Tutorial

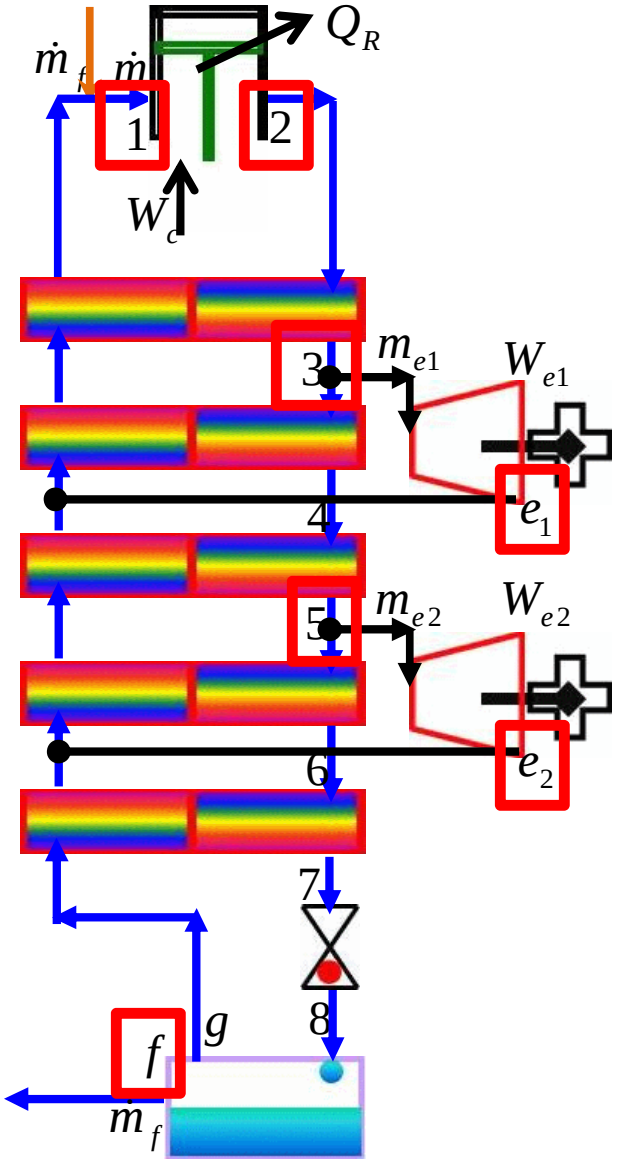
- Determine **y**, **W / m_f**, **FOM** for a Collins System with Helium as working fluid. The system operates between 1.013 bar (1 atm) and 15.19 bar (15 atm). The expander flow ratios are **$x_1 = 0.6$**, **$x_2 = 0.2$** respectively. The expander inlet conditions are as mentioned below.

Exp.	Inlet Cond.
I	60 K, 15 atm
II	15 K, 15 atm

Tutorial

Given
Cycle : Collins System
Working Pressure : 1 atm → 15 atm
Working Fluid : Helium
Expander 1: 15 atm, 60 K, x_1=0.4
Expander 2: 15 atm, 15 K, x_2=0.2

For above System, Calculate	
1	Work/unit mass of gas liquefied
2	FOM



Tutorial

	1	2	3
p (bar)	1.013	15.19	15.19
T (K)	300	300	60
h (J/g)	1587	1570	328
s (J/gK)	31.5	25.6	17.5

