CROSS-CONNECTION IDENTIFICATION

CONTINUING EDUCATION
PROFESSIONAL DEVELOPMENT COURSE

Technical Learning College

Printing and Saving Instructions

TLC recommends that you download and save this pdf document and assignment to your computer desktop and open it with Adobe Acrobat DC reader.

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Printing Instructions: Once you have purchased the program, we will give you permission to print this document. If you are going to print this document, it was designed to be printed double-sided or duplexed but can be printed single-sided.

Link to Assignment…
http://www.abctlc.com/downloads/PDF/CrossConnectionIDASS.pdf

State Approval Listing Link, check to see if your State accepts or has pre-approved this course. Not all States are listed. Not all courses are listed. Do not solely trust our list for it may be outdated. It is your sole responsibility to ensure this course is accepted for credit. No refunds.

Professional Engineers; Most states will accept our courses for credit but we do not officially list the States or Agencies.

State Approval Listing URL…
http://www.ABCTLC.com/downloads/PDF/CEU%20State%20Approvals.pdf

You can obtain a printed version from TLC for an additional $129.95 plus shipping charges.

All downloads are electronically tracked and monitored for security purposes.

Some States and many employers require the final exam to be proctored.

Do not solely depend on TLC's Approval list for it may be outdated.

Most of our students prefer to do the assignment in Word and e-mail or fax the assignment back to us. We also teach this course in a conventional hands-on class. Call us and schedule a class today.

Contributing Editors

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Important Information about this Manual

This manual has been prepared to educate operators in the general awareness of cross-connections and backflow prevention. The scope of cross-connection control and backflow prevention is quite large, requiring a major effort to bring it under control.

Water customers' health and safety, as well as that of the operators, depend upon careful application of backflow prevention methods and effective cross-connection control procedures/programs. The manner in which we deal with such hazards will affect the earth and its inhabitants for many generations to come.

This manual covers general laws, regulations, required procedures and work rules relating to cross-connection control. It should be noted, however, that the regulation of backflow prevention and plumbing codes is an ongoing process and subject to change over time. For this reason, a list of resources is provided to assist in obtaining the most up-to-date information on various subjects.

This manual should not be used as a guidance document for employees who are involved with cross-connection control. It is not designed to meet the requirements of the United States Environmental Protection Agency (EPA) or the Department of Labor-Occupational Safety and Health Administration (OSHA) or your state environmental or health agency. Technical Learning College or Technical Learning Consultants, Inc. make 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 educational purposes and is not considered a legal document. Individuals who are responsible for cross-connection control, backflow prevention or water distribution 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.

Top, a highly trained General Backflow Assembly Tester is working on a fireline assembly.

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 distance educational format. 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 to finish the material at your convenience. Students can also receive course materials through the mail. The CEU course or e-manual will contain all your lessons, activities and instruction to obtain the 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.)

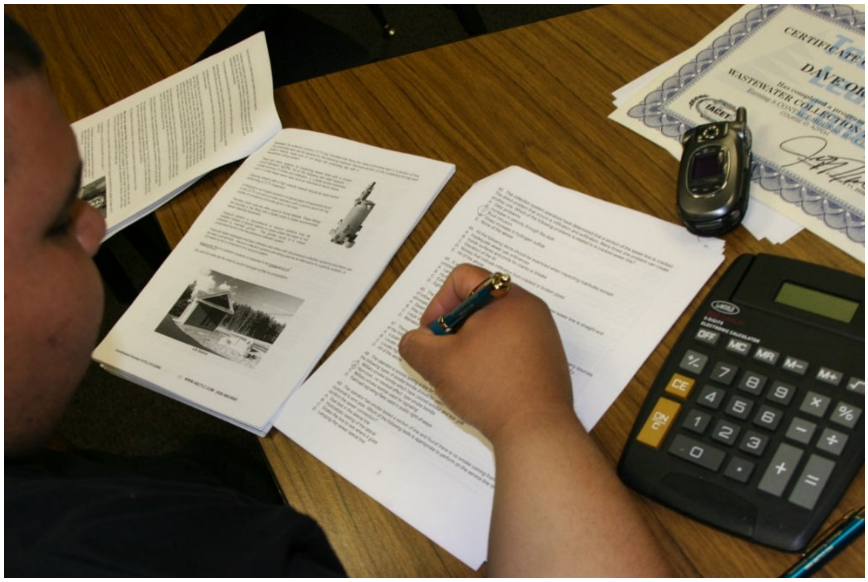
Students have direct contact with their instructor—primarily by e-mail or telephone. TLC's CEU courses may use such technologies as the World Wide Web, e-mail, CD-ROMs, videotapes and hard copies. (See the course description.) Make sure you have access to the necessary equipment before enrolling; i.e., 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 (S.M.E.) are assigned at the beginning of each course providing the academic support you need to successfully complete each course. Please call or email us for assistance.

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.

Contact Numbers

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

CEU Course Description

Cross-Connection Identification CEU Training Course

Review of backflow prevention and plumbing related fundamentals and principles. This course will cover the basics of backflow prevention, cross-connection control, water quality issues and hydraulic fundamentals. 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). ***You will not need any other materials for this course.***

Water Distribution, Well Drillers, Pump Installers, Water Treatment Operators, Wastewater Treatment Operators, Wastewater Collection Operators, Industrial Wastewater Operators and General Backflow Assembly Testers. The target audience for this course is the person interested in working in a water or wastewater treatment or distribution/collection facility and/or wishing to maintain CEUs for certification license or to learn how to do the job safely and effectively, and/or to meet education needs for promotion.

Prerequisites: None

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. All students will be tracked by a unique number assigned to the student.

Instructions for Written Assignments

The Cross-Connection Identification CEU training course uses a multiple choice answer key. You can find a copy of the exam in a Word format on TLC's website under the Assignment Page. You can also find complete course support under the Assignment Page.

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.

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 of the course assignment or lesson.

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 Cross-Connection Identification 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.

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. Please check with your State for special instructions.

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.

If you should need any assistance, please email all concerns and the final test to:
info@tlch2o.com.

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 and environmental education,

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.

Texas TCEQ CSI Rule Notice

TCEQ rule adoption effective July 30, 2015

Rule Project No. 2013-046-290-OW
Background and reason(s) for the rulemaking:
This rulemaking adopts changes to Chapter 290:

- for consistency with Texas Water Code (TWC), §12.013 and Chapter 13, as amended during the 83rd Legislature, 2013, by §2.96 of House Bill (HB) 1600, authored by Representative Byron Cook, and §§1, 4, 95, and 96 of Senate Bill (SB) 567, sponsored by Senators Kirk Watson and Robert Nichols, related to transfer of the utilities and rates program to the Public Utility Commission of Texas (PUC);
- to implement federal changes to the lead and *Escherichia Coli (E. coli)* thresholds; and
  - to provide clarification on and streamlining of existing rules, including:
  - desalination;
  - chloramination;
    - plan review submittal process;
    - enforceability of exceptions; and
    - other drinking water matters.

Scope of the rulemaking:
A.) Summary of what the rulemaking will do:
State statutes – HB 1600 and SB 567 amended TWC, §12.013 and Chapter 13, transferring the utilities and rates program from the Texas Commission on Environmental Quality (TCEQ) to the PUC, effective September 1, 2014. This rulemaking removes a requirement for the submission of Certificate of Public Convenience and Necessity (CCN) information in existing §290.39(j)(3) as the TCEQ no longer has jurisdiction over CCNs. The majority of the rule changes to implement HB 1600 and SB 567 will occur under Rule Project No. 2013-057-291-OW.

Federal regulations
Reduction of Lead in Drinking Water Act – The federal requirement for lead content of pipes, pipe fittings, and plumbing fittings and fixtures was reduced from 8.0% to 0.25%, effective January 4, 2014, as announced in 2011 to allow time for manufacturers to change their products. TCEQ's public drinking water rules only apply to public water systems (PWSs) and include allowable lead content requirements that must be revised to maintain consistency with applicable federal law. PWSs will now need to procure plumbing fixtures that comply with the allowable lead level, but because the federal act applies to all manufacturers, there should only be products that meet the criteria on the market.
E. coli Threshold – The federal Long Term 2 Enhanced Surface Water Treatment Rule (LT2) required PWSs with surface water, or groundwater under the influence of surface water, sources to monitor for *Cryptosporidium*. The United States Environmental Protection Agency (EPA) gave states the discretion to allow small PWSs — those with a population less than 10,000 — to monitor for *E. coli* instead. The TCEQ adopted the alternate monitoring process and established an *E. coli* trigger level of 50 E. coli/100 milliliters or 10 *E. coli*/100 milliliters based on the water source. Subsequent federal guidance established an *E. coli* trigger level of 100 *E. coli*/100 milliliters, no matter the water's source. By raising the TCEQ's *E. coli* trigger level, fewer small PWSs have monitored for *Cryptosporidium* because the higher level is more commonly achieved.

Additional staff recommendations – The staff-initiated changes to Chapter 290 are necessary to formalize existing procedures into the rules, while also clarifying requirements and streamlining existing agency practices. The items that will formalize existing procedures include: adding the requirements of existing well design standards to the rule, and changing the tank design requirements to clarify tank types. To clarify the rules, the TCEQ adopts additional criteria to help PWSs find all of the criteria within a rule while also incorporating the necessary elements into the design, rather than adding the criteria at a later date. To ensure consistency in the pipe encasement design, the TCEQ's water and wastewater requirements for water distribution pipe crossings will be expanded to include other subsections of the rule. The remainder of the adopted staff-initiated changes streamlines existing practices on: the process for submitting plans; TCEQ's ability to cite a violation for failure to comply with a condition of a granted exception; allowing the use of chloramines without an exception; allowing the use of desalination technology without an exception; and adding additional options for overflow pipe outlets without an exception.

B.) Scope required by federal regulations or state statutes:

***State statutes* –** This adopted rulemaking implements HB 1600 and SB 567 by removing a requirement in existing §290.39(j)(3) as the TCEQ no longer has jurisdiction over CCNs.

Federal regulations

***Reduction of Lead in Drinking Water Act* –** This adopted rulemaking amends §§290.41, 290.44, 290.46, and 290.47 for consistency with the federal reduction in the lead content of pipes, pipe fittings, and plumbing fittings and fixtures from 8.0% to 0.25%.

***E. coli Threshold* –** The TCEQ has been applying the revised *E. coli* trigger level since it was released by the EPA in 2010. This adopted rulemaking amends §290.111 to be consistent with federal guidance and continue providing additional monitoring cost savings to small PWSs.

C.) Additional staff recommendations that are not required by federal rule or state statute:

***Process for Approving Desalination Technology* –** This adopted rulemaking amends §§290.38, 290.39, 290.42, 290.45, and 290.46 to allow the use of desalination technologies for chemical removal without an exception request, which has been required when approving the use of innovative/alternate treatment technologies. The use of reverse osmosis membranes and other desalination technologies for water treatment has been in use for decades. Over 15,000 desalination plants were in use worldwide in 2002. Following extensive input from the regulated community and interested stakeholders, this adopted rulemaking establishes design, operation, maintenance, monitoring, and reporting standards.

***Chloramine Disinfection Criteria* –** As the use of chloramines has become a common practice among PWSs, this adopted rulemaking amends §§290.39, 290.41 - 290.43, 290.46, 290.47, 290.110, 290.111, and 290.116 to allow the use of chloramines without requiring an exception review by including the design, operation, maintenance, monitoring, and documentation criteria within the rules to simplify the process for the TCEQ and PWSs. In the proposal, the executive director's staff sought public comment on the placement of sample taps in relation to chloramine chemical injection.

***Modification of the Plan Review Submittal Process* –** Existing §290.39 instructs PWSs to first notify the TCEQ of significant changes and then submit plans and specifications upon the TCEQ's request. This adopted rulemaking amends §290.39 by: requiring PWSs to submit plans and specifications for significant changes. Simplifying the criteria for a change to be considered significant will reduce confusion in the regulated community and reduce staffs' processing time currently spent issuing requests for the submission of plans and specifications.

***Enforceability of Exceptions* –** Under existing §290.39(l)(2), if a PWS does not meet the requirements of a granted exception, the exception can be revoked and a violation subsequently issued in a time-consuming, cumbersome process. To streamline this process and ensure that

PWSs follow the conditions established in the granted exception, this adopted rulemaking clarifies that failing to follow the conditions of a granted exception is a violation.

Clarification for Well Construction Review Process – This adopted rulemaking amends §290.41 by incorporating language from an existing standard into the rule and providing specific cementing requirements for PWS wells in order to consolidate the requirements in one location, thus making them more accessible to the PWSs.
Alternative Appurtenances for Overflow Devices – The existing rule requires a "gravity-hinged and weighted cover" at the end of the overflow pipe on water storage tanks. Other designs have also proven to be effective in preventing backflow and the entrance of contaminants; however, a PWS has been required to apply for a case-by-case exception to use other devices. This adopted rulemaking amends §290.43, streamlining the process for PWSs to use other devices and reduces staffs' time currently spent reviewing these exception requests.
Water Storage – This adopted rulemaking amends §290.43 to remove the sentence referencing American Water Works Association (AWWA) Standard D103. A rule petition which in part raised AWWA Standard D103 as an issue was denied during the April 23, 2013, agenda; at that agenda, staff was directed to consider amending the rule during a subsequent rulemaking.
Water Distribution Crossings – *During a rule change in 1995, language applicable to waterlines crossing under wastewater lines was added into §290.44 which created potential conflict with the requirement for wastewater lines in 30 TAC §217.53. This adopted rulemaking amends §290.44 for consistency with §217.53 to be protective of public health.*
Appendices – The amended rule removes three figures, or appendices, in existing §290.47. Based upon the revision of federal law regarding the lead content in pipes, fittings, and fixtures, the commission proposed amending Figure: 30 TAC §290.47(b). During its amendment of Figure: 30 TAC §290.47(b), the commission revisited the other figures in existing §290.47 and proposed the removal of Figures: 30 TAC §290.47(c), (d), and (f) to allow PWSs an editable form that can be modified without retyping the figure.

Statutory authority:
TWC, §§5.102, 5.103, 5.105, 12.013 and Chapter 13; and Texas Health and Safety Code, Chapter 341.

Effect on the:
A.) Regulated community:
The TCEQ regulates approximately 7,000 PWSs, including PWSs owned by units of local, state and federal government, as well as for profit businesses or individually owned PWSs. This rulemaking does not create a new group of affected persons.
State statutes – There will be no fiscal impact on the regulated community from the adopted amendment implementing the transfer of the CCN program to the PUC.
Federal regulations
Reduction of Lead in Drinking Water Act – PWSs with an existing stockpile of plumbing materials that do not meet the 0.25% lead level will not be able to install these materials. The Reduction of Lead in Drinking Water Act was enacted in January 2011, and PWSs were given advance notice of the federal change, allowing them the opportunity to use their stockpiled materials. Because of this advance notice, any impact from this adopted rulemaking upon the regulated community is expected to be minimal.
E. coli Threshold – There is no impact anticipated upon the regulated community as the TCEQ has followed the federal guidance since its issuance.

Additional staff recommendations

Process for Approving Desalination Technology – Placing the desalination requirements in the rule may reduce expenses and construction time for PWSs.

Chloramine Disinfection Criteria – By allowing the use of chloramines without an exception request, the regulated community can save time and effort currently spent on requesting the exception from the TCEQ.

Modification of the Plan Review Submittal Process – The adopted rule will provide a more efficient submittal process for the regulated community and will clarify the criteria constituting a "significant change," which has caused confusion in the past for the regulated community.

Enforceability of Exceptions – The adopted rule will allow a PWS to provide the corrective action for a specific violation, instead of reapplying for a revoked exception.

Clarification for Well Construction Review Process – By placing the PWS well construction requirements in the rule, PWSs will have one location to find information about well design, thus making the requirements more accessible to the PWSs.

Alternative Appurtenances for Overflow Devices – Allowing the use of alternative appurtenances will permit PWSs to use these designs without requesting an exception, which will save such PWSs time and expense.

Water Storage – PWSs will be allowed more flexibility when designing water storage tanks by allowing tanks of other materials approved by the AWWA. The adopted rule will also reduce confusion in the regulated community by removing the reference to one specific AWWA Standard, D103.

Water Distribution Crossings – This adopted rule will align the TCEQ's water and wastewater requirements for water distribution pipe crossings and provide PWSs with consistency in the TCEQ's applicable rules which will also help PWSs protect public health by ensuring that wastewater lines are not located over waterlines.

Appendices – By moving some appendices to forms, the regulated community can save time and effort currently spent on potentially retyping the appendices to customize the forms for PWS use.

B.) Public:

State statutes – The adopted amendment will not impact the public.

Federal regulations – Any costs or cost avoidance experienced by the PWSs may be passed on to the public. The impact of this adopted rulemaking upon the public is anticipated to be minimal.

Additional staff recommendations – Any cost savings experienced by the PWSs are anticipated to be minimal and may be passed on to the public.

C.) Agency programs:

State statutes – No impact is anticipated from the adopted amendment.

Federal regulations – There will be minimal impact to the TCEQ's programs. Staff may receive questions from PWSs about the federal changes.

Additional staff recommendations – The staff-initiated rule efficiencies will save TCEQ staff resources by removing, clarifying, and streamlining TCEQ processes, while affording staff the opportunity to concentrate their efforts on other, more complex innovative treatment reviews. There will be minimal impact to the TCEQ's programs. Staff may receive questions from PWSs about the changes. **Association with the support of the American Membrane Technology Association and two individuals.**

The comments focused on the reverse osmosis and nanofiltration requirements and the chloramination requirements. The comments on reverse osmosis and nanofiltration included questions on: a reverse osmosis and nanofiltration definition; the water sources that may be treated by reverse osmosis and nanofiltration; when a plan review and a baseline study is required; the location of conductivity samples; the use of historical classes for training requirements; the maintenance of records; when a module must be replaced; and, the calibration interval for instruments. The comments on chloramination included questions on: when a nitrification action plan is required; where the nitrification action plan samples can be taken; disinfection sample collection; mixing requirements, drain requirements; sample accuracy limits; and, color comparators. The comments have been summarized in the Response to Comments section of the preamble.

Significant changes from proposal:
None, though in response to comment, some proposed rules were revised.

Potential controversial concerns and legislative interest:
The legislature, interested stakeholders, and the regulated community continue to express interest in using desalination to treat water and produce a new drinking water source without undertaking an exception process.

Does this rulemaking affect any current policies or require development of new policies?
This adopted rulemaking merely formalizes existing policies into Chapter 290; no additional policies are planned for development.

State statutes –Without approval, Chapter 290 will be inconsistent with existing state statutes. If not adopted within this rulemaking, the removal of a requirement in existing §290.39(j)(3) related to CCNs could be addressed in Rule Project No. 2013-057-291-OW.
Federal regulations – The TCEQ could attempt to implement both federal changes, lead content and LT2 sampling, directly from the federal law or guidance. However, TCEQ investigators are authorized to enforce state law, not federal, and the state rules governing lead content without amendment would be inconsistent with and less stringent than the federal law.
Additional staff recommendations – Instead of adopting design, operation, maintenance, and recordkeeping rules, the TCEQ could continue requiring the submission of exception requests which can be supported by computer models instead of physical studies for desalination that meets primary drinking water standards.

Agency contacts:
Marlo Wanielista Berg, P.E., Rule Project Manager, (512) 239-6967, Water Supply
Ruth Takeda, Staff Attorney, (512) 239-6635
Derek Baxter, Texas Register Coordinator, (512) 239-2613

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Topic Legend

This CEU course covers several educational topics/functions/purposes/objectives of backflow prevention and cross-connection control compliance. The topics listed below are to assist in determining which educational objective or goal is covered for a specific topic area:

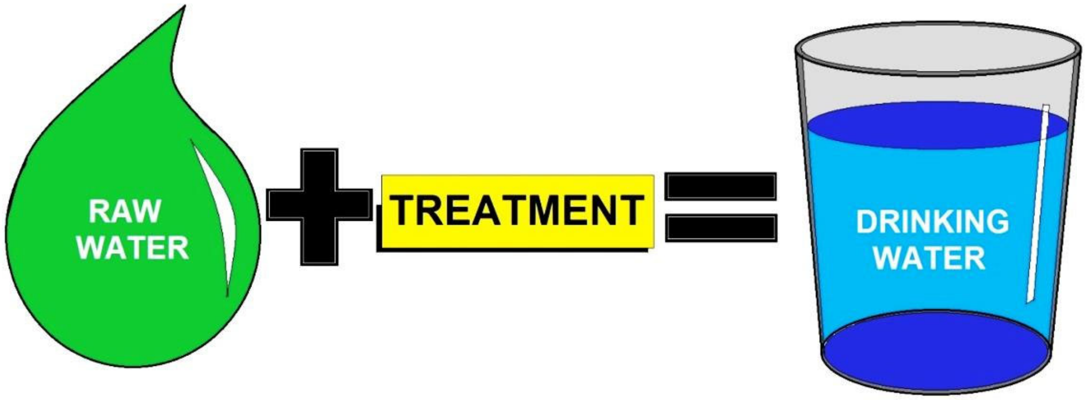
CRAO: The regulatory and compliance component. May be a requirement of the SDWA act or State Regulations, i.e. backflow prevention, plumbing or other drinking water related rule requirement. This EPA or regulatory information is to satisfy the regulatory portion of your operator or tester training.

O&M: This area is for normal operation and/or maintenance of a backflow prevention assembly, method, hydraulics or plumbing or information necessary to perform job function. Part of O&M training requirement for many operators and testers.

TECHNICAL (TECH): The history, or mechanical or physical portion of hydraulics, including process, component or theory related to backflow prevention or general hydraulic concerns or information necessary to preform job duties. Part of O&M training for many operators and testers.

WQ: Having to do with water quality or pollutants, i.e., hard water to primary water standards. May be a requirement of the SDWA and/or backflow, cross-connection control rules or concerns. This along with the EPA information is to satisfy the regulatory portion of your operator or tester training.

Preface



Safe Drinking Water Act of 1974 Introduction

(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 CFR142
- 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.

Part of this Act was the establishing of Cross-Connection Control regulations to ensure that the water system is free of contamination. This rule ensures the installation and maintenance of an approved backflow prevention assembly at the water service connection whenever a potential hazard is determined to exist in a customer's system.

Backflow Prevention, also referred to as Cross-Connection Control, addresses a serious health issue. This issue was addressed on the federal level by passage of the "*Federal Safe Drinking Water Act*" as developed by the Environmental Protection Agency (E.P.A.) and passed into law on December 16, 1974.

When drinking water piping connects to various plumbing fixtures or water utilizing equipment a ***cross-connection*** is created. If improperly protected, contamination can result when a ***backflow*** event occurs; allowing contaminates to reverse flow from the fixture/equipment back into the drinking water piping. Backflow is the flow of water or other liquids, mixtures, or substances into the distributing pipes of a potable water supply from any source other than the intended source of the potable water supply.

A cross-connection is any physical link or route that makes it possible for contamination to flow into the potable water system.

While a cross-connection provides the physical link, there must also be a pressure differential that acts to force the contamination into the potable water system. Backflow will occur when the pressure in the potable water system is lower than the pressure in the system containing the contamination.

The physical link could be a drain line, a hose dropped into a mud puddle, a sprayer attached to a bathtub faucet, or any other condition that would allow flow of a contaminant into the potable water supply. Backflow will also occur across a service connection to the public water system thereby introducing contamination into the public drinking water supply.

Without proper protection devices, cross connections can occur. A cross connection between your drinking water and another source of water that combines the two can result in a backflow condition which can cause contamination. Backflow is when the water in your pipes (the pipes after the water meter) goes backward (the opposite direction from the normal flow).

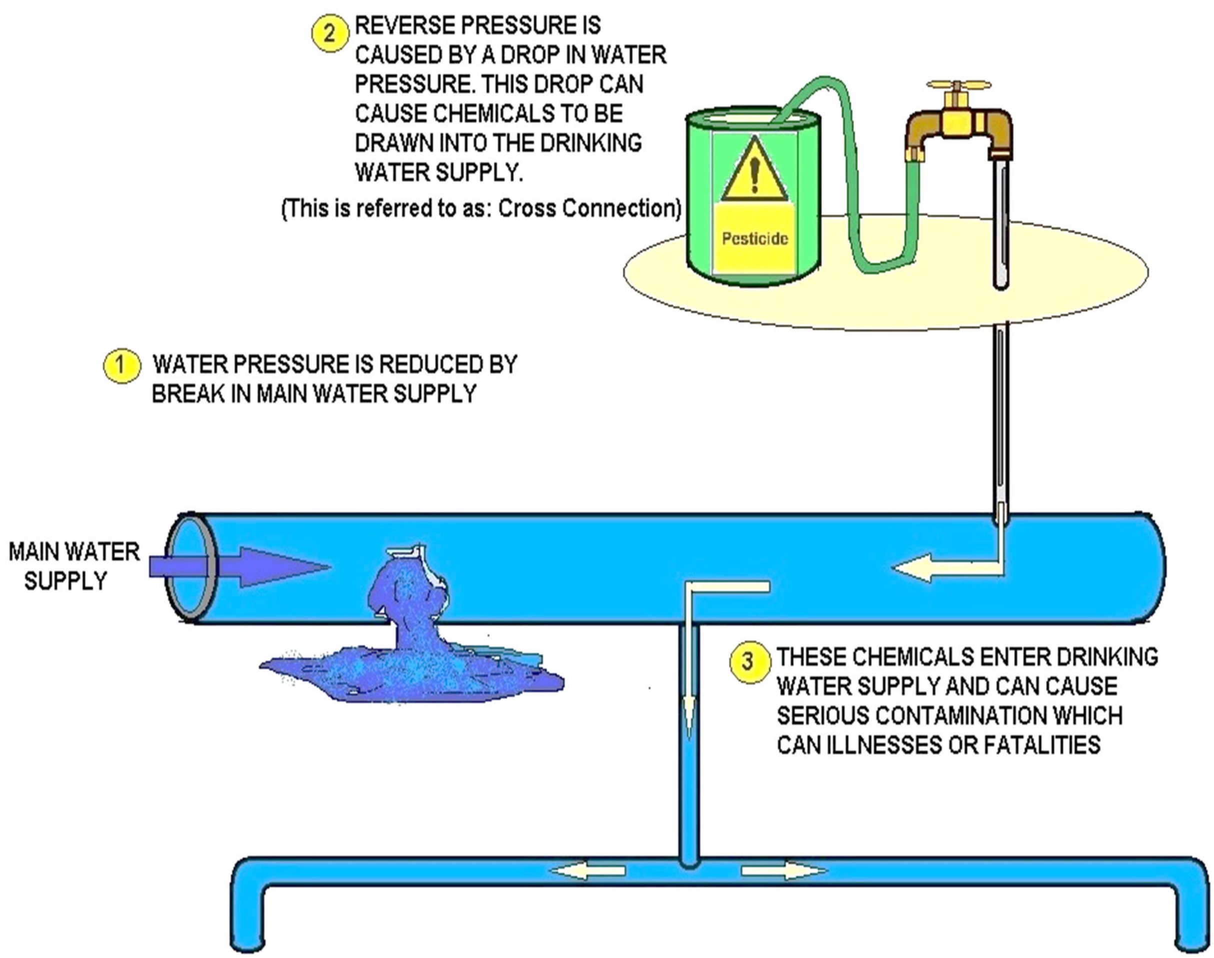
The potential hazard of backflow occurring in almost any public water system is quite possible. In many homes, factories and public buildings the existence of improper plumbing connections present cross-connections that may, under certain conditions, make it possible for water to flow the “wrong way”.

The probability of backflow occurring at any given outlet may be actually very small, but, due to the large number of possible situations, the probability becomes significant and must be proactively addressed. From the EPA Cross-Connection Manual.

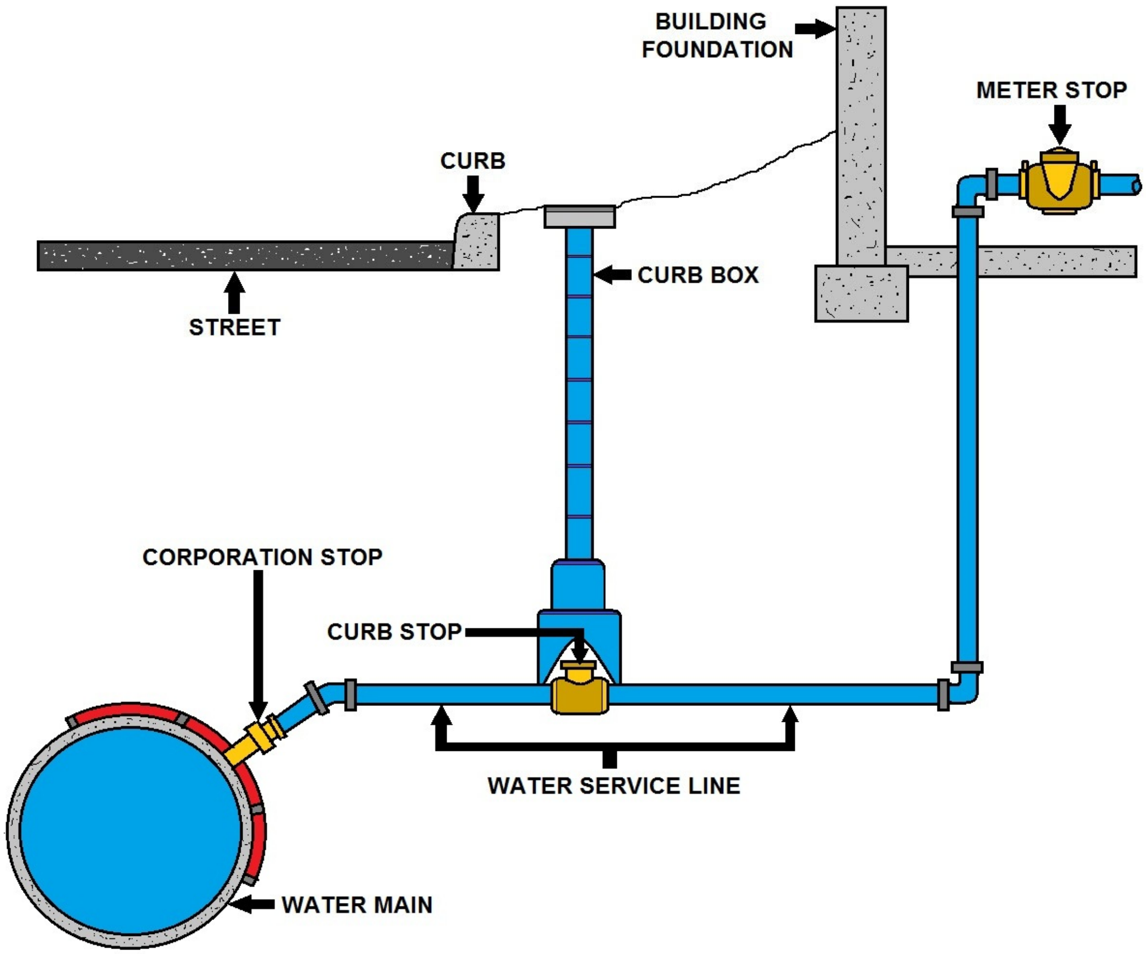
Topic 1 - Cross-Connection Control Section

Section Focus: You will learn the basics of cross-connection control. At the end of this section, you the student will be able to understand and describe cross-connection control and various backflow prevention assemblies. There is a post quiz at the end of this section to review your comprehension and a final examination in the Assignment for your contact hours.

Scope/Background: The Safe Drinking Water Act (SDWA) requires the Administrative or Regulatory Authority to set up a cross-connection control program to protect public health from contaminants which may occur from cross-connections, therefore we need backflow prevention assembly protection.



Above is one example of a commonly found cross-connection. This type pf cross-connection happens every time the water pressure in the water main is reduced or shut-down.



ONE VARIATION OF COMMON WATER METER INSTALLATION METHOD

Above is an example of a water service installation. Normally, we like to see a backflow prevention assembly immediately following the water meter on the customer's side of the water meter. This practice is known as "containment protection or secondary protection."

Backflow Introduction

Backflow Prevention, also referred to as Cross-Connection Control, addresses a serious health issue. This issue was addressed on the federal level by passage of the "*Federal Safe Drinking Water Act*" as developed by the Environmental Protection Agency (E.P.A.) and passed into law on December 16, 1974.

This Act tasked each state with primary enforcement responsibility for a program to assure access to safe drinking water by all citizens. Such state program regulations as adopted are required to be at least as stringent as the federal regulations as developed and enforced by the E.P.A.

The official definition of a cross-connection is *"the link or channel connecting a source of pollution with a potable water supply*." There are two distinct levels of concern with this issue. The first is protection of the general public and the second is protection of persons subject to such risks involving service to a single customer, be that customer an individual residence or business.

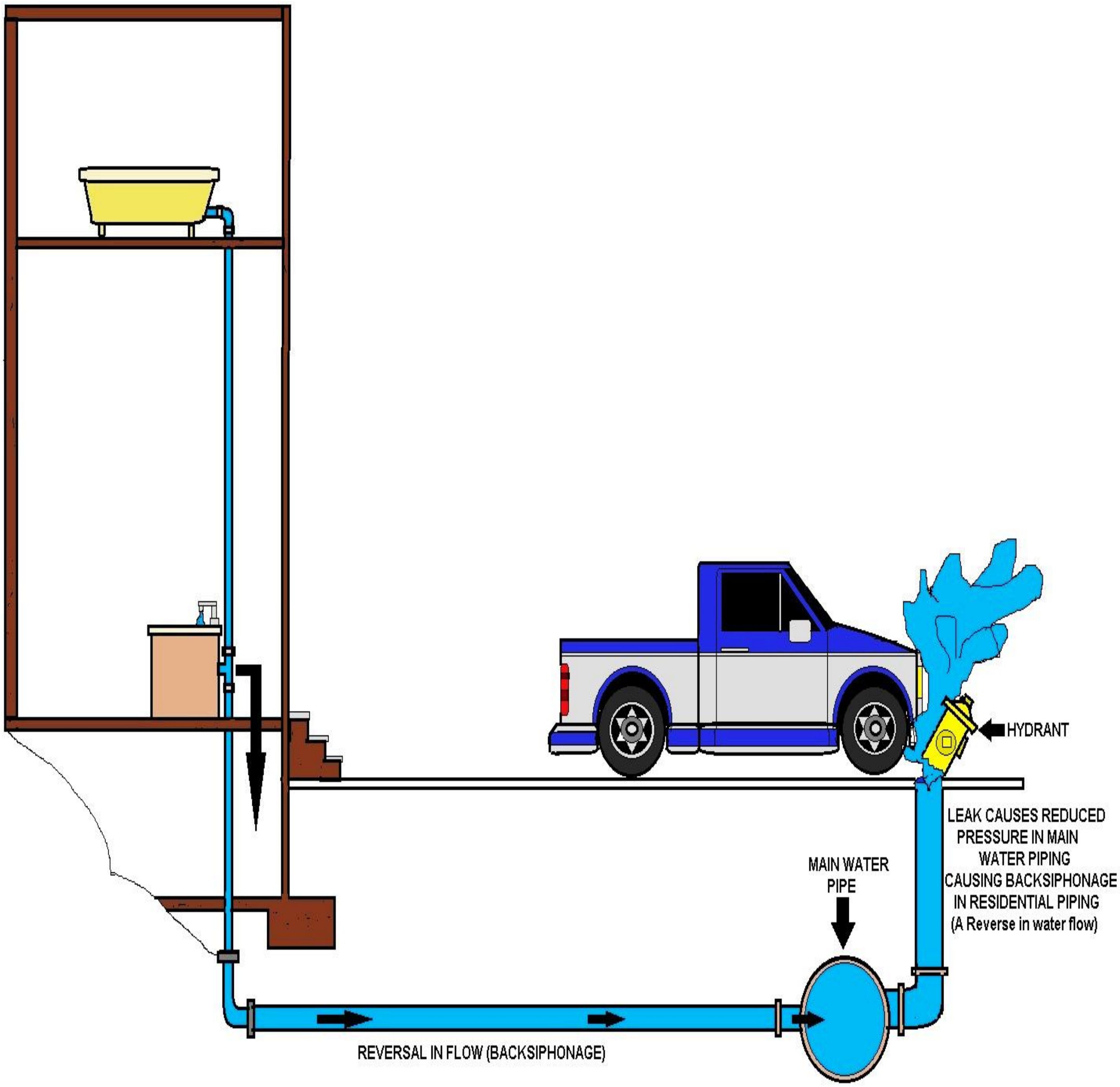
Sources of pollution which may result in a danger to health are not always obvious and such cross-connections are certainly not usually intentional. They are usually the result of oversight or a non-professional installation.

As source examples, within a business environment the pollutant source may involve the unintentional cross-connection of internal or external piping with chemical processes or a heating boiler. In a residential environment the pollutant source may be an improper cross-connection with a landscape sprinkler system or reserve tank fire protection system.

Or, a situation as simple as leaving a garden hose nozzle submerged in a bucket of liquid or attached to a chemical sprayer.

Another potential hazard source within any environment may be a cross-connection of piping involving a water well located on the property. This is a special concern with older residences or businesses, which may have been served by well water prior to connection to the developed water system. There are many other potential sources of pollutant hazards.

Control of cross-connections is possible but only through knowledge and vigilance. Public education is essential, for many that are educated in piping and plumbing installations fail to recognize cross-connection dangers.



BACKSIPHONAGE

Actual Backflow Events

Paraquat
In June 1983, "*yellow gushy stuff*" poured from some faucets in the Town of Woodsboro, Maryland. Town personnel notified the County Health Department and the State Water Supply Division. The State dispatched personnel to take water samples for analysis and placed a ban on drinking the Town's water.

Firefighters warned residents not to use the water for drinking, cooking, bathing, or any other purpose except flushing toilets. The Town began flushing its water system. An investigation revealed that the powerful agricultural herbicide Paraquat had backflowed into the Town's water system.

Someone left open a gate valve between an agricultural herbicide holding tank and the Town's water system and, thus, created a cross-connection. Coincidentally, water pressure in the Town temporarily decreased due to failure of a pump in the Town's water system.

The herbicide Paraquat was backsiphoned into the Town's water system. Upon restoration of pressure in the Town's water system, Paraquat flowed throughout much of the Town's water system. Fortunately, this incident did not cause any serious illness or death. The incident did, however, create an expensive burden on the Town. Tanker trucks were used temporarily to provide potable water, and the Town flushed and sampled its water system extensively.

Mortuary
The chief plumbing inspector in a large southern city received a telephone call advising that blood was coming from drinking fountains at a mortuary (i.e., a funeral home). Plumbing and health inspectors went to the scene and found evidence that blood had been circulating in the potable water system within the funeral home. They immediately ordered the funeral home cut off from the public water system at the meter.

City water and plumbing officials did not think that the water contamination problem had spread beyond the funeral home, but they sent inspectors into the neighborhood to check for possible contamination. Investigation revealed that blood had backflowed through a hydraulic aspirator into the potable water system at the funeral home.

The funeral home had been using a hydraulic aspirator to drain fluids from bodies as part of the embalming process. The aspirator was directly connected to a faucet at a sink in the embalming room. Water flow through the aspirator created suction used to draw body fluids through a needle and hose attached to the aspirator.

When funeral home personnel used the aspirator during a period of low water pressure, the potable water system at the funeral home became contaminated. Instead of body fluids flowing into the wastewater system, they were drawn in the opposite direction--into the potable water system.

U.S. Environmental Protection Agency, Cross-Connection Control Manual, 1989

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 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 contaminates 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.

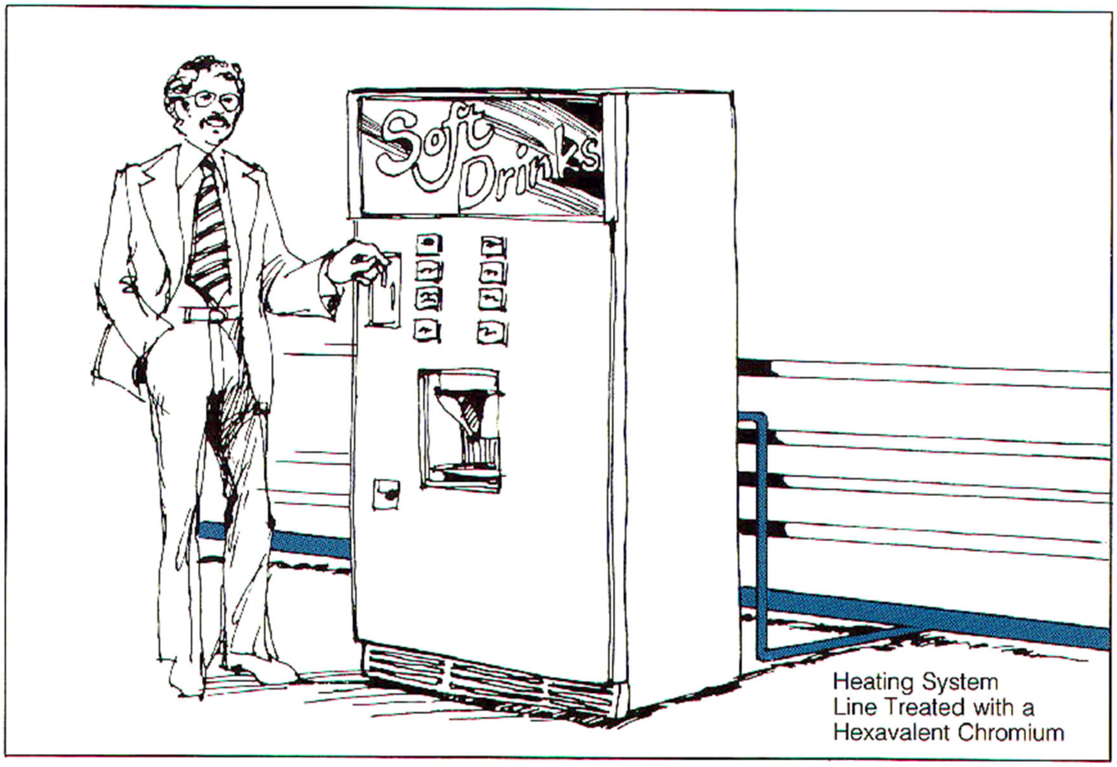
Washington 1994
An Ethylene Glycol cooling system was illegally connected to the domestic water supply at a veterinarian hospital.

Ohio 1994
An ice machine connected to a sewer sickened dozens of people attending a convention.

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 non-potable 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.



Several cross-connection have been made to soda machines, the one to worry about is when you have a copper water line hooked to CO_2 without a backflow preventer.

The reason is that the CO_2 will mix in the water and create copper carbonic acid which can be deadly. This is one reason that you will see clear plastic lines at most soda machines and no copper lines. Most codes require a stainless steel RP backflow assembly at soda machines.

Why does a soft drink dispensing machine require backflow protection?
Soft drink dispensers (post-mix carbonators) use carbonated water mixed under pressure with syrup and water to provide soft drinks beverages.

Many, if not most water pipes are made of copper. When carbonated water comes into contact with copper, it chemically dissolves the copper from the pipe. This copper-carbonate solution has been proven to be a risk to the digestive system.

Cross-Connection Occurrence

Under intended flow conditions, distribution systems are pressurized to deliver finished water from the treatment plant to the customer. However, two situations can cause the direction of flow to reverse: pressure in the distribution system can drop due to various conditions or an external system connected to the distribution system may operate at a higher pressure than the distribution system. These differences in pressure can cause contaminants to be drawn or forced into the distribution system.

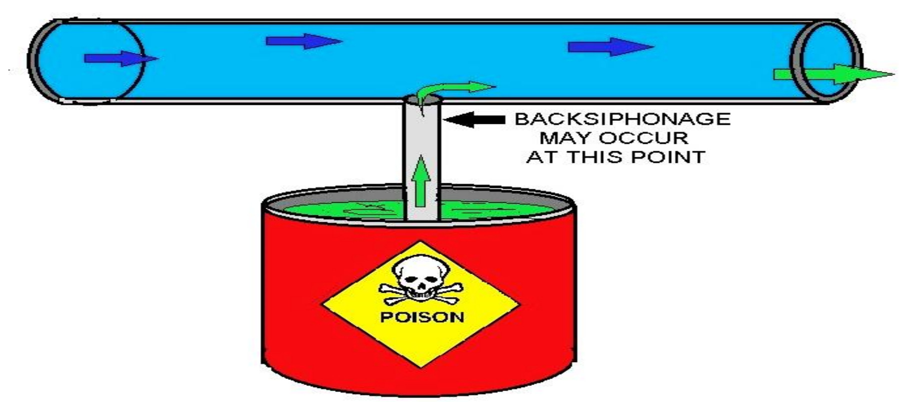
Contamination introduced due to backflow into the distribution system may then flow freely into other customer connections.

The following conditions must be present for contamination to occur through cross-connections.

- A cross-connection exists between the potable water distribution system and a nonpotable source.
- The pressure in the distribution system either becomes negative (backsiphonage), or the pressure of a contaminated source exceeds the pressure inside the system (backpressure).
- The cross-connection is not protected, or the connection is protected and the mechanism failed, allowing the backflow incident.

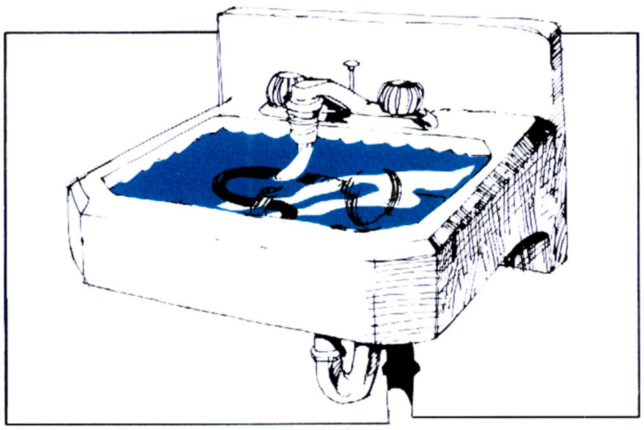
The extent of contamination in the distribution system depends, in part, on the location of the cross-connection, the concentration of the contaminant entering the distribution system and the magnitude and duration of the pressure difference causing the backflow.

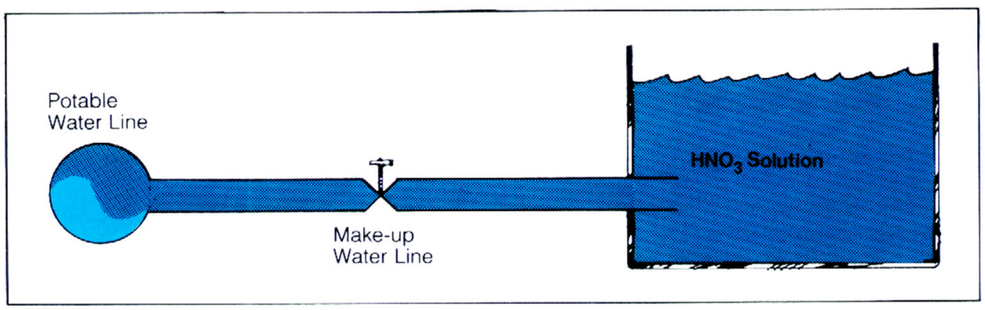
This section of the course describes the theory of backflow and cross-connections, provides examples of conditions that can create backflow, and lists a number of factors that affect the likelihood and magnitude of backflow through a cross-connection. From the EPA Cross-Connection Manual.

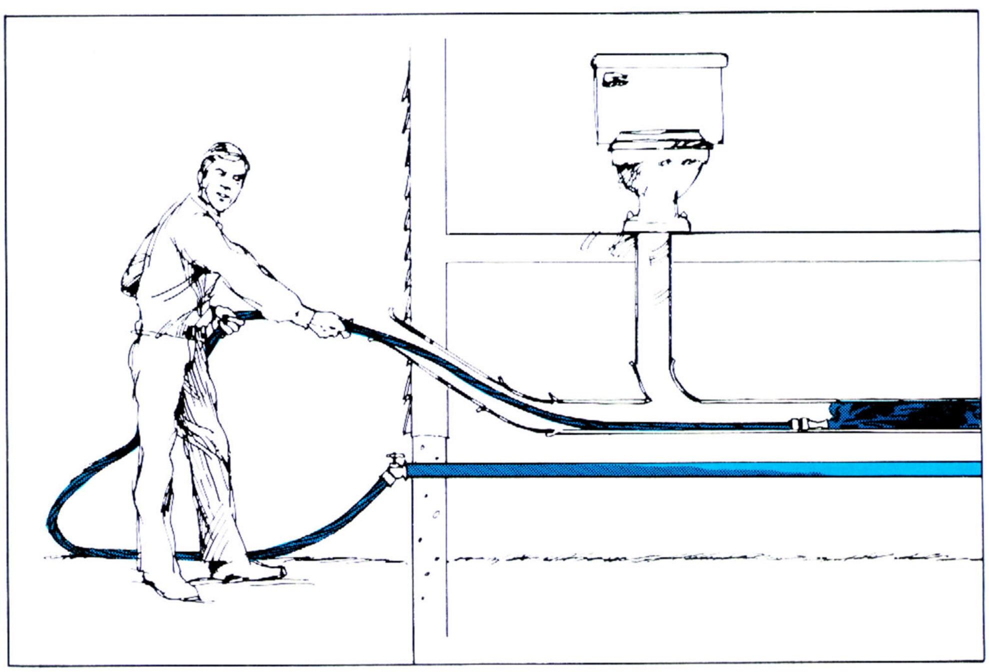


ASPIRATOR EFFECT

Common Cross-Connections







Bottom, a direct connection between water and sewage. *A perfect cross-connection and it happens all day long.*

Backflow Occurrence and Contamination Factors

Operating Pressure

A minimum operating pressure of 20 psi at all locations in a distribution system is suggested by various manuals and codes of good operating practice (Kirmeyer et al., 2001). Some states also have minimum operating pressure requirements. Local operating pressure in a system varies among zones. In a highly pressurized system, a great deal of backpressure would be needed to force water to backflow; a system or part of a system with relatively low pressure would generally be more susceptible to backpressure. Systems with normal operating pressure lower than recommended by manuals and codes of good practice may have a higher risk of backpressure events.

Reduced pressures that can lead to backflow occur from a variety of sources. Water main breaks, hilly terrain, limited pumping capacity, high demand by consumers, firefighting flows, rapidly opening or closing a valve within the distribution system, power loss, and hydrant flushing can reduce pressure and contribute to lower or extremely fluctuating water pressures (Kirmeyer et al., 2001).

A study of a distribution system (LeChevallier et al., 2001) observed that during a pump test, routine operation, and a power outage, pressures as low was -10.1 psi were recorded, with durations ranging from 16 to 51 seconds.

During these times of negative pressure, the chance that water external to the distribution system intruded into the distribution system due to backsiphonage or backpressure increased. In a simple single pipe model employed in the study, a surge generated by a simulated power failure to a pump predicted 69 gallons of external water would intrude into the pipe within 60 seconds. A surge caused by a main break predicted 78 gallons of water intruding within 60 seconds.

A survey of 70 systems reported 11,186 pressure reduction incidents in the past year; 34.8 percent of the incidents were from routine flushing, 19.2 percent were due to main breaks, and 16.2 percent incidents were due to service line breaks (ABPA, 2000).

Hills and other elevations compound pressure loss effects caused by main breaks, fire flows, and other events (ABPA, 2000). Limited pumping capacity may cause periodic termination of water supply in areas of the system. Without sufficient redundancy in the distribution system, backsiphonage conditions may occur if one or more major components of the distribution system go offline or otherwise cease functioning.

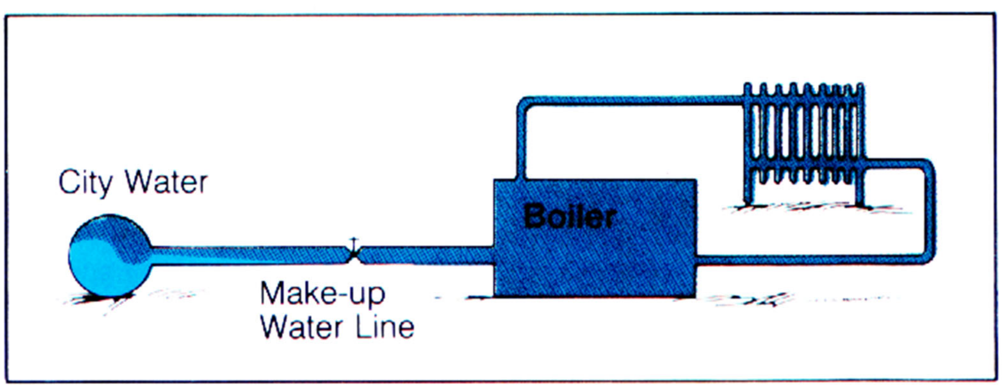
Physical Security of the Distribution System

Homeland security initiatives include attention to the physical security of water distribution systems. The subject of homeland security is well beyond the scope of this paper, but it is relevant to note that the potential for intentional contamination of a distribution system through cross-connections and backflow of chemical and biological contaminants is possible (Dreazen, 2001). From the EPA Cross-Connection Manual.

Backflow

Backflow is the undesirable reversal of flow of non-potable 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

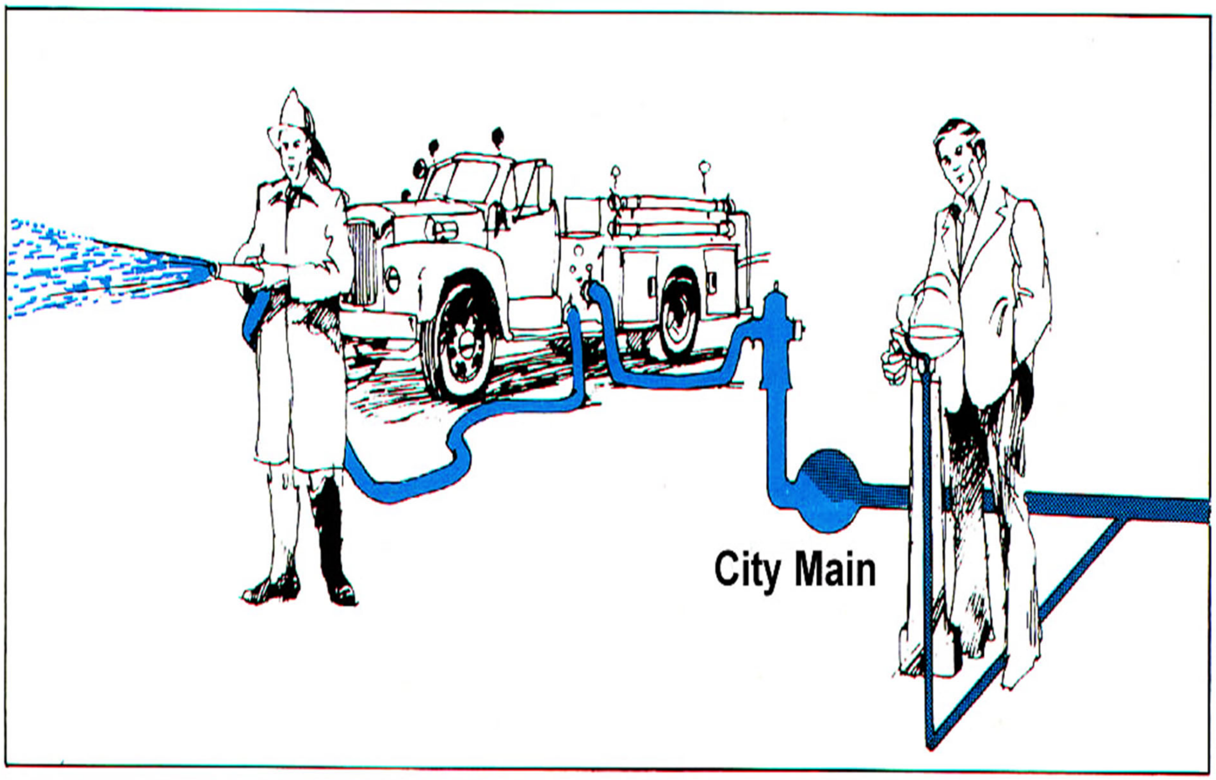


Backpressure caused by heat.

