methods of conveying the heat output from heat pumps to the space served are indicated in Table 1. The main types of heat pumps and the characteristics of heat sources utilized are discussed in Chapter 37.

In the case of heat pumps using air as heat source, it is shown theoretically and found in practice that heat delivery capacity falls off rapidly as outdoor temperature decreases, whereas the heat requirement increases directly with indoor-outdoor temperature difference. Deficiency at temperatures below the *balance point* can be made up by supplementary electric resistance elements, but this adds disproportionately to power demand. Moreover, seasonal energy consumption by such resistance heating, per kilowatt of demand established, is much less than for the heat-pump cycle itself, and the combination gives load characteristics unfavorable to the utility company for rendering low-cost electric service. An alternative provision for cold-weather peaks is thermal storage in chemical salts and by other devices; such processes are still in the development stage.

The installed cost of residential heat-pump systems is two to three times that of resistance types. However, in practically all cases the summer air-conditioning service obtained with conventional heat pumps is as valuable to the user as the winter heating. Resistance heating systems, except the minority using mechanical air circulation through ducts, do not lend themselves to consolidation with summer air conditioning features, and consequently, an independent cooling installation is necessary. Heat pumps thus have an advantage over such dual systems.

HEATING WATER BY ELECTRICITY

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.

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 secondary unit and 20 watts for 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 the accompanying Table 2.

The wattages listed in Table 2 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.

Table 2. 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	

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