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Introduction to Continuing Education Class on Residential Water Heaters for Utah Plumbers (Video)

Hello and welcome to this class on one of the most essential plumbing features in every home – the water heater. The way a customer views a water heater system is complex. Most of a house's plumbing system either works or it doesn't. There are two components of the plumbing system – water pressure and whether or not there's a ready supply of hot water at just the right temperature – these are quality of life issues. And, in most cases, it's probably the water heater that matters most of all.

A well-designed water heater that delivers hot water at the right temperature, day or night, equally during low-demand and peak periods, and with the least possible delay makes users happy and avoids the wasteful running of water to get the right temperature. The ability to provide this type of impeccable system, in the real world, must be balanced against the cost. In other words, how much more does the customer want to spend to gain marginal improvements?

No compromise, however, can ever be made when it comes to three critical safety issues:

- ➢ Excessive pressure;
- ➢ Excessive temperatures; and
- ➢ Microbial contamination.

As familiar an appliance as the domestic water heater has become, never forget that a water heater not behaving properly can represent a profound hazard, either by incubating dangerous microbes or by turning into a virtual bomb. Although less dramatic, minor issues such as a leaking valve or taking far too much energy for the amount of hot water provided, can become a steady drip-drip-drip that can lead to greater problems down the road.

This class will look at water heaters from every angle, including,

- ➢ How they work and available options;
- ➢ Proper sizing;
- ➢ Codes and Standards;
- ➢ Managing pressure;

- ➢ Managing temperature & scalding risk;
- ➢ Using water heaters to heat spaces, floors, and driveways;
- ➢ Green water heaters; and
- ➢ Eradicating harmful microbes.

The class will end with a brief look at overall best practices in water heaters, including what to do about do-it-yourself water heater follies.

The class is comprised of 10 lessons and three videos. Each of these lessons will be followed by a review question, which gives you a chance to use the information just covered as well as giving state regulators a way to verify your active participation in the class. You need to answer the question correctly to progress to the next lesson. If you answer incorrectly, you're given a chance to review the material before making a second attempt. If you take a break from the class after answering a question, you'll resume at the start of the next lesson or video when you return. If you leave before finishing a lesson and answering the question, you'll restart at the beginning of that lesson when you resume the class.

There's a lot to cover, so let's get started.

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[QUESTIONHEADER]

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Which of the following was NOT listed in the introduction as one of the three critical hazards presented by a domestic water heater?	Long delays in providing hot water	Excessive pressure	Microbial contamination	Excessive temperatures

[QUESTIONBOTTOM]

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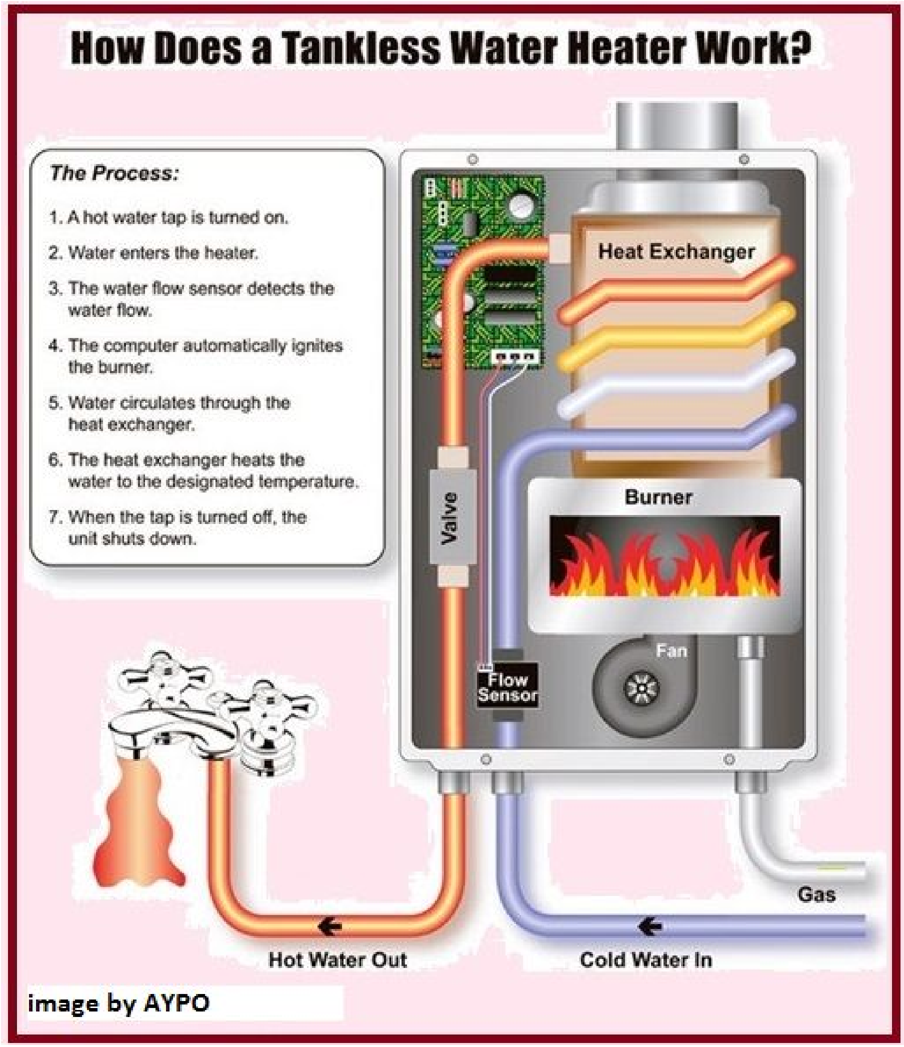
Types of Water Heaters

Although there are many types of water heaters available, the predominant type for domestic use (including homes, condos, apartments, small businesses, offices, etc.) is the direct-fired automatic storage water heater. These water heaters may use electricity, fuel oil, or natural gas, generally operate at a relatively low Btu rate (with the heating of the water spread over the design hour), and are sold widely, giving numerous options at a relatively modest price. Among the less common types of water heaters are:

1. Instantaneous-type (or tankless) water heaters;

    ➢ In the past, this form of water heater was most often used for hot tubs, spas, and swimming pools where water-heating demands are constant over long periods, or in commercial applications such as restaurant dishwashers or industrial applications where they would boost already available hot water to a higher temperature.

    ➢ Microprocessor controls have allowed wider application in homes (particularly where space is limited). Selection of the type for home use is based on the maximum demand for an instantaneous flow of hot water.



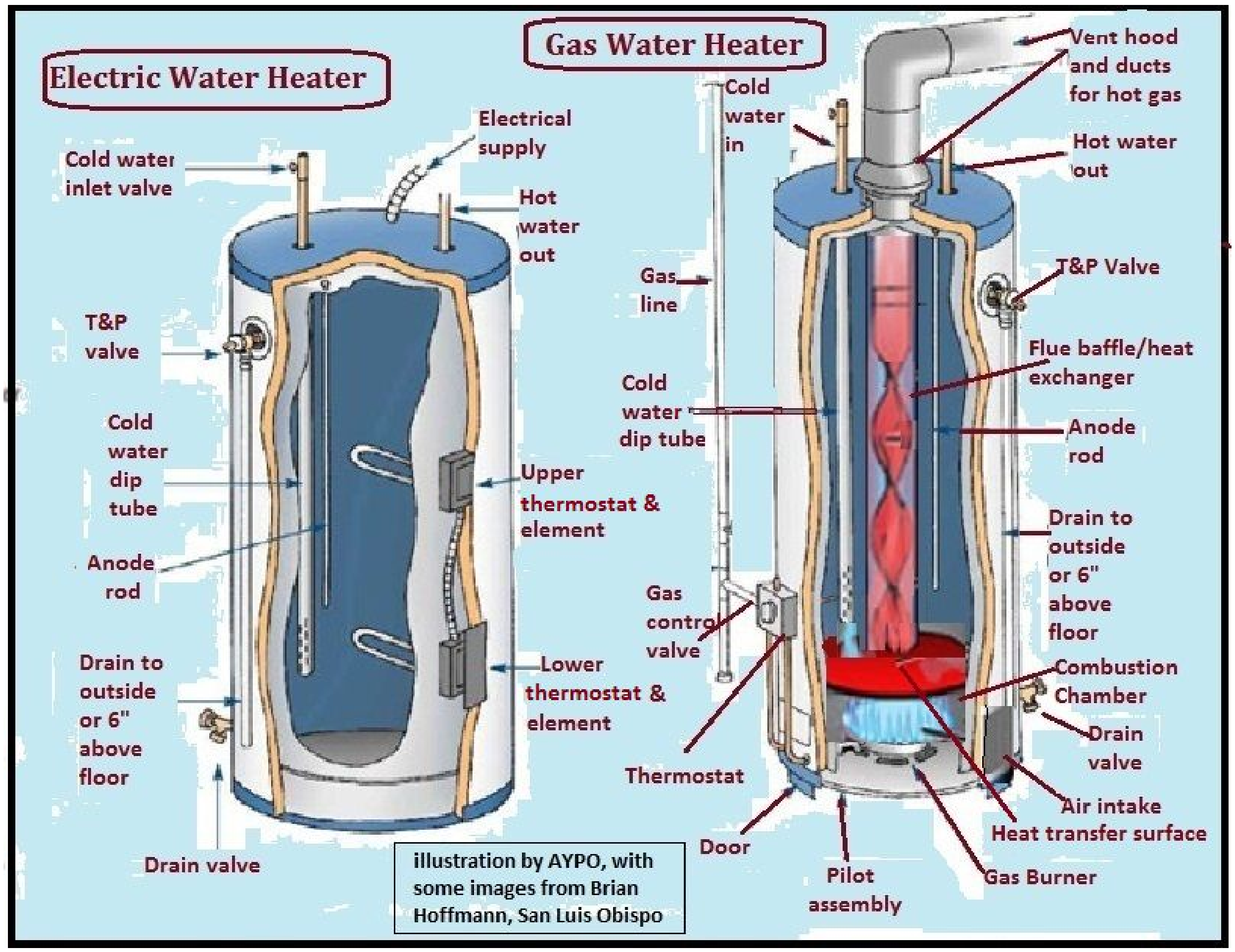
2. Semi-instantaneous heaters have small storage tanks (10 to 20 gallons) and use microprocessor control units to react to sudden fluctuations in water flow and activate in order to maintain the outlet water temperature within ±5°F (2.7°C).

3. Booster heaters that raise the temperature of the regular hot water supply in order to perform special functions, such as commercial dishwashers and sterilizers. In general, these are not centrally located but placed near their point of intended use. Unlike tankless water heaters for domestic use, they do not have many control features but rely on simple on/off operation.

4. Indirect-fired water heaters (such as solar thermal systems or steam indirect-fired systems), use heat exchangers to transfer the heating energy generated either by solar radiation or by a boiler in another area to water in a storage tank. The reason for using these systems is to take advantage of the energy efficiencies when physically separating the production of the necessary heating energy (e.g., boiler or solar collector) from the

hot water storage tank.

How a Direct-Fired Automatic Storage Water Heater Works



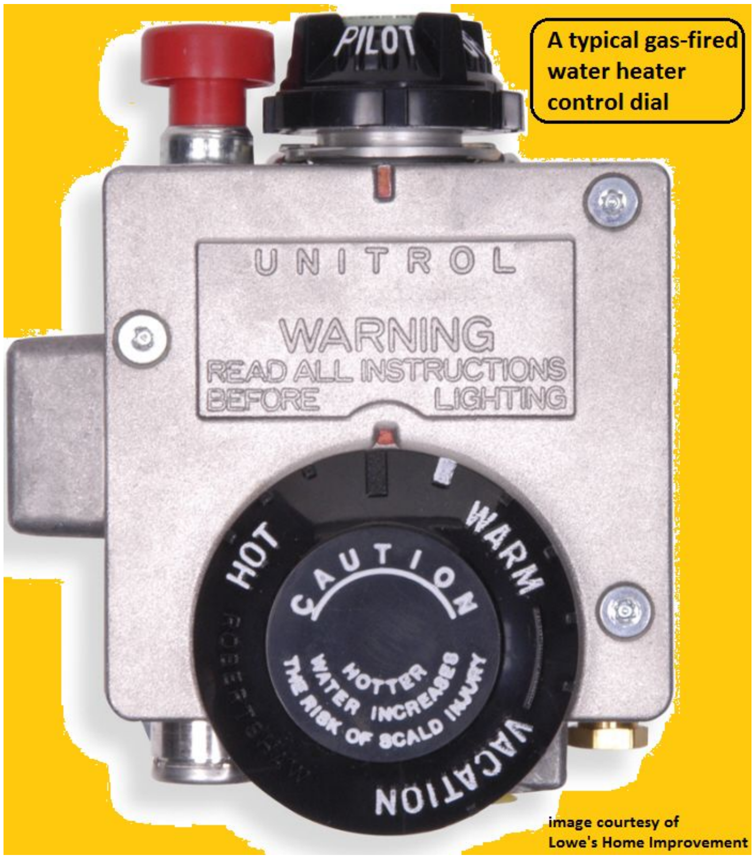
Although electric and gas-fired water heaters share many features, gas-fired heaters are more complex and heat water at the bottom, with a central core that spreads the heat energy from the heat transfer surface throughout the water. Electric water heaters typically have two heating elements to take into account warm water rising so that each element only provides as much heat energy as needed for that stratum of water.

There are a few basic issues with regard to installation to be addressed:

1. Controls;
2. Stratification in Storage-Type Heaters and Tanks;
3. Condensation and Overflow Water;
4. Venting; and

5. Cathodic Protection.

Controls



Water heater controls are installed by the equipment manufacturer. Although controls vary by manufacturer and type of water heater, the controls are typically rudimentary. There are two critical issues with regard to controls on water heaters:

1. The preset by the manufacturer is almost always well below optimal temperature for use, while a setting by the user may either be far above or far below optimum; and

2. Codes forbid using the dial on the heater itself as the sole means for providing acceptable hot or tepid water.

As stated in the 2015 IPC®:

607.1.1 Temperature Limiting Means. A thermostat control for a water heater shall not serve as the temperature limiting means for the purposes of complying with the requirements of this code for maximum allowable hot or tempered water delivery temperature at fixtures.

As controls for many other appliances have become digitized, programmable, and elaborate, the control dial on a water heater is generally far simpler, in part to discourage users from relying on a digital readout as representing the delivered temperature. As you well know, travel distance, ambient temperature, water pressure, and insulation all affect delivery temperature so that the temperature at the water heater outlet may not be the same as it is at the point of delivery. Even as water heater controls are likely to follow the trend and become more elaborate, there's still no substitute for testing water temperature at the tap.

Stratification

Heat in water is simply a result of the molecules moving more quickly, which also decreases the density, causing it to rise above cooler water. This results in stratification, whereby the early flows will be significantly warmer than water provided from lower in the storage tank. Some water heaters address this by circulating water within the tank, to provide a more even delivery temperature and reduce the recovery time for the tank, as a whole, after part of the stored water is used.

Stratification is not necessarily a negative. It might be useful during periods of high demand, providing more water at a usable temperature for short periods. The average temperature of the tank may be lower than a circulating tank, but the water at the top will be warmer than if it was mixed with newly incoming cold water.

Condensation and Overflow Water

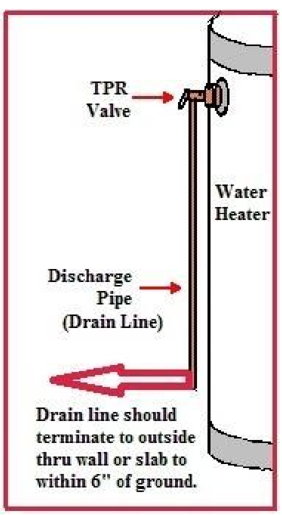


Image by AYPO

As noted in the previous slide, heat in water is a factor of how fast the molecules are moving such that, as heat rises, density falls and the volume of liquid increases. Since the water is contained, it has nowhere to go and, instead, increases the pressure exerted against the tank walls. The issue of water pressure will be addressed later in the class. What is critical for installation is to have a means for evacuating the water without exposing the surrounding area to water damage.

For gas-fired water heaters, condensation can also be an issue. Ironically, a more efficient water heater produces MORE condensate. To understand why, it may be useful to review the principles of combustion.

Combustion is a chemical reaction of oxygen with a combustible material (such as gas fuel) producing light and heat and (in the case of gas fuel) a by-product called "flue gas" composed of varying amounts of carbon monoxide, carbon dioxide, hydrogen or nitrogen, and water vapor. The higher percentage of the gas fuel that is burned, the more heat, less carbon monoxide, and the more water vapor is created. Perfect combustion (that burns 100% of the natural gas) would have a by-product of one cubic foot of carbon dioxide and two cubic feet of water vapor for every cubic foot of natural gas (and no carbon monoxide).

In fact, perfect combustion is never achieved. Older water heaters might achieve up to 80% efficiency. As a result, very little water vapor is created but much more carbon monoxide than newer, high-efficiency water heaters that achieve 92% or higher ratings for percentage of fuel gas burned. Therefore, the associated condensate is much greater in high-efficiency appliances. The installer must make provision for its removal, particularly if the condensate becomes acidic (due to the burning of contaminants in the gas fuel, including the Sulphur added as an odorant that can become Sulphuric acid). Local codes may require that acds in commercial high-efficiency appliance condensate be neutralized before being added to drainage systems.

The requirement for a drain pan to catch condensate will be addressed in the lesson on codes and standards.