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 firefighting, a break in a water main, etc.



Every day, our public water system has several backsiphonage occurrences, Think of people that use water driven equipment, from a device that drains water-beds to pesticide applicators.

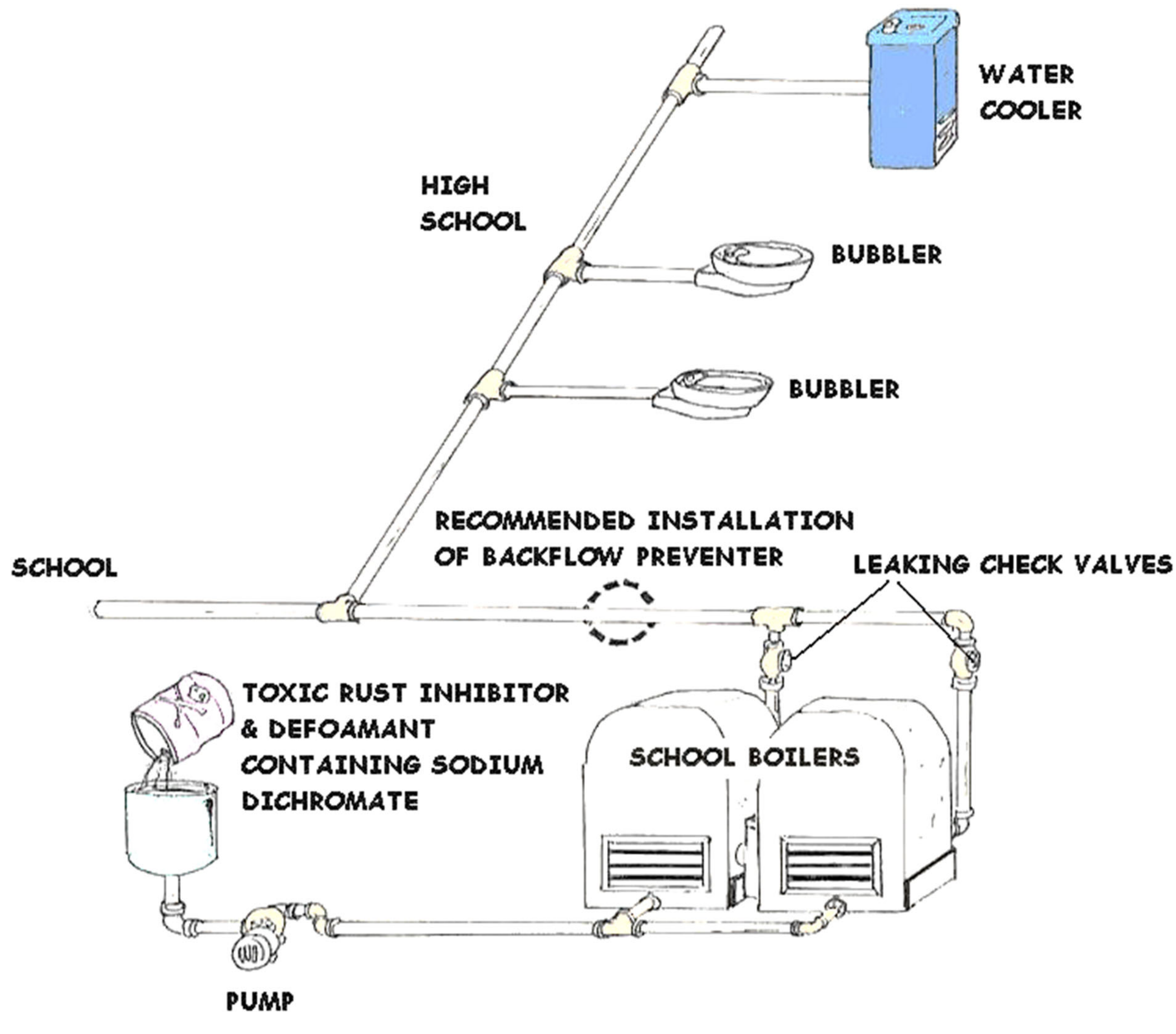
Backpressure is rarer, but does happen in areas of high elevation, like tall buildings or buildings with pumps.

A good example is the pressure exerted by a building that is 100 feet tall is about 43 PSI, the water main feeding the building is at 35 PSI. The water will flow back to the water main. Never drink water or coffee inside a funeral home, vet clinic or hospital.

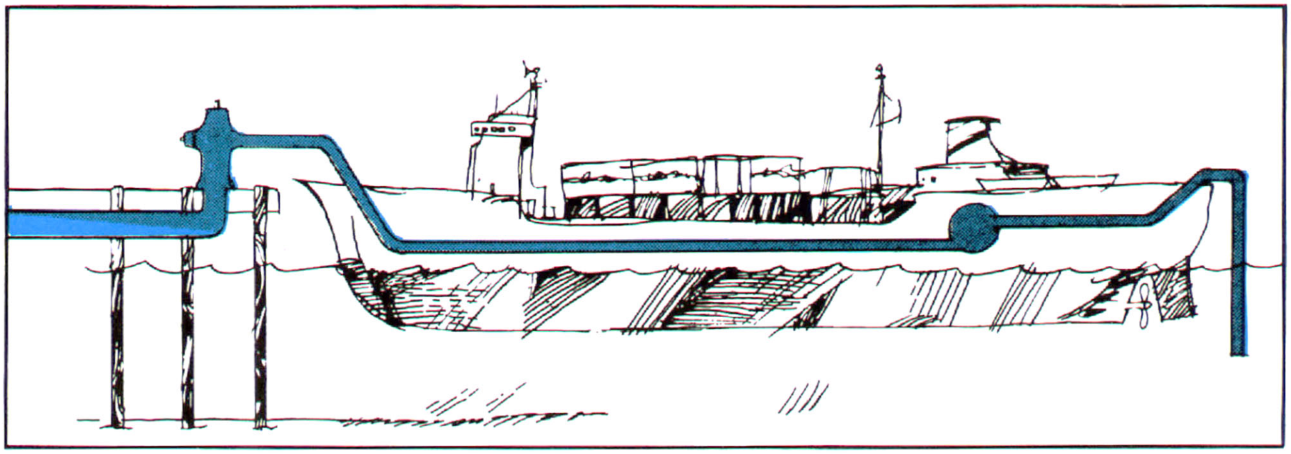
Backpressure

Backpressure backflow 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, 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, firefighting, or breaks in water mains.



Backpressure Examples
Booster pumps, pressure vessels, elevation, heat



Here we see the backpressure of salt water back into the public water system from a ship's pressure pump. Most water providers are now requiring a RP assembly at the hydrant.

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.

Residential Dual Check Valve
A secondary type of mechanical backflow preventer is the residential dual check valve. We do not recommend the installation of dual checks because there is no testing method or schedule for these devices. Once these devices are in place, they, like all mechanical devices, are subject to failure and will probably be stuck open.

Some type of debris will keep the device from working properly.

Problems Associated with Backflow Incidents

This section discusses other negative effects associated with cross-connections and backflow that, although not a direct threat to health, can cause other undesired effects such as negative publicity, consumer complaints, damage to the water system, and impediments to system operation. Negative effects discussed are: 1.) corrosion; 2.) microbial growth; and 3.) taste, odor, and color problems.

FINISHED WATER REPORT	UNITS OF MEASURE	
FINISHED WATER TURBIDITY	NTU	Neophelometric Turbidity Unit
FINSHED WATER TEMPERATURE	Deg. C	Degrees Celcius
FINISHED WATER pH	SU	Standard Units
FINISHED WATER ALKALINITY	mg/l	Milligrams per Liter
FINISHED WATER HARDNESS	mS/cm	Millisiemens per Centimeter
FINISHED WATER CONDUCTIVITY	mg/l	Milligrams per Liter
FINISHED WATER TOTAL DISSOLVED SOLIDS	mg/l	Milligrams per Liter
FINISHED WATER FLUORIDE	mg/l	Milligrams per Liter
FINISHED WATER IRON	mg/l	Milligrams per Liter
FINISHED WATER MANGANESE	mg/l	Milligrams per Liter
FINISHED WATER PHOSPHATE	mg/l	Milligrams per Liter
HARDNESS PER GALLON	GRAINS	

WATER QUALITY REPORT INCLUDING UNITS OF MEASUREMENT

Technical Learning College

Corrosion

Many contaminants, such as acids and carbon dioxide, can corrode pipes and other distribution system materials. Many incidents of corrosion induced by carbon dioxide backflow have released toxic amounts of copper into drinking water systems (AWWA PNWS, 1995). Many of these incidents were reported because the corrosion was rapid enough and large enough in extent to produce concentrations of corroded metal high enough to be toxic or to lead to complaints about taste and odor.

Corrosion in iron pipes is much less likely to be noticed because iron is not as toxic as copper, and corrosion of iron and steel is relatively slow, leading to lower concentrations. But slow corrosion is a problem: corroded iron pipes can lead to discolored water, stained laundry, and taste complaints (McNeil and Edwards, 2001). Corrosion can also weaken the integrity of pipes, causing leaks that can allow contaminants in through intrusion or catastrophic breaks, which can in turn cause reduced pressure (McNeil and Edwards, 2001). Corrosion of iron pipes can also form tubercles that can shelter microbes (including pathogens) from disinfection (US EPA, 1992).

Microbial Growth
When backflow through cross-connections introduces microbes into the distribution system, these organisms can attach to pipe walls in places where the disinfectant residual may be inadequate to inactivate the microbes, such as in dead ends. Such organisms, even if they are not pathogenic themselves, can be a concern because they can colonize on the pipe walls, forming biofilms (US EPA, 1992) that trap and concentrate nutrients, promoting growth of pathogens (Costerton and Lappin-Scott, 1989). The biofilm can lead to total coliform violations, even in the absence of contamination events. Biofilm can also cause complaints about taste and odor and harbor potentially pathogenic organisms from disinfection (Characklis, 1988). Backflow through cross-connections can also introduce nutrients that support the growth of pre-existing biofilms.

Taste, Odor, and Color Problems
Some contaminants introduced through cross-connections and backflow may not cause illness but may result in consumer complaints about the tastes, odors, or color of the water (e.g., seawater and dyes (AWWA PNWS, 1995)). Such incidents can lower consumer confidence in the water system, require water and employee time to flush the system to remove the offending contaminant, and initiate an investigation to identify and correct the cross-connection.

Preventive Measures
Systems look to minimize the risk posed to their distribution systems from a customer's plumbing system, and therefore conduct hazard assessments in order to determine the level of protection needed and what approach should be taken. The appropriate type of protection depends on the physical characteristics of the cross-connection (e.g., whether there is a potential for backpressure in addition to backsiphonage) and the degree of the potential hazard. The degree of hazard is a function of both the probability that backflow may occur and the toxicity or pathogenicity of the contaminant involved.

A high hazard can be defined as,
"a condition, device, or practice which is conducive to the introduction of waterborne disease organisms, or harmful chemical, physical, or radioactive substances into a public water system, and which presents an unreasonable risk to health" (BMI, 1996).

Low hazard can be defined as,
"a hazard that could cause aesthetic problems or have a detrimental secondary effect on the quality of the public potable water supply" (BMI, 1996).

Another reason for conducting risk assessments is to determine and help manage legal liability due to public health risk; therefore, these definitions of high and low hazard are ultimately subjective and depend upon the risk aversion of the water system, appropriate local regulations, and the particular risk assessment conducted by the system.

Types of Backflow Prevention Methods and Assemblies

There are two basic types of backflow preventers: testable and non-testable.

Testable Backflow Preventers
also referred to as Backflow Prevention Assemblies; Backflow Assemblies; Testable Assemblies; or simply, Assemblies. Backflow Prevention Assemblies are generally required on the more hazardous cross connection applications, see below. By federal, state and local requirements as well as the manufacturer's product listing, annual testing is required to ensure the assembly is good working order. This is due in part because the working components of a backflow assembly have a fairly short life expectancy and/or because sediment and debris can easily block their proper function.

When required testing fails to produce satisfactory results, assemblies must be cleaned and/or rebuilt as needed and retested. Un-repairable or obsolete assemblies must be replaced. See more below, for reporting, permitting, and licensing requirements.

Non-Testable Backflow Preventers
also referred to as Backflow Prevention Devices; Backflow Devices; Non-Testable Devices; or simply Devices. Backflow Prevention Devices are generally required on the less hazardous cross-connection applications, see below. Some devices are required to be replaced every five years; while others are good for the life of the fixture they serve or until they visibly fail (leak externally).

Application of Backflow Preventers
The following is a general view of applications that require either a testable or non-testable backflow preventer. For more specific information and installation standards, refer to your plumbing code or the Foundation of Cross-Connection Control and Hydraulic Research manual.

Testable Application
Irrigation, in ground (All Homes & Businesses)
Commercial Boilers
Cooling Towers
Medical Equipment
Laboratory Uses
Commercial Water Treatment
Vehicle Washing Facilities
Commercial Fire Sprinklers
Processing Plants

Non-Testable Applications
Residential Hose Bibbs
Hand Held Shower Heads
Emergency Eye Wash
Residential Fire Sprinkler*
Residential Boilers
Commercial Ice Makers *
Beverage Dispensers*
Residential Humidifiers
Food Service Equipment*
*May require a testable device, depending upon Regulatory Authority

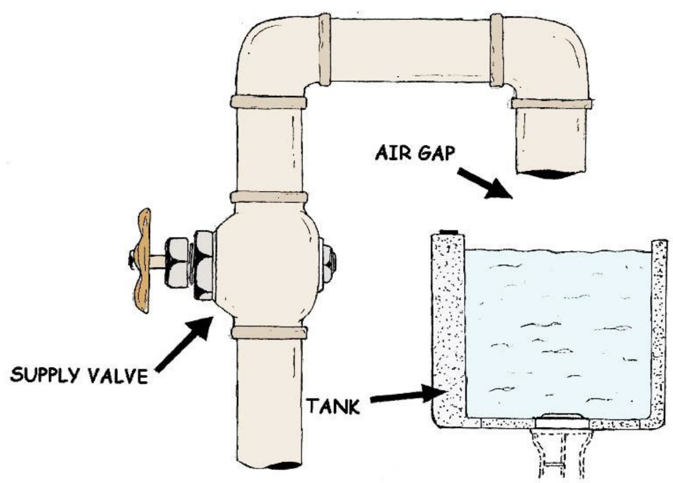
Common Testable Backflow Devices
Cross connections must either be physically disconnected or have an approved backflow prevention device installed to protect the public water system. There are five types of approved devices/methods:

1. **Air gap-** ***Is not really a device but is a method.***
2. Atmospheric vacuum breaker
3. Pressure vacuum breaker
4. Double check valve
5. Reduced pressure principle backflow preventer (RP device)

The type of device selected for a particular installation depends on several factors. First, the degree of hazard must be assessed. A high hazard facility is one in which a cross connection could be hazardous to health, such as a chrome plating shop or a sewage treatment plant. A low hazard situation is one in which a cross connection would cause only an aesthetic problem such as a foul taste or odor.

Second, the plumbing arrangement must be considered.

Third, it must be determined whether protection is needed at the water meter or at a location within the facility. A summary of these factors and the recommended device selection is given in Table 7-1.



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 has an approved air gap? Here is a better question; would you use the ice from this ice machine? This is where all those stories about cockroaches and stomach flu originate.

Air Gap Defined

An air gap is a physical disconnection between the free flowing discharge end of a potable water pipeline and the top of an open receiving vessel. The air gap must be at least two times the diameter of the supply pipe and not less than one inch. This type of protection is acceptable for high hazard installations and is theoretically the most effective protection. However, this method of prevention can be circumvented if the supply pipe is extended.

Physical Separation
Air gaps, if designed and maintained properly, make backflow physically impossible as they ensure that there is no connection between the supply main and the nonpotable source.

An effective air gap is a physical separation of a supply pipe from the overflow rim of a receiving receptacle, by at least twice the diameter (minimum of one inch) of the incoming supply pipe (USC FCCCHR, 1993; BMI, 1996).

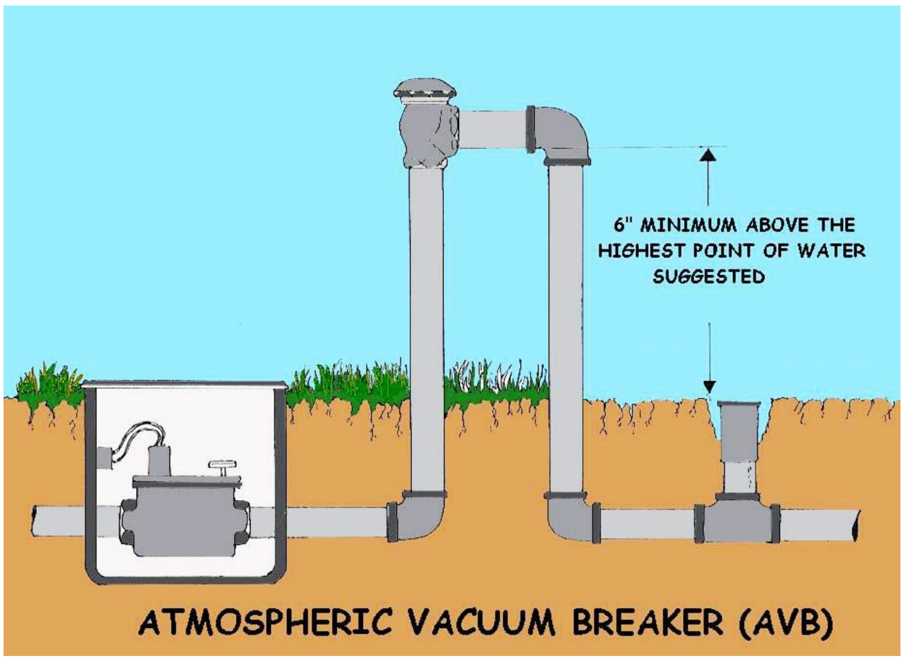
The distance between the end of a faucet and the overflow of a utility sink is an example of an air gap. While air gaps provide physical assurances against backflow, they are often tampered with as people extend the end of the pipe to prevent splashing and thus potentially create a cross-connection.

By the AWWA standard, air gaps are acceptable in lieu of mechanical backflow prevention assemblies beyond the service connection only if installed and maintained by the local cross-connection control program enforcement agency (AWWA, 1999).

Vacuum Breakers

There are two types of vacuum breakers, atmospheric and pressure. The difference between them is that the pressure vacuum breaker is spring loaded to assist the device's opening. Both devices open the pipeline to atmosphere in the event of backsiphonage only. Neither device is approved for backpressure conditions. Both devices are only suitable for low hazard applications. Their primary purpose is to protect the water system from cross connections due to submerged inlets, such as irrigation systems and tank applications.

Shutoff valves may not be installed downstream of atmospheric vacuum breakers but are allowed on pressure vacuum breakers. The devices must be installed above the highest downstream piping.



Atmospheric Vacuum Breaker (AVB)

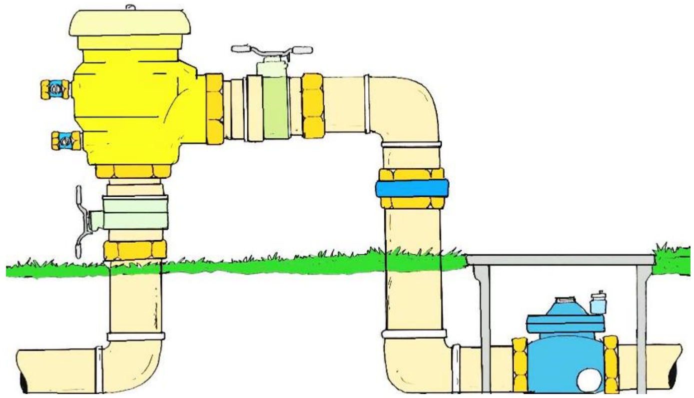
The Atmospheric Vacuum Breaker contains a float check (poppet), a check seat, and an air inlet port. The device allows air to enter the water line when the line pressure is reduced to a gauge pressure of zero or below. The air inlet valve is not internally loaded. To prevent the air inlet from sticking 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, non-pressurized 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)

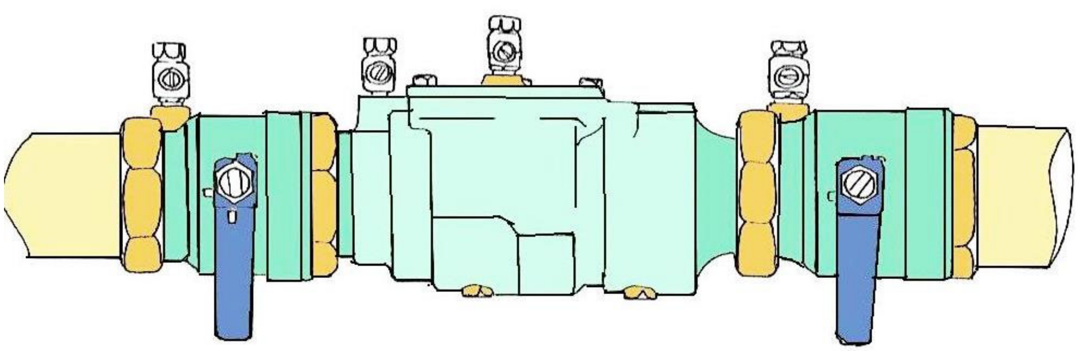
The Pressure Vacuum Breaker Assembly consists of a spring loaded check valve, an independently operating air inlet valve, two resilient seated shutoff valves, and two properly located resilient seated test cocks. It shall be installed as a unit as shipped by the manufacturer. The air inlet valve is internally loaded to the open position, normally by means of a spring, allowing installation of the assembly on the pressure side of a shutoff valve. The PVB needs to be installed 12 inches above the highest downstream outlet to work correctly.

PRESSSURE VACUUM BREAKER ASSEMBLY



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 or pollutional concerns only. The double check valve should be installed in an accessible location and protected from freezing. The DC needs to be installed 12 inches above the ground for testing purposes only.



DOUBLE CHECK VALVE ASSEMBLY

Reduced Pressure Backflow Assembly (RP)

The reduced pressure 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. The RP needs to installed 12 inches above the ground for testing purposes only.

Two brand new RPs ready for inspection.

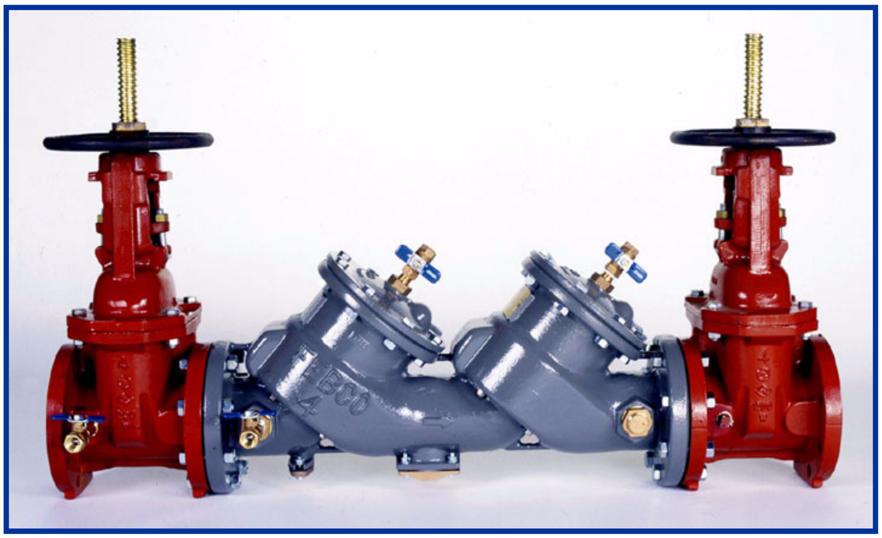
Different Types of RPs

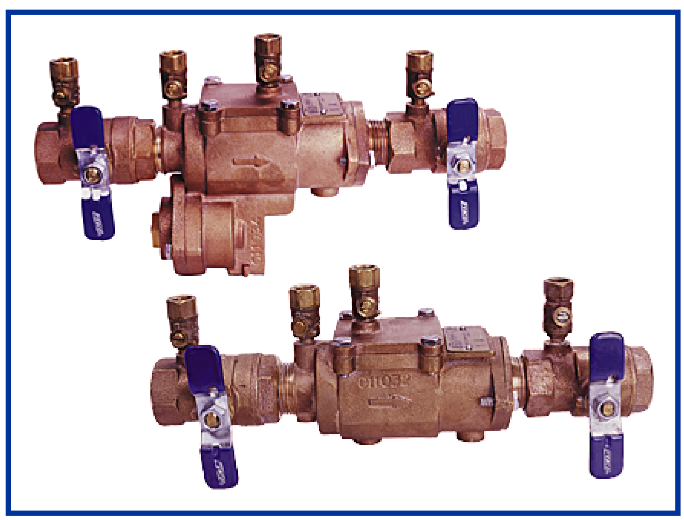
The RP consists of two internally loaded (weighted or spring loaded) check valves separated by a reduced pressure zone with a relief port to vent water to the atmosphere.

The reduced pressure device can be used for high hazard situations under both backpressure and backsiphonage conditions. Under normal conditions, the second check valve should prevent backflow.

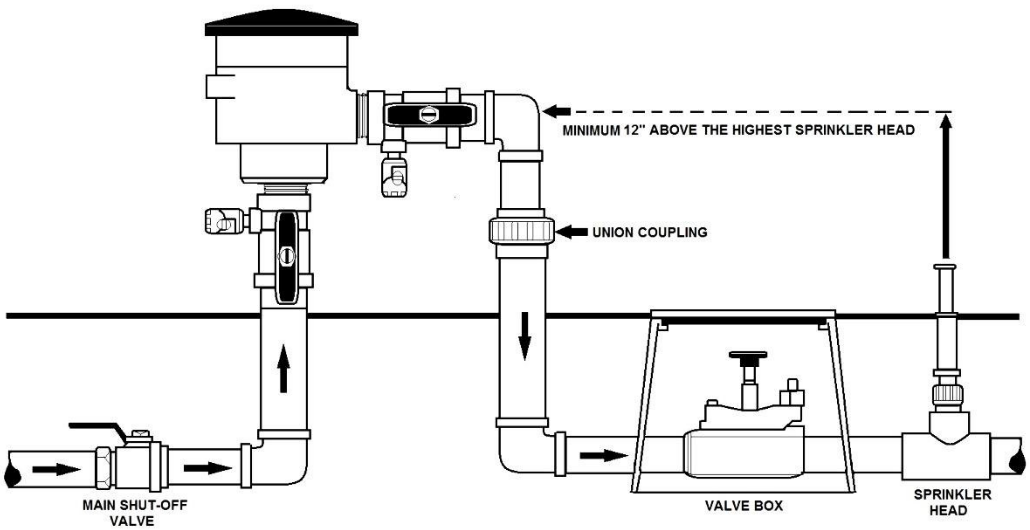
However, if the second check valve fails or becomes fouled and backflow into the reduced pressure zone occurs, the relief port vents the backflow to atmosphere.

The reduced pressure zone port opens anytime pressure in the zone comes within 2 psi of the supply pressure.

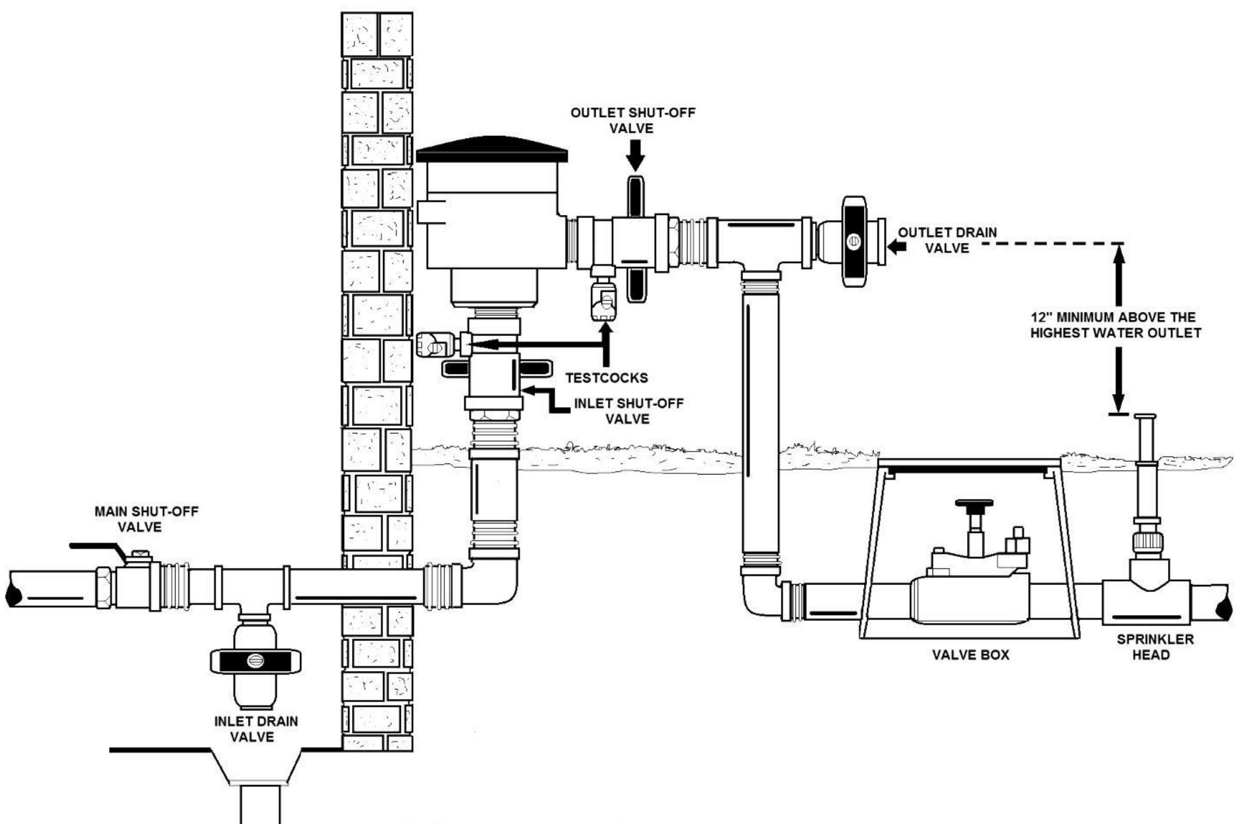




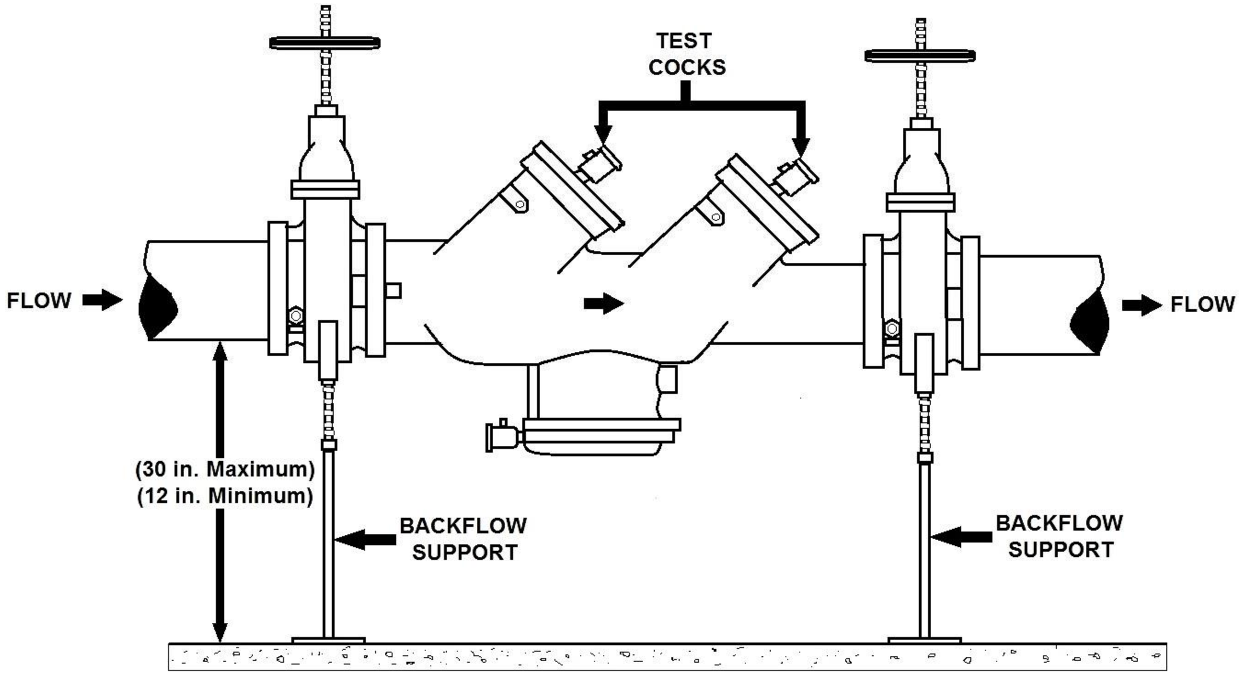
Standard Installation Diagrams



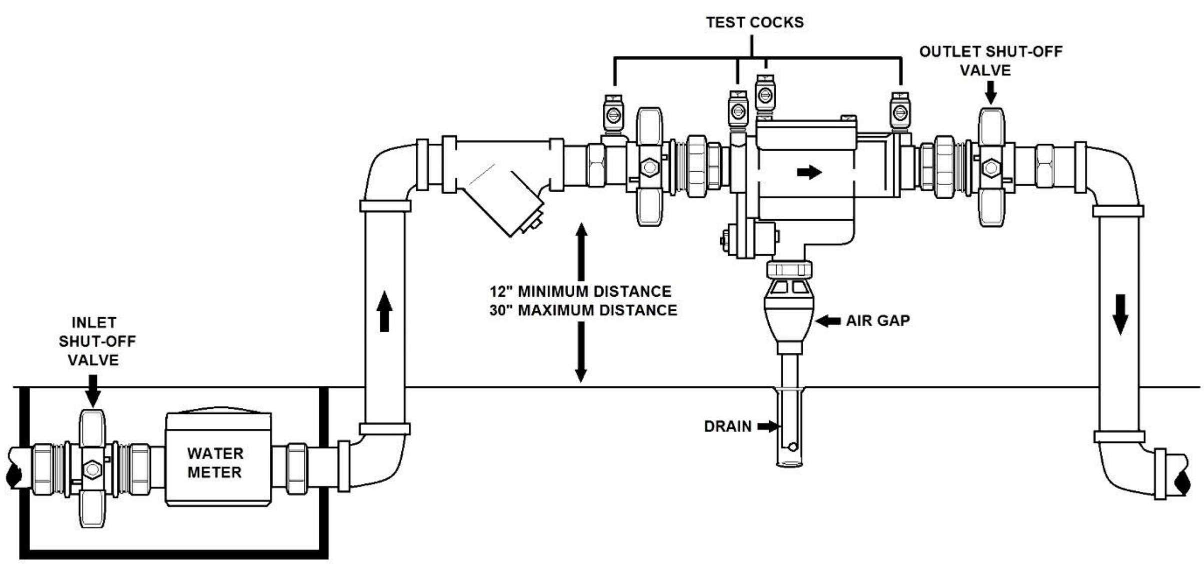
PRESSURE VACUUM BREAKER BACKFLOW PREVENTER



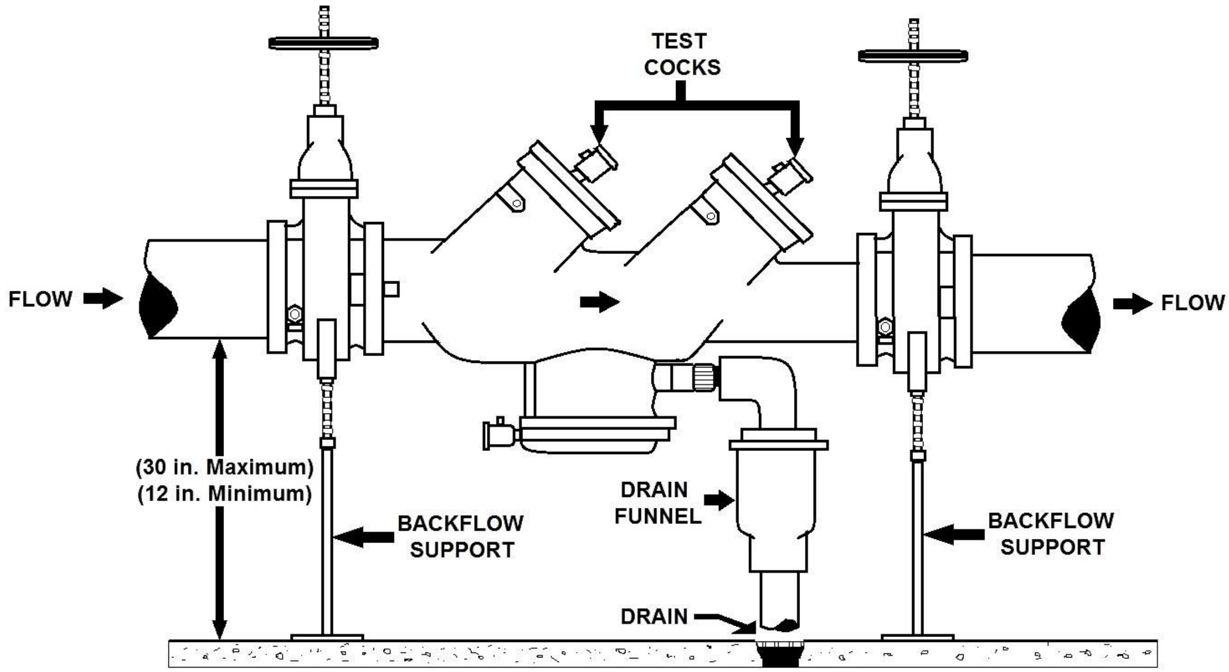
PRESSURE VACUUM BREAKER



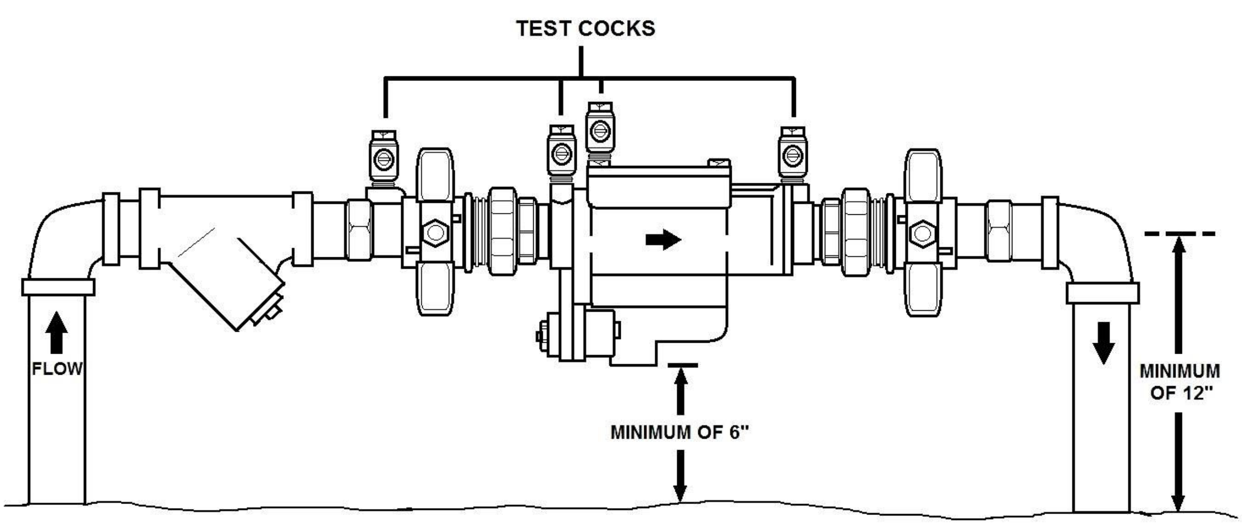
DOUBLE CHECK VALVE



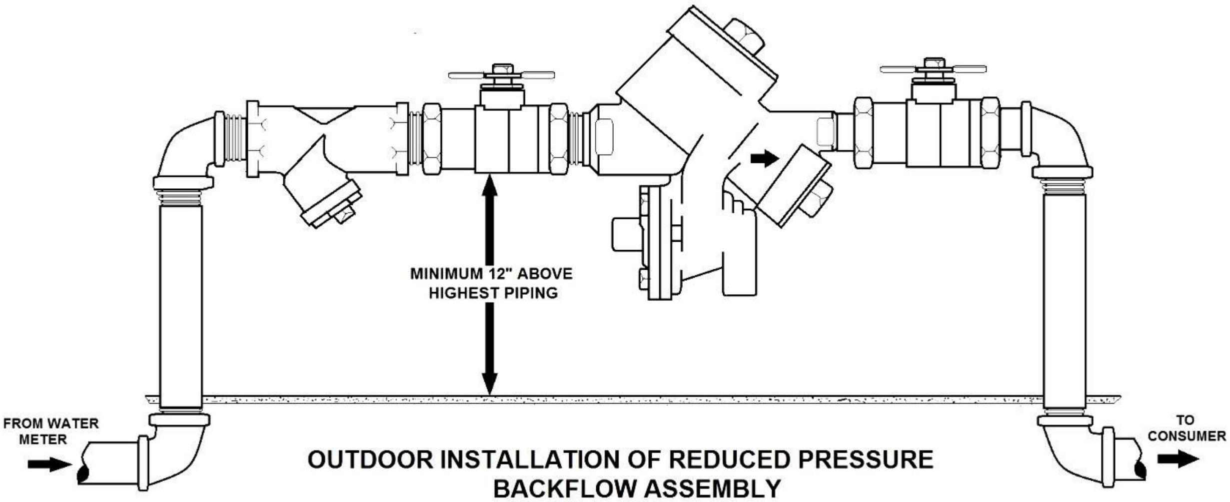
REDUCED PRESSURE BACKFLOW PREVENTER



REDUCED PRESSURE BACKFLOW PREVENTER
(Indoor Installation)



REDUCED PRESSURE BACKFLOW PREVENTER



OUTDOOR INSTALLATION OF REDUCED PRESSURE
BACKFLOW ASSEMBLY

Texas Students Only
Special Notice to all TCEQ Students

§ 344.51. SPECIFIC CONDITIONS AND CROSS-CONNECTION CONTROL.

(d) If an irrigation system is designed or installed on a property that is served by an on-site sewage facility, as defined in Chapter 285 of this title (relating to On-Site Sewage Facilities), then:

(1) all irrigation piping and valves must meet the separation distances from the On-Site Sewage Facilities system as required for a private water line in §285.91(10) of this title (relating to Minimum Required Separation Distances for On-Site Sewage Facilities);

(2) any connections using a private or public potable water source must be connected to the water source through a reduced pressure principle backflow prevention assembly as defined in §344.50 of this title (relating to Backflow Prevention Methods); and

(3) any water from the irrigation system that is applied to the surface of the area utilized by the On-Site Sewage Facility system must be controlled on a separate irrigation zone or zones so as to allow complete control of any irrigation to that area so that there will not be excess water that would prevent the On-Site Sewage Facilities system from operating effectively.

Common Backflow Questions and Answers

1. What is a cross connection, what two types of backflow can cause one, and what methods of protection can be used to prevent them?

Backflow: Water that flows back to the distribution system. It is sometimes caused by a loss of pressure in the water system. A reverse flow condition.

Cross-Connection: A physical connection between potable water and any other source or non-potable water.

Backpressure: Backpressure backflow 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, 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, firefighting, or breaks in water mains.

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 firefighting, a break in a water main, etc.

2. Why do water suppliers need to control cross-connections and protect their public water systems against backflow?
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.

3. 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: (I) 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; and (S) 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.

4. Air gap: An air gap is a vertical, physical separation between the end of a water supply outlet and the flood-level rim of a receiving vessel. This separation must be at least twice the diameter of the water supply outlet and never less than one inch. An air gap is considered the maximum protection available against backpressure backflow or backsiphonage but is not always practical and can easily be bypassed.

5. RP: An RP or reduced pressure principle backflow prevention assembly is a mechanical backflow preventer that consists of two independently acting, spring-loaded check valves with a hydraulically operating, mechanically independent, spring-loaded pressure differential relief valve between the check valves and below the first check valve. It includes shutoff valves at each end of the assembly and is equipped with test cocks. An RP is effective against backpressure backflow and backsiphonage and may be used to isolate health or non-health hazards.

6. DC: A DC or double check is a mechanical backflow preventer that consists of two independently acting, spring-loaded check valves. It includes shutoff valves at each end of the assembly and is equipped with test cocks. A DC is effective against backpressure backflow and backsiphonage but should be used to isolate only non-health hazards.

7. Vacuum breaker: A PVB is a mechanical backflow preventer that consists of an independently acting, spring-loaded check valve and an independently acting, spring-loaded, air inlet valve on the discharge side of the check valve. It includes shutoff valves at each end of the assembly and is equipped with test cocks. A PVB may be used to isolate health or non-health hazards but is effective against backsiphonage only.

8. What is thermal expansion and what are the considerations with regards to backflow assemblies and devices?
A backflow assembly will create a closed system. A closed system will not allow built up pressure to be released. You need to release excessive pressure in a closed system. One method is by installing expansion tanks or blow-offs.

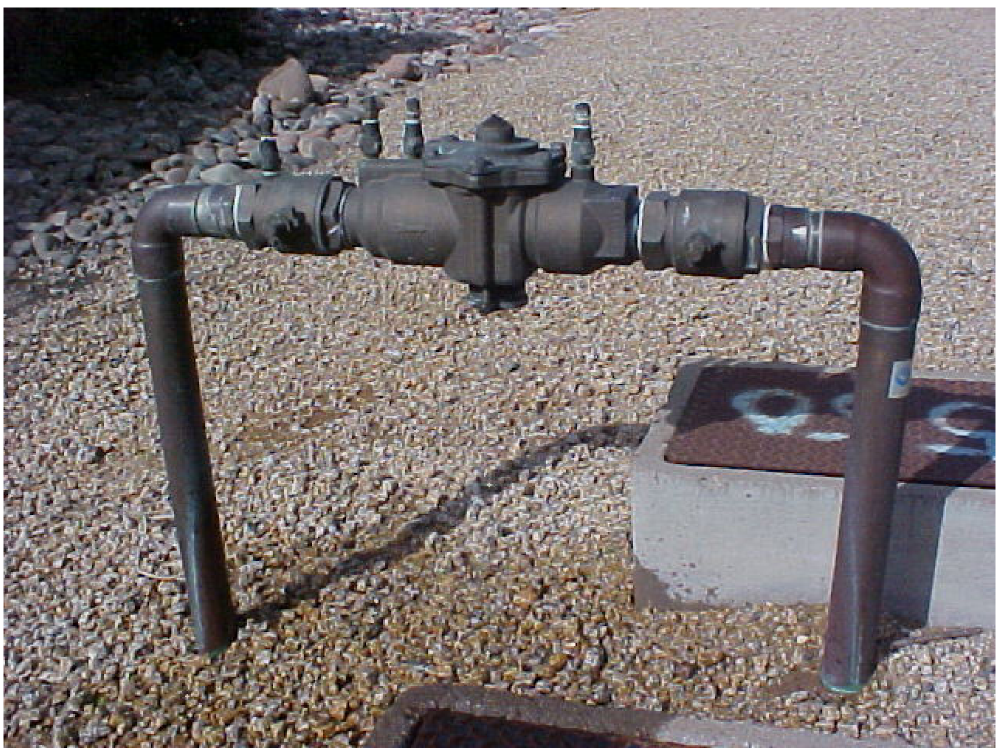
(9) Document all findings and recommendations prior to preparing the written report. Include as many sketches with the final report as possible and specifically state the size and generic type of backflow preventer required at each cross-connection found.

Why do Backflow Preventors have to be Tested Periodically?

Mechanical backflow preventors have internal seals, springs, and moving parts that are subject to fouling, wear, or fatigue. Also, mechanical backflow preventors and air gaps can be bypassed. Therefore, all backflow preventors have to be tested periodically to ensure that they are functioning properly. A visual check of air gaps is sufficient, but mechanical backflow preventors have to be tested with properly calibrated gauge equipment.

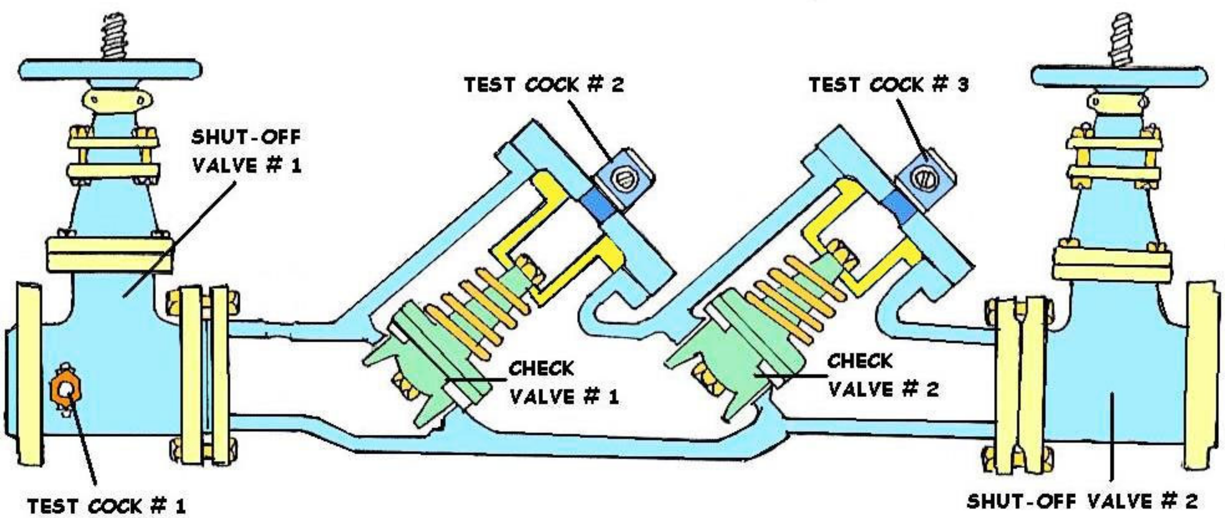
Backflow prevention devices must be tested annually to ensure that they work properly. It is usually the responsibility of the property owner to have this test done and to make sure that a copy of the test report is sent to the Public Works Department or Water Purveyor.

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--have your assemblies tested annually or more often. Re-test after repairs and problems. A RP should not leak more than 1 or 2 minute—any more than that, there is a problem; a piece of debris or stuck check is causing the RP's hydraulic relief port to dump.

Here is an RP that had never been tested and leaked every day until the grass was 3 feet high and the owner notified the Water Department of a water leak. The water meter reader should have caught this problem in the first couple months.



DOUBLE CHECK BACKFLOW ASSEMBLY

Fireline Backflow Assemblies Sub-Section

Example of an inline and vertical Reduced Pressure Backflow Assembly.

Fire Suppression Systems

- ✓ Properly designed and installed fixed fire suppression systems enhance fire safety in the workplace. Automatic sprinkler systems throughout the workplace are among the most reliable firefighting means. The fire sprinkler system detects the fire, sounds an alarm and puts the water where the fire and heat are located.

- ✓ Automatic fire suppression systems require proper maintenance to keep them in serviceable condition. When it is necessary to take a fire suppression system out of service while business continues, the employer must temporarily substitute a fire watch of trained employees standing by to respond quickly to any fire emergency in the normally protected area. The fire watch must interface with the employers' fire prevention plan and emergency action plan.

- ✓ Signs must be posted about areas protected by total flooding fire suppression systems which use agents that are a serious health hazard such as carbon dioxide, Halon 1211, etc. Such automatic systems must be equipped with area pre-discharge alarm systems to warn employees of the impending discharge of the system and allow time to evacuate the area. There must be an emergency action plan to provide for the safe evacuation of employees from within the protected area. Such plans are to be part of the overall evacuation plan for the workplace facility.

- ✓

Halon Systems

Fire System Classifications

Industrial fire protection systems will usually consist of sprinklers, hose connections, and hydrants. Sprinkler system may be dry or wet, open or closed. Systems of fixed-spray nozzles may be used indoors or outdoors for protection of flammable-liquid and other hazardous processes. It is standard practice, especially in cities, to equip automatic sprinkler systems with fire department pumper connections.

For cross-connection control, fire protection systems may be classified on the basis of water source and arrangement of supplies as follows:

1. **Class 1**--direct connections from public water mains only; no pumps, tanks, or reservoirs; no physical connection from other water supplies; no antifreeze or other additives of any kind; all sprinkler drains discharging to atmosphere, dry wells, or other safe outlets.

2. **Class 2**--same as class 1, except that booster pumps may be installed in the connections from the street mains (Booster pumps do not affect the potability of the system; it is necessary, however, to avoid drafting so much water that pressure in the water main is reduced below 10 psi.)

3. **Class 3**--direct connection from public water supply main plus one or more of the following: elevated storage tanks; fire pumps taking suction from above-ground covered reservoirs or tanks; and pressure tanks (All storage facilities are filled or connected to public water only, the water in the tanks to be maintained in potable conditions. Otherwise, Class 3 systems are the same as Class 1.)

4. **Class 4**--directly supplied from public mains similar to Classes 1 and 2, and with an auxiliary water supply on or available to the premises; or an auxiliary water supply may be located within l,700 ft. of the pumper connection.

5. **Class 5**--directly supplied from public mains, and interconnected with auxiliary supplies, such as: pumps taking suction from reservoirs exposed to contamination, or rivers and ponds; driven wells; mills or other industrial water systems; or where antifreeze or other additives are used.

6. **Class 6**--combined industrial and fire protection systems supplied from the public water mains only, with or without gravity storage or pump suction tanks.

