CURSO INTENSIVO

TERMODINÂMICA E APLICAÇÕES DE ENGENHARIA

CICLOS DE POTÊNCIA A AVANÇADOS – 1/2

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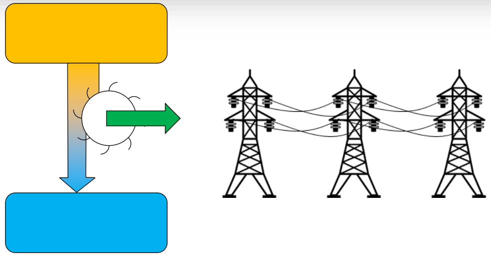
Attention to Filler Words

Melhor aproveitamento de uma fonte de calor para o recuperação de seu conteúdo exergético...

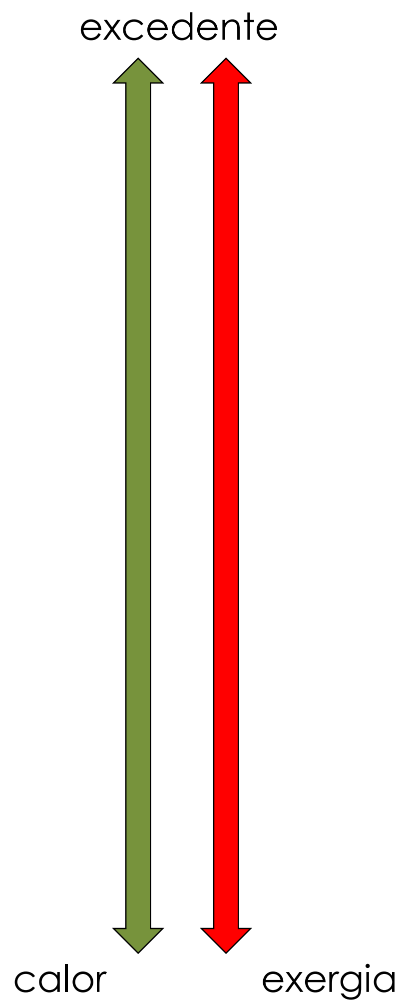


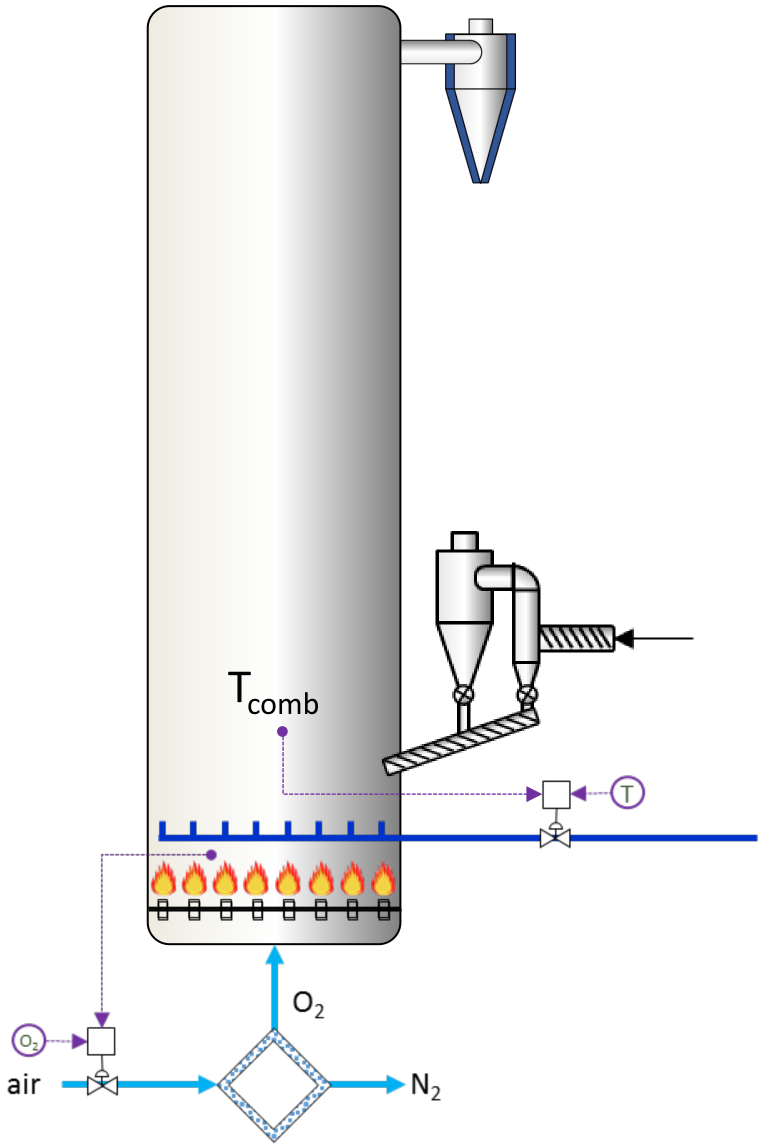
Thermal efficiency of power generation

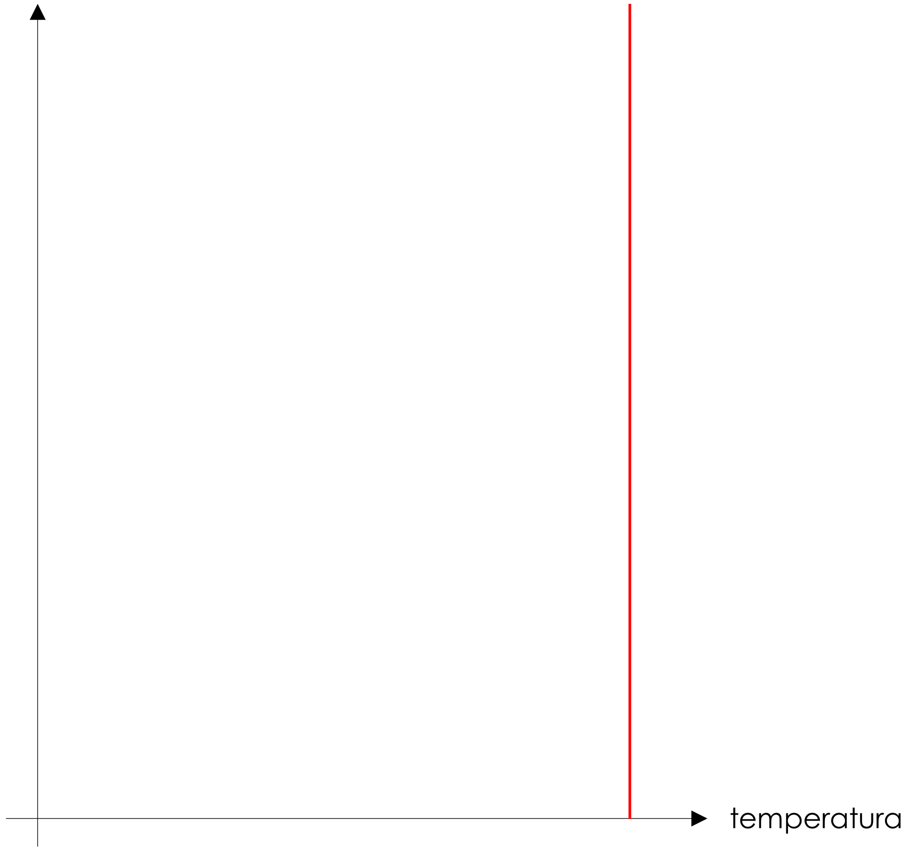
Type of power plant	Efficiency %
Open cycle gas turbine	25 - 35
sub-critical coal	30 - 38
supercritical coal	35 - 45
solar thermal	32 - 38
nuclear	32 - 36
gas turbine combined cycle	45 - 60


Combustível
- Bagaço de cana
Capacidade
- 200.000 kg/h
Pressão
- 67 kgf/cm²
Temperatura
- 510 °C

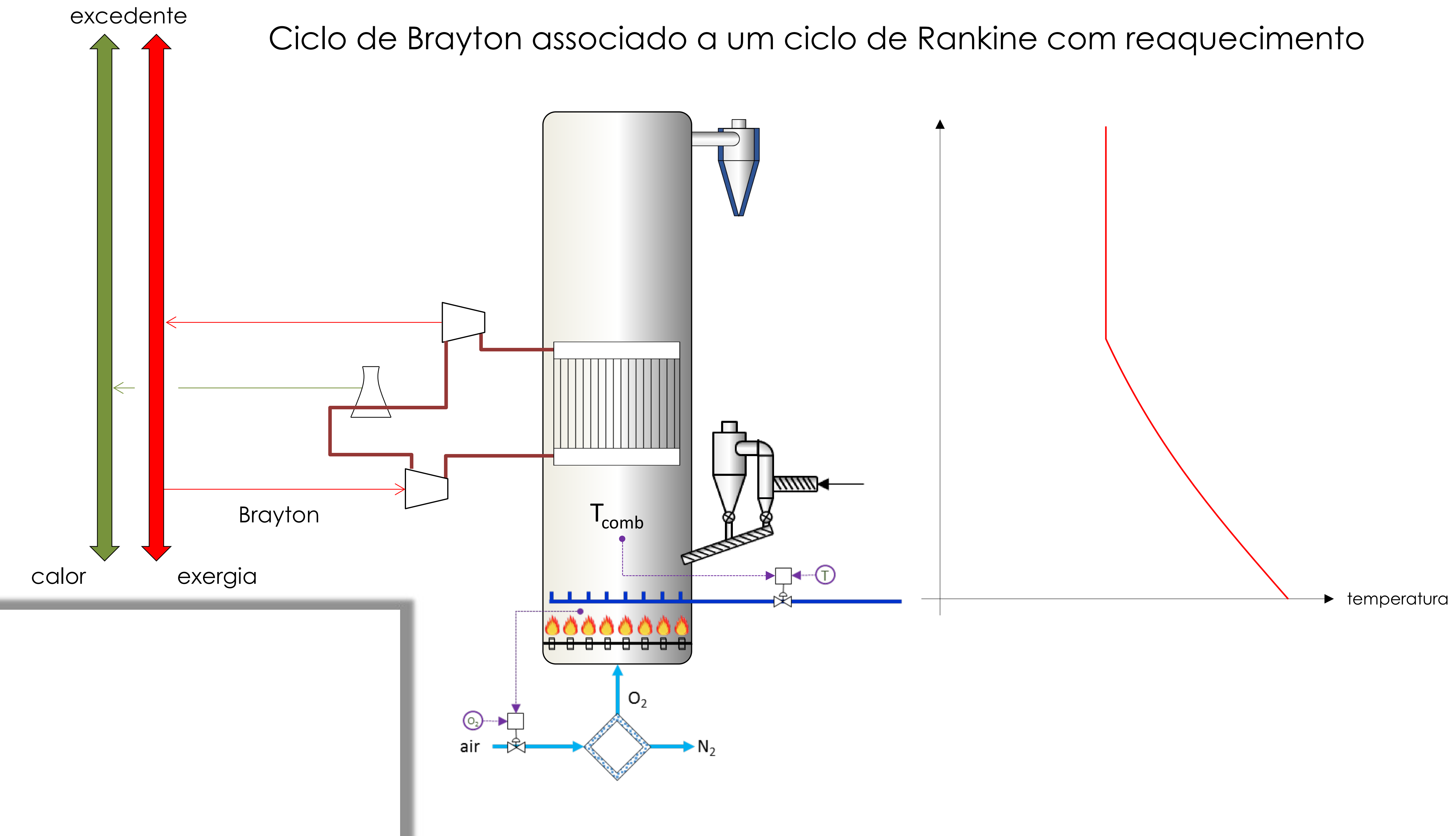
Ciclo de Brayton associado a um ciclo de Rankine com reaquecimento



