



MANUAL OF RECOMMENDED PRACTICE

Construction Practices for Potable Water



IAPMO Manual 4-2023

PUBLISHED BY THE IAPMO GROUP

The International Association of Plumbing and Mechanical Officials

The International Association of Plumbing and Mechanical Officials (IAPMO) is an accredited, by the Standards Council of Canada (SCC) and the American National Standards Institute (ANSI), standards development organization working in the building mechanical and plumbing field. IAPMO has been protecting the public's health and safety for ninety years by working in concert with government and industry to implement comprehensive plumbing and mechanical systems globally.

As a membership-based association, IAPMO utilizes an open consensus process in the development of its document such as the ANSI/SCC accredited standards, industry standards, and its flagship Uniform Plumbing Code® and Uniform Mechanical Code®. These codes and standards are established through scientific research, debate, and analysis, strengthening IAPMO's position at the forefront of the plumbing and mechanical industries.

The IAPMO Group is a complete service organization, providing standards development and code development assistance, industry-leading education, and a manufacturer-preferred quality assurance program. Each component of the IAPMO Group works toward the ultimate goal of protecting the health of people everywhere.

Published by

International Association of Plumbing and Mechanical Officials (IAPMO)

4755 East Philadelphia Street, Ontario, California, 91761, USA

1-800-854-2766 • 1-909-472-4100

Visit the IAPMO Online Store at: www.IAPMOstore.org

Visit the IAPMO Standards website at: www.IAPMOstandards.org

Copyright © 2024 by

International Association of Plumbing and Mechanical Officials (IAPMO)

All rights reserved.

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without prior written permission of the publisher.

Printed in the United States of America

Contents

Foreword, Purpose and Audience	ii
Working Groupiii
101.0 General	1
101.1 Scope.	1
101.2 Applicability.	1
101.3 Building Types.	1
101.4 Regional and Local Concerns.	1
101.5 Terminology.	2
101.6 Units of Measurement.	2
102.0 Reference Publications	2
103.0 Definitions	3
103.0 Definition of Terms.	3
104.0 Pre-Construction Design Criteria.	6
104.1 Design Considerations.	6
104.2 Utility Coordination.	7
104.3 Water Quality Considerations.	7
104.4 Water Management Minimum Design Needs, by Building Type.	10
104.5 Flushing.	11
105.0 Construction Means and Methods.	14
105.1 Construction Water Usage.	14
105.2 Pressure Testing Impacts on Water Quality	14
105.3 Alternative to Using the Permanent Water System for Construction Water	14
105.4 Pre-Installation Material Management	16
105.5 Flushing Methods & Locations	17
105.6 Water Quality Testing	18
106.0 Construction Project Scope, Schedule & Testing	20
106.1 Construction Schedule to Minimize Risk and Conserve Water	20
106.2 Construction Risk Assessment	22
106.3 Construction Project Schedule Development and Documentation	23
107.0 Water Management During Construction	23
107.1 Equipment Requirements	23
107.2 Overview of Water Management Activities	27
107.3 Develop a Water Management Program (Building Categories B, C and D)	27
107.4 Sanitary Storage and Handling of Plumbing Materials (All Buildings)	29
107.5 Scoping and Staging to Limit Contamination Risk & Conserve Water (All Buildings) ...	29
107.6 Cross Connection Control and Backflow Prevention (All Buildings)	30
107.7 Filling the System (All Buildings)	30

107.8	Initial System Flush (All Buildings)	31
107.9	Water Turn-Over After Filling and Prior to Disinfection	32
107.10	<i>Legionella</i> and Water Quality Monitoring (Verification and Validation, Building Types C and D)	32
107.11	Pre-occupancy Disinfection and Building Opening	33

Annex A: IAPMO/ESPRI Manual 5-2023 - Manual of Water Quality for Plumbing Industry Professionals and Building Managers	Annex A-1
---	------------------

Annex B: Premise Plumbing System Distribution Types	Annex B-1
--	------------------

Annex C: USEPA System Opening or Reopening Checklist	Annex C-1
---	------------------

Public Comment
Draft

Foreword

This manual provides education and guidance to help plumbers and other personnel responsible for the design, construction and commissioning of water systems reduce the likelihood of contaminating plumbing systems during construction. If unmanaged, construction and commissioning activities contribute to the growth and spread of opportunistic premise plumbing pathogens (OPPPs) in potable and non-potable building water systems. According to the CDC, 75% of the unmanaged external changes that have resulted in outbreaks of Legionnaires' disease were attributable to construction activities. This manual describes activities that can and should be practiced during installation and commissioning of new water systems to reduce the likelihood that water systems begin their service life contaminated. Recommended practices include many practices and procedures that make up water management programs that govern operation and monitoring of operational water systems and that are required for many building types such as health care facilities. Other practices are specific to risks associated with construction activities. Healthy building water systems are the shared responsibility of design engineers, plumbers and construction personnel, public water systems and other water purveyors, system operators and building owners and managers.

Purpose

Systematic water management during construction of new and existing buildings (including significant additions to the envelope of an existing building) is necessary to manage the risk of building water systems contaminated with pathogenic organisms such as *Legionella pneumophila* (the etiological agent responsible for most cases of Legionnaires' disease) and to prevent infections of contractors and others at or near the site during the construction process. This manual will outline a process for developing guidance for contractors and subcontractors installing and managing building water systems during construction.

Audience

Architects
Building Owners and Operators
Construction Management
Design Engineers
Facility Engineers
Plumbers and Pipefitters
Plumbing Inspectors and Officials
Project Management
Public Health Administrators

Working Group

IAPMO Construction Practices Task Group

Timothy Bartrand – Chair

Robert Bowcock – Member

Melissa Cain – Member

Michael Castro – Member

Alberto Comazzi – Member

Michael Cudahy – Member

Kook Kim Dean – Member

James Dipping – Member

Michael Dodson – Member

Robert Fields – Member

Edwin Gonzalez – Member

Roger Griffith – Member

Chris Haldiman – Member

Joe Hannigan – Member

Gary Klein – Member

Oleh Kowalskyj – Member

John Lansing – Member

Christoph Lohr – IAPMO Staff

Bruce Meiners – Member

Alex Mofidi – Member

John Mullen – IAPMO Staff

Paul Olson – Member

Rodolfo Perez – Member

David Pierre – Member

William Rhoads – Member

Bill Siegmund – Member

Wayne Swartz – Member

Andrew Ward – Member

Manual of Recommended Practice

Construction Practices for Potable Water

101.0 General.

101.1 Scope. The IAPMO Manual of Recommended Construction Practices for Potable Water, provides guidance on risk management practices specific to potable and non-potable water supply systems, during new building construction, expansion, renovation, and replacement projects.

101.2 Applicability. This Manual is applicable to the building water utilized during the various stages of construction in accordance with potable water systems. Within this guidance, the potable water system includes, but is not limited to:

- (1) The incoming water supply or supplies
- (2) Alternative water supplies (e.g., onsite wells/groundwater, rainwater collection, onsite reuse/reclaimed water)
- (3) Water processing steps (e.g., softening, filtration)
- (4) Domestic cold water
- (5) Domestic hot water
- (6) Utility water systems (e.g., chillers/heat exchangers)

101.3 Building Types. This Manual shall be applicable to the following building types:

- (1) Non-residential (low- and high-rise)
 - (a) Office
 - (b) Commercial Retail
 - (c) Institutions
 - (d) Hospitality
 - (e) Public Assembly
 - (f) Industrial and manufacturing
 - (g) Healthcare
- (2) Residential
 - (a) Multiunit residential
 - (b) All except single family residence
- (3) Mixed use
 - (a) Multiunit residential
 - (b) Other Non-residential

Note: Although the best practices presented in this guidance are applicable to all buildings, the manner and detail in which they are applied differs with building type and purpose and with the characteristics of the ultimate system users. For example, operational water quality monitoring recommendations might not apply for installations that are completed quickly and that are not complex.

101.4 Regional and Local Concerns.

101.4.1 Regional Concerns. The effect of cold weather and hot weather climate considerations on water quality parameters such as temperature, disinfectant residual concentrations, and biological growth should be considered in the application of the recommendations of this Manual. Climate change has likely elevated the density of *Legionella* in the environment, particularly in cooler regions. Studies have shown that higher precipitation levels occurring in warm summer months lead to more legionellosis cases.

101.4.2 Local Concerns. When multiple sources of water supply are purveyed, documenting the conditions shall be included as part of the construction water safety management plan. Changes in municipal disinfectants or water characteristics shall be considered.

101.5 Terminology.

- (1) “shall” is used to express a requirement, i.e., a provision that the user is obliged to satisfy to comply with the manual.
- (2) “should” is used to express a recommendation, but not a requirement.
- (3) “may” is used to express an option or something permissible within the scope of the manual; and
- (4) “can” is used to express a possibility or a capability.

Note: Accompanying sections of the Standard do not specify requirements or alternative requirements; their purpose is to separate explanatory or informative material from the text. Notes to tables and figures are considered part of the table or figure and can be written as requirements.

101.6 Units of Measurement. Inch/pound units are the primary units of record in global commerce. In this Manual, the inch/pound units are shown in parentheses. The values stated in each measurement system are equivalent in application, but each unit system is to be used independently. All references to gallons are to U.S. gallons.

102.0 Reference Publications. This Standard refers to the following publications and, where such reference is made, it shall be to the current edition of those publications, including all amendments published thereto.

American Water Works Association (AWWA) Responding to Water Stagnation in Buildings with Reduced or No Water Use

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE): ANSI/ASHRAE 188 Legionellosis: Risk Management for Building Water Systems

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE): ANSI/ASHRAE Guideline 12 Minimizing the Risk of Legionellosis Associated with Building Water Systems

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE): ANSI/ASHRAE Standard 514-2023 - Risk Management for Building Water Systems: Physical, Chemical, and Microbial Hazards (ANSI approved)

International Association of Plumbing and Mechanical Officials (IAPMO): IAPMO/ANSI UPC-1 Uniform Plumbing Code

American Society of Plumbing Engineers (ASPE): Engineering Methodologies to Reduce the Risk of *Legionella* in Premise plumbing Systems

AWWA Standards: C651 (Disinfecting Water Mains) and C652 (Disinfection of Water Storage Facilities)

Centers for Disease Control and Prevention (CDC): Developing a Water Management Program to Reduce *Legionella* Growth & Spread in Buildings

Centers for Disease Control and Prevention (CDC): Water Infection Control Risk Assessment (WICRA) for Healthcare Settings

Centers for Disease Control and Prevention (CDC): Routine Testing for *Legionella*
(<https://www.cdc.gov/legionella/wmp/control-toolkit/routine-testing.html>)

Veterans Administration (VA): Directive 1061: Prevention of health care-associated *legionella* disease and scald injury from water systems

103.0 Definition of Terms. The definitions of terms are arranged alphabetically according to the first word of the term.

-A-

Authority Having Jurisdiction (AHJ). The organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, installations, or procedures. The Authority Having Jurisdiction shall be a federal, state, local, or other regional department or an individual such as a plumbing official, mechanical official, labor department official, health department official, building official, or others having statutory authority. In the absence of statutory authority, the Authority Having Jurisdiction may be some other responsible party. This definition shall include the Authority Having Jurisdiction's duly authorized representative.

-B-

Backflow. The flow of water or other liquids, mixtures, or substances into the distributing pipes of a potable supply of water from sources other than its intended source.

Backflow Preventer. A backflow prevention device, an assembly, or another method to prevent backflow into the potable water system.

Building is Vacant or Partially-Occupied. The state of a building water system when the building is closed and not in use (vacant) or major portions of the building water system is not in use, or the typical use is significantly reduced (partially-occupied). This includes the off hours of operation and buildings that are shut down for long periods of time (weeks to years). This could include the construction period before initial opening.

Building Supply. The pipe is carrying potable water from the water meter or another source of water supply to a building or other point of use or distribution on the lot.

-C-

Commissioning. A systematic process that provides documented confirmation that specific and interconnected fire and life safety systems function according to the intended design criteria set forth in the project documents and satisfy the owner's operational needs, including compliance requirements of any applicable laws, regulations, codes, and standards requiring fire and life safety systems.

Construction Activities. The set of actions that is taken to ready a building, renovated portion of a building, or building addition for an initial occupancy.

Construction Documents. Plans, specifications, written, graphic, and pictorial documents prepared or assembled for describing the design, location, and physical characteristics of the elements of a project necessary for obtaining a permit.

Cross-Connection. A connection or arrangement, physical or otherwise, between a potable water supply system and a plumbing fixture or a tank, receptor, equipment, or device, through which it may be possible for nonpotable, used, unclean, polluted, and contaminated water, or other substances to enter into a part of such potable water system under any condition.

-D-

Dead Leg. A section of potable water pipe which contains water that has no flow or does not circulate.

Disinfectant. Chemical agent or physical treatment used to kill or inactivate pathogens.

Disinfectant residual. The net amount (concentration) of a chemical disinfectant remaining in treated water after chemical demand exerted by the water is satisfied.

Disinfection. The process of killing or inactivating pathogens. Disinfection may be by chemical exposures (free chlorine, monochloramine, chlorine dioxide, hydrogen peroxide and other disinfectants), thermal (high temperature), or UV.

Distal Sites. The plumbing fixture outlets providing cold water and are downstream from the water service entrance. Those plumbing fixture outlets providing hot water that are downstream from the domestic water heating equipment.

Drinking Fountain. A plumbing fixture connected to the potable water distribution system and sanitary drainage system that provides drinking water in a flowing stream so that the user can consume water directly from the fixture without the use of accessories. Drinking fountains should also incorporate a bottle filling station and can incorporate a water filter and a cooling system for chilling the drinking water.

-F-

Fixture Branch. A water supply pipe between the fixture supply pipe and the water distribution pipe.

Fixture Supply. A water supply pipe is connecting the fixture with the fixture branch.

-H-

Hot Water. Water at a temperature exceeding or equal to 120°F (49°C).

Hot Water Systems. Water heating equipment and all connected downstream pipe fitting and components.

Hot Water Circulation Systems. A system of potable hot water supply and return piping with shutoff valves, balancing valves, circulating pumps, and a method of controlling the circulating system.

-I-

Initial/Remedial/Full Flush/Turnover-Approach. Initial/Remedial/Full/Turnover-Approach flushing is a one-time event intended to replace all the water in the system (complete system turnover) with fresh water from the water supplier to reduce the presence and/or risk of exposure to contaminants. The water needs to flow at a rate to scour the pipes. Spend as few hours as possible completing this task.

Interruption of Normal Operations (System Shut Down Process). The set of actions that should be taken to ready a building for an extended period of no or limited operations.

-L-

Listed (Third-Party Certified). Equipment or materials included in a list published by a listing agency (accredited conformity assessment body) that maintains periodic inspection of current production of listed equipment or materials and whose listing states either that the equipment or material complies with approved standards or has been tested and found suitable for use in a specified manner.

Legionella. The name of the genus of bacteria that can cause a pneumonia called Legionnaires' disease or a flu-like illness called Pontiac fever when inhaled, aspirated or directly introduced into the lungs of susceptible individuals. *Legionella* are common aquatic bacteria found in natural and building water systems, as well as in some soils.

Legionellosis. The term used to describe Legionnaires' disease, Pontiac fever, and any illness caused by exposure to *Legionella* bacteria.

-M-

Monitoring. Conducting a planned sequence of observations or measurements of the physical and chemical characteristics of control measures. Control measures are actions taken towards maintaining a physical or chemical parameter within a pre-established range.

-N-

Normal Operations The state of a building water system when the building is open and being used as intended. This includes the normal hours of operation and the number of people that occupy the building.

-P-

Potable Water. Water that is satisfactory for drinking, culinary, and domestic purposes and that meets the requirements of the Health Authority Having Jurisdiction.

Plumbing Fixture. An approved type installed receptacle, device or appliance that is supplied with water or that receives liquid or liquid-borne wastes and discharges such wastes into the drainage system to which it may be directly or indirectly connected. Industrial or commercial tanks, vats, and similar processing equipment are not plumbing fixtures, but may be connected to or discharged into approved traps or plumbing fixtures where and as otherwise provided for elsewhere in this manual.

Plumbing System. Includes all potable water, alternate water sources, building supply, and distribution pipes; all plumbing fixtures and traps; all drainage and vent pipes; and all building drains and building sewers, including their respective joints and connections, devices, receptors, and appurtenances within the property lines of the premises and shall include potable water piping, potable water treating or using equipment, medical gas and medical vacuum systems, liquid and fuel gas piping, and water heaters and vents for same.

Process flow diagram. A step-by-step drawing of a building water system that includes the location of all water processing steps including, but not limited to, conditioning, storing, heating, cooling, recirculation, and distribution that are part of the building water system.

Program Team. The group or individual designated by the building owner or designee to be responsible for developing, implementing, and maintaining the Program.

Public Water System. A system for the provision to the public of water for human consumption through pipes or other constructed conveyances if such system has at least fifteen service connections or regularly serves an average of twenty-five individuals daily for at least 60 days per year.

-R-

Remote Outlet. Where used for sizing water piping, it is the furthest outlet dimension, measuring from the meter, either the developed length of the cold-water piping or through the water heater to the furthest outlet on the hot-water piping.

Riser. A water supply pipe that extends vertically one full story or more to convey water to branches or fixtures.

Risk. The potential for harm to humans resulting from exposure to *Legionella*.

Risk management. Systematic activities to reduce risk.

Roughing-In. The installation of all parts of the plumbing system that can be completed prior to the installation of fixtures. This includes drainage, water supply, gas piping, vent piping, and the necessary fixture supports.

-S-

Service Line and Supply Line. Water service lines and building supply lines connect water purveyor water mains to buildings potable water systems and sometimes to supply fire protection systems. In some cases, the service lines is the property and responsibility of the water purveyor whereas the supply line is the property and responsibility of the building owner.

System Reopening. The set of actions that should be taken to ready a building for normal operations after an extended period of no or limited operations.

-T-

Thermostatic (Temperature Control) Valve. A mixing valve that senses outlet temperature and compensates for fluctuations in incoming hot or cold water temperatures.

Toilet Facility. A room or space containing not less than one lavatory and one water closet.

-W-

Water Distribution Pipe. In a building or premises, a pipe that conveys potable water from the building supply pipe to the plumbing fixtures and other water outlets.

Water Main (Street Main). A water supply pipe for public or community use.

Water/Wastewater Utility. A public or private entity which may treat, deliver or do both functions to reclaimed (recycled) water, potable water, or both to wholesale or retail customers.

Water Management Commissioning Plan. A risk management plan to help building managers identify risks to water quality and water safety prior to occupancy of any building (e.g., newly constructed, renovated, unoccupied and re-opened, change of use or occupancy and building acquisition). This plan includes clear procedures for managing these risks at various points in the building lifecycle, including start-up, normal operation, under occupancy, water system shut-down, and water system restart. A WMP can be used to manage any health risk associated with loss of chemical or microbiological water quality or with water safety (scalding).

Water Management Program (WMP). The implementation of a water management commissioning plan.

Water-using Mechanical Systems. Includes building HVAC systems with chillers, compressors, blowers, boilers, pumps, and cooling towers.

Wetted Plumbing Systems. potable water systems that are filled with water.