Industrial Fluids - shall mean any fluid or solution which may chemically, biologically or otherwise contaminated or polluted in a form or concentration such as would constitute a health, system, pollutional or plumbing hazard if introduced into an approved water supply.

This may include, but not be limited to: polluted or contaminated used water; all types of process waters and "*used waters*" originating from the public water system which may deteriorate in sanitary quality; chemicals in fluids from: plating acids and alkalies; circulated cooling waters connected to an open cooling tower and/or cooling waters that are chemically or biologically treated or stabilized with toxic substances; contaminated natural waters such as from wells, springs, streams, rivers, bays, harbors, seas, irrigation canals or systems, etc.; oils, gases, glycerin, paraffins, caustic and acid solutions and other liquid and gaseous fluids used in industrial or other processes or for firefighting purposes.

In some states, Fire lines need backflow prevention assemblies for certain criteria: a. Class 1 and 2 fire systems are not currently required to have any backflow prevention equipment at the service connection other than the equipment that is required for those systems under the state fire code standards. b. Class 3 fire systems may be converted to Class 1 or 2 systems by removing the tank. However, you must have the approval of the fire authority. c. Class 4 and 5 must comply with backflow requirements. Class 5 includes those fire systems that use antifreeze or other additives (RPDA required). This may apply to residential homes over 3,000 sq. ft. d. Class 6 fire systems require an on-site review to determine backflow requirements.

Double Check Backflow Assembly (Notice chain common on OS&Y).

Pipe and Connections - Types of Pipes

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 has been used extensively 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.

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.

Ductile/Cast-iron pipe, sometimes called cast-iron pressure pipe, is used for water mains and frequently for service pipe up to a building. Unlike cast-iron soil pipe, cast-iron water pipe is manufactured in 20-ft lengths rather than 5-ft lengths. Besides bell-and-spigot joints, cast-iron water pipes and fittings are made with flanged, mechanical, or screwed joints. The screwed joints are used only on small-diameter pipe.

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.

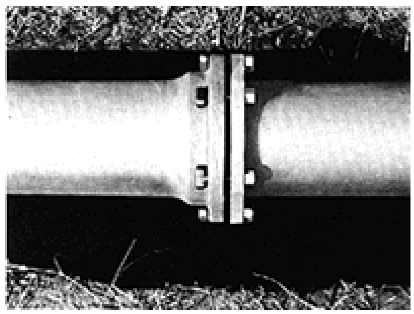
Type K copper tubing is available in either rigid (hard temper) or flexible (soft temper) and is primarily used for underground service in the water distribution systems. Soft temper tubing is available in 40- or 60-ft coils, while hard temper tubing comes in 12- and 20-ft straight lengths.

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.

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.



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 does 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 so as to provide optimum drainage of the line.

Elbows (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 closed 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.

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 pipes of dissimilar metals are connected.

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. 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.

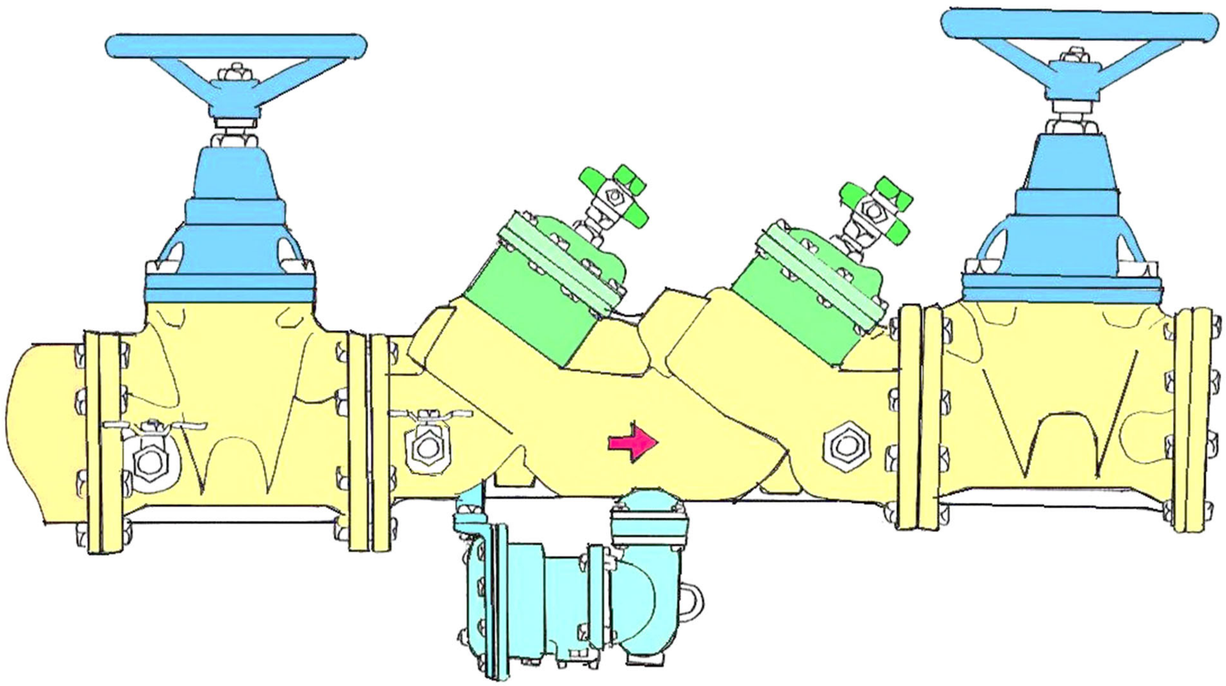
Unions— There are two types of pipe unions. The GROUND JOINT UNION consists of three pieces, and the FLANGE UNION is made in two parts. Both types are used for joining two pipes together and are designed so that they can be disconnected easily. When joined, the two pieces of pipe will not be in line with each other, but they can be installed so as to provide optimum drainage of the line.

Thermal Expansion Tank *(Closed Loop System*)
However, the installation of backflow preventors may require some modification to your home plumbing. Prior to the installation of the backflow device, the volume of water in your home's pipes, which can expand when heated, could easily flow back into the public water system. With the installation of the backflow preventer, the water pressure in your home may build up, particularly when the hot water system is activated.

To prevent thermal expansion, the Administrative Authority or Water Provider will suggest having a thermal expansion tank installed.

If after the backflow prevention device is installed you notice your faucets leak or the emergency relief valve on the hot water tank is continuously activated, you should call a plumbing professional, as damage to your system may occur. For many homeowners, merely lowering the temperature on the hot water tank will eliminate the need for plumbing work. A setting between 115-125 degrees is considered appropriate for most household users.

A thermal expansion tank is a small tank with an air/ water bladder. The air in the bladder can be compressed, enabling the water to expand into this tank, relieving pressure on other fixtures. This tank is to be located on the cold water side of the hot water tank.



REDUCED PRESSURE BACKFLOW ASSEMBLY

New EPA Rules for Distribution
Reduction of Lead in Drinking Water Act

Congress passed Public Law 111-380 or The Reduction of Lead in Drinking Water Act, in 2010. It went into effect Jan. 4, 2014, which means municipalities, water districts and developers who work with and pay for water infrastructure need to lead compliance.

Lead, a metal found in natural deposits, is commonly used in household plumbing materials and water service lines. The greatest exposure to lead is swallowing or breathing in lead paint chips and dust.

But lead in drinking water can also cause a variety of adverse health effects. In babies and children, exposure to lead in drinking water above the action level can result in delays in physical and mental development, along with slight deficits in attention span and learning abilities. In adults, it can cause increases in blood pressure. Adults who drink this water over many years could develop kidney problems or high blood pressure.

Lead is rarely found in source water, but enters tap water through corrosion of plumbing materials. Homes built before 1986 are more likely to have lead pipes, fixtures and solder. However, new homes are also at risk: even legally “lead-free” plumbing may contain up to 8 percent lead. The most common problem is with brass or chrome-plated brass faucets and fixtures which can leach significant amounts of lead into the water, especially hot water.

Congress enacted the Reduction of Lead in Drinking Water Act on January 4, 2011, to amend Section 1417 of the Safe Drinking Water Act (SDWA) regarding the use and introduction into commerce of lead pipes, plumbing fittings or fixtures, solder and flux. The Act established an effective date of January 4, 2014, which provided a three year timeframe for affected parties to transition to the new requirements.

Pervasive Environmental Contaminant

Lead is a pervasive environmental contaminant. The adverse health effects of lead exposure in children and adults are well documented, and no safe blood lead threshold in children has been identified. Lead can be ingested from various sources, including lead paint and house dust contaminated by lead paint, as well as soil, drinking water, and food. The concentration of lead, total amount of lead consumed, and duration of lead exposure influence the severity of health effects. Because lead accumulates in the body, all sources of lead should be controlled or eliminated to prevent childhood lead poisoning.

Beginning in the 1970s, lead concentrations in air, tap water, food, dust, and soil began to be substantially reduced, resulting in significantly reduced blood lead levels (BLLs) in children throughout the United States. However, children are still being exposed to lead, and many of these children live in housing built before the 1978 ban on lead-based residential paint. These homes might contain lead paint hazards, as well as drinking water service lines made from lead, lead solder, or plumbing materials that contain lead. Adequate corrosion control reduces the leaching of lead plumbing components or solder into drinking water.

The majority of public water utilities are in compliance with the Safe Drinking Water Act Lead and Copper Rule (LCR) of 1991. However, some children are still exposed to lead in drinking water. EPA is reviewing LCR, and additional changes to the rule are expected that will further protect public health.

Childhood lead poisoning prevention programs should be made aware of the results of local public water system lead monitoring measurement under LCR and consider drinking water as a potential cause of increased BLLs, especially when other sources of lead exposure are not identified.

This review describes a selection of peer-reviewed publications on childhood lead poisoning, sources of lead exposure for adults and children, particularly children aged <6 years, and LCR. What is known and unknown about tap water as a source of lead exposure is summarized, and ways that children might be exposed to lead in drinking water are identified.

This report does not provide a comprehensive review of the current scientific literature but builds on other comprehensive reviews, including the *Toxicological Profile for Lead* and the 2005 CDC statement *Preventing Lead Poisoning Among Young Children*). When investigating cases of children with BLLs at or above the reference value established as the 97.5 percentile of the distribution of BLLs in U.S. children aged 1–5 years, drinking water should be considered as a source. The recent recommendations from the CDC Advisory Committee on Childhood Lead Poisoning Prevention to reduce or eliminate lead sources for children before they are exposed underscore the need to reduce lead concentrations in drinking water as much as possible.

Background
Lead is a relatively corrosion-resistant, dense, ductile, and malleable metal that has been used by humans for at least 5,000 years. During this time, lead production has increased from an estimated 10 tons per year to 1,000,000 tons per year, accompanying population and economic growth. The estimated average BLL for Native Americans before European settlement in the Americas was calculated as 0.016 μg/dL. During 1999–2004, the estimated average BLL was 1.9 μg/dL for the non-institutionalized population aged 1–5 years in the United States, approximately 100 times higher than ancient background levels, indicating that substantial sources of lead exposure exist in the environment.

January 4, 2014
On January 4, 2014, the "Reduction of Lead in Drinking Water Act" became effective nationwide. This amendment to the 1974 Safe Drinking Water Act reduces the allowable lead content of drinking water pipes, pipe fittings and other plumbing fixtures.

Specifically, as of January 4, 2014, it shall be illegal to install pipes, pipe fittings, and other plumbing fixtures that are not "lead free." "Lead free" is defined as restricting the permissible levels of lead in the wetted surfaces of pipes, pipe fittings, other plumbing fittings and fixtures to a weighted average of not more than 0.25%.

This new requirement does not apply to pipes, pipe fittings, plumbing fittings or fixtures that are used exclusively for non-potable services such as manufacturing, industrial processing, irrigation, outdoor watering, or any other uses where water is not anticipated to be used for human consumption. The law also excludes toilets, bidets, urinals, fill valves, flushometer valves, tub fillers, shower valves, service saddles, or water distribution main gate valves that are 2 inches in diameter or larger.

Accordingly, effective January 4, 2014, only accepted products that are "lead free" may be utilized with regards to any plumbing providing water for human consumption (unless meeting the exception outlined above). Installers and inspectors may check their products to determine if they meet these requirements by looking to see if the products are certified to the following standards:

A. NSF/ANSI 61-G;
B. NSF/ANSI 61, section 9-G; OR
C. Both NSF/ANSI 61 AND NSF/ANSI 372.

As existing products may still be utilized for non-potable purposes. The burden of following these requirements shall be on installers. Plumbing inspectors (who will be covering these requirements in continuing education) shall have the right to question installers, who must be able to prove that no non-compliant products are installed on or after January 4, 2014.

What does the law say?
It reduces the maximum amount of lead that can be used in the wetted surfaces of service brass from 8 percent to 0.25 percent. It prohibits the sale of traditional brass pipe fittings, valves and meters for potable water applications as well as their installation after Jan. 4, 2014.

Does The Reduction of Lead in Drinking Water Act apply to all water infrastructure?
No. Service brass used in industrial or non-potable infrastructure is exempt from the law. Also, the law only applies to wetted surfaces. Saddles and other exterior pipe are also exempt.

Are there any exceptions to the New Regulations?
Exceptions to the new lead-free law include: pipes, pipe fittings, plumbing fittings, or fixtures, including backflow preventers, that are used exclusively for non-potable services such as manufacturing, industrial processing, irrigation, outdoor watering, or any other uses where the water is not anticipated to be used for human consumption. In addition, toilets, bidets, urinals, fill valves, flushometer valves, tub fillers, shower valves, service saddles, or water distribution main gate valves that are 2 inches in diameter or larger are excluded from the new lead-free law.

Who does the New Regulations apply to?
If you use or introduce into commerce any pipe, valves, plumbing fittings or fixtures, solder, or flux intended to convey or dispense water for human consumption, your products must comply with the law. Additionally, if you introduce into commerce solder or flux, your products must comply with the law.

If I am a homeowner, how do I know my water system is lead-free?
Many manufacturers have already complied with the January 4th, 2014 implementation date of the federal “Reduction of Lead in Drinking Water Act.” Even without federal certification requirements regarding the lead content of plumbing products, California’s mandate for third-party certification will be followed by most manufacturers seeking a single approval path that covers both federal and state requirements. For that reason, it is important to use and install only clearly marked low-lead products.

If you are a homeowner and are concerned about potential lead exposure from your private water system, have your water tested by a state certified water testing laboratory in your area.

Is there a difference between low-lead and no-lead brass?
No. There are several terms flying around to refer to the low-lead service brass products – no lead, lead free, low lead, and others. They all refer to the same products: service brass with 0.25 percent or less lead on wetter surfaces.

How are the new alloys different?
Functionally, there is almost no difference. For water utilities and contractors working with the material, it will handle just like traditional service brass. The difference is in the manufacturing. Lead has traditionally been used to fill gaps, seal the surface and create a smooth pipe interior that doesn't have gaps or pits where debris can settle and erode the metal.

Instead of lead, manufacturers will have to use different and more expensive materials and take more care in the manufacturing process. That means the cost of the new low-lead brass will be 25 to 40 percent higher than traditional brass pipe fittings and meters.

What are the biggest concerns for developers, municipalities and water districts?
There are two big concerns that should inspire anyone responsible for laying water infrastructure to act soon. If you have inventory of traditional services brass, now is the time to find a place to use it.

The second concern is cost. If you don't have an inventory of traditional brass but you have upcoming projects, this might be the ideal time to start them. Order traditional brass pipe fittings and meters from suppliers who are offering their traditional service brass at steep discounts ahead of the new law. After the law goes into effect, service brass costs will skyrocket and significantly increase your costs.

Lead-free Alternatives
There are several materials that utilities should consider when selecting a lead-free meter alternative. Various options include epoxy coated ductile and cast iron, stainless steel, low lead bronze and composite.

When choosing a lead-free alternative material, utilities must consider traditional meter requirements such as strong flow capability and durability. However, the difference between lead-free and zero lead meters should also be considered. Some "lead-free" meters contain as much as 0.25 percent lead.

While a 0.25 percentage of lead in meters allows utilities to meet current regulations, implementing these "lead-free" meters could put utilities at risk for the cost of another meter change out should future regulations require complete lead elimination from water meters.

Most water meters are expected to last more than 20 years, meaning that the next amendment to SDWA could come before the meter fleet must be replaced. This could be potentially devastating for utility companies still using older systems should completely lead-free meters become mandated.

Composite Meters
Composite meters are one example of a zero lead alternative that is not susceptible to future no-lead regulations. This meter material is also gaining popularity due to its strength and cost stability. Composite meters do not depend on metal pricing fluctuations and, more importantly, have zero lead as opposed to low lead or even bronze meters.

Made of materials that have already proven their strength and durability in the automotive and valve industries, composite meters boast longevity and resistance to corrosion from aggressive water and from the chlorinated chemicals used to make water drinkable. Composite meters are also equipped to withstand the pressure required to maintain a water system.

Composite meters are constructed using a blend of plastic and fiberglass. When compared to bronze water meter products, composites are lighter and require less time and energy to manufacture, ship and install. Composite meters attached with composite threads have been found to eliminate the "friction feeling" typically experienced with metal threads and metal couplings, facilitating easier installation.

Through comprehensive testing, composite meters have demonstrated a burst pressure that is significantly greater than bronze and an equal longevity. Composite technology today allows for better, more environmentally friendly composite products that will last up to 25 years in residential applications. Manufacturers have a wide range of "lead-free" or zero lead products on the market and it is critical that utilities consider all of their options when selecting a new fleet of meters.

Most importantly, everyone deserves access to safe, clean water. It is essential that manufacturers continually develop and deliver products that meet the highest standards for safety, quality, reliability and accuracy to ensure availability to, and conservation of, this most precious resource.

Lead in Drinking Water
Lead is unlikely to be present in source water unless a specific source of contamination exists. However, lead has long been used in the plumbing materials and solder that are in contact with drinking water as it is transported from its source into homes. Lead leaches into tap water through the corrosion of plumbing materials that contain lead. The greater the concentration of lead in drinking water and the greater amount of lead-contaminated drinking water consumed, the greater the exposure to lead. In children, lead in drinking water has been associated both with BLLs ≥10 μg/dL as well as levels that are higher than the U.S. GM level for children (1.4 μg/dL) but are <10 μg/dL.

History of Studies on Lead in Water
In 1793, the Duke of Württemberg, Germany, warned against the use of lead in drinking water pipes, and in 1878, lead pipes were outlawed in the area as a result of concerns about the adverse health effects of lead in water. In the United States, the adverse health consequences of lead-contaminated water were recognized as early as 1845. A survey conducted in 1924 in the United States indicated that lead service lines were more prevalent in New England, the Midwest, Montana, New York, Oklahoma, and Texas. A nationwide survey conducted in 1990 indicated that 3.3 million lead service lines were in use, and the areas where they were most likely to be used were, again, the Midwestern and northeastern regions of the United States. This survey also estimated that approximately 61,000 lead service lines had been removed through voluntary programs during the previous 10 years.

Research on exposure to lead in water increased as concern about the topic increased, and efforts were made to establish a level of lead in water that, at the time of the studies, was considered acceptable. A 1972 study in Edinburgh, Scotland, obtained 949 first-flush water samples (i.e., samples of water from the tap that have been standing in the plumbing pipes for at least 6 hours) matched with 949 BLLs, as well as 205 running water samples matched to 205 BLLs . No dose-response relationship could be determined when comparing BLLs with four levels of lead in both first-flush water and in running water (<0.24 *μ*mol/L; 0.24–0.47 *μ*mol/L; 0.48–1.43 *μ*mol/l; and ≥1.44 *μ*mol/L).

The study concluded that the findings challenged whether it was necessary to lower the water lead concentration to <100 ppb, which at that time was the acceptable concentration established by the World Health Organization. However, the study also reported that low levels of environmental lead exposure could have adverse health effects; therefore, knowing the degree of lead exposure from household water relative to other sources is important. Another study, in 1976, of 129 randomly selected homes in Caernarvonshire, England, reported a similar finding, describing the relationship between blood and water lead as slight.

Monitoring and Reporting
To ensure that drinking water supplied by **all** public water supply systems as defined by the EPA meet Federal and State requirements, water system operators are required to collect samples regularly and have the water tested. The regulations specify minimum sampling frequencies, sampling locations, testing procedures, methods of keeping records, and frequency of reporting to the State. The regulations also mandate special reporting procedures to be followed if a contaminant exceeds an MCL.

All systems must provide periodic monitoring for microbiological contaminants and some chemical contaminants. The frequency of sampling and the chemicals that must be tested for depend on the physical size of the water system, the water source, and the history of analyses. General sampling procedures are covered in more detail under the topic of Public Health Considerations to follow.

State policies vary on providing laboratory services. Some States have laboratory facilities available to perform all required analyses or, in some cases, a certain number of the required analyses for a system. In most States, there is a charge for all or some of the laboratory services. Sample analyses that are required and cannot be performed by a State laboratory must be taken or sent to a State-certified private laboratory.

If the analysis of a sample exceeds an MCL, resampling is required, and the State should be contacted immediately for special instructions. There is always the possibility that such a sample was caused by a sampling or laboratory error, but it must be handled as though it actually was caused by contamination of the water supply. The results of all water analyses must be periodically sent to the State of origin. Failure to have the required analysis performed or to report the results to the State usually will result in the water system being required to provide PN. States typically have special forms for submitting data, and specify a number of days following the end of the monitoring period by which the form is due.

General Disinfection Requirements
Disinfection is absolutely required for all water systems using surface water sources. Various chemicals other than chlorine can be used for treatment of surface water, but as the water enters the distribution system, it must carry a continuous chlorine residual that will be retained throughout the distribution system. Water samples from points on the distribution system must be analyzed periodically to make sure an adequate chlorine residual is being maintained.

In spite of the fact that use of chlorine has almost completely eliminated occurrences of waterborne diseases in the United States, there is no concern for byproducts formed when chlorine reacts with naturally occurring substances in raw water (such as decaying vegetation containing humic and fulvic acids).

The first group of byproduct chemicals identified was tri-halo-methane (THM), a group of organic chemicals that are known carcinogens (cancer-forming) to some animals, so they are assumed also to be carcinogenic to humans. Other byproducts of disinfection have been identified that may be harmful, and there also is concern now that disinfectants themselves may cause some adverse health reactions.

Consumer Confidence Reports
One of the very significant provisions of the 1996 SDWA amendments is the consumer confidence report (CCR) requirement. The purpose of the CCR is to provide all water customers with basic facts regarding their drinking water so that individuals can make decisions about water consumption based on their personal health. This directive has been likened to the requirement that packaged food companies disclose what is in their food product.

The reports must be prepared yearly by every community water supply system. Water systems serving more than 10,000 people must mail the report to customers. Small systems must notify customers as directed by the State primacy agency.

A water system that only distributes purchased waster (i.e., a satellite system) must prepare the report for their consumers. Information on the source water and chemical analyses must be furnished to the satellite system by the system selling the water (parent company).

Some States are preparing much of the information for their water systems, but the system operator still must add local information. Templates for preparing a report also are available from the American Water Works Association (AWWA) and the National Rural Water Association (NRWA).

Water system operators should keep in mind that CCRs provide an opportunity to educate consumers about the sources and quality of their drinking water. Educated consumers are more likely to help protect drinking water sources and be more understanding of the need to upgrade the water system to make their drinking water safe.

Summary

Cross-connections and backflow represent a significant public health risk (US EPA, 2000b) by allowing chemical and biological contaminants into the potable water supply (a conclusion of the Microbial/Disinfection Byproducts Federal Advisory Committee (M/DBP FACA)).

Of the 459 backflow incidents from 1970-2001 on which EPA has information, an estimated 12,093 cases of illness resulted. Fifty-seven of these cross-connection-related waterborne disease outbreaks were reported to CDC from 1981-1998, and resulted in at least 9,734 cases of illness. A wide number and range of chemical and biological contaminants have been reported to enter the distribution system through cross-connections and backflow.

Pesticides, sewage, antifreeze, coolants, and detergents were the most frequent types of contaminants reported. Although a wide range of contaminants have been reported, the number on contamination incidents is considered a likely underestimate due to problems in detecting, reporting, and documenting incidents.

These problems include: an inability to detect incidents without health effects; incidents with health effects that are unreported because affected individuals do not realize a connection between their illness and the drinking water; no requirement on either health officials or water system officials to report detected backflow incidents; and no central repository for reported illness. Where undetected, cross-connections may also expose consumers to contaminants from backflow long-term.

Cross-connections can be prevented through mechanical means and through programs administered by local or state officials to specifically locate and eliminate cross-connections and prevent backflow. Officials can also take measures to correct deficiencies that either have the potential to lead to backflow incidents or have already caused a backflow incident, and they can increase monitoring for indicators of potential problems to improve reaction time to future incidents.

Topic 1- Cross-Connection Control Section Post Quiz

The answers are found in the rear after the Appendix.

Link to Assignment…
http://www.abctlc.com/downloads/PDF/CrossConnectionIDASS.pdf

1. According to the text, an 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.
A. True B. False

2. ______________________ must either be physically disconnected or have an approved backflow prevention device installed to protect the public water system.

3. The type of device selected for a particular installation depends on several factors.
A. True B. False

4. An air gap is a physical disconnection between the free flowing discharge end of a potable water pipeline and the top of an?

5. According to the text, air gap separations must be vertically orientated a distance of at least twice the inside diameter of the supply, but never less than?

6. An air gap is acceptable for _________________ and is theoretically the most effective protection.

7. Which device can have two types: atmospheric and pressure?

8. Both types of vacuum breaker devices primary purpose is to protect the water system from cross connections due to submerged inlets, such as irrigation systems and tank applications.
A. True B. False

9. Both vacuum breakers devices are only suitable for?

10. _________________ may not be installed downstream of atmospheric vacuum breakers but are allowed on pressure vacuum breakers.

11. The vacuum breaker devices must be installed above the highest?

12. The Atmospheric vacuum breaker allows water to enter the air inlet when the line pressure is increased to a gauge pressure of zero or below.
A. True B. False

13. Atmospheric vacuum breakers Uses: Irrigation systems, commercial dishwasher and laundry equipment, chemical tanks and laboratory sinks.
A. True B. False

14. Double Check Valve Assembly (DC) 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
A. True B. False

15. The double check valve assembly is designed to prevent backflow caused by backpressure and backsiphonage from high health hazards.
A. True B. False

16. The DC needs to be installed 12 inches ____________________for testing purposes only.

17. Reduced Pressure Backflow Assembly (RP) 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.
A. True B. False

18. According to the text, the RP needs to installed 12 inches above the ground for testing purposes only.
A. True B. False

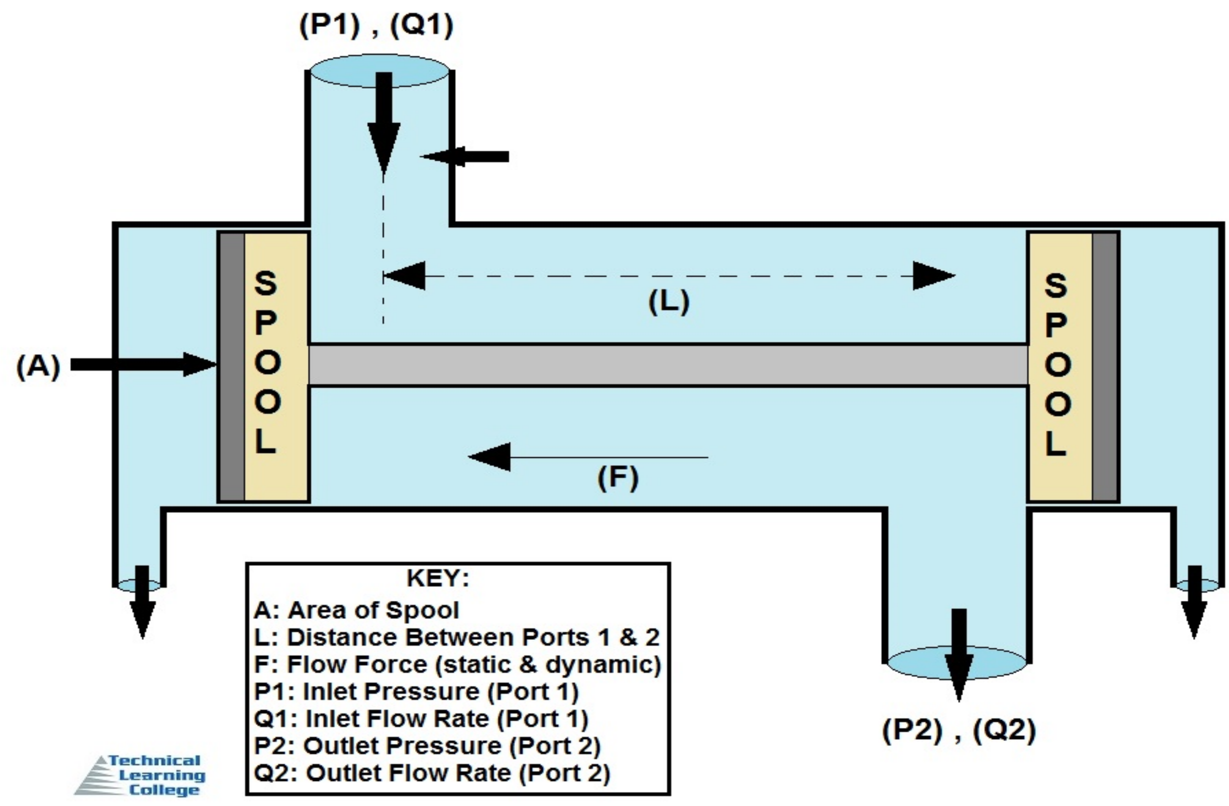
19. The Reduced pressure backflow assembly can be used for high hazard situations under backpressure only. Under normal conditions, the second check valve should never close.
A. True B. False

20. According to the text, the Reduced pressure zone port opens anytime pressure in the zone comes within 2 psi of the supply pressure.
A. True B. False

Topic 2 - Hydraulic Principles Section

Section Focus: You will learn the basics of hydraulics and pressure. At the end of this section, you the student will be able to understand and describe various hydraulic principles associated with cross-connections. There is a post quiz at the end of this section to review your comprehension and a final examination in the Assignment for your contact hours.

Scope/Background: In cross-connection control, as with any technical topic, a full understanding cannot come without first becoming familiar with basic hydraulic terminology and governing principles. This section will demonstrate various hydraulic principles and laws (pascal and Bernoulli) that are the foundation for understanding water pressure and cross-connection control.

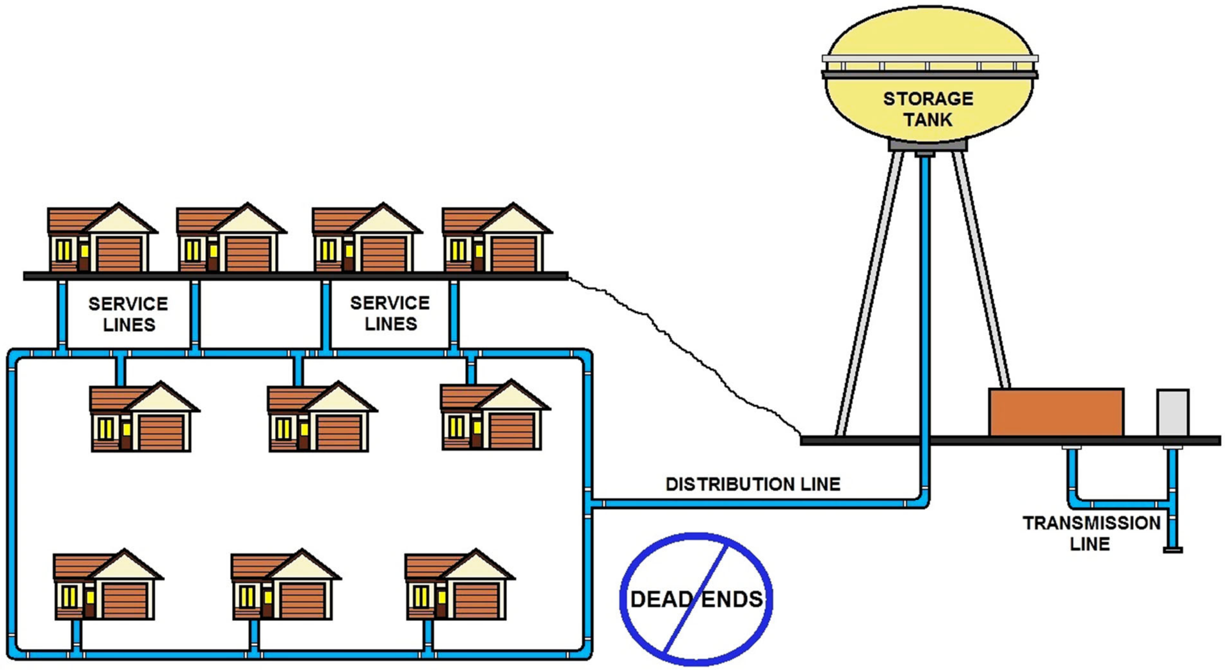


BASIC HYDRAULIC PRINCIPAL

The purpose of a specific hydraulic system may vary, but all hydraulic systems work through the same basic concept.

Defined simply, hydraulic systems function and perform tasks through using a fluid that is pressurized. Another way to say this is the pressurized fluid makes things work. Pressurized water makes backflow prevention assemblies work correctly, protecting city water supplies from customer services.

The basic principles of hydraulics are few and simple and are as follows:
1. Liquids have no shape of their own.
2. Liquids can NOT compress.
3. Liquids transmit applied pressure in all directions.
4. Liquids provide great increase in work force.



EXAMPLE OF BASIC WATER DISTRIBUTION SYSTEM

The storage tank stores water that is gravity feed to the mains, thus making its way to the customer.

A customer can unintentionally over –pressurize their water service and make the water reverse back towards the water storage tank, thus contaminating the either potable water system.

If the gravity pressure (static) is 35 PSI, the customer could easily create 50 PSI with a pump and backflow back into the water supply system.

Key Terms

ABSOLUTE PRESSURE: The pressure above zone absolute, i.e. the sum of atmospheric and gauge pressure. In vacuum related work it is usually expressed in millimeters of mercury. (mmHg).

AIR BREAK: A physical separation which may be a low inlet into the indirect waste receptor from the fixture, or device that is indirectly connected. You will most likely find an air break on waste fixtures or on non-potable lines. You should never allow an air break on an ice machine.

AIR GAP SEPARATION: A physical separation space that is present between the discharge vessel and the receiving vessel, for an example, a kitchen faucet.

ATMOSPHERIC PRESSURE: Pressure exerted by the atmosphere at any specific location. (Sea level pressure is approximately 14.7 pounds per square inch absolute, 1 bar = 14.5psi.)

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. See Cross-connection control.

BACKFLOW: 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.

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.

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.

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.

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.

DISINFECT: To kill and inhibit growth of harmful bacterial and viruses in drinking water.

DISINFECTION: The treatment of water to inactivate, destroy, and/or remove pathogenic bacteria, viruses, protozoa, and other parasites.

ELEVATION HEAD: The energy possessed per unit weight of a fluid because of its elevation. 1 foot of water will produce .433 pounds of pressure head.

ENERGY: The ability to do work. Energy can exist in one of several forms, such as heat, light, mechanical, electrical, or chemical. Energy can be transferred to different forms. It also can exist in one of two states, either potential or kinetic.

FLOOD RIM: The point of an object where the water would run over the edge of something and begin to cause a flood. See Air Break.

FRICTION HEAD: The head required to overcome the friction at the interior surface of a conductor and between fluid particles in motion. It varies with flow, size, type and conditions of conductors and fittings, and the fluid characteristics.

GAUGE PRESSURE: Pressure differential above or below ambient atmospheric pressure.

HAZARDOUS ATMOSPHERE: An atmosphere which by reason of being explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen deficient, toxic, or otherwise harmful, may cause death, illness, or injury.

HEAD: The height of a column or body of fluid above a given point expressed in linear units. Head is often used to indicate gauge pressure. Pressure is equal to the height times the density of the liquid. The measure of the pressure of water expressed in feet of height of water. 1 psi = 2.31 feet of water. There are various types of heads of water depending upon what is being measured. Static (water at rest) and Residual (water at flow conditions).

HYDRAULICS: Engineering science pertaining to liquid pressure and flow.

HYDROKINETICS: Engineering science pertaining to the energy of liquid flow and pressure.

IRRIGATION: Water that is especially furnished to help provide and sustain the life of growing plants. It comes from ditches; it is sometimes treated with herbicides and pesticides to prevent the growth of weeds and the development of bugs in a lawn and a garden.

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.

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.

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.

ML: milliliter

PASCAL'S LAW: A pressure applied to a confined fluid at rest is transmitted with equal intensity throughout the fluid.

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.

PIPELINE APPURTENANCE: Pressure reducers, bends, valves, regulators (which are a type of valve), etc.

POTABLE: Good water which is safe for drinking or cooking purposes. Non-Potable: A liquid or water that is not approved for drinking.

POLLUTION: To make something unclean or impure. Some states will have a definition of pollution that relates to non-health related water problems, like taste and odors. See Contaminated.

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.

PRESSURE HEAD: The height to which liquid can be raised by a given pressure.

PRESSURE: The application of continuous force by one body upon another that it is touching; compression. Force per unit area, usually expressed in pounds per square inch (Pascal or bar).

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).

SOLDER: A fusible alloy used to join metallic parts. Solder for potable water pipes shall be lead-free.

SHOCK: Also known as superchlorination or break point chlorination. Ridding a pool of organic waste through oxidization by the addition of significant quantities of a halogen.

STATIC HEAD: The height of a column or body of fluid above a given point

STATIC PRESSURE: The pressure in a fluid at rest.

STUFFING BOX: That portion of the pump which houses the packing or mechanical seal.

SUMMERGED: To cover with water or liquid substance.

TURBIDITY: A measure of the cloudiness of water caused by suspended particles.

VALVE: A device that opens and closes to regulate the flow of liquids. Faucets, hose bibs, and Ball are examples of valves.

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.

VIBRATION: A force that is present on construction sites and must be considered. The vibrations caused by backhoes, dump trucks, compactors and traffic on job sites can be substantial.

VOLUTE: The spiral-shaped casing surrounding a pump impeller that collects the liquid discharge by the impeller.

WATER PURVEYOR: The individuals or organization responsible to help provide, supply, and furnish quality water to a community.

WATER WORKS: All of the pipes, pumps, reservoirs, dams and buildings that make up a water system.

WATERBORNE DISEASES: 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).

Hydraulic Principles - Introduction

Definition: **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.

Hydraulics: ***The Engineering science pertaining to liquid pressure and flow.***
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.

Hydrostatics, the consideration of liquids at rest, involves problems of buoyancy and flotation, pressure on dams and submerged devices, and hydraulic presses. 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.

Hydrostatics
Hydrostatics is about the pressures exerted by a fluid at rest. Any fluid is meant, not just water. Research and careful study on water yields many useful results of its own, however, such as forces on dams, buoyancy and hydraulic actuation, and is well worth studying for such practical reasons.

Hydrostatics is an excellent example of deductive mathematical physics, one that can be understood easily and completely from a very few fundamentals, and in which the predictions agree closely with experiment.

There are few better illustrations of the use of the integral calculus, as well as the principles of ordinary statics, available to the student. A great deal can be done with only elementary mathematics. Properly adapted, the material can be used from the earliest introduction of school science, giving an excellent example of a quantitative science with many possibilities for hands-on experiences.

The definition of a fluid deserves careful consideration. Although time is not a factor in hydrostatics, it enters in the approach to hydrostatic equilibrium. It is usually stated that a fluid is a substance that cannot resist a shearing stress, so that pressures are normal to confining surfaces. Geology has now shown us clearly that there are substances which can resist shearing forces over short time intervals, and appear to be typical solids, but which flow like liquids over long time intervals. Such materials include wax and pitch, ice, and even rock.

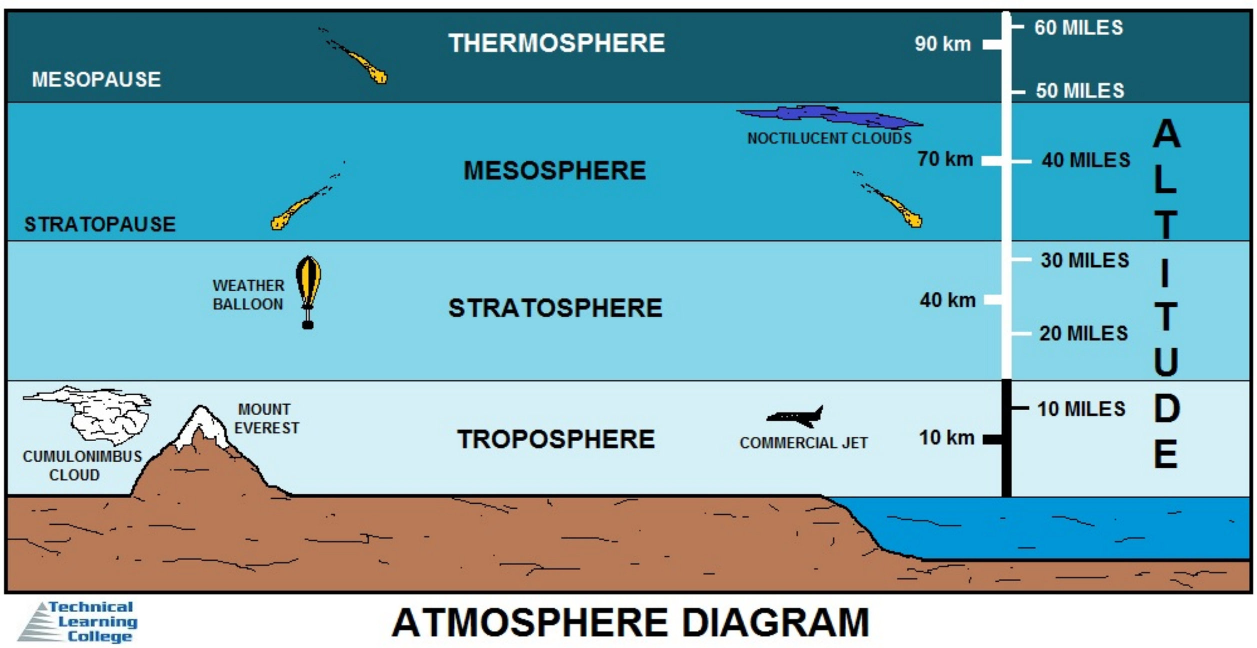
A ball of pitch, which can be shattered by a hammer, will spread out and flow in months. Ice, a typical solid, will flow in a period of years, as shown in glaciers, and rock will flow over hundreds of years, as in convection in the mantle of the earth.

Shear earthquake waves, with periods of seconds, propagate deep in the earth, though the rock there can flow like a liquid when considered over centuries. The rate of shearing may not be strictly proportional to the stress, but exists even with low stress.

Viscosity may be the physical property that varies over the largest numerical range, competing with electrical resistivity.

There are several familiar topics in hydrostatics which often appears in expositions of introductory science, and which are also of historical interest and can enliven their presentation.

Let's start our study with the principles of our atmosphere.



ATMOSPHERE DIAGRAM

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.

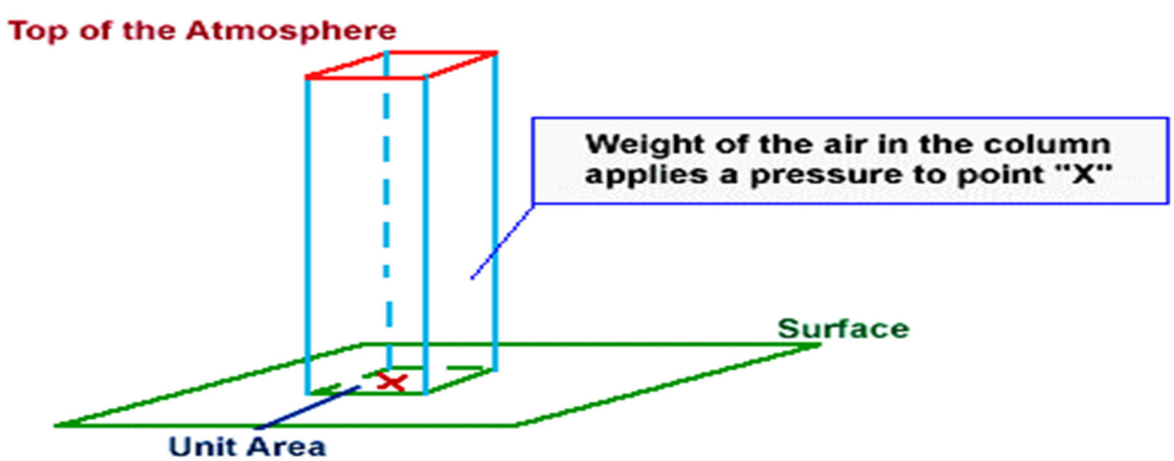
As one ascends, the atmospheric pressure decreases by approximately 1.0 psi for every 2,343 feet. However, below sea level, in excavations and depressions, atmospheric pressure increases. Pressures under water differ from those under air only because the weight of the water must be added to the pressure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

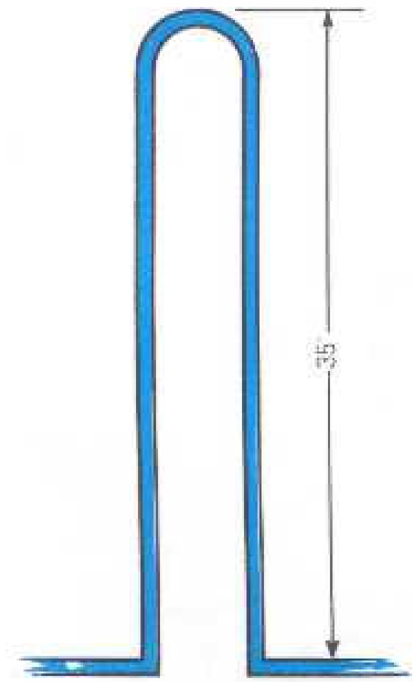
Another device used to measure atmospheric pressure is the aneroid barometer. The aneroid barometer uses the change in shape of an evacuated metal cell to measure variations in atmospheric pressure. The thin metal of the aneroid cell moves in or out with the variation of pressure on its external surface. 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. It changes very rapidly. 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, 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.



Barometric Loop



The barometric loop consists of a continuous section of supply piping that abruptly rises to a height of approximately 35 feet and then returns back down to the originating level. It is a loop in the piping system that effectively protects against backsiphonage. It may not be used to protect against back-pressure.

Its operation, in the protection against backsiphonage, is based upon the principle that a water column, at sea level pressure, will not rise above 33.9 feet. In general, barometric loops are locally fabricated, and are 35 feet high.

Pressure may be referred to using an absolute scale, pounds per square inch absolute (**psia**), or gauge scale, (**psiag**).

Absolute pressure and gauge pressure are related.

Absolute pressure is equal to gauge pressure plus the atmospheric pressure. At sea level, the atmospheric pressure is 14.7 psai.

Absolute pressure is the total pressure.

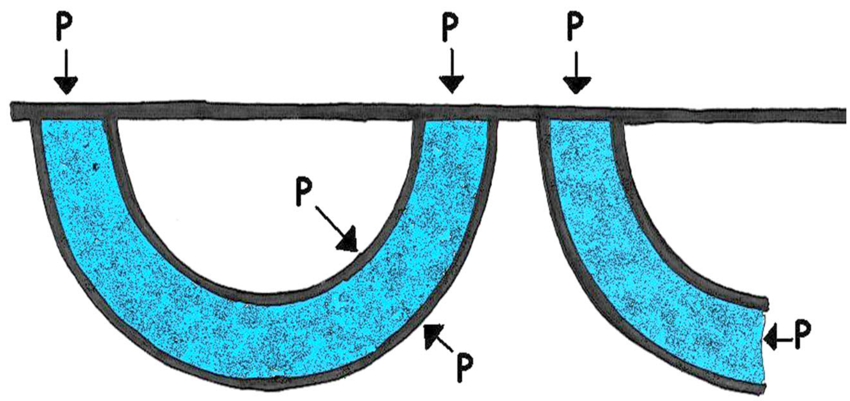
Gauge pressure is simply the pressure read on the gauge. If there is no pressure on the gauge other than atmospheric, the gauge will read zero. Then the absolute pressure would be equal to 14.7 psi, which is the atmospheric pressure.

UNIT	ABBREVIATION	EQUIVALENT NUMBER OF PASCALS
ATMOSPHERE	atm	1 atm = 101,325 Pa
BAR	bar	1 bar = 100,025 Pa
MILLIMETER OF MERCURY	mmHg	1 mmHg = 133.322 Pa
INCHES OF MERCURY	inHg	1 inHg = 3386 Pa
PASCAL	Pa	1
KILOPASCAL	kPa	1 kPa = 1000 Pa
POUNDS PER SQUARE INCH	psi	1 psi = 6,893 Pa
TORR	torr	1 torr = 133.322 Pa

DIFFERENT UNITS OF PRESSURE

Water Pressure

By a fluid, we have a material in mind like water or air, two very common and important fluids. Water is incompressible, while air is very compressible, but both are fluids. Water has a definite volume; air does not. Water and air have low viscosity; that is, layers of them slide very easily on one another, and they quickly assume their permanent shapes when disturbed by rapid flows. Other fluids, such as molasses, may have high viscosity and take a long time to come to equilibrium, but they are no less fluids. The coefficient of viscosity is the ratio of the shearing force to the velocity gradient. Hydrostatics deals with permanent, time-independent states of fluids, so viscosity does not appear, except as discussed in the Introduction.



Equality of Pressure Diagram- Curtain Rings

A fluid, therefore, is a substance that cannot exert any permanent forces tangential to a boundary. Any force that it exerts on a boundary must be normal to the boundary. Such a force is proportional to the area on which it is exerted, and is called a pressure. We can imagine any surface in a fluid as dividing the fluid into parts pressing on each other, as if it were a thin material membrane, and so think of the pressure at any point in the fluid, not just at the boundaries.

In order for any small element of the fluid to be in equilibrium, the pressure must be the same in all directions (or the element would move in the direction of least pressure), and if no other forces are acting on the body of the fluid, the pressure must be the same at all neighboring points.

Therefore, in this case the pressure will be the same throughout the fluid, and the same in any direction at a point (Pascal's Principle). Pressure is expressed in units of force per unit area such as dyne/cm^2, N/cm^2 (pascal), pounds/in^2 (psi) or pounds/ft^2 (psf). The axiom that if a certain volume of fluid were somehow made solid, the equilibrium of forces would not be disturbed is useful in reasoning about forces in fluids.

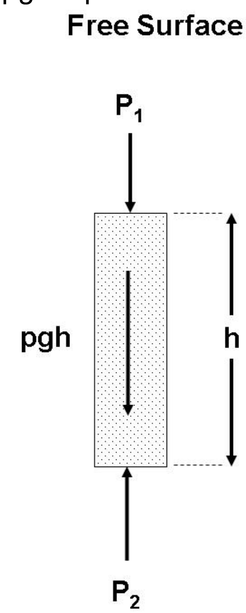
On earth, fluids are also subject to the force of gravity, which acts vertically downward, and has a magnitude γ = ρg per unit volume, where g is the acceleration of gravity, approximately 981 cm/s^2 or 32.15 ft/s^2, ρ is the density, the mass per unit volume, expressed in g/cm^3, kg/m^3, or $slug/ft^3$, and γ is the specific weight, measured in lb/in^3, or lb/ft^3 (pcf). Gravitation is an example of a body force that disturbs the equality of pressure in a fluid. The presence of the gravitational body force causes the pressure to increase with depth, according to the equation dp = ρg dh, in order to support the water above.

We call this relation the barometric equation, for when this equation is integrated, we find the variation of pressure with height or depth. If the fluid is incompressible, the equation can be integrated at once, and the pressure as a function of depth h is p = ρgh + p0.

The density of water is about 1 g/cm^3, or its specific weight is 62.4 pcf. We may ask what depth of water gives the normal sea-level atmospheric pressure of 14.7 psi, or 2117 psf.

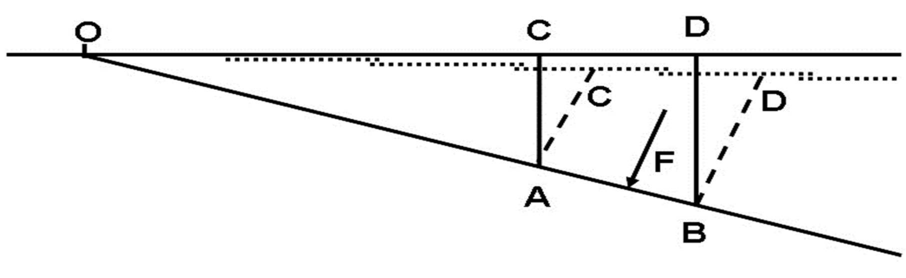
This is simply 2117 / 62.4 = 33.9 ft of water. This is the maximum height to which water can be raised by a suction pump, or, more correctly, can be supported by atmospheric pressure. Professor James Thomson (brother of William Thomson, Lord Kelvin) illustrated the equality of pressure by a "curtain-ring" analogy shown in the diagram. A section of the toroid was identified, imagined to be solidified, and its equilibrium was analyzed.

The forces exerted on the curved surfaces have no component along the normal to a plane section, so the pressures at any two points of a plane must be equal, since the fluid represented by the curtain ring was in equilibrium. The right-hand part of the diagram illustrates the equality of pressures in orthogonal directions.



Increase of Pressure with Depth

This can be extended to any direction whatever, so Pascal's Principle is established. This demonstration is similar to the usual one using a triangular prism and considering the forces on the end and lateral faces separately.



Thrust on a Plane

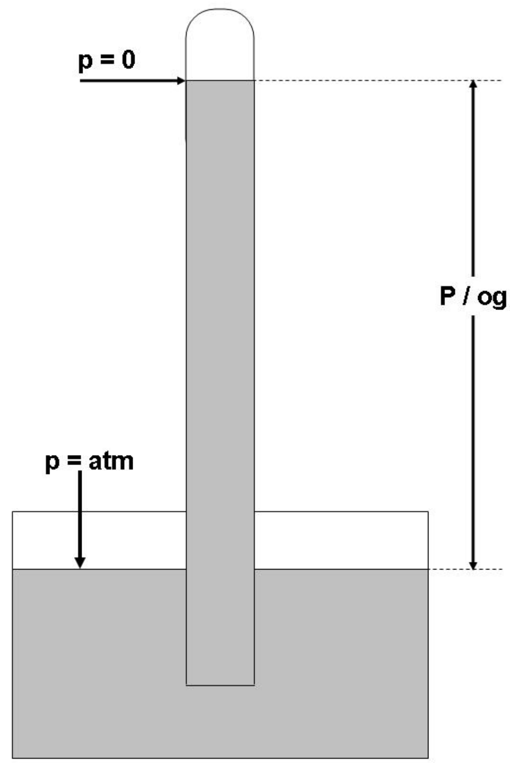
Free Surface Perpendicular to Gravity

When gravity acts, the liquid assumes a free surface perpendicular to gravity, which can be proved by Thomson's method. A straight cylinder of unit cross-sectional area (assumed only for ease in the arithmetic) can be used to find the increase of pressure with depth. Indeed, we see that p2 = p1 + ρgh. The upper surface of the cylinder can be placed at the free surface if desired. The pressure is now the same in any direction at a point, but is greater at points that lie deeper. From this same figure, it is easy to prove Archimedes' s Principle that the buoyant force is equal to the weight of the displaced fluid, and passes through the center of mass of this displaced fluid.

