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1: "Diseño de la cámara de combustión"
2:
3: "Criterio Aerodinámico"
4:
5: A_ref_a=(R_air/2*(m_dot_2*sqrt(T_2)/P_2)**2*(delta_1/delta_2))**0,5
6: D_ext_a=D_in + 2*D_ref_a
7:
8: A_ref_a=pi*(D_ref_a**2+D_ref_a*D_in)
9: R_air=287
10: m_dot_2=m_dot_air "Conservación de la masa"
11: P_2=2,601*convert(bar;Pa)
12: T_2=convertTEMP(C;K;170,8)
13: delta_1=20 "deltaP_2_3/q_ref para cámara de combustión anular"
14: delta_2=6/100 "deltaP_2_3/P_2 para cámara de combustión anular"
15:
16: m_dot_2*(sqrt(T_2))/A_ref_a/P_2 =X
17:
18: "Criterio Químico"
19: theta=P_2**1,75*A_ref_quim*D_ref_quim**0,75*exp(T_3/b)/m_dot_2
20:
21: D_ext_quim=D_in + 2*D_ref_quim
22: A_ref_quim=pi*(D_ref_quim**2+D_ref_quim*D_in)
23:
24:
25: m_dot_fuel_butano=0,001508 [Kg/s]
26: m_dot_air=0,1507 [Kg/s]
27: {phi_pz=1/lambda_pz
28: lambda_pz=1+m_dot_air_steq}
29: m_dot_air_steq=0,02317
30: T_3=convertTEMP(C;K;600)
31: {"b=170*(2+ln(phi_pz)) Para 1<phi_pz <1,4"
32: b=245*(2+ln(phi_pz)) "Para 0,6<phi_pz <1"}
33: b=300
34: theta=7,333*10**7 "Melconian & Moldak (1985) sugiere este valor value"
35:
36:
37: "Linealización"
38:
39:
40: D_in=0,03 "Se asume de acuerdo a las encontradas en el mercado"
41: D_ext=D_in + 2*D_ref_lin "Diámetro de carcaza"
42: D_ref_lin=0,03 "Altura de referencia"
43: A_ref_lin=pi*(D_ref_lin**2+D_ref_lin*D_in)
44: A_ref_lin_cm=A_ref_lin*convert(m^2;cm^2)
45: {AAAA=(143,5*(m_dot_2*sqrt(T_2)/P_2)**2*(53/40))**0,5}
46:
47:
48:
49: "Flame tube"
50: A_L=0,66*A_ref_lin
51: D_ft=A_L/(D_in+D_ref_lin)/pi "Altura del liner"
52: D_m=D_in+D_ref_lin "Diámetro medio"
53: D_ext_liner=D_m+D_ft "Diámetro exterior del liner"
54: D_int_liner=D_ext-2*D_ft "Diámetro interior del liner"
55: A_an=A_ref_lin-A_L "Area anular"
56:
57: L_L=(-D_ft)/(0,05*2*delta_1*ln(1-TQ)) "Longitud del liner"
58: L_zp=3/4*D_ft "longitud zona primaria"
59: L_zs=1/2*D_ft "longitud zona secundaria"
60: L_dz/D_ft=3,83-11,38*TQ+13,4*TQ**2 "Longitud zona de dilución"
61: L_total=L_dz+L_zp+L_zs

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62:
63: TQ=(T_max-T_3)/(T_3-T_2) "Factor de patrón"
64: T_max-T_3=50 "Se asume un delta de Temperatura no mayor por diseño"
65:
66: Coolingair=0,10*T_2-30 "Porcentaje de aire de enfriamiento"
67: Coolingair=(m_dot_cool/m_dot_2)*100
68: m_dot_2-m_dot_cool=m_dot_rest
69:
70: AC_butano=15,36 "masa aire/masa combustible"
71: Dz_ratio=AC_butano
72: m_dot_air_dz=m_dot_2 - (m_dot_air_pz + m_dot_air_sz + m_dot_cool)
73: Pz_ratio=AC_butano/0,6
74: Pz_ratio=m_dot_air_pz/m_dot_fuel_butano
75: Percent_air_pz=m_dot_air_pz/m_dot_air*100
76: Sz_ratio=AC_butano/0,8
77: Sz_ratio=m_dot_air_sz/m_dot_fuel_butano
78: m_dot_air_szreal=m_dot_air_sz + m_dot_cool
79: Percent_air_sz=m_dot_air_sz/m_dot_air*100
80:
81: A_snout_outer=A_an*m_dot_2/m_dot_an
82: m_dot_an=m_dot_air - m_dot_Rz
83: m_dot_Rz=m_dot_dome_cooling + m_dot_swirler
84: m_dot_dome_cooling=0,08*m_dot_air
85: m_dot_swirler=m_dot_air_pz/2
86: Percent_air_swirler=m_dot_swirler/m_dot_air
87: Percent_air_an=m_dot_an/m_dot_air
88:
89: D_so=A_snout_outer/(D_in+D_ref_lin)/pi "diámetro a la salida de la boca de la cámara de combustión"
90:
91: "Londitud de difusor"
92: L_dif=(R_snout_outer-R_2)/tan(-gamma)
93: R_snout_outer=D_so/2
94: R_2=D_2/2
95: A_2=8,2*10**(-4)
96:
97: deltaP_dif/P_2=1,75*R_air*(m_dot_2*sqrt(T_2)/P_2)**2*(((tan(gamma))**1,22)/A_2**2)*(1-A_2/A_snout_outer)**2"ángulo
    del difusor"
98: deltaP_dif/P_2=0,01
99: A_2=pi*R_2**2
100:
101: beta_h=m_dot_h/m_dot_an
102: m_dot_h=m_dot_cool
103: {m_dot_h=m_dot_air_pz}
104: {m_dot_h=m_dot_air_sz}
105: {m_dot_h=m_dot_air_dz}
106:
107: C_d_h=0,6176 "Cool"
108: {C_d_h=0,6169} "Primary zone"
109: {C_d_h=0,6173} "Secondary zone"
110: {C_d_h=0,6159} "Dilution zone"
111:
112: deltaP_ft/P_2=0,06
113: deltaP_ft/P_2=(143,5*m_dot_h**2*T_2)/(P_2**2*C_d_h**2*A_h**2)
114:
115: alpha_h=A_h/A_an
116: mu_h=beta_h/alpha_h
117:
118:
119: K=1+delta*(2*mu_h**2+(4*mu_h**4+(mu_h**2/delta**2)*(4*Beta_h-Beta_h**2))**0,5)
120: delta=0,8