Venting

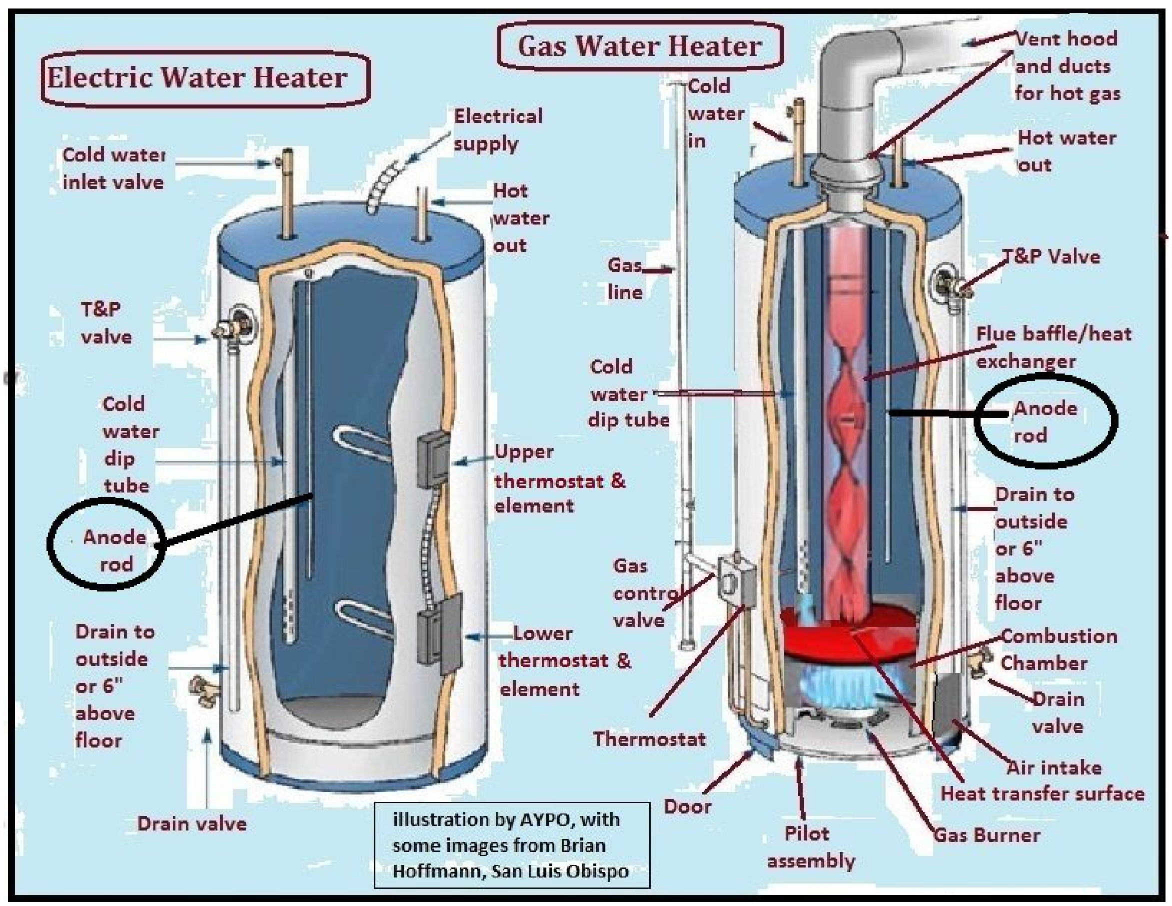
The previous slide outlined the typical composition of “flue gas” – varying amounts of carbon monoxide, carbon dioxide, hydrogen or nitrogen, and water vapor. Since several of these are an asphyxiant and/or inflammable, it’s important to bear them away from contained spaces and avoid their accumulation in any space.

Most water heaters use direct venting. Direct venting requires:

1. An upward direction of the vent pipes (i.e., horizontal vents will not serve direct-vent appliances);
2. Easy access to the outside air, either through a dedicated vent or by venting into an existing chimney or vent channel;
3. Suitable clearances from the vent to outside, as provided for by codes.

Where direct venting is not available, a powered (i.e., fan) venting system provides flexibility in installation, but the noise of its operation may make it less desirable to some customers.

Cathodic Protection



There is a feature shown in the illustration in both the electric and gas-fired water heater – the anode rod. This critical feature is an excellent example of “cathodic protection”.

Cathodic protection is a widely practiced technique for protecting a more valuable metal structure by combining it with another metal in an electrochemical relationship of “anode” (receiver of an electric current) and “cathode” (emitter of an electric current). Certain metals can have a passive galvanic reaction whereby, without introducing an outside current, the metal that emits the current is protected from corrosion and the one receiving the current becomes the “sacrificial” metal and corrodes for the both of them.

The action is similar to that in a standard battery, except that the current exchanges from cathode to anode is not harvested for use but protects the tank from corrosion. The sacrificial anode is made from magnesium, aluminum or a combination of zinc and aluminum.

Note that the sacrificial anode decays into the stored water. Aluminum is highly toxic and, although the concentrations in water from storage tanks is small, it is not recommended for potable use, particularly for young children.

A six-year-warranty residential tank will have one, while a 12-year-warranty tank will have two anodes (or an extra-large primary one). Commercial tanks may have as many as five. To prevent the steel in a six-year warranty tank from failing, sacrificial anodes should be replaced about once every three to five years, with longer time frames for longer warranty tanks. A sacrificial anode's lifespan depends on the quality of the water, the amount of use the tank gets, the water temperature, water salinity (salt water is more corrosive), and the quality of the tank. Water softening (i.e., the removal of calcium, magnesium, and other minerals) will decrease the amount of sediment that may accumulate in the tank, but water that has been “over-softened” can corrode anodes in as little as six months. Advise your customers not to soften water to “zero” and, instead, to leave 50-120 ppm of hardness [Note: This may require some plumbing to add unsoftened water to softened water].

Replacing anodes is relatively straight-forward. Sacrificial anodes typically screw into the top of the tank, but the tank must be drained and the water and power (if electric) turned off. Since the anode rod is long, there must be adequate clearance to remove it and insert a new one.

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[QUESTIONHEADER]

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What is the relationship between the efficiency of gas-fired water	The more efficient the gas-fired combustion the more water vapor	The more efficient the gas-fired combustion the less water vapor it	There is no correlation between gas-fired combustion efficiency and the	There are no circumstances whereby water vapor would be a

heater combustion and the amount of water vapor produced as a byproduct?	it produces as a byproduct	produces as a byproduct	amount of water vapor produced	byproduct of combustion

[QUESTIONBOTTOM]

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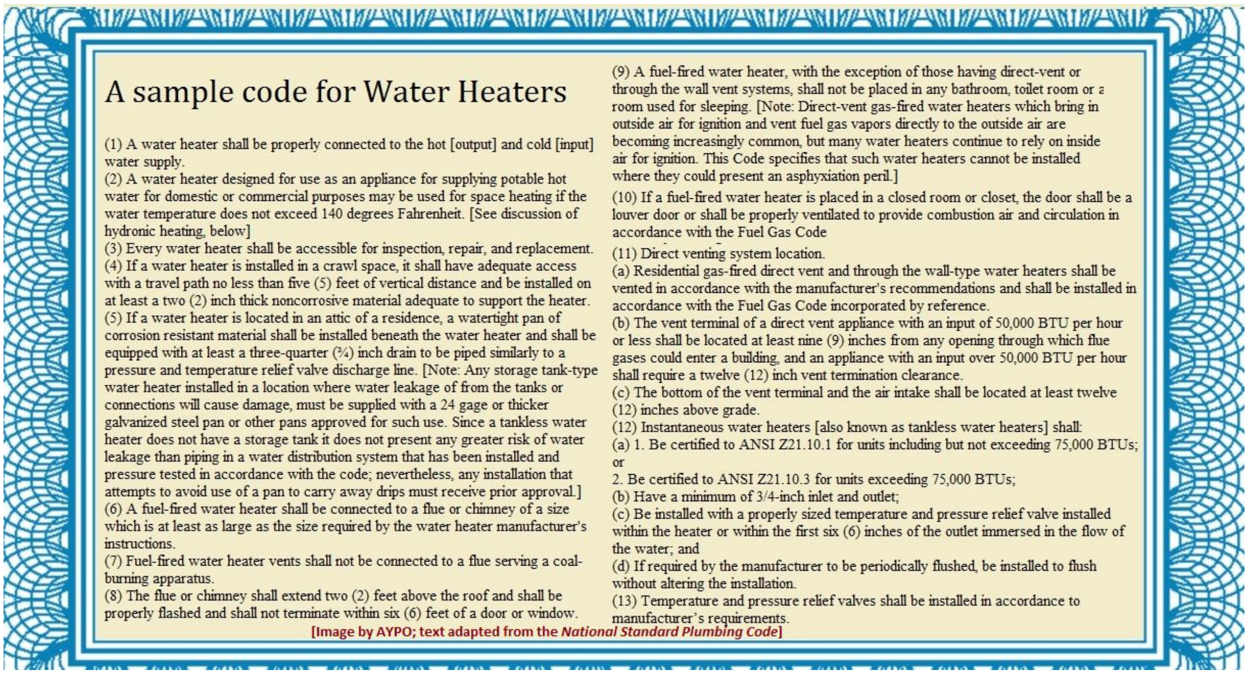
Code & Standards



A sample code for Water Heaters

(1) A water heater shall be properly connected to the hot [output] and cold [input] water supply.
(2) A water heater designed for use as an appliance for supplying potable hot water for domestic or commercial purposes may be used for space heating if the water temperature does not exceed 140 degrees Fahrenheit. [See discussion of hydronic heating, below]
(3) Every water heater shall be accessible for inspection, repair, and replacement.
(4) If a water heater is installed in a crawl space, it shall have adequate access with a travel path no less than five (5) feet of vertical distance and be installed on at least a two (2) inch thick noncorrosive material adequate to support the heater.
(5) If a water heater is located in an attic of a residence, a watertight pan of corrosion resistant material shall be installed beneath the water heater and shall be equipped with at least a three-quarter (¾) inch drain to be piped similarly to a pressure and temperature relief valve discharge line. [Note: Any storage tank-type water heater installed in a location where water leakage of from the tanks or connections will cause damage, must be supplied with a 24 gage or thicker galvanized steel pan or other pans approved for such use. Since a tankless water heater does not have a storage tank it does not present any greater risk of water leakage than piping in a water distribution system that has been installed and pressure tested in accordance with the code; nevertheless, any installation that attempts to avoid use of a pan to carry away drips must receive prior approval.]
(6) A fuel-fired water heater shall be connected to a flue or chimney of a size which is at least as large as the size required by the water heater manufacturer's instructions.
(7) Fuel-fired water heater vents shall not be connected to a flue serving a coal-burning apparatus.
(8) The flue or chimney shall extend two (2) feet above the roof and shall be properly flashed and shall not terminate within six (6) feet of a door or window.
(9) A fuel-fired water heater, with the exception of those having direct-vent or through the wall vent systems, shall not be placed in any bathroom, toilet room or a room used for sleeping. [Note: Direct-vent gas-fired water heaters which bring in outside air for ignition and vent fuel gas vapors directly to the outside air are becoming increasingly common, but many water heaters continue to rely on inside air for ignition. This Code specifies that such water heaters cannot be installed where they could present an asphyxiation peril.]
(10) If a fuel-fired water heater is placed in a closed room or closet, the door shall be a louver door or shall be properly ventilated to provide combustion air and circulation in accordance with the Fuel Gas Code
(11) Direct venting system location.
(a) Residential gas-fired direct vent and through the wall-type water heaters shall be vented in accordance with the manufacturer's recommendations and shall be installed in accordance with the Fuel Gas Code incorporated by reference.
(b) The vent terminal of a direct vent appliance with an input of 50,000 BTU per hour or less shall be located at least nine (9) inches from any opening through which flue gases could enter a building, and an appliance with an input over 50,000 BTU per hour shall require a twelve (12) inch vent termination clearance.
(c) The bottom of the vent terminal and the air intake shall be located at least twelve (12) inches above grade.
(12) Instantaneous water heaters [also known as tankless water heaters] shall:
(a) 1. Be certified to ANSI Z21.10.1 for units including but not exceeding 75,000 BTUs; or
2. Be certified to ANSI Z21.10.3 for units exceeding 75,000 BTUs;
(b) Have a minimum of 3/4-inch inlet and outlet;
(c) Be installed with a properly sized temperature and pressure relief valve installed within the heater or within the first six (6) inches of the outlet immersed in the flow of the water; and
(d) If required by the manufacturer to be periodically flushed, be installed to flush without altering the installation.
(13) Temperature and pressure relief valves shall be installed in accordance to manufacturer's requirements.

[Image by AYPO; text adapted from the *National Standard Plumbing Code*]

For such a widely used consumer product, water heaters' manufacture and installation must comply with a bewildering array of codes and standards.

First and foremost is the plumbing code as adopted for the municipality where it is to be installed. These municipal codes are based on model codes, such as the International Plumbing Code (IPC®), International Residential Code (IRC®), and Uniform Plumbing Code (UPC®). Remember that the codes that govern water heater installation are located in the model code Chapter dedicated to water heaters, but also by codes under water supply (for temperature control), on vents, and so on. Codes may vary depending on whether it's a new installation or a replacement water heater.

Additionally, you may need to comply with the Energy Code of your municipality (possibly based on ANSI/ASHRAE/IES 90.1: *Energy Standard for Buildings Except Low-Rise Residential Buildings,* and/or the International Energy Efficiency Code (IECC®).

Most importantly, numerous municipalities require a permit for water heater installation OR replacement. As the hazards of an improperly installed (or DIY-installed) water heater have become more well-known, many states or localities have decided to require permitting for water heaters. This shows how seriously state regulators take the installation and replacement of water heaters, as distinct from most minor plumbing repairs and replacements that do NOT require permitting.

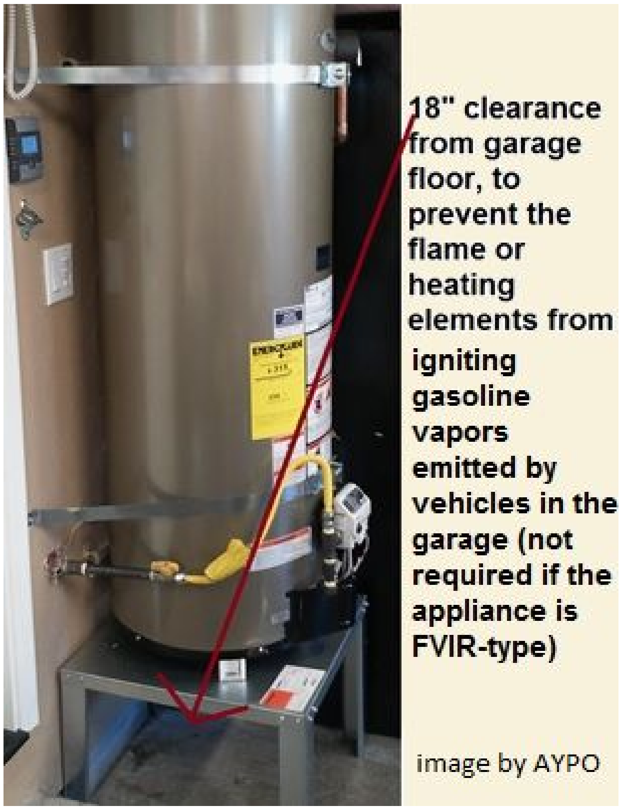
Some of the other codes and standards that may be relevant are:

- ASHRAE Guideline 12: *Minimizing the Risk of Legionellosis Associated with Building Water Systems*;
- International Boiler and Pressure Vessel Code;
- CSA/ANSI Z21.22: *Relief Valves for Hot Water Supply Systems;*
- Underwriters Laboratories (UL) listings for electrical components;
- NSF International listings for potable drinking pipes, fittings, containers, tanks, etc.;
- American Gas Association (AGA) listings for gas-burning components;
- National Fire Protection Association (NFPA) standards, in particular NFPA 70 (the National Electrical Code); and
- ASSE International standards.

Significant Code Provisions for Water Heater Installation

The following is a small selection of provisions from the two major national model plumbing codes that provide guidance in important aspects of water heater installation.

2015 UPC® Section 507.13 – Installation in Garage



UPC® 507.13 Water Heaters; Installation in Garages. Gas utilization equipment, or any equipment that generates a glow, spark, or flame, in residential garages and in adjacent spaces that open to the garage and are not part of the living space of a dwelling unit shall be installed so that burners, and burner-ignition devices, and heating elements are located not less than 18 inches (450 mm) above the floor unless listed as flammable vapor ignition resistant. [NFPA 54:9.1.10.1]

Propane, liquefied petroleum gas (LPG), and vapors that are emitted from gasoline or diesel fuel are all heavier than air and therefore tend to accumulate closer to the ground. The requirement to provide 18 inches of clearance is therefore not intended to protect the appliance as much as it is to prevent an unintentional ignition of atmospheric gases which, through accident or inefficient functioning, have tended to accumulate in a confined space, such as a residential garage.

The code, as written for the UPC, refers to water heaters primarily because it is located in Chapter 5 that regulates water heaters. The UPC recognizes that a water heater is not the only potential source of unintentional ignition and therefore adds "any equipment that generates a glow, spark, or flame" to the clearance above the ground requirement of 507.13 and for the same reason, adds "heating elements", since a heating element can also ignite flammable vapor.

