Given: $kJ := 1000J$

Liquid methane is commonly used in various cryogenic applications. The critical temperature of methane is 191 K and must be maintained below this temperature to remain in the liquid phase. Methane enters a pump at 110 K and 1 MPa and leaves at 120 K and 5 MPa.

$T_{cr} := 191K$ $T_{in} := 110K$ $P_{in} := 1MPa$ $T_{out} := 120K$ $P_{out} := 5MPa$

Properties of Liquid Methane

Temp T, K	Pressure P, MPa	Density 1, kg/m³	Enthalpy h, kJ/kg	Entropy s, kJ/kg K	Specific Heat c_p, kJ/kg K
110	0.5	425.3	208.3	4.878	3.476
	1	425.8	209.0	4.875	3.471
	2	426.6	210.5	4.867	3.460
	5	429.1	215.0	4.844	3.432
120	0.5	410.4	243.4	5.185	3.551
	1	411.0	244.1	5.180	3.543
	2	412.0	245.4	5.171	3.528
	5	415.2	249.6	5.145	3.486

Required:

Determine the entropy change during this process by

(a) using the table given and

(b) using the Tds relations.

Solution:

Referring to the table @ $T_{in} = 110K$ & $P_{in} = 1 \cdot MPa$ shows

$$s_{in} := 4.875 \frac{kJ}{kg \cdot K} \qquad c_{pin} := 3.471 \frac{kJ}{kg \cdot K}$$

Referring to the table @ $T_{out} = 120K$ & $P_{out} = 5 \cdot MPa$ shows

$$s_{out} := 5.145 \frac{kJ}{kg \cdot K} \qquad c_{pout} := 3.486 \frac{kJ}{kg \cdot K}$$

Thus the change in entropy when using the tables is

$$\boxed{\Delta s_{table} := s_{out} - s_{in} = 0.27 \cdot \frac{kJ}{kg \cdot K}} \quad \text{(a)}$$

The average c_p value over the process is found by

$$c_{pavg} := \frac{c_{pin} + c_{pout}}{2} = 3.478 \cdot \frac{kJ}{kg \cdot K}$$

Solution (contd.):

For an incompressible substance the change in entropy is given by

$$\boxed{\Delta s_{Tds} := c_{pavg} \cdot \ln\left(\frac{T_{out}}{T_{in}}\right) = 0.3027 \cdot \frac{kJ}{kg \cdot K}} \quad \text{(b)}$$

The percent difference is found by

$$\%diff := \frac{\left|\Delta s_{table} - \Delta s_{Tds}\right|}{\Delta s_{table}} = 12.1 \cdot \%$$