Tutorial – 1

- Determine the **y**, **y_{max}**, the work/unit mass compressed, work/unit mass liquefied and FOM for the Simple and Precooled Linde – Hampson systems with Nitrogen as working fluid. The R134A is the refrigerant for the precooling system with ratio **r** as 0.08. The liquefaction system is operated between 1.013 bar (1 atm) and 101.3 bar (100 atm) at 300 K. The following is the data for R134a. Comment on the results.

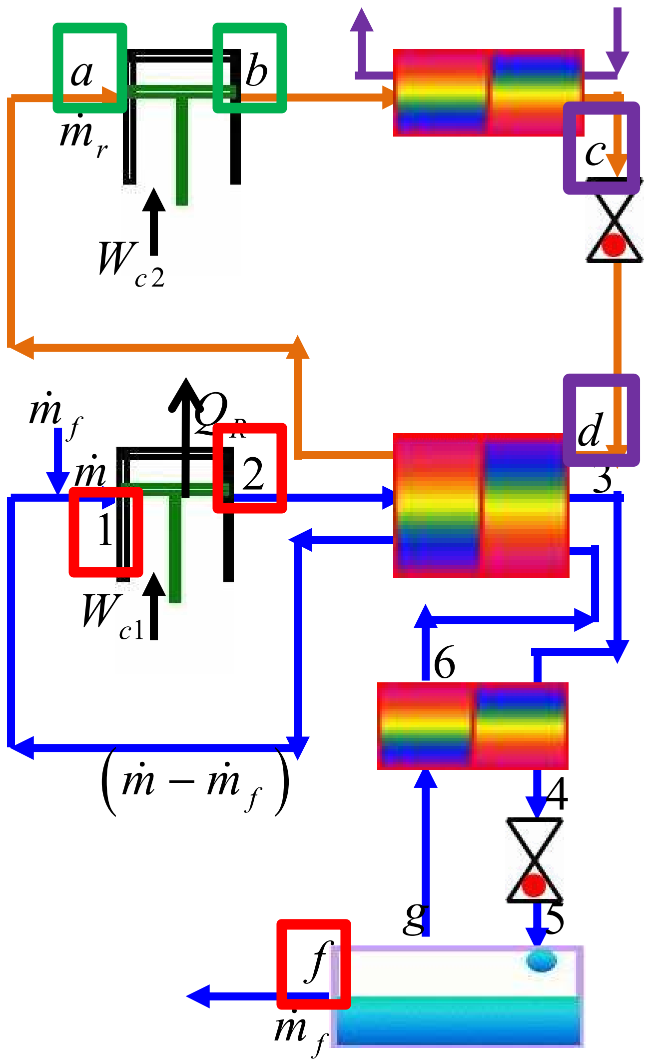
	a	b	c
p (bar)	1.013	10.13	10.13
T (K)	300	373	300
h (J/g)	390	482	260

Tutorial – 1

Given
Cycle : Simple and Precooled L – H System
Working Fluid : Nitrogen
Pressure : 1 atm → 100 atm
Temperature : 300 K
Refrigerant : R134a, 1 atm → 10 atm
Mass ratio(r) : 0.08

For above cycles, Calculate and comment	
1	Liquid Yield **y**, $\mathbf{y_{max}}$
2	Work/unit mass of gas compressed
3	Work/unit mass of gas liquefied
4	FOM

Tutorial – 1



	1	2	f
p (bar)	1.013	101.3	1.013
T (K)	300	300	77
h (J/g)	462	445	29
s (J/gK)	4.42	3.1	0.42

	a	b	c
p (bar)	1.013	10.13	10.13
T (K)	300	373	300
h (J/g)	390	482	260
s (J/gK)	R134a		

- $h_d = h_c$, since the expansion is isenthalpic.

