Engineering Software

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Engineering Assumptions

When dealing with energy conversion and considering ideal (isentropic) operation and the working fluid is air, the following assumptions are valid:

Power Cycles
Single species consideration -- fuel mass flow rate is ignored and its impact on the properties of the working fluid
Basic equations hold (continuity, momentum and energy equations)
Specific heat is constant

Power Cycle Components/Processes
Single species consideration
Basic equations hold (continuity, momentum and energy equations)
Specific heat is constant

Compressible Flow
Single species consideration
Basic equations hold (continuity, momentum and energy equations)
Specific heat is constant

Thermodynamic and Transport Properties
Single species consideration
Ideal gas approach is used (pv=RT)
Specific heat is not constant
Coefficients describing thermodynamic and transport properties were obtained from the NASA Glenn Research Center at Lewis Field in Cleveland, OH -- such coefficients conform with the standard reference temperature of 298.15 K (77 F) and the JANAF Tables

Basic Conservation Equations

Continuity Equation

$m = \rho v A$ [kg/s]

Momentum Equation

$F = (vm + pA)_{out - in}$ [N]

Energy Equation

$Q - W = ((h + v^2/2 + gh)m)_{out - in}$ [kW]

Basic Engineering Equations

Ideal Gas State Equation

$pv = RT$ [kJ/kg]

Perfect Gas

c_p = constant [kJ/kg*K]

Kappa

$\chi = c_p/c_v$ [/]

For air: $\chi = 1.4$ [/], $R = 0.2867$ [kJ/kg*K] and $c_p = 1.004$ [kJ/kg*K]

Power Cycles Engineering Equations

Cycle Efficiency

$$\eta = W_{net}/Q\ [/]$$

Heat Rate

$$HR = (1/\eta)3{,}412\ [\text{Btu/kWh}]$$

Carnot Cycle Efficiency

$$\eta = 1 - T_R/T_A$$

Brayton Cycle Efficiency

$$\eta = 1 - 1/r_p^{(\chi-1)/\chi}$$

Otto Cycle Efficiency

$$\eta = 1 - 1/\varepsilon^{(\chi-1)}$$

Diesel Cycle Efficiency

$$\eta = 1 - (\phi^{\chi}-1)/\ (\chi\varepsilon^{(\chi-1)}(\phi-1))$$

$$r_p = p_2/p_1\ [/];\ \varepsilon = V_1/V_2\ [/];\ \phi = V_3/V_2\ [/]$$

Power Cycles Engineering Equations

Brayton Cycle

$$w_{net} = q_h - q_l = c_p(T_3 - T_2) - c_p(T_4 - T_1) \text{ [kJ/kg]}$$

$$W_{net} = w_{net}m \text{ [kW]}$$

Otto Cycle

$$w_{net} = q_h - q_l = c_v(T_3 - T_2) - c_v(T_4 - T_1) \text{ [kJ/kg]}$$

$$W_{net} = w_{net}m \text{ [kW]}$$

Diesel Cycle

$$w_{net} = q_h - q_l = c_p(T_3 - T_2) - c_v(T_4 - T_1) \text{ [kJ/kg]}$$

$$W_{net} = w_{net}m \text{ [kW]}$$

Power Cycle Components/Processes Engineering Equations

Isentropic Compression

$$T_2/T_1 = (p_2/p_1)^{(X-1)/X} \; [/]$$

$$T_2/T_1 = (V_1/V_2)^{(X-1)} \; [/]$$

$$p_2/p_1 = (V_1/V_2)^{X} \; [/]$$

$$w_c = c_p(T_2 - T_1) \; [kJ/kg]$$

$$W_c = c_p(T_2 - T_1)m \; [kW]$$

Power Cycle Components/Processes Engineering Equations

Combustion is ideal, complete with no heat loss and at stoichiometric conditions.

