34.1 **$500\frac{lb}{hr}$ of superheated steam at $900°F$ and $500psia$ enters a turbine and expands to atmospheric pressure. The turbine is 70% efficient and powers a 90% efficient generator. What is the output power?**

A. $29KW$

B. $33KW$

C. $36KW$

D. $52KW$

The energy delivered by the turbine generator is a function of the enthalpy given up by the steam during expansion in the Turbine, the turbine efficiency, and the generator efficiency. To start, bring up the steam table in the reference handbook by searching for properties of Superheated Steam and properties of Saturated Water and Steam by pressure and determine the enthalpy entering and leaving the turbine. Call the entering condition State 1 and the leaving condition State 2.

For State 1, the superheated steam is fully defined since the temperature and pressure are known. In addition to the enthalpy, note the entropy for State 1.

$$T_1 = 900°F$$

$$P_1 = 500psia$$

$$h_1 = 1466.9\frac{Btu}{lb}$$

$$s_1 = 1.699\frac{Btu}{lb°F}$$

For state 2, start by assuming isentropic (ideal) expansion in the turbine. Use the entropy to determine the quality, and use the quality to determine the enthalpy for State 2 *ideal*. In the subsequent step the *actual* State 2 will be distinguished.

$$P_2 = 14.7psia$$

$$s_2 = s_1 = 1.699\frac{Btu}{lb°F}$$

$$s_f = .3122\frac{Btu}{lb°F} \; ; \; s_{fg} = 1.4443\frac{Btu}{lb°F}$$

$$\chi_2 = \frac{s_2 - s_f}{s_{fg}} = \frac{1.699\frac{Btu}{lb°F} - .3122\frac{Btu}{lb°F}}{1.4443\frac{Btu}{lb°F}} = .96$$

$$h_f = 180.2\frac{Btu}{lb} \; ; \; h_{fg} = 970.1\frac{Btu}{lb}$$

$$h_2 = h_f + \chi_2 h_{fg} = 180.2\frac{Btu}{lb} + (.96)\left(970.1\frac{Btu}{lb}\right) = 1111.7\frac{Btu}{lb}$$

Unlike with a compressor or a pump, a turbine efficiency is the ratio of the *actual* energy that comes out divided by the energy that goes in. Since the goal is to produce output power, a less efficient turbine will put out less than it could if it were more efficient. Therefore, we can write the turbine efficiency and calculate the *actual* change in enthalpy for the expansion process.

$$\eta_t = \frac{\Delta h_{actual}}{\Delta h_{ideal}} = \frac{h_1 - h_2^{'}}{h_1 - h_2}$$

$$0.7 = \frac{\Delta h_{actual}}{\left(1466.9\frac{Btu}{lb} - 1111.7\frac{Btu}{lb}\right)} \rightarrow \Delta h_{actual} = 248.7\frac{Btu}{lb}$$

Finally, use the known mass flow rate and the change in enthalpy to determine the power output from the generator, accounting for the generator efficiency and converting units to KW.

$$P_{generator} = \eta_{gen}\dot{m}\Delta h_{actual} = (0.9)\left(500\frac{lb}{hr}\right)\left(248.7\frac{Btu}{lb}\right)\left(\frac{1KW}{3412\frac{Btu}{hr}}\right) = 32.8KW$$

Answer B