**Building Science Education Solution Center—Plumbing**

## Proficiency Level 4: Analyze

### Learning Objective 4.1

* For your specific climate zone, research, identify, and list key building processes, materials, and design elements plumbers should apply 1) to prevent water leaks and facilitate leak detection and repair and 2) to prevent condensation on cold water lines and fixtures.

### Lecture Notes 4.1

The following notes are from U.S. Environmental Protection Agency. December 2013. *Moisture Control Guidance for Building Design, Construction and Maintenance*. EPA 402-F-13053, EPA. <https://www.epa.gov/sites/production/files/2014-08/documents/moisture-control.pdf>

The Moisture problems associated with plumbing equipment include:

* Leaks in pressurized pipes and vessels, in appliances that use water and in pipes that drain wastewater.
* Condensation on cold-water lines, chilled water lines and toilets. The colder these surfaces are, the more likely condensation will form.
* Mold growth on partitions, ceilings and floors enclosing spaces that are subject to repeated wetting.

Water conservation is important but not always thought of as related to the integration of building systems and/or building science. Therefore, it is separated into its own learning objective 4.2.

Once installed, plumbing is difficult and expensive to replace and relocate, so good design is very important. Moisture problems associated with poorly designed plumbing can cause damage that can affect almost any location in the building, including places that are not often seen or inspected or are difficult to access. Unnoticed mold growth can result from leaks, posing a health risk to building occupants. Gaining access to poorly designed plumbing for repair or replacement can necessitate demolishing obstructions, which leads to higher repair costs.

**Goals**

1. Plumbing System Design Goal 1: Design supply lines, drain lines, and fixtures to prevent water leaks and facilitate leak detection and repair.
2. Plumbing System Design Goal 2: Design plumbing systems to prevent condensation on cold water lines and fixtures.
3. Plumbing System Design Goal 3: Select materials to minimize mold growth in areas that are unavoidably wet.

**Guidance**

*Plumbing System Design Goal 1: Design supply lines, drain lines and fixtures to prevent water leaks and to facilitate leak detection and repair.*

*Guidance 1: Reduce initial leaks by specifying testing of supply lines, drain lines and fixtures.*

Determine specifications for pressure tests of supply and drain lines and fixtures to identify leaks in plumbing.

* Design specifications should require, at a minimum, the testing of supply lines in accordance with section 312.5 of the International Plumbing Code, or relevant sections of other applicable local codes, but they may require testing at higher pressures depending on the requirements of the equipment and plumbing system and the intent of the design.
* Design specifications should require, at a minimum, testing the drain and vent side of the plumbing system as required by the relevant building code. For example, designs should specify a gravity test of the drain and vent side of the system according to sections 312.2, 312.3, and 312.4 of the International Plumbing Code, or relevant sections of applicable local codes. If all or a portion of the drain side of the system will be pressurized during operation, appropriate pressure testing must be specified.
* Identify the test method and the design test pressure.
* Specify when the tests should be conducted in relation to the completeness of the plumbing system and the closing of the cavities (e.g., while lines are exposed for inspection, but before enclosing).
* Identify the appropriate testing party. Depending on the scale of the project and the parties involved, the appropriate testing party may be a commissioning agent; a testing, adjusting, balancing (TAB) contractor; a subcontractor to the general contractor; or a plumbing contractor.
* Specify how the results should be documented, judged and accepted or rejected.
* Specify the remedies if any portion of the plumbing system fails the test.

*Guidance 2: Design the plumbing system for easy inspection and repair of components (e.g., pipes, valves, traps, grease traps, tanks, controls, heaters, filters and connections to appliances).*

Place pipes and valves where they can be easily inspected and repaired, where leaks will be seen quickly, and where even a small leak will not wet a cavity made from moisture-sensitive materials. Avoid locating water lines and other plumbing components in exterior wall or ceiling cavities insulated with porous insulation. NOTE: If pipes must be located in an exterior wall or ceiling, they must be protected so that outdoor temperatures do not affect them and outdoor air cannot leak in to them. In addition to any required pipe insulation, place a layer of closed-cell board or spray-foam insulation between the pipe and the exterior sheathing or curtain wall. If board foam is used, it must be air sealed at the joints and edges and connected in an airtight way to the air barrier system at all perimeter edges. The object is to surround the pipe with warm interior air when it is cold outdoors and with cool, dry, conditioned air in air conditioning mode.