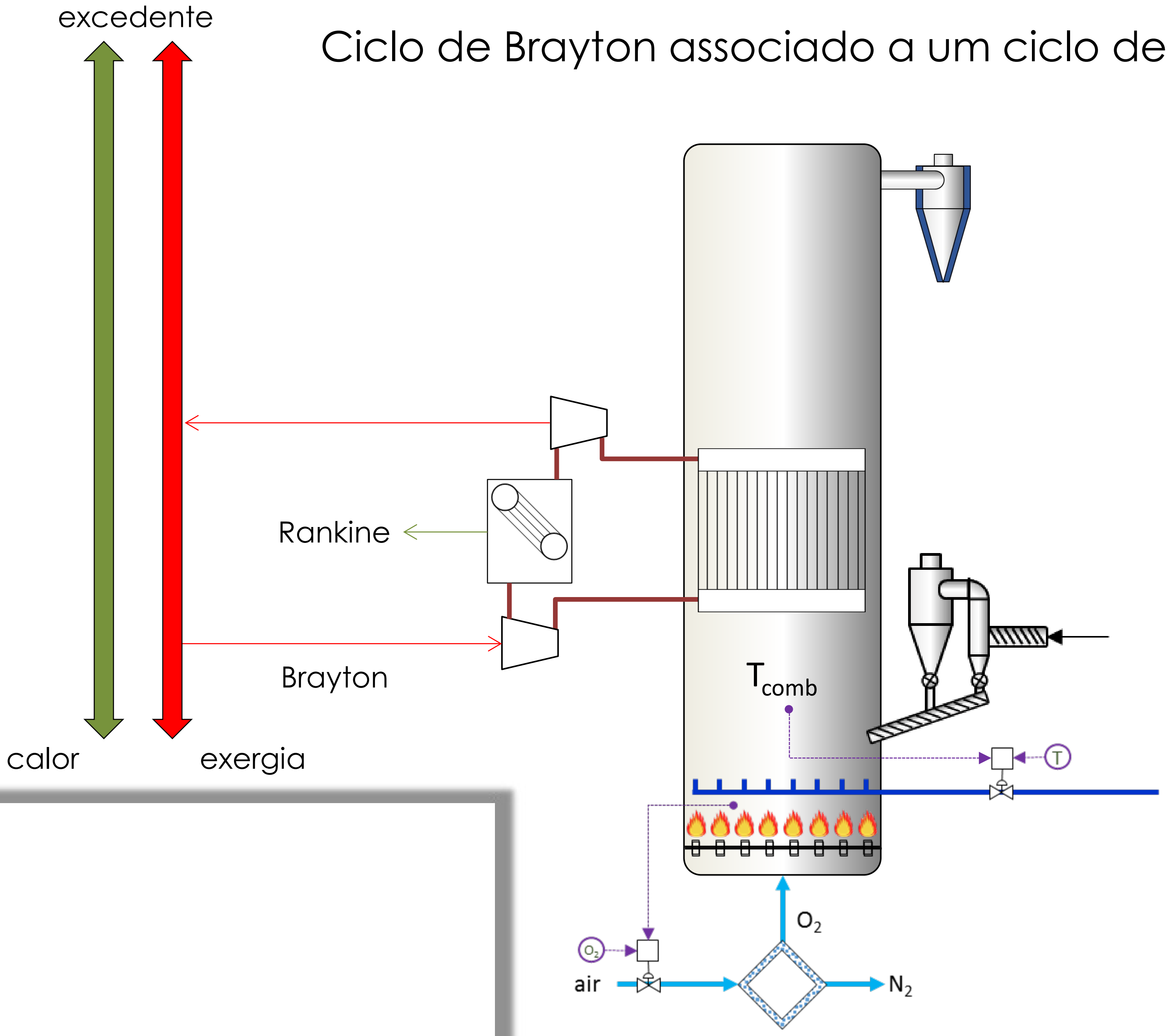


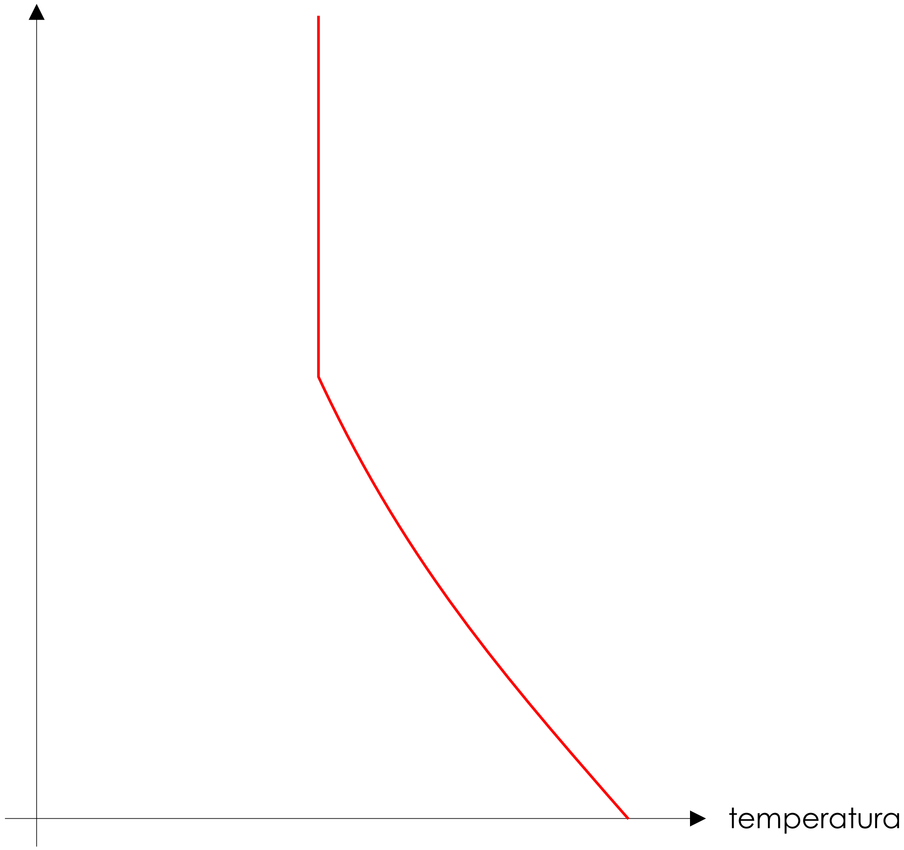


Ciclo de Brayton associado a um ciclo de Rankine com reaquecimento

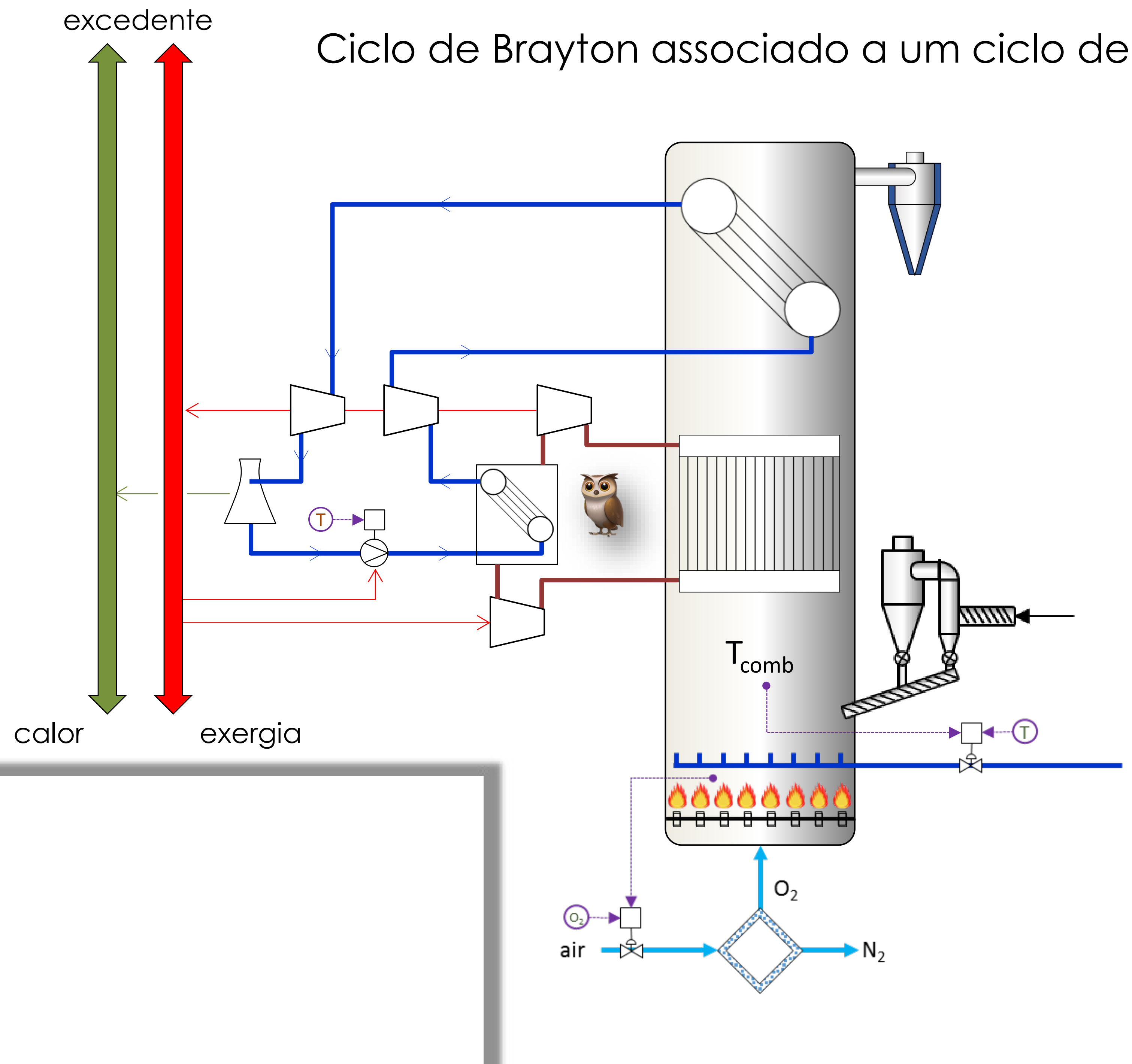


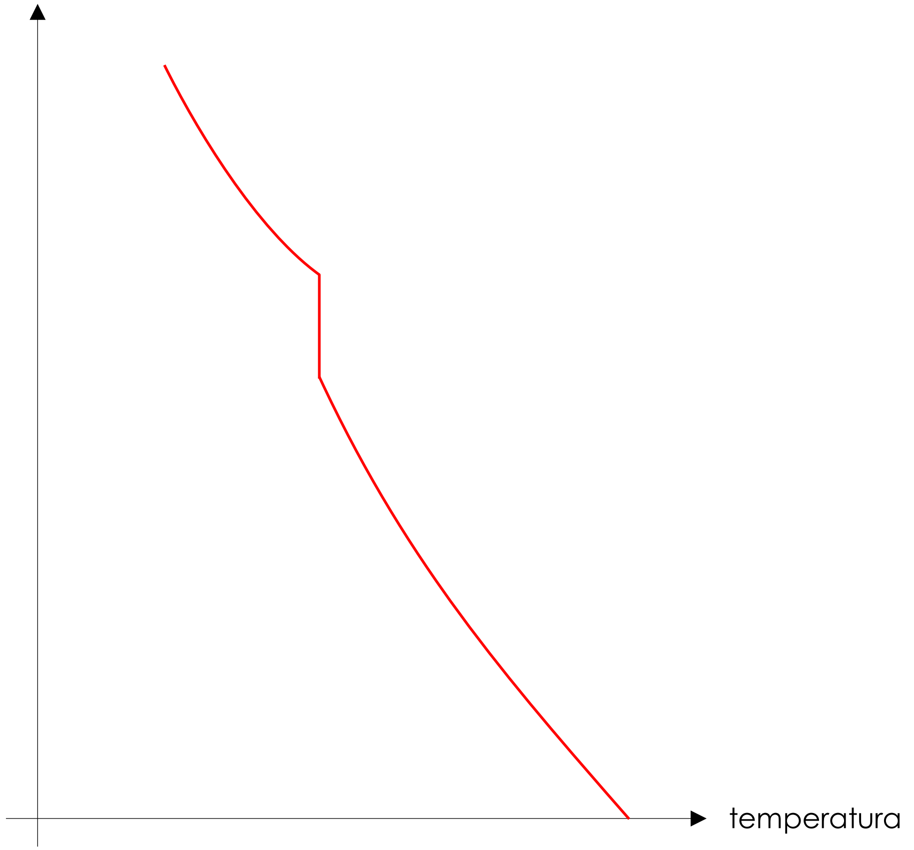
Ciclo de Brayton associado a um ciclo de Rankine com reaquecimento



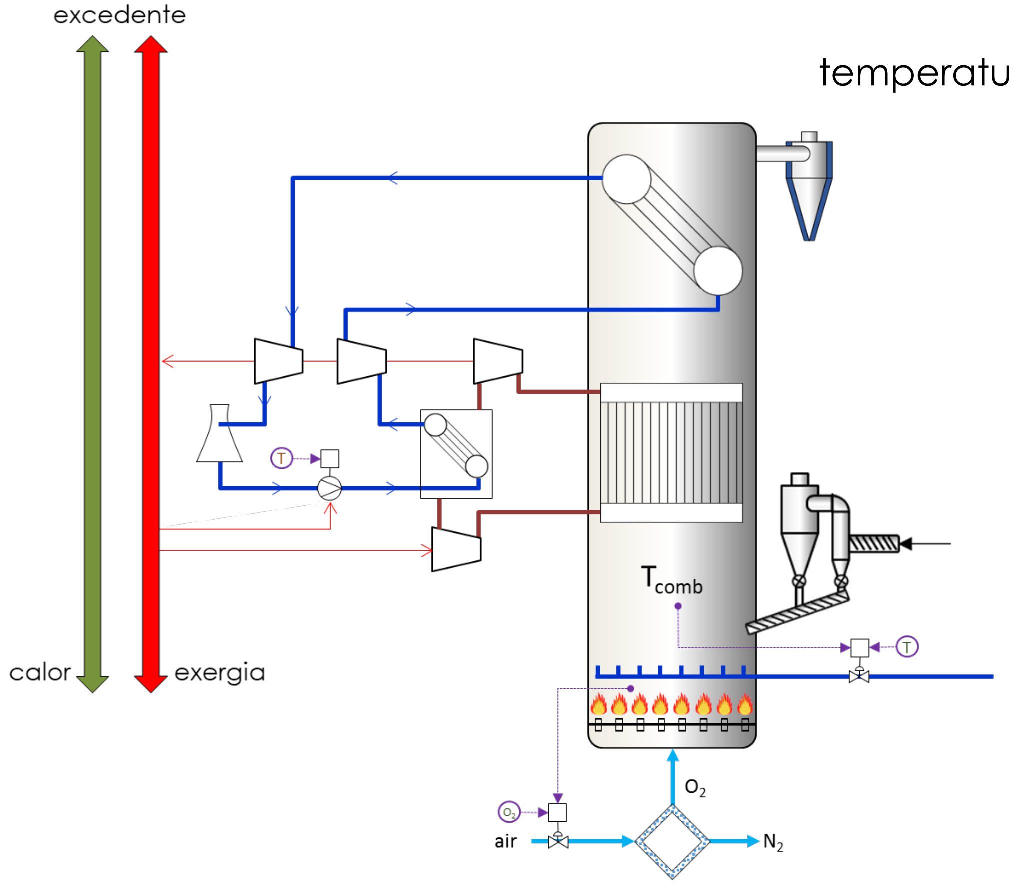


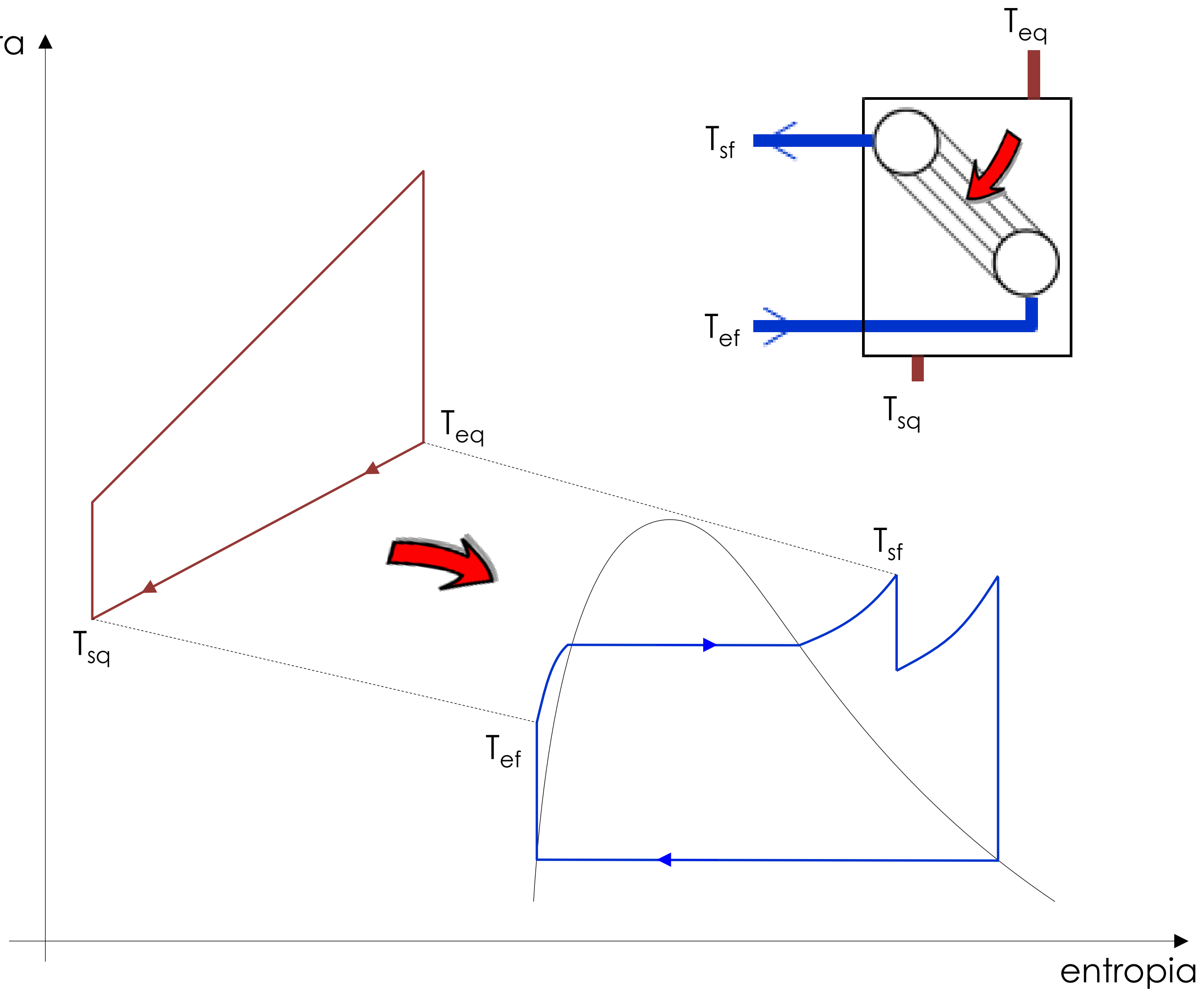
Ciclo de Brayton associado a um ciclo de Rankine com reaquecimento

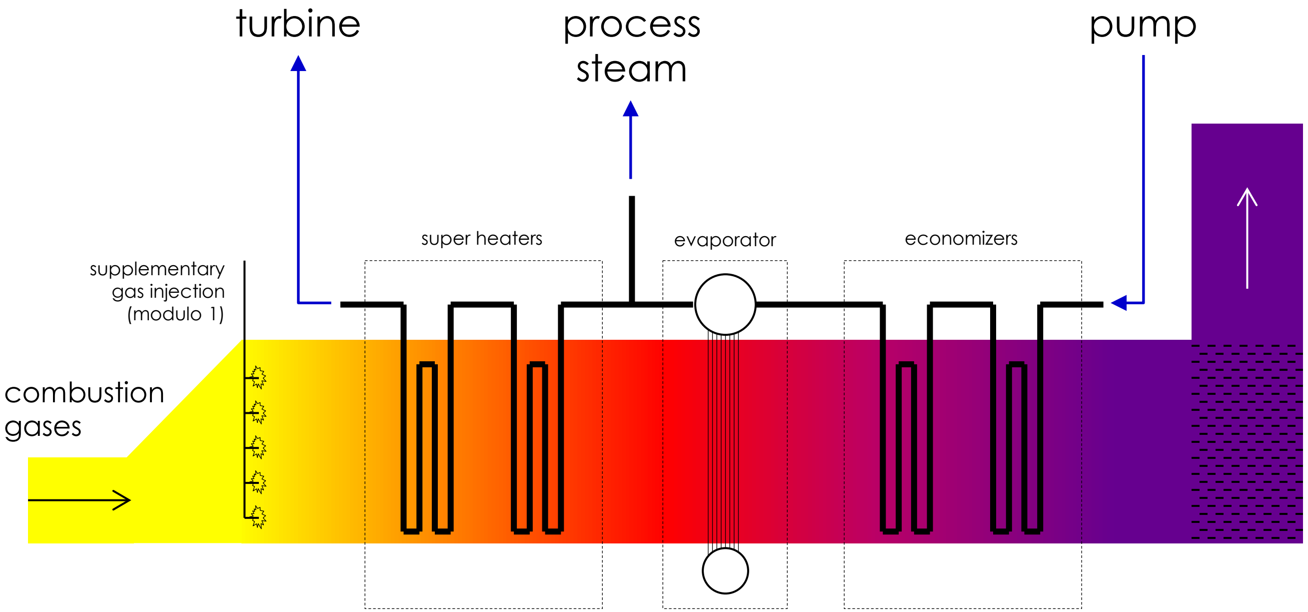


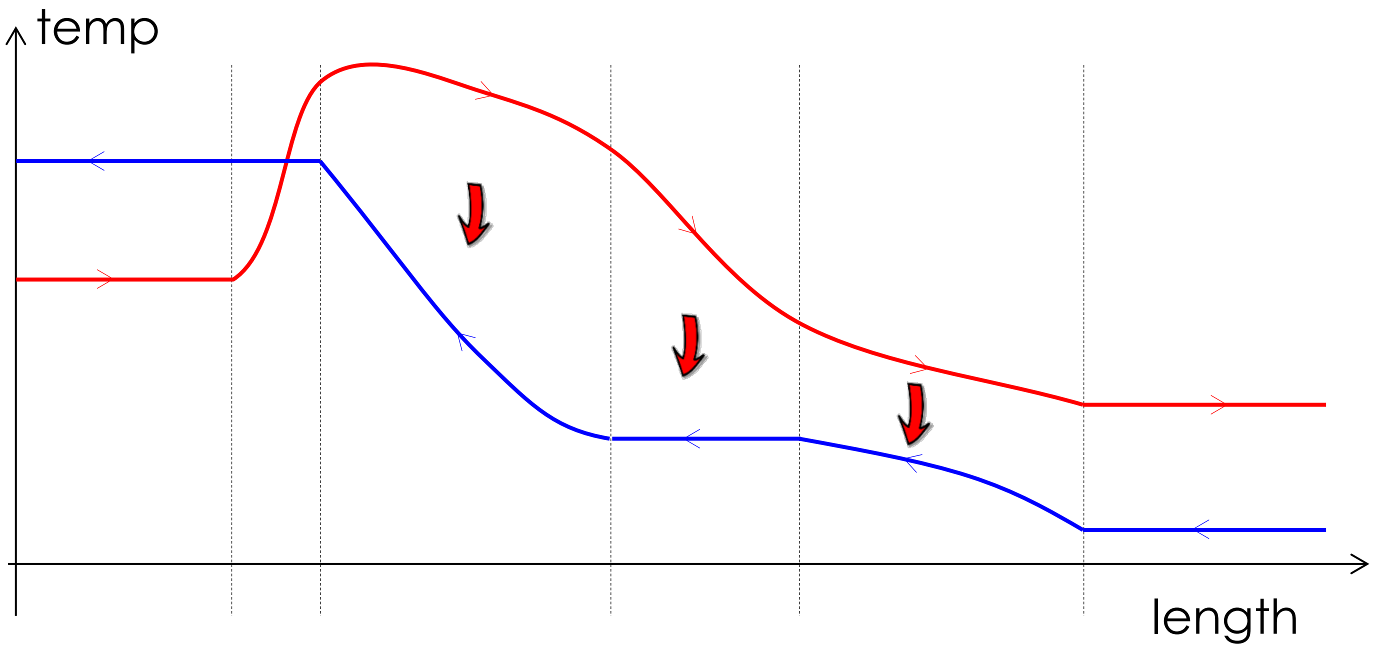


Ciclo de Brayton associado a um ciclo de Rankine com reaquecimento






turbine
process
steam
pump
super heaters
evaporator
economizers
supplementary
gas injection
(modulo 1)
combustion
gases