A Note on FVIR

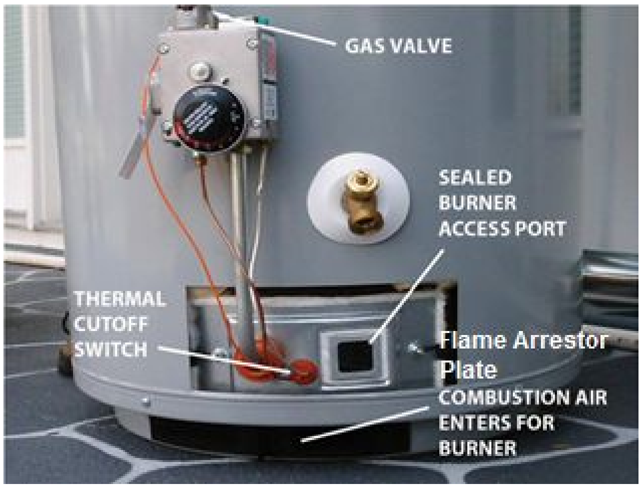


image by AYPO

Water heaters typically include installation instructions that require clearance for accessibility and safety. With regard to the requirement in 507.13 to have gas utilization equipment in garages elevated at least 18 inches unless the appliance is Flammable Vapor Ignition Resistant (FVIR), it’s worth noting that all water heaters built in the U.S. since 2003 incorporate FVIR features that limit chances for accidental fires and explosions.

The FVIR provision was first added to the UPC in 2003. The original code was created in response to findings from the Consumer Products and Safety Commission that thousands of fires, injuries, and deaths were related to water heaters, mostly due to improper storage or handling/spillage of gasoline. The new exception was added to the 2003 UPC to take into account the development of FVIR appliances.

A FVIR appliance has the following components: 1) a device to prevent ignited vapors from passing out of the combustion chamber, 2) a one-way intake system to control the movement of makeup air into the combustion chamber, 3) an inner door and burner assembly to create a sealed junction with the combustion chamber, preventing combustion air and flammable vapors from entering the chamber through the access panel. Generally, the design will include:

1) A flame arrestor plate. Located under the burner, the metal plate is designed to allow combustion air into the combustion chamber but keep flames from escaping downward and igniting flammable vapors below.

2) Thermal cutoff switch. It is designed to shut down the heater if it senses excessive temperatures caused by inadequate combustion air inside the chamber. Inadequate combustion air can be caused by an explosion of flammable vapors, inadequate venting, inadequate makeup air or the accumulation of lint, dust, or oil on the screen.

3) A lint, dust, and oil screen. The screen is designed to protect the combustion process from lint, dust, or oil. The screen openings can become clogged, especially when the tank is located in a basement or utility room.

In the case where trace amounts of flammable vapors are present in the air flowing into the chamber, the vapors are harmlessly ignited by the burner/pilot flame. If flammable vapors are in sufficient quantity to prevent normal combustion, the burner/pilot flame is shut down. Should the flammable vapors continue to the burner, the flame arrestor plate prevents the flames from traveling backwards and igniting vapors outside of the combustion chamber. The calibrated, multi-purpose thermal switch recognizes this and shuts down the pilot and main burner. This switch also deactivates the burner and pilot in the unlikely event of restricted airflow caused by severe lint, dust, or oil accumulation on the arrestor plate.

It should be emphasized that simply having FVIR protection for an appliance does not remove the need to ensure that proper clearance from potential sources of ignition is provided. Access for cleaning and maintenance as well as provision of adequate air flow is also needed. FVIR is an extra level of protection, not a license to evade prudent installation methods.

2015 IPC® Section 504.6 – Requirements for Discharge Piping

The following set of provisions from the 2015 IPC® is a useful reminder of the proper methods for the overflow discharge system. Installers often forget that the outlet of a temperature and pressure relief valve is a potable water outlet that must be protected against backflow conditions. The floor where the pipe discharges could become flooded, or the waste receptor could become clogged and overflow. The air gap of twice the pipe diameter provides a minimum level of backflow protection.

The air gap of two times the pipe diameter required in item #10 is typical of the air gap requirements through the model codes.

IPC® 504.6 Requirements for Discharge Piping. The discharge piping serving a pressure relief valve, temperature relief valve or combination thereof shall:

1. Not be directly connected to the drainage system.

2. Discharge through an *air gap* located in the same room as the water heater.

3. Not be smaller than the diameter of the outlet of the valve served and shall discharge full size to the *air gap*.

4. Serve a single relief device and shall not connect to piping serving any other relief

device or equipment.

5. Discharge to the floor, to the pan serving the water heater or storage tank, to a waste receptor or to the outdoors.

6. Discharge in a manner that does not cause personal injury or structural damage.

7. Discharge to a termination point that is readily observable by the building occupants.

8. Not be trapped.

9. Be installed so as to flow by gravity.

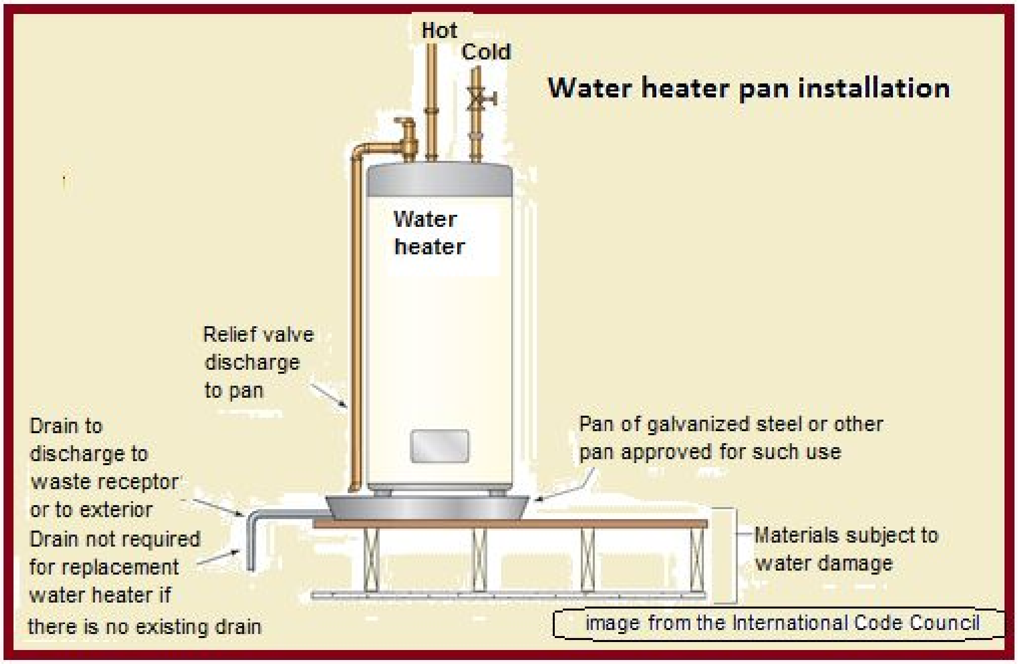
10. Terminate not more than 6 inches (152 mm) above and not less than two times the discharge pipe diameter above the floor or *flood level rim* of the waste receptor.

11. Not have a threaded connection at the end of such piping.

12. Not have valves or tee fittings.

13. Be constructed of those materials listed in Section 605.4 or materials tested, rated and *approved* for such use in accordance with ASME A112.4.1.

2015 IPC® Section 504.7 & 2015 UPC® Section 507.5 – Drainage Pan



The model codes also provide some excellent guidance with regard to the drain pan requirement. This requirement has been modified and strengthened in the past decade and is one of the most often violated codes when it comes to installation of water heaters.

Where a storage tank-type water heater or a hot water storage tank is installed in a location where water leakage from the tank will cause damage, the 2015 IPC® requires a galvanized steel pan having a material thickness of not less than 0.0236 inch (0.6010mm) (No. 24 gage), or other pans approved for such use. The model code does make some allowances for situations where it's impractical to have the pan under the water heater drain, such as a water heater installation where the code did not require the original installation to have a drain for the T&P valve or a drain for a drip pan OR an installation where, even though a drain was required, it was never installed.

The replacement of an existing water heater must be installed to the current code as if it was a new installation. If the original water heater installation did not require a pan, then in many cases, there is not a suitable disposal point for a pan drain. However, if the installation requires a pan, the current code requires that the pan have a pan drain. Since replacement of the water heater is governed by the current code, a drain is theoretically required regardless of the difficulty or cost. Many times, there is not a way to provide for a suitable disposal point for the pan drain. For example, consider a slab-on-grade building in which the water heater is located in the center of the building where there is not a floor drain or waste receptor. Therefore, the Subsection 504.7.2 provides an exception for replacement water heaters to not be required to have a pan drain, if the installation requires a pan.

IPC® Section 504.7 does NOT apply to an instantaneous water heater where there is no substantial water tank.

IPC® 504.7 Required Pan. Where a storage tank-type water heater or a hot water storage tank is installed in a location where water leakage from the tank will cause damage, the tank shall be installed in a galvanized steel pan having a material thickness of not less than 0.0236 inch (0.6010 mm) (No. 24 gage), or other pans *approved* for such use.

504.7.1 Pan Size and Drain. The pan shall be not less than 1½ inches (38 mm) in depth and shall be of sufficient size and shape to receive all dripping or condensate from the tank or water heater. The pan shall be drained by an indirect waste pipe having a diameter of not less than ¾ inch (19 mm). Piping for safety pan drains shall be of those materials listed in Table 605.4.

504.7.2 Pan Drain Termination. The pan drain shall extend full size and terminate over a suitably located indirect waste receptor or floor drain or extend to the exterior of the building and terminate not less than 6 inches (152 mm) and not more than 24 inches (610 mm) above the adjacent ground surface. Where a pan drain was not previously installed, a pan drain shall not be required for a replacement water heater installation.

Note, however, that the code still requires the pan, even if there is no pan drain. The logic behind this is that if the tank begins to leak, the building occupant may notice water in the pan and realize that it is not a normal condition. This is opposed to a situation where there is no pan and the leaking water is allowed to spread, unobserved, potentially creating damage and mold issues. A pan without a drain will provide a contained area that might allow more time for the leak to become detected. A pan, especially one without a drain, can also be used as a location to place a water alarm sensor that could alert the occupant of leaking water.

Note also that the depth of the pan is specified. This minimum depth is important in order to ensure that enough space is provided for the drain connection fitting (generally located on the side of the pan)

Whereas IPC® Section 504.7 requires the pan where leakage could cause damage, the 2015 UPC® provides specific guidance regarding what installation locations would fall into this category:

> **UPC® 507.5 Drainage Pan.** Where a water heater is located in an attic, in or on an attic-ceiling assembly, floor-ceiling assembly, or floor-subfloor assembly where damage results from a leaking water heater, a watertight pan of corrosion-resistant materials shall be installed beneath the water heater with not less than ¾ of an inch (20 mm) diameter drain to an approved location. Such pan shall be not less than 1½ inches (38 mm) in depth.

[SLIDECUT]

[QUESTIONHEADER]

gn_plumbing_electives_ce_01_Q03

Gas-fired water heaters manufactured in the U.S. have all incorporated the safety feature of a Flammable Vapor Ignition Resistant (FVIR) plate since the following year:	2003	2013	1989	U.S manufactured gas-fired water heaters do not customarily have Flammable Vapor Ignition Resistant plates

[QUESTIONBOTTOM]

[SLIDECUT]

Pressure

A water heater without working safety features is a bomb waiting to explode.

If you consider this an exaggeration, reflect for a moment on how many ways we harness the pressure (force) created when water is heated, from the steam engine to electric power plant turbines.

When water is heated, it expands. A 40-gallon water heater heated to its thermostat setting will expand by approximately ½ gallon and every degree above that yields expansion at a higher rate (i.e., not an even rate but an ever-faster rate). The extra volume created by this expansion has to go somewhere or pressure will dramatically increase, such as when water is heated in a teapot that has no vent (i.e., the “whistle”). If it is allowed to increase past the endurance of the storage tank walls, the water heater may rupture with explosive force.

The images, below, show the kind of devastation possible when a water heater explodes.

Home in New Zealand, after water heater explosion

Police speak to witnesses nearby; part of water heater in foreground

Images from New Zealand Department of Building and Housing

Safety Features

Water heaters are required to come equipped with the following three safety features:

1. Thermostat (calibrated to prevent overheating);
2. Electronic relay (calibrated to turn off power if the thermostat malfunctions)
3. A combination temperature and pressure (T&P) relief valve.

This redundancy of safety features is critical and all must be maintained in good working order at all times in order to provide a full measure of safety. As described by the International Association of Plumbers and Mechanical Officials (IAPMO) Technical Committee, “The primary stage is the thermostat. Should the thermostat fail, the secondary stage or high-limit switch will turn off the source of energy to the heater. If the high-limit switch fails, the combination T&P valve opens to prevent a catastrophic failure of the water heater… The combination T&P valve is a lifesaver and is treated [by code officials] accordingly.” Only an approved T&P valve can provide protection in the event of a malfunction in the water heater’s operation.

Before the widespread adoption of the combination T&P valve, some valves were only designed to relieve pressure. This type of safety valve is no longer accepted by the national model codes. Previously approved but no longer allowed methods such as pressure relief valves (but not the temperature and pressure relief valve on the hot water storage tank) are flawed because they waste water and are frequently removed or plugged because tenants are upset by the leaking of water.

T&P Relief Valves

Water-heating systems must be protected from excessive temperatures and pressures by relief valves. T&P relief valves offer economical and effective protection, but only if they are properly maintained. A relief valve on a water supply system is exposed to elements such as corrosive water that attacks materials and deposits of lime that close up waterways and flow passages. For these reasons, T&P relief valves should be tested on a regular basis to ensure safe and proper operation. In addition, the minimum size of the valve should be ¾ inch for inlet and outlet connections.

Manufacturers recommend that the heat sensor of a T&P valve be immersed within the top six inches of a tank (since heat rises, the hottest part of the tank). Water with a high mineral content can cause scaling severe enough to render a valve inoperable within a few months. In locations where the water supply is very hard water, it is advisable to manually clear the valve every three months; in other areas, annual purging of the valve can verify it is operating properly.

Codes mandate that T&P valves selected for storage water heater systems must, at a minimum, relieve pressure at the maximum pressure the tank can withstand. This is a common sense regulation. What good would a pressure relief be if it didn't relieve pressure that was at the limit of the container's ability to withstand pressure? At the same time, a T&P valve cannot be set to relieve pressure that is well within the tank's capacity. The rule of thumb is 90% – the T&P valve is set to allow steam to vent and relieve pressure when the psig or temperature is more than 90% above the normal operating pressure and temperature.

Temperature and pressure (T&P) ASME, ANSI and CSA approved relief valves used on residential water heaters are typically designed and manufactured to relieve on pressure at 150 psig and on temperature at 210°F.

In normal operation of the water heater and T&P valve, no water should be discharged from the valve. A T&P valve that discharges is an indication of an abnormal condition in the system and by discharging, the T&P valve is meeting its designed safety purpose. The causes of discharge can be thermal expansion, excess system pressure, low temperature relief, too high a setting on the water heater, or something in the water heater causing excess temperatures in the heater.

The discharge from a T&P valve can be very hot. It is very important that all T&P valves be installed properly with a discharge line piped downward to an adequate drain to avoid property damage and to minimize possible human contact. In addition, frequent relief discharges can cause a buildup of natural mineral deposits on the valve seat, rendering the valve inoperative.

[Note: Instantaneous water heaters having an inside diameter of three inches or less are exempt from having a T&P valve, since such small units are without a storage reservoir (having only a heating coil) and therefore cannot experience significant thermal expansion.]

Expansion Tanks

Thermal expansion tank

When water is heated, it expands. Older homes simply allowed the expanded water to push back into the water main, which created the potential for contamination. As a result, most newer homes have backflow prevention valves (as integral valves or inside water softeners or water meters) to stop the water from re-entering the water supply.

Since the expanded water now has nowhere to go, the water pressure in the house's pipes can increase dramatically, forcing the Temperature and Pressure Relief (T&P) Valve to discharge frequently, T&P relief valves are intended to only operate on rare occasions. They are not designed for – nor capable of – routine operation.

Where a water heater may be configured so as to regularly experience spikes in pressure or where the system design would make pressure spikes more likely, the model codes now require the installation of an expansion tank. Thermal expansion tanks are manufactured with an internal air bladder (or bladders) that absorb the expanded water. A thermal expansion tank is now the only code-approved method for controlling the pressure and explosive potential of water being heated in a “closed” system. The most common situation that would need an expansion tank would be where there is a “closed” system, created by having a backflow preventer upstream of the water heater. As explained in the following code Section from the 2015 UPC, a check valve or other backflow prevention assemblage upstream of the water heater, would trap pressure back to the water heater and allow it to rise more quickly, requiring an expansion tank to relieve the pressure. [Note: There is a misunderstanding throughout the industry that, if a tankless water heater is installed, an expansion tank is not necessary; this is not true. The highlighted portion of code, below, clarifies that regardless of the type of water heater installed, thermal expansion can still occur in the cold water supply line. Therefore, an approved expansion tank or other approved device needs to be installed.]

608.3 Expansion Tanks, and Combination Temperature and Pressure-Relief Valves. A water system provided with a check valve, backflow preventer, or other normally closed device that prevents dissipation of building pressure back into the water main, independent of the type of water heater used, shall be provided with an approved, listed, and adequately sized expansion tank or other approved device having a similar function to control thermal expansion. Such expansion tank or other approved device shall be installed on the building side of the check valve, backflow preventer, or other device and shall be sized and installed in accordance with the manufacturer's installation instructions.

A water system containing storage water heating equipment shall be provided with an approved, listed, adequately sized combination temperature and pressure-relief valve, except for listed non-storage instantaneous heater having an inside diameter of not more than 3 inches (80 mm). Each such approved combination temperature and pressure-relief valve shall be installed on the water-heating device in an approved location based on its listing requirements and the manufacturer's installation instructions. Each such combination temperature and pressure-relief valve shall be provided with a drain in accordance with Section 608.5.

Installation

Thermal expansion tanks are suggested by most storage water heater manufacturers because repeated pressure increases can shorten the life expectancy of the hot water storage tanks. The code does not prescribe methods for sizing thermal expansion tanks. Nevertheless, proper sizing of the required thermal expansion tank is vital in order to limit the water system pressure to 80 psi or less. Thermal expansion tank manufacturers or plumbing-system design engineers should be consulted for proper sizing of the tanks for each application.