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121: C_d_h_comprobacion=(K-1)/(delta*(4*K**2-K*(2-beta_h)**2)**0,5)
122:
123: A_h_cool=0,0001392
124: A_h_pz=0,0002479
125: A_h_sz=0,001858
126: A_h_dz=0,003953
127:
128: d_h_cool=2*sqrt(A_h_cool/pi/N_h_cool)
129: d_h_cool=5/64*0,0254
130: N_h_cool_ext=N_h_cool - N_h_cool_int
131: N_h_cool_int=N_h_cool_ext/2
132: {N_h_cool=36}
133: d_h_pz=2*sqrt(A_h_pz/pi/N_h_pz)
134: d_h_pz=1/8*0,0254
135: N_h_pz_ext=21
136: N_h_pz_int=11
137: {N_h_pz=36}
138: d_h_sz=2*sqrt(A_h_sz/pi/N_h_sz)
139: d_h_sz=3/8*0,0254
140: N_h_sz_ext=18
141: N_h_sz_int=8
142: {N_h_sz=24}
143: d_h_dz=2*sqrt(A_h_dz/pi/N_h_dz)
144: d_h_dz=9/16*0,0254
145: N_h_dz_ext=16
146: N_h_dz_int=8
147: {N_h_dz=24}
148:
149:
150: {tan(gamma)=((deltaP_dif/P_2*A_2**2*P_2**2/(502,4*(1-A_2/A_snout_outer)**2*m_dot_2*T_2)))**(1/1,22)}
151: deltaP_dif/P_2=0,01
152: A_2=pi*R_2**2}
153:
154:
155: {Ldif=0,00170
156: Ldif=(Ro-R3)/tan(gamma)
157: Ro=Do/2
158: R3=D3/2
159: Do=0,02593
160: gamma=60,14}
161:
162:
163:
164:
165:

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Diseño de la cámara de combustión

Criterio Aerodinámico

$$A_{\text{ref};a} = \left[\frac{R_{\text{air}}}{2} \cdot \left(\dot{m}_2 \cdot \frac{\sqrt{T_2}}{P_2} \right)^2 \cdot \frac{\delta_1}{\delta_2} \right]^{0,5}$$

$$D_{\text{ext};a} = D_{\text{in}} + 2 \cdot D_{\text{ref};a}$$

$$A_{\text{ref};a} = \pi \cdot [D_{\text{ref};a}^2 + D_{\text{ref};a} \cdot D_{\text{in}}]$$

$$R_{\text{air}} = 287$$

$$\dot{m}_2 = \dot{m}_{\text{air}} \quad \text{Conservación de la masa}$$

$$P_2 = 2,601 \cdot \left| 100000 \cdot \frac{\text{Pa}}{\text{bar}} \right|$$

$$T_2 = \text{ConvertTemp} [\text{C}; \text{K}; 170,8]$$

$$\delta_1 = 20 \quad \text{delta} P_{2,3}/q_{ref} \text{ para cámara de combustión anular}$$

$$\delta_2 = \frac{6}{100} \quad \text{delta} P_{2,3}/P_2 \text{ para cámara de combustión anular}$$

$$\dot{m}_2 \cdot \frac{\sqrt{T_2}}{A_{ref,a} \cdot P_2} = X$$

Criterio Químico

$$\theta = P_2^{1,75} \cdot A_{ref,quim} \cdot D_{ref,quim}^{0,75} \cdot \frac{\exp\left[\frac{T_3}{b}\right]}{\dot{m}_2}$$

$$D_{ext,quim} = D_{in} + 2 \cdot D_{ref,quim}$$

$$A_{ref,quim} = \pi \cdot [D_{ref,quim}^2 + D_{ref,quim} \cdot D_{in}]$$

$$\dot{m}_{fuel;butano} = 0,001508 \quad [\text{kg/s}]$$

$$\dot{m}_{air} = 0,1507 \quad [\text{kg/s}]$$

$$\dot{m}_{air;steq} = 0,02317$$

$$T_3 = \text{ConvertTemp} [\text{C}; \text{K}; 600]$$

$$b = 300$$

$$\theta = 7,333 \cdot 10^7 \quad \text{Melconian \& Moldak (1985) sugiere este valor value}$$

