CURSO INTENSIVO

TERMODINÂMICA E APLICAÇÕES DE ENGENHARIA

EXERGIA – Processos de Separação evaporadores multiestágio

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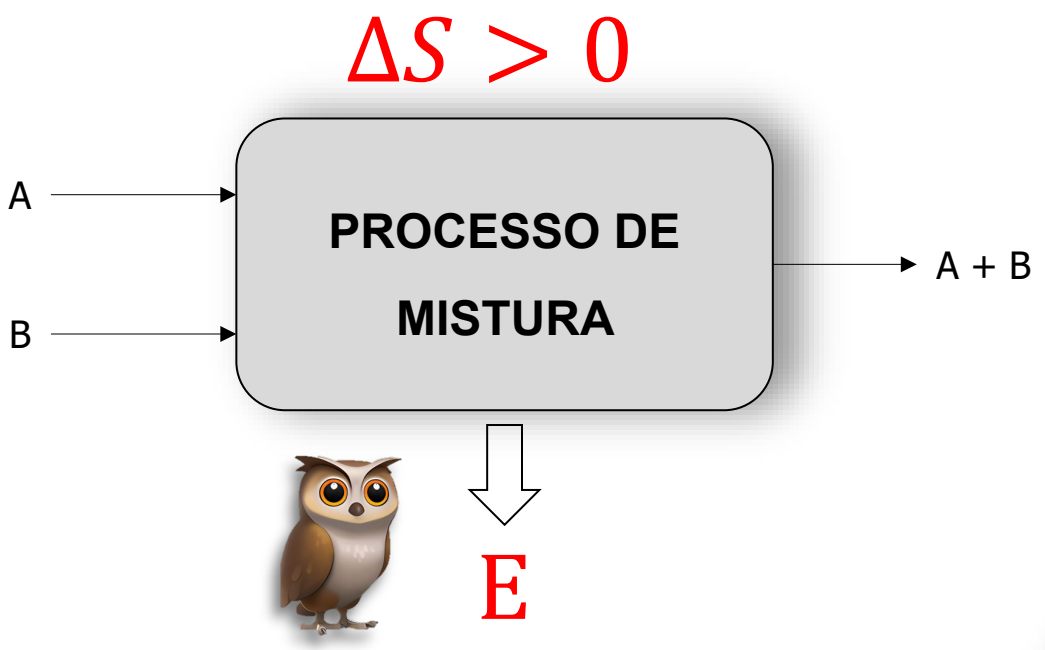
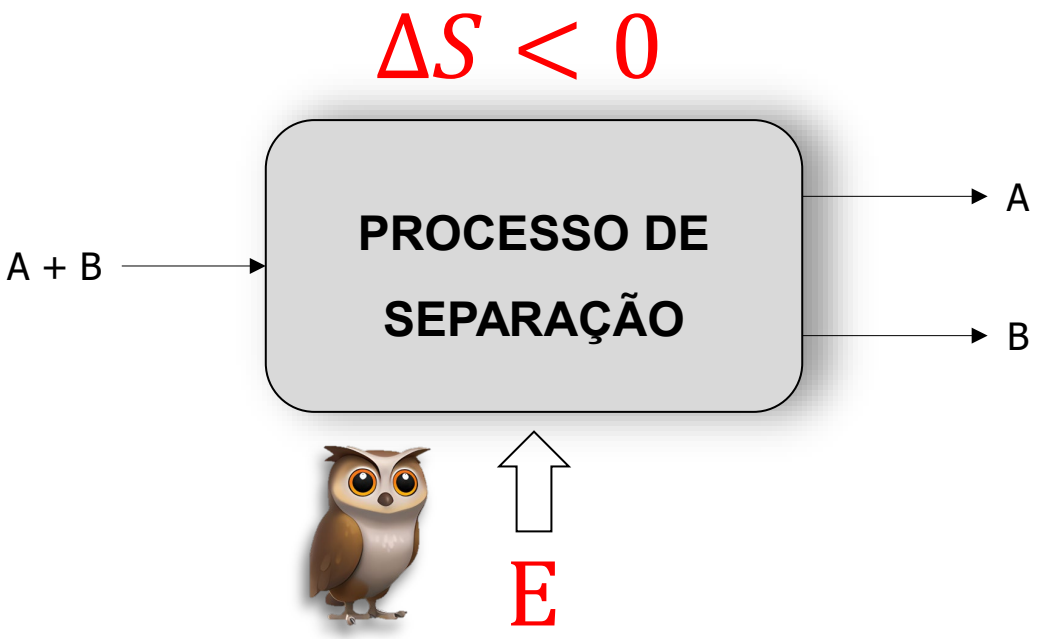
Universidade de São Paulo

Attention to Filler Words


$\Delta S > 0$
A
B
PROCESSO DE MISTURA
A + B
E

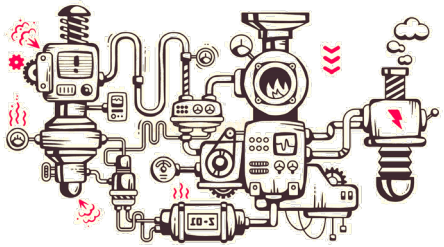

$\Delta S < 0$
A + B
PROCESSO DE SEPARAÇÃO
A
B
E

SYSTÈMES DE CAPTURE ET DE STOCKAGE DIRECT DU CARBONE

aujourd'hui
360ppm

énergie

1800
300ppm



$$\begin{bmatrix} \gamma_{N2}^{e} \\ \gamma_{O2}^{e} \\ \gamma_{Ar}^{e} \\ \gamma_{CO2}^{e} \end{bmatrix} = \begin{bmatrix} 78.0840\% \\ 20.9460\% \\ 0.9340\% \\ \mathbf{0.0360\%} \end{bmatrix}$$

SYSTÈME DE CAPTURE ET STOCKAGE DU CARBONE

$$\begin{bmatrix} \gamma_{N2} \\ \gamma_{O2} \\ \gamma_{Ar} \\ \gamma_{CO2} \end{bmatrix} = \begin{bmatrix} 78.0887\% \\ 20.9473\% \\ 0.9341\% \\ \mathbf{0.0300\%} \end{bmatrix} \leftarrow \gamma_k = \frac{1-\gamma_{CO2}}{1-\gamma_{CO2}^{e}} \cdot \gamma_k^{e}$$

$$\sum \left(1 - \frac{T_0}{T_k}\right) \dot{Q}_k - \left(\dot{W} - P_0 \frac{dV_{vc}}{dt}\right) + \sum \dot{m}_e x_e - \sum \dot{m}_s x_s - \dot{X}_{dest} = \frac{dX_{vc}}{dt}$$

$$\Rightarrow \quad w = RT_0 \cdot \sum_k \gamma_k \cdot \left[\ln(\gamma_{e,k}) - \ln(\gamma_k)\right]$$

$$\begin{bmatrix} \gamma_{N2}^{e} \\ \gamma_{O2}^{e} \\ \gamma_{Ar}^{e} \\ \gamma_{CO2}^{e} \end{bmatrix} = \begin{bmatrix} 78.0840\% \\ 20.9460\% \\ 0.9340\% \\ \mathbf{0.0360\%} \end{bmatrix}$$

$$w = RT_0 \cdot \sum_k \gamma_k \cdot \left[\ln(\gamma_{e,k}) - \ln(\gamma_k)\right]$$

$$\begin{bmatrix} \gamma_{N2} \\ \gamma_{O2} \\ \gamma_{Ar} \\ \gamma_{CO2} \end{bmatrix} = \begin{bmatrix} 78.0887\% \\ 20.9473\% \\ 0.9341\% \\ \mathbf{0.0300\%} \end{bmatrix}$$

$$w = 8.314(25 + 273.15)(0.780887[\ln(0.780887) - \ln(0.780840)] + 0.209473[\ln(0.209473) - \ln(0.209460)] \ldots$$

universal
gas constant

$$\ldots 0.009341[\ln(0.009341) - \ln(0.009340)] + 0.000300[\ln(0.000300) - \ln(0.000360)])$$

$$w_{\min} = -0.01563\, Joules/mol$$

molar mas of
atmospheric air

total mas of
earth's atmosphere

$$W_{\min} = -0.01563\, \frac{Joules}{mol} \cdot \frac{1mol}{28.97g} \cdot 5.1480 \times 10^{18} kg = -2.777 \times 10^{15}\, kJoules$$

$$W_{\text{world}} \approx 96 \times 10^{15}\, kJoules$$

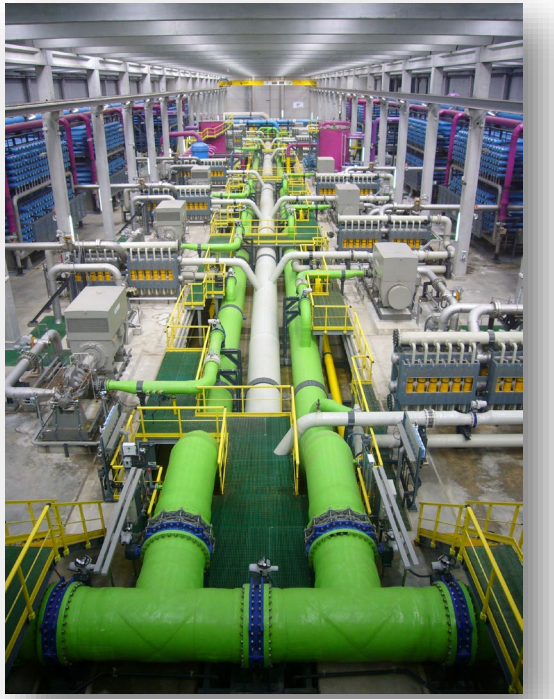
world's electricity
consumption

$$W_{\min} \approx 11\ days\ of\ power\ generation\ !!!$$

Motivação: qual é o menor dispêndio de exergia para promover a separação de componentes de uma mistura ?

Attention to Filler Words

Separação de um sólido dissolvido em um líquido



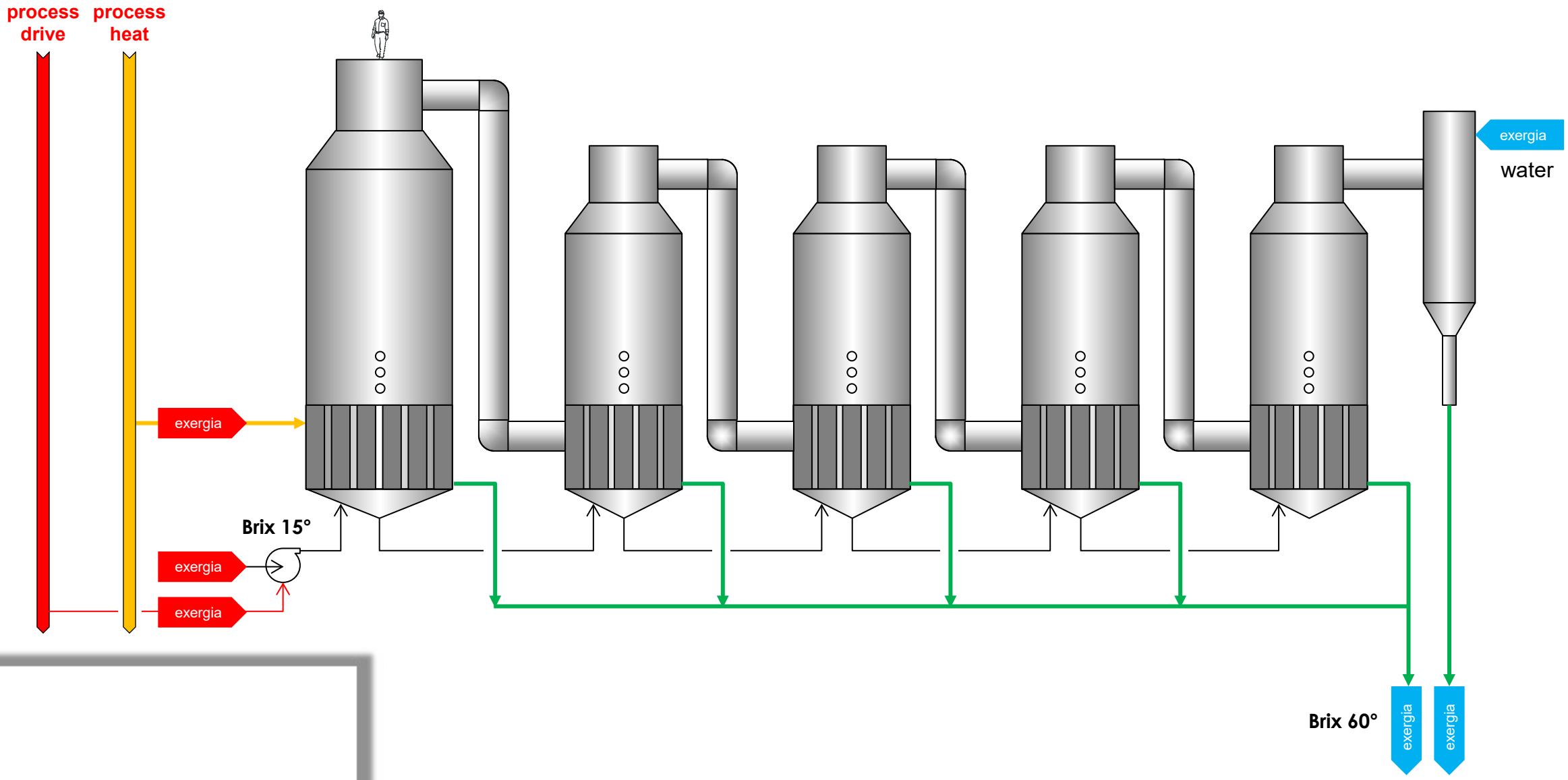
Plantas de dessalinização

Egito->

Separação de um sólido dissolvido em um líquido

Sistema de Evaporação em multiestágios concentradores de caldo

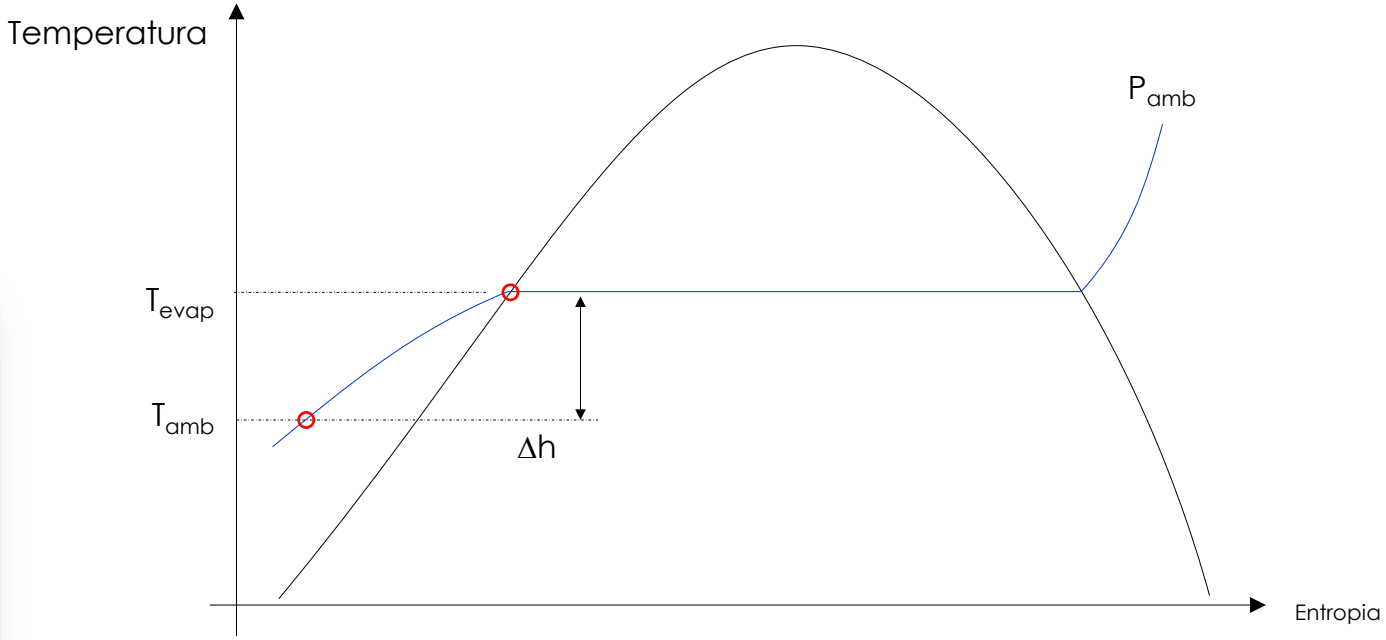
Tratamento de caldo na usina Ouroeste, da Bunge


process drive
process heat
exergia
exergia
exergia
Brix 15°
exergia
water
Brix 60°
exergia
exergia

Evaporação de um líquido a baixa temperatura...

grain
189K subscribers

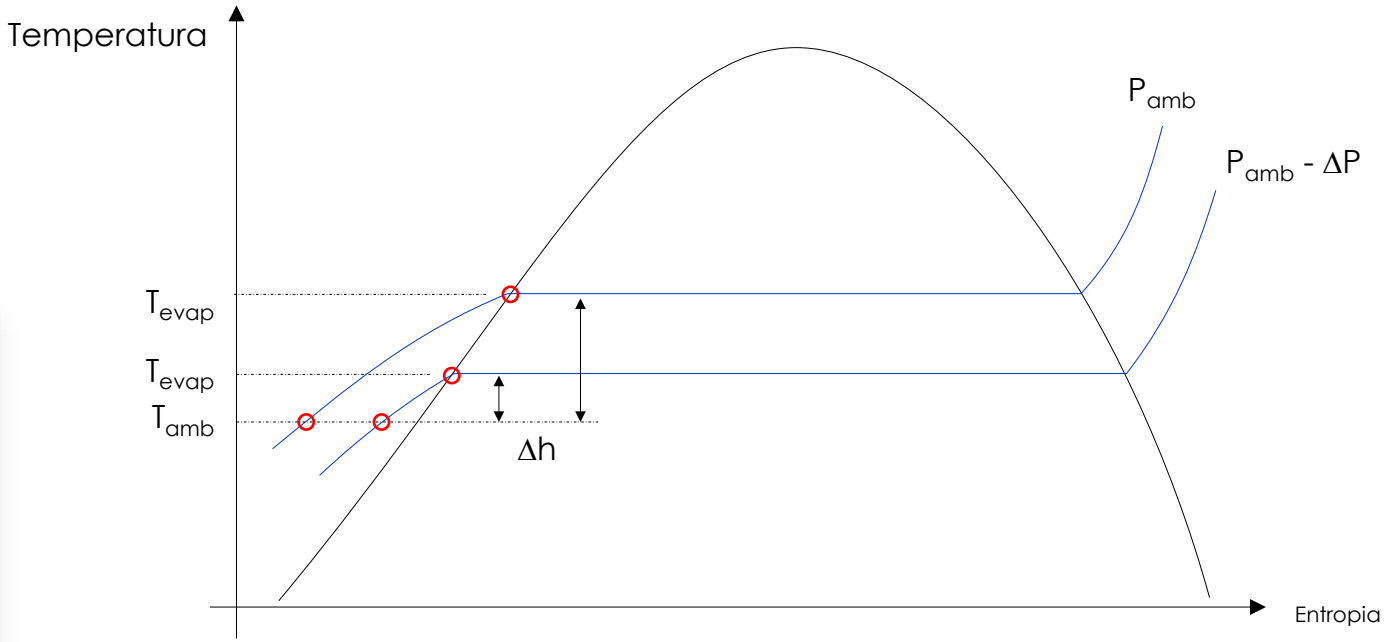
Evaporação de um líquido a baixa temperatura...



1: water: V/L sat. p=0,1 to 1, bar

	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	45,806	0,10000	989,83	0,068166	0,0010103	14,670	191,80	2437,2	191,81	2583,9	0,64920	8,1488
2	60,058	0,20000	983,13	0,13075	0,0010172	7,6480	251,40	2456,0	251,42	2608,9	0,83202	7,9072
3	69,095	0,30000	978,25	0,19126	0,0010222	5,2284	289,24	2467,7	289,27	2624,5	0,94407	7,7675
4	75,857	0,40000	974,30	0,25044	0,0010264	3,9930	317,58	2476,3	317,62	2636,1	1,0261	7,6690
5	81,317	0,50000	970,94	0,30864	0,0010299	3,2400	340,49	2483,2	340,54	2645,2	1,0912	7,5930
6	85,926	0,60000	967,99	0,36607	0,0010331	2,7317	359,84	2489,0	359,91	2652,9	1,1454	7,5311
7	89,932	0,70000	965,34	0,42287	0,0010359	2,3648	376,68	2493,9	376,75	2659,4	1,1921	7,4790
8	93,486	0,80000	962,93	0,47914	0,0010385	2,0871	391,63	2498,2	391,71	2665,2	1,2330	7,4339
9	96,687	0,90000	960,70	0,53494	0,0010409	1,8694	405,10	2502,1	405,20	2670,3	1,2696	7,3943
10	99,606	1,0000	958,63	0,59034	0,0010432	1,6939	417,40	2505,6	417,50	2674,9	1,3028	7,3588

Evaporação de um líquido a baixa temperatura...



