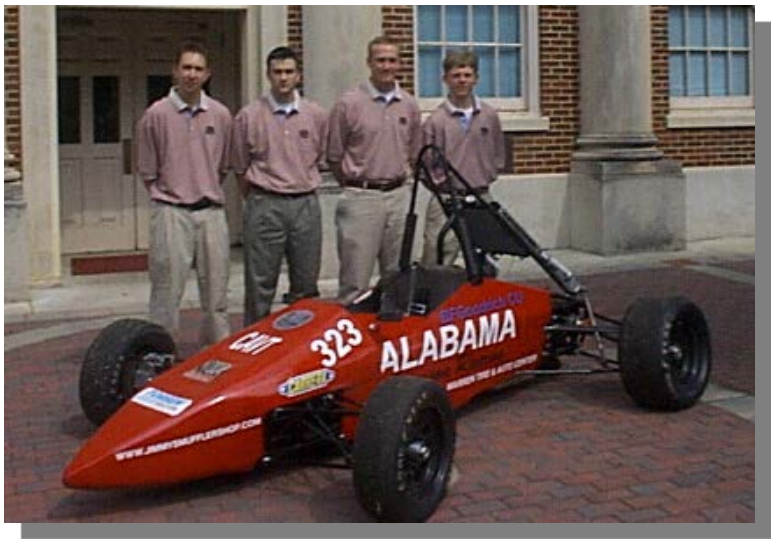


Basic Energy Units, Terms and Calculations

War Eagle!



Roll Tide!

THE UNIVERSITY OF ALABAMA ENGINEERING

Energy Units

- Need to distinguish between *energy* and *power*
- Common energy units:
  - Btu (British Thermal Unit)- energy required to heat one lbm of water one degree Fahrenheit
    - 1 Btu = 778.16 ft-lbf = 1.055 kJ = 0.252 Cal
    - Commonly used measure of fuel energy, heating and cooling quantities
    - 1 MBtu = 1000 BTU; 1 MMBtu = 10^6 Btu
    - 1 Quad = 10^{15} Btu (billion 10^9, trillion 10^{12}, **quad**rillion)
    - 1 Q = 10^{18} Btu

Energy Units

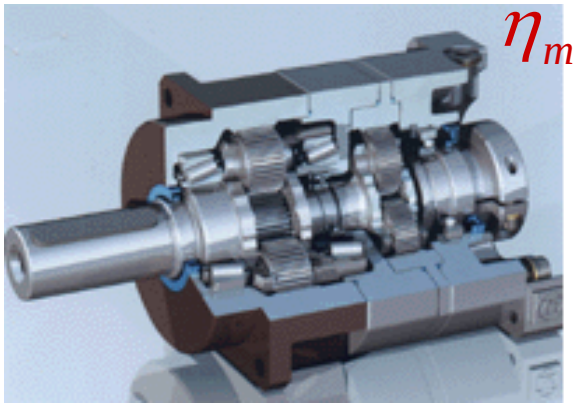
- kJ- standard SI-mks energy unit
  - 1 kJ = 1000 J = 1000 N-m
  - kJ used to measure fuel energy and heating and cooling quantities
- kWh- used to measure electrical energy
  - 1 kWh = 3412 Btu = 3600 kJ = 860 Cal
- Calorie- used to measure food energy, technically should be called a “kilocalorie.”
  - Chemist’s “calorie” (lower case c) is the energy needed to raise 1 g of water 1 degree C.
  - 1 Cal = 1000 cal = 4.186 kJ = 3.968 Btu

Power Units

- Horsepower- used to measure rate of mechanical work
  - 1 hp = 2545 Btu/hr = 0.746 kW
- kW- SI power unit used for both work and heat transfer. Sometimes see "kW_{th}" for thermal kW.
  - 1 kW = 3412 Btu/hr = 1.34 hp = 0.2843 Tons
- Ton- American unit of cooling rate commonly employed to measure air conditioning capacity
  - 1 Ton = 12,000 Btu/hr = 3.517 kW_{th}

Performance Measures

- The following measures are used by energy engineers to rate equipment performance:
  - Mechanical efficiency is used to measure efficiency of transforming one form of work to another. The theoretical limit is 100%.



$$\eta_{mech} = \frac{useful\ power\ output}{total\ power\ input}$$

Performance Measures

- Thermal efficiency measures efficiency of converting heat to work (heat engines). The upper limit is fixed by heat engine Carnot efficiency.

$$\eta_{th} = \frac{useful\ work\ output}{total\ energy\ input}$$

- Heat rate is the reciprocal of thermal efficiency, and represents fuel energy in Btu required to produce a kWh of electricity.

$$HR = \frac{fuel\ energy\ input\ rate\ (Btu/hr)}{useful\ \ power\ output\ (kW)}$$

Performance Measures

- Annual fuel utilization efficiency is the average fraction of fuel energy converted to useful heating by a furnace or hot water heater. AFUE ≤ 1.

$$AFUE = \frac{useful\ heating\ output}{total\ \ fuel\ energy\ input}$$

(DOE)

- Coefficient of Performance is the dimensionless measure of effectiveness of delivering a desired heat transfer rate (heating, cooling) with an electrical power input. The maximum COP is limited by Carnot refrigeration cycle efficiency.

Performance Measures

$$COP = \frac{useful\ heat\ \ transferred}{total\ electric\ \ power\ input}$$

- Energy efficiency ratio is the same as COP used for *cooling* except it has dimensions of cooling in Btu/hr per W of electricity input. Typically the seasonal EER → SEER is used to rate air conditioners.

$$EER = \frac{useful\ cooling\ \ rate\ (Btu/hr)}{total\ electric\ \ power\ input\ (W)}$$

(DOE)

Performance Measures

- Heating Seasonal Performance Factor is the same as COP used for *heating* except it has dimensions of cooling in Btu/hr per W of electricity input. HSPF is the heating equivalent of SEER and is used to rate heat pumps in heating mode.

$$HSPF = \frac{useful\ heating\ \ rate\,(Btu/hr)}{total\ electric\ \ power\ input\ \ (W)}$$

(DOE)

Energy Calculation Examples

1. A typical home natural gas furnace is rated at 75,000 Btu/hr. A typical electric space heater (~$20 at Wal-Mart) is rated at 1500 W. About how many electric space heaters would be required to provide the heat output of the gas furnace?
2. A coal-fired powerplant produces 1200 MW of electricity using 380 tons/hr of coal with a heating value of 14,000 Btu/lbm. Find the thermal efficiency and heat rate of the plant.

Energy Calculation Examples

3. A 3.5 Ton air conditioner with an SEER of 10 Btu/W-hr runs 20% of the time over a 30 day period. If electricity costs 8¢/kWh, how much does it cost to operate the A/C over this period?
4. A natural gas water heater has an AFUE of 80%. Over a month the water heater heats 10,000 gallons of water from 60 to 130°F. Natural gas has a heating value of 1000 Btu/ft^3 and costs about $0.50 per CCF (1 CCF = 100 ft^3). What is the water heater operating cost?

Energy Calculation Examples

5. A $150 garage door opener has a ½ hp motor with a motor efficiency of 20%. Motor efficiency is the same as mechanical efficiency because it represents the fraction of electrical work input converted to mechanical shaft work output. An open/close cycle takes 20 s and electricity costs 8¢ kWh. A car at idle uses about 10 hp with thermal efficiency of 15%. Gasoline has a heating value of about 125,000 Btu/gal, and costs about $3.50/gal. If the car operates 40 s longer for the driver to manually open the garage door, how many open/close cycles are needed to pay the costs of the garage door opener?