The expansion tank is installed on the cold water supply line, downstream from a check valve or backflow preventer, and at least 18 inches from the cold water inlet to the water heater. The expansion tank is an auxiliary to a properly functioning T&P valve. The pressure of the tank should be adjusted to equal the incoming water pressure. .If the incoming water pressure exceeds 80 psig, a pressure-reducing valve may also be required upstream of the expansion tank. The pressure in the tank can be checked with a standard tire gauge and increased to the desired psig with a standard car/bicycle tire pump. [NOTE: To check tank pressure via the air charging valve, piping system must be at 0 PSI, or tank must be off the system.]

In general, expansion tanks are designed to either be free-standing or supported by the system piping in the vertical (up or down) position. Horizontal installation would require independent support for the tank.

To install, shut off power supply and cold water supply to the water heater, drain the water, and leave the valve open to prevent vacuum build-up in the water heater. Check all joints for leaks after system is fully installed and back in operation.

[SLIDECUT]

[QUESTIONHEADER]

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A 40-gallon water heater heated to its thermostat setting will expand by the following amount:	Approximately one-half of a gallon	Approximately one pint	Approximately five gallons	90%

[QUESTIONBOTTOM]

[SLIDECUT]

Water Heater Sizing

Information Gathering

There are no hard-and-fast rules when it comes to proper sizing of a water heater. You could say that it’s more an art than science but, in truth, it’s a mixture of the two.

Like a good scientist, the first step is to gather empirical data, but like an artist, it’s also good to gather a “sense” of how the water heater will be used. The information to be collected is therefore a mixture of the measurable and the immeasurable. Some may be available in the design stage while other information can only be obtained from the eventual occupants.

It's a good idea to develop a checklist of the information to be gathered so that you won't miss an important consideration. The following is a sample list compiled by ASPE (American Society of Plumbing Engineers):

Information Gathered	Question
	In what type of building will the system be installed?
	Where is the building located?
	What codes should be followed?
	Do any local code amendments apply?
	How much space is available for the system?
	Does the owner or operator of the building have any unusual requirements?
	Does the owner or operator of the building prefer a particular type of system?
	How much system redundancy does the owner or operator of the building want?
	Does the building have any other hot water systems?
	What area of the building will the system serve?
	What is the area used for?
	How many plumbing fixtures will be installed?
	Who will be using the plumbing fixtures?
	How many showers will be used simultaneously and for what duration?
	Are any high-usage fixtures, such as hot tubs, included?
	Does the owner plan to expand the facility in the future?
	Does the building include laundry, foodservice, or health club areas?
	How many areas will be used simultaneously?
	Where in the building will the equipment be placed?
	What energy sources are available?
	Will flues or combustion air be a problem due to the location?
	What is the building's cold water source?
	What are the water hardness, pH, total dissolved solids, and other water quality parameters?
	Will the system be inactive for long periods?
	How far from the heater will the furthest fixture be?

Sizing Methods

Once enough information has been collected, two different profiles may be derived:

1. The load profile; and
2. Peak demand.

There are numerous methods used to create these profiles. Different methods may be of more use in different situations. Using more than one method may give more insight when sizing. Water heater manufacturers may suggest a sizing methodology, while other methodologies may be suggested by government regulators, professional societies, or colleagues. The following are two sizing methods recommended by ASPE:

Method 1: Average Hourly Demand

This is a simple method, but it comes with several limitations:

1. It can be applied only to the types of facilities listed in *Sizing Table A* (below);
2. It can be used only for storage tank systems;
3. It doesn't take the types of occupants into account; and
4. It doesn't take into account high-use or high-volume fixtures.

This method relies on average hourly data in gallons per hour (gph) for various types of buildings and occupancies, as compiled in *Sizing Table A*. To calculate using this method, count the fixtures, multiply the number of fixtures by the gph for the fixture in the particular type of building, add them, then multiply this total by the simultaneous usage factor to get the maximum hourly demand for the system.

The minimum recommended storage volume is then derived by multiplying the total demand by the storage factor.

Sizing Table A

Hot Water Demand per Fixture for Various Types of Buildings at a Final Temperature of 140°F (60°C), gph (L/h)										
Fixture	Apartment	Club	Gymnasium	Hospital	Hotel	Industrial Plant	Office	Private Residence	School	YMCA
Basins, private lavatory	2 (7.6)	2 (7.6)	2 (7.6)	2 (7.6)	2 (7.6)	2 (7.6)	2 (7.6)	2 (7.6)	2 (7.6)	2 (7.6)
Basins, public lavatory	4 (15)	6 (23)	8 (30)	6 (23)	8 (30)	12 (45.5)	6 (23)		15 (57)	8 (30)
Bathtubs	20 (76)	20 (76)	30 (114)	20 (76)	20 (76)		20 (76)		30 (114)	
Dishwashers[1]	15 (57)	50-150 (190-570)		50-150 (190-570)	50-200 (190-760)	20-100 (76-380)		15 (57)	20-100 (76-380)	20-100 (76-380
Foot basins	3 (11)	3 (11)	12 (46)	3 (11)	3 (11)	12 (46)		3 (11)	3 (11)	12 (46)
Kitchen sink	10 (38)	20 (76)		20 (76)	30 (114)	20 (76)	20 (76)	10 (38)	20 (76)	20 (76)
Laundry, stationary tubs	20 (76)	28 (106)		28 (106)	28 (106)		20 (76)		28 (106)	
Pantry sink	5 (19)	10 (38)		10 (38)	10 (38)		10 (38)	5 (19)	10 (38)	10 (38)
Showers	30 (114)	150 (568)	225 (850)	75 (284)	75 (284)	225 (850)	30 (114)	30 (114)	225 (850)	225 (850)
Service sink	20 (76)	20 (76)		20 (76)	30 (114)	20 (76)	20 (76)	15 (57)	20 (76)	20 (76)
Hydrotherapeutic showers				400 (1,520)						
Hubbard baths				600 (2,270)						
Leg baths				100 (380)						
Arm baths				35 (130)						
Sitz baths				30 (114)						
Continuous-flow baths				165 (625)						
Circular wash sinks				20 (76)	20 (76)	30 (114)	20 (76)		30 (114)	
Semicircular wash sinks				10 (38)	10 (38)	15 (57)	10 (38)		15 (57)	
Demand factor	0.30	0.30	0.40	0.25	0.25	0.40	0.30	0.30	0.40	0.40
Storage capacity factor[2]	1.25	0.90	1.00	0.60	0.80	1.00	2.00	0.70	1.00	1.00

1 - Dishwasher requirements should be taken from this Table or from manufacturers' data for the model to be used, if this is known

2 - Ratio of storage tank capacity to probable maximum demand per hour. Storage capacity may be reduced where an unlimited supply of steam is available from a central street steam system or large boiler plant.

Source: 2011 ASHRAE Handbook—HVAC Applications - *Note: Data predates low-flow fixtures.*

Method 2: Occupancy Type

The second method of calculating hot water usage (derived from ASPE's *Domestic Water Heating Design Manual*) doesn't address all types of facilities, but provides accurate calculations for those it does address. It bases calculations on the type of building, then adjusts the calculations to take into account a building's individual operating characteristics. This method can be used to establish the sizing for systems using a storage tank, instantaneous heater, or semi-instantaneous heater, as well as providing for high-usage and high-volume fixtures.

First, refer to Sizing Table B to ascertain whether the occupancy should be classified as High, Medium, or Low Demand, then use Sizing Table C to see how each demand classification can be met for various time periods.

Sizing Table B – Occupant Demographic Classifications

No occupants work outside the home Public assistance and low income (mix) Family and single-parent households (mix) High percentage of children Low income	High Demand
Families Public assistance Singles Single-parent households	Medium Demand
Couples High population density Middle income Seniors One person works, one stays home All occupants work	Low Demand

Sizing Table C – Hot Water Demand and Use for Multi-Family Buildings, gal (L)/person

	Peak 5 Minutes	Peak 15 Minutes	Peak 30 Minutes	Maximum per Hour	Maximum 2 Hours	Maximum 3 Hours	Maximum Day	Average Day
High Demand	0.4 (1.5)	1.0 (4.0)	1.7 (6.5)	2.8 (10.5)	4.5 (17.0)	6.1 (23.0)	20.0 (76.0)	14.0 (54.0)
Medium Demand	0.7 (2.6)	1.7 (6.4)	2.9 (11.0)	4.8 (18.0)	8.0 (31.0)	11.0 (41.0)	49.0 (185.0)	30.0 (113.6)
Low Demand	1.2 (4.5)	3.0 (11.5)	5.1 (19.5)	8.5 (32.5)	14.5 (55.0)	19.0 (72.0)	90.0 (340.0)	54.0 (205.0)
Note: These volumes are for domestic hot water delivered to the tap at 120° F (49° C).								

Electric Water Heater Calculation

If the water heater to be installed is electric, it's useful to know how the kilowatt (kW) rating of the unit translates into actual performance. To clarify the terms, a "watt" is a measurement of electrical output that is equal to the voltage (available charge) times the amperage (rate or speed of current flow), a kilowatt is 1,000 watts, and a kilowatt hour (kWh) represents the output (in kilowatts) per hour. One kWh can raise 410 gallons of water 1°F [where 1 Btu is defined as the amount of heat needed to raise one pound of water 1°F; 1 kWh=3,413 Btu and 1 gallon of water=8.33 pounds.]

The kWh rating for the water heater needed can be obtained by dividing the needed gph by the number of gallons per kWh that can be increased from the incoming temperature to the desired output temperature. For example, where incoming water is 40°F and the desired output temperature is 140°F (i.e., a temperature rise of 100°F), a kWh would supply 4.1 gallons. If the needed supply of hot water is 40 gph, the following calculation [*40 gph/4.1 = 9.8 kWh needed*] would indicate that a water heater rated at 9.8 kWh or larger is needed.

Conclusion

This lesson was only intended to provide examples of sizing methodologies. The key is to be sure you have all the information you need about how it will be used and then apply both sound calculation and sound judgment.

It may be tempting to just leap to providing a water heater sized far above the most usage it's likely to face – "better safe than sorry". Just remember that a larger tank takes more energy to get to the desired temperature and to maintain stored water at the desired level which, in addition to raising the unit cost to the customer, would violate rules on energy efficiency and inflate the customer's monthly gas or electric bill, as well as multiply the damage it could cause in the event of a serious malfunction.

As with so many design decisions, the "three bears" solution (not too big or too small, but "just right") should be your goal in water heater sizing calculations.

[SLIDECUT]

[QUESTIONHEADER]

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According to the material provided in this class, one kWh can raise the following volume of water by 1°F:	410 gallons	41 gallons	1,111 gallons	16 gallons

[QUESTIONBOTTOM]

[SLIDECUT]

Temperature Maintenance

The primary use of a domestic water heater is – of course – providing hot water for sinks and lavatories, showers and baths, dishwashers, washing machines, bidets, and general household use.

The previous lesson in this class dealt with sizing, an important part of temperature maintenance. Ultimately, however, it's the temperature at the tap, nozzle, or shower head that must be maintained. This lesson will focus on how that's accomplished.

Codes

The two predominant national model codes, the IPC® and UPC® define hot water differently. The IPC®, in addition to its definition for hot water, defines warm or tepid water under the term "tempered water", as follows:

2015 IPC®

HOT WATER. Water at a temperature greater than or equal to 110°F (43°C).

TEMPERED WATER. Water having a temperature range between 85°F (29°C) and 110°F (43°C).

2015 UPC®

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

Despite these different definitions, the maximum permissible temperatures at specific fixtures is the same in both model codes. The IPC® and UPC® set the maximum temperature for bidets at 110°F and for other fixtures in residences (sinks, lavatories, and showers/baths, including whirlpools and spas) at 120°F. They diverge in the maximum permissible temperature at public lavatories: the UPC® permits 120°F in public lavatories, lowering the limit to 110°F for public lavatories in restrooms, while the IPC® uses the defined term "tempered water" as the permissible maximum for all public lavatories.

That does not mean that the water heater must be set to low storage temperatures. The thermostat dial on the water heater cannot in any case be relied on to control the hot water system temperature. The thermostat is located at the bottom of the heater to sense the incoming cold water. It controls the "on-off" function of the heating element or burner in the water heater; it does not sense the hot water temperature at the top of the water heater. For that reason, the IPC® added the following Section to the 2012 edition:

IPC® 607.1.1 Temperature Limiting Means. A thermostat control for a water heater shall not serve as the temperature limiting means for the purposes of complying with the requirements of this code for maximum allowable hot or tempered water delivery temperature at fixtures.

By adding this provision, the IPC® requires that other means aside from the thermostat on the water heater must be used to meet maximum temperature requirements on water supplied to plumbing fixtures. Similarly, the UPC includes the following that clarifies that a thermostatic device is the only permissible way to meet the temperature limitation [a similar provision is located at Section 409.4 regarding bathtubs/whirlpool bathtubs]:

UPC® 407.3 Limitation of Hot Water Temperature for Public Lavatories. Hot water delivered from public-use lavatories shall be limited to a maximum temperature of 120°F (49°C) by a device that is in accordance with ASSE 1070 or CSA B125.3. The water heater thermostat shall not be considered a control for meeting this provision.

image courtesy of Lowe's Home Improvement

Optimal Temperature for Hot Water

Although the codes regulate maximum temperatures for some specific fixture types, they don't address optimal temperature. The chart below provides some suggested temperatures for various purposes.

Typical Hot Water Temperatures for Plumbing Fixtures and Equipment	
Use	**Temperature, °F (°C)**
Handwashing sink	105 (40)
Shaving sink	115 (45)
Surgical scrubbing sink	110 (43)
Showers and tubs	110 (43)
Therapeutic baths	95 (35)
Commercial and institutional laundry	140–180 (60–82)
Residential dishwashing and laundry	120 (48)
Commercial, spray-type dishwashing, single- or multiple-tank hood or rack type [wash]	150 min. (66 min.)

Commercial, spray-type dishwashing, single- or multiple-tank hood or rack type [final rinse]	180–195 (82–91)
Commercial, spray-type dishwashing, single-tank conveyor type [wash]	160 min. (71 min.)
Commercial, spray-type dishwashing, single-tank conveyor type [final rinse]	180–195 (82–91)
Commercial, spray-type dishwashing, single-tank rack or door type, single-temperature [wash and rinse]	165 min. (74 min.)
Commercial, spray-type dishwashing, chemical sanitizing glassware [wash]	140 (60)
Commercial, spray-type dishwashing, chemical sanitizing glassware [rinse]	75 min. (24 min.)
Note: Be aware that temperatures, as dictated by codes, owners, equipment manufacturers, or regulatory agencies, may differ from those shown.	

History of Hot Water

Although current codes may define hot water as either 110° or 120°, it was not always so. Prior to the 1973 oil embargo, domestic water heaters were routinely set at 160°, which is their design temperature. ASPE at the time defined "hot water" as 140° or above so that, when a code required that hot water be delivered to a fixture, a temperature of 140° was generally used. With the 1973 embargo, numerous building codes were reexamined for ways to save energy. By 1978, ASPE lowered their definition of hot water to 120° or above and codes were adjusted to require no more than 120° at the point of delivery for most domestic uses.

This effort to save energy by defining hot water lower was matched in the 1980s by water conservation efforts, for example lowering the maximum flow rate through a shower head to 3 gpm at 80 psi, a significant decrease from the flow rate before limitations were initiated of 5 to 10 gpm. This had an ironic and unintended impact on water temperature. In response to an inexplicable increase in scalding incidents in showers (prompting lawsuits against manufacturers), numerous studies found that lower flows from shower heads were far more reactive to temperature changes. For example, one study showed that a full-flowing shower head only rose a few degrees (5° to 7°) when there was a change in water pressure, while a showerhead restricted to 3 gpm could spike 35° to 45° when pressure changed, which could result in a scalding injury within a few seconds.

As a result of the numerous lawsuits, new warnings were added to the labeling and manuals for water heaters along with a manufacturer's recommended maximum setting of 125° or 120°. [Most warnings declared that any temperature above 125° could result in severe scalding or even death.]

Plumbing codes initially focused on setting maximum temperatures only at shower heads, requiring a thermostatic (or compensating) device (or valve) that would insure showers would not deliver water above maximum code limits. More recently, the requirement has been extended to some other fixtures.

