46.79 **$25gpm$ of water at $300psia$ and $250°F$ goes through a boiler where it is converted to $500psia$ steam at $1000°F$. What is the heat load being delivered by the boiler?**

A. $360 boiler\ hp$

B. $420 boiler\ hp$

C. $460 boiler\ hp$

D. $490 boiler\ hp$

Consider the water entering the boiler as a State 1 and the superheated steam exiting the boiler as State 2. Determine the enthalpy at State 1. Use the properties of Saturated Water and Steam table by pressure and obtain h_f at $P_1 = 300psia$. Since $T_1 < T_{sat}$, the water is subcooled. Solve for the enthalpy at T_1.

$$T_{sat@300psia} = 417.33°F$$

$$h_{sat} = h_{f@300psia} = 393.93\frac{Btu}{lb}$$

$$h_{sat} - h_1 = c_p\left(T_{sat} - T_1\right)$$

$$h_1 = h_{sat} - c_p\left(T_{sat} - T_1\right) = 393.93\frac{Btu}{lb} - \left(1\frac{Btu}{lb°F}\right)(417.33°F - 250°F) = 226.6\frac{Btu}{lb}$$

Approximate the density at State 1 using the Properties of Water table and extrapolating to $250°F$. The pressure is much higher than atmospheric pressure, but this approach yields a fairly accurate result since water incompressible.

$T\,[°F]$	$\rho\left[\frac{lb}{ft^3}\right]$
200	60.1
212	59.83
250	ρ

$$\frac{212°F - 200°F}{250°F - 200°F} = \frac{59.83\frac{lb}{ft^3} - 60.1\frac{lb}{ft^3}}{\rho - 60.1\frac{lb}{ft^3}}$$

$$0.24 = \frac{-0.27\frac{lb}{ft^3}}{\rho - 60.1\frac{lb}{ft^3}}$$

$$\rho - 60.1\frac{lb}{ft^3} = -1.125\frac{lb}{ft^3}$$

$$\rho = 58.98\frac{lb}{ft^3}$$

The density value obtained from compressed water tables not available in the Reference Handbook is $58.8\frac{lb}{ft^3}$ for a deviation of only 0.3%.

Find the heat load for the boiler. Replace mass flow rate with the product of density and volume flow rate. Convert units to $\frac{Btu}{hr}$, then finally to *boiler hp*.

$$\dot{Q} = \dot{m}\Delta h = \rho Q \Delta h$$

$$\dot{Q} = \left(58.98\frac{lb}{ft^3}\right)\left(25\frac{gal}{min}\right)\left(\frac{1ft^3}{7.48gal}\right)\left(\frac{60min}{1hr}\right)\left(1521\frac{Btu}{lb} - 226.6\frac{Btu}{lb}\right) = 1.53 \times 10^7\frac{Btu}{hr}$$

$$\dot{Q} = \frac{1.53 \times 10^7\frac{Btu}{hr}}{33,470\frac{Btu}{hr \cdot boiler\,hp}} = 457 boiler\,hp$$

Answer C

46.80 $1\frac{lb_m}{s}$ **of saturated liquid water at** $50psia$ **enters a mixing chamber along with** $1\frac{lb_m}{s}$ **of superheated steam at** $50psia$ **and** $500°F$**.** $2\frac{lb_m}{s}$ **of the resulting mixture is discharged after thorough mixing. What is the quality of the mixture?**

A. 0.44

B. 0.50

C. 0.56

D. 0.62

Sketch the mixing chamber. Let State 1 represent the entering saturated liquid, State 2 represent the entering saturated steam, and State 3 represent the exiting mixture. Write the energy balance for the mixing process.

$$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3$$

All mass flow rates are known. Use the Properties of Saturated Water and Steam (Pressure) table to obtain the enthalpy at State 1, h_1.

$$P_1 = 50psia$$

$$h_1 = h_f = 250.2\frac{Btu}{lb}$$

Use the Properties of Superheated Steam table to obtain the enthalpy at State 2.

$$P_2 = 50psia$$

$$T_2 = 500°F$$