Geometric Arguments

Ingenious geometric arguments can be used to substitute for easier, but less transparent arguments using calculus. For example, the force acting on one side of an inclined plane surface whose projection is AB can be found as in the diagram on the previous page. O is the point at which the prolonged projection intersects the free surface. The line AC' perpendicular to the plane is made equal to the depth AC of point A, and line BD' is similarly drawn equal to BD. The line OD' also passes through C', by proportionality of triangles OAC' and OAD'.

Therefore, the thrust F on the plane is the weight of a prism of fluid of cross-section AC'D'B, passing through its centroid normal to plane AB. Note that the thrust is equal to the density times the area times the depth of the center of the area; its line of action does not pass through the center, but below it, at the center of thrust. The same result can be obtained with calculus by summing the pressures and the moments, of course.



Barometer

Atmospheric Pressure and its Effects

Suppose a vertical pipe is stood in a pool of water, and a vacuum pump applied to the upper end. Before we start the pump, the water levels outside and inside the pipe are equal, and the pressures on the surfaces are also equal and are equal to the atmospheric pressure.

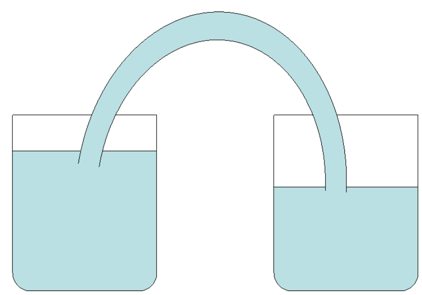
Now start the pump. When it has sucked all the air out above the water, the pressure on the surface of the water inside the pipe is zero, and the pressure at the level of the water on the outside of the pipe is still the atmospheric pressure. Of course, there is the vapor pressure of the water to worry about if you want to be precise, but we neglect this complication in making our point. We require a column of water 33.9 ft high inside the pipe, with a vacuum above it, to balance the atmospheric pressure. Now do the same thing with liquid mercury, whose density at 0 °C is 13.5951 times that of water. The height of the column is 2.494 ft, 29.92 in, or 760.0 mm.

Standard Atmospheric Pressure Defined

This definition of the standard atmospheric pressure was established by Regnault in the mid-19th century. In Britain, 30 in. Hg (inches of mercury) had been used previously. As a practical matter, it is convenient to measure pressure differences by measuring the height of liquid columns, a practice known as manometry. The barometer is a familiar example of this, and atmospheric pressures are traditionally given in terms of the length of a mercury column. To make a barometer, the barometric tube, closed at one end, is filled with mercury and then inverted and placed in a mercury reservoir. Corrections must be made for temperature, because the density of mercury depends on the temperature, and the brass scale expands for capillarity if the tube is less than about 1 cm in diameter, and even slightly for altitude, since the value of g changes with altitude.

The vapor pressure of mercury is only 0.001201 mmHg at 20°C, so a correction from this source is negligible. For the usual case of a mercury column (α = 0.000181792 per °C) and a brass scale (& alpha = 0.0000184 per °C) the temperature correction is -2.74 mm at 760 mm and 20°C. Before reading the barometer scale, the mercury reservoir is raised or lowered until the surface of the mercury just touches a reference point, which is mirrored in the surface so it is easy to determine the proper position.

An aneroid barometer uses a partially evacuated chamber of thin metal that expands and contracts according to the external pressure. This movement is communicated to a needle that revolves in a dial. The materials and construction are arranged to give a low temperature coefficient. The instrument must be calibrated before use, and is usually arranged to read directly in elevations.



Siphon

An aneroid barometer is much easier to use in field observations, such as in reconnaissance surveys. In a particular case, it would be read at the start of the day at the base camp, at various points in the vicinity, and then finally at the starting point, to determine the change in pressure with time.

The height differences can be calculated from h = 60,360 log (P/p) [1 + (T + t - 64)/986) feet, where P and p are in the same units, and T, t are in °F. An absolute pressure is referring to a vacuum, while a gauge pressure is referring to the atmospheric pressure at the moment. A negative gauge pressure is a (partial) vacuum. When a vacuum is stated to be so many inches, this means the pressure below the atmospheric pressure of about 30 in. A vacuum of 25 inches is the same thing as an absolute pressure of 5 inches (of mercury).

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- Weight of Water

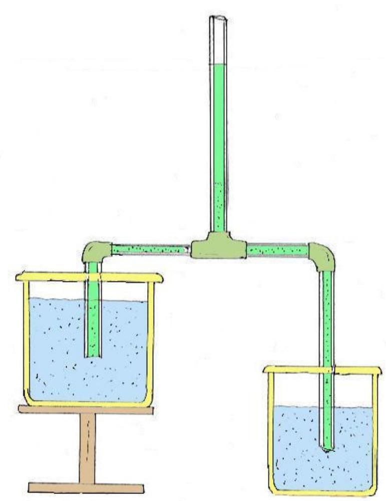
The weight of a cubic foot of water is 62.4 pounds per square foot. The base can be subdivided into 144-square inches with each subdivision being subjected to a pressure of 0.433 psig. Suppose you placed another cubic foot of water on top of the first cubic foot. The pressure on the top surface of the 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.

Pressures are very frequently stated in terms of the height of a fluid. If it is the same fluid whose pressure is being given, it is usually called "head," and the factor connecting the head and the pressure is the weight density ρg. In the English engineer's system, weight density is in pounds per cubic inch or cubic foot. A head of 10 ft is equivalent to a pressure of 624 psf, or 4.33 psi. It can also be considered an energy availability of ft-lb per lb. Water with a pressure head of 10 ft can furnish the same energy as an equal amount of water raised by 10 ft. Water flowing in a pipe is subject to head loss because of friction.

Take a jar and a basin of water. Fill the jar with water and invert it under the water in the basin. Now raise the jar as far as you can without allowing its mouth to come above the water surface. It is always a little surprising to see that the jar does not empty itself, but the water remains with no visible means of support. By blowing through a straw, one can put air into the jar, and as much water leaves as air enters. In fact, this is a famous method of collecting insoluble gases in the chemical laboratory, or for supplying hummingbird feeders. It is good to remind oneself of exactly the balance of forces involved.

Another application of pressure is the siphon. The name is Greek for the tube that was used for drawing wine from a cask. This is a tube filled with fluid connecting two containers of fluid, normally rising higher than the water levels in the two containers, at least to pass over their rims.

In the diagram, the two water levels are the same, so there will be no flow. When a siphon goes below the free water levels, it is called an inverted siphon. If the levels in the two basins are not equal, fluid flows from the basin with the higher level into the one with the lower level, until the levels are equal.



PASCAL'S SIPHON

A siphon can be made by filling the tube, closing the ends, and then putting the ends under the surface on both sides. Alternatively, the tube can be placed in one fluid and filled by sucking on it. When it is full, the other end is put in place. The analysis of the siphon is easy, and should be obvious. The pressure rises or falls as described by the barometric equation through the siphon tube. There is obviously a maximum height for the siphon which is the same as the limit of the suction pump, about 34 feet. Inverted siphons are sometimes used in pipelines to cross valleys. Differences in elevation are usually too great to use regular siphons to cross hills, so the fluids must be pressurized by pumps so the pressure does not fall to zero at the crests.

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/in^2) or grams per square centimeter (gm/cm^2). 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:

Development of Hydraulics - History

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.

Evangelista Torricelli

Evangelista Torricelli (1608-1647), Galileo's student and secretary, and a member of the Florentine Academy of Experiments, invented the mercury barometer in 1643, and brought the weight of the atmosphere to light. The mercury column was held up by the pressure of the atmosphere, not by horror vacui as Aristotle had supposed. Torricelli's early death was a blow to science, but his ideas were furthered by Blaise Pascal (1623-1662).

Pascal had a barometer carried up the 1465 m high Puy de Dôme, an extinct volcano in the Auvergne just west of his home of Clermont-Ferrand in 1648 by Périer, his brother-in-law. Pascal's experimentum crucis is one of the triumphs of early modern science. The Puy de Dôme is not the highest peak in the Massif Central--the Puy de Sancy, at 1866 m is, but it was the closest. Clermont is now the center of the French pneumatics industry.

Burgomeister of Magdeburg

The remarkable Otto von Guericke (1602-1686), Burgomeister of Magdeburg, Saxony, took up the cause, making the first vacuum pump, which he used in vivid demonstrations of the pressure of the atmosphere to the Imperial Diet at Regensburg in 1654. Famously, he evacuated a sphere consisting of two well-fitting hemispheres about a foot in diameter, and showed that 16 horses, 8 on each side, could not pull them apart. An original vacuum pump and hemispheres from 1663 are shown at the right (photo edited from the Deutsches Museum). He also showed that air had weight, and how much force it did require to separate the evacuated hemispheres. Then, in England, Robert Hooke (1635-1703) made a vacuum pump for Robert Boyle (1627-1691). Christian Huygens (1629-1695) became interested in a visit to London in 1661 and had a vacuum pump built for him. By this time, Torricelli's doctrine had triumphed over the Church's support for horror vacui. This was one of the first victories for rational physics over the illusions of experience, and is well worth consideration.

Pascal demonstrated that the siphon worked by atmospheric pressure, not by horror vacui. The two beakers of mercury are connected by a three-way tube, with the upper branch open to the atmosphere. As the large container is filled with water, pressure on the free surfaces of the mercury in the beakers pushes mercury into the tubes. When the state shown is reached, the beakers are connected by a mercury column, and the siphon starts, emptying the upper beaker and filling the lower. The mercury has been open to the atmosphere all this time, so if there were any horror vacui, it could have flowed in at will to soothe itself.

Torr

The mm of mercury is sometimes called a torr after Torricelli, and Pascal also has been honored by a unit of pressure, a newton per square meter or 10 dyne/cm^2. A cubic centimeter of air weighs 1.293 mg under standard conditions, and a cubic meter 1.293 kg, so air is by no means even approximately weightless, though it seems so.

The weight of a sphere of air as small as 10 cm in diameter is 0.68 g, easily measurable with a chemical balance. The pressure of the atmosphere is also considerable, like being 34 ft under water, but we do not notice it. A bar is 106 dyne/cm^2, very close to a standard atmosphere, which is 1.01325 bar. In meteorology, the millibar, mb, is used. 1 mb = 1.333 mmHg = 100 Pa = 1000 dyne/cm^2.

A kilogram-force per square centimeter is 981,000 dyne/cm^2, also close to one atmosphere. In Europe, it has been considered approximately 1 atm, as in tire pressures and other engineering applications. As we have seen, in English units the atmosphere is about 14.7 psi, and this figure can be used to find other approximate equivalents.

For example, 1 psi = 51.7 mmHg. In Britain, tons per square inch has been used for large pressures. The ton in this case is 2240 lb, not the American short ton. 1 tsi = 2240 psi, 1 tsf = 15.5 psi (about an atmosphere!). The fluid in question here is air, which is by no means incompressible. As we rise in the atmosphere and the pressure decreases, the air also expands.

To see what happens in this case, we can make use of the ideal gas equation of state, $p = \rho RT/M$, and assume that the temperature T is constant. Then the change of pressure in a change of altitude dh is $dp = -\rho g\, dh = -(pM/RT)gdh$, or $dp/p = -(Mg/RT)dh$.

This is a little harder to integrate than before, but the result is $\ln p = -Mgh/RT + C$, or $\ln(p/p0) = -Mgh/RT$, or finally $p = p0\exp(-Mgh/RT)$.

In an isothermal atmosphere, the pressure decreases exponentially. The quantity $H = RT/Mg$ is called the "height of the homogeneous atmosphere" or the scale height, and is about 8 km at T = 273K.

This quantity gives the rough scale of the decrease of pressure with height. Of course, the real atmosphere is by no means isothermal close to the ground, but cools with height nearly linearly at about 6.5°C/km up to an altitude of about 11 km at middle latitudes, called the tropopause.

Above this is a region of nearly constant temperature, the stratosphere, and then at some higher level the atmosphere warms again to near its value at the surface. Of course, there are variations from the average values. When the temperature profile with height is known, we can find the pressure by numerical integration quite easily.

Meteorology

The atmospheric pressure is of great importance in meteorology, since it determines the winds, which generally move at right angles to the direction of most rapid change of pressure, that is, along the isobars, which are contours of constant pressure.

Certain typical weather patterns are associated with relatively high and relatively low pressures, and how they vary with time.

The barometric pressure may be given in popular weather forecasts, though few people know what to do with it. If you live at a high altitude, your local weather reporter may report the pressure to be, say, 29.2 inches, but if you have a real barometer, you may well find that it is closer to 25 inches.

At an elevation of 1500 m (near Denver, or the top of the Puy de Dôme), the atmospheric pressure is about 635 mm, and water boils at 95 °C.

In fact, altitude is quite a problem in meteorology, since pressures must be measured at a common level to be meaningful.

The barometric pressures quoted in the news are reduced to sea level by standard formulas that amount to assuming that there is a column of air from your feet to sea level with a certain temperature distribution, and adding the weight of this column to the actual barometric pressure.

This is only an arbitrary 'fix' and leads to some strange conclusions, such as the permanent winter highs above high plateaus that are really imaginary.

Review Statements

Hydrostatics is an excellent example of deductive mathematical physics, and in which the predictions agree closely with experiment and is usually stated that a fluid is a substance that cannot resist a shearing stress, so that pressures are normal to confining surfaces.

Hydrostatics may be the physical property that varies over the largest numerical range, competing with electrical resistivity.

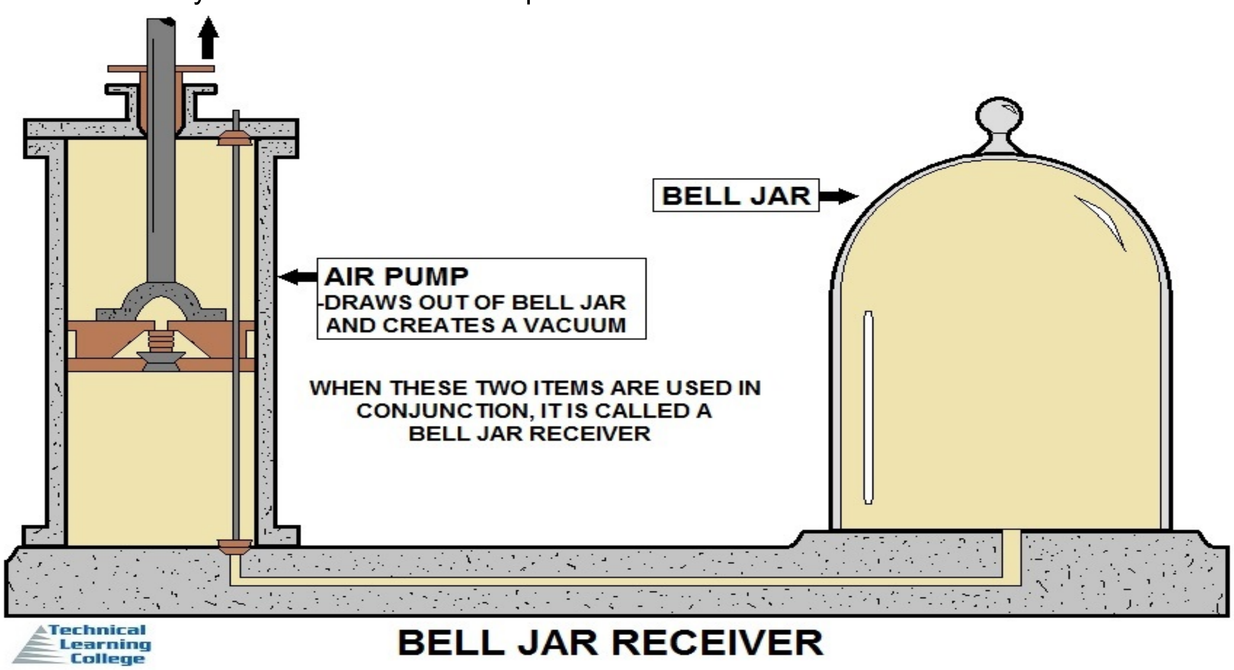
Pressure
Water is incompressible, while air is very compressible. A fluid is a substance that cannot exert any permanent forces tangential to a boundary and any force that it exerts on a boundary must be normal to the boundary. Both air and water are considered to be fluids.
Water possess volume while air does not.

A force is proportional to the area on which it is exerted, and is called a pressure.

Water Pressure
Pressure are very frequently stated in terms of the height of a fluid.

Water with a pressure head of 20 ft can provide the same energy as an equal amount of water raised by 20 ft.

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. This is one of our key foundation for backflow prevention.



One of the first "pumps".

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 face 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 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 x 0.433, or 1.299 pounds, and the pressure at the bottom will be 1.299 lb/in^2 (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.

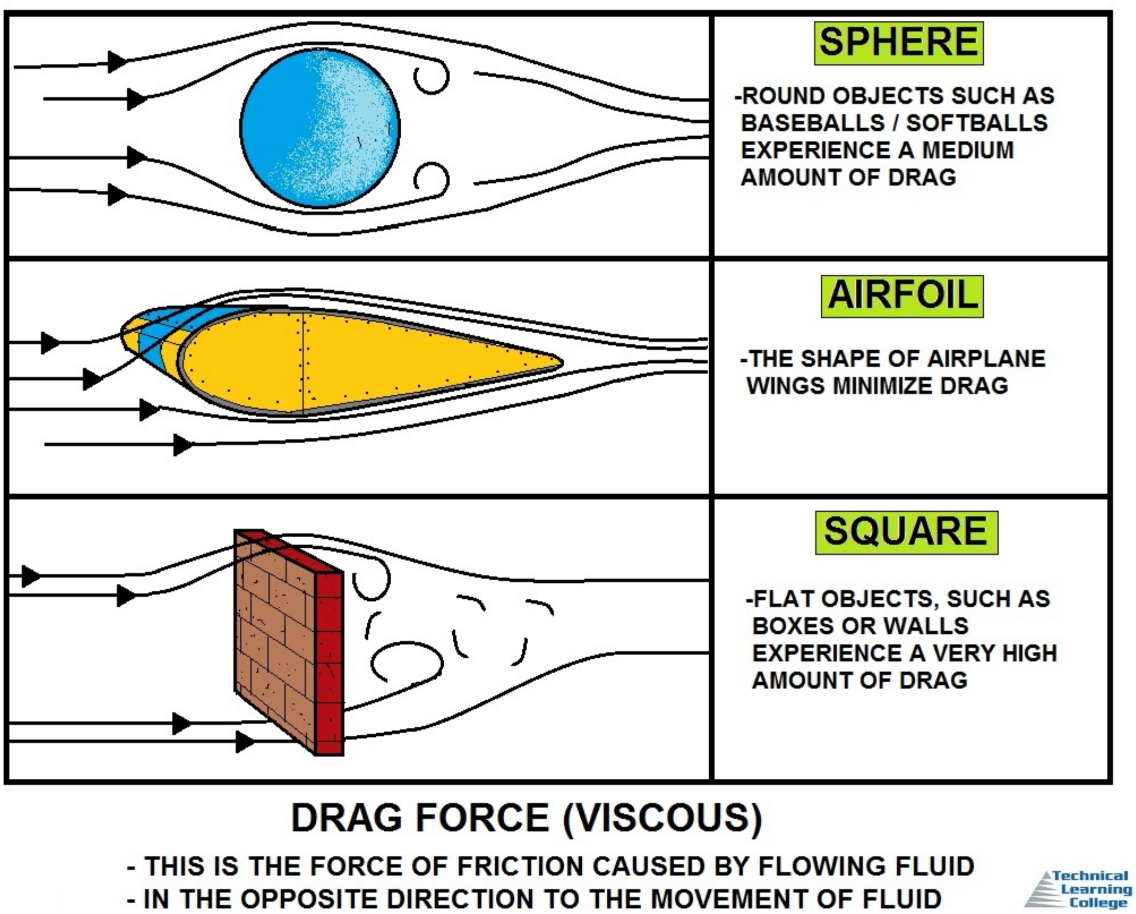
Static Pressure

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.



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.

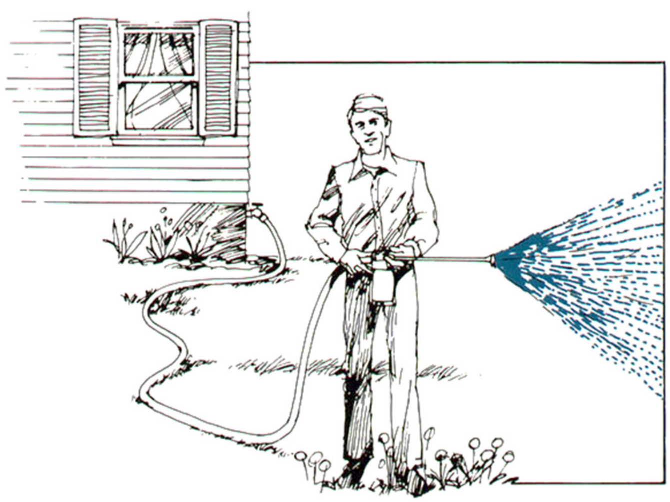
Volume and velocity of flow are often considered together. With other conditions unaltered—that is, with volume of input unchanged—the velocity of flow increases as the cross section or size of the pipe decreases, and the velocity of flow decreases as the cross section increases. For example, the velocity 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 (or fall) in pressure in a flowing fluid must always be accompanied by a decrease (or increase) in the speed, and conversely, if an increase (decrease) in, the speed of the fluid results in a decrease (or 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.

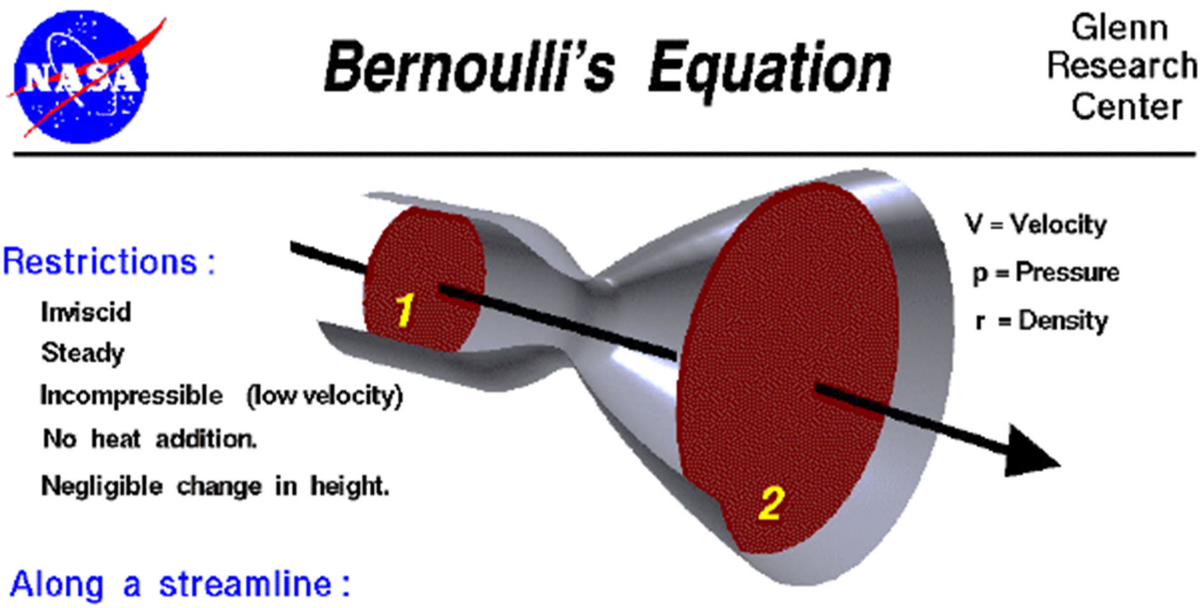


Action of a spray atomizer.

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.

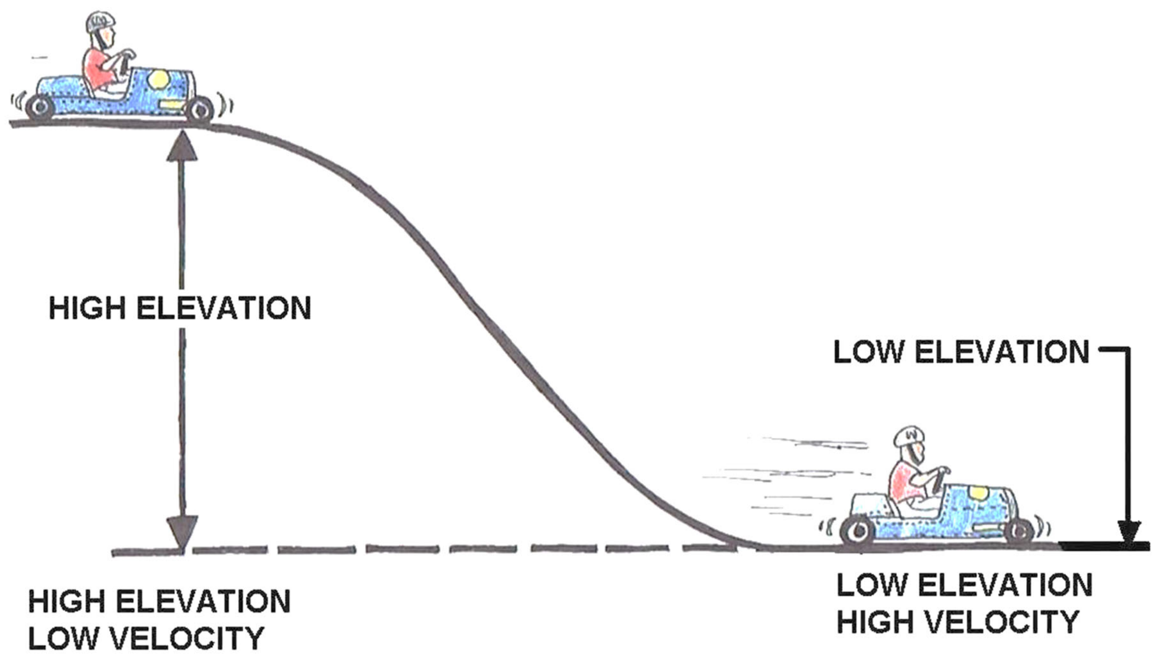
The difference in force pushes the windows outward, and hence they explode. If you know that a hurricane is coming it is therefore better to open as many windows as possible, to equalize the pressure inside and out.

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.



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

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



Understanding the Venturi

It is not easy to understand the reason low pressure occurs in the small diameter area of the venturi. This explanation may seem to help the principle.

It is clear that all the flow must pass from the larger section to the smaller section. Or in other words, the flow rate will remain the same in the large and small portions of the tube. The flow rate is the same rate, but the velocity changes. The velocity is greater in the small portion of the tube. There is a relationship between the pressure energy and the velocity energy; if velocity increases the pressure energy must decrease.

This is known as the principle of conservation of energy at work which is also Bernoulli's law. This is similar to the soapbox derby car in the illustration at the top of a hill. At the top or point, the elevation of the soapbox derby car is high and the velocity low.

At the bottom the elevation is low and the velocity is high, elevation (potential) energy has been converted to velocity (kinetic) energy. Pressure and velocity energies behave in the same way. In the large part of the pipe the pressure is high and velocity is low, in the small part, pressure is low and velocity high.

Summary

The basis for all hydraulic systems (backflow prevention assemblies or customer's water systems) can be expressed by Pascal's law.

This law states that the pressure exerted anywhere upon an enclosed liquid is transmitted undiminished, in all directions, to the interior of the pipe or assembly. Pascal's law allows large forces to be generated with relatively little effort.

As little as 5-pound force exerted against a 1-inch square area creates an internal pressure of 5 psi. This pressure, acting against the 10 square inch area develops 50 pounds of force.

Water pressure is most often expressed as **"pounds per square inch"** usually abbreviated as **"PSI"**. (If you maintain a water system you are familiar with PSI, it is used to measure the air pressure at customer's water taps.) PSI and feet head are both values used to measure water pressure.

PSI measures the amount of pressure in pounds that the water would exert against a 1 square inch area.

In order to be a backflow tester or a certified operator, you must understand that weight per square inch calculation.

Water pressures and pressure differences (differentials) are necessary information for the backflow assembly performance, and for pressure measuring equipment (pressure gauges or test kits).

One thing that is important is for you to know that you can easily convert PSI values to feet head and vice versa. You can easily convert back and forth between Feet Head and PSI using two formulas:

Feet Head x 0.433 = PSI

PSI x 2.31 = Feet Head

Topic 2 - Hydraulic Principles Section Post Quiz

1. Pressures under water differ from those under air only because the weight of the water must be added to the?

2. Hydraulics can be divided into two areas, what term and hydrokinetics?

3. 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.
A. True B. False

4. What term includes the study of liquids in motion, is concerned with such matters as friction and turbulence generated in pipes by flowing liquids?

5. What is the term that can be measured by any of several methods, one method is the mercury column barometer?

6. 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 2.31 psi.
A. True B. False

7. What is the term that can be measured an absolute scale, pounds per square inch absolute (psia), or gauge scale, (psiag)?

8. Absolute pressure is equal to gauge pressure plus the atmospheric pressure.
A. True B. False

9. The barometric loop consists of a continuous section of supply piping that abruptly rises to a height of approximately 35 feet and *then returns back down* to the originating level.
A. True B. False

10. The barometric loop *may be used* to protect against backsiphonage.
A. True B. False

11. Which of the following terms at sea level is 14.7 psai?

12. What is the term that can be measured as the total pressure?

13. 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 2.31.
A. True B. False

14. Backsiphonage results from ______________________ exerted on a liquid, forcing it toward a supply system that is under a vacuum.

Water Pressure
15. 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. This is one of our key foundation for backflow prevention.
A. True B. False

16. What term is frequently stated in terms of the height of a fluid?

17. Water with a pressure head of 10 ft can provide the same _________as an equal amount of water raised by 10 ft.

18. What term is to be made effective for practical applications, it was necessary to have a piston that "fit exactly?"

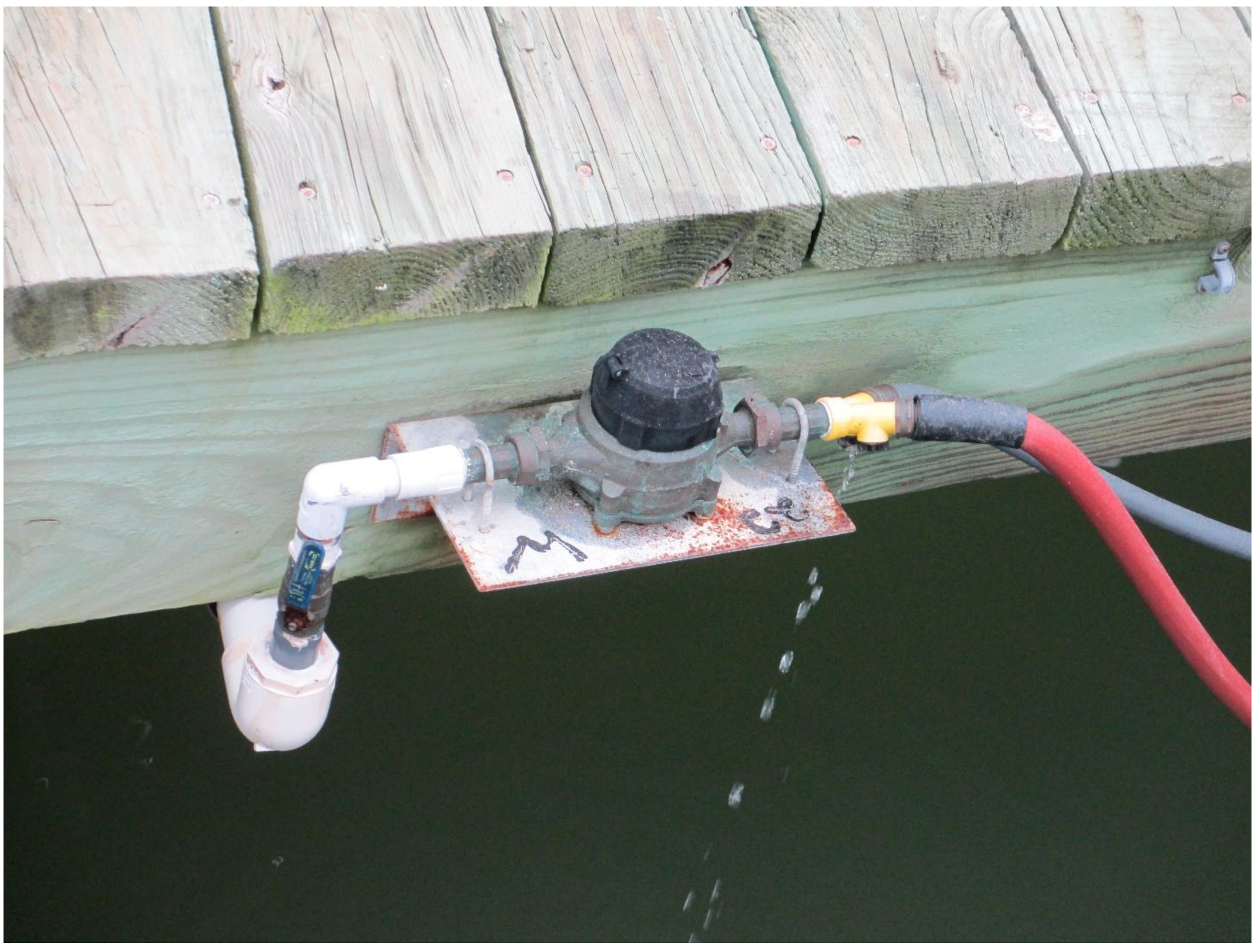
19. According to the text, valves, pumps, actuating cylinders, and motors have been developed and refined to make hydraulics one of the leading methods of transmitting power.
A. True B. False

20. Liquids will flow in the direction which will tend to make the surface level, if the surface is not level.
A. True B. False

Topic 3 - Cross-Connection Control Responsibility Section

Section Focus: You will learn the basics of cross-connection control program (regulatory control). At the end of this section, you the student will be able to understand and describe regulatory cross-connection control measures. There is a post quiz at the end of this section to review your comprehension and a final examination in the Assignment for your contact hours.

Scope/Background: Backflow into the public water distribution system can be prevented by eliminating cross-connections or protecting the potable water supply using backflow prevention devices and assemblies. This is done by ordinances or other forms of control which are set in place by the Administrative or Regulatory Authority. Many water systems educate the public to prevent cross-connections, and maintain and inspect the distribution system to correct those found.



The above photo is of a unprotected water meter at a boat dock.

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 the compromised as its delivery through the distribution system.

This is specified in the Code of Federal Regulations (Volume 40, Para. 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.

Cross-Connection Control Program

All public water system operators are required to maintain an active cross connection control program to identify and eliminate or isolate all cross connections within their systems. This program should provide for inspections of premises which may contain cross connections, installation of approved backflow prevention devices and annual testing of installed devices.

A cross connection ordinance (or other enabling authority) that prohibits water service to any premise on which a cross connection exists without proper protection is required. The ordinance can also specify who will do the inspections and can specify testing of devices.

Only backflow prevention devices that are approved by the State Environ-mental Quality or Health Division may be installed. Backflow prevention devices must be tested annually by certified testers to be sure the devices are functioning properly.

Responsibility Administration of a Cross-Connection Program
Under the provisions of the Safe Drinking Water Act of 1974, the Federal Government has established, through the EPA (Environmental Protection Agency), national standards of safe drinking water. The states are responsible for the enforcement of these standards as well as the supervision of public water supply systems and the sources of drinking water.

The water purveyor (supplier) is held responsible for compliance to the provisions of the Safe Drinking Water Act, to include a warranty that water quality provided by his operation is in conformance with the EPA standards at the source, and is delivered to the customer without the quality being compromised es a result of its delivery through the distribution system. As specified in the Code of Federal Regulations

(Volume 40, Paragraph 141.2, Section (c)) "*Maximum contaminant level, means the maximum 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 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."

Containment
There are several options that are open to a water purveyor when considering cross-connection protection to commercial, industrial, and residential customers. He may elect to work initially on the "*containment*" theory. 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.

While it is recognized that "*containment"* does not protect the customer within his building, it does effectively remove him from possible contamination to the public water supply system.

If the water purveyor elects to protect his customers on a domestic internal protective basis and/or *"fixture outlet protective basis*," then cross-connection control protective devices are placed at internal high hazard locations as well as at all locations where cross-connections exist at the "*last free-flowing outlet*."

This approach entails extensive cross-connective survey work on behalf of the water superintendent as well as constant policing of the plumbing within each commercial, industrial and residential account.

In large water supply systems, fixture outlet protection cross-connection control philosophy, in itself, is a virtual impossibility 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 industrial and commercial establishments that do not require the water department to license or otherwise endorse or ratify when contemplated or completed.

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.

Developing a Cross-Connection Control Program

Introduction
Establishing a cross connection control program for a small water utility can be a daunting task. The responsibility of creating and implementing the program will often fall on the operator, who will most likely be responsible for water, sewer, roads, parks and other public work projects as well. This can seem overwhelming, but with an organized approach an effective program can be established.

What is a Cross-Connection?
Before anyone can start a cross connection program, he or she must understand what cross connections are, why they are dangerous, and how they can be corrected. Therefore, the first step must be education. The approach to learning about cross connection control will vary depending on time and funding constraints.

The best approach will be to attend a training course that is specifically designed to teach cross connection control practices for public water systems. If this is not possible, then the operator will have to pursue other avenues. Some agencies and organizations offer training courses that include sessions on cross connection control for little or no cost. Some areas have committees, associations or other groups dedicated to cross connection control.

These groups can be a great source of information and networking. Many cross connection control publications and videos are available. It is also advisable for the operator to contact neighboring water utilities for information on their cross connection control programs.

Legal Authority
Once the operator has a good understanding of cross connection control, the next task will be to prepare a written document that will establish legal authority for the program. This may be in the form of an ordinance, resolution, by-law, etc., depending on the organization of the water system. This document will define the utility's cross connection control requirements, such as what circumstances will require the installation of a backflow preventer; who will be responsible for the installation, testing and maintenance costs; program enforcement; approval of backflow preventors and installation requirements.

This document must avoid conflicts with other agencies. It is important to consider the requirements of local building, plumbing and fire codes in addition to Health Services requirements. It is useful to obtain copies of ordinances from nearby utilities and consider their requirements. It is preferable for utilities to have similar requirements when possible.

This will minimize confusion for those who work in several districts and are expected to be familiar with local requirements, such as backflow assembly testers, plumbers and vendors. It will also help avoid critical comparisons between utilities.

"The Board"
A cross connection ordinance will be useless without the approval of the board of directors or city council. This fact can present problems of its own. As is often the case, the operator will be given the responsibility of running a cross connection control program but will not have the authority to create and enforce the ordinance.

For this reason, it is extremely important to have the support of the board.

Board members must be educated about cross connection control. They need to understand the hazards cross connections present to the safety of the water supply, and the liability they are vulnerable to in the event of a backflow incident. Once they understand the importance of a cross connection control program, they can be strong allies in adopting an effective ordinance and implementing the program.

Organize the Program
Once an ordinance has been adopted, it must be implemented. This requires an organized approach. The responsibilities of each person involved in the program must be clearly defined; a system for coordinating with other agencies must be developed; a plan to educate the public must be in place; an efficient system for keeping records is critical; and various form letters and notices will need to be developed.

Work Responsibilities
It is important to identify who is responsible for each element in the cross connection control program. Who will determine when a backflow preventer is required? Who will prioritize installations? Who will verify the correct installation of the backflow preventer? Who will test backflow preventors?

Who will send out letters and notices? Who will track the testing and maintenance of the backflow preventors in the system? Who will respond to customer inquiries and complaints? These are all questions that need to be answered before the program is presented to the customers.

Agency Coordination
Working with other agencies can be a great benefit to the cross connection control program. The local building department plan review process can be a useful tool. If an agreement can be made to include the water utility in the plan review process, any needed backflow preventors can be included in the planning stage. A good relationship with local plumbing inspectors can be a great benefit to the program. They can serve as extra eyes to spot any variations from building plans that might create a need for backflow prevention. Working with fire officials is extremely important.

The installation of backflow preventors on fire lines will increase the pressure loss, and this needs to be considered in the system design. Good working relationships with these officials will eliminate the headache of retrofitting a new building, and the bad publicity that follows a lack of coordination between agencies.

Public Education
Public education is an important aspect of cross connection control that is too often overlooked or minimized. This can have disastrous consequences. If a customer receives a notice to install a backflow preventer with no explanation, they will often have a negative response. It is important to educate the customers to the dangers of cross connections and the importance of installing backflow preventors when needed.

It is also very important to explain the program priorities so the customers don't feel singled out. If one customer is notified to install a backflow preventer and their neighbor isn't, they will want to know why.

It is better for the utility to answer these questions with public education, rather than leave the customers wondering, or worse yet, doubting the sensibility of the cross connection control program. Most customers will be willing to support the cross connection control program when they understand that the safety of their drinking water is at stake.

Record-keeping, Forms and Notices

An active cross connection control program will generate information that must be organized and tracked. It is important to give careful consideration to record keeping methods before information begins to accumulate.

Once information is stored, changing the format becomes quite difficult. A system needs to be in place for notifying customers when backflow preventors must be installed, tested or repaired, and for tracking the responses. Backflow preventors must be tested regularly, so a system of tracking due dates is needed in order to send notices on time.

Certain letters will be sent out frequently, so it is helpful to have a standard form prepared for these occasions. Cross connection software is available to assist with this aspect of the program. The software is available in a wide range of prices and capabilities.

Cross-Connection Program Implementation

Once these preparations have been completed, the cross connection control program is ready for implementation. Public education can be initiated to gain customer support for the program.

The operator will be ready to identify cross connection hazards in the system and begin the process of eliminating or isolating them. As the program begins to function, the utility will be prepared to handle the paper flow and phone calls that are generated. Creating an effective cross connection control program is an important and challenging responsibility.

An organized approach in the beginning will help avoid many problems and conflicts once the program begins to function. Once the program is established, the utility can take pride in the knowledge that they are taking an active role in protecting the public water supply from potentially life-threatening contamination.

What is 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 firefighting, a break in a water main, etc.

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 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 code(s). In addition, he may be required to install, test, maintain all backflow protection assemblies.

Method of Action
In addition, internal plumbing cross-connection control survey work is generally foreign to the average water purveyor and is not normally a portion of his job description or duties.

While it is admirable for the water purveyor to accept and perform survey work, he should be aware that he runs the risk of additional liability in an area that may be in conflict with plumbing inspectors, maintenance personnel and other public health officials.

Even where extensive "*fixture outlet protection*," cross-connection control programs are in effect through the efforts of an aggressive and thorough water supply cross-connection control program, the water authorities should also have an active "*containment*" program in order to address the many plumbing changes that are made and that are inherent within commercial and industrial establishments.

In essence, fixture outlet protection becomes an extension beyond the "*containment*" program. Also, in order for the supplier of water to provide maximum protection of the water distribution system, consideration should be given to requiring the owner of a premise (commercial, industrial, or residential) to provide at his own expense, adequate proof that his internal water system complies with the local or state plumbing code(s).

In addition, he may be required to install, have tested, and maintain, all backflow protection devices that would be required - at his own expense! The supplier of water should have the right of entry to determine degree of hazard and the existence of cross-connections in order to protect the potable water system.

By so doing he can assess the overall nature of the facility and its potential impact on the water system (determine degree of hazard), personally see actual cross-connections that could contaminate the water system, and take appropriate action to insure the elimination of the cross-connection or the installation of required backflow devices. To assist the water purveyor in the total administration of a cross-connection control program requires that all public health officials, plumbing inspectors, building managers, plumbing installers, and maintenance men participate and share in the responsibility to protect the public health and safety of individuals from cross-connections and contamination or pollution of the public water supply system.

A complete cross-connection control program requires a carefully planned and executed initial action plan followed by aggressive implementation and constant follow-up. Proper staffing and education of personnel is a requirement to insure that an effective program is achieved.

A recommended plan of action for a cross-connection control program should include the following characteristics:

(1) Establish a cross-connection control ordinance at the local level and have it approved by the water commissioners, town manager, etc., and ensure that it is adopted by the town or private water authority as a legally enforceable document.

(2) Conduct public informative meetings that define the proposed cross-connection control program, review the local cross-connection control ordinance, and answer all questions that may arise concerning the reason for the program, why and how the survey will be conducted, and the potential impact upon the industrial, commercial and residential water customers. Have state authorities and the local press and radio attend the meeting.

(3) Place written notices of the pending cross-connection control program in the local newspaper, and have the local radio station make announcements about the program as a public service notice.

(4) Send employees who will administer the program, to a course, or courses, on backflow tester certification, backflow survey courses, backflow device repair courses, etc.

(5) Equip the water authority with backflow device test kits.

(6) Conduct meeting(s) with the local plumbing inspection people, building inspectors, and licensed plumbers in the area who will be active in the inspection, installations and repair of backflow devices. Inform them of the intent of the program and the part that they can play in the successful implementation of the program.

(7) Prior to initiating a survey of the established commercial and industrial installations, prepare a list of these establishments from existing records, then prioritize the degree of hazard that they present to the water system, i.e., plating plants, hospitals, car wash facilities, industrial metal finishing and fabrication, mortuaries, etc.

These will be the initial facilities inspected for cross-connections and will be followed by less hazardous installations.

(8) Ensure that any new construction plans are reviewed by the water authority to assess the degree of hazard and ensure that the proper backflow preventer is installed concurrent with the potential degree of hazard that the facility presents.

(9) Establish a residential backflow protection program that will automatically ensure that a residential backflow device is installed automatically at every new residence.

(10) As water meters are repaired or replaced at residences, ensure that a residential backflow preventer is set with the new or reworked water meter. Be sure to have the owner address thermal expansion provisions.

Containment Practices- 1 Method

Mechanical backflow prevention devices and assemblies offer protection of the potable water system if other protective approaches fail. Backflow prevention devices and assemblies may be installed at the service connection to a facility (effectively “containing” a potential contaminant within a customer’s plumbing system and preventing it from entering the distribution system).

Alternatively, devices and assemblies can also be installed at high and low hazard cross-connections inside the facility, including all outlets where cross-connections could potentially be created (this type of approach is called “isolation” or “fixture outlet protection”). Some drinking water authorities prefer isolation to containment because personnel working beyond the service connection are protected and, in most cases, the assembly can be sized smaller because of smaller piping beyond the service connection. However, backflow devices and assemblies used for isolation could be bypassed through changes to internal plumbing, inadvertently creating an unprotected cross-connection.

There are two types of mechanical protection available to systems: backflow prevention “devices” and backflow prevention “assemblies”. Backflow prevention devices function by stopping the reversal of flow, but are not testable once installed because they do not have inlet and outlet shut-off valves or test cocks (USC FCCCHR, 1993).

Backflow prevention assemblies, by contrast, include an inlet and outlet shut-off valve and test cocks to facilitate testing of the assembly while it is in its functional environment (in-line) (USC FCCCHR, 1993).

Backflow prevention assemblies include pressure vacuum breakers (PVBs), spill resistant vacuum breakers (SVBs), double check valve assemblies (DCVAs), and reduced pressure principle backflow assemblies (RPs) (USC FCCCHR, 1993) (BMI, 1996). PVBs are vertically positioned assemblies that include spring-loaded check valves designed to close when flow stops (USC FCCCHR, 1993). They also have an air inlet valve that is designed to open when the internal pressure is lower than the atmospheric pressure, preventing backsiphonage but not backpressure.

PVBs must be a minimum of 12 inches above all downstream piping and the flood level rim of a receptor to function properly. PVBs are designed to protect against low- or high-hazard situations.

SVBs are similar in design to PVBs with the addition of a diaphragm seal that stops water from spilling out the air inlet whenever the assembly is pressurized. As with PVBs, they protect against backsiphonage only (BMI, 1996).

A DCVA consists of two internally loaded, independently operating check valves together with tightly closing resilient seated shut-off valves upstream and downstream from the check valves (USC FCCCHR, 1993). These assemblies require a minimum of 1 foot of clearance at the bottom for maintenance purposes to allow for the worker to get to the assembly. These assemblies are used for protection against either backsiphonage or backpressure, but only for situations of low hazard.

RPs consist of two internally loaded, independently operating check valves and a mechanically independent, hydraulically dependent relief valve located between the check valves (USC FCCCHR, 1993).

The relief valve maintains a zone of reduced pressure between the two check valves. The RP also has tightly closing, resilient seated shut-off valves upstream and downstream of the water supply. RPs must have a minimum of 1-foot clearance at the bottom of the assembly for maintenance purposes. RPs protect against backsiphonage or backpressure in low- or high-hazard situations.

One common backflow prevention device is an atmospheric vacuum breaker (AVB). AVBs rely on atmospheric instead of water pressure to work, and are installed downstream from all shut-off valves.

AVBs contain an air inlet valve that closes when the water flows in the normal direction. But, as water ceases to flow, the air inlet valve opens and prevents backsiphonage. AVBs must be a minimum of 6 inches above all downstream piping and the flood level rim of a receptor to function properly (USC FCCCHR, 1993). Household hose bib vacuum breakers and frost-proof wall hydrant faucets are examples of AVBs. According to some, AVBs do not protect against backpressure and are used in situations of low hazard (BMI, 1999); however, some plumbing codes recognize AVBs as high hazard assemblies.

Cost Verses Risk

The selection of any particular assembly or device is a function of the hazard assessment that balances the likelihood of backpressure and backsiphonage and the potential contaminants involved. The total cost of installing and maintaining a particular device or assembly can also be a factor for some water systems. In cases of low hazard and backsiphonage only, systems typically install less expensive AVBs or PVBs. If backpressure is a concern, many systems use double check valve assemblies, and if the degree of hazard is high, many systems install a reduced pressure principle backflow assembly.

The cost of backflow preventers has been reported by industry experts to be a deterrent in starting and maintaining and backflow prevention program. The cost of backflow preventers can range from $25 to over $25,000, depending on the size and preventer type. Installation costs are typically borne by the water system and passed along to consumers, or are borne directly by consumers.

Cross-Connection Control and Backflow Prevention Programs

Many states and local jurisdictions require cross-connection control and backflow prevention programs. However, many utilities do not have programs, or have programs that are insufficient to provide reasonable protection from cross-connections (ABPA, 1999).

The program requirements vary widely between states: they may be part one or more of various regulations, including the drinking water regulations, health code, plumbing code, policy decision of the utility itself and building codes.

A 1993 U.S. General Accounting Office report on the review of 200 sanitary surveys and a nationwide questionnaire of states identified inadequate cross-connection control programs as the most common deficiency (US GAO, 1993).

Programs and their level of effort are often tailored to the perceived risk of backflow and the types of hazards that can be introduced into the distribution system (USC FCCCHR, 1993).

These factors may contribute to determining whether a containment or isolation program is implemented locally, as well as what types of backflow preventers are required. The need for backflow prevention in a water system is determined through a variety of means, including: surveys of new sites; retrofit programs; and change of occupancy inspections. Some programs inspect a site upon request. In many of these cases, identification of hazards determines the need for backflow prevention.

Testing and Repair
Many systems that have cross-connection control and backflow prevention programs require testing to ensure that backflow preventers are working correctly. As in any mechanical device, backflow assemblies can deteriorate and fail as they get older. Testing intervals typically are annual, semi-annual, or risk-based (USC FCCCHR, 1993).

Many states require in regulation or code specific components that make up a testing program. A testing program frequently identifies the appropriate standards that a backflow prevention device or assembly must meet (e.g., standards set by the USC FCCCHR, AWWA, or in the Uniform Plumbing Code (UPC)), as well as specifies a routine testing frequency to ensure adequate performance of the devices. In many cases, assemblies are then tested by a certified backflow assembly tester.

Possible Indicators of a Backflow Incident

This section discusses events, occurrences, or signals that help indicate to a water system or regulatory authority that a backflow incident is occurring or has occurred. A problem for water systems in detecting cross-connections is that there is little immediate warning that a backflow incident is occurring. In some cases, it is not known for some time after an incident, and in other cases it is never discovered. With an active monitoring program, cross-connections may be detected by routine inspection, and deficiencies in the distribution system that could lead to backflow could be corrected. However, the efficacy of a cross-connection control program might only be known to the extent that new backflow incidents are not detected.

Possible indicators of backflow include:
1) customer complaints of water quality;
2) drops in operating pressure;
3) drops in disinfectant residual;
4) water meters running in reverse; and
5) coliform detections.

It is also possible that cross-connections and contamination due to backflow events can occur in the absence of these indicators.

Customer Complaints
The primary indicator of backflow has been customer complaints of odor, discoloration of the water, or direct physical harm from contact with the water. Generally, it is unknown how long a backflow incident may have occurred before it is detected through aesthetic or health concerns.

Drops in operating pressure Continual monitoring for reduced pressure can give immediate warning of a potential backflow incident. It may also identify the area where a pressure drop may have originated, and thus help isolate areas affected by backflow.

A drop in operating pressure can only indicate that a backflow event may have already occurred; it cannot stop an event in progress or prevent an incident, unless the root cause is corrected.

Drops in Disinfectant Residual
A drop in the disinfectant residual of a distribution system can be an indicator of a backflow event. Many factors influence the concentration of the disinfectant residual in the distribution system, including the assimilable organic carbon level, the type and concentration of disinfectant, water temperature, and system hydraulics (Trussell, 1999). Entry of foreign material into the distribution system from backflow (or other events) may alter these factors and contribute to a loss of residual.

Water Meters Running in Reverse
During periods of reversed water flow, water meters can reverse their counters. When investigating a water quality complaint at a restaurant in Kennewick, WA, a cross-connection specialist found the meter at the site running backwards; the dual check valves for the carbon dioxide tanks were impaired, allowing the pressurized carbon dioxide to backflow into the water supply line (AWWA PNWS, 1995). Based on a survey of water systems, many have the ability to detect meters running backwards and have detected this occurrence on several occasions (Schwartz, 2002).

Total Coliform Detections and Heterotrophic Plate Count Changes
A sudden spike in total coliform detections, or a sudden change in heterotrophic bacterial densities (measured by heterotrophic plate count) is an indication that contaminants could have entered the distribution system (40 CFR 141). Persistent coliform contamination may indicate a long-standing cross-connection. Monitoring for coliform and other microbial indicators of contamination, as well as more extensive monitoring, may help identify instances of backflow contamination.

Occurrence of Cross-Connections and Backflow

Cutting out a damaged water main section.