Linealización

$$D_{in} = 0,03 \quad \text{Se asume de acuerdo a las encontradas en el mercado}$$

$$D_{ext} = D_{in} + 2 \cdot D_{ref,lin} \quad \text{Diámetro de carcaza}$$

$$D_{ref,lin} = 0,03 \quad \text{Altura de referencia}$$

$$A_{ref,lin} = \pi \cdot [D_{ref,lin}^2 + D_{ref,lin} \cdot D_{in}]$$

$$A_{ref,lin;cm} = A_{ref,lin} \cdot \left| 10000 \cdot \frac{\text{cm}^2}{\text{m}^2} \right|$$

Flame tube

$$A_L = 0,66 \cdot A_{ref,lin}$$

$$D_{ft} = \frac{A_L}{[D_{in} + D_{ref,lin}] \cdot \pi} \quad \text{Altura del liner}$$

$$D_m = D_{in} + D_{ref,lin} \quad \text{Diámetro medio}$$

$$D_{ext;liner} = D_m + D_{ft} \quad \text{Diámetro exterior del liner}$$

$$D_{\text{int;liner}} = D_{\text{ext}} - 2 \cdot D_{\text{ft}} \quad \text{Diámetro interior del liner}$$

$$A_{\text{an}} = A_{\text{ref;lin}} - A_L \quad \text{Area anular}$$

$$L_L = \frac{-D_{\text{ft}}}{0,05 \cdot 2 \cdot \delta_1 \cdot \ln[1 - TQ]} \quad \text{Longitud del liner}$$

$$L_{\text{zp}} = 3 / 4 \cdot D_{\text{ft}} \quad \text{longitud zona primaria}$$

$$L_{\text{zs}} = 1 / 2 \cdot D_{\text{ft}} \quad \text{longitud zona secundaria}$$

$$\frac{L_{\text{dz}}}{D_{\text{ft}}} = 3,83 - 11,38 \cdot TQ + 13,4 \cdot TQ^2 \quad \text{Longitud zona de dilución}$$

$$L_{\text{total}} = L_{\text{dz}} + L_{\text{zp}} + L_{\text{zs}}$$

$$TQ = \frac{T_{\text{max}} - T_3}{T_3 - T_2} \quad \text{Factor de patrón}$$

$$T_{\text{max}} - T_3 = 50 \quad \text{Se asume un delta de Temperatura no mayor por diseño}$$

$$\text{Coolingair} = 0,1 \cdot T_2 - 30 \quad \text{Porcentaje de aire de enfriamiento}$$

$$\text{Coolingair} = \frac{\dot{m}_{\text{cool}}}{\dot{m}_2} \cdot 100$$

$$\dot{m}_2 - \dot{m}_{\text{cool}} = \dot{m}_{\text{rest}}$$

$$AC_{\text{butano}} = 15,36 \quad \text{masa aire/masa combustible}$$

$$Dz_{\text{ratio}} = AC_{\text{butano}}$$

$$\dot{m}_{\text{air;dz}} = \dot{m}_2 - [\dot{m}_{\text{air;pz}} + \dot{m}_{\text{air;sz}} + \dot{m}_{\text{cool}}]$$

$$Pz_{\text{ratio}} = \frac{AC_{\text{butano}}}{0,6}$$

$$Pz_{\text{ratio}} = \frac{\dot{m}_{\text{air;pz}}}{\dot{m}_{\text{fuel;butano}}}$$

$$\text{Percent}_{\text{air;pz}} = \frac{\dot{m}_{\text{air;pz}}}{\dot{m}_{\text{air}}} \cdot 100$$

$$Sz_{\text{ratio}} = \frac{AC_{\text{butano}}}{0,8}$$

$$Sz_{\text{ratio}} = \frac{\dot{m}_{\text{air;sz}}}{\dot{m}_{\text{fuel;butano}}}$$

$$\dot{m}_{\text{air;szreal}} = \dot{m}_{\text{air;sz}} + \dot{m}_{\text{cool}}$$

$$\text{Percent}_{\text{air;sz}} = \frac{\dot{m}_{\text{air;sz}}}{\dot{m}_{\text{air}}} \cdot 100$$

$$A_{\text{snout;outer}} = A_{\text{an}} \cdot \frac{\dot{m}_2}{\dot{m}_{\text{an}}}$$

$$\dot{m}_{\text{an}} = \dot{m}_{\text{air}} - \dot{m}_{\text{Rz}}$$

$$\dot{m}_{Rz} = \dot{m}_{\text{dome;cooling}} + \dot{m}_{\text{swirler}}$$

$$\dot{m}_{\text{dome;cooling}} = 0,08 \cdot \dot{m}_{\text{air}}$$

$$\dot{m}_{\text{swirler}} = \frac{\dot{m}_{\text{air;pz}}}{2}$$

$$\text{Percent}_{\text{air;swirler}} = \frac{\dot{m}_{\text{swirler}}}{\dot{m}_{\text{air}}}$$

$$\text{Percent}_{\text{air;an}} = \frac{\dot{m}_{\text{an}}}{\dot{m}_{\text{air}}}$$

$$D_{\text{so}} = \frac{A_{\text{snout;outer}}}{[D_{\text{in}} + D_{\text{ref;lin}}] \cdot \pi} \quad \text{diámetro a la salida de la boca de la cámara de combustión}$$

