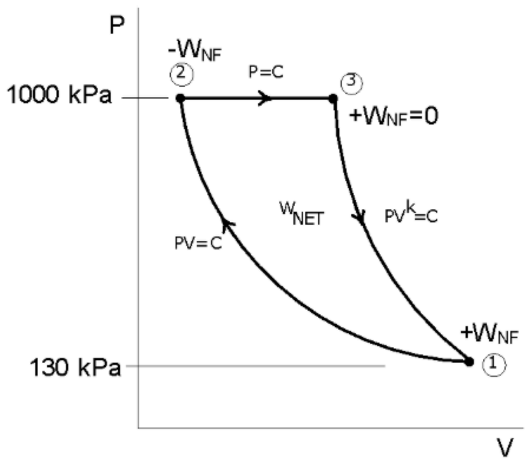

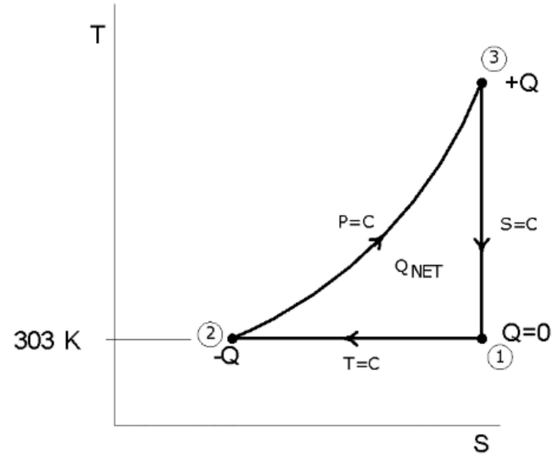

<u>Step 1:</u> Calculate T_3

Since Process 1-2 is **isothermal compression**, the temperature remains uniform throughout the first stage: $T_2 = T_1 = 303$ K

Because Process 2-3 is an **isobaric process**, the pressure at State 3 is identical to the pressure at State 2 ($P_3 = P_2 = 1000$ kPa).

$$T_3 = T_1\left[\frac{P_2}{P_1}\right]^{\frac{k-1}{k}} = (303\ K)\left[\frac{1000\ kPa}{130\ kPa}\right]^{\frac{1.4-1}{1.4}} = 542.752\ K$$

<u>Step 2:</u> Next, we calculate the total heat added (ΣQ_A). Heat enters the system exclusively during the constant-pressure expansion stage (Process 2-3), where it is equal to the change in enthalpy (ΔH):

$$\frac{Q_A}{m} = \frac{Q_{2-3}}{m} = C_p\left(T_3 - T_1\right) = \left(1.0062\ \frac{kJ}{kg-K}\right)(542.752 - 303)K = 241.2388\ \frac{kJ}{kg}$$

<u>Step 3:</u> Calculate the Specific Work for Each Process (W_{NF})

- **Process 1-2 (Isothermal Compression):** The work done during a constant-temperature process is calculated using the natural log of the pressure ratio:

$$\frac{W_{1-2}}{m} = RT_1 ln\left(\frac{P_1}{P_2}\right) = \left(0.287\ \frac{kJ}{kg-K}\right)(303\ K)\left(\frac{130\ kPa}{1{,}000\ kPa}\right) = -\ 177.4196\ \frac{kJ}{kg}$$

- **Process 2-3 (Isobaric Expansion/Heat Addition):** The work done during a constant-pressure process reduces to PΔv, which can be rewritten using the ideal gas equation as RΔT:

$$\frac{W_{2-3}}{m} = R\left(T_3 - T_2\right) = \left(0.287\ \frac{kJ}{kg-K}\right)(542.752 - 303)K = 68.8089\ \frac{kJ}{kg}$$

- **Process 3-1 (Isentropic Expansion):** For a reversible adiabatic expansion where Q=0, the non-flow work output equals the negative change in internal energy:

$$\frac{W_{3-1}}{m} =- C_v\left(T_1 - T_3\right) =- \left(0.7186\ \frac{kJ}{kg-K}\right)(303\ -\ 542.752)K\ =\ 172.2860\ \frac{kJ}{kg}$$

By summing the total work transfers along the process paths $\left(\Sigma W_{NET} = \frac{W_{1-2}}{m} + \frac{W_{2-3}}{m} + \frac{W_{3-1}}{m}\right)$, the net specific work output equals:

$$\Sigma W_{NET} =-\ 177.4196\ \frac{kJ}{kg} +\ 68.8089\ \frac{kJ}{kg}\frac{W_{3-1}}{m} +\ 172.2860\ \frac{kJ}{kg} =\ 63.6753\frac{kJ}{kg}$$

Thermal Efficiency (e_{cycle})

Using these values, the cycle thermal efficiency is determined by:

$$e_{cycle} = \frac{\Sigma W_{NET}}{\Sigma Q_A} = \frac{63.6753\ \frac{kJ}{kg}}{241.2388\ \frac{kJ}{kg}} =\ 26.40\%$$

This thermodynamic cycle highlights an important engineering concept: the efficiency of **isothermal compression**.

In real-world industrial systems, compressing a gas naturally causes its temperature to rise, which increases its specific volume and requires more work input to compress it further. By using a water-jacketed cooling system or an intercooler to keep the compression stage as close to isothermal (T=constant) as possible, we minimize the volume of the gas during compression. This directly reduces the mechanical work required to run the compressor (keeping W_{1-2} as low as possible).