Also,

Flame Temperature [K]

$$h_{reactants} = h_{products} \ [kJ/kg]$$

Power Cycle Components/Processes Engineering Equations

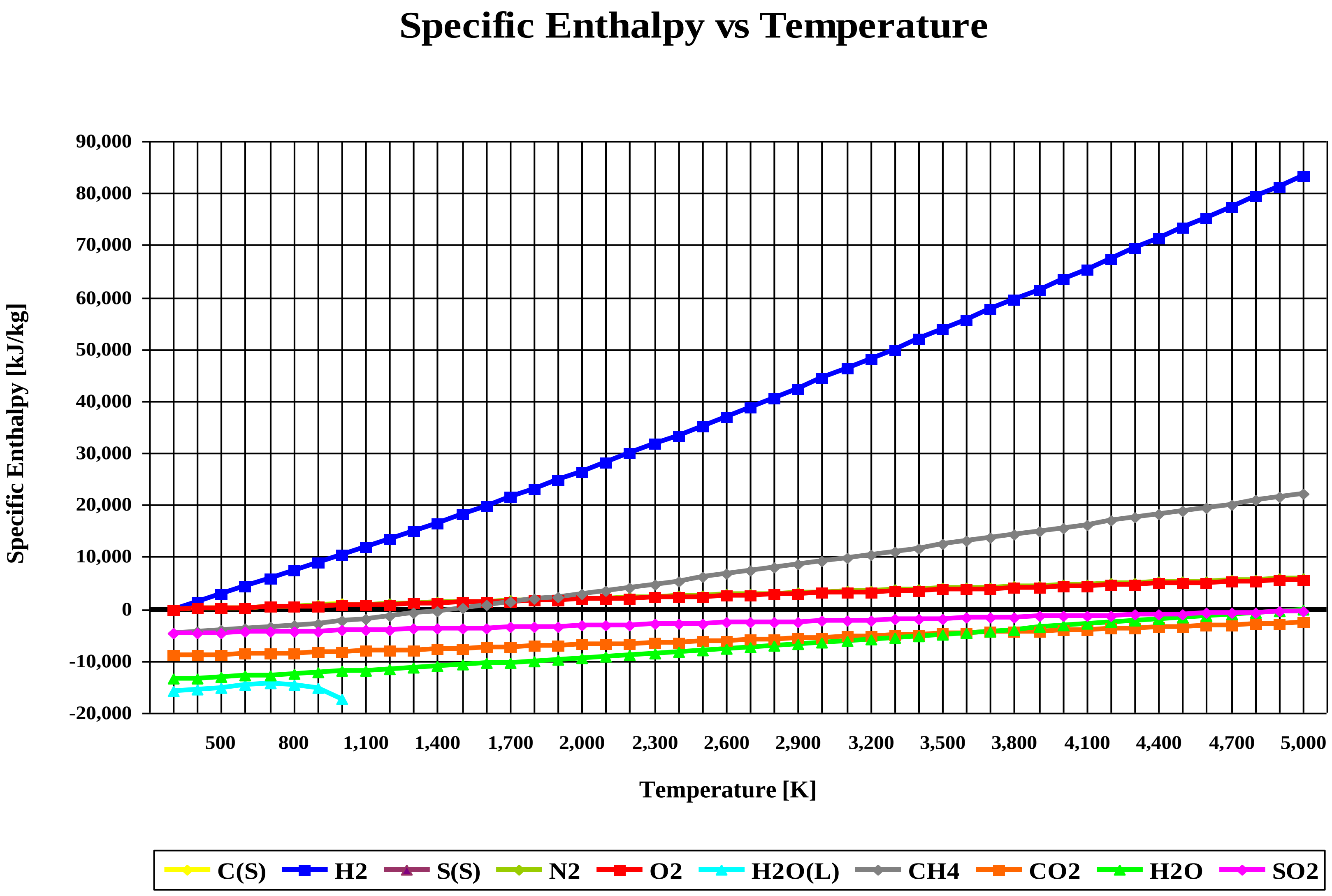
Combustion Schematic Layout

Fuel

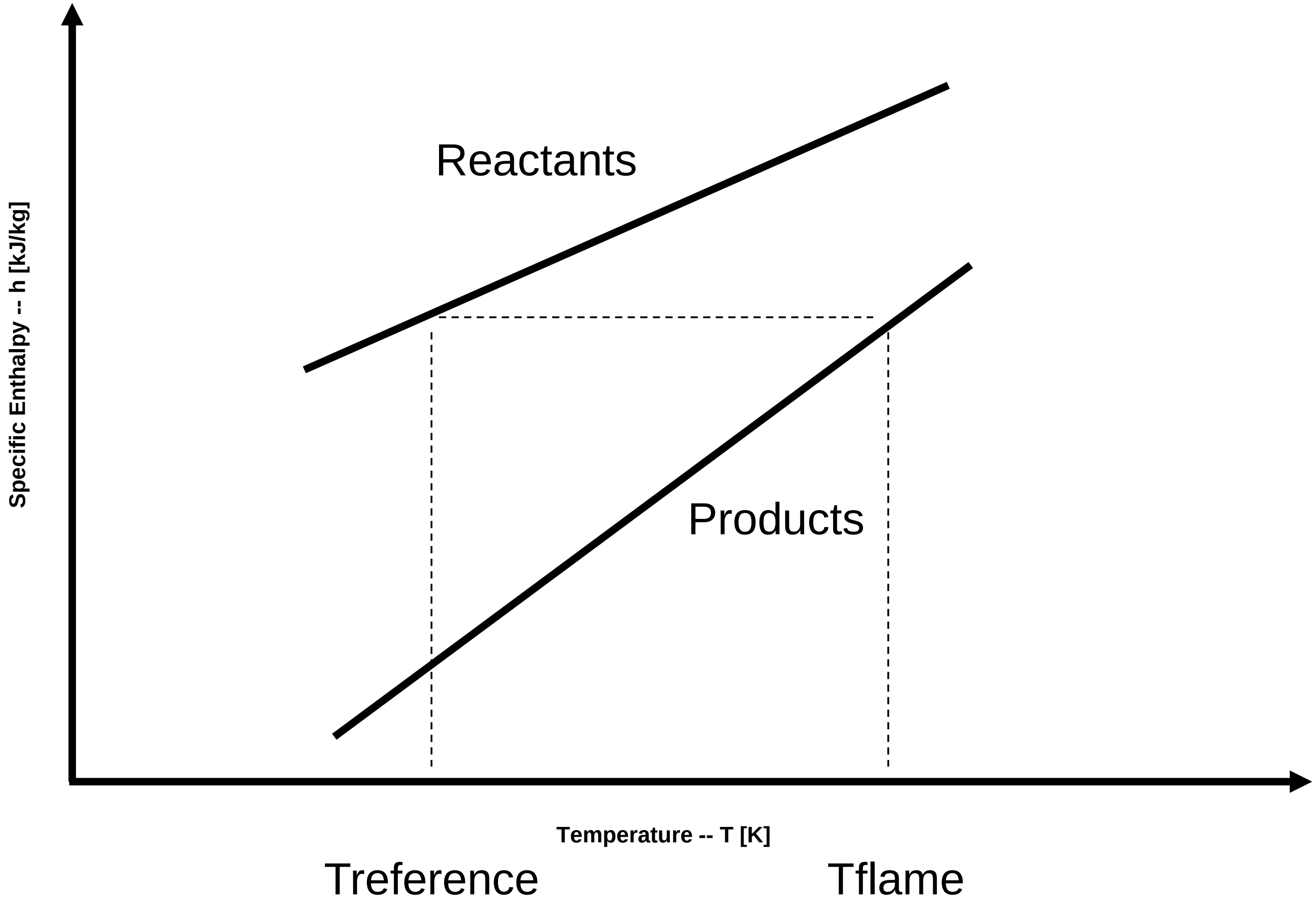
Combustion Products

Oxidant -- Air

Power Cycle Components/Processes Engineering Equations



Power Cycle Components/Processes Engineering Equations



Combustion h – T Diagram

Power Cycle Components/Processes Engineering Equations

Isentropic Expansion

$$T_1/T_2 = (p_1/p_2)^{(X-1)/X} \ [/]$$

$$T_1/T_2 = (V_2/V_1)^{(X-1)} \ [/]$$

$$p_1/p_2 = (V_2/V_1)^{X} \ [/]$$

$$w_e = c_p(T_1 - T_2) \ [kJ/kg]$$

$$W_e = c_p(T_1 - T_2)m \ [kW]$$

Compressible Flow Engineering Equations

Sonic Velocity

$v_s = (\chi\ RT)^{1/2}$ [m/s]

Mach Number

$M = v/v_s$ [/]

Compressible Flow Engineering Equations

Isentropic Flow

$$T_t/T = (1 + M^2(\chi - 1)/2)\ [/]$$

$$p_t/p = (1 + M^2(\chi - 1)/2)^{\chi/(\chi-1)}\ [/]$$

$$h_t = (h + v^2/2)\ [kJ/kg]$$

$$T_t = (T + v^2/(2c_p))\ [K]$$

$$\text{Thrust} = vm + (p - p_a)A\ [N]$$