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 $0.935 \times 0.934 = 0.873$ which would mean $40 \times 0.873 = 34.92$ 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 2. 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 $1195 - 108.39 = 1086.61$.

RE-HEATED EXHAUST STEAM

Installations have been made recently where exhaust steam is re-heated and its temperature raised before being distributed. This re-heating and drying-out process is accomplished by passing the exhaust steam through a closed heater where high-pressure, high-temperature steam is present on the closed side. Usually this high-pressure, high-temperature steam is on its way between the stages of a turbine or a compound engine. The effect of pre-heating the exhaust steam is to increase its range of distribution.

For additional information on this subject, see Utilization of Waste Heat, by Perry West (*Heating, Piping and Air Conditioning*, November, 1930).

Chapter 22

DISTRICT HEATING

Underground Steam Piping; Selection of Pipe Sizes; Provision for Expansion; Capacity of Returns with Various Grades; Pipe Conduits; Pipe Tunnels; Service Connections; Steam per Square Foot of Heating Surface; Fluid Meters and Metering.

THIS chapter deals with those phases of district heating which frequently fall within the province of the heating engineer. Data and information are included for solving incidental problems in connection with institutions and factories and for the design of building heating systems which are to be supplied with purchased steam. A complete district heating installation should not be attempted without a thorough study of the entire problem by men competent and experienced in that industry. The Handbook and other publications of the *National District Heating Association*, and the references at the end of this chapter should be consulted.

UNDERGROUND STEAM PIPING

The methods used in district heating work for the distribution of steam are applicable to any problem involving the supply of steam to a group of buildings. The first step is to establish the route of the pipes and in this matter the local conditions so fully control the layout that little can be said regarding it.

Having established the route of the pipes, the next step is to calculate the pipe sizes. In district heating work it is common practice to design the piping system on the basis of pressure drop. The initial pressure and the minimum permissible terminal pressure are specified and the pipe sizes are so chosen that the required amount of steam, with suitable allowances for future increases, will be transmitted without exceeding this pressure drop. The steam velocity is therefore almost disregarded and may reach a very high figure. Velocities of 35,000 fpm are not considered high. By the use of this method the pipe sizes are kept to a minimum with consequent savings in investment.

The steam flowing through any section of the piping can be computed from a study of the requirements of the several buildings served. In general a condensation rate of 0.25 lb per hour per square foot of equivalent heating surface is a safe figure. This allows for line condensation which, however, is a small part of the total at times of maximum load. Any unusual requirements such as those for process steam should be individually calculated.