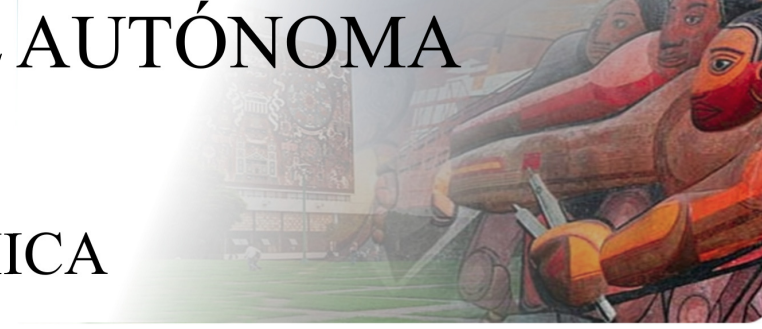
UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO

FACULTAD DE QUÍMICA



3.- Combustión

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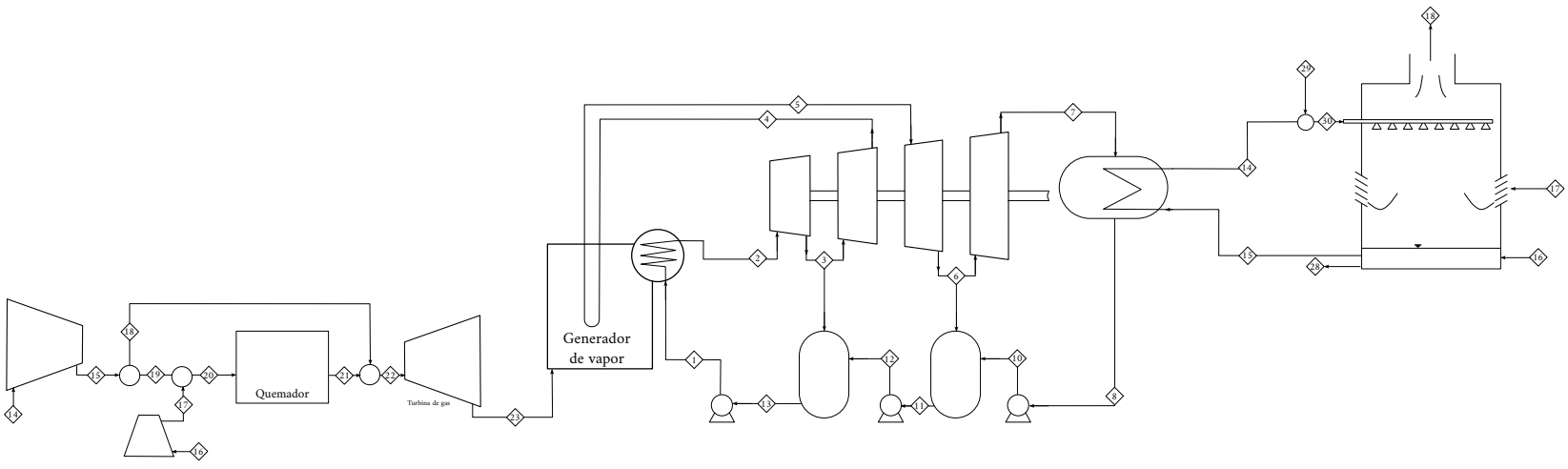
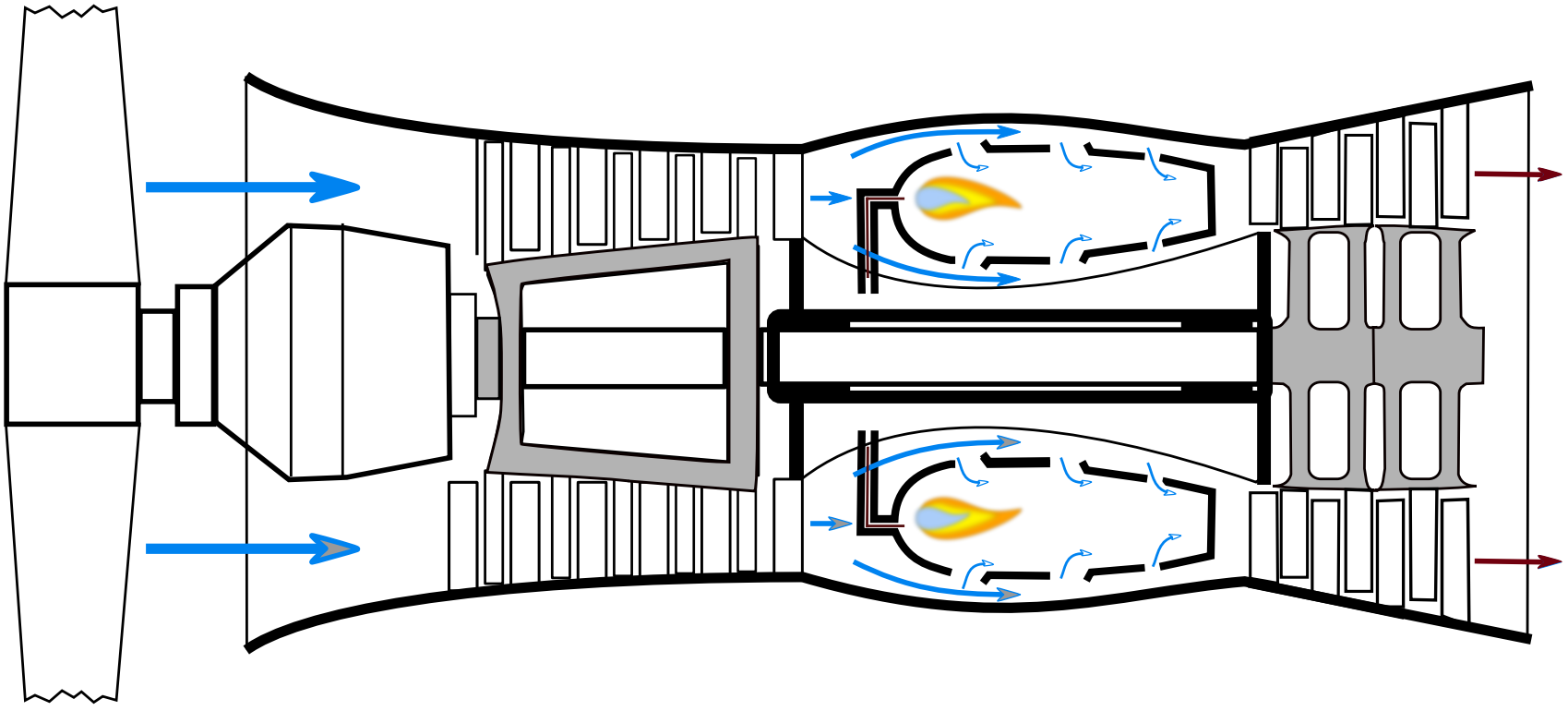
Ciclo Combinado