temp
length

Estudo comparativo Rankine, Brayton, Brayton+Rankine @ 750°C / 25°C

PARTE 1

Attention to Filler Words

água

$$w_{12} = h_1 - h_2 = -0{,}7 \text{ kJ/kg}$$

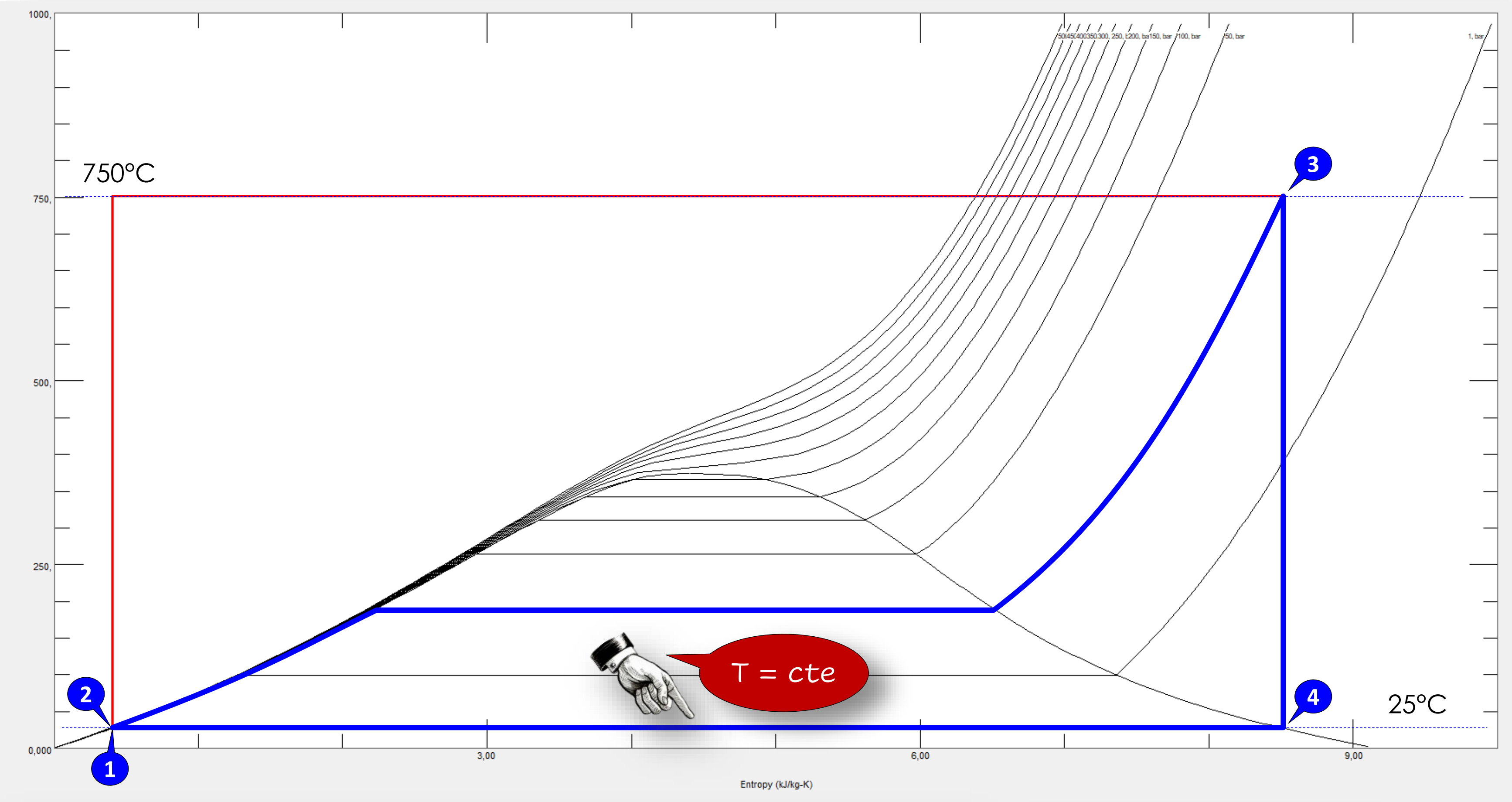
$$q_{23} = h_3 - h_2 = 3935{,}27$$

$$w_{34} = h_3 - h_4 = 1494{,}3$$

$$q_{41} = h_1 - h_4 = -2441{,}67$$

$$\eta = \frac{w_{12} + w_{34}}{q_{23}} = 37{,}95\%$$

Carnot = 70,9 %



27: water: Saturation points (at equilibrium)

	Temperature (°C)	Pressure (bar)	Liquid Density (kg/m³)	Vapor Density (kg/m³)	Liquid Volume (m³/kg)	Vapor Volume (m³/kg)	Liquid Int. Energy (kJ/kg)	Vapor Int. Energy (kJ/kg)	Liquid Enthalpy (kJ/kg)	Vapor Enthalpy (kJ/kg)	Liquid Entropy (kJ/kg-K)	Vapor Entropy (kJ/kg-K)
1	25,000	0,031699	997,00	0,023075	0,0010030	43,337	104,83	2409,1	104,83	2546,5	0,36722	8,5566
2												

28: water: Specified state points

	Temperature (°C)	Pressure (bar)	Density (kg/m³)	Volume (m³/kg)	Int. Energy (kJ/kg)	Enthalpy (kJ/kg)	Entropy (kJ/kg-K)	Quality (kg/kg)
1	750,00	7,0017	1,4851	0,67333	3569,4	4040,8	8,5566	Superheated
2	25,012	7,0017	997,31	0,0010027	104,82	105,53	0,36722	Subcooled
3								

nitrogênio @ 100bar

$$w_{12} = h_1 - h_2 = -184{,}38 \text{ kJ/kg}$$

$$q_{34} = h_4 - h_3 = +405{,}17$$

$$w_{45} = h_4 - h_5 = +407{,}21$$

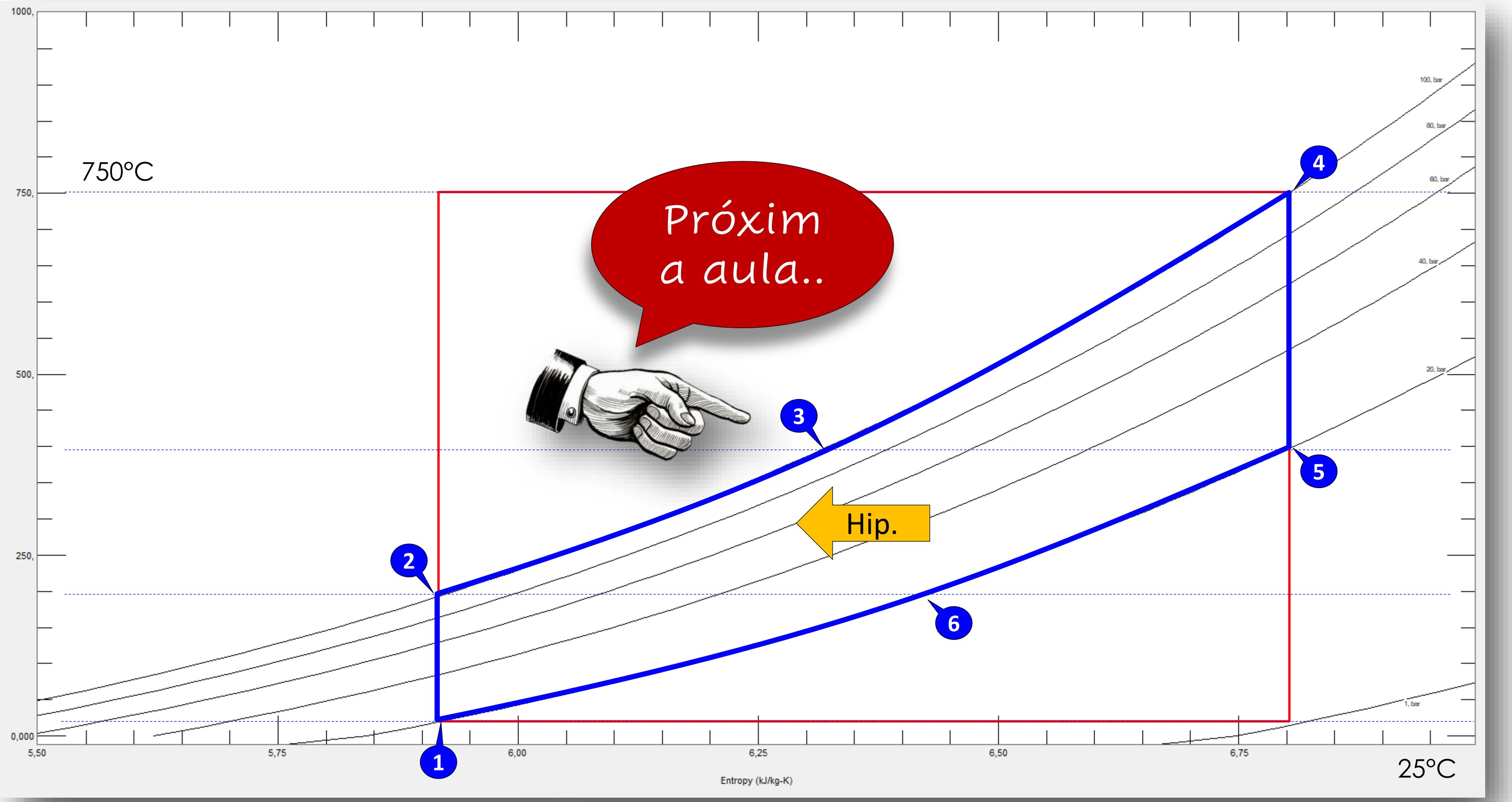
$$q_{61} = h_1 - h_6 = -187{,}51$$

$$\eta = \frac{w_{12} + w_{45}}{q_{34}} = 54{,}99\%$$

$$q_{23} = h_3 - h_2 = +215{,}45$$

$$q_{61} = h_1 - h_6 = -210{,}28$$

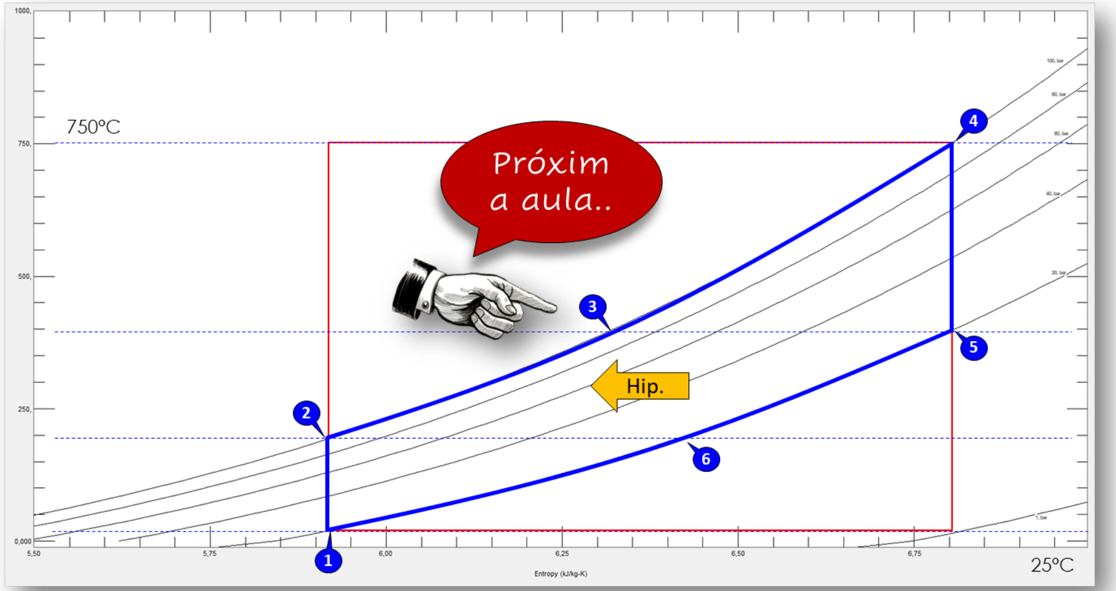
Carnot = 70,9 %

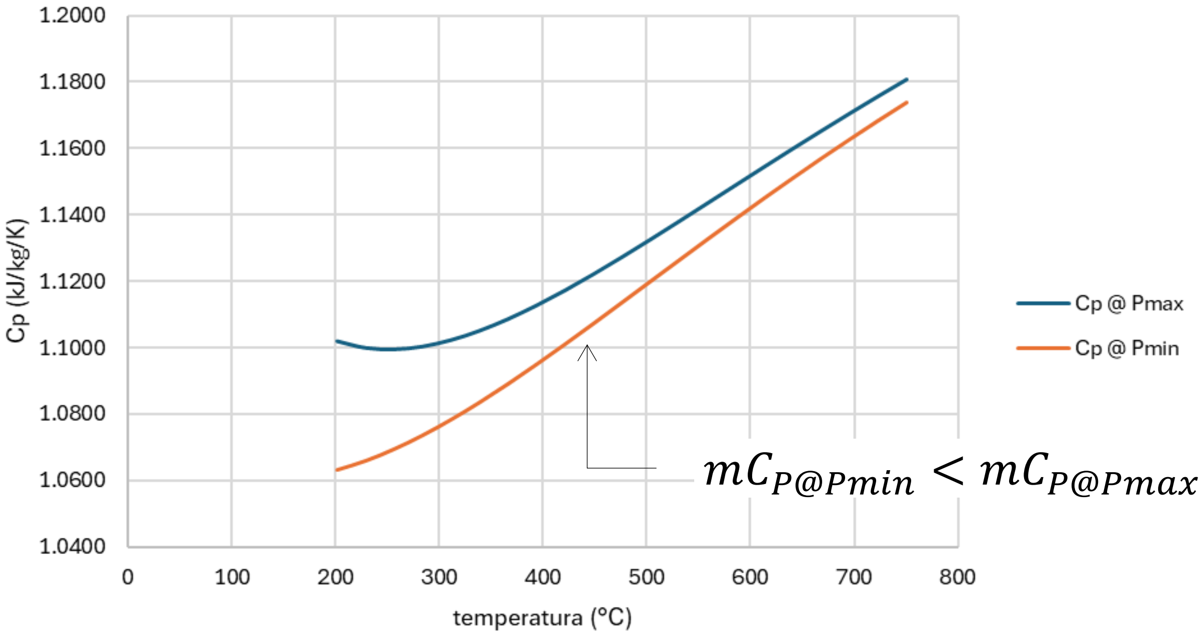


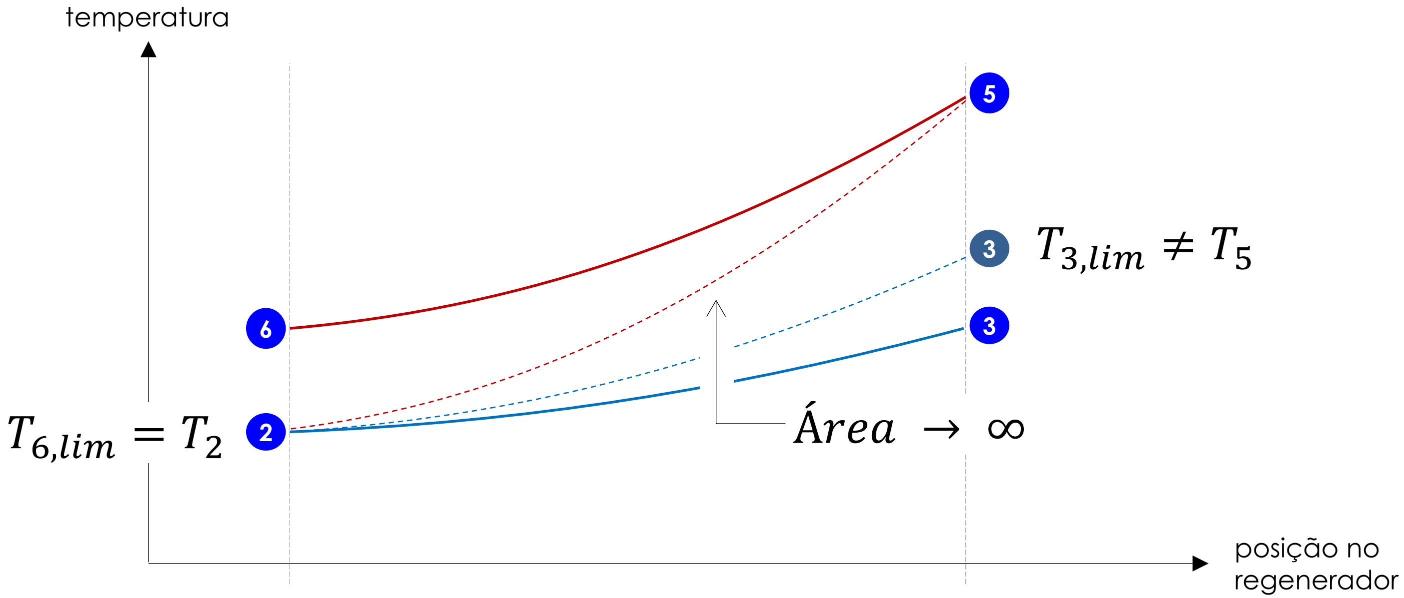
$$q_{23} \neq q_{56}$$ ⁉

34: nitrogen: Specified state points

	Temperature (°C)	Pressure (bar)	Density (kg/m³)	Volume (m³/kg)	Int. Energy (kJ/kg)	Enthalpy (kJ/kg)	Entropy (kJ/kg-K)	Quality (kg/kg)
1	25,000	20,000	22,670	0,044111	216,88	305,10	5,9371	Superheated
2	201,39	100,00	68,013	0,014703	342,45	489,48	5,9371	Undefined
3	396,62	100,00	48,201	0,020747	497,46	704,93	6,3173	Undefined
4	750,00	100,00	31,837	0,031410	796,02	1110,1	6,8021	Undefined
5	396,62	20,000	9,9766	0,10023	502,42	702,89	6,8021	Superheated
6	201,39	20,000	14,089	0,070976	350,65	492,61	6,4313	Superheated
7								


750°C
Próxim a aula..
Hip.
25°C
1
2
3
4
5
6


Cp (kJ/kg/K)
temperatura (°C)
Cp @ Pmax
Cp @ Pmin
$mC_{P@Pmin} < mC_{P@Pmax}$

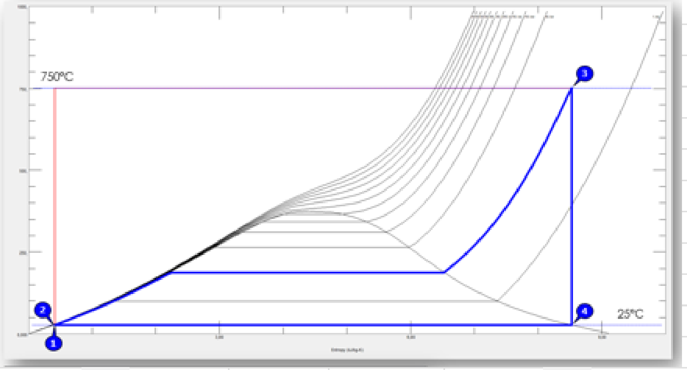

temperatura
posição no regenerador
$T_{6,lim} = T_2$
$T_{3,lim} \neq T_5$
$Área \rightarrow \infty$
2
3
3
5
6