From a 1999 American Backflow Prevention Association (ABPA) survey, ABPA estimated that 42 percent of cross-connection surveys conducted (by 135 respondents, representing 30 states) identified a cross-connection. The most common cross-connections reported were from irrigation (62 percent of respondents identified an irrigation cross-connection), fire systems (43 percent), garden/washdown hoses (43 percent), and boilers (38 percent).

A total of 233 backflow incidents were reported by 51 percent of respondents, or 1.7 incidents per system (ABPA, 1999). These numbers only reflect those backflow incidents detected; many go undetected because it is not practical for systems to continuously monitor their distribution systems for changes in pressure or the presence of contaminants.

In addition, ABPA conducted a survey in 2000, which included a question on the occurrence of low pressure events which may lead to backflow where unprotected.

A survey of 70 systems responding to the survey reported 11,186 pressure reduction incidents in the previous year; 34.8% of the incidents were from routine flushing, 19.2% were due to main breaks, and 16.2% of the incidents were due to service line breaks (ABPA, 2000). From the EPA Cross-Connection Manual.

Within distribution systems there exist points called cross-connections where nonpotable water can be connected to potable sources. These cross-connections can provide a pathway for backflow of nonpotable water into potable sources.

Backflow can occur either because of reduced pressure in the distribution system (termed backsiphonage) or the presence of increased pressure from a nonpotable source (termed backpressure).

Backsiphonage may be caused by a variety of circumstances, such as main breaks, flushing, pump failure, or emergency firefighting water drawdown.

Backpressure may occur when heating/cooling, waste disposal, or industrial manufacturing systems are connected to potable supplies and the pressure in the external system exceeds the pressure in the distribution system. Both situations act to change the direction of water, which normally flows from the distribution system to the customer, so that nonpotable and potentially contaminated water from industrial, commercial, or residential sites flows back into the distribution system through a cross-connection.

During incidents of backflow, these chemical and biological contaminants have caused illness and deaths, with contamination affecting a number of service connections. The number of incidents actually reported is believed to be a small percentage of the total number of backflow incidents in the United States.

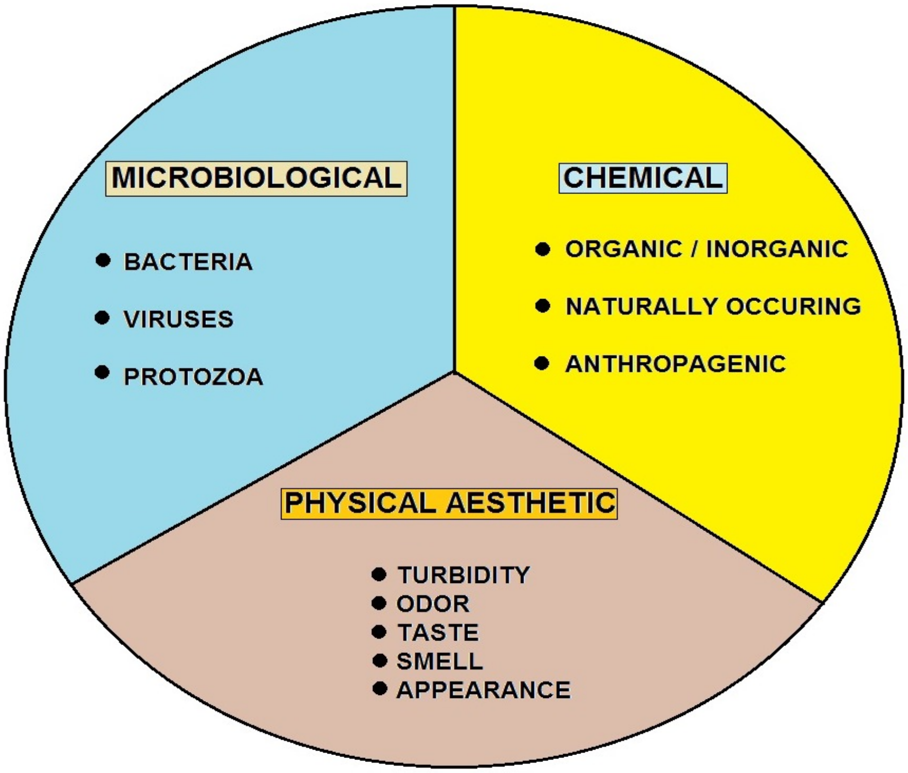
The risk posed by backflow can be mitigated through preventive and corrective measures. For example, preventative measures include the installation of backflow prevention devices and assemblies and formal programs to seek out and correct cross-connections within the distribution system and, in some cases, within individual service connections.

Corrective measures include activities such as flushing and cleaning the distribution system after a detected incident. These may help mitigate any further adverse health effects from any contaminants that may remain in the distribution system.

The risk posed by backflow can be mitigated through preventive and corrective measures. For example, preventative measures include the installation of backflow prevention devices and assemblies

Maintenance Activities
Maintenance levels and practices within the distribution system can affect the likelihood of occurrence of cross-connections and backflow. In a South Carolina system in 1978 fifteen people became ill due to backsiphonage of chlordane from an exterminator truck during meter repair (USC FCCCHR, 1993).

Cross-Connections and Contaminants and Health Effects



WATER QUALITY BROKEN DOWN INTO 3 BROAD CATEGORIES

A variety of contaminants have been introduced into distribution systems by cross-connections and backflow, indicated by the backflow occurrence discussed in this course. The likelihood and severity of illness and number of people affected depend on various factors including how much contamination enters the system, the dilution factor, the type of contaminant, the number of users exposed, and the health status of each person at the time of exposure.

Contamination from cross-connections and backflow can occur not only where the cross-connection is located but at sites upstream and downstream, as contaminants spread. The fate and transport of a contaminant are often system-specific and can be difficult to predict because they depend on multiple parameters such as the hydraulics of the distribution system and the physical, chemical, or biological properties of the contaminant.

The contaminant may remain as a slug, resulting in very high concentrations in localized areas, or it may disperse, contaminating large volumes of water at lower concentrations. It may adsorb to the interior of pipes, necessitating their cleaning or replacement. It may degrade, or in the case of microorganisms, be inactivated or injured by residual disinfectant. It may also become concentrated within the biofilms and be slowly released through erosion or as a slug through biofilm sloughing. Scales within the piping may adsorb the contaminants for later release.

Chemical Contaminants

The use of chemicals at residential, industrial, and commercial facilities with direct or indirect connections to potable water systems presents an opportunity for contamination from cross-connections and backflow (USC FCCCHR, 1993). Many of these chemicals have some degree of toxicity, and exposure to these chemicals can have either acute or long-term health effects, depending on the nature and concentration of the contaminant, duration of exposure, and a person's immune status.

Exposure from contamination through a cross-connection can be either acute or chronic. While waterborne outbreaks are under-reported in general, rarely are waterborne chemical outbreaks reported to CDC. From the EPA Cross-Connection Manual.

The reasons for under-reporting of chemical outbreaks above and beyond that of microbial outbreaks include:

1) most poisonings of this nature (e.g., lead and copper from plumbing) probably occur in private residences, affect relatively few people and, thus, may not come to the attention of public health officials;

2) exposure to chemicals via drinking water may cause illness that is difficult to attribute to chemical intoxication, or it may cause non-specific symptoms that are difficult to link to a specific agent; and

3) the chemical outbreak detection mechanisms, as well as the reporting requirements are not as well established as they are for microbial agents (CDC, 1996). Most reported incidents are acute exposures, however, chronic exposures are possible if immediate water quality or health effects are not noticed, or if cross-connections remain uncorrected long-term. This can result in some of the chronic health effects, when the consumer is exposed to the chemicals listed for a long period of time. Depending on the contaminant, these chronic exposures can cause long-term health effects, including cancer, which may not be identified until many years after the initial exposure. Acute health risks include vomiting, burns, poisoning, and other reactions—some potentially life-threatening.

Because few backflow incidents are reported, it is important to note that a variety of chemicals have the potential to enter the distribution system through cross-connections, and the number of those reported only represent a subset. For example, agricultural applications contain many fertilizers, herbicides, and insecticides and industrial sources such as cooling systems, plating plants, steam boiler plants, and dye plants have a number of toxic chemicals in day-to-day use that have the potential to contaminate the distribution system (USC FCCCHR, 1993). The most common chemical contaminants reported, according to information EPA has obtained from backflow incident records, are (in order of decreasing occurrence): copper, chromium, ethylene glycol, detergents, chlordane, malathion, propylene glycol, Freon, and nitrite.

Chlordane and malathion are pesticides; ethylene glycol is used as antifreeze in heating and cooling systems, propylene glycol is used as antifreeze and as a food additive; detergents are extensively used in many industries; copper is used in plumbing; chromium VI was used in the past in cooling towers as a rust and corrosion inhibitor; and nitrite is a reduced form of nitrate, an agricultural fertilizer. This summary discusses these and other related chemical contaminants (grouped into four categories—pesticides, metals, synthetic organic compounds, and nitrates and nitrites) in terms of potential health effects and examples of reported backflow incidents. From the EPA Cross-Connection Manual.

Pesticides
Pesticides (including insecticides, herbicides, and fungicides) as a group are contaminants in 45 reported incidents. Chlordane, malathion, heptachlor, and diazinon were reported as contaminants in 11, 5, 3, and 2 incidents, respectively. In one 1976 incident in Chattanooga, TN, chlordane was being used for termite extermination and contaminated a three-block area of residential homes; 17 people reported they drank the suspect water. Reported symptoms by those people were nausea, abdominal pain, gastrointestinal problems, and neurological effects such as dizziness, blurred vision, irritability, headache, paresthesia, muscle weakness, and twitching (AWWA PNWS, 1995).

In 1980, heptachlor and chlordane contaminated a portion of distribution system in Allegheny, PA that serviced approximately 300 people. A pesticide contractor created the cross-connection with a garden hose submerged in the chemical mixing tank. There were no reports of illness, however, residents were without water for 27 days (Watts, 1998).

Another pesticide incident involved diazinon contamination in Tucson, AZ in 1989. Diazinon entered the system through a residential connection where a home-made pesticide pump system was hooked up to a garden hose.

The combination of backpressure from the pump system and the water use by a next-door neighbor washing a car caused the pesticide to flow into the distribution system (Tucson Citizen, 1989). No illnesses were reported. In 1986, two employees of a Kansas grain mill became ill after drinking water contaminated with malathion that was backsiphoned into the plant's water supply (AWWA PNWS, 1995).

In 1988, a Florida man died of insecticide intoxication after he stepped off his mower, filled his water bottle, and drank from the bottle that was filled with contaminated water from a faucet at an airstrip. Officials suspected backflow as the cause of the water supply contamination (AWWA PNWS, 1995).

An example of a small amount of contamination resulting in a public health threat is a 1991 incident where 2.5 gallons of the herbicide TriMec backsiphoned into the Uintah Highlands water system in Utah affecting 2,000 homes (US EPA, 1989). Shortly thereafter, concentrations of the active ingredients, 2,4-D and Dicamba, at a consumer's tap were measured at 638 and 64.8 parts per million (ppm), respectively. This incident also affected a nursing home and a day-care facility, both of which serve higher risk subpopulations. The health advisory level of both 2,4-D and Dicamba over a 10-day period is 0.3 ppm (US EPA, 2000a). Chronic health effects of 2,4-D and Dicamba include damage to the nervous system, kidney, and liver (US EPA, 2002a). However, only acute exposures were documented.

Metal Contamination from Cross-Connections

FACTOR	TYPE	SOURCE(S)	PROBLEM
FECAL COLIFORM BACTERIA	BIOLOGICAL	HUMAN SEWAGE; LIVESTOCK WASTE	POSSIBLE PRESENCE OF PATHOGENIC (DISEASE-CAUSING) ORGANISMS
DISSOLVED OXYGEN (DO)	CHEMICAL	AIR; AQUATIC PLANTS	LOW LEVELS CAN KILL AQUATIC ORGANISMS
NITROGEN AND PHOSPHORUS	CHEMICAL	FERTILIZERS AND DETERGENTS FROM LAWNS AND RUNOFF	EXCESSIVE ALGAE GROWTH CAN LEAD TO LOW DO
ZINC, ARSENIC, LEAD, MERCURY, CADMIUM, NICKEL	CHEMICAL	LANDFILLS; INDUSTRIAL DISCHARGES; RUNOFF	GENETIC MUTATIONS OR DEATH IN FISH & WILDLIFE (HUMAN HEALTH THREATS AS WELL)
SALT	CHEMICAL	SALTWATER INTRUSION (IF NEAR OCEAN)	KILLS FRESHWATER SPECIES OF PLANTS AND ANIMALS
MUD, SAND, OTHER SOLID PARTICLES (TURBIDITY)	PHYSICAL	EROSION AND RUNOFF FROM DEVELOPMENT; AGRICULTURE	REDUCES PHOTOSYNTHESIS IN AQUATIC VEGETATION; INTERFERES WITH RESPIRATION IN AQUATIC ANIMALS

WATER QUALITY FACTORS

There are 73 reported backflow incidents with metal contaminants—55 with copper and 18 with hexavalent chromium. Copper contamination is most commonly associated with backflow incidents at restaurants, where carbonated water can dissolve portions of water or soft drink dispenser piping made of copper. In 1987, a child in Minnesota suffered acute copper toxicity when the backflow from a carbon dioxide machine contaminated a restaurant's potable system (AWWA PNWS, 1995).

A similar incident at a fair in Springfield, MO, caused vomiting and abdominal pain in three people who drank soft drinks from a soft drink machine that had a faulty check valve (AWWA PNWS, 1995).

Potential health effects due to copper poisoning include vomiting, nausea, and liver and kidney damage; refer to the Chemical Health Effects Table for other potential health effects (US EPA, 2002a). CDC reports that the observed acute health effects due to copper poisoning outbreaks are gastrointestinal illness (CDC, 1996).

Chromium is used as a corrosion inhibitor. In 1970, a cross-connection between a chromate treated cooling system and the water supply at Skidmore College in New York, New York, caused five people to become nauseated (USC FCCCHR, 1993). In another incident in New Jersey in 1970, hexavalent chromium contamination occurred through a cross-connection of a building heating system and soft drink machine causing 11 people to become nauseated (USC FCCCHR, 1993). Potential chronic health effects are listed in the Chemical Health Effects Table (US EPA, 2002a).

Synthetic and volatile organic compounds Synthetic and volatile organic compounds as a group are contaminants in 66 reported incidents, with the most frequent contaminants being ethylene glycol (used in antifreeze), propylene glycol (used in antifreeze and as a food additive), freon (refrigerant), and propane (fuel).

Ethylene and propylene glycol were contaminants in 16 and 5 reported incidents, respectively. Examples include one incident in 1982, when ethylene glycol backsiphoned from an air conditioning system's water holding tank into a group of dialysis machines contributing to the death of "several" patients in Illinois (AWWA PNWS, 1995).

In 1985, backpressure from a hospital air conditioning system caused the introduction of ethylene glycol into the water system of a New York hospital. One woman died after being exposed while undergoing dialysis (CDC, 1987). In 1987, a cross-connection with a heating system contaminated the plumbing at a municipal building in North Dakota with ethylene glycol, causing acute illness in 29 people. Water from a spigot used to make flavored drinks contained 9 percent ethylene glycol. Reported health effects included excessive fatigue and dizziness, while two children experienced vomiting, excessive fatigue, and hematuria (CDC, 1987). Backflow of propylene glycol from a fire suppression system in 1993 into the potable water system of a park in Arizona occurred for at least 2 months before the point of entry was identified. Several employees reported nausea and intestinal upsets after drinking water during the period of contamination (Watts, 1998), which was discovered by taste and odor complaints.

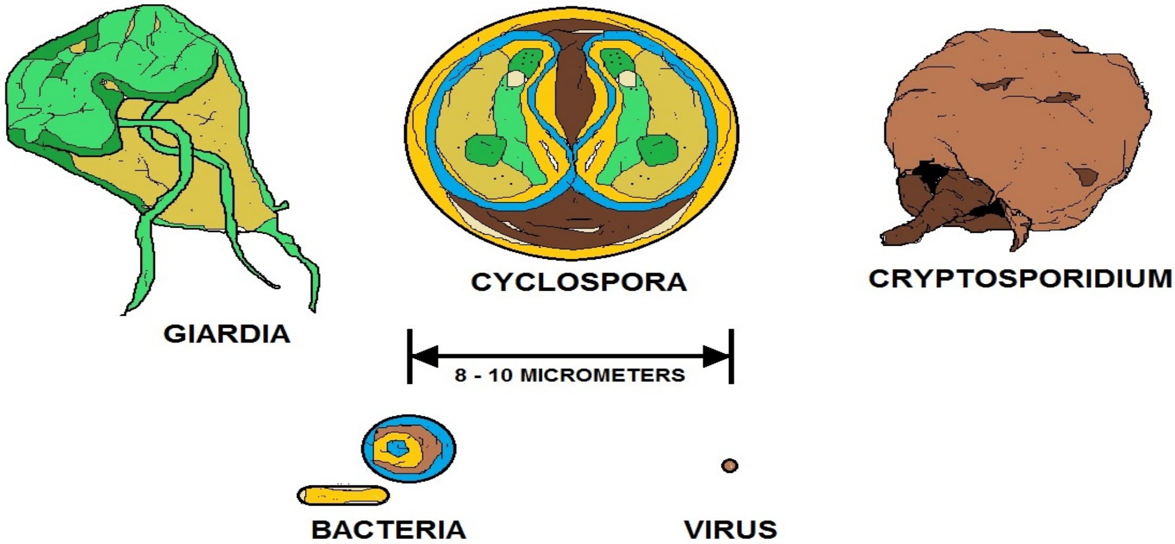
Freon and propane were contaminants in four and three reported incidents, respectively. In 1989, backpressure from a propane tank car forced propane into the water supply of Fordyce, Arkansas. Three people in separate buildings were injured from explosions after flushing toilets, and two houses were destroyed and a business was damaged by explosions and subsequent fires (AWWA PNWS, 1995). Backpressure from an air conditioning unit caused Freon to backflow into the distribution system in Franklin, NE. The contamination was detected when city residents complained of bad tasting water that caused a burning sensation in the mouth (AWWA PNWS, 1995).

Detergents were contaminants in nine reported incidents. Contamination of concentrated soap in 1995 from an incorrectly installed soap dispenser at a health care facility in Iowa affected 13 people was reported a burning sensation in their mouths and symptoms resembling the flu (CDC, 1998). In 1993 in Seattle, WA a temporary cross-connection at a car wash facility allowed soapy water in the distribution system, affecting an eight block area and causing two unconfirmed cases of illness (AWWA PNWS, 1992).

Nitrates and nitrites Nitrates and nitrites were contaminants in four reported incidents. Nitrate is a common ion found in natural waters and is used in fertilizers. Nitrite is typically not observed at significant levels (AWWA, 2001), however nitrate reduces to nitrite in the human body. In one incident in the county courthouse building of Monterey, CA, sodium nitrate from the boiler and cooler system backflowed into the potable water supply through a faulty backflow prevention device.

Nineteen people became sick and needed medical attention from drinking coffee from the courthouse snack bar (AWWA PNWS, 1995). An incident of nitrite contamination at a school in California caused illness in three people; a faulty double-check valve allowed chemicals from the chilling system to enter the school's potable water system (CDC, 1998). Another backflow incident through a cross-connection with a boiler and a faulty backflow prevention device occurred in New Jersey, causing six people to become ill with methemoglobinemia caused by nitrites (CDC, 1998). From the EPA Cross-Connection Manual.

Biological Contaminants from Cross-Connections



COMPARATIVE SIZES OF PROTOZOAN PARASITES

The risks posed by backflow of biological contaminants vary dramatically depending on the disease vector, the concentration and degree of infectivity of the pathogen, the level of disinfectant residual maintained by the water system, and the health of the individual exposed (Rusin et al., 1997). Infective dose studies of non-primary (opportunistic) pathogens on healthy individuals and animals, using the oral and intranasal route, demonstrate that very high doses (e.g., for bacteria, 106 -1010 cells) are needed for infection or disease (Rusin et al., 1997).

Pathogenic microorganisms (e.g., Giardia, some strains of E. coli) have contaminated potable water supplies through cross-connections with sewer lines, untreated surface water sources, reclaimed water supplies, equipment at medical facilities and mortuaries, and utility sinks, pools, and similar receptacles. In addition, drain lines, laboratories, and illegal connections of private wells and cisterns to public water supplies are primary sources of contamination (USC FCCCHR, 1993).

A majority of microbial incident reports (32 of 58) list the microbial contaminant as “sewage” or nonspecific microbes. In the summer of 1990, 1,100 guests of a country club in Tennessee suffered intestinal disorders in two mass incidents after consuming the club’s contaminated water supplied from an auxiliary well that had become contaminated with sewage due to a cross-connection (AWWA PNWS, 1995).

In February, 1990, a cross-connection between an auxiliary irrigation system supporting a golf course and country club and the Seattle Water Department’s distribution system resulted in total and fecal coliform contamination that was detected by neighboring systems purchasing water (AWWA PNWS, 1995).

The health effects from pathogens are often not specifically reported in the incident reports, making it more difficult to determine the type of microbial contaminant.

The combination of these reporting issues leads to underreporting of contamination linked to a specific pathogen.

The general health effects of most microbial pathogens include fever, nausea, and diarrhea, while some diseases have long-term and/or life-threatening effects. For example, the protozoan Giardia (a contaminant in 12 reported incidents) causes severe and potentially long-term diarrhea, accompanied by excessive gas, bloating, and weight loss. From backflow incident records collected by EPA, the most common microbial contaminants and their potential health effects are listed below with examples of backflow incidents.

Shigella
Shigella species are a cause of gastroenteritis, and are reported as contaminants in five incidents. The associated symptoms are vomiting, diarrhea, fever, and convulsions (US EPA, 2002b). All species of Shigella are highly infectious in humans and are spread through ingestion of fecal contamination (US FDA, 2001a). In one incident in 1977, a cross-connection led to four cases of shigellosis in an apartment house in Chicago, Illinois (USC FCCCHR, 1993). It is unknown whether the cross-connection spread Shigella into the distribution system.

E. coli
E. coli, a common biological contaminant (reported as a contaminant in two incidents) that is found in sewage, is normally a benign intestinal bacterium that is present in every human. However, some strains of E. coli are pathogenic, and can cause a variety of internal disorders. The most common effect is watery diarrhea, with some strains causing fever or dysentery. In rarer cases, some strains of E. coli can cause persistent diarrhea in young children, and have hemolytic properties. An infamous strain of E. coli is strain O157:H7, which, in addition to causing bloody diarrhea, can cause kidney failure (US EPA, 2002b). In 2000, two outbreaks of E. coli occurred in Medina County, OH, where approximately 30 became ill (Cleveland Plain Dealer, 2001).

Salmonella
Salmonella is one of the primary intestinal bacterial waterborne pathogens (reported as a contaminant in one incident). Depending on the strain, health effects can include typhoid fever, gastroenteritis (salmonellosis) (Benenson, 1995), and septicemia (US EPA, 2002b). In one incident, 750 people became ill with Salmonella enteritidis in Richland, Washington, in 1983. The incident involved new plumbing and contaminated ice (CDC, 1984). A person infected with the Salmonella enteritidis bacterium usually has fever, abdominal cramps, and diarrhea beginning 12 to 72 hours after consuming a contaminated food or beverage. The diarrhea can be severe, and the person may be ill enough to require hospitalization (CDC DBMD, 2001).

Campylobacter jejuni
Campylobacter jejuni is an avian gut bacteria that is the primary cause of bacterial diarrhea in the United States (CDC, 2002b). It is estimated that Campylobacter infects over two million people a year, and 10,000 cases are reported to the CDC annually, despite limited monitoring. Although Campylobacter is primarily a foodborne pathogen, it has been implicated in waterborne disease outbreaks in the past (CDC, 1996).
This bacteria can cause gastroenteritis with symptoms including bloody diarrhea, fever, and

abdominal cramping (US EPA, 2002b). In extreme cases, a Campylobacter infection may lead to Guillain-Barre syndrome where the immune system attacks part of the nervous system (CDC, 2002b). In 1986, 250 people became ill with diarrhea due to Campylobacter contamination in Noble, OK (CDC, 1996).

Cyanobacteria
Cyanobacteria are photosynthetic free-living bacteria. They produce algal blooms in fresh water, which can result in elevated toxin levels. Cyanobacterial toxins can produce acute neurotoxicity, hepatotoxicity, gastroenteritis, respiratory ailments, skin irritation, and allergic reactions through contact or ingestion (CDC, 2002c). In one incident in 1992, in Ritzville, Washington, backsiphonage from a drain sump near a new reservoir caused a reoccurring contamination of cyanobacteria (AWWA PNWS, 1995). From the EPA Cross-Connection Manual.

Norwalk and Norwalk-like viruses
The Norwalk family of viruses is a cause of viral gastroenteritis with symptoms of vomiting, diarrhea, upper respiratory problems, and fever (US EPA, 2002b). Although viral gastroenteritis is caused by a number of viruses, it is estimated that Norwalk or Norwalk-like viruses are responsible for about 1/3 of the cases of viral gastroenteritis not involving the 6-to-24-month age group (US FDA, 2001b).

People often develop immunity to the Norwalk virus, however, it is not permanent and reinfection can occur (US FDA, 2001b). In developing countries, the percentage of individuals who have developed immunity is very high at an early age. In the United States, the percentage increases gradually with age, reaching 50 percent in the part of the population over 18 years of age. Norwalk or Norwalk-like viruses were reported as a contaminant in two incidents.

In one incident in 1980 in Lindale, Georgia, 1,500 people became ill with a Norwalk-like acute gastrointestinal illness as a result of a contamination incident for which the specific chemical or microbiological contaminant was never determined (CDC, 1982).

Giardia
Giardia was a contaminant in 12 reported incidents. Giardia are intestinal parasites that exist in natural waters in a non-reproductive stage (cysts). They can cause diarrhea, as well as vomiting, cramps, and bloating (US EPA, 2002b). The mode of infection is through ingestion of fecally contaminated food or water.

The infections from these parasites are usually self-limiting, but among children, the elderly, and the immunocompromised, the infections can lead to chronic diarrhea, anemia, fever, and possibly death (Hoxie et al., 1997; US EPA, 1998; CDC, 2002a).

In 1979, Giardia was responsible for 2,000 illnesses after backpressure effluent from a tree bubbler system in an Arizona State park (Lake Havasu) contaminated the potable water supply (USC FCCCHR, 1993). In 1994, dozens of people became ill from Giardia contamination through a cross-connection between a drain and an ice machine at a convention in Columbus, Ohio (AWWA PNWS, 1995).

Other contaminants Biological contaminants that are non-microbial can also enter the distribution system. For example, due to a cross-connection at a funeral home, human blood and bodily fluids from the embalming process were backsiphoned into the distribution system, and blood flowed from water fountains and other water fixtures (US EPA, 1989). Human bodily fluids can be a vector for disease as well as being an aesthetic concern. From the EPA Cross-Connection Manual.

Evaluation of Hazard Policy - *Example*

The Department shall evaluate potential hazard to the public water supply which may be created as a result of a condition on a user's premises. However, the Department shall not be responsible for abatement of cross-connection that may exist within the user's premises.

This evaluation shall give particular consideration to the premises that involve the following type of situations of water uses:

(1) Premises where substances harmful to health are handled under pressure.
(2) Premises that boost the pressure of water delivered by the public water system.
(3) Premises which could expose the public water system to backflow.
(4) Premises having an auxiliary water supply.
(5) Premises where water from the public water system, under normal circumstances, could develop a polluted water source.
(6) Premises where entry for investigation or information regarding water use is restricted.
(7) Premises that contain a degree of piping system complexity and the potential for routine system modification.

1. Hazard Types
The type and degree of hazard potential to the public potable water supply and system from a customer's water supply system shall be determined using the following hazard factors:

a. **Plumbing Hazard** - an actual or potential plumbing type cross-connection that is not properly protected by an approved backflow prevention method.

b. **System Hazard** - an actual or potential threat that may cause severe damage to the physical facilities of the public water supply system or that may have a protracted effect on the quality of the water in the system.

2. Degree of Hazard
a. **Pollution** - (non-health) an actual or potential threat to the physical facilities of the public water supply system or to the public water supply that, although not dangerous to health, would constitute a nuisance or be aesthetically objectionable, or could cause damage to the system or its appurtenances.

b. **Contamination** - (health) any condition, device or practice that, in the judgment of the Department, may create a danger to the health and well-being of the public water users.

Water Quality Inspector-Backflow Unit Program Duty - *Example*

The technical and administrative demands for a Backflow Prevention Program are extensive for a water system the size of the City of Sunflower. These responsibilities cannot be met merely by delegating additional duties among existing staff and field personnel. Personnel possessing the appropriate administrative, technical and clerical skills need to be organized as a "*Backflow Prevention Unit*" to form the nucleus for such a program.

General Duties - Responsible for the enforcement of the City's Backflow Prevention Program and policy that include: system review, determining new service and retrofit replacements; field investigation and correction of backflow occurrences; and the review of testing and repair reports to ensure compliance.

Specific Duties:

(1) Conduct surveys of commercial and industrial water users to determine backflow prevention compliance.

(2) Meet with affected business groups to explain and promote the City's backflow prevention objectives.

(3) Act as Department representatives involving various requests regarding backflow prevention requirements.

(4) Review test report forms of backflow prevention devices.

(5) Investigate reported incidents of cross-connections or backflow problems.

(6) Perform quality assurance tests on backflow prevention assemblies repaired by certified general testers.

(7) Establish and update maintenance history files of backflow prevention assemblies.

(8) Monitor and track progress of retrofit requirements placed on individual commercial and industrial users.

(9) Remain current with backflow technology in order to answer general and technical inquiries about backflow prevention requirements.

(10) Maintain General Tester certification.

Backflow Requirements - *Example*
TABLE 7.1

Facilities or Activities Requiring Backflow Assembly
The following criteria will be used to determine the backflow prevention requirements for all service connections:

1. Specified Facilities or Activities
When any of the following activities are conducted on premises served by the public potable water system, a potential hazard to the public potable water supply shall be presumed and a backflow prevention method, of the type specified for that activity herein, must be utilized or installed at the service connection for that premise.

(1) Aircraft and missile plants: RP
(2) Animal clinics and animal grooming shops: RP
(3) Any premises where a cross-connection is maintained: RP
(4) Automotive repair with steam cleaner, acid cleaning equipment, or solvent facilities: RP
(5) Auxiliary water system: RP
(6) Bottling plants, beverage or chemical: RP
(7) Breweries: RP
(8) Buildings with house pumps and/or potable water storage tank: RP
(9) Buildings with landscape fountains, ponds, or baptismal tanks: Air Gap or RP
(10) Building with sewage ejector: Air Gap or RP
(11) Canneries, packing houses, and reduction plants: RP
(12) Car wash facilities: RP
(13) Centralized heating and air conditioning plants: RP
(14) Chemical plants: RP
(15) Chemically treated potable or nonpotable water system: RP
(16) Civil works (government owned or operated facilities not open for inspection by the Department): RP
(17) Commercial laundries: RP
(18) Dairies and cold storage plants: RP
(19) Dye works: RP
(20) Film processing laboratories: RP
(21) Fire system-American Water Works Association Classes 1, 2. Any system constructed of a piping material not approved as a potable water system material per the Uniform Plumbing Code as adopted by the City: DC
(22) Fire system-American Water Work Association Classes 3, 4, 5, 6: RP
(23) Food processing plants: RP
(24) High schools, trade schools and colleges: RP
(25) Holding tank disposal stations: RP
(26) Hospitals and mortuaries: RP

(27) Irrigation systems (not to include single family detached residences):

a. Premises having separate systems used in elevated areas: RP

b. Premises having nonpotable water piping (lawn sprinklers) two (2) inches and smaller: PVB

(28) Laboratories using toxic materials: RP

(29) Manufacturing, processing, and fabricating plants: RP

(30) Medical and dental buildings, sanitariums, rest and convalescent homes engaged in diagnosis, care or treatment of human illness: RP

(31) Motion picture studios: RP

(32) Multiple Services Interconnected: RP or DC

(33) Multiple Use Facilities/activities - When two or more of the activities listed above are conducted on the same premises and served by the same service connection, the most restrictive backflow prevention method required for any of the activities conducted on the premises shall be required at the service connection. The order of the most restrictive to least restrictive backflow prevention method shall be as follows:

(A) Air Gap (most restrictive)

(B) Reduced Pressure Principle Assembly (RP)

(C) Pressure vacuum Breaker Assembly (PVB)

(D) Double Check Valve Assembly (DC) (least restrictive)

(34) Oil and gas production plants: RP

(35) Paper and paper production plants: RP

(36) Plating plants: RP

(37) Portable insecticide and herbicide spray tanks: Air Gap or RP

(38) Power plants: RP

(39) Radioactive materials processing facilities: RP

(40) Recreational vehicle parks, trailer parks (seasonal): RP (41) Restricted, classified, or other closed facilities: RP

(42) Rubber plants: RP

(43) Sand and gravel plants: RP

(44) Sewage and storm drainage facilities: Air Gap or RP

(45) Street sweepers, steel wheeled rollers: Air Gap or RP

(46) Temporary Services-Construction water: Air Gap or RP

(47) Water trucks, water tanks, hydraulic sewer cleaning equipment: Air Gap or RP

2. Non-Specified Facilities or Activities

The Department shall determine backflow prevention requirements for all other facilities or activities not specified herein. This determination will be on a case by case basis and shall require the consumer to comply with all other provisions within the policy.

3. Private Fire Hydrants

When a single fire service connection provides service solely to privately owned fire hydrants upon a premise no protection is required provided: 1) The fire system is designed, furnished, installed and tested in conformance with current department specifications. 2) The entire route of the service pipe shall constantly remain visible from the point of connection.

Installation Requirements - *Example*

1. **General Requirements:**
(a) Backflow prevention assemblies shall be installed by the user, at the user's expense, in compliance with the standards and specifications adopted by the City, at the service connection. The assembly or assemblies shall be sized equivalent to the diameter of the service connection.

(b) All assemblies shall be installed in a manner as to be readily accessible for testing and maintenance. It will be located as close as practicable to the point of service delivery. A reduced pressure principle assembly, a double check valve assembly and a pressure vacuum breaker assembly shall be installed above ground. With the Department's approval, a double check valve assembly may be installed in below ground vault.

(c) An air-gap separation shall be located as close as practicable to the user's point of service delivery. All piping between the user's connection and receiving tank shall be entirely visible unless otherwise approved by the City.

(d) It shall be unlawful, and punishable as a misdemeanor, for any person to bypass or remove a backflow prevention method without the approval of the City.

(e) **Fire Protection Systems** - the user shall make proper application to the Fire Department for a permit prior to installation of an assembly on an existing fire system.

2. **Continuous Water Supply**
(a) **Domestic or Building Supply Systems** - when a customer desires a continuous water supply during testing and repairs, two or more backflow prevention assemblies shall be installed parallel to one another at the service connection to allow a continuous water supply during testing of the backflow prevention assemblies.

(b) **Fire Protection Systems -** where it is determined by the Sunflower Fire Department that a fire sprinkler system shall have a continuous water supply that may not be interrupted during testing and maintenance of the backflow prevention assembly, the user shall install two backflow prevention assemblies parallel to one another at the service connection.

The diameter of each assembly shall be as approved by the Fire Department.

Testing Frequency

1. **General Requirements:**
(a) The user shall test backflow prevention assemblies at least once a year. Affected user will be notified of the testing due date. If the test reveals the assembly to be defective or in unsatisfactory operating condition, the user shall perform any necessary repairs, including replacement of the assembly if necessary, which will return the assembly to satisfactory operating condition.
(b) As a condition of water service, the user is responsible for the effective operating condition of the backflow prevention assembly at all times.
(c) All expenses associated with the annual testing and maintenance of backflow prevention assemblies shall be the responsibility of the user.
(d) The Department reserves the right to require more testing.

Qualified Certified General Testers List *Policy Example*
The purpose of this list is to identify qualified general testers for user/customer to contact and hire for backflow assembly testing.

(a) The Department may recognize other agencies or organizations involved with the training and certification of testers.
(b) It is the responsibility of the certified general tester to submit accurate and current certification to the Backflow Unit of the Water Quality Division. A list of certified general testers will be maintained by the Department and made available upon request to all users required to install or maintain a backflow prevention assembly.
(c) The Department may disqualify a tester, at any time, without warning, for any malfeasance or misrepresentation.

Compliance Program *Example*

1. New Service Connections
(a) An approved backflow prevention assembly shall be installed and maintained at every service connection to a user's water system when the Department determines that the water supplied by the public water system may be subject to contamination, pollution or other deterioration in sanitary quality by conditions within the user's water system.

(b) The backflow prevention method to be utilized shall be determined by the Department. The method shall be sufficient to protect against the potential hazard, as determined by the Department, to the public water supply.

2. Existing Service Connections
(a) The provision herein shall apply to all new water customers and all water customers existing prior to enactment date of this policy.

(b) Backflow prevention assemblies installed prior to enactment of this policy that do not comply with these requirements shall be replaced at the user's expense with assemblies that comply with the standards set forth herein.

(c) All existing water service connections will be subject to a survey by the Water and Wastewater Department to identify water user premises where service protection is required. The selection of service connections to be surveyed will be determined by the Department and based on suspected hazards. A letter of notification will be sent to all users identified to install, upgrade, or utilize a backflow prevention assembly. The user shall have no more than twelve (12) months from the date of notification to comply with requirements set forth in this policy.

(d) A water user survey will automatically be initiated should a user apply for a building permit to install or modify existing plumbing. This investigation may be performed by the Development Services Department in conjunction with the plan review or the permit application process. The issuance of a building permit requiring that a backflow prevention assembly be installed, upgraded, or utilized shall constitute written notice and shall hold the user responsible to the provisions set forth in this policy.

(e) A permit from the Fire Department, Division of Fire Prevention, shall be secured prior to issuance of a Building Permit for any retrofit application.

Failure to Comply

1. **Notice of Violation**
(a) Prior to disconnecting any water service, the Department shall make written notification to the user describing the violation and give notice that the condition must be remedied within forty-five (45) days. If such condition is not remedied within (45) days, the Department shall send a second notice, by certified mail, notifying the user that water service will be discontinued in fifteen (15) days if the condition is not remedied within such time period.

2. **Discontinuance of Water Service *Example***
(a) If the customer within the time specified in this section:
- fails to install a required backflow prevention assembly; or
- fails to properly test; or
- fails to properly maintain a backflow device; or
- bypasses or removes a backflow device; or
- fails to submit records of tests and repair of a backflow device; or
- has an identified unprotected cross-connection existing in the user's water system; then water service to that service connection shall be discontinued. Their service shall not be restored until the condition is remedied. See Appendix I - Section IV.

(b) Water services to a fire protection system shall not be subject to disconnection under this section. If the situation is not remedied within the time specified to the user, the user may be issued a citation for a misdemeanor offense. Each day the situation is allowed to continue thereafter shall constitute a separate violation of this section.
(c) The Department shall disconnect, without notice, water service to any customer when the Department discovers or determines that the customer's water system is contaminating the public water supply.

3. **Citations *Example***
(a) If a situation, which would otherwise result in discontinuance of water service in section (2), subsection (b) above, is not remedied within the time provided in the notice sent to the customer, the customer may be issued a citation for a misdemeanor offense. Each day the situation is allowed to continue, thereafter, shall constitute a separate violation of this section.

(b) If a customer commits a deliberate act to fraud, misrepresent, falsify or act in an unauthorized capacity in violation of this policy relating to falsification of records, the deliberate bypass of a backflow prevention device, the illegal restoration of a service or the willful withholding or concealing of information or activity for the purpose of avoiding service protection requirements, a citation for a misdemeanor offense may be issued for each separate violation of this policy. See Appendix I - Section V.

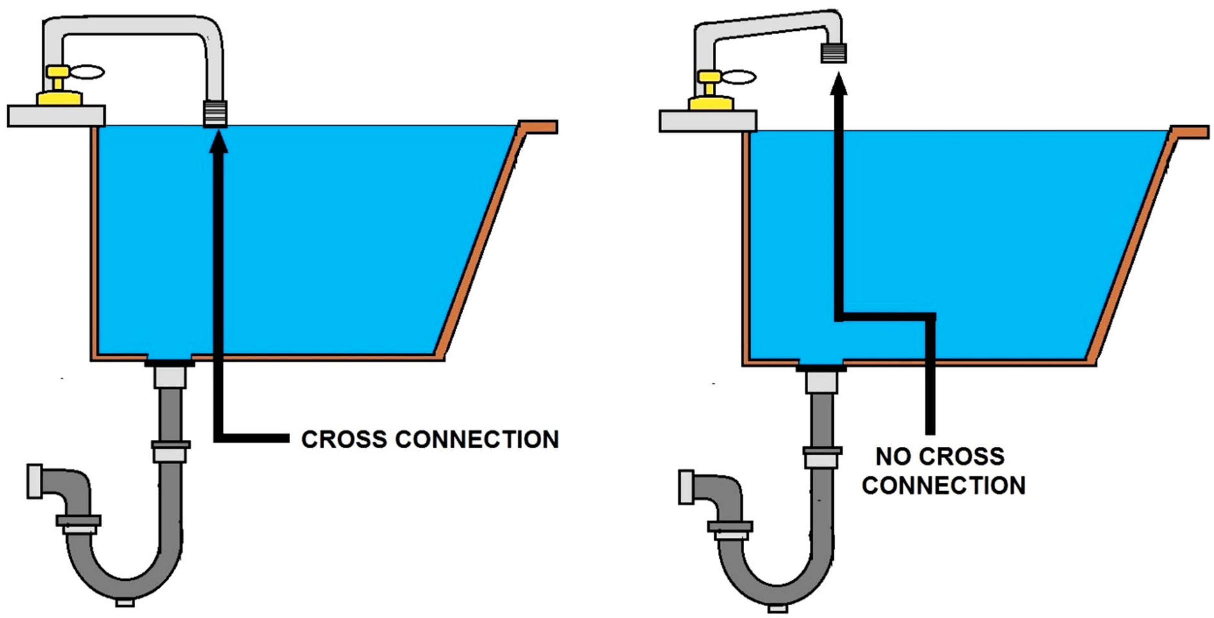
Records Requirements - *Policy Example*

(a) The user/customer shall submit on forms approved by the Department, results of all tests, repairs to, or replacement of backflow prevention assemblies.

(b) Submitted records shall be completed and signed by a certified general tester.

(c) The user/customer shall be responsible for prompt submission of records to the Department after completion of the activity for which the record is made. Failure to submit records within the time frames established by the Department shall constitute a violation of this policy. Refer to Section VI.E., Failure to Comply, for more details.

(d) It is recommended records be kept by the user and tester for at least three (3) years.



Incident Response Plan *Example*

1. **Introduction**

This is a reference document to be used in incident and emergency incident response situations affecting public drinking water supplies. Although every effort has been made to make this document as complete as possible, the user must recognize that not every situation can be anticipated. The responder may be called upon to use their best judgment in a given situation.

(a) **Incident Response** ***Example***

A customer complaint is usually handled by contacting Customer Services, 262-6215 between 8:00 a.m. and 5:30 p.m. on weekdays and Water Distribution, 261-8000 after 5:30 p.m. and on weekends. If the complaint concerns system problems (pressure, leaks) the complaint is referred to the Water Distribution Division.

If the complaint is in reference to the quality of the water (taste, odor, color), the complaint is referred to the Water Quality Division, Water Monitoring Unit.

The Water Monitoring Unit will perform a phone interview to determine the seriousness and magnitude of the water quality problem. If it is felt that the situation warrants, a member of the Water Monitoring Unit will visit the site to perform an inspection and sample the water at the site.

The samples will be delivered to the Water Quality Laboratory for analysis. If the inspector suspects the water has been contaminated by an outside source through a possible cross-connection, the Backflow Prevention Unit will be notified.

Upon notification of a possible backflow incident, the Backflow Prevention Unit will visit the site, perform an inspection of the premise for possible cross-connections, and evaluate the water use within the premises. A determination of the proper backflow protection will be made and notification to install the assembly may be issued.

The water may be turned off at the service connection if it is determined that the user's water system is contaminating the public water system.

The appropriate Customer Services Area Field Supervisor will be notified of the water being turned off. Also notify Customer Services that the water was turned off.

Emergency Incident Response *Example*

An emergency incident response to a possible backflow situation would be triggered if it involved a health hazard concerning the potable water system. Notification of such an incident could come from the Health Department directly to the Water Quality Division or from 911. The 911 dispatcher then notifies the City Operator that there is an incident involving the water distribution system, who in turn notifies the Water Distribution 24 hour Emergency Dispatcher.

This dispatcher then notifies the Water Distribution Superintendent, the Water Quality Superintendent and the Water and Wastewater Information Officer. The Water Distribution Superintendent notifies and dispatches the appropriate crews to isolate, flush, or neutralize the contamination. The Water Quality Superintendent will notify the Chief Water Quality Inspector who will then dispatch the Water Monitoring Unit and/or the Backflow Prevention Unit to perform their duties as described in the incident response section. The Water Quality Lab would submit a written report to the Water and Wastewater Information Officer who would handle all media contact. See Appendix I - Section VI.

2. Reports and Records *Example*

(a) Customer

In the event the customer's water system or the public water system is contaminated or polluted due to a cross-connection or other cause, and the customer has knowledge of such an event, the Department shall be promptly notified by the customer so that the appropriate measures may be taken to overcome the contamination. The customer shall submit a written incident report within 72 hours of first knowledge of the event.

The report shall address all of the following:

1. Date and time of discovery;
2. Nature of the problem;
3. Affected area;
4. Cause of the problem;
5. Public health impact;
6. Corrective action taken;
7. Date of completion of corrective actions.

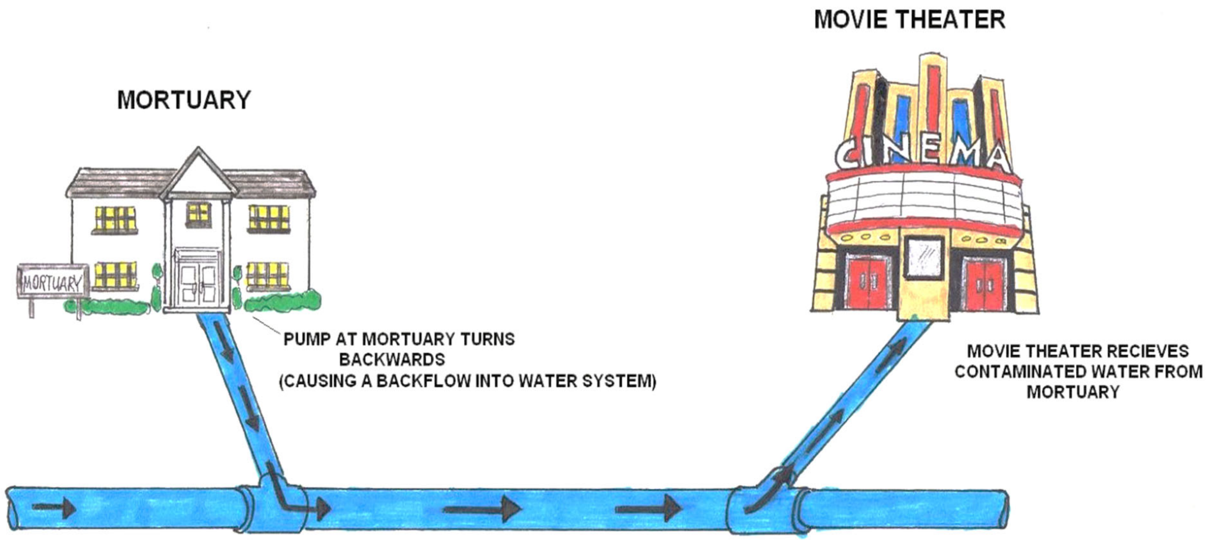
(b) Water Purveyor

The water purveyor shall submit a written cross-connection incident report within five business days to the Department of Environmental Quality or equivalent agency and the local health authority whenever a cross-connection problem has occurred which resulted in contamination of the public water system.

The report shall address all of the following:

1. Date and time of discovery of the unprotected cross-connection;
2. Nature of the cross-connection problem;
3. Affected area;
4. Cause of the cross-connection problem;
5. Public health impacts;
6. Dates and text of any public health advisories issued;
7. Corrective actions taken; and
8. Date of completion of corrective actions.

Accurate records and reports must be written and maintained because unfortunately the end result of a backflow incident will probably be a court case, and the damages ensuing may be partly the water purveyor's responsibility.

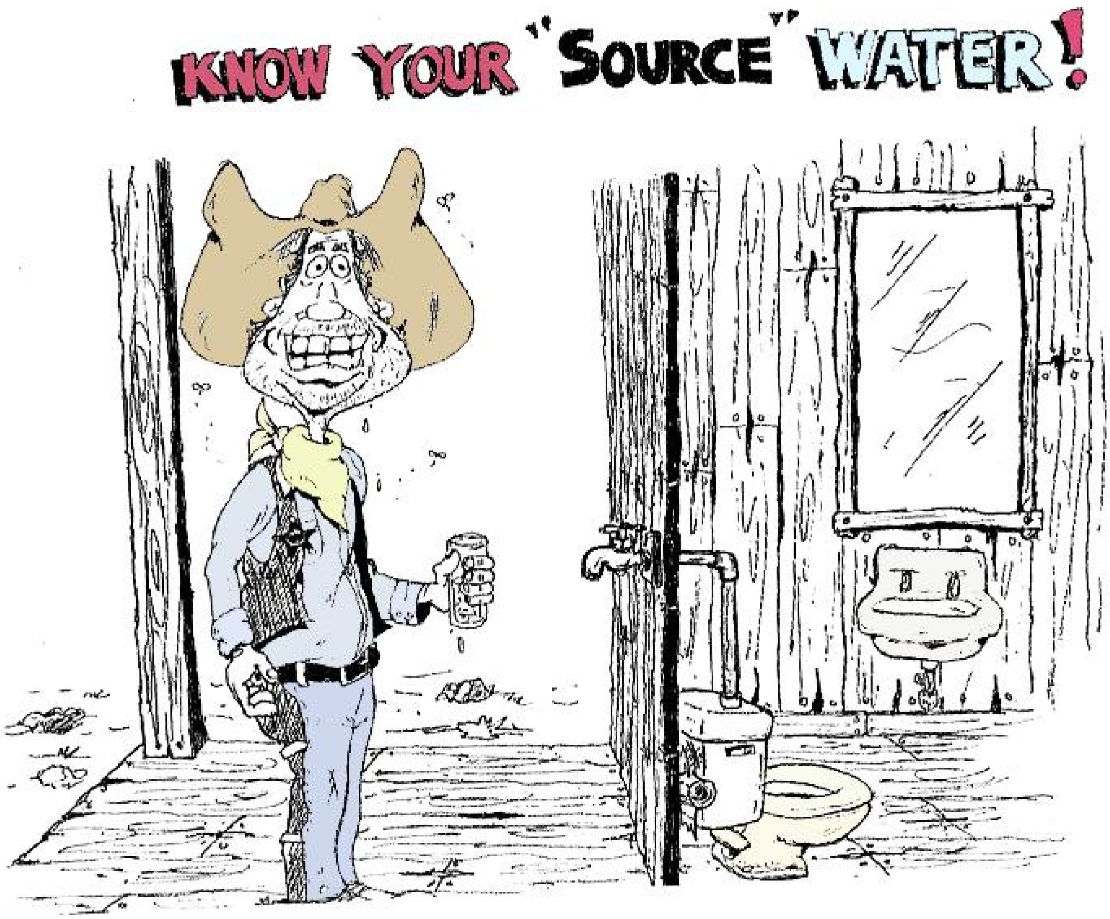


Notification Letters/Forms Examples and Related Documents

Example of frost protection.

I've seen everything from a fake rock to a fake statue to protect or hide an assembly. This frost protection and assembly protection stuff has grown into a full blown industry. There are people that only install protective devices and don't even test the assembly because they have too much work.

The following are several examples of backflow related letters and notices.


KNOW YOUR "SOURCE" WATER!

April 30, 2021

ABC Company
12345 North Beeline Highway
Sunflower, Arizona 85547

Dear Wyatt Curtiss:

Example of a regulatory letter

In order to protect the public water supply from contamination, State and local regulations require approved backflow prevention assemblies for your water service lines. These assemblies, which should be located on your domestic, fire sprinkler and/or landscape water supply lines, are due for an annual operation test. This test must be performed by a backflow prevention assembly tester who possesses a valid certification. A list of certified testers recognized by the Sunflower Water Department has been enclosed to assist you in selecting a qualified contractor.

Prices charged for installation, testing and/or repair of assemblies can vary widely between contractors. So, for your own protection, carefully check service costs and qualifications before employing a contractor for your assemblies. Generally, testing costs range from approximately $35-50 per assembly. If needed, repairs are usually an additional expense.

You are responsible for submitting test results for your assemblies *on the proper form* to the Town of Sunflower Water Department no later than June 07, 2005. Test forms and information packages are available at no charge from the Town of Sunflower Water Department located at 303A North Beeline Highway.

If you have any questions about the testing requirements, or need additional information, please contact me at (520) 474-5242, Ext. 235 or Michael Ploughe at Ext. 284.

Sincerely,

Jim Bevan
Water Resources Specialist

< DATE > <CERTIFIED MAIL>

< CONTACT > OR
< TITLE >
< COMPANY NAME> <HAND DELIVERED TO:>
< STREET ADDRESS >
< CITY AND STATE AND ZIP >

REMINDER NOTICE

Annual Testing Requirement Example

Dear------------------------:

In reviewing our files, we have been unable to find this year's test results for your backflow device(s) (see attached).

City Ordinances G3672 / G3674 require yearly testing of all containment backflow devices. These Ordinances also require reporting the results to:

City of Sunflower
Pollution Control Division
Backflow Prevention Unit
2303 West Beeline Street
Sunflower, AZ 85009

We are notifying each customer at least 30 days in advance of their yearly test date. If we have missed notifying you previously, please accept this letter as that notification. If you have forgotten to test or mail the test results, please consider this letter a reminder. We appreciate your continued co-operation.

Should you have any questions please contact me at (602) 534-2140. Our office hours are 8:00 a.m. to 5:00 p.m., Monday through Friday.

Sincerely,

Scott Stratton
Senior Water Quality Inspector
Backflow Prevention Unit

Enclosure

< DATE > <CERTIFIED MAIL>

< CONTACT > OR
< TITLE >
< COMPANY NAME> <HAND DELIVERED TO:>
< STREET ADDRESS >
< CITY AND STATE AND ZIP >

NOTICE OF FAILURE TO COMPLY

Annual Testing Requirement *EXAMPLE*

Two notices have been sent to you requesting the annual testing of the containment backflow prevention assembly(s) (see attached notices). We have not received the test report(s) as of the date of this letter.