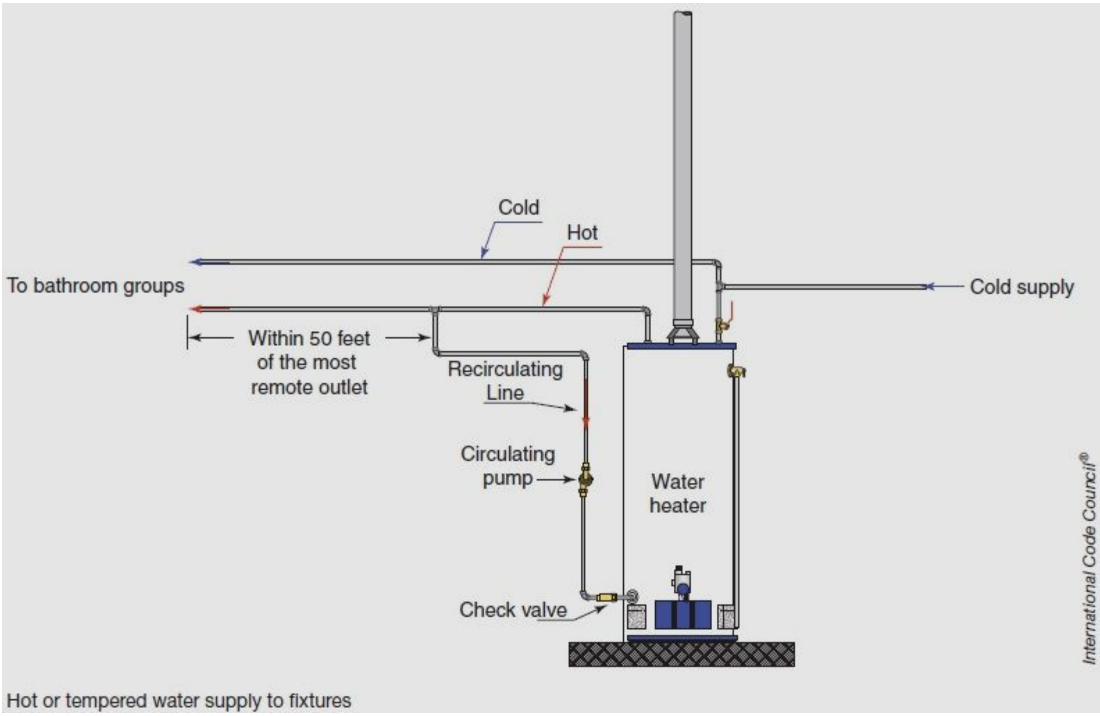
Thermostatic Mixing Valves

As noted in an earlier slide, water heater thermostats cannot be relied upon to control the outlet hot water temperature of a water heater. Although water heater manufacturers have been recommending that installers set thermostats at 120°F to 125°F, and most water heaters are shipped with lower temperature settings, this effort at limiting the temperature has not been sufficient. A water heater is sized based on 140°F, so if the temperature setting is turned down, the user will most likely run out of hot water during peak periods. This can cause a problem if, instead of re-adjusting this valve, the hot water heater is turned up to make the shower warm enough, creating a scalding risk at other fixtures served by the water heater.

Hot water in excess of 120°F is a scalding or thermal shock hazard. Scalding is a burn injury caused by exposure to hot water and can occur anywhere that a hot water system is not designed, installed, or maintained in a safe condition [scalding and thermal shock are addressed in the next lesson.]

The solution to this problem was initially thought to be a simple mixing valve that would blend hot water with cold water to ensure constant, safe shower and bath outlet temperatures, preventing scalding. Recent studies suggest that this may be insufficient in some cases, and that devices that limit pressure spikes along with thermostatic mixing offer more substantial protection.
Pressure-balancing valves address thermal shock by sensing the supply pressure of the cold or hot water; if either one drops, the water flow to the opposite temperature is reduced proportionally to maintain a constant outlet temperature. The balancing of pressure between the hot and cold water is accomplished with either a piston or diaphragm that reacts to changes in water pressure.

Domestic Hot Water Recirculation and Self-Regulating Heat-Trace Systems



Some consumers wish to avoid the wastefulness involved in running water from the hot water tap for a long period before it reaches optimal temperature. There's plenty of hot water available, but it's being stored in pipes that connect to the water heater so that, over time, it gets cold. You could almost think of this stored water as an extension of the storage tank for the water heater, but one where the heating elements have no effect. Where a water heater is distant and/or pipes pass through unconditioned spaces that can get very cold in winter, the wait for hot water can be considerable.

Domestic hot water recirculation systems solve this by pumping water that is being stored in pipes back to the water heater (entering at the bottom) so that it can be reheated and displaced by water that has been heated from the top of the water heater tank. This system means that hot water is always available near the fixtures for ready delivery. The connection to the return system is made near the end of a branch supplying hot water to one or more fixtures needing temperature maintenance. The connection is followed by a balancing valve to throttle the flow and check valve to prevent reversal of flow caused by the discharging of fixtures. The return system passes the water that has dropped below the design temperature back to the water heater to be reheated. The total flow through the system is controlled by the pump. Sizing the return piping is dependent on the flow in each segment.

Since the system is designed to maintain an optimal temperature in the supply pipes, it's critical that the recirculated water is delivered to the pipe through a thermostatic valve. Some of the recirculated water may be routed to the mixing valve instead of back to the water heater so that the mixing in the valve is not done with cold water, but with the warm recirculated water.

A heat-trace system is a much simpler way to achieve a similar result. Similar to heat-trace systems used to prevent pipe freezing, it can minimize heat loss during transport or provide for hot water temperature maintenance at a desired delivery temperature. It's vital that this system, if installed, utilizes self-regulating electrical cable that uses a controller that adjusts the cable's power output to compensate for variations in water and ambient temperatures. It produces more heat if the temperature drops and less heat if the temperature rises so as to avoid overheating the water.

Sample Code

The following is from the 2015 IPC® (and is consistent with the IECC®):

IPC® 607.2.1 Hot water temperature maintenance system controls. For hot water distribution system circulating pumps or and heat-trace, the pumps and heat-trace shall be arranged to be turned off automatically when there is no hot water demand. Ready access shall be provided to the operating controls. This section and Section 607.2.1.1 shall not apply to hot water temperature maintenance system controls in Group R2, R3 and R4 occupancies that are 3 stories or less in height above grade plane. Hot water temperature maintenance system controls in Group R2, R3 and R4 occupancies that are 3 stories or less in height above grade plane shall be in accordance with Section R403.4.1 of the International Energy Conservation Code.

607.2.1.1 Storage tank hot water circulation systems. Circulating pumps intended to maintain storage tank water temperature shall have controls that will limit operation of the pump from heating cycle start up to not greater than 5 minutes after the end of the cycle. Ready access shall be provided to the operating controls.

[SLIDECUT]

[QUESTIONHEADER]

gn_plumbing_electives_ce_01_Q06

What is the maximum permissible temperature at shower-heads (as regulated in the IPC® and UPC®)?	120°F	110°F	140°F	100°F

[QUESTIONBOTTOM]

[SLIDECUT]

Thermal Shock and Scalding

The previous lesson introduced the serious issue of thermal shock and scalding. Scalding is by far the more serious, so it's important to understand how it can be caused. A Harvard Medical School study on scalding looked at what exposures to different water temperatures would produce a first-degree burn (the least serious type of burn, with no irreversible damage). They found that a 3-second exposure to 140°F (60°C) water may produce a first-degree burn, a 20-second exposure at 130°F (54°C), and about eight minutes at 120°F (49°C) before sustaining a first-degree burn (which would therefore only make it a hazard where mobility or ability to evade the flow was compromised).

Time Factor for Skin Damage at Different Water Temperatures (derived from the first evidence of skin damage observed in testing on adult males)	
Water Temperature, °F (°C)	**Elapsed Time (in seconds)**
> 140 (> 60)	< 1
140 (60)	2.6
135 (58)	5.5
130 (54)	15
125 (52)	50
120 (49)	290

That doesn't mean that water temperature has to be above 130°F to present a hazard. The normal threshold of pain is approximately 118°F (48°C), and anyone exposed to 120°F (49°C) water would immediately experience discomfort and the attempt to escape the flow could result in accidental injury. Any hot water in excess of 120°F is a scalding or thermal shock hazard. These two terms are defined as follows:

Thermal shock is a bather's reaction to a sudden change in temperature. Thermal shock injuries are often caused by slips and falls in reaction to a sudden increase or decrease in water temperature. Many injuries occur when a bather steps into a tub of very hot water, slips and falls. Pressure-balancing valves address thermal shock by sensing the supply pressure of the cold or hot water; if either one drops, the water flow to the opposite temperature is reduced proportionally to maintain a constant outlet temperature. The balancing of pressure between the hot and cold water is accomplished with either a piston or diaphragm that reacts to changes in water pressure.

Scalding is a burn injury caused by exposure to hot water and can occur anywhere that a hot water system is not designed, installed or maintained in a safe condition. The degree of the scald burn injury is dependent on the temperature of the water, the amount of time the skin is exposed to the water and the thickness of the skin. The study on which current codes rely suggest it would take at least five minutes' exposure to a greater than 120°F temperature to suffer a second degree burn

How to Prevent Thermal Shock and Scalding

Every year, thousands of people suffer serious thermal shock and/or scalding injuries in showers or combination tub/shower fixtures. This is true, in some cases, even when a code compliant anti-scald or safety shower valve has been installed but not properly adjusted. Anti-scald and safety valves that are not properly adjusted are not "anti-scald" or "safe". Changes in the supply system pressure or temperature can affect the mixed water temperature. An incident can occur when the water heater temperature is adjusted.

It should be noted, however, that many manufacturers, to be safe, ship shower valves with the limit stop adjusted to restrict or limit the valve rotation toward the hot water outlet of the shower valve. This can cause a problem if, instead of re-adjusting this valve, the hot water heater is turned up to make this shower warm enough, creating a scalding risk at other fixtures served by the water heater.

At the same time, lowering the setting on a water heater to 120°F increases the chances that legionella or other bacterial manifestations will be allowed to propagate. Water heaters are designed to operate at 140°F, a temperature sufficient to kill legionella. Any method for mixing water that has been heated to 140°F from the heater with cooler water to bring it down to 120°F or lower (thermostatic mixing valve or supplemental mixing booster tank) can prevent thermal shock and scalding while substantially limiting the amount of time and space bacteria will have to propagate. Through the use of 135°F-140°F water and mixing down to a safe delivery temperature around 120°-125°F, a constant hot water delivery temperature is attained and sufficient hot water is provided for the consumer’s needs without creating a scalding risk.

To set the limit stop on a shower or tub/shower valve:

- Let the water run long enough until both hot and cold water temperatures stabilize.
- Rotate the handle fully to the hottest position.
- Place a thermometer in a plastic container and hold the container in the water stream.

If the water temperature is above the maximum temperature allowed by the local plumbing code, remove the handle and adjust the limit stop to reduce the maximum water temperature to a safe temperature.

Replacements and Alterations

Replacements are also a time of particular hazard. Replacing a water heater changes the temperature in the hot water system along with every other performance characteristic of the system and, if the temperature limit stop on a shower valve is not readjusted when a water heater is replaced, it can easily cause thermal shock or scalding. In many scald cases, a water heater had been replaced but the shower valve was not code compliant. The limit stop should be readjusted on a compensating type shower valve and a non-compensating valve should be replaced with an ASSE 1016 code compliant shower valve. If the non-compensating valve is not replaced, some other form of temperature controls should be added to the system. Temperature control and/or pressure-balancing devices or a combination of devices conforming to ASSE 1017, ASSE 1070, ASSE 1066, or ASSE 1062 can be used.

A system alteration of another component may have the same effect. Some in the plumbing industry fail to realize the need to check limit stops when making system alterations. Altering a plumbing system by replacing components such as a faucet, mixing valve, or piping changes the hydraulic and temperature performance of the system. Pressure imbalances from altered flow rates can cause thermal shock and scald hazards. During an addition or remodel, a code compliant valve should be installed or some other approved temperature and pressure control device should be utilized to minimize the hazard.

It’s also worth noting that a significant number of scald incidents involve two-handle, non-compensating type shower valves. It has been estimated that well in excess of 50 percent of all tub/shower valves in existence today were installed prior to the early 80s and are this type. Pressure-balancing, thermostatic or combination pressure-balancing/thermostatic valves conforming to ASSE 1016 or CSA B125.1 are designed for controlling thermal shock and scalding in showers and tub/shower combination units. ASSE, ASME and CSA recently published a harmonized standard for shower valves.

Conclusion

Plumbers and water heater installers have a thoroughgoing responsibility to take every possible step that may help to prevent thermal shock and scalding. This responsibility will only become more pressing as the population ages and these risks become increasingly widespread.

[SLIDECUT]

[QUESTIONHEADER]

gn_plumbing_electives_ce_01_Q07

According to the Harvard study cited in this lesson, what exposure to 140°F water may cause a first-degree burn on an adult male?	2.6 seconds	40 seconds	20 seconds	Four minutes

[QUESTIONBOTTOM]

[SLIDECUT]

[VIDEOHEADER]

Best Practices (Video)

The focus of this class has been to give you the tools that will help you provide the highest possible level of service to your customers. The goal is to provide something beyond the focus on codes, standards, regulations, and other requirements that is typical of most mandatory continuing education classes. Having that as a focus of continuing education makes a lot of sense. This framework of regulation has been enormously successful in making the plumbing systems of the U.S. safe, effective, and reliable.

Codes and other requirements are, however, a minimum standard and are intended, above all, to protect public health and safety. As valuable as this is, most of us hope to provide something more than a minimally acceptable plumbing system. In order to help you to do that, this class has focused wherever possible on the best practices available to a modern plumber.

We're already well past halfway through this class. The rest of the class will be looking at best practices available for underfloor and underground heating coils fed by water heaters, for sustainable plumbing, and for the prevention of bacterial infestation in water heater tanks.

[VIDEOBOTTOM]

[SLIDECUT]

[QUESTIONHEADER]

gn_plumbing_electives_ce_01_Q08

According to the material provided in this class, mandatory continuing	To support regulatory efforts to protect public health and safety by enforcing	Because working plumbers already know whatever they need to know about the practice	Because codes, standards, and regulations also comprise the best practices for	Because state regulators are only empowered to enforce codes and regulations,

education for plumbers often focuses on codes, standards, and regulations, etc., for the following reason:	minimum acceptable plumbing standards	of plumbing, but may be deficient in their knowledge of codes	plumbers in every case	they shall not require that plumbers pursue education in any areas or topics aside from codes and regs

[QUESTIONBOTTOM]

[SLIDECUT]

Hydronic Heating

An increasingly popular option for home heating (and a potential additional revenue source for plumbers) is hydronic heating, which is typically hot water circulating through piping imbedded under the floor. Hydronic heating can use other fluids aside from water and may be installed in walls or ceilings or could even be used to melt snow or heat pools outside.

Hydronic systems all have the same elements:

- A means to heat the liquid (boiler, standard water heater, solar water heater, or a combination of these elements);

- A pump or pumps to circulate the fluid;
- Thermostatic controls which can easily be configured to heat individual spaces separately;
- PEX tubing (the introduction and acceptance of PEX has aided in the development of these systems); and
- Heat exchangers which can be the tubes themselves or some form of radiator.

The comfort afforded by hydronic heat is considered superior by most people. It's silent (unlike forced air), doesn't require unsightly ductwork and vents, doesn't dry out the air, doesn't force air out through the building envelope through unequal pressure (as does forced air), and heats surfaces so that (unlike forced air) there are fewer cold spots in a room which can make an ambient temperature seem lower. It takes longer to heat a space than forced air, cannot be combined with air conditioning, and may be more expensive to install, but it is more efficient and cheaper to operate in addition to the advantages in terms of comfort. Although forced air can be designed to heat different zones, it lacks the ease of flexibility of zone heating inherent with hydronic systems. Hydronic systems also work naturally with solar power, although the heated water must still pass through a boiler or water heater before entering the system. Hydronic heating is therefore embraced by those seeking green alternatives.

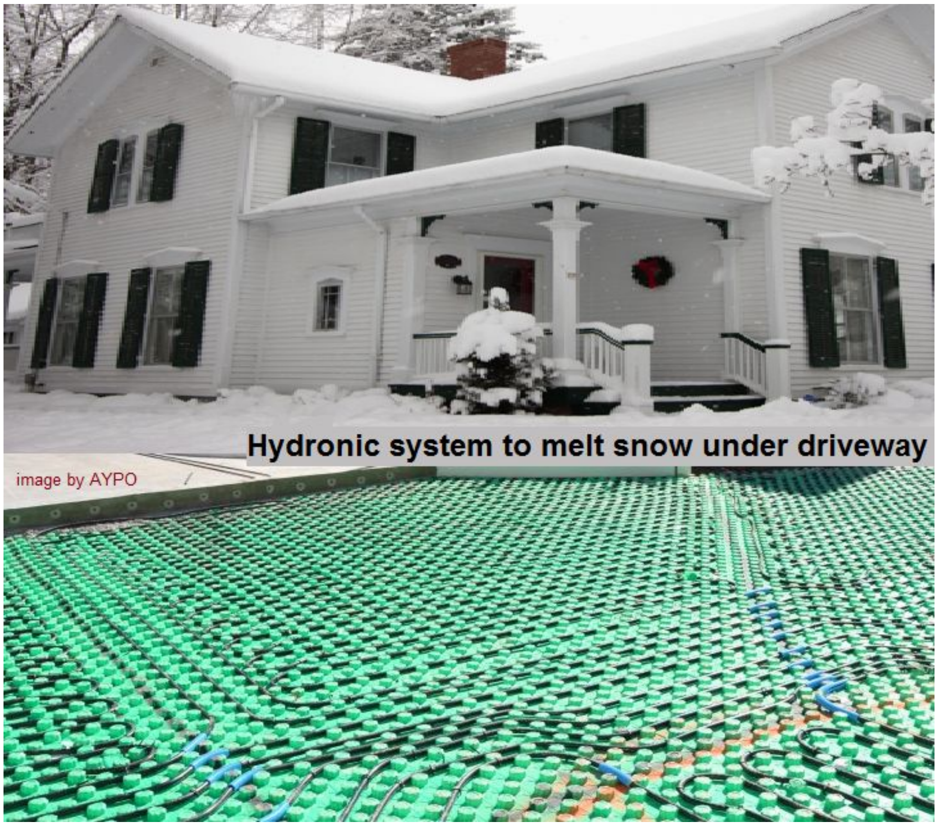
Codes

Both predominant national model codes (the IPC® and UPC®) restrict the temperature setting for a water heater used for hydronic heating to 140°F (unless specifically required to be at a higher temperature by the manufacturer).

This is not because a higher temperature would damage the PEX (which comfortably handles temperatures up to 180 degrees F).

It is also not intended to mitigate the risk that a leaking system at a higher setting could injure someone or damage property. Water damage occurs at any temperature and the leak would have to be so considerable and directed before it would cause injury that a temperature of 140°F would, in itself, be hazardous and a lower limit would need to be enforced.

The rationale for this limit on the temperature of water supplied to hydronic heating is that residential water heaters are engineered to operate safely for their life span at settings up to 140 degrees Fahrenheit. The codes are intended to ensure the longevity and effectiveness of the water heaters.



