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Measure Guideline: Transitioning to a Tankless Water Heater

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IBACOS, Inc.

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Building America
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Definitions

BEopt	Building Energy Optimization software
Btu	British thermal unit
EF	Energy factor
gpm	Gallons per minute
ICC-ES	International Code Council Evaluation Service
PEX	Cross-linked polyethylene
UPS	Uninterruptible power supply
VAC	Volts alternating current

Executive Summary

This Measure Guideline was developed to help residential builders and retrofitters transition from tank-type water heaters to tankless water heaters. More specifically, it will aid in the design, specification, selection, implementation, installation, and maintenance of tankless water heaters.

Tankless water heaters are compact, wall-mounted units that provide hot water as needed, without storing it as traditional tank-type water heaters do. A tankless water heater is a highly efficient system when it is carefully specified and selected, appropriately sized, centrally located, properly installed, and regularly maintained. When included with other energy-saving measures in a residential new construction or retrofit project, a tankless water heater can become part of an energy-efficient, systems-integrated measures package. Tankless water heaters are becoming more popular throughout the home construction and retrofitting industries as new energy codes and voluntary compliance programs continue to raise their energy savings targets. This Measure Guideline is intended to provide builders, retrofitters, and other industry professionals with useful information on how and when to adopt tankless water heaters and how to maximize their benefits.

This Measure Guideline is organized into three main sections to address the adoption of tankless water heaters. Section 2, Home and Document Inspection, examines the issues that must be anticipated and addressed during the design, construction, and warranty periods. Section 3, Tradeoffs, presents a cost and performance analysis of selection criteria for tankless water heaters and provides an overview of interactions between the tankless water heater and other functional elements of a house. Section 4, Measure Implementation Details, provides a more detailed description of the installation considerations of tankless water heaters, including risk identification and mitigation.

1 Introduction

This Measure Guideline aids in the specification, selection, sizing, location, implementation, installation, and maintenance of gas-fired and electric tankless water heaters. These units, in conjunction with improvements to the water distribution system, can reduce water and energy consumption in new and retrofit construction. Such savings are critical for builders and retrofitters as new energy codes and voluntary compliance programs continue to raise their energy savings targets.

Tankless water heaters, as shown in Figure 1, are compact units that provide hot water as needed, without storing it as traditional tank-type water heaters do. When a hot water tap is turned on, cold water enters the unit from the cold water supply. A sensor detects the water flow and activates a heating device, which quickly raises the water temperature to a preset level. When the water flow from the fixture or appliance stops, the heating element shuts off. Unlike traditional tank-type water heaters, tankless water heaters do not store a reservoir of hot water. They significantly reduce *standby losses*, which makes them an energy-efficient alternative to traditional water heaters. Tankless water heaters can thus significantly reduce home energy use and can help customers save on utility costs.

> **Important Definition:**
> *Standby losses* – In a tank-type water heater, water loses heat to its surroundings when it is warmer than the surroundings (which is typically the case). This energy loss, which can occur when the unit is waiting to be used, causes the water temperature in the tank to drop. To make up for this energy loss, the water is reheated to maintain the preset temperature and consequently uses energy when there is no demand for hot water.

Figure 1. Tankless water heater

This Measure Guideline explains the benefits, in terms of energy savings and customer satisfaction, of a tankless water heater over a tank-type water heater and helps builders and retrofitters who would like to adopt tankless water heaters. This guideline also identifies the potential issues associated with the specification, selection, sizing, location, and installation of tankless water heaters and provides risk mitigation strategies. In addition, the guideline covers cost and constructability considerations, such as hot water demand, equipment costs, operation costs, water distribution options, and maintenance requirements. Also presented are several options of tankless water heaters that influence their overall cost and performance. Finally, this Measure Guideline provides installation considerations for a tankless water heater to ensure high-quality results.

This Measure Guideline is intended to help a variety of industry professionals make informed decisions about whether to adopt tankless water heaters as an energy-saving measure. These professionals try to minimize cost increases by adopting new energy-saving measures that align as closely as possible with their current construction practices and that involve the fewest possible significant design changes. Thus, architects, engineers, illustrators, and other professionals can use this guideline as a reference for making informed design changes. Builders, retrofitters, and specifiers will find information about important aspects of the design and specification, installation, and warranty phases. Plumbing trade contractors also can use this guideline to scope new work proposals and to reinforce their awareness of the benefits and risks of installing tankless water heaters. Overall, this Measure Guideline offers guidance on how to maximize the benefits of tankless water heaters.

2 Home and Document Inspection

Tankless water heaters can provide many energy- and cost-saving benefits, as well as flexibility, durability, reliability, and comfort. Compared to tank-type water heaters, tankless water heaters have a longer life expectancy, may use significantly less energy to operate, and can deliver more hot water per hour. Because they are small and wall mounted, they require less floor space; therefore, they can be installed in a variety of indoor (and some outdoor) locations. To maximize the comfort, reliability, and durability offered by tankless water heaters, the potential issues associated with their use must first be identified and addressed. This section focuses on the issues associated with specifying, sizing, locating, installing, and maintaining tankless water heaters and provides strategies to successfully mitigate any problems. A better understanding of these issues before a system is selected can ensure greater customer satisfaction.

