SHIP Egypt

Session 02

Thermodynamic basics

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Overview

- Definitions of energy
- Demands for energy
- Energy and power
- Forms of energy

- Quality of energy
- Energy conversion
- Coefficients of efficiency
- Basic of Heat transfer
- Steam

Energy

- **The word energy has its origins in the Greek word ENERGIA**
  - activity, drive, vigor, force, power strength

- **Capacity to perform work or heating or cooling**

- **Energy is one of the most important concepts of natural sciences**
- **Nevertheless it is very difficult to define it in few words**

Needs for Energy = Needs for Energy Services

Energy covers our requirements

- **Basic needs**
  - ⇨ Preparation of food
  - ⇨ Heating and cooling
  - ⇨ Personal hygiene
  - ⇨ Light
  - ⇨ Work

- **Needs in the industrial society**
  - ⇨ Production
  - ⇨ Transportation
  - ⇨ Goods
  - ⇨ Commodities

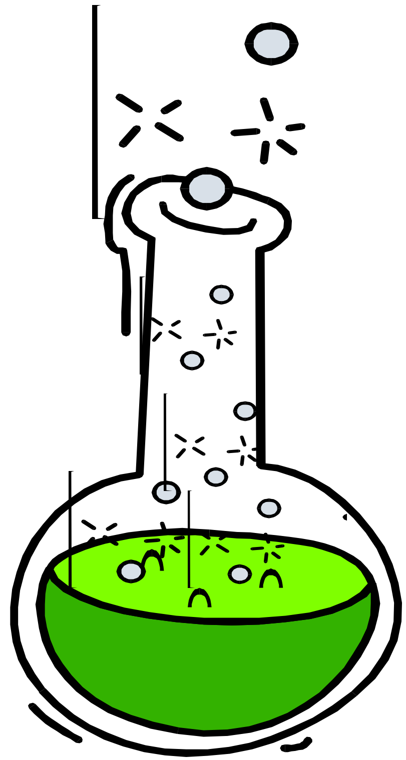
Energy Use and Its Impact on the Environment

Emissions of

CO_2, NO_x, SO_2,...

Sources of energy

Sun
Hydro
Oil
Gas
Coal
Nuclear
Bio
Wind
Ocean



- **Energy services**

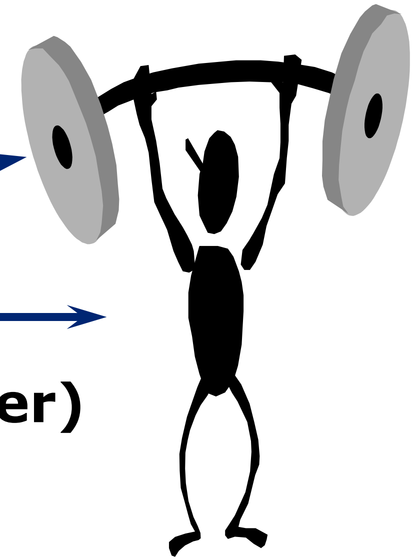
  Heating
  Cooling
  Work
  Light

Losses

5

Energy and Power

- Energy is capacity to do work



- Energy = Force x Distance
- J (Joule) = N (Newton) x m (meter)

- Power = Energy / Time
- W (Watt) = J (Joule) / s (second)

- Energy = Power x Time
- J (Joule) = W (Watt) x s (second)

Energy and Power Units

- 1 J = 1 Ws
- 1000 J = 1000 Ws
- 1 kJ = 1 kWs
- 3600 J = 3600 Ws
- 3,6 kJ = 1 Wh
- 3,6 MJ = 1 kWh
- 3,6 PJ = 1 TWh

- 10^3 = k - kilo
- 10^6 = M - mega
- 10^9 = G - giga
- 10^{12} = T - tera
- 10^{15} = P - peta
- 10^{18} = E - exa

Quantity of Energy of 1 kWh

- **Enables one person to travel by means of:**
  - Plane for 1,3 km
  - Car for 2,0 km
  - Buss for 3,3 km
  - Train for 10,0 km

- **Is developed by combustion of:**
  - 1 cup (1 dl) oil
  - 1/3 kg municipal waste
  - 1 m² space facing solar thermal in Malaysia

