per square foot of grate, if the heating value of the fuel is 12,500 Btu per pound, and the efficiency is 60 per cent?

$$\text{Substituting: } \frac{100 \times 8.3 \times (180 - 50)}{12{,}500 \times 0.60 \times 4.5} = 3.2 \text{ sq ft.}$$

The quantity of gas, oil, or other fuel required per hour for water heating may be calculated by the Equation 2.

$$F = \frac{W\,(t_2 - t_1) \times 100}{H \times E} \tag{2}$$

where

F = units of fuel (lb, cu ft, gal, etc).
H = heating value of fuel, Btu per unit.
W = weight of water, pounds per hour.
$t_2 - t_1$ = temperature difference between entering and leaving water, degrees Fahrenheit
E = efficiency, per cent.

Efficiencies for oil and gas may be taken as 75 and 80 per cent respectively. The heating value of the fuel and the temperature rise should be determined to suit local conditions.

COMPUTING AREA OF HEAT TRANSMITTING SURFACE

The area of the inside surface of a heating coil may be determined from the following Equation 3.

$$A = \frac{Q \times 8.33\,(t_2 - t_1)}{K_o \times t_m} \tag{3}$$

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.
K_o = coefficient of heat transmission, Btu per hour per square foot surface. For copper or brass coils K_o = 240 (steam) and 100 (hot water). For iron coils K_o = 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. t_m is approximately = $t_s - \left[\frac{(t_o + t_i)}{2}\right]$
t_s = temperature of the coil surface, degrees Fahrenheit.

Equation 3 may be used to check the heating coil ratings under temperature conditions differing from those stated in the manufacturer's published ratings.

Example 10. What area of copper transfer surface will be required to heat 70 gal per hour from 40 to 180 F with boiler water at 220 F?

$$t_m = \left[220 - \frac{(180 + 40)}{2}\right] = 110$$

$$A = \frac{70 \times 8.33\,(180 - 40)}{100 \times 110} = 7.39 \text{ sq ft.}$$

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 is 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 when steam is used with gravity circulation from the boiler and when there is a sudden demand followed by an inflow of cold water, the bottom of a steam heating transfer element always should be at least 30 in. above the boiler water line, and the steam and condensate return pipes should be of liberal size. Otherwise water hammer and reduced capacity may result due to imperfect drainage of condensate.

When connecting a transfer-type hot water heater below the water line of a cast-iron steam boiler having vertical sections, there should be a separate tapping for water circulation into every section of the boiler, as shown in Fig. 9. Ordinarily in steam boilers of this type the top connecting nipples between the sections are in the steam space and thus no full internal circulation of water can occur. If a connection to any section is omitted, steaming may take place in that section during summer operation when steam generation is undesirable. Water heating capacity would also be reduced.

CONTROL OF SERVICE WATER TEMPERATURE

With coal-fired heaters the usual arrangement of control is by an aquastat in the heated water, which opens or closes draft dampers at the heater to adjust the rate of combustion. When oil or gas is burned the aquastat controls the oil burner motor or the magnetic gas valve and the pilot flame usually burns continuously. When electric heaters are used the aquastat operates a switch on the source of energy.

When steam or hot water is the carrier of heat to transfer surface submerged in the water of a tank, the aquastat controls a valve in the transmitting line. In small residence installations using water as the carrier a combined aquastat and butterfly valve all in one simple fitting may be installed in the transmitting circuit to prevent overheating of the service water.

In many residences heated by mechanically circulated hot water, the house temperature is controlled by operating the circulating pump intermittently, while domestic hot water is warmed by transfer from the house heating water, independent of the pump operation. The domestic water may be heated by the main boiler the year around. Under such an arrangement, to prevent overheating the house by thermal circulation when the pump is not running, it is usual to insert a weighted check-valve in the house heating main, so that no circulation to the house heating system can occur unless the pump operates. In summer the fire may be controlled to maintain a limited water temperature, generally about 20 F warmer than that desired in the out-going domestic hot water.

In buildings which have restaurants it is generally desirable to install two separate service hot water systems so that water at about 180 F minimum may be available for dish washing, while water at 140 F maximum may be used for lavatory and bath purposes.