Ultimately, a gas-fired tankless water heater provides the same function as a tank-type gas-fired water heater; however, it does so with slightly different componentry. In a tank-type gas-fired water heater, the incoming cold water flows into a tank, and a gas burner heats a large volume of water. A tankless water heater uses a gas burner and heat exchanger assembly that efficiently transfers the heat energy from the fuel source to a small volume of water that is flowing through the water heater on its way to the fixture in need. Many tankless water heaters can modulate the heat output on the flow of water running through the unit, so occupants receive the same output water temperature at differing velocities. It is important to note that there is a short delay (1–3 s) between the time when the water begins flowing and when the heater's flow detector activates the heating elements or gas burner. Figure 2 illustrates the main components of a gas-fired tankless water heater: heat exchanger, burner, valve, fan, flow sensor, gas line, and incoming and outgoing water lines.

Critical Takeaway:
How much and how quickly a tankless water heater provides water depend on factors such as the capacity of the unit, the cold water inlet temperature, and the efficiency of the water distribution system.

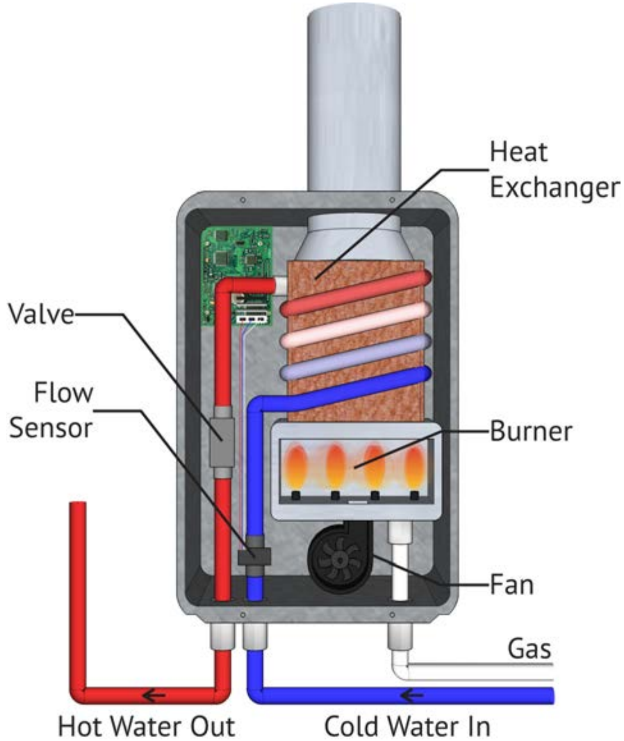

Figure 2. Components of a gas-fired tankless water heater

Tankless water heaters can provide continuous hot water, but their ability to meet occupant demand for instantaneous and limitless hot water is significantly affected by several important factors. Before specifying a unit, it is important to identify a tankless water heater of the appropriate size or capacity, often measured in gallons per minute (gpm), based on demand and the incoming water temperature. The demand for hot water is related to the number of water fixtures in the house, and the incoming water temperature is related to climatic conditions. Whether conventional or tankless, the location of the water heater in the house has an impact on hot water delivery. To provide the most comfortable and reliable performance, a water heater should be located centrally or as close as possible to the points of use. It also is important to minimize the plumbing runs to each point of use, as well as to install or retrofit (where practical) plumbing lines of the appropriate diameter for each point of use. Furthermore, the cold water supply must be evaluated because hard water will damage the tankless water heater. The following sections explore the issues that must be addressed during the specification, selection, and installation of tankless water heaters.

2.1 Unit Sizing

The size of the tankless water heater determines its capacity—its *flow rate* measured in gpm—to meet the demand for hot water. The maximum demand at any given time, as well as the *temperature rise* that will be needed, must be used to size the unit. Manufacturers provide charts to help builders and retrofitters determine the unit size needed for the maximum flow rate of hot water demanded and the maximum temperature rise needed. It is important to select a tankless water heater with the capacity needed for the climate in which the house is located. A house in a cold climate has a higher demand because energy is needed to raise the temperature of the cooler ambient incoming water to the desired temperature. If the unit is too small, the hot water supply will be limited.

Important Definition:
Flow rate – The volume of water passing through a pipe, typically measured in gallons per minute (gpm).

Important Definition:
Temperature rise – The difference between the incoming water temperature and the desired output temperature.

2.2 Unit Location

The location of the tankless water heater within the floor plan directly affects its performance. During specification and layout, it is good practice to locate a tankless water heater centrally between multiple points of use to keep plumbing runs as short and direct as possible. The location also should favor closeness to major hot water users such as the main bathing and showering bathroom. Keeping the unit close to its delivery point will enable the hot water to arrive at its destination sooner and at a warmer temperature. This practice also should be followed when installing a unit in a retrofit where possible, although making changes to an existing water distribution system would be expensive. In some climate zones, a tankless water heater that is specifically designed for the application may be installed on an outside wall to facilitate greater flexibility for location. The cost and performance tradeoffs of any installation must be considered.

