanes (THM): Four separate compounds including chloroform, dichlorobromom-ethane, dibromochloromethane, and bromoform. The most common class of disinfection by-products created when chemical disinfectants react with organic matter in water during the disinfection process. See *Disinfectant Byproducts*.

Tubercles: The creation of this condition is of the most concern regarding corrosive water effects on a water system. Tubercles are formed due to joining dissimilar metals, causing electro-chemical reactions. Like iron to copper pipe. We have all seen these little rust mounds inside cast iron pipe.

Turbidimeter: Monitoring the filter effluent turbidity on a continuous basis with an in-line instrument is a recommended practice. Turbidimeter is best suited to perform this measurement.

Turbidity Interferes with Disinfection: The primary reason turbidity of water be minimized.

Turbidity: One physical characteristic of water. A measure of the cloudiness of water caused by suspended particles. The cloudy appearance of water caused by the presence of tiny particles. High levels of turbidity may interfere with proper water treatment and monitoring. If high quality raw water is low in turbidity, there will be a reduction in water treatment costs. Turbidity is undesirable because it causes health hazards. An MCL for turbidity established by the EPA because turbidity interferes with disinfection. This characteristic of water changes the most rapidly after a heavy rainfall. The following conditions may cause an inaccurate measure of turbidity; the temperature variation of a sample, a scratched or unclean sample tube in the nephelometer and selecting an incorrect wavelength of a light path

U.S. Environmental Protection Agency: In the United States, this agency responsible for setting drinking water standards and for ensuring their enforcement. This agency sets federal regulations which all state and local agencies must enforce.

Under Pressure in Steel Containers: After chlorine gas is manufactured, it is primarily transported in steel containers.

Unit Filter Run Volume (UFRV): One of the most popular ways to compare filter runs. This technique is the best way to compare water treatment filter runs.

Valve 20 or 30 Feet Per Inch: The typical scale of a Valve and Hydrant map using an intersection method of indexing.

Valves: A gate valve should be operated in any position between fully open and fully closed.

Vane: That portion of an impeller that throws the water toward the volute.

Velocity Head: The vertical distance a liquid must fall to acquire the velocity with which it flows through the piping system. For a given quantity of flow, the velocity head will vary indirectly as the pipe diameter varies.

Venturi: If water flows through a pipeline at a high velocity, the pressure in the pipeline is reduced. Velocities can be increased to a point that a partial vacuum is created.

VOC waiver that a public water system using groundwater could receive: The longest term VOC waiver that a public water system using groundwater could receive is 9 years.

VOC's: The reporting limit for all regulated VOC's is 0.0005 mg/L.

Volatile Organic Chemical: VOC.

Voltage: 1,000 volts is the maximum number of volts that electrical equipment can be insulated with a lower limit of 1 megaohm.

Volute: The spiral-shaped casing surrounding a pump impeller that collects the liquid discharge by the impeller.

Vulnerability Assessment: An evaluation of drinking water source quality and its vulnerability to contamination by pathogens and toxic chemicals.

Waivers: Monitoring waivers for nitrate and nitrite are prohibited.

Water Hammer: A surge in a pipeline resulting from the rapid increase or decrease in water flow. Water hammer exerts tremendous force on a system and can be highly destructive.

Water Level: The probe may be coated by calcium carbonate is a common problem with an electrical probe that is used to measure the level of water.

Water Meter: A water meter that is removed from service for repair should be handled by sealing the meter to retain water.

Water Meter: Head loss may occur with the use of a water meter. The three main classifications of water meters. Compound, Displacement, Velocity. Peak day demand is the greatest amount of water used for any one day in a calendar year.