Longitud de difusor

$$L_{\text{dif}} = \frac{R_{\text{snout;outer}} - R_2}{\tan[-\gamma]}$$

$$R_{\text{snout;outer}} = \frac{D_{\text{so}}}{2}$$

$$R_2 = \frac{D_2}{2}$$

$$A_2 = 8,2 \cdot 10^{-4}$$

$$\frac{\delta P_{\text{dif}}}{P_2} = 1,75 \cdot R_{\text{air}} \cdot \left[\dot{m}_2 \cdot \frac{\sqrt{T_2}}{P_2} \right]^2 \cdot \frac{\tan^{1,22}[\gamma]}{A_2^2} \cdot \left[1 - \frac{A_2}{A_{\text{snout;outer}}} \right]^2 \quad \text{ángulo del difusor}$$

$$\frac{\delta P_{\text{dif}}}{P_2} = 0,01$$

$$A_2 = \pi \cdot R_2^2$$

$$\beta_h = \frac{\dot{m}_h}{\dot{m}_{\text{an}}}$$

$$\dot{m}_h = \dot{m}_{\text{cool}}$$

$$C_{\text{d;h}} = 0,6176 \quad \text{Cool}$$

Primary zone

Secondary zone

Dilution zone

$$\frac{\delta P_{\text{ft}}}{P_2} = 0,06$$

$$\frac{\delta P_{\text{ft}}}{P_2} = \frac{143,5 \cdot \dot{m}_h^2 \cdot T_2}{P_2^2 \cdot C_{\text{d;h}}^2 \cdot A_h^2}$$

$$\alpha_h = \frac{A_h}{A_{\text{an}}}$$

$$\mu_h = \frac{\beta_h}{\alpha_h}$$

$$K = 1 + \delta \cdot \left[2 \cdot \mu_h^2 + \left(4 \cdot \mu_h^4 + \frac{\mu_h^2}{\delta^2} \cdot [4 \cdot \beta_h - \beta_h^2] \right)^{0,5} \right]$$

$$\delta = 0,8$$

$$C_{d,h;comprobacion} = \frac{K - 1}{\delta \cdot [4 \cdot K^2 - K \cdot (2 - \beta_h)^2]^{0,5}}$$

