which, when substituted into the preceding equation leads to

$$\frac{\Delta d_2}{d_0} = -\frac{\nu E \alpha_l (T_0 - T_f)}{E} = -\nu \alpha_l (T_0 - T_f)$$

And, solving for Δd_2 from this expression

$$\Delta d_2 = -d_0 \nu \alpha_l (T_0 - T_f)$$

The total Δd is just $\Delta d = \Delta d_1 + \Delta d_2$, and

$$\Delta d = d_0 \alpha_l (T_f - T_0) + d_0 \nu \alpha_l (T_f - T_0) = d_0 \alpha_l (T_f - T_0)(1 + \nu)$$

The values of ν and α_l for nickel are 0.31 and 13.3 x 10^{-6} $(°C)^{-1}$, respectively (Tables 6.1 and 19.1). Incorporating, into the above equation, these values, as well as those for Δd, d_0, and T_0 cited in the problem statement gives

$$-(0.023 \text{ mm}) = (12.000 \text{ mm}) \left[13.3 \times 10^{-6} \, (°C)^{-1}\right] (T_f - 70°C)(1 + 0.31)$$

And, finally, solving the above expression for T_f yields $T_f = -40°C$.