

BUO - BUOYANT FLAME PROCEDURE

At the end-of-flame location X_F ; for conventional vertical flares; units to be consistent Btu; lbm; ft; °R sec

a) determine the flow characteristics for the discharged gas

- q_F = heat flux
- CV = calorific value
- ρ_O = density
- C_L = lean flammability limit
- ε = flame emissivity

b) determine the physical characteristics of the flare

- H_S = stack height
- D_S = stack top outer diameter
- r_O = inner radius

c) determine the ambient conditions

- U_A = wind speed
- T_A = temperature
- ρ_A = density
- Cp_A = specific heat

d) determine the atmospheric conditions

- | | | | |
|--------------------|----------|-----------------------------------|-------------|
| Stability category | varies | A / B / C / D | default = D |
| S | = varies | 0.039 / 0.0459 / 0.0318 / 0.0142 | |
| N | = varies | 2.0016 / 1.8580 / 1.7973 / 1.7727 | |

e) determine the terrain conditions

- H_O = wind speed reference height
- M = wind height exponent (varies; 1/5 to 1/11.5 - ref relevant wind code) default = 1/9.5

d) estimate or calculate corrected values of

- X_C = down wind travel to mid flame
- H_C = mid flame height
- U_{AS} = $z_F^M * U_A$ for $z_F = H_S / H_O$ = wind speed at stack height
- U_{AC} = $z_C^M * U_A$ for $z_C = H_C / H_O$ = wind speed at mid flame
- S_X = $S * X_C^{(N-2)}$ = stability constant at mid flame
- g = 32.174 = gravitational constant
- K_B = 1.6 = buoyancy constant
- K_M = 2.3 = momentum constant
- K_S = $[1 / (2 * \pi * S_X)]$ = stability constant
- K_F = $CV * \rho_O * C_L$ = flame constant
- t_F = $[(q_F * K_S) / (K_F * U_{AC}^3)]^{(1/2)}$ = flame dwell time
- X_F = $[U_{AC} * t_F]$ = downwind flame length
- U_O = $[(q_F / (CV * \rho_O * \pi * r_O^2))]$ = true discharge velocity
- U_D = $[(2 * \rho_A / \rho_O)^{1/2} * U_{AS}]$ = downwash velocity modifier
- U_{O1} = $[U_O - U_D]$ = modified discharge velocity
- F_B = $[1 - (\rho_O / \rho_A)] * U_{O1}^2 * r_O^2$ = density buoyancy factor
- F_H = $[g / (\pi * Cp_O * T_A * \rho_A)]$ = thermal buoyancy factor
- F_F = $F_H * [1 - 1.5 * \varepsilon]$ = flame buoyancy factor
- F_M = $[(\rho_O / \rho_A) * U_{O1}^2 * r_O^2]$ = momentum factor
- ΔH_D = $[5 * D_S * U_{O1} / U_D] <= 0$ = downwash estimate
- ΔH_{F1} = $\{ 0.5 * K_B * [(F_F^{(1/3)} * q_F^{(1/3)}) / U_{AF}] * X_F^{(2/3)} \}$ = buoyant rise of flame
- ΔH_M = $[K_M * [F_M^{(1/3)} / U_{AF}^{(2/3)}] * X_F^{(1/3)}]$ = momentum rise
- ΔH_F = $\Delta H_{F1} + \Delta H_M + \Delta H_D$ = total rise

Down wind plume rise in any condition is given by

- ΔH_P = $\{ \Delta H_{P1} \text{ or } \Delta H_{P2} \text{ or } \Delta H_{P3} \} + \Delta H_M + \Delta H_D$
- ΔH_{P1} = $\{ K_B * [(F_B^{(1/3)} / U_{AS}) * X_F^{(2/3)}]$ = buoyant rise; raw gas ; density base
- ΔH_{P2} = $\{ K_B * [(F_H^{(1/3)} * q^{(1/3)}) / U_{AF}] * X_F^{(2/3)} \}$ = buoyant rise; hot gas; thermal base
- ΔH_{F3} = $[\Delta H_{P2} - \Delta H_E\{X_F\}]$ = buoyant rise; flue gas beyond flame
- $\Delta H_E\{X_F\}$ = $\Delta H_{P2}\{X_F\} - \Delta H_{F1}\{X_F\}$ = height correction at flame end