Tutorial – 1

- **Ideal Work Requirement**

$$-\frac{\dot{W}_i}{\dot{m}} = T_1\left(s_1 - s_f\right) - \left(h_1 - h_f\right)$$

	1	2	f
p (bar)	1.013	101.3	1.013
T (K)	300	300	77
h (J/g)	462	445	29
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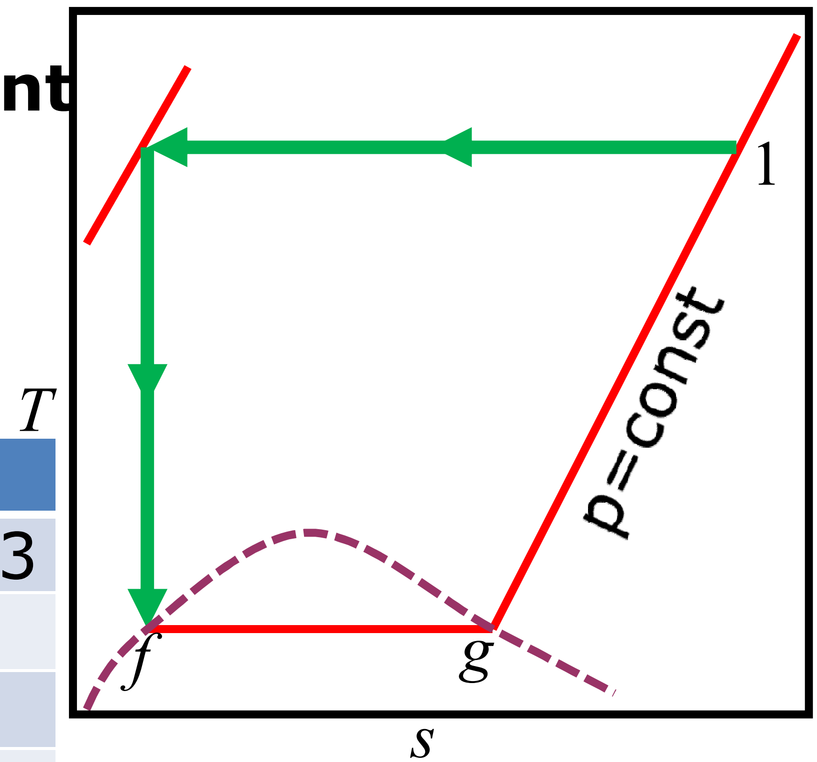


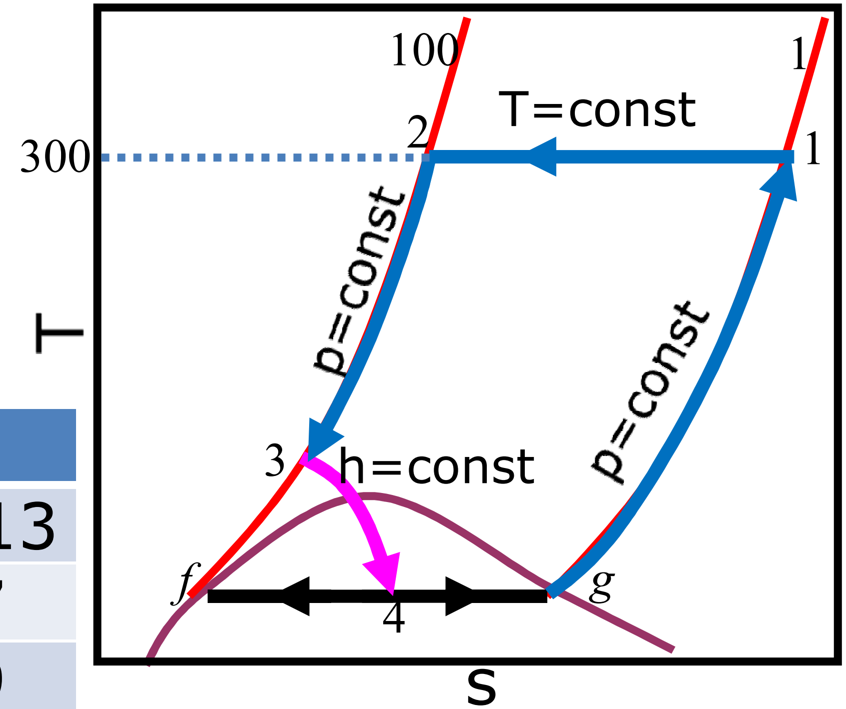
$$-\frac{W_c}{\dot{m}} = 300\left(4.42 - 0.42\right) - \left(462 - 29\right) = 767\ J/g$$