Protection of Water Supply

In order to address a situation where the same water heater provides both for the residence's potable hot water and water for the hydronic system, the IPC® adopted the following code:

> **IPC® 501.2 Water Heater as Space Heater.** Where a combination potable water heating and space heating system requires water for space heating at temperatures greater than 140°F (60°C), a master thermostatic mixing valve complying with ASSE 1017 shall be provided to limit the water supplied to the potable *hot water* distribution system to a temperature of 140°F (60°C) or less. The potability of the water shall be maintained throughout the system.

Mechanical Code Provisions

Since hydronic systems are intended to heat either spaces or surfaces, the relevant provisions are generally located in mechanical codes. The 2015 International Mechanical Code (IMC®) and 2015 Uniform Mechanical Code (UMC®) each devote their Chapter 12 to the piping used by these systems. Since this class only addresses the water heater component of hydronic heating, the relevant provisions from the mechanical codes can be found in Chapter 10. The following is an example of these provisions:

2015 IMC® Section 1002 Water Heaters.
1002.1 General. Potable water heaters and hot water storage tanks shall be listed and labeled and installed in accordance with the manufacturer's instructions, the *International Plumbing Code* and this code. All water heaters shall be capable of being removed without first removing a permanent portion of the building structure. The potable water connections and relief valves for all water heaters shall conform to the requirements of the *International Plumbing Code*. Domestic electric water heaters shall comply with UL 174 or UL 1453. Commercial electric water heaters shall comply with UL 1453. Oil-fired water heaters shall comply with UL 732. Solid-fuel-fired water heaters shall comply with UL 2523. Thermal solar water heaters shall comply with Chapter 14 and UL 174 or UL 1453.

1002.2 Water Heaters Utilized for Space Heating. Water heaters utilized both to supply potable hot water and provide hot water for space-heating applications shall be *listed* and *labeled* for such applications by the manufacturer and shall be installed in accordance with the manufacturer's instructions and the *International Plumbing Code*.

1002.2.1 Sizing. Water heaters utilized for both potable water heating and space-heating applications shall be sized to prevent the space-heating load from diminishing the required potable water-heating capacity.

1002.2.2 Temperature Limitation. Where a combination potable water-heating and space-heating system requires water for space heating at temperatures higher than 140°F (60°C), a temperature-actuated mixing valve that conforms to ASSE 1017 shall be provided to temper the water supplied to the potable hot water distribution system to a temperature of 140°F (60°C) or less.

1002.3 Supplemental Water-Heating Devices. Potable water-heating devices that utilize refrigerant-to-water heat exchangers shall be *approved* and installed in accordance with the *International Plumbing Code* and the manufacturer's instructions.

[SLIDECUT]

[QUESTIONHEADER]

gn_plumbing_electives_ce_01_Q09

According to the information provided in this lesson, why do the model codes generally restrict water temperature	To take into account that domestic water heaters are designed to provide water at 140°F to promote	Because a higher temperature would damage the PEX used in hydronic piping	To mitigate the hazard that a leaking system at a higher setting could injure someone or damage property	All of these are correct

from water heaters to hydronic systems to no more than 140°F?	longevity for the water heater			

[QUESTIONBOTTOM]

[SLIDECUT]

Green Water Heater Systems

In the past 40 years, the people of the United States, along with most of the rest of the world, have become increasingly aware of the need to conserve both energy and water. Plumbers and manufacturers in the United States have been among the leaders in responding to the challenges of protecting the ecosystem while still providing a high quality of life.

As a working plumber, there are many advantages to your business when you incorporate “green” plumbing practices. You may feel some measure of satisfaction in doing your part to help your community with conservation efforts, but there are more tangible benefits as well:

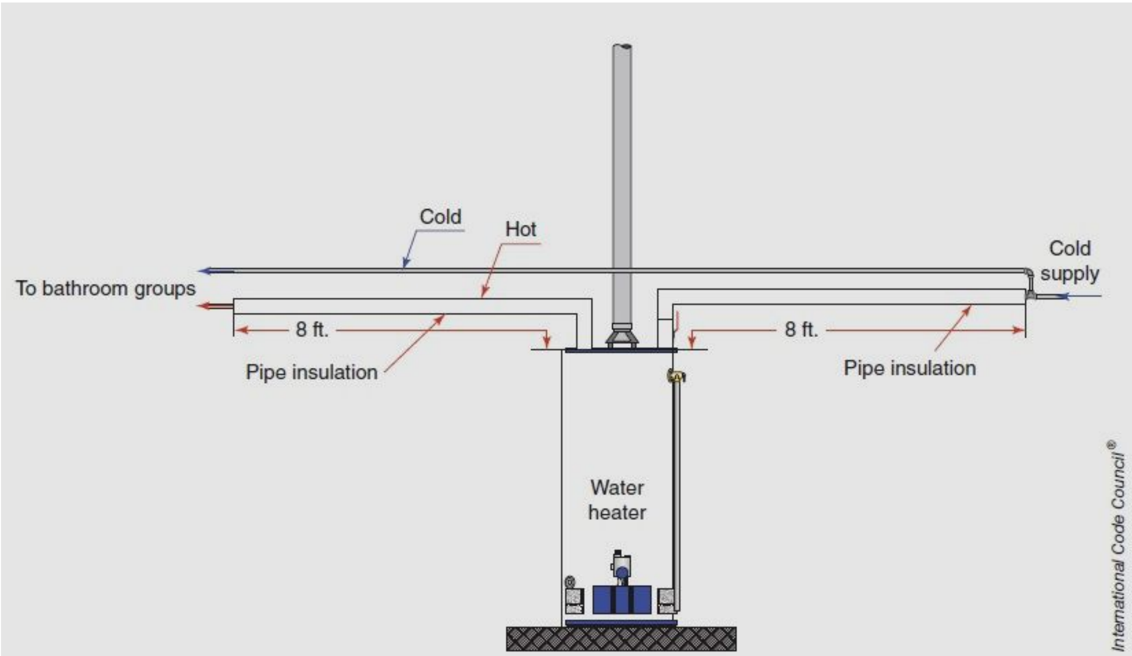
(1) It provides a way to distinguish your business from others in your area. A “green” designation for your practice is valued highly among many customers and may be the main reason your business is chosen ahead of others.

(2) Green practices may have higher upfront costs (which may enhance the profit margin to your business) but almost always provide long-term savings to the customer. This is usually

appreciated and will foster customer loyalty and encourage them to refer your business to others in the community.

(3) Green practices open up new markets, may require more creative solutions, and have beneficial impacts on the environment of the community in which you also have a residence.

Enhanced Water Heater Efficiency



Noncirculating system with no heat traps installed

These efforts have, naturally, extended to water heaters. The most obvious sustainable or "green" plumbing initiative has been to increase water heater efficiency in order to save energy. Energy efficiency is achieved in a variety of ways:

1. Lowering temperatures at which water is used;
2. Increasing insulation of heater and pipes;
3. Using alternative energy sources (e.g. solar);
4. Netting more heat energy from fuel (e.g. more efficient use of fuel gas), and
5. Blocking convection of heated water into pipes when the system is not in use and recovering ambient heat energy.

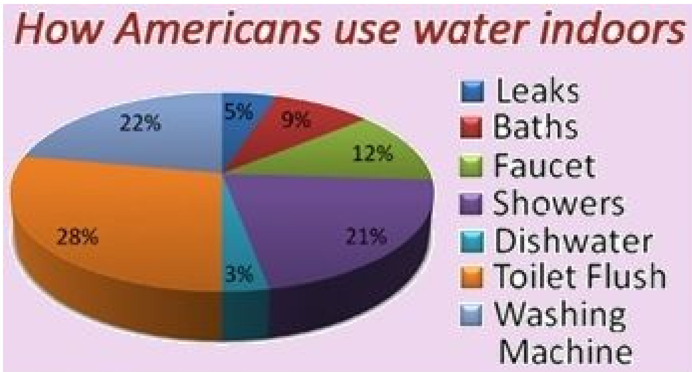
Not only have these efforts helped to make homes and businesses more energy efficient – the net effect of all of these initiatives has the additional benefit of lowering greenhouse gas emissions related to water heater use.

There are numerous strategies that can achieve efficiencies in water heating, such as using heat pumps that transfer energy from the surrounding air to water in a storage tank. These water heaters are much more efficient than electric resistance water heaters and most effective in warm climates with long cooling seasons. The U.S Government's "Energy Star®" program estimates the potential energy savings of four potential strategies in the chart, shown below:

Type of High-Efficiency Water Heater	Energy Savings vs. Minimum Standards	Best Climates	Expected Energy Savings Over Equipment Lifetime	Expected Lifetime	Major Advantages
High-Efficiency Storage (Tank & Pipes)	10%–20%	Any	Up to $500	8-10 Years	Lowest first cost
Elec. Heat Pump	35% (Compared to electric resistance)	Med-Hot	Up to $900	10 Years	Most efficient electric heater option
Demand Recirculating - or - Tankless	45%–60%	Any	Up to $1,800	20 Years	Unlimited supply of hot water
Solar with Electric Back-Up	70%–90%	Med-Hot	Up to $2,200	20 Years	Greatest energy savings using a renewable energy source

[Energy Star® is a voluntary partnership between the government and more than 9,000 organizations, to build more efficient homes and design more efficient products. The Energy Star® logo is obtained from the EPA when standards are met. It identifies new homes, buildings, and more than 50 types of products including windows, heating and cooling equipment, lighting, and appliances.]

Water Conservation

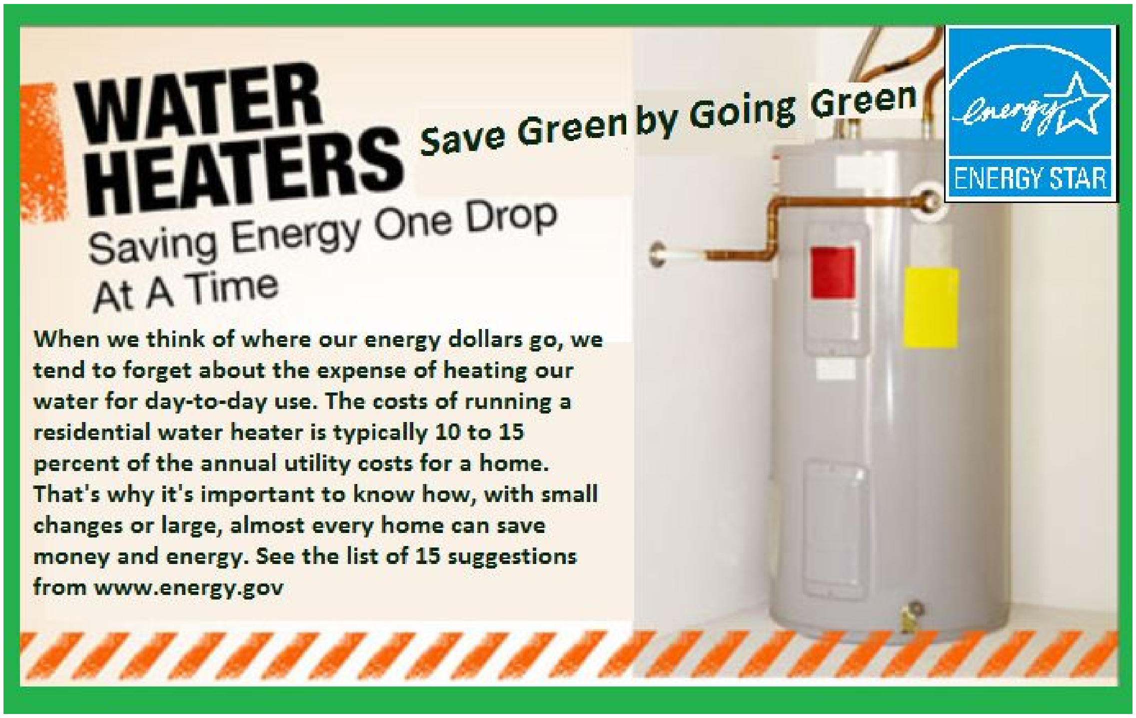


Figures from the E.P.A. 2010

Although energy efficiency has been the main focus for “green” water heaters, the potential savings in water use are not negligible. A large amount of both water (as well as energy) is wasted unnecessarily while running the water and waiting for properly heated water to get to the outlet.

As a rule, when we consider water use in American homes and businesses, we’re talking about hot water more often than not. According to the E.P.A., most commercial structures (other than restaurants) use anywhere from 1% to 10% of the water supplied to the building for human consumption. Even residences typically consume only about 10 to 15% of their water supply (see epa.gov/watersense). The pie chart provided by the E.P.A (above) shows how much of this water is devoted to baths, showers, dishwashers, and washing machines (54 percent), with a significant portion of the water from sink faucets (a total of 12 percent of the “pie”) also delivered as hot or tempered water.

Hot water supply is an area where the proper design of the system is critical to both energy and water savings.


WATER HEATERS
Save Green by Going Green
energy
ENERGY STAR
Saving Energy One Drop At A Time
When we think of where our energy dollars go, we tend to forget about the expense of heating our water for day-to-day use. The costs of running a residential water heater is typically 10 to 15 percent of the annual utility costs for a home. That's why it's important to know how, with small changes or large, almost every home can save money and energy. See the list of 15 suggestions from www.energy.gov

Obviously, not everyone is in a position to go out and buy a new water heater, but we can all do something to use less water and save on our bills. Whether you're looking for no-cost habit changes, low-cost purchases or improvements, or large investments like new waterheaters or appliances, there's something here for you:

1. Take short showers instead of baths. Of course, your savings here depends on your and your family's habits. A long, hot shower may use a lot more hot water than a bath where the tub isn't filled to the brim. But even a bath with only a few inches of water can use a heck of a lot of water if you have one of those HUGE jetted bathtubs! A warm bath is a nice luxury, but for daily bathing stick with a short shower. And if you can stand it, you might even try turning off the water while soaping up, shampooing, or shaving!
2. Reduce your time in the shower. I know I sometimes spend too long in the shower because I'm just too cold to get out! This is anecdotal, but keeping the bathroom door tightly closed seems to keep the air much warmer; just run the fan to take care of the steam. Having a big towel and big fluffy robe nearby also helps!
3. Lower the temperature on your water heater to 120°F; for every 10ºF reduction in temperature, you can save from 3%–5% on your water heating costs. Learn more about lowering your water heating temperature.
4. Don't let the water run. Are you guilty of leaving the water on while you brush your teeth? Or when you step away to grab dirty dishes, or find the soap? All of those extra minutes can add up to a lot of wasted water. It only takes a second to shut it off!
5. Use cold water for most laundry loads, and always use cold water for the rinse cycle.
6. Use your dishwasher efficiently. Wash only full loads, choose shorter wash cycles, and activate the booster heater if your dishwasher has one.
7. Fix leaks. A leak of one drip per second can cost $1 per month. That may not seem like much, but this drip calculator from the American Water Works Association puts it into perspective: at 60 drips per minute, you waste 8.64 gallons per day, 259 gallons per month, and just over 3,153 gallons per year. That is a LOT of good, clean water just going to waste!
8. Install low-flow fixtures. Federal regulations require new showerheads and faucets to have low flow rates. Showerheads and faucets that pre-date 1992 can use more than twice as much water as new ones. For a small investment, you can achieve water savings of 25%–60%. Learn more about low-flow showerheads and faucets.
9. Install heat traps on your water heater tank. You could save $15–$30 on your water heating bill. You may need a professional to help you install them on your existing tank, but some new storage water heaters include heat traps. Learn more about heat traps.
10. Insulate your hot-water storage tank. For electric tanks, be careful not to cover the thermostat, and for natural gas or oil hot water storage tanks, be careful not to cover the water heater's top, bottom, thermostat, or burner compartment. (Follow the manufacturer's recommendations). Learn more about insulating your hot water tank.
11. Insulate the first few feet of the hot and cold water pipes connected to the water heater. Learn more about insulating your water pipes.
12. Install a timer that turns off your electric water heater at night or times when you don't use it. You could also use it to turn off the water heater during your utility's peak demand times.
13. Consider upgrading your clothes washer. ENERGY STAR® says that you could fill three backyard swimming pools with the water you save over the life of a new ENERGY STAR-qualified washer. If you're replacing a washer that's over 10 years old, you can save over $135 per year.
14. Consider purchasing an ENERGY STAR-qualified dishwasher that uses 31% less energy and 33% less water.
15. Consider purchasing a new water heater. Don't limit yourself to just conventional storage water heaters! There are other efficient options that might be right for you. Learn more about your options and considerations when selecting a new water heat

ENERGY.GOV

Heat Recovery and Heat Traps

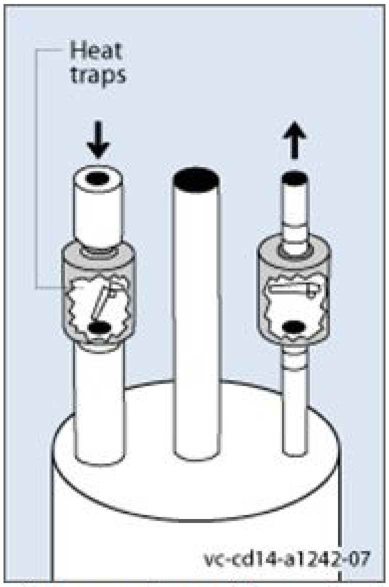


image courtesy of Gummi Joels from his "Go Green" blog

A heat trap is a type of check valve for non-recirculating water systems. It’s a simple way to prevent heated water from the storage tank from rising (as a result of the natural convection of heated water) into a vertical pipe run and displacing the cold water in the pipes. Without the heat trap, the heated water would move from a well-insulated tank into the less well-insulated pipe and force the heater to work harder to heat the new cold water that will now enter at the bottom of the tank. Most newer water heaters incorporate a heat trap as a standard feature. It can also be added as an aftermarket addition. It is highly recommended to do so where the manufacturer did not provide one.

