Heating Effect of a Current

Lecture#3

Electrical Technology
By Admirality

Prof. Dr. Suhail A. Qureshi.
Elect. Engg. Deptt. UET, LHR.

WHEN AN electric current flows through a conductor electrical energy is transformed into heat energy and the temperature of the conductor rises.

The Kilocalorie

The amount of heat required to raise the temperature of one kilogram of water through 1°C is called a *kilocalorie*, and it is found by experiment that 4187 joules of electrical or mechanical energy, if wholly converted to heat, produce 1 kilocalorie of heat energy.

1 kg calorie = 4187 joules.

When current I amperes flows through a resistance R ohms for seconds the electrical energy expended is I^2Rt joules.

$$\therefore \quad \text{Heat produced} = \frac{I^2Rt}{4187} \text{ kilocalories} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (28)$$

$$= \frac{VIt}{4187} \text{ kilocalories} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (29)$$

$$= \frac{V^2t}{4187R} \text{ kilocalories} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (30)$$

The British Thermal Unit

The unit of heat used by British engineers is called the *British thermal unit* (B.t.u.). It is the amount of heat required to raise the temperature of 1 lb of water through 1°F.

$$\text{Since 1 lb} = 0{\cdot}4536 \text{ kg and } 1°\text{F} = \frac{5}{9}°\text{C}$$

$$1 \text{ B.t.u.} = 0{\cdot}4536 \times \frac{5}{9} = 0{\cdot}252 \text{ kcal}$$

It should be noted that one gallon of water weighs 10 lb.

Example 1. How long will it take to raise the temperature of 880 grams of water from 16°C to boiling point? The heater takes 2 amperes and 220 volts and its efficiency is 90 per cent.

$$\text{Heat required} = 0{\cdot}88 \times (100 - 16)$$

$$= 0{\cdot}88 \times 84 \text{ kcal}$$

$$\text{Heat generated} = \frac{VIt}{4187} = \frac{220 \times 2 \times t}{4187} = \frac{440 \times t}{4187} \text{ kcal}$$

$$\text{Useful heat} = \frac{90}{100} \times \frac{440 \times t}{4187} = \frac{396 \times t}{4187} \text{ kcal}$$

$$\therefore \frac{396 \times t}{4187} = 0{\cdot}88 \times 84$$

$$\therefore t = \frac{0{\cdot}88 \times 84 \times 4187}{396} \text{ seconds}$$

$$= 782 \text{ seconds}$$

$$= 13{\cdot}03 \text{ minutes}$$

Example 2. An electric kettle is required to raise the temperature of $\frac{1}{2}$ gallon of water from 20°C to 100°C in 15 minutes. Calculate the resistance of the heating elements if the kettle is to be used on a 240 volts supply. Assume an efficiency of 80 per cent.

$$\text{Weight of } \tfrac{1}{2} \text{ gallon of water} = 5 \text{ lb}$$
$$= 5 \times 0{\cdot}4536 \text{ kg}$$
$$= 2{\cdot}268 \text{ kg}$$
$$\text{Heat required} = 2{\cdot}268 \times 80 \text{ kcal}$$
$$\text{Useful heat generated in kettle} = \frac{80}{100} \times \frac{V^2 t}{4187R} \text{ kcal}$$
$$\therefore \quad \frac{80 \times 240^2 \times 15 \times 60}{100 \times 4187 \times R} = 2{\cdot}268 \times 80$$
$$\therefore \quad R = \frac{80 \times 240^2 \times 15 \times 60}{100 \times 4187 \times 2{\cdot}268 \times 80}$$
$$= 54{\cdot}6 \text{ ohms}$$