$$A_{h;cool} = 0,0001392$$

$$A_{h;pz} = 0,0002479$$

$$A_{h,sz} = 0,001858$$

$$A_{h,dz} = 0,003953$$

$$d_{h;cool} = 2 \cdot \sqrt{\frac{A_{h;cool}}{\pi \cdot N_{h;cool}}}$$

$$d_{h;cool} = \frac{5}{64} \cdot 0,0254$$

$$N_{h;cool;ext} = N_{h;cool} - N_{h;cool;int}$$

$$N_{h;cool;int} = \frac{N_{h;cool;ext}}{2}$$

$$d_{h;pz} = 2 \cdot \sqrt{\frac{A_{h;pz}}{\pi \cdot N_{h;pz}}}$$

$$d_{h;pz} = 1 / 8 \cdot 0,0254$$

$$N_{h;pz;ext} = 21$$

$$N_{h;pz;int} = 11$$

$$d_{h,sz} = 2 \cdot \sqrt{\frac{A_{h,sz}}{\pi \cdot N_{h,sz}}}$$

$$d_{h,sz} = 3 / 8 \cdot 0,0254$$

$$N_{h,sz;ext} = 18$$

$$N_{h,sz;int} = 8$$

$$d_{h,dz} = 2 \cdot \sqrt{\frac{A_{h,dz}}{\pi \cdot N_{h,dz}}}$$

$$d_{h,dz} = \frac{9}{16} \cdot 0,0254$$

$$N_{h,dz;ext} = 16$$

$$N_{h,dz,int} = 8$$

SOLUTION

Unit Settings: SI C kPa kJ mass deg

$$AC_{butano} = 15,36$$

$$A_2 = 0,00082$$

$$A_h = 0,0001392$$

$$A_{h,dz} = 0,003953$$

$$A_{h,sz} = 0,001858$$

$$A_{ref,a} = 0,00267 \text{ [m}^2\text{]}$$

$$A_{ref,lin,cm} = 56,55 \text{ [cm}^2\text{]}$$

$$A_{snout,outer} = 0,002428 \text{ [m}^2\text{-kg/s]}$$

$$\beta_h = 0,1818 \text{ [s/kg]}$$

$$C_{d,h} = 0,6176$$

$$\delta = 0,8$$

$$\delta P_{ft} = 15606$$

$$\delta_2 = 0,06$$

$$D_2 = 0,03231$$

$$D_{ext,a} = 0,06557 \text{ [m]}$$

$$D_{ext,quim} = 0,07356 \text{ [m]}$$

$$d_{h,cool} = 0,001984$$

$$d_{h,pz} = 0,003175$$

$$D_{in} = 0,03 \text{ [m]}$$

$$D_m = 0,06 \text{ [m]}$$

$$D_{ref,lin} = 0,03 \text{ [m]}$$

$$D_{so} = 0,01288 \text{ [m-kg/s]}$$

$$K = 21,4$$

$$L_{dz} = 0,05319 \text{ [m]}$$

$$L_{total} = 0,07794 \text{ [m]}$$

$$L_{zs} = 0,0099 \text{ [m]}$$

$$\dot{m}_2 = 0,1507 \text{ [kg/s]}$$

$$\dot{m}_{air,dz} = 0,06145 \text{ [kg/s]}$$

$$\dot{m}_{air,steq} = 0,02317 \text{ [kg/s]}$$

$$\dot{m}_{air,szreal} = 0,05065$$

$$\dot{m}_{cool} = 0,02169 \text{ [kg/s]}$$

$$\dot{m}_{fuel,butano} = 0,001508 \text{ [kg/s]}$$

$$\dot{m}_{rest} = 0,129 \text{ [kg/s]}$$

$$\dot{m}_{swirler} = 0,0193 \text{ [kg/s]}$$

$$N_{h,cool,ext} = 30,01$$

$$N_{h,dz} = 24,66$$

$$N_{h,dz,int} = 8$$

$$N_{h,pz,ext} = 21$$

$$N_{h,sz} = 26,08$$

$$N_{h,sz,int} = 8$$

$$\text{Percent}_{air,pz} = 25,62 \text{ [s/kg]}$$

$$\text{Percent}_{air,sz} = 19,21$$

$$P_2 = 260100 \text{ [Pa]}$$

$$R_{air} = 287$$

$$SZ_{ratio} = 19,2 \text{ [s/kg]}$$

$$TQ = 0,1165 \text{ [1/K]}$$

$$T_3 = 873,2 \text{ [K]}$$

$$X = 0,004572 \text{ [kg-K}^5\text{/s-m}^2\text{-Pa]}$$

$$\alpha_h = 0,07238 \text{ [1/m}^2\text{]}$$

$$A_{an} = 0,001923 \text{ [m}^2\text{]}$$

$$A_{h,cool} = 0,0001392$$

$$A_{h,pz} = 0,0002479$$

$$A_L = 0,003732 \text{ [m}^2\text{]}$$

$$A_{ref,lin} = 0,005655 \text{ [m}^2\text{]}$$

$$A_{ref,quim} = 0,003543 \text{ [m}^2\text{]}$$

$$b = 300$$

$$\text{Cooling}_{air} = 14,4 \text{ [%]}$$

$$C_{d,h,comprobacion} = 0,6076$$

$$\delta P_{dif} = 2601$$

$$\delta_1 = 20$$

$$DZ_{ratio} = 15,36$$

$$D_{ext} = 0,09 \text{ [m]}$$

$$D_{ext,liner} = 0,0798 \text{ [m]}$$

$$D_{ft} = 0,0198 \text{ [m]}$$

$$d_{h,dz} = 0,01429$$

$$d_{h,sz} = 0,009525$$

$$D_{int,liner} = 0,0504 \text{ [m]}$$

$$D_{ref,a} = 0,01779 \text{ [m]}$$

$$D_{ref,quim} = 0,02178 \text{ [m]}$$

$$\gamma = 15,25$$

$$L_{dif} = 0,03564$$

$$L_L = 0,07993 \text{ [m]}$$

$$L_{zp} = 0,01485 \text{ [m]}$$

$$\mu_h = 2,512 \text{ [s-m}^2\text{/kg}^{-1}\text{]}$$

$$\dot{m}_{air} = 0,1507 \text{ [kg/s]}$$

$$\dot{m}_{air,pz} = 0,0386 \text{ [kg/s]}$$

$$\dot{m}_{air,sz} = 0,02895 \text{ [kg/s]}$$

$$\dot{m}_{an} = 0,1193 \text{ [kg/s]}$$

$$\dot{m}_{dome,cooling} = 0,01206 \text{ [kg/s]}$$

$$\dot{m}_h = 0,02169 \text{ [kg/s]}$$

$$\dot{m}_{Rz} = 0,03136 \text{ [kg/s]}$$

$$N_{h,cool} = 45,01$$

$$N_{h,cool,int} = 15$$

$$N_{h,dz,ext} = 16$$

$$N_{h,pz} = 31,31$$

$$N_{h,pz,int} = 11$$

$$N_{h,sz,ext} = 18$$

$$\text{Percent}_{air,an} = 0,7919$$

$$\text{Percent}_{air,swirler} = 0,1281 \text{ [s/kg]}$$

$$PZ_{ratio} = 25,6 \text{ [s/kg]}$$

$$R_2 = 0,01616 \text{ [m-kg/s]}$$

$$R_{snout,outer} = 0,00644 \text{ [m-kg/s]}$$

$$\theta = 7,333E+07$$

$$T_2 = 444 \text{ [K]}$$

$$T_{max} = 923,2 \text{ [K]}$$

12 potential unit problems were detected.

EES suggested units (shown in purple) for α_h A_{an} A_L A_{snout_outer} β_h D_m .

There are a total of 95 equations in the Main program.

