

44.6 A locker room has 12 showers supplied with hot water from a steam heat exchanger. The shower heads are rated for 5gpm each. Expected demand can be estimated as 25% of maximum. Cold water enters the heat exchanger at 55°F and leaves at 115°F. 500 $\frac{lb}{hr}$ of 5psig steam is supplied to the heat exchanger and leaves saturated. What is the efficiency of the heat exchanger?

- A. 90%
- B. 92%
- C. 94%
- D. 96%

The heat transferred to the water is less than the heat given up by the steam due to losses. The efficiency is determined by calculating both quantities.

For the water side of the heat exchanger, use the sensible heating rule of thumb for water to find the heat added. Before solving, apply the diversity in the flow rate demand. It is not necessary to size the heat exchanger for all 12 shower heads to supply the full 5gpm simultaneously.

$$Demand = (12 \text{ showers}) \left(5 \frac{gpm}{\text{shower}} \right) (.25) = 15gpm$$

$$\dot{Q}_w = 500gpm\Delta T$$

$$\dot{Q}_{water} = 500(15)(115 - 55) = 450,000 \frac{Btu}{hr}$$

For the steam side of the heat exchanger, look up the heat of vaporization for 20psia steam in the steam table, [Properties of Saturated Water](#) (by Pressure). Make sure to convert psig to psia before obtaining values. Calculate the energy given up by the steam using $Q = m\Delta h$:

$$\dot{Q}_{steam} = \dot{m}\Delta h = \dot{m}h_{fg}$$

$$\dot{Q}_{steam} = \left(500 \frac{lb}{hr} \right) \left(960 \frac{Btu}{lb} \right) = 480,000 \frac{Btu}{hr}$$

Calculate the efficiency of the heat exchanger:

$$\eta = \frac{\dot{Q}_{water}}{\dot{Q}_{steam}} = \frac{450,000 \frac{Btu}{hr}}{480,000 \frac{Btu}{hr}} = 93.75\%$$

Answer C

44.7 Due to acoustical considerations, the compressor and condenser for a 2ton refrigerator with a COP of 5 are located remotely in a nearby storage closet. Neglecting lights and other ancillary heat sources, what is the required cooling capacity for the storage closet?

- A. $24,000 \frac{Btu}{hr}$
- B. $25,000 \frac{Btu}{hr}$
- C. $29,000 \frac{Btu}{hr}$
- D. $33,000 \frac{Btu}{hr}$

The cooling system for the closet needs to be able to support the full heat rejection from the system, which includes the compressor and the condenser. As with all refrigeration cycles, the compressor energy is added to the refrigerant, therefore the heat rejection at the condenser is already exhaustive, with the possible minor exception of local heat loss from the compressor due to any inefficiency. However, even in that case, any local heat generation is being added to the room directly rather than the refrigerant loop, and will no longer need to be rejected from the condenser. Ultimately, the sum of the heat generated, and thus the cooling required for the room, is nothing more or less than Q_{out} for the cycle.

Apply the **Coefficient of Performance** (COP) for a refrigerator to calculate the compressor power:

$$COP_R = \frac{\dot{Q}_{in}}{\dot{W}_{in}} \rightarrow \dot{W}_{in} = \frac{\dot{Q}_{in}}{COP_R} = \frac{2tons}{5} = .4tons$$

Calculate the heat rejection from the condenser, and convert to $\frac{Btu}{hr}$:

$$\dot{Q}_{out} = \dot{Q}_{in} + \dot{W}_{in} = 2tons + .4tons = 2.4tons$$

$$\dot{Q}_{out} = 2.4tons \left(\frac{12,000 \frac{Btu}{hr}}{ton} \right) = 28,800 \frac{Btu}{hr}$$

Answer C