@ sat

fixo

	A	B	C	E	F	G
1	fluido	water				
2	Pmin	0.0317	bar			
3	Tmin	25.0000	ºC			
4	hmin	104.8292	kJ/kg	w12	-0.6989	kJ/kg
5	smin	0.3672	kJ/kg/K	q23	3935.2809	kJ/kg
6				w34	1494.3036	kJ/kg
7	Pmax	7.0010	bar	q41	-2441.6762	kJ/kg
8	Tmax	750.0000	ºC			
9	hmax	4040.8090	kJ/kg	inbalance	0.0000	kJ/kg
10	smax	8.5566	kJ/kg/K	wliq	1493.6047	kJ/kg
11				rend	37.95%	

P1	T1	h1	s1	P2	T2	h2	s2	P3	T3	h3	s3	P4	T4	h4	s4
0.0317	25.0000	104.8292	0.3672	7.0010	25.0128	105.5281	0.3672	7.0010	750.0000	4040.8090	8.5566	0.0317	25.0000	2546.5054	8.5566



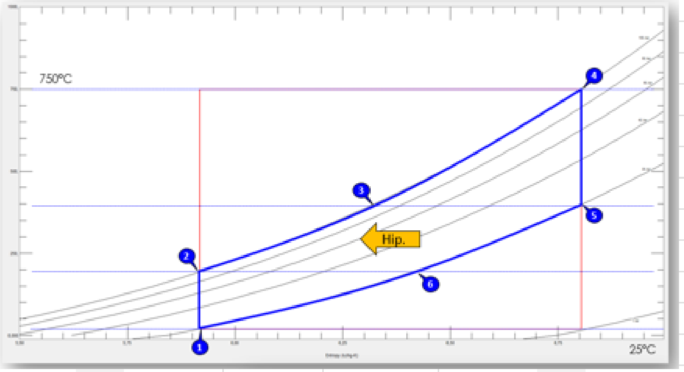
	A	B	C	E	F	G
18	fluido	nitrogen				
19	Pmin	20.0000	bar			
20	Tmin	25.0000	ºC			
21	hmin	305.0985	kJ/kg			
22	smin	5.9371	kJ/kg/K			
24	Pmax	100.0000	bar	w12	-184.3611	kJ/kg
25	Tmax	750.0000	ºC	q23	215.4369	kJ/kg
26	hmax	1110.1129	kJ/kg	q34	405.2164	kJ/kg
27	smax	6.8021	kJ/kg/K	w45	407.2534	kJ/kg
28				q56	-210.2743	kJ/kg
29				q61	-187.4867	kJ/kg @
31				imbal	0.0000	kJ/kg
32				imbal int	5.1626	kJ/kg
33				wliq	222.8923	kJ/kg
34				rend	55.01%	

P1	T1	h1	s1	P2	T2	h2	s2	P4	T4	h4	s4	P5	T5	h5	s5
20.0000	25.0000	305.0985	5.9371	100.0000	201.3703	489.4596	5.9371	100.0000	750.0000	1110.1129	6.8021	20.0000	396.5907	702.8595	6.8021

P3	T3	h3	s3	P6	T6	h6	s6
100.0000	396.5907	704.8965	6.3172	20.0000	201.3703	492.5852	6.4312

Calor trocada a alta temperatura

T61avg	113.1851	ºC
e61avg	42.8125	kJ/kg
e61/wliq	19.2%	



cálculo das vazões mássicas

$$Q_{61} + Q_{89} = 0$$

$$m_B \cdot (h_1 - h_6) + m_R \cdot (h_9 - h_8) = 0$$

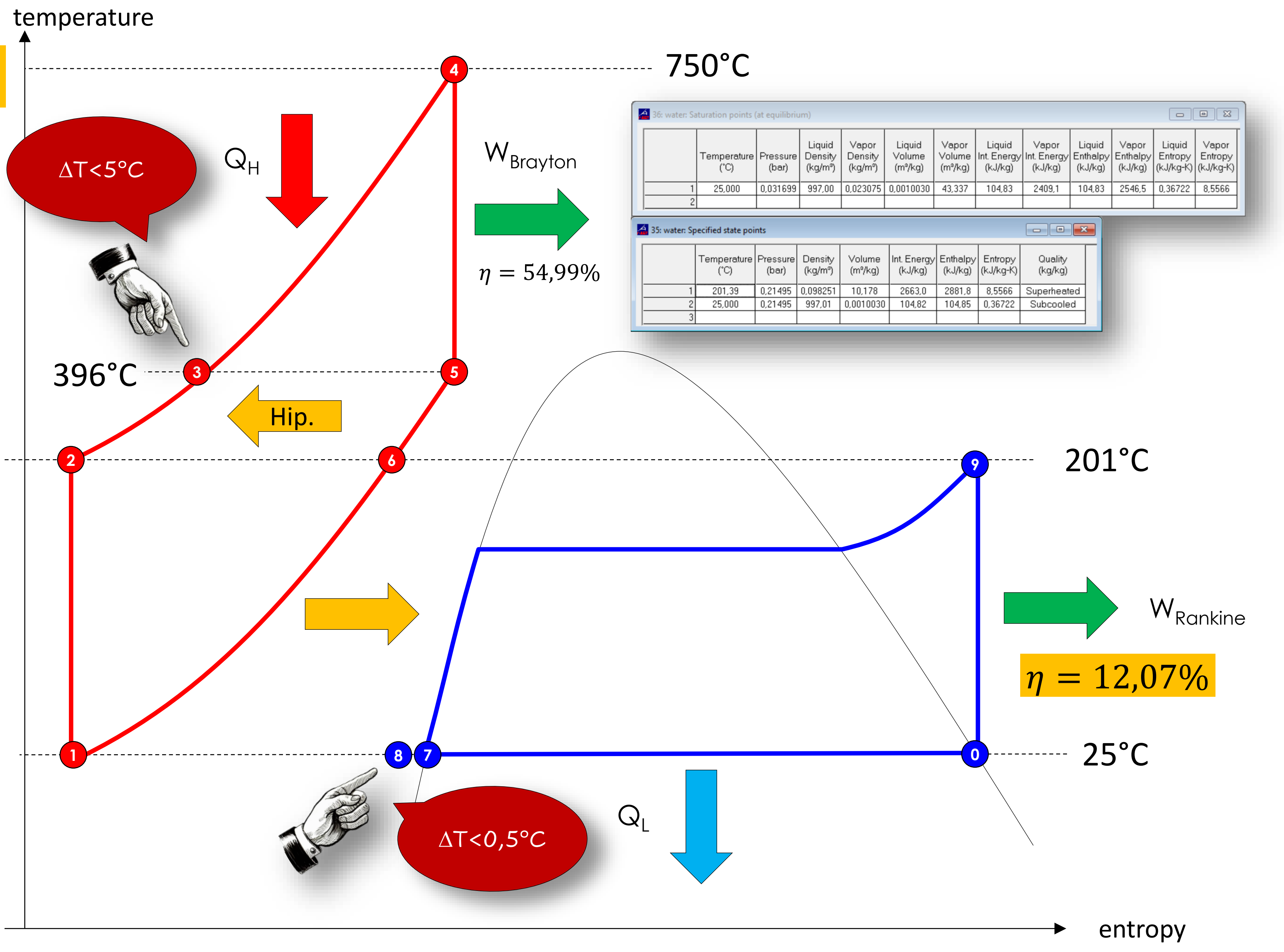
$$\alpha = \frac{m_B}{m_R} = \frac{h_9 - h_8}{h_6 - h_1} = 14{,}81$$

$$\eta = \frac{\alpha(w_{45} + w_{12}) + (w_{90} + w_{78})}{\alpha q_{34}}$$

$$\eta = \cdots = 60{,}58\%$$

$$\Delta\eta = 5{,}58\%$$

Carnot = 70,9 %



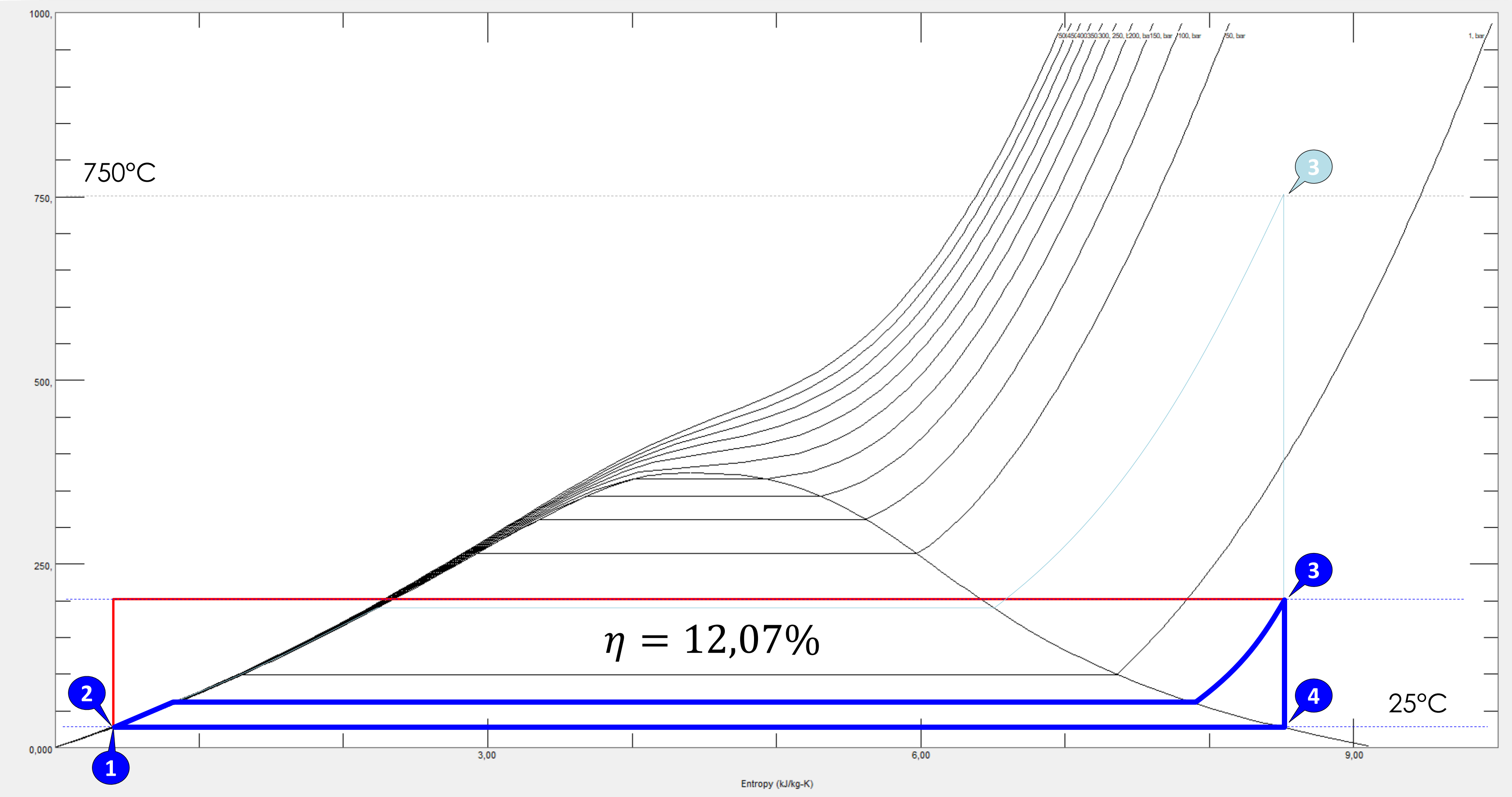
36: water: Saturation points (at equilibrium)

	Temperature (°C)	Pressure (bar)	Liquid Density (kg/m³)	Vapor Density (kg/m³)	Liquid Volume (m³/kg)	Vapor Volume (m³/kg)	Liquid Int. Energy (kJ/kg)	Vapor Int. Energy (kJ/kg)	Liquid Enthalpy (kJ/kg)	Vapor Enthalpy (kJ/kg)	Liquid Entropy (kJ/kg-K)	Vapor Entropy (kJ/kg-K)
1	25,000	0,031699	997,00	0,023075	0,0010030	43,337	104,83	2409,1	104,83	2546,5	0,36722	8,5566
2												

35: water: Specified state points

	Temperature (°C)	Pressure (bar)	Density (kg/m³)	Volume (m³/kg)	Int. Energy (kJ/kg)	Enthalpy (kJ/kg)	Entropy (kJ/kg-K)	Quality (kg/kg)
1	201,39	0,21495	0,098251	10,178	2663,0	2881,8	8,5566	Superheated
2	25,000	0,21495	997,01	0,0010030	104,82	104,85	0,36722	Subcooled
3								

O ciclo de Rankine simples com água não é adequado a temperaturas tão baixas (25°C) e nem tão altas (750°C)



36: water: Saturation points (at equilibrium)

	Temperature (°C)	Pressure (bar)	Liquid Density (kg/m³)	Vapor Density (kg/m³)	Liquid Volume (m³/kg)	Vapor Volume (m³/kg)	Liquid Int. Energy (kJ/kg)	Vapor Int. Energy (kJ/kg)	Liquid Enthalpy (kJ/kg)	Vapor Enthalpy (kJ/kg)	Liquid Entropy (kJ/kg-K)	Vapor Entropy (kJ/kg-K)
1	25,000	0,031699	997,00	0,023075	0,0010030	43,337	104,83	2409,1	104,83	2546,5	0,36722	8,5566
2												

35: water: Specified state points

	Temperature (°C)	Pressure (bar)	Density (kg/m³)	Volume (m³/kg)	Int. Energy (kJ/kg)	Enthalpy (kJ/kg)	Entropy (kJ/kg-K)	Quality (kg/kg)
1	201,39	0,21495	0,098251	10,178	2663,0	2881,8	8,5566	Superheated
2	25,000	0,21495	997,01	0,0010030	104,82	104,85	0,36722	Subcooled
3								

Carnot = 70,9 %

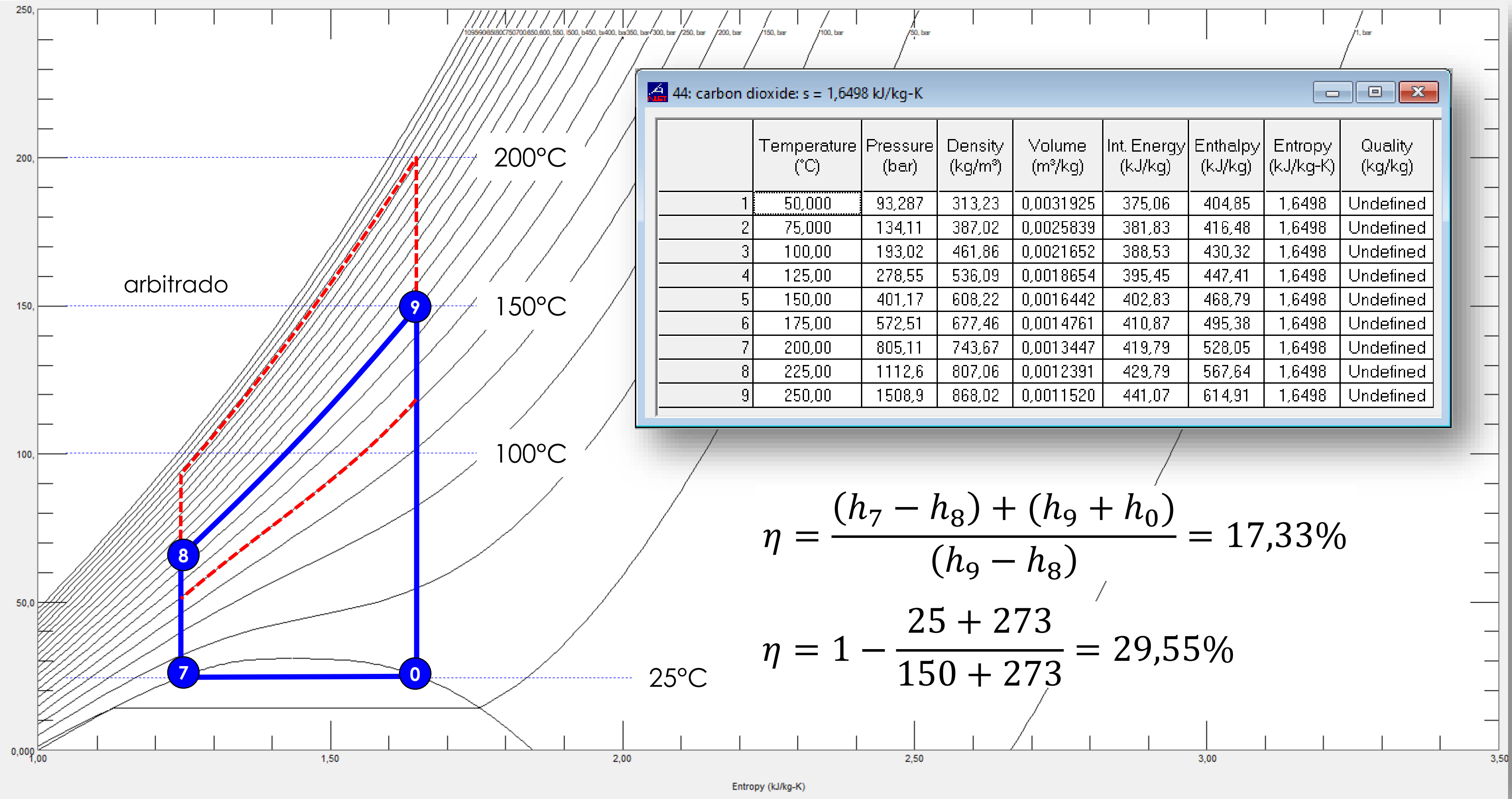
$$\alpha = \frac{m_B}{m_R} = \frac{h_9 - h_8}{h_6 - h_1} = 0{,}746$$

$$\eta = \frac{\alpha(w_{45} + w_{12}) + (w_{90} + w_{78})}{\alpha q_{34}}$$

$$\eta = \cdots = 61{,}95\%$$

$$\Delta\eta = 6{,}96\%$$

Carnot = 70,9 %



44: carbon dioxide: s = 1,6498 kJ/kg-K

	Temperature (°C)	Pressure (bar)	Density (kg/m³)	Volume (m³/kg)	Int. Energy (kJ/kg)	Enthalpy (kJ/kg)	Entropy (kJ/kg-K)	Quality (kg/kg)
1	50,000	93,287	313,23	0,0031925	375,06	404,85	1,6498	Undefined
2	75,000	134,11	387,02	0,0025839	381,83	416,48	1,6498	Undefined
3	100,00	193,02	461,86	0,0021652	388,53	430,32	1,6498	Undefined
4	125,00	278,55	536,09	0,0018654	395,45	447,41	1,6498	Undefined
5	150,00	401,17	608,22	0,0016442	402,83	468,79	1,6498	Undefined
6	175,00	572,51	677,46	0,0014761	410,87	495,38	1,6498	Undefined
7	200,00	805,11	743,67	0,0013447	419,79	528,05	1,6498	Undefined
8	225,00	1112,6	807,06	0,0012391	429,79	567,64	1,6498	Undefined
9	250,00	1508,9	868,02	0,0011520	441,07	614,91	1,6498	Undefined

$$\eta = \frac{(h_7 - h_8) + (h_9 + h_0)}{(h_9 - h_8)} = 17{,}33\%$$

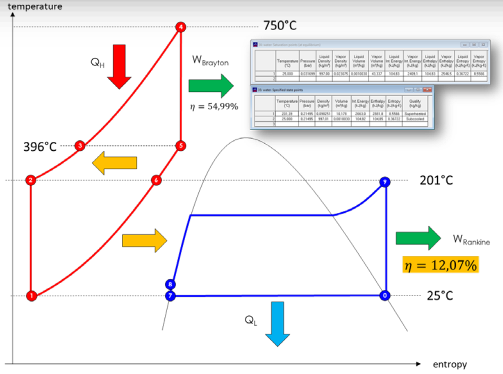
$$\eta = 1 - \frac{25 + 273}{150 + 273} = 29{,}55\%$$