2.3 Water Distribution System

Although a tankless water heater can produce hot water quickly, the hot water must flow from the water heater to the point of use. The pathway of piping from the tankless water heater to an individual fixture or appliance directly affects how long it will take for the hot water to arrive at the point of use. A properly installed homerun water distribution system (as discussed in Section 3.2.1) delivers hot water quickly, whereas a traditional trunk and branch water distribution system delivers hot water more slowly because the water travels a longer distance through piping. During specification, it is important to consider the water distribution system and, if possible, to install a homerun plumbing system to maximize the benefits of a tankless water heater. In a retrofit, outfitting the house with a homerun piping distribution system may not be feasible, and it is important to consider the impact of the existing plumbing system on how well a tankless water heater will deliver the hot water to the fixtures. An on-demand recirculation system added to the distribution system can be used to activate the water

Critical Takeaway:
During specification and layout, it is good practice to locate a tankless water heater centrally between multiple points of use to keep plumbing runs short and direct.

Important Definition:
Point-of-use unit – A small tankless water heater that services one to three fixtures or appliances at the point of demand rather than being centrally located.

heater before a hot water valve or faucet is opened, thereby reducing wait times for hot water and minimizing wasting of water.

2.4 Plumbing Line Length and Diameter

The length and diameter of individual plumbing lines directly affect the rate at which the tankless water heater will deliver hot water to the individual points of use. Therefore, the plumbing lines running to individual points of use must be appropriately sized. Pipe diameter significantly affects the wait time for hot water. The larger the pipe diameter, the more water will remain in the line after the fixture is turned off. It is critical to size each plumbing line so only the needed amount of water is heated. When a fixture or appliance is turned on, any cold water remaining in the plumbing lines is pushed out first; the longer the plumbing line and the greater its diameter, the more water will remain in the line after use has stopped.

> **Critical Takeaway:**
> It is critical to size each plumbing line so only the needed amount of water is heated.

For example, if a ½-in.-diameter cross-linked polyethylene (PEX) pipe 50 ft long held 0.46 gal at a flow rate of 1 gpm, it would take 28 s for all the cold water to be pushed out and for hot water to reach the fixture or appliance. However, if the same 50 ft of PEX pipe were only ⅜-in. in diameter and consequently held only 0.25 gal of water at a flow rate of 1 gpm, this same operation would take only 15 s.

The water pressure in the distribution system also will affect the velocity of water in piping with low-pressure systems, causing water to move more slowly. These types of low-pressure systems are quite common in older homes.

2.5 Water Quality and Maintenance

Tankless water heaters have a risk of corrosion from *scaling*—scale and lime from calcium and other minerals in the water supply that build up in the copper heat exchanger inside the unit. Although scaling also occurs in tank-type water heaters, the scaling builds up at the bottom of the tank and has much less effect on the water flow and tank performance than with a tankless water heater. Scale in a tankless water heater can restrict the flow of water through the heat exchanger and diminish the life of the unit.

Tankless units should be flushed according to the manufacturer's instructions to prevent calcium buildup that can decrease efficiency, restrict water flow, and damage the unit. Manufacturers will recommend different flushing frequencies, depending on the model, frequency of use, and water quality. Flushing frequency can vary from twice per year to once every three years, depending on the manufacturer and individual use patterns.

> **Important Definition:**
> *Scaling* – A buildup of mineral deposits on the interior of a water heater from the formation of scale inside the heat exchanger or other components.

Manufacturers also have varying requirements for the use of water softeners. If the hardness of the supply water exceeds 8 grains per gal (136 ppm) to 14 grains per gal (239 ppm) or higher, manufacturers may require that a water softener be installed to maintain efficiency or prevent unit failure.

2.6 Water Heater Performance—Frequent On/Off Use

A relatively infrequent minor comfort issue affecting tankless water heaters is commonly known as the *cold water sandwich effect*: the introduction of cold water into the hot water supply line during frequent on/off operations. When this occurs, occupants may experience a sudden drop in water temperature for a few seconds. This issue is rare because most units remain in a "ready to fire" state; therefore, if water flows through the heater within the first minute following water flow stoppage, the water heater will fire back up within 1–2 s. The effect does not appear during steady uses of water; it occurs only during frequent on/off operations, which are uncommon. This issue cannot be completely removed from tankless water heaters because safety standards require a delay in their ignition sequence. However, if occupants experience comfort issues, a possible remedy recommended by several manufacturers (Rinnai 2008; Takagi 2012) is to install a storage tank on the hot water pipe from the water heater to handle this effect. The added storage tank will experience standby losses, so the efficiency of the water heating system will decrease as a result. Other approaches were suggested by Burch et al. (2008).

> **Important Definition:**
> *Cold water sandwich effect* – The undesired introduction of cold water into the hot water supply line on occasions of frequent on/off operations.

2.7 Electrical Backup

The electric controls of a tankless water heater, similar to those of other electronic ignition water heaters, are not operational during a power outage. In this case, an uninterruptible power supply (UPS) battery backup would be needed to keep the tankless water heater operational during power outages. A UPS battery backup should have enough capacity to handle the electricity needs of the water heater.