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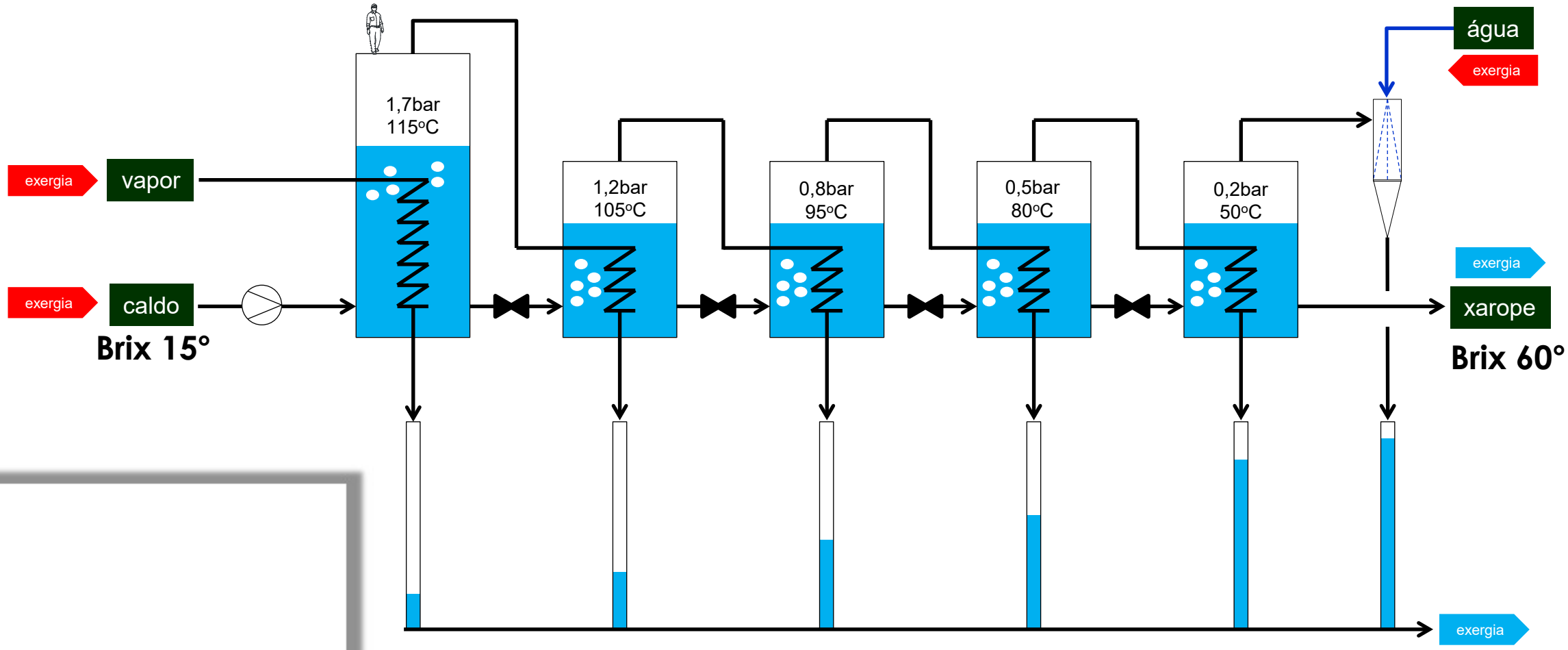
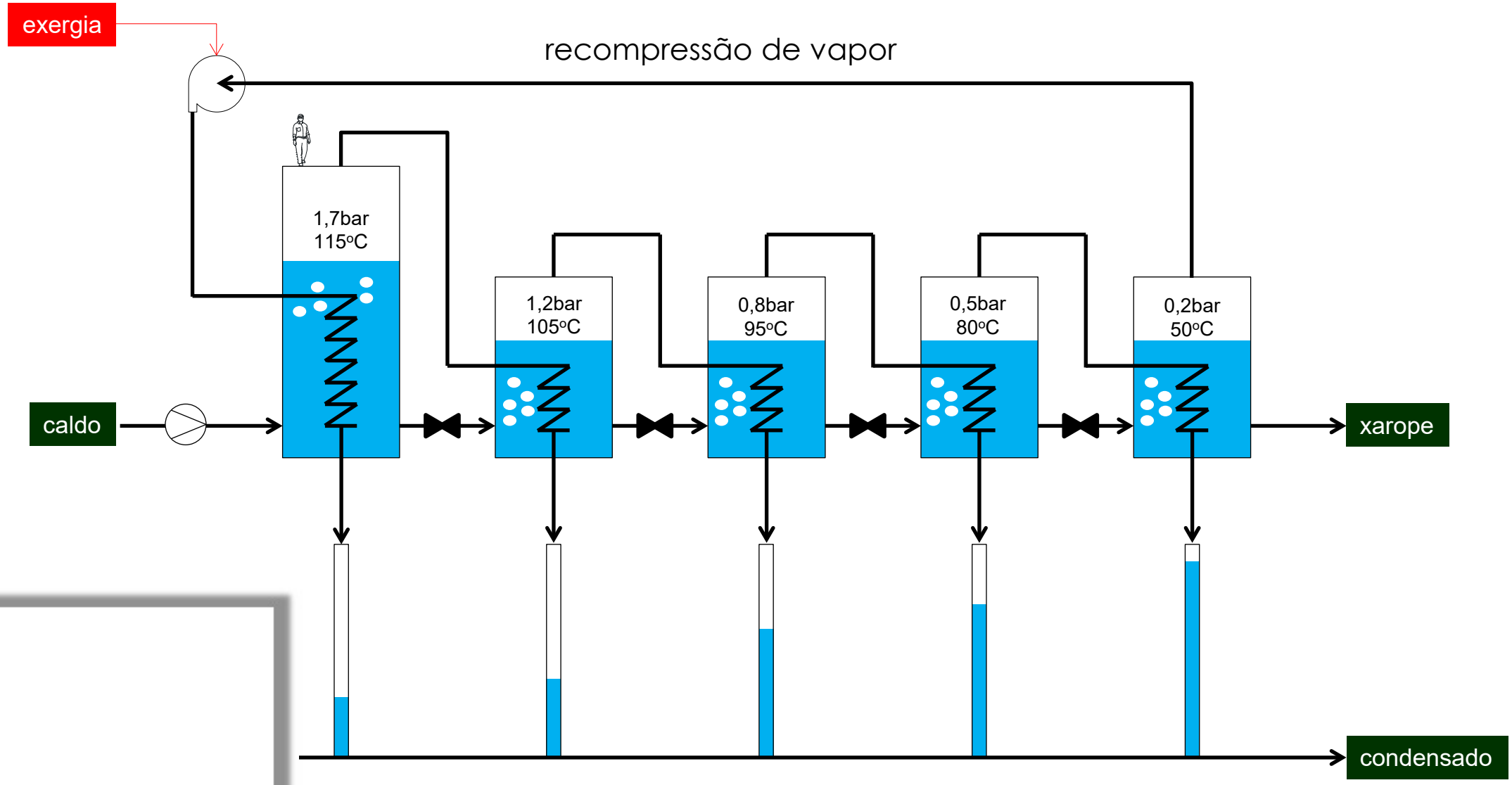
Sistema de Evaporação em Multiestágios (T↓) – concentradores de caldo

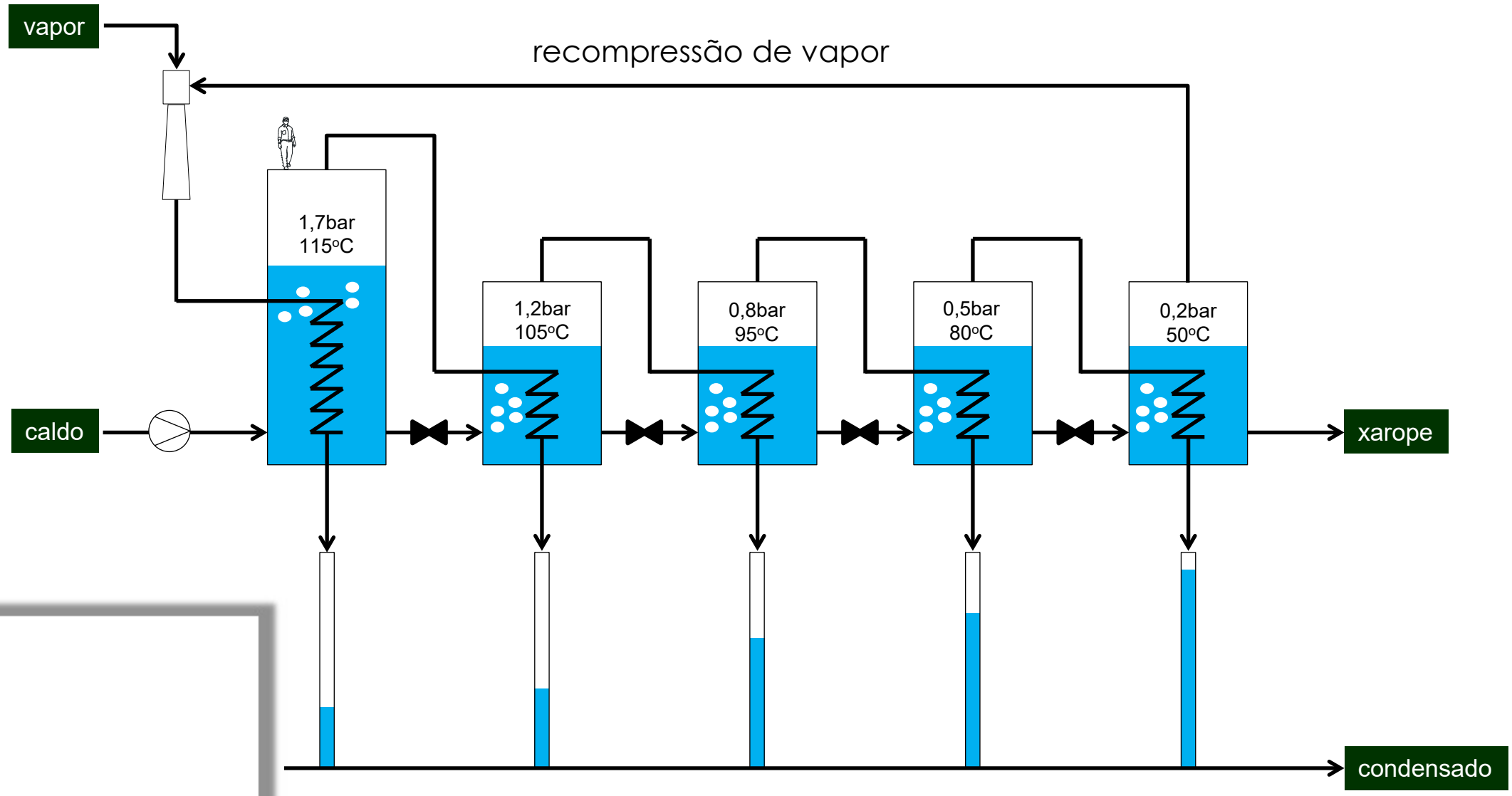


Um grau Brix (1°Bx) =1g de açúcar por 100 g de solução

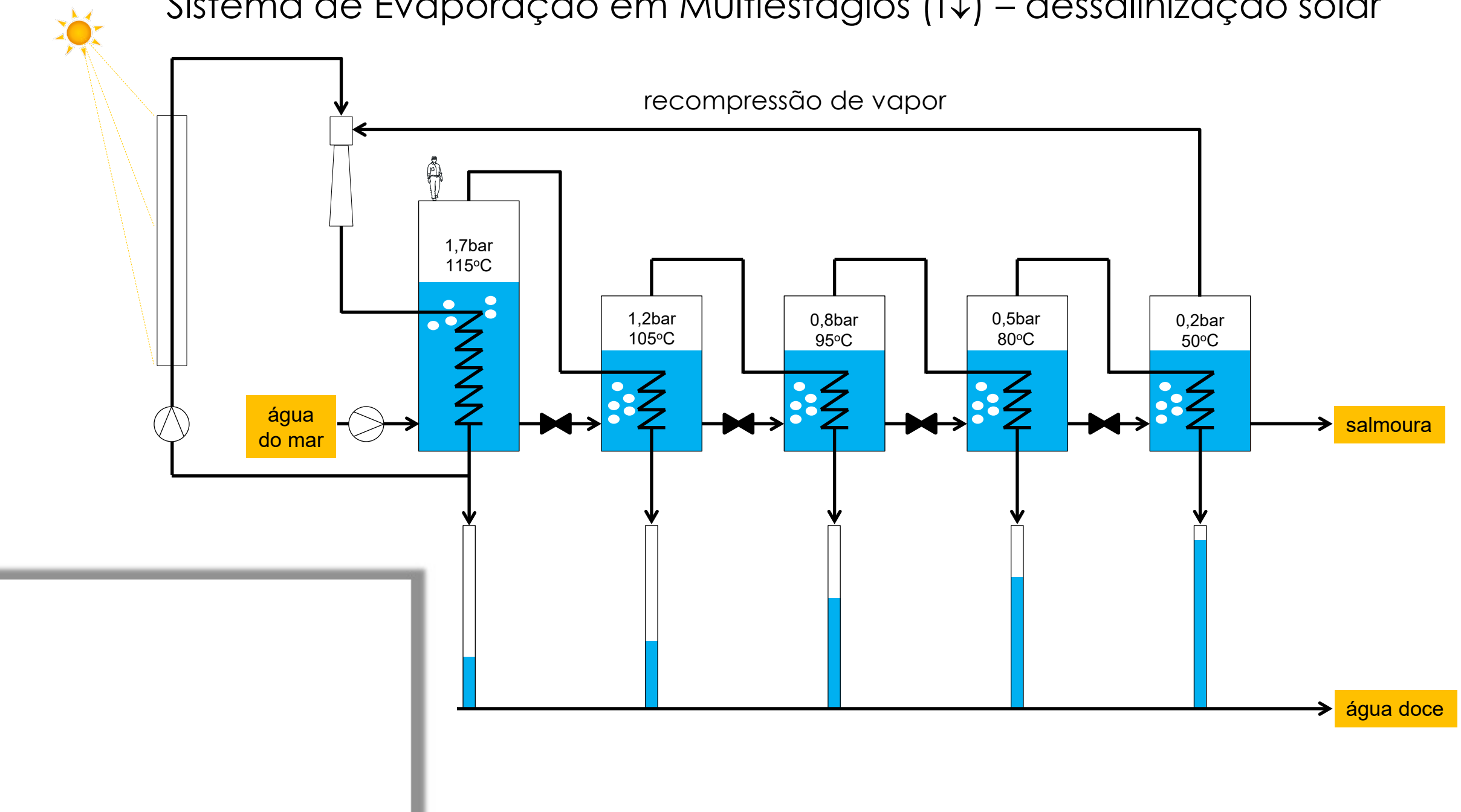
Sistema de Evaporação em Multiestágios (T↓) – concentradores de caldo



Sistema de Evaporação em Multiestágios (T↓) – concentradores de caldo

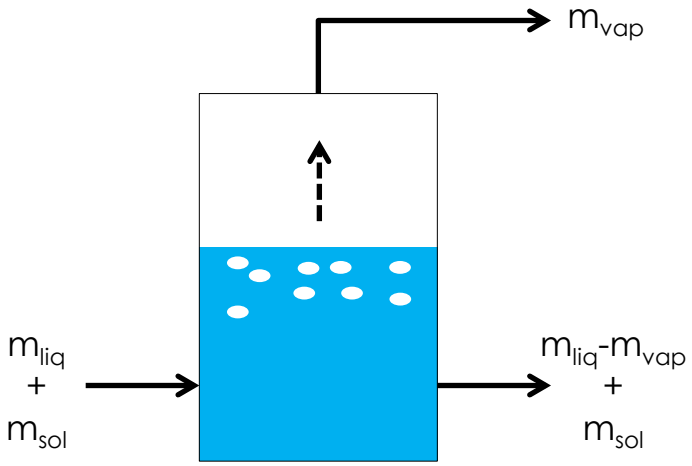


Sistema de Evaporação em Multiestágios (T↓) – dessalinização solar



Sistema de Evaporação em Multiestágios (T↓) – concentradores de caldo

Remoção da água do caldo para aumentar a concentração (15º para 60º aprox.)



Concentração na entrada

$$C_e = \frac{m_{sol}}{m_{sol} + m_{liq}}$$

Concentração na saída

$$C_s = \frac{m_{sol}}{m_{sol} + (m_{liq} - m_{vap})}$$

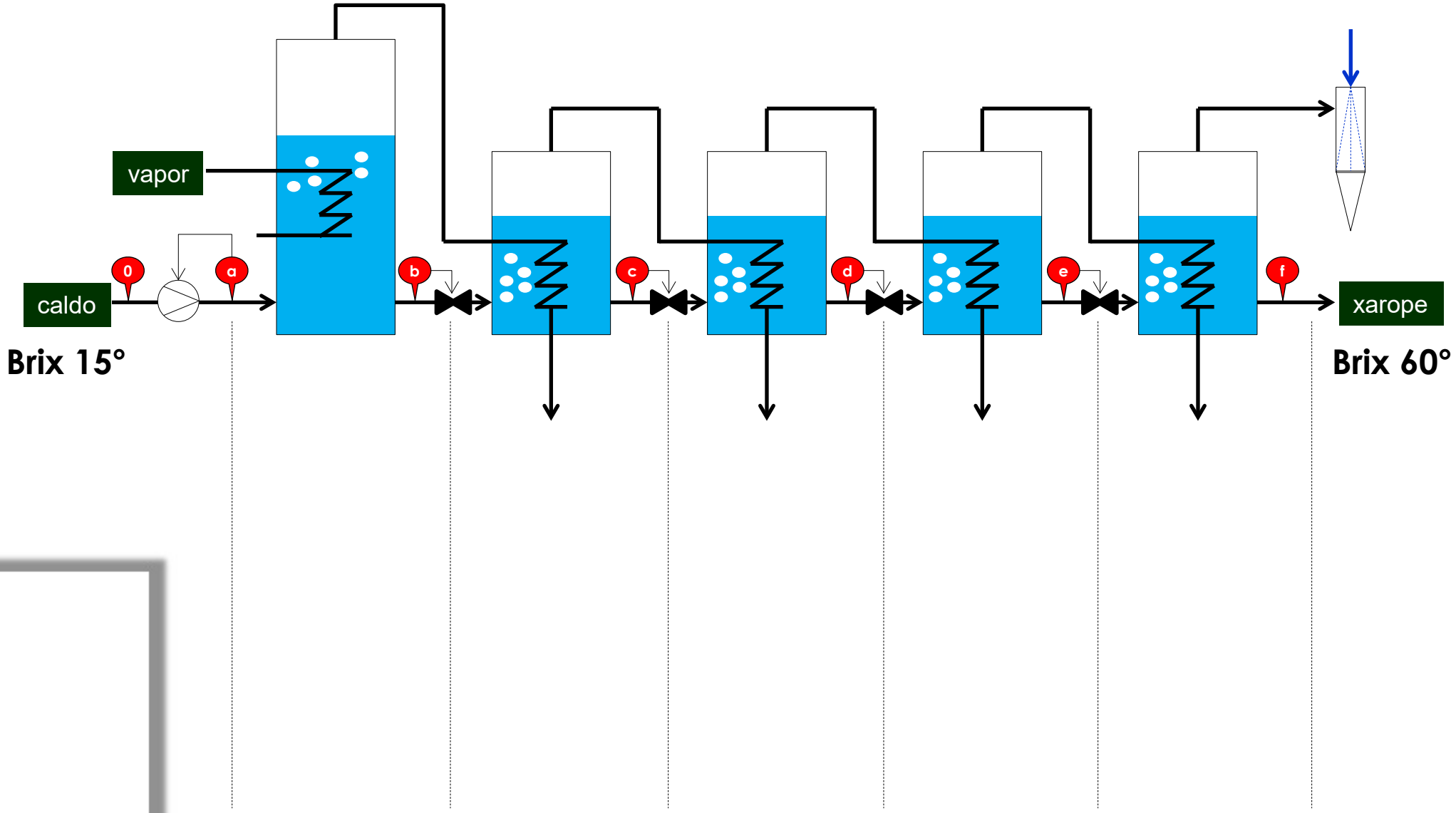
Temperatura de ebulição:

a presença de sólidos dissolvidos produz aumento na temperatura de ebulição

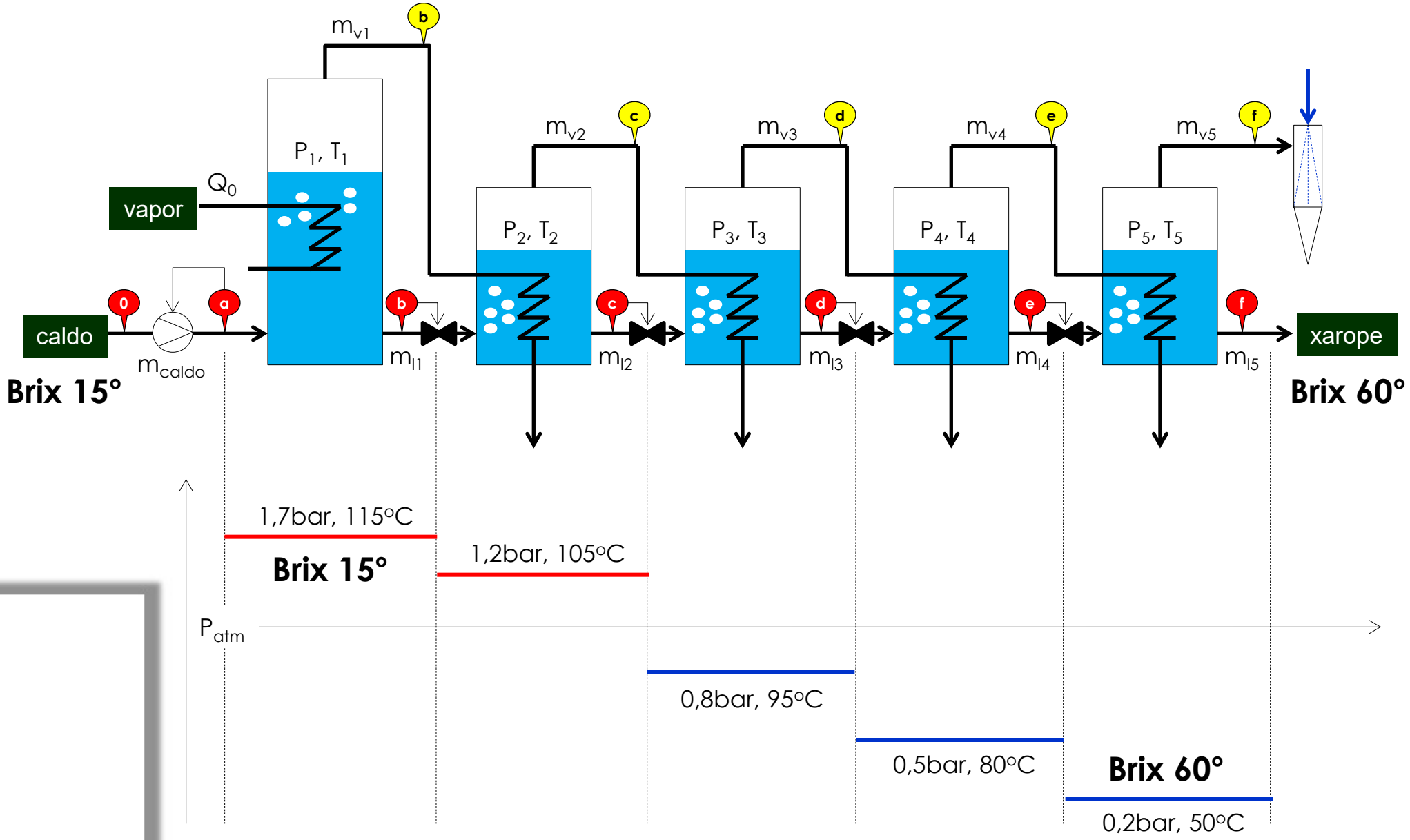
$$\Delta T_{ebulição} \cong \frac{2 \cdot C}{100\% - C}$$