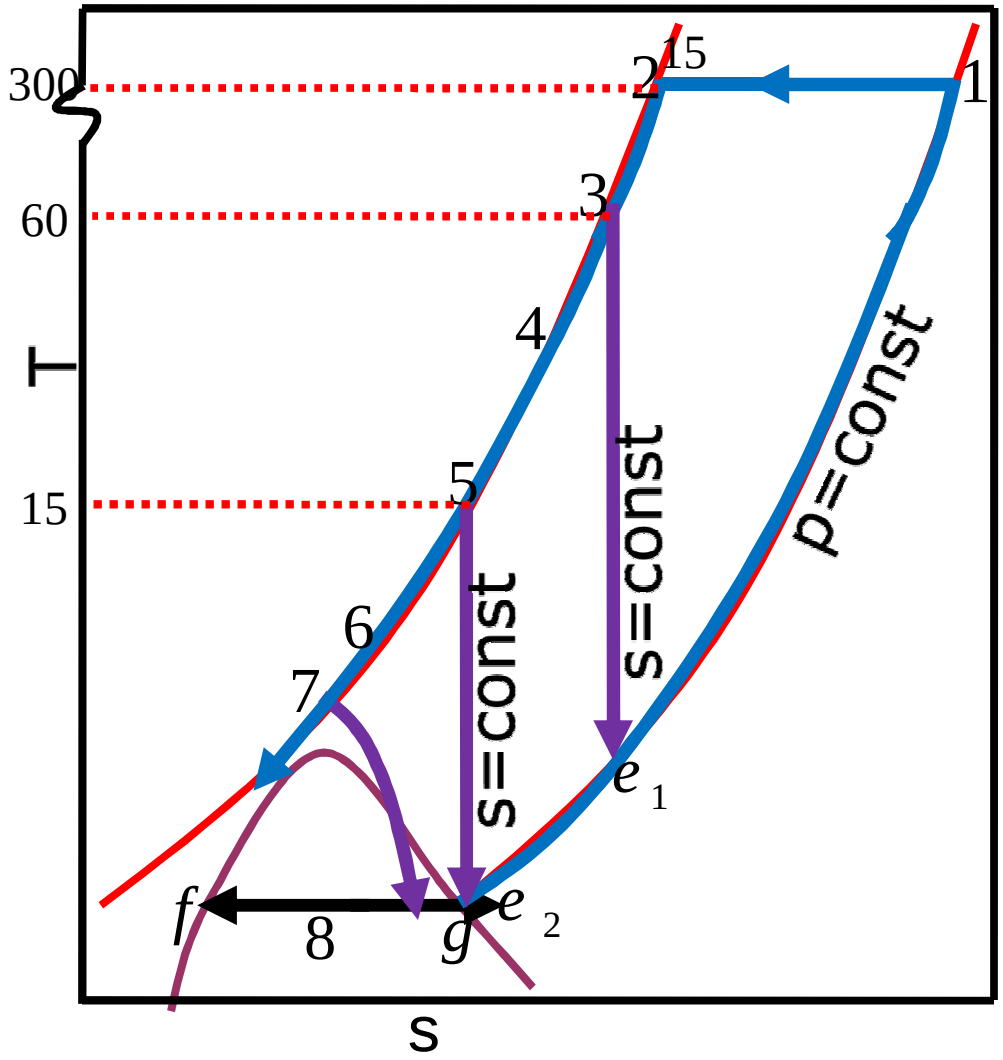
	5	e_1	e_2	f
p (bar)	15.19	1.013	1.013	1.01
T (K)	15	22	4.8	4.2
h (J/g)	81	130.0	38	9.5
s (J/gK)	9.25	17.5	9.25	3.4

* Points **e_1** and **e_2** are located on p=1bar line by drawing vertical lines from point **3** and **5**.

Tutorial

- The T – s diagram for a Collins System is as shown (not to scale).

- The expander inlet conditions are
  - 60 K
  - 15 K



Tutorial

- **Liquid yield**

$$y = \left(\frac{h_1 - h_2}{h_1 - h_f}\right) + x_1\left(\frac{h_3 - h_{e1}}{h_1 - h_f}\right) + x_2\left(\frac{h_5 - h_{e2}}{h_1 - h_f}\right)$$

	1	2	3	5	e_1	e_2	f
p	1.013	15.19	15.19	15.19	1.013	1.013	1.01
T	300	300	60	15	22	4.8	4.2
h	1587	1570	328	81	130.0	38	9.5
s	31.5	25.6	17.5	9.25	17.5	9.25	3.4

$$y = \frac{(1587 - 1570)}{(1587 - 9.5)} + 0.4\frac{(328 - 130.0)}{(1587 - 9.5)} + 0.2\frac{(81 - 38)}{(1587 - 9.5)} = 0.066$$

Tutorial

- **Work / unit mass of He compressed**

$$\frac{-W_{net}}{\dot{m}} = \left(T_1\left(s_1 - s_2\right) - \left(h_1 - h_2\right)\right) - x_1\left(h_3 - h_{e1}\right) - x_2\left(h_5 - h_{e2}\right)$$

	1	2	3	5	e_1	e_2	f
p	1.013	15.19	15.19	15.19	1.013	1.013	1.01
T	300	300	60	15	22	4.8	4.2
h	1587	1570	328	81	130.0	38	9.5
s	31.5	25.6	17.5	9.25	17.5	9.25	3.4

$$-\frac{W_{net}}{\dot{m}} = \begin{cases} 300\left(31.5 - 25.6\right) - \left(1587 - 1570\right) \\ -0.4\left(328 - 130.0\right) - 0.2\left(81 - 38\right) \end{cases} = 1665.2\ J/g$$

Tutorial

- **Work / unit mass of He liquefied**

$$-\frac{W_{net}}{\dot{m}} = 1665.2$$

$$y = 0.066$$

$$-\frac{W_{net}}{\dot{m}_f} = -\frac{W_{net}}{y\dot{m}} = \frac{1665.2}{0.066} = 25230.3\,J/g$$

- **Figure of Merit (FOM)**

$$-\frac{W_{net}}{\dot{m}_f} = 25230.3$$

$$-\frac{W_i}{\dot{m}_f} = 6837$$

$$FOM = \frac{W_i}{\dot{m}_f} / \frac{W_{net}}{\dot{m}_f} = \frac{6837}{25230.3} = 0.271$$