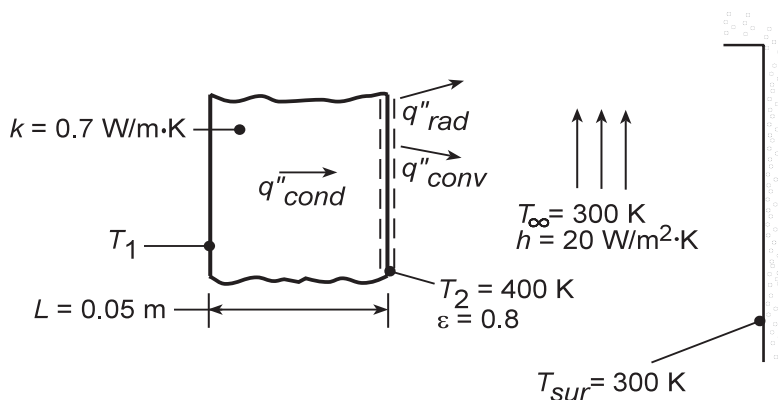


PROBLEM 1.76

KNOWN: Thickness and thermal conductivity, k , of an oven wall. Temperature and emissivity, ϵ , of front surface. Temperature and convection coefficient, h , of air. Temperature of large surroundings.

FIND: (a) Temperature of back surface, (b) Effect of variations in k , h and ϵ .

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state, (2) One-dimensional conduction, (3) Radiation exchange with large surroundings.

ANALYSIS: (a) Applying an energy balance, Eq. 1.13 to the front surface and substituting the appropriate rate equations, Eqs. 1.2, 1.3a and 1.7, find

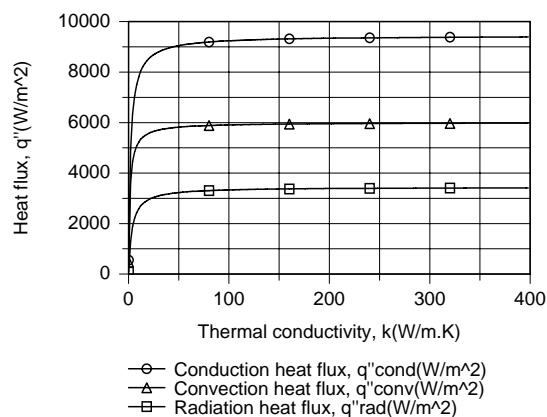
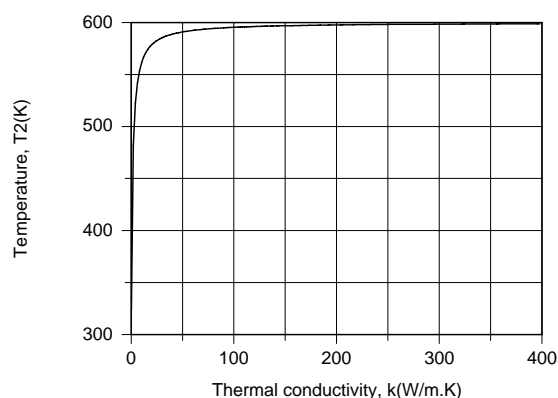
$$k \frac{T_1 - T_2}{L} = h(T_2 - T_\infty) + \epsilon \sigma (T_2^4 - T_{sur}^4).$$

Substituting numerical values, find

$$T_1 - T_2 = \frac{0.05 \text{ m}}{0.7 \text{ W/m} \cdot \text{K}} \left[20 \frac{\text{W}}{\text{m}^2 \cdot \text{K}} 100 \text{ K} + 0.8 \times 5.67 \times 10^{-8} \frac{\text{W}}{\text{m}^2 \cdot \text{K}^4} \left[(400 \text{ K})^4 - (300 \text{ K})^4 \right] \right] = 200 \text{ K}.$$

Since $T_2 = 400 \text{ K}$, it follows that $T_1 = 600 \text{ K}$.