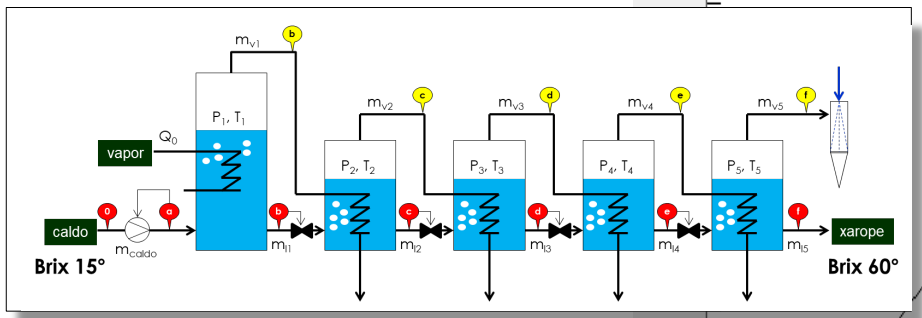
C=60%
↓
ΔT = 3°

Princípio de funcionamento dos evaporadores sem recompressão de vapor

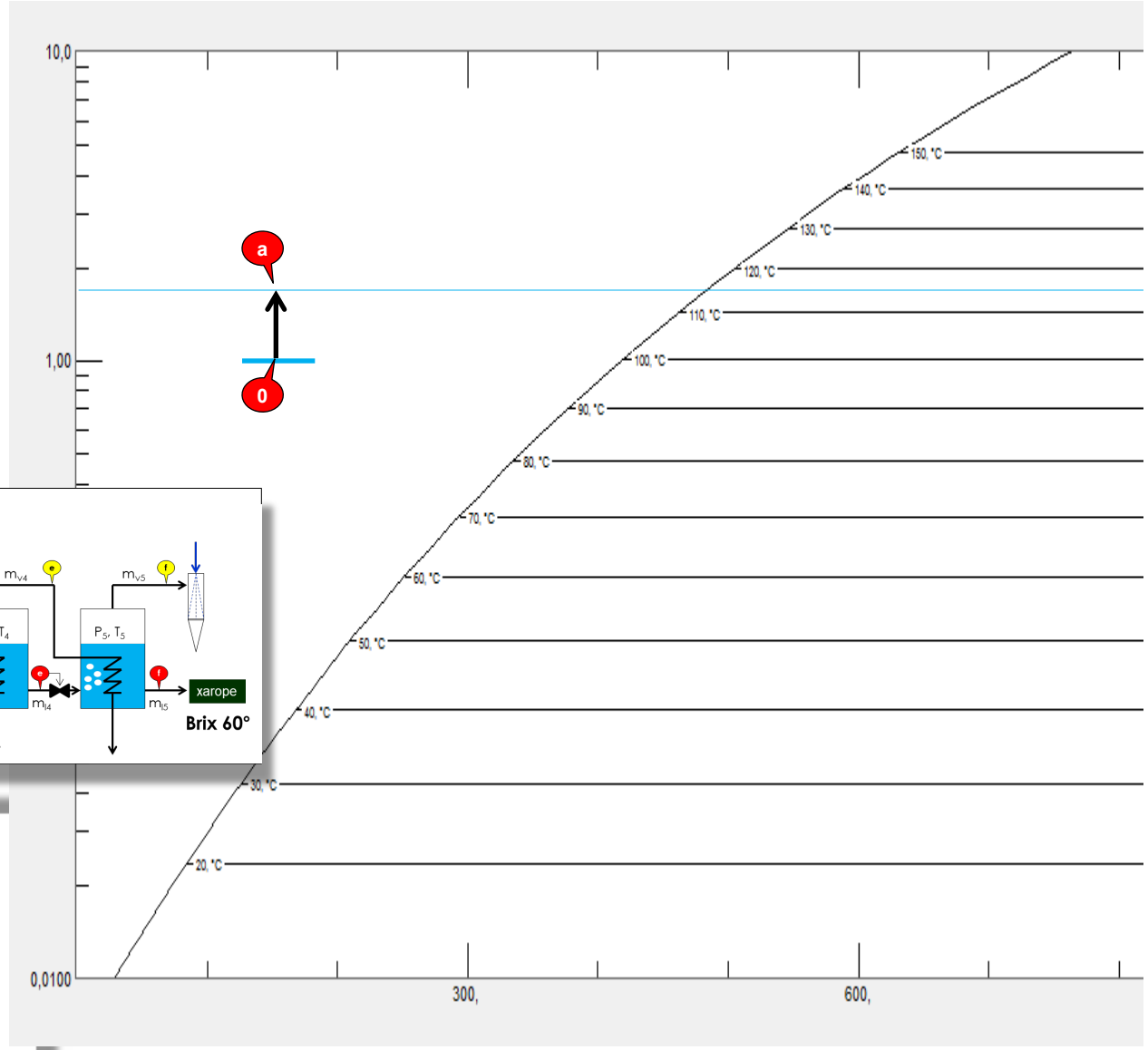


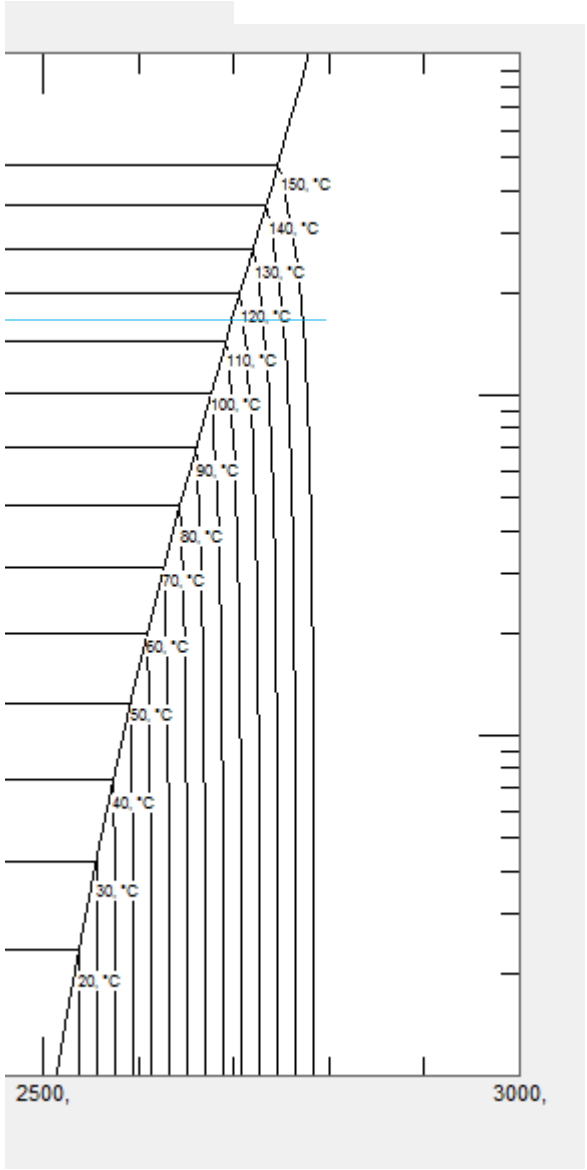
Princípio de funcionamento dos evaporadores sem recompressão de vapor



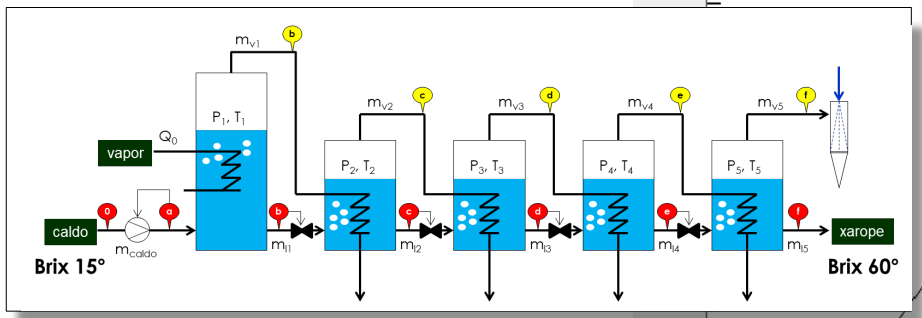


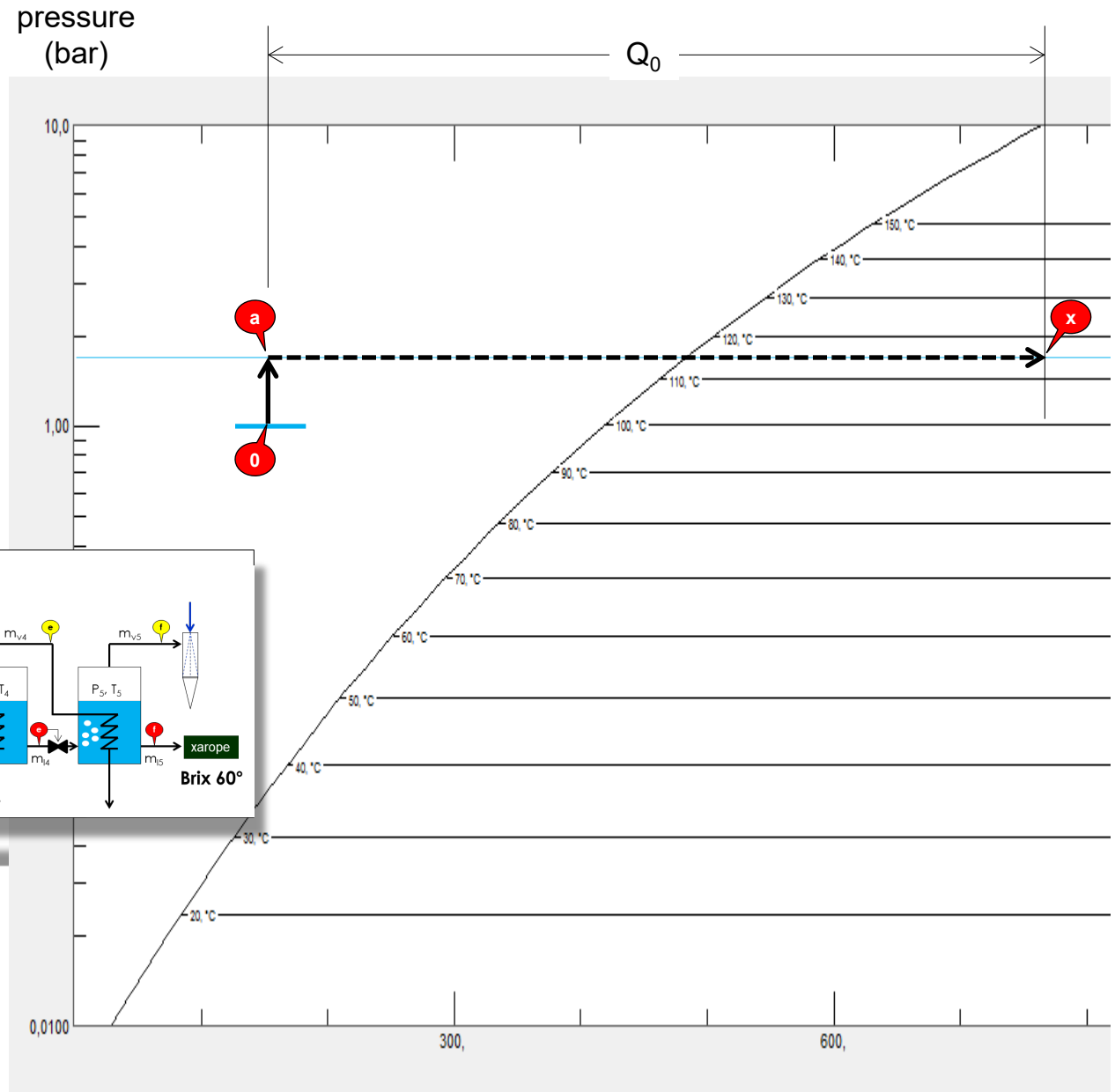
pressure
(bar)

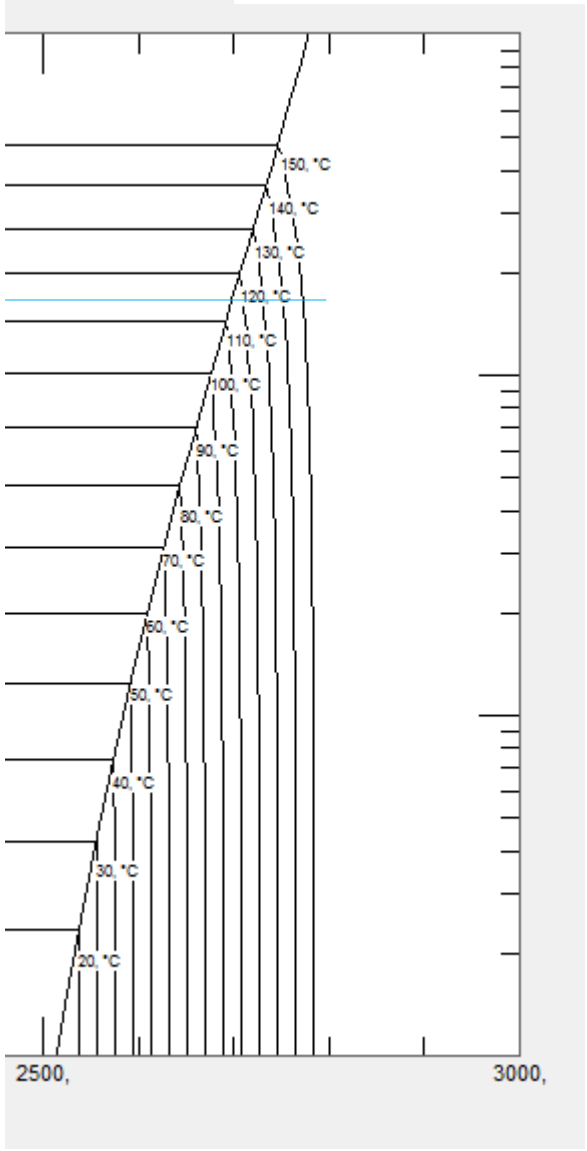


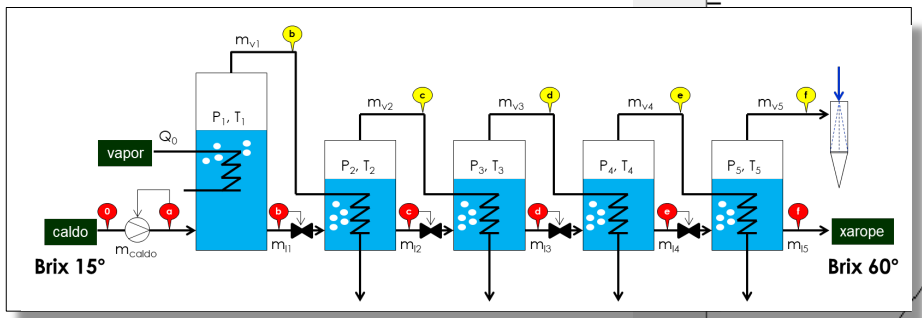


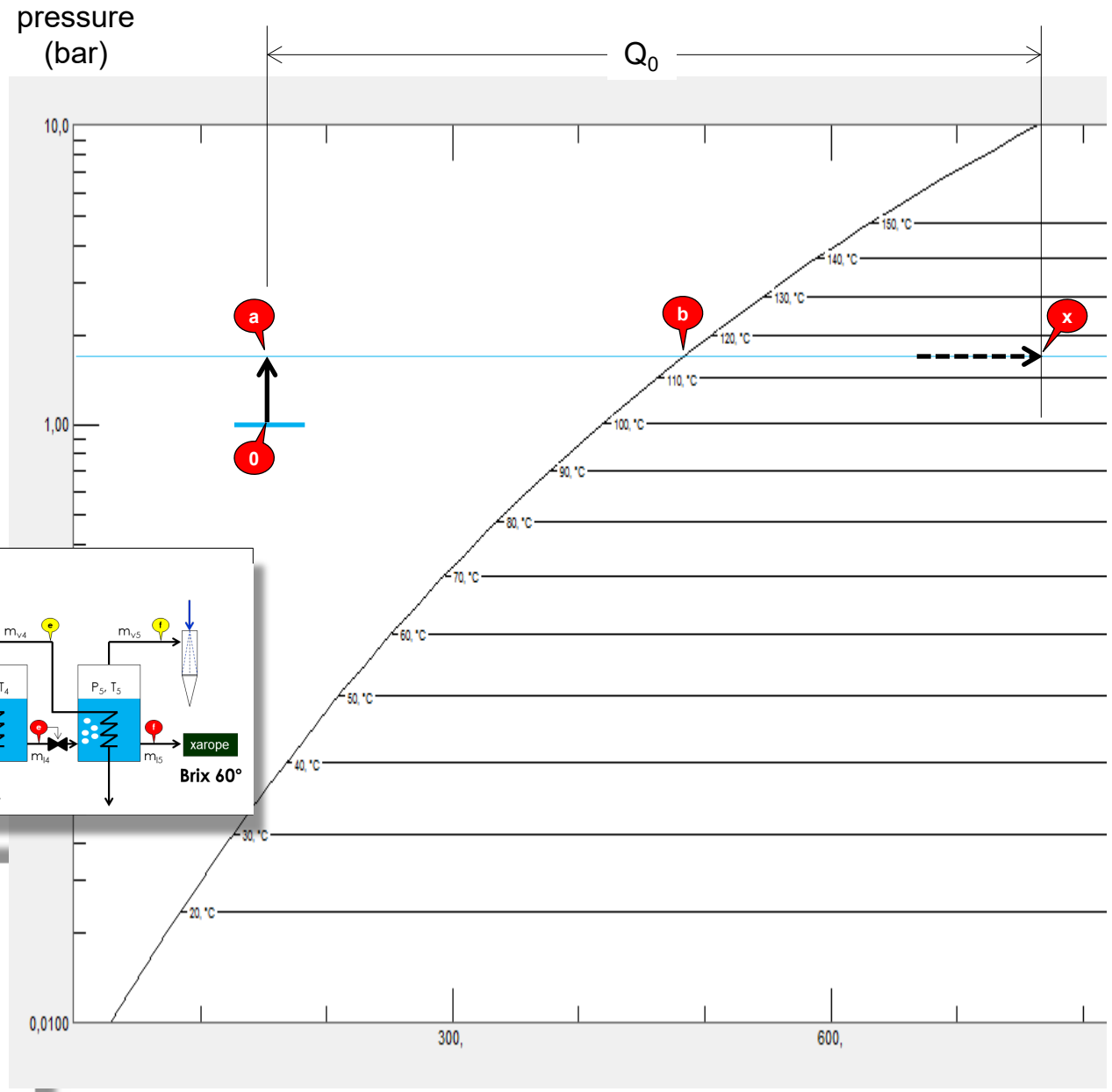
enthalpy (kJ/kg)

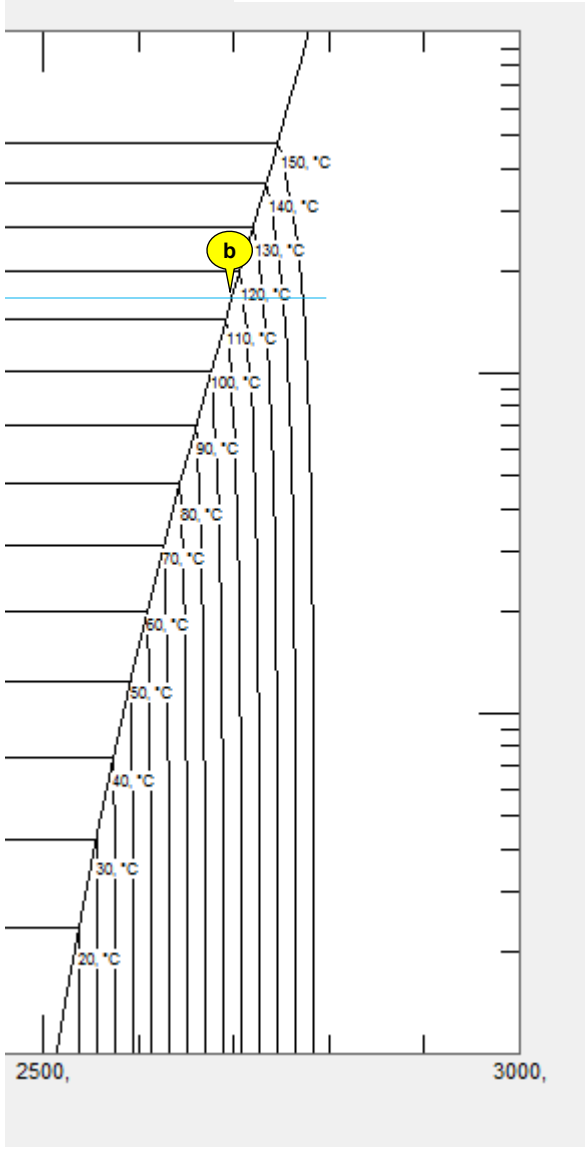

vapor
caldo
Brix 15°
xarope
Brix 60°
Q_0
m_{caldo}
m_{v1}
m_{v2}
m_{v3}
m_{v4}
m_{v5}
m_{l1}
m_{l2}
m_{l3}
m_{l4}
m_{l5}
P_1, T_1
P_2, T_2
P_3, T_3
P_4, T_4
P_5, T_5

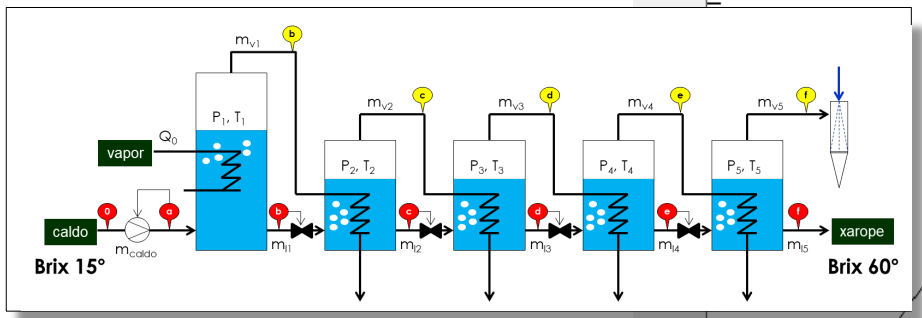

pressure
(bar)
Q_0
10,0
1,00
0,0100
300,
600,
enthalpy (kJ/kg)
a
x
0
150, °C
140, °C
130, °C
120, °C
110, °C
100, °C
90, °C
80, °C
70, °C
60, °C
50, °C
40, °C
30, °C
20, °C

