# Energy and Resource Conservation in Plumbing Systems

Continuing Education from the American Society of Plumbing Engineers

CEU 188

JUNE 2012

ASPE.ORG/ReadLearnEarn

Note: In determining your answers to the CE questions, use only the material presented in the corresponding continuing education article. Using information from other materials may result in a wrong answer.

Prior to the 1973–1974 OPEC oil embargo, energy was considered inexhaustible and expendable. As energy costs grew, society turned its attention toward energy conservation. The Energy Policy and Conservation Act (EPCA) of 1975 was the first major piece of legislation that addressed federal energy management. Additional laws soon followed, including the Resource Conservation and Recovery Act of 1976, National Energy Conservation Policy Act of 1978, Federal Energy Management Improvement Act (FEMIA) of 1988, and the most recent Energy Policy Act (EPAct) of 2005, which expanded on the previous legislation.

Along with the federal government, other sectors of society made strides to reduce energy consumption. The automotive industry, which was heavily impacted by the oil embargo, was quick to adapt by producing smaller, lighter, more fuel-efficient cars. The construction market also made strides by adopting model energy codes, efficiency standards, and alternate fuel sources. A green movement has spread across the nation, pushing for the implementation of efficient and sustainable technologies.

One of the highest energy-consuming plumbing systems is domestic hot water, often consuming 2 to 4 percent of the total energy used in an office building and 8 percent in residential properties. This plumbing system has a great need for energy-conservation measures.

Just as important as energy conservation is resource conservation. Obviously, a resource greatly affected by plumbing system design is water. Water use in the United States has more than doubled in the past half-century, from approximately 180 billion gallons per day in 1950 to more than 400 billion gallons a day in 2000. Because of increases in population and demand, at least 36 states are projecting water shortages by 2013.

Each American uses an average of 100 gallons of water a day at home, and it is important to note that by reducing hot water use, both energy and water are conserved. For example, if one in every 10 homes in the United States were to install low-flow faucets or faucet accessories in their bathrooms, it could save 6 billion gallons of water and more than $50 million in the energy costs to supply, heat, and treat that water.

This chapter is intended to provide a plumbing engineer with design techniques that conserve both energy and water and to assist them in selecting energy- and water-efficient equipment and systems. Where the recommendations set forth in this chapter do not meet the minimum provisions of the local code, the code shall apply.

## DESIGN TECHNIQUES FOR DOMESTIC HOT WATER SYSTEM ENERGY CONSERVATION

Hot water use can vary from handwashing, showering, and janitorial needs to cooking, dishwashing, and laundering needs. Design techniques that can be employed to conserve energy when heating water follow.

### Eliminate Leaks

One of the first and easiest actions to take to conserve energy and resources is by repairing leaking fixtures, appliances, and hot water piping.

### Reduce Domestic Hot Water Temperature

Many domestic water-heating systems are designed to deliver 140°F water based on the anticipated needs of kitchen and janitorial uses, though water for human contact typically is delivered between 110 °F and 105°F. Often, 105°F water is produced by blending 140°F hot water with cold water. While this reduces the amount of hot water required, it does not decrease the energy used to heat the water. Many energy codes and standards for new buildings require the domestic hot water system to be set at 110°F. (It is important to note that setting a water heater below 120°F may allow Legionella bacteria to grow inside the domestic hot water tank.)

The temperature, after mixing two or more volumes (or flows) of water, is calculated using the following equation:

***Equation 7-1***

$$t_m = \frac{Q_1 \times t_1 + Q_2 \times t_2}{Q_1 + Q_2}$$

*where*

$t_m$ = Temperature of mixture
$t_1$ = Temperature of flow $Q_1$
$t_2$ = Temperature of flow $Q_2$
$Q_1$ = Cold water, gallons per minute (gpm) (liters per second [L/s])
$Q_2$ = Hot water, gpm (lpm)

***Example 7-1***

What is the temperature of 45 gpm (2.84 L/s) of 155°F (68.5°C) water mixed with 55 gpm (3.47 L/s) of 75°F (23.9°C) water?

$$\frac{45 \times 155 + 55 \times 75}{45 + 55} = 111°F$$

In SI units:

$$\left(\frac{2.84 \times 68.5 + 3.47 \times 23.9}{2.84 + 3.47} = 44°C\right)$$

The ratio (percentage) of hot water required to be mixed with cold water to provide a mixed water requirement is determined using the following equation:

***Equation 7-2***

$$\text{Ratio HW} = \frac{t_m - t_1}{t_2 - t_1}$$

***Example 7-2***

How much hot water is required to provide 80 gallons per hour (gph) (0.084 L/s) of 110°F (43°C) mixed water with 155°F (68.5°C) hot water and 75°F (23.9°C) cold water?

$$\frac{110 - 75}{155 - 75} = 0.44 \text{ or } 44\% \text{ hot water}$$

80 gph x 0.44 = 35 gph of 155°F hot water

(0.084 L/s x 0.44 = 0.037 L/s of 68.5°C hot water)

How much hot water is required to provide 80 gph (0.084 L/s) of 110°F (43°C) mixed water with 125°F (51.5°C) hot water and 75°F (23.9°C) cold water?

$$\frac{110 - 75}{125 - 75} = 0.70 \text{ or } 70\% \text{ hot water}$$

80 gph × 0.70 = 56 gph of 125°F hot water

(0.084 L/s × 0.70 = 0.059 L/s of 51.5°C hot water)

As shown, the reduction in domestic water temperature in itself does not necessarily result in a reduction in energy input related to the water consumed.

## Reduce Fixture Flow Rates

The EPAct of 1992 set maximum water usages for specific fixtures (e.g., 1.6 gallons per flush [gpf] for water closets). Reduced flow rates result in less water needing to be pumped and heated, smaller pipe sizes, and less heat loss from piping, consequently saving energy. Fixture flow rates vary depending on the supply fitting design and water pressure. Manufacturers' test results have shown that flows for lavatories and showers can be quite high, making them prime candidates for fixture flow reduction. Providing automatic flow-control fittings can reduce fixture flow rates. On lavatories, the type of faucet and spout usually dictates the location of these fittings. In showers, the type of head and arm determines the fitting location. After being fitted with a flow-control device, reduced flow rates of 1 gpm or less usually are seen in lavatories and 2.5 gpm or less in showers.

Figure 7-1 provides a way to translate fixture flow rate to annual consumption and is useful in determining the most energy-efficient design flow rate. By varying the percent of hot water at the fixture, annual energy consumption can be predicted. Figure 7-1 can be used as a design tool for many purposes, some of which are to predict energy consumption, anticipated utility costs, and payback calculations for fixture replacement.

Manufacturers of flow-control devices describe in greater detail their design and installation requirements. The installation of this water-conserving device has resulted in the savings of millions of gallons of water per year throughout the country. This reduction in water demand translates into water the local utility company does not have to pump, the purification plant does not have to handle and process, and the waste treatment plant does not have to treat.

***Example 7-3***

A faucet using 3.25 gallons of 150°F hot water per day with a 100 percent faucet flow rate equates to an annual energy use of 774,000 British thermal units (Btu) per year (3.25 gal × 8.33 lb/gal × 110°F$\Delta$T × 260 days). A 50 percent flow rate reduces energy use to 387,000 Btu per year.

## Apply Economical Thermal Insulation

Economical thermal insulation is the amount of insulation that annually produces the lowest sum of energy lost versus the annual cost of insulation. In addition to conserving energy by retarding heat loss, insulation provides additional benefits such as protection against burns, reduction of noise, and control of condensation. The North American Insulation Manufacturers Association (NAIMA) has developed software called 3E Plus, which calculates the thermal performance of both insulated and uninsulated piping, ducts, and equipment; translates Btu losses into actual dollars; and calculates greenhouse gas emission and reductions.

