TEMPERATURE OF COMBUSTION

Definition of temperature of combustion

Calorimetric temperature: $\mathbf{T_{c,c}}$ – the highest temperature of the un-dissociated exhaust gases due to adiabatic and isobaric combustion of fuel with stechiometric amount of air.

Theoretical temperature of combustion: $\mathbf{T_{c,t}}$ **-** the highest temperature of exhaust gases due to adiabatic and isobaric combustion of fuel in excess of air, including dissociation .

Combustion temperature: $\mathbf{T_c}$ – may change accordingly to heat losses in combustion process.

Theoretical temperature of combustion

Under constant pressure theoretical temp. of combustion T_c is evaluated from the balance of subtracts and products enthalpies.

$$m_{pp}\left(\Delta h^{tw,st}(pal) + \int_{T_{st}}^{T_{fuel}} c_p(pal)\,dT\right) + m_{air}\int_{T_{st}}^{T_{fuel}} c_p(pow)\,dT =$$

$$m_{sp}\left(\Delta h^{tw,st}(sp) + \int_{T_{st}}^{T_s} c_p(sp)\,dT\right)$$

Notation: m_{pp} – the stream of fuel mass, m_{air} – the stream of air mass, m_{sp} – the stream of exhaust gases mass, T_{st} – standard temperature (298 K), T_c – combustion temperature

Calculations theoretical temperature of combustion

Having c_p in the polynomial form, for example:

$$\mathbf{c_p = a_1 + a_2T + a_3T^2 + a_4T^{-2}}$$

we obtain after integration:

$$\mathbf{\tfrac{1}{3}\, a_3T_s^{\,4} + \tfrac{1}{2}a_2T_s^{\,3} + a_1T_s^{\,2} + f{*}T_s - a_4 = 0}$$

We solve above equation with T_c as a variable

Simplified evaluation of theoretical temperature of combustion

Considering average specific heat:

$$c_p(\text{fuel}) = c_p(\text{air}) = c_p(\text{flue gas})$$

$$T_f = T_a = T_0$$

we obtain:

$$\mathbf{(T_c - T_o) * c_{p,fuel} * m_{flue\ gas} = Q_{HHV} * m_{fuel}}$$

$$\mathbf{T_c = T_o + (Q_{HHV} * m_{fuel})/(m_{flue\ gas} * c_{p,flue\ gas})}$$

Error range of T_c under this estimation: 10-20%.

Real temperature of combustion

Real temperature of combustion is lower than calorimetric temperature of combustion due to:

- heat losses from the flame
- in-complete combustion (dissociation),
- non-total combustion.

TEMPERATURE OF COMBUSTION OF DIFFERENT TYPES OF FUEL

Heat losses from flame result mainly from radiation. This is the reason why deviation from the calorimetric temperature depends on emission ability of flame:

Temperature deviation from $T_{c,t}$

- gas flames: 30-50°,
- oil flames: 200-300°,
- dust flames: 500-600°.

EXAMPLES OF TEMPERATURE OF COMBUSTION OF SELECTED FUELS

FUEL	OXIDIZER	FUEL FRACTION, %vol	TEMPERATURE, °C
Hydrogen, H_2	Air	31.6	2045
Hydrogen	Oxygen	78	2660
CO	Air	20	1650
Methane, CH_4	Air	10	1875
Butane, C_4H_{10}	Air	3.2	1895
Acetylene, C_2H_2	Air	9	2325
Acetylene	Oxygen	33	3007
Propane, C_5H_{12}	Air	4.15	1925
Ethane, C_2H_6	Air	5.8	1895
Ammonia, NH_3	Air	21	1700
$CO + N_2$	Air	47.3	1675
$CH_4 + N_2$	Air	17.5	1725
$9CH_4 + H_2$	Air	10.5	1880