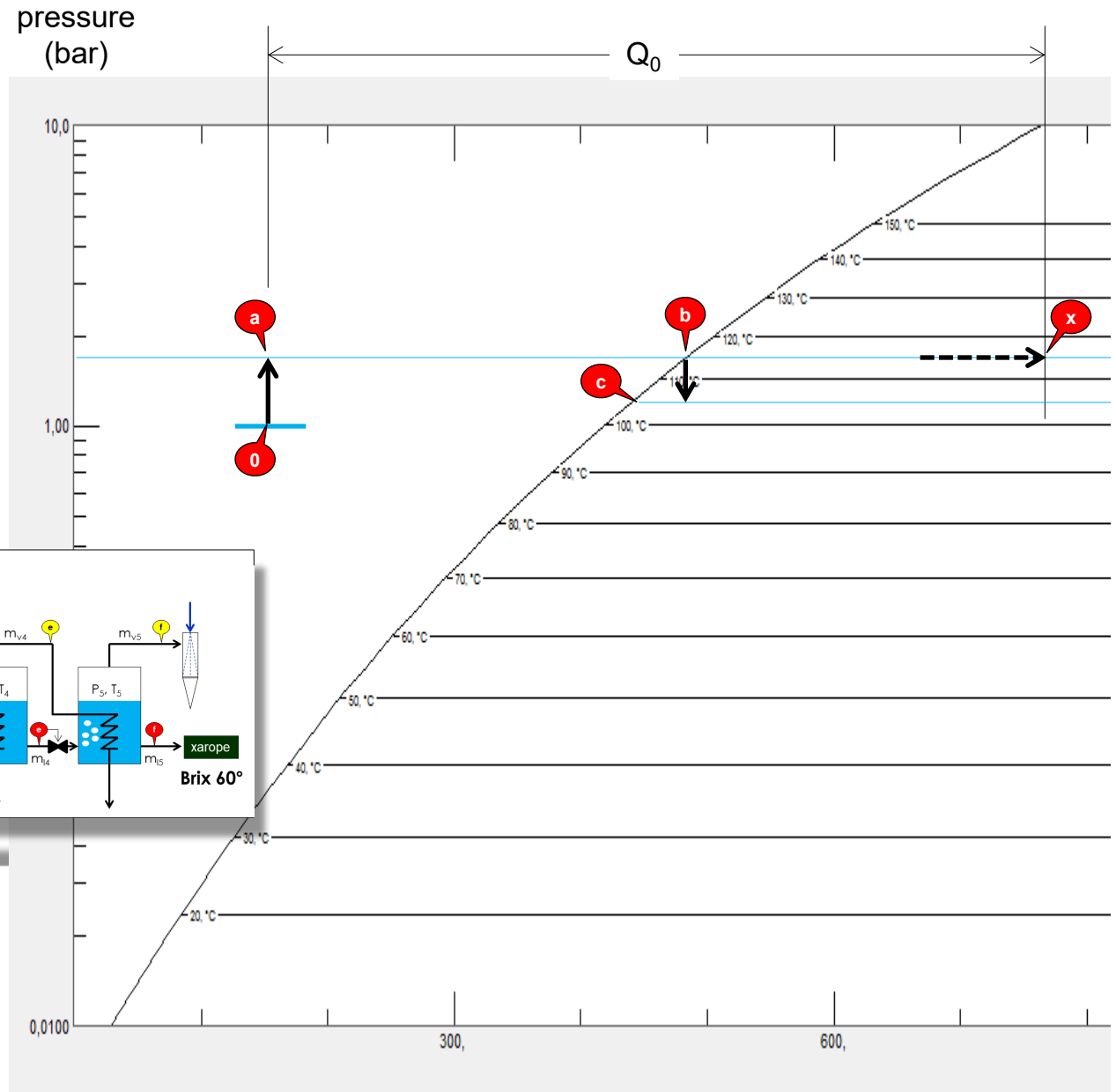

2500,
3000,
150, °C
140, °C
130, °C
120, °C
110, °C
100, °C
90, °C
80, °C
70, °C
60, °C
50, °C
40, °C
30, °C
20, °C

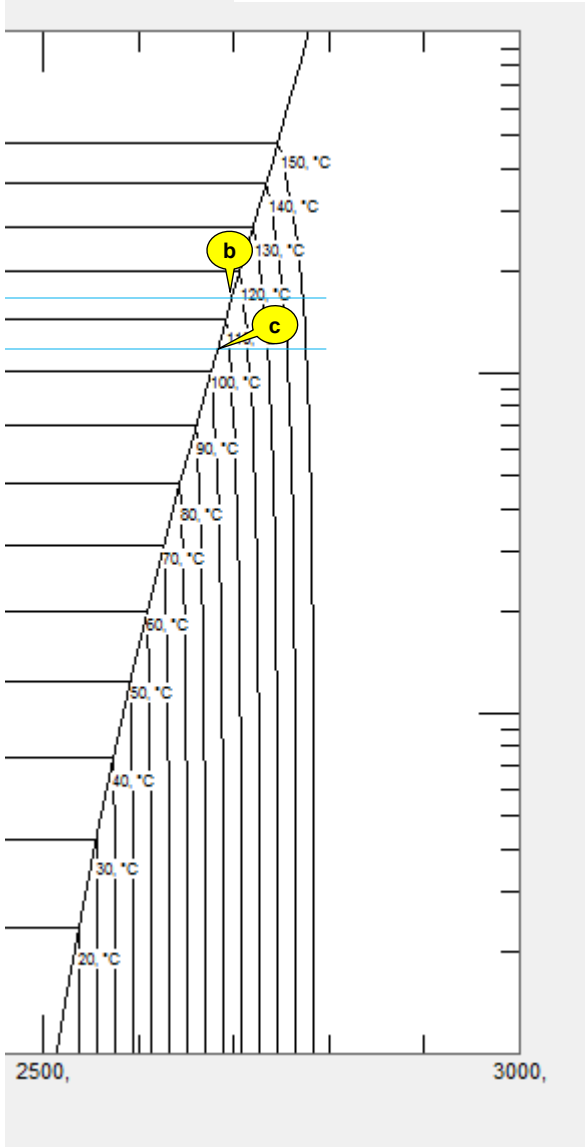

vapor
caldo
Brix 15°
xarope
Brix 60°
Q_0
m_{caldo}
m_{v1}
m_{v2}
m_{v3}
m_{v4}
m_{v5}
m_{l1}
m_{l2}
m_{l3}
m_{l4}
m_{l5}
P_1, T_1
P_2, T_2
P_3, T_3
P_4, T_4
P_5, T_5

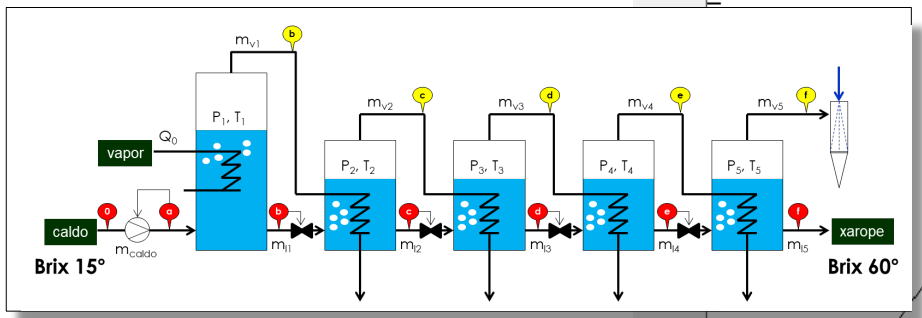

pressure
(bar)
Q_0
10,0
1,00
0,0100
300,
600,
enthalpy (kJ/kg)
a
b
x
0
150, °C
140, °C
130, °C
120, °C
110, °C
100, °C
90, °C
80, °C
70, °C
60, °C
50, °C
40, °C
30, °C
20, °C


b
150, °C
140, °C
130, °C
120, °C
110, °C
100, °C
90, °C
80, °C
70, °C
60, °C
50, °C
40, °C
30, °C
20, °C
2500,
3000,


m_{v1}
P_1, T_1
Q_0
vapor
caldo
m_{caldo}
Brix 15°
m_{l1}
m_{v2}
P_2, T_2
m_{l2}
m_{v3}
P_3, T_3
m_{l3}
m_{v4}
P_4, T_4
m_{l4}
m_{v5}
P_5, T_5
m_{l5}
xarope
Brix 60°


pressure
(bar)
Q_0
10,0
1,00
0,0100
300,
600,
enthalpy (kJ/kg)
a
b
c
0
x
150, °C
140, °C
130, °C
120, °C
100, °C
90, °C
80, °C
70, °C
60, °C
50, °C
40, °C
30, °C
20, °C


b
c
150, °C
140, °C
130, °C
120, °C
100, °C
90, °C
80, °C
70, °C
60, °C
50, °C
40, °C
30, °C
20, °C
2500,
3000,


vapor
caldo
Brix 15°
xarope
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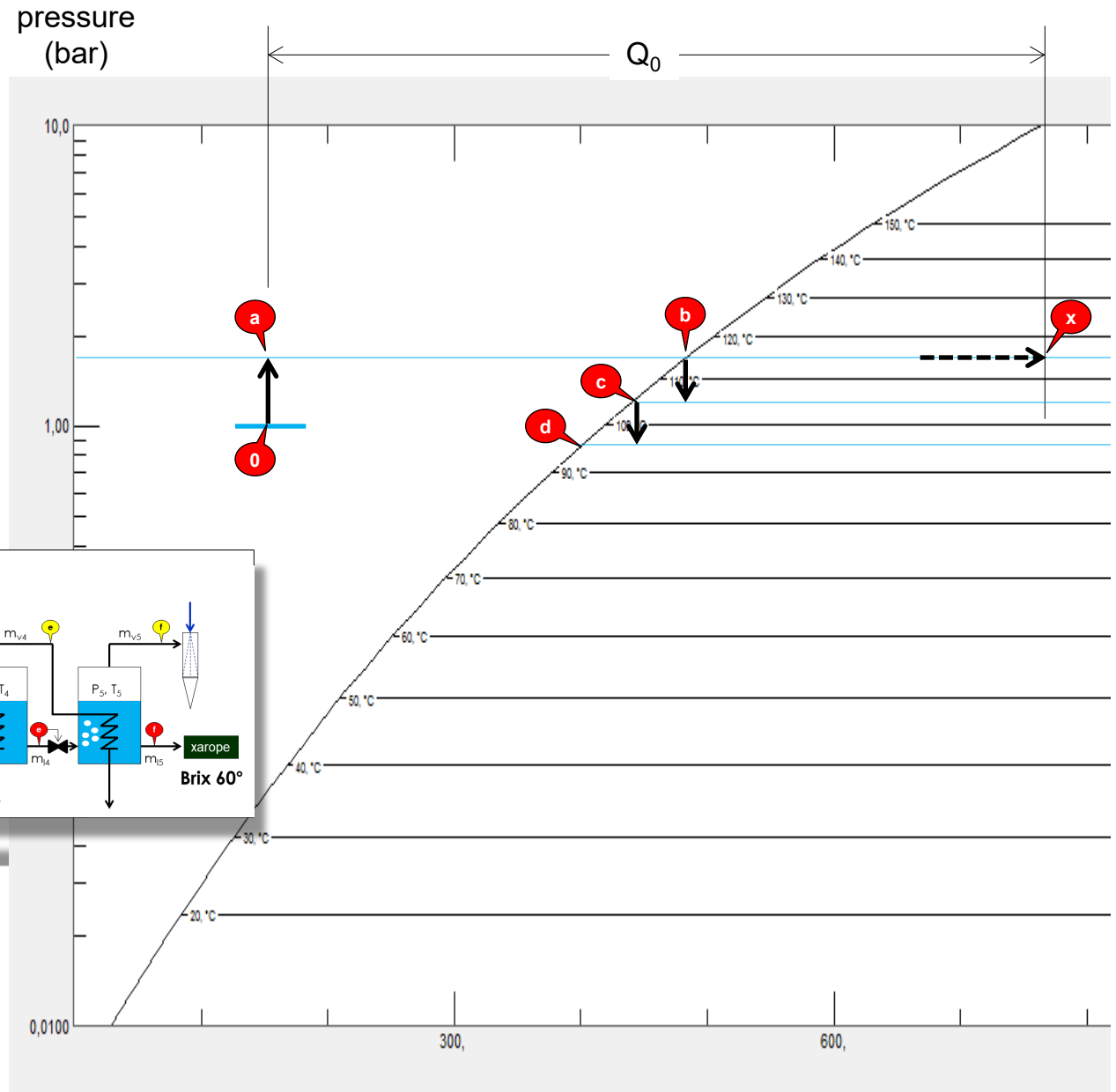
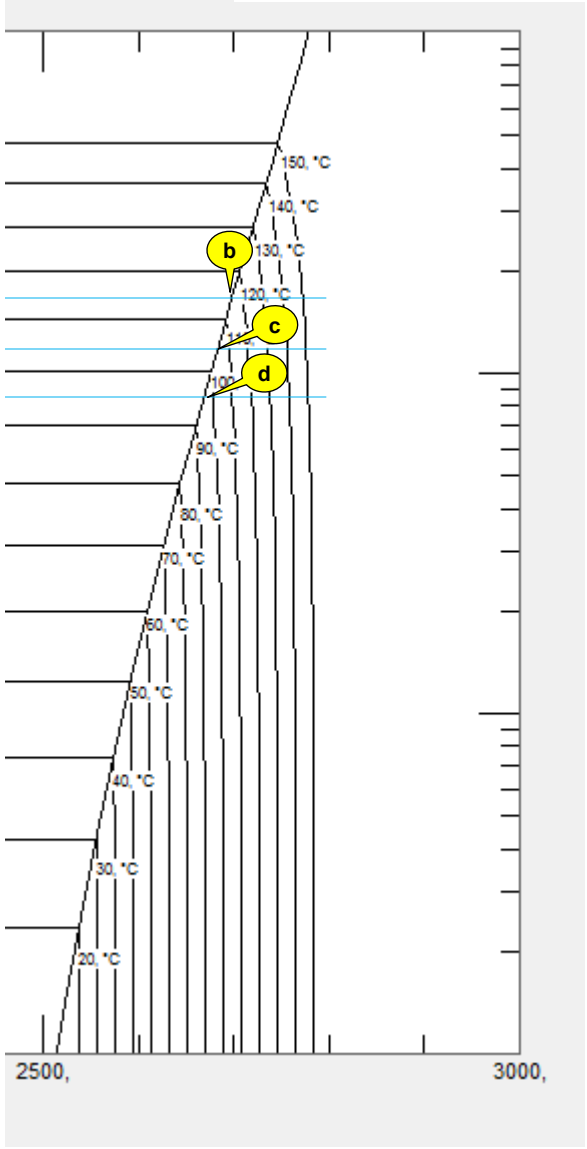
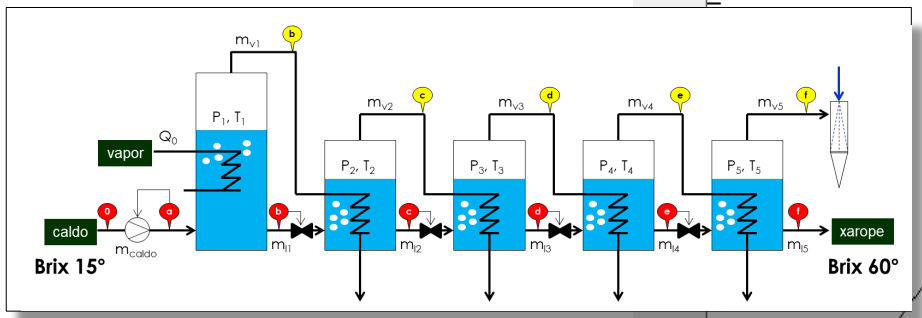
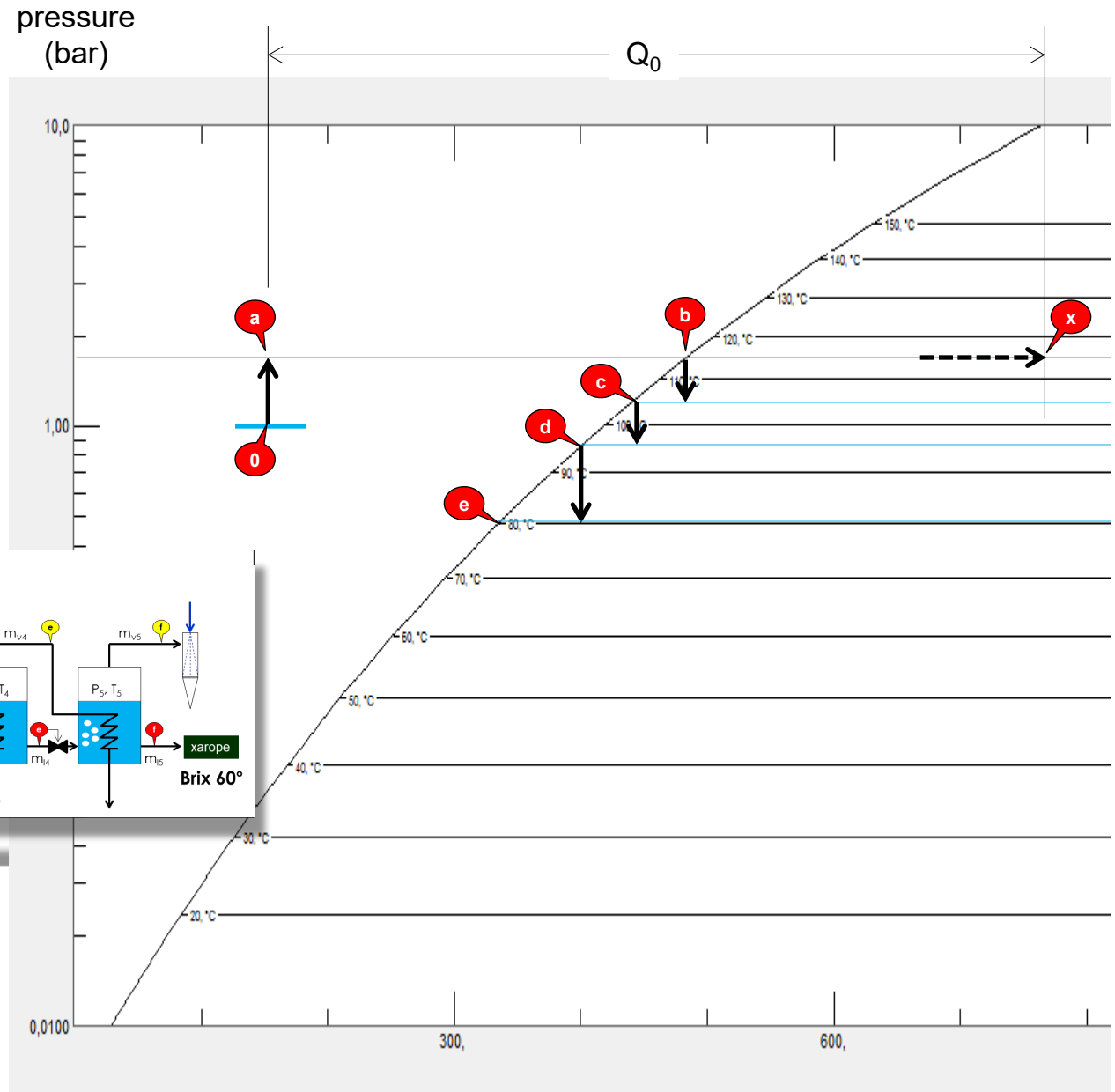
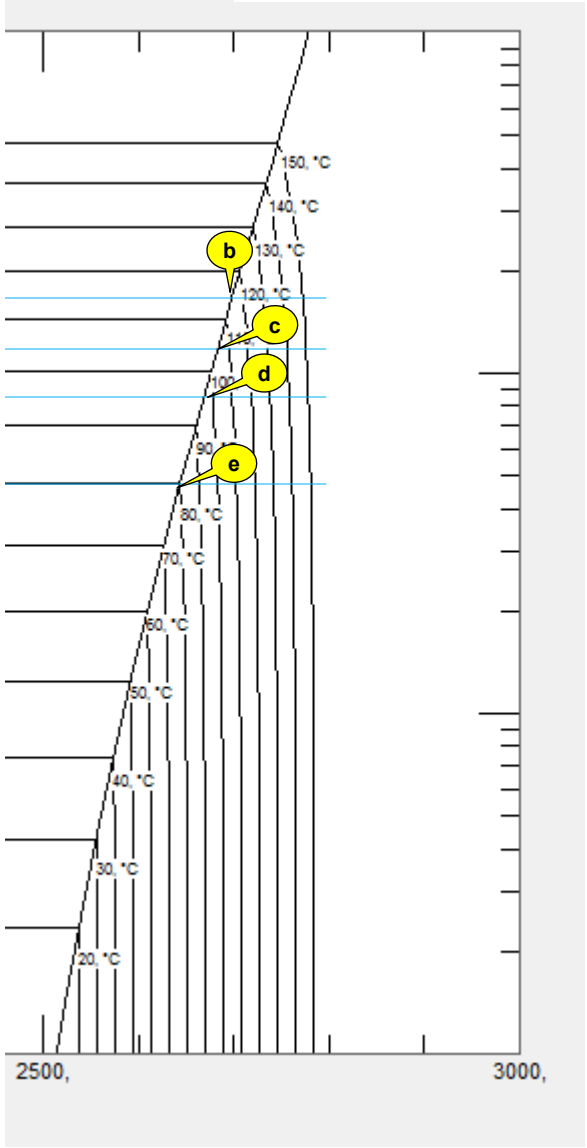
Q_0
m_{caldo}
m_{v1}
m_{v2}
m_{v3}
m_{v4}
m_{v5}
m_{l1}
m_{l2}
m_{l3}
m_{l4}
m_{l5}
P_1, T_1
P_2, T_2
P_3, T_3
P_4, T_4
P_5, T_5

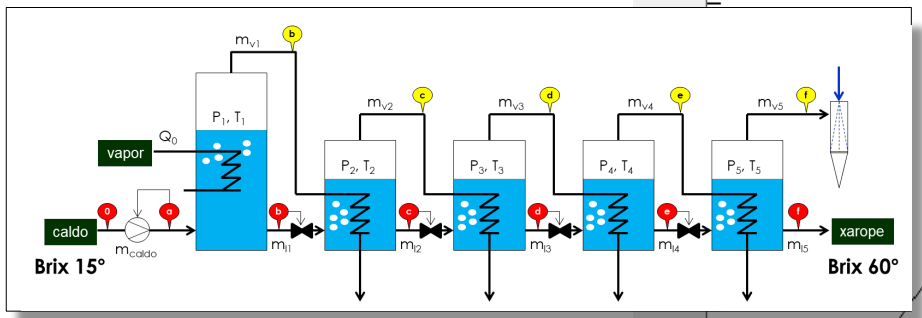

pressure
(bar)
Q_0
10,0
1,00
0,0100
300,
600,
enthalpy (kJ/kg)
a
b
c
d
0
x
150, °C
140, °C
130, °C
120, °C
90, °C
80, °C
70, °C
60, °C
50, °C
40, °C
30, °C
20, °C