38: carbon dioxide: Saturation points (at equilibrium)

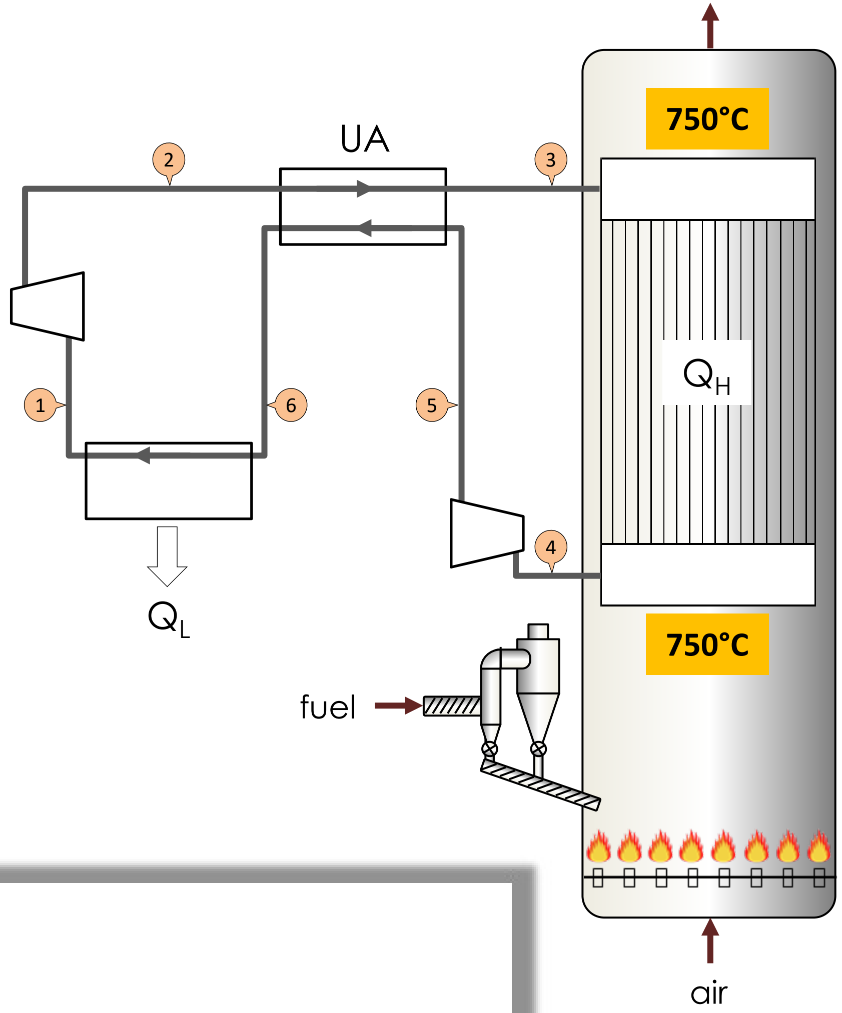
	Temperature (°C)	Pressure (bar)	Liquid Density (kg/m³)	Vapor Density (kg/m³)	Liquid Volume (m³/kg)	Vapor Volume (m³/kg)	Liquid Int. Energy (kJ/kg)	Vapor Int. Energy (kJ/kg)	Liquid Enthalpy (kJ/kg)	Vapor Enthalpy (kJ/kg)	Liquid Entropy (kJ/kg-K)	Vapor Entropy (kJ/kg-K)
1	25,000	64,342	710,50	242,73	0,0014075	0,0041198	265,73	367,92	274,78	394,43	1,2485	1,6498
2												

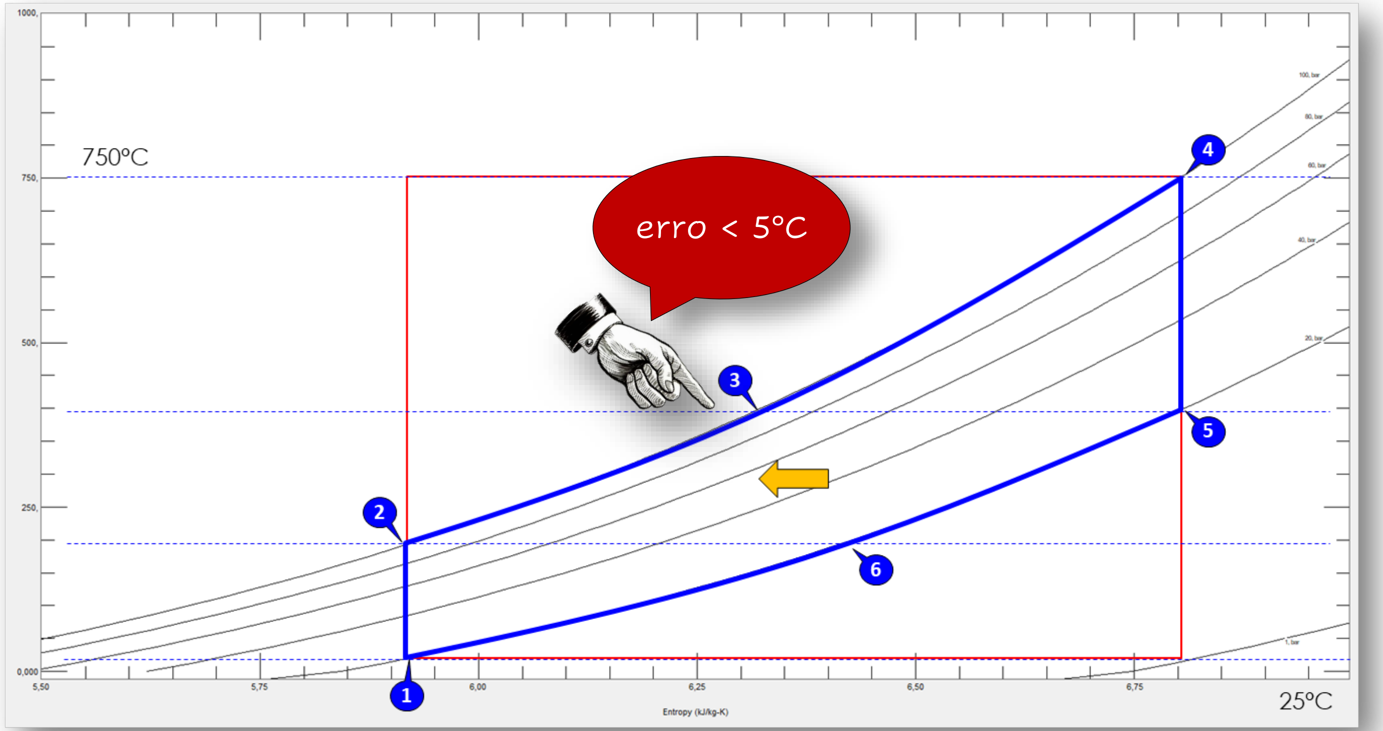
47: carbon dioxide: Specified state points

	Temperature (°C)	Pressure (bar)	Density (kg/m³)	Volume (m³/kg)	Int. Energy (kJ/kg)	Enthalpy (kJ/kg)	Entropy (kJ/kg-K)	Quality (kg/kg)
1	150,00	401,17	608,22	0,0016442	402,83	468,79	1,6498	Undefined
2	73,021	401,17	847,24	0,0011803	281,54	328,89	1,2845	Undefined
3								



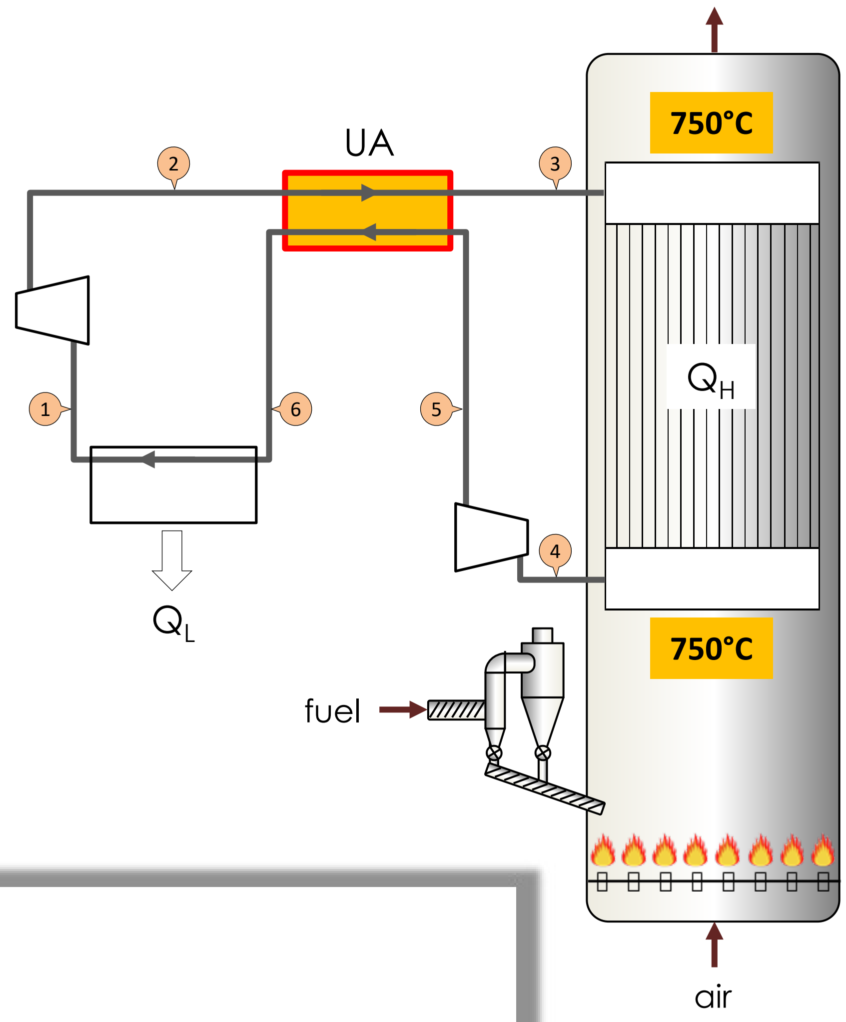
Análise entrópica do ciclo de potência...





34: nitrogen: Specified state points

	Temperature (°C)	Pressure (bar)	Density (kg/m³)	Volume (m³/kg)	Int. Energy (kJ/kg)	Enthalpy (kJ/kg)	Entropy (kJ/kg-K)	Quality (kg/kg)
1	25,000	20,000	22,670	0,044111	216,88	305,10	5,9371	Superheated
2	201,39	100,00	68,013	0,014703	342,45	489,48	5,9371	Undefined
3	396,62	100,00	48,201	0,020747	497,46	704,93	6,3173	Undefined
4	750,00	100,00	31,837	0,031410	796,02	1110,1	6,8021	Undefined
5	396,62	20,000	9,9766	0,10023	502,42	702,89	6,8021	Superheated
6	201,39	20,000	14,089	0,070976	350,65	492,61	6,4313	Superheated
7								



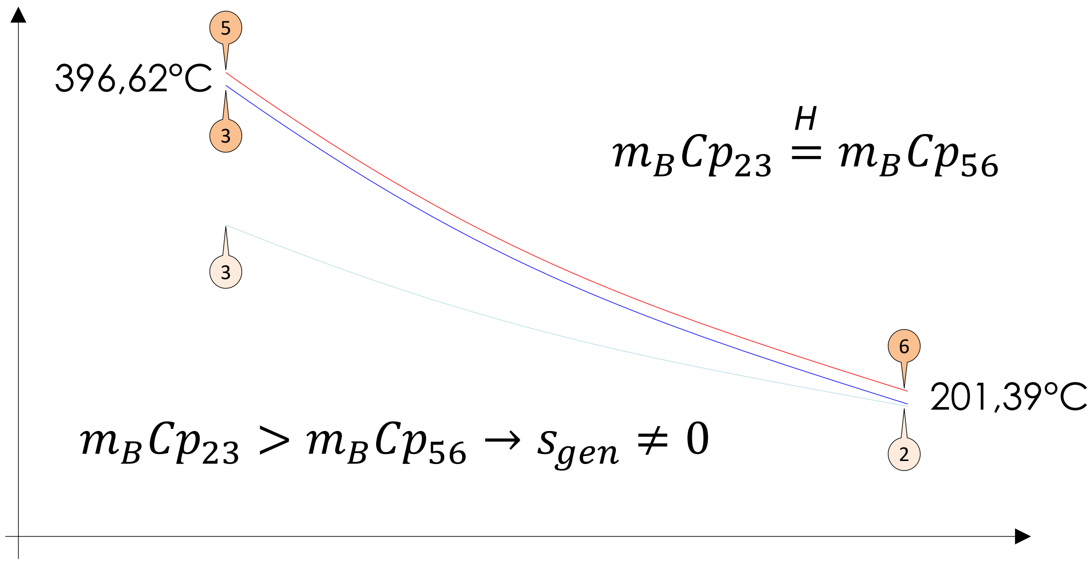
$$\Sigma \frac{Q_k}{T_k} + \Sigma m_{i,k} s_{i,k} - \Sigma m_{o,k} s_{o,k} + S_{gen} = 0$$

Obs.: regime permanente

$$S_{gen} = m_B s_3 - m_B s_2 + m_B s_6 - m_B s_5$$

$$S_{gen}/m_B = s_{gen} = s_3 - s_2 + s_6 - s_5 = \cdots < 0$$

⁉

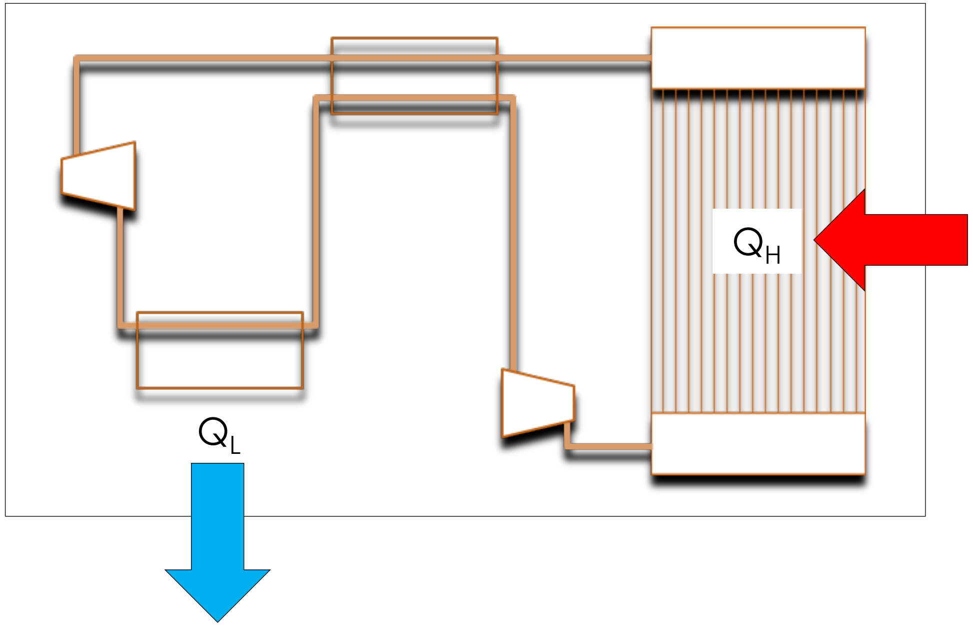


$$m_B Cp_{23} \overset{H}{=} m_B Cp_{56}$$

$$m_B Cp_{23} > m_B Cp_{56} \rightarrow s_{gen} \neq 0$$

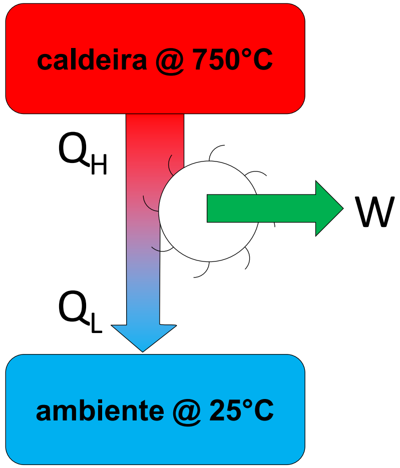
$$\Sigma\frac{Q_k}{T_k} + \Sigma m_{i,k}s_{i,k} - \Sigma m_{o,k}s_{o,k} + S_{gen} = 0$$

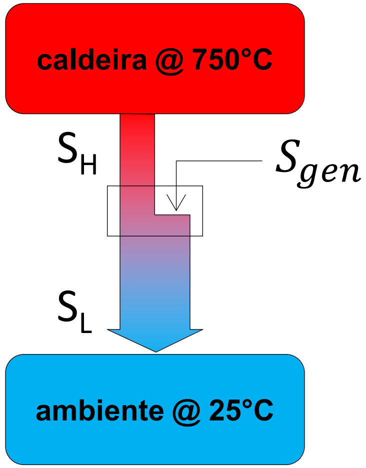
Obs.: regime permanente



$$\frac{Q_H}{T_H} + \frac{Q_L}{T_L} + S_{gen} = 0 \rightarrow S_{gen} = \frac{-Q_H}{T_H} + \frac{-Q_L}{T_L}$$

$$S_{gen} = \frac{-m_B(h_4 - h_3)}{T_H} + \frac{-m_B(h_1 - h_6)}{T_L} \rightarrow s_{gen} = 0{,}233\ \frac{kJ}{kg\ K}$$