Tutorial – 1

- **Liquid yield**

$$y = \left(\frac{h_1 - h_2}{h_1 - h_f} \right)$$

	1	2	f
p (bar)	1.013	101.3	1.013
T (K)	300	300	77
h (J/g)	462	445	29
s (J/gK)	4.42	3.1	0.42



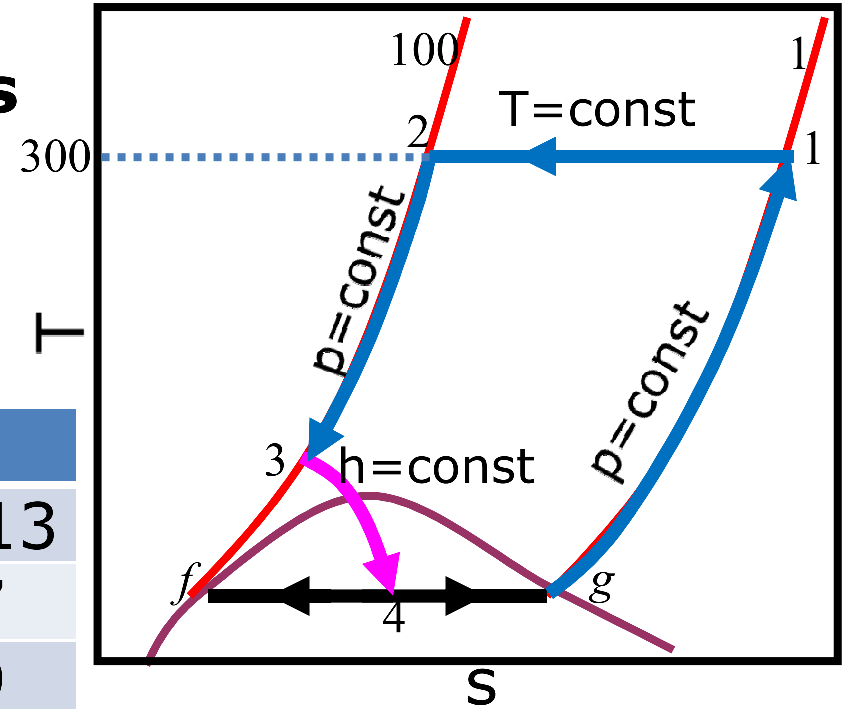
$$y = \left(\frac{h_1 - h_2}{h_1 - h_f} \right) = \left(\frac{462 - 445}{462 - 29} \right) = \left(\frac{17}{433} \right) = 0.04$$

Tutorial – 1

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

$$-\frac{W_c}{\dot{m}} = T_1\left(s_1 - s_2\right) - \left(h_1 - h_2\right)$$

	1	2	f
p (bar)	1.013	101.3	1.013
T (K)	300	300	77
h (J/g)	462	445	29
s (J/gK)	4.42	3.1	0.42



