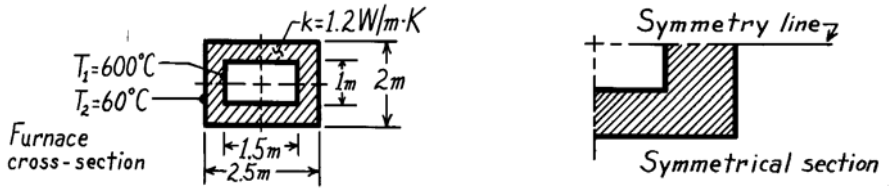
PROBLEM 4S.1

KNOWN: Long furnace of refractory brick with prescribed surface temperatures and material thermal conductivity.

FIND: Shape factor and heat transfer rate per unit length using the flux plot method

SCHEMATIC:

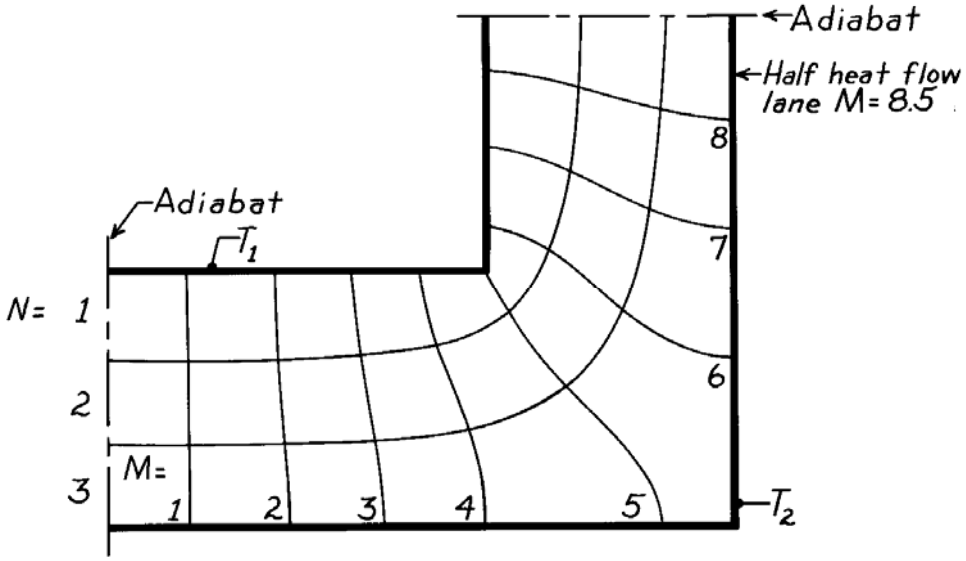


ASSUMPTIONS: (1) Furnace length normal to page, ℓ, >> cross-sectional dimensions, (2) Two-dimensional, steady-state conduction, (3) Constant properties.

ANALYSIS: Considering the cross-section, the cross-hatched area represents a symmetrical element. Hence, the heat rate for the entire furnace per unit length is

$$q' = \frac{q}{\ell} = 4\frac{S}{\ell}k\left(T_1 - T_2\right) \tag{1}$$

where S is the shape factor for the symmetrical section. Selecting three temperature increments (N = 3), construct the flux plot shown below.



From Equation 4S.7, $S = \dfrac{M\ell}{N}$ or $\dfrac{S}{\ell} = \dfrac{M}{N} = \dfrac{8.5}{3} = 2.83$ <

and from Equation (1), $q' = 4 \times 2.83 \times 1.2 \dfrac{W}{m \cdot K}\left(600 - 60\right)^{\circ} C = 7.34$ kW/m. <

COMMENTS: The shape factor can also be estimated from the relations of Table 4.1. The symmetrical section consists of two plane walls (horizontal and vertical) with an adjoining edge. Using the appropriate relations, the numerical values are, in the same order,

$$S = \frac{0.75m}{0.5m}\ell + 0.54\ell + \frac{0.5m}{0.5m}\ell = 3.04\ell$$

Note that this result compares favorably with the flux plot result of 2.83ℓ.