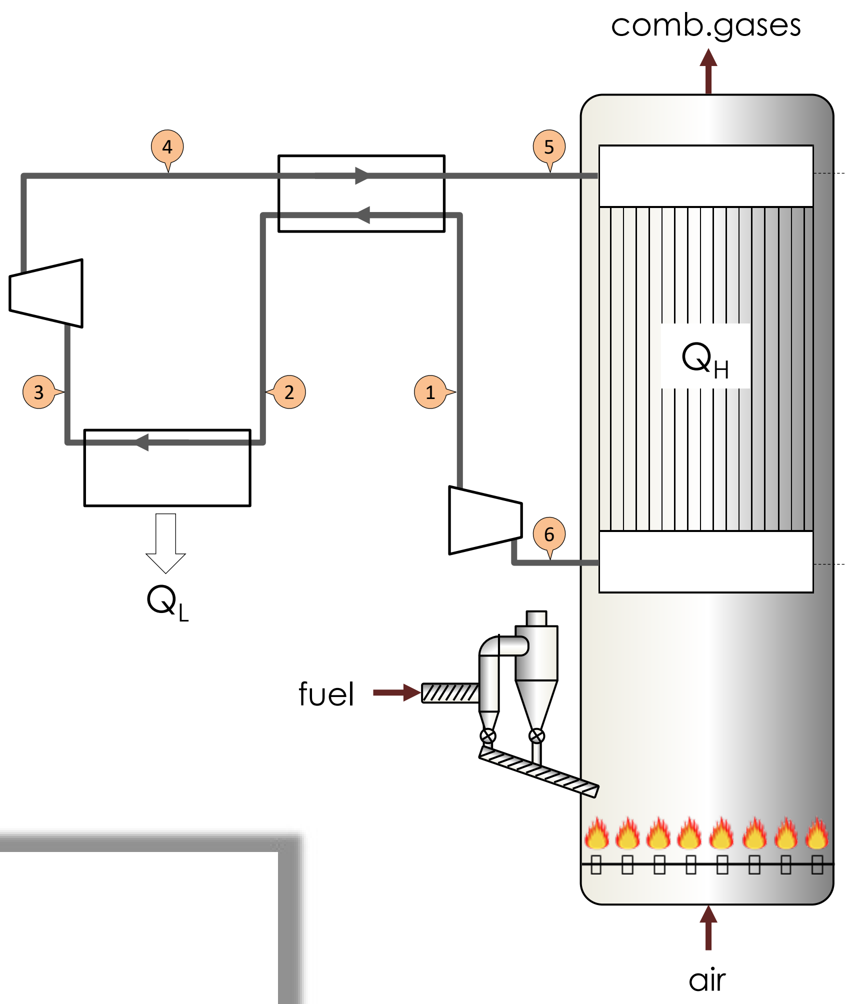


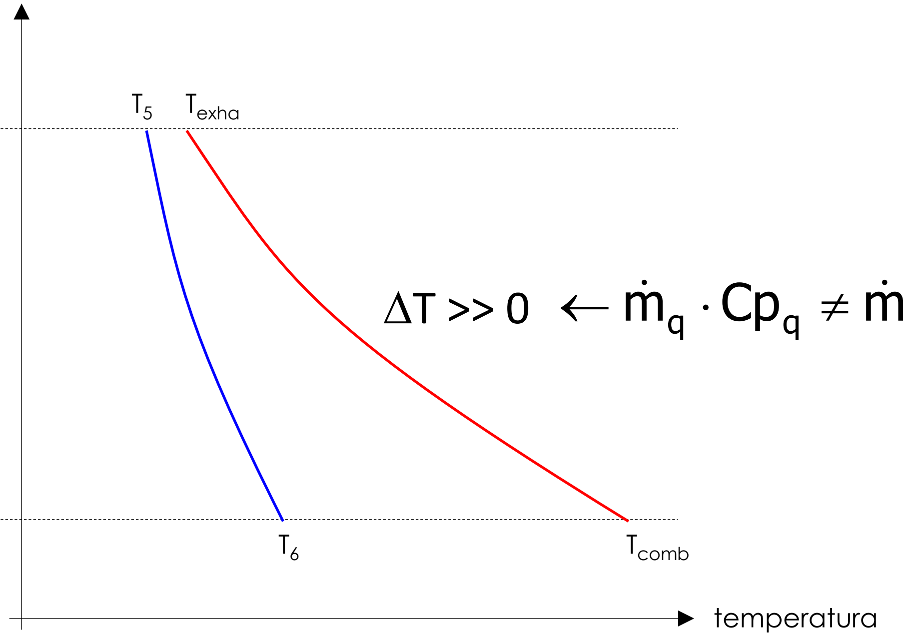


Melhor aproveitamento de uma fonte de calor → minimizar a geração de entropia.

Attention to Filler Words

Variação da temperatura da fonte (não ideal) de calor

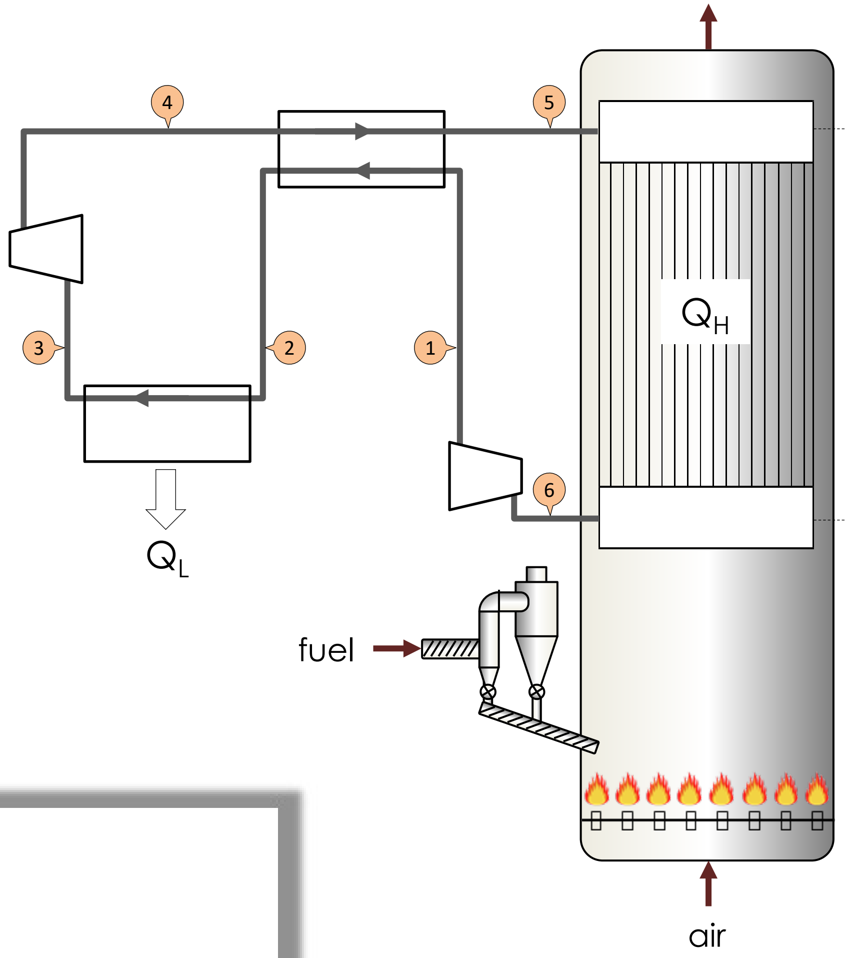


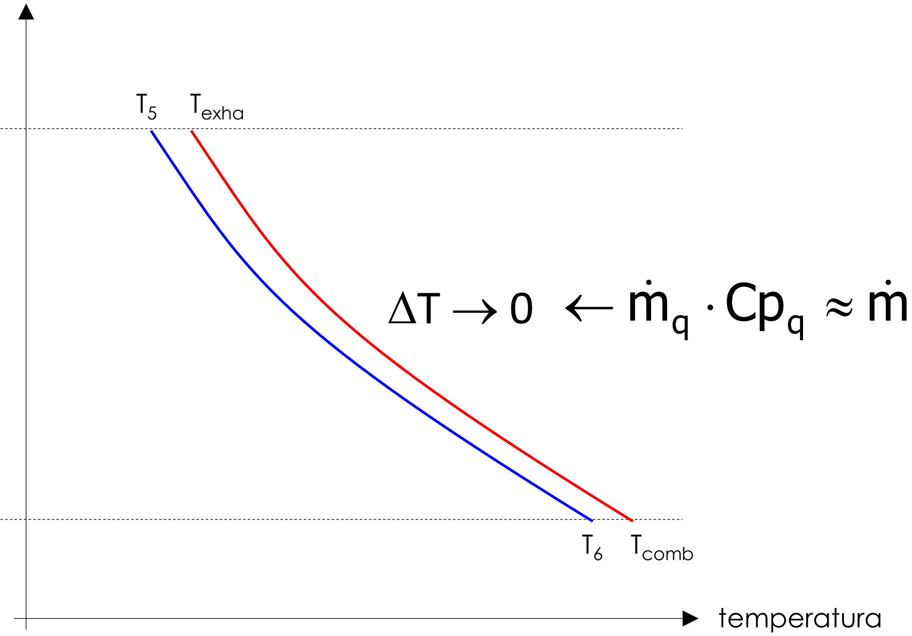


$$\Delta T >> 0 \leftarrow \dot{m}_q \cdot Cp_q \neq \dot{m}_f \cdot Cp_f$$

Pode-se tentar ajustar a pressão para aproximar as capacidades térmicas do fluido de trabalho (gás) e dos produtos de combustão...

Variação da temperatura da fonte (não ideal) de calor



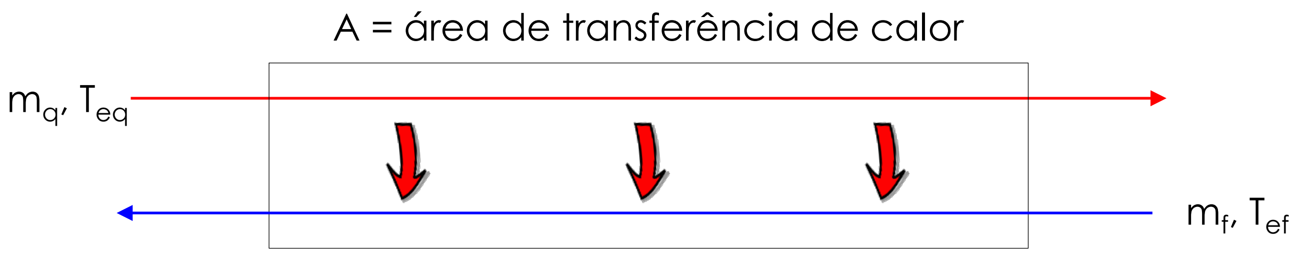


$$\Delta T \rightarrow 0 \leftarrow \dot{m}_q \cdot Cp_q \approx \dot{m}_f \cdot Cp_f$$

A geração de entropia é minimizada

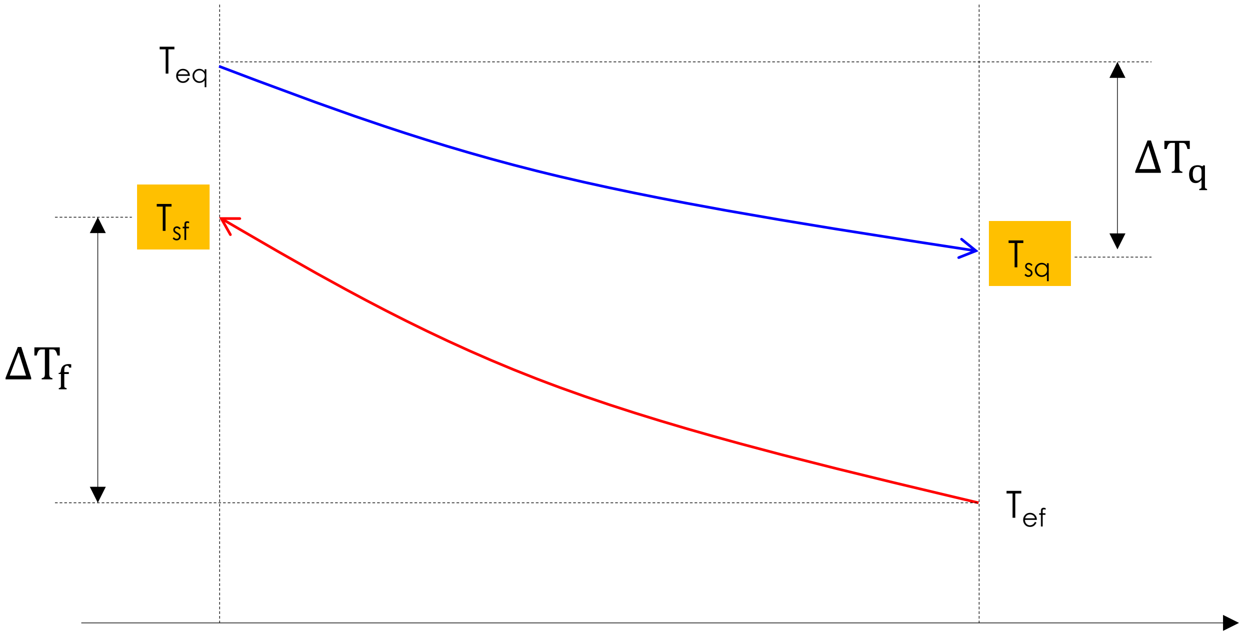
$$Q = m_q C_{P,q} \cdot (T_{eq} - T_{sq})$$

$$Q = m_f C_{P,f} \cdot (T_{ef} - T_{sf})$$



$$\Rightarrow \quad \frac{T_{eq} - T_{sq}}{T_{sf} - T_{ef}} = \frac{\Delta T_q}{\Delta T_f} = \frac{m_f C_{P,f}}{m_q C_{P,q}}$$

$$m_q C_{P,q} > m_f C_{P,f} \rightarrow \Delta T_q < \Delta T_f$$



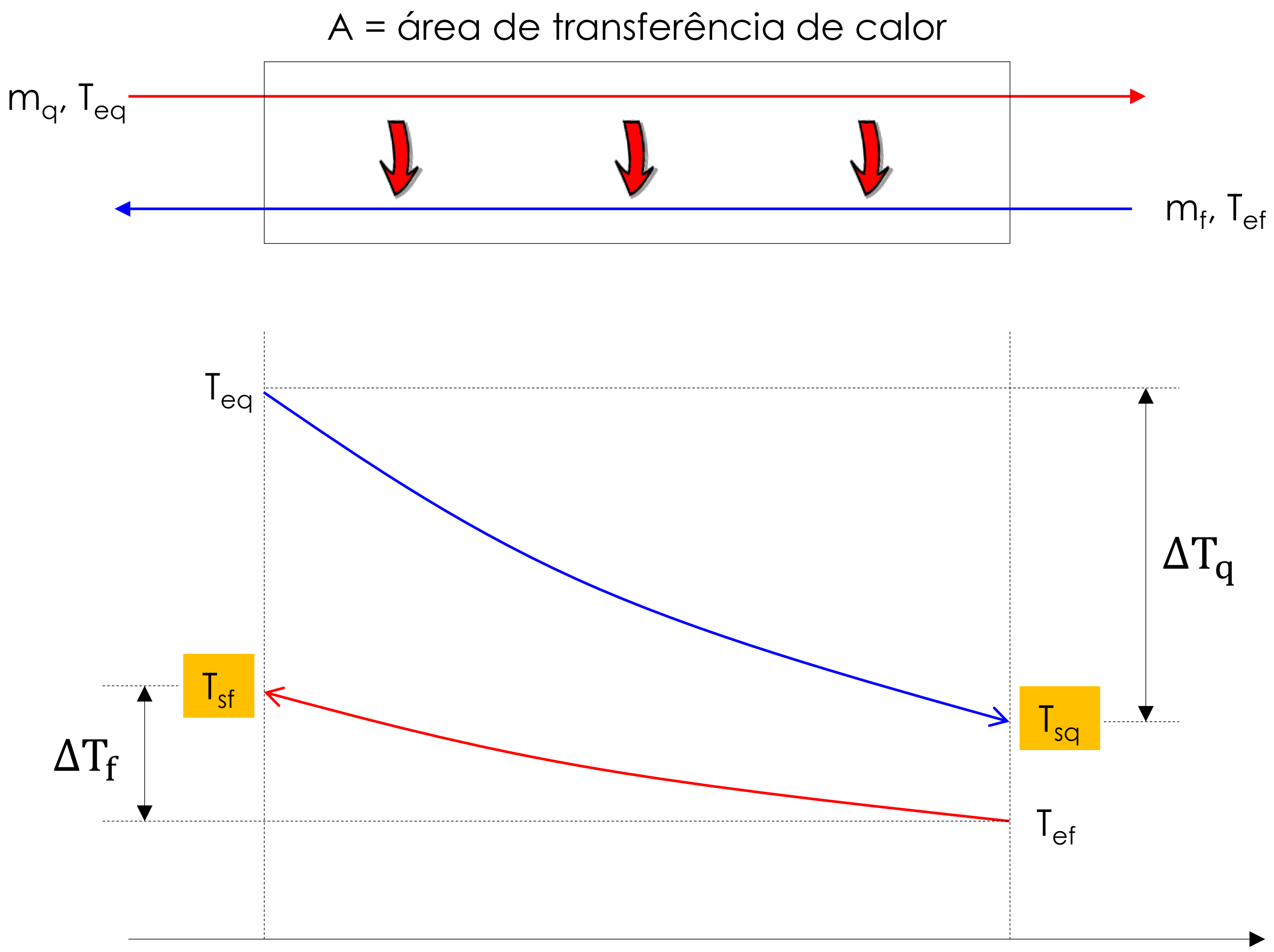
$$Q = m_q C_{P,q} \cdot (T_{eq} - T_{sq})$$

$$Q = m_f C_{P,f} \cdot (T_{ef} - T_{sf})$$

$$\Rightarrow \frac{T_{eq} - T_{sq}}{T_{sf} - T_{ef}} = \frac{\Delta T_q}{\Delta T_f} = \frac{m_f C_{P,f}}{m_q C_{P,q}}$$

$$m_q C_{P,q} > m_f C_{P,f} \rightarrow \Delta T_q < \Delta T_f$$

$$m_q C_{P,q} < m_f C_{P,f} \rightarrow \Delta T_q > \Delta T_f$$



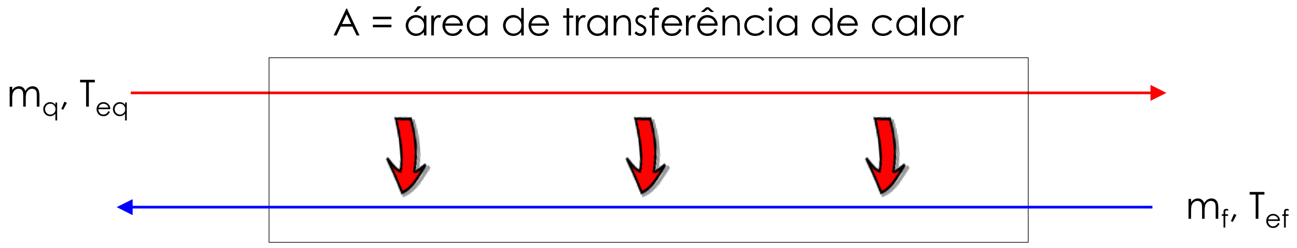
$$Q = m_q C_{P,q} \cdot (T_{eq} - T_{sq})$$

