10-65E The thermal resistance of an epoxy glass laminate across its thickness is to be reduced by planting cylindrical copper fillings throughout. The thermal resistance of the epoxy board for heat conduction across its thickness as a result of this modification is to be determined.

Assumptions **1** Steady operating conditions exist. **2** Heat transfer through the plate is one-dimensional. **3** Thermal conductivities are constant.

Properties The thermal conductivities are given to be k = 0.10 Btu/h·ft·°F for epoxy glass laminate and k = 223 Btu/h·ft·°F for copper fillings.

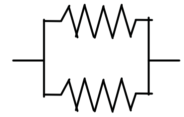
Analysis The thermal resistances of copper fillings and the epoxy board are in parallel. The number of copper fillings in the board and the area they comprise are

$$A_{total} = (6/12\text{ ft})(8/12\text{ ft}) = 0.333\text{ ft}^2$$

$$n_{copper} = \frac{0.33\text{ ft}^2}{(0.06/12\text{ ft})(0.06/12\text{ ft})} = 13{,}333\text{ (number of copper fillings)}$$

$$A_{copper} = n\frac{\pi D^2}{4} = 13{,}333\frac{\pi(0.02/12\text{ ft})^2}{4} = 0.0291\text{ ft}^2$$

$$A_{epoxy} = A_{total} - A_{copper} = 0.3333 - 0.0291 = 0.3042\text{ ft}^2$$



The thermal resistances are evaluated to be

$$R_{copper} = \frac{L}{kA} = \frac{0.05/12\text{ ft}}{(223\text{ Btu/h}\cdot\text{ft}\cdot{}^\circ\text{F})(0.0291\text{ ft}^2)} = 0.00064\text{ h}\cdot{}^\circ\text{F/Btu}$$

$$R_{epoxy} = \frac{L}{kA} = \frac{0.05/12\text{ ft}}{(0.10\text{ Btu/h}\cdot\text{ft}\cdot{}^\circ\text{F})(0.3042\text{ ft}^2)} = 0.137\text{ h}\cdot{}^\circ\text{F/Btu}$$

Then the thermal resistance of the entire epoxy board becomes

$$\frac{1}{R_{board}} = \frac{1}{R_{copper}} + \frac{1}{R_{epoxy}} = \frac{1}{0.00064} + \frac{1}{0.137} \longrightarrow R_{board} = \mathbf{0.00064\text{ h}\cdot{}^\circ\text{F/Btu}}$$

Heat Conduction in Cylinders and Spheres

10-66C When the diameter of cylinder is very small compared to its length, it can be treated as an infinitely long cylinder. Cylindrical rods can also be treated as being infinitely long when dealing with heat transfer at locations far from the top or bottom surfaces. However, it is not proper to use this model when finding temperatures near the bottom and the top of the cylinder.

10-67C Heat transfer in this short cylinder is one-dimensional since there will be no heat transfer in the axial and tangential directions.

10-68C No. In steady-operation the temperature of a solid cylinder or sphere does not change in radial direction (unless there is heat generation).