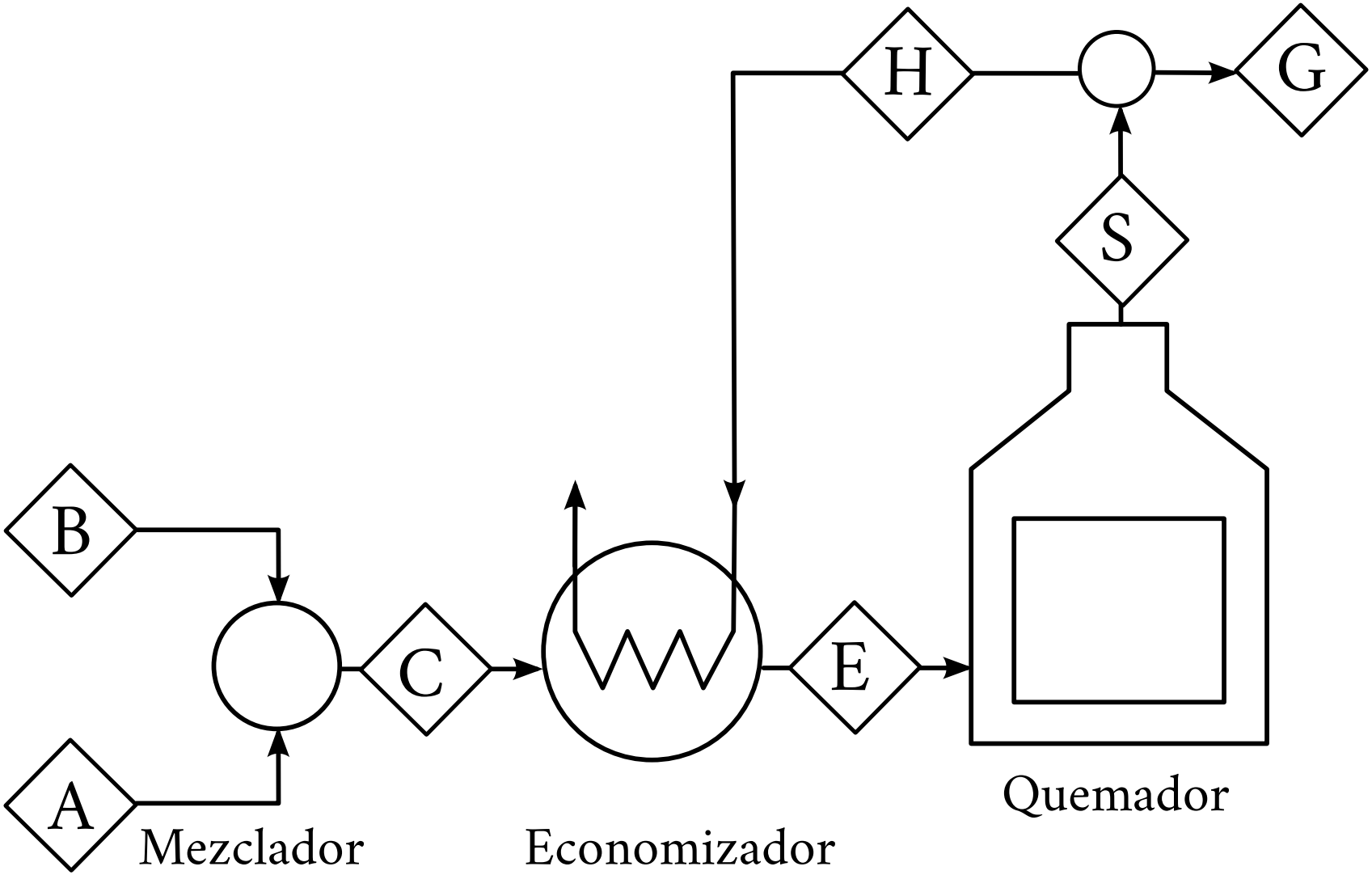


Ciclo Combinado



Combustión

Arreglo para la combustión



Balance de materia

$$N_i^A = x_i^A N^A \tag{1}$$

Balance de materia con reacción química:

Salida = Entra -Consume + Produce

Balance de materia

$$\alpha_{11}\mathrm{A}_1 + \alpha_{21}\mathrm{A}_2 \longrightarrow \alpha_{31}\mathrm{A}_1 + \alpha_{41}\mathrm{A}_2$$

$$\xi_1$$

$$\alpha_{12}\mathrm{A}_1 + \alpha_{22}\mathrm{A}_2 \longrightarrow \alpha_{32}\mathrm{A}_1 + \alpha_{42}\mathrm{A}_2$$

$$\xi_2$$

Balance de materia

Balance de materia por componente

$$N_i^S = N_i^E + \sum_{j=1}^{n_R} \alpha_{ij}\xi_j \tag{2}$$

Balance de materia total

$$N^S = N^E + \sum_{i=1}^{n_c}\sum_{j=1}^{n_R} \alpha_{ij}\xi_j \tag{3}$$

Donde α_{ij} son los coeficientes estequimétricos y ξ_j son los avances de reacción.

Balance de materia

Balance de materia por componente

$$N_i^S = N_i^E + \sum_{j=1}^{n_R} \alpha_{ij}\xi_j \tag{4}$$

Balance de materia total

$$N^S = N^E + \sum_{i=1}^{n_c}\sum_{j=1}^{n_R} \alpha_{ij}\xi_j \tag{5}$$

Donde α_{ij} son los coeficientes estequimétricos y ξ_j son los avances de reacción.

