Since 2546 Btu per hour = one horsepower-hour and 3415 Btu per hour = one kilowatt-hour the heat extracted in performing work per pound of steam used may be obtained by dividing these figures by the water rates of the units per indicated horsepower hour or per kilowatt hour, respectively, of work done by the steam. From 1 per cent to 2 per cent may be deducted for radiation and other heat losses, depending upon the size of unit.

Example. A 200-kw turbine is operating on saturated steam at 150 lb gage pressure and consuming 40 lb of steam per kilowatt hour delivered, at full load. Determine the heat available in the exhaust for heating.

Solution. The mechanical efficiency of the turbine is 0.935 and the efficiency of the generator is 0.934 (See Table 1), giving a combined efficiency of 0.935 × 0.934 = 0.873 which would mean 40 × 0.873 = 34.92 lb per kilowatt hour of external work actually done by the steam. The total heat of the steam under the conditions as fed to the turbine is 1195 Btu per pound.

The heat extracted in external work = $\frac{3415}{34.92}$ = 97.74 Btu per pound of steam. To this add 1½ per cent for heat lost by radiation, or 97.74 + 1.47 = 99.21 Btu which is the total heat loss per pound of steam in passing through the turbine. This leaves 1195 − 99.21 = 1095.79 Btu in each pound of the exhaust.

If the exhaust is to be used and condensed at atmospheric pressure there will be a further deduction of 180 Btu per pound for the heat of the liquid at this pressure. This leaves 1095.79 − 180 = 915.79 Btu per pound of steam fed to the turbine as being available in the exhaust for heating at atmospheric pressure.

In a similar manner the heat available per pound in the exhaust from an engine driven unit for heating may be estimated by dividing the heat equivalent per unit of work by the number of pounds of steam fed to the unit per unit of actual external work done, adding to this from 1 per cent to 2 per cent for radiation, and subtracting this sum from the total heat in a pound of the steam as fed to the unit and then subtracting from this remainder the heat per pound in the condensate or rejected steam leaving the heating system.

In the case of an engine-driven unit, the heat equivalent of a horsepower hour (2546 Btu) should be divided by the water rate per indicated horsepower. If the water rate is given per kilowatt hour delivered by the generator, this may be reduced to pounds per indicated horsepower hour by dividing by 1.34 and multiplying by the mechanical efficiency of the unit and the efficiency of the generator.

Example. A 200-kw engine-driven unit operates under the same conditions as the turbine unit in the preceding example, and delivers one kilowatt-hour on 37.8 lb of water. The mechanical efficiency of the unit is 0.905 and the efficiency of the generator is 0.934 (See Table 1). The water rate per indicated horsepower is therefore

$$\frac{37.8}{1.34} \times 0.905 \times 0.934 = \frac{37.8}{1.34} \times 0.845 = 23.84$$

The heat equivalent of the external work done per pound of steam is $\frac{2546}{23.84}$ = 106.79 Btu. To this add 1½ per cent for radiation, or 106.79 + 1.60 = 108.39 Btu which is the total heat lost per pound of steam in passing through the engine. Deduct this from the total heat per pound in the steam fed to the engine, or 1195 − 108.39 = 1086.61.

For additional information on this subject, see Utilization of Waste Heat, by Perry West [A.S.H.V.E. Journal Section (*Heating, Piping and Air Conditioning*), November, 1930].

Part II. Electric Heating

Advantages of Electric Heating; Types of Electric Heaters; Storage or Off-Peak System; Heating Costs with Electricity; Heat Equivalents.

THE use of electricity as a direct heating medium, employing so-called space or radiant heaters, is confined largely to mild climates, or to localities where electric rates are low. Direct electrical heaters take energy co-incidentally with the heater requirements, which means that the load usually comes directly on the power station's peaks. The thermal storage system uses off-peak electrical energy for which commercially economical rates are now being made available. Therefore, this off-peak form of electrical heating is becoming practicable in many northern climates as well as in milder climates. In some cases electricity is used as a supplementary means of heating such as in industrial plants for the heating of remote spaces.

ADVANTAGES OF ELECTRIC HEATING

The following are some of the important advantages of electric heating:

1. Minute and exact regulation of temperatures.
2. Extreme simplicity and automatism of operation with minimum maintenance.
3. Freedom from the dangers attending the presence of a flame.
4. Freedom from handling and disposition of resulting products of combustion.
5. Reliability of source of supply.
6. Maximum efficiency of conversion of the energy into usefulness.
7. Cleanliness.

From the foregoing items it is apparent that electricity embraces all the requirements of an ideal heating agent, excepting low cost. Consequently, where electrical energy is sufficiently low in cost, it is being used more or less for heating buildings.

TYPES OF ELECTRIC HEATERS

The various commercial types of electric heaters may be classified as follows:

1. Direct Heaters

a. Radiant Type. For quick intermittent heating. The heating element operates at a relatively high temperature, and the heat transfer is principally by radiation.

b. Convection Type. For continuous heating. The heating element operates at a relatively low temperature and the heat transfer is mainly by air currents.

c. Contact Type. Electric strip heaters placed in direct contact by clamping to objects to be heated. They may be used to prevent freezing of pipes and tanks.