Another way to achieve a higher rate of efficiency is a water heater heat pump system. Unlike a conventional electric water heater heating element, that generates heat energy, heat pump water heaters use electricity to move heat from one place to another. Therefore, they can be two to three times more energy efficient than conventional electric resistance water heaters.

To move the heat, heat pumps work like a refrigerator in reverse. While a refrigerator pulls heat from inside a box and dumps it into the surrounding room, a stand-alone air-source heat pump water heater pulls heat from the surrounding air and dumps it – a higher temperature – into a tank to heat water. Although most often engineered as new installations, it’s also possible to retrofit an existing electric water heater with a heat pump.

Heat pump water heaters require installation in locations that remain in the 40º–90ºF (4.4º–32.2ºC) range year-round and provide at least 1,000 cubic feet (28.3 cubic meters) of air space around the water heater. Cool exhaust air can be exhausted to the room or outdoors. Install them in a space with excess heat, such as a furnace room. Heat pump water heaters will not operate efficiently in a cold space. They tend to cool the spaces they are in.

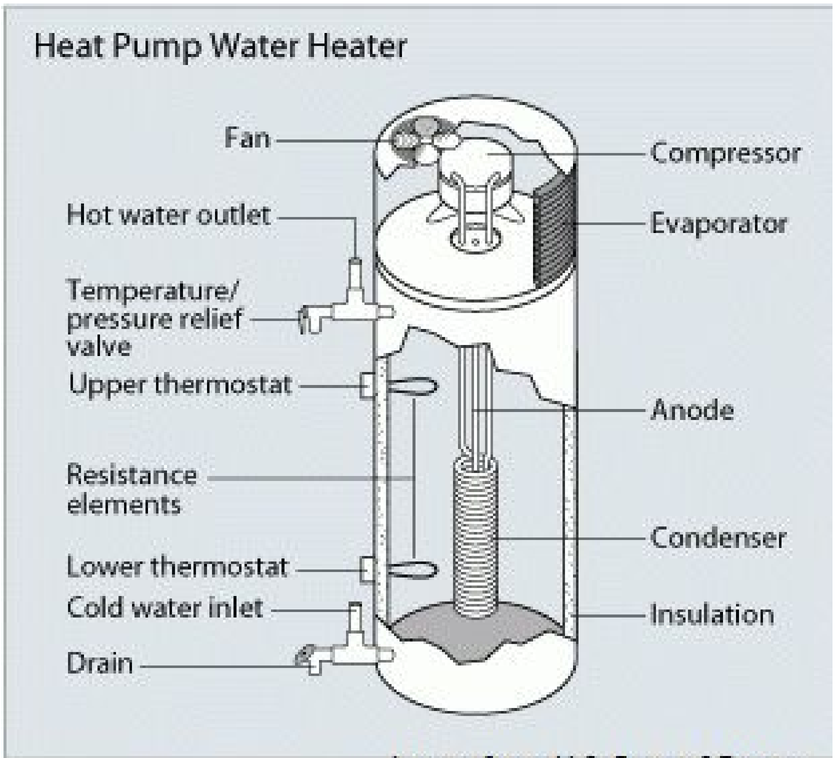


image from U.S. Dept of Energy

Geothermal

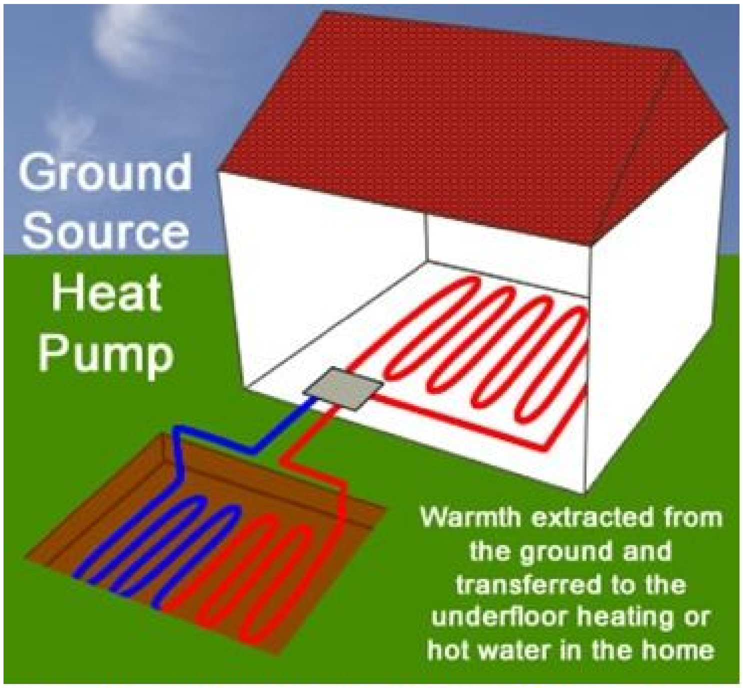
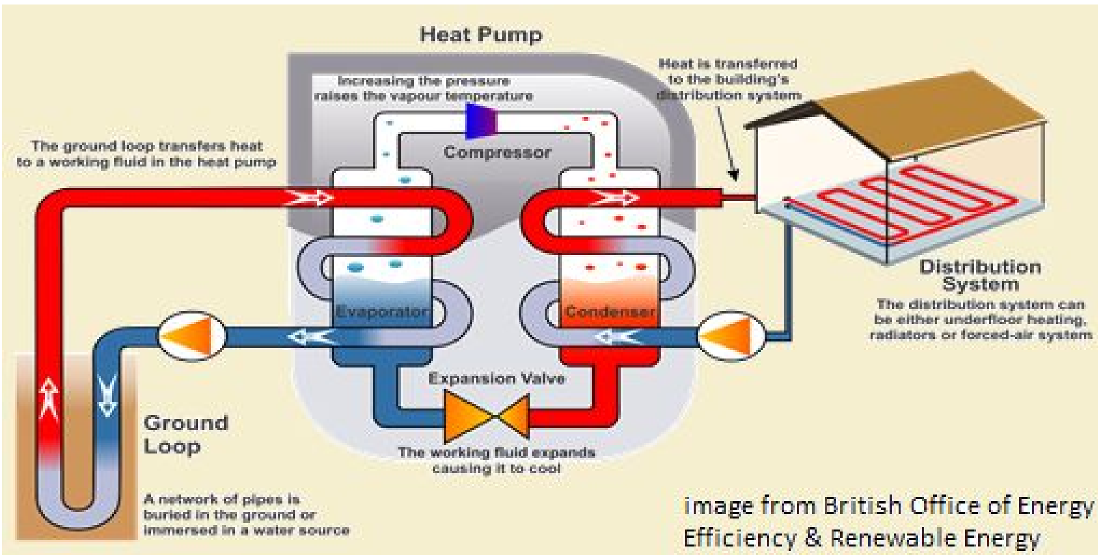


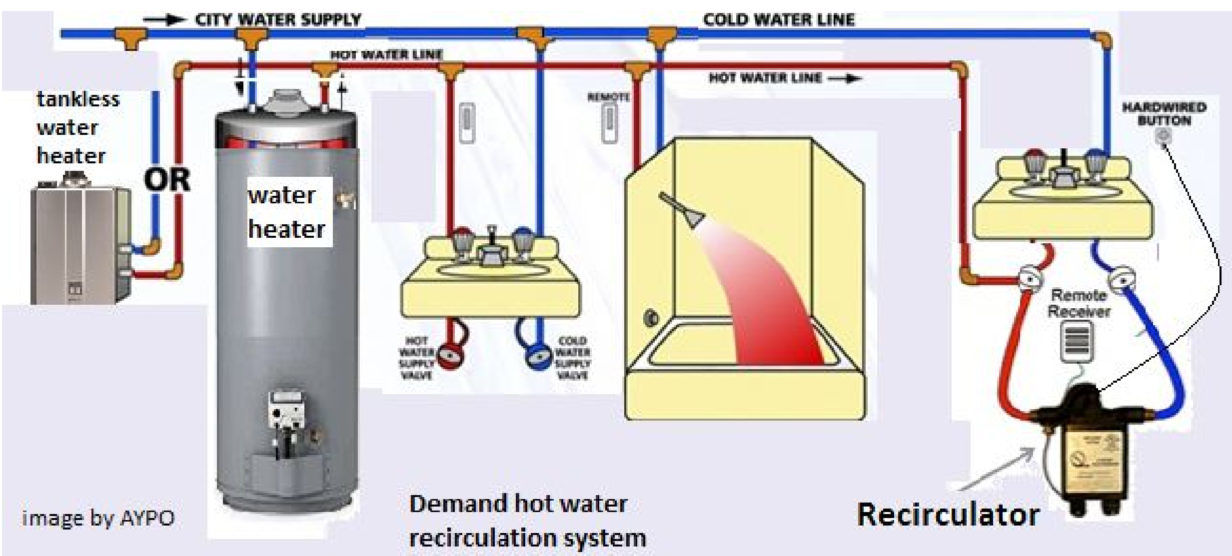
image courtesy Steven Banks Plumbing, Heating & Eco Energies, Ltd

A more involved form of heat pump utilizes geothermal energy to draw heat from the ground during the winter and from the indoor air during the summer. Water heating is accomplished by adding a desuperheater to a geothermal heat pump system. A desuperheater is a small, auxiliary heat exchanger that uses superheated gases from the heat pump's compressor to heat water. This hot water then circulates through a pipe to the home's storage water heater tank. Desuperheaters are also available for tankless or demand-type water heaters. In the summer, the desuperheater uses the excess heat that would otherwise be expelled to the ground. Therefore, when the geothermal heat pump runs frequently during the summer, it can heat all of your water. During the fall, winter, and spring – when the desuperheater isn't producing as much excess heat – a standard heat pump or electric heating element would be needed to heat the water.

[Note: How a residential geothermal system works: Outdoor temperatures fluctuate but, thanks to the insulating properties of the earth, underground temperatures are relatively stable. Only four to six feet below ground, temperatures remain relatively constant year-round. A geothermal system, which typically consists of an indoor handling unit and a buried system of pipes, called an earth loop, and/or a pump to reinjection well, capitalizes on these constant temperatures to provide “free” energy. The pipes that make up an earth loop are usually made of polyethylene and can be buried under the ground horizontally or vertically, depending on the characteristics of the site. If an aquifer is available, engineers may prefer to design an “open loop” system, in which a well is drilled into the underground water. Water is pumped up, run past a heat exchanger, and then the water is returned to the same aquifer, through “reinjection.” In winter, fluid circulating through the system's earth loop or well absorbs stored heat from the ground and carries it indoors. The indoor unit compresses the heat to a higher temperature, as if it were an air conditioner running in reverse.]



Demand Hot Water Recirculating Systems



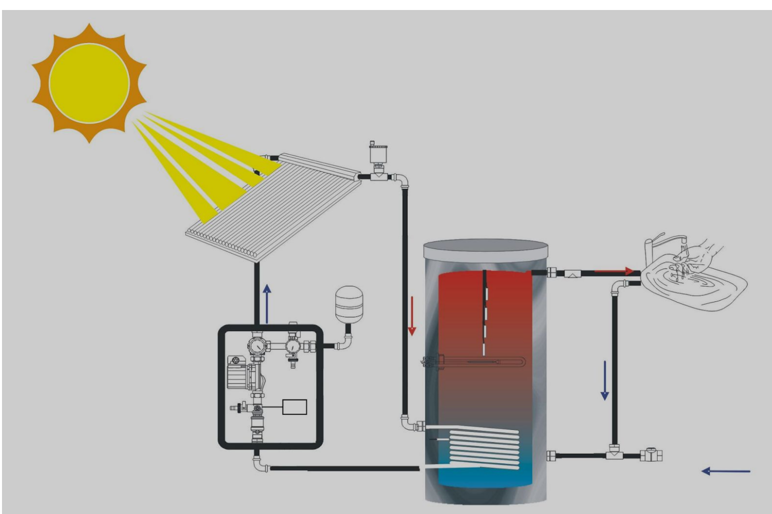
Recirculation systems that operate continuously are NOT considered to be consistent with sustainable plumbing practices. These systems will typically use MORE energy, due to hot water being held in the pipes where it cools and then the cooling water is reheated (where demand for hot water is only occasional) without being used and cycles through again and again in a wasteful energy cycle. In a conventional system with a central water heater, any cold water standing in the pipes between the heater and the point-of-use is dumped down the drain as hot water travels from the heater, wasting water but not using as much energy.

Demand recirculating pumps have the potential to solve the problem of a long wait for hot water at a distant fixture, not wasting water while simultaneously saving energy. In a demand recirculating system, when the system is activated the pump starts recirculating cooled water that's been sitting in the hot water line and sends it back to the water heater through the cold water line. When the water reaches a desired temperature a control turns off the pump. This process is similar to turning on the hot water faucet and letting the water run until it gets hot, but instead of the water going down the drain, it is simply returned back to the water heater — saving energy and water.

As a result, the occupant no longer has to send cold water down the drain while waiting for warm or hot water. Instead, recirculating pumps rapidly pull hot water from a water heater, while simultaneously sending cool water from the hot water lines back to the water heater to be reheated and reused. Demand systems can be controlled by the push of a button, a timer, or motion sensor.

A variation on this is the integrated loop system in which hot water is re-circulated intermittently. Hot water is returned to the water heater through the cold water pipes. This process raises the temperature of the cold water slightly, but it returns to the usual cold temperature in a short time.

Solar Water Heaters



A homeowner can, of course, use photovoltaic solar systems to generate energy and use some of that energy to power a water heater. Thermal solar water heating systems are far simpler. They utilize rooftop collectors to transfer the sun’s radiant energy to a circulating fluid. These can be “passive systems” that work essentially like a garden hose left out in the sun, except the container for the water is much, much larger. The radiant energy is directed to the water in a large, rooftop tank, which then flows down into the plumbing system. If the water has not yet reached the temperature selected on the thermostat, a conventional water heater will need to kick in to finish the job. A more common “active” system transfers the radiant energy to a heat-exchange fluid that is pumped to a storage tank where the water can be heated by that transfer fluid passing through it in copper pipes. Although far more expensive, it has the advantage of working during the cold weather months, as long as there is sunshine to be collected.

Applications for these systems include the water heater that supplies hot water throughout the home, heating the water in a pool, hot tub, or other feature, or for some industrial uses. Solar water heaters for pools are particularly popular. Thermal solar systems are also used to provide radiant heat for some residences, but this application is less common than solar water heating. Solar water heaters became widespread even as PV electric-generating solar systems were only adopted slowly. From 2005 to 2010 the number of U.S. households using solar water heaters increased from 1.6 million to 15.3 million. Most systems were able to supply well over half of typical needs and may fill as much as 90% of household hot water needs.

Aside from systems to be used to heat pools, solar water heating systems require a back-up system for heating water conventionally when the solar system cannot meet current needs, particularly on cloudy days or times of increased demand, as well as to bring water up to a specified temperature where the solar heating was unable to do so. Some local codes require a conventional hot water system to supplement the service of a solar water heater for domestic use.

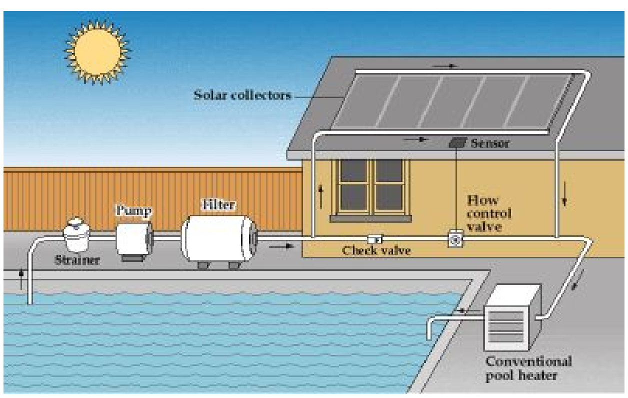


image from U.S. DOE.

[SLIDECUT]

[QUESTIONHEADER]

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According to figures on U.S. water use from the E.P.A. (as reported in this	54%	10 to 15%	20%	80%

class), hot or tempered water comprises at least the following share of total water used in a typical residence:				

[QUESTIONBOTTOM]

[SLIDECUT]

Nasty Microbes

Legionella pneumophila, tinted to be more visible [magnified image from the Centers for Disease Control & Prevention]

As discussed in an earlier lesson, as unfortunate side-effect of energy efficiency for water heaters along with initiatives to prevent thermal shock and scalding was a frightening uptick in incidences of illnesses that have been traced to the microbes that were now allowed to fester in water heater tanks. As you know, many bacteria thrive in a warm, moist, and dark environment, all of which is present in a water heater tank that is not heated to a temperature sufficient to inhibit bacterial growth.

The main concern with regard to bacterial growth in a water heater is Legionellosis, more commonly known as "Legionnaires' Disease." The name was applied after an outbreak of this disease in Philadelphia in 1976 centered among American Legion convention attendees led to the bacterium causing the illness to be named *legionella pneumophila*.

Prevention and control of Legionella bacteria is a major concern in healthcare facilities. While there are several potential sources of the bacteria in hospitals (water features are especially problematic), for the purposes of this section, only Legionella in domestic hot water systems is addressed.

What is Legionnaires' Disease?

Legionnaires' disease is a severe form of pneumonia (a lung inflammation usually caused by infection). In this case, Legionnaires' disease is a form of pneumonia caused by the bacterium known as Legionella. Although Legionnaires' disease primarily affects the lungs, it occasionally can cause infections in wounds and in other parts of the body, including the heart. Older adults, smokers and people with weakened immune systems are particularly susceptible to Legionnaires' disease. [Note: In a hospital, organ transplant patients, cancer patients receiving radiation or chemotherapy, patients with HIV, and surgical patients are most susceptible to Legionella infection.]