The International Energy Conservation Code requires automatic-circulating hot water system piping to be insulated with 1 in. of insulation having a conductivity not exceeding 0.27 Btu per inch/h × $ft^2$.

Energy savings, in Btu, can be determined by the following formula:

***Equation 7-3***

$$S = g \times L$$

*where*

S=Energy savings, Btu per hour (Btuh) (kilojoules per hour [kJ/h])

g=Factors taken from Table 7-1 or 7-2 at a particular $\Delta$T, Btuh/ft (kJ/h/m)

L=System length, ft (m)

Hot water pipes should be continuously insulated from the heater to the end use, while cold water lines should be insulated near the water heater tank to minimize convective losses.

## Limit Water Heater and Circulation Pump Operation

Buildings with large hot water distribution systems use circulating loops to ensure that hot water is available to all fixtures within a timely manner. By limiting the hours of operation of these pumps and water heaters, substantial savings can be realized.

An automatic thermostatic control should be installed to cycle the pump on and off in response to the temperature of water returning to the water heater through the recirculation piping. The minimum differential, or deadband, of the control shall not be less than 20°F.

Time clocks can be used to control hot water circulating pumps. The energy saved when using time clocks can be calculated as follows:

***Equation 7-4***

Motor kilowatts (kW) × off hours
× electric rate ($/kWh) = total savings ($)

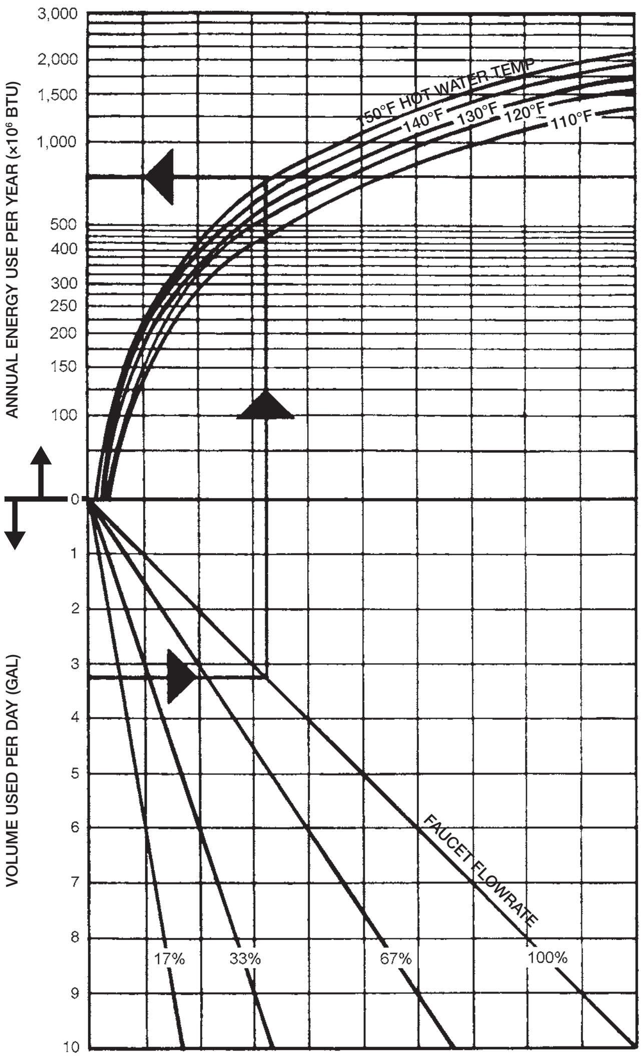


Chart allows user to estimate domestic hot water heating use in terms of water temperature and faucet flow rate.

*Source*: Cassidy 1982.

**Figure 7-1 Energy Savings from Reduced Faucet Flow Rates**

### Consume Off-peak Power

One of a plumbing engineer's responsibilities is to size the domestic water heating equipment to meet the needs of the building's occupants in the most energy-efficient manner. While using off-peak power to heat and circulate water does not change the amount of Btu required, it does allow the building's owner and tenants to benefit from lower utility costs. Power companies encourage their commercial customers to purchase power during off-peak hours in hopes of flattening or evening out the demand on their generating equipment. Some utility companies not only offer lower rates for electricity purchased during off-peak and semi-peak periods, but in many instances also have no customer demand charges. The plumbing engineer can obtain electric rate schedules from the utility serving the site and observe the off-peak periods to program the operation of domestic water heating equipment. Typically, the highest demand for hot water takes place when electrical costs are at their peak. To account for this, the hot water system can maintain the heated water at an elevated temperature, which is blended to achieve the desired temperature levels, saving the system from having to operate during the day. Depending on the difference in electrical rates, an off-peak powered hot water system generally pays (in a few years) for the additional equipment required, including the effects of equipment heat losses during periods of standby.

### Upgrade to More Efficient Equipment

Equipment specifications need to be examined to ensure that only hot water heating equipment meeting minimum energy standards is approved for installation. The following factors contribute to the efficiency of gas-fired water heaters and need to be taken into consideration when selecting this equipment: combustion equipment and its adjustment, tank insulation, heat exchanger effectiveness, firing rate, pickup and demand, and standby stack losses.

### Water Heater Location

Many hot water heaters are installed in central locations, requiring long supply and return piping runs to reach plumbing fixtures. Moving these heaters near the most frequent points of use can minimize piping heat loss.

## DOMESTIC HOT WATER HEATING EQUIPMENT

There are many different means of generating hot water. Each has its own advantages and disadvantages, and it is the plumbing engineer's responsibility to determine which technology is best suited for an application. The recovery efficiency and standby losses of water heating equipment should comply with the latest codes and regulations for the manufacturer. State energy codes also mandate the use of energy-efficient equipment and should be checked by the plumbing engineer prior to the preparation of specifications.

Listed below are several hot water heating technologies.

### Storage Water Heaters

Tank-type water heaters are self-contained units that heat and store water within the same storage tank. Insulation is added around the exterior of the tank to prevent heat from escaping. Because the tanks maintain a stored water temperature, there is an associated standby energy loss. Compared to tankless heaters, storage water heaters have the advantage of using energy (gas or electricity) at a relatively slow rate, storing the heat for later use.

**Electric** The heating element for electric tank-type water heaters is immersed directly into the water, allowing energy to transfer from the element to the water fast and efficiently. They can be used for many applications ranging from commercial and industrial to booster heaters for dishwashing needs.