Quantity of Energy of 1 kWh

- **Electricity gives the opportunity to**
  - Watch TV for 1 hour a day in 15 days
  - Light up a 60 W light bulb for 17 hours

- **By means of muscular activity is sufficient to**
  - Fulfill a marathon run of 42,3 km that lasts for app. 2,5 hours
  - Lift app. 14 500 roofing tiles up to the roof that is 10 m high
  - Accomplish app. 17 500 push ups

Forms of Energy

- Potential
- Kinetic
- Mechanical

- Electric
- Heat

Renewable Energy Resources

- **Solar radiation**
- **Hydro**
- **Wind**
- **Ocean related energy**
  - Wave, tidal, thermal gradient, salinity gradient
- **Biomass**
  - Crops, wood, forest residues, waste
- **Biogas**
- **Geothermal**

Non-Renewable Energy Resources

- **Chemical energy**
  - Fossil fuels
    - **coal, oil, gas,**
    - **Peat, oil shale, tar sand**

- **Nuclear energy**
  - Uranium

Conversion of Energy - Electricity Production

- **Hydro power plants**

- **Solar energy**
- **Evaporation**
- **Condensation**
- **Elevation**
- **Motion**
- **Mechanical work**
- **Electricity**

The Basic Laws of Thermodynamics

- **The Second Law of Thermodynamics**

  Explain to which extent the conversion from one form of energy to an other is possible

- **Second Law**

  Entropy always increases, it is always positive in a closed system. It is a measure of the lack of potential or quality of energy; and once that energy has been exchanged or converted, it cannot revert back to a higher state.

Example

Consider a teapot filled with a certain quantity of water containing 200 kJ of heat energy at 100°C (373 K) and it cools down to the surrounding temperature.

The temperature of the surrounding air is at 20°C, and that the amount of heat in the teapot water would be 40 kJ at the end of the process.

The second law of thermodynamics also states that heat will always flow from a hot body to a colder body.

$$\text{Initial enthalpy in the teapot} = 200 \text{ kJ}$$

$$\text{Initial teapot temperature} = 373 \text{ K} \quad (100°\text{C})$$

$$\text{Final teapot temperature (the air temperature)} = 293 \text{ K} \ (20°\text{C})$$

$$\text{Mean teapot temperature } T_{(mean)} = \frac{373 \text{ K} + 293 \text{ K}}{2}$$

$$\mathbf{Mean\ teapot\ temperature\ T_{(mean)} = 333\,K\ (60°C)}$$

$$\text{Final enthalpy in the teapot} = 40 \text{ kJ}$$

$$\text{Enthalpy delivered by the teapot to its surroundings} = 200 - 40 \text{ kJ}$$

$$\mathbf{Enthalpy\ delivered\ by\ the\ teapot\ to\ its\ surroundings = 160\ kJ}$$

$$\text{Entropy delivered by the teapot to its surroundings} = \frac{\text{Enthalpy change}}{T_{(mean)}}$$

$$\text{Entropy delivered by the teapot to its surroundings} = \frac{160 \text{ kJ}}{333 \text{ K}}$$

$$\mathbf{Entropy\ delivered\ by\ the\ teapot\ to\ its\ surroundings = -0.48\ kJ/K}$$

$$T_{(mean)} \text{ for the air} = 293\text{ K } (20°C)$$

$$\text{Entropy received by the air} = \frac{160\text{ kJ}}{293\text{ K}}$$

$$\textbf{Entropy received by the air} = \mathbf{+\ 0.546\ kJ/K}$$

The overall change in entropy of the teapot and surroundings = - 0.48 + 0.546 kJ/K

The overall change in entropy of the teapot and surroundings = + 0.066 kJ/K

Source: Spirax&Sarco

Quality of energy

- **Second Law is a low of energy quality**
- **Quality of energy – there are three grades of energy quality**
- **Mechanical energy is the energy form with higher quality than heat energy**

Quality of Energy

$$EQ = \frac{\text{Maximum achievable amount of mechanical work}}{\text{Supplied energy}}$$

$$EQ = \frac{W_{max}}{Q}$$

Three Grades of Energy

- **Energy of 1.Grade**

  might be converted to any other form of energy without any limitations

  - ⇨ Mechanical: work, potential, kinetic, pressure
  - ⇨ Electrical: electromagnetic (sun), electrostatic
  - ⇨ Chemical: fuels
  - ⇨ Nuclear: fission, fusion