This is the last notification. A passing test report for the containment device(s) must be received by <DATE>. The mailing address is:

City of Sunflower
Pollution Control Division
Backflow Prevention Unit
2303 West Beeline Street
Sunflower, AZ 85009

FAILURE TO COMPLY WITH THE REQUIREMENTS OF THIS LETTER MAY RESULT IN A REVIEW MEETING BEING SCHEDULED TO DISCUSS THE FOLLOWING APPLICABLE ENFORCEMENT ACTIONS OUTLINED IN CHAPTER 37 OF THE SUNFLOWERCITY CODE.

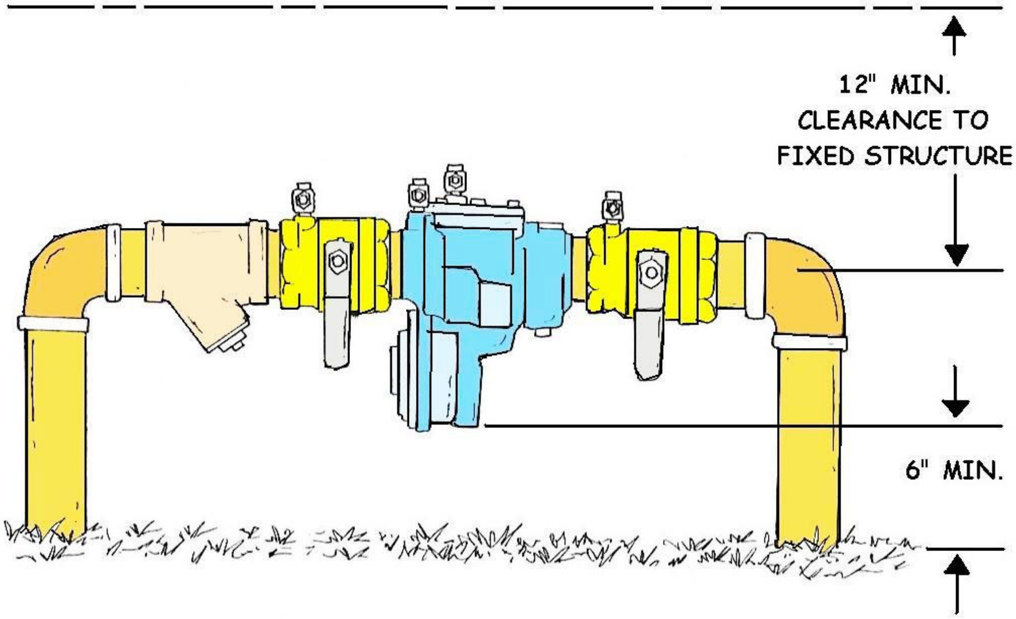
- A civil penalty not to exceed one thousand percent per billing period on the charges for all water used beginning from the date the corrective action was required and until the corrective action has been completed by the customer.
- Publication in the largest daily newspaper published in the City as a violator of the requirements of Chapter 37.
- TERMINATION OF WATER SERVICE.
- All costs, fees, expenses incurred, surcharges, and penalties relating to the termination and restoration of water service shall be paid by the customer prior to the water service being restored.

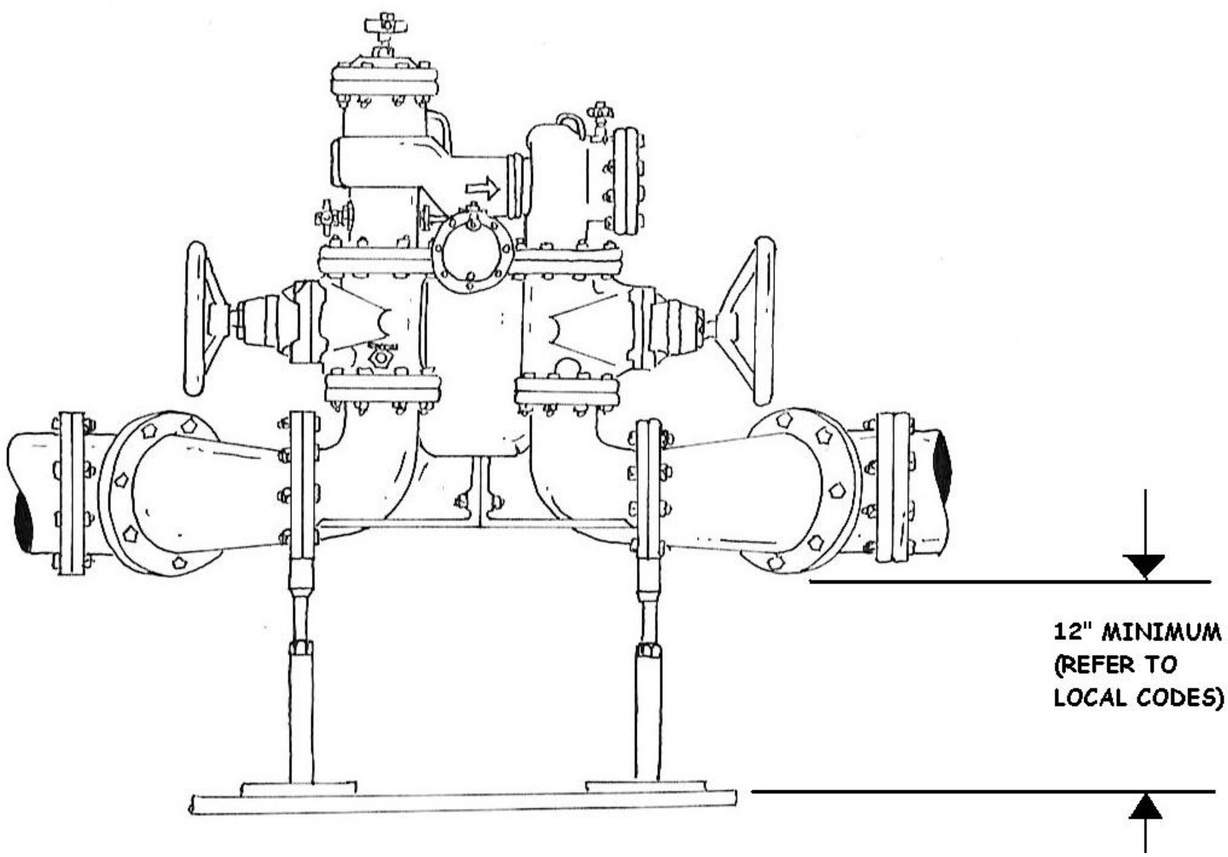
Should you have any questions regarding this Notice, please call me at 534-9506. Our office hours are 8:00 a.m. through 4:30 p.m., Monday through Friday.

Sincerely,

Bill Fields
Chief Water Quality Inspector
Backflow Prevention Unit

Enclosures


12" MIN.
CLEARANCE TO
FIXED STRUCTURE
6" MIN.


12" MINIMUM
(REFER TO
LOCAL CODES)

Date: December 11, 2021

To: Bill Fields, Public Works Director

From: Chris Mitchell, Water Resource Specialist

RE: Owner's refusal to install Required Backflow Prevention Assembly at Sunflower Car Wash - 114 W. Kiedel Street

<u>Current State and Local Backflow Requirements</u>

Current state drinking water regulations adopted by the Arizona Department of Environmental Quality require a water supplier to "protect its public water system from contamination caused by backflow through unprotected cross connections by requiring the installation and periodic testing of backflow prevention assemblies" (A.A.C., Title 18, Chapter 4, Article 1, Section R18-4-115). In addition, Sunflower Town Ordinance Number 422 adopts Resolution Number 1016 which establishes rules, regulations and penalties relative to cross connection control for users of the public water supply.

Section 13-4-3, Part I of Town of Sunflower Resolution Number 1016 [Discontinuance of Service] states the penalty for failure to comply with backflow prevention requirements as follows:

"Service of water to any premises may be discontinued by the Department if a backflow prevention assembly required by this ordinance is not installed, tested and maintained; if it has been found that a backflow prevention assembly has been removed or bypassed; or if a cross connection exists on the premises. Service will not be restored until such conditions or defects are corrected. Sunflower may also terminate a user's service upon twenty (20) days' notice in writing in non-emergency."

<u>Procedure Used to Notify Sunflower Water Customers of Backflow Prevention Requirements</u>

Sunflower Water Department staff has designed a backflow prevention program that is designed to help customers achieve compliance with state regulations and local ordinance. Customers who are required to install a backflow prevention assembly at their water meter are notified of the requirement as follows:

Water Department staff mailed a "First Notice" letter to customers who are required to install a backflow assembly at their water meter. If the customer does not comply with the requirement after 30 days, a "***Second Notice***" letter is mailed. If the water customer does not install and test the required backflow assembly after 60 days, a "***Water Service Shutoff Notice"*** is mailed to the customer [Refer to copies of attached letters].

Water Department staff also telephone the water system customer to verify that they have received the backflow prevention letters, to answer their questions about the requirements and to advise them that their water service will be discontinued if the specified assemblies are not properly installed and tested.

Schedule of Notification for Sunflower Car Wash

On June 04, 2017, a first notice letter was mailed to the property owner of Sunflower Car Wash located at 114 West Kiedel Street. A second notice letter was mailed on July 29, 2017. The owner of the car wash, Mr. Duane Smith, did not respond to either letter. Finally, on November 07, 2013, Town staff mailed a letter to advise Mr. Jones that his water service would be discontinued if he did not comply with the backflow prevention requirements within thirty (30) days of the final notice.

Mike Ploughe, Hydrogeologist for the Sunflower Water Department, attempted to contact Mr. Jones several times after mailing the final notice. During the third week in November, 2013, Mr. Jones left a voice mail message at my extension, and said that he didn't think an assembly was needed at his car wash. I asked Mike Ploughe to contact him and schedule an on-site survey. Mike was unable to contact Mr. Jones until Tuesday, December 10, 2017.

On Wednesday morning, December 11, 2016, Mike surveyed the site, but was uncertain if the mixing basins for the car wash chemicals were properly air-gapped. As a result, I contacted Mr. Jones at the car wash in the afternoon and resurveyed the site. Several backflow hazards exist at the facility. First, the mixing basins for the car wash chemicals are not properly air-gapped. The water inlet for the basins is below the rim of the receiving vessel, which violates the air-gap requirements of the Uniform Plumbing Code. Furthermore, the car wash facility has two hose bibs with attached hoses that are not protected against backsiphonage.

Owner's Refusal To Comply With Backflow Prevention Requirements

When I showed Mr. Jones the backflow hazards and explained the requirements for installation and testing of a backflow prevention assembly, Mr. Jones told me that he would not comply with the requirements if it would cost him too much money.

He looked through a plumbing supply catalog for a few minutes and estimated that he would probably need to pay $500-900 for the installation and an additional $50 - 75 for the testing. Then he told me that he had already contacted his lawyer, and that we should shut off his water and he would see us in court.

TOWN OF SUNFLOWER
Backflow Prevention Program *(Checklist Example)*

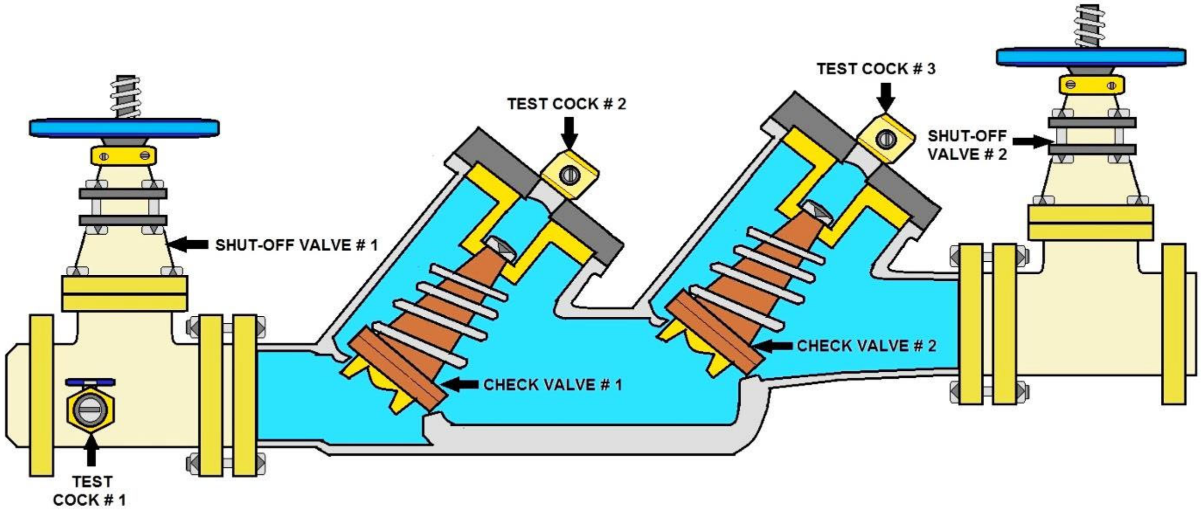
Developers, Contractors and Sunflower Residents:

An approved backflow prevention assembly may be required on your water service line(s) to protect the public water system from the possibility of contamination. The assemblies, required by State and local regulations are not needed on most single family residential water services, but are required for most industrial, commercial, irrigation and fire sprinkler service connections.

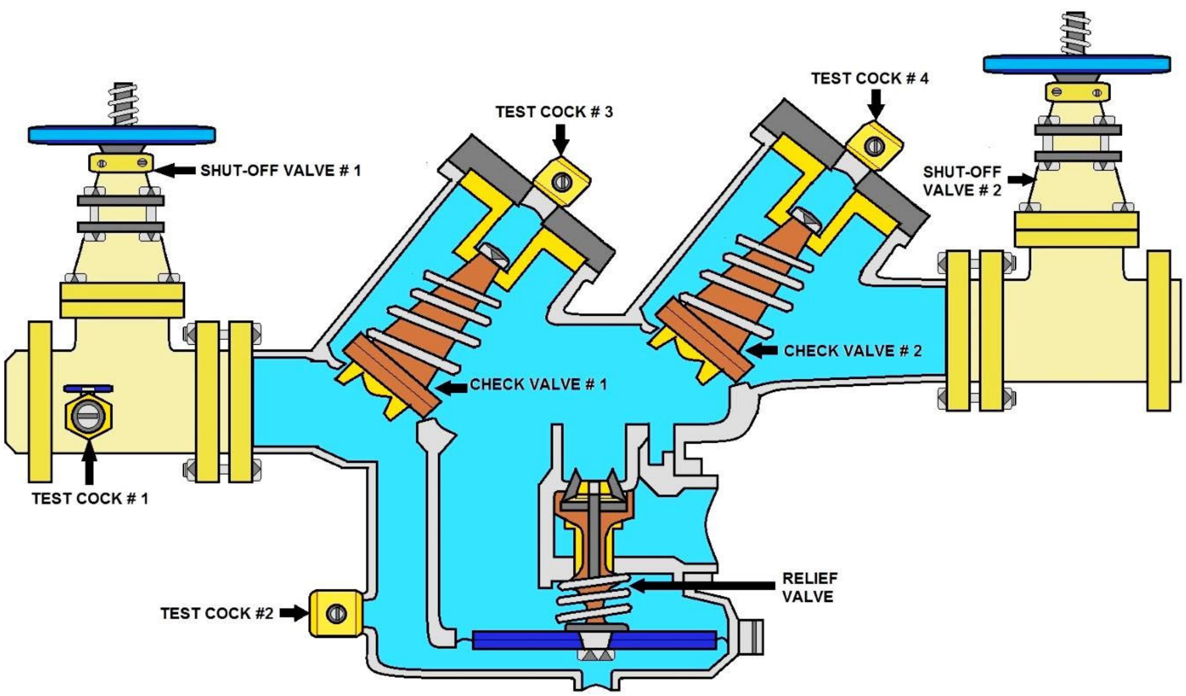
This information package is designed to explain the Town of Sunflower's Backflow Prevention Program and provide you with information you will need to install and test your backflow prevention assemblies.

Inside you will find the following information:

- **Backflow: Protecting Our Water Quality**: General backflow prevention information.
- **Program:** Outlines customer and Sunflower Water Department's responsibilities for backflow prevention.
- **Customer Checklist:** Lists steps necessary for permitting, installation, testing and final approval.
- **Permit Application:** Application and two signed forms needed to obtain an installation permit.
- **Freeze and Theft Protection:** A list of manufacturers who produce heating devices and locking enclosures to safeguard your assemblies.
- **Standard Details and Approved Assemblies:** Sunflower Water Department Standard Details for assembly installation and information on currently approved assemblies.
- **Testers:** A directory of Sunflower Water Department approved Certified Backflow Testers. This list is presented in random order and may not include recent changes. Ask the contractor about current registration with Sunflower Water and insurance coverage before work is performed.
- **Fire:** Special information relating to fire services and systems.



DOUBLE-CHECK BACKFLOW ASSEMBLY



REDUCED PRESSURE BACKFLOW PREVENTION ASSEMBLY

CUSTOMER CHECKLIST FOR NEW AND RETROFIT INSTALLATIONS *(Example)*

INSTALLATION OF A BACKFLOW PREVENTION ASSEMBLY REQUIRES THE FOLLOWING ITEMS:

STEP 1) Inspections Required: Install required assemblies and call the Backflow Prevention Staff at 978-5242, Ext. 379 to schedule an inspection.

a) Inspection for Correct Installation (Use Attached Town of Sunflower Standard Details).

b) Inspection of Underground Piping- *DOES* ***NOT BACKFILL THE TRENCH UNTIL SUNFLOWER WATER DEPARTMENT STAFF HAVE APPROVED YOUR INSTALLATION.***

c) Inspection for Adequate Clearance from obstructions to permit proper testing.

d) Inspection for use of assemblies approved by the University of Southern California Foundation for Cross Connection Control and Hydraulic Research (USC FCCCHR) approved assemblies [Call the Sunflower Water Department to check on current approvals].

***** The Town of Sunflower will specify what types of assemblies are needed to protect each service connection during the plan review process. Specific locations of installed assemblies must be reported to the Water Department for testing and recordkeeping purposes. Assemblies must be installed as close to the service connection (downstream side of the water meter) as practical, unless an alternate installation location has been approved by the Sunflower Water Department. [Town Ordinance Article 13, Section 13-4-3, Number 422] [State of Arizona Administrative Code - Title 18, R18-4-115]

STEP 2) Testing Requirements:

a) After the installation inspection and approval, each backflow prevention assembly must be tested by a certified contractor prior to active use (refer to attached list of backflow prevention assembly general testers). Water service will be discontinued if backflow assemblies are not properly tested prior to occupancy!

b) Submit test reports to the Sunflower Water Department after completion of the tests (Use Attached Form) at the following address:

Attention: Backflow Prevention Program
Town of Sunflower Water Department
978A North Beeline Highway
Sunflower, Arizona 85547

c) Annual testing of each assembly is required. Reminder notices will be sent by the Water Department.

STEP 3) Requirements for Final Approval:
a) All Final Inspections and Testing Complete
b) Chains and locks on fire lines to keep them in the open position and prevent system shut off.

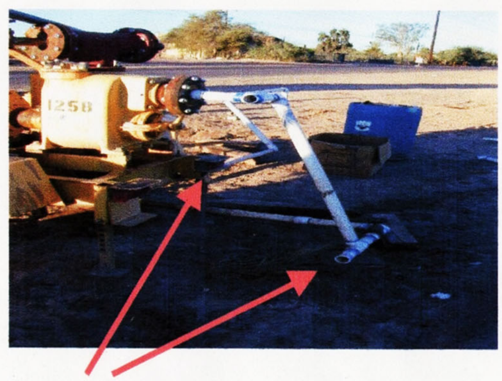
If you have any questions about this program, please contact the Backflow Prevention Department at (520) 978-5242, Ext. 379.

Possible Bad Connection

Direct connection from hyrant to pump.

Air Gap

Fitting at hydrant



Lines cut but it had been connected to a chemical barrel earlier.

Why does a soft drink dispensing machine require backflow protection?
Soft drink dispensers (post-mix carbonators) use carbonated water mixed under pressure with syrup and water to provide soft drinks beverages. Many, if not most water pipes are made of copper. When carbonated water comes into contact with copper, it chemically dissolves the copper from the pipe. This copper-carbonate solution has been proven to be a risk to the digestive system.

Closed-Loop Water System Form *(Example)*

WARNING - HOT WATER HEATER LEAK, RUPTURE OR EXPLOSION HAZARD!
Normally, cold water flows in from your water service line and fills your hot water heater. Then, as the water is heated, it expands and flows back out through the pipe towards the water meter. As long as the flow of the expanded water is not blocked, the water pressure in the service line remains normal. However, when a backflow preventer is installed, the hot expanded water can no longer escape out through the water meter.

In this case, the only way to prevent excessive heat and pressure from building up in the service line is to install a temperature and pressure (T&P) relief valve on the water heater and an expansion tank to the water system (1991 Uniform Plumbing Code- Section 1007). Other forms of added protection include toilet tank relief valves and in-line relief valves.

The T&P relief valve should be checked regularly to ensure that it is functioning properly. This test should be performed on an annual basis when the backflow prevention assembly is tested.

If you understand this information, please sign and return this form to obtain your assembly installation permit. If you do not understand this information, please contact the Backflow Prevention Office at (520) 978-5242, Ext. 379.

I, the undersigned, do hereby state that I fully understand the potential hazards of a closed water system and the consequences which may occur if the temperature and pressure relief valve on my hot water heater is not functioning as designed OR if expansion tanks and/or relief valves are not added to the water system when needed.

SIGNATURE: ____

NAME: (Please print) ______________________________ DATE: ___/___/

ADDRESS: ____

CITY: __________________ STATE: ______________ ZIP CODE: ________

**A SIGNED COPY OF THIS FORM MUST BE SUBMITTED TO OBTAIN YOUR BACKFLOW ASSEMBLY INSTALLATION PERMIT

Fire Services and Systems Policy - *Example*

- Class 1 and 2 fire systems are not currently required to have any backflow prevention equipment at the service connection other than the equipment that is required for those systems under the state fire code standards. However, backflow prevention assemblies may be required on all Class 1 and 2 fire systems after future legislative review. (Refer to the Suggested Removable Pipe Spool Installation for Class 1 and 2 Fire Sprinkler Systems@ - Standard Detail W1-07 in this information package).

- Class 3 fires systems may be converted to Class 1 or 2 systems by removing the tank. However, you must have the approval of the fire authority. Contact your fire authority prior to making any changes to your existing fire system. If the system cannot be modified, a backflow assembly will be required.

- Class 4 and 5 must comply with backflow requirements. Class 5 includes those fire systems that use antifreeze or other additives (RPDA required). This may apply to residential homes over 3000 sq. ft.

- Class 6 fire systems require an on-site review to determine backflow requirements.

- Customers who want to increase the size of an incoming service line must comply with backflow requirements prior to the completion of construction. Contact the Sunflower Water Department at 978-5242, Ext. 379 or e-mail for more information.

- Customers who will receive reclaimed water must comply with backflow prevention requirements prior to completion of construction and before receiving reclaimed water. Contact the Sunflower Water Department at 978-5242, Ext. 379 for more information.

I've seen this type of poor installation many times and is a common site because of un-educated Inspectors and/or backflow personnel. This line feeds an irrigation system, no protection at all and was in place for many years.

Backflow Prevention Program *Responsibilities Example*

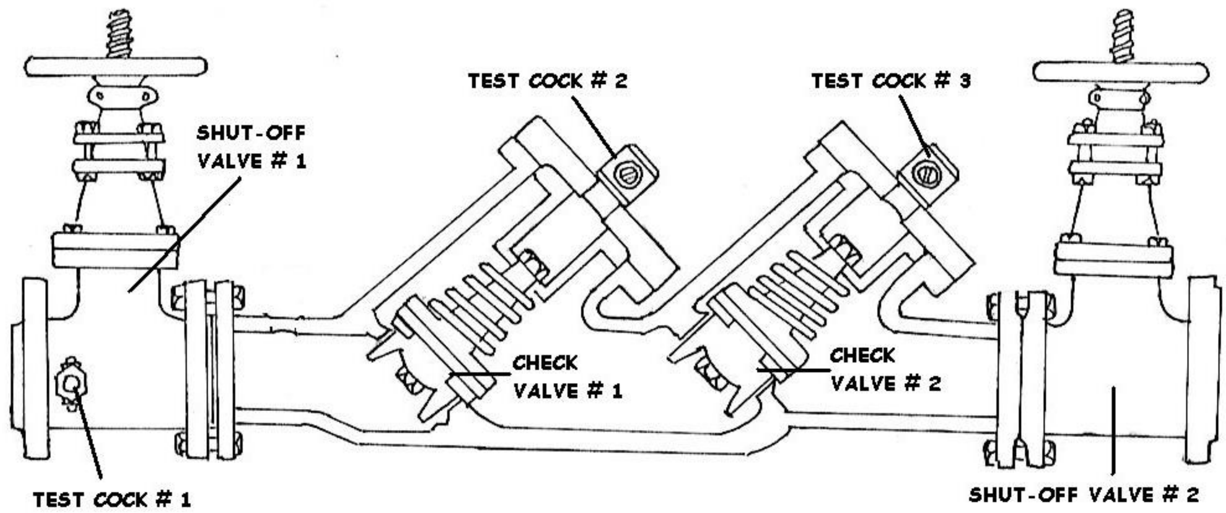
Customer Responsibilities

- Installation of Approved Backflow Assembly
- Maintenance, Repair and Annual Testing of Assembly
- Annual inspection of check valve assemblies for Class I and 2 fire sprinkler systems by an L-16 or C-16 contractor (Refer to Fire System Section in this information package)

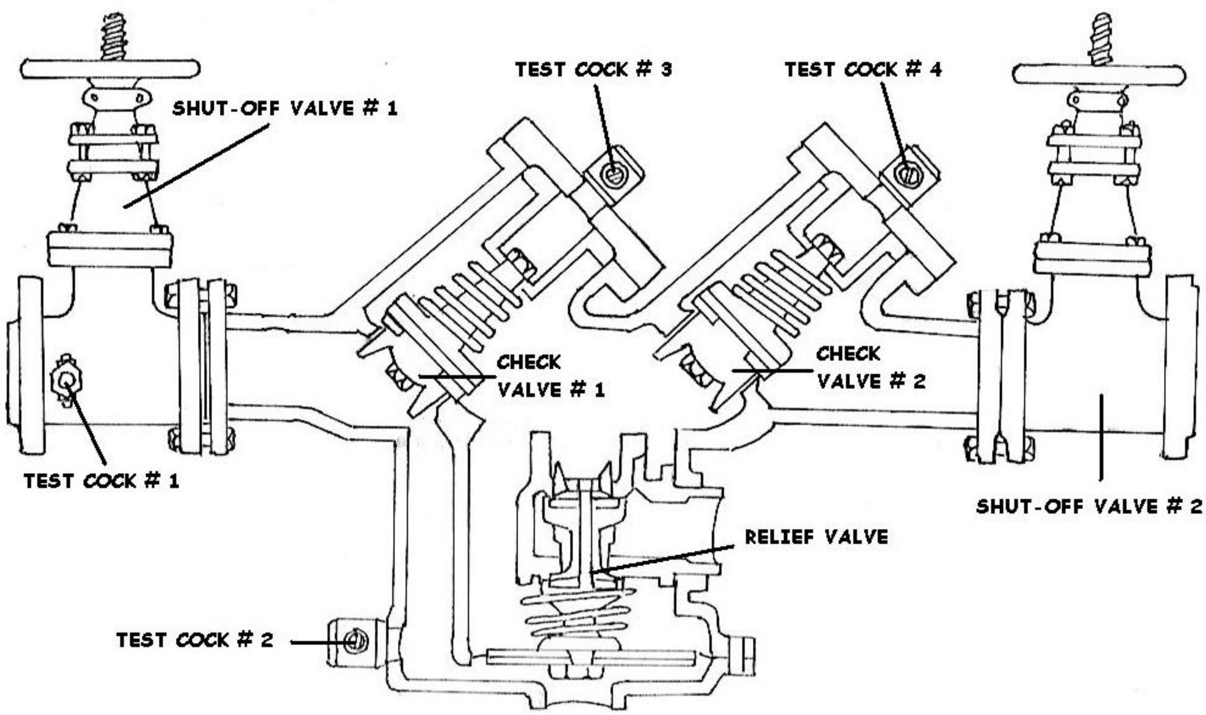
Sunflower Water Department Responsibilities

- Assurance of Water Quality
- Enforcement of Laws, Ordinances and Codes
- Implementation of Backflow Prevention Program
- Inspections, Surveys and Water Service Evaluations
- Retain Inventory and Service Records of All Backflow Prevention Assemblies
- Submit Reports to the State

Rust Particles



DOUBLE CHECK BACKFLOW ASSEMBLY



REDUCED PRESSURE BACKFLOW PRINCIPLE ASSEMBLY

Freeze and Theft Protection for Backflow Prevention Assemblies *Example*

If a backflow prevention assembly is installed outside in a location subject to freezing weather, it must be protected to prevent damage and to ensure proper operation. Several manufacturers of enclosures designed to protect assemblies from freeze and theft damage are listed below:

1) **Heat Hut from Northern Arizona Backflow, Inc**.
   Flagstaff, Arizona
   Contact: Rick Williams at (520) 527-8919

2) **HydroCowl, Inc.**
   Nashville, TN
   (615) 833-0233 Fax: (615) 831-0156
   1-800-245-6333

3) **FreezeGuard from Astra Industrial Services**
   1-800-776-1464 Fax: (805) 499-9084

4) **Hot Box from Hot Box-NFE, Inc.**
   250 N. Lane Avenue
   Jacksonville, Florida 32254

   (904) 786-0204 Fax: (904) 783-6965
   1-800-736-0238

5) **Just Set Thermo Shelters from Pennsylvania Insert Corporation**
   Bridge Street
   Spring City, Pennsylvania 19475
   (610) 948-9688 Fax: (610) 948-9750

Facility owners may install assemblies inside the building with approval from the Backflow Prevention Section of the Sunflower Water Department at (520) 978-5242, Ext. 379, or e-mail.

All customers whether installing an assembly outdoors or indoors must complete and submit a copy of the attached Freeze Protection Installation Approval Form when applying for a backflow assembly permit.

Freeze Protection Installation Approval Form *Example*

Please check the appropriate box.

☐ Outdoor Installation:

I, the undersigned, do hereby agree to install all required backflow prevention assemblies for my facility or residence in an *outdoor* location (as close to the meter as possible) with adequate freeze protection to prevent damage to the assembly and to ensure its proper operation. I understand that the Town of Sunflower Backflow Ordinance prohibits any taps between the water meter and backflow assembly or any bypass lines around the assembly and certify that no such taps or bypasses exist on my domestic, fire or irrigation water service lines.

☐ Indoor Installation with Water Department Approval:

I, the undersigned, have obtained approval from the Backflow Prevention Section of the Water Department to install all required backflow prevention assemblies for my facility or residence *inside the building* in a location (as close to the meter as practical) that will protect the assembly from freeze damage. I understand that the Town of Sunflower Backflow Ordinance prohibits any taps between the water meter and backflow assembly or any bypass lines around the assembly and certify that no such taps or bypasses exist on my domestic, fire or irrigation water service lines. I also understand the potential for flooding that may result within my facility if an installed reduced pressure principle assembly reaches a full port dump condition. I agree to accept all responsibility for damage if this situation occurs.

SIGNATURE:
NAME: (Please print) ___________________________________ DATE: ___/___/

ADDRESS: ____

CITY: ______________________ STATE: _____________ ZIP CODE: __________

TELEPHONE: (_____) _______________________________

**A SIGNED COPY OF THIS FORM MUST BE SUBMITTED TO OBTAIN YOUR BACKFLOW

Assembly Installation Permit *Example*

BACKFLOW ASSEMBLY PERMIT APPLICATION

WATER CUSTOMER MAILING ADDRESS **ASSEMBLY INFORMATION**

Name: ________________________________ Serial No.

Address: ________________________________ MFR: ________ Model _______ Size

City, State, Zip __________________________ Water Meter No:

PROJECT NAME:

PROJECT CONTRACTOR:

SERVICE ADDRESS: ____CITY, STATE, ZIP: ____CONTACT PERSON: ______________________________ TELEPHONE:

PAGER: ___________ASSEMBLY LOCATION:

1) What type of assembly will be installed? ☐ Reduced Pressure Principle Assembly (RP)
(Please Check One) ☐ Double Check Valve Assembly (DC)

☐ Pressure Vacuum Breaker (PVB)

☐ Reduced Pressure Principle Detector Assembly (RPDA) - *Fire Systems Only*

☐ Double Check Detector Assembly (DCDA) - *Fire Systems Only*

2) What size is your service line? ☐ 3/4 inch ☐ 3 inch

☐ 1 inch ☐ 4 inch

☐ 1 1/2 inch ☐ Other, Please specify

☐ 2 inch

3) Which Town of Sunflower Standard Detail will you be using to install the backflow prevention assembly?

☐ Reduced Pressure Principle Assembly (RP) - 3" and larger Detail # W1-01

☐ Double Check Valve Assembly (DC) - 3" and larger Detail # W1-02

☐ Reduced Pressure Principle Assembly (RP) - INDOOR - 2 1/2 " and less Detail # W1-03

☐ Reduced Pressure Principle Assembly (RP) - OUTDOOR - 21/2 " and less Detail # W1-04

☐ Double Check Valve Assembly (DC) - 21/2 " and less Detail # W1-05

☐ Pressure Vacuum Breaker (PVB) Detail # W1-06

☐ Suggested Spool Installation for Class 1 and 2 Fire Sprinkler System Detail # W1-07

☐ Safety Post - MAG STANDARD DETAIL #140

TOWN OF SUNFLOWER - BACKFLOW PREVENTION CODE OF CONDUCT FOR CERTIFIED TESTERS *Example*

Backflow prevention general testers recognized by the Town of Sunflower must test, repair, and install assemblies under the direction of the Town of Sunflower Water Department and according to Town of Sunflower Ordinance # Article 13, Section 13-4-3, Number 422. The backflow prevention program for the Town has been established as follows:

- Monthly test notices will be mailed on the first day of each month to customers whose backflow prevention assemblies are due for testing in that month. A copy of the approved list of testers will be sent with the notification letter. The customer will be responsible for contacting a certified tester.

- The Town will recognize testers who have been certified by AWWA, USC FCCCHR, ASETT Center, and the Pipe Industry Progress and Education Fund (P.I.P.E.) . A copy of the tester's certification, the test gauge calibration certificate, insurance certificate and Plumber or Contractor's License must be on file with the Town of Sunflower Water Department. Testers must use recognized test equipment and provide proof of its accuracy annually.

- All backflow assemblies must be tested in accordance with the procedures outlined in Section 9 of the *9th edition* of the USC FCCCHR Manual of Cross Connection Control. In addition, testers must perform a backpressure check on each pressure vacuum breaker. Testers who are unsure of the current procedure to check for backpressure may contact the Sunflower Water Department at (520) 978-5242, Ext. 379.

- The Town will provide test forms to testers. **Forms other than that provided by the Town will not be accepted.** Each form must be filled out correctly and completely after each test or repair is performed on any assembly within the jurisdiction of the Town of Sunflower.

- All tests must be performed during the month for which they are designated. Early tests will not be accepted.

- Completed **original** test forms must be returned by the certified tester to the Town by the due date indicated on the monthly mailing record. Any test performed during the appropriate time interval, but received after the due date will be considered late, and handled as follows:

1) A written warning will be issued to the tester whenever the form is received late.
2) Testers receiving two warnings within a six-month period will have their certification suspended for a period of three months.
3) Testers receiving two warnings within any six-month interval, after having a three-month suspension, will have their certification revoked permanently.
4) Tests performed after the monthly deadline, because of a delay caused by the owner, will not result in a written warning, if the tester provides a written explanation for the delay. The explanation shall be attached to the test form.
5) Incomplete test forms will not be accepted.

- Testers who dismantle an assembly are responsible for having replacement parts readily available so that the assembly may be restored to proper working condition within the same working day. Under no circumstances should a customer's water be left shut off while a tester attempts to obtain repair parts.

- A tester may be suspended or removed from the list of certified testers for improper testing, maintenance, reporting or any other practices determined to be improper by the Backflow Program Manager.

I, ____________________________________ have received a copy of the Town of Sunflower Backflow Prevention Ordinance and read the above information. As a certified tester recognized by the Town of Sunflower, I will follow all established laws and accepted practices for installation, testing and repair of backflow prevention assemblies.

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Topic 3- Cross-Connection Control Program Post Quiz

1. Once the operator has a good understanding of cross connection control, the next task will be to prepare a ________________________that will establish legal authority for the program.

2. _______________________ will be useless without the approval of the board of directors or city council. This fact can present problems of its own.

3. Once an ordinance has been adopted, it must be __________________.

4. The installation of backflow preventors on fire lines will ________________the pressure loss, and this needs to be considered in the system design.

5. It is important to educate the customers to the _______________and the importance of installing backflow preventors when needed.

6. _____________________ must be tested regularly, so a system of tracking due dates is needed in order to send notices on time.

7. Once the program is established, the utility can take pride in the knowledge that they are taking an active role in protecting the public water supply from _____________________.

8. In a large water supply system, __________________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.

9. Internal protection is the most expensive and ____________________for both the water purveyor and the customer alike, but is very difficult to maintain.

10. A complete cross-connection control program requires a carefully planned and executed initial action plan followed by ___________________and constant follow-up.

11. _____________________and assemblies offer protection of the potable water system if other protective approaches fail.

12. Some drinking water authorities prefer isolation to containment because personnel working beyond the service connection are protected and, in most cases, the assembly can be sized smaller because of smaller piping beyond the____________________.

13. SVBs are similar in design to PVBs with the addition of a diaphragm seal that stops water from spilling out the air inlet whenever the assembly is pressurized. As with PVBs, they protect against _______________only.

14. _________________ consist of two internally loaded, independently operating check valves and a mechanically independent, hydraulically dependent relief valve located between the check valves.

15. AVBs must be a minimum of ________________above all downstream piping and the flood level rim of a receptor to function properly (USC FCCCHR, 1993).

16. If backpressure is a concern, many systems use double check valve assemblies, and if the degree of hazard is______________, many systems install a reduced pressure principle backflow assembly.

17. Programs and their level of effort are often tailored to the perceived ___________of backflow and the types of hazards that can be introduced into the distribution system.

18. A problem for water systems in detecting cross-connections is that there is _____________ warning that a backflow incident is occurring.

BACKFLOW GLOSSARY

A

Absolute Pressure: The pressure above zone absolute, i.e. the sum of atmospheric and gauge pressure. In vacuum related work it is usually expressed in millimeters of mercury. (mmHg).

Aerodynamics: The study of the flow of gases. The Ideal Gas Law - For a perfect or ideal gas the change in density is directly related to the change in temperature and pressure as expressed in the Ideal Gas Law.

Aeronautics: The mathematics and mechanics of flying objects, in particular airplanes.

Air Break: A physical separation which may be a low inlet into the indirect waste receptor from the fixture, or device that is indirectly connected. You will most likely find an air break on waste fixtures or on non-potable lines. You should never allow an air break on an ice machine.

Air Gap Separation: A physical separation space that is present between the discharge vessel and the receiving vessel, for an example, a kitchen faucet.

Altitude-Control Valve: 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.

Angular Motion Formulas: Angular velocity can be expressed as (angular velocity = constant):

$\omega = \theta / t$ *(2a)*

where
ω *= angular velocity (rad/s)*
θ *= angular displacement (rad)*
t *= time (s)*

Angular velocity can be expressed as (angular acceleration = constant):
$\omega = \omega_o + \alpha t$ *(2b)*

where
ω_o *= angular velocity at time zero (rad/s)*
α *= angular acceleration (rad/s²)*

Angular displacement can be expressed as (angular acceleration = constant):
$\theta = \omega_o t + 1/2 \alpha t^2$ *(2c)*

Combining 2a and 2c:
$\omega = (\omega_o^2 + 2 \alpha \theta)^{1/2}$

Angular acceleration can be expressed as:
$\alpha = d\omega / dt = d^2\theta / dt^2$ *(2d)*

where
$d\theta$ *= change of angular displacement (rad)*
dt *= change in time (s)*

Atmospheric Pressure: Pressure exerted by the atmosphere at any specific location. (Sea level pressure is approximately 14.7 pounds per square inch absolute, 1 bar = 14.5psi.)

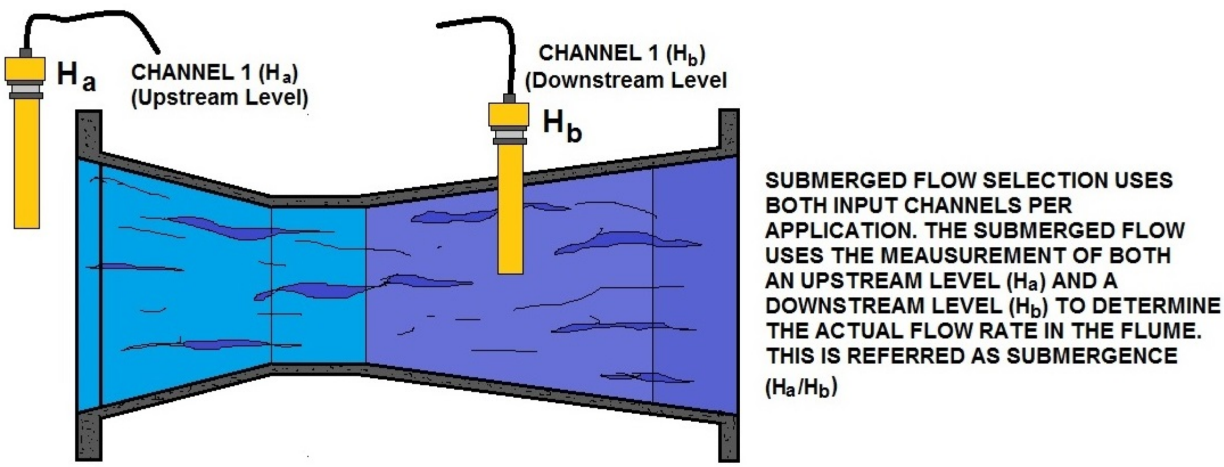
B

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. See Cross-connection control.

Backflow: 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.

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. 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.

Bernoulli's Equation: Describes the behavior of moving fluids along a streamline. The Bernoulli Equation can be considered to be a statement of the conservation of energy principle appropriate for flowing fluids. The qualitative behavior that is usually labeled with the term "***Bernoulli effect***" is the lowering of fluid pressure in regions where the flow velocity is increased. This lowering of pressure in a constriction of a flow path may seem counterintuitive, but seems less so when you consider pressure to be energy density. In the high velocity flow through the constriction, kinetic energy must increase at the expense of pressure energy.



Technical Learning College

SUBMERGED FLOW IN PARSHALL FLUMES

A special form of the Euler’s equation derived along a fluid flow streamline is often called the **Bernoulli Equation.**

$$\frac{\partial}{\partial s}\left(\frac{v^2}{2}+\frac{p}{\rho}+g\cdot h\right)=0 \qquad (1)$$

where

v = flow speed

p = pressure

ρ = density

g = gravity

h = height

$$\frac{v^2}{2}+\frac{p}{\rho}+g\cdot h=\text{Constant} \qquad (2)$$

$$\frac{v^2}{2\cdot g}+\frac{p}{\gamma}+h=\text{Constant} \qquad (3)$$

where

$\gamma=\rho\cdot g$

$$\frac{\rho\cdot v^2}{2}+p=\text{Constant} \qquad (4)$$

$$\frac{\rho\cdot v^2}{2}=p_d \qquad (5)$$

$$\frac{\rho\cdot v_1^2}{2}+p_1=\frac{\rho\cdot v_2^2}{2}+p_2=\text{Constant} \qquad (6)$$

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For steady state incompressible flow the Euler equation becomes (1). If we integrate (1) along the streamline it becomes (2). (2) can further be modified to (3) by dividing by gravity.

Head of Flow: Equation (3) is often referred to as the **head** because all elements have the unit of length.

Dynamic Pressure

(2) and (3) are two forms of the Bernoulli Equation for steady state incompressible flow. If we assume that the gravitational body force is negligible, (3) can be written as (4). Both elements in the equation have the unit of pressure and it's common to refer the flow velocity component as the **dynamic pressure** of the fluid flow (5).

Since energy is conserved along the streamline, (4) can be expressed as (6). Using the equation we see that increasing the velocity of the flow will reduce the pressure, decreasing the velocity will increase the pressure.

This phenomena can be observed in a **venturi meter** where the pressure is reduced in the constriction area and regained after. It can also be observed in a **pitot tube** where the **stagnation** pressure is measured. The stagnation pressure is where the velocity component is zero.

Bernoulli's Equation Continued:
Pressurized Tank
If the tanks are pressurized so that product of gravity and height (g h) is much less than the pressure difference divided by the density, (e4) can be transformed to (e6).
The velocity out from the tanks depends mostly on the pressure difference.

Example - outlet velocity from a pressurized tank
The outlet velocity of a pressurized tank where

$p_1 = 0.2\ MN/m^2,\ p_2 = 0.1\ MN/m^2\ A_2/A_1 = 0.01,\ h = 10\ m$

can be calculated as
$V_2 = [(2/(1-(0.01)^2)\ (\ (0.2 - 0.1)x10^6\ /1x10^3 + 9.81\ x\ 10)]^{1/2} = \underline{19.9\ m/s}$

Coefficient of Discharge - Friction Coefficient
Due to friction the real velocity will be somewhat lower than this theoretical example. If we introduce a **friction coefficient** *c* (coefficient of discharge), (e5) can be expressed as (e5b). The coefficient of discharge can be determined experimentally. For a sharp edged opening it may be as low as 0.6. For smooth orifices it may be between 0.95 and 1.

Bingham Plastic Fluids: Bingham Plastic Fluids have a yield value which must be exceeded before it will start to flow like a fluid. From that point the viscosity will decrease with increase of agitation. Toothpaste, mayonnaise and tomato catsup are examples of such products.

Boundary Layer: The layer of fluid in the immediate vicinity of a bounding surface.

Bulk Modulus and Fluid Elasticity: An introduction to and a definition of the Bulk Modulus Elasticity commonly used to characterize the compressibility of fluids.

The Bulk Modulus Elasticity can be expressed as
$E = - dp / (dV / V)$ *(1)*

where
E = bulk modulus elasticity
dp = differential change in pressure on the object
dV = differential change in volume of the object
V = initial volume of the object

The Bulk Modulus Elasticity can be alternatively expressed as
$E = - dp / (d\rho / \rho)$ *(2)*

where
dρ = differential change in density of the object
ρ = initial density of the object

An increase in the pressure will decrease the volume (1). A decrease in the volume will increase the density (2).
- The SI unit of the bulk modulus elasticity is N/m^2 (Pa)
- The imperial (BG) unit is lb_f/in^2 (psi)

- 1 lb_f/in^2 (psi) = 6.894 10^3 N/m^2 (Pa)

A large Bulk Modulus indicates a relatively incompressible fluid.

Bulk Modulus for some common fluids can be found in the table below:

Bulk Modulus - *E*	Imperial Units - BG (psi, lb_f/in^2) x 10^5	SI Units (Pa, N/m^2) x 10^9
Carbon Tetrachloride	1.91	1.31
Ethyl Alcohol	1.54	1.06
Gasoline	1.9	1.3
Glycerin	6.56	4.52
Mercury	4.14	2.85
SAE 30 Oil	2.2	1.5
Seawater	3.39	2.35
Water	3.12	2.15

C

Capillarity: (or capillary action) The ability of a narrow tube to draw a liquid upwards against the force of gravity.

The height of liquid in a tube due to capillarity can be expressed as

$h = 2\,\sigma\cos\theta / (\rho\, g\, r)$ *(1)*

where
h = height of liquid (ft, m)
σ = surface tension (lb/ft, N/m)
θ = contact angle
ρ = density of liquid (lb/ft^3, kg/m^3)
g = acceleration due to gravity (32.174 ft/s^2, 9.81 m/s^2)
r = radius of tube (ft, m)

Cauchy Number: A dimensionless value useful for analyzing fluid flow dynamics problems where compressibility is a significant factor.
The Cauchy Number is the ratio between inertial and the compressibility force in a flow and can be expressed as

$C = \rho\, v^2 / E$ *(1)*

where
ρ = density (kg/m^3)
v = flow velocity (m/s)
E = bulk modulus elasticity (N/m^2)

The bulk modulus elasticity has the dimension pressure and is commonly used to characterize the compressibility of a fluid.

The Cauchy Number is the square root of the Mach Number

$M^2 = Ca$ (3)

where
C = Mach Number

Cavitation: Under the wrong condition, cavitation will reduce the components life time dramatically. Cavitation may occur when the local static pressure in a fluid reach a level below the vapor pressure of the liquid at the actual temperature. According to the Bernoulli Equation this may happen when the fluid accelerates in a control valve or around a pump impeller. The vaporization itself does not cause the damage - the damage happens when the vapor almost immediately collapses after evaporation when the velocity is decreased and pressure increased. Cavitation means that cavities are forming in the liquid that we are pumping. When these cavities form at the suction of the pump several things happen all at once: We experience a loss in capacity. We can no longer build the same head (pressure). The efficiency drops. The cavities or bubbles will collapse when they pass into the higher regions of pressure causing noise, vibration, and damage to many of the components. The cavities form for five basic reasons and it is common practice to lump all of them into the general classification of cavitation.

This is an error because we will learn that to correct each of these conditions we must understand why they occur and how to fix them. Here they are in no particular order: Vaporization, Air ingestion, Internal recirculation, Flow turbulence and finally the Vane Passing Syndrome.

Avoiding Cavitation

Cavitation can in general be avoided by:

- increasing the distance between the actual local static pressure in the fluid - and the vapor pressure of the fluid at the actual temperature

This can be done by:

- reengineering components initiating high speed velocities and low static pressures
- increasing the total or local static pressure in the system
- reducing the temperature of the fluid

Reengineering of Components Initiating High Speed Velocity and Low Static Pressure

Cavitation and damage can be avoided by using special components designed for the actual rough conditions.

- Conditions such as huge pressure drops can - with limitations - be handled by Multi Stage Control Valves
- Difficult pumping conditions - with fluid temperatures close to the vaporization temperature - can be handled with a special pump - working after another principle than the centrifugal pump.

Cavitation Continued: Increasing the Total or Local Pressure in the System
By increasing the total or local pressure in the system, the distance between the static pressure and the vaporization pressure is increased and vaporization and cavitation may be avoided.

The ratio between static pressure and the vaporization pressure, an indication of the possibility of vaporization, is often expressed by the Cavitation Number. Unfortunately it may not always be possible to increase the total static pressure due to system classifications or other limitations. Local static pressure in the component may then be increased by lowering the component in the system. Control valves and pumps should in general be positioned in the lowest part of the system to maximize the static head. This is common for boiler feeding pumps receiving hot condensate (water close to 100 ^{o}C) from a condensate receiver.

Cavitation Continued: Reducing the Temperature of the Fluid
The vaporization pressure is highly dependent on the fluid temperature. Water, our most common fluid, is an example:

Temperature (^{o}C)	Vapor Pressure (kN/m^2)
0	0.6
5	0.9
10	1.2
15	1.7
20	2.3
25	3.2
30	4.3
35	5.6
40	7.7
45	9.6
50	12.5
55	15.7
60	20
65	25
70	32.1
75	38.6
80	47.5
85	57.8
90	70
95	84.5
100	101.33

As we can see - the possibility of evaporation and cavitation increases dramatically with the water temperature.

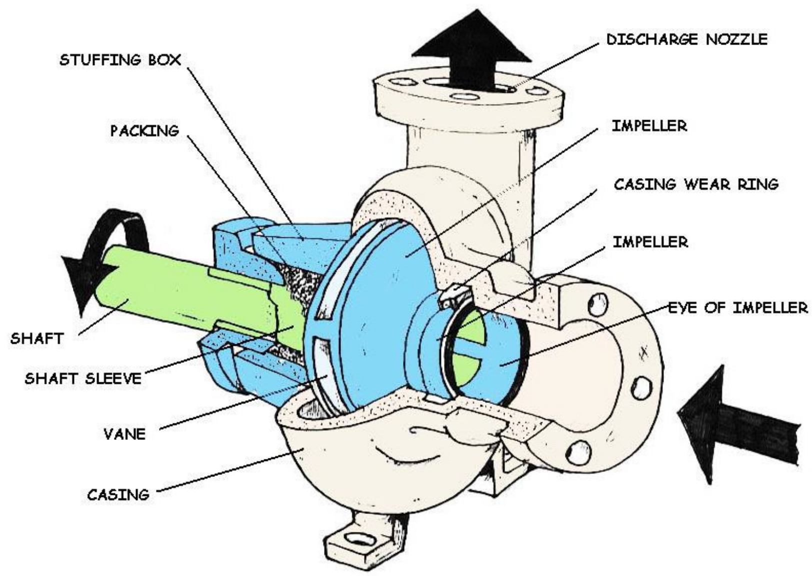
Cavitation can be avoided by locating the components in the coldest part of the system. For example, it is common to locate the pumps in heating systems at the "cold" return lines. The situation is the same for control valves. Where it is possible they should be located on the cold side of heat exchangers.

Cavitations Number: A "special edition" of the dimensionless Euler Number.

The Cavitations Number is useful for analyzing fluid flow dynamics problems where cavitations may occur. The Cavitations Number can be expressed as

$$Ca = (p_r - p_v) / 1/2 \rho v^2 \quad (1)$$

where
Ca = Cavitations number
p_r = reference pressure (Pa)
p_v = vapor pressure of the fluid (Pa)
ρ = density of the fluid (kg/m^3)
v = velocity of fluid (m/s)



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.

Chezy Formula: Conduits flow and mean velocity. The Chezy formula can be used to calculate mean flow velocity in conduits and is expressed as

$$v = c (R S)^{1/2} \quad (1)$$

where
v = mean velocity (m/s, ft/s)
c = the Chezy roughness and conduit coefficient
R = hydraulic radius of the conduit (m, ft)
S = slope of the conduit (m/m, ft/ft)

In general the Chezy coefficient - *c* - is a function of the flow Reynolds Number - Re - and the relative roughness - *ε/R* - of the channel.
ε is the characteristic height of the roughness elements on the channel boundary.

Coanda Effect: The tendency of a stream of fluid to stay attached to a convex surface, rather than follow a straight line in its original direction.

Colebrook Equation: The friction coefficients used to calculate pressure loss (or major loss) in ducts, tubes and pipes can be calculated with the Colebrook equation.

$$1 / \lambda^{1/2} = -2 \log ((2.51 / (Re\ \lambda^{1/2})) + ((k / d_h) / 3.72)) \quad (1)$$

where
λ = *D'Arcy-Weisbach friction coefficient*
Re = Reynolds Number
k = roughness of duct, pipe or tube surface (m, ft)
d_h = *hydraulic diameter (m, ft)*

The Colebrook equation is only valid at turbulent flow conditions.
Note that the friction coefficient is involved on both sides of the equation and that the equation must be solved by iteration.

The Colebrook equation is generic and can be used to calculate the friction coefficients in different kinds of fluid flows - air ventilation ducts, pipes and tubes with water or oil, compressed air and much more.

Common Pressure Measuring Devices: 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.

