perature at which the lime, magnesia, etc., collect on hot surfaces, varies with the character and proportions of the solids, but generally such deposits are not a serious trouble below 140 F.

Direct-Fired Water Heaters

Coal-burning, direct-fired water heaters may be constructed of cored cast-iron sections, or of steel. In some cases the external appearance of the cast-iron sections is the same as in heating boilers, but internally the cores are changed to enable the sections to withstand the city water pressure. In small capacity water heaters, efficiency is not considered so important as low first cost and ability to maintain a fire at a low rate of combustion, and consequently, such heaters are generally built with a *dry* section or firebrick lining at the base of the firepot to prevent too much chilling of the fuel. While mud and scale will eventually clog the waterways of any direct-fired heater, increased life may be obtained by providing a three-way cock in the return line between the heater and the bottom of the storage tank, so that water can be blown through the heater or the tank separately, at full line pressure, to clean out loose sediment. Cleanout openings in the bottom of the heater are advantageous, if used by operators of water heaters for periodic cleaning out of sediment.

Oil-burning, direct-fired water heaters usually are of steel, and operate with higher flame temperature and better efficiency than commensurate sized coal-burning heaters. As they have the same tendency as coal boilers to accumulate lime deposits, the water passages should be large in cross-section and accessible for periodic cleaning.

Gas-burning, direct-fired water heaters may be of the instantaneous or storage type. Instantaneous heaters are generally constructed of spiral water tubes of copper, around which the products of combustion circulate 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.

Chimney connections for all direct-fired, fuel-burning water heaters are an important consideration. Refer to Chapter 36.

Electric Water Heaters

Electric water heaters for hot water service in residences and commercial buildings are predominantly of the automatic storage type. These generally have a cylindrical tank mounted vertically, with a primary electric heating element or resistor near the bottom and a secondary unit located within the upper one-quarter of the tank. Water heaters of single-heating-unit type have an element only at the bottom. The first cost of automatic electric heaters is somewhat higher than that of fuel-fired types, owing to the need for larger tank storage to compensate for the limitation of recovery rate, since for economical electric service the connected load should be kept low. Large tank capacity is necessary also with off-peak operation, where there are low electric rates for this class of service.

Table 11 .... Standard Rated Capacities of Electric Water Heaters

Tank Size Gallons		Rated Input, Watts		
		Two-Unit Heater		Single-Unit Heater
Nominal	Range	Primary	Secondary	
30	30 to 35	600	1000	1500
40	35 to 45	750	1250	2000
52	45 to 55	1000	1500	2500
66	55 to 70	1250	2000	3000
80	70 to 90	1500	2500	4000
110	90 to 115	2000	3000	
120	115 to 135	2500	4000	
140	135 to 175	3000	4000	

Instantaneous heaters are used in special cases only, because of the high electric power input required, for example, 15 kw to deliver 1 gpm with 100 deg temperature rise.

Capacities of household automatic storage-type water heaters, as partially standardized within the electrical industry, range from 30 to 140 gal nominal tank capacity with input 1600 to 7000 watts. Wattage input ratings of two-unit heaters are based on approximately 30 watts per gallon of tank capacity for the secondary unit and 20 watts for the primary unit. Single-unit heaters have tank sizes up to 80 gal with an input of 4000 watts, the ratings being based on 50 watts per gallon. The schedule of heater capacities shown in *ASA Standard* C72.1-1949 is reproduced in Table 11.

The wattages listed in Table 11 are minimum recommended values for continuous service. Some departure from the standardized watts-per-gallon ratios is to be expected, as experience indicates that increased hot water use with automatic laundry machines and dishwashers may call for larger heating units than have heretofore been found desirable. With off-peak operation the watts-per-gallon ratio likewise must be raised.

Rated voltage for water heaters is 240 volts, with a range 220 volts minimum to 248 volts maximum, but specified test performance is required to be met only at the 236 volts taken as normal design voltage. Thermostats controlling the heating units are normally set for 150 F, with upper limit of adjustment range of 170 to 180 F.

Heating units are of three general types, all of which give approximately the same service efficiency if selected to suit the operating conditions, as follows:

1. Immersion element, inserted horizontally through a threaded or flanged opening in side of tank.
2. Strap-on unit, externally mounted directly against the tank shell and held in close contact by a band or strap encircling the tank.
3. Side-arm or *outside circulation* unit, consisting of a vertical cylindrical housing or heat exchanger which contains an immersion heating element, connected by pipes into top and bottom of the storage tank.

For the third type, which is less commonly used, thermostats separate from the heating units are mounted within the storage tank.

A fourth type of heater, applied only in exceptional cases and for large installations with alternating current, employs the water itself as a resistor in which electrodes are immersed. Close temperature regulation and compensation for the effect of variable amount and composition of solids and gases in the water are difficult to obtain with small unattended heaters of this kind. The electrode type of construction has in the past been used also for generating steam in so-called electric boilers, mainly for industrial plants; however, in only few instances today is electric energy obtainable at cost low enough to make it competitive with fuel-fired boilers for steam production.

Tanks of electric heaters are regularly constructed to withstand a 300 psig hydrostatic test pressure and are rated for a safe working pressure of 127.5 psig. Materials in contact with the water are selected to resist corrosion caused by solid and gaseous impurities occurring in some locations. It may be desirable also to provide *sacrificial metal* anodes of magnesium, zinc, or alloys to protect the tank and its piping connections. A safety relief valve of pressure-actuated type must be included; it may optionally be actuated also by internal temperature. A heat trap at the hot water outlet, if not provided by manufacturer within or outside the tank shell and inside the insulated jacket, may be placed in the external piping. The trap consists of vertical pipe at least 6 in. long having downward flow, to retard circulation of hot water within the distribution piping system under standby conditions.

Occasionally, an uninsulated tempering tank is installed ahead of an electric water heater, enabling the cold inlet water to absorb heat from the basement or room air—if conditions are such that objectionable sweating does not occur. The practice of connecting a tempering tank with a firebox coil, so that the electric heater furnishes heat only when there is deficiency from the boiler or furnace, is not recommended.

Delivery performance efficiency of heaters meeting the electrical-industry standard 24-hour operation test is 90 percent minimum, which allows 10 percent for thermal loss through the jacket insulation. In service, the quantity of water withdrawn from an automatic storage heater has considerable influence on overall efficiency. With increasing quantities, service efficiency rises and approaches the upper limit fixed solely by the jacket thermal loss; on the other hand, if little or no water is drawn, efficiency approaches zero since no useful work is done. Hence oversizing a water heater by having too large a tank impairs the service efficiency. Excessive heating-unit wattage causes undesirably high electric demand. Undersizing of heaters obviously results in inadequate and unsatisfactory hot water service.

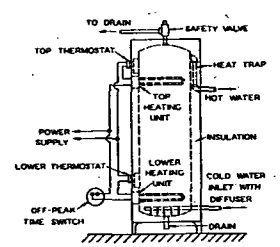


Fig. 8 .... Domestic Hot Water Heater for Off-Peak Service

Selection of electric heater capacity for residences is made by reference to rating tables which take into account the 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, 8, 9 and 10 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 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. 8, 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. 9. 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

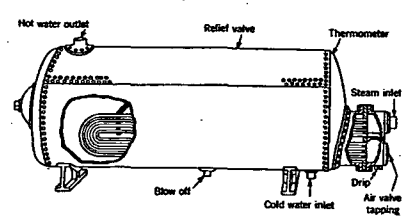


Fig. 9 .... Indirect Water Heater