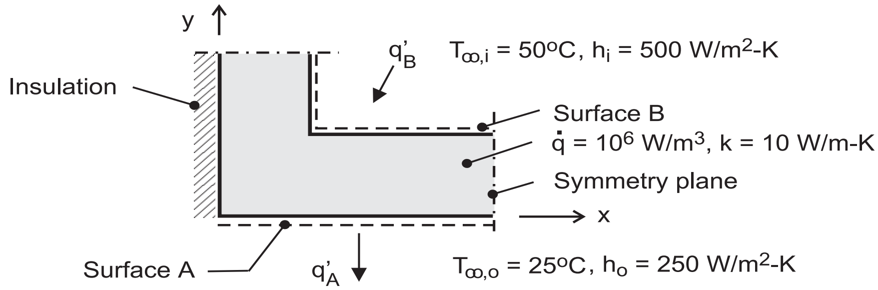
PROBLEM 4.90

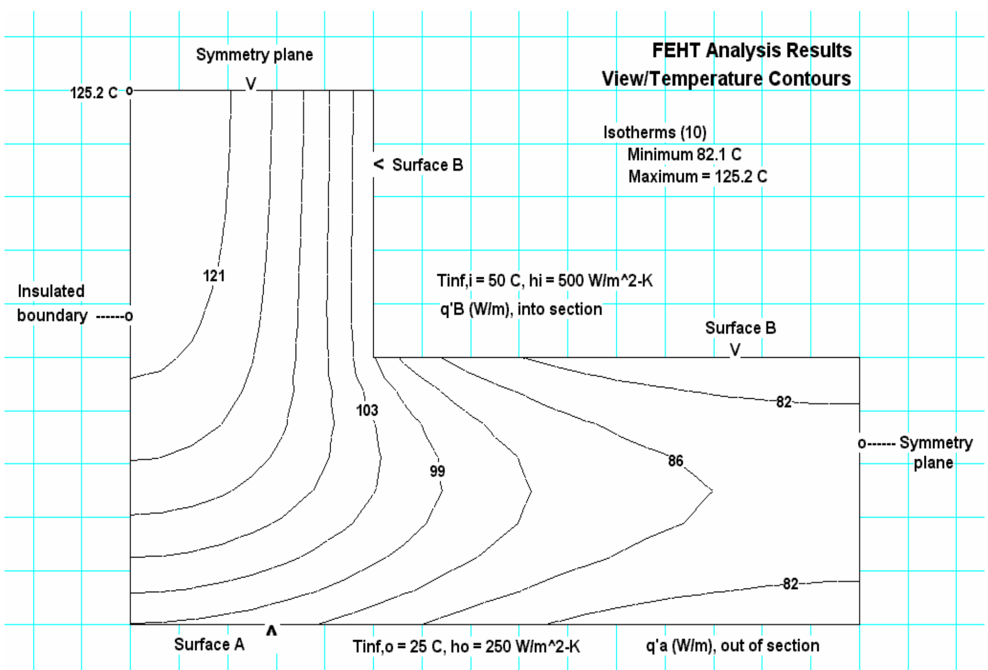
KNOWN: Symmetrical section of a flow channel with prescribed values of $\dot{q}$ and k, as well as the surface convection conditions. See Problem 4.57.

.
FIND: Using the finite-element method of FEHT, (a) Determine the temperature distribution and plot the isotherms; identify the coolest and hottest regions, and the region with steepest gradients; describe the heat flow field, (b) Calculate the heat rate per unit length (W/m) from the outer surface A to the adjacent fluid, (c) Calculate the heat rate per unit length (W/m) to surface B from the inner fluid, and (d) Verify that the results are consistent with an overall energy balance on the section.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state, two-dimensional conduction, (2) Constant properties.
ANALYSIS: (a) The symmetrical section shown in the schematic is drawn in FEHT with the specified boundary conditions, material property and generation. The *View | Temperature Contours* command is used to represent ten isotherms (isopotentials) that have minimum and maximum values of 82.1°C and 125.2°C.



The hottest region of the section is the upper vertical leg (left-hand corner). The coolest region is in the lower horizontal leg at the far right-hand boundary. The maximum and minimum section temperatures (125°C and 77°C), respectively, are higher than either adjoining fluid. Remembering that heat flow lines are normal to the isotherms, heat flows from the hottest corner directly to the inner fluid and downward into the lower leg and then flows out surface A and the lower portion of surface B.

Continued …

PROBLEM 4.90 (Cont.)

(b, c) Using the *View* | *Heat Flows* command considering the boundaries for surfaces A and B, the heat rates are:

$$q'_S = 1135\ \mathrm{W/m} \qquad\qquad q'_B = -1365\ \mathrm{W/m}. \qquad <$$

From an energy balance on the section, we note that the results are consistent since conservation of energy is satisfied.

$$\dot{E}'_{in} - \dot{E}'_{out} + \dot{E}_g = 0$$

$$-q'_A + q'_B + \dot{q}\forall' = 0$$

$$-1135\ \mathrm{W/m} + (-1365\ \mathrm{W/m}) + 2500\ \mathrm{W/m} = 0 \qquad <$$

where $\dot{q}\forall = 1\times10^6\ \mathrm{W/m^3} \times [25\times50 + 25\times50]\times10^{-6}\mathrm{m^2} = 2500\ \mathrm{W/m}.$

COMMENTS: (1) For background on setting up this problem in FEHT, see the tutorial example of the User's Manual. While the boundary conditions are different, and the internal generation term is to be included, the procedure for performing the analysis is the same.

(2) The heat flow distribution can be visualized using the *View* | *Temperature Gradients* command. The direction and magnitude of the heat flow is represented by the directions and lengths of arrows. Compare the heat flow distribution to the isotherms shown above.