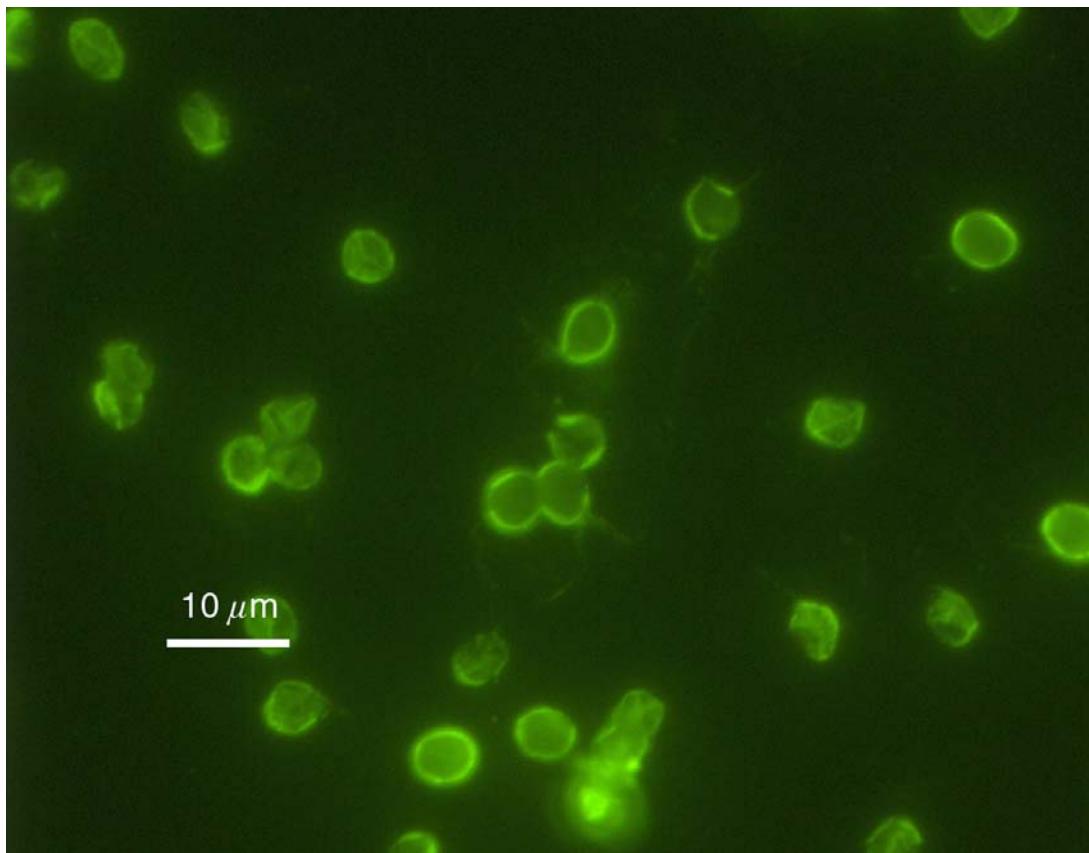
Water Purveyor: The individual or organization responsible to help provide, supply, and furnish quality water to a community.

Water Quality: The 4 broad categories of water quality are: Physical, chemical, biological, radiological. Pathogens are disease causing organisms such as bacteria and viruses. A positive bacteriological sample indicates the presence of bacteriological contamination. Source water monitoring for lead and copper is performed when a public water system exceeds an action level for lead or copper.

Water Vapor: A characteristic unique to water vapor in the atmosphere is it does not contain salts.

Waterborne Disease: A disease, caused by a virus, bacterium, protozoan, or other microorganism, capable of being transmitted by water (e.g., typhoid fever, cholera, amoebic dysentery, gastroenteritis).

Watershed: An area that drains all of its water to a particular water course or body of water. The land area from which water drains into a stream, river, or reservoir.



Cryptosporidium

Teaching Math In 1960

A logger sells a truckload of lumber for \$100. His cost of production is $\frac{4}{5}$ of the price. What is his profit?

Teaching Math In 1970

A logger sells a truckload of lumber for \$100. His cost of production is $\frac{4}{5}$ of the price, or \$80. What is his profit?

Teaching Math In 1980

A logger sells a truckload of lumber for \$100. His cost of production is \$80. Did he make a profit?

Teaching Math In 1990

A logger sells a truckload of lumber for \$100. His cost of production is \$80 and his profit is \$20 Your assignment: Underline the number 20.

Teaching Math In 2000

A logger cuts down a beautiful forest because he is selfish and inconsiderate and cares nothing for the habitat of animals or the preservation of our woodlands. He does this so he can make a profit of \$20. What do you think of this way of making a living? Topic for class participation after answering the question: How did the birds and squirrels feel as the logger cut down their homes? (There e are no wrong answers.)