Compressible Flow: We know that fluids are classified as Incompressible and Compressible fluids. Incompressible fluids do not undergo significant changes in density as they flow. In general, liquids are incompressible; water being an excellent example. In contrast compressible fluids do undergo density changes.

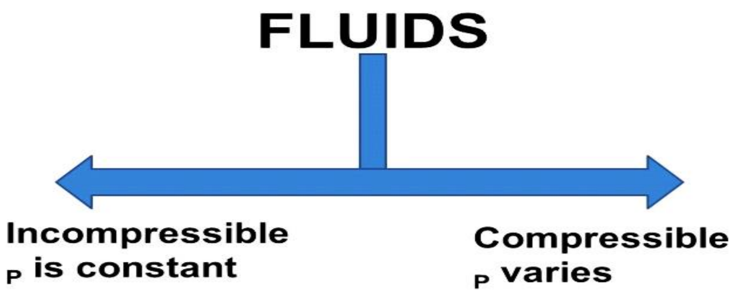
Gases are generally compressible; air being the most common compressible fluid we can find. Compressibility of gases leads to many interesting features such as shocks, which are absent for incompressible fluids. Gas dynamics is the discipline that studies the flow of compressible fluids and forms an important branch of Fluid Mechanics. In this book we give a broad introduction to the basics of compressible fluid flow.

In a compressible flow the compressibility of the fluid must be taken into account. The Ideal Gas Law - For a perfect or ideal gas the change in density is directly related to the change in temperature and pressure as expressed in the Ideal Gas Law. Properties of **Gas Mixtures** - Special care must be taken for gas mixtures when using the ideal gas law, calculating the mass, the individual gas constant or the density. The Individual and **Universal Gas Constant** - The Individual and Universal Gas Constant is common in fluid mechanics and thermodynamics.

Compression and Expansion of Gases: If the compression or expansion takes place under constant temperature conditions - the process is called **isothermal.** The isothermal process can on the basis of the Ideal Gas Law be expressed as:

p / ρ = constant (1)

where
p = absolute pressure
ρ = density



Confined Space Entry: 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.

Conservation Laws: The conservation laws states that particular measurable properties of an isolated physical system does not change as the system evolves: Conservation of energy (including mass). Fluid Mechanics and Conservation of Mass - The law of conservation of mass states that mass can neither be created or destroyed.

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.

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.

Cross-Contamination: The mixing of two unlike qualities of water. For example, the mixing of good water with a polluting substance like a chemical.

D

Darcy-Weisbach Equation: The **pressure loss** (or major loss) in a pipe, tube or duct can be expressed with the D'Arcy-Weisbach equation:

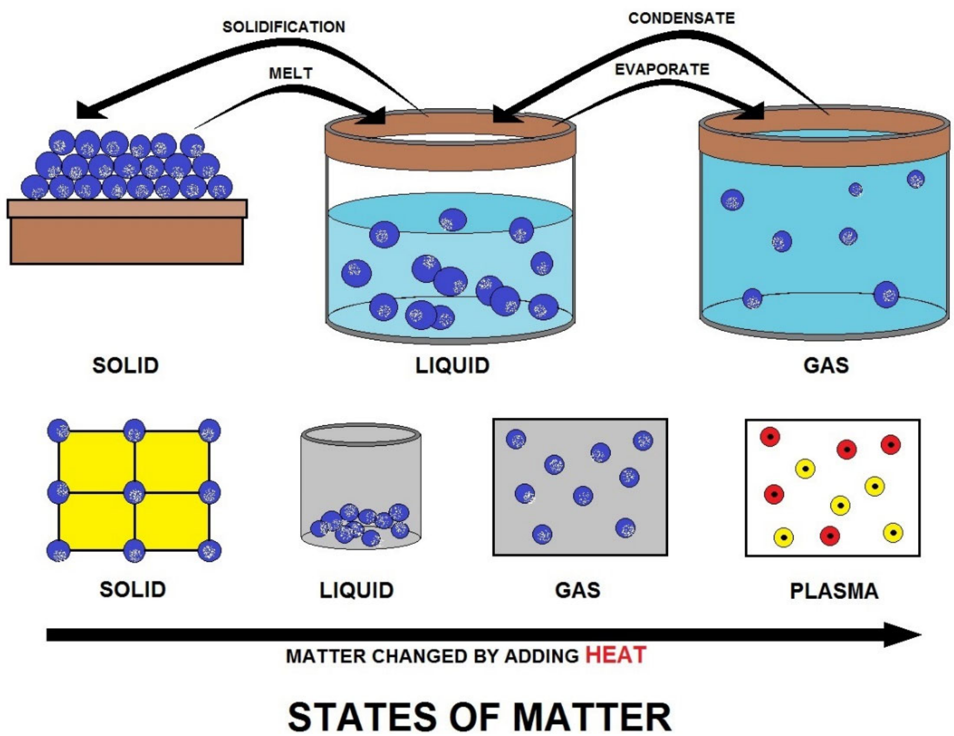
$\Delta p = \lambda (l / d_h) (\rho v^2 / 2)$ *(1)*

where
Δp = pressure loss (Pa, N/m^2, lb$_f$/ft^2)
λ = D'Arcy-Weisbach friction coefficient
l = length of duct or pipe (m, ft)
d_h = hydraulic diameter (m, ft)
ρ = density (kg/m^3, lb/ft^3)

Note! Be aware that there are two alternative friction coefficients present in the literature. One is 1/4 of the other and (1) must be multiplied with four to achieve the correct result. This is important to verify when selecting friction coefficients from Moody diagrams.

Density: Is a physical property of matter, as each element and compound has a unique density associated with it.

Density defined in a qualitative manner as the measure of the relative "heaviness" of objects with a constant volume. For example: A rock is obviously more dense than a crumpled piece of paper of the same size. A Styrofoam cup is less dense than a ceramic cup. Density may also refer to how closely "packed" or "crowded" the material appears to be - again refer to the Styrofoam vs. ceramic cup.



Each box has the same volume. ***If each ball has the same mass, which box would weigh***

more? Why?

The box that has more balls has more mass per unit of volume. This property of matter is called density. The density of a material helps to distinguish it from other materials. Since mass is usually expressed in grams and volume in cubic centimeters, density is expressed in grams/cubic centimeter. We can calculate density using the formula:

Density= Mass/Volume

The density can be expressed as

$\rho = m / V = 1 / v_g$ *(1)*

where
ρ *= density (kg/m³)*
m *= mass (kg)*
V *= volume (m³)*
v_g *= specific volume (m³/kg)*

The SI units for density are kg/m^3. The imperial (BG) units are lb/ft^3 (slugs/ft^3). While people often use pounds per cubic foot as a measure of density in the U.S., pounds are really a measure of force, not mass. Slugs are the correct measure of mass. You can multiply slugs by 32.2 for a rough value in pounds. The higher the density, the tighter the particles are packed inside the substance. Density is a physical property constant at a given temperature and density can help to identify a substance.

Example - Use the Density to Identify the Material:
An unknown liquid substance has a mass of 18.5 g and occupies a volume of 23.4 ml. (milliliter).

The density can be calculated as

$\rho = [18.5\ (g) / 1000\ (g/kg)] / [23.4\ (ml) / 1000\ (ml/l)\ 1000\ (l/m^3)\ ]$
$= 18.5\ 10^{-3}\ (kg) / 23.4\ 10^{-6}\ (m^3)$
$= \underline{790}\ kg/m^3$

If we look up densities of some common substances, we can find that ethyl alcohol, or ethanol, has a density of <u>790</u> kg/m^3. Our unknown liquid may likely be ethyl alcohol!

Example - Use Density to Calculate the Mass of a Volume
The density of titanium is 4507 kg/m^3 . Calculate the mass of 0.17 m^3 titanium!

$m = 0.17\ (m^3)\ 4507\ (kg/m^3)$
$= \underline{766.2}\ kg$

Dilatant Fluids: Shear Thickening Fluids **or** Dilatant Fluids increase their viscosity with agitation. Some of these liquids can become almost solid within a pump or pipe line. With agitation, cream becomes butter and Candy compounds, clay slurries and similar heavily filled liquids do the same thing.

Disinfect: To kill and inhibit growth of harmful bacterial and viruses in drinking water.

Disinfection: The treatment of water to inactivate, destroy, and/or remove pathogenic bacteria, viruses, protozoa, and other parasites.

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.

Drag Coefficient: Used to express the drag of an object in moving fluid. Any object moving through a fluid will experience a drag - the net force in direction of flow due to the pressure and shear stress forces on the surface of the object.

The drag force can be expressed as:

$$F_d = c_d \ 1/2 \ \rho \ v^2 \ A \quad (1)$$

where
F_d = *drag force (N)*
c_d = *drag coefficient*
ρ = *density of fluid*
v = *flow velocity*
A = *characteristic frontal area of the body*

The drag coefficient is a function of several parameters as shape of the body, Reynolds Number for the flow, Froude number, Mach Number and Roughness of the Surface.
The characteristic frontal area - *A* - depends on the body.

Dynamic or Absolute Viscosity: The viscosity of a fluid is an important property in the analysis of liquid behavior and fluid motion near solid boundaries. The viscosity of a fluid is its resistance to shear or flow and is a measure of the adhesive/cohesive or frictional properties of a fluid. The resistance is caused by intermolecular friction exerted when layers of fluids attempts to slide by another.

Dynamic Pressure: Dynamic pressure is the component of fluid pressure that represents a fluids kinetic energy. The dynamic pressure is a defined property of a moving flow of gas or liquid and can be expressed as

$$p_d = 1/2 \ \rho \ v^2 \quad (1)$$

where
p_d = dynamic pressure (Pa)
ρ = density of fluid (kg/m^3)
v = velocity (m/s)

Dynamic, Absolute and Kinematic Viscosity: The viscosity of a fluid is an important property in the analysis of liquid behavior and fluid motion near solid boundaries. The viscosity is the fluid resistance to shear or flow and is a measure of the adhesive/cohesive or frictional fluid property. The resistance is caused by intermolecular friction exerted when layers of fluids attempts to slide by another.

Viscosity is a measure of a fluid's resistance to flow.
The knowledge of viscosity is needed for proper design of required temperatures for storage, pumping or injection of fluids.

Common used units for viscosity are
- CentiPoises (cp) = CentiStokes (cSt) × Density
- SSU[1] = Centistokes (cSt) × 4.55
- Degree Engler[1] × 7.45 = Centistokes (cSt)
- Seconds Redwood[1] × 0.2469 = Centistokes (cSt)

[1]centistokes greater than 50

There are two related measures of fluid viscosity - known as **dynamic** (**or absolute**) and **kinematic** viscosity.

Dynamic (absolute) Viscosity: The tangential force per unit area required to move one horizontal plane with respect to the other at unit velocity when maintained a unit distance apart by the fluid. The shearing stress between the layers of non-turbulent fluid moving in straight parallel lines can be defined for a Newtonian fluid as:

The dynamic or absolute viscosity can be expressed like

$τ = μ\, dc/dy$ (1)

where
τ = shearing stress
μ = dynamic viscosity

Equation (1) is known as the **Newton's Law of Friction**.

In the SI system the dynamic viscosity units are **$N\ s/m^2$**, **Pa s** or **kg/m s** where
- *1 Pa s = 1 $N\ s/m^2$ = 1 kg/m s*

The dynamic viscosity is also often expressed in the metric CGS (centimeter-gram-second) system as **g/cm.s**, **$dyne.s/cm^2$** or **poise (p)** where
- *1 poise = dyne s/cm^2 = g/cm s = 1/10 Pa s*

For practical use the Poise is to large and its usual divided by 100 into the smaller unit called the **centiPoise (cP)** where

- *1 p = 100 cP*

Water at 68.4°F (20.2°C) has an absolute viscosity of one - 1 - centiPoise.

E

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.

Elevation Head: The energy possessed per unit weight of a fluid because of its elevation. 1 foot of water will produce .433 pounds of pressure head.

Energy: The ability to do work. Energy can exist in one of several forms, such as heat, light, mechanical, electrical, or chemical. Energy can be transferred to different forms. It also can exist in one of two states, either potential or kinetic.

Energy and Hydraulic Grade Line: The hydraulic grade and the energy line are graphical forms of the Bernoulli equation. For steady, in viscid, incompressible flow the total energy remains constant along a stream line as expressed through the Bernoulli

Equation:

$p + 1/2\ \rho\ v^2 + \gamma\ h$ = *constant along a streamline (1)*

where
p = *static pressure (relative to the moving fluid)*
ρ = *density*
γ = *specific weight*
v = *flow velocity*
g = *acceleration of gravity*
h = *elevation height*

Each term of this equation has the dimension *force per unit area* - psi, lb/ft^2 or N/m^2.

The Head

By dividing each term with the specific weight - $\gamma = \rho\ g$ - (1) can be transformed to express the "head":

$p / \gamma + v^2 / 2\ g + h$ = *constant along a streamline* = *H (2)*
where
H = the total head

Each term of this equation has the dimension length - ft, m.

The Total Head

(2) states that the sum of **pressure head** - p / γ -, **velocity head** - $v^2 / 2\ g$ - and **elevation head** - h - is constant along the stream line. This constant can be called **the total head** - H -.
The total head in a flow can be measured by the stagnation pressure using a pitot tube.

The Piezometric Head

The sum of pressure head - p / γ - and elevation head - h - is called **the piezometric head**. The piezometric head in a flow can be measured through an flat opening parallel to the flow.

Energy and Hydraulic Grade Line Continued:
The Energy Line
The Energy Line is a line that represents the total head available to the fluid and can be expressed as:

$EL = H = p / \gamma + v^2 / 2 g + h$ *= constant along a streamline (3)*

where
EL = Energy Line
For a fluid flow without any losses due to friction (major losses) or components (minor losses) the energy line would be at a constant level. In the practical world the energy line decreases along the flow due to the losses.

A turbine in the flow will reduce the energy line and a pump or fan will increase the energy line.

The Hydraulic Grade Line
The Hydraulic Grade Line is a line that represent the total head available to the fluid minus the velocity head and can be expressed as:

$HGL = p / \gamma + h$ *(4)*

where
HGL = Hydraulic Grade Line

The hydraulic grade line lies one velocity head below the energy line.

Entrance Length and Developed Flow: Fluids need some length to develop the velocity profile after entering the pipe or after passing through components such as bends, valves, pumps, and turbines or similar.

The Entrance Length: The entrance length can be expressed with the dimensionless Entrance Length Number**:**

$El = l_e / d$ *(1)*

where
El = Entrance Length Number
l_e *= length to fully developed velocity profile*
d = tube or duct diameter

The Entrance Length Number for Laminar Flow
The Entrance length number correlation with the Reynolds Number for laminar flow can be expressed as:

$El_{laminar} = 0.06\ Re$ *(2)*

where

Re = Reynolds Number

The Entrance Length Number for Turbulent Flow
The Entrance length number correlation with the Reynolds Number for turbulent flow can be expressed as:

$$El_{turbulent} = 4.4\ Re^{1/6} \quad (3)$$

Entropy in Compressible Gas Flow: Calculating entropy in compressible gas flow
Entropy change in compressible gas flow can be expressed as

$$ds = c_v \ln(T_2 / T_1) + R \ln(\rho_1 / \rho_2) \quad (1)$$

or

$$ds = c_p \ln(T_2 / T_1) - R \ln(p_2 / p_1) \quad (2)$$

where
ds = entropy change
c_v *= specific heat capacity at a constant volume process*
c_p *= specific heat capacity at a constant pressure process*
T = absolute temperature
R = individual gas constant
ρ *= density of gas*
p = absolute pressure

Equation of Continuity: The Law of Conservation of Mass states that mass can be neither created nor destroyed. Using the Mass Conservation Law on a **steady flow** process - flow where the flow rate doesn't change over time - through a control volume where the stored mass in the control volume doesn't change - implements that inflow equals outflow. This statement is called **the Equation of Continuity.** Common application where **the Equation of Continuity** can be used are pipes, tubes and ducts with flowing fluids and gases, rivers, overall processes as power plants, diaries, logistics in general, roads, computer networks and semiconductor technology and more.

The Equation of Continuity and can be expressed as:

$$m = \rho_{i1} v_{i1} A_{i1} + \rho_{i2} v_{i2} A_{i2} +..+ \rho_{in} v_{in} A_{im}$$
$$= \rho_{o1} v_{o1} A_{o1} + \rho_{o2} v_{o2} A_{o2} +..+ \rho_{om} v_{om} A_{om} \quad (1)$$

where
m = mass flow rate (kg/s)
ρ *= density* (kg/m^3)
v = speed (m/s)
A = area (m^2)
With uniform density equation (1) can be modified to

$$q = v_{i1} A_{i1} + v_{i2} A_{i2} +..+ v_{in} A_{im}$$
$$= v_{o1} A_{o1} + v_{o2} A_{o2} +..+ v_{om} A_{om} \quad (2)$$

where
q = flow rate (m^3/s)
$\rho_{i1} = \rho_{i2} = . . = \rho_{in} = \rho_{o1} = \rho_{o2} = . . = \rho_{om}$

Example - Equation of Continuity
10 m^3/h of water flows through a pipe of 100 mm inside diameter. The pipe is reduced to an inside dimension of 80 mm. Using equation (2) the velocity in the 100 mm pipe can be calculated as

(10 m^3/h)(1 / 3600 h/s) = v_{100} (3.14 x 0.1 (m) x 0.1 (m) / 4)
or
v_{100} = (10 m^3/h)(1 / 3600 h/s) / (3.14 x 0.1 (m) x 0.1 (m) / 4)
= <u>0.35</u> m/s

Using equation (2) the velocity in the 80 mm pipe can be calculated
(10 m^3/h)(1 / 3600 h/s) = v_{80} (3.14 x 0.08 (m) x 0.08 (m) / 4)
or
v_{100} = (10 m^3/h)(1 / 3600 h/s) / (3.14 x 0.08 (m) x 0.08 (m) / 4)
= <u>0.55</u> m/s

Equation of Mechanical Energy: The Energy Equation is a statement of the first law of thermodynamics. The energy equation involves energy, heat transfer and work. With certain limitations the mechanical energy equation can be compared to the Bernoulli Equation and transferred to the Mechanical Energy Equation in Terms of Energy per Unit Mass.

The mechanical energy equation for a **pump or a fan** can be written in terms of **energy per unit mass**:

$$p_{in} / \rho + v_{in}^2 / 2 + g\ h_{in} + w_{shaft} = p_{out} / \rho + v_{out}^2 / 2 + g\ h_{out} + w_{loss} \quad (1)$$

where
p = static pressure
ρ = density
v = flow velocity
g = acceleration of gravity
h = elevation height
w_{shaft} = net shaft energy inn per unit mass for a pump, fan or similar
w_{loss} = loss due to friction

The energy equation is often used for incompressible flow problems and is called **the**

Mechanical Energy Equation or **the Extended Bernoulli Equation**.

The mechanical energy equation for a **turbine** can be written as:

$p_{in} / \rho + v_{in}^2 / 2 + g\ h_{in} = p_{out} / \rho + v_{out}^2 / 2 + g\ h_{out} + w_{shaft} + w_{loss}$ *(2)*

where
w_{shaft} *= net shaft energy out per unit mass for a turbine or similar*

Equation (1) and (2) dimensions are
energy per unit mass (ft^2/s^2 *= ft lb/slug or* m^2/s^2 *= N m/kg)*

Efficiency
According to (1) a larger amount of loss - w_{loss} - result in more shaft work required for the same rise of output energy. The efficiency of a **pump or fan process** can be expressed as:

$\eta = (w_{shaft} - w_{loss}) / w_{shaft}$ *(3)*

The efficiency of a **turbine process** can be expressed as:
$\eta = w_{shaft} / (w_{shaft} + w_{loss})$ *(4)*

The Mechanical Energy Equation in Terms of Energy per Unit Volume
The mechanical energy equation for a **pump or a fan** (1) can also be written in terms of **energy per unit volume** by multiplying (1) with fluid density - ρ:

$p_{in} + \rho\ v_{in}^2 / 2 + \gamma\ h_{in} + \rho\ w_{shaft} = p_{out} + \rho\ v_{out}^2 / 2 + \gamma\ h_{out} + w_{loss}$ *(5)*

where
$\gamma = \rho\ g$ *= specific weight*

The dimensions of equation (5) are
energy per unit volume (ft.lb/ft^3 *= lb/*ft^2 *or N.m/*m^3 *= N/*m^2*)*

The Mechanical Energy Equation in Terms of Energy per Unit Weight involves Heads
The mechanical energy equation for a **pump or a fan** (1) can also be written in terms of **energy per unit weight** by dividing with gravity - *g*:

$p_{in} / \gamma + v_{in}^2 / 2\ g + h_{in} + h_{shaft} = p_{out} / \gamma + v_{out}^2 / 2\ g + h_{out} + h_{loss}$ *(6)*

where
$\gamma = \rho\ g$ *= specific weight*
$h_{shaft} = w_{shaft} / g$ *= net shaft energy head inn per unit mass for a pump, fan or similar*
$h_{loss} = w_{loss} / g$ *= loss head due to friction*

The dimensions of equation (6) are

energy per unit weight (ft.lb/lb = ft or N.m/N = m)

Head is the energy per unit weight.

h_{shaft} can also be expressed as:
$h_{shaft} = w_{shaft} / g = W_{shaft} / m\ g = W_{shaft} / \gamma\ Q$ *(7)*

where
W_{shaft} *= shaft power*
m = mass flow rate
Q = volume flow rate

Example - Pumping Water
Water is pumped from an open tank at level zero to an open tank at level 10 ft. The pump adds four horsepowers to the water when pumping 2 ft^3/s.
Since $v_{in} = v_{out} = 0$, $p_{in} = p_{out} = 0$ and $h_{in} = 0$ - equation (6) can be modified to:

$h_{shaft} = h_{out} + h_{loss}$
or
$h_{loss} = h_{shaft} - h_{out}$ (8)

Equation (7) gives:

$h_{shaft} = W_{shaft} / \gamma\ Q = (4\ hp)(550\ ft.lb/s/hp) / (62.4\ lb/ft^3)(2\ ft^3/s) = 17.6\ ft$

- specific weight of water 62.4 lb/ft^3
- 1 hp (English horse power) = 550 ft. lb/s

Combined with (8):
$h_{loss} = (17.6\ ft) - (10\ ft) = 7.6\ ft$

The pump efficiency can be calculated from (3) modified for head:
$\eta = ((17.6\ ft) - (7.6\ ft)) / (17.6\ ft) = 0.58$

Equations in Fluid Mechanics: Common fluid mechanics equations - Bernoulli, conservation of energy, conservation of mass, pressure, Navier-Stokes, ideal gas law, Euler equations, Laplace equations, Darcy-Weisbach Equation and the following:
The Bernoulli Equation
- The Bernoulli Equation - A statement of the conservation of energy in a form useful for solving problems involving fluids. For a non-viscous, incompressible fluid in steady flow, the sum of pressure, potential and kinetic energies per unit volume is constant at any point.

Conservation laws
- The conservation laws states that particular measurable properties of an isolated physical system does not change as the system evolves.
- Conservation of energy (including mass)
- Fluid Mechanics and Conservation of Mass - The law of conservation of mass states that mass can neither be created nor destroyed.
- The Continuity Equation - The Continuity Equation is a statement that mass is conserved.

Darcy-Weisbach Equation
- Pressure Loss and Head Loss due to Friction in Ducts and Tubes - Major loss - head loss or pressure loss - due to friction in pipes and ducts.

Euler Equations

- In fluid dynamics, the Euler equations govern the motion of a compressible, inviscid fluid. They correspond to the Navier-Stokes equations with zero viscosity, although they are usually written in the form shown here because this emphasizes the fact that they directly represent conservation of mass, momentum, and energy.

Laplace's Equation
- The Laplace Equation describes the behavior of gravitational, electric, and fluid potentials.

Ideal Gas Law
- The Ideal Gas Law - For a perfect or ideal gas, the change in density is directly related to the change in temperature and pressure as expressed in the Ideal Gas Law.
- Properties of Gas Mixtures - Special care must be taken for gas mixtures when using the ideal gas law, calculating the mass, the individual gas constant or the density.
- The Individual and Universal Gas Constant - The Individual and Universal Gas Constant is common in fluid mechanics and thermodynamics.

Navier-Stokes Equations
- The motion of a non-turbulent, Newtonian fluid is governed by the Navier-Stokes equations. The equation can be used to model turbulent flow, where the fluid parameters are interpreted as time-averaged values.

Mechanical Energy Equation
- The Mechanical Energy Equation - The mechanical energy equation in Terms of Energy per Unit Mass, in Terms of Energy per Unit Volume and in Terms of Energy per Unit Weight involves Heads.

Pressure
- Static Pressure and Pressure Head in a Fluid - Pressure and pressure head in a static fluid.

Euler Equations: In fluid dynamics, the Euler equations govern the motion of a compressible, inviscid fluid. They correspond to the Navier-Stokes equations with zero viscosity, although they are usually written in the form shown here because this emphasizes the fact that they directly represent conservation of mass, momentum, and energy.

Euler Number: The Euler numbers, also called the secant numbers or zig numbers, are defined for $|x| < \pi/2$ by

$$\operatorname{sech} x - 1 \equiv -\frac{E_1^* x^2}{2!} + \frac{E_2^* x^4}{4!} - \frac{E_3^* x^6}{6!} + \dots$$

$$\sec x - 1 \equiv \frac{E_1^* x^2}{2!} + \frac{E_2^* x^4}{4!} + \frac{E_3^* x^6}{6!} + \dots,$$

where $\operatorname{sech}(z)$the hyperbolic secant and sec is the secant. Euler numbers give the number of odd alternating permutations and are related to Genocchi numbers. The base *e* of the natural logarithm is sometimes known as Euler's number. A different sort of Euler number, the Euler number of a finite complex K, is defined by

$$\chi(K) = \sum (-1)^p \operatorname{rank}(C_p(K)).$$

This Euler number is a topological invariant. To confuse matters further, the Euler characteristic is sometimes also called the "Euler number," and numbers produced by the prime-generating polynomial $n^2 - n + 41$ are sometimes called "Euler numbers" (Flannery and Flannery 2000, p. 47).

F

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 remove particles from water.

Flood Rim: The point of an object where the water would run over the edge of something and begin to cause a flood. See Air Break.

Fluids: A fluid is defined as a substance that continually deforms (flows) under an applied shear stress regardless of the magnitude of the applied stress. It is a subset of the phases of matter and includes liquids, gases, plasmas and, to some extent, plastic solids. Fluids are also divided into liquids and gases. Liquids form a free surface (that is, a surface not created by their container) while gases do not.

The distinction between solids and fluids is not so obvious. The distinction is made by evaluating the viscosity of the matter: for example silly putty can be considered either a solid or a fluid, depending on the time period over which it is observed. Fluids share the properties of not resisting deformation and the ability to flow (also described as their ability to take on the shape of their containers).

These properties are typically a function of their inability to support a shear stress in static equilibrium. While in a solid, stress is a function of strain, in a fluid, stress is a function of rate of strain. A consequence of this behavior is Pascal's law which entails the important role of pressure in characterizing a fluid's state. Based on how the stress depends on the rate of strain and its derivatives, fluids can be characterized as: Newtonian fluids: where stress is directly proportional to rate of strain, and Non-Newtonian fluids : where stress is proportional to rate of strain, its higher powers and derivatives (basically everything other than Newtonian fluid).

The behavior of fluids can be described by a set of partial differential equations, which are based on the conservation of mass, linear and angular momentum (Navier-Stokes equations) and energy. The study of fluids is fluid mechanics, which is subdivided into fluid dynamics and fluid statics depending on whether the fluid is in motion or not. Fluid **Related Information**: The Bernoulli Equation - A statement of the conservation of energy in a form useful for solving problems involving fluids. For a non-viscous, incompressible fluid in steady flow, the sum of pressure, potential and kinetic energies per unit volume is constant at any point. Equations in Fluid Mechanics - Continuity, Euler, Bernoulli, Dynamic and Total Pressure. Laminar, Transitional or Turbulent Flow? - It is important to know if the fluid flow is laminar, transitional or turbulent when calculating heat transfer or pressure and head loss.

Friction Head: The head required to overcome the friction at the interior surface of a conductor and between fluid particles in motion. It varies with flow, size, type and conditions of conductors and fittings, and the fluid characteristics.

G

Gas: A gas is one of the four major phases of matter (after solid and liquid, and followed by plasma) that subsequently appear as solid material when they are subjected to increasingly higher temperatures. Thus, as energy in the form of heat is added, a solid (e.g., ice) will first melt to become a liquid (e.g., water), which will then boil or evaporate to become a gas (e.g., water vapor). In some circumstances, a solid (e.g., "dry ice") can directly turn into a gas: this is called sublimation. If the gas is further heated, its atoms or molecules can become (wholly or partially) ionized, turning the gas into a plasma. Relater Gas Information: The Ideal Gas Law - For a perfect or ideal gas the change in density is directly related to the change in temperature and pressure as expressed in the Ideal Gas Law. Properties of Gas Mixtures - Special care must be taken for gas mixtures when using the ideal gas law, calculating the mass, the individual gas constant or the density. The Individual and Universal Gas Constant - The Individual and Universal Gas Constant is common in fluid mechanics and thermodynamics.

Gauge Pressure: Pressure differential above or below ambient atmospheric pressure.

H

Hazardous Atmosphere: An atmosphere which by reason of being explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen deficient, toxic, or otherwise harmful, may cause death, illness, or injury.

Hazen-Williams Factor: Hazen-Williams factor for some common piping materials. Hazen-Williams coefficients are used in the Hazen-Williams equation for friction loss calculation in ducts and pipes.

Hazen-Williams Equation - Calculating Friction Head Loss in Water Pipes
Friction head loss (ft H2O per 100 ft pipe) in water pipes can be obtained by using the empirical Hazen-Williams equation. The Darcy-Weisbach equation with the Moody diagram are considered to be the most accurate model for estimating frictional head loss in steady pipe flow. Since the approach requires a not so efficient trial and error solution, an alternative empirical head loss calculation that does not require the trial and error solutions, as the Hazen-Williams equation, may be preferred:

$$f = 0.2083\ (100/c)^{1.852}\ q^{1.852} / d_h^{4.8655} \quad (1)$$

where
f = *friction head loss in feet of water per 100 feet of pipe* (ft_{h20}*/100 ft pipe)*
c = *Hazen-Williams roughness constant*
q = *volume flow (gal/min)*
d_h = *inside hydraulic diameter (inches)*

Note that the Hazen-Williams formula is empirical and lacks physical basis. Be aware that the roughness constants are based on "normal" condition with approximately 1 m/s (3 ft/sec).

The Hazen-Williams formula is not the only empirical formula available. Manning's formula is common for gravity driven flows in open channels.

The flow velocity may be calculated as:

$v = 0.4087\ q / d_h^2$

where
v = flow velocity (ft/s)

The Hazen-Williams formula can be assumed to be relatively accurate for piping systems where the Reynolds Number is above 10^5 (turbulent flow).

- 1 ft (foot) = 0.3048 m
- 1 in (inch) = 25.4 mm
- 1 gal (US)/min =6.30888×10^{-5} m^3/s = 0.0227 m^3/h = 0.0631 dm^3(liter)/s = 2.228×10^{-3} ft^3/s = 0.1337 ft^3/min = 0.8327 Imperial gal (UK)/min

Note! The Hazen-Williams formula gives accurate head loss due to friction for fluids with kinematic viscosity of approximately 1.1 cSt. More about fluids and kinematic viscosity.

The results for the formula are acceptable for cold water at 60^o F (15.6^o C) with kinematic viscosity 1.13 cSt. For hot water with a lower kinematic viscosity (0.55 cSt at 130^o F (54.4^o C)) the error will be significant. Since the Hazen Williams method is only valid for water flowing at ordinary temperatures between 40 to 75^o F, the Darcy Weisbach method should be used for other liquids or gases.

Head: The height of a column or body of fluid above a given point expressed in linear units. Head if often used to indicate gauge pressure. Pressure is equal to the height times the density of the liquid. The measure of the pressure of water expressed in feet of height of water. 1 psi = 2.31 feet of water. There are various types of heads of water depending upon what is being measured. Static (water at rest) and Residual (water at flow conditions).

Hydraulics: Hydraulics is a branch of science and engineering concerned with the use of liquids to perform mechanical tasks.

Hydrodynamics: Hydrodynamics is the fluid dynamics applied to liquids, such as water, alcohol, and oil.

I

Ideal Gas: The Ideal Gas Law - For a perfect or ideal gas the change in density is directly related to the change in temperature and pressure as expressed in the Ideal Gas Law. Properties of Gas Mixtures - Special care must be taken for gas mixtures when using the ideal gas law, calculating the mass, the individual gas constant or the density. The Individual and Universal Gas Constant - The Individual and Universal Gas Constant is common in fluid mechanics and thermodynamics.

Isentropic Compression/Expansion Process: If the compression or expansion takes place under constant volume conditions - the process is called **isentropic.** The isentropic process on the basis of the Ideal Gas Law can be expressed as:

p / ρ^k = constant (2)

where
$k = c_p / c_v$ - the ratio of specific heats - the ratio of specific heat at constant pressure - c_p - to the specific heat at constant volume - c_v

Irrigation: Water that is especially furnished to help provide and sustain the life of growing plants. It comes from ditches. It is sometimes treated with herbicides and pesticides to prevent the growth of weeds and the development of bugs in a lawn and a garden.

K

Kinematic Viscosity: The ratio of absolute or dynamic viscosity to density - a quantity in which no force is involved. Kinematic viscosity can be obtained by dividing the absolute viscosity of a fluid with its mass density as

$$v = \mu / \rho \quad (2)$$

where
v = kinematic viscosity
μ = absolute or dynamic viscosity
ρ = density

In the SI-system the theoretical unit is m^2/s or commonly used **Stoke (St)** where

- *1 St = 10^{-4} m^2/s*

Since the Stoke is an unpractical large unit, it is usual divided by 100 to give the unit called **Centistokes (cSt)** where

1 St = 100 cSt
1 cSt = 10^{-6} m^2/s

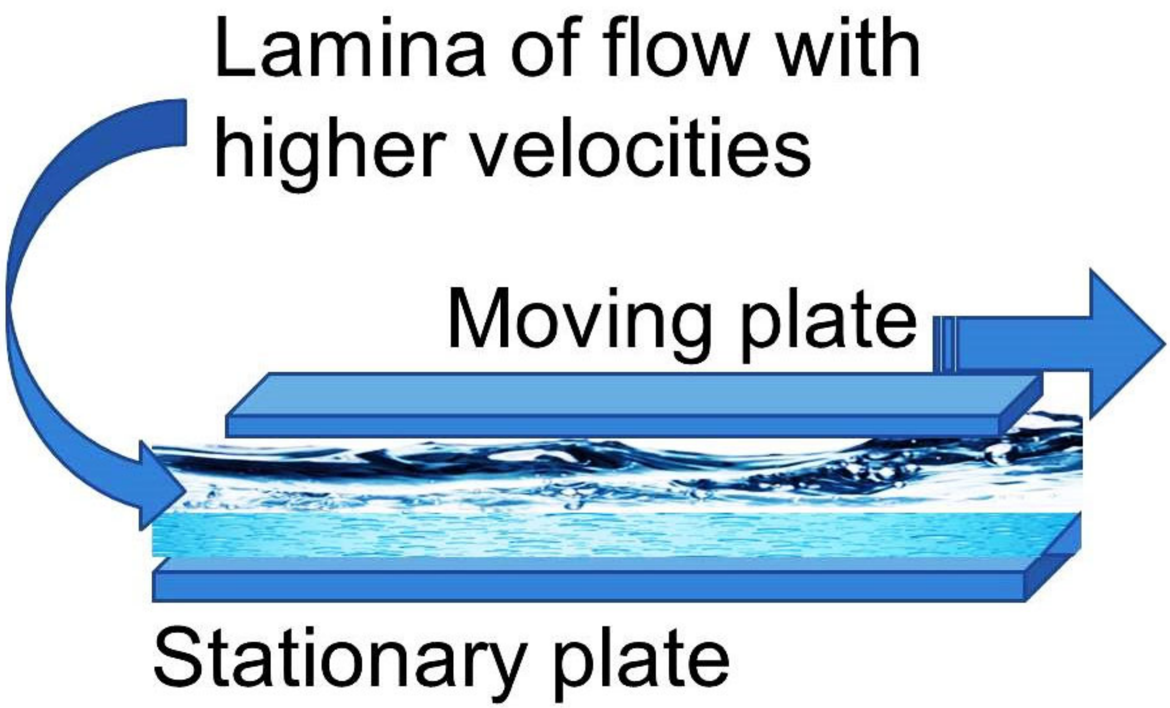
Since the specific gravity of water at 68.4°F (20.2°C) is almost one - 1, the kinematic viscosity of water at 68.4°F is for all practical purposes 1.0 cSt.

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.

Knudsen Number: Used by modelers who wish to express a non-dimensionless speed.

L

Laminar Flow: The resistance to flow in a liquid can be characterized in terms of the viscosity of the fluid if the flow is smooth. In the case of a moving plate in a liquid, it is found that there is a layer or lamina which moves with the plate, and a layer which is essentially stationary if it is next to a stationary plate. There is a gradient of velocity as you move from the stationary to the moving plate, and the liquid tends to move in layers with successively higher speed. This is called laminar flow, or sometimes "streamlined" flow. Viscous resistance to flow can be modeled for laminar flow, but if the lamina break up into turbulence, it is very difficult to characterize the fluid flow.



The common application of laminar flow would be in the smooth flow of a viscous liquid through a tube or pipe. In that case, the velocity of flow varies from zero at the walls to a maximum along the centerline of the vessel. The flow profile of laminar flow in a tube can be calculated by dividing the flow into thin cylindrical elements and applying the viscous force to them. Laminar, Transitional or Turbulent Flow? - It is important to know if the fluid flow is laminar, transitional or turbulent when calculating heat transfer or pressure and head loss.

Laplace's Equation: Describes the behavior of gravitational, electric, and fluid potentials.

The scalar form of Laplace's equation is the partial differential equation

$$\nabla^2 \psi = 0, \qquad (1)$$

where ∇^2 is the Laplacian.

Note that the operator ∇^2 is commonly written as Δ by mathematicians (Krantz 1999, p. 16).

Laplace's equation is a special case of the Helmholtz differential equation

$$\nabla^2 \psi + k^2 \psi = 0 \qquad (2)$$

with $k = 0$, or Poisson's equation

$$\nabla^2 \psi = -4 \pi \rho \tag{3}$$

with $\rho = 0$.

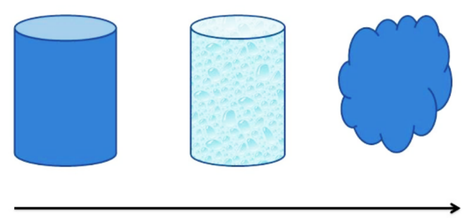
The vector Laplace's equation is given by

$$\nabla^2 \mathbf{F} = \mathbf{0}. \tag{4}$$

A function ψ which satisfies Laplace's equation is said to be harmonic. A solution to Laplace's equation has the property that the average value over a spherical surface is equal to the value at the center of the sphere (Gauss's harmonic function theorem). Solutions have no local maxima or minima. Because Laplace's equation is linear, the superposition of any two solutions is also a solution.

Lift (Force): Lift consists of the sum of all the aerodynamic forces normal to the direction of the external airflow.

Liquids: An in-between state of matter. They can be found in between the solid and gas states. They don't have to be made up of the same compounds. If you have a variety of materials in a liquid, it is called a solution. One characteristic of a liquid is that it will fill up the shape of a container. If you pour some water in a cup, it will fill up the bottom of the cup first and then fill the rest. The water will also take the shape of the cup. It fills the bottom first because of **gravity**. The top part of a liquid will usually have a flat surface. That flat surface is because of gravity too. Putting an ice cube (solid) into a cup will leave you with a cube in the middle of the cup; the shape won't change until the ice becomes a liquid.



Another trait of liquids is that they are difficult to compress.

When you compress something, you take a certain amount and force it into a smaller space. Solids are very difficult to compress and gases are very easy. Liquids are in the middle but tend to be difficult. When you compress something, you force the atoms closer together. When pressure go up, substances are compressed. Liquids already have their atoms close together, so they are hard to compress. Many shock absorbers in cars compress liquids in tubes.

A special force keeps liquids together. Solids are stuck together and you have to force them apart. Gases bounce everywhere and they try to spread themselves out. Liquids actually want to stick together. There will always be the occasional evaporation where extra energy gets a molecule excited and the molecule leaves the system. Overall, liquids have **cohesive** (sticky) forces at work that hold the molecules together. Related Liquid Information: Equations in Fluid Mechanics - Continuity, Euler, Bernoulli, Dynamic and Total Pressure

M

Mach Number: When an object travels through a medium, then its Mach number is the ratio of the object's speed to the speed of sound in that medium.

Magnetic Flow Meter: Inspection of magnetic flow meter instrumentation should include checking for corrosion or insulation deterioration.

Manning Formula for Gravity Flow: Manning's equation can be used to calculate cross-sectional average velocity flow in open channels

$v = k_n/n\ R^{2/3}\ S^{1/2}$ *(1)*

where
v = cross-sectional average velocity (ft/s, m/s)
k_n = 1.486 for English units and k_n = 1.0 for SI units
A = cross sectional area of flow (ft^2, m^2)
n = Manning coefficient of roughness
R = hydraulic radius (ft, m)
S = slope of pipe (ft/ft, m/m)

The volume flow in the channel can be calculated as
$q = A\ v = A\ k_n/n\ R^{2/3}\ S^{1/2}$ *(2)*

where
q = volume flow (ft^3/s, m^3/s)
A = cross-sectional area of flow (ft^2, m^2)

Maximum Contamination Levels or (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. Or provide adequate backflow protection.

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.

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.

ML: milliliter

N

Navier-Stokes Equations: The motion of a non-turbulent, Newtonian fluid is governed by the Navier-Stokes equation. The equation can be used to model turbulent flow, where the fluid parameters are interpreted as time-averaged values.

Newtonian Fluid: Newtonian fluid (named for Isaac Newton) is a fluid that flows like water—its shear stress is linearly proportional to the velocity gradient in the direction perpendicular to the plane of shear. The constant of proportionality is known as the viscosity. Water is Newtonian, because it continues to exemplify fluid properties no matter how fast it is stirred or mixed.

Contrast this with a non-Newtonian fluid, in which stirring can leave a "hole" behind (that gradually fills up over time - this behavior is seen in materials such as pudding, or to a less rigorous extent, sand), or cause the fluid to become thinner, the drop in viscosity causing it to flow more (this is seen in non-drip paints). For a Newtonian fluid, the viscosity, by definition, depends only on temperature and pressure (and also the chemical composition of the fluid if the fluid is not a pure substance), not on the forces acting upon it. If the fluid is incompressible and viscosity is constant across the fluid, the equation governing the shear stress. Related Newtonian Information: A Fluid is Newtonian if viscosity is constant applied to shear force. Dynamic, Absolute and Kinematic Viscosity - An introduction to dynamic, absolute and kinematic viscosity and how to convert between CentiStokes (cSt), CentiPoises (cP), Saybolt Universal Seconds (SSU) and degree Engler.

Newton's Third Law: Newton's third law describes the forces acting on objects interacting with each other. Newton's third law can be expressed as

- *"If one object exerts a force **F** on another object, then the second object exerts an equal but opposite force **F** on the first object"*

Force is a convenient abstraction to represent mentally the pushing and pulling interaction between objects.

It is common to express forces as vectors with magnitude, direction and point of application. The net effect of two or more forces acting on the same point is the vector sum of the forces.

Non-Newtonian Fluid: Non-Newtonian fluid viscosity changes with the applied shear force.

O

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.

P

Pascal's Law: A pressure applied to a confined fluid at rest is transmitted with equal intensity throughout the fluid.

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.

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.

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).

Pipeline Appurtenances: Pressure reducers, bends, valves, regulators (which are a type of valve), etc.
Peak Demand: The maximum momentary load placed on a water treatment plant, pumping station or distribution system is the Peak Demand.

Pipe Velocities: For calculating fluid pipe velocity.

Imperial units
A fluids flow velocity in pipes can be calculated with Imperial or American units as

$v = 0.4085\ q / d^2$ *(1)*

where
v = velocity (ft/s)
q = volume flow (US gal. /min)
d = pipe inside diameter (inches)

SI units
A fluids flow velocity in pipes can be calculated with SI units as

$v = 1.274\ q / d^2$ *(2)*

where
v = velocity (m/s)
q = volume flow (m^3/s)
d = pipe inside diameter (m)

Pollution: To make something unclean or impure. Some states will have a definition of pollution that relates to non-health related water problems, like taste and odors. See Contaminated.

Positive Flow Report-back Signal: 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.

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.

Prandtl Number: The Prandtl Number is a dimensionless number approximating the ratio of momentum diffusivity and thermal diffusivity and can be expressed as

$Pr = v / \alpha$ (1)
where
Pr = Prandtl's number
v = kinematic viscosity (Pa s)
α = thermal diffusivity (W/m K)

The Prandtl number can alternatively be expressed as

$Pr = \mu c_p / k$ (2)

where
μ = absolute or dynamic viscosity (kg/m s, cP)
c_p = specific heat capacity (J/kg K, Btu/(lb ^oF))
k = thermal conductivity (W/m K, Btu/(h ft^2 ^oF/ft))
The Prandtl Number is often used in heat transfer and free and forced convection calculations.

Pressure: An introduction to pressure - the definition and presentation of common units as psi and Pa and the relationship between them.

The pressure in a fluid is defined as
"the normal force per unit area exerted on an imaginary or real plane surface in a fluid or a gas"

The equation for pressure can expressed as:
$p = F / A$ (1)

where
p = pressure [lb/in^2 (psi) or lb/ft^2 (psf), N/m^2 or kg/ms^2 (Pa)]
F = force [1), N]
A = area [in^2 or ft^2, m^2]
1) In the English Engineering System special care must be taken for the force unit. The basic unit for mass is the pound mass (lb_m) and the unit for the force is the pound (lb) or pound force (lb_f).

Absolute Pressure
The **absolute pressure** - p_a - is measured relative to the *absolute zero pressure* - the pressure that would occur at absolute vacuum.

Gauge Pressure
A **gauge** is often used to measure the pressure difference between a system and the surrounding atmosphere. This pressure is often called the **gauge pressure** and can be expressed as
$p_g = p_a - p_o$ (2)

where
p_g = gauge pressure
p_o = atmospheric pressure

Atmospheric Pressure
The atmospheric pressure is the pressure in the surrounding air. It varies with temperature and altitude above sea level.

Standard Atmospheric Pressure
The **Standard Atmospheric Pressure** (atm) is used as a reference for gas densities and volumes. The Standard Atmospheric Pressure is defined at sea-level at 273°K (0°C) and is **1.01325 bar** or 101325 Pa (absolute). The temperature of 293°K (20°C) is also used.

In imperial units the Standard Atmospheric Pressure is 14.696 psi.
- *1 atm = 1.01325 bar = 101.3 kPa = 14.696 psi (lb_f/in^2)= 760 mmHg =10.33 mH_2O = 760 torr = 29.92 in Hg = 1013 mbar = 1.0332 kg_f/cm^2 = 33.90 ftH_2O*

Pressure Head: The height to which liquid can be raised by a given pressure.

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.

Pressure Units: Since 1 Pa is a small pressure unit, the unit hectopascal (hPa) is widely used, especially in meteorology. The unit kilopascal (kPa) is commonly used designing technical applications like HVAC systems, piping systems and similar.
- *1 hectopascal = 100 pascal = 1 millibar*
- *1 kilopascal = 1000 pascal*

Some Pressure Levels
- 10 Pa - The pressure at a depth of 1 mm of water
- 1 kPa - Approximately the pressure exerted by a 10 g mass on a 1 cm^2 area
- 10 kPa - The pressure at a depth of 1 m of water, or
  the drop in air pressure when going from sea level to 1000 m elevation
- 10 MPa - A "high pressure" washer forces the water out of the nozzles at this pressure
- 10 GPa - This pressure forms diamonds

Some Alternative Units of Pressure
- *1 bar - 100,000 Pa*
- *1 millibar - 100 Pa*
- *1 atmosphere - 101,325 Pa*
- *1 mm Hg - 133 Pa*
- *1 inch Hg - 3,386 Pa*

A **torr** (torr) is named after Torricelli and is the pressure produced by a column of mercury 1 mm high equals to 1/760th of an atmosphere. 1 atm = 760 torr = 14.696 psi

Pounds per square inch (psi) was common in U.K. but has now been replaced in almost every country except in the U.S. by the SI units. The Normal atmospheric pressure is 14.696 psi, meaning that a column of air on one square inch in area rising from the Earth's atmosphere to space weighs 14.696 pounds.

The **bar** (bar) is common in the industry. One bar is 100,000 Pa, and for most practical purposes can be approximated to one atmosphere even if

1 Bar = 0.9869 atm

There are 1,000 **millibar** (mbar) in one bar, a unit common in meteorology.

1 millibar = 0.001 bar = 0.750 torr = 100 Pa

R

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).

Reynolds Number: The Reynolds number is used to determine whether a flow is laminar or turbulent. The Reynolds Number is a non-dimensional parameter defined by the ratio of dynamic pressure (ρu^2) and shearing stress ($\mu u / L$) - and can be expressed as

$$Re = (\rho u^2) / (\mu u / L)$$
$$= \rho u L / \mu$$
$$= u L / v \quad (1)$$

where

Re = Reynolds Number (non-dimensional)

ρ = density (kg/m^3, lb_m/ft^3)

u = velocity (m/s, ft/s)

μ = dynamic viscosity (Ns/m^2, $lb_m/s\ ft$)

L = characteristic length (m, ft)

v = kinematic viscosity (m^2/s, ft^2/s)

Richardson Number: A dimensionless number that expresses the ratio of potential to kinetic energy.

S

Sanitizer: A chemical which disinfects (kills bacteria), kills algae and oxidizes organic matter.

Saybolt Universal Seconds (or SUS, SSU): Saybolt Universal Seconds (or SUS) is used to measure viscosity. The efflux time is Saybolt Universal Seconds (SUS) required for 60 milliliters of a petroleum product to flow through the calibrated orifice of a Saybolt Universal viscometer, under carefully controlled temperature and as prescribed by test method ASTM D 88. This method has largely been replaced by the kinematic viscosity method. Saybolt Universal Seconds is also called the SSU number (Seconds Saybolt Universal) or SSF number (Saybolt Seconds Furol).

Kinematic viscosity versus dynamic or absolute viscosity can be expressed as

$$v = 4.63\, \mu / SG \quad (3)$$

where

v = kinematic viscosity (SSU)

μ = dynamic or absolute viscosity (cP)

Scale: Crust of calcium carbonate, the result of unbalanced pool 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. You will often find major scale deposits inside a backflow prevention assembly.

Shock: Also known as superchlorination or break point chlorination. Ridding a pool of organic waste through oxidization by the addition of significant quantities of a halogen.

Shock Wave: A shock wave is a strong pressure wave produced by explosions or other phenomena that create violent changes in pressure.

Solder: A fusible alloy used to join metallic parts. Solder for potable water pipes shall be lead-free.

Sound Barrier: The sound barrier is the apparent physical boundary stopping large objects from becoming supersonic.

Specific Gravity: The Specific Gravity - *SG* - is a dimensionless unit defined as the ratio of density of the material to the density of water at a specified temperature. Specific Gravity can be expressed as

$SG = = \rho / \rho_{H2O}$ *(3)*

where
SG = specific gravity
ρ *= density of fluid or substance* (kg/m^3)
ρ_{H2O} *= density of water* (kg/m^3)

It is common to use the density of water at 4° C (39°F) as a reference - at this point the density of water is at the highest. Since Specific Weight is dimensionless it has the same value in the metric SI system as in the imperial English system (BG). At the reference point the Specific Gravity has same numerically value as density.

Example - Specific Gravity
If the density of iron is 7850 kg/m^3, 7.85 grams per cubic millimeter, 7.85 kilograms per liter, or 7.85 metric tons per cubic meter - the specific gravity of iron is:
$SG = 7850\ kg/m^3 / 1000\ kg/m^3$
$= \underline{7.85}$
(the density of water is 1000 kg/m^3)

Specific Weight: Specific Weight is defined as weight per unit volume. Weight is a **force**.
- Mass and Weight - the difference! - What is weight and what is mass? An explanation of the difference between weight and mass.

Specific Weight can be expressed as

$\gamma = \rho\ g$ *(2)*

where
γ *= specific weight* (kN/m^3)

g = acceleration of gravity (m/s^2)

The SI-units of specific weight are kN/m^3. The imperial units are lb/ft^3. The local acceleration *g* is under normal conditions 9.807 m/s^2 in SI-units and 32.174 ft/s^2 in imperial units.

Example - Specific Weight Water
Specific weight for water at 60 ^oF is 62.4 lb/ft^3 in imperial units and 9.80 kN/m^3 in SI-units.

Example - Specific Weight Some other Materials

Product	Specific Weight - γ	
	Imperial Units (lb/ft^3)	SI Units (kN/m^3)
Ethyl Alcohol	49.3	7.74
Gasoline	42.5	6.67
Glycerin	78.6	12.4
Mercury	847	133
SAE 20 Oil	57	8.95
Seawater	64	10.1
Water	62.4	9.80

Static Head: The height of a column or body of fluid above a given point

Static Pressure: The pressure in a fluid at rest.

Static Pressure and Pressure Head in Fluids: The pressure indicates the normal force per unit area at a given point acting on a given plane. Since there is no shearing stresses present in a fluid at rest - the pressure in a fluid is independent of direction.

For fluids - liquids or gases - at rest the pressure gradient in the vertical direction depends only on the specific weight of the fluid.

How pressure changes with elevation can be expressed as

$dp = - \gamma\ dz$ *(1)*

where
dp = change in pressure
dz = change in height
γ = specific weight

The pressure gradient in vertical direction is negative - the pressure decrease upwards.

Specific Weight: Specific Weight can be expressed as:

$\gamma = \rho\ g$ *(2)*

where
γ = specific weight

g = acceleration of gravity

In general, the specific weight - γ - is constant for fluids. For gases the specific weight - γ - varies with the elevation.

Static Pressure in a Fluid: For an incompressible fluid - as a liquid - the pressure difference between two elevations can be expressed as:

$p_2 - p_1 = - \gamma (z_2 - z_1)$ *(3)*

where

p_2 *= pressure at level 2*

p_1 *= pressure at level 1*

z_2 *= level 2*

z_1 *= level 1*

(3) can be transformed to:

$p_1 - p_2 = \gamma (z_2 - z_1)$ *(4)*

or

$p_1 - p_2 = \gamma h$ *(5)*

where

$h = z_2 - z_1$ *difference in elevation - the depth down from location* z_2*.*

or

$p_1 = \gamma h + p_2$ *(6)*

Static Pressure and Pressure Head in Fluids Continued:

The Pressure Head

(6) can be transformed to:

$h = (p_2 - p_1) / \gamma$ *(6)*

h express **the pressure head** - the height of a column of fluid of specific weight - γ - required to give a pressure difference of $(p_2 - p_1)$.