(b) Parametric effects may be evaluated by using the IHT *First Law Model* for a *Nonisothermal Plane Wall*. Changes in k strongly influence conditions for $k < 20 \text{ W/m} \cdot \text{K}$, but have a negligible effect for larger values, as T_2 approaches T_1 and the heat fluxes approach the corresponding limiting values

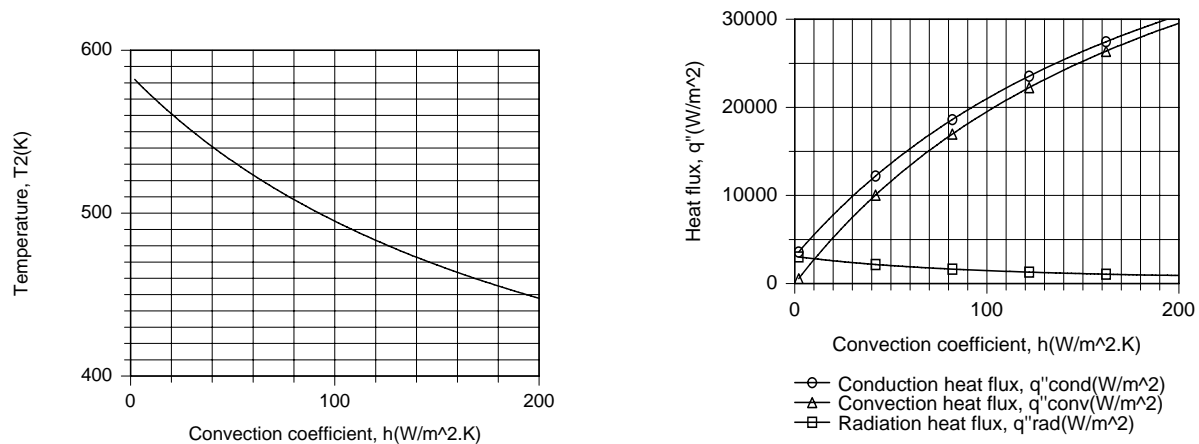


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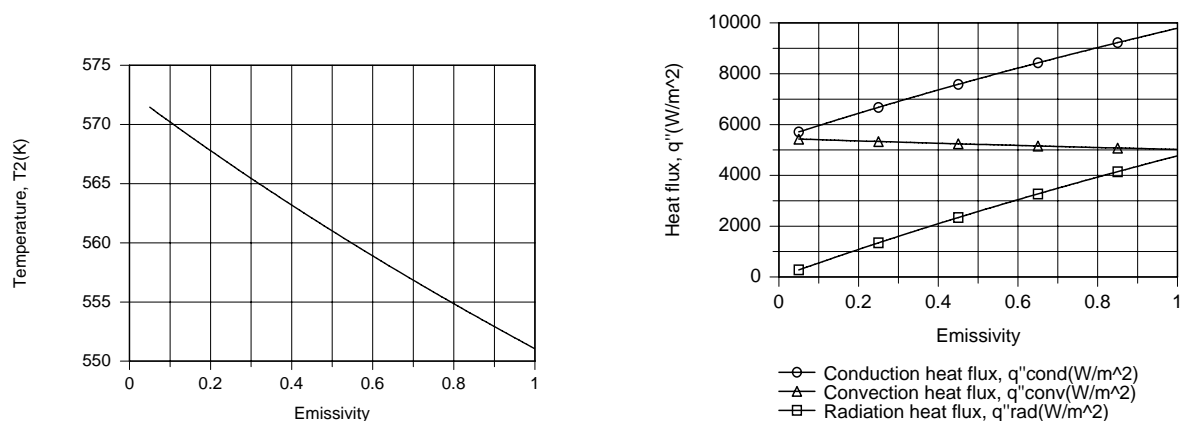
PROBLEM 1.76 (Cont.)

The implication is that, for $k > 20 \text{ W/m}\cdot\text{K}$, heat transfer by conduction in the wall is extremely efficient relative to heat transfer by convection and radiation, which become the *limiting* heat transfer processes. Larger fluxes could be obtained by increasing ε and h and/or by decreasing T_∞ and T_{sur} .

With increasing h , the front surface is cooled more effectively (T_2 decreases), and although q''_{rad} decreases, the reduction is exceeded by the increase in q''_{conv} . With a reduction in T_2 and fixed values of k and L , q''_{cond} must also increase.



The surface temperature also decreases with increasing ε , and the increase in q''_{rad} exceeds the reduction in q''_{conv} , allowing q''_{cond} to increase with ε .



COMMENTS: Conservation of energy, of course, dictates that irrespective of the prescribed conditions, $q''_{\text{cond}} = q''_{\text{conv}} + q''_{\text{rad}}$.