**Gas Fired** A gas-fired tank-type water heater uses natural gas or propane to heat stored water.

### Tankless Water Heaters

These water heaters heat the water as the water flows through the device (demand based) and do not retain any water internally, except for what is in the heat exchanger coil. Tankless water heaters often have minimum flow

### Table 7-1 Energy Savings Chart for Steel Hot Water Pipes and Tanks

| ΔT °F (°C) | Pipe Size, in. (mm) | | | | | | | Hot Water Tanks, Btu/h/ft$^2$ (kJ/h/m$^2$) | |
|---|---|---|---|---|---|---|---|---|---|
| | ½ (12.7) | ¾ (19.1) | 1 (25.4) | 1¼ (31.8) | 1½ (38.1) | 2 (50.8) | 2½ (63.5) | with Insulation | with out Insulation |
| 40 (4.4) | 14 (48.44) | 17 (58.8) | 21 (72.7) | 26 (90.0) | 29 (100.3) | 35 (121.1) | 42 (145.3) | 6 (68.1) | 57 (647.3) |
| 45 (7.2) | 16 (55.36) | 20 (69.2) | 24 (83.0) | 30 (103.8) | 33 (114.2) | 41 (141.9) | 48 (166.1) | 6 (68.1) | 65 (738.2) |
| 50 (10.0) | 18 (62.28) | 22 (76.1) | 27 (93.4) | 34 (117.6) | 38 (131.5) | 47 (162.6) | 55 (190.3) | 7 (79.5) | 73 (829.1) |
| 55 (12.8) | 20 (69.20) | 25 (86.5) | 31 (107.3) | 38 (131.5) | 42 (145.3) | 52 (179.9) | 62 (214.5) | 7 (79.5) | 83 (942.6) |
| 60 (13.6) | 23 (79.58) | 28 (96.9) | 35 (121.1) | 42 (145.3) | 48 (166.1) | 58 (200.7) | 69 (238.7) | 9 (102.2) | 92 (1044.8) |
| 65 (18.3) | 25 (86.50) | 31 (107.3) | 38 (131.5) | 47 (162.6) | 53 (183.4) | 65 (224.9) | 77 (266.4) | 9 (102.2) | 102 (1158.4) |
| 70 (21.1) | 28 (96.88) | 34 (117.6) | 42 (145.3) | 52 (179.9) | 58 (200.7) | 71 (245.7) | 84 (290.6) | 10 (113.6) | 112 (1272.0) |
| 75 (23.9) | 30 (103.8) | 36 (124.6) | 46 (159.2) | 56 (193.8) | 64 (221.4) | 78 (269.9) | 91 (314.9) | 11 (124.9) | 122 (1385.6) |
| 80 (26.7) | 33 (114.2) | 41 (141.9) | 50 (173.0) | 61 (211.1) | 69 (238.7) | 84 (290.6) | 99 (342.5) | 11 (124.9) | 132 (1499.1) |
| 85 (28.4) | 36 (124.6) | 44 (152.2) | 54 (186.8) | 67 (231.8) | 74 (256.0) | 91 (314.9) | 107 (370.2) | 12 (136.3) | 142 (1612.7) |
| 90 (32.2) | 38 (131.5) | 47 (162.6) | 58 (200.7) | 72 (249.1) | 80 (276.8) | 98 (339.1) | 116 (401.4) | 12 (136.3) | 154 (1749.0) |
| 95 (35.0) | 42 (145.3) | 51 (176.5) | 62 (214.5) | 77 (266.4) | 86 (297.6) | 105 (363.3) | 124 (429.0) | 14 (159.0) | 164 (1862.5) |
| 100 (37.8) | 45 (155.7) | 54 (186.8) | 66 (228.4) | 82 (283.7) | 93 (321.8) | 113 (391.0) | 133 (460.2) | 14 (159.0) | 175 (1987.5) |
| 105 (38.0) | 47 (162.6) | 58 (200.7) | 72 (249.1) | 87 (301.0) | 98 (339.1) | 120 (415.2) | 141 (487.9) | 15 (170.4) | 187 (2123.8) |
| 110 (43.0) | 51 (176.5) | 62 (214.5) | 75 (259.5) | 93 (321.8) | 104 (359.8) | 128 (442.9) | 150 (519.0) | 16 (181.7) | 198 (2248.7) |
| 115 (46.0) | 54 (186.8) | 65 (224.9) | 80 (276.8) | 98 (339.1) | 110 (380.6) | 135 (467.1) | 159 (550.1) | 16 (181.7) | 210 (2385.0) |
| 120 (49.0) | 56 (193.8) | 69 (238.7) | 85 (294.1) | 104 (359.8) | 117 (404.8) | 143 (494.8) | 169 (584.7) | 17 (193.1) | 222 (2521.3) |

Source: San Diego Gas & Electric Co.

Notes: 1. Savings are in Btu/h/linear ft. (kJ/h/linear m), unless otherwise indicated.

2. Figures are based on an assumption of 1 in. (25.4 mm) of insulation.

3. $\Delta T = t_o - t_a$ where $t_o$ = Hot water circulating temperature and $t_a$ = Air temperature surrounding piping system.

### Table 7-2 Energy Savings Chart for Copper Hot Water Pipes

| ΔT °F (°C) | Pipe Size, in. (mm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | ½ (12.7) | ¾ (19.1) | 1 (25.4) | 1¼ (31.8) | 1½ (38.1) | 2 (50.8) | 2½ (63.5) | 3 (76.2) |
| 40 (4.4) | 8 (27.68) | 12 (41.5) | 14 (48.4) | 17 (58.8) | 20 (69.2) | 25 (86.5) | 30 (103.8) | 35 (121.1) |
| 45 (7.2) | 10 (34.6) | 13 (45.0) | 16 (55.5) | 20 (69.2) | 23 (79.6) | 29 (100.3) | 35 (121.1) | 40 (138.4) |
| 50 (10.0) | 12 (41.5) | 15 (51.9) | 19 (65.7) | 23 (79.6) | 26 (90.0) | 33 (114.2) | 40 (138.4) | 46 (159.2) |
| 55 (12.8) | 13 (45.0) | 17 (58.8) | 21 (72.7) | 26 (90.0) | 30 (103.8) | 38 (131.5) | 45 (155.7) | 52 (179.9) |
| 60 (13.6) | 15 (51.9) | 20 (69.2) | 24 (83.0) | 29 (100.3) | 34 (117.6) | 42 (145.3) | 51 (176.5) | 58 (200.7) |
| 65 (18.3) | 16 (55.4) | 21 (72.7) | 27 (93.4) | 32 (110.7) | 37 (128.0) | 47 (162.6) | 56 (193.8) | 65 (224.9) |
| 70 (21.1) | 18 (62.3) | 24 (83.0) | 30 (103.8) | 35 (121.1) | 41 (141.9) | 52 (180.0) | 62 (214.5) | 71 (245.7) |
| 75 (23.9) | 20 (69.2) | 26 (90.0) | 33 (114.2) | 39 (134.9) | 44 (152.2) | 56 (193.8) | 67 (231.8) | 76 (263.0) |
| 80 (26.7) | 21 (72.7) | 28 (96.7) | 35 (121.1) | 42 (145.3) | 49 (169.5) | 61 (211.1) | 73 (252.6) | 85 (294.1) |
| 85 (29.4) | 22 (76.1) | 31 (107.3) | 38 (131.5) | 45 (155.7) | 53 (183.4) | 66 (228.4) | 79 (273.3) | 92 (318.3) |
| 90 (32.2) | 24 (83.0) | 33 (114.2) | 41 (141.9) | 49 (169.5) | 57 (197.2) | 71 (245.7) | 85 (294.1) | 99 (342.5) |
| 95 (35.0) | 26 (90.0) | 36 (124.6) | 44 (152.2) | 53 (183.4) | 61 (211.1) | 76 (263.0) | 91 (314.9) | 106 (366.7) |
| 100 (37.8) | 28 (96.7) | 38 (131.5) | 48 (166.1) | 57 (197.2) | 65 (224.9) | 82 (283.7) | 98 (339.1) | 113 (391.0) |
| 105 (38.0) | 30 (103.8) | 41 (141.9) | 51 (176.5) | 60 (207.6) | 70 (242.2) | 87 (301.0) | 104 (359.8) | 121 (418.7) |
| 110 (43.0) | 32 (110.7) | 43 (148.8) | 54 (186.8) | 65 (224.9) | 74 (256.0) | 93 (321.8) | 111 (384.1) | 128 (442.9) |
| 115 (46.0) | 34 (117.6) | 46 (159.2) | 57 (197.2) | 68 (235.3) | 78 (269.9) | 98 (339.1) | 118 (408.3) | 136 (470.6) |
| 120 (49.0) | 36 (124.6) | 49 (169.5) | 61 (211.1) | 72 (249.1) | 83 (287.2) | 104 (359.8) | 125 (432.5) | 144 (498.2) |

Source: San Diego Gas & Electric Co.