Water Supply System. The building supply pipe, the water distribution pipes, and the necessary connecting pipes, fittings, control valves, backflow prevention devices, and all appurtenances carrying or supplying potable water in or adjacent to the building or premises.

104.0 Pre-Construction Design Criteria.

104.1 Design Considerations. Plumbing system design is an important part of the overall Legionellosis risk management process and the design of plumbing systems impacts water quality and water quality management over the lifespan of the system as well as during construction. Other important parts and players in the overall management of water quality and risks such as legionellosis are the water supply, practices used during construction and installation, and operations during beneficial occupancy (**Figure 104.1**). Some elements of design such as inclusion of flushing points used during construction and building commissioning relate to construction practices, while others do not. Plumbing system design has a lasting impact on water quality and water quality management over the beneficial use lifespan of the system and on water quality and water quality management during construction.

Note: This section focuses on design aspects that impact water quality and water quality management during construction. Other guidance such as the ASPE's *Engineering Methodologies to Reduce the Risk of Legionella in Plumbing Premise System* provides guidance for design professionals for long-term water quality management that is outside the scope of this guidance. Because this document focuses on construction, this section lists important design guidance documents for education purposes and focuses on design elements that are important to construction.

Design aspects directly related to water quality and water quality management during construction include but are not limited to:

- (1) Location and type of flushing points in system design
- (2) Pipe sizing to ensure target scouring velocities can be met during flushing
- (3) Ensuring access in the system for critical water quality measurements and verification
- (4) Consideration of worker safety

104.1.1 Basic Design Features Related to Installation and Construction.

- (1) Temporary connections with associated drainage
- (2) Permanent connections with associated drainage
- (3) Alternate means for testing
- (4) Cross-connection control concerns
- (5) Flushing points that are used during construction

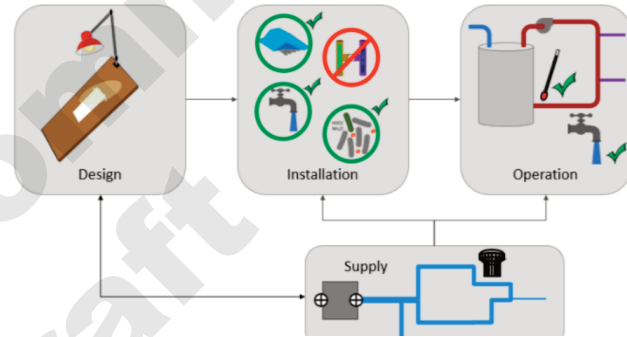


FIGURE 104.1
BUILDING WATER QUALITY MANAGEMENT

- (6) Water quality measurement locations
- (7) Phasing considerations
- (8) Construction Water Uses

104.1.2 Pre-Construction Design Criteria. Plumbing and mechanical plumbing systems are dynamic systems with ever-changing water quality profiles. The impact on water quality and water safety from construction and commissioning activities have resulted in cases and outbreaks of Legionellosis after beneficial occupancy. Section 104.2 of ANSI/ASHRAE 188 requires the owner of a building to survey each existing building, new building, and any renovation, addition, or modification to a building. The survey must occur prior to occupancy of a new building and before construction begins on renovation, additions, or modifications to an existing building. The standard is silent on how to perform the survey and follow-on actions. Water quality management needs to be an active process where the water management team is anticipating risk management needs prior to construction and commissioning activities and responding to changes in water quality and water safety. The initial step should be to review and confirm the water system design with the engineer/designer, contractor, installers, and the owner/operator. This should include a review of this guideline, and responsibilities and expectations during construction and at substantial completion (i.e., beneficial occupancy) confirmed.

Note: For existing buildings, initial water quality data should be reviewed if available and documented to compare with subsequent measurements. The minimum water quality data should include the disinfectant residual, the temperature (hot and cold water), and total heterotrophic aerobic bacteria (THAB) from water systems in the construction space. As risk is defined as the probability and severity of an event occurring, the owner should assess the complexity and size of the construction project and determine the types of persons (e.g. elderly, immunocompromised) who may be exposed.

104.2 Utility Coordination. Waterborne disease risk management is the responsibility of design professionals, construction professionals, and professionals operating water systems and public water systems. Prior to construction, the plumbing design professional should coordinate with the water-supplier (typically a regulated community water system [CWS], but sometimes a regulated Non-Transient Non-Community Water System [NTNCWS]) to determine the water system supply water quality characteristics. As water quality impacts both construction and normal operation of the building, having this information early is vital.

104.3 Water Quality and Water Safety Considerations.

This section describes water quality and water safety parameters that should be considered prior to and during construction and renovation activities. A more complete review of water quality and characteristics is presented in Annex A.

104.3.1 Water temperature. *Legionella* grows rapidly between 68-113 °F (45° C). To maintain water temperatures outside the optimal growth range for *Legionella*, heat transfer to cold water systems should be minimized, hot water system operations shall be delayed until necessary and the temperature within the hot water system must be maintained to compensate for heat loss. Maintenance personnel should monitor cold and hot water temperatures at critical control locations to confirm water management controls are effective. Because temperature is an important factor affecting microbial growth in building plumbing, all buildings should accurately measure and record water temperatures throughout construction and renovation. Within water management programs, temperature data are used to evaluate plumbing water age by identifying system components that may support the growth of pathogenic organisms and to develop strategies for control of pathogen growth. Temperatures should be evaluated in both cold-water and hot water systems. This is to identify potential sources of environmental heat gain in the cold water system and to maintain hot water control limits.

104.3.2 Water Stagnation. Prior to construction activities, the water management team should determine the locations or water systems that may be impacted due to construction activities including locations where water is not flowing or restricted from use. This determination should be used to identify strategies to reduce water age and prevent excessive water stagnation such as by means of manual flushing by personnel or by installation of automatic flushing strategies in accordance with the water management program. Because disinfectant must

be present consistently to maintain biological control and because disinfectants decay, water must be turned over (refreshed) regularly to bring fresh disinfectant through the distribution system. Because plumbing components do not behave as “ideal” reactors, turning over the water in a given component requires up to five times the volume of water in the component.

Note: When water is not drawn through a plumbing system or other building water system over an extended period of time, the water becomes stagnant. During periods of stagnation, disinfectants decay which results in accelerated growth of many harmful microorganisms, such as *Legionella*. Other impacts of stagnation are loss of corrosion control, release of metals into potable water, and tepid temperatures, all of which support the growth of *Legionella* and other environmental pathogens. Pathogens that survive and grow in the building water environment are typically opportunistic pathogens that pose greater risks to the elderly and immunosuppressed populations.

104.3.3 Disinfectant Residuals. Disinfectant in the water from the water purveyor impacts building water systems in multiple ways. A basic understanding of disinfectants and microbial control can promote informed decisions during construction through the reopening process into normal operation, as well as in flushing and pre-occupancy disinfection procedures. The disinfectant in a building’s water supply is intended as a bacteriostatic agent (preservative), not a primary disinfectant. As a bacteriostatic agent, the disinfectant creates conditions adverse to organisms (including pathogens like *Legionella*) that can grow in biofilms on pipe, fitting, and fixture surfaces. Because the disinfectant is a bacteriostatic agent, it does not need to be consistently present at concentrations as high as needed for pre-occupancy disinfection or for remediation, but it does need to be present consistently and it needs to penetrate biofilms and have contact with unwanted organisms. Ideally, disinfection is part of a multi-barrier approach to biological control and used in concert with other activities and controls such as flushing and temperature management.

Free chlorine and monochloramine (ammonia added to chlorine) are the most common secondary disinfectants in domestic water systems. Both free chlorine and monochloramine decay over time, chloramines at a slower rate than free chlorine. However, nitrification (a condition associated with certain organisms that use ammonia as an energy source) can rapidly deplete monochloramine and is common in water distribution networks with a monochloramine disinfectant. Chlorine can produce a greater reduction in the concentration of planktonic bacteria with lower concentrations and contact times than monochloramine whereas monochloramine penetrates biofilm more readily than free chlorine.

The minimum disinfectant residual concentration that public water systems are required to maintain to the distal ends of their distribution systems varies by state. Some states maintain different minimum disinfectant residual requirements for free chlorine and monochloramine and might also require higher minimum disinfectant residual requirements if the pH is high or based on other water quality characteristics. A 2017 study of disinfectant concentration measurements in public water systems assessed that disinfectant residual measurements above 0.2 mg/L indicate an effective disinfectant is present, whereas lower concentrations might arise from interference with commonly-used disinfectant measurement protocols and devices. Because disinfectant residual is an important factor affecting microbial control in building plumbing, all buildings should accurately measure and record disinfectant residuals and use this data to manage plumbing water age.

Disinfectant residual concentrations should be measured in both cold-water and hot water systems, as disinfectant levels in hot water are more difficult to maintain but shall consider the following recommendations:

- (1) All building water systems should have an accurate digital chlorine residual test kit that uses an EPA-approved test method for use in drinking water compliance. (*See chlorine residual testing standard operating procedure – Annex*).
- (2) Building owners should contact their water provider and find out whether they practice ‘free chlorination’ or ‘chloramination’.
- (3) Building owners should measure free chlorine if the utility disinfects using free chlorine.
- (4) Building owners should measure total chlorine if the utility disinfects using chloramine.

NOTE: A low cost chlorine test should be practiced from the start of construction with testing throughout the duration for safety and detailed history, made part of the water management plan.

104.3.4 Suspended Solids. Sediment in the water has an impact on plumbing systems as it can clog strainers and cause ball valves to seize. Sediment can increase during periods of stagnation due to the oxidizing disinfectants corroding the metallic piping as the water is stagnant. It also has an impact on the microbiology and disinfectant of the building as sediment can:

- (1) Reduce the residual disinfectant by consuming the disinfectant.
- (2) Provide a food source for bacteria, as sediment can and will provide a carbon source of various quantities to support bacteriological life; and
- (3) Shield bacteria from disinfection as the pathogens can attach themselves to sediment. The sediment can then carry the pathogen into an area in the building where water quality conditions are ideal for its' growth.

Although there are laboratory and field methods for measuring suspended solids in water, visual inspection of water is an important means of early detection of suspended solids and related water quality problems. Turbid (cloudy) water, water with color and water with visible sediments are all causes for concern and should trigger follow-up measures including investigation of the cause of the sediments or color and mitigation (e.g., via high velocity flushing or implementation of corrosion control).

104.3.5 Legionella Considerations. Microbiological test results including *Legionella* spp. provides a measure of water safety. *Legionella* spp. is a genus of naturally occurring environmental bacteria (i.e., bacteria that can survive in certain environmental niches and that do not need to be inside a host to replicate) that thrive in stagnant and recirculated waters between 20 °C and 45 °C (68 °F and 113 °F). Not all species of *Legionella* bacteria are known to cause human infection and, in the United States, the majority of identified legionellosis cases have been associated with the species *Legionella pneumophila*. Because *Legionella* is a leading cause of waterborne disease outbreaks and cases, many water management programs (WMPs) focus on *Legionella* management, though WMPs, if developed as intended, can and should address other contaminants, both chemical hazards and other microbial species. Water samples for *Legionella* analysis should be analyzed by a culture method by an accredited laboratory, or other laboratory approved by the AHJ where *Legionella* culture appears on the laboratory's scope of accreditation. Results from the samples collected should be interpreted using the CDC's assessment tool (**Figure 104.3.5**). Note that only results from culture assays are referenced in the CDC's tool; results from other assays (e.g., qPCR) are fundamentally different from those from culture assays and should be used in concert with culture samples to confirm the presence/absence of viable *Legionella*.

	WATER PARAMETER	CONTROL MEASURE	RECOMMENDATIONS
S	Sediment and Biofilm	Flushing, cleaning, and maintenance	<ul style="list-style-type: none"> • Flush after an intrusion event (e.g., water main break). • Clean and maintain water system components such as water heaters, mixing valves, aerators, showerheads, hoses, and filters regularly as indicated by water quality measurements.
T	Temperature	Control limits	<ul style="list-style-type: none"> • Store hot water above 140°F (60°C) and maintain circulating hot water above 120°F (49°C). • Store and maintain circulating cold water below the growth range most favorable to <i>Legionella</i> (77–113°F, 25–45°C). Note that <i>Legionella</i> may grow at temperatures as low as 68°F (20°C).
A	Water Age	Flushing	<ul style="list-style-type: none"> • Flush low-flow pipe runs and dead legs at least weekly. • Flush infrequently used fixtures regularly.
R	Disinfectant Residual*	Control limits	<ul style="list-style-type: none"> • Chlorine: Detectable residual as directed by WMP. • Monochloramine: Detectable residual as directed by WMP

Reference: CDC Toolkit / **Note:** *Disinfectant residual recommendations apply to disinfectant delivered by the municipal water authority. Supplemental disinfection system control limits are not prescribed here and must be dictated by the water treatment professional and water management program.

FIGURE 104.3.5
CDC TOOLKIT FOR CONTROLLING LEGIONELLA IN COMMON SOURCES OF EXPOSURE
LEGIONELLA CONTROL MEASURES FOR POTABLE WATER SYSTEMS

Note: The CDC assessment tool considers the concentration of legionellae in individual samples, the frequency of detection at a given sample location and the extent of positive detections on a given sampling day. Knowing whether a building has *Legionella* both in terms of concentrations and frequency of detections enables a data-based assessment of building water quality and can guide appropriate actions to protect water users. This includes a number of samples and locations that adequately represent the water system. Consider selecting a laboratory that has *Legionella* proficiency as demonstrated by CDC ELITE program certification, or another internationally recognized proficiency program (such as the PHE *Legionella* isolation scheme).

104.3.6 Water Treatment Types.

104.3.6.1 Supplemental Disinfection Systems. If the building has supplemental disinfection of any type, the building owner or their designated operator must monitor and record treatment operational parameters daily that the treatment operates. Every water supplemental disinfection system presents a risk to building users from overfeeding of chemicals or by contamination of byproducts from disinfectant loss of treatment and control of microbes. Building owners and operators should routinely inspect the treatment system for proper working order (chemical concentrations if adding chemicals) and be able to adjust the treatment when needed. Continuous monitoring is an appropriate frequency for validation of supplemental disinfection systems.

Note: Many states apply the federal safe drinking water act regulations to any building that adds treatment to the water that they receive from a utility. Building owners and operators should check with the state drinking water primacy agency to determine any additional monitoring and reporting requirements as well as specific limits and corrective actions for these measurements. The state primacy agency regulates the utility and purveys water.

104.3.6.2 Additional Treatment Types. Water softeners, reverse osmosis filtration systems, carbon filters, copper-silver ionization disinfection systems and other additional treatment systems are frequently deployed in building water systems and must be installed and operated according to manufacturer specifications and per code requirements. Treatment systems can impact water quality in multiple ways, and systems should be designed and operated to ensure all water quality objectives are met. For example, over-softening can generate corrosive water and carbon filtration can remove disinfectant and interfere with *Legionella* risk management. Installation and filling of additional treatment should be delayed until necessary to avoid stagnant conditions, growth of biofilm on treatment system media and other phenomena that can degrade water quality. Prior to installation, treatment appurtenances should be stored in a sanitary manner and intake and discharge ports should be capped or wrapped.

104.4 Water Quality Data Tracking and Evaluation. The purpose of testing water quality parameters is to obtain data to help a building owner not only better manage building water systems but also to provide documentation as part of a legal defense. All building water sampling efforts should have an electronic spreadsheet for entering results. Store all monitoring information to comply with all state and federal regulations. Consult legal counsel to determine statute of limitations for jurisdiction and store data and relevant documentation until at least that point in time.

104.4.1 Water Management Minimum Design Needs, by Building Type. Building intended use and anticipated occupancy are related to the level of water quality management required during both construction and during the building service life. Categories of buildings with different water management requirements are presented in Table 104.4.1. Water management activities recommended by building category are presented in Table 104.4.1.

All buildings of categories C and D should be disinfected per governing code and their designs must include disinfectant injection ports and sample ports for drawing water samples for measuring disinfectant concentration. Disinfectant injection points should be designed such that they are not functional dead legs when not in use. Disinfection injection points can also be used during beneficial occupancy if the system design includes supplemental disinfection post-occupancy. Long-term supplemental disinfection often triggers extensive environmental regulatory requirements under the Safe Drinking Water Act and should be fully considered before it is added to a system.

TABLE 104.4.1
WATER MANAGEMENT MINIMUM DESIGN NEEDS REQUIREMENTS, BY BUILDING TYPE

CATEGORY	DESCRIPTION
A	Buildings with <i>low</i> likelihood of human exposure to aerosols such as: Single-family residences, duplexes, town homes and other small residential buildings
B	Buildings with <i>low/moderate</i> likelihood of human exposure to aerosols such as: <ul style="list-style-type: none"> • Commercial buildings without showering facilities • Retail buildings • Warehouses, server farms and other low occupancy buildings with low incidence of occupant exposure to aerosolized potable water
C	Buildings with <i>moderate</i> likelihood of human exposure to aerosols with sensitive occupants/users (excludes healthcare) such as: <ul style="list-style-type: none"> • Institutions, schools, and childcare facilities • Hotels and resorts • Gyms and Recreational facilities • Large office buildings
D	Buildings with <i>high</i> likelihood of human exposure to aerosols including healthcare facilities with sensitive occupants/users such as: <ul style="list-style-type: none"> • Senior facilities (e.g., assisted living) • Nursing and rehabilitation facilities • All other health care facilities including those providing out-patient care

Note: Buildings in categories C and D have specific water quality management requirements that must be considered in water system design.

Buildings of categories C and D also require flushing to remove debris when the system is first filled, regular flushing after filling and before final disinfection and flushing following final disinfection. Buildings of types A and B can also benefit from flushing upon filling and regular turn-over of water until beneficial occupancy. System designs must include accessible flushing points able to meet flow requirements (target velocities) and drainage to accommodate flushed water. Flushing may be manual or automated.

Note: Flushing points, sampling points and injection points as described in this table could be utilized for similar purposes and functions for management of the potable water system.

104.4.2 Water Conservation Objectives. Building water systems can be designed and operated to minimize water waste during both construction and beneficial occupancy while maintaining safety. Decisions regarding implementation of low-use water fixtures or water conservation initiatives may be addressed during the design phases. Designs that conserve water can achieve recognition under private and/or public building rating systems.

Note: Water waste during construction may include water flushed to drain to maintain water quality when a system is filled earlier than necessary, temporary use of fixtures that are not water conserving, and leakage. Design engineers can promote water conservation by minimizing the water volume in pipes requiring flushing, including flushing points that allow strategic flushing of the system and including automated leak detection and mitigation in the system design.

