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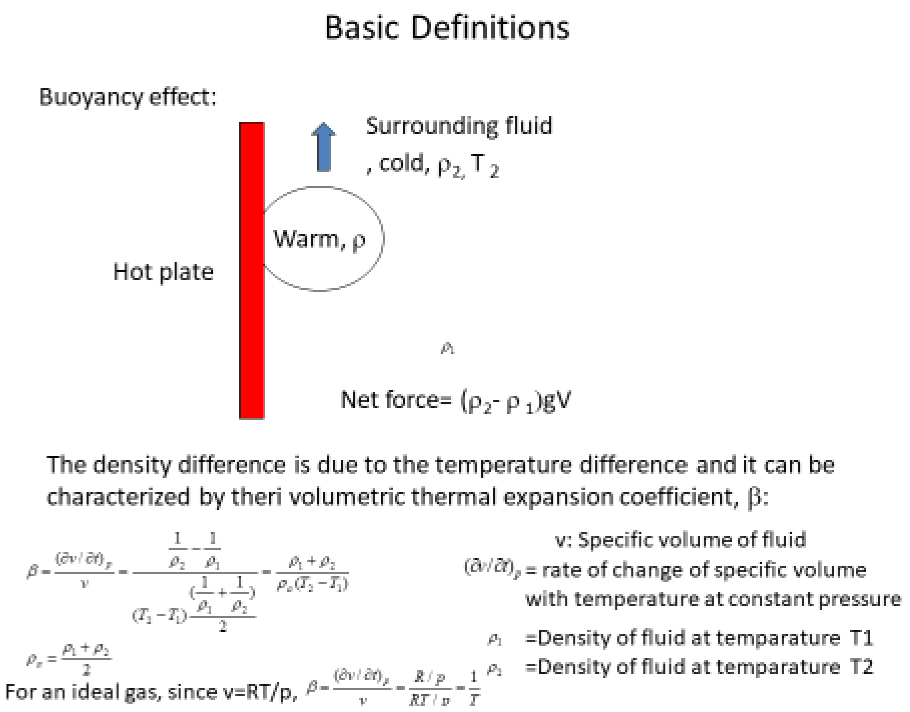
11. Heat transfer by natural convection



For single horizontal cylinders, the heat transfer coefficient can be correlated by an equation containing three dimensionless groups, the Nusselt number, the Prandlt number and the Grashof number or specifically,

$$Nu = 0.53(Gr * \Pr)_f^{0.25}$$

Naturel convection to air from vertical shapes and horizontal planes

Equations for heat transfer in naturel convection between fluids and solids of definite geometric shape are of the form

$$\frac{hL}{k} = b(\frac{Cp\mu_f}{k_f}, \frac{L^3 \rho_f{}^2 \beta_f \Delta T}{\mu_f{}^2})^n$$

$$Nu_f = b(N_{Pr}, N_{Gr})^n$$

Where b,n are const

L= height of vertical surface or length of horizontal square surface, ft

Example:

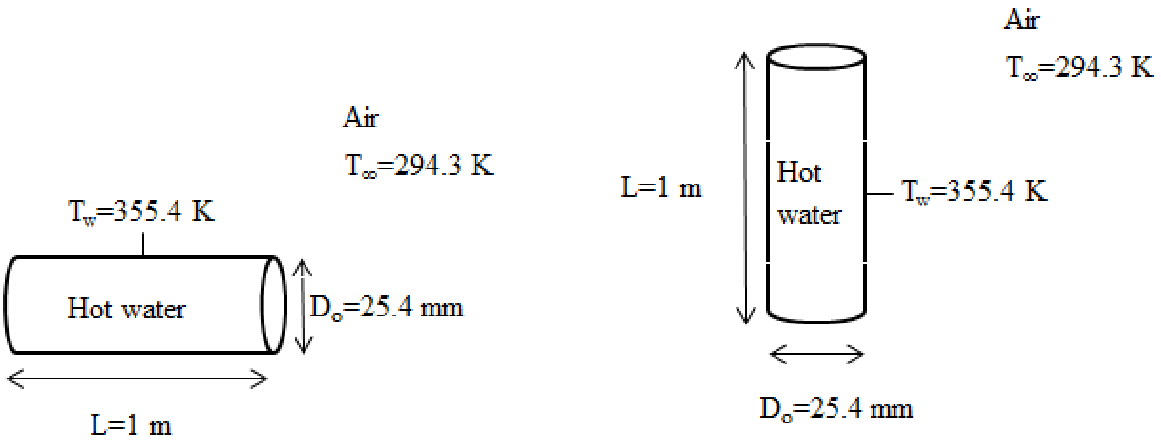


Figure 1. Heat Loss from a horizontal tube and vertical tube

$$Nu = b(Gr.\Pr)_f{}^n$$

Flow around a mere pipe

$$Gr = \frac{D_o{}^3 . \rho_f{}^2 . g . \beta . \Delta T_o}{\mu_f{}^2}$$

$$T_f = \frac{T_w + T_\infty}{2} = \frac{355.4 + 294.3}{2} = 324.85\ K$$

D_o=0.0254 m

g=9.81 m/s^2

β=1/T=1/(324.85 K)=3.07x10^{-3}

$\Delta T_o = T_w - T_\infty$=355.4-294.3=61.1 K

The properties of air at $T_f = 324.85\ K$ are read from Table 5

ρ_f= 1.088 kg/m^3, C_{pf}=1007 J/(kg.°C), μ_f=1.96x10^{-5} kg/(m.s), k_f=0.028 W/(m.°C), Pr_f=0.702

Horizontal case

$$Gr = \frac{D_o{}^3 . \rho_f{}^2 . g . \beta . \Delta T_o}{\mu_f{}^2}$$

$$Gr = \frac{(0.0254)^3 . (1.088)^2 . (9.81) . (3.07x10^{-3}) . x61.1}{(1.96x10^{-5})^2} = 92917.04$$

$$(Gr.\Pr) = 92917.04x0.702 = 65227.7$$

$\log(Gr.\Pr) = 4.81$>4 Flow around a mere horizontal pipe or

From Table 15 for horizontal cylinder 10^4<Gr.Pr= 65227.7<10^9 b=0.53 n=0.25

$$Nu = 0.53(Gr.\Pr)_f{}^{0.25}$$

$$\frac{hD_o}{k} = \frac{hx0.0254}{0.028} = 0.53(Gr.\Pr)_f{}^{0.25} = 0.53(65227.7)^{0.25}$$

h=9.33 W/(m^{2o}C)

Vertical case

$$Gr = \frac{(1)^3 . (1.088)^2 . (9.81) . (3.07x10^{-3}) . x61.1}{(1.96x10^{-5})^2} = 5.67x10^9$$

$$(Gr.\Pr) = 5.67x10^9 x0.702 = 3.98x10^9$$

From Table 15 for vertical cylinder 10^9<Gr.Pr= 3.98x10^9<10^{12} b=0.13 n=0.33

$$Nu = 0.13(Gr.\Pr)_f{}^{0.33}$$

$$\frac{hL}{k} = \frac{hx1}{0.028} = 0.13(Gr.\Pr)_f{}^{0.33} = 0.13(3.98x10^9)^{0.33}$$

h=5.35 W/(m^{2o}C)

$$\frac{q_{horizontal}}{q_{vertical}} = \frac{h_{horizontal}}{h_{vertical}} . \frac{\pi D_o L}{\pi D_o L} \frac{(T_w - T_\infty)}{(T_w - T_\infty)} = \frac{9.33}{5.35} = 1.74$$