- **Pure Exergy**

Three Grades of Energy

- **Energy of 2.Grade**

  might be converted to other forms of energy but only to a limited extent

  - Thermal: heat
  - Internal: temperature, state change

- **Mixture of Exergy and Anergy**

Three Grades of Energy

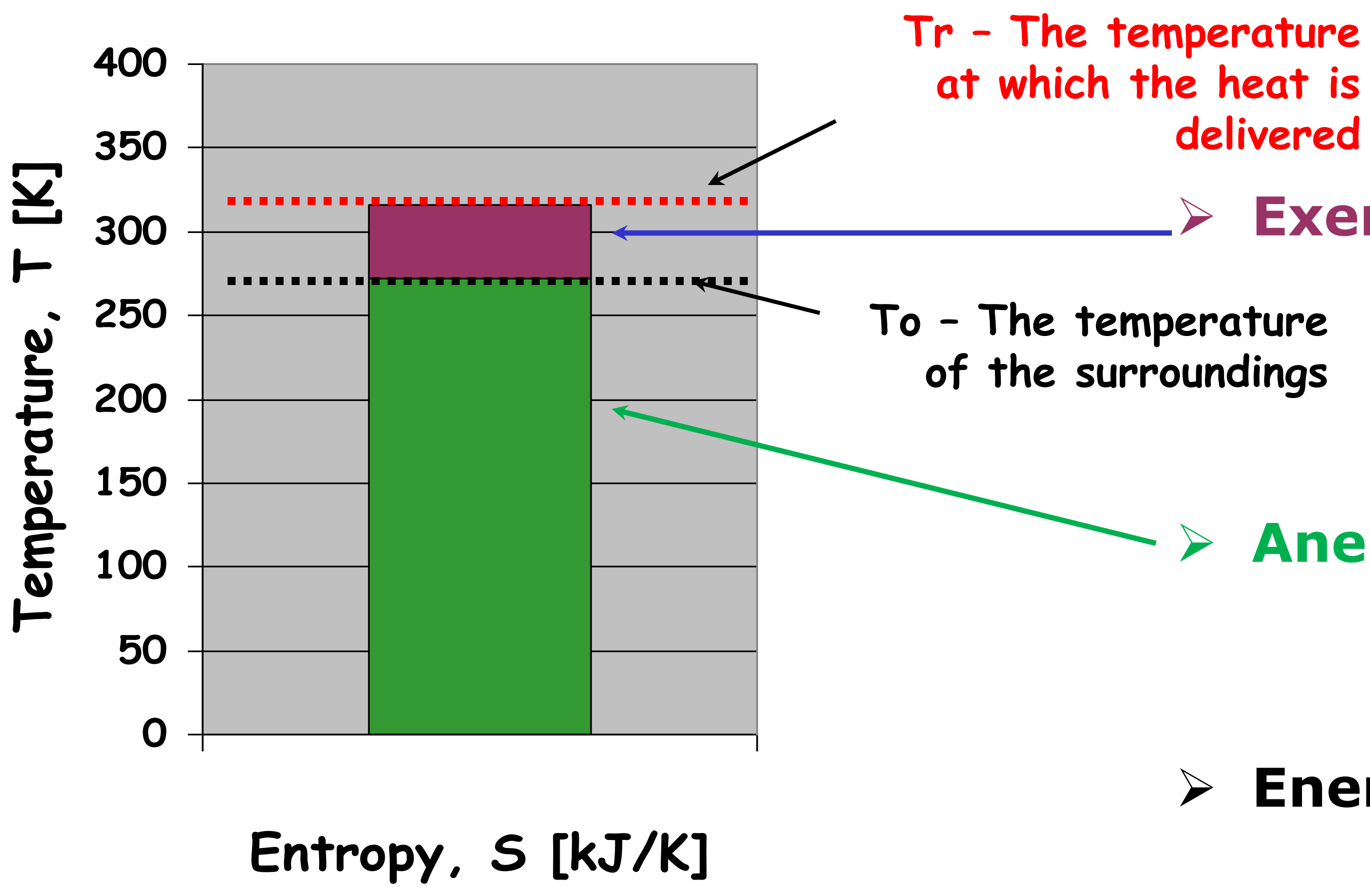
- **Energy of 3.Grade**

  can not be converted to any other form of energy

  ⇨ Internal energy in surroundings

- **Pure Anergy**

Quality of Thermal Energy



- Exergy
- Anergi
- Energy

Utilization of Energy

- **Efficiency of energy utilization**

- **Useful energy versus energy input**
  - Coefficient of efficiency

- **Energy indicators**
  - Specific energy consumption (SEP)
  - Energy intensity