Balance de materia

Composición a la salida:

$$y_i^S = \frac{N_i^S}{N^S} \tag{6}$$

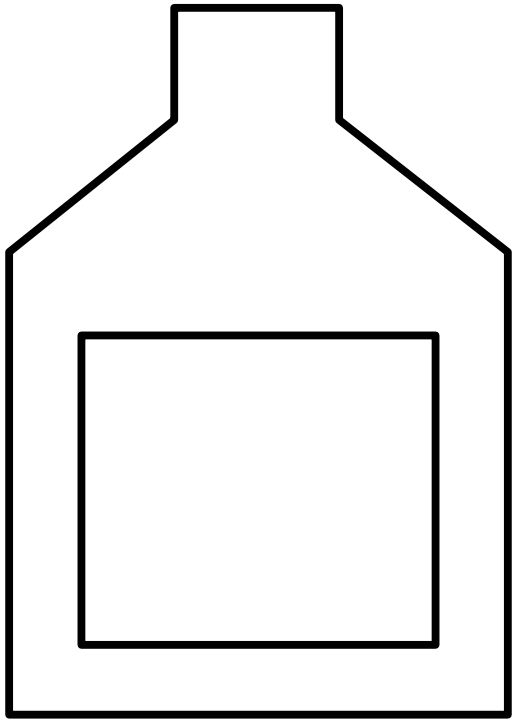
Balance de energía

Balance de energía general

$$N^S h_S - N^E h_E = \dot{Q} + \dot{W} \tag{7}$$

$$\sum_{j=1}^{n_R} \xi_j \Delta h^o_{r,j} + N^S h_S - N^E h_E = \dot{Q} + \dot{W} \tag{8}$$

Temperatura de flama adiabática



Quemador

$$\dot{Q} = 0 \qquad \dot{W} = 0$$

Temperatura de flama adiabática

Temperatura de flama adiabática:

$$\sum_{j=1}^{n_R} \xi_j \Delta h^o_{r,j} + N^S h_S - N^E h_E = 0 \tag{9}$$

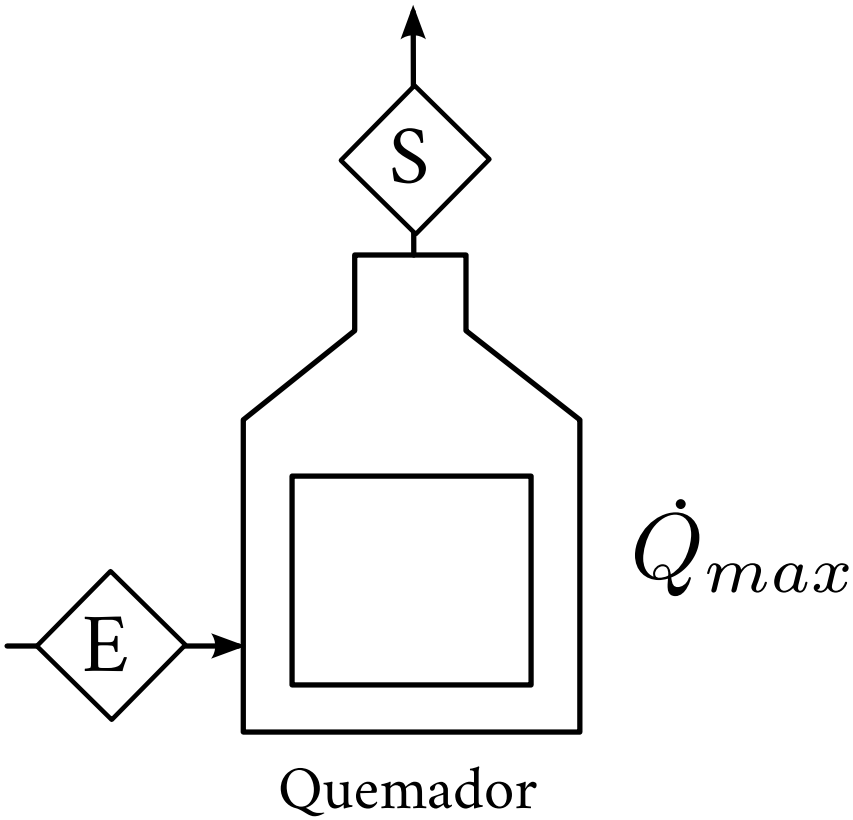
Aproximaciones:

$$\sum_{j=1}^{n_R} \xi_j \Delta h^o_{r,j} + N^S \langle c_p^{\#} \rangle_S \left(T_S - T_o\right) - N^E \langle c_p^{\#} \rangle_E \left(T_E - T_o\right) = 0 \tag{10}$$

Temperatura de flama adiabática

$$T_S = \frac{N^E \langle c_p^{\#} \rangle_E \left(T_S - T_o\right) - \sum_{j=1}^{n_R} \xi_j \Delta h_{r,j}^o}{N^S \langle c_p^{\#} \rangle_S} + T_o \tag{11}$$

