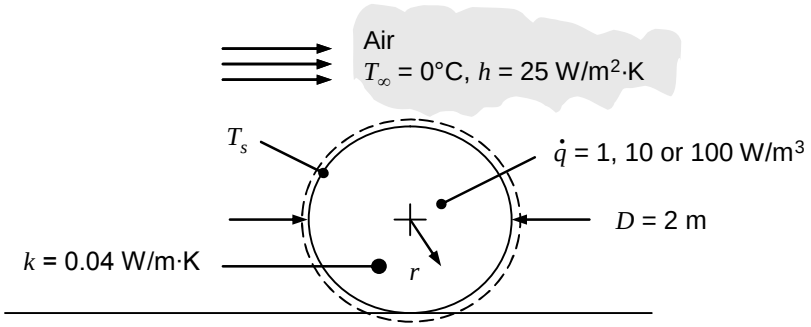
PROBLEM 3.82

KNOWN: Diameter, thermal conductivity and microbial energy generation rate in cylindrical hay bales. Ambient conditions.

FIND: The maximum hay temperature for $\dot{q}$ = 1, 10, and 100 W/m^3.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) Constant properties, (3) One-dimensional heat transfer (4) Uniform volumetric generation, (5) Negligible radiation, (6) Negligible conduction to or from the ground.

PROPERTIES: k = 0.04 W/m·K (given).

ANALYSIS: The surface temperature of the dry hay is (Eq. 3.60)

$$T_s = T_\infty + \frac{\dot{q} r_o}{2h} = 0°\text{C} + \frac{1\text{W/m}^3 \times 1\text{m}}{2 \times 25\text{W/m}^2 \cdot \text{K}} = 0.02°\text{C} \quad <$$

whereas T_s = 0.2°C and 2.0°C for the moist and wet hay, respectively. <

The maximum hay temperature occurs at the centerline, r = 0. From Eq. 3.58, for the dry hay,

$$T_{\max} = \frac{\dot{q} r_o^2}{4k} + T_s = \frac{1\text{W/m}^3 \times (1\text{m})^2}{4 \times 0.04\ \text{W/m} \cdot \text{K}} + 0.02°\text{C} = 6.27°\text{C} \quad <$$

whereas $T_{\max}$ = 62.7°C and 627°C for the moist and wet hay, respectively. <

COMMENTS: (1) The hay begins to lose its nutritional value at temperatures exceeding 50°C. Therefore the center of the moist hay bale will lose some of its nutritional value. (2) The center of the wet hay bale can experience very high temperatures without combusting due to lack of oxygen internal to the hay bale. However, when the farmer breaks the bale apart for feeding, oxygen is suddenly supplied to the hot hay and combustion may occur. (3) The outer surface of the hay bale differs by only 2°C from the dry to the wet condition, while the centerline temperature differs by over 600 degrees. The farmer cannot anticipate the potential for starting a fire by touching the outer surface of the hay bale. (4) See Opuku, Tabil, Crerar and Shaw, "Thermal Conductivity and Thermal Diffusivity of Timothy Hay," *Canadian Biosystems Engineering*, Vol. 48, pp. 3.1 - 3.6, 2006 for hay property information.