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. 10. 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 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of the difficulty of preventing the hot and cold water from mixing, especially when large quantities of water are withdrawn.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. 11 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. 10. This arrangement with vertical tank is commonly used for small domestic installations.

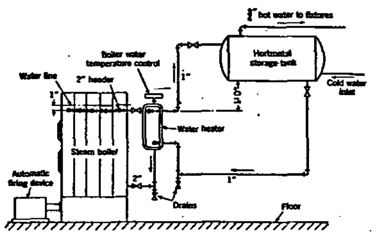

Fig. 10 .... Indirect Water Heater Mounted on Side of Boiler

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 placed in the stream 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 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. Water characteristics, the effect of impurities, and means of improving the quality of the water are important items, as brought out in Chapter 55.

COMPUTING HEAT-TRANSFER SURFACE

The area of the inside surface of a heating coil may be determined from Equation 2.

$$A = \frac{Q \times 8.33(t_2 - t_1)}{U \times t_m} \qquad (2)$$

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).

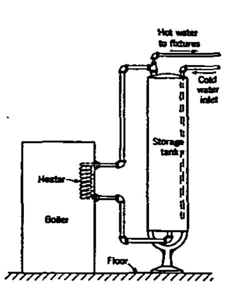

Fig. 11 .... Indirect Water Heater Placed in Boiler

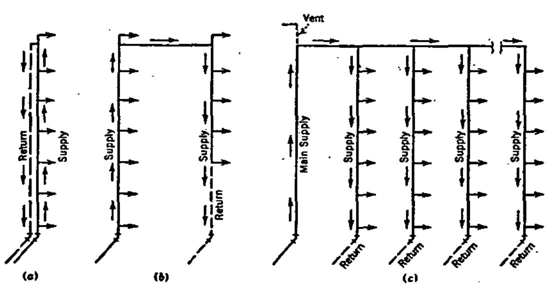

Fig. 12 .... Methods of Arranging Hot Water Circulation Lines

Table 12 .... Coefficient of Heat Transfer of Instantaneous Water Heaters

U = Btu per (hr) (sq ft) (Fahrenheit degree logarithmic mean temperature difference)

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

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, Fahrenheit.

Equation 2 may be used to check the heating coil ratings under temperatures other than those stated in the manufacturer's published ratings.

Example 6: 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:

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

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

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 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 12, 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 gravity circulation from the boiler, particularly when there is a sudden demand followed by an inflow of cold water, the bottom of a steam heat 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 waterline 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. 10, unless the boiler has large top nipple ports providing intersectional circulation. If the top nipples are entirely within the boiler steam space, no internal circulation occurs between sections. Steaming may then occur in the boiler sections not connected to the heater and, further, the unconnected sections will not deliver any heat to the water heater.

HOT WATER SUPPLY PIPING

It is common practice to provide circulating piping in all hot water supply systems in which it is desirable to have hot water available continuously at the fixtures. In average-sized and small residences and systems, in which the piping from the heater to the fixtures is short, return circulating piping is generally omitted in order to reduce installation cost, and to reduce heat loss from the piping, particularly during periods of no water demand.

The hot water supply may be distributed by either an up-feed or down-feed piping system. Three common methods of arranging the circulating lines are shown in Fig. 12. Although the diagrams apply to multi-story buildings, the arrangements (*a*) and (*b*) are sometimes used in residential designs.

A check valve should be provided in the runout from each return riser to prevent temporary reversal of flow in the piping when a faucet is open. Proper air venting of a circulating system is extremely important, particularly if gravity circulation is employed. In Fig. 12 (*a*) and (*b*), this is accomplished by connecting the circulating line below the top fixture supply. With this arrangement, air is eliminated from the system each time the top fixture is opened.

Where an overhead supply main is located above the highest fixture as in Fig. 12 (*c*), an automatic float-type air vent is installed at the highest point of the system, or a fixture branch is connected to the top of the main where air venting is desired, and then dropped to the fixture outlet.

It is sometimes necessary to make an allowance for pressure drop through the heater when sizing hot water lines, particularly where instantaneous hot water heaters are used and the available pressure is low.

The principles involved in the sizing of the hot water supply pipes are the same as those for the sizing of cold water supply lines. For small and medium sized installations a ¾-in. hot water return will be ample. For larger installations, the size of the hot water return may be computed from considerations of the heat losses in the hot water piping.[4] A throttling valve should be placed in the hot water return pipe so that the rate of circulation may be adjusted.

Where the hot water piping system is exceedingly long, a water circulator is frequently installed. It is controlled by an immersion thermostat (in the return line) set to start and stop the pump over approximately a 20 F deg temperature range. In calculating the pump capacity, the product of (1) the pounds of water circulated and (2) the temperature difference (usually 20 deg) between the flow and return, must be equivalent to the Btu heat loss from the piping at the average temperature of the water. Insulation reduces the heat loss and pump capacity required. The friction head against which the pump must operate may be calculated from the tables and charts in Chapter 28, Hot Water Heating Systems. The friction head seldom exceeds 6 to 10 feet.

Since service water is corrosive due to the high oxygen content and high temperature, circulating pumps should be made of bronze.