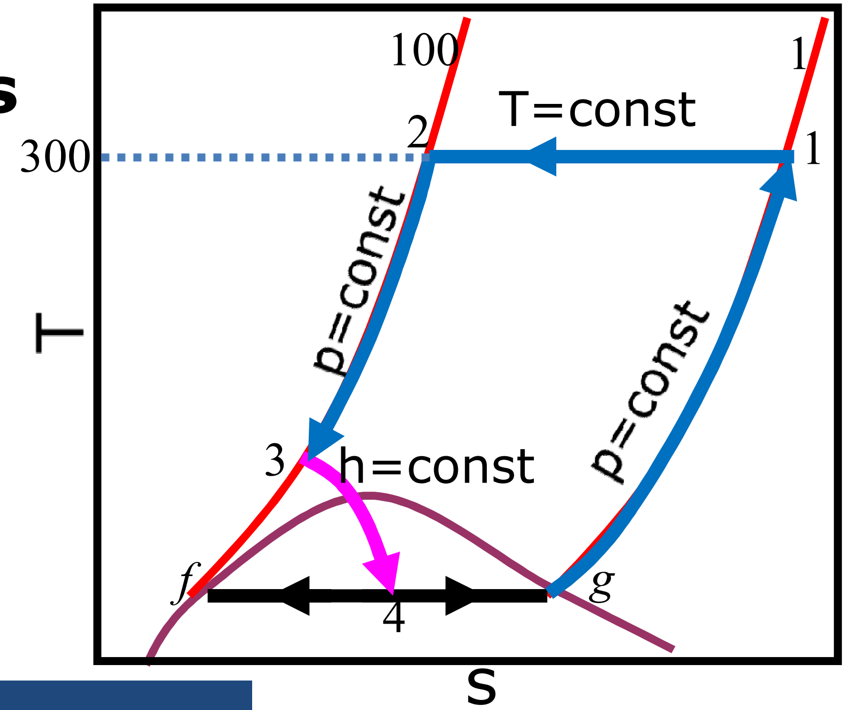
$$-\frac{W_c}{\dot{m}} = 300\left(4.42 - 3.1\right) - \left(462 - 445\right) \quad = 379\ J/g$$

Tutorial – 1

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

$$-\frac{W_c}{\dot{m}} = 379$$

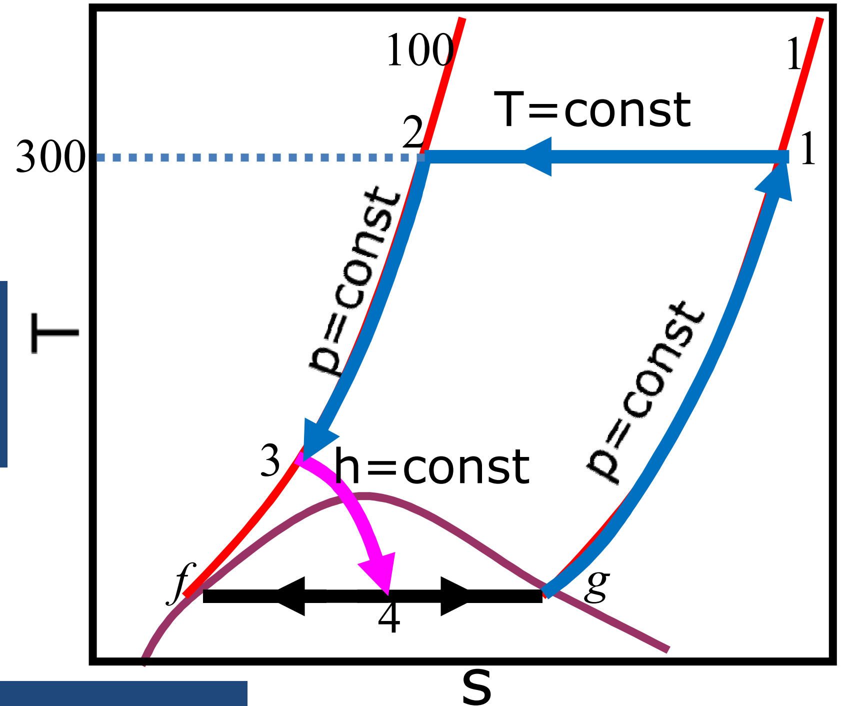
$$y = 0.04$$



$$-\frac{W_c}{\dot{m}_f} = -\frac{W_c}{y\dot{m}} \quad = \frac{379}{0.04} \quad = 9475\ J/g$$