Notes: 1. Savings are in Btu/h/linear ft (kJ/h/linear m).

2. Figures are based on an assumption of 1 in. (25.4 mm) of insulation.

3. $\Delta T = t_o - t_a$ where $t_o$ = Hot water circulating temperature and $t_a$ = Air temperature surrounding piping system.

### Table 7-3 The Effect of Stopping Circulation

| Operating Temperature, °F (°C) | Piping Insulation Thickness, in. (mm) | Energy Conserved, Btu/yr (kJ/yr) |
|---|---|---|
| 140 (60) | ½ (12.7) | $1428 \times 10^6$ ($1506.5 \times 10^6$) |
| 125 (51.5) | ½ (12.7) | $1153 \times 10^6$ ($1216 \times 10^6$) |
| 110 (43) | ½ (12.7) | $824 \times 10^6$ ($869.3 \times 10^6$) |
| 140 (60) | 1 (25.4) | $934 \times 10^6$ ($985.4 \times 10^6$) |
| 125 (51.5) | 1 (25.4) | $714 \times 10^6$ ($753.3 \times 10^6$) |
| 110 (43) | 1 (25.4) | $522 \times 10^6$ ($550.7 \times 10^6$) |

requirements before the heater is activated, and this can result in a gap between the cold water temperature and the coolest warm water temperature that can be achieved with a hot and cold water mix.

**Electric** Electric tankless water heaters consume large amounts of energy when operating. This has relegated their use to remote areas with low fixture counts and infrequent use. They usually are installed near the point of use to minimize pipe heat loss.

**Gas Fired** These heaters can be found in commercial, industrial, and residential applications. They are typically direct-vent exhaust and carry a very high rate of efficiency.

**Condensing** Condensing gas water heaters recover the heat created by the combustion gases. The recovered heat is referred to as the latent heat of vaporization and is directed back into the water, increasing the unit's efficiency. A condensing water heater operates at approximately 95 percent efficiency compared to 80–85 percent for a noncondensing water heater. The condensate generated from a condensing unit needs to be drained, but care must be taken to account for its acidic nature. With a pH rating of approximately 5, the condensate must be either diluted until it reaches an acceptable pH range or drained to a neutralization tank.

**Steam Fired** Steam-fired tankless water heaters generate hot water through the use of a heat exchanger. They are used in hospitals, industrial plants, restaurants, apartment houses, laundries, universities, and hotels, among other applications. They can be combined in parallel to meet high flow requirements while requiring less space than comparable tank-type units. The installation of a mixing valve is recommended to ensure that steam does not enter the hot water system in the event of a heat-exchanger breach.

**Direct Fired** These heaters are used in applications where several hundred gallons of hot water are needed per minute. These units use a direct exchange between the water and combustion products produced by the burner assembly. This process eliminates standby losses and can achieve operating efficiencies in excess of 98 percent.

## ALTERNATIVE RESOURCES

As the consumption of fossil fuels increases, so does the need to develop alternative fuel sources. One of these sources is solar energy. Energy captured from sunlight can be converted to power to heat domestic water. Other forms of alternative energy are geothermal and solid wastes, which have been used to heat water while reducing the load placed on mainstream resources. The designer may choose to use alternative energy resources for all or part of the hot water system. This helps meet restrictions placed on domestic water heating systems by energy codes in many parts of the country.

### Solar Energy

One of the most cost-effective ways to include renewable technologies in a building is by incorporating solar hot water. A typical residential solar water heating system reduces the need for conventional water heating by about two-thirds. It minimizes the expense of electricity or fossil fuel to heat the water and reduces the associated environmental impacts. Most solar water heating systems for buildings have two main parts: a solar collector and a storage tank. The most common collector used in solar hot water systems is the flat-plate collector.

Solar water heaters use the sun to heat either water or a heat-transfer fluid in the collector. Heated water then is held in the storage tank ready for use, with a conventional system providing additional heating as necessary. The tank can be a modified standard water heater, but it is usually larger and very well insulated. Solar water heating systems can be either active or passive, but the most common are active systems.

Active solar water heaters rely on electric pumps and controllers to circulate water or other heat-transfer fluids through the collectors. Following are the three types of active solar water heating systems:

1. Direct-circulation systems use pumps to circulate pressurized potable water directly through the collectors. These systems are appropriate in areas that do not freeze for long periods and do not have hard or acidic water. These systems are not approved by the Solar Rating and Certification Corp. (SRCC) if they use recirculation freeze protection (circulating warm tank water during freeze conditions) because that requires electrical power for the protection to be effective.
2. Indirect-circulation systems pump heat-transfer fluids through collectors. Heat exchangers transfer the heat from the fluid to the potable water. Some indirect systems have overheat protection, which is a means to protect the collector and the glycol fluid from becoming super-heated when the load is low and the intensity of incoming solar radiation is high. The two most common indirect systems are:
   - Antifreeze: The heat transfer fluid is usually a glycol-water mixture with the glycol concentration depending on the expected minimum temperature. The glycol is usually food-grade propylene glycol because it is nontoxic.
   - Drainback: This system uses pumps to circulate water through the collectors. The water in the collector loop drains into a reservoir tank when the pumps stop. This makes drainback systems a good choice in colder climates. Drainback systems must be carefully installed to ensure that the piping always slopes downward, so that the water will completely drain from the piping. This can be difficult to achieve in some circumstances.
3. Passive solar water heaters rely on gravity and the tendency for water to naturally circulate as it is heated. Because they contain no electrical components, passive systems are generally more reliable, easier to maintain, and possibly have a longer work life than active systems. The two most popular types of passive systems follow:
   - Integral-collector storage systems consist of one or more storage tanks placed in an insulated box with a glazed side facing the sun. These solar collectors are suited for areas where temperatures rarely go below freezing. They are also good in households with significant daytime and evening hot water needs, but they do not work well in households with predominantly

morning draws because they lose most of the collected energy overnight.

- Thermosyphon systems are an economical and reliable choice, especially in new homes. These systems rely on the natural convection of warm water rising to circulate water through the collectors and to the tank (located above the collector). As water in the solar collector heats, it becomes lighter and rises naturally into the tank above. Meanwhile, the cooler water flows down the pipes to the bottom of the collector, enhancing the circulation. Some manufacturers place the storage tank in the house's attic, concealing it from view. Indirect thermosyphons (that use a glycol fluid in the collector loop) can be installed in freeze-prone climates if the piping in the unconditioned space is adequately protected.

## Solid-waste Disposal Energy

Solid-waste collection and disposal systems produce various gases during decomposition. One of these is methane, which can be recovered and burned to produce heat. A second source of methane is leachate evaporation systems in landfill closures. Lastly, solid-waste incineration systems constructed to stringent pollution-control rules and regulations are another source of methane. These systems potentially can provide large volumes of steam and/or domestic hot water.

The use of these alternate energy sources should be within reasonable proximity to the resource. Typical applications include industrial plants with large volumes of burnable materials such as trash, paper, scrap wood, and plastics. A solid-waste incinerator system typically consists of a waste-disposal plant with a conveyer, loading system, boiler, ash-disposal equipment, heat exchanger, insulated piping, circulating pump, and controls.

## Geothermal Energy

Geothermal energy is heat from the earth. In states where this form of energy is believed to be available at reasonable depths, the U.S. Department of Energy (DOE) is supporting various state energy commissions in their funding of geothermal assessment programs. The temperature of the available liquid or gas (created when water flows through heated, permeable rock) and the cost of retrieval dictate the viability of geothermal energy. Some geothermal energy uses include steam for the generation of electricity, building domestic hot water systems with a minimum temperature of 150°F, and space and water heating needs for industrial parks.