The Legionella bacterium also causes Pontiac fever, a milder illness resembling the flu. Separately or together, the two illnesses are sometimes called legionellosis. Pontiac fever usually clears on its own, but untreated Legionnaires' disease can be fatal. Prompt treatment with antibiotics usually cures Legionnaires' disease, although some people continue to experience problems after treatment.

Legionnaires' disease is not contracted from person-to-person contact. Instead, most people get legionnaires' disease from inhaling the bacteria, often when it has proliferated in a water heater and is then delivered in water for a shower. The Legionella bacteria can be found in many domestic hot and cold water systems in trace amounts. There are no health concerns with the bacteria until it colonizes (forming higher concentrations), and the bacteria are atomized and inhaled or aspirated. In most documented cases of Legionnaires’ disease, transmission occurred when water containing the organism was aerosolized in respirable droplets (1–5 micrometers in diameter) and inhaled or aspirated by a susceptible host. No data indicates that the bacteria are of concern when swallowed, and no data supports Legionella being spread through person-to-person transmission.

Temperature Settings and Bacterial Development

Legionella can thrive at temperatures below 115°F. At temperatures from 115°F to 130°F, the bacteria can survive but reproduces more slowly or not at all. Any temperatures above 130°F will kill the bacteria; although – to be safe – some analysts recommend that the minimum temperature setting should be 140°F. There is a delicate balance between providing water that is hot enough to prevent the growth of Legionella bacteria and other organic pathogens, yet is below 120°F at showers and bathtubs and below 110°F at bidets. This can be accomplished by storing hot water at temperatures above 135°F-140°F then using a master mixing valve to distribute the water at about 125°F and using compensating type shower valves with the maximum temperature limit stop adjusted to reduce the maximum temperature to those required by codes.

All available information indicates that almost all bacteria die at temperatures above 130°F (54°C); the higher the temperature, the faster the bacteria die.

Where Legionella May Propagate in the Water Heater System

As mentioned above, available information indicates almost all Legionella bacteria die at temperatures above 130°F (54°C), therefore the most common place where the bacteria can fester is the water heater storage tank. In addition, older piping systems that don't have thermostatic mixing valves at all outlets also cannot be kept at 130°F or above and still deliver water at temperatures that comply with codes. Bacterial growth is most prominent in stagnant areas such as the dead ends of piping. Since they typically grow in the biofilm, scale, slime, and sediment, they are not likely to be abundant in sections of the piping system that are actively flowing and have little biofilm or sediment buildup. Increased water velocity in a piping system can help reduce biofilm, but excessive water velocity can be detrimental to a piping system. Legionella bacteria also can reside in spas, whirlpools, water features, and in the scale buildup on shower heads. There also have been reports of bacteria growing on natural rubber washers.

Other Methods of Controlling Legionella

Although temperature settings and thermostatic mixing valves are the most common means to inhibit bacterial growth, there are other methods that may be needed if a serious colonization of the system by Legionella bacteria has occurred. These include:

- ➢ Heat and flush cycles;
    - Elevate the system temperature to 150°F (66°C) or higher and flush the heated water through every outlet for at least 30 minutes [large quantities of biofilm in the piping system might require additional contact time with the high-temperature water];
- ➢ Copper-silver ionization;
    - A flow-through ionization chamber containing copper-silver electrodes that release positively charged copper and silver ions are released into the water system when electricity is applied. The positively charged ions bond to the microorganisms, causing them to die [recommended only when severe immunodeficiencies require sterilization of the system];
- ➢ Chlorine dioxide injection, hyper-chlorination, filtration/rechlorination, ozonation, halogenization, ultraviolet (UV) radiation, etc.
    - Methods typical of water management which may either kill bacteria throughout the system or only in the immediate area where the treatment is applied. Some treatments may damage piping over time and they are highly unusual outside of medical settings.

Of the above methods, the most immediately available form of disinfection is usually the heat and flush method. This will involve the least capital investment; it can be quickly implemented and, when properly executed, will eradicate most existing bacteria colonies.

Prevention Checklist

ASPE has developed a checklist for existing domestic hot water piping systems to help minimize system-wide Legionella growth.

- ✓ Remove dead legs in the domestic hot water system. Establish a policy of removing leftover piping.
- ✓ Replace heavily scaled showerheads.
- ✓ Extend hot water recirculation lines to the furthest point from the supply to ensure full system circulation.
- ✓ All new piping should be copper, which is more corrosion-resistant than galvanized steel piping. The formation of rust pockets is conducive toward biofilm proliferation and Legionella growth. Corrosion also leads to slime and scale buildup.
- ✓ Change the water and sanitize the integral piping in whirlpools and spas frequently.
- ✓ If the disease is detected and confirmed, disinfection of the piping system will be required.

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[QUESTIONHEADER]

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What is the temperature below which Legionella bacteria has been shown to thrive?	Any temperature above freezing and below 115°F	Any temperature above 115°F	Any temperature above freezing and below 130°F	Any temperature below 100°F

[QUESTIONBOTTOM]

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Best Practices

This final lesson will briefly look at some of the best practices these days that allow a working plumber to provide the highest level of service to customers for their water heaters and the modern comforts the hot water system can provide.

Proper sizing, selection, installation, maintenance, troubleshooting, and deciding whether and how to replace or upgrade an existing water heater is so much more complex than the general public thinks. It requires expertise in the technical, mechanical, and legal aspects, in the physics of pressure and temperature, the chemistry of water and metals, the typical habits of current and future residents, the requirements of appliances to be served by that water heater, the quality, performance, price, and value of the models that will suit the installation, and the things that can go wrong in the installation, initial phases, and long-term. More often than not, this is all to be accomplished in a residence or business whose plumbing system may or may not be well-designed or well-serviced over the years and the details of which are not always clear or easily discovered, but where any problems that arise afterward are certain to be blamed on you, whether or not the work you did contributed to those problems.

Given all these challenges, it’s vital that there is no attempt to cut corners when it comes to water heater installation and servicing or to offer services that try to cut prices by compromising too greatly on quality. As working plumbers, we’re very aware of the dire health and safety risks that can so easily develop if sloppy or defective plumbing is done.

Helping Select the Water Heater

The degree of independent judgment a plumber can utilize when selecting a hot water system varies greatly from one job to another. For the vast majority of jobs, the customer wants your best advice before they make a decision. They don’t want to be talked into anything, but are often open to solid information, if delivered in a collaborative manner. That means that, for any customer that hasn’t begun the transaction by being certain of their selection (most often occurring when they desire a like-for-like replacement), the key is to gather all relevant information before presenting the customer with your best recommendation. The information to be gathered would include:

1. The customer’s budgetary constraints;

2. Understanding the hot water needs, with special consideration with regard to a replacement heater whether the former heater met those needs and whether there has been or is likely to be a change in needs, such as adding another bathroom;

3. Know the brands – the one aspect that gives a professional an advantage over the homeowner when it comes to designing a system is the simple fact that the professional is in a better position to know which brands give the best value and are best suited to the task at hand.

4. Drainage – Only a trained professional will be able to assess and provide for drainage needs in a way that meets codes, protects property, and is accessible for

troubleshooting and servicing [A critical element in communicating the importance of hiring a plumber for water heater installation, servicing, and replacement];

5. Supply and Delivery – very few customers are aware of the critical role of water pressure, both at the point of supply and at the point of delivery. Along with temperature maintenance, one of the first steps in installation, servicing, and replacement is to check all relevant points of pressure and temperature and, if necessary, inform the customer of the need to install the appropriate regulators to provide for a safe, sound, and durable hot water system.

6. Venting – Proper design of the flue and vent system for gas water heaters is a critical safety issue. If not a new installation, be sure to check if any work done since the initial installation has interfered or blocked the vent system in any way and that it is compatible with code requirements.

7. Permitting – An increasing number of states and municipalities are requiring that both installation and replacement of water heaters is permitted by the appropriate authority; a DIY installer may be unaware of this requirement.

Alternate Water Heaters

A tankless gas or electric instantaneous demand water heater has become an increasingly popular option – one that some customers believe they can install in a “plug-and-go” manner. The selection and installation of this alternative is far more complex than it might seem. They may also not understand that an “instantaneous” on-demand tankless water heater will have the same delay in arrival of hot water when it is distant from the point of delivery and the water in the intervening pipes has been allowed to cool. If electric, a tankless water heater will likely require more power than the standard electric water heater it replaces. If gas, the venting needs may affect where the customer would like it located. More importantly, an instantaneous gas water heater is likely to function at a much higher btu than a conventional gas water heater and is likely to require vastly different venting and/or air supply and air replacement and circulation.

Every installation or replacement of water heaters should provide guidance to customers on how they can:

1. Save energy;

2. Save water; and

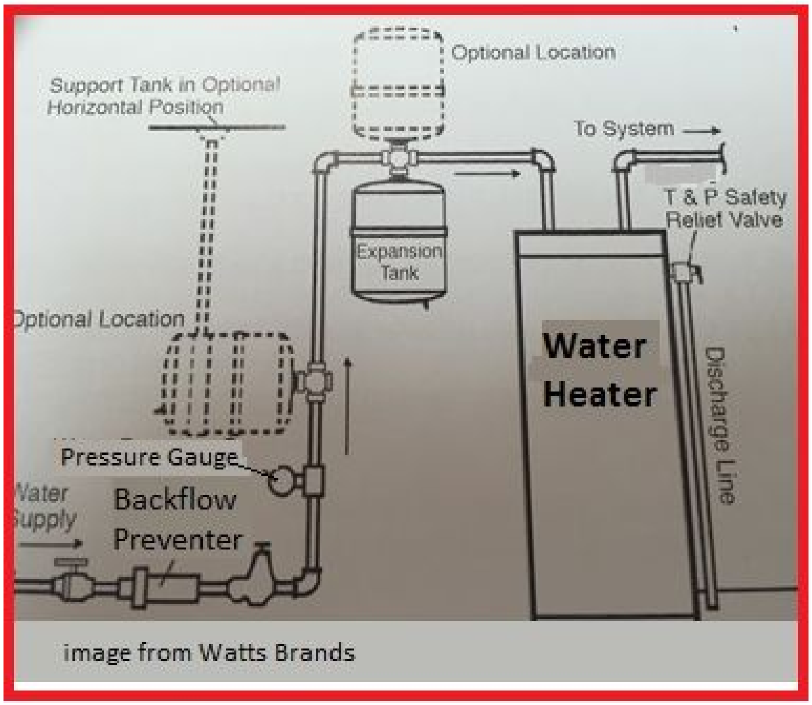
3. Have hot water delivered more quickly

The various options available of recirculating systems, enhanced insulation, self-regulating heat-trace systems should all be evaluated and, if realistic, presented to the customer as the best value for them over the long term.

If looking to install or replace an electric water heater, some customers may be interested in a heat pump water heater system. Be sure to have relevant information on types and brands, rebates (often available from the utility and/or state), and the type of monthly savings in electricity billing they might enjoy. The modern heat pump is vastly improved over earlier models, but many customers are unaware of this as a “green” option.

In general, installing an alternate system will have a higher profit margin for your business, as well as establishing your business as one that cares about the community and the environment.

Expansion Tanks



Few customers are aware of new code requirements for expansion tanks and the reason for as well as best installation of this additional safety feature. Many older homes have no check valve or backflow preventer; if pressure is allowed to back up to the meter, the meter itself could be damaged. The entire system is endangered when there is backflow from the heater. Most newer homes are built with backflow protection, which means that an expansion tank is unquestionably required. If a T&P valve is leaking in an existing system, it might mean that replacing the valve will fix the problem, but it often means that the T&P relief valve is being damaged by being triggered repeatedly. An expansion tank may fix the problem, but only if it is properly installed.

The expansion tank (potable water type) should be installed on the inlet cold-water line. It can be installed anywhere in the building on the cold-water supply (after the regulator). Expansion tanks are limited to a working pressure of 150 psi and up to 200°F, so incoming pressure should be regulated so that it stays within the limits suggested by the manufacturer. Although vertically-installed expansion tanks can be supported by some horizontal pipe branches, any additional support that can be installed should be added, whether it’s a wall-mounted bracket that uses stainless steel bands to secure and support the tank or an iron band from the ceiling to a “belly strap” on the tank to the ceiling. Horizontally-installed tanks, of course, must be fully independently supported.

When adjusting the air pressure in the tank (never assume the manufacturer precharge of the tank is adequate for your installation) make sure to get a water pressure reading on a cold-water spigot when the line is not already hot. Once it’s installed, turn the water back on and bleed the air out of the water heater and allow hot water to run until it comes out clean. If a laundry sink is available, it’s a good option for this purpose since it usually has no aerator that mineral deposits in that early flow can clog.

Maintenance

It is recommended that the T&P relief valve be tested annually. Depending on water quality and type of use, the tank should be periodically drained and flushed. The sacrificial anode should be checked with every maintenance visit. If more than one anode, they must be replaced at the same time even if one is more worn than the other.

Commercial clients are often more open to having a maintenance contact while private customers are far more likely to only call for emergencies or clear and pressing needs. The truth is that regular maintenance can vastly extend the lifespan of the water heater as well as ensure its optimal performance. In many cases, the cost of maintenance is less than or comparable to the costs of replacement or emergency calls that may result from inadequate maintenance.

The expansion tank should be also checked every time you do plumbing work. One factor to be aware of is that the membrane in an expansion tank that separates the water from the compressed air is semipermeable and will allow a small amount of air to travel through the membrane at a rate of around 1 psi per year. If the tank has lost enough of an air charge over enough of a time period, it could rupture and be overtaken by the water pressure. If the tank was not installed correctly, the membrane could rupture in normal operation. When checking the tank, it may be obvious that the tank has become waterlogged (i.e., water where air should be), or pressure on the Schrader core could cause water to come out instead of air. If the tank has lost enough of an air charge over enough of a time period, it could rupture and be overtaken by the water pressure.

If the T&P relief valve needs replacement, consider installing a replacement expansion tank as well in case it has suffered from the same over-pressure situation that damaged the T&P valve.

What to Do About DIY Plumbing

One of the great wildcards when performing maintenance or repairs is the potential damage from amateur work that preceded you. It should be emphasized that homeowner do-it-yourselfers relying on YouTube video instruction is most often the reason, but a handyman in a commercial setting or a contractor who affected the plumbing when completing another type of job (such as a kitchen remodel) often qualifies as an amateur if not licensed to do plumbing work. On some rare occasions, the work of a previous plumber will be deficient.

The key in every case is to be sure of two things:

1. That the customer is fully informed of what kind of previous work created problems; and
2. That you are tactful when communicating it. If a DIY situation, the person you inform may be the one who did the work and does not want to be shamed. If a contractor, it is unethical and unprofessional to criticize the work of a colleague unless it has created a clear safety hazard or was demonstrably fraudulent.

At the same time, it is also wise to highlight the quality and value of the work you are proposing or have already done. As a working plumber, you not only represent yourself but the entire trade. Making a customer aware of quality and value will help the customer decide to contact a plumber for future work, helping to ensure that their safety and needs will be best met. Many customers will not be aware of the services you've offered but ALL will be aware of the amount charged for the work.

Finally, don't compromise on safety and make no compromises on quality that are not made to meet the explicit demands of the customer. The most vital best practice when it comes to water heaters is not to offer the lowest price, but a fair price that still provides a high-quality product and professional workmanship while providing for your financial well-being and the well-being of your company.

We're at a wonderful time when it comes to safe and efficient water heaters that can meet and exceed the quality of life demands of our customers. We owe the customer our best practices to continue to make that possible.

[SLIDECUT]

[QUESTIONHEADER]

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Should special provisions for venting be made when replacing a conventional water heater with a tankless, instantaneous gas water heater?	Yes - since a tankless, instantaneous gas water heater often operates at a higher btu, venting needs are likely to be more demanding	No - whatever venting was provided for the conventional gas water heater is always sufficient for a tankless model	No - tankless, instantaneous gas water heaters are designed so as not to require venting	Yes - codes require tankless, instantaneous gas water heaters to have powered venting; most conventional models do not

[QUESTIONBOTTOM]

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End of Class (Video)

That completes this class on water heaters, offered as an elective for continuing education credit for licensed plumbers.

The class focused, in particular, on how to make sure the water heater system never presents a serious hazard in terms of illness, scalding, or explosive pressure. We also had a chance to review some key codes and standards, addressed numerous ways to make the hot water system more efficient, and touched on some of the smaller, yet still troubling, problems that may arise in a water heater system and how they may be fixed or prevented.

A properly designed domestic hot water distribution system should do the following:

- ➔ Provide adequate amounts of water at the prescribed temperature to all fixtures and equipment at all times of use;
- ➔ Perform its designed function safely;
- ➔ Utilize an economical heat source;
- ➔ Contribute to a cost-effective, efficient, and durable overall plumbing installation;
- ➔ Provide an economical operating system, with reasonable maintenance demands placed on users; and
- ➔ Minimize risk to those using the fixtures it serves.

More than that, the water heater system should exceed every demand placed on it during its normal use and comply with all the best practices and designs available to the modern plumber, within reasonable budgetary restraints. This class is intended to sharpen the tools you already have to accomplish all those aims.

Thank you for taking this continuing education class from AYPO. Think of us again when you or a colleague have additional continuing education needs.

[VIDEOBOTTOM]

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[QUESTIONHEADER]

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From the information provided in this class, is there any reason to advise users not to consume water from direct-fired storage-type water heaters and, if so, what is the reason?	Yes – in part, because the sacrificial anodes in the storage tank will leach aluminum (a toxic substance) into the water	No – when most potable water pipes were made from lead, it made sense, but that is no longer an issue	Yes – because Legionella bacteria can cause severe illness if ingested	No – in fact, since it has both been heated and stored so that some sediments will be removed, it is safer to drink than cold water from the tap

[QUESTIONBOTTOM]

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