*Plumbing System Design Goal 2: Design plumbing systems to prevent condensation on cold water lines and fixtures.*

*Guidance 1: Design the plumbing system’s insulation and water vapor controls so the pipes, tanks and other equipment that convey or contain water cooler than the dew point of the outdoor air—or cooler than the expected dew point of the air in the enclosure where the equipment will be located—are free of condensation.*

* Specify the design temperature and humidity conditions for the spaces that contain plumbing components conveying cool or cold water (e.g., chilled water lines, cold water lines, toilets, cold water storage tanks or water treatment tanks) and the expected surface temperatures of these items during the design condition.
* Specify the required R-value of the insulation and the permeability and location of the water vapor control element to prevent condensation on the surface of the insulation or on the surface of the pipe or plumbing component.
* Specify air-sealing methods and materials at joints and seams in the insulation and water vapor control elements.
* Provide details showing the continuity of the insulation and water vapor control where pipes pass through walls, ceilings or floors and where pipes join other plumbing components such as valves, gauges, pumps and tanks.
* Require the inspection of condensation controls for components that convey cool or cold water and specify when in the construction sequence the inspections must take place, the party responsible for performing the inspections, the methods that should be used to document the results of the inspections and any remedies for failed inspections.

*Plumbing System Design Goal 3: Select materials to minimize mold growth in areas that are unavoidably wet.*

*Guidance 1: In unavoidably wet areas, use materials that tolerate repeated wetting and drying.*

* Identify areas in the building that will get wet because of their use (e.g., entryway floors, bathroom floors, tub surrounds, showers, locker rooms, pool and spa rooms, and kitchens). Specify materials that are highly resistant to the growth of mold. Among these materials are ceramic tile, glass, plastic resins, metals and cement-based products.
* For materials known to be vulnerable to mold growth (e.g., untreated paper-faced gypsum board and OSB), use products and paints that are resistant to mold growth. Specify mold-resistance testing criteria that are appropriate for these materials (e.g., a score of 10 when tested using ASTM D3273 Standard Test Method for Resistance to Growth of Mold on the Surface of Interior Coatings in an Environmental Chamber).
* Avoid specifying materials that provide nutrients and sustain mold growth. Such materials include untreated paper-based products and composite wood materials.

Verification of Plumbing Designs

Piping, Valves and Controls

* Confirm that drawings and specifications document the location of pipes, valves and other plumbing system components and the location, size and type of access panels for inspection and repair.
* Confirm that the pressure test requirements of supply and drain lines, the specific responses to success or failure, the testing schedule, the responsible testing party and the required documentation have all been specified.
* Provide a list of critical details and a schedule for inspecting the plumbing system including supply lines, drain lines, air vents, plumbing fixtures, appliances that use water, tanks and vessels. Specify the inspection sequence, the parties responsible for the inspections and the required documentation of the inspection results.

Insulation and Vapor Retarders

* Confirm that drawings and specifications include the design conditions, condensation control elements, inspection procedures, responsible parties and documentation as required.
* Provide a list of critical details and a schedule for inspecting the plumbing system insulation and vapor retarders, including supply lines and drain lines. Specify the inspection sequence, the parties responsible for the inspections and the required documentation of the inspection results.

