The enthalpy of the liquid at the exit is

$$H_2 = H_1 + W_s,$$

and this value, along with pressure, define the exit state. If the value of β is known, eqs. (5.29) and (5.30). Alternatively, the properties at the outlet may be calculated from saturated tables by interpolation at the known enthalpy (recall that the properties of compressed liquid are to a very good approximation equal to those of the saturated liquid at the same temperature).

Example 6.19: Calculation of Pump

Water is pumped from 1 bar, 20°C, to ~~15~~ 20 bar bar. The pump efficiency is 75%. Calculate the required amount of work.

Solution The properties at the inlet state are

$$V_1 = 0.001002 \text{ m}^3/\text{kg}, \quad H_1 = 83.92 \text{ kJ/kg}, \quad S_1 = 0.2965 \text{ kJ/kg K}.$$

The work in the pump is

$$W = \frac{(0.001002 \text{ m}^3/\text{kg})(\text{~~15~~}\,20 - 1) \times 10^3 \text{ kJ/m}^3}{0.75} = 2.538 \text{ kJ/kg}.$$

The enthalpy at the pump exit is

$$H_2 = H_1 + W_s = (83.92) + (2.53) = 86.458 \text{ kJ/kg}.$$

The state at the exit of the pump is calculated by interpolation in the saturated tables at $H = 86.45$ kJ/k:

$$T_2 = 20.6, \quad H_2 = 86.458 \text{ kJ/kg}, \quad S_2 = 0.3051 \text{ kJ/kg K}.$$

The entropy generation is

$$S_{\text{gen}} = (0.3051) \text{ minus } (0.2965) = 0.0086 \text{ kJ/kh K}.$$

Comments Compared to compression of steam over the same pressure difference (Example 6.18), the compression of liquid water involves much less work, and is accompanied by very small changes in the properties of the fluid except pressure. In general, the compression of liquid requires less work than the compression of gases because liquids are nearly incompressible. Consider compression of a fluid by a piston: Under an applied force F the piston moves by δx and the corresponding work is $F\delta x$. A compressible fluid yields under pressure and the displacement of the piston is substantial. For an incompressible fluid the displacement of the force is very small, and the work is correspondingly small.