104.5 Flushing.

104.5.1 Inclusion of flushing points. Flushing is a key element of water management during and after construction. Flushing points for key segments of the system should be included in the system design. As described in Section 105.5, at least three types of flushing are required during water management during: (i) an initial flush

conducted when the system is first connected to remove sediments and gross materials accumulated in the water system ; (ii) routine flushing to maintain water quality and conducted under a construction water management program (WMPs are described in Section 107.3); and (iii) flushing associated with final system disinfection immediately prior to transfer of water system responsibility to the building owner. The primary objective of the initial flush and post-disinfection flush is removal of debris and, to the extent practicable, biofilm. As relatively high velocities are required to meet those objectives, the plumbing system should be designed with sufficient drainage capability for the large volumetric flows required. As biofilm can be tightly attached to pipe surfaces and can be present in components of the system that are poorly scoured (e.g., in low flow or dead zones in a mixing valve), complete removal of biofilm is not possible through flushing alone and should not be a design criterion for flushing. Flushing points should be chosen strategically and performed methodically such that contaminants, sediments, and other water quality hazards and hazardous conditions are not entrained deeper into the plumbing system, and such that target flushing velocities can be achieved. Segments of a plumbing system that are beneficial to flush separately and that require flushing points include the service line, cold water distribution trunks, hot water distribution trunks, and hot water recirculation loops. Generally, branches can be flushed from fixtures with flow restrictors removed and hot water storage tanks are fitted with drain ports. See Table 104.5.1

104.5.2 Monitoring Water Quality Parameters During Flushing. Initial water quality and water safety parameters including those in Section 104.3 should be monitored. Initial data may be obtained from water suppliers or can be monitored.

Water quality and water quality parameters can, and in some cases must be made at multiple times and for several purposes during water system construction and installation. Water quality monitoring shall include the following:

- (1) Collection of water quality data to inform system design,
- (2) Collection of water quality when a service connection is made and prior to first filling the system,
- (3) Routine monitoring as a component of a construction water management program (Section 107.10)
- (4) Water monitoring during pre-occupancy disinfection.

Note: Each of these monitoring activities is associated with a specific set of water quality parameters and characteristics, a set of locations that should be monitored, a monitoring frequency and an action level or interpretation. Water quality monitoring is described in greater detail in Section 105.6.

Key water quality information that informs system design shall include the following:

- (1) The type of disinfectant residual in the building water supply (free chloramine, monochloramine or none)
- (2) The typical disinfectant residual concentration in the building water supply
- (3) Water supply pH, hardness and alkalinity (these tend to be consistent throughout water systems, though can vary if the water suppliers blended water from multiple sources and treatment plants)
- (4) Total coliform positive samples in the water supplier distribution system in the vicinity of the building to be constructed, and
- (5) Recent main breaks or other losses of system integrity in the water supplier distribution system in the vicinity of the building to be constructed.

Note: The type of disinfectant residual and the water supply pH, hardness and alkalinity are reported in the water supplier's customer confidence report (CCR) which is available on the web sites of most utilities or can be obtained from US EPA websites. Other parameters may be requested from the water supplier or, if the water supplier is unable to provide the parameters specific to the building location, water samples may be collected and analyzed to determine the other parameters.

**TABLE 104.5.1
RECOMMENDED WATER MANAGEMENT CRITERIA, BY BUILDING TYPE**

BUILDING TYPE	FLUSHING POINTS	SAMPLING POINTS	TEMPERATURE AND FLOW	WATER QUALITY HAZARDS
Education	All public use locations (sinks, drinking fountains, showers)	Drinking fountains Accessible distal locations Designated valves As required by AHJ	Temp Range: max allowed per AHJ Flow: Continuous	Dissolved inorganics (lead, copper) <i>Legionella pneumophila</i> Implement construction-specific validation responses (e.g., flushing, disinfection)
Healthcare (D)	Strategic locations (closest to riser, distal locations) flushed at a rate/frequency required to simulate occupancy Programmable automatic flushing strategies to reliably turnover water. Confirm if emergency water systems are being flushed. If not, include it in flushing plan.	Drinking fountains Accessible distal locations, Distal points, (sink, shower, ice machine) Designated valves As required by AHJ	Temp Range: max allowed per AHJ Flow: Continuous	Disinfection by-products (DBP) Dissolved inorganics Clinically significant microbial pathogens (e.g., <i>Legionella</i> , <i>Pseudomonas</i> , <i>M. Abscessus</i>) Implement construction-specific validation responses (e.g., flushing, disinfection) Provide and install injection points for preoccupancy disinfection or as required by the Authority Having Jurisdiction.
Hospitality (C)	Strategic locations (closest to riser, distal locations) flushed at a rate/frequency required to simulate occupancy Programmable automatic flushing strategies to reliably turnover water.	Drinking fountains Accessible distal locations, Distal points, (sink, shower, ice machine) Designated valves As required by AHJ	Temp Range: max allowed per AHJ Flow: Continuous	Dissolved inorganics (lead, copper) DBPs <i>Legionella pneumophila</i> Implement construction-specific validation responses (e.g., flushing, disinfection)
Commercial (B)	All public use locations (sinks, drinking fountains, drink stations, ice machines)	Accessible Distal Outlets, Designated valves, As required by AHJ	Temp Range: max allowed per AHJ Flow: Continuous	Dissolved inorganics (lead, copper) <i>Legionella pneumophila</i> Implement construction-specific validation responses (e.g., flushing, disinfection)
Multi-Family (A/B)	All public use locations (sinks, showers, ice machines)	Accessible Distal Outlets, Designated valves, As required by AHJ	Temp Range: max allowed per AHJ Flow: Continuous	Dissolved inorganics (lead, copper) <i>Legionella pneumophila</i> Implement construction-specific validation responses (e.g., flushing, disinfection)

105.0 Construction Means and Methods.

105.1 Construction Water Usage. Water is used for many purposes during construction. The impacts of those uses on water quality during and post-construction need to be addressed in planning and scoping, and during construction activities. Contaminants that can be or have been introduced during construction may include sediment and debris, chemical contaminants (e.g. disinfection byproducts, inorganics), and waterborne pathogens, the presence of which should be minimized and kept independent from the potable water system, through means of an approved cross connection device.

Cross connection prevention devices should be installed prior to use of water systems to prevent the ingress of debris, chemical contaminants, and waterborne pathogens. In many cases, required flow rates and frequency of use for construction water uses are significantly different from those during beneficial occupancy. The differences between water use during construction and after beneficial occupancy require system design elements to accommodate construction water uses and practices that reduce the likelihood of contamination of the water system during construction and that promote worker safety and safety of nearby building occupants during construction.

Note: Common construction water uses are listed and reviewed in Table 105.1. Water used during construction may be supplied by temporary connections either to the water supply or to a segment of the building water system that is already connected and active. In both of these cases, backflow prevention should be practiced and may be required by code. Temporary connections can sometimes be left in place after construction and can pose water quality challenges because they are stagnant, oversized, or otherwise interfere with the turnover of water in the plumbing system. Temporary supplies can also have different drainage requirements than the post-construction plumbing system and drainage that can accommodate construction wastewater must be available prior to use of temporary supplies.

Note: Any temporary hoses used for potable drinking or handwashing shall be maintained not to have additional non-potable connections to them. Unmanaged plumbing systems with building water supply connections may pose a hazard and contaminate the water system and/or supply. This will pose a health risk to construction workers and future occupants. All of the construction water uses described in Table 105.1 pose potential backflow risks.

105.2 Pressure Testing Impacts on Water Quality. Pressure testing can be conducted with water, air, or dry nitrogen purging. Air and nitrogen testing allow delay of filling the system and have water quality and water conservation benefits. When pressure testing is conducted with water, the system must be filled with potable water; water for pressure testing must be from a regulated water supplier or a regulated and tested community water system (if self-supplied). Tests to ensure water quality is fit for purpose include visual inspection of water clarity, confirmation that there is no unusual odor to the water (beyond the smell of disinfectant), disinfectant concentration, and pH. Other tests that should be considered are total coliforms (an indicator of sewage contamination) and HPC (if high, an indication of poorly controlled biological water quality). Total coliform and HPC tests must be conducted by a certified laboratory and may require more than 24 hours to produce a result. Water should be considered unsuitable for human consumption if water quality samples are positive for total coliforms or if water samples have HPC > 500 / mL. Pressure testing with water should be conducted according to manufacturer testing considerations and methods.

105.3 Alternative to Using the Permanent Water System for Construction Water. Alternatives to using the permanent potable water system during extensive construction or renovation projects should be considered. Use of alternative systems can postpone filling the permanent system, can prevent the oversizing of pipes to accommodate higher than normal construction water flows that can be higher than those during normal operation and can promote water conservation. Temporary systems should be isolated from the permanent system via backflow prevention devices and should be labeled "temporary use." When construction is completed, branches to temporary piping should be removed and capped to avoid the creation of dead legs.

TABLE 105.1
CONSTRUCTION ACTIVITIES AND METHODOLOGIES FOR CONSTRUCTION USE OF POTABLE WATER

CONSTRUCTION USE FOR POTABLE WATER	CROSS CONNECTION CONTROL METHODS, DEVICES AND ASSEMBLIES	POTENTIAL IMPACTS ON WATER QUALITY
<p>Temporary construction toilet facilities (Bathrooms, pantry, etc.)</p>	<p>All faucet types shall have an airgap ASME A112.1.2 between the spout and bowl. Spout shall be without hose threads.</p> <p>Temporary piping shall be of NSF 61 approved materials for potable water or faucet. Temporary piping should be labeled "Non-potable: do not drink."</p> <p>Tank type water closets shall have an approved ASSE 1002 ballcock.</p> <p>Flush Valve water closets and urinals shall have an approved ASSE 1037 flush valve.</p>	<p>Permanent or temporary connections into the water system; requires sufficient drainage to accommodate maximum flow.</p> <p>Backflow and cross connection installation and maintenance required.</p> <p>Document in the water management program with location and fixtures installed.</p> <p>Characteristics list: Infrequent turnover of water Water in unconditioned spaces Exposed piping to the elements Dead legs and temporary unused piping not removed</p>
<p>Drinking water (hydration stations)</p>	<p>All faucet types shall have an airgap ASME A112.1.2 between the spout and bowl. Spout shall be without hose threads.</p> <p>Airgap ASME A112.1.2 on faucets any temporary piping shall be of approved materials for potable water. If supplied by a hose, the hose shall be composed of ANSI/NSF 61 certified material. The hose shall not supply water to any other non-potable outlet.</p>	<p>Connections to drinking water or hydration stations must be onto a commissioned and disinfected potable water system that is maintained under a building water management plan.</p> <p>Characteristics list: Infrequent turnover of water Water in unconditioned spaces Exposed piping to the elements Dead legs if temporary and unused piping not removed</p>
<p>Material mixing (Cement, grout, etc.)</p>	<p>If supplied by continuous pressure it shall be protected by an ASSE 1056, ASSE 1020, or an ASSE 1013 certified vacuum breaker.</p> <p>All backflow prevention devices shall be installed per the applicable standards and local codes.</p> <p>Label "non-potable, do not drink" downstream of the assembly. If supplied by a non-continuous hose supplied by an ASSE 1019, ASSE 1011, or ASSE 1052 Hose bib, labeled "non-potable, do not drink until commissioned and documented" downstream.</p> <p>All devices, assemblies and mechanisms intended to protect water supplies relative to cross connection or backflow shall be of a type recognized and approved.</p>	<p>Connections to material mixing water or point of use hose connections points must be protected by an approved cross connection device at the point of use.</p> <p>All piping designed to supply potable water shall be maintained separate from non-potable and shall not supply non potable water.</p> <p>A site-specific water management program shall be maintained for the duration of the construction process including a log of all cross-connection devices serving temporary construction water. All cross-connection installations shall be in accordance with the AHJ.</p> <p>Any temporary piping shall be removed in its entirety prior to commissioning of the potable water system. This can prevent situations like dead legs and in active areas of the system resulting in water age.</p> <p>Characteristics list: Infrequent turnover of water Water in unconditioned spaces Exposed piping to the elements Dead legs if temporary and unused piping not removed</p>

TABLE 105.1 (continued)
CONSTRUCTION ACTIVITIES AND METHODOLOGIES FOR CONSTRUCTION USE OF POTABLE WATER

CONSTRUCTION USE FOR POTABLE WATER	CROSS CONNECTION CONTROL METHODS, DEVICES AND ASSEMBLIES	POTENTIAL IMPACTS ON WATER QUALITY
<p>Washdown (Dust-suppression, hydro-demolition, power washing)</p>	<p>If supplied by continuous pressure it shall be protected by an ASSE 1056, ASSE 1020, or an ASSE 1013 certified vacuum breaker.</p> <p>All backflow prevention devices shall be installed per the applicable standards and local codes. Labeled “non-potable, do not drink” downstream of the assembly. If supplied by a non-continuous hose supplied by an ASSE 1019, ASSE 1011, or ASSE 1052 Hose bib, labeled “non-potable, do not drink” downstream.</p>	<p>Characteristics list: Infrequent turnover of water Water in unconditioned spaces Exposed piping to the elements Dead legs if temporary and unused piping not removed</p>
<p>Construction equipment with reservoirs (Cutting, paving, tankers)</p>	<p>If supplied by continuous pressure it shall be protected by an ASSE 1056, ASSE 1020, or an ASSE 1013. All installations shall be per the standards and local codes. Labeled “non-potable, do not drink” downstream of the assembly.</p> <p>If supplied by a non-continuous hose supplied by an ASSE 1019, ASSE 1011, or ASSE 1052 Hose bibb, labeled “non-potable, do not drink” downstream. If supplied by non-continuous pressure downstream of an ASSE 1001 pipe applied vacuum breaker. If supplied by non-continuous pressure Airgap (ASME A112.1.2) or an Airgap fitting (ASME A112.1.3)</p>	<p>Characteristics list: Infrequent turnover of water Water in unconditioned spaces Exposed piping to the elements Dead legs if temporary and unused piping not removed</p>
<p>Interim Fire Hydrant building water supply</p>	<p>ASSE 1013 labeled “non-potable, do not drink” downstream of the assembly.</p>	<p>Characteristics list: Infrequent turnover of water. (Needs approval from local Fire Dept and Municipality to connect)</p>
<p>Hose Bibbs, yard hydrants and other.</p>	<p>ASSE 1019, ASSE 1011, or ASSE 1052, labeled “non-potable, do not drink” downstream.</p>	<p>Characteristics list: Infrequent turnover of water</p>

105.4 Pre-Installation Material Management. Prior to installation, plumbing materials should be stored in a manner that protects them from contamination. Sanitary storage and handling of pipes and distribution system components is a common requirement for contractors for installation of new mains for drinking water systems and has been demonstrated to reduce the likelihood of contamination after installation and the effort required to disinfect new mains before they are put into service. The same benefits can be expected from sanitary storage of building water system plumbing materials.

105.4.1 Practices to Prevent Contamination Onsite. Practices to prevent contamination during storage and pre-installation shall include but are not limited to the following best practices:

- (1) Capping or wrapping pipe, valves, and other plumbing material;
- (2) Capping or sealing the intake, discharge, and drain ports of water heaters and other water treatment devices such as water softeners;
- (3) Storing plumbing system components in well-drained areas with low likelihood of water accumulation; and
- (4) Avoiding long-term on-site storage of plumbing components prior to installation.

Note: Plumbing system components accidentally exposed to non-potable water or otherwise contaminated during storage should be disinfected and flushed prior to installation.

105.5 Flushing Methods & Locations.

105.5.1 Flushing Activity Purposes. Flushing is conducted for at least three purposes during construction of building water systems. The three types of flushing, their objectives and characteristics of the flushing protocols are presented in Table 105.5.1.

**TABLE 105.5.1
FLUSHING ACTIVITY PURPOSES, OBJECTIVES AND CHARACTERISTICS**

FLUSHING TYPE	PURPOSES	CHARACTERISTICS
Initial flushing (Prior to system filling and before disinfection)	(1) Removes debris, construction residuals, and environmental contaminants introduced into plumbing components during storage and installation	Velocity high enough to mobilize sediment; flushing from near point of entry outward to distal locations to avoid entrainment of contaminants deeper into the system; flushing duration required to turnover the supply line at least five times the volume of the pipe.
Routine flushing (After the system is filled and before disinfection)	(1) Simulate occupancy by replacing old water with new water with disinfectant and maintain temperature outside the growth range of environmental pathogens (2) Remove loose biofilm and organisms that accumulated during stagnation	Flushing conducted daily (building type D) or once per three days (building type C); when feasible, flow started impulsively (not gradual) with aerators and other flow-restricting components removed; flushing can be conducted via fixtures or flushing locations at distal outlets at the end of the branches
Supplemental Flushing (After the system is filled and event based)	(1) Remove water with high disinfectant concentration (2) Remove detached and degraded biofilm and other materials generated during disinfection	Flushing conducted per standards specified in code

105.5.2 Flushing Target Velocity and Duration. Dedicated flushing points and plumbing fixtures used for flushing branches should be sized to generate a velocity of at least 5 fps in as much of the system as feasible and no less than 2.5 fps throughout the system. Required flows to achieve 5 fps and 2.5 fps velocities for different pipe sizes are provided in Table 105.5.2. This table reinforces the need for dedicated flushing points and sufficient drainage, particularly for flushing large diameter pipes. Note that flushing points must also have drains that can accommodate the required flow.

**TABLE 105.5.2
FLOWS TO ACHIEVE 5 FPS VELOCITY**

PIPE NOMINAL DIAMETER (INCHES)	PEX			COPPER TYPE L		
	INNER DIAMETER (INCHES)	FLOW (GPM) TO ACHIEVE 5 FPS	FLOW (GPM) TO ACHIEVE 2.5 FPS	INNER DIAMETER (INCHES)	FLOW (GPM) TO ACHIEVE 5 FPS	FLOW (GPM) TO ACHIEVE 2.5 FPS
3/8	0.36	1.59	0.79	0.43	2.26	1.13
1/2	0.485	2.88	1.44	0.545	3.64	1.82
3/4	0.681	5.68	2.84	0.785	7.54	3.77
1	0.875	9.37	4.69	1.025	12.86	6.43
1½	–	–	–	1.505	27.72	13.86
2	–	–	–	1.985	48.23	24.11

105.5.3 Water Volume / Flushing Duration Calcs. Due to hydraulics and mixing in pipes and fittings, flushing a single pipe volume of water does not reliably remove contaminants from the pipe. A minimum of 4-5 pipe volumes must be flushed at the target velocity to achieve a high level of contaminant removal. Table 105.5.3 provides the volume in five pipe volumes of water and the flushing time required at 5 gpm for 10 linear feet of pipe of various diameter.

**TABLE 105.5.3
FLUSHING BY PIPE SIZE AND VOLUME**

PIPE NOMINAL DIAMETER (INCHES)	PEX				COPPER TYPE L			
	INNER DIAMETER (INCHES)	VOLUME IN 10 FT OF LINEAR PIPE (GAL)	VOLUME TO FLUSH TO COMPLETELY TURN OVER 5 VOLUMES FOR 10 FT OF LINEAR PIPE (GAL)	TIME TO FLUSH 10 FT OF LINEAR PIPE AT 5 GPM (SEC)	INNER DIAMETER (INCHES)	VOULME IN 10 FT OF LINEAR PIPE (GAL)	VOLUME TO FLUSH TO COMPLETELY TURN OVER 5 VOLUMES FOR 10 FT OF LINEAR PIPE (GAL)	TIME TO FLUSH 10 FT OF LINEAR PIPE AT 5 GPM (SEC)
3/8	0.36	0.05	0.26	3.17	0.43	0.08	0.38	4.53
1/2	0.485	0.10	0.48	5.76	0.545	0.12	0.61	7.27
3/4	0.681	0.19	0.95	11.4	0.785	0.25	1.26	15.1
1	0.875	0.31	1.56	18.7	1.025	0.43	2.14	25.7
1½	–	–	–	–	1.505	0.92	4.62	55.5
2	–	–	–	–	1.985	1.61	8.04	96.5

105.6 Water Quality Testing. Generally, water quality monitoring should be conducted as specified by ANSI/ASHRAE 188 and the CDC report “Developing a Water Management Program to Reduce *Legionella* Growth & Spread in Buildings.” Because those resources provide only general recommendations and requirements for monitoring and because those documents address only operational buildings, additional recommendations specific to water quality monitoring during construction are presented below.