Math Conversion Factors

1 PSI = 2.31 Feet of Water
1 Foot of Water = .433 PSI
1.13 Feet of Water = 1 Inch of Mercury
454 Grams = 1 Pound
1 Gallon of Water = 8.34 lbs/gallon
1 mg/L = 1 PPM
17.1 mg/L = 1 Grain/Gallon
1% = 10,000 mg/L
694 Gallons per Minute = MGD
1.55 Cubic Feet per Second = 1 MGD
60 Seconds = 1 Minute
1440 Minutes = 1 Day
.746 kW = 1 Horsepower

LENGTH

12 Inches = 1 Foot
3 Feet = 1 Yard
5280 Feet = 1 Mile

AREA

144 Square Inches = 1 Square Foot
43,560 Square Feet – 1 Acre

VOLUME

1000 Milliliters = 1 Liter
3.785 Liters = 1 Gallon
231 Cubic Inches = 1 Gallon
7.48 Gallons = 1 Cubic Foot of Water
62.38 Pounds = 1 Cubic Foot of Water

Dimensions

SQUARE: Area (sq.ft) = Length X Width
Volume (cu.ft) = Length (ft) X Width (ft) X Height (ft)

CIRCLE: Area (sq.ft) = $3.14 \times \text{Radius (ft)} \times \text{Radius (ft)}$

CYLINDER: Volume (Cu. ft) = $3.14 \times \text{Radius (ft)} \times \text{Radius (ft)} \times \text{Depth (ft)}$

SPHERE: $\frac{(3.14)(\text{Diameter})^3}{(6)}$ Circumference = $3.14 \times \text{Diameter}$

General Information

POUNDS PER DAY = Concentration (mg/L) X Flow (MG) X 8.34

Percent Efficiency = $\frac{\text{In} - \text{Out}}{\text{In}} \times 100$

TEMPERATURE: ${}^{\circ}\text{F} = ({}^{\circ}\text{C} \times 9/5) + 32$
 ${}^{\circ}\text{C} = ({}^{\circ}\text{F} - 32) \times 5/9$

CONCENTRATION: Conc. (A) X Volume (A) = Conc. (B) X Volume (B)

FLOW RATE (Q): $Q = A \times V$ (Quantity = Area X Velocity)

FLOW RATE (gpm): Flow Rate (gpm) = $\frac{2.83 \text{ (Diameter, in)}^2 \text{ (Distance, in)}}{\text{Height, in}}$

% SLOPE = $\frac{\text{Rise (feet)}}{\text{Run (feet)}} \times 100$

ACTUAL LEAKAGE = $\frac{\text{Leak Rate (GPD)}}{\text{Length (mi.)} \times \text{Diameter (in)}}$

VELOCITY = $\frac{\text{Distance (ft)}}{\text{Time (Sec)}}$

WATER HORSEPOWER = $\frac{\text{Flow (gpm)} \times \text{Head (ft)}}{3960}$

BRAKE HORSEPOWER = $\frac{\text{Flow (gpm)} \times \text{Head (ft)}}{3960 \times \text{Pump Efficiency}}$

MOTOR HORSEPOWER = $\frac{\text{Flow (gpm)} \times \text{Head (ft)}}{3960 \times \text{Pump Eff.} \times \text{Motor Eff.}}$

MEAN OR AVERAGE = $\frac{\text{Sum of the Values}}{\text{Number of Values}}$

TOTAL HEAD (ft) = Suction Lift (ft) X Discharge Head (ft)

SURFACE LOADING RATE = $\frac{\text{Flow Rate (gpm)}}{(\text{gal/min/sq.ft}) \times (\text{Surface Area (sq. ft)})}$

MIXTURE = $(\text{Volume 1, gal}) (\text{Strength 1, \%}) + (\text{Volume 2, gal}) (\text{Strength 2, \%})$

STRENGTH (%) $= \frac{(\text{Volume 1, gal}) + (\text{Volume 2, gal})}{(\text{Volume 1, gal}) + (\text{Volume 2, gal})}$

FLUORIDE ION PURITY = $\frac{(\text{Molecular weight of Fluoride}) (100\%)}{(\%) \text{ Molecular weight of Chemical}}$

INJURY FREQUENCY RATE = $\frac{(\text{Number of Injuries})}{(\text{Number of hours worked per year})} \times 1,000,000$

DETENTION TIME (hrs) = $\frac{\text{Volume of Basin (gals)} \times 24 \text{ hrs}}{\text{Flow (GPD)}}$

BY-PASS WATER (gpd) = $\frac{\text{Total Flow (GPD)} \times \text{Plant Effluent Hardness (gpg)}}{\text{Filtered Hardness (gpg)}}$

Filtration Conversions

FILTRATION RATE = $\frac{\text{Flow Rate (gpm)}}{(\text{gpm/sq. ft}) \quad \text{Surface Area (sq. ft)}}$

BACKWASH PUMPING RATE = Filter Area (sq. ft) X Backwash Rate (gpm/sq. ft)
(gpm)

FILTRATION RATE = $\frac{\text{Flow Rate (gpm)}}{(\text{gpm/sq. ft}) \quad \text{Filter Area (sq. ft)}}$



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