31.5 A $1200 ft^3$ room is filled with atmospheric air at $95°F$. The room air is cooled to $70°F$ under constant pressure. How much work is done on the air in the room?

A. $2 Btu$

B. $150 Btu$

C. $520 Btu$

D. $1330 Btu$

For a Closed System with No Change in Kinetic or Potential Energy, work can be expressed for a constant pressure process as such:

$$w = P\Delta v = P(v_1 - v_2)$$

Assuming air behaves as an ideal gas, rearrange the ideal gas law and substitute for specific volume.

$$PV = mRT \rightarrow Pv = RT \rightarrow v = \frac{RT}{P}$$

$$w = P\left(\frac{RT_1}{P_1} - \frac{RT_2}{P_2}\right)$$

Since the process is constant pressure, $P_2 = P_1 = P$.

$$w = R(T_1 - T_2)$$

Substitute and solve.

$$w = \frac{\left(53.35 \frac{ft \cdot lb_f}{lb_m \cdot R}\right)(95°F - 70°F)\left(\frac{°R}{°F}\right)}{778 \frac{ft \cdot lb_f}{Btu}} = 1.71 \frac{Btu}{lb_m}$$

This is the work per unit mass. Since the answer choices are total work $[Btu]$, multiply by the total mass in the room. Use the ideal gas law and either state. State 1 is arbitrarily chosen here.

$$m = \frac{PV}{RT} = \frac{\left(14.7 \frac{lb_f}{in^2}\right)\left(\frac{144 in^2}{ft^2}\right)(1200 ft^3)}{\left(53.35 \frac{ft \cdot lb_f}{lb_f \cdot R}\right)\left[(95 + 460)° R\right]} = 85.8 lb_m$$

Calculate the work.

$$W = mw = (85.8 lb_m)\left(1.71 \frac{Btu}{lb_m}\right) = 146.7 Btu$$

Answer B