105.6.1 Water Quality Parameters. Water quality data can be found in water supplier water quality reports (consumer confidence reports). These parameters can be measured at key milestones during construction and compared to data in the consumer confidence report. Measurements that should be collected, documented, and analyzed include, but are not limited to the following:

- (1) Disinfectant residual type
- (2) Disinfectant residual concentration
- (3) Water temperature
- (4) Water pressure
- (5) Flow rate
- (6) pH and
- (7) *Legionella* concentration (for building types C and D).

Process control parameter measurement (e.g. disinfectant concentration, water temperature and pH) should be made for each *Legionella* sample collected. Analysis of this data allows better interpretation of *Legionella* results and assessment of whether *Legionella* are well controlled. Measurements that can also be made, documented, and analyzed shall include the following:

- (1) HPC or THAB (Total Heterotrophic Aerobic Bacteria)

- (2) Turbidity
- (3) Conductivity

Note: In general, HPC, THAB, turbidity and conductivity trends are more indicative of water quality and system control than individual measurements, although single extremely high measurements can signal water quality or process control problems that require immediate attention.

105.6.2 When to Measure. Water quality should be assessed and sampled:

- (1) Prior to design
- (2) At the time of service connection
- (3) Periodically, after the system is filled and prior to disinfection and
- (4) During and after disinfection, per the disinfection standard adopted by the AHJ.

105.6.3 Where to Measure. Minimum water quality measurements should include but not be limited to the following locations:

- (1) the plumbing system entry point (as near to the service connection as possible)
- (2) the discharge of water storage facilities
- (3) at control locations or locations used for verification monitoring (process control), and
- (4) at representative plumbing fixtures on each branch of the system, including the most distal points. Measurements should be taken at distal distribution system locations since the risk of stagnation in a potable water system is highest at these locations.

Flow should be measured at the plumbing system entry point and on trunk lines of the cold and hot water distribution. Sample collection locations should be included in the plumbing system design and should include at least one sample collection location near enough to the service connection that building plumbing system processes do not significantly alter water quality of the samples and samples are representative of the water supply.

105.6.4 How to Measure. Contractor water monitoring instruments/equipment shall include the following:

- (1) Colorimeter (digital)
- (2) Temperature (digital)
- (3) Reagents
- (4) Calibration solutions

Note: In addition, contractors should also have an adequate supply of sample bottles suitable for microbial sampling (sterile and containing a solution for quenching the disinfectant residual). Sample bottles are usually provided by the laboratory conducting the microbial assays.

105.6.5 Water Draws for Testing. Water quality and water age vary widely within a plumbing system and two types of samples are required for assessing water quality in the system. First draw samples are used to assess conditions in the portion of the system nearest the sample collection point. First draw samples typically include volumes of water that have been stagnant and represent worst case water quality. Long-draw flush samples are collected to allow assessment of water quality in main distribution plumbing, in the building service line or in the building supply. Water quality in first-draw samples is never representative of the building supply (from the purveyor) because water quality can degrade significantly over a short time in building plumbing. During construction, fixtures typically used in sample collection might not be available and the system design should explicitly include sample collection locations/ports. Sample collection locations should be installed, at a minimum, near the service entrance, along the main hot and cold distribution and at representative distal locations.

Note: For measures of biological water quality (HPC, coliforms, *Legionella* and other microorganisms) for both first-draw and long draw sample types, aseptic techniques must be practiced during sample collection to reduce the likelihood of sample contamination. Samples can be contaminated by contact with fixture surfaces, samplers' skin or clothing or from splash. Samplers must follow the CDC protocol for sample collection (<https://www.cdc.gov/legionella/downloads/cdc-sampling-procedure.pdf>) or a similar protocol. Recommended procedures for collection of first-draw and long-draw flushed samples follow.

105.6.5.1 First-Draw. Remove aerator or other flow restricting fittings, open fixture and collect first water out of fixture to determine disinfectant residual that is available at faucet that use may see. First draw samples often have no disinfectant residual due to decay and demand during stagnation. First draw samples can have much higher microbiological concentrations than flushed samples.

105.6.5.2 Long-Draw Flush. Determine distance into water main or branch inside building that results are desired for. Calculate the time needed to flush (volume of water based on pipe size, divide by flow rate of fixture) in order to obtain water from that portion. Flush for three to five times longer than that time, and then collect sample. Long-draw will give a better indication of the water quality in the water main. The longer the flush before the draw, the further upstream in the piping system the test results will describe.

106.0 Construction Project Scope, Schedule & Testing.

106.1 Construction Schedule to Minimize Risk and Conserve Water. By following the requirements described in Section 107, the building owner should be able to demonstrate acceptable potable and non-potable water quality upon beneficial occupancy and that assessments of the water system were carried out to prevent unintended consequences from construction-related activities. The facility should develop and maintain a construction project schedule to identify the risk management activities and key milestones that impact water quality. The construction schedule should include the analytical testing events that are necessary to monitor water quality and water safety up until the first date of operations. All phases of a construction or renovation project should be addressed in the schedule with the determination of risk (e.g. extensive renovation, sensitive exposed population) and risk management and testing activities.

Note: A simplified timeline for construction-related potable water systems activities is shown in **Figure 106.1**. For complex installations, the five phases shown in **Figure 106.1** frequently overlap (e.g., when a system is commissioned in stages) and require the coordination of multiple parties such as design engineers, prime contractors, plumbing professionals, and subcontractors such as consultants specializing in commissioning and pre-occupancy disinfection. Because protecting the potable water system is the shared responsibility of multiple parties, potable water system construction and commissioning should be under the governance of an overarching construction water management program that is administered by a designated authority and with responsibilities of all parties clearly delineated.

Each of the phases shown in **Figure 106.1** can be designed and executed to protect the potable water system from contamination and reduce the likelihood that potable water systems begin their service life contaminated. Construction potable water system management is similar to water management during normal

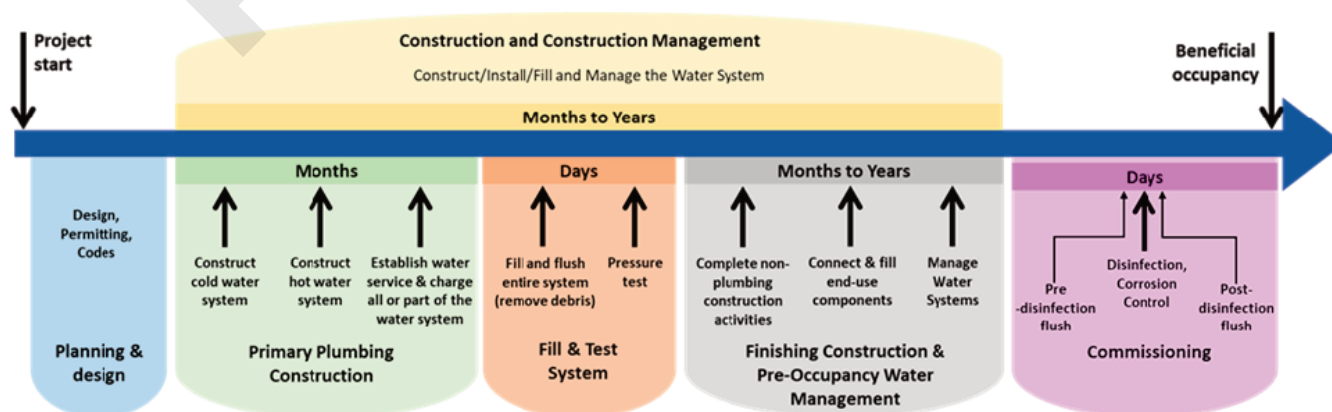


FIGURE 106.1
CONSTRUCTION WATER ACTIVITIES TIMELINE

operation with the addition of several activities that address hazards or hazardous conditions that are present during construction but not normal operation. Construction potable water system activities that can contribute to water quality control both during construction and after beneficial occupancy are listed in Table 106.1.

A fundamental aspect of this manual is that all of these activities are a part of water management during construction. At present, there is a misplaced conception that disinfection alone is sufficient for ensuring a potable water system is ready for beneficial occupancy. The reality is that many potable water systems that were designed and installed by conscientious professionals and disinfected according to requirements in place at the time have entered their service life contaminated, resulting in avoidable illnesses and expenses to the building owner. Although addressing water quality management during all of the potable water system construction activities is not a guarantee that all systems will be contamination free at beneficial occupancy, it does represent the highest standard of care possible during construction and will reduce the likelihood of contamination.

TABLE 106.1
CONSTRUCTION WATER ACTIVITIES TIMELINE

POTABLE WATER SYSTEM CONSTRUCTION ACTIVITY	GENERAL DESCRIPTION
Pre-construction supply water assessment and design for maintaining water quality	The water quality of the future potable water system supply is tested and results are used to determine controls required during construction. System design includes features related to water quality management such as dedicated flushing points and associated drainage. Certified plumbing materials and designs are chosen to be compatible with the water supply characteristics.
Construction water uses	Construction water uses that impact the potable water system are documented and designed to ensure non-potable water does not enter the potable water system and that construction water components do not present a residual risk when construction is completed, and construction water plumbing is disconnected.
Transport, storage and handling of plumbing equipment	Plumbing materials are transported, stored, and handled to minimize the risk that contaminants are present. Contaminants present in the system can be hazardous, can reduce the effectiveness of disinfectants in the water and can present conditions for biofilm growth and water quality degradation.
Charging (filling) the potable water system	Only potable water is used to charge the system. Practices are in place to ensure a sanitary connection to the water supply. If the water quality of the supply does not meet specifications, supplemental treatment may be required. Pressure testing is conducted to minimize the likelihood that contaminants are introduced. After connection, flushing is conducted to eliminate debris and contaminants present in the system prior to installation and debris and contaminants introduced during installation.
Staging	Construction of the water system is staged to reduce the possibility of contamination between filling and disinfection, to the extent feasible. For example, downstream system components are not connected to active parts of the system until necessary.
Preventing non-potable water from entering the potable water system	Backflow prevention and cross connection control activities are in place, monitored and documented.
Potable water system management between filling and disinfection or beneficial occupancy	Potable water system management between filling and disinfection is similar to water management during normal operation and is governed by a water management program that requires a system assessment, implementation of water quality controls, regular turn-over of water throughout the connected system and monitoring of both the controls and the biological water quality.
Pre-occupancy disinfection and commissioning	The potable water system is disinfected according to standards Disinfection requires pre- and post-disinfection flushing, maintaining a target disinfectant residual throughout the system for a specified duration and monitoring to ensure that the target disinfectant concentration and contact duration are met.

106.2 Construction Risk Assessment. Conducting risk assessments prior to and during construction and renovation projects allows the facility to establish and maintain potable and non-potable water of acceptable quality. The risk assessment should be reviewed once the water system is operational and include the risk determination based on the extensiveness of the project and the areas in which people may be exposed. The construction risk assessment is overseen by the construction water steward (Section 107.3.1) and the steward and water management team should consult the following in developing and reviewing the risk assessment:

- (1) Architectural composite floor plans.
- (2) As-built drawings.
- (3) Historical water quality data, if available.
- (4) Commissioning requirements for plumbing systems.
- (5) Water management programs, if programs have been developed for post-occupancy or if the project is a major renovation of a building with an operational water management program.

106.2.1 Developing a Risk Assessment. A risk assessment shall include the following:

- (1) Identification of the hazards, hazardous conditions, and hazardous locations potentially present on the construction site or within the water system.
- (2) Assigning a qualitative (high, medium, low) risk to the hazard or hazardous condition based on the likelihood of occurrence and severity of negative outcome associated with not controlling the risk.
- (3) Determining locations and conditions that require controls because they pose medium or high risks.

The first step of the risk assessment is hazard identification. The water management team should identify and document the hazards, hazardous conditions, and locations where hazardous conditions could be present on the construction site and in the water system. The output of this process is a list of hazards that could be present in the absence of controls and a notated version of the process flow diagram identifying all control locations and conditions in the building water system under construction.

106.2.2 Defining the Risk. The hazards of general concern for water systems include the following:

- (1) **Environmental pathogens** (pathogens that can grow in the plumbing system ecosystem). Based on their prevalence in water systems and their burden of disease, the most important environmental pathogens are *Legionella*, *Pseudomonas aeruginosa*, nontuberculous mycobacteria (NTM), and free-living amoebae (FLA). Although only some FLA species infect humans, many can harbor environmental pathogens such as *Legionella* and NTM. Given their importance as an agent of waterborne disease, *Legionella* are typically the only environmental pathogens specifically monitored and controlled in water systems. Other pathogens should be considered in the risk assessment for health care facilities or buildings intended to serve sensitive populations based on guidance in such standards as ANSI/ASHRAE 514
- (2) **Fecal pathogens** introduced to the system via non-potable water, intrusion of sewage, cross connections, backflow, poor system integrity etc. Fecal pathogens is a wide grouping of organisms that includes viruses, bacteria and protozoa. The diversity of fecal pathogens makes their direct measurement impractical and the potential for the presence of fecal contamination is usually inferred based on the presence/absence of indicator bacteria such as *E. coli* or fecal coliforms.
- (3) **Toxic plumbing system construction residues** such as solvents and compounds used for joining pipe.
- (4) **Sediments and debris** are present in plumbing materials prior to installation or introduced during installation.

106.2.3 Common Hazards and Risks. The hazardous conditions of greatest concern and that are most common during construction of water systems include:

- (1) Plumbing system components with temperatures in the range 20-45 °C (68-113 °F)
- (2) Water ages greater than 1-3 days
- (3) Cold water system components with no disinfectant (if disinfection is the primary strategy for maintaining biological control)

- (4) Storage (including water heater tanks), particularly with incomplete turn-over of water, temperature in the *Legionella* growth range or with no disinfectant residual.
- (5) Showerheads and shower hoses that are used infrequently.
- (6) Connections to the potable water system with the potential for backflow
- (7) Unprotected storage of plumbing system components prior to installation.

Note: A risk assessment is performed to determine whether hazardous conditions have adequate controls and, if not, what controls are required to protect water quality during water system construction. Table 106.2.3 shows a framework for risk assessment for the most common hazardous conditions and locations likely to be present during water system construction. Alternative frameworks can be found in other reference documents on WSPs and WMPs. The risk associated with a given location or hazardous condition is assessed based on the likelihood of loss of control and the severity of the consequences if control is lost.

106.3 Construction Project Schedule Development and Documentation. Key events and critical milestones for the construction/installation of new water systems and major renovations are presented in Table 106.3.1. With the exception of building types, A and B (small residential buildings and buildings with low likelihood of aerosol exposure for construction workers or future occupants), the events in Table 106.3 must be documented in the project's construction water management program.

Note: Most construction of building water system requirements can be administered by multiple stakeholders. Ensure all responsible stakeholders and authorities having jurisdiction (AHJ) are consulted in the scheduling process.

107.0 Water Management during Construction. This section of the manual specifies the activities that should be undertaken to manage potable water systems during construction and which activities should be undertaken, depending on the type of building, anticipated uses for the water system and anticipated population that will occupy the building post-construction. Many of the activities suggested in this section are already recommendations or requirements within water management frameworks such as ANSI/ASHRAE 188, The WHO's Water Safety Planning for Buildings, the CDC's Water Management Toolkit and VHA Directive 1061(1). Because some activities are relevant only during construction and not during normal occupancy, additional activities are specified beyond those of WMPs/WSPs for use during normal occupancy.

Note: Additional activities beyond those of normal occupancy WMPs/WSPs are pointed out.

107.1 Equipment Requirements.

107.1.1 Personal Protective Equipment (PPE). Personnel that perform flushing shall utilize appropriate personal protective equipment (PPE) based on a task specific risk assessment and any OSHA requirements.

107.1.2 Other Equipment Requirements. The following equipment shall be required for plumbing system evaluation:

- (1) Appropriate sampling bottles/supplies for laboratory samples. Sample bottles for microbial parameters (HPC, *Legionella* and others) must be sterile and contain a disinfectant quenching agent.
- (2) A chlorine meter/test kit with an accuracy of +/- 3 percent.
- (3) A digital thermometer for measuring water temperature. Thermometers should be accurate to within +/- 2°F (+/- 1°C).
- (4) Tools for removing aerators and supply stop covers (check with the appropriate manufacturers)

Note: Additional equipment recommendations can include a digital camera, record book (for documentation), stopwatch, graduated measuring device (which, in combination with the stopwatch, can be used to estimate flowrates and calculate flush volumes) turbidimeter and pH probe.