2.8 Code Issues

Tankless water heaters are covered by the same code provisions as tank-type water heaters, except that a combination pressure and temperature relief valve is not required on tankless water heaters per ANSI Z21.10.3 (ANSI 2011). However, local codes may require a pressure and temperature relief valve. In accordance with the manufacturer's installation instructions, a pressure relief valve is required for tankless water heaters.

Water heating equipment is covered by the International Residential Code (2009) in the following locations within that code:

- Chapter 20 – Boilers and Water Heaters
- Chapter 24 – Fuel Gas
- Chapter 26 – General Plumbing Requirements
- Chapter 28 – Water Heaters

It also is covered by the International Plumbing Code (2003) in the following locations within that code:

- Chapter 3 – General Regulations
- Chapter 5 – Water Heaters

2.9 Trade Resources

Although tankless water heaters are not new to the residential construction industry, they may be new to local plumbing trades. Manufacturers can usually provide local plumbing contractors with training specific to their products.

3 Tradeoffs

The following sections explore the criteria for selecting a tankless water heater over a tank-type water heater, interactions with other building systems that may affect their cost and performance, and variations among tankless water heaters that have cost and performance implications.

3.1 Measure Selection Criteria

Tankless water heaters offer many benefits over tank-type water heaters. Although the initial installed cost of a tankless water heater is significantly higher than that of a tank-type water heater, the tankless water heater costs less annually to operate. Table 1 shows that the initial cost of a tankless water heater is 1½–2 times as much as that of a tank-type water heater.

Table 1. Initial Cost of Tank-Type and Tankless Water Heaters in New Construction

Water Heater	Initial Cost[a]
Gas	
Gas Tank Type	$ 700
Gas Tankless Conventional	$1,160
Gas Tankless Condensing	$1,760
Electric	
Electric Tank Type	$ 500
Electric Tankless	$ 650
Electric Heat Pump	$1,400

[a] All prices are industry averages. (Source: BEopt, version 1.1)

Depending on the fuel type and efficiencies of a tankless water heater, it can cost 5%–40% less annually to operate than a tank-type water heater using the same fuel type. The efficiency of a water heater is determined by its energy factor (EF), a value determined by standardized testing. The higher the EF rating, the more efficiently the unit uses energy. As with automobiles, the actual efficiency of the product depends on the operating conditions. The EF for residential gas-fired tank water heaters can be 0.57–0.70. Gas-fired tankless water heaters typically have an EF of 0.82–0.94, depending on whether it is a standard or condensing unit. Recent research has shown that the EF value for tankless units may be derated for additional thermal losses (Burch et al. 2008).

Using the energy modeling software BEopt, a two-story, three-bedroom house was modeled with different natural gas-fired water heaters using typical EF values. Based on this modeling, the operating costs and source energy use of three different water heaters are compared in Figure 3 and Figure 4, respectively.

