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

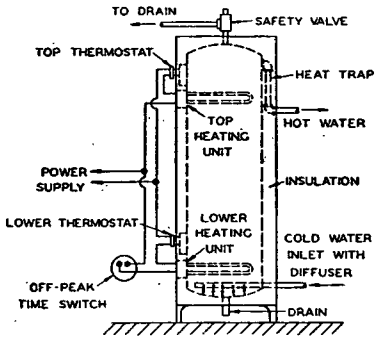

FIG. 2. DOMESTIC HOT-WATER HEATER FOR OFF-PEAK SERVICE

fire-box coil, the electric heater then furnishing 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 In service, the quantity of water withdrawn from an automatic storage heater has considerable influence on overall efficiency.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.

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 in Chapter 49 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 so-called *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.

One arrangement of domestic hot-water heater for off-peak service, shown in Fig. 2, has the lower heating unit under control of an off-peak switch. Upper unit is connected directly to the line, so that in case 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.

Water heaters employing the heat-pump principle are now in limited trial use, obtaining annual performance factor (sometimes called coefficient of performance) approaching 2.5. This value represents the ratio of useful heat delivered, to the direct heat equivalent of total electric input. The predominant models have tank capacity of approximately 55 gal, hermetic type compressors rated $\frac{1}{3}$ or $\frac{1}{2}$ hp, and small circulating fans. So-called *vagrant* heat occurring within the basement or utility room is generally the heat source. In some cases there is secondary benefit from dehumidifying, and an appreciable cooling effect is produced. Present limitations include high initial cost, low recovery rate, restricted maximum temperature, and necessity of condensate drain connections, compared with conventional electric resistance-type and fuel-fired water heaters.

CALCULATING CAPACITIES

The procedure outlined in Chapter 12 for calculating the heating load should be used for electric systems. Load expressed in Btu per hour is converted to kilowatts by the divisor 3413 Btu per kilowatt. All the energy applied to a resistor transforms itself into heat, unaffected by temperatures of the surrounding air and of surfaces receiving radiated heat. However, both electric power input and heat output are directly affected by voltage at the resistor terminals, being proportional to square of the voltage. Thus, a resistor rated 1000 watts at 240 volts, if used on a circuit at 220 volts, delivers 840 watts or 16 percent under the rated value, while at 208 volts the shortage is 25 percent.

Selection of proper indoor and outdoor temperatures for design of electric heating systems is more critical than for those using fuel, since in case the installed heating capacity is found deficient, the only recourse is to add more electric heating units or to bring the supply voltage up to the permissible maximum. On the other hand, fuel-operated systems ordinarily permit raising the rate of combustion somewhat above the nominal rating,