**TABLE 106.2.3
HAZARD IDENTIFICATION AND RISK ASSESSMENT FRAMEWORK**

LOCATION	POTENTIALLY HAZARDOUS CONDITION	CONTROLS	STATUS	LIKELIHOOD OF HAZARDOUS CONDITION, CONTROLS	SEVERITY OF POTENTIAL CONSEQUENCE OF HAZARDOUS CONDITION
Meter pit	Flooding and intrusion during low pressure transients	Periodic inspection: meter pit designed and built to promote drainage	Date of most recent inspection	Low	Medium
Service connection(s) (listed separately)	Low quality water enters the building water system.	Water supply flushed prior to establishing service connection; supply water temperature, disinfectant concentration, pH and turbidity measured after supply is flushed; if water supply quality does not meet design criteria (e.g., disinfectant concentration ≥ 0.3 mg/L and no color or visible particles), supplemental treatment may be applied.	Date of service connection and results of water quality tests.	Low	Medium
Service line(s)	High water age and low velocity if service line is oversized or sized for meeting both fire protection and potable water flows	Water fully exchanged in each service line a minimum of once per day; velocity during daily water exchange of at least 5 ft/s (1.5 m/s); service line flushing point with sufficient drainage designed into the system; where code allows, fire protection system separate from potable water system and service line right sized.	Service line flushing point noted on process flow diagram and log of flushing maintained.	Low	Medium
Storage tank(s), including storage water heaters	High water age	Cycling to maintain $t_{90} < 1.5$ days	Flushing log maintained	Medium	Medium
	Sediment accumulation	Periodic cleaning; at a minimum, during the initial water system flush and prior to final disinfection before occupancy	Date of most recent flush/cleanout	Medium	Medium
	Low disinfectant residual (daily average < 0.3 mg/L)	Monitoring; if low residual observed, increased flushing and/or supplemental treatment may be considered	Monitoring results and dates of corrective actions	Medium	Medium
	Temperature in the range 22-42°C (72-108°F)	Water heating not initiated until necessary; water temperature measured weekly	Monitoring results logged	Low	High

TABLE 106.2.3 (continued)
HAZARD IDENTIFICATION AND RISK ASSESSMENT FRAMEWORK

LOCATION	POTENTIALLY HAZARDOUS CONDITION	CONTROLS	STATUS	LIKELIHOOD OF HAZARDOUS CONDITION, CONTROLS	SEVERITY OF POTENTIAL CONSEQUENCE OF HAZARDOUS CONDITION
Branches (each assessed individually)	High water age	Water fully exchanged in all branches a minimum of once per day for health care facilities and facilities expected to serve susceptible populations and at least once per three days for all other water systems. [†]	Schedule of water exchange; if automated flushing, so noted.	Medium	Medium
	Persistent low disinfectant residual (daily average < 0.3 mg/L)	Disinfectant residual concentration monitored and maintained at the control level via flushing (introducing fresh residual from the water supply) or via supplemental disinfection.	Record of disinfectant concentrations for flushed samples;	High	Medium
	Average daily temperature in the range 22-42°C (72-108°F)	Monitoring and frequent water turn-over; maintaining hot water system as cold until required	Record of temperature measurements	High	Medium
Fixtures	High water age and unmanaged biofilm growth	Fixtures not connected until required, particularly showerheads and hoses; connected fixtures flushed a minimum of once per day for health care facilities and facilities expected to serve susceptible populations and at least once per three days for all other water systems.	Fixture connection dates recorded	High	Low
Materials storage	Debris and environmental organisms in components prior to installation	Pipes and plumbing materials capped/sealed during storage; plumbing materials stored in a well-drained or protected area without the potential for water pooling	Storage SOP	Medium	Low
Construction water connections to main system	Backflow and cross connections	Cross connection control program implemented and documented, and no connections made with potential for backflow (checks and air gaps)	Cross connection control program documented; inspections documented	Medium	High

Note: [†] Recommendations are consistent with findings of recent research (Grimard-Conea, M, and Prévost, M., 2023. Controlling *Legionella pneumophila* in Showerheads: Combination of Remedial Intervention and Preventative Flushing. *Microorganisms* 11, 1361 (<https://doi.org/10.3390/microorganisms11-1061361>) and with guidance for health care facilities. Because water systems are highly diverse and microbial growth in operational systems is not fully understood, water turn over recommendations should be reviewed by the water management team and, if circumstances require, flushing frequency should be increased. Conducting risk assessments prior to and during construction and renovation projects allows the facility to establish and maintain potable and non-potable water of acceptable quality. The risk assessment should be reviewed once the water system is operational and include the risk determination based on the extensiveness of the project and the areas in which people may be exposed.

**TABLE 106.3
KEY EVENTS AND MILESTONES**

KEY EVENT OR MILESTONE	DETAILS AND REQUIREMENTS
Service connection to water supply	(1) Water provider to determine schedule for connections in coordination with the construction project schedule and shall ensure adequate flushing in accordance with the Authority Having Jurisdiction. (2) Document the following dates: Taps and connections, shutdowns and lockouts, flushing events prior to connection or any service interruptions.
Construction start date	(1) Document temporary water connection requirements and or permits in Water Management Plan/Program. (Such as hydrant connections) (2) Document permanent water connection requirements and or permits in the Water Management Plan/Program.
Cold water activation start date	(1) Document first time the system is filled or charged (a) Partial system activation dates (2) Document adequate flushing (a) Partial system flushing dates (3) Document cross connection device testing reports (4) Testing
Hot water system activation start date	(1) Document permanent start date (activation) (2) Document temporary start date (activation) (3) Document temperatures (4) Equipment maintenance schedules
Piping system installation (cold, hot, sanitary, storm)	(1) Determine schedule to minimize the risk (2) Inspection records (3) Drainage scheduling for flushing availability (4) Insulation (5) Punch List (6) AHJ inspections
Equipment installation (ice machines, etc.)	(1) All equipment start up documentation (2) Procedures for health and safety
System purging (sediment and debris)	(1) Dry Nitrogen (2) Strainers/equip
Flushing protocols (start and duration)	<i>See Section 105.5</i>
Installation testing	(1) Pressure testing
Water quality testing	(1) Flushing (2) Analytical water testing (a) Dates (b) Level/results
Disinfection	(1) Procedure and testing results documented
Beneficial occupancy (substantial completion)	(1) AHJ final inspections/certificate of occupancy
Building owner transition to on-going operations	(1) Utilities on and commissioned
First day of business operations to public	(1) Actual occupancy

107.2 Overview of Water Management Activities. Potable water system construction activities differ with building type and users. Some activities such as preventing cross connections and backflow and keeping non-potable water out of the potable water system at all times apply to all building types. Other activities such as *Legionella* monitoring differ with building type and the characteristics of future building occupants. For example, *Legionella* monitoring during construction is not recommended for single family residences, should be conducted for schools and should be more intensive for health care facilities. Construction activities for four classes of buildings are outlined in Table 107.2 and specific guidance on activities is provided in the subsequent sections of this chapter.

Note: This manual of recommended practices addresses only potable water systems, including domestic hot water systems. Water quality concerns are not limited to potable water systems and plumbers and other construction personnel should refer to appropriate guidance to ensure water quality is managed during construction for other water assets such as cooling towers and fire protection systems.

107.3 Develop a Water Management Program. (Building Categories B, C and D) As noted in Table 107.2, a formal construction water management program (WMP) is required for large buildings with a high likelihood that occupants will be exposed to aerosols from showers, faucets and other fixtures and for all health care facilities and buildings expected to serve elderly and sensitive populations. No requirements of a formal WMP for some residences and low-risk buildings does not relieve plumbers of the responsibility of using best practices for delivering systems free of contamination. Rather, it reduces the administrative responsibilities of plumbers and reduces water quality monitoring requirements.

Note: Similar to requirements in ANSI/ASHRAE 188, the construction water management plan is one or more documents.

TABLE 107.2
CONSTRUCTION WATER ACTIVITIES AND SCOPE

WHAT?	HOW? (RELEVANT SECTIONS)	WHERE?			
		A ¹	B ²	C ³	D ⁴
Develop a formal construction water management program	106.2, 107.3			☑	☑
Sanitary storage and handling of plumbing system components	107.4	☑	☑	☑	☑
Scoping and staging to limit contamination risk & conserve water	106.1, 107.5	☑	☑	☑	☑
Cross connection control and backflow prevention	107.6	☑	☑	☑	☑
Filling the system	107.7	☑	☑	☑	☑
Initial flush	107.8	☑	☑	☑	☑
Water turn-over after filling and prior to disinfection	107.9	☑	☑	☑	☑☑
<i>Legionella</i> and water quality monitoring (verification and validation)	107.10			☑	☑☑
Pre-occupancy disinfection and flushing	107.22		☑	☑	☑

¹ Single-family residences, duplexes, town homes and other small residential buildings.

² Buildings with low likelihood of human exposure to aerosols. E.g.,

- Commercial buildings without showering facilities, child care facilities or medical offices
- Retail buildings
- Warehouses, server farms and other low occupancy buildings

³ Other buildings excluding health care facilities and buildings with sensitive occupants/users. Explicitly includes schools and child care facilities, hotels and resorts, gyms and recreational facilities, large office buildings .

⁴ Health care facilities and buildings with sensitive occupants/users. Examples include senior facilities (e.g., assisted living), nursing and rehabilitation facilities, senior centers, all health care facilities including those providing out-patient care...

⁵ A single check (☑) indicates the activity should be conducted; a double check (☑☑) indicates more stringent requirements.

107.3.1 Developing a Team. Refer to ASSE 12000 series, ANSI/ASHRAE 188 or the WHO WSP for Buildings Guidance on how to assemble the team. Differences from those documents are that there is not a single operator and responsibility for the water system is shared by:

- (1) Community Water System Representative
- (2) Project Water Steward
- (3) Site owner
- (4) Prime contractor
- (5) Prime Plumbing Contractor
- (6) Plumbing Design Professional (Registered)
- (7) Third Party Contractors
- (8) Other water system contractors such as subcontractors that will conduct pre-occupancy disinfection

107.3.1.1 Team Member Roles. A designated water steward maintains overall responsibility and oversight of the team and is a liaison between the team, the building owner, the water supplier, and other contractors. Roles and responsibilities that may fall to the water steward or may be designated to other team members shall include:

- (1) Sampling for water quality
- (2) Data logging and updating the Water management plan (WMP)
- (3) Water quality assessment and management (*i.e., analyze and interpret test results and recommend actions*)
- (4) Plumbing installation and repair
- (5) Third party inspections

Note: These roles should be transferred to the building owner and building operations team after construction and at the onset of beneficial occupancy.

107.3.2 System Characterization and Assessment. The water management team conducts a system characterization and risk assessment, as described in Section 106.2 and below.

107.3.2.1 System characterization. A process flow diagram is developed and reviewed by the construction water management program team. The diagram must be sufficiently detailed to allow identification of system components with the potential for contamination and pipe dimensions (diameters and lengths). Pipe dimensions allow calculation of volumes that are used in determining flushing durations. The diagram shall include, at a minimum the following recommendations:

- (1) The water system entry point and service connection
- (2) The service line and meter
- (3) Backflow prevention devices
- (4) Main hot and cold water distribution plumbing
- (5) Water heaters and associated ASSE 1070-listed mixing valves
- (6) Storage tanks including water heaters with storage
- (7) Branches to building areas likely to be used by sensitive populations (e.g., individuals undergoing treatment involving immunosuppression, wings of assisted living and elderly care facilities etc.)
- (8) Temporary connections for construction water and associated temporary distribution.

107.3.2.2 System assessment. The water management team lists all hazards that might be present on the construction site or in the plumbing system, identifies hazardous conditions that could promote the amplification/occurrence of hazards on the process flow diagram and locations within the water system with the potential for hazardous conditions. Locations with the potential for hazardous conditions are noted on the process flow diagram. The hazards list, hazardous location identification and notated process flow document are incorporated into the water management plan.

A hazard is a source or a situation with the potential for human injury or ill-health, damage to property, damage to the environment, avoidable economic cost, or a combination of these. For building water systems and on construction sites, the primary hazards of concern are pathogenic organisms, disinfectants and other oxidants at concentrations posing risk of damage to plumbing system components, toxic chemicals, sediments, and

avoidable water wastage. Chlorine and monochloramine should be considered safe at long-term concentrations less than 4 ppm and safe for short durations at concentrations less than 20 ppm. Some construction sites will have other hazards and hazardous conditions beyond those listed here and they should be identified. Hazardous conditions are plumbing system physical characteristics or operating conditions that can promote the occurrence or amplification of hazards. The primary hazardous conditions on construction sites are stagnant water and water with excessive age, water temperature in the growth range of *Legionella* and other opportunistic environmental pathogens, cross connections, and potential for backflow, and low or no disinfectant residual in cold water plumbing components.

For each of the hazardous conditions identified on the process flow diagram, the water management team determines the risk in the absence of controls, identifies controls in place to mitigate the risk and assesses whether controls are adequate. In nearly all cases, the risk assessment for each hazardous condition will be qualitative (high/medium/low).

107.3.3 Identify Controls, Control Points and Control Limits. Based on the risk assessment and system characterization (Sections 107.3.1 and 107.3.2), the water management team identifies control points and control limits that are applied and monitored at those control points. The most common controls applicable to construction water management are flushing (limiting water age), maintaining a disinfectant residual of at least 0.2 mg/L in filled portions of the water system and regulating temperature outside the optimal growth range of *Legionella* bacteria (i.e., cold water distribution temperature is maintained at less than 22°C (72°F) and hot water portions of the system are maintained at temperature greater than 42°C (108 °F). Specification of controls entails identifying the control point (location where control is applied and measured), the control limit (a numerical target or range for the control parameter), the measurement frequency and the actions that will be taken if a control parameter measurement is outside the control limit range for each of the control points. Controls, control points, control limits and monitoring data are maintained in the water management program documentation.

107.3.4 Process Control Parameter and *Legionella* Monitoring. Based on the risk assessment and system characterization (Sections 107.3.1 and 107.3.2), the water management team identifies control points and control limits that are applied and monitored at those control points. The most common controls applicable to construction water management are flushing (limiting water age) and maintaining a disinfectant residual in filled portions of the water system.

107.4 Sanitary Storage and Handling of Plumbing Materials. All building types shall safely store plumbing materials and manage diligently to prevent contamination with sediments, debris, sewage, microorganisms, and other contaminants to the extent practicable. *Legionella*, *Mycobacterium*, free living amoebae and other environmental pathogenic organisms survive and grow in soils and natural waters and pose a contamination risk for unprotected plumbing materials. Best practices for materials management are described in Section 105.4 shall include but are not limited to the following:

- (1) Capping pipes and fixtures during storage
- (2) Storage only in well-drained and covered areas
- (3) Storage away from and physically separated from chemical and fuel storage facilities and sewage collection systems.

Note: Pipes, fixtures and other plumbing materials known or suspected to have been contaminated during storage should be flushed and disinfected prior to installation.

107.5 Scoping and Staging to Limit Contamination Risk & Conserve Water. System components should not be filled until necessary. Leaving components dry until necessary delays formation of biofilms and conserves water because water turn-over is not required until the system is filled (Section 107.10). Opportunities for delaying filling the system and system components are:

- (1) Dry system pressure testing (Nitrogen, etc.)
- (2) Filling the system in stages
- (3) Temporary water supply (separate from the permanent distribution system) for construction water.

107.5.1 Pressure Testing.

107.5.1.1. Dry System Procedures. Leave the system dry until two weeks prior to occupancy. No additional actions are required.

Note: Consider sloping all domestic hot and cold-water supply piping and providing drain valves in a way that allows the systems to be completely drained with no standing water or ponding. This would assist in keeping dry pipes during construction or during system shut down.

107.5.1.2 Wetted System Procedures.

107.5.1.2.1 Filling the System in Stages. Downstream system components should be filled and commissioned only when necessary. Once a part of the system is filled, it is subject to biofilm formation and water must be turned over regularly; delaying filling until necessary can reduce the risk of contamination and has water savings benefits. When the system is filled in stages, the upstream, filled portion of the system is the supply for the newly connected and filled downstream component. The water quality at the point of connection should be assessed prior to connection of the downstream segment. At a minimum, flushed water samples from the upstream system water should have a disinfectant concentration of at least 0.2 mg/L and should be visibly clear. The upstream portion of the system should be thoroughly flushed prior to connecting the downstream portion.

107.6 Cross Connection Control and Backflow Prevention. All buildings must have cross connection control programs in place and must apply backflow prevention as specified in the governing code. Cross connections and backflow risks are never acceptable, even for temporary plumbing installed for use during construction. Cross connection control for construction water uses is described in Section 105.1. Locations often associated with cross connections and that should be addressed specifically in cross connection control include, but are not limited to, connections to non-potable water systems (e.g., for make-up water), the main water intake, and fire suppression system off-takes. The responsible person with overall authority for water management shall ensure the following:

- (1) Routine inspections to identify and, if found, disconnect cross connections.
- (2) Routine inspections to identify and, if found, remediate configurations/connections with the potential for backflow.

Note: Backflow and backflow prevention are defined and described in plumbing codes. When cross connections are found, affected system segments must be disinfected and flushed as described in Section 107.10. Disinfection is a significant undertaking with the potential to significantly delay construction and avoiding cross connections with a robust cross connection control program is much less costly than remediation.

107.7 Filling the Building Water System. For all building types filling considerations shall include, only verified potable water may be introduced into the system, even though the system will be flushed and disinfected. Prior to filling the system, the water steward should (i) communicate with the water purveyor to coordinate the connection and to verify that water quality in the intended supply meets goals and specifications and (ii) develop a plan to ensure only water from a suitable, potable supply is used for filling the system and that no non-potable water from environmental sources near the connection (e.g., ground or surface waters, ponded water from pre-connection flushing of the water service, soils or sewage in the vicinity of the service connection) intrude into the plumbing system. For buildings of type C and D, the plan should be documented and incorporated into the water management program document. When the building water supply is a public water system (PWS), the water purveyor should be contacted prior to connection and the following information should be requested:

- (1) Annual average and minimum disinfectant concentration for the PWS monitoring location nearest the new connection.
- (2) Whether main breaks or other significant events occurred in the vicinity of the new connection over the past year.

- (3) Whether there were any total coliform positive samples or *E. coli* positive samples in the vicinity of the new connection over the past year.

If the annual average disinfectant concentration is less than 0.2 mg/L or does not meet regulatory requirements or if there have been recent main breaks or total coliform positive results, the water management team should consider supplemental treatment while filling the system. Supplemental treatment can be temporary and removed after the system is filled or can become a permanent component of the water system. Permanent supplemental treatment is a major design modification with long-term implications and must be coordinated with the system design engineer and building owner.

When water is self-supplied (e.g., onsite wells, rainwater systems, onsite reuse systems), the supply should be a regulated community water system or transient non-community system and should be tested. Self-supplied water should be tested, at a minimum, for total coliforms and *E. coli*, turbidity, pH, hardness, nitrate and, if the supply system includes disinfection, disinfectant type and concentration. The following indicate water quality is not sufficient for filling the system:

- (1) Positive total coliform and *E. coli* results,
- (2) nitrate concentration > 10 mg/L as nitrogen
- (3) visibly cloudy, colored or turbid water after flushing and
- (4) disinfectant concentrations less than the design concentration for the supply.

Nitrate, appearance, and disinfectant concentration can be tested on-site and within a short time frame. Total coliform samples must be collected in appropriate sample bottles and analyzed by a certified laboratory. If the supply is determined to be of too low quality to fill the system, supplemental treatment such as filtration and UV or chemical disinfection can be used to polish the water prior to filling the system. Supplemental treatment may be deployed temporarily or may become a permanent element of the water system.

To fill the system, the supply is flushed until the supply water is visibly clear, the supply is connected to the building water system and hot and cold water distribution systems are filled with cold water. Sufficient drainage should be available at the point of connection to ensure water does not pool and there is no opportunity for flushed water to enter the newly-connected building water system. In some cases, the water purveyor will have standard operating procedures (SOPs) for connecting new building water systems; the water management team should request an SOP and the connection process should follow the SOP.

Note: As outlined in Section 107.5, water systems can be filled in stages. Staging has both water quality and water conservation benefits. When a downstream portion of a distribution system is filled by the upstream system, the supply water for the downstream portion is the water in the upstream portion. Prior to filling the downstream portion, the upstream portion should be flushed at the connection and water quality (temperature, appearance, and disinfectant concentration) of the flushed water should be tested.

107.8 Initial System Flush. All building types shall follow and document the introduction of water into newly constructed plumbing distribution systems, the system should be flushed to remove sediments, debris, loose deposits, and other residuals from the system installation process.

High velocities are required to transport sediments and debris through the system and a target velocity of 5 ft/s should be used for the initial system flush. For portions of the system unable to achieve 5 ft/s flushing velocities (e.g., large diameter service lines or distal locations with insufficient pressure), the velocity during initial flush should be at least 2.5 ft/s. To achieve the target velocity, aerators, showerheads, and other flow regulating fixtures should be removed prior to flushing and sufficient drainage must be in place to accommodate flushing flows. To the extent possible, valves should be opened quickly; opening valves quickly produces a rapid change in shear at pipe walls and can contribute to more complete removal of sediments. At least five pipe volumes should be flushed to account for nonideal flow and mixing in pipes. Water heaters with storage should be flushed through their drainage port. Water heaters should remain off (non-heating) during the flush and until necessary. Other appurtenances with storage (e.g., water softeners) should be flushed according to manufacturer instructions. Cold water storage tanks should be cleaned prior to filling and flushed to drain. Flushing

should be conducted sequentially from the service line toward the distal system segments; progressive flushing prevents entrainment of contaminants deeper into the system.