Example - Pressure Head

A pressure difference of 5 psi (lbf/in^2) is equivalent to

$5\ (lbf/in^2)\ 12\ (in/ft)\ 12\ (in/ft)\ /\ 62.4\ (lb/ft^3) = \underline{11.6}$ *ft of water*

$5\ (lbf/in^2)\ 12\ (in/ft)\ 12\ (in/ft)\ /\ 847\ (lb/ft^3) = \underline{0.85}$ *ft of mercury*

when specific weight of water is 62.4 (lb/ft^3) and specific weight of mercury is 847 (lb/ft^3).

Streamline - Stream Function: A streamline is the path that an imaginary particle would follow if it was embedded in the flow.

Strouhal Number: A quantity describing oscillating flow mechanisms. The Strouhal Number is a dimensionless value useful for analyzing oscillating, unsteady fluid flow dynamics problems.

The Strouhal Number can be expressed as

$St = \omega\ l / v$ *(1)*

where
St = Strouhal Number
ω = oscillation frequency
l = characteristic length
v = flow velocity

The Strouhal Number represents a measure of the ratio of inertial forces due to the unsteadiness of the flow or local acceleration to the inertial forces due to changes in velocity from one point to another in the flow field.

The vortices observed behind a stone in a river, or measured behind the obstruction in a vortex flow meter, illustrate these principles.

Stuffing Box: That portion of the pump which houses the packing or mechanical seal.

Submerged: To cover with water or liquid substance.

Supersonic Flow: Flow with speed above the speed of sound, 1,225 km/h at sea level, is said to be supersonic.

Surface Tension: Surface tension is a force within the surface layer of a liquid that causes the layer to behave as an elastic sheet. The cohesive forces between liquid molecules are responsible for the phenomenon known as surface tension. The molecules at the surface do not have other like molecules on all sides of them and consequently they cohere more strongly to those directly associated with them on the surface. This forms a surface "film" which makes it more difficult to move an object through the surface than to move it when it is completely submersed. Surface tension is typically measured in dynes/cm, the force in dynes required to break a film of length 1 cm. Equivalently, it can be stated as surface energy in ergs per square centimeter. Water at 20°C has a surface tension of 72.8 dynes/cm compared to 22.3 for ethyl alcohol and 465 for mercury.

Surface tension is typically measured in *dynes/cm* or *N/m*.

Liquid	Surface Tension	
	N/m	dynes/cm
Ethyl Alcohol	0.0223	22.3
Mercury	0.465	465
Water 20°C	0.0728	72.75
Water 100°C	0.0599	58.9

Surface tension is the energy required to stretch a unit change of a surface area. Surface tension will form a drop of liquid to a sphere since the sphere offers the smallest area for a definite volume.

Surface tension can be defined as

$$\sigma = F_s / l \quad (1)$$

where
σ = surface tension (N/m)
F_s = stretching force (N)
l = unit length (m)

Alternative Units
Alternatively, surface tension is typically measured in dynes/cm, which is
- the force in dynes required to break a film of length 1 cm

or as surface energy J/m^2 or alternatively ergs per square centimeter.
- 1 dynes/cm = 0.001 N/m = 0.0000685 lb_f/ft = 0.571 10^{-5} lb_f/in = 0.0022 poundal/ft = 0.00018 poundal/in = 1.0 mN/m = 0.001 J/m^2 = 1.0 erg/cm^2 = 0.00010197 kg_f/m

Common Imperial units used are lb/ft and lb/in.
Water surface tension at different temperatures can be taken from the table below:

Temperature (°C)	Surface Tension - σ - (N/m)
0	0.0757
10	0.0742
20	0.0728
30	0.0712
40	0.0696
50	0.0679
60	0.0662

70	0.0644
80	0.0626
90	0.0608
100	0.0588

Surface Tension of some common Fluids

- benzene : 0.0289 (N/m)
- diethyl ether : 0.0728 (N/m)
- carbon tetrachloride : 0.027 (N/m)
- chloroform : 0.0271 (N/m)
- ethanol : 0.0221 (N/m)
- ethylene glycol : 0.0477 (N/m)
- glycerol : 0.064 (N/m)
- mercury : 0.425 (N/m)
- methanol : 0.0227 (N/m)
- propanol : 0.0237 (N/m)
- toluene : 0.0284 (N/m)
- water at 20^{o}C : 0.0729 (N/m)

Surge Tanks: 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.

T

Telemetering Systems: 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. Devices 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.

Thixotropic Fluids: Shear Thinning Fluids or **Thixotropic Fluids** reduce their viscosity as agitation or pressure is increased at a constant temperature. Ketchup and mayonnaise are examples of thixotropic materials. They appear thick or viscous but are possible to pump quite easily.

Transonic: Flow with speed at velocities just below and above the speed of sound is said to be transonic.

Turbidity: A measure of the cloudiness of water caused by suspended particles.

U

U-Tube Manometer: Pressure measuring devices using liquid columns in vertical or inclined tubes are called manometers. One of the most common is the water filled u-tube manometer used to measure pressure difference in pitot or orifices located in the airflow in air handling or ventilation systems.

V

Valve: A device that opens and closes to regulate the flow of liquids. Faucets, hose bibs, and Ball are examples of valves.

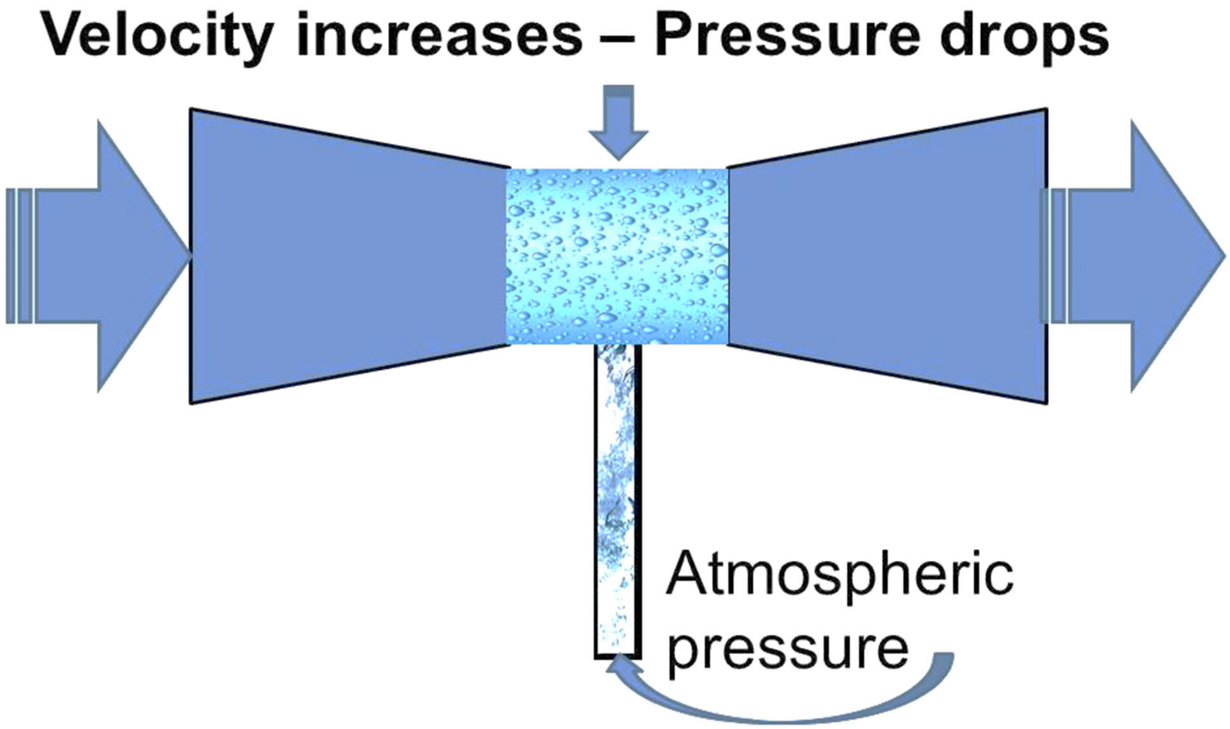
Vane: That portion of an impeller which throws the water toward the volute.

Vapor Pressure: For a particular substance at any given temperature there is a pressure at which the vapor of that substance is in equilibrium with its liquid or solid forms.

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: A system for speeding the flow of the fluid, by constricting it in a cone-shaped tube. Venturi are used to measure the speed of a fluid, by measuring the pressure changes from one point to another along the venture. A venturi can also be used to inject a liquid or a gas into another liquid. A pump forces the liquid flow through a tube connected to:

- A venturi to increase the speed of the fluid (restriction of the pipe diameter)
- A short piece of tube connected to the gas source
- A second venturi that decrease the speed of the fluid (the pipe diameter increase again)
- After the first venturi the pressure in the pipe is lower, so the gas is sucked in the pipe. Then the mixture enters the second venturi and slow down. At the end of the system a mixture of gas and liquid appears and the pressure rise again to its normal level in the pipe.
- This technique is used for ozone injection in water.



The newest injector design causes complete mixing of injected materials (air, ozone or chemicals), eliminating the need for other in-line mixers. Venturi injectors have no moving parts and are maintenance free. They operate effectively over a wide range of pressures (from 1 to 250 psi) and require only a minimum pressure difference to initiate the vacuum at the suction part. Venturis are often built in thermoplastics (PVC, PE, PVDF), stainless steel or other metals.

The cavitation effect at the injection chamber provides an instantaneous mixing, creating thousands of very tiny bubbles of gas in the liquid. The small bubbles provide and increased gas exposure to the liquid surface area, increasing the effectiveness of the process (i.e. ozonation).

Vibration: A force that is present on construction sites and must be considered. The vibrations caused by backhoes, dump trucks, compactors and traffic on job sites can be substantial.

Viscosity: Informally, viscosity is the quantity that describes a fluid's resistance to flow. Fluids resist the relative motion of immersed objects through them as well as to the motion of layers with differing velocities within them. Formally, viscosity (represented by the symbol η "eta") is the ratio of the shearing stress (F/A) to the velocity gradient ($\Delta v_x/\Delta z$ or dv_x/dz) in a fluid.

$$\eta = \left(\frac{F}{A}\right) \div \left(\frac{\Delta v_x}{\Delta z}\right) \quad \text{or} \quad \eta = \left(\frac{F}{A}\right) \div \left(\frac{dv_x}{dz}\right)$$

The more usual form of this relationship, called Newton's equation, states that the resulting shear of a fluid is directly proportional to the force applied and inversely proportional to its viscosity. The similarity to Newton's second law of motion ($F = ma$) should be apparent.

$$\frac{F}{A} = \eta\frac{\Delta v_x}{\Delta z} \quad \text{or} \quad \frac{F}{A} = \eta\frac{dv_x}{dz}$$

$$\Updownarrow \qquad\qquad\qquad \Updownarrow$$

$$F = m\frac{\Delta v}{\Delta t} \quad \text{or} \quad F = m\frac{dv}{dt}$$

The SI unit of viscosity is the pascal second [Pa·s], which has no special name. Despite its self-proclaimed title as an international system, the International System of Units has had very little international impact on viscosity. The pascal second is rarely used in scientific and technical publications today. The most common unit of viscosity is the dyne second per square centimeter [dyne·s/cm^2], which is given the name poise [P] after the French physiologist Jean Louis Poiseuille (1799-1869). Ten poise equal one pascal second [Pa·s] making the centipoise [cP] and millipascal second [mPa·s] identical.

1 pascal second = 10 poise = 1,000 millipascal second
1 centipoise = 1 millipascal second

There are actually two quantities that are called viscosity. The quantity defined above is sometimes called dynamic viscosity, absolute viscosity, or simple viscosity to distinguish it from the other quantity, but is usually just called viscosity. The other quantity called kinematic viscosity (represented by the symbol v "nu") is the ratio of the viscosity of a fluid to its density.

$$v = \frac{\eta}{\rho}$$

Kinematic viscosity is a measure of the resistive flow of a fluid under the influence of gravity. It is frequently measured using a device called a capillary viscometer -- basically a graduated can with a narrow tube at the bottom. When two fluids of equal volume are placed in identical capillary viscometers and allowed to flow under the influence of gravity, a viscous fluid takes longer than a less viscous fluid to flow through the tube. Capillary viscometers are discussed in more detail later in this section. The SI unit of kinematic viscosity is the square meter per second [m^2/s], which has no special name. This unit is so large that it is rarely used. A more common unit of kinematic viscosity is the square centimeter per second [cm^2/s], which is given the name stoke [St] after the English scientist George Stoke. This unit is also a bit too large and so the most common unit is probably the square millimeter per second [mm^2/s] or centistoke [cSt].

Viscosity and Reference Temperatures: The viscosity of a fluid is highly temperature dependent and for either dynamic or kinematic viscosity to be meaningful, the **reference temperature** must be quoted. In ISO 8217 the reference temperature for a residual fluid is 100^{o}C. For a distillate fluid the reference temperature is 40^{o}C.

- For a liquid - the kinematic viscosity will **decrease** with higher temperature.
- For a gas - the kinematic viscosity will **increase** with higher temperature.

Volute: The spiral-shaped casing surrounding a pump impeller that collects the liquid discharged by the impeller.

Vorticity: Vorticity is defined as the circulation per unit area at a point in the flow field.

Vortex: A vortex is a whirlpool in the water.

W

Water Freezing: The effects of water freezing in storage tanks can be minimized by alternating water levels in the tank.

Water Storage Facility Inspection: 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.

Wave Drag: Wave drag refers to a sudden and very powerful drag that appears on aircrafts flying at high-subsonic speeds.

Water Purveyor: The individuals or organization responsible to help provide, supply, and furnish quality water to a community.

Water Works: All of the pipes, pumps, reservoirs, dams and buildings that make up a water system.

Waterborne Diseases: 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).

Weber Number: A dimensionless value useful for analyzing fluid flows where there is an interface between two different fluids. Since the Weber Number represents an index of the inertial force to the surface tension force acting on a fluid element, it can be useful analyzing thin films flows and the formation of droplets and bubbles.

Appendixes and Charts

Density of Common Liquids

The density of some common liquids can be found in the table below:

Liquid	Temperature - *t* - (ºC)	Density - *ρ* - (kg/m^3)
Acetic Acid	25	1049
Acetone	25	785
Acetonitrile	20	782
Alcohol, ethyl	25	785
Alcohol, methyl	25	787
Alcohol, propyl	25	780
Ammonia (aqua)	25	823
Aniline	25	1019
Automobile oils	15	880 - 940
Beer (varies)	10	1010
Benzene	25	874
Benzyl	15	1230
Brine	15	1230
Bromine	25	3120
Butyric Acid	20	959
Butane	25	599
n-Butyl Acetate	20	880
n-Butyl Alcohol	20	810
n-Butylhloride	20	886
Caproic acid	25	921
Carbolic acid	15	956
Carbon disulfide	25	1261
Carbon tetrachloride	25	1584
Carene	25	857
Castor oil	25	956
Chloride	25	1560
Chlorobenzene	20	1106
Chloroform	20	1489
Chloroform	25	1465
Citric acid	25	1660
Coconut oil	15	924
Cotton seed oil	15	926
Cresol	25	1024
Creosote	15	1067
Crude oil, 48º API	60ºF	790

Crude oil, 40° API	60°F	825
Crude oil, 35.6° API	60°F	847
Crude oil, 32.6° API	60°F	862
Crude oil, California	60°F	915
Crude oil, Mexican	60°F	973
Crude oil, Texas	60°F	873
Cumene	25	860
Cyclohexane	20	779
Cyclopentane	20	745
Decane	25	726
Diesel fuel oil 20 to 60	15	820 - 950
Diethyl ether	20	714
o-Dichlorobenzene	20	1306
Dichloromethane	20	1326
Diethylene glycol	15	1120
Dichloromethane	20	1326
Dimethyl Acetamide	20	942
N,N-Dimethylformamide	20	949
Dimethyl Sulfoxide	20	1100
Dodecane	25	755
Ethane	-89	570
Ether	25	73
Ethylamine	16	681
Ethyl Acetate	20	901
Ethyl Alcohol	20	789
Ethyl Ether	20	713
Ethylene Dichloride	20	1253
Ethylene glycol	25	1097
Fluorine refrigerant R-12	25	1311
Formaldehyde	45	812
Formic acid 10%oncentration	20	1025
Formic acid 80%oncentration	20	1221
Freon - 11	21	1490
Freon - 21	21	1370
Fuel oil	60°F	890
Furan	25	1416
Furforol	25	1155
Gasoline, natural	60°F	711
Gasoline, Vehicle	60°F	737
Gas oils	60°F	890
Glucose	60°F	1350 - 1440
Glycerin	25	1259

Glycerol	25	1126
Heptane	25	676
Hexane	25	655
Hexanol	25	811
Hexene	25	671
Hydrazine	25	795
Iodine	25	4927
Ionene	25	932
Isobutyl Alcohol	20	802
Iso-Octane	20	692
Isopropyl Alcohol	20	785
Isopropyl Myristate	20	853
Kerosene	60ºF	817
Linolenic Acid	25	897
Linseed oil	25	929
Methane	-164	465
Methanol	20	791
Methyl Isoamyl Ketone	20	888
Methyl Isobutyl Ketone	20	801
Methyl n-Propyl Ketone	20	808
Methyl t-Butyl Ether	20	741
N-Methylpyrrolidone	20	1030
Methyl Ethyl Ketone	20	805
Milk	15	1020 - 1050
Naphtha	15	665
Naphtha, wood	25	960
Napthalene	25	820
Ocimene	25	798
Octane	15	918
Olive oil	20	800 - 920
Oxygen (liquid)	-183	1140
Palmitic Acid	25	851
Pentane	20	626
Pentane	25	625
Petroleum Ether	20	640
Petrol, natural	60ºF	711
Petrol, Vehicle	60ºF	737
Phenol	25	1072
Phosgene	0	1378
Phytadiene	25	823
Pinene	25	857
Propane	-40	583

Propane, R-290	25	494
Propanol	25	804
Propylenearbonate	20	1201
Propylene	25	514
Propylene glycol	25	965
Pyridine	25	979
Pyrrole	25	966
Rape seed oil	20	920
Resorcinol	25	1269
Rosin oil	15	980
Sea water	25	1025
Silane	25	718
Silicone oil		760
Sodium Hydroxide (caustic soda)	15	1250
Sorbaldehyde	25	895
Soya bean oil	15	924 - 928
Stearic Acid	25	891
Sulfuric Acid 95%onc.	20	1839
Sugar solution 68 brix	15	1338
Sunflower oil	20	920
Styrene	25	903
Terpinene	25	847
Tetrahydrofuran	20	888
Toluene	20	867
Toluene	25	862
Triethylamine	20	728
Trifluoroacetic Acid	20	1489
Turpentine	25	868
Water - pure	4	1000
Water - sea	77ºF	1022
Whale oil	15	925
o-Xylene	20	880

1 kg/m^3 = 0.001 g/cm^3 = 0.0005780 oz/in^3 = 0.16036 oz/gal (Imperial) = 0.1335 oz/gal (U.S.) = 0.0624 lb/ft^3 = 0.000036127 lb/in^3 = 1.6856 lb/yd^3 = 0.010022 lb/gal (Imperial) = 0.008345 lb/gal (U.S) = 0.0007525 ton/yd^3

Dynamic or Absolute Viscosity Units Converting Table

The table below can be used to convert between common dynamic or absolute viscosity units.

Multiply by	Convert to				
Convert from	Poiseuille (Pa s)	Poise (dyne s/ cm^2 = g / cm s)	centiPoise	kg / m h	kg_f s / m^2
Poiseuille (Pa s)	1	10	10^3	3.63 10^3	0.102
Poise (dyne s / cm^2 = g / cm s)	0.1	1	100	360	0.0102
centiPoise	0.001	0.01	1	3.6	0.00012
kg / m h	2.78 10^{-4}	0.00278	0.0278	1	2.83 10^{-5}
kg_f s / m^2	9.81	98.1	9.81 10^3	3.53 10^4	1
lb_f s / $inch^2$	6.89 10^3	6.89 10^4	6.89 10^6	2.48 10^7	703
lb_f s / ft^2	47.9	479	4.79 10^4	1.72 10^5	0.0488
lb_f h / ft^2	1.72 10^5	1.72 10^6	1.72 10^8	6.21 10^8	1.76 10^4
lb / ft s	1.49	14.9	1.49 10^3	5.36 10^3	0.152
lb / ft h	4.13 10^{-4}	0.00413	0.413	1.49	4.22 10^{-5}

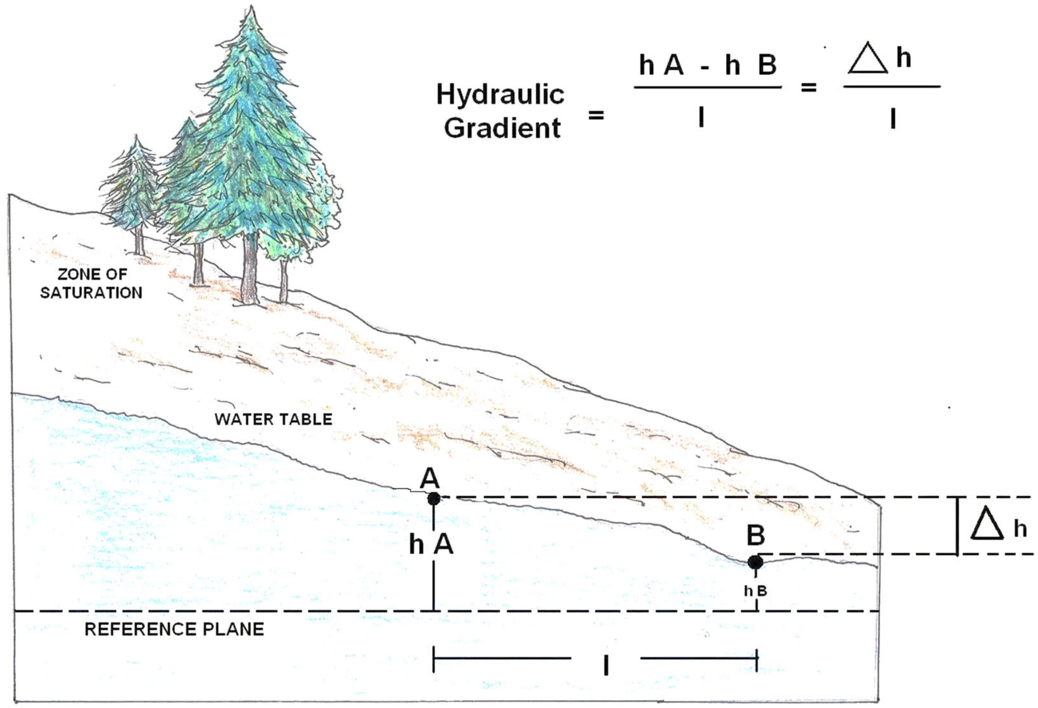
Multiply by	Convert to				
Convert from	lb_f s / $inch^2$	lb_f s / ft^2	lb_f h / ft^2	lb / ft s	lb / ft h
Poiseuille (Pa s)	1.45 10^{-4}	0.0209	5.8 10^{-6}	0.672	2.42 10^3
Poise (dyne s / cm^2 = g / cm s)	1.45 10^{-5}	0.00209	5.8 10^{-7}	0.0672	242
centiPoise	1.45 10^{-7}	2.9 10^{-5}	5.8 10^{-9}	0.000672	2.42
kg / m h	4.03 10^{-8}	5.8 10^{-6}	1.61 10^{-9}	0.000187	0.672
kg_f s / m^2	0.00142	20.5	5.69 10^{-5}	6.59	2.37 10^4
lb_f s / $inch^2$	1	144	0.04	4.63 10^3	1.67 10^7
lb_f s / ft^2	0.00694	1	0.000278	32.2	1.16 10^5
lb_f h / ft^2	25	3.6 10^3	1	1.16 10^5	4.17 10^8
lb / ft s	0.000216	0.0311	8.63 10^{-6}	1	3.6 10^3
lb / ft h	6 10^{-8}	1.16 10^5	2.4 10^{-9}	0.000278	1

Friction Loss Chart

The table below can be used to indicate the friction loss - feet of liquid per 100 feet of pipe - in standard schedule 40 steel pipes.

Pipe Size (inches)	Flow Rate		Kinematic Viscosity - SSU					
	(gpm)	(l/s)	31 (Water)	100 (~Cream)	200 (~Vegetable oil)	400 (~SAE 10 oil)	800 (~Tomato juice)	1500 (~SAE 30 oil)
1/2	3	0.19	10.0	25.7	54.4	108.0	218.0	411.0
3/4	3	0.19	2.5	8.5	17.5	35.5	71.0	131.0
	5	0.32	6.3	14.1	29.3	59.0	117.0	219.0
1	3	0.19	0.8	3.2	6.6	13.4	26.6	50.0
	5	0.32	1.9	5.3	11.0	22.4	44.0	83.0
	10	0.63	6.9	11.2	22.4	45.0	89.0	165.0
	15	0.95	14.6	26.0	34.0	67.0	137.0	
	20	1.26	25.1	46	46.0	90.0	180.0	
1 1/4	5	0.32	0.5	1.8	3.7	7.6	14.8	26.0
	10	0.63	1.8	3.6	7.5	14.9	30.0	55.0
	15	0.95	3.7	6.4	11.3	22.4	45.0	84.0
1 1/2	10	0.63	0.8	1.9	4.2	8.1	16.5	31.0
	15	0.95	1.7	2.8	6.2	12.4	25.0	46.0
	20	1.26	2.9	5.3	8.1	16.2	33.0	61.0
	30	1.9	6.3	11.6	12.2	24.3	50.0	91.0
	40	2.5	10.8	19.6	20.8	32.0	65.0	121.0
2	20	1.26	0.9	1.5	3.0	6.0	11.9	22.4
	30	1.9	1.8	3.2	4.4	9.0	17.8	33.0
	40	2.5	3.1	5.8	5.8	11.8	24.0	44.0
	60	3.8	6.6	11.6	13.4	17.8	36.0	67.0
	80	5.0	1.6	3.0	3.2	4.8	9.7	18.3
2 1/2	30	1.9	0.8	1.4	2.2	4.4	8.8	16.6
	40	2.5	1.3	2.5	3.0	5.8	11.8	22.2
	60	3.8	2.7	5.1	5.5	8.8	17.8	34.0
	80	5.0	4.7	8.3	9.7	11.8	24.0	44.0
	100	6.3	7.1	12.2	14.1	14.8	29.0	55.0
3	60	3.8	0.9	1.8	1.8	3.7	7.3	13.8
	100	6.3	2.4	4.4	5.1	6.2	12.1	23.0
	125	7.9	3.6	6.5	7.8	8.1	15.3	29.0
	150	9.5	5.1	9.2	10.4	11.5	18.4	35.0
	175	11.0	6.9	11.7	13.8	15.8	21.4	40.0
	200	12.6	8.9	15.0	17.8	20.3	25.0	46.0
4	80	5.0	0.4	0.8	0.8	1.7	3.3	6.2
	100	6.3	0.6	1.2	1.3	2.1	4.1	7.8
	125	7.9	0.9	1.8	2.1	2.6	5.2	9.8

	150	9.5	1.3	2.4	2.9	3.1	6.2	11.5
	175	11.0	1.8	3.2	4.0	4.0	7.4	13.7
	200	12.6	2.3	4.2	5.1	5.1	8.3	15.5
	250	15.8	3.5	6.0	7.4	8.0	10.2	19.4
6	125	7.9	0.1	0.3	0.3	0.52	1.0	1.9
	150	9.5	0.2	0.3	0.4	0.6	1.2	2.3
	175	11.0	0.2	0.4	0.5	0.7	1.4	2.6
	200	12.6	0.3	0.6	0.7	0.8	1.6	3.0
	250	15.8	0.5	0.8	1.0	1.0	2.1	3.7
	300	18.9	1.1	8.5	10.0	11.6	12.4	23.0
	400	25.2	1.1	1.9	2.3	2.8	3.2	6.0
8	250	15.8	0.1	0.2	0.3	0.4	0.7	1.2
	300	18.9	0.3	1.2	1.4	1.5	2.5	4.6
	400	25.2	0.3	0.5	0.6	0.7	1.1	2.0
10	300	18.9	0.1	0.3	0.4	0.4	0.8	1.5
	400	25.2	0.1	0.2	0.2	0.2	0.4	0.8



The *hydraulic gradient* is a vector gradient between two or more hydraulic head measurements over the length of the flow path. It is also called the 'Darcy slope', since it determines the quantity of a Darcy flux, or discharge. A dimensionless hydraulic gradient can be calculated between two piezometers as:

$$i = \frac{dh}{dl} = \frac{h_2 - h_1}{\text{length}}$$

where

i is the hydraulic gradient (dimensionless),
dh is the difference between two hydraulic heads (Length, usually in m or ft), and
dl is the flow path length between the two piezometers (Length, usually in m or ft)

The hydraulic gradient can be expressed in vector notation, using the del operator. This requires a hydraulic head field, which can only be practically obtained from a numerical model, such as MODFLOW. In Cartesian coordinates, this can be expressed as:

$$\nabla h = \left(\frac{\partial h}{\partial x}, \frac{\partial h}{\partial y}, \frac{\partial h}{\partial z}\right) = \frac{\partial h}{\partial x}\mathbf{i} + \frac{\partial h}{\partial y}\mathbf{j} + \frac{\partial h}{\partial z}\mathbf{k}$$

This vector describes the direction of the groundwater flow, where negative values indicate flow along the dimension, and zero indicates 'no flow'. As with any other example in physics, energy must flow from high to low, which is why the flow is in the negative gradient. This vector can be used in conjunction with Darcy's law and a tensor of hydraulic conductivity to determine the flux of water in three dimensions.

Hazen-Williams Coefficients

Hazen-Williams factor for some common piping materials. Hazen-Williams coefficients are used in the Hazen-Williams equation for friction loss calculation in ducts and pipes. Coefficients for some common materials used in ducts and pipes can be found in the table below:

Material	Hazen-Williams Coefficient - *C* -
Asbestos Cement	140
Brass	130 - 140
Brick sewer	100
Cast-Iron - new unlined (CIP)	130
Cast-Iron 10 years old	107 - 113
Cast-Iron 20 years old	89 - 100
Cast-Iron 30 years old	75 - 90
Cast-Iron 40 years old	64-83
Cast-Iron, asphalt coated	100
Cast-Iron, cement lined	140
Cast-Iron, bituminous lined	140
Cast-Iron, wrought plain	100
Concrete	100 - 140
Copper or Brass	130 - 140
Ductile Iron Pipe (DIP)	140
Fiber	140
Galvanized iron	120
Glass	130
Lead	130 - 140
Plastic	130 - 150
Polyethylene, PE, PEH	150
PVC, CPVC	150
Smooth Pipes	140
Steel new unlined	140 - 150
Steel	
Steel, welded and seamless	100
Steel, interior riveted, no projecting rivets	100
Steel, projecting girth rivets	100
Steel, vitrified, spiral-riveted	90 - 100
Steel, corrugated	60
Tin	130
Vitrified Clays	110
Wood Stave	110 - 120

Pressure Head

A pressure difference of 5 psi (lbf/in^2) is equivalent to

5 (lbf/in^2) 12 (in/ft) 12 (in/ft) / 62.4 (lb/ft^3) = 11.6 ft of water

5 (lbf/in^2) 12 (in/ft) 12 (in/ft) / 847 (lb/ft^3) = 0.85 ft of mercury

When specific weight of water is 62.4 (lb/ft^3) and specific weight of mercury is 847 (lb/ft^3).
Heads at different velocities can be taken from the table below:

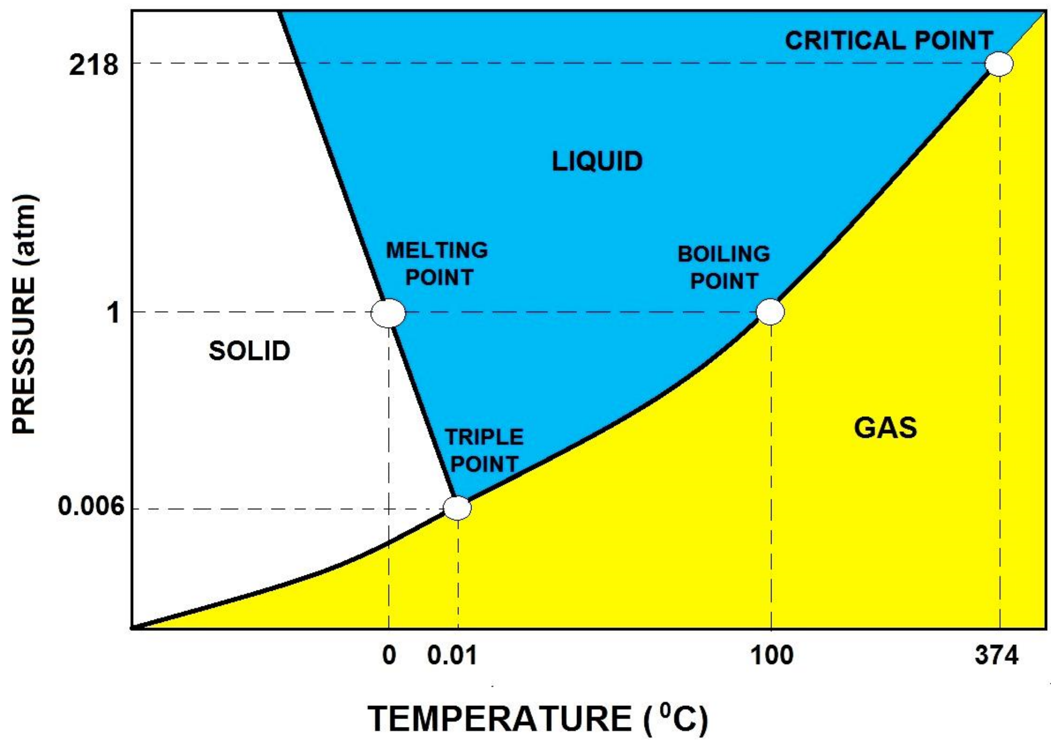
Velocity (ft/sec)	Head Water (ft)
0.5	0.004
1.0	0.016
1.5	0035
2.0	0.062
2.5	0.097
3.0	0.140
3.5	0.190
4.0	0.248
4.5	0.314
5.0	0.389
5.5	0.470
6.0	0.560
6.5	0.657
7.0	0.762
7.5	0.875
8.0	0.995
8.5	1.123
9.0	1.259
9.5	1.403
10.0	1.555
11.0	1.881
12.0	2.239
13.0	2.627
14.0	3.047
15.0	3.498
16.0	3.980
17.0	4.493
18.0	5.037
19.0	5.613
20.0	6.219
21.0	6.856
22.0	7.525

1 ft (foot) = 0.3048 m = 12 in = 0.3333 yd.

Thermal Properties of Water

Temperature - t - (°C)	Absolute pressure - p - (kN/m^2)	Density - ρ - (kg/m^3)	Specific volume - v - ($m^3/kgx10^{-3}$)	Specific Heat - c_p - (kJ/kgK)	Specific entropy - e - (kJ/kgK)
0	0.6	1000	100	4.217	0
5	0.9	1000	100	4.204	0.075
10	1.2	1000	100	4.193	0.150
15	1.7	999	100	4.186	0.223
20	2.3	998	100	4.182	0.296
25	3.2	997	100	4.181	0.367
30	4.3	996	100	4.179	0.438
35	5.6	994	101	4.178	0.505
40	7.7	991	101	4.179	0.581
45	9.6	990	101	4.181	0.637
50	12.5	988	101	4.182	0.707
55	15.7	986	101	4.183	0.767
60	20.0	980	102	4.185	0.832
65	25.0	979	102	4.188	0.893
70	31.3	978	102	4.190	0.966
75	38.6	975	103	4.194	1.016
80	47.5	971	103	4.197	1.076
85	57.8	969	103	4.203	1.134
90	70.0	962	104	4.205	1.192
95	84.5	962	104	4.213	1.250
100	101.33	962	104	4.216	1.307
105	121	955	105	4.226	1.382
110	143	951	105	4.233	1.418
115	169	947	106	4.240	1.473
120	199	943	106	4.240	1.527
125	228	939	106	4.254	1.565
130	270	935	107	4.270	1.635
135	313	931	107	4.280	1.687
140	361	926	108	4.290	1.739
145	416	922	108	4.300	1.790
150	477	918	109	4.310	1.842
155	543	912	110	4.335	1.892
160	618	907	110	4.350	1.942
165	701	902	111	4.364	1.992
170	792	897	111	4.380	2.041
175	890	893	112	4.389	2.090
180	1000	887	113	4.420	2.138

185	1120	882	113	4.444	2.187
190	1260	876	114	4.460	2.236
195	1400	870	115	4.404	2.282
200	1550	863	116	4.497	2.329
220					
225	2550	834	120	4.648	2.569
240					
250	3990	800	125	4.867	2.797
260					
275	5950	756	132	5.202	3.022
300	8600	714	140	5.769	3.256
325	12130	654	153	6.861	3.501
350	16540	575	174	10.10	3.781
360	18680	526	190	14.60	3.921



WATER PHASE DIAGRAM

Viscosity Converting Chart

The viscosity of a fluid is its resistance to shear or flow, and is a measure of the fluid's adhesive/ cohesive or frictional properties. This arises because of the internal molecular friction within the fluid producing the frictional drag effect. There are two related measures of fluid viscosity which are known as **dynamic** and **kinematic** viscosity.

Dynamic viscosity is also termed "**absolute viscosity**" and is the tangential force per unit area required to move one horizontal plane with respect to the other at unit velocity when maintained a unit distance apart by the fluid.

Centipoise (CPS) Millipascal (mPas)	Poise (P)	Centistokes (cSt)	Stokes (S)	Saybolt Seconds Universal (SSU)
1	0.01	1	0.01	31
2	0.02	2	0.02	34
4	0.04	4	0.04	38
7	0.07	7	0.07	47
10	0.1	10	0.1	60
15	0.15	15	0.15	80
20	0.2	20	0.2	100
25	0.24	25	0.24	130
30	0.3	30	0.3	160
40	0.4	40	0.4	210
50	0.5	50	0.5	260
60	0.6	60	0.6	320
70	0.7	70	0.7	370
80	0.8	80	0.8	430
90	0.9	90	0.9	480
100	1	100	1	530
120	1.2	120	1.2	580
140	1.4	140	1.4	690
160	1.6	160	1.6	790
180	1.8	180	1.8	900
200	2	200	2	1000
220	2.2	220	2.2	1100
240	2.4	240	2.4	1200
260	2.6	260	2.6	1280
280	2.8	280	2.8	1380
300	3	300	3	1475
320	3.2	320	3.2	1530

340	3.4	340	3.4	1630
360	3.6	360	3.6	1730
380	3.8	380	3.8	1850
400	4	400	4	1950
420	4.2	420	4.2	2050
440	4.4	440	4.4	2160
460	4.6	460	4.6	2270
480	4.8	480	4.8	2380
500	5	500	5	2480
550	5.5	550	5.5	2660
600	6	600	6	2900
700	7	700	7	3380
800	8	800	8	3880
900	9	900	9	4300
1000	10	1000	10	4600
1100	11	1100	11	5200
1200	12	1200	12	5620
1300	13	1300	13	6100
1400	14	1400	14	6480
1500	15	1500	15	7000
1600	16	1600	16	7500
1700	17	1700	17	8000
1800	18	1800	18	8500
1900	19	1900	19	9000
2000	20	2000	20	9400
2100	21	2100	21	9850
2200	22	2200	22	10300
2300	23	2300	23	10750
2400	24	2400	24	11200

Various Flow Section Channels and their Geometric Relationships:

Area, wetted perimeter and hydraulic diameter for some common geometric sections like

- rectangular channels
- trapezoidal channels
- triangular channels
- circular channels.

Rectangular Channel

Flow Area

Flow area of a rectangular channel can be expressed as

A = b h (1)

where

A = flow area (m^2, in^2)

b = width of channel (m, in)

h = height of flow (m, in)

Wetted Perimeter

Wetted perimeter of a rectangular channel can be expressed as

P = b + 2 h (1b)

where

P = wetted perimeter (m, in)

Hydraulic Radius

Hydraulic radius of a rectangular channel can be expressed as

R_h = b h / (b + 2 y) (1c)

where

R_h = hydraulic radius (m, in)

Trapezoidal Channel

Flow Area

Flow area of a trapezoidal channel can be expressed as

A = (a + z h) h (2)

where

z = see figure above (m, in)

Wetted Perimeter

Wetted perimeter of a trapezoidal channel can be expressed as

$P = a + 2 h (1 + z^2)^{1/2}$ (2b)

Hydraulic Radius

Hydraulic radius of a trapezoidal channel can be expressed as

$R_h = (a + z h) h / a + 2 h (1 + z^2)^{1/2}$ (2c)

Triangular Channel

Flow Area

Flow area of a triangular channel can be expressed as

$A = z h^2$ (3)

where

z = see figure above (m, in)

Wetted Perimeter

Wetted perimeter of a triangular channel can be expressed as

$P = 2 h (1 + z^2)^{1/2}$ (3b)

Hydraulic Radius

Hydraulic radius of a triangular channel can be expressed as

$R_h = z h / 2 (1 + z^2)^{1/2}$ (3c)

Circular Channel

Flow Area

Flow area of a circular channel can be expressed as

$A = D^2/4 (\alpha - \sin(2 \alpha)/2)$ (4)

where

D = diameter of channel

$\alpha = \cos^{-1}(1 - h/r)$

Wetted Perimeter

Wetted perimeter of a circular channel can be expressed as

$P = \alpha D$ (4b)

Hydraulic Radius

Hydraulic radius of a circular channel can be expressed as

$R_h = D/8 [1 - \sin(2 \alpha) / (2 \alpha)]$ (4c)

Velocity Head: Velocity head can be expressed as

$h = v^2/2g$ (1)

where

v = velocity (ft, m)

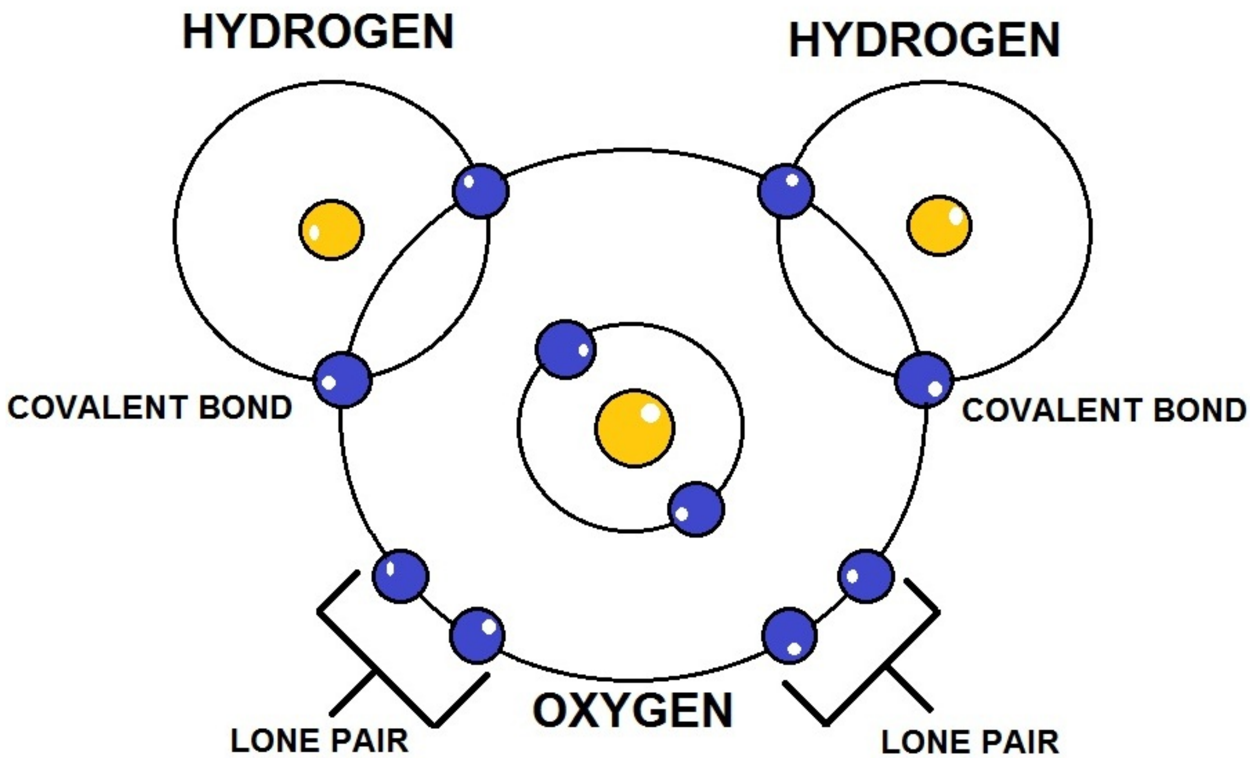
g = acceleration of gravity ($32.174\ ft/s^2$, $9.81\ m/s^2$)

Heads at different velocities can be taken from the table below:

Velocity - *v* - (ft/sec)	Velocity Head - $v^2/2g$ - (ft Water)
0.5	0.004
1.0	0.016
1.5	0035
2.0	0.062
2.5	0.097
3.0	0.140
3.5	0.190
4.0	0.248
4.5	0.314
5.0	0.389
5.5	0.470
6.0	0.560
6.5	0.657
7.0	0.762
7.5	0.875
8.0	0.995
8.5	1.123
9.0	1.259
9.5	1.403
10.0	1.555
11.0	1.881
12.0	2.239
13.0	2.627
14.0	3.047
15.0	3.498
16.0	3.980
17.0	4.493
18.0	5.037
19.0	5.613
20.0	6.219
21.0	6.856
22.0	7.525

Some Commonly used Thermal Properties for Water

- Density at 4 °C - 1,000 kg/m^3, 62.43 Lbs./Cu.Ft., 8.33 Lbs./Gal., 0.1337 Cu.Ft./Gal.
- Freezing temperature - 0 °C
- Boiling temperature - 100 °C
- Latent heat of melting - 334 kJ/kg
- Latent heat of evaporation - 2,270 kJ/kg
- Critical temperature - 380 - 386 °C
- Critical pressure - 23.520 kN/m^2
- Specific heat capacity water - 4.187 kJ/kgK
- Specific heat capacity ice - 2.108 kJ/kgK
- Specific heat capacity water vapor - 1.996 kJ/kgK
- Thermal expansion from 4 °C to 100 °C - 4.2×10^{-2}
- Bulk modulus elasticity - 2,068,500 kN/m^2



WATER MOLECULE

Reynolds Number

Turbulent or laminar flow is determined by the dimensionless **Reynolds Number.**

The Reynolds number is important in analyzing any type of flow when there is substantial velocity gradient (i.e., shear.) It indicates the relative significance of the viscous effect compared to the inertia effect. The Reynolds number is proportional to inertial force divided by viscous force.

A definition of the Reynolds' Number:
The flow is

- **laminar** if Re < 2300
- **transient** if 2300 < Re < 4000
- **turbulent** if 4000 < Re

The table below shows Reynolds Number for one liter of water flowing through pipes of different dimensions:

Pipe Size										
(inches)	1	1 ?	2	3	4	6	8	10	12	18
(mm)	25	40	50	75	100	150	200	250	300	450
Reynolds number with **one (1) liter/min**	835	550	420	280	210	140	105	85	70	46
Reynolds number with **one (1) gal/min**	3800	2500	1900	1270	950	630	475	380	320	210

Linear Motion Formulas

Velocity can be expressed as (velocity = constant):

$v = s / t$ *(1a)*

where
v = *velocity (m/s, ft/s)*
s = *linear displacement (m, ft)*
t = *time (s)*

Velocity can be expressed as (acceleration = constant):
$v = V_0 + a\ t$ *(1b)*

where
V_0 = *linear velocity at time zero (m/s, ft/s)*

Linear displacement can be expressed as (acceleration = constant):
$s = V_0\ t + 1/2\ a\ t^2$ *(1c)*

Combining 1a and 1c to express velocity
$v = (V_0^2 + 2\ a\ s)^{1/2}$ *(1d)*

Velocity can be expressed as (velocity variable)
$v = ds / dt$ *(1f)*

where
ds = *change of displacement (m, ft)*
dt = *change in time (s)*

Acceleration can be expressed as
$a = dv / dt$ *(1g)*

where
dv = *change in velocity (m/s, ft/s)*

Water - Dynamic and Kinematic Viscosity

Dynamic and Kinematic Viscosity of Water in Imperial Units (BG units):

Temperature - *t* - (°F)	Dynamic Viscosity - *μ* - 10^{-5} (lbs./ft²)	Kinematic Viscosity - *ν* - 10^{-5} (ft²/s)
32	3.732	1.924
40	3.228	1.664
50	2.730	1.407
60	2.344	1.210
70	2.034	1.052
80	1.791	0.926
90	1.500	0.823
100	1.423	0.738
120	1.164	0.607
140	0.974	0.511
160	0.832	0.439
180	0.721	0.383
200	0.634	0.339
212	0.589	0.317

Dynamic and Kinematic Viscosity of Water in SI Units:

Temperature - *t* - (°C)	Dynamic Viscosity - *μ* - 10^{-3} (N.s/m²)	Kinematic Viscosity - *ν* - 10^{-6} (m²/s)
0	1.787	1.787
5	1.519	1.519
10	1.307	1.307
20	1.002	1.004
30	0.798	0.801
40	0.653	0.658
50	0.547	0.553
60	0.467	0.475
70	0.404	0.413
80	0.355	0.365
90	0.315	0.326
100	0.282	0.294

Water and Speed of Sound

Speed of sound in water at temperatures between 32 - 212°F (0-100°C) - imperial and SI units

Speed of Sound in Water - in imperial units (BG units)

Temperature - *t* - (°F)	Speed of Sound - *c* - (ft/s)
32	4,603
40	4,672
50	4,748
60	4,814
70	4,871
80	4,919
90	4,960
100	4,995
120	5,049
140	5,091
160	5,101
180	5,095
200	5,089
212	5,062

Speed of Sound in Water - in SI units

Temperature - *t* - (°C)	Speed of Sound - *c* - (m/s)
0	1,403
5	1,427
10	1,447
20	1,481
30	1,507
40	1,526
50	1,541
60	1,552
70	1,555
80	1,555
90	1,550
100	1,543

Post Quiz Answers

Topic 1- Cross-Connection Control Section Post Quiz
1. True, 2. Cross-connection, 3. True, 4. Open receiving vessel, 5. 1 inch, 6. High hazard installations, 7. Vacuum breaker(s), 8. True, 9. High hazard installations, 10. Shut offs, 11. Downstream piping, 12. False, 13. True, 14. True, 15. False, 16. Above the ground, 17. True, 18. True, 19. False, 20. False

Topic 2 - Hydraulic Principles Section Post Quiz
1. Pressure(s) of the air, 2. Hydrostatics, 3. True, 4. Hydrokinetics, 5. Atmospheric pressure, 6. False, 7. Pressure, 8. True, 9. True, 10. True, 11. 11. Atmospheric pressure, 12. Absolute pressure, 13. False, 14. Atmospheric pressure, 15. True, 16. Pressure(s), 17. Energy, 18. Pascal's law, 19. True, 20. True

Topic 3- Cross-Connection Control Program Post Quiz
1. Written document, 2. A cross connection ordinance, 3. Implemented, 4. Increase, 5. Dangers of cross connections, 6. Backflow preventors, 7. Potentially life-threatening contamination, 8. Internal protection, 9. Best type of backflow protection, 10. Aggressive implementation, 11. Mechanical backflow prevention devices, 12. Service connection, 13. Backsiphonage, 14. RPs, 15. 6 inches, 16. High, 17. Risk, 18. Little immediate

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
5,280 Feet = 1 Mile
AREA
144 Square Inches = 1 Square Foot
43,560 Square Feet = 1 Acre
VOLUME
1000 Milliliters = 1 Liter
3.785 Liters = 1Gallon
231 Cubic Inches = 1 Gallon
7.48 Gallons = 1 Cubic Foot of Water
62.38 Pounds = 1 Cubic Foot of Water

Conversion Factors
1 acre = 43,560 square feet
1 cubic foot = 7.48 gallons
1 foot = 0.305 meters
1 gallon = 3.785 liters
1 gallon = 8.34 pounds
1 grain per gallon = 17.1 mg/L
1 horsepower = 0.746 kilowatts
1 million gallons per day = 694.45 gallons per minute
1 pound = 0.454 kilograms
1 pound per square inch = 2.31 feet of water
1% = 10,000 mg/L
Degrees Celsius = (Degrees Fahrenheit - 32) (5/9)
Degrees Fahrenheit = (Degrees Celsius * 9/5) + 32
64.7 grains = 1 cubic foot
1,000 meters = 1 kilometer
1,000 grams = 1 kilogram

Cross-Connection CEU Training Course Practice Exam

The focus of this course is a basic understanding of Backflow Prevention/Cross-Connection. This course is **NOT** designed to certify you as a General Tester or a Cross-Connection Specialist.

Practice Exam, the final assignment is a 200 multiple choice question examination. You can find a copy of the final assignment on TLC's website under the Assignment page, both in Adobe Acrobat and Microsoft Word formats.

1. Define the term BACKFLOW.

2. Define the term BACKPRESSURE.

3. Define the term BACKSIPHONAGE.

4. Why is backflow a concern?

5. Do you believe backflow is a reasonable concern to you? Why?

6. When should a water supplier require a backflow-prevention assembly to be installed?

Define the following abbreviations:

7. AG

8. RP

9. PVB

10. DC

11. What does your State use for a reference or standard for determining what type of backflow assembly can be used? Please provide the name/title or reference of this Rule or Regulation.

12. What State agency is responsible for backflow protection?

13. Are single family residences in your State required to have a backflow assembly?

14. What is the standard or description for an Air Gap?

15. Give one example of an Air Gap that you have seen.

16. Give two examples of how a PVB can be used.

17. Give one example of a backflow prevention assembly, manufactures name, model number, and type of assembly.

18. Explain Pascal's Law.

19. Explain Bernoulli’s Principle.

20. Explain in detail a backflow/cross-connection occurrence. If you are unfamiliar with a backflow/cross-connection occurrence, please use the library or the Internet and you will be able to find several occurrences. We would prefer an actual report of a backflow occurrence that you know of or have seen.

21. How could the previous backflow /cross-connection event or incident have been prevented? Explain in detail. 100 word minimum.

22. Do you believe that backflow prevention is reasonable? Explain why in 100 words.

23. Do you believe that backflow prevention is unreasonable or could be excessive in some way? Explain why in less than 100 words.

24. Have you learned anything about backflow or your State Rule? How would you improve the Rules?

25. What is meant by the expression "**Closed-Loop**" commonly caused by placing a RP on a service line?

26. Do Firelines need backflow prevention assemblies? Explain

27. Does backflow in any way relate to your profession? Explain in detail. 100 word minimum

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