Three prime areas of concern must be addressed when planning and developing geothermal energy:

1. Competitive institutional processes
2. Adequate temperature and flow rate
3. Thermal loads to make the system economically viable

A geothermal energy system typically consists of production and disposal wells, water-to-water heat exchangers (usually shell-and-tube type and two are required—one for operation while the other is being cleaned of deposits), insulated piping, a circulating pump, and a control system. The plumbing engineer should consult with the state energy office (Department of Energy or the Geothermal Resources Council) for resource information to apply this high-capital, low operating cost, alternate energy source.

## Heat Recovery

Heat recovery is the capture and reuse of energy that normally would be lost from a facility. It could be in the form of a liquid or a gas. Common waste heat sources are:

- Heat rejected from air-conditioning and commercial refrigeration processes
- Heat reclaimed from steam condensate
- Heat generated by cogeneration plants
- Heat pumps and heat reclamation systems
- Heat from wastewater

When considering heat recovery, it is important to determine if the hot water demand justifies the equipment and maintenance costs and if the heat recovered is sufficient to serve as a heat source. Facilities that typically have the proper blend of demand and waste heat are hospitals, military bases, and industrial facilities.

**Air-conditioning and Commercial Refrigeration** Systems with air- or water-cooled or evaporative condensers reject heat from air-conditioning and refrigeration systems that can be reclaimed. Within the refrigerant cycle is a condenser that rejects heat while an evaporator creates a cooling effect. For example, for every 1 Btuh of cooling effect produced by a 40°F evaporator, a 105°F condensing unit rejects 1.15 Btuh of heat. Systems with an air-cooled or evaporative condensor can be supplemented with a heat exchanger in the compressor's hot gas discharge line to capture the rejected heat. (Refer to Figure 7-2.)

Systems with water-cooled condensers can be supplemented with a heat exchanger in the hot water return line from the condenser to the cooling tower. (Refer to Figure 7-3.) System efficiency can be improved by providing a storage tank with a tube bundle. (Refer to Figure 7-4.)

An advantage of the system shown in Figure 7-4 is that simultaneous use of the domestic water and refrigeration systems does not need to occur for heat recovery. Another advantage of the system shown in Figure 7-4 is when an insufficient amount of heat is rejected, a backup water heater can be used to bring the water in the storage tank to the proper design temperature. The backup heater can operate on fossil fuel, electricity, or steam or may be fitted with a tube bundle utilizing hot water.

**Steam Condensate** When steam is used as a source for space heating, water heating, or process work, steam condensate generally is produced. The heat content of the condensate can be captured and reused for heating with the use of a heat exchanger. Laundries are a prime example of facilities where heat reclaimed from steam condensate can be put to use in heat recovery. It is essential to select a system with adequate storage to compensate for fluctuations in the condensate and domestic water flow. When deciding whether to capture and reuse steam condensate, remember that energy will not be saved if the boiler used to raise the