After flushing, disinfectant residual and temperature should be measured at representative fixtures and flushing points. For building types C and D, disinfectant and temperature measurements post-flush should be recorded in the water management program document. Those values serve as baseline values. New copper pipe can exert a very high disinfectant demand and it is likely that the disinfectant concentration at distal locations in the system that are plumbed with copper pipe will be much less than the disinfectant concentration in the building supply and for locations nearer to the service line.

107.9 Water Turn-Over after Filling and Prior to Disinfection. For buildings that will service sensitive/susceptible populations (type D), water is turned over in all filled components at least once per day. Turning over the water requires opening faucets or flushing point fixtures until at least 5 pipe volumes of the connected plumbing have been discharged. For other buildings (types A, B and C), water in filled system components is turned over at least once every three days. As noted in Section 107.5, delaying filling of system components until necessary can prevent water wastage and contamination and should be practiced when possible.

Note: Flushing should be conducted with aerators, flow restrictors and shower heads removed.

Taps/valves/fixtures used for flushing should be opened as quickly as possible (not gradually) to promote rapid changes in shear at pipe walls; sudden changes in shear have been shown to promote removal of biofilm that accumulates during stagnation.

107.10 Legionella and Water Quality Monitoring. After the system is filled, samples should be collected and tested monthly for *Legionella* and weekly for other water quality parameters (process control parameters including, at a minimum, disinfectant concentration, temperature, and water age) for building types C and D or as required by the local Authority Having Jurisdiction.

107.10.1 Legionella Testing. For buildings with high likelihood of exposure of building occupants to aerosols and that are required to develop construction Water Management Programs (categories C & D in Table 107.2.1), test the building supply and at least 5 percent but no more than 20 plumbing fixtures monthly for *Legionella*. First-draw cold and hot water samples are collected and analyzed for each fixture except the building entry point. *Legionella* samples should be taken from the building entry point (cold water sample only) and locations determined to be elevated risk of *Legionella* growth. Locations with elevated risk of *Legionella* growth are fixtures at distal ends of the distribution system, discharge of storage (cold water only), and fixtures used infrequently. Water quality information including disinfectant concentration, temperature, pH and, if the water management plan includes it, HPC should be collected with each *Legionella* sample, recorded and referenced to the *Legionella* sample (e.g., recorded with the sample identification number of the *Legionella* sample). The additional water quality data are essential for diagnosing causes of frequent or high *Legionella* detections.

Note: Results from *Legionella* monitoring should be used to assess whether the system is well controlled, per the CDC framework for determining the level of control of *Legionella* (Table 104.3.1). Only results from culture *Legionella* assays may be used within the CDC framework; results from molecular assays such as qPCR are fundamentally different from those of culture assays and cannot be used within the CDC framework. Cultural assays must be performed by a qualified laboratory and may be for *Legionella* spp. or specific to *L. pneumophila*.

107.10.2 Other Water Quality Testing. Disinfectant residual concentration, water temperature and other water quality measures related to process control should be monitored at a sufficient frequency to ensure hazardous conditions are detected early and to allow assessment of process control. Process control monitoring should be conducted at least weekly and should be conducted more frequently when results are outside control limits. New copper pipe is known to exert a high disinfectant demand and disinfectant measurements downstream of long runs of new copper pipe may be low or zero, even when disinfectant in the building supply is within control limits.

107.11 Pre-occupancy Disinfection and Building Opening.

107.11.1 General. System Opening is the set of actions that should be taken to ready a building for normal operations after an extended period of no or limited operations. Systems that are being reopened after prolonged vacancy or partial vacancy shall comply with AWWA-IAPMO *Responding to Water Stagnation in Buildings with Reduced or No Water Use*, ANSI/ASHRAE 188, and Section 107.11.

107.11.2 Pre-Occupancy Disinfection. Biofilms and, potentially, environmental pathogens are likely in any plumbing system, even those managed as described in this guidance and other guidelines such as ANSI/ASHRAE 188. As directed in plumbing codes, building water systems must be purged and disinfected after construction/installation and prior to occupancy. Disinfection reduces the biofilm mass in the water system and reduces the concentration of pathogens that might be present, though it is unlikely to completely eradicate pathogen populations established in the system. Disinfection entails filling the building water system with a high concentration solution of disinfectant, holding the disinfectant in the system for sufficient time for the disinfectant to reduce the microbial population, and flushing the system to remove the high-concentration disinfectant solution, inactivated organisms, and biofilm materials.

Note: At present, disinfection is conducted per AWWA Standard C561 (Disinfecting Water Mains) or 652 (Disinfection of Storage Facilities). Standard C651 was developed for disinfection of water mains in public water systems and directs use of very high concentrations of disinfectant – much higher than those required for effective disinfection of building water systems and high enough to pose a damage risk to plumbing system components. An alternative AWWA standard more appropriate to new building water systems is under development and should be considered for adoption in code when it is complete.

107.11.3. Opening Process.

107.11.3.1. Opening Communication. An occupancy date and communicate date of occupancy to all building occupants shall be determined and the steps required from maintenance staff shall be provided and available. The required steps shall provide clear instructions to occupants on how to avoid hazards and how to report concerns once a building is occupied.

107.11.3.2 Pre-Startup inspection – The preparation of the documentation and pre-startup inspection shall be conducted by a qualified person. The required inspection shall include but is not limited to:

- (1) visually assessing the potable water system
- (2) inspecting all components for the presence of contaminants and other adverse conditions
- (3) checking that the equipment is working properly
- (4) ensuring that records are complete.

Annex A: (Informative)

Foreword and Purpose

This publication provides basic guidance to help plumbing system design engineers, building owners, and water system managers obtain important information from their water suppliers (PWSs; water suppliers or purveyors) to help them design, install, and manage potable water systems that maintain water quality all the way to the end users and help protect the pipes, fittings, fixtures, and other components that make up their plumbing systems.

Water Quality for Plumbing Industry Professionals and Building Managers

Consumer Confidence Reports – Information That Water Purveyors Provide to Their Customers

Public water suppliers provide a Consumer Confidence Report, or report on water quality, to their customers on an annual basis. Often it is available through the water supplier's Intranet site. This report summarizes important information for you to understand but it may not provide all of the information that is important for your building's water system because its main purpose is to provide a status of regulatory compliance under the federal Safe Drinking Water Act. However, some water utilities do provide additional information that is helpful to their customers.

The US Environmental Protection Agency (EPA), under the Safe Drinking Water Act (SDWA), requires that all public water systems test and report on regulated water quality to their primacy agencies or regulators. In most situations, individual states have primacy for enforcing the regulations under the SDWA, to which they may also add requirements that are important within their states. The regulations focus on drinking water contaminants that could cause a public health risk; these are primary drinking water regulations such as Maximum Contaminant Levels (MCLs). When a contaminant reaches its MCL, the EPA has determined that it could be unsafe for consumers. The EPA has also provided Secondary Maximum Contaminant Levels (SMCLs) which are guidelines for aesthetic water quality such as taste and odor, color, and corrosivity. The EPA does not enforce SMCLs although some states do enforce them in various ways.

Even when water that is delivered to your building meets all SDWA and state regulations, and is safe to consume, it may not meet all of the requirements for your building's water system to operate effectively and provide good quality water at the outlets. For example, a water supply can be safe but contain very hard water which can cause scaling problems within a building's plumbing system. Or a water system may have old cast iron mains that periodically release iron rust which enters plumbing systems and settles there, causing colored water and stains. In addition, once water enters a building's service line and plumbing system, the quality of the water changes before it is used. For example, safe drinking water is not sterile or devoid of background microorganisms. If water is warmed and left stagnant inside a section of building plumbing, microorganisms can grow and cause associated problems. Conditions that promote a loss in the chlorine residual exacerbate this problem and can lead to the amplification of pathogens such as *Legionella* as well as an increase in disinfection by-products (e.g., trihalomethanes).

How Consumer Confidence Reports Can Help Design Engineers and System Operators

Engineers designing plumbing systems, building managers, and water system operators need a background understanding of water quality for their building's supply. That information helps them anticipate and avoid water quality degradation in their system, promotes healthier and more aesthetically pleasing water for building occupants, and extends the life of their plumbing system while also reducing maintenance costs. Examples of problems that can arise if water quality is not considered in system design and operation include:

- corrosion,
- staining of fixtures,
- scale formation leading to increased pressure loss, reduced efficiency of water heaters, and creation of environments where pathogenic microorganisms thrive,
- blooms of *Legionella pneumophila*, the bacterium that causes Legionnaires' disease (LD), and
- episodes of discolored or bad smelling or tasting water.

Overview of the Water Quality Information that is Most Important for Designers and System Managers

Building water supplies are not "pure" but contain a variety of natural and introduced chemicals and microorganisms. Completely pure water is corrosive and less pleasant tasting. Some of the chemicals in water are beneficial, added to the water by the water supplier to protect the water while it is in the water supplier's distribution system and to protect the water after it enters a customer's building system. Other chemicals and microorganisms are known to be harmful and are maintained at levels that the USEPA and state regulatory agencies believe are protective of public health. Some chemicals in water can be a nuisance and cause odors, staining of fixtures, and scale development. Finally, some constituents in the building water supply are neither beneficial nor potentially harmful but can have an influence on what happens to water in building systems. Without deliberate management, building water systems can add a "surcharge" to contaminants; that surcharge increases risks to building occupants. Figure 1 provides an overview of the connectedness between the water supply, the building's water system, and the water quality at the endpoints where water is used.

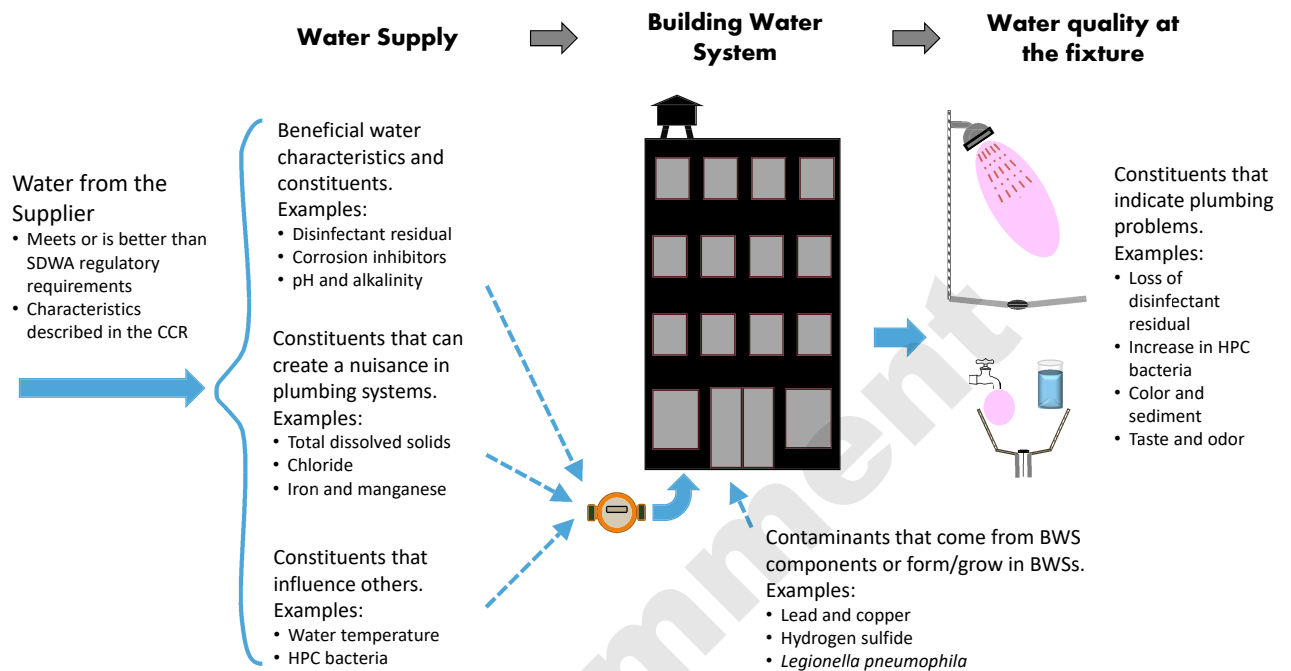


FIGURE 1
WATER QUALITY CHARACTERISTICS OF WATER SUPPLIES AND BUILDING WATER SYSTEMS

Table 1 lists water quality characteristics or parameters for which a water utility may or may not have information to help you understand the water supplied to your specific building. Contract laboratories can help fill in missing information using water samples that you collect and send to them. Smaller water utilities tend not to test as many parameters as larger systems simply due to cost. Also, a water utility may have information for the overall water system but not for the water supplied to your specific building. Some parameters are very conservative (they do not change over time) and some change with time and distance from the water treatment plant. In some cases, water quality can change significantly from one time of day to another depending on water demand, or from day to day depending on which water source the water utility is using to supply your area of the system.

**TABLE 1
IMPORTANT WATER QUALITY PARAMETERS FOR BUILDING WATER SYSTEMS**

PARAMETERS OF INTEREST	INFORMATION TO REQUEST	WHY THEY ARE IMPORTANT
Parameters That Are Beneficial		
Chlorine or Chloramine Residual	Target residual for your area; actual annual maximum and minimum	Chlorine acts as a preservative, limiting bio-film and microbiological activity
pH	Annual average pH for your area and whether it's adjusted for corrosion control	pH can affect corrosion and changes in pH affect water chemistry
Alkalinity	5-year average, minimum, and maximum	Sufficient alkalinity deters changes in pH and helps with corrosion control
Phosphate Inhibitor	Does the utility use a phosphate inhibitor for corrosion control?	Phosphate inhibitors can help to reduce corrosion.
Parameters That Cause a Nuisance		
Total Dissolved Solids	5-year average, minimum, and maximum	Solids can accumulate in plumbing and affect processes in use
Hardness	5-year average, minimum, and maximum	Hard water has calcium and magnesium carbonates which form scales
Conductivity	5-year average, minimum, and maximum	Conductivity is a general measure of the various salts in water and can affect processes in use.
Sodium	5-year average, minimum, and maximum	Sodium can, at high levels, cause a salty taste.
Chloride	5-year average, minimum, and maximum	Chlorides can cause a salty or bitter taste and can impact on corrosion.
Iron Manganese	5-year average, minimum, and maximum; whether iron and manganese are treated for reductions from the source of water supply	Iron and manganese can accumulate as sediment, cause staining, and color the water. Iron can cause a metallic flavor and decrease the chlorine residual.
Sulfate	5-year average, minimum, and maximum	Sulfate is a source of sulfur which can cause odors. Sulfate can also impact on corrosion.
Sulfides	Whether sulfides are treated for and a cause of customer complaints	Sulfides can cause odors such as with hydrogen sulfide.
Taste and Odor	Taste and odor issues that can occur and cause customer complaints	Tastes and odors cause complaints from consumers of water.
Color	5-year average, minimum, and maximum	Colored water is not aesthetically acceptable.
Parameters of Health Concern		
Copper	The water supplier's 90% reported value under the Lead and Copper Rule	Copper can cause staining, colored water, and a metallic flavor.
Lead	The water supplier's 90% reported value under the Lead and Copper Rule	Lead is of health concern.
Total Coliform and <i>E. coli</i>	Whether the water utility is experiencing SDWA violations	Coliform bacteria are indicators of possible water contamination.
Parameters That Influence Others		
Water Temperature	Annual maximum and minimum	Warmer water has greater microbiological and chemical activity.
Ammonia	Maximum free ammonia and whether nitrification is experienced	Ammonia can encourage microbiological activity such as nitrification.
Heterotrophic Plate Count	Average and maximum for the warmest months of the year	Background levels of bacteria indicate whether the water is conducive for microorganisms to grow.

Sampling and testing of parameters can be arranged by you, as needed. In many cases, you will have to arrange for a certified contract laboratory who will provide you with sampling instructions and sample bottles. Different parameters have different requirements for sampling. Some require very careful sampling protocols. A few measurements must be done by yourself, onsite, such as for chlorine residual, pH, and water temperature. Some parameters are more expensive to test for, and by running a group of them together you can sometimes save on costs (such as for the metals including iron, manganese, copper, lead) but the turnaround time could be long. Many parameters are inexpensive and turnaround times are quick.

Detailed Explanations of the Parameters

Parameters That Are Beneficial

Disinfectant Residual

Background: In the United States, the typical disinfectant residual (that is, the disinfectant that is maintained in the water after it leaves the treatment plant and passes through the distribution system pipes) that water suppliers carry in their drinking water is either a free chlorine residual or a chloramine (chlorine combined with ammonia) residual. The concentration of residual is expressed as mg/L or ppm. This parameter is not conservative because both chlorine and chloramine dissipate with time, more quickly in warmer water and more quickly when exposed to other conditions wherein there is a demand for chlorine; for example, dissolved iron will exert a demand for chlorine. New copper pipe will exert a demand for chlorine. Biofilm will exert a demand for chlorine. Therefore, the chlorine or chloramine residual varies quite significantly. In general, chlorine dissipates faster than chloramine, though, under some conditions, chloramine can decay rapidly. Those conditions are well known by drinking water suppliers who often have control plans in place when those conditions arise.

Guidelines or Standards: The US EPA requires that a minimum detectable residual (not currently defined as a numeric value at the national level) be maintained in most public drinking waters, but that it not exceed an average of 4.0 mg/L. Many state primacy agencies have set numeric minimum residual level requirements that can be different for chlorine and chloramine. Not all public water supplies that use groundwater carry a disinfectant residual.

Importance to Building Water Systems: A free chlorine or chloramine residual acts as a preservative or deterrent to the regrowth of microorganisms in water. The longer water sits in plumbing and the warmer the water temperature is, the greater the rate of dissipation. Free chlorine is more likely to dissipate more quickly than chloramine. Once the disinfectant dissipates to a low enough level, it no longer deters regrowth of microorganisms. The timely turnover of water in building plumbing can help to bring in fresher water containing an adequate chlorine residual.

Information to Request: This information should already be available in your water utility's Consumer Confidence Report. However, you want to know whether the water provided to your building has a free chlorine or chloramine residual, what the maximum and minimum level for your area is, what target residual they aim for and whether that varies seasonally. Request an average, maximum, and minimum for the most recent year. Also ask if the water utility performs any "chlorine burns" which is when the utility switches from a chloramine to a free chlorine residual for weeks at a time to manage microorganism activity in their system.

