CHAPTER 5 CONVECTION AND INFILTRATION IN ROOMS AND CAVITIES

5.1 Natural Convection in Wall Cavities and Windows

Cavities (air spaces) exist in walls, windows, etc. The unit cavity conductance is given for different surface emissivities in several design handbooks (ASHRAE 1989). This conductance is the sum of the radiative and convective heat transfer coefficients. Here, we consider primarily the convective coefficient. Combined radiation and convection are considered in **Section 6.3**.

There are a number of relationships for heat transfer by convection across a rectangular cavity. These are usually correlations of experimental data in terms of three dimensionless parameters: the Nusselt number, Nu, the Rayleigh number, Ra, and the Prandtl number, Pr.

$$Nu = h \cdot \frac{L}{k} \qquad Ra = \frac{g \cdot \beta \cdot \Delta T \cdot L^3}{\nu \cdot \alpha}$$

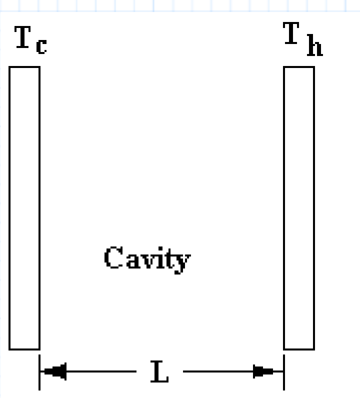
$$Pr = \frac{\nu}{\alpha} = \frac{kinematic\_viscosity}{thermal\_diffusivity}$$

L = width of cavity

$\beta = \frac{1}{T}$ expansion coefficient for air (approximated as ideal gas) at temperature T, K

For parallel plates, the Nusselt number is the ratio of a pure conduction resistance to a convection resistance (Nu=(L/k)/(1/h)). A Nusselt number of unity represents pure conduction across the air gap.

The convective heat transfer coefficient (hc) for vertical cavities is conveniently determined as follows (see El Sherbiny et al 1982):



Temperatures:

$Th := 15\ \Delta°C$ hot surface

$Tc := 0\ \Delta°C$ cold surface

$i := 3, 4 .. 20$

$L_i := i \cdot mm$

$p := 1$ pressure (atmospheres)

$$Tm := \frac{Th + Tc}{2} + 273\ \Delta°C \qquad a := \frac{100\ \Delta°C}{Tm}$$

$$k_{air} := \frac{0.002528 \cdot Tm^{1.5}}{Tm + 200 \cdot \Delta°C} \cdot \frac{W}{m \cdot \Delta°C^{\frac{1}{2}}}$$ thermal conductivity of air

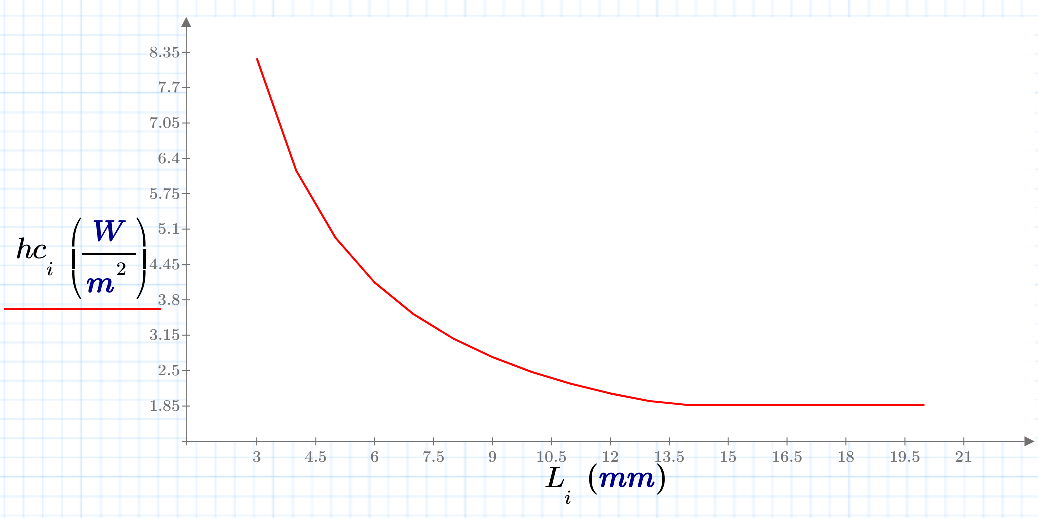
$$Ra_i := 2.737 \cdot (1 + 2 \cdot a)^2 \cdot a^4 \cdot (Th - Tc) \cdot \left(\frac{L_i}{mm}\right)^3 \cdot p^2$$ Rayleigh number

$$Nu1_i := 0.0605 \cdot \left(Ra_i\right)^{\frac{1}{3}} \cdot \frac{1}{\Delta°C^{\frac{1}{3}}}$$ Nusselt number

$$Nu2_i := \left(1 + \frac{0.104 \cdot \left(Ra_i\right)^{0.293} \cdot \frac{1}{\Delta°C^{\frac{46}{157}}}}{\left(1 + \left(\frac{6310 \cdot \Delta°C}{Ra_i}\right)^{1.36}\right)^3}\right)^{\frac{1}{3}}$$

$$hc_i := \frac{k_{air}}{L_i} \cdot \mathrm{if}\left(Nu1_i > Nu2_i, Nu1_i, Nu2_i\right)$$

Note that the convective heat transfer coefficient hc reaches its minimum value for a cavity width equal to 13 mm.



$$hc_{13} = 1.939\ \frac{W}{m^2}$$

$$q_c := hc_{13} \cdot (Th - Tc) = 29.091\ \frac{W \cdot \Delta°C}{m^2}$$ corresponding heat flux

References

ASHRAE. 1989. *ASHRAE Handbook of Fundamentals*. Atlanta, GA.

El-Sherbiny, et al. 1982. *ASME Journal of Heat Transfer,*Vol. 104, pp. 96-102.