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

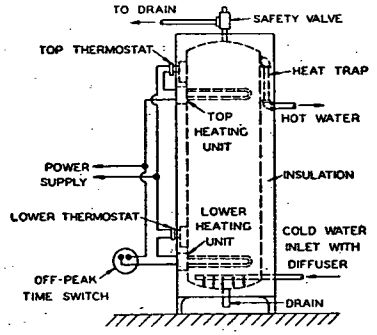


FIG. 2. DOMESTIC HOT-WATER HEATER FOR OFF-PEAK SERVICE

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.

INDUCTION AND DIELECTRIC HEATING

These methods, employed for industrial processes requiring extreme speed or close control of heat location, do not lend themselves to space or water heating. However, since they are sometimes proposed for consideration, the operating principles are described briefly.

Any electrically conducting material placed in an alternating magnetic field develops eddy currents that generate heat. The rate of internal heating is so high that conduction away from the zone to be treated does not unduly lower the temperature. The field is created by coils connected to an alternating-current power source such as motor-generator set, a mercury arc, or an electronic-tube or spark-discharge oscillator, producing frequencies usually between 250 and 10,000 cycles per second, but for some applications up to 500,000 cps. The coils are generally copper tubes through which cooling water is circulated. Induction heating apparatus must be specifically designed for each application such as melting metals, brazing, heat treating internally or in zones, and surface hardening without oxide scale formation or distortion.

Dielectric heating, for materials that are non-conductors of electricity and are poor thermal conductors, requires a high-frequency electrostatic field produced at high voltage and very high frequencies reaching 50 million cps. The method is well adapted to continuous-flow production process including manufacture of bonded plywood, drying of deep-pile fabrics, dehydration of granular or crystalline materials, and sterilization of foods.

POWER PROBLEMS

Rates for Electric Service

The cost of electricity varies due to several factors. The main elements are the annual charges, including taxes, on capital invested and those expenses necessary to keep the electric utility system at all times in a state of *readiness to serve* the load. The cost of generating the energy is secondary. Electricity is not stored, but must be produced instantaneously when and as required by the user. Consequently, the time of power use, both daily and seasonally, and relation between rate-of-use or demand and the energy consumed within a period (load factor) have large effects on costs and the rates charged. Special low rates sometimes are available during certain prescribed *off-peak* hours of use, when the system load is low.

Space heating is a load whose magnitude is determined basically by weather, and is affected to a much lesser extent by the electric customer's use of his premises. Most of the heating loads in a region occur simultaneously, thereby tending to create peaks for which the capacity of the electric system must be adequate. Accordingly, rates contain in one way