

$$t_1 := \text{time}(0)$$

$$\mu\text{rad} \equiv 10^{-6} \cdot \text{rad}$$

$$\text{mrad} \equiv 10^{-3} \cdot \text{rad}$$

$$\mu\text{m} \equiv 10^{-6} \text{ m}$$

$$\text{nm} := 10^{-9} \text{ m}$$

$$\text{ms} \equiv 10^{-3} \cdot \text{s}$$

$$\mu\text{s} \equiv 10^{-6} \text{ s}$$

$$\text{ns} \equiv 10^{-9} \cdot \text{s}$$

$$\text{kt} \equiv 1852 \frac{\text{m}}{\text{hr}}$$

$$\text{nmi} := 1852 \cdot \text{m}$$

$$^{\circ}\text{C} \equiv \text{K}$$

$$c \equiv 2.99792458 \cdot 10^8 \frac{\text{m}}{\text{s}}$$

$$h \equiv 6.62606876 \cdot 10^{-34} \text{ J} \cdot \text{s}$$

$$r_e \equiv 6378140 \cdot \text{m}$$

$$\sigma \equiv 5.670400 \cdot 10^{-8} \cdot \frac{\text{watt}}{\text{m}^2 \cdot \text{K}^4}$$

$$\text{mJ} \equiv 10^{-3} \text{ J}$$

$$\text{MW} \equiv 10^6 \text{ W}$$

$$\text{nW} \equiv 10^{-9} \text{ W}$$

$$\mu\text{W} \equiv 10^{-6} \text{ W}$$

$$\text{mW} \equiv 10^{-3} \text{ W}$$

$$\text{time}(0) - t_1 = 0.0780$$

$$\text{flow} := 44000 \frac{\text{ft}^3}{\text{min}}$$

$$\text{thk} := \frac{3}{8} \text{ in}$$

$$\text{ID} := 20 \text{ in} - 2 \cdot \text{thk}$$

$$\text{area} := \left(\frac{\text{ID}}{2} \right)^2 \pi$$

$$\text{vel} := \frac{\text{flow}}{\text{area}}$$

$$\text{vel} = 110.5930 \frac{\text{m}}{\text{s}}$$

$$T_{\text{in}} := 210 \text{ R}$$

$$T_{\text{air}} := 70 \text{ R}$$

$$k := 40 \frac{\text{W}}{\text{m} \cdot \text{K}}$$

$$T_{\text{R}} := 459 \text{ R}$$

$$h := 5 \frac{\text{W}}{\text{m}^2 \cdot \text{K}}$$

$$\frac{k}{\text{thk}} = 4199.4751 \frac{\text{W}}{\text{m}^2 \cdot \text{K}}$$

$$T_{\text{tube}} := 190 \text{ R}$$

$$\varepsilon := 1$$

given

$$\frac{k}{\text{thk}} \cdot (T_{\text{in}} - T_{\text{tube}}) = h \cdot (T_{\text{tube}} - T_{\text{air}}) + \sigma \cdot \varepsilon \cdot \left[(T_{\text{tube}} + T_{\text{R}})^4 - (T_{\text{air}} + T_{\text{R}})^4 \right]$$

$$T_{\text{tube}} := \text{find}(T_{\text{tube}})$$

$$T_{\text{tube}} = 116.4181 \text{ K}$$

$$\sigma \cdot \varepsilon \cdot \left[(T_{\text{tube}} + T_{\text{R}})^4 - (T_{\text{air}} + T_{\text{R}})^4 \right] = 656.1050 \frac{\text{W}}{\text{m}^2}$$

$$h \cdot (T_{\text{tube}} - T_{\text{air}}) = 387.6462 \frac{\text{W}}{\text{m}^2}$$

$$\frac{k}{\text{thk}} \cdot (T_{\text{in}} - T_{\text{tube}}) = 1043.7512 \frac{\text{W}}{\text{m}^2}$$