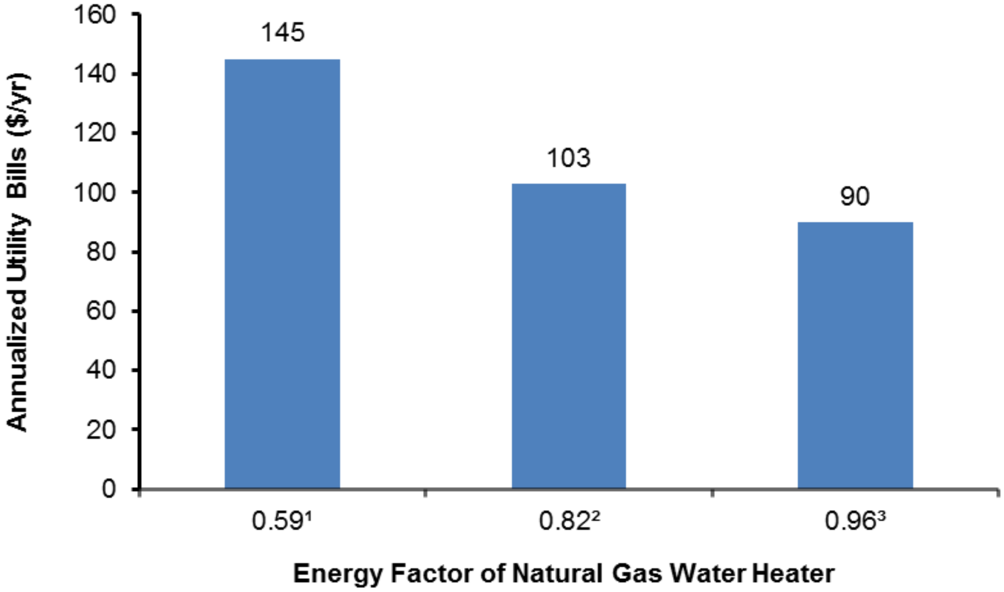

Figure 3. Operating costs of different gas-fired water heaters

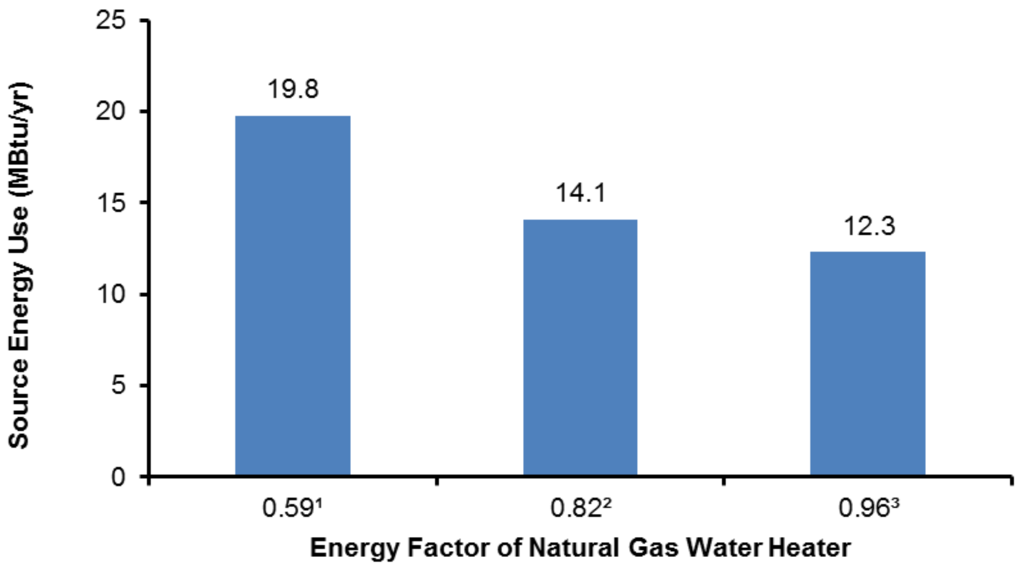

Figure 4. Source energy use of different gas-fired water heaters

[1] 40-gal, natural gas-fired, tank-type water heater with an EF of 0.59.
[2] Natural gas-fired, tankless water heater with an EF of 0.82.
[3] Natural gas-fired, condensing tankless water heater with an EF of 0.94.

With electric water heaters, the difference in efficiency levels between tank-type and tankless units is less pronounced, and the potential cost savings are less. Electric tank-type water heaters typically used in housing have an EF of 0.88–0.95. Electric tankless water heaters have an EF of 0.98–1.00. At best, an electric tankless water heater could save about 12% in energy costs over an electric tank-type unit.

Tankless water heaters are generally considered to last up to 20 years, compared to 10–15 years for tank-type water heaters.

3.2 System Interactions

This section explores possible performance interactions between a tankless water heater and other parts of a residential plumbing system. Before specifying a tankless water heater, it is important to consider the water distribution system because it will significantly affect the delivery of hot water to individual fixtures and appliances. Before a retrofit, it also is important to evaluate the size of the existing cold water supply line because the gpm output of the tankless water heater will require a cold water inlet of a specified line size. An evaluation of existing natural gas and electricity services (i.e., gas line and electric panel) also should be conducted to ensure that gas-fired and electric tankless units, respectively, will have enough input energy to operate effectively. In any house, low-flow fixture uses must be considered as well because the sensor of the tankless water heater may not be sensitive enough to detect very low flows of water, such as a trickle of hot water from a faucet or a low-flow shower head.

3.2.1 Strategies for Distribution of Water Supply Lines

The water distribution system directly affects the delivery time of hot water from a tankless water heater to individual fixtures and appliances. There are three main types of water distribution systems: homerun, remote manifold, and trunk and branch. A homerun distribution system with PEX is the most efficient system to deliver hot water from a tankless water heater. Figure 5 shows an example of a homerun water distribution system for use with a tankless water heater.

> **Critical Takeaway:**
> A homerun distribution system with cross-linked polyethylene piping (PEX) is the most efficient system to deliver hot water from a tankless water heater.

Figure 5. Example of a homerun water distribution strategy for use with a tankless water heater

Descriptions of the three water distribution systems and their effects on hot water delivery from a tankless (or tank-type) water heater follow.

- **Homerun system.** In this system, the plumbing consists of two manifolds located near the water heater—one for hot water and the other for cold water—that feed individual supply lines to each fixture and appliance. The main cold water line and the main water heater output line feed the manifolds. Dedicated lines run from the two manifolds to the individual fixtures. The hot water manifold is installed as near as possible to the water heater, allowing for code-required clearances, to minimize the delivery time. Homerun systems generally use PEX piping. With a PEX homerun system, most fittings between the manifold and a fixture can be eliminated to maximize flow capacity and minimize the risk of leaks from pipe joints in concealed spaces.
- **Remote manifold system.** In this system, hot and cold trunk lines run to small, remote manifolds, where branch lines run to each fixture. These systems use more fittings than homerun systems but fewer fittings than trunk and branch systems. They also need less piping than homerun systems; however, because of their fittings and shared distribution piping, remote manifold systems generally deliver hot water more slowly than homerun systems.
- **Trunk and branch system.** In this system, hot and cold trunk lines supply smaller branch lines to specific fixtures. A trunk line serves numerous branch lines; each branch line serves one to three closely grouped fixtures or appliances. Copper, chlorinated polyvinyl chloride, or PEX can be used to deliver hot water. The flexible nature of PEX allows for sweeping turns and reduces the number of fittings. However, regardless of the material used, a trunk and branch system is the least efficient way to deliver water from a tankless water heater.