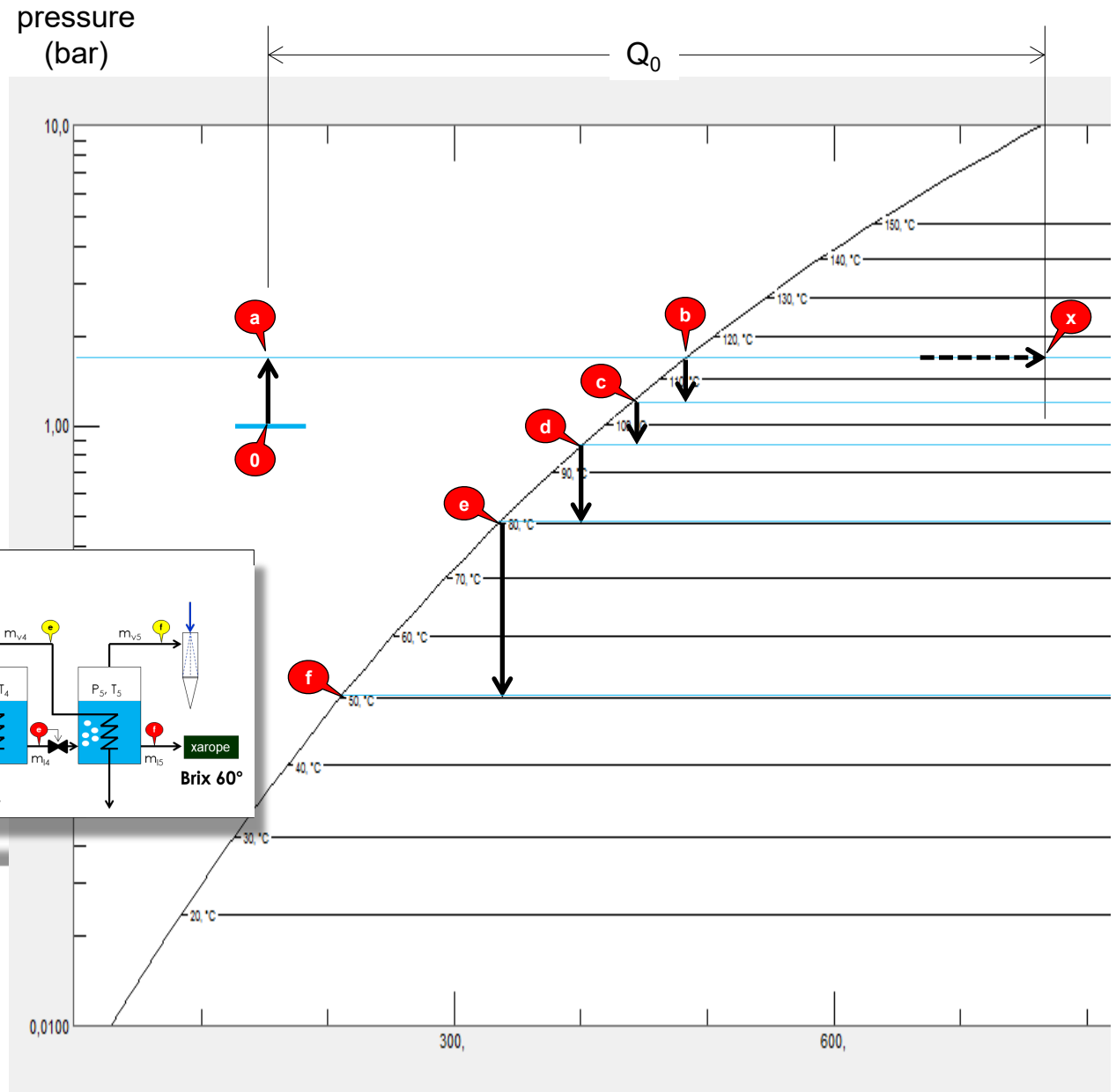

2500,
3000,
b
c
d
150, °C
140, °C
130, °C
120, °C
90, °C
80, °C
70, °C
60, °C
50, °C
40, °C
30, °C
20, °C

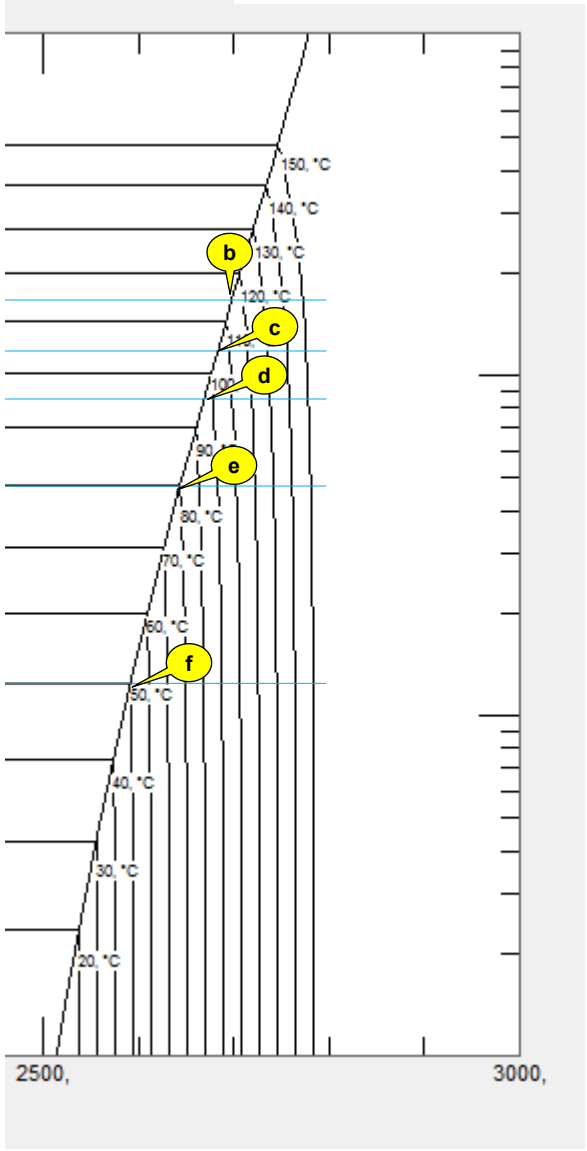

vapor
caldo
Brix 15°
xarope
Brix 60°
Q_0
m_{caldo}
m_{v1}
m_{v2}
m_{v3}
m_{v4}
m_{v5}
m_{l1}
m_{l2}
m_{l3}
m_{l4}
m_{l5}
P_1, T_1
P_2, T_2
P_3, T_3
P_4, T_4
P_5, T_5


pressure
(bar)
Q_0
10,0
1,00
0,0100
300,
600,
enthalpy (kJ/kg)
a
b
c
d
e
x
0
150, °C
140, °C
130, °C
120, °C
80, °C
70, °C
60, °C
50, °C
40, °C
30, °C
20, °C


2500,
3000,
b
c
d
e
150, °C
140, °C
130, °C
120, °C
80, °C
70, °C
60, °C
50, °C
40, °C
30, °C
20, °C


vapor
caldo
Brix 15°
xarope
Brix 60°
Q_0
m_{caldo}
m_{v1}
m_{v2}
m_{v3}
m_{v4}
m_{v5}
m_{l1}
m_{l2}
m_{l3}
m_{l4}
m_{l5}
P_1, T_1
P_2, T_2
P_3, T_3
P_4, T_4
P_5, T_5

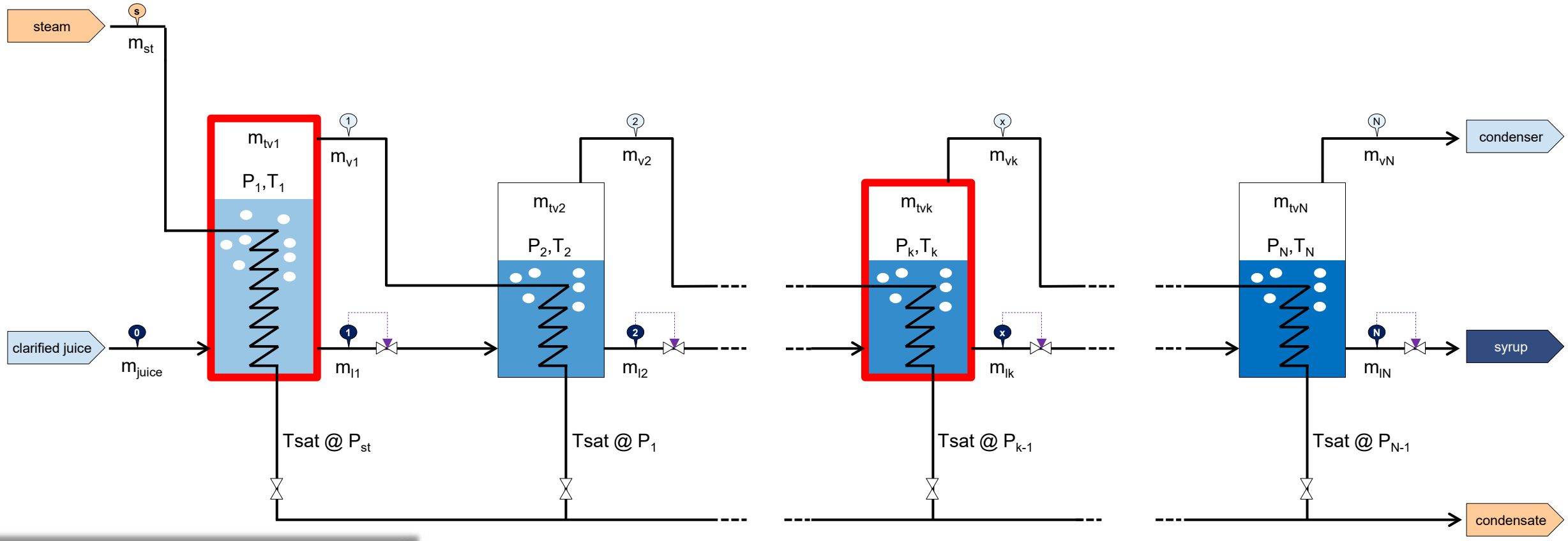

pressure
(bar)
Q_0
10,0
1,00
0,0100
300,
600,
enthalpy (kJ/kg)
a
0
b
c
d
e
f
x
150, °C
140, °C
130, °C
120, °C
80, °C
70, °C
60, °C
50, °C
40, °C
30, °C
20, °C


2500,
3000,
b
c
d
e
f
150, °C
140, °C
130, °C
120, °C
80, °C
70, °C
60, °C
50, °C
40, °C
30, °C
20, °C

Equacionamento

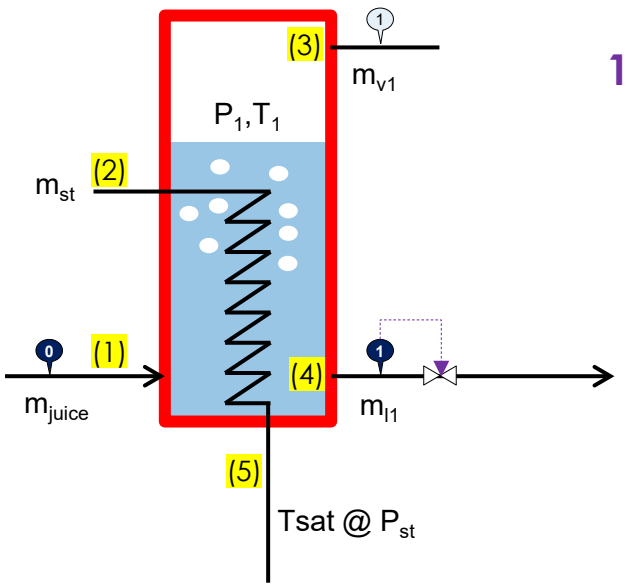
Attention to Filler Words

Princípio de funcionamento dos evaporadores sem recompressão de vapor



vazão mássica de vapor produzida no módulo = **vaporização devido ao flasheamento** + **vaporização por absorção de calor**

Princípio de funcionamento dos evaporadores sem recompressão de vapor



inv. massa → $m_{l,0} = m_{l,1} + m_{v,1}$

1ra Lei → $m_{l,0}h_{l,0} + m_{st}h_{st} - m_{v,1}h_{v,1} - m_{l,1}h_{l,1} - m_{st}h_{l,sat} = 0$

(1) (2) (3) (4) (5)

$$m_{l,0}h_{l,0} + m_{st}h_{st} - m_{v,1}h_{v,1} - (m_{l,0} - m_{v,1})h_{l,1} - m_{st}h_{l,sat} = 0$$

$$m_{l,0}(h_{l,0} - h_{l,1}) + m_{st}(h_{st} - h_{l,sat})m_{v,1}h_{v,1} - m_{v,1}(h_{lv1} - h_{l,1}) = 0$$

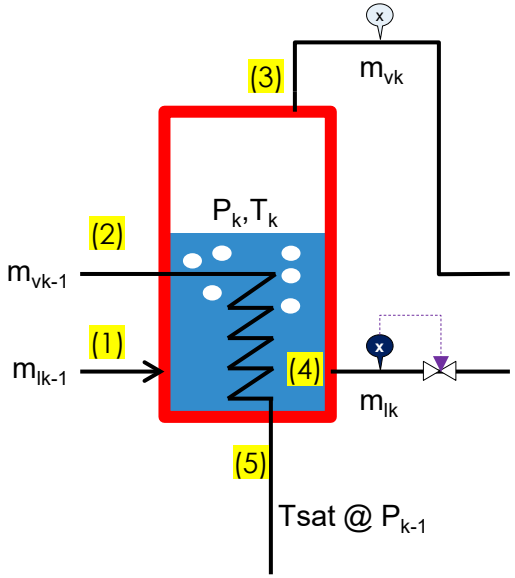
$$m_{v,1} = \underbrace{m_{l,0}\left(\frac{h_{l,0} - h_{l,1}}{h_{v,1} - h_{l,1}}\right)}_{\text{Flasheamento devido à expansão isentálpica na válvula}} + \underbrace{m_{st}\left(\frac{h_{st} - h_{l,sat}}{h_{v,1} - h_{l,1}}\right)}_{\text{Evaporação devido ao calor liberado pela condensação do vapor superaquecido}}$$

Princípio de funcionamento dos evaporadores sem recompressão de vapor

inv. massa → $m_{l,k-1} = m_{l,k} + m_{v,k}$

1ra Lei → $m_{l,k-1}h_{l,k-1} + m_{v,k-1}h_{v,k-1} - m_{v,k}h_{v,k} - m_{l,k}h_{l,k} - m_{v,k-1}h_{l,k-1} = 0$

(1) (2) (3) (4) (5)



rearranjando...

$$m_{v,k} = \underbrace{m_{l,k-1}\left(\frac{h_{l,k-1} - h_{l,k}}{h_{v,k} - h_{l,k}}\right)}_{\text{Flasheamento devido à expansão isentálpica na válvula}} + \underbrace{m_{v,k-1}\left(\frac{h_{v,k-1} - h_{l,k-1}}{h_{v,k} - h_{l,k}}\right)}_{\text{Evaporação devido ao calor liberado pela condensação do vapor do estágio anterior}}$$

$$m_{v,k} = m_{flash,k} + m_{evap,k}$$

k=1 $$m_{v,1} = m_{l,0}\left(\frac{h_{l,0} - h_{l,1}}{h_{v,1} - h_{l,1}}\right) + m_{st}\left(\frac{h_{st} - h_{l,sat}}{h_{v,1} - h_{l,1}}\right) \qquad m_{l,1} = m_{l,0} - m_{v,1}$$

k=2 $$m_{v,2} = m_{l,1}\left(\frac{h_{l,1} - h_{l,2}}{h_{v,2} - h_{l,2}}\right) + m_{v,1}\left(\frac{h_{v,1} - h_{l,1}}{h_{v,2} - h_{l,2}}\right) \qquad m_{l,2} = m_{l,1} - m_{v,2}$$

k=3 $$m_{v,3} = m_{l,2}\left(\frac{h_{l,2} - h_{l,3}}{h_{v,3} - h_{l,3}}\right) + m_{v,2}\left(\frac{h_{v,2} - h_{l,2}}{h_{v,3} - h_{l,3}}\right) \qquad m_{l,3} = m_{l,2} - m_{v,3}$$

$$\vdots \qquad \vdots \qquad \vdots$$

k=N $$m_{v,N} = m_{l,N-1}\left(\frac{h_{l,N-1} - h_{l,N}}{h_{v,N} - h_{l,N}}\right) + m_{v,N-1}\left(\frac{h_{v,N-1} - h_{l,N-1}}{h_{v,N} - h_{l,N}}\right) \qquad m_{l,N} = m_{l,N-1} - m_{v,N}$$

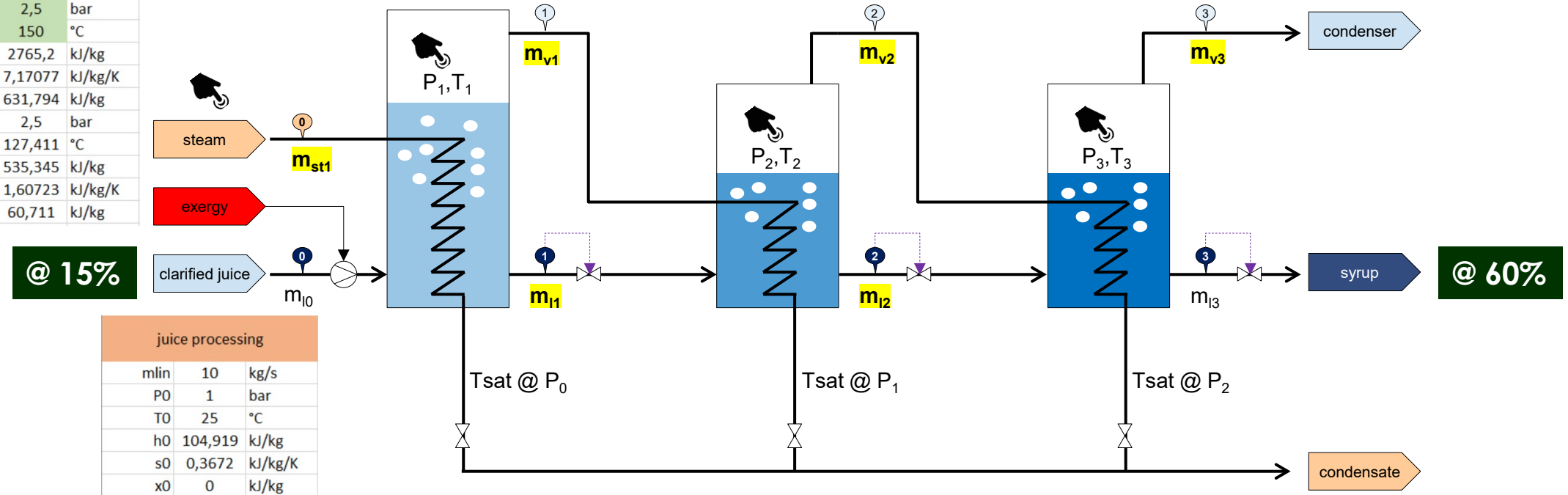
Obs.: as entalpias só dependem das pressões especificadas nos módulos

$\rightarrow$ 2N equações $\times$ 2N incógnitas

Configuração de referência...

