

upward from high capacity burners. Storage-type heaters may include in one unit an insulated storage tank, a combustion chamber, flues, burner equipment and controls, or may consist of a separate storage tank and external direct-fired water heater, which may be a so-called *side-arm* heater for small capacity or a gas-fired boiler for larger capacity. Gas boilers used for direct hot water supply must be able to withstand the city water operating pressure. While direct-fired gas heaters are used generally for residences and small installations of 100 gal storage capacity or less, indirect heaters are recommended for larger installations.

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. 2. The coils usually are of copper and are *U*-shaped to permit expansion and contraction. The shell may be of steel, copper, or with a special inside protective lining. 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. 3. 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 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 smaller than 18 or 20 in. diameter are not recommended because of the difficulty of preventing the hot and cold water from mixing, and especially is this an important consideration when large quantities of water are withdrawn. In Fig. 4 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. 3. 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 coil may be located in the steam space above the water line of a steam boiler, it operates more satisfactorily when below the water line since clogging of the water tubes may thereby be delayed. This method is widely used without storage tanks since the intimate contact and efficient circulation of the water in this arrangement permit the utilization of the heat stored in the water of the boiler. A thermostatic three-way mixing valve is frequently used to maintain a uniform temperature of the hot water supply to the plumbing fixtures.

In order to reduce clogging by precipitated solids, water heating plants sometimes develop steam in a closed circuit, transferring the heat through a tubular heater to the domestic 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.

COMPUTING AREA OF HEAT TRANSMITTING SURFACE

The area of the inside surface of a heating coil may be determined from Equation 1.

$$A = \frac{Q \times 8.33 (t_2 - t_1)}{U \times t_m} \quad (1)$$

where

A = surface area of coil, square feet.

Q = quantity of water heated, gallons per hour.

t_2 = hot water outlet temperature, degrees Fahrenheit.

t_1 = cold water inlet temperature, degrees Fahrenheit.

U = coefficient of heat transmission, Btu per (hour) (square foot) (degree Fahrenheit 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).

t_m = logarithmic mean of the difference between the temperature of the heating medium and the average water temperature and is *approximately*:

$$t_s - \left[\frac{(t_2 + t_1)}{2} \right]$$

t_s = temperature of the heating medium, degrees Fahrenheit.

Equation 1 may be used to check the heating coil ratings under temperatures other than those stated in the manufacturer's published ratings.

TABLE 3. COEFFICIENT OF HEAT TRANSFER OF INSTANTANEOUS WATER HEATERS.

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

Boiler Water Temperature.....	210	200	180
U	225	175	150

Example 4. 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?

$$t_m = \left[220 - \frac{(180 + 40)}{2} \right] = 110 \quad A = \frac{70 \times 8.33 (180 - 40)}{100 \times 110} = 7.39 \text{ sq ft.}$$

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 surrounding the coil were circulating slowly. Ratings of instantaneous water heating coils will therefore vary greatly depending upon the assumptions made regarding the conditions of operation. The values of the coefficient of heat transmission for instantaneous heaters shown in Table 3 are conservative.

For a coil in which heat is transferred from steam to water the value of $U = 300 \sqrt{v}$ may safely be used (v = velocity of water in feet per second).

The rate of heat transfer between steam or water as the carrier and the domestic water is influenced by the rate of movement of both the carrier and the water which receives the heat. For this reason, where the transfer occurs from heating system water to domestic water, it is good practice to install a circulating pump to insure rapid movement of the boiler water.

In view of the high condensation rates obtained when steam is used with