Coefficient of Efficiency

- **Qin = Quseful + Qlosses**

  - The ratio of useful energy and total energy imput in a process is called coefficient of efficiency of energy transformation (or transformation efficiency)

- $$\eta = \frac{\text{Useful energy}}{\text{Energy input}} = \frac{Q_{in} - Q_{loss}}{Q_{in}}$$

- **System boundaries have to be determined!**

Coefficient of Efficiency

- **The overall level of efficiency can be expressed as the product of the individual steps of efficiency of energy transformation:**

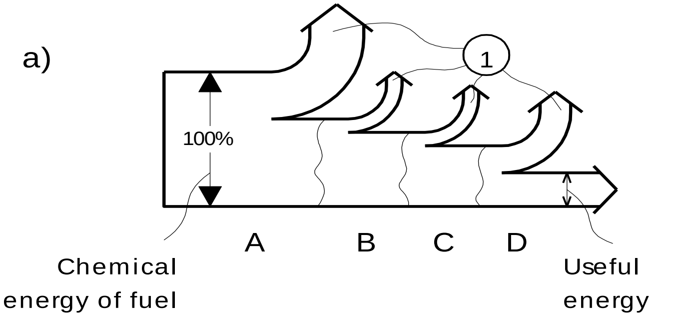
- $\boldsymbol{\eta_{tot} = \eta_a \times \eta_b \times \eta_c \times \eta_d \times \ldots}$

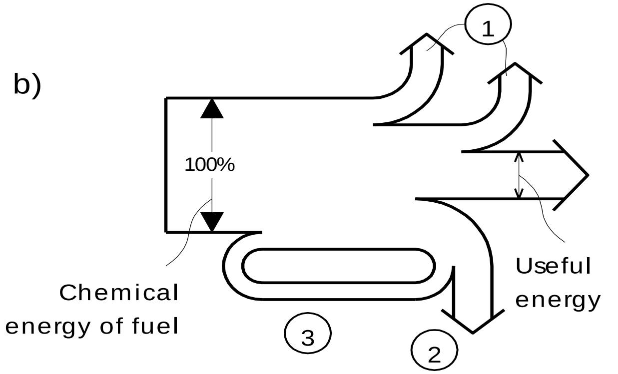
- $\boldsymbol{\eta_{tot} = \Sigma \eta_i}$

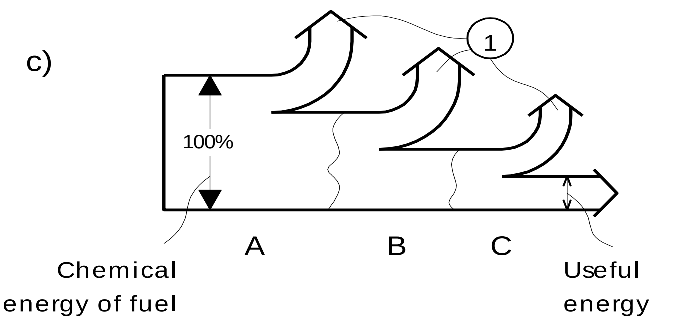
a) The use of el.energy: A-Production of el.en., B-Transport, C-Distribution, D-Transformation in a final consumption;

b) Processes in industrial furnaces: 1-Losses in energy transformations, 2 Losses in flue gases, 3-Recuperaition of flue gases waste heat

c) Low temperature processes: A-Production of hot water, hot air, or steam, B-internal energy transport, C-Transformation by final user