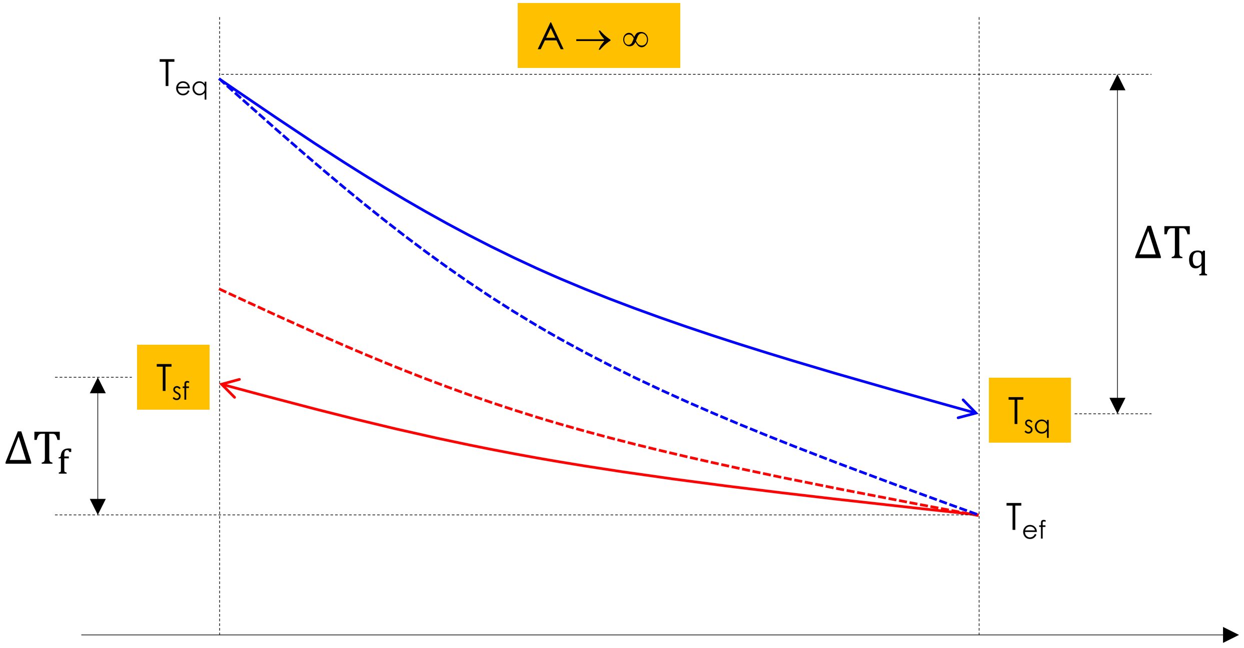
$$Q = m_f C_{P,f} \cdot (T_{ef} - T_{sf})$$

$$\Rightarrow \quad \frac{T_{eq} - T_{sq}}{T_{sf} - T_{ef}} = \frac{\Delta T_q}{\Delta T_f} = \frac{m_f C_{P,f}}{m_q C_{P,q}}$$

$$m_q C_{P,q} > m_f C_{P,f} \rightarrow \Delta T_q < \Delta T_f$$

$$m_q C_{P,q} < m_f C_{P,f} \rightarrow \Delta T_q > \Delta T_f$$





$$A \rightarrow \infty \implies T_{sq} \rightarrow T_{ef}$$

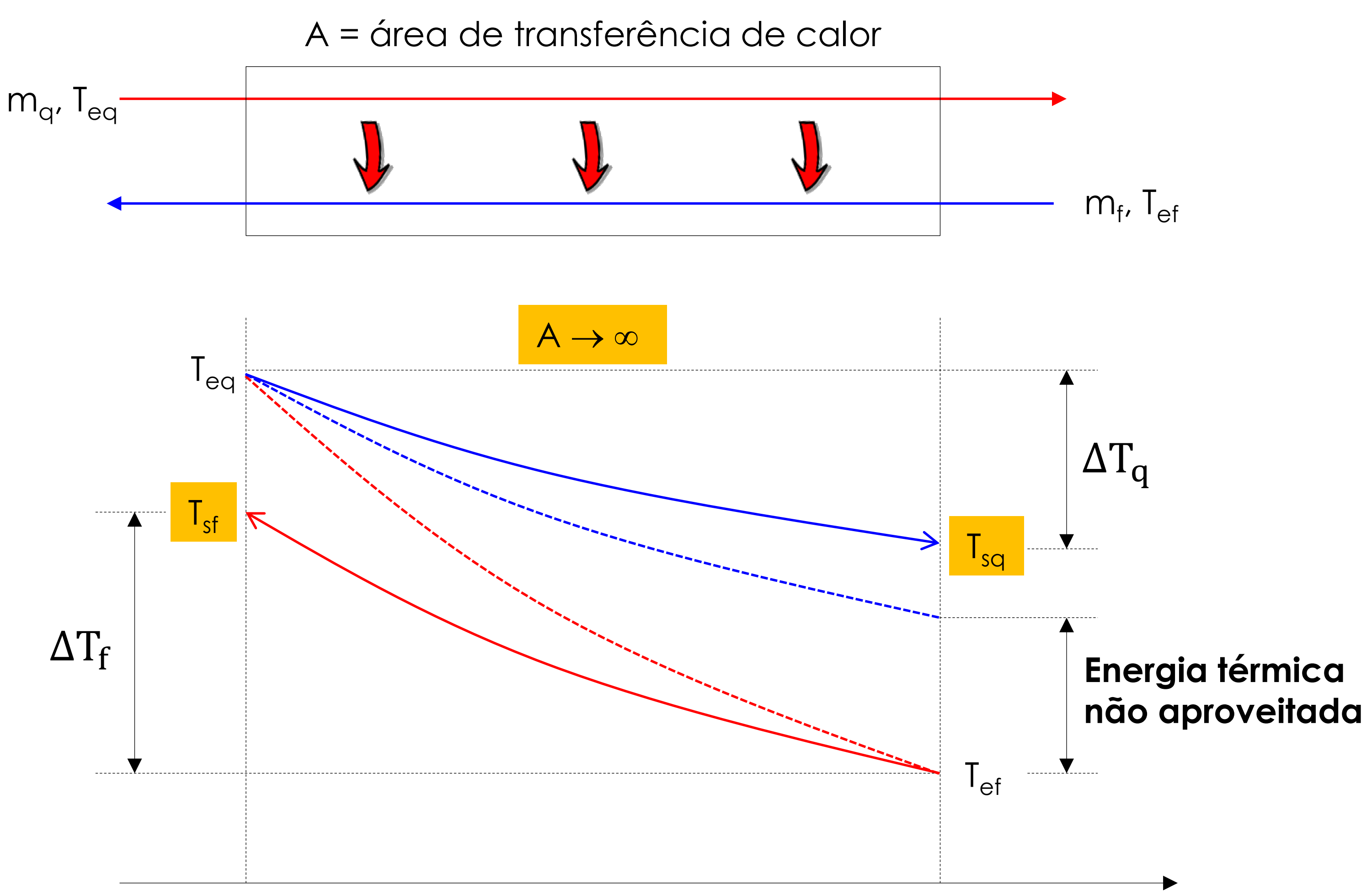
$$Q = m_q C_{P,q} \cdot (T_{eq} - T_{sq})$$

$$Q = m_f C_{P,f} \cdot (T_{ef} - T_{sf})$$

$$\Rightarrow \frac{T_{eq} - T_{sq}}{T_{sf} - T_{ef}} = \frac{\Delta T_q}{\Delta T_f} = \frac{m_f C_{P,f}}{m_q C_{P,q}}$$

$$m_q C_{P,q} > m_f C_{P,f} \rightarrow \Delta T_q < \Delta T_f$$

$$m_q C_{P,q} < m_f C_{P,f} \rightarrow \Delta T_q > \Delta T_f$$



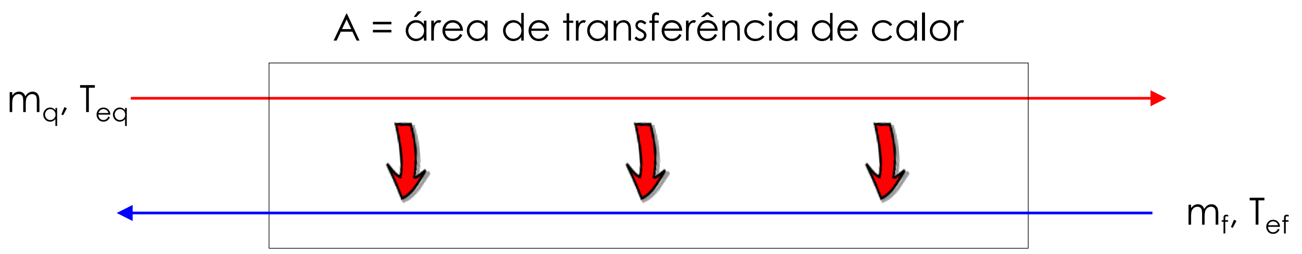
$$A \rightarrow \infty \implies T_{sf} \rightarrow T_{eq}$$

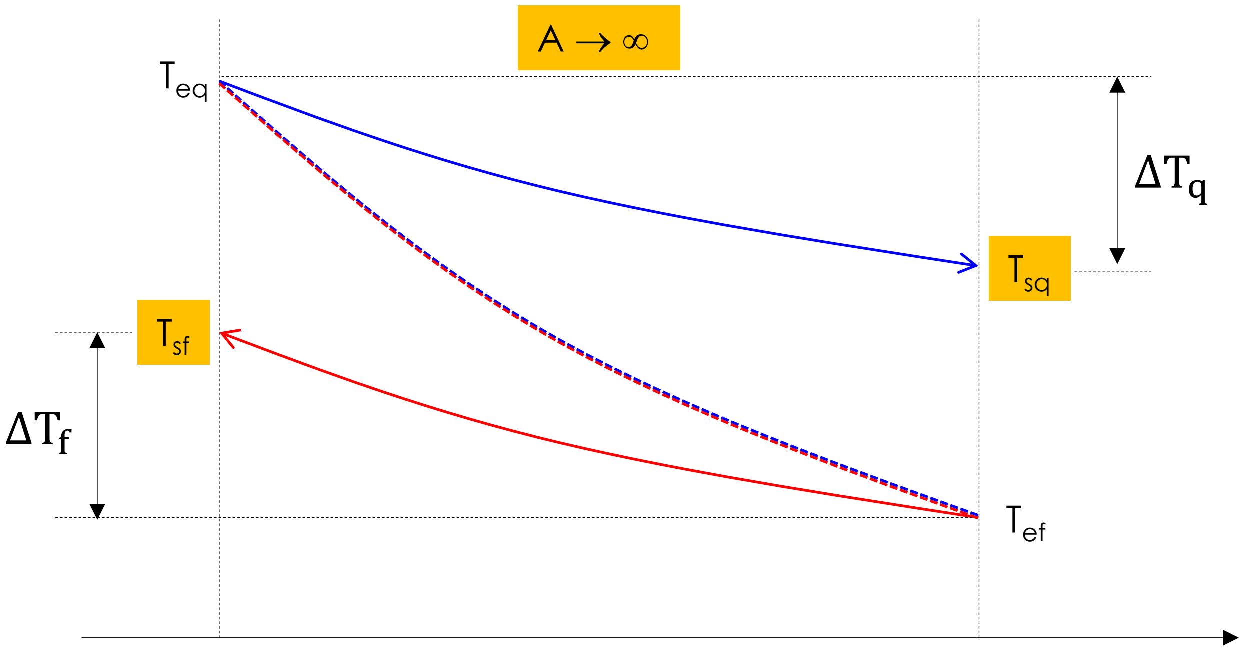
$$Q = m_q C_{P,q} \cdot (T_{eq} - T_{sq})$$

$$Q = m_f C_{P,f} \cdot (T_{ef} - T_{sf})$$

$$\Rightarrow \quad \frac{T_{eq} - T_{sq}}{T_{sf} - T_{ef}} = \frac{\Delta T_q}{\Delta T_f} = \frac{m_f C_{P,f}}{m_q C_{P,q}}$$

$$m_q C_{P,q} = m_f C_{P,f} \rightarrow \Delta T_q = \Delta T_f$$





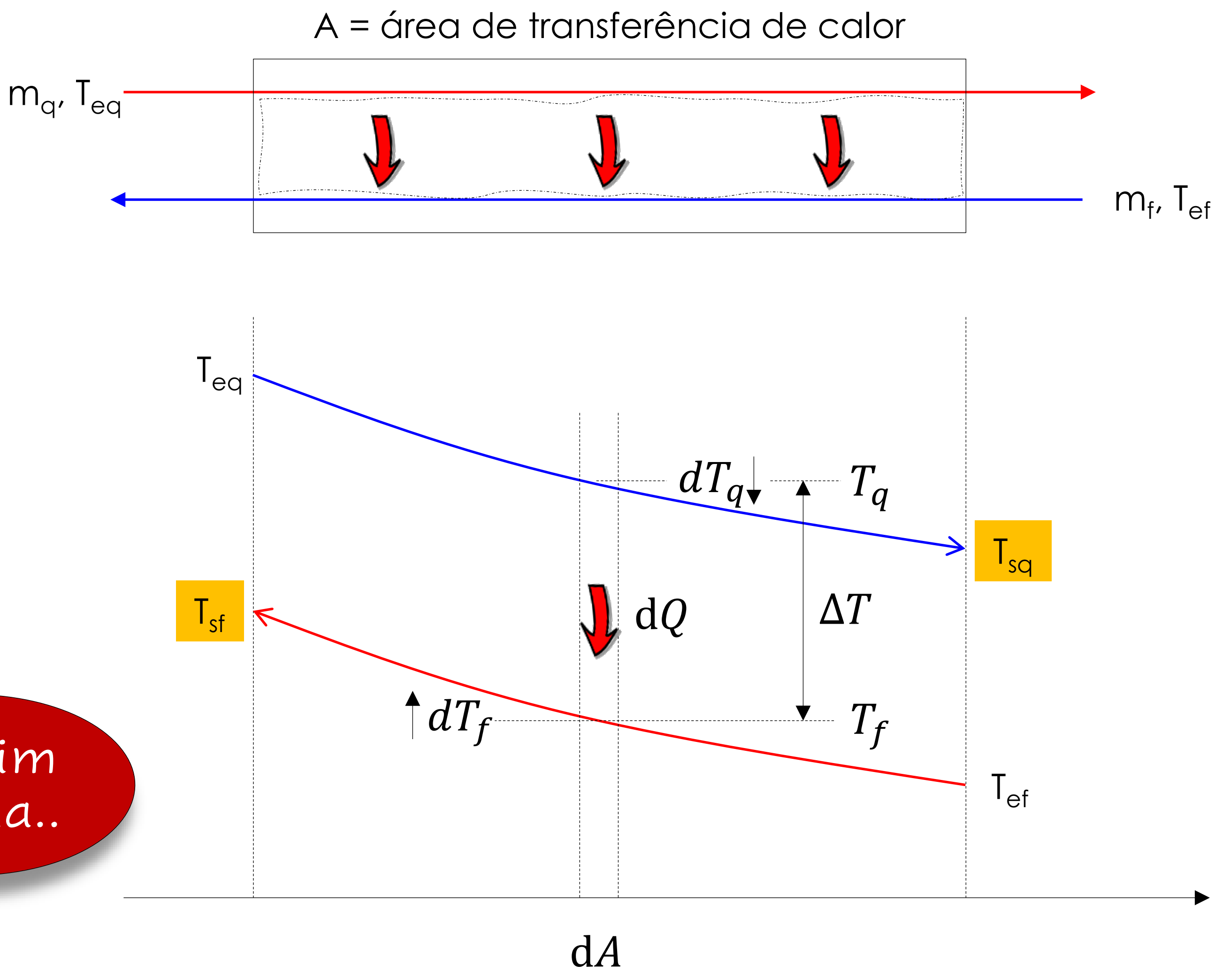
$$A \rightarrow \infty \implies T_{sf} = T_{eq} \;\text{ e }\; T_{sq} = T_{ef}$$

NÃO HÁ GERAÇÃO DE ENTROPIA ! ($T_q - T_f \equiv 0$)

$$dQ = -m_q\, C_{P,q} \cdot dT_q$$

$$dQ = -m_f\, C_{P,f} \cdot dT_f$$

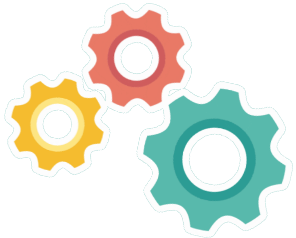
$$dQ = +U \cdot A\,(T_q - T_f)$$

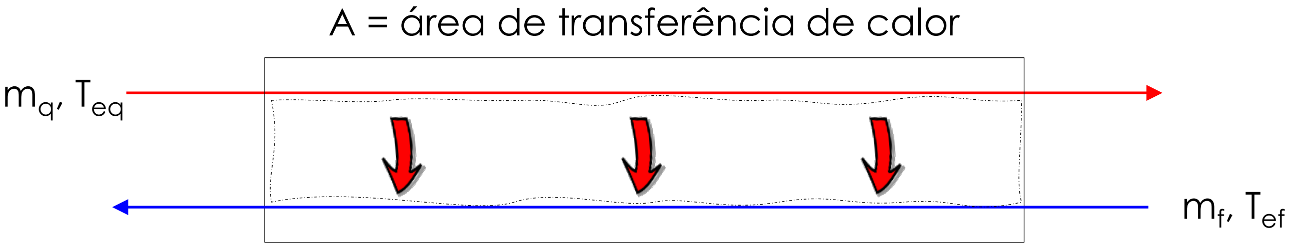


$$dQ = -m_q \, C_{P,q} \cdot dT_q$$

$$dQ = -m_f \, C_{P,f} \cdot dT_f$$

$$dQ = +U \cdot A \left(T_q - T_f \right)$$



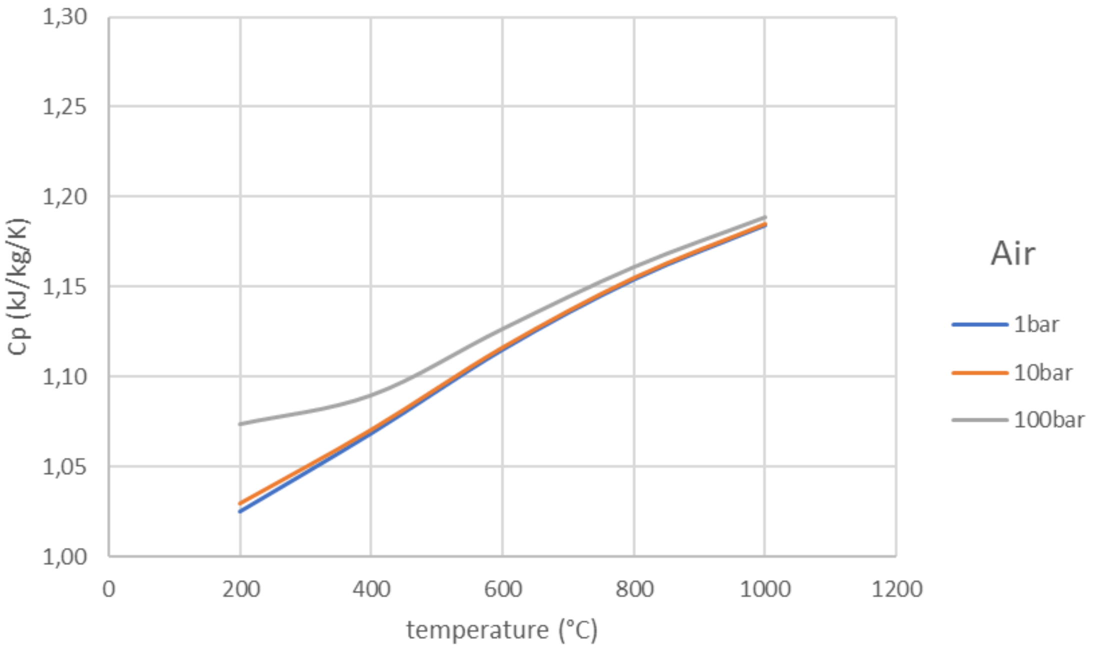


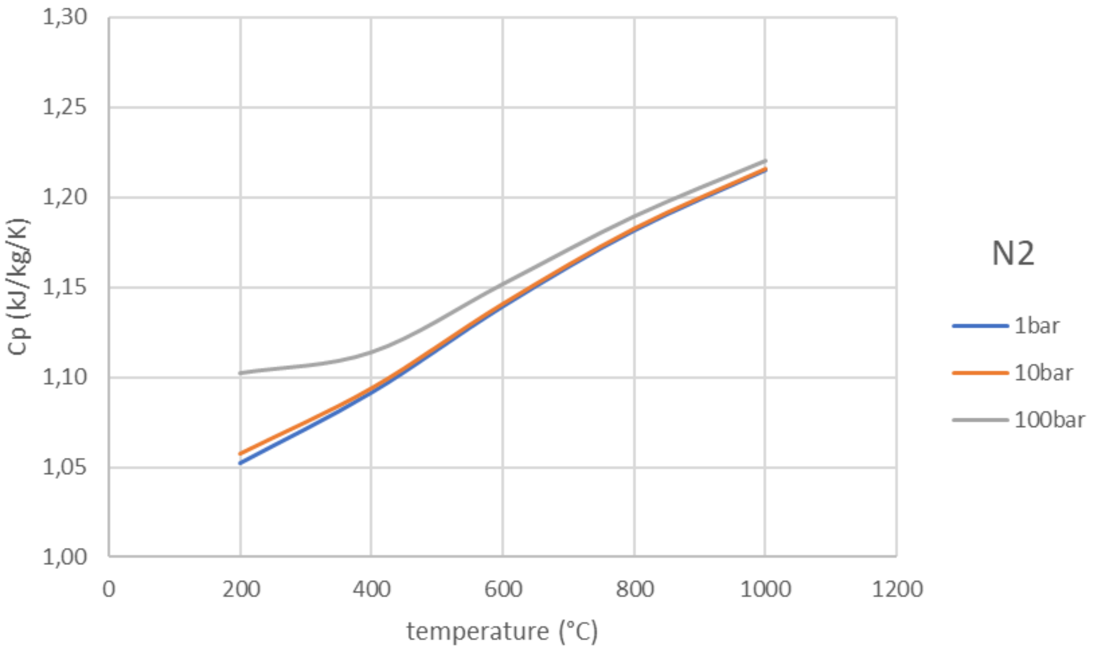
$$Q = UA \, \frac{\left(T_{eq} - T_{sf}\right) - \left(T_{sq} - T_{ef}\right)}{ln\left(\dfrac{T_{eq} - T_{sf}}{T_{sq} - T_{ef}}\right)}$$

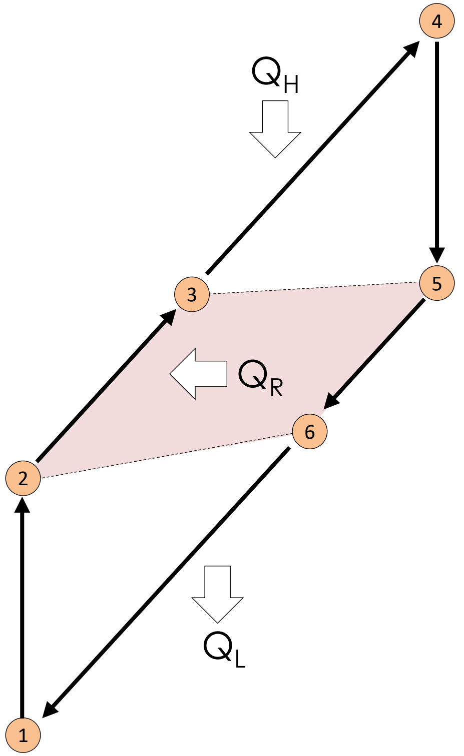
$$Q = m_q C_{P,q} \cdot \left(T_{eq} - T_{sq}\right)$$

$$Q = m_f \, C_{P,f} \cdot \left(T_{ef} - T_{sf}\right)$$

Variação do calor específico com a temperatura e pressão...



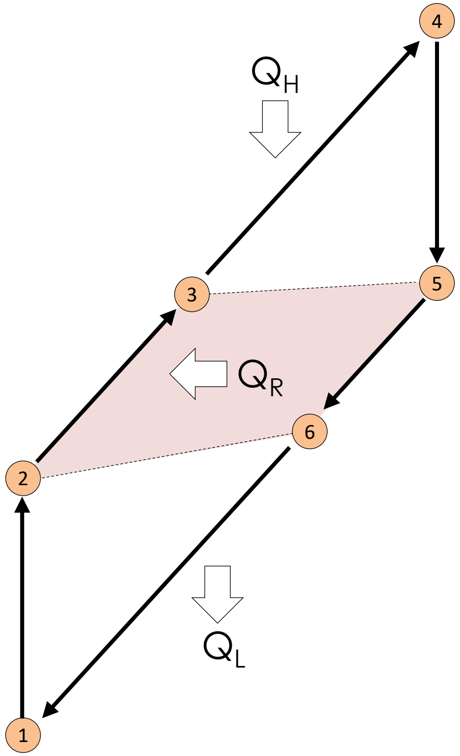




$$Q_R = UA \frac{(T_5 - T_3) - (T_6 - T_2)}{ln\left(\frac{T_5 - T_3}{T_6 - T_2}\right)}$$

$$Q_R = \dot{m} \cdot (h_5 - h_6)$$

$$Q_R = \dot{m} \cdot (h_3 - h_2)$$



$$Q_R = UA \frac{(T_5 - T_3) - (T_6 - T_2)}{ln\left(\frac{T_5 - T_3}{T_6 - T_2}\right)}$$

$$Q_R = \dot{m} \cdot (h_5 - h_6)$$

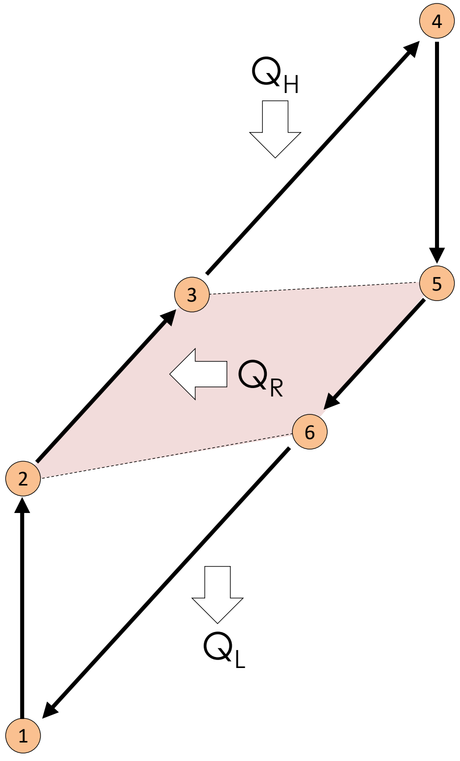
$$Q_R = \dot{m} \cdot (h_3 - h_2)$$

$$f_1 = Q_R - \dot{m} \cdot (h_3(T_3) - h_2) = 0$$

$$f_2 = Q_R - \dot{m} \cdot \left(h_5 - h_6(T_6)\right) = 0$$

$$f_3 = (T_5 - T_3) - (T_6 - T_2) \cdot exp\left(\frac{UA}{Q_R}\left((T_5 - T_3) - (T_6 - T_2)\right)\right) = 0$$

BBls proprietárias x BBLs Organizações Tabajara (Excel)

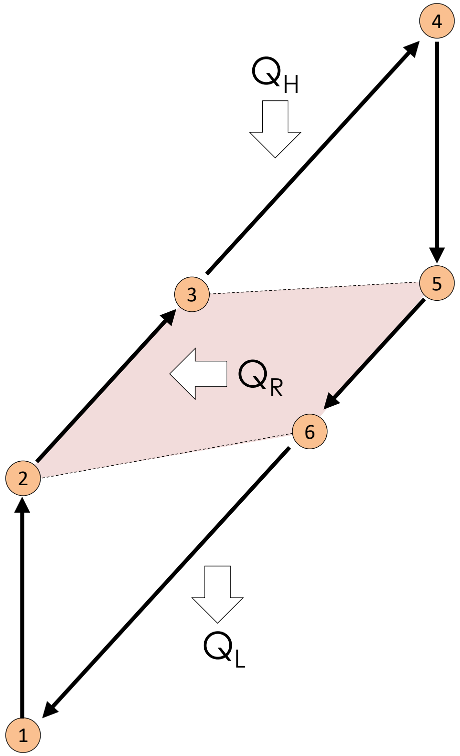


$$Q_R = \dot{m} \cdot (h_3(T_3) - T_2)$$

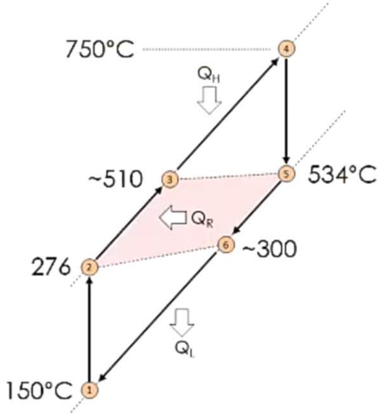
$$\hookrightarrow h_3(T_3) = h(T) \quad @ \; 100bar$$

$$Q_R = \dot{m} \cdot (h_5 - h_6(T_6))$$

$$\hookrightarrow h_6(T_6) = h(T) \quad @ \; 20bar$$



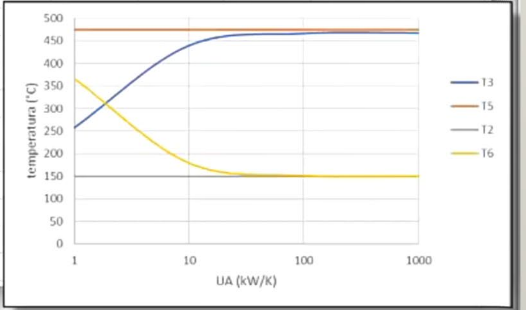
Aula 11



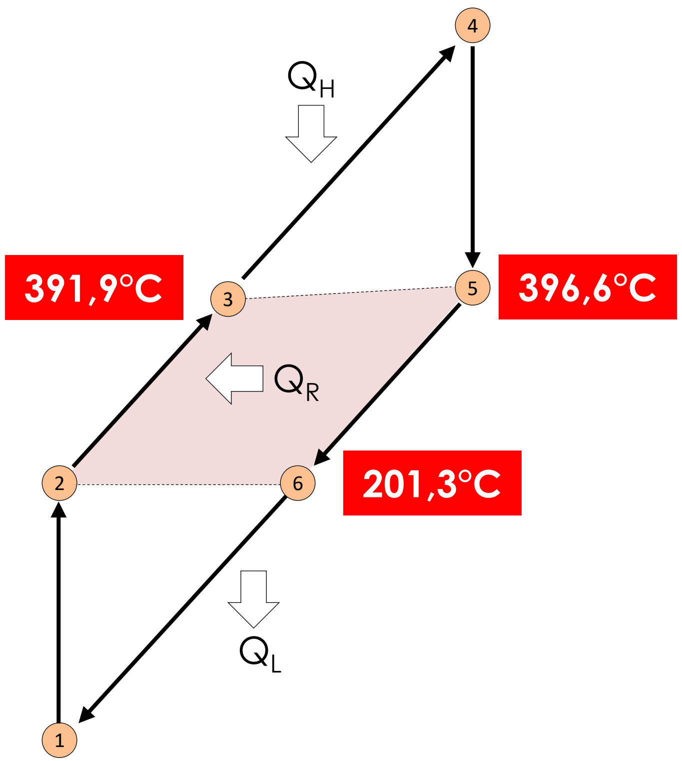
B1 | nitrogen

$$\vec{x}_{n+1} = \vec{x}_n - \left[\partial f_i / \partial x_j\right]_n^{-1} \cdot \vec{f}_n$$

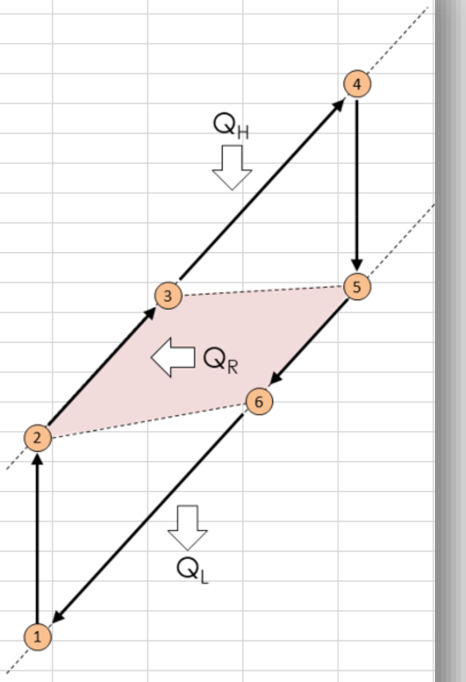
	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Fluido	nitrogen											
2	P1	40	bar			xk			fk		QR	T3	T6
3	T1	150	°C		QR	257,201	kW	f1	0	1	1	-1,13337	0
4	h1	436,504	kJ/kg		T3	507,084	°C	f2	0	2	1	0	1,08311
5	s1	6,09815	kJ/kg/K		T6	301,009	°C	f3	0,00000	3	0,00736	0,03593	-0,0377
6													
7	P2	100	bar			xk+1			dxk		QR	T3	T6
8	T2	276,192	°C		QR	257,201	kW	dQr	0	1	0,4293	0,47101	13,5407
9	h2	571,783	kJ/kg		T3	507,084	°C	dT3	0	2	-0,50354	0,41559	11,9472
10	s2	6,09815	kJ/kg/K		T6	301,009	°C	dT6	0	3	-0,39636	0,4884	-12,5017
11													
12	P4	100	bar										
13	T4	750	°C										
14	h4	1110,11	kJ/kg										
15	s4	6,80206	kJ/kg/K										
16													
17	P5	40	bar										
18	T5	533,729	°C										
19	h5	856,188	kJ/kg										
20	s5	6,80206	kJ/kg/K										
21													
22	m	1	kg/s										
23	UA	10	kW/k										
24	eps	0,001	-										



$p/UA \to \infty$



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Fluido	nitrogen											
2	P1	20	bar			xk			fk		QR	T3	T6
3	T1	25	°C		QR	210,274	kW	f1	0	1	1	-1,11262	0
4	h1	305,099	kJ/kg		T3	391,952	°C	f2	0	2	1	0	1,06303
5	s1	5,93705	kJ/kg/K		T6	201,37	°C	f3	-0,00002	3	0,48659	21,0072	########
6													
7	P2	100	bar			xk+1			dxk		QR	T3	T6
8	T2	201,37	°C		QR	210,274	kW	dQr	-6E-15	1	5,3E-09	1	2,8E-10
9	h2	489,46	kJ/kg		T3	391,952	°C	dT3	-5,4E-15	2	-0,89878	0,89878	2,5E-10
10	s2	5,93705	kJ/kg/K		T6	201,37	°C	dT6	5,6E-15	3	-5E-09	5,1E-09	-2,6E-10
11													
12	P4	100	bar										
13	T4	750	°C				396,591	T5					
14	h4	1110,11	kJ/kg		T3	391,952	↵		4,63854	delta			
15	s4	6,80206	kJ/kg/K										
16							201,37	T6					
17	P5	20	bar		T2	201,37	↵		1,2E-09	delta			
18	T5	396,591	°C										
19	h5	702,859	kJ/kg										
20	s5	6,80206	kJ/kg/K		h3	699,734		w12	-184,361				
21					s3	6,30947		w45	407,253				
22	m	1	kg/s								0	= balanço energia	
23	UA	1000	kW/k		h6	492,585		q34	410,379		0,00158	= balanço de entropia	
24	eps	0,001	-		s6	6,43122		q61	-187,487				
25													
26								q23	210,274				
27								q56	-210,274				
28													



Mostrar que com a diminuição de UA, os delta T's aumentam e, conseq., aumenta também a geração de entropia.

$$\Sigma q - \Sigma w = 0$$

$$\Sigma \frac{Q_k}{T_k} + \Sigma m_{i,k} s_{i,k} = 0$$

$$S_{gen} = m_B s_3 - m_B s_2 + m_B s_6 - m_B s_5$$

$$s_{gen} = \cdots = 0{,}00158\ kJ/kg/K$$

Curso de Termodinâmica

TUTORIAL CICLOS
parte 1/2

aula 14/20