Tutorial – 1

- **Figure of Merit (FOM)**



$$-\frac{W_c}{\dot{m}_f} = 9475$$

$$-\frac{W_i}{\dot{m}_f} = 767$$

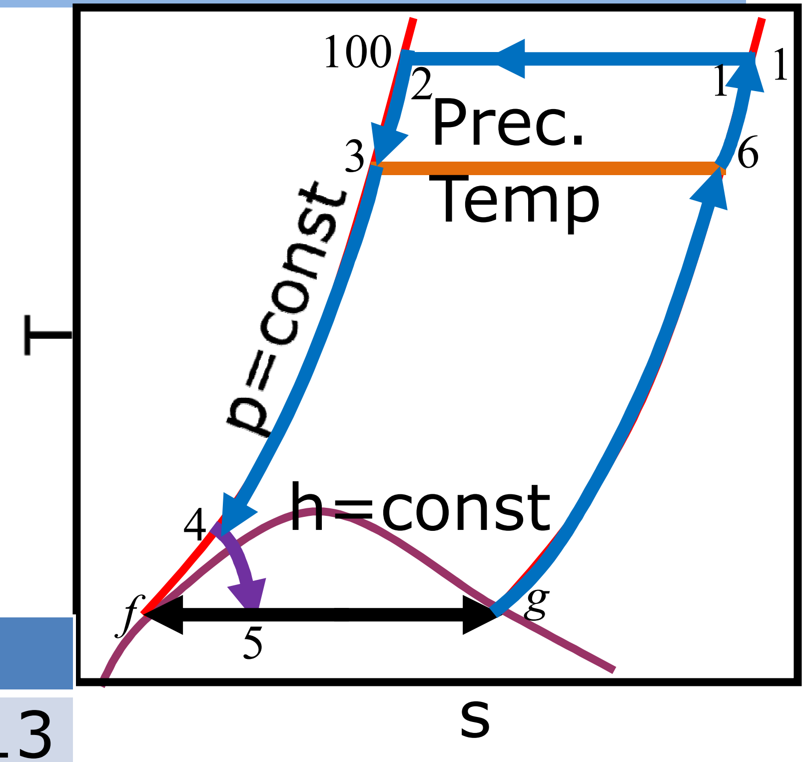
$$FOM = \frac{W_i}{\dot{m}_f} \bigg/ \frac{W_c}{\dot{m}_f} = \frac{767}{9475} = 0.081$$

Tutorial – 1

- The T – s diagram for a Precooled Linde – Hampson system is as shown.

- The state properties are as tabulated below.

	1	2	f
p (bar)	1.013	101.3	1.013
T (K)	300	300	77
h (J/g)	462	445	29
s (J/gK)	4.42	3.1	0.42



Tutorial – 1

- **Liquid yield**

$$y = \frac{\dot{m}_f}{\dot{m}} = \frac{h_1 - h_2}{h_1 - h_f} + r\left(\frac{h_{a,r} - h_{d,r}}{h_1 - h_f}\right)$$

$$r = 0.08$$

	1	2	f	a	b	c
p (bar)	1.013	101.3	1.013	1.013	10.13	10.13
T (K)	300	300	77	300	373	300
h (J/g)	462	445	29	390	482	260
s (J/gK)	4.42	3.1	0.42	**R134a**		

$$y = \frac{(462-445)}{(462-29)} + 0.08\frac{(390-260)}{(462-29)} = \frac{(17)}{(433)} + 0.08\frac{(130)}{(433)} = 0.063$$