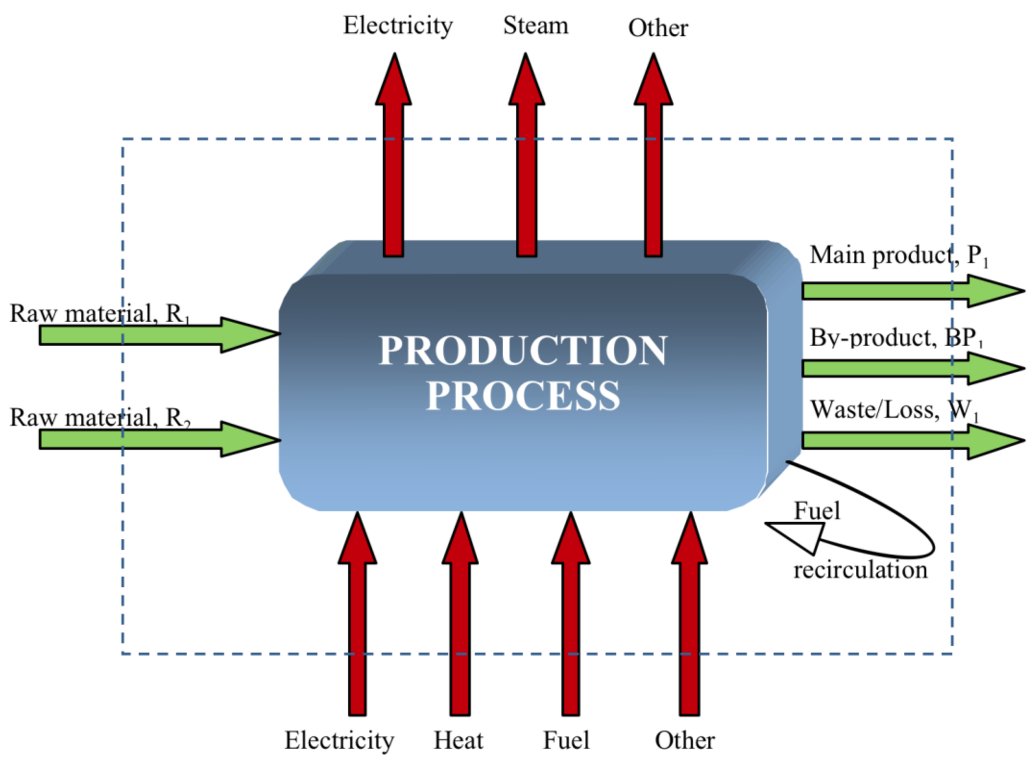


Energy indicators

- **Specific energy consumption (SEP)**

- **Energy intensity**

Energy indicators



The Basic of Heat transfer

- **Heat Conduction**
- **Convection**
- **Thermal radiation**

Heat Conduction

- **The heat equation follows from the conservation of energy for a small element within the body**

heat conducted in + heat generated within=

heat conducted out+ change in energy stored within

- **We can combine the heats conducted in and out into one "net heat conducted out" term to give net heat conducted out= heat generated within-change in energy stored within**

$$Q = k * (t1 - t1+n) * F \qquad \text{(steady state)}$$

$$k = 1/\left(\sum \delta i/\lambda i\right)$$

Thermal radiation

- **Thermal radiation is energy emitted by matter as electromagnetic waves, due to the pool of thermal energy in all matter with a temperature above absolute zero. Thermal radiation propagates without the presence of matter through the vacuum of space.**

- **Heat transfer via radiation from one to another gray surface**
  - $Q_{12} = C_{12} * H_{12}*[(T_1/100)^4 - (T_2/100)^4]$
  - $C_{12} = 5.67 * \varepsilon_{red}$
- **Heat transfer via radiation of gases to gray surface**
  - $Q_{12} = 5.67 * \varepsilon_{z'} * H*[\varepsilon_g * (T_1/100)^4 - a_g * (T_2/100)^4]$

Convection

- **$Q = \alpha F (t_2 - t_1)$**
- **Convective heat transfer, or convection, is the transfer of heat from one place to another by the movement of fluids, a process that is essentially the transfer of heat via mass transfer. Bulk motion of fluid enhances heat transfer between a solid surface and the fluid. Convection is usually the dominant form of heat transfer in liquids and gases.**
- **Transfer of heat through a phase transition in the medium (phase changes) involves significant energy and is exploited in many ways – steam as heat carrier**

Steam

- **Steam – different conditions and change of state**
- **Steam - heat transfer –why to use steam as heating medium**
- **Important for efficient heat exchange when using steam as heating medium**

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