Attention to Filler Words

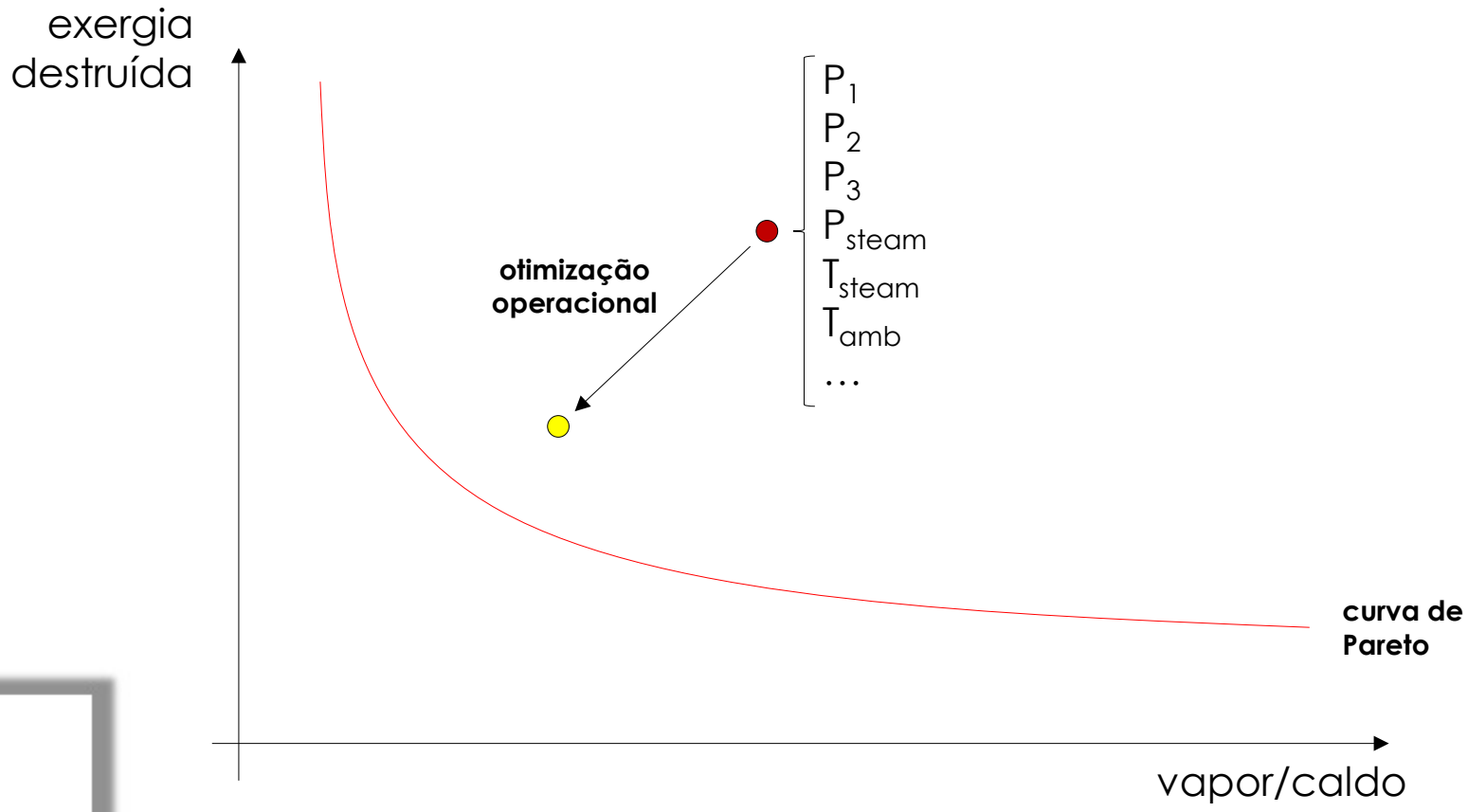
steam supply		
mstin	?	kg/s
Pst	2,5	bar
Tst	150	°C
hst	2765,2	kJ/kg
sst	7,17077	kJ/kg/K
xst	631,794	kJ/kg
Pcond	2,5	bar
Tcond	127,411	°C
hcond	535,345	kJ/kg
scond	1,60723	kJ/kg/K
xcond	60,711	kJ/kg

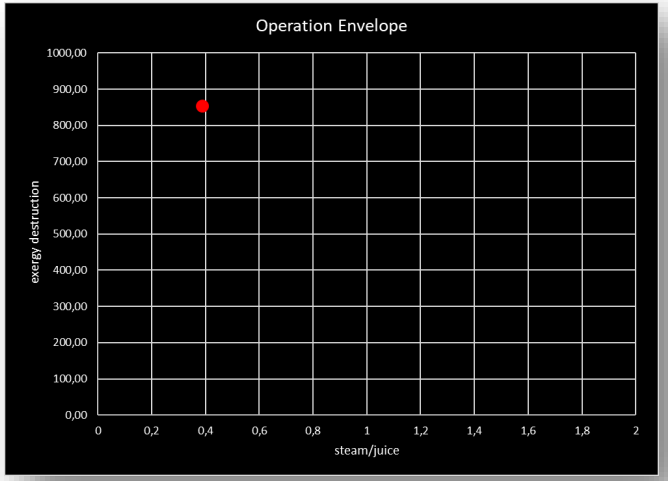


juice processing		
mlin	10	kg/s
P0	1	bar
T0	25	°C
h0	104,919	kJ/kg
s0	0,3672	kJ/kg/K
x0	0	kJ/kg
Cin	15%	kg/kg
Cout	60%	kg/kg
mlout	2,5	kg/s

$$\left.\begin{aligned} r_0 &= \frac{m_{açúcar}}{m_{l,0}} \\ r_3 &= \frac{m_{açúcar}}{m_{l,3}} \end{aligned}\right\} \quad m_{l,3} = m_{l,0}\frac{r_3}{r_0} \quad \Rightarrow \quad \left\{\begin{aligned} &m_{steam} \\ &m_{l,1}, m_{v,1} \\ &m_{l,2}, m_{v,2} \\ &m_{v,3} \end{aligned}\right.$$

Envelope operacional do processo



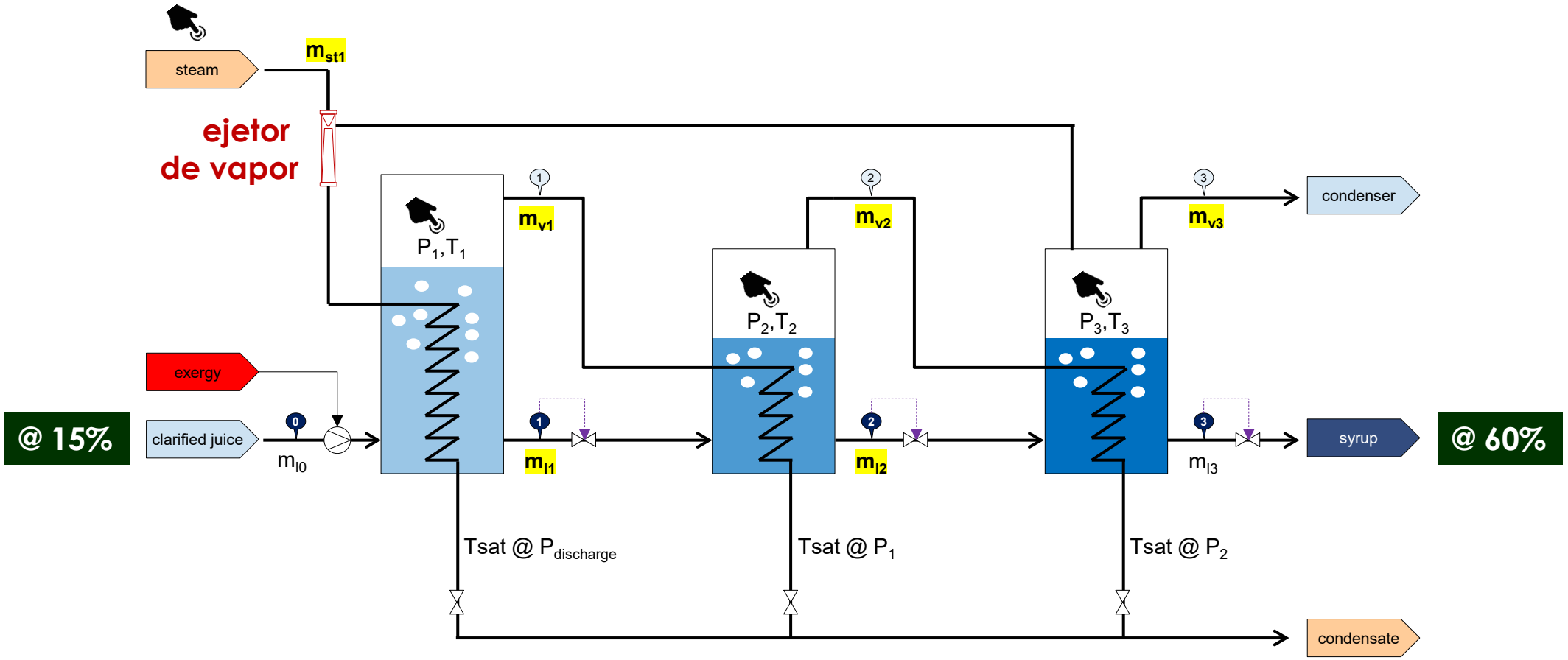


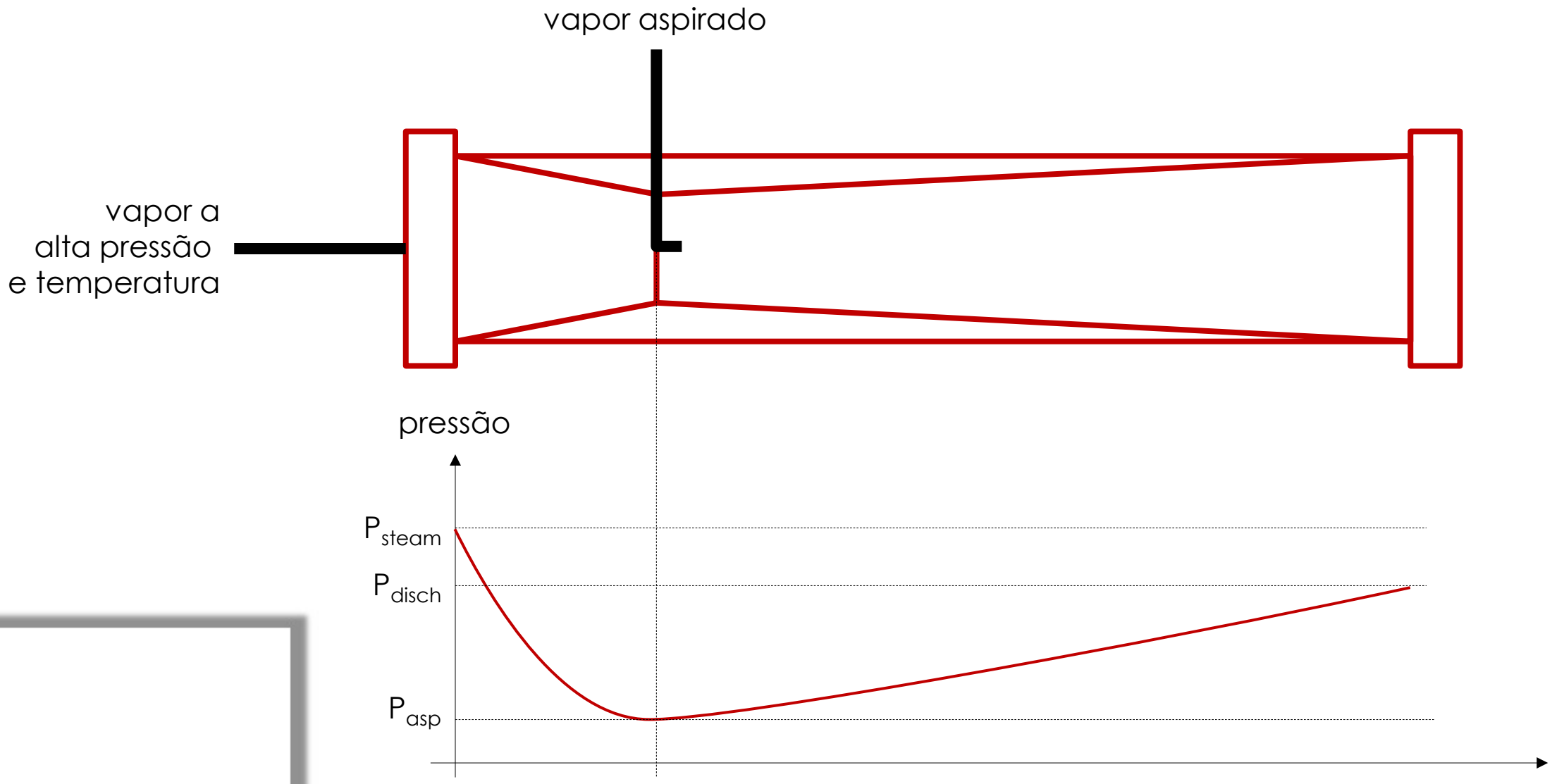
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	fluid and dead state				evaporator									
2														
3	fluid	water			evaps	P	T	hl	hv	sl	sv	xl	xv	
4	Pamb	1	bar		1	1	99,6059	417,504	2674,95	1,30276	7,35885	33,6484	485,469	
5	Tamb	25	°C		2	0,9	96,6871	405,198	2670,31	1,26964	7,39427	31,2157	470,273	
6	hamb	104,919	kJ/kg		3	0,8	93,4855	391,71	2665,18	1,23304	7,43394	28,6403	453,312	
7	samb	0,3672	kJ/kg/K											
8	juice processing				performance									
9														
10	mlin	10	kg/s		ml0	10,0000	kg/s	mv0	3,904	kg/s				
11	P0	1	bar		ml1	7,5286	kg/s	mv1	2,471	kg/s				
12	T0	25	°C		ml2	5,0246	kg/s	mv2	2,504	kg/s				
13	h0	104,919	kJ/kg		ml3	2,5000	kg/s	mv3	2,525	kg/s				
14	s0	0,3672	kJ/kg/K											
15	x0	0	kJ/kg							steam consumption =		3,9038	kg/s	ok
16	Cin	15%	kg/kg							steam/juice =		0,39	kg/kg	ok
17	Cout	60%	kg/kg											
18	mlout	2,5	kg/s							steam exergy input =		2466,42	kW	ok
19										pump exergy input =		0,00	kW	ok
20	steam supply									juice exergy input =		0,00	kW	ok
21										condensate @ evap#1 exergy output =		237,01	kW	ok
22	mstin	?	kg/s							condensate @ evap#2 exergy output =		83,16	kW	ok
23	Pst	2,5	bar							condensate @ evap#3 exergy output =		78,16	kW	ok
24	Tst	150	°C	ok						vapor @ evap#3 exergy output =		1144,42	kW	ok
25	hst	2765,2	kJ/kg							liquid @ evap#3 exergy output =		71,60	kW	ok
26	sst	7,17077	kJ/kg/K											
27	xst	631,794	kJ/kg							overall exergy input =		2466,42	kW	ok
28	Pcond	2,5	bar							overall exergy output =		1614,35	kW	ok
29	Tcond	127,411	°C							overall exergy destruction =		852,07	kW	ok
30	hcond	535,345	kJ/kg							everall exergy destructed to exergy input =		34,55%	kW/kW	ok
31	scond	1,60723	kJ/kg/K							evaporation exergetic efficiency =		16,15%	kW/kW	ok
32	xcond	60,711	kJ/kg											
33														
34														
35														
36														

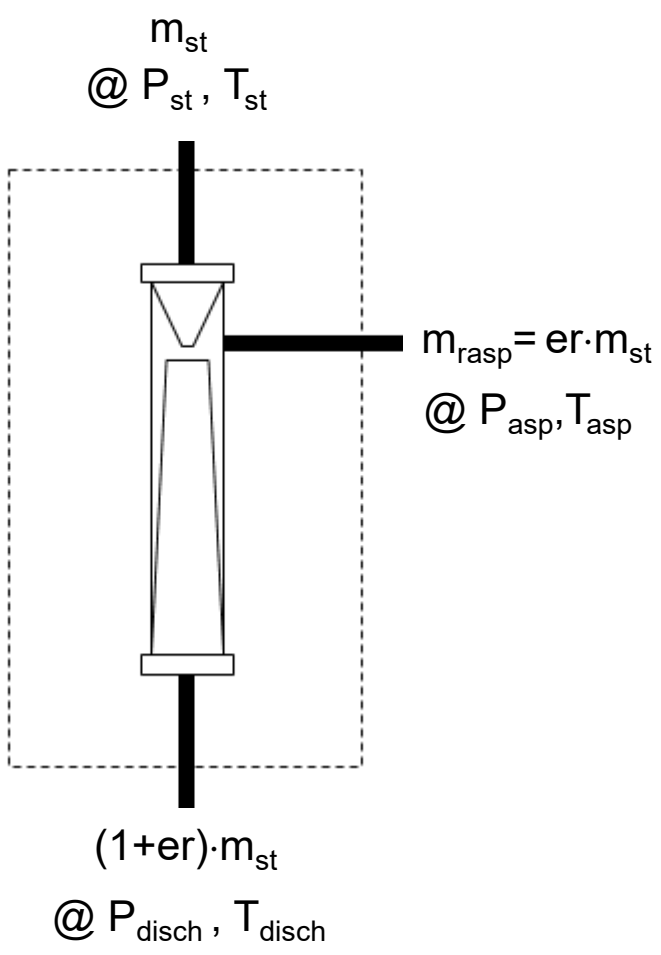
configuração
de referência

Configuração otimizada (termocompressão)...

Attention to Filler Words


steam
m_{st1}
ejetor de vapor
P_1, T_1
P_2, T_2
P_3, T_3
m_{v1}
m_{v2}
m_{v3}
condenser
exergy
@ 15%
clarified juice
m_{l0}
m_{l1}
m_{l2}
m_{l3}
syrup
@ 60%
Tsat @ $P_{discharge}$
Tsat @ P_1
Tsat @ P_2
condensate


vapor aspirado
vapor a
alta pressão
e temperatura
pressão
P_{steam}
P_{disch}
P_{asp}



Balanço de energia:

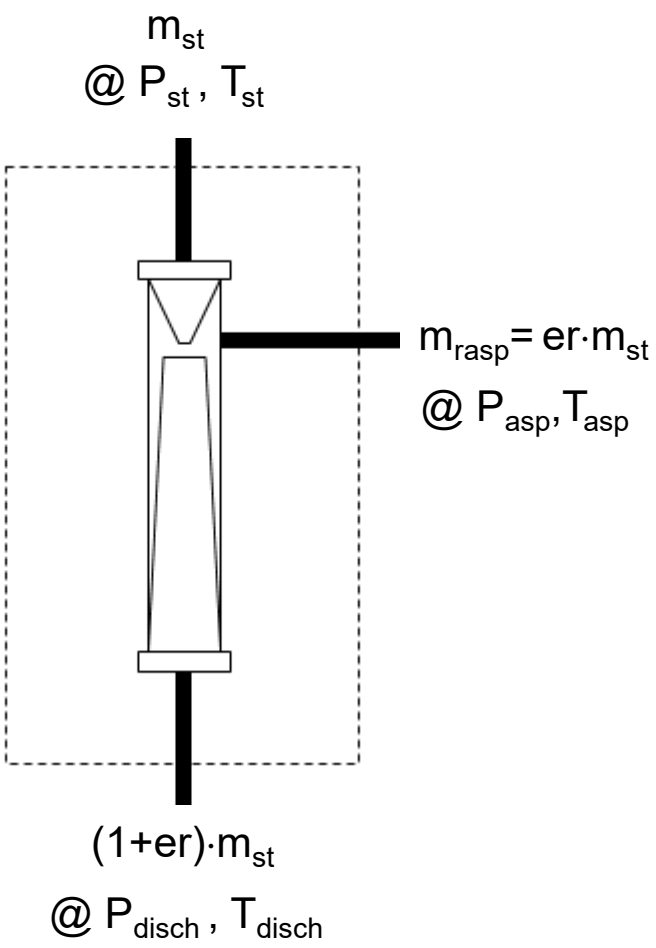
$$m_{st} \cdot h_{st} + er \cdot m_{st} \cdot h_{asp} - (1 + er) \cdot m_{st} \cdot h_{distch} = 0$$

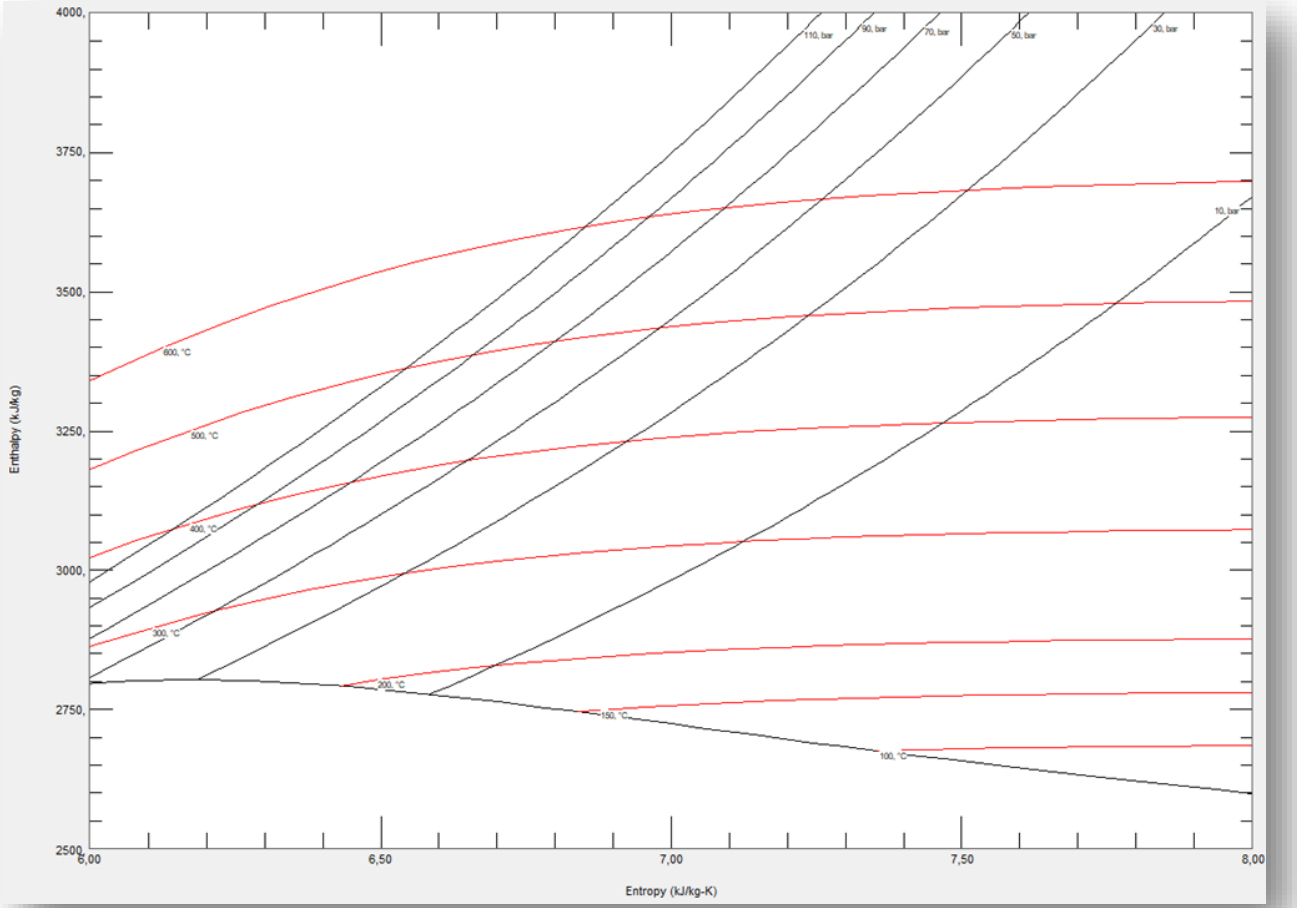
$$\rightarrow \quad h_{distch} = \frac{h_{st}}{1 + er} + \frac{er \cdot h_{asp}}{1 + er}$$

Inventários de entropia:

$$m_{st} \cdot s_{st} + er \cdot m_{st} \cdot s_{asp} - (1 + er) \cdot m_{st} \cdot s_{distch} + \dot{s}_{geração} = 0$$

$$\rightarrow \quad s_{distch} = \frac{s_{st}}{1 + er} + \frac{er \cdot s_{asp}}{1 + er}$$