Tutorial – 1

- **Work/unit mass of N_2 compressed**

$$-\frac{W_c}{\dot{m}} = T_1(s_1 - s_2) - (h_1 - h_2) + r(h_{b,r} - h_{a,r})$$

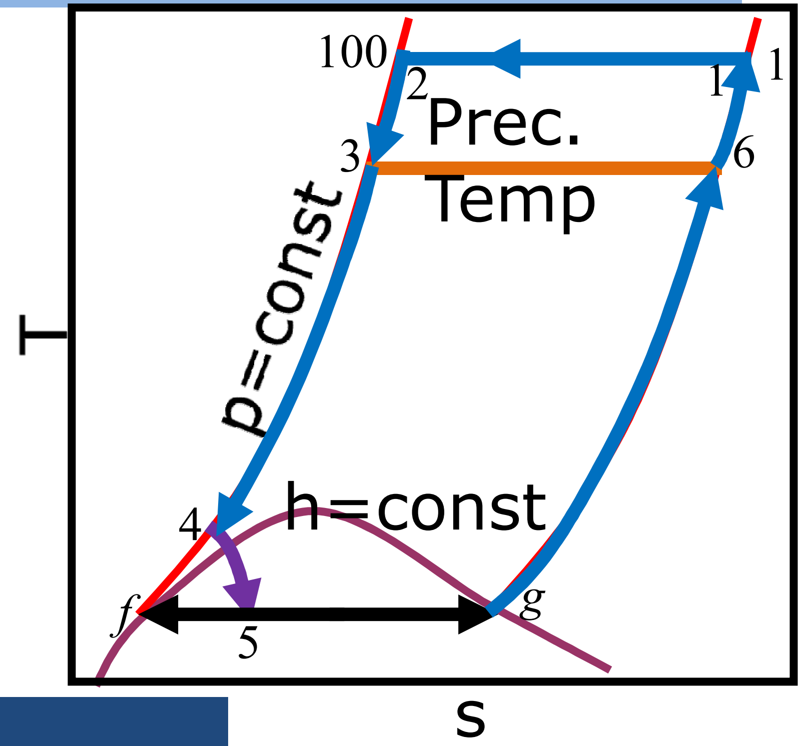
$$r = 0.08$$

	1	2	f	a	b	c
p (bar)	1.013	101.3	1.013	1.013	10.13	10.13
T (K)	300	300	77	300	373	300
h (J/g)	462	445	29	390	482	260
s (J/gK)	4.42	3.1	0.42	**R134a**		

$$-\frac{W_c}{\dot{m}} = 300(4.42 - 3.1) - (462 - 445) + 0.08(482 - 390) = 386.3\ J/g$$