Block Rel. Res. Abs. Res. Units Calls Time(ms) Equations

0	0.000E+00	0.000E+00	OK	1	0	R_{air} =287
0	0.000E+00	0.000E+00	OK	1	0	delta_1 =20
0	0.000E+00	0.000E+00	OK	1	0	m_dot_fuel_butano =0,001508[Kg/s]
0	0.000E+00	0.000E+00	OK	1	0	m_dot_air =0,1507[Kg/s]
0	0.000E+00	0.000E+00	OK	1	0	m_dot_air_steq =0,02317
0	0.000E+00	0.000E+00	OK	1	0	b =300
0	0.000E+00	0.000E+00	OK	1	0	D_{in} =0,03
0	0.000E+00	0.000E+00	OK	1	0	D_{ref_lin} =0,03
0	0.000E+00	0.000E+00	OK	1	0	AC_{butano} =15,36
0	0.000E+00	0.000E+00	OK	1	0	C_{d_h} =0,6176
0	0.000E+00	0.000E+00	OK	1	0	delta =0,8
0	0.000E+00	0.000E+00	OK	1	0	A_{h_cool} =0,0001392
0	0.000E+00	0.000E+00	OK	1	0	A_{h_pz} =0,0002479
0	0.000E+00	0.000E+00	OK	1	0	A_{h_sz} =0,001858
0	0.000E+00	0.000E+00	OK	1	0	A_{h_dz} =0,003953
0	0.000E+00	0.000E+00	OK	1	0	N_{h_pz_ext} =21
0	0.000E+00	0.000E+00	OK	1	0	N_{h_pz_int} =11
0	0.000E+00	0.000E+00	OK	1	0	N_{h_sz_ext} =18
0	0.000E+00	0.000E+00	OK	1	0	N_{h_sz_int} =8
0	0.000E+00	0.000E+00	OK	1	0	N_{h_dz_ext} =16
0	0.000E+00	0.000E+00	OK	1	0	N_{h_dz_int} =8
0	0.000E+00	0.000E+00	OK	4	0	P₂ =2,601*convert(bar;Pa)
0	0.000E+00	0.000E+00	OK	4	0	T₂ =convertTEMP(C;K;170,8)
0	0.000E+00	0.000E+00	OK	4	0	delta_2 =6/100
0	0.000E+00	0.000E+00	OK	4	0	T₃ =convertTEMP(C;K;600)
0	0.000E+00	0.000E+00	OK	4	0	theta =7,333*10**7
0	0.000E+00	0.000E+00	OK	4	0	A_{ref_lin} =pi*(D _{ref_lin} **2+D _{ref_lin} *D _{in})
0	0.000E+00	0.000E+00	OK	4	0	A_{ref_lin_cm} =A _{ref_lin} *convert(m^2;cm^2)
0	0.000E+00	0.000E+00	OK	4	0	A_L =0,66*A _{ref_lin}
0	0.000E+00	0.000E+00	OK	4	0	D_{ft} =A _L /(D _{in} +D _{ref_lin})/pi
0	0.000E+00	0.000E+00	OK	4	0	D_m =D _{in} +D _{ref_lin}
0	0.000E+00	0.000E+00	OK	4	0	D_{ext_liner} =D _m +D _{ft}
0	0.000E+00	0.000E+00	OK	4	0	A_{an} =A _{ref_lin} -A _L
0	0.000E+00	0.000E+00	OK	4	0	L_{zp} =3/4*D _{ft}
0	0.000E+00	0.000E+00	OK	4	0	L_{zs} =1/2*D _{ft}
0	0.000E+00	0.000E+00	?	4	0	T_{max} -T ₃ =50
0	0.000E+00	0.000E+00	?	4	0	Coolingair =0,10*T ₂ -30
0	0.000E+00	0.000E+00	OK	4	0	Dz_ratio =AC _{butano}
0	0.000E+00	0.000E+00	OK	4	0	Pz_ratio =AC _{butano} /0,6
0	0.000E+00	0.000E+00	OK	4	0	Pz_ratio =m_dot _{air_pz} /m_dot _{fuel_butano}
0	0.000E+00	0.000E+00	OK	4	0	Percent_{air_pz} =m_dot _{air_pz} /m_dot _{air} *100
0	0.000E+00	0.000E+00	OK	4	0	Sz_ratio =AC _{butano} /0,8
0	0.000E+00	0.000E+00	OK	4	0	Sz_ratio =m_dot _{air_sz} /m_dot _{fuel_butano}
0	0.000E+00	0.000E+00	OK	4	0	Percent_{air_sz} =m_dot _{air_sz} /m_dot _{air} *100
0	0.000E+00	0.000E+00	OK	4	0	m_dot_dome_cooling =0,08*m_dot _{air}
0	0.000E+00	0.000E+00	OK	4	0	m_dot_swirler =m_dot _{air_pz} /2
0	0.000E+00	0.000E+00	OK	4	0	Percent_{air_swirler} =m_dot _{swirler} /m_dot _{air}
0	0.000E+00	0.000E+00	OK	4	0	A₂ =8,2*10**(-4)
0	8,470E-20	-8,470E-22	?	4	0	deltaP_{dif} /P ₂ =0,01
0	1,113E-08	-9,128E-12	OK	15	0	A₂ =pi*R ₂ **2
0	0.000E+00	0.000E+00	?	4	0	deltaP_{ft} /P ₂ =0,06
0	0.000E+00	0.000E+00	OK	4	0	d_{h_cool} =5/64*0,0254
0	0.000E+00	0.000E+00	OK	4	0	d_{h_pz} =1/8*0,0254
0	0.000E+00	0.000E+00	OK	4	0	d_{h_sz} =3/8*0,0254
0	0.000E+00	0.000E+00	OK	4	0	d_{h_dz} =9/16*0,0254
0	0.000E+00	0.000E+00	OK	4	0	m_dot_2 =m_dot _{air}
0	0.000E+00	0.000E+00	OK	4	0	D_{ext} =D _{in} +2*D _{ref_lin}
0	0.000E+00	0.000E+00	OK	4	0	D_{int_liner} =D _{ext} -2*D _{ft}
0	0.000E+00	0.000E+00	OK	4	0	TQ =(T _{max} -T ₃)/(T ₃ -T ₂)
0	0.000E+00	0.000E+00	?	4	0	Coolingair =(m_dot _{cool} /m_dot ₂)*100