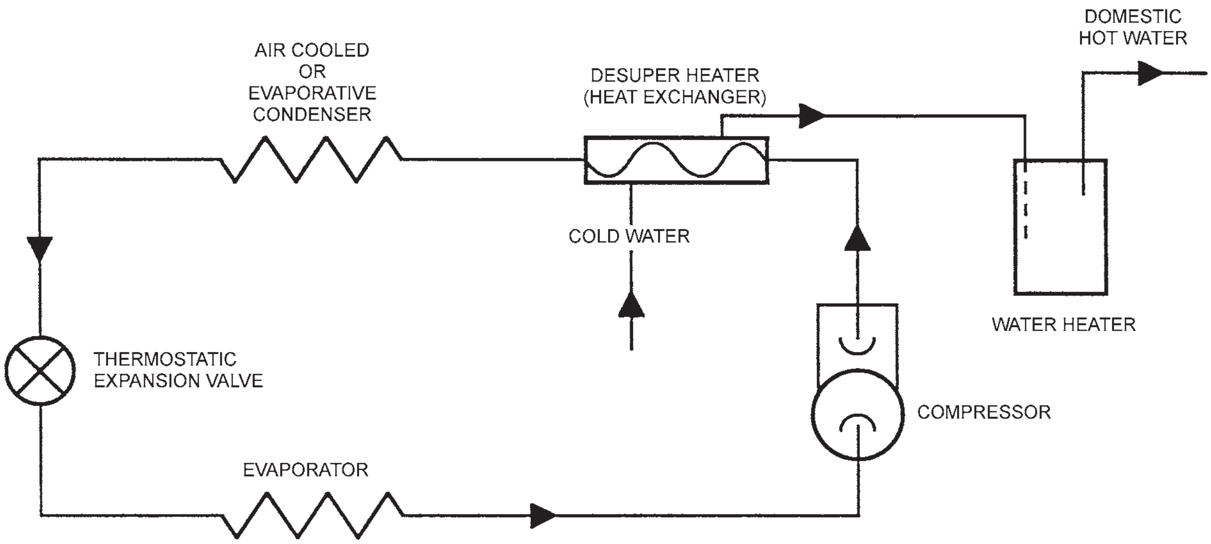


**Figure 7-2 Refrigeration Waste Heat Recovery**

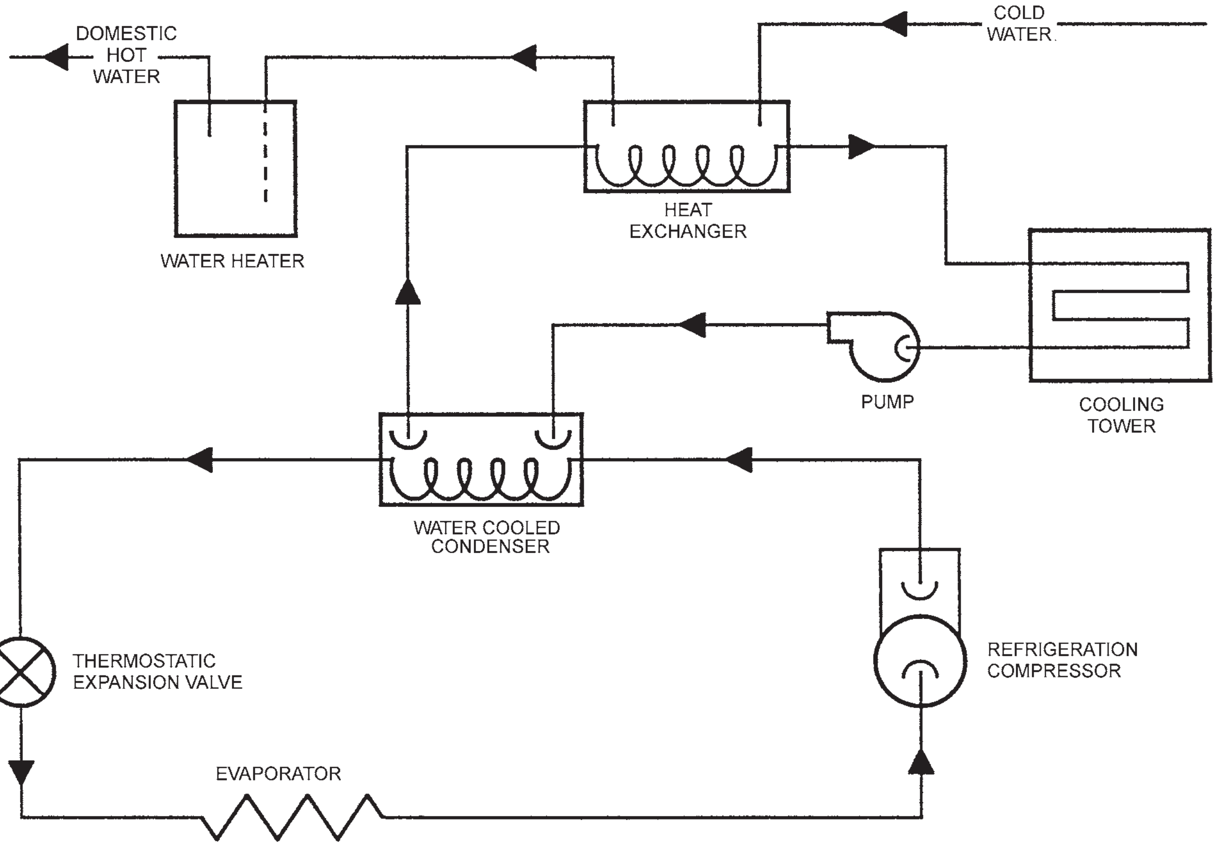


**Figure 7-3 Condenser Water Heat Recovery**

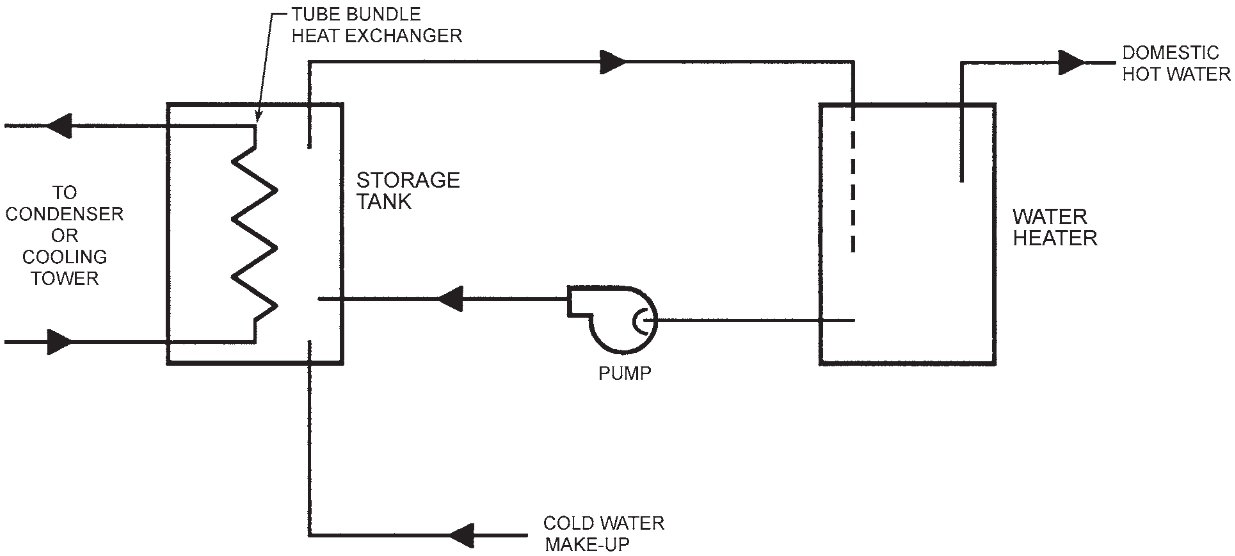


**Figure 7-4 Condenser Water Heat Recovery with Storage Tank**

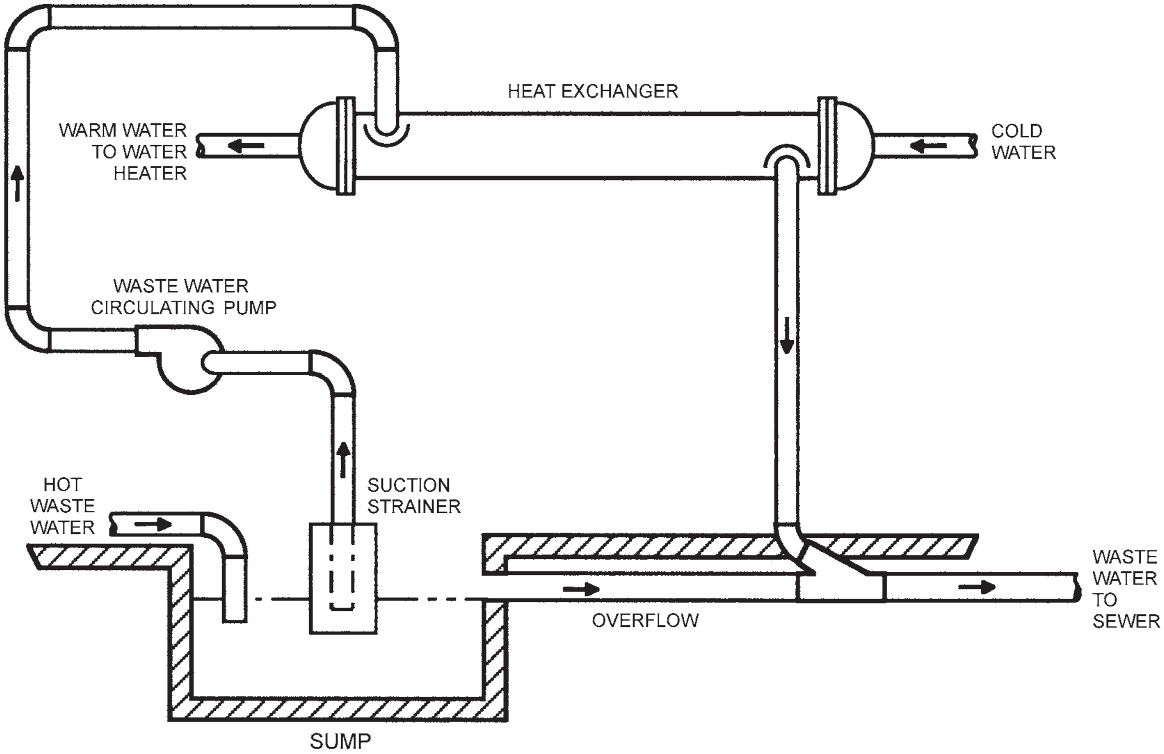


**Figure 7-5 Wastewater Heat Recovery**

temperature of the returned condensate is less efficient than the primary water heater.

**Cogeneration Plants** The heat produced as a by-product of generating electricity from reciprocating engines or gas turbines can be reclaimed from the cooling systems and exhaust gases by using a waste heat boiler and heat exchanger. The heat then can be used to produce steam or medium-temperature water. To be economically viable, most systems must have a year-round thermal heat load. Reheating makeup water and maintaining temperature in a domestic hot water system are excellent ways to maintain high overall thermal efficiencies.

**Heat Pumps** In today's buildings where computer rooms are continuously generating heat and industrial plants are producing waste heat, heat pumps can be used to transfer this heat to the domestic hot water systems, resulting in energy conservation. Either direct-expansion or chilled-water heat pumps can be used to transfer heat through the refrigeration process from the surrounding air to a water storage tank. The mechanics of this system are to extract heat from a warm environment directly, either through a heat exchanger or cooling coil.

**Drainline Heat Reclaim Systems** It has been estimated that 80–90 percent of all hot water energy is wasted. The U.S. DOE estimates this amount of energy to be 235 billion kWh a year. One method of recouping some of this energy is using a drainline heat reclaim system. This device can be a passive or active piece of equipment installed in the wastewater drainline of a building. Passive devices use a copper coil wrapped around a vertical portion of a waste line. Domestic water is fed through the copper coil to the hot water heater. As hot water is drained, heat is transferred from the drainline to the incoming domestic water. It has been estimated that these exchangers have an operating efficiency of up to 60 percent and can raise the incoming water temperature by as much as 36°F. Active systems utilize a wastewater circulating pump in conjunction with the heat exchanger. This system is shown in Figure 7-5.