3.2.2 Cold Water Supply

For retrofit construction, it is important to consider the size of the main cold water supply and to ensure it will provide sufficient flow to the tankless unit, as is the case for all water heaters. Typically, tankless water heaters require a ¾-in. or 1-in. supply line. An old house may have only a ½-in. main supply line. In specifying a tankless water heater, the main cold water supply line should be sized according to the manufacturer’s specifications—usually ¾ in. diameter, although some manufacturers allow for smaller-diameter piping for certain retrofit situations.

3.2.3 Low Flows

In a tankless water heater, the firing sequence is ignited when water flows from a fixture. Each unit has a minimum water flow requirement (0.4–0.9 gpm) that activates it. Very low flows of water, such as a trickle of hot water from a faucet, may not require enough hot water for the tankless water heater to start operation. In such cases, an occupant may have to increase the flow of hot water from the faucet used or turn on an additional fixture so hot water is delivered to the desired fixture.

3.3 Performance Considerations

This section describes the performance tradeoffs for different versions of tankless water heaters. Manufacturers of gas-fired tankless water heaters offer a range of models that can be categorized into two levels of energy efficiency: conventional and condensing. In addition, as tankless water heaters are available for electricity, natural gas, and propane fuel, this section describes the cost and performance tradeoffs of gas and electric units. Although propane carries a greater energy content per cubic foot than natural gas, the operations of water heaters using either fuel type are similar; therefore, natural gas heaters will be discussed here as a representative model of all gas-fired water heaters.

3.3.1 Gas-Fired Units

In cold regions, a gas-fired unit is typically more cost effective to operate than an electric unit because gas fuel usually is less expensive than electricity. Even so, tankless water heaters draw large amounts of fuel to quickly heat the incoming water supply. A gas-fired tankless unit will add 175,000 Btu or more to the total annual gas load. The fuel requirements of a gas-fired unit may necessitate a larger gas line to the house gas meter. A dedicated supply line also may be needed to provide the necessary natural gas capacity. In a retrofit, it is important to consider whether the incoming gas line has the capacity to supply the required Btu input. In most cases, the in-house gas line that will serve the unit will need to be ¾ in. diameter.

3.3.1.1 Conventional Gas-Fired Tankless Units

Conventional gas-fired tankless units, which have an EF of 0.82, are introductory-level products to the market. Conventional units use gas fuel in a standard manner and vent hot combustion gases through a flue. Conventional units cost less upfront; however, they cost more to operate than higher efficiency units because they use more fuel. Conventional units also have a copper heat exchanger, which is more susceptible to corrosion from scaling.

3.3.1.2 Tankless Condensing Gas-Fired Units

A tankless condensing gas-fired unit, which has an EF of 0.92 or higher, has a stainless steel condensing heat exchanger that can recover the latent heat of the condensation that otherwise would be lost. Because condensation is a combustion by-product, its removal must be properly addressed during installation.

3.3.2 Electric Tankless Units

Electric tankless water heaters are available in a variety of capacities. However, the operating costs of a whole-house electric unit often are much higher than those of a comparable gas-fired tankless unit. Also, the large amount of electricity that electric tankless units draw (50 amps or greater) requires an evaluation of the capacity of the house electrical panel to ensure the unit does not interfere with the operation of other electrical devices. In warm regions, an electric tankless unit may be an appropriate option. However, in cold regions, it may be cost prohibitive as a whole-house option because so much electricity is needed to heat the water and because of the relatively high cost of that electricity. On the other hand, electric tankless units provide highly effective point-of-use water heating for individual rooms and fixtures.

Builders and retrofitters should check with the local electric utility company to determine the cost of operation before specifying a whole-house electric unit. If a whole-house electric unit is specified, it is important to consider the following to ensure it can meet the demand for hot water:

- **Voltage.** Electric tankless water heaters require much higher voltage than gas-fired tankless units to provide the amount of power required to quickly heat the incoming water supply. Most electric tankless units require 208 or 240 volts alternating current (VAC), depending on the unit.
- **Amperage.** Electric tankless water heaters have differing requirements in amp draw. It is important to ensure the electrical supply can support the demand of the unit. Most electric tankless units require 50–200 amps, depending on the size of the unit.
- **Circuitry.** Electric tankless water heaters may require multiple circuits and, in some cases, a larger service size. It may be necessary to place the unit on its own circuit.

3.4 Combination Units

Some tankless models, called combination units, operate as both gas boilers and water heaters to provide central heating and domestic hot water. Before selecting a combination unit, it is important to consider the heating and hot water needs of the house and to size the unit accordingly. Also, the total load must be calculated for space conditioning and the total hot water demand.

4 Measure Implementation Details

This section provides details to prepare for the proper installation of a tankless water heater. For tankless water heaters, which are preassembled and arrive on site for installation by a trained professional, the responsibility of the builder or retrofitter lies primarily in the field and document inspections. Section 4.1 focuses on the design and specification phases. It addresses the evaluation of the cold water supply, the gas fuel supply, the electric fuel supply, the combustion air supply, and the venting pathway to ensure the efficacy of the tankless water heater and its capacity to achieve comfort, reliability, durability, and energy efficiency. This section also addresses unit sizing and location, which should be carefully planned during the design and specification phase, prior to purchase and installation. Manufacturer instructions will address a durable and reliable installation procedure, and code requirements will address proper verification and testing.

