$$h_2 = h_f + \chi_2 h_{fg} = 180.18\frac{Btu}{lb} + (0.856)\left(970.07\frac{Btu}{lb}\right) = 1010.2\frac{Btu}{lb}$$

Determine the *actual* change in enthalpy by applying the efficiency. This is the specific work produced by the turbine.

$$\eta = \frac{h_1 - h_2^{'}}{h_1 - h_2}$$

$$w = h_1 - h_2^{'} = \eta\left(h_1 - h_2\right) = 0.75\left(1338.4\frac{Btu}{lb} - 1010.2\frac{Btu}{lb}\right) = 246.2\frac{Btu}{lb}$$

Answer A

46.71 The overall efficiency of a gas turbine combined cycle is 55%. The gas turbine cycle standing alone has an efficiency of 40%. What is the efficiency of the Rankine cycle?

A. 9%

B. 25%

C. 75%

D. 91%

Refer to the Brayton Cycle for the gas turbine standing alone. Refer to the Combined Cycle when waste heat recovery is included. The heat recovery section can be modeled as a Rankine Cycle. The product of the *losses* from the Brayton Cycle and the *losses* from the Rankine Cycle equals the *losses* from the Combined Cycle. Solve for the efficiency of the Rankine Cycle.

$$\left(1 - \eta_{Brayton}\right)\left(1 - \eta_{Rankine}\right) = \left(1 - \eta_{Combined}\right)$$

$$\left(1 - 0.4\right)\left(1 - \eta_{Rankine}\right) = \left(1 - 0.55\right)$$

$$1 - \eta_{Rankine} = \left(\frac{0.45}{0.6}\right) = 0.75$$

$$\eta_{Rankine} = 0.25$$

Another way to conceptualize this scenario is to notice that since the standalone Brayton Cycle has 40% efficiency, that implies 60% losses. Reason that to increase the overall efficiency of the combined cycle to from 40% to 55%, 15% of the wasted 60% must be converted into useful work, which is one fourth or 25% of the waste energy from the Brayton Cycle which is heat input to the Rankine Cycle.

Answer B

46.72 Water is pumped from an open tank by a pump located $15ft$ below the top of the tank's waterline. The pump adds $50ft$ of total head. The discharge pressure is $28psig$. Neglecting losses on the suction side of the pump, what is the velocity of the flowing water?

A. $5\frac{ft}{s}$

B. $11\frac{ft}{s}$

C. $18\frac{ft}{s}$

D. $47\frac{ft}{s}$

Sketch the reservoir and pump. Consider the reservoir as State 1 and the pump discharge as State 2. Write the modified Bernoulli equation for the total head added by a pump. A useful version may be obtained by starting with the Mechanical Energy Equation in section 9.6.4 of the Reference Handbook.

$$h_A = \frac{P_2 - P_1}{\gamma} + \frac{v_2^2 - v_1^2}{2g} + (z_2 - z_1)$$

The head added by the pump is given as $h_A = 50ft$. The static pressure at the source, State 1, is atmospheric pressure and the static pressure at the pump discharge, State 2, is measured by a gauge as $28psig$. Since the difference in pressure is needed, it is not necessary to convert to absolute pressure terms. Simply subtract and use the conversion factor rule of thumb, $2.31\frac{ft}{psi}$ to convert the units of the static pressure term from psi to ft.

$$\frac{P_2 - P_1}{\gamma} = (28psig - 0psig)\left(2.31\frac{ft}{psi}\right)$$

For the velocity term, the velocity of the water in the reservoir is zero. The velocity at the pump discharge, State 2, is the unknown being sought in this problem.

$$\frac{v_2^2 - v_1^2}{2g} = \frac{v_2^2}{2g}$$

For the elevation term, the pump is $15ft$ below the top of the reservoir, therefore the Δz term will be negative, which aligns with the expectation that *less* work will need to be done by the pump since the source water on the suction side is at a relatively higher elevation.

$$z_2 - z_1 = 0ft - 15ft = -15ft$$

Substitute and solve for the velocity term, then solve for the discharge velocity, v_2.

$$50ft = (28psig - 0psig)\left(2.31\frac{ft}{psi}\right) + \frac{v_2^2}{2g} - 15ft$$

$$\frac{v_2^2}{2g} = 0.32ft$$