

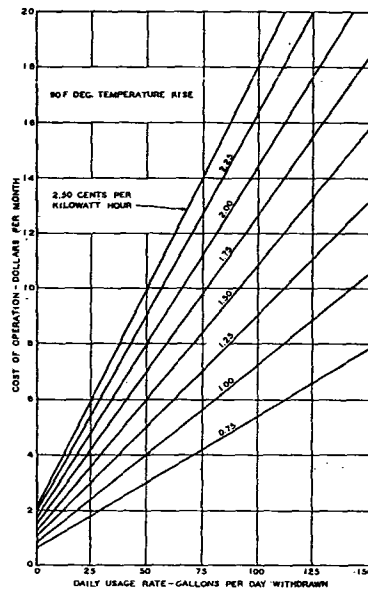


Fig. 9.... Monthly Cost of Operation of Electric Water Heaters<sup>1</sup>

number of occupants, number of bathrooms or plumbing fixtures, and presence of appliances such as laundry equipment, dishwashers, and the like. Information of this kind is given in Tables 2, 10, 11 and 12 and in design manuals issued by the electric utility industry and by heater manufacturers. For commercial applications, the hourly hot water requirements must be analyzed and the best combination of tank capacity and heating element rating determined, with due

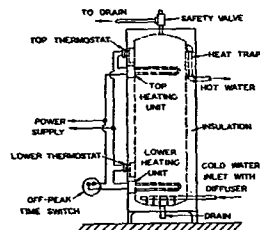


Fig. 10.... Domestic Hot Water Heater for Off-Peak Service

consideration of electric power demand created in relation to the user's other electric demands.

A common type of electric service for water heating is the off-peak service under which the charge for energy consumed during designated hours is lower than for normal or unrestricted service. With this system, the operation of heaters is confined to such hourly intervals during the 24 hours as will (a) avoid creating peak electrical demands by the customer in excess of the demand resulting from the customer's other uses of electricity, or (b) keep the water heating load off the electric utility system during peak hours. In general, Case (a) occurs where rate schedules contain a demand charge component, and Case (b) where a special low rate applies to off-peak consumption. Water heater circuits are controlled with relays actuated by an electric-clock mechanism or by a carrier-current impulse impressed at suitable intervals on the electric distribution system, or by an automatic load-limiting type of control.

For general information on automatic control see Chapter 43.

One arrangement of domestic hot water heater for off-peak service, shown in Fig. 10, has the lower heating unit under control of an off-peak switch. Upper unit is connected directly to the line, so that if the reserve of hot water becomes depleted, the top thermostat brings its heating unit into operation only until the upper portion (usually about 25 percent) of tank contents reaches the thermostat temperature setting.

#### Indirect Water Heaters

In the indirect method, either steam or hot water is used for heating the water. With steam, the water to be heated is preferably circulated around the outside of the steam tubes which are submerged within a tank. A typical indirect heater using steam is shown in Fig. 11. The coils usually are of copper, and are U-shaped to permit expansion and contraction. The shell may be of steel, with a protective coating or with a special inside protective lining, or may be of copper or copper alloy. Where straight heating tubes are used, one end of the tube is usually expanded into a floating head to take care of expansion. The coils should be capable of easy withdrawal for inspection and for removal of scale. Instead of steam, the heating medium may also be hot water inside the tubes.

Another method of transferring heat from a heating boiler to the domestic water is illustrated in Fig. 12. The water heater is generally a cast-iron shell within which there is located a spiral copper coil. Hot water from the boiler circulates inside the shell and around the coil, and returns to the boiler, while domestic water from the storage tank circulates

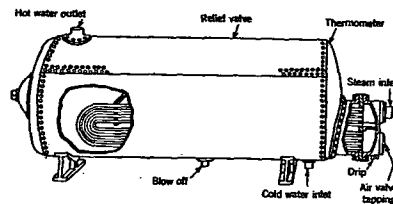


Fig. 11.... Indirect Water Heater

#### Water Services

inside the coil. The storage tank should be installed with the bottom of the tank as far above the boiler as possible. Horizontal storage tanks of less than 18- or 20-in. diameter are not recommended because of the difficulty of preventing the hot and cold water from mixing, especially when large quantities of water are withdrawn. In Fig. 13 the heat-transfer surface is placed inside the boiler instead of in a separate vessel, but otherwise the operation is similar to that of Fig. 12. This arrangement with vertical tank is commonly used for small domestic installations.

