



Isentropic efficiency

Steam enters a turbine at $T = 400 \text{ }^{\circ}\text{C}$ and $P = 3 \text{ MPa}$. It leaves with a pressure of 50 kPa and the turbine has an isentropic efficiency of 0.8. How much specific work does this turbine generate?

Answer: 659.

Explanation: The first step is to determine the two known independent thermodynamic properties in each state. To be able to make use of the isentropic efficiency and extra point is added, point 2 as if it was the turbine was ideal. This is tabulated to make it easier to order.

property	P [kPa]	T [C]	h [kJ/kg]	S [kJ/kg · K]	x	η_{iso}
State 1	3000	400				
State 2	50					0.8
State 2s	50			s₁		

The bold values are the initially known properties. Corresponding values for state 1 can be looked up in table A6. The quality of state 2s can now be determined using the s_f and s_g found in table A5 at the corresponding pressure.

$$x_{2s} = \frac{s - s_f}{s_g - s_f} = \frac{6.9235 - 1.0912}{7.5931 - 1.0912} = 0.897$$

Now h_{2s} can be determined using:

$$h_{2s} = x \cdot h_{fg} + h_f = 0.897 \cdot 2304 + 341 = 2408 \frac{\text{kJ}}{\text{kg}}$$

Using the formula for isotropic efficiency h_2 can be calculated

$$h_2 = h_1 - \eta_{iso} \cdot (h_1 - h_{2s}) = 3232 - 0.8 \cdot (3232 - 2408) = 2573 \frac{\text{kJ}}{\text{kg}}$$

To calculate the specific work output:

$$w_{out} = h_1 - h_2 = 3232 - 2573 = 659 \frac{\text{kJ}}{\text{kg}}$$