Tutorial – 1

- **Work/unit mass of N_2 liquefied**



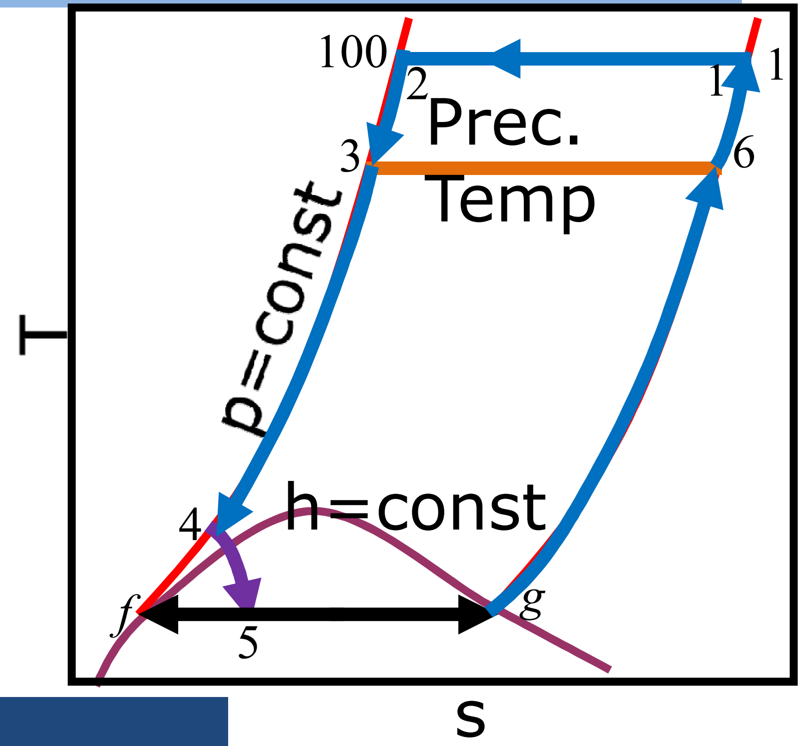
$$-\frac{W_c}{\dot{m}} = 386.3$$

$$y = 0.063$$

$$-\frac{W_c}{\dot{m}_f} = -\frac{W_c}{y\dot{m}} = \frac{386.3}{0.063} = 6131.7\ J/g$$

Tutorial – 1

- **Figure of Merit (FOM)**



$$-\frac{W_c}{\dot{m}_f} = 6131.7$$

$$-\frac{W_i}{\dot{m}_f} = 767$$

$$FOM = \frac{W_i}{\dot{m}_f} \Big/ \frac{W_c}{\dot{m}_f} = \frac{767}{6131.7} = 0.1251$$

Tutorial – 1

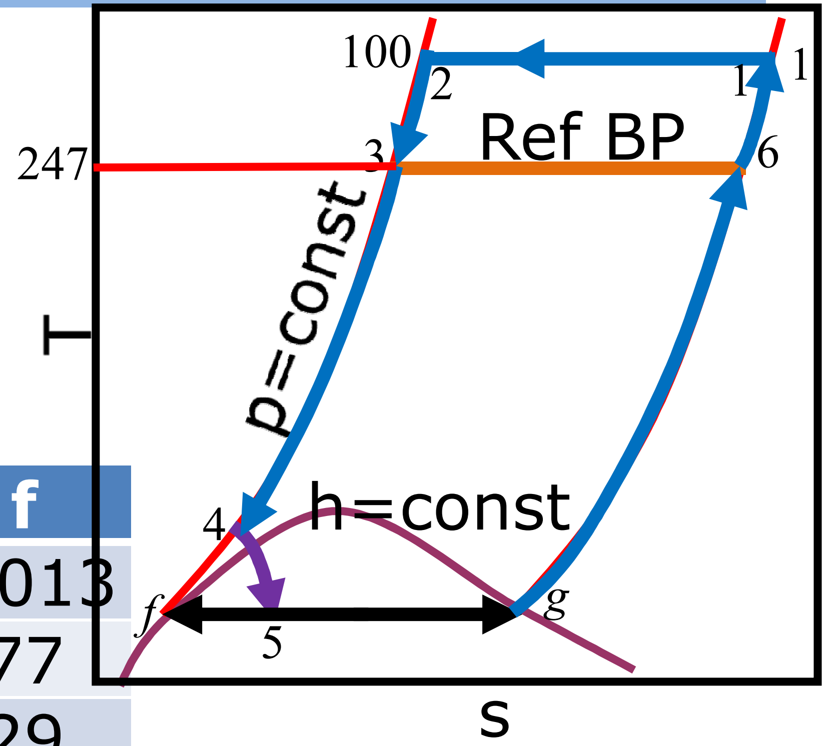
- **Maximum Liquid yield**

$y = y_{max}$

$T_3 = T_6 = T_d = 247\,K$

$$y_{max} = \frac{h_6 - h_3}{h_6 - h_f}$$

$r = 0.08$



	3	6	f
p (bar)	101.3	1.013	1.013
T (K)	247	247	77
h (J/g)	380	408	29

$$y_{max} = \frac{(408-380)}{(408-29)} = \frac{(28)}{(379)} = 0.074$$

Tutorial – 1

	Simple	Precooled	Max.
y	0.04	0.063	0.074
$-\frac{W_c}{\dot{m}}$	379	386.3	386.3
$-\frac{W_c}{\dot{m}_f}$	9475	6131.7	5220.2
FOM	0.081	0.1251	0.147

- Tabulating the results, we have the above comparison for Simple and Precooled Linde – Hampson System.