Sometimes the heating element is located inside of the larger-type fire tube boilers and small residential boilers. In this case the heat-transfer surface is in the form of a number of straight copper tubes, with rear U-bends or a floating head, inserted through a special opening in the boiler. While the

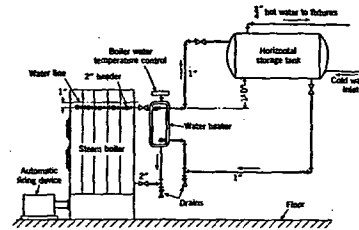


Fig. 12.... Indirect Water Heater Mounted on Side of Boiler

coil may be placed in the steam space above the waterline of a steam boiler, it is usually placed below the waterline. Long coils of small diameter tubing, immersed in the water, are widely used without storage tanks. The rate of flow through the coil is limited by the friction loss in the coil, and by fittings and restrictions, so that the water attains the desired temperature in one passage through the coil. This arrangement is frequently found in oil burner installations where the heating boiler, either steam or hot water type, is used to supply hot water during the summer. A thermostatic three-way mixing valve should be used to maintain a uniform temperature of the hot water supply to the plumbing fixtures and prevent danger of scalding.

In order to reduce clogging by precipitated solids, water heating plants sometimes develop steam in a closed circuit, and transfer the heat through a tubular heater to the domestic service water. The water in the primary heater, exposed to the high temperature of the fire, is repeatedly used and hence, has no appreciable tendency to deposit scale, while the domestic water, heated by steam at a much lower temperature than that of the fire, also exhibits a much reduced tendency to precipitate dissolved salts. Water characteristics, the effect of impurities, and means of improving the quality of the water are important items discussed in Chapter 55.

Where plentiful steam supply is available, and sometimes where gas firing is to be used directly, it is advantageous to use instantaneous type heaters. This minimizes first cost and avoids the radiation losses of large storage tanks. Instantaneous heaters have the advantage also where hot water demands are either very steady or very infrequent.

Since the instantaneous heater must heat the water as it is

used it should be sized for the same water volume in gallons per minute used for calculating the size of the hot water main. Since there is no mixing of cold water and hot water, as would occur in a storage tank, the instantaneous heater is to be selected for a temperature rise only sufficient to produce the required delivery temperature.

#### COMPUTING HEAT-TRANSFER SURFACE

The area of the inside surface of a heating coil may be determined from Equation 4.

$$A = \frac{Q \times 8.33(t_2 - t_1)}{U \times \Delta t_m} \quad (4)$$

where

- A = surface area of coil, square feet.
- Q = quantity of water heated, gallons per hour.
- $t_2$  = hot water outlet temperature, Fahrenheit.
- $t_1$  = cold water inlet temperature, Fahrenheit.
- U = coefficient of heat transmission, Btu per (hour) (square foot) (Fahrenheit degree logarithmic mean temperature difference).
- For copper or brass coils  $U = 240$  (steam) and 100 (hot water).
- For iron coils  $U = 160$  (steam) and 67 (hot water).
- $\Delta t_m$  = logarithmic mean of the difference between the temperature of the heating medium and the average water temperature, and is approximately:

$$\Delta t_m = \frac{(t_2 - t_1)}{2}$$

$t_2$  = temperature of the heating medium, Fahrenheit.

Equation 4 may be used to check the heating coil ratings under temperatures other than those stated in the manufacturers' published ratings.

**Example 9:** What area of copper transfer surface will be required to heat 70 gal of water per hour from 40 to 180 F with boiler water at 220 F?

**Solution:**

$$\Delta t_m = \frac{220 - (180 + 40)}{2} = 110$$

$$A = \frac{70 \times 8.33(180 - 40)}{100 \times 110} = 7.42 \text{ sq ft}$$

For instantaneous submerged heaters, the surface required will depend upon (1) the velocity of water in the tubes, (2) the boiler water temperature, (3) the inlet water temperature, (4) the outlet water temperature, (5) the cleanliness of the coil surface, and (6) the condition of the boiler water surrounding the coil. If the heater is located in the water of an actively steaming part of a boiler, the heat transfer may be twice as great as would be obtained if the water surround-

Table 17.... Coefficient of Heat Transfer of Instantaneous Water Heaters

$$U = \text{Btu per (hr) (sq ft) (Fahrenheit degree logarithmic mean temperature difference)}$$

| Boiler water temperature..... | 210 | 200 | 180 |
|-------------------------------|-----|-----|-----|
| U.....                        | 225 | 175 | 150 |