## DESIGN TECHNIQUES FOR WATER MANAGEMENT

Conserving water benefits both the building's owner and the local municipality. The owner saves by having lower utility costs, while the municipality saves resources by having to treat and circulate less water and wastewater. To realize these savings, the plumbing engineer must provide designs that reduce water consumption without compromising a fixture's operation.

For a water management program to be successful in renovation projects, it is important to first establish the building's current water consumption. The U.S. DOE has developed eight steps to make a successful water management plan:

1. Gather information
2. Conduct a comprehensive facility survey
3. Explore and evaluate water management options
4. Conduct life-cycle cost analysis and explore financing options
5. Develop a water management plan and work schedule
6. Inform building occupants about water management
7. Implement the water management plan
8. Monitor the water management plan

For more information, refer to the U.S. DOE's *Greening Federal Facilities Guide*.

Some design techniques previously mentioned are:

- Eliminate faucet and pipe leaks
- Reduce fixture flow rates

Other methods of unique water management are:

- Alternate sources of freshwater
- Reclaimed and graywater

### Eliminate Faucet and Pipe Leaks

Similar to hot water conservation, this is one of the easiest and first actions that should be taken. Leaks in both the cold and hot water piping should be repaired as well as any leaking faucets. This will reduce the amount of water being wasted and avoid more expensive repairs later.

### Reduce Fixture Flow Rates

Replacing old plumbing fixtures can save huge quantities of water. The standards established for water consumption by the EPAct restrict showerheads to 2.5 gpm (9.5 lpm), urinals to 1 gpf (3.8 lpf), faucets to 2.2 gpm (8.3 lpm) at 60 psi (410 kPa), and toilets to 1.6 gpf (6 lpf) at 80 psi (550 kPa).

### Alternate Sources of Fresh Water

Rainwater harvesting is the collection, storage, treatment, and use of rainwater. Harvested water can be used for irrigation, nonpotable, and potable uses. A rainwater harvesting system typically starts with a catch area that collects rainwater, usually on a building's roof. To ensure that potential contaminants and pollutants do not enter the system's storage tank, a wash system is installed that diverts the initial portion of the rainfall away from the storage tank while cleaning the catch area. A screen usually is installed in the catch area to keep out debris. Piping routes the collected rainwater to a storage tank, which can be located indoors, outdoors, aboveground, or underground. It is important to provide a lid on the storage tank to keep light out to discourage algae growth. Water typically is delivered to the building through the use of a domestic water booster pump system, and final water treatment may be needed depending on the application and quality of water collected.

### Reclaimed and Graywater

Reclaimed water and graywater collection systems can be used to reduce the amount of domestic water consumed by a building. Graywater typically is collected from showers, tubs, lavatories, washing machines, and drinking fountains. It contains a minimal amount of contamination and is reused in certain landscape applications such as subsurface irrigation of lawns, flowers, trees, and shrubs, but it should not be used for vegetable gardens because of the potential absorption of cleaning and washing chemicals.

Similar to rainwater harvesting, graywater is collected, stored, and filtered prior to use. A graywater storage container should be fitted with overflow protection that is connected to the sanitary sewer system in the event the amount of water collected is more than the amount of water being consumed, a distribution pipe becomes clogged, or collected water is not used in a timely manner.

Wastewater treatment plants are constructed to provide reclaimed or recycled water to buildings through a second municipal water system where two water lines enter a building. One line is used to deliver potable water for domestic use, and a second provides treated wastewater that can be used for nonpotable applications such as landscape irrigation, cooling tower makeup, toilet flushing, and fire protection.

## WATER MANAGEMENT EQUIPMENT

The goal of effective water management is to reduce water consumption without compromising the performance of equipment and fixtures. Replacing or retrofitting water closets, urinals, showerheads, and faucets with low-flow versions can considerably lower a building's water consumption.

### Water Closets

Americans flush about 4.8 billion gallons (18.2 billion liters) of water down toilets each day, according to the U.S. Environmental Protection Agency. According to the Plumbing Foundation, replacing all existing toilets with 1.6-gpf (6-lpf) ultra-low-flow models would save almost 5,500 gallons (25,000 liters) of water per person each year. A widespread toilet replacement program in New York City apartment buildings found an average 29 percent reduction in total water use for the buildings studied. The entire program, in which 1.3 million toilets were replaced, is estimated to be saving 60–80 million gallons (230–300 million liters) per day.

Ultra-low-flow water closets consume 1.6 gpf (6 lpf) and are available in three different classifications:

1. Tank type
2. Flush valve
3. Specialty

While the problems associated with ultra-low-flow toilets when they first became available have been corrected, some low-cost models continue to exhibit poor performance.

**Tank Type** Water is drained from this water closet by gravity and is most commonly used in residential applications. Prior to ultra-low-flow models, these fixtures consumed 3.5 gpf. A low-cost method of conserving water in these earlier models and in today's ultra-low-flow version is using a refill diverter. When a tank-type water closet is flushed, water starts to refill the tank as it is emptying. The time elapsed between the open and closed position of the flapper allows excess water to flow through the bowl, into the bowl, and consequently to the drain. While refilling the tank, this water is wasted. A diverter keeps this water in the tank, saving ½ to 1 gallon when installed on older toilets and ¼ gallon on ultra-low-flow models.

**Flush Valve** Flush valve water closets use the building's water pressure to exert a force when operating. They typically require 25 to 40 pounds per square inch gauge (psig) to operate and are most commonly used in commercial buildings. Older models can be retrofitted by adjusting the flush valve, but care must be taken to not overly constrain the valve, which could cause it to malfunction. Early closure devices also can be used to cause the flush valve to stop the flow of water sooner than normal, limiting the amount of water discharged.

**Specialty** Some specialty water closets are pressure-assisted tank type, dual flush, and composting. Pressure-assisted tank-type water closets can be used in applications where it is desired to use a gravity tank-type water closet, but there is concern about flushing performance. When water conservation beyond ultra-low-flow is desired, dual-flush water closets can be used. These have two flush settings: one for normal operation to flush solids and a second, reduced amount for liquids, saving approximately 1 gpf. Composting systems are high-capital ventures that require a lot of space and typically are used in unique locations where no water supply exists. They are popular choices in parks and camping facilities. Composting toilets are gaining acceptance in other areas of the world for mainstream use in households.

**High-efficiency Toilets (HET)** The HET is defined as a fixture that flushes at 20 percent below the 1.6 gpf ultra-low-flow toilet. This includes dual-flush technology.

### Urinals

Ultra-low-flow urinals consume 1 gpf, but water conservation methods can go beyond this level. Flush valves that consume as low as 1 pint per flush have been employed with success. Waterless urinals that do not consume any water also are being used. Waterless urinals utilize a specially designed trap insert that prevent odors from passing through the urinal trap. Traps can be mechanical or filled with a liquid sealant. The lighter-than-water sealant floats on top of the urine collected in the U-bend. The cartridge and/or sealant must be replaced periodically. A waterless urinal could save anywhere between 15,000 and 45,000 gallons (approximately between 56,800 and 170,000 liters) of water per urinal per year. Waterless urinals can be installed in high-traffic facilities and in situations where providing a water supply may be difficult or where water conservation is desired.