Temperatura de flama adiabática



$$\dot{Q}_{\max} = N^S h_S = N^S \langle c_p^{\#} \rangle_S \left(T_S - T_o \right) \quad (12)$$

Combustión Gas Natural

Reacciones

$$CH_4 + 2\,O_2 \longrightarrow CO_2 + 2\,H_2O$$

$$C_2H_6 + 3.5\,O_2 \longrightarrow 2\,CO_2 + 3\,H_2O$$

Ecuaciones de balance de materia:

$$N^S_{CH_4} = N^E_{CH_4} - \xi_1 \quad (13)$$

$$N^S_{C_2H_6} = N^E_{C_2H_6} - \xi_2 \quad (14)$$

$$N^S_{O_2} = N^E_{O_2} - 2\xi_1 - 3.5\xi_2 \quad (15)$$

$$N^S_{CO_2} = N^E_{CO_2} + \xi_1 + 2\xi_2 \quad (16)$$

$$N^S_{H_2O} = N^E_{H_2O} + 2\xi_1 + 3\xi_2 \quad (17)$$

Conversión

Metano:

$$N_{CH_4}^S = (1 - \epsilon_{CH_4})\, N_{CH_4}^E \tag{18}$$

$$\xi_1 = -\frac{\epsilon_{CH_4} N_{CH_4}^E}{\alpha_{CH_4,1}} \tag{19}$$

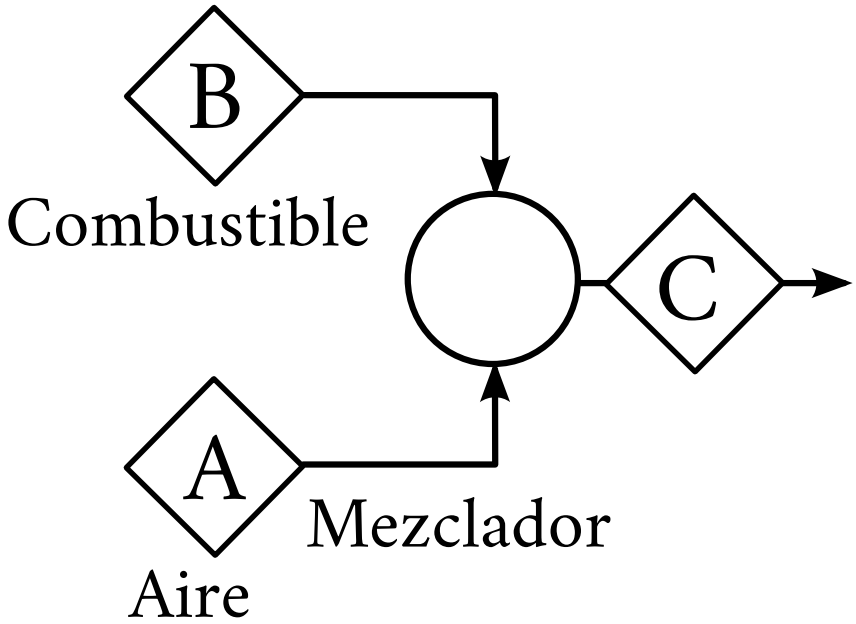
Etano:

$$N_{C_2H_6}^S = (1 - \epsilon_{C_2H_6})\, N_{C_2H_6}^E \tag{20}$$

$$\xi_2 = -\frac{\epsilon_{C_2H_6} N_{C_2H_6}^E}{\alpha_{C_2H_6,2}} \tag{21}$$

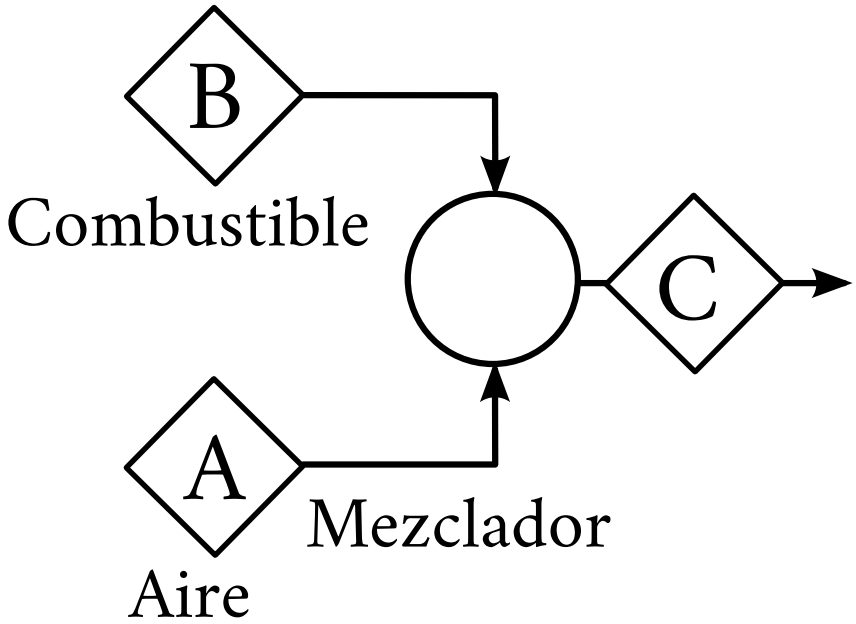
Aire en exceso

Aire en exceso



$$N_i^A + N_i^B = N_i^C \tag{22}$$

Aire en exceso



$$N_{O_2}^{A} = y_{O_2}^{A} N_{\text{aire}}^{A} \tag{23}$$

Aire en exceso

$$\mathrm{CH_4} + 2\,\mathrm{O_2} \longrightarrow \mathrm{CO_2} + 2\,\mathrm{H_2O}$$

$$\mathrm{C_2H_6} + 3.5\,\mathrm{O_2} \longrightarrow 2\,\mathrm{CO_2} + 3\,\mathrm{H_2O}$$

$$N_{O_2}^{Ao} = 2N_{CH_4}^{B} + 3.5N_{C_2H_6}^{B} \tag{24}$$

$$N_{\text{aire}}^{Ao} = \frac{2N_{CH_4}^{B} + 3.5N_{C_2H_6}^{B}}{y_{O_2}^{A}} \tag{25}$$

Demostración ir a página 26

Aire en exceso

$$\varphi_{\text{aire}} = \frac{N^{A}_{\text{aire}} - N^{Ao}_{\text{aire}}}{N^{Ao}_{\text{aire}}} = \frac{N^{A}_{O_2} - N^{Ao}_{O_2}}{N^{Ao}_{O_2}} = \varphi_{O_2} \tag{26}$$

$$N^{A}_{O_2} = (1 + \varphi_{\text{aire}})\, N^{Ao}_{O_2} \tag{27}$$

$$N^{A}_{\text{aire}} = (1 + \varphi_{\text{aire}})\, N^{Ao}_{\text{aire}} \tag{28}$$

Aire en exceso

$$N_{O_2}^{A} = (1 + \varphi_{\text{aire}}) \left(2N_{CH_4}^{B} + 3.5N_{C_2H_6}^{B}\right) \tag{29}$$

$$N_{\text{aire}}^{A} = \frac{(1 + \varphi_{\text{aire}}) \left(2N_{CH_4}^{E} + 3.5N_{C_2H_6}^{E}\right)}{y_{O_2}^{A}} \tag{30}$$

Aire en exceso

$$N^A_{O_2} = y^A_{O_2} N^A_{\text{aire}} \tag{31}$$

$$N^A_{N_2} = y^A_{N_2} N^A_{\text{aire}} \tag{32}$$

$$N^A_{H_2O} = y^A_{H_2O} N^A_{\text{aire}} \tag{33}$$

Aire en exceso

Demostración ecuación 24

$$N^S_{CH_4} = N^E_{CH_4} - \xi^o_1 = 0 \qquad \xi^o_1 = N^E_{CH_4} \tag{34}$$

$$N^S_{C_2H_6} = N^E_{C_2H_6} - \xi^o_2 = 0 \qquad \xi^o_2 = N^E_{C_2H_6} \tag{35}$$

$$N^S_{O_2} = N^{Eo}_{O_2} - 2\xi^o_1 - 3.5\xi^o_2 = 0 \tag{36}$$

$$N^{Eo}_{O_2} = 2\xi^o_1 + 3.5\xi^o_2 \tag{37}$$

$$N^{Eo}_{O_2} = 2N^E_{CH_4} + 3.5N^E_{C_2H_6} \tag{38}$$