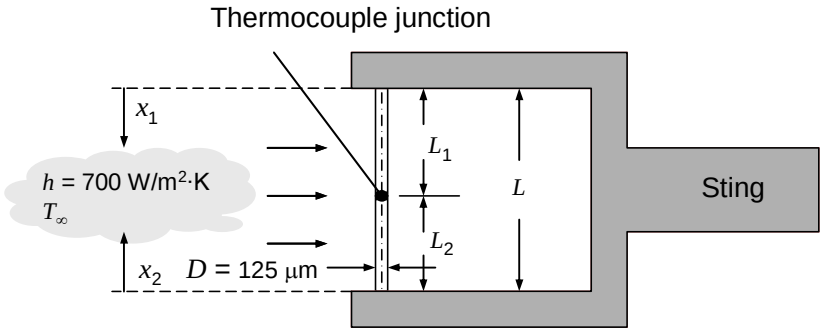
PROBLEM 3.114

KNOWN: Wire diameters associated with a thermocouple junction, value of the convection heat transfer coefficient.

FIND: Minimum wire lengths necessary to ensure the junction temperature is at the gas temperature.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state, one-dimensional conditions, (2) Negligible radiation heat transfer, (3) Constant properties, (4) Infinitely long fin behavior.

PROPERTIES: *Table A-1*, Copper ($\bar{T}$ = 300 K): k = 401 W/m·K; Constantan ($\bar{T}$ = 300 K): k = 23 W/m·K; *Given*, Chromel: k = 19 W/m·K; Alumel: k = 29 W/m·K.

ANALYSIS: To ensure the junction temperature is at the gas temperature (that is, the junction temperature is not influenced by the sting temperature) we require the two wires to behave as infinitely long fins. From Example 3.9, Comment 1, the requirement is,

$$L_1 \geq 4.6\left(\frac{k_1 A_c}{hP}\right)^{1/2}; L_2 \geq 4.6\left(\frac{k_2 A_c}{hP}\right)^{1/2}$$

where $L = L_1 + L_2$. With $A_c = \pi D^2/4 = \pi \times (125 \times 10^{-6}\text{m})^2/4 = 12.27 \times 10^{-9}\text{m}^2$ and $P = \pi D = \pi \times 125 \times 10^{-6}$ m $= 393 \times 10^{-6}$ m, we may calculate the following values of L_1, L_2, and L.

Material	L_1 (mm)	L_2 (mm)		
(1) Copper	19.5	-		
(2) Constantan	-	4.70		
$L = L_1 + L_2$			24.2 mm	<
(1) Chromel	4.24	-		
(2) Alumel	-	5.23		
$L = L_1 + L_2$			9.47 mm	<

COMMENTS: Use of the chromel-alumel thermocouple junction leads to a substantial reduction in the size of the measurement device, while simultaneously minimizing measurement error associated with conduction along the wires to or from the sting.