4.1 Field and Document Inspections

This section addresses possible barriers to implementing a tankless water heater and explains how to evaluate and plan to ensure the unit will provide hot water quickly and reliably.

- **Evaluate the gas supply.** For gas-fired tankless units, consider whether the incoming gas line to the unit has the capacity to supply the required Btu input for the equipment. Follow the manufacturer's recommendations and plumbing code for gas line sizing. In a retrofit application, the gas line serving the house may need to be enlarged.
- **Evaluate the electricity supply.** For gas units, consider the location of the electrical outlet. For electric units, confirm that adequate capacity is available. Most units require 208 or 240 VAC and 50–200 amps, depending on the size of the unit.
- **Identify and route the venting.** For gas units, measure the vent route, and consider whether the vent will exit through a sidewall, the roof, or a chimney. In existing houses, cumbersome and expensive cutting through walls or band joists or venting through a chimney using the appropriate flue may be necessary. At the vent termination, it is important to follow local codes, in accordance with ANSI Z21.10.3 (2011) and the National Fuel Gas Code, ANSI Z223.1/NFPA 50 (2005), and CAN/CGA B149.1 Natural Gas and Propane Installation Code (2010). These code references consider the necessary clearances from windows, other vent terminals, and the outside grade (if applicable). To minimize the length of venting runs, locate the unit close to where the venting will terminate. Venting materials include plastic and metal products. Use only venting products listed and tested for the particular unit. Gas-fired tankless water heaters must be vented according to local codes and the manufacturer's instructions.
- **Provide for condensate disposal.** Condensate from venting systems that serve conventional tankless water heaters must be collected or disposed unless the vents are installed specifically to prevent it. Condensing tankless water heaters require that condensate from combustion be removed.
- **Evaluate the combustion air supply.** If the gas unit is "sealed combustion" (i.e., draws combustion air from outside and vents combustion gases to outside), combustion air is not an issue. However, if the unit is only "power vented," it is important to ensure adequate combustion air in the interior space where the unit will be located.

- **Size the tankless water heater appropriately.** Manufacturers offer a range of sizes in tankless water heaters by flow rate in gpm to meet a wide range of demands. The size is based on the *maximum temperature rise* (i.e., cold inlet to hot outlet) needed and the *maximum flow rate* (gpm) demanded. To size a tankless water heater, the builder or retrofitter must first determine the maximum temperature rise using the incoming water temperature and the desired output temperature. The incoming water temperature is provided by the local water utility (a minimum value), and the desired output temperature is 120°F for most uses. The builder or retrofitter must then identify all fixtures and appliances in the house and their flow rates to determine the maximum flow rate of hot water demand at any given time. The temperature rise needed and the maximum flow rate demanded will determine the unit size as follows:

  Maximum Temperature Rise (°F) and Maximum Flow Rate (gpm) → Unit Size

- **Consider the flow rate of each water-consuming fixture and appliance in conjunction with the temperature rise needed.** For example, if the incoming water temperature is 65°F and the desired temperature is 105°F, then for a 2.0-gpm shower, the selected unit must provide a 40°F temperature rise at a 2.0-gpm flow rate. Table 2 shows typical flow rates for fixtures and appliances. When selecting the appropriate temperature rise, the minimum incoming water temperature must be considered.

Table 2. Typical Flow Rates*

Fixtures and Appliances	Flow Rate (gpm)
Bathroom	
Bathtub	2.4–4.0
Shower	2.5
Kitchen and Utility	
Kitchen Sink	2.5
Laundry Sink	4.0
Dishwasher	1.9

*Source: Domestic Water Heating Design Manual, ASPE, 2006.

To determine the maximum flow rate demand at any given time in a house, the builder or retrofitter must consider the number and types of fixtures and appliances, as well as typical simultaneous demands, such as the simultaneous use of a clothes washer, a dishwasher, a shower, and a bathroom sink. It will be necessary to combine the flow rates of various fixtures to determine the overall hot water demand and then find the temperature rise necessary to meet that demand. Manufacturers provide a flow table such as the one shown in Figure 6 to assist in determining if the unit noted will provide sufficient temperature rise and flow rate.