0	0.000E+00	0.000E+00	OK	4	0	$m_dot_2 - m_dot_cool = m_dot_rest$
0	0.000E+00	0.000E+00	OK	4	0	$m_dot_air_dz = m_dot_2 - (m_dot_air_pz + m_dot_air_sz + m_dot_cool)$
0	0.000E+00	0.000E+00	OK	4	0	$m_dot_air_szreal = m_dot_air_sz + m_dot_cool$
0	0.000E+00	0.000E+00	OK	4	0	$m_dot_Rz = m_dot_dome_cooling + m_dot_swirler$
0	0.000E+00	0.000E+00	OK	4	0	$R_2 = D_2/2$
0	0.000E+00	0.000E+00	OK	4	0	$m_dot_h = m_dot_cool$
0	3,464E-09	1,039E-07	?	25	0	$\Delta P_ft/P_2 = (143,5 * m_dot_h^{**2} * T_2) / (P_2^{**2} * C_d * h^{**2} * A_h^{**2})$
0	0.000E+00	0.000E+00	OK	4	0	$\alpha_h = A_h/A_an$
0	1,433E-08	-2,843E-11	OK	13	0	$d_h_cool = 2 * \sqrt{A_h_cool / \pi / N_h_cool}$
0	5,625E-07	-1,786E-09	OK	12	0	$d_h_pz = 2 * \sqrt{A_h_pz / \pi / N_h_pz}$
0	8,483E-08	-8,080E-10	OK	12	0	$d_h_sz = 2 * \sqrt{A_h_sz / \pi / N_h_sz}$
0	4,508E-08	-6,440E-10	OK	12	0	$d_h_dz = 2 * \sqrt{A_h_dz / \pi / N_h_dz}$
0	0.000E+00	0.000E+00	?	4	0	$A_ref_a = (R_air/2 * (m_dot_2 * \sqrt{T_2}) / P_2)^{**2} * (\Delta_1 / \Delta_2)^{**0,5}$
0	1,348E-10	-3,599E-13	OK	14	0	$A_ref_a = \pi * (D_ref_a^{**2} + D_ref_a * D_in)$
0	0.000E+00	0.000E+00	OK	4	0	$m_dot_2 * (\sqrt{T_2}) / A_ref_a / P_2 = X$
0	0.000E+00	0.000E+00	OK	4	0	$L_L = (-D_ft) / (0,05 * 2 * \Delta_1 * \ln(1 - TQ))$
0	8,073E-20	2,168E-19	OK	4	0	$L_dz/D_ft = 3,83 - 11,38 * TQ + 13,4 * TQ^{**2}$
0	0.000E+00	0.000E+00	OK	4	0	$L_total = L_dz + L_zp + L_zs$
0	0.000E+00	0.000E+00	OK	4	0	$m_dot_an = m_dot_air - m_dot_Rz$
0	0.000E+00	0.000E+00	OK	4	0	$Percent_air_an = m_dot_an / m_dot_air$
0	0.000E+00	0.000E+00	OK	4	0	$\beta_h = m_dot_h / m_dot_an$
0	0.000E+00	0.000E+00	OK	4	0	$\mu_h = \beta_h / \alpha_h$
0	0.000E+00	0.000E+00	?	4	0	$K = 1 + \Delta * (2 * \mu_h^{**2} + (4 * \mu_h^{**4} + (\mu_h^{**2} / \Delta^{**2}) * (4 * \beta_h - \beta_h^{**2}))^{**0,5})$
0	0.000E+00	0.000E+00	?	4	0	$C_d_h_comprobacion = (K - 1) / (\Delta * (4 * K^{**2} - K * (2 - \beta_h)^{**2}))^{**0,5}$
0	0.000E+00	0.000E+00	OK	4	0	$D_ext_a = D_in + 2 * D_ref_a$
0	0.000E+00	0.000E+00	OK	4	0	$A_snout_outer = A_an * m_dot_2 / m_dot_an$
0	0.000E+00	0.000E+00	OK	4	0	$D_so = A_snout_outer / (D_in + D_ref_lin) / \pi$
0	0.000E+00	0.000E+00	OK	4	0	$R_snout_outer = D_so/2$
0	6,789E-07	6,789E-09	?	7	0	$\Delta P_dif/P_2 = 1,75 * R_air * (m_dot_2 * \sqrt{T_2}) / P_2^{**2} * (((\tan(\gamma))^{**1,22}) / A)$
0	0.000E+00	0.000E+00	?	4	0	$L_dif = (R_snout_outer - R_2) / \tan(-\gamma)$
1	4,078E-09	2,990E-01	?	28	0	$\theta = P_2^{**1,75} * A_ref_quim * D_ref_quim^{**0,75} * \exp(T_3/b) / m_dot_2$
1	1,660E-09	-5,880E-12	OK	28	0	$A_ref_quim = \pi * (D_ref_quim^{**2} + D_ref_quim * D_in)$
2	2,764E-19	2,033E-20	OK	3	0	$D_ext_quim = D_in + 2 * D_ref_quim$
3	6,216E-14	1,865E-12	OK	4	0	$N_h_cool_ext = N_h_cool - N_h_cool_int$
3	1,156E-19	-3,469E-18	OK	4	0	$N_h_cool_int = N_h_cool_ext/2$