Where to Sample and How to Test: Total and free chlorine residual can be measured using test kits that are readily available. Testing should be done soon after a water sample is collected. Samples should be collected at the service connection, representing water entering the building, and at distal taps to determine how much the residual dissipates within the building's plumbing system. When a fixture is first used after a long stagnation period, the water usually has no chlorine left in it. Once the fixture has been run (flushed) until the water temperature is relatively steady, the disinfectant concentration increases to the concentration in the water supply. Hot water may not sustain a disinfectant residual.

pH

Background: pH is expressed as units. It ranges from 0 to 14 with 7 being neutral. pH is a measure of the acidity of water; a level below 7 is in the acidic range and a level above 7 is in the basic range. Water pH does not have any health implications. pH changes, especially when the alkalinity is low, for various reasons. Surface water systems tend to manage the pH of the water because their treatment process is affected by pH and because the type of corrosion control they use may be based on pH. Hopefully, your water utility manages pH for optimum corrosion control.

Guidelines or Standards: The EPA's SMCL is a range of ideal pH between 6.5 and 8.5 units.

Importance to Building Water Systems: In general, a high pH water may deposit carbonate scale and a low pH water can be corrosive to metal pipe. If the water supplier has corrosion control treatment, then it may be adjusting its pH to reduce the likelihood of corrosion in their customers' plumbing. pH influences the chemical and microbiological activity of a water system in various ways. It is helpful to know how variable or stable the pH is for the water supplied to your building.

Information to Request: You should ask if pH is adjusted as part of the corrosion control program, and the average pH for the water provided to your building.

Where to Sample and How to Test: The water utility's information on pH should be sufficient unless you suspect that pH could be changing within your building's plumbing system, such as if the water supplier reports a low alkalinity for the water supplied, or if your plumbing shows signs of advanced corrosion. There are measurement kits by which to readily check pH onsite and pH should be measured soon after sample collection.

Alkalinity

Background: The concentration for alkalinity is expressed as mg/L or ppm. Alkalinity is the buffering capacity (tendency to resist changes in pH) of water and is based on carbonate chemistry. At a neutral pH, bicarbonates are favored over carbonates, and adding carbon dioxide to water results in more bicarbonates instead of lowering the water pH. Sufficient alkalinity helps deter changes in pH and is typically associated with harder water and the presence of calcium carbonates. The carbonate/bicarbonate chemistry, or alkalinity is important in determining the availability and occurrence of minerals in water. Alkalinity, for surface water sources, will vary according to climate conditions; it will decrease with an increase in rainfall, for example, due to dilution of the carbonates in the source water. Alkalinity is often adjusted in treatment and remains fairly stable after it leaves the treatment plant.

Guidelines or Standards: Natural alkalinity can range from around 20 mg/L to over 200 mg/L. Alkalinity could be a required part of the water supplier's corrosion control treatment.

Importance to Building Water Systems: It is helpful to know the corrosion control provided by the water supplier, and whether alkalinity is part of that program, especially if corrosion is important for your plumbing system.

Information to Request: Since alkalinity can vary, it would be good to obtain a 5-year average, minimum, and maximum for your region of the distribution system.

Where to Sample and How to Test: The water utility's information on alkalinity should be sufficient unless you suspect that pH could be changing within your building's plumbing system. Alkalinity would be measured by a certified laboratory. If you decide to collect samples, a sample from the service connection should be adequate.

Phosphate Inhibitor

Background: Orthophosphate is a common corrosion inhibitor used in corrosion control treatment. A phosphate inhibitor is intended to help coat water mains as well as building plumbing to reduce the corrosive action of the water on the infrastructure. Other forms of corrosion inhibitors may also be used.

Guidelines or Standards: If the water utility uses a corrosion inhibitor, then it has a permit from the state that prescribes the levels that must be maintained.

Importance to Building Water Systems: The use of a corrosion inhibitor is good information for a building water system as it will help protect the building plumbing from corrosion.

Information to Request: Ask if the water utility uses corrosion control treatment and how that is achieved (by adjusting the pH, by adjusting the alkalinity, or by adding a phosphate or other corrosion inhibitor to the water).

Where to Sample and How to Test: The water utility's information on phosphate inhibitors should be sufficient. Testing would be done by a certified laboratory. If you decide to collect samples, a sample from the service connection should be adequate.

Parameters That Cause a Nuisance

Total Dissolved Solids

Background: The concentration of total dissolved solids (TDS) is expressed as mg/L or ppm. It is a measure of anions and cations, or minerals, in water. TDS changes for surface water sources depending on climate conditions; for example, during a drought, TDS will increase because the minerals in the source water are less diluted. During times of plentiful rainfall, minerals will be more dilute and TDS will decrease. TDS does not tend to change in a distribution system but will change when a building's point-of-entry treatment is used, especially reverse osmosis.

Guidelines or Standards: The EPA's SMCL is 500 mg/L to avoid taste problems, solids accumulation, and staining. Typical tap water ranges, for low, moderate, and high TDS waters are <100, 101-250, and 251-500 mg/L, respectively. Mineral waters have high TDS.

Importance to Building Water Systems: TDS can accumulate in plumbing systems and affect corrosion, and TDS can affect processes in use within the building.

Information to Request: Since TDS can vary, obtain a 5-year average, minimum, and maximum TDS for your region of the distribution system.

Where to Sample and How to Test: The water utility's information on TDS should be sufficient unless your building water system uses point-of-entry treatment. Testing would be done by a certified laboratory. If you decide to collect samples, a sample from the service connection should be adequate as well as a sample following any water treatment system.

Hardness

Background: Calcium and magnesium hardness is expressed as mg/L or ppm as calcium carbonate (magnesium is usually very low thus making calcium the primary component), and sometimes as grains per gallon which is different. Hardness is conservative for the most part. That is, it tends to be steady as water passes through building water systems. Hardness is largely due to the water source for the water utility and tends to be higher for systems with groundwater sources than for those using surface water. However, some water systems treat their source water, or soften it, because it is very hard. For surface water supplies, hardness can vary according to climate conditions; it will decrease following heavy rainfall as calcium and magnesium carbonates are diluted down.

Guidelines or Standards: Water is considered soft at 0-60 mg/L, moderately hard to hard at 60-180 mg/L, and very hard when over 180 mg/L.

Importance to Building Water Systems: Hard water makes it harder to wash with soap and it also deposits a residual or scale. Deposits can build up in the bottom of water heaters where they can make the heaters less efficient and can contribute to degraded water quality.

Information to Request: Since hardness can vary, it would be good to obtain a 5-year average, minimum, and maximum for your region of the distribution system.

Where to Sample and How to Test: The water utility's information on hardness should be sufficient unless you have a water softening system for the building. Testing would be done by a certified laboratory. If you decide to collect samples, a sample from the service connection should be adequate as well as a sample following any treatment.

Conductivity

Background: Conductivity is expressed as $\mu\text{mho/cm}$. Conductivity is conservative as a measure of the natural salts in water and would not be expected to change during the distribution of water. It will vary according to climate conditions; when water levels are high then it would be more dilute. Also, salts can be washed into source water during the winter when road salt is applied to roadways, and most water treatment systems do not remove these salts. Desalination technologies would reduce conductivity.

Guidelines or Standards: The conductivity of water can vary from <10 to $> 1000 \mu\text{mho/cm}$. Pure water has a conductivity close to zero and sea water can exceed $1000 \mu\text{mho/cm}$.

Importance to Building Water Systems: Conductivity is a measure of the salts in water, and as such can affect a process being used within the building and can affect any water treatment systems in use. Also, high conductivity causes a salty or bitter taste thus causing complaints from consumers. Rapid changes in conductivity (e.g., as is sometimes observed during runoff of road salt) can also change the scale that has built up on pipes and can contribute to the release of scale and colored water events, or periods of higher metals concentration, at fixtures.

Information to Request: Since conductivity can vary, it would be good to obtain a 5-year average, minimum, and maximum for your region of the distribution system.

Where to Sample and How to Test: The water utility's information on conductivity should be sufficient. Testing would be done by a certified laboratory. However, if conductivity is important for a process used within the building, then conductivity meters, which are reliable and relatively inexpensive, can be used.

Sodium

Background: Sodium concentration is expressed as mg/L or ppm. Sodium is conservative and usually remains steady during the distribution of water. It varies according to climate conditions; when water levels are high, sodium is more dilute. Also, it can be washed into source water when road salt, that is applied to roadways, runs off into streams. Most water treatment systems do not remove sodium, though water treatment systems using desalination or reverse osmosis do remove sodium.

Guidelines or Standards: A sodium level of 30-60 mg/L would be on the high end for natural levels. Much higher levels that affect the water's taste can occur due to severe drought, saltwater intrusion of well supplies, and winter runoff of road salt.

Importance to Building Water Systems: Water softening systems might add more sodium to the water. High enough levels can impart a salty taste and affect processes used within the building. Very high sodium concentrations can pose a health risk to sodium sensitive building occupants.

Information to Request: Since sodium can vary, it would be good to obtain a 5-year average, minimum, and maximum for your region of the distribution system.

Where to Sample and How to Test: The water utility's information on sodium should be sufficient. Testing would be done by a certified laboratory. If you decide to collect samples, a sample from the service connection should be adequate.

Chloride

Background: Chloride concentration is expressed as mg/L or ppm. Chloride is conservative and usually remains steady during the distribution of water. It will vary according to climate conditions; when water levels are high then chloride is more dilute. Also, it can be washed into source water during the winter when road salt is applied to roadways, and most water treatment systems do not remove chloride unless they apply desalination technologies. Some water treatment systems introduce chloride to the water such as when ferric chloride is used as a coagulant in the treatment process.

Guidelines or Standards: The EPA's SMCL is 250 mg/L. Higher levels can affect the water's taste, and can occur during severe drought, saltwater intrusion, and winter runoff of road salt.

Importance to Building Water Systems: Chloride can affect corrosion, and it can impart a salty or bitter taste to the water that would cause complaints from consumers of the drinking water.

Information to Request: Since chloride concentration can vary widely with time, it would be good to obtain a 5-year average, minimum, and maximum for your region of the distribution system.

Where to Sample and How to Test: The water utility's information on chloride should be sufficient. Testing would be done by a certified laboratory. If you decide to collect samples, a sample from the service connection should be adequate.

Iron and Manganese

Background: Iron and manganese concentrations are expressed as mg/L or ppm. They come from source waters, may be reduced during water treatment, and can accumulate as sediment and as part of scale in water mains. Iron and manganese are very complicated in their chemistry. Only some forms found in water cause aesthetic or taste problems or accumulate as sediment. Iron can be released from old, unlined cast iron water mains and from corroding galvanized service lines. When water-main work is done, or water hydrants are flushed, episodes of rusty water can occur.

Guidelines or Standards: The EPA's SMCL guidance is 0.3 mg/L for iron to prevent staining, rust color, and taste; and 0.05 mg/L for manganese to prevent staining and color.

Importance to Building Water Systems: Iron and manganese can accumulate as sediment, clog filters, and make water aesthetically unacceptable. Iron and manganese sediment can also contain other contaminants of health concern. Those other contaminants can be released into water when iron and manganese scales are disturbed.

Information to Request: Since iron and manganese can vary, it would be good to obtain a 5-year average, minimum, and maximum for your region of the distribution system. Ask if the water utility treats to remove iron or manganese from their source water, and whether they experience customer complaints concerning these parameters.

Where to Sample and How to Test: The water utility's information on iron and manganese should be sufficient if you experience no possible problems. Testing for total iron and total manganese would be done by a certified laboratory. If you decide to collect samples, a sample from the service connection could be combined with samples from taps where you experience problems, as well as from hot water systems or any storage tanks.

Sulfate

Background: The concentration of sulfate is expressed as mg/L or ppm. Sulfate is somewhat conservative and usually remains steady during the distribution of water. It varies with climate conditions; when source water levels are high it is more dilute. Some water treatment systems introduce sulfate to the water such as when ferric sulfate is used as a coagulant during water treatment. Sulfate is a source of sulfur and can be biologically converted to inorganic sulfide such as hydrogen sulfide.

Guidelines or Standards: The EPA's SMCL is 250 mg/L for taste and higher levels can cause intestinal discomfort for consumers of the drinking water.

Importance to Building Water Systems: Sulfate can be a precursor for sulfide odors as can occur in water heaters and storage tanks. Sulfate can also encourage corrosion and be a source of nutrient for bacteria that participate in corrosion.

Information to Request: Since sulfate can vary, it would be good to obtain a 5-year average, minimum, and maximum for your region of the distribution system.

Where to Sample and How to Test: The water utility's information on sulfate should be sufficient. Testing would be done by a certified laboratory. If you decide to collect samples, a sample from the service connection should be adequate.

Sulfides

Background: Inorganic sulfides would be expressed as mg/L or ppm. Some groundwater supplies have sulfides in them, such as hydrogen sulfide. Water utilities may treat the water to reduce sulfides. Sulfides can change in chemical nature during water distribution since some microorganisms utilize sulfides. Sulfides can also be liberated during the corrosion of iron as from unlined cast iron water mains.

Guidelines or Standards: Some state primacy agencies have recommendations for sulfides. They are mostly found at levels of concern in groundwaters. Inorganic sulfur chemicals can occur as hydrogen sulfide or other sulfides. These can occur naturally or be produced microbiologically. Hydrogen sulfide at 1 mg/L can be a nuisance. Sulfides can also produce a burnt match odor along with turbidity. A low pH favors the nuisance odor of rotten eggs.

Importance to Building Water Systems: Sulfides can accumulate in plumbing systems where they can cause odors that are objectionable. Hot water systems and storage tanks would be more prone to this problem. Sulfide odors can also signal active corrosion conditions.

Information to Request: Ask if your water utility treats for the removal of sulfides in their source water. Ask if the water utility receives customer complaints concerning sulfide odors (rotten egg, burnt match, sewer-like smell).

Where to Sample and How to Test: The water utility's information on sulfides should be sufficient. Testing for hydrogen sulfide would be done by a certified laboratory. If you decide to collect samples, a sample from where a problem is reported is appropriate.

Taste/Odor Issues

Background: A variety of contaminants in water can affect its taste (e.g., iron, copper, TDS) and odor (e.g., chlorine, chloramine, hydrogen sulfide and other sulfides). Groundwater sources can have natural problems (e.g., iron and sulfides) as well as manmade problems (e.g., chemical contamination). Surface water sources can have natural problems (e.g., iron, sulfides, earthy and musty odors from cyanobacterial blooms, stormwater and snowmelt runoff) as well as chemical contamination such as from industrial spills. There are water treatment technologies to control these problems. The water distribution system can also contribute tastes and odors (e.g., due to iron corrosion, stagnant water, backflow through cross connections).

Guidelines or Standards: The basic guideline for drinking water is to be free of a noticeable odor and pleasing to the taste. Note that most public water supplies have a noticeable odor from the chlorine residual they carry as a preservative. This is unavoidable. As for taste, truly pure water does not have a pleasant taste because good tasting water requires a background of cations and anions, or minerals, to taste good.

Importance to Building Water Systems: Taste and odor problems can cause complaints from users of the water. Such problems can also arise within plumbing systems because of stagnant water, corrosion, cross connections, hot water systems, and newly installed plastic pipe. Taste and odor problems arising in plumbing systems can often be addressed through changes in operations and materials of the plumbing system.

Information to Request: Ask the water utility about their typical customer complaints concerning taste and odor; when and where they tend to occur, and what they are caused by.

Where to Sample and How to Test: The water utility's information should be sufficient. Testing would be done by a certified laboratory but if the cause is not known, then it could cost a lot of money to test for all possible causes. If the cause originates within the building's plumbing, then investigations should be done to identify the cause.

Color

Background: Color can be measured in various ways; often it is expressed as color units. Source water can have color such as from tannins and organic matter, and water utilities would apply treatment to control it.

Guidelines or Standards: The EPA's SMCL is 15 color units. Essentially, water should not have a noticeable color.

Importance to Building Water Systems: Drinking water with a color will cause complaints from consumers and users. Color can be an indication of backflow through a cross connection within the building or of active corrosion.

Information to Request: Since color can vary in water supplies, it would be good to obtain a 5-year average, minimum, and maximum for your region of the distribution system and to know if the water treatment process addresses color.

Where to Sample and How to Test: The water utility's information on color should be sufficient. Testing would be done by a certified laboratory. If you decide to collect samples, a sample from the location where a color problem is being experienced is appropriate. However, visible color often provides a clue as to the cause and, therefore, follow-up testing should be done to verify the cause (such as for iron, manganese, or copper).

Parameters of Health Concern

Copper

Background: Copper concentration is expressed as mg/L or ppm. Copper is most often introduced to potable water from the corrosion of copper plumbing. Copper occurs in a dissolved and oxidized form for which issues vary depending on the chemical form.

Guidelines or Standards: The EPA's SMCL for copper is 1 mg/L to avoid taste and staining. The EPA's Action Level for copper is 1.3 mg/L under the Lead and Copper Rule.

Importance to Building Water Systems: A building water system may need to have water samples collected and tested to know what the copper levels are for drinking water in the building since copper comes from copper plumbing. Copper can cause unpleasant taste, color, and staining.

Information to Request: The water utility's Consumer Confidence Report should already provide information on the 90th percentile level of copper for samples taken from homes with copper plumbing, as compared to the Lead

and Copper Rule's Action Level for the 90th percentile copper at 1.3 mg/L. This provides a general idea of the corrosivity of the water utility's water toward copper.

Where to Sample and How to Test: The water utility's information on copper helps to identify the potential for copper to be an issue. Testing would be done by a certified laboratory. Since copper comes from building plumbing, samples should be collected at distal taps after water has been sitting stagnant for about 6 hours or longer.

Lead

Background: The concentration of lead is often expressed as ug/L or ppb because the ideal drinking water should have no detectable lead. Lead is typically introduced to potable water from lead service lines and piping, lead-based solder, and older brass fixtures and valves. Galvanized pipe and iron deposits can also be a source of lead. Building water supplies seldom and perhaps never contain appreciable concentrations of lead. Lead can occur dissolved in water or as a particulate, and it can be associated with iron.

Guidelines or Standards: The EPA's Lead and Copper Rule set a 15 ppb Action Level for lead based on the 90th percentile of a number of homes in the water system. Levels above this concentration, or lower if a state regulator has set a lower action level, should result in action taken to reduce the lead since it is a direct health hazard.

Importance to Building Water Systems: Water that is used for consumption should have low or no detectable levels of lead in order to protect the health of the consumer. A building would need to have its water tested, from taps used for drinking and cooking purposes, to determine if lead is a problem. If problematic lead concentrations are observed, lead plumbing system components should be identified and removed and remedial actions should be followed until lead is cleared out of the plumbing system.

Information to Request: The water utility's Consumer Confidence Report should already provide information on the 90th percentile level of lead for samples taken from homes with leaded materials in their plumbing, as compared to the Lead and Copper Rule's Action Level for the 90th percentile lead at 15 ppb. This information provides a clue as to whether the corrosion of lead-based materials is an issue.

Where to Sample and How to Test: The water utility's information on lead helps to identify the potential for lead to be an issue. Testing would be done by a certified laboratory. But to know if lead is an issue, since it would come from a lead service line and building plumbing, then samples should be collected at distal taps after water has been sitting stagnant for about 6 hours or longer. The building's service should be examined as to whether it consists of lead.