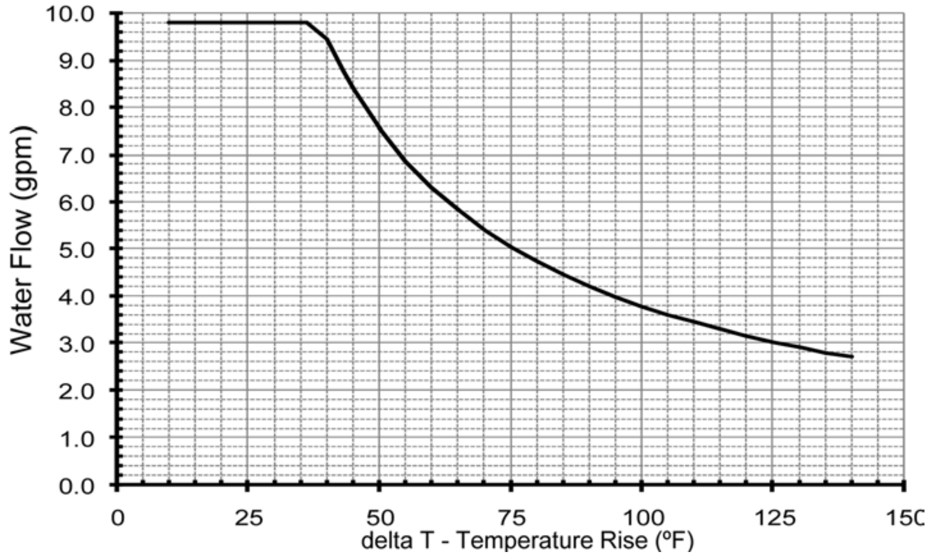

Figure 6. Outlet flow table
(Courtesy of Rinnai Corporation)

- **Locate the central unit.** The location of the tankless water heater will significantly affect its efficacy. Centrally locating the tankless unit between points of use will reduce pipe lengths and thereby deliver hot water more efficiently. In a retrofit, the unit can be wall mounted near the location of the original tank-type water heater to save costs, or the installer can move it to a more efficient central location, which would likely increase installation costs. If the unit is relocated, additional plumbing lines may need to be installed.
- **Locate any point-of-use units.** If needed, small electric point-of-use units, which have a lower rated capacity and often serve only one end use, can be installed to provide hot water directly to remote areas, saving water that ordinarily would be wasted while waiting for hot water from a centrally located water heater.
- **Use a water recirculation system.** An on-demand recirculation system, usually installed near a frequently used remote fixture, activates the water heater before a hot water valve of a faucet is opened. The system consists of a recirculating pump, flexible piping and connections, and a remote sensor. A user can trigger a remote sensor that activates the recirculation pump in anticipation of hot water use. This pump then begins circulating stagnant water in the hot water pipe back to the water heater through a connection made to the cold water pipe. The result is that hot water arrives at the fixture before a valve or faucet is opened, which significantly reduces hot water wait times and prevents cool stagnant water from going down the drain.

4.2 Installation Procedure

During the installation of a tankless water heater and its accessories (e.g., venting), builders and retrofitters must refer to the manufacturer's instructions for specific procedures covering the system to be installed. Best practices focus on only the selection, sizing, and location of the equipment prior to installation rather than on the physical installation of the equipment. Appendix A provides some references for standards and specifications for the installation of tankless water heaters.

4.3 Verification Procedures and Tests

Plumbing verification procedures and tests are similar for tankless water heaters and tank-type water heaters. Builders and retrofitters must refer to the manufacturer's instructions and applicable codes for verification procedures and tests.

5 Summary

Tankless water heaters are compact and highly efficient systems that can provide greater energy savings and customer satisfaction than a traditional tank-type water heater can provide. In tankless water heaters, the energy savings are accomplished primarily because hot water is provided only when needed, whereas traditional tank-type water heaters store and reheat water to maintain a consistent temperature, regardless of demand.

Various factors are important in determining whether to use a tankless water heater. The size and location of the unit are critical, along with proper installation and maintenance. Likewise, the interactions of the unit with the water distribution system and the plumbing line length and diameter must be evaluated.

Issues to consider are the increased risk of scaling in tankless water heaters from hard water, the cold water sandwich effect that can occur with frequent on/off use, electrical backup during power outages, and code issues.

Other considerations related to tankless water heaters include the choice of an electric unit versus a gas-fired unit; higher initial costs versus reduced annual operating costs; possible plumbing modifications required to the distribution system in a retrofit situation; adequate capacity for water, gas or electric, and venting; and the impact of climate on the performance of the unit.

However, when all factors are properly addressed, tankless water heaters can offer numerous benefits and energy savings.

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ANSI Z223.1/NFPA 50 (2005). NFPA 50: Standard for Bulk Oxygen Systems at Consumer Sites. Quincy, MA. National Fire Protection Association.

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Rinnai (2008). Direct Vent Tankless Water Heater Operation and Installation Manual. Peachtree City, GA: Rinnai America Corporation.

Takagi (2012). Takagi Tankless Water Heaters. Irvine, CA: Takagi. www.takagi.com. Accessed March 7, 2012.

Appendix A References to Material Specifications for Tankless Water Heaters

The following reports from the International Code Council Evaluation Service (ICC-ES) can be referenced for the standards and specifications for the installation of tankless water heaters:

AC122 (October 2007). Acceptance Criteria for PP, PEX, PEX-AL-PEX, and PP-AL-PP Piping, Tube and Fittings Used in Radiant Heating and Water Supply Systems. Whittier, CA: International Code Council Evaluation Service (ICC-ES).

AC311 (October 2007). Acceptance Criteria for Push-Fit and Press-Connection Fittings for Potable Water Tube and Radiant Heating Systems. Whittier, CA: International Code Council Evaluation Service (ICC-ES).

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