Wet Spaces

* Confirm that the drawings and specifications identify appropriate moisture-resistant materials for use in wet locations including bathrooms, showers, locker rooms, pool and spa rooms, and kitchens.
* Provide a list of inspection and maintenance requirements for the moisture-resistant materials used in the unavoidably wet areas.
* Provide a list of critical details and a schedule for inspecting the moisture-resistant materials and associated liquid-water-control elements specified for use in unavoidably wet areas. Specify the inspection sequence, the parties responsible for the inspections and the required documentation of the inspection results.

### Learning Objective 4.2

Analyze how the EPA WaterSense® New Home Specification can be applied to a new home built to code in your climate zone to use approximately 20% less water.

### Lecture Notes 4.2

The EPA WaterSence® New Home Specifications (effective July 24, 2014) are described at this link: <https://www.epa.gov/sites/production/files/2017-01/documents/ws-homes-spec.pdf>

The WaterSense® Labeled New Home Inspection Checklist is located at this link: <https://www.epa.gov/sites/production/files/2017-01/documents/ws-homes-inspection-checklist.pdf>

Information about WaterSense best practices are available on the Building America Solution Center here: <https://basc.pnnl.gov/checklists/epa-watersense> .

To minimize water wasted while waiting for hot water, the hot water distribution system shall store no more than 0.5 gallons (1.9 liters) of water in any piping/manifold between the hot water source and any hot water fixture. To account for the additional water that must be removed from the system before hot water can be delivered, no more than 0.6 gallons (2.3 liters) of water shall be collected from the hot water fixture before hot water is delivered. Recirculation systems must be demand-initiated. Systems that are activated based solely on a timer and/or temperature sensor do not meet his requirement.

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| Notes about this learning objective, it requires the following:To calculate the volume of water stored in the hot water delivery system:1. Obtain copies of the plumbing layouts [provided by the professor].
2. Identify the type of piping that will be used (e.g., Copper M, CPVC, PEX);
3. Identify the hot water fixtures farthest from the water heater and note:
	1. Nominal diameter of each individual pipe segment between the water heater and the fixture.
	2. Length of each pipe segment running from the water heater to the fixture.
4. Using the piping volumes provided in Table 1, calculate the volume of water stored in each pipe segment.
5. Total the volume of water stored in all pipe segments running from the water heater to the fixture. The total should be less than 0.5 gallons if the design meets the WaterSense new home specification criteria.

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| **Table 1. Internal Volume of Various Water Distribution Piping** |
| **Ounces of Water Per Foot of Hot Water Tubing** |
| **Nominal Diameter in inches (in)** | **Copper M** | **Copper L** | **Copper K** | **CPVC CTS SDR 11** | **CPVC SCH 40** | **PEX-Al-PEX ASTM F 1281** | **PE-AL-PE** | **PEX CTS SDR 9** |
| ⅜ | 1.06 | 0.97 | 0.84 | N/A | 1.17 | 0.63 | 0.63 | 0.64 |
| ½ | 1.69 | 1.55 | 1.45 | 1.25 | 1.89 | 1.31 | 1.31 | 1.18 |
| ¾ | 3.43 | 3.22 | 2.90 | 2.67 | 3.38 | 3.39 | 3.39 | 2.35 |
| 1 | 5.81 | 5.49 | 5.17 | 4.43 | 5.53 | 5.56 | 5.56 | 3.91 |
| 1 ¼ | 8.70 | 8.36 | 8.09 | 6.61 | 9.66 | 8.49 | 8.49 | 5.81 |
| 1 ½ | 12.18 | 11.83 | 11.45 | 9.22 | 13.20 | 13.88 | 13.88 | 8.09 |
| 2 | 21.08 | 20.58 | 20.04 | 15.79 | 21.88 | 21.48 | 21.48 | 13.86 |
| Source: Modified from *2009 International Plumbing Code Table E202.1. International Code Council.**January.* |

Conversions: 1 gallon (3.8 liters) = 128 ounces; 1 ounce = 0.00781 gallons (0.0296 liters); 0.5 gallons (1.9 liters) = 64 ounces; 0.6 gallons (2.3 liters) = 76.8 ounces |