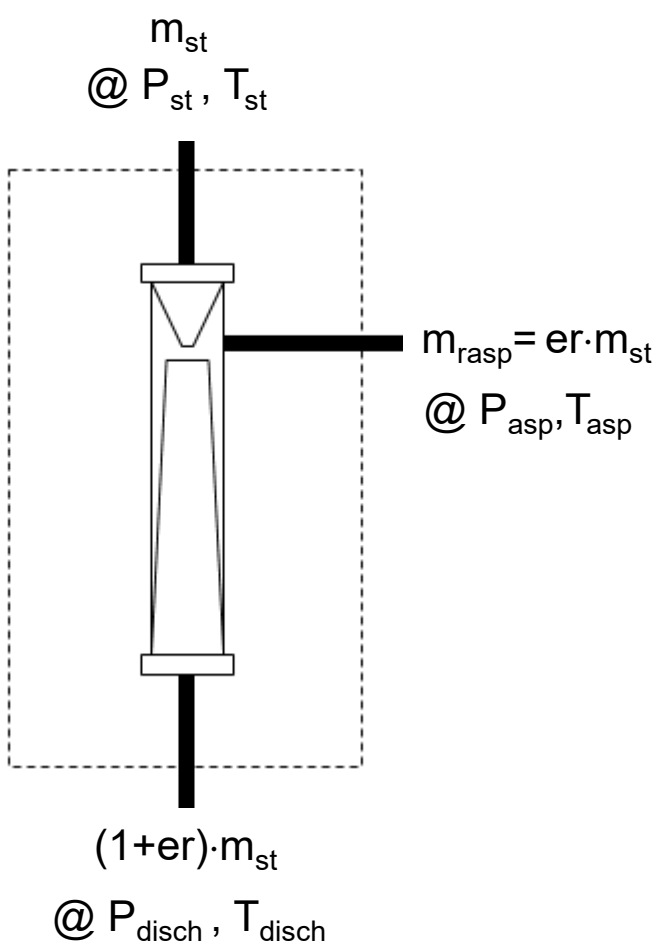


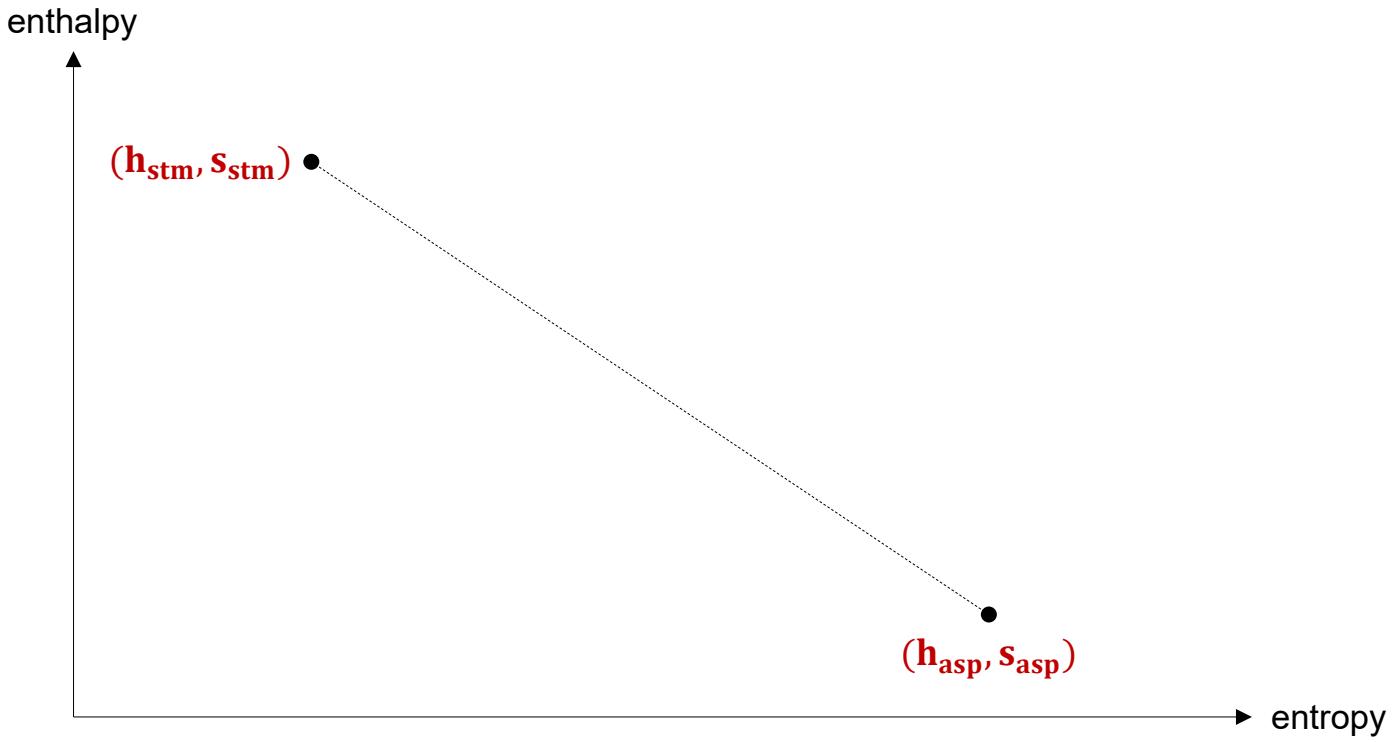
2 x 2

$$\begin{cases} h_{distch}(T_{distch}) = \dfrac{h_{st}}{1+er} + \dfrac{er \cdot h_{asp}}{1+er} \\ s_{distch}(T_{distch}) = \dfrac{s_{st}}{1+er} + \dfrac{er \cdot s_{asp}}{1+er} \end{cases}$$

P_{disch} ⇒ er, T_{distch}

Newton-Raphson

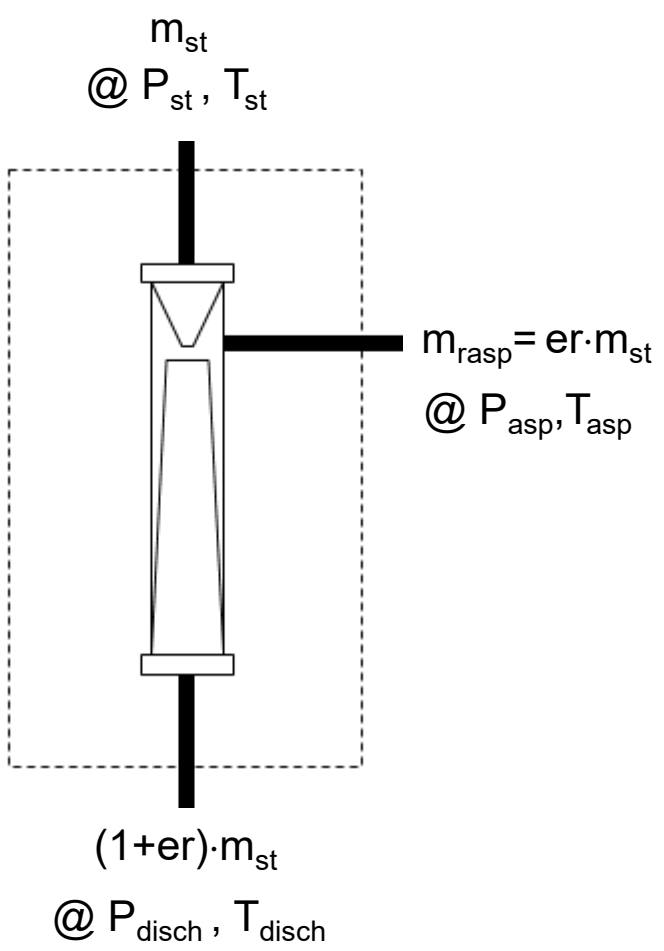


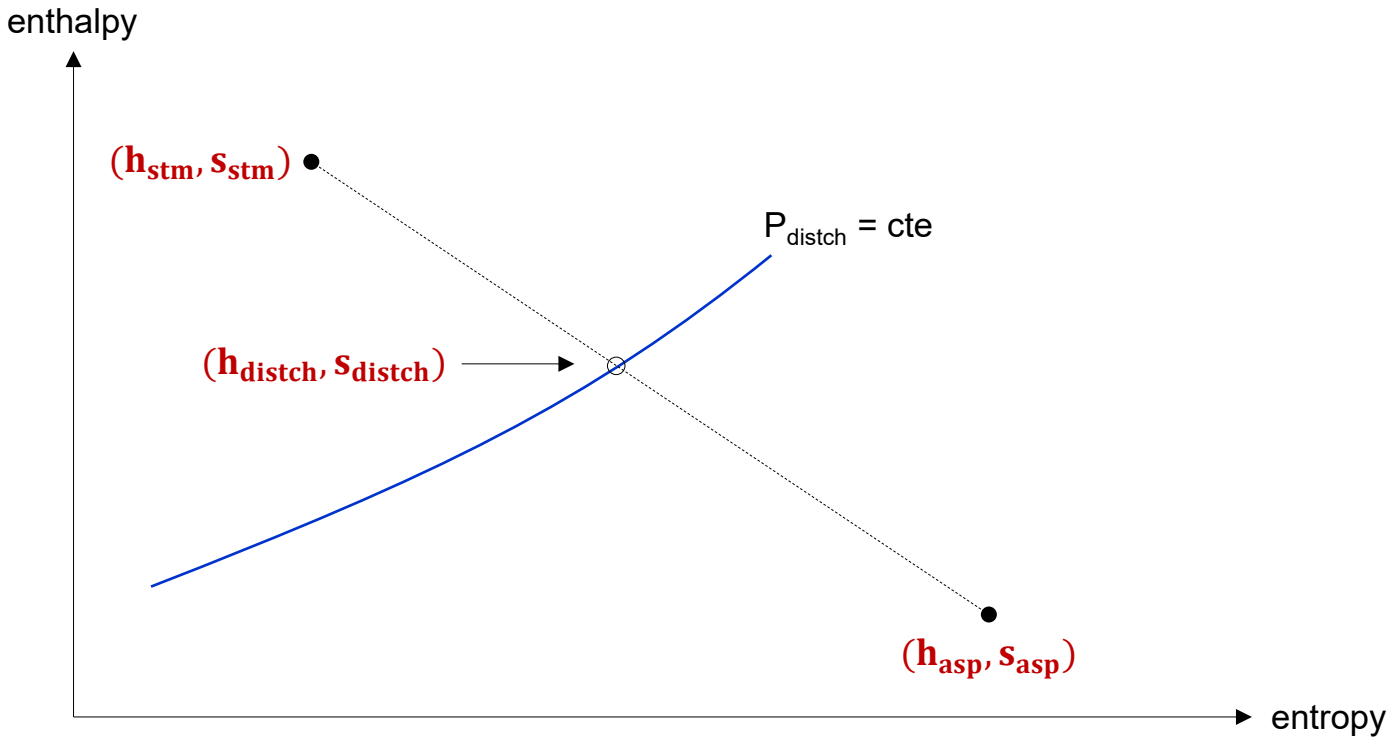


2 x 2

$$\begin{cases} h_{distch}(T_{distch}) = \dfrac{h_{st}}{1+er} + \dfrac{er \cdot h_{asp}}{1+er} \\ s_{distch}(T_{distch}) = \dfrac{s_{st}}{1+er} + \dfrac{er \cdot s_{asp}}{1+er} \end{cases}$$

P_{disch} ⇒ Newton-Raphson ⇒ er, T_{distch}



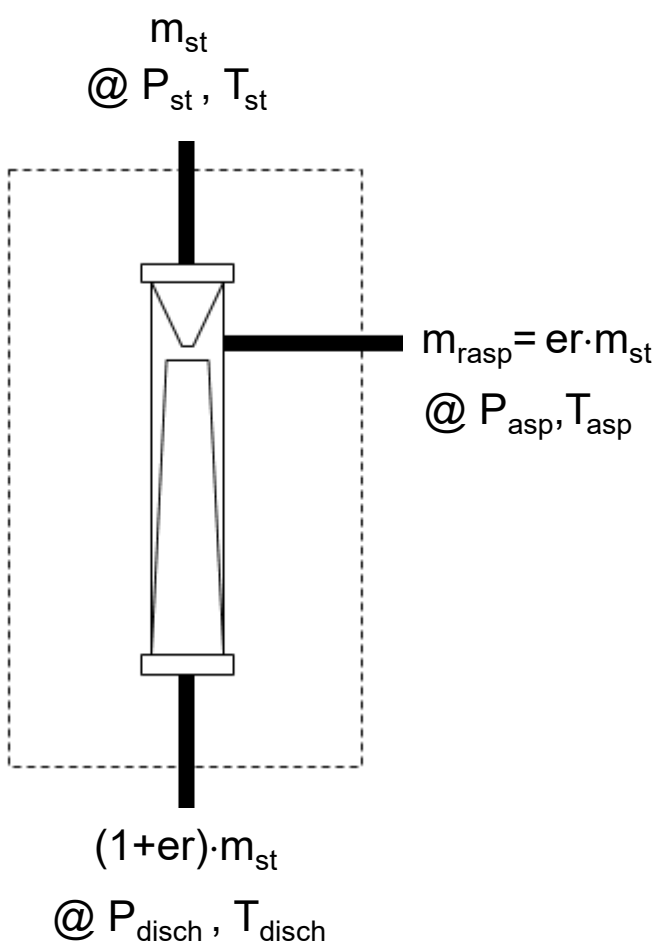


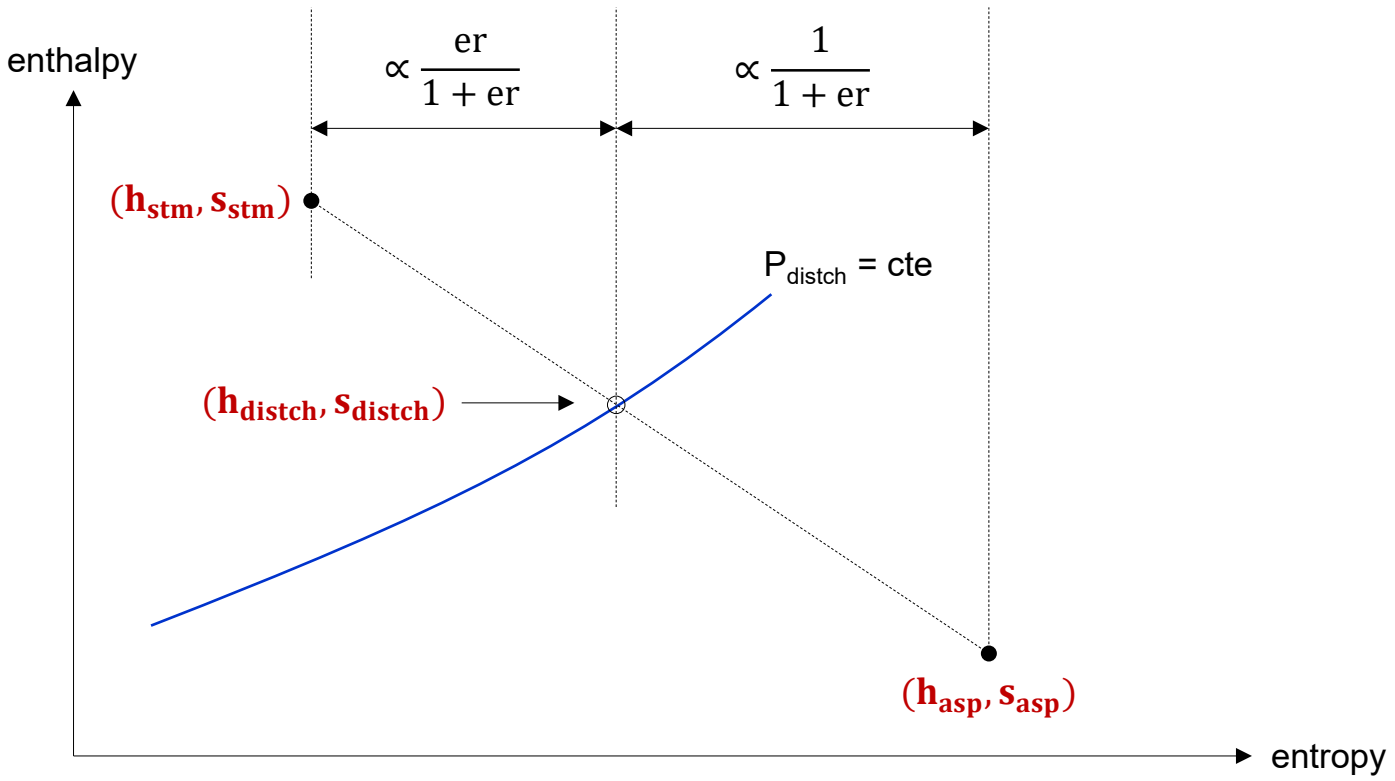
2 x 2

$$\begin{cases} h_{distch}(T_{distch}) = \dfrac{h_{st}}{1+er} + \dfrac{er \cdot h_{asp}}{1+er} \\ s_{distch}(T_{distch}) = \dfrac{s_{st}}{1+er} + \dfrac{er \cdot s_{asp}}{1+er} \end{cases}$$

P_{disch} $\Rightarrow$ er, T_{distch}

Newton-Raphson



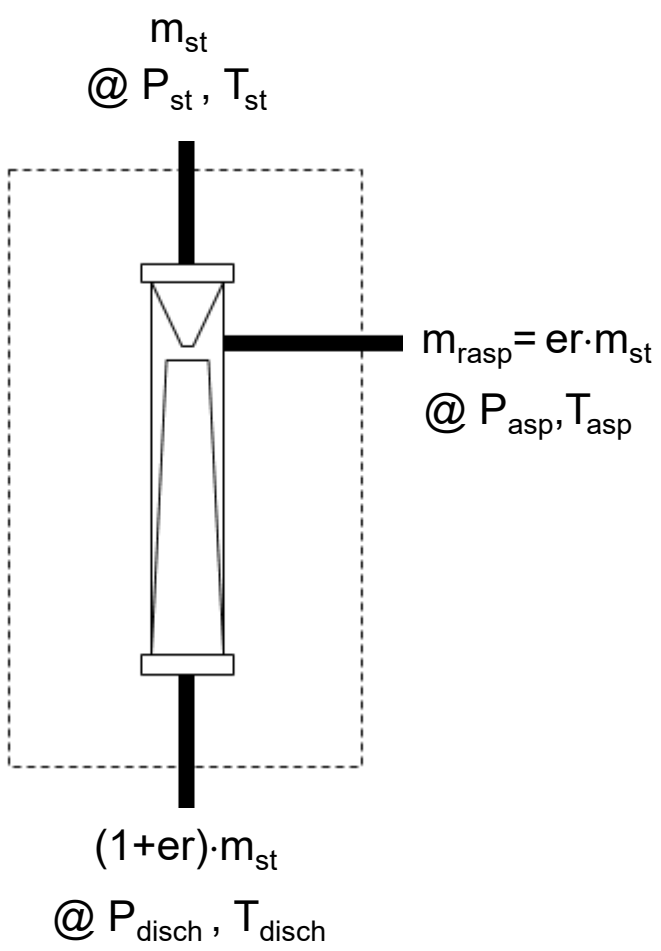


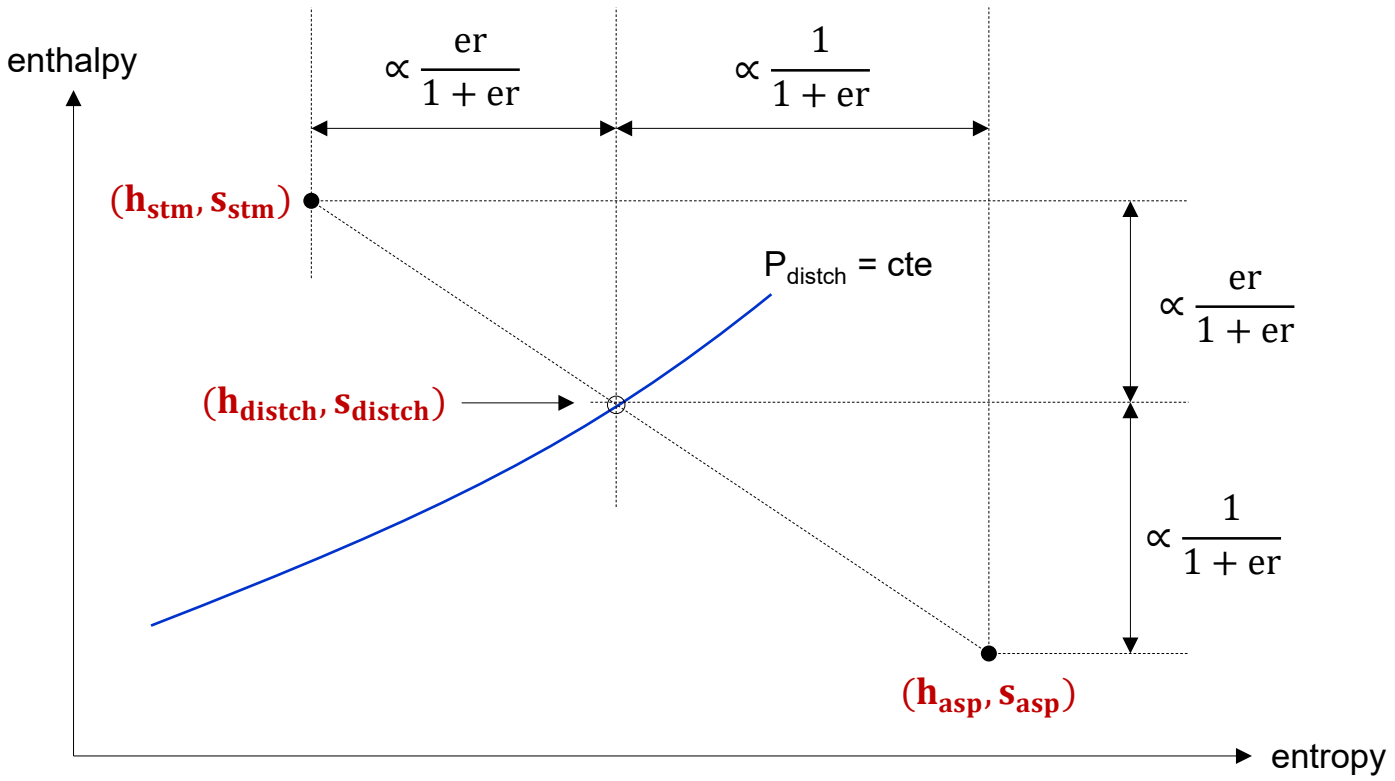
2 x 2

$$\begin{cases} h_{distch}(T_{distch}) = \dfrac{h_{st}}{1+er} + \dfrac{er \cdot h_{asp}}{1+er} \\[2ex] s_{distch}(T_{distch}) = \dfrac{s_{st}}{1+er} + \dfrac{er \cdot s_{asp}}{1+er} \end{cases}$$