Total Coliform and E. coli

Background: Total coliforms are an indicator of the sanitary condition of water. They are a group of bacteria that should be readily controlled by disinfection. When they are detected in drinking water, a follow-up investigation should be done to make sure that the water has not been contaminated. However, they can occur and grow in drinking water systems. The same test that looks for coliform bacteria also looks for the presence of *E. coli* (a member of the coliform group of organisms), which can be an actual pathogen, and which more clearly indicates that the water is likely contaminated. Again, detection of *E. coli* should be followed up with an investigation. A water system can detect total coliform bacteria on occasion without having water contamination, but such detection should not be a regular occurrence. *E. coli* should never be detected. However, there are instances of detection due to unsanitary sampling conditions and poor sampling practices.

Guidelines or Standards: Total coliform and *E. coli* can be expressed as colony forming units (cfu) or most probable number (MPN) per 100 mL, however, the SDWA regulation only requires the measurement of their presence or absence from a sample of water.

Importance to Building Water Systems: The detection of either total coliform bacteria or *E. coli* at or within a building water system should be followed up with an investigation such as for the occurrence of backflow through a cross connection.

Information to Request: It is helpful to know whether the water supplier is or has been experiencing violations of the SDWA regulation for total coliform or *E. coli*. This should be published in the Consumer Confidence Report or sent out with notifications when boil water advisories are issued.

Where to Sample and How to Test: The water utility's information on coliforms should be sufficient. Testing would be done by a certified laboratory. If you decide to collect samples, a sample from where a problem is suspected is appropriate, along with a sample from the service connection. It is easy to contaminate a sample and protocols for sanitary sample collection should be established and reviewed prior to sampling.

Parameters That Influence Others

Water Temperature

Background: Water temperature can vary naturally from a low of about 5 °C to a high of about 30 °C for water sources that are affected seasonally such as rivers and reservoirs. Water temperature remains more consistent in groundwater sources. Water temperature tends to change when water enters building plumbing or is stored for extended time in storage tanks; more typically warming up.

Guidelines or Standards: In general, it is best to keep water as cold as possible as one would do with any consumable product. Colder water reduces chemical and microbiological activity.

Importance to Building Water Systems: In general, the higher the water temperature, the greater the rates of microorganism activity and growth, chlorine residual dissipation, corrosion, and other water quality changes.

Information to Request: You should ask for the annual minimum and maximum water temperature for the water provided to your region of the distribution system.

Where to Sample and How to Test: The water utility's information on water temperature should be sufficient for the water supplied to your building. Using a common water thermometer, you can test yourself at the distal taps throughout the building's plumbing system to understand how water temperature varies, at different times of year, within the plumbing system. Unusually warm water could indicate stagnant conditions or conditions that favor water quality deterioration.

Ammonia

Background: Free ammonia concentration is expressed as mg/L or ppm. Some water sources have levels of ammonia which affect the chlorination of water during water treatment. Ammonia reacts with free chlorine to form chloramine. Many water treatment plants add ammonia to the finished water to form chloramine, and as a result the drinking water has a residual of free ammonia. Ammonia can be used by bacteria in the water system and converted to nitrate and nitrite, a process called nitrification.

Guidelines or Standards: Free ammonia should be minimized, such as below 0.3 mg/L, to prevent nitrification; nitrification can promote corrosion and dissipate the chlorine residual.

Importance to Building Water Systems: Nitrification in a building plumbing system can exacerbate corrosion and increase microbiological activity in the water. Studies indicate that nitrification is very common in building plumbing systems that are supplied by water with chloramine disinfectant.

Information to Request: If the water utility provides a chloramine residual, then it also has a free ammonia residual in its water. Higher chloramine residuals usually mean higher ammonia residuals. In addition, when chloramine dissipates it releases ammonia to the water. In this case, ask the water utility if they experience nitrification in your region of the distribution system.

Where to Sample and How to Test: The water utility's information on ammonia residual should be sufficient. Testing would be done by a certified laboratory. If you decide to collect samples, a sample from the service connection is a starting point.

Heterotrophic Plate Count

Background: Heterotrophic Plate Count (HPC) is an indicator of the background level of bacteria in water. There are many species of heterotrophic bacteria, most of which pose no health risk. Water utilities who measure this parameter establish a baseline from which they can observe when conditions favor the amplification or growth of bacteria. This growth can indicate whether undesirable conditions are occurring such as advanced corrosion and uncontrolled biofilm development.

Guidelines or Standards: HPC is expressed as colony forming units (cfu) or most probable number (MPN) per mL. The two-day incubation test should indicate cfu/mL less than 500; ideally less than 100. A 5-7 day incubation test produces much higher numbers and results should be interpreted against the water system's baseline.

Importance to Building Water Systems: Bacterial regrowth and amplification can lead to nuisance problems (e.g., corrosion, odors, biofilm, nitrification) as well as indicate conditions that are favorable for opportunistic pathogens such as *Legionella*.

Information to Request: It would be helpful to know the average and maximum cfu/mL for HPC for the water supply in your area of the distribution system, during the warmest months of the year when bacterial growth is at its greatest rate. It is also important to know which test method the water utility uses.

Where to Sample and How to Test: The water utility's information on HPC provides a baseline for the water supply. Testing would be done by a certified laboratory and should use the same test method as the water supplier. If you decide to collect samples, samples from distal taps in the plumbing system would be informative, especially following low water usage periods. It is easy to contaminate a sample and protocols for sanitary sample collection should be established and reviewed prior to sampling.

Additional Information to Understand

Water Sources for Supply: It can be important to know whether your water utility's source of water supply is surface water (e.g., rivers, reservoirs) or groundwater (wells) or a combination of the two. Various water quality characteristics can change depending on the type of source water that is used. In some cases, differences in water quality can vary from one surface water source to another, or from one groundwater source to another. These changes may occur based on drought conditions, seasonal changes, and changes in water demand.

Water Main Supplying your Water Service: It may be important to know the age, size, and material of the water main(s) that supplies water to your building's service connection(s). For example, an old water main consisting of unlined cast iron could release iron rust to your water. An over-sized water main for the local demand could result in high water age which reduces the chlorine residual of the water entering your building.

Location and Position of Valves for the Water Main Supplying your Water Service: It may be important to ask if there are any closed valves or dead ended conditions on the water main that serves as the source of water supply for your building. Water utilities can perform a valve check if they are unsure. Closed valves can increase turbidity and rust build-up due to corrosion, allow chlorine residual to decay due to extended water age, and increase the bacterial numbers and sediment entering the building's water service.

Water Pressure: It is important to understand the range of water pressure that the water utility experiences for your water service area. Low water pressure, depending on your building's size, can allow backflow to occur through unprotected cross connections.

Infrastructure Planning: Significant planned infrastructure changes can have impacts on water quality and water pressure. During infrastructure work, water utilities may close valves and bring water in from different water sources. They might flush hydrants and operate valves which can stir up rust and sediment.

Flushing Programs: Some water utilities have programs to flush areas of the system when certain conditions exist or at a certain planned frequency. It could be important to know when they flush the system in your area so you can minimize water usage at that time, thus reducing the risk of pulling in water that is of impacted quality due to the disturbance caused by flushing.

For More Information

USEPA Primary Drinking Water Regulations at:

www.epa.gov/ground-water-and-drinking-water/primary-drinking-water-regulation

USEPA Secondary Drinking Water Regulations at:

www.epa.gov/sdwa/secindary-drinking-water-standards-guidance-nuisance0chemicals

Standards, manuals of practice, and other publications from the drinking water industry can be found at American Water Works Association: www.awwa.org

Information for residential, commercial, and industrial water systems can be found at Water Quality Association: <https://wqa.org>

Check your state's drinking water quality website for water quality regulations or facts that could be helpful to know.

Annex B: (Informative)

Premise Plumbing System Distribution Types

Note: This Annex is not a mandatory part of this Manual but is written in mandatory language for adoption by Jurisdictions for the safe closure and reopening of building water systems.

B.1 Horizontal Distribution Systems – Horizontal distribution systems occur when domestic water main branches are routed horizontally and only serve the fixtures on the floor. These horizontal main branches are shared only by occupants of a single floor, and other floors are served by separate horizontal main branches.

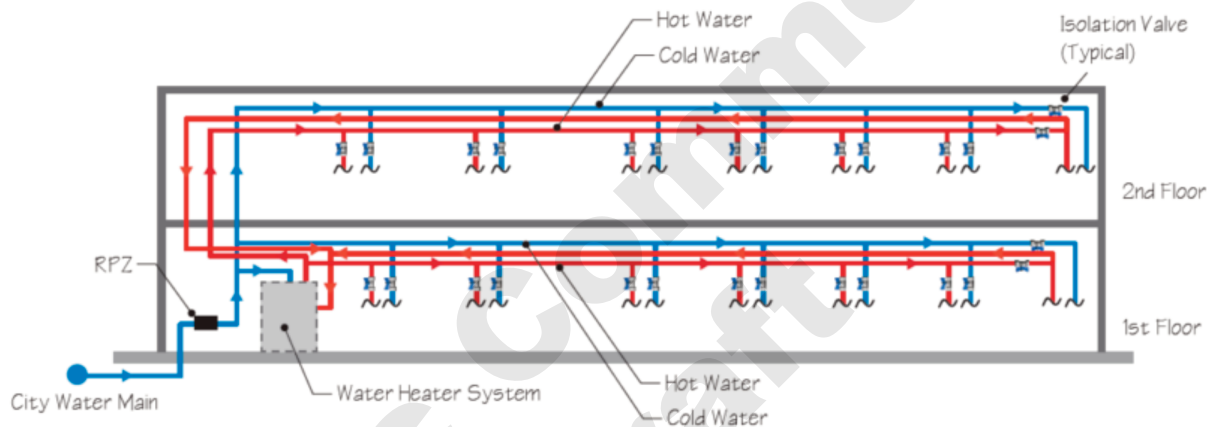


FIGURE B.1
HORIZONTAL DISTRIBUTION SYSTEM

B.2 Vertical Distribution Systems (Simple or Complex) – Vertical distribution systems occur when domestic water main branches are routed vertically and serve fixtures of rooms that are stacked one over the other. These vertical main branches are shared by occupants of multiple floors. There are two types of Vertical distribution systems: Section B.2(A) (Simple) and Section B.2(B) (Complex).

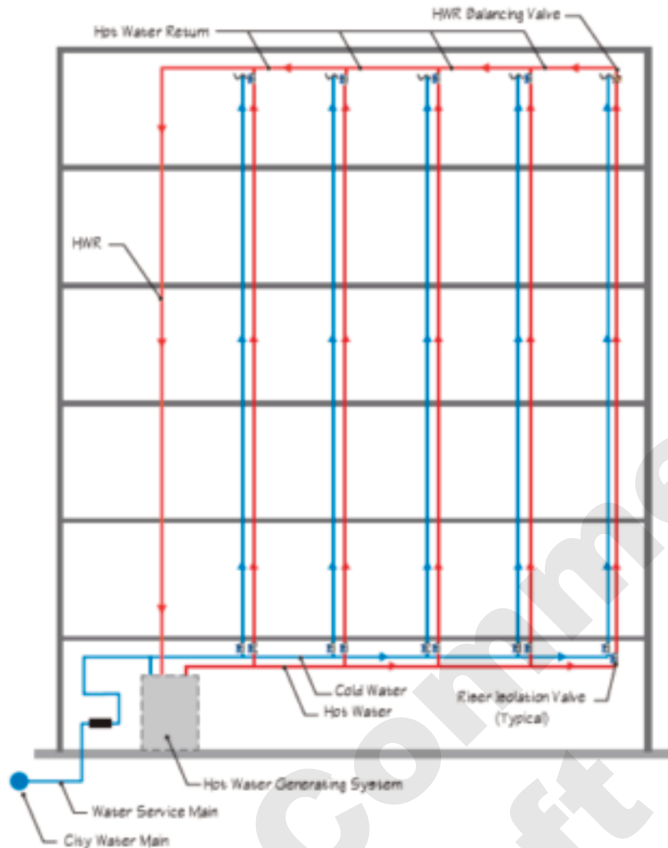


FIGURE B.2(A)
VERTICAL DISTRIBUTION SYSTEM (SIMPLE)

B.2 (A) Simple Vertical Distribution Systems – these systems are common in service select hotels, or similar buildings that are 6 stories tall or less. They typically will only have one pressure zone for the entire building. They may or may not have a booster pump.

B.2 (B) Complex Vertical Distribution Systems - these systems are common in high-rise hotels, or similar buildings that are more than 6 stories tall. They typically will only have multiple pressure zones within the building. They will have a booster pump serving either part or the entire building. Determine if water system is top feed or bottom feed. Consult a plumbing engineer to help make determination

Top Fed: If water is fed through PRV and pressure is close to 40 pounds per square inch (psi) (276 kPa) at PRV the system is likely top feed, and has multiple pressure zones.

- (1) Confer with plumber or plumbing engineer to confirm floors/zones and find the furthest room(s) and most hydraulically remote location(s) on lateral branches.
- (2) Similarly, find furthest point(s) on vertical stacks (not express main) on floors below distribution floor.

Bottom Fed: If water is fed through PRV and pressure is close to 80 psi (552 kPa) at the PRV the system is likely bottom feed and has multiple pressure zones. Complete the following actions:

- (1) Confer with plumber or plumbing engineer to confirm floors/zones and find the furthest room(s) and most hydraulically remote location(s) on lateral branches.
- (2) Similarly, find furthest point(s) on vertical stacks (not express main) on floors above distribution floor.

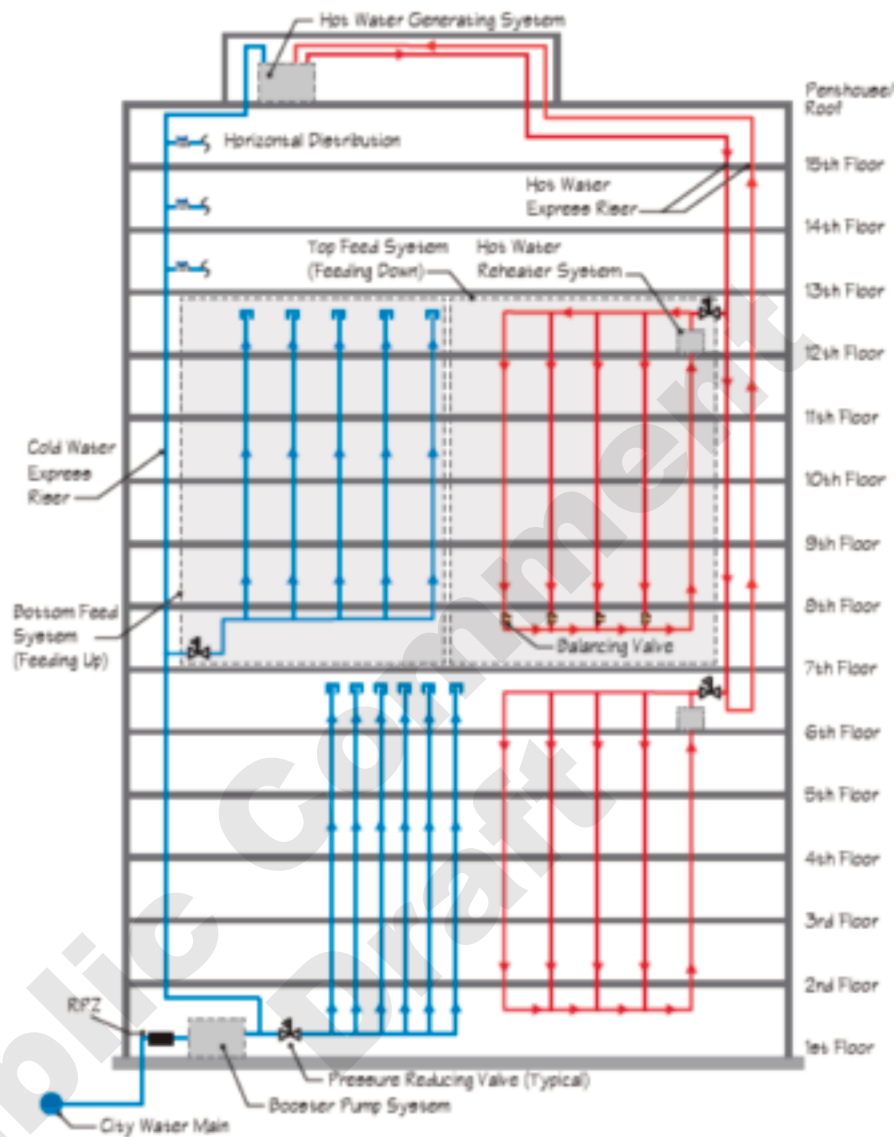


FIGURE B.2(B)
VERTICAL DISTRIBUTION SYSTEM (COMPLEX)

Note: When working on building water systems, unforeseen problems can present themselves, resulting in severe water damage. Additionally, system complexity can vary and understanding... Therefore, it is highly recommended that the flushing process be performed by registered plumbing professionals.

Note: Perhaps adding manifold systems for residential types.

Annex C: (Informative)

USEPA System Opening or Reopening Checklist

[Click here](#) to access the checklist on the EPA website.

www.epa.gov/sites/production/files/2020-05/documents/final_checklist_for_maintaining_building_water_quality_5-6-2020.pdf

Note: *This Annex is not a mandatory part of this Manual but is written in mandatory language for adoption by Jurisdictions for the safe closure and reopening of building water systems.*

System Opening Checklist. The following action items shall be done to safely reopen building:

(1) Before flushing buildings

- (a) Contact your water utility about local water quality and to coordinate maintenance activities.
- (b) Check information from your local public health department for any local requirements for reopening.
- (c) Follow appropriate regulations and policies for worker safety and health.

(2) Steps for flushing buildings

- (a) Review how water moves through your building, from the street to each point of use.
- (b) Inspect the plumbing.
- (c) Maintain any water treatment systems (e.g., filters, water-softeners) following manufacturer's instructions.
- (d) Ensure the hot water system is operating as specified.
- (e) Flush the service line that runs from the water main to the building.
- (f) Flush the cold-water lines.
- (g) Drain and clean water storage facilities and hot water heaters.
- (h) Flush the hot water lines.
- (i) Flush, clean, and maintain devices connected to the plumbing system following manufacturer's instructions.
- (j) Test the building water for residual disinfectant at taps.
- (k) Upon confirmation of item 2j above, then test water for metals, opportunistic pathogens and microbial contamination.

(3) Other actions to consider

- (a) Notify your building occupants of the status of the water systems and the flushing program.
- (b) Limit access to or use of the water as an appropriate cautionary phase.
- (c) Determine if proactive disinfection/heat treatment is necessary.
- (d) Develop a water management program.

Published by
International Association of Plumbing and Mechanical Officials (IAPMO)



Copyright Notice

The information provided herein is copyright protected by IAPMO. All rights reserved. No part of this Manual may be reproduced in any form without the prior permission of IAPMO.

Requests for permission to reproduce this publication or parts thereof should be addressed to:

International Association of Plumbing and Mechanical Officials (IAPMO)
Attention Technical Services & Research Dept.,
at technicalservices@iapmo.org or,
alternatively, at 4755 East Philadelphia Street, Ontario, California, 91761, USA
1-800-854-2766 • 1-909-472-4100

Copyright violators will be prosecuted to the full extent of the law.



WWW.IAPMO.ORG



Public Comment