### Showerheads

The 1992 EPAct set the maximum flow rates for showerheads and faucets at 2.5 gpm. Prior to this act, showerhead flow rates were between 3 and 7 gpm. Water-conserving showerheads incorporate a more narrow spray jet and introduce a greater volume of air when compared to conventional heads. The use of flow restrictors in conventional showerheads is not recommended because they typically restrict the showerhead too much, providing poor water pressure from the head.

### Faucets

Faucets manufactured after 1993 consume no more than 2.5 gpm at 80 psig, meeting the requirements of the 1992 EPAct. Replacing the faucet's tip with an aerator, which mixes air into the faucet's discharge and reduces its flow rate to 2.5 gpm, can retrofit older faucets, which consume between 3 and 5 gpm.

With manual valve faucets, replacing the screw-in tip of the faucet is all that typically is necessary to reduce water use. While faucet aerators that mix air into the water stream are commonly used in residential faucets, they are specifically prohibited in health facilities because they can harbor germs and pathogens. Instead, these facilities use nonaerating, low-flow faucet tips (including those providing a smooth, laminar stream of water). Choose 2.2- to 2.5-gpm (8.3- to 9.5-lpm) devices for kitchens. In washrooms, 0.5- to 1.25-gpm (1.9- to 4.7-lpm) models often prove adequate for personal washing purposes. Metered (metered valve or electronic sensor) faucets deliver a preset amount of water and then shut off. For water management purposes, the preset amount of water can be reduced by adjusting the flow valve. The Americans with Disabilities Act requires a 10-second minimum on-cycle time. To maximize water savings, choose the lowest-water-use models—typically 0.5 gpm (1.9 lpm).

## GLOSSARY

***British thermal unit (Btu)*** A heat unit equal to the amount of heat required to raise 1 pound of water 1 degree Fahrenheit.

***Coefficient of performance (COP)*** The ratio of the rate of heat removal to the rate of energy input, in consistent units, generally relating to a refrigeration system under designated operating conditions.

***Condenser*** A heat exchanger that removes heat from a vapor, changing it to its liquid state.

***Delta T ($\Delta T$)*** Temperature differential.

***Domestic water heating*** Supply of hot water for domestic or commercial purposes other than comfort heating.

***Domestic water heating demand*** The maximum design rate of energy withdrawal from a domestic water heating system in a specified period of time.

***Efficiency, thermal (overall system)*** The ratio of useful energy at the point of ultimate use to the energy input.

***Energy*** The force required for doing work.

***Energy, non-depletable*** Energy derived from incoming solar radiation and phenomena resulting therefrom, including wind, waves, tides, and lake or pond thermal differences, and energy derived from the internal heat of the earth (geothermal)—including nocturnal thermal exchanges.

***Energy, recovered*** A by-product of energy used in a primary system that otherwise would be wasted from an energy utilization system.

***Heat, latent*** The quantity of heat required to effect a change in state.

***Heat, sensible*** Heat that results in a temperature change but not a change in state.

***Life-cycle cost*** The cost of the equipment over its entire life, including operating and maintenance costs.

***Makeup*** Water supplied to a system to replace that lost by blowdown, leakage, evaporation, etc.

***Solar energy source*** Source of chemical, thermal, or electrical energy derived from the conversion of incident solar radiation.

***System*** An arrangement of components (including controls, accessories, interconnecting means, and terminal elements) by which energy is transformed to perform a specific function.

***Terminal element*** The means by which the transformed energy from a system is ultimately delivered.

## RESOURCES

1. Cassidy, Victor M. 1982. “Energy saving and the plumbing system.” *Specifying Engineering* (February).
2. San Diego Gas & Electric Company. Commercial Energy Conservation Manual.
3. U.S. Department of Energy: energy.gov.

# ASPE Continuing Education Application Form

**This form is valid up to one year from date of publication.** Expiration date: Continuing education credit will be given for this examination through **June 30, 2013.** Applications received after that date will not be processed.
Submit this form with payment via mail (ASPE Read, Learn, Earn, 2980 S. River Road, Des Plaines, IL 60018), fax (847-296-2963), or email aspeeducation@aspe.org.

Please print or type; this information will be used to process your credits.

Name_______________________________ ASPE Membership No. ____________

Organization_______________________ Daytime telephone ______________

Billing Address ___________________________________________________

City ________________ State/Province ______________ Zip____________

E-mail ____________________________ Fax ____________________________

PE State ___________________________ PE No. _________________________

Notice for North Carolina Professional Engineers: State regulations for registered PEs in North Carolina now require you to complete ASPE's online CEU validation form to be eligible for continuing education credits. After successfully completing this quiz, just visit ASPE's CEU Validation Center at aspe.org/CEUValidationCenter.

Reading the article and completing the form will allow you to apply to ASPE for CEU credit. If you earn a grade of 90 percent or higher on the test, you will be notified that you have logged 0.1 CEU, which can be applied toward CPD renewal or numerous regulatory-agency CE programs. (Please note that it is your responsibility to determine the acceptance policy of a particular agency.) CEU information will be kept on file at the ASPE office for three years.

I certify that I have read the article indicated above.

________________________
Signature

Payment:
❏ Member: Free
❏ Nonmember: Each examination: $35
❏ Personal Check (payable to ASPE)
❏ Business or government check
❏ DiscoverCard ❏ VISA ❏ MasterCard ❏ AMEX

*If rebilling of a credit card charge is necessary, a $25 processing fee will be charged.*

ASPE is hereby authorized to charge my CE examination fee to my credit card

________________________
Account Number

________________________
Expiration date

________________________
Signature

________________________
Cardholder's name (Please print)

## CE Questions —
## "Energy and Resource Conservation in Plumbing Systems"
## (CEU 188) Circle the correct answers below.

1. **What was the first major piece of legislation addressing federal energy management?**
   a. EPAct
   b. EPCA
   c. RCRA
   d. FEMIA

2. **The domestic hot water system in a new building should be set at ________ according to many energy codes.**
   a. 140°F
   b. 120°F
   c. 110°F
   d. 105°F

3. **How much hot water is needed to provide 0.084 L/s of 43°C mixed water with 68.5°C hot water and 23.9°C cold water?**
   a. 0.037 L/s
   b. 0.059 L/s
   c. 56 gph
   d. none of the above

4. **Thermal insulation is beneficial because it ________.**
   a. retards heat loss
   b. reduces noise
   c. controls condensation
   d. all of the above

5. **Delta T is calculated by subtracting the air temperature surrounding the piping system from ________.**
   a. hot water circulating temperature
   b. length of pipe
   c. thickness of insulation
   d. diameter of pipe

6. **A condensing water heater operates at approximately ________ efficiency.**
   a. 80 percent
   b. 85 percent
   c. 90 percent
   d. 95 percent

7. **What type of water heater is best when several hundred gallons of hot water are needed per minute?**
   a. tankless
   b. steam fired
   c. direct fired
   d. condensing

8. **________ solar water heating systems rely on the natural convection of warm water rising to circulate water through the collectors and to the tank.**
   a. drainback
   b. thermosyphon
   c. direct-circulation
   d. indirect-circulation

9. **Waste heat can be recovered from ________.**
   a. steam condensate
   b. wastewater
   c. heat pumps
   d. all of the above

10. **Approximately how much of all hot water energy is wasted?**
    a. 70–80 percent
    b. 80–90 percent
    c. 95 percent
    d. none of the above

11. **A high-efficiency toilet flushes at ________ below the 1.6 gpf toilet.**
    a. 5 percent
    b. 10 percent
    c. 15 percent
    d. 20 percent

12. **________ is the quantity of heat required to effect a change in state.**
    a. recovered energy
    b. sensible heat
    c. latent heat
    d. British thermal unit