P_{disch} $\Rightarrow$ er, T_{distch}

Newton-Raphson





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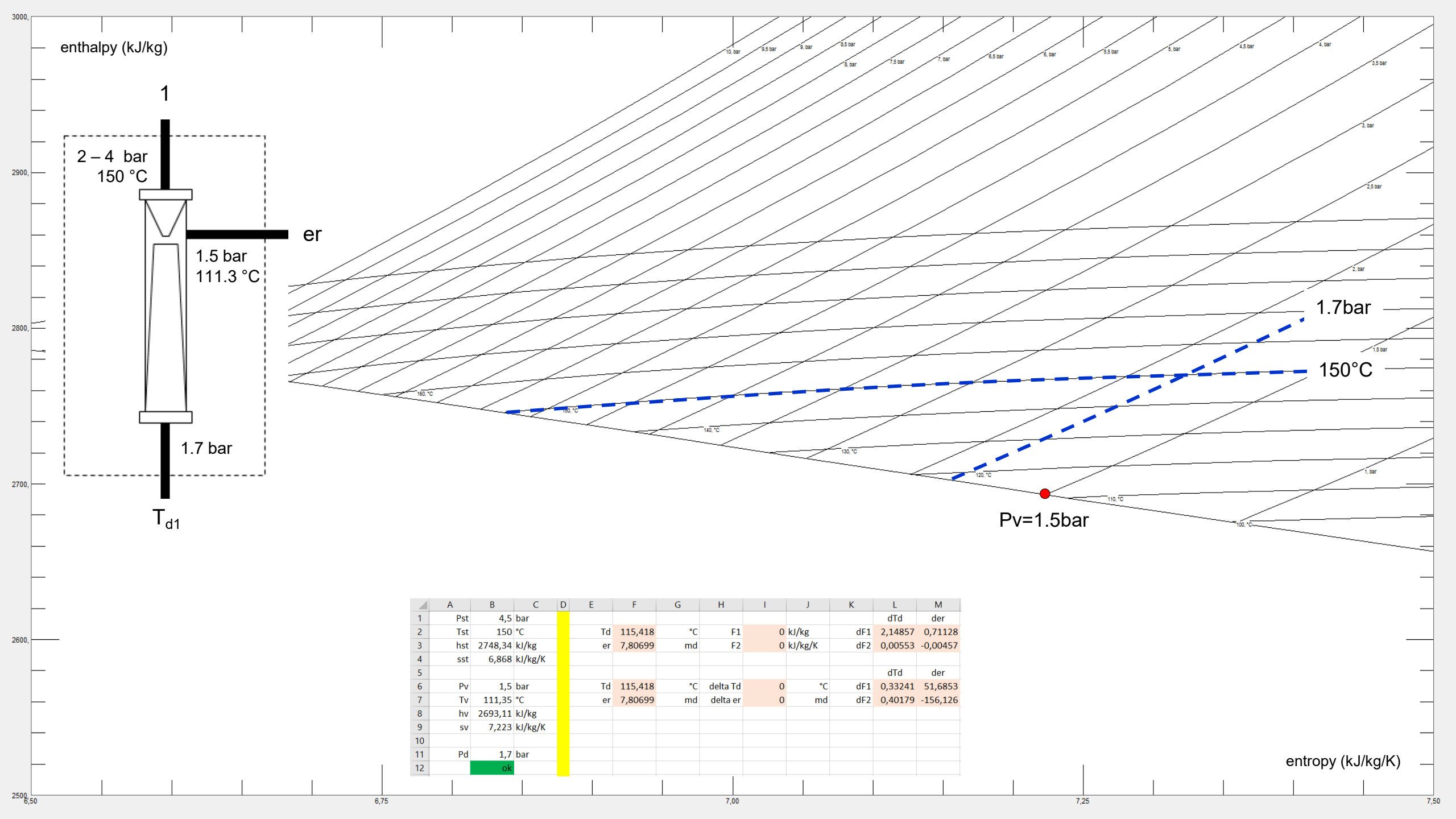
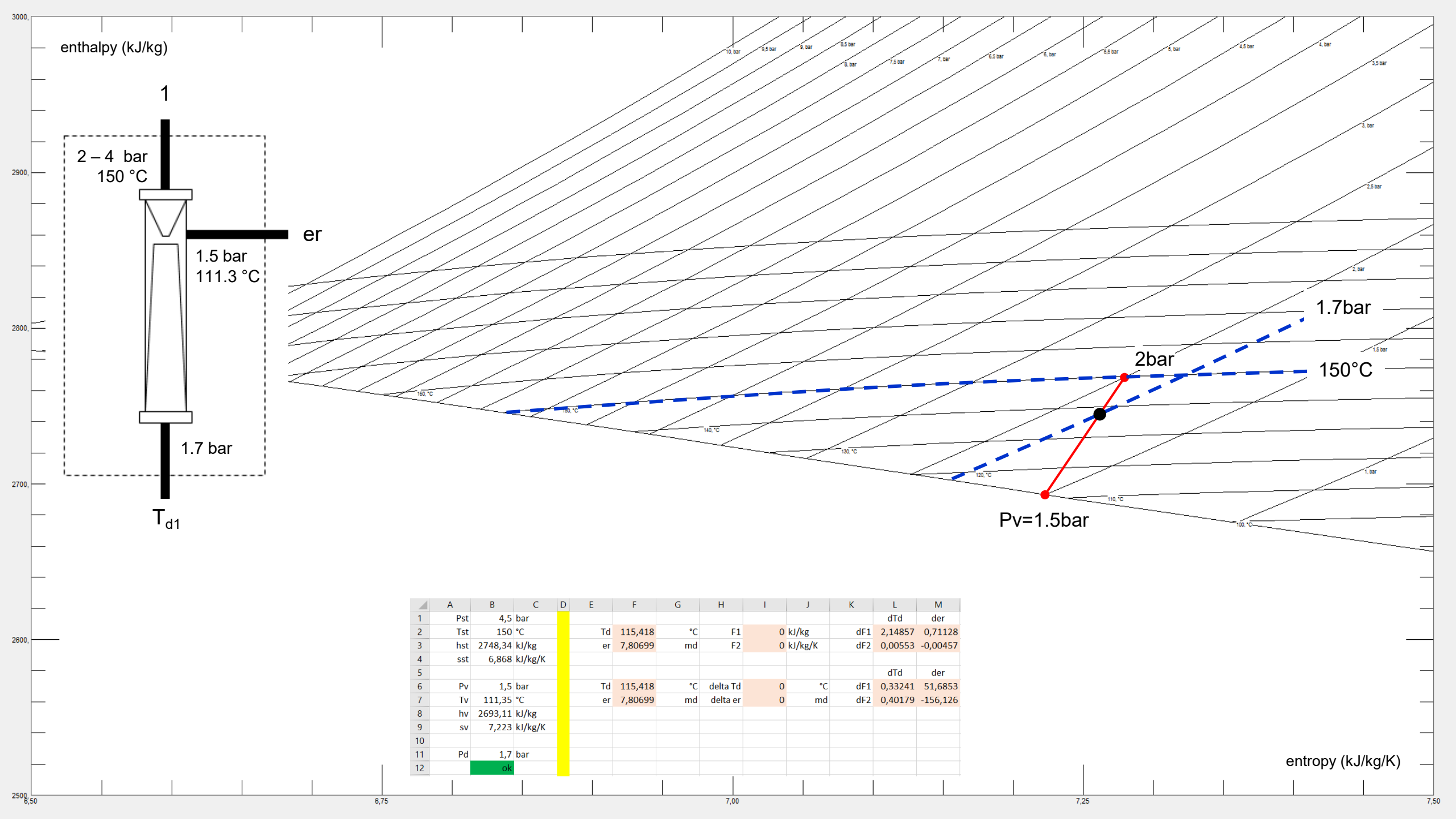


	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Pst	4,5	bar									dTd	der
2	Tst	150	°C		Td	115,418	°C	F1	0	kJ/kg	dF1	2,14857	0,71128
3	hst	2748,34	kJ/kg		er	7,80699	md	F2	0	kJ/kg/K	dF2	0,00553	-0,00457
4	sst	6,868	kJ/kg/K										
5												dTd	der
6	Pv	1,5	bar		Td	115,418	°C	delta Td	0	°C	dF1	0,33241	51,6853
7	Tv	111,35	°C		er	7,80699	md	delta er	0	md	dF2	0,40179	-156,126
8	hv	2693,11	kJ/kg										
9	sv	7,223	kJ/kg/K										
10													
11	Pd	1,7	bar										
12		ok											



	A	B	C	D	E	F	G	H	I	J	K	L	M
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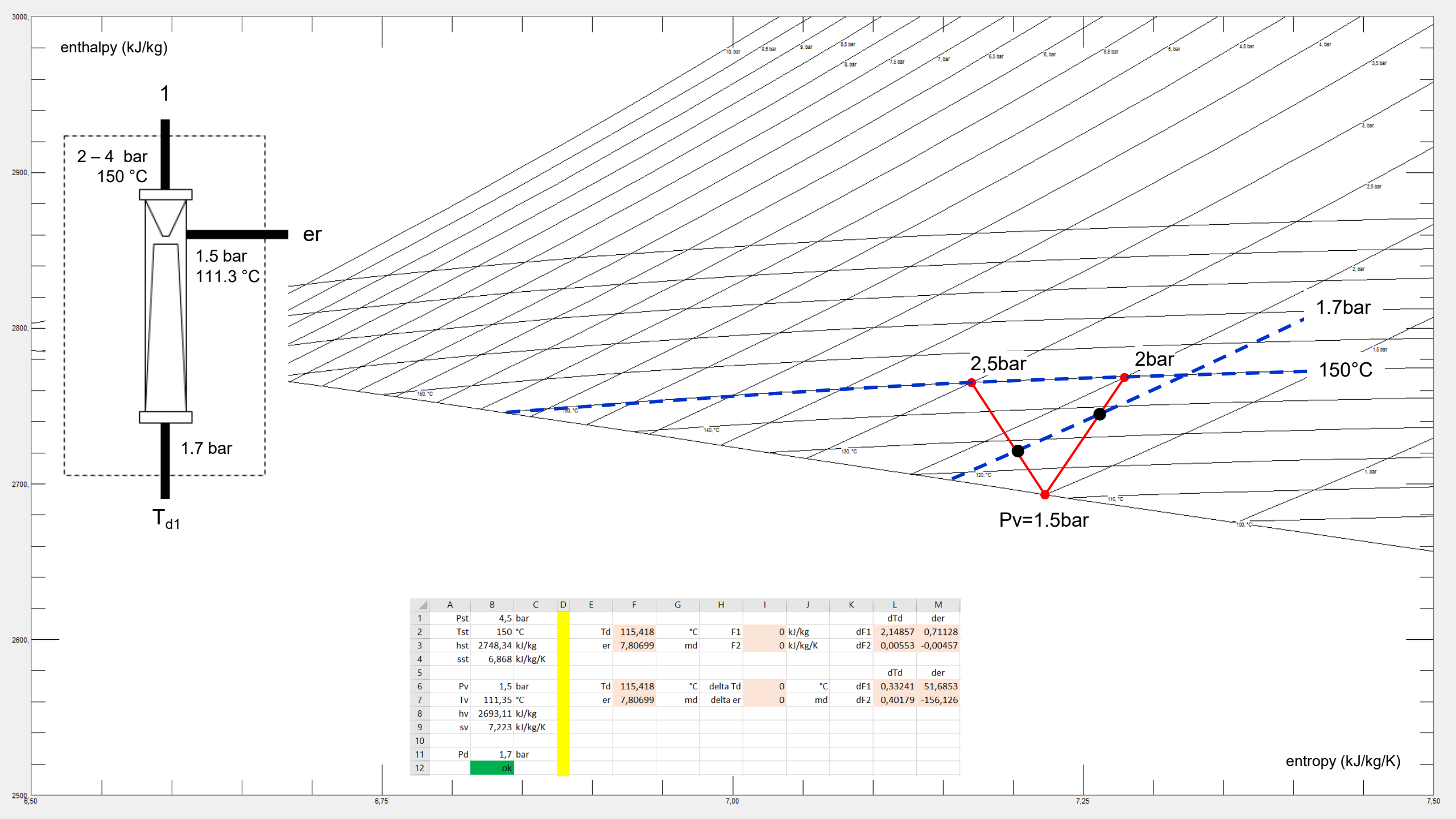

	A	B	C	D	E	F	G	H	I	J	K	L	M
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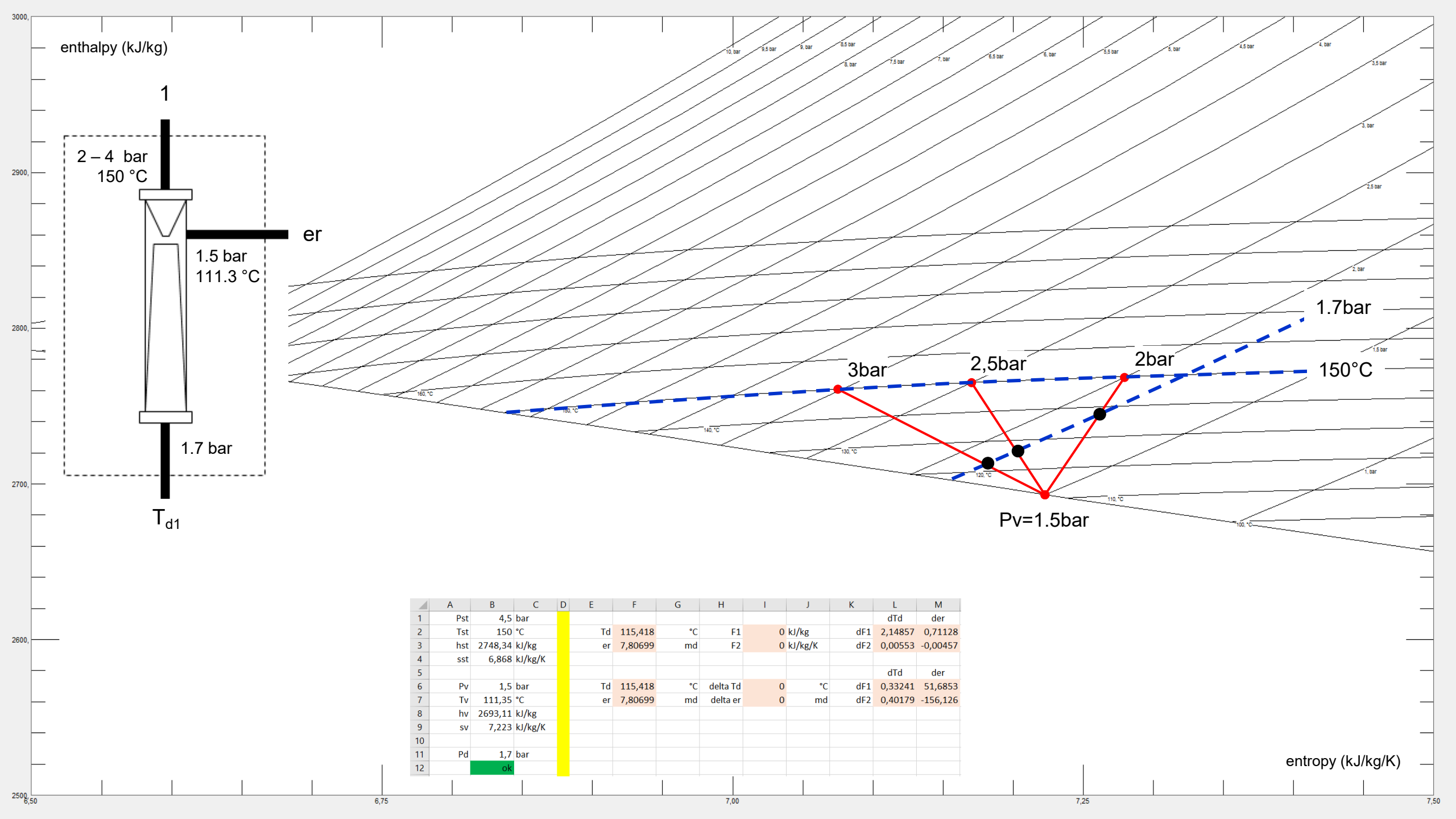

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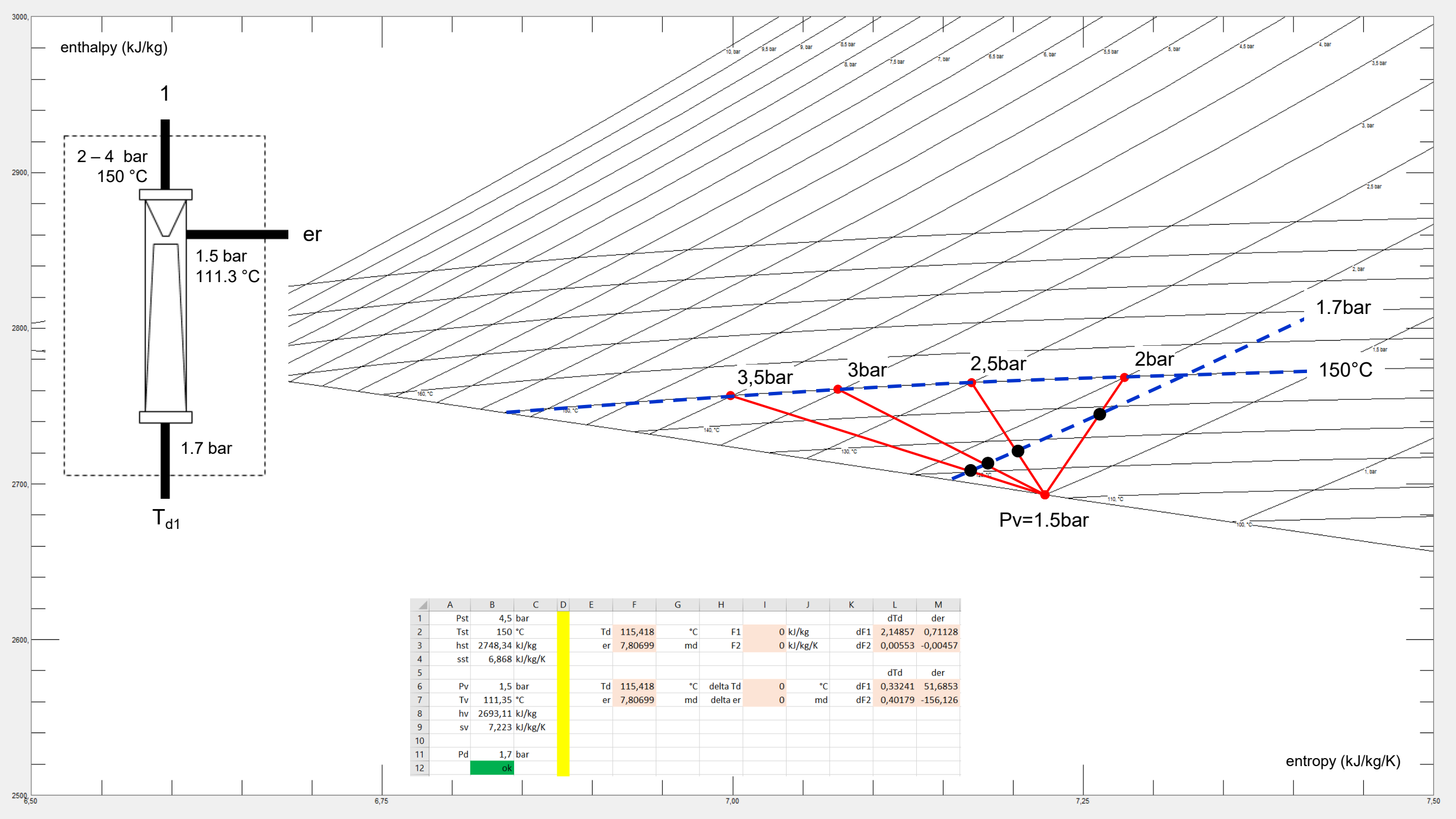

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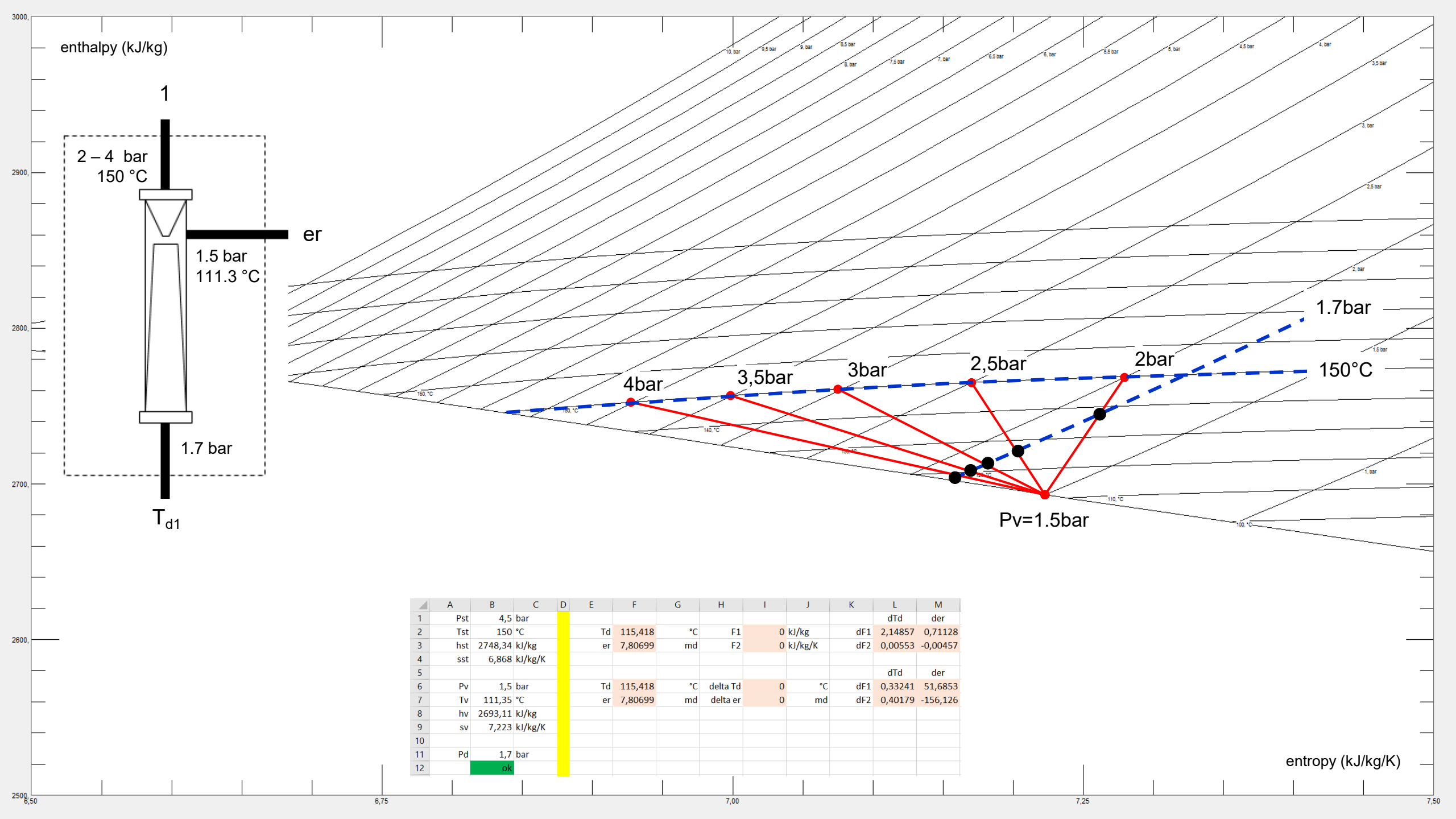

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