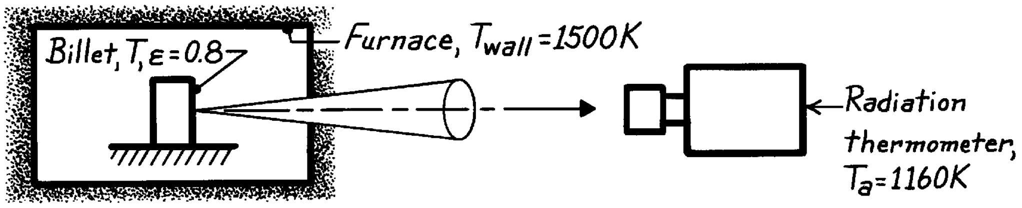
PROBLEM 12.79

KNOWN: Radiation thermometer (RT) viewing a steel billet being heated in a furnace.

FIND: Temperature of the billet when the RT indicates 1160K.

SCHEMATIC:



ASSUMPTIONS: (1) Billet is diffuse-gray, (2) Billet is small object in large enclosure, (3) Furnace behaves as isothermal, large enclosure, (4) RT is a radiometer sensitive to total (rather than a prescribed spectral band) radiation and is calibrated to correctly indicate the temperature of a black body, (5) RT receives radiant power originating from the target area on the billet.

ANALYSIS: The radiant power reaching the radiation thermometer (RT) is proportional to the radiosity of the billet. For the diffuse-gray billet within the large enclosure (furnace), the radiosity is

$$J = \varepsilon E_b(T) + \rho G = \varepsilon E_b(T) + (1-\varepsilon)E_b(T_w)$$

$$J = \varepsilon\sigma T^4 + (1-\varepsilon)\sigma T_w^4 \qquad (1)$$

where $\alpha = \varepsilon$, $G = E_b(T_w)$ and $E_b = \sigma T^4$. When viewing the billet, the RT indicates $T_a = 1100K$, referred to as the apparent temperature of the billet. That is, the RT *indicates* the billet is a blackbody at T_a for which the radiosity will be

$$E_b(T_a) = J_a = \sigma T_a^4. \qquad (2)$$

Recognizing that $J_a = J$, set Eqs. (1) and (2) equal to one another and solve for T, the billet true temperature.

$$T = \left[\frac{1}{\varepsilon}T_a^4 - \frac{1-\varepsilon}{\varepsilon}T_w^4\right]^{1/4}.$$

Substituting numerical values, find

$$T = \left[\frac{1}{0.8}(1160\text{K})^4 - \frac{1-0.8}{0.8}(1500\text{K})^4\right]^{1/4} = 999\text{K}. \qquad <$$

COMMENTS: (1) The effect of the reflected wall irradiation from the billet is to cause the RT to indicate a temperature higher than the true temperature.

(2) What temperature would the RT indicate when viewing the furnace wall assuming the wall emissivity were 0.85?

(3) What temperature would the RT indicate if the RT were sensitive to spectral radiation at 0.65 μm instead of total radiation? Hint: in Eqs. (1) and (2) replace the emissive power terms with spectral intensity. Answer: 1365K.