LECTURE NOTES – II

« HYDROELECTRIC POWER PLANTS »

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CHAPTER 2

MEASURES

In the field of hydroelectric development, work and energy (output of a power plant) are expressed generally in kilowatt-hours (kWh).

Power (capacity of a power plant) is usually expressed in kilowatts (kW) and sometimes the power of hydraulic machinery is in horsepower (HP).

$$1 \text{ megawatt (MW)} = 1000 \text{ kW}$$
$$1 \text{ megawatt-hours (MWh)} = 1000 \text{ kWh}$$
$$1 \text{ gigawatt-hours (GWh)} = 10^6 \text{ kWh}$$

$$1 \text{ HP} = 75 \text{ kgm/sec} = 736 \text{ watts} = 0.736 \text{ kW}$$
$$75 \text{ kgm/sec} = 75\times 9.81 \approx 736 \text{ Nm/sec} = \text{Joule/sec} = \text{Watt}$$
$$1 \text{ kW} = 1.36 \text{ HP}$$
$$1 \text{ kW} = \frac{75}{0.736} = 102 \text{ kgm/sec}$$

$$1 \text{ HP-hour} = 0.736 \text{ kWh}$$
$$1 \text{ HP-hour} = 75\times 3600 = 270000 \text{ kgm}$$
$$1 \text{ HP-hour} = 75\times 9.81\times 3600 = 2648700 \text{ Nm (Joule)}$$
$$1\text{Kwh} = \frac{270000}{0.736} = 367000 \text{ kgm} = 3.6\times 10^6 \text{ Joule}$$
$$1 \text{ kgm} = 9.81 \text{ joules (Nm)}$$
$$1 \text{ kgm/sec} = 9.81 \text{ joules/sec} = 9.81 \text{ watt}$$

In the field of thermal power generation, work and energy are also measured in kilogram-calories (Cal).

$$1 \text{ Cal} = 427 \text{ kgm}$$
$$1\text{kWh} = \frac{367000}{427} = 860 \text{ Cal}$$

Example 2.1: Calculate the quantity in kWh of the energy generated from 1 kg of coal of 4000 calories by a thermal power plant having an overall efficiency of 24%.

Solution: Considering that $\eta = 0.24$, from 1 kg of coal of 4000 calories, the thermoelectric plant generates a quantity of electric energy that corresponds to,

$$0.24\times 4000 = 960 \text{ Calories}$$

As,

$$1 \text{ kWh} = 860 \text{ Cal}$$

The electric energy generated from 1 kg of coal is,

$$\frac{960}{860} = 1.12kWh$$

Example 2.2: Compute in kg weight of coal saved per annum by a hydroelectric plant operating at an annual average capacity of 8000 kW, supposing the fuel consumption of the substituting thermal plant is 3500 Cal/kWh, and the quality of coal is characterized by 4000 Cal/kg.

Solution: The hydroelectric produces an annual output of,

$$8000 \times 365 \times 24 = 70 \times 10^6 kWh$$

When generating the same quantity of energy, the consumption of the substituting thermal plant would be,

$$3500 Cal/kWh \times 70 \times 10^6 kWh = 24.5 \times 10^{10} Cal$$

Accordingly, the annual saving in coal attained by operating the hydroelectric plant amounts to,

$$\frac{24.5 \times 10^{10}}{4 \times 10^3} = 6.12 \times 10^7 kg = 61200ton$$

Example 2.3: How long does it take a 100 W bulb to consume the same quantity of energy as is required for a tourist of 70 kg in weight carrying an outfit of 35 kg to climb a mountain of 970 m in height? The tourist is assumed to set out on his way to the top of the 970 m mountain from a hostel situated 340 m above sea level.

Solution: The work done by the tourist is,

$$(970 - 340) \times (70 + 35) = 66150kgm$$
$$66150 \times 9.81 = 648932 Nm(Joule)$$

The hourly consumption of a 100 W bulb is 0.10 kWh,

$$1Kwh = \frac{1000 \times 3600}{9.81} \cong 367000kgm$$

The electric energy consumed per hour by the bulb is equivalent to a mechanical work of 0.1×367000 = 36700 kgm. Accordingly, the electric energy equivalent to the work done by the tourist is consumed in,

$$\frac{66150}{36700} = 1.80hours$$

Example 2.4: A laborer working at an average capacity shovels 8 m^3 of earth a day up to a vertical distance of 1.60 m from a material having specific weight of 1.8 ton/m^3. Compute in kg the quantity of coal of 4200 Cal required for obtaining the same work if the thermal station operates at an efficiency of 24%.

Solution: The work done daily by the laborer is,

$$8 \times 1.8 \times 1.6 = 23.04 tm = 23040 kgm$$
$$23040 \times 9.81 \cong 226000 Joule(Nm)$$

$$1 Cal = 427 kgm$$
$$\frac{23040}{427} \cong 54 Cal$$

In case of a 24% efficiency, from the coal having a calorific value of 4200,

$$\frac{54}{0.24 \times 4200} = 0.054 kg = 54 gr$$

Coal is required to substitute the work done in 1 day by the laborer.

Example 2.5: Determine the quantity of heat generated by braking and stopping a goods train consisting of 50 wagons and traveling at a velocity of 36 km/hour. Calculate the time required for a small hydroelectric power plant of 15 kW capacity to generate an equivalent amount of electric energy. The average weight of each wagon is 20 ton.

Solution: The mass of goods train amounts to,

$$\frac{50 \times 20000}{9.81} \cong 102000 kg \sec^2 / m$$

In the process of braking the goods train running at a speed of 36 km/hour = 10 m/sec, the kinetic energy converted into heat equals,

$$\frac{mV^2}{2} = \frac{102000 \times 10^2}{2} = 5.1 \times 10^6 kgm$$
$$\frac{5.1 \times 10^6}{367000} = 13.9 kWh$$

Consequently, the small hydroelectric plant of 15 kW capacity is capable of producing an equivalent electric energy in,

$$\frac{13.9}{15} = 0.926 hour = 56 \min$$