Parametric Table: Table 1

	A_h	$C_{d,h}$
Run 1	0,0001719	0,5
Run 2	0,0001701	0,5053
Run 3	0,0001683	0,5105
Run 4	0,0001666	0,5158
Run 5	0,0001649	0,5211
Run 6	0,0001633	0,5263
Run 7	0,0001617	0,5316
Run 8	0,0001601	0,5368
Run 9	0,0001585	0,5421
Run 10	0,000157	0,5474
Run 11	0,0001555	0,5526
Run 12	0,000154	0,5579
Run 13	0,0001526	0,5632
Run 14	0,0001512	0,5684
Run 15	0,0001498	0,5737
Run 16	0,0001484	0,5789
Run 17	0,0001471	0,5842
Run 18	0,0001458	0,5895
Run 19	0,0001445	0,5947

Parametric Table: Table 1

	A_h	$C_{d,h}$
Run 20	<i>0,0001432</i>	0,6

Parametric Table: Table 2

	A_h	$C_{d,h}$	$C_{d,h;comprobacion}$
Run 1	<i>0,0003991</i>	0,61	<i>0,6158</i>
Run 2	<i>0,0003989</i>	0,6102	<i>0,6158</i>
Run 3	<i>0,0003988</i>	0,6104	<i>0,6158</i>
Run 4	<i>0,0003987</i>	0,6106	<i>0,6158</i>
Run 5	<i>0,0003985</i>	0,6108	<i>0,6158</i>
Run 6	<i>0,0003984</i>	0,611	<i>0,6158</i>
Run 7	<i>0,0003983</i>	0,6112	<i>0,6158</i>
Run 8	<i>0,0003981</i>	0,6114	<i>0,6158</i>
Run 9	<i>0,000398</i>	0,6116	<i>0,6158</i>
Run 10	<i>0,0003979</i>	0,6118	<i>0,6158</i>
Run 11	<i>0,0003977</i>	0,612	<i>0,6158</i>
Run 12	<i>0,0003976</i>	0,6122	<i>0,6158</i>
Run 13	<i>0,0003975</i>	0,6124	<i>0,6158</i>
Run 14	<i>0,0003973</i>	0,6127	<i>0,6158</i>
Run 15	<i>0,0003972</i>	0,6129	<i>0,6158</i>
Run 16	<i>0,0003971</i>	0,6131	<i>0,6158</i>
Run 17	<i>0,000397</i>	0,6133	<i>0,6159</i>
Run 18	<i>0,0003968</i>	0,6135	<i>0,6159</i>
Run 19	<i>0,0003967</i>	0,6137	<i>0,6159</i>
Run 20	<i>0,0003966</i>	0,6139	<i>0,6159</i>
Run 21	<i>0,0003964</i>	0,6141	<i>0,6159</i>
Run 22	<i>0,0003963</i>	0,6143	<i>0,6159</i>
Run 23	<i>0,0003962</i>	0,6145	<i>0,6159</i>
Run 24	<i>0,000396</i>	0,6147	<i>0,6159</i>
Run 25	<i>0,0003959</i>	0,6149	<i>0,6159</i>
Run 26	<i>0,0003958</i>	0,6151	<i>0,6159</i>
Run 27	<i>0,0003956</i>	0,6153	<i>0,6159</i>
Run 28	<i>0,0003955</i>	0,6155	<i>0,6159</i>
Run 29	<i>0,0003954</i>	0,6157	<i>0,6159</i>
Run 30	<i>0,0003952</i>	0,6159	<i>0,6159</i>
Run 31	<i>0,0003951</i>	0,6161	<i>0,6159</i>
Run 32	<i>0,000395</i>	0,6163	<i>0,6159</i>
Run 33	<i>0,0003949</i>	0,6165	<i>0,6159</i>
Run 34	<i>0,0003947</i>	0,6167	<i>0,616</i>
Run 35	<i>0,0003946</i>	0,6169	<i>0,616</i>
Run 36	<i>0,0003945</i>	0,6171	<i>0,616</i>
Run 37	<i>0,0003943</i>	0,6173	<i>0,616</i>
Run 38	<i>0,0003942</i>	0,6176	<i>0,616</i>
Run 39	<i>0,0003941</i>	0,6178	<i>0,616</i>
Run 40	<i>0,0003939</i>	0,618	<i>0,616</i>
Run 41	<i>0,0003938</i>	0,6182	<i>0,616</i>
Run 42	<i>0,0003937</i>	0,6184	<i>0,616</i>
Run 43	<i>0,0003935</i>	0,6186	<i>0,616</i>
Run 44	<i>0,0003934</i>	0,6188	<i>0,616</i>
Run 45	<i>0,0003933</i>	0,619	<i>0,616</i>
Run 46	<i>0,0003932</i>	0,6192	<i>0,616</i>
Run 47	<i>0,000393</i>	0,6194	<i>0,616</i>
Run 48	<i>0,0003929</i>	0,6196	<i>0,616</i>
Run 49	<i>0,0003928</i>	0,6198	<i>0,616</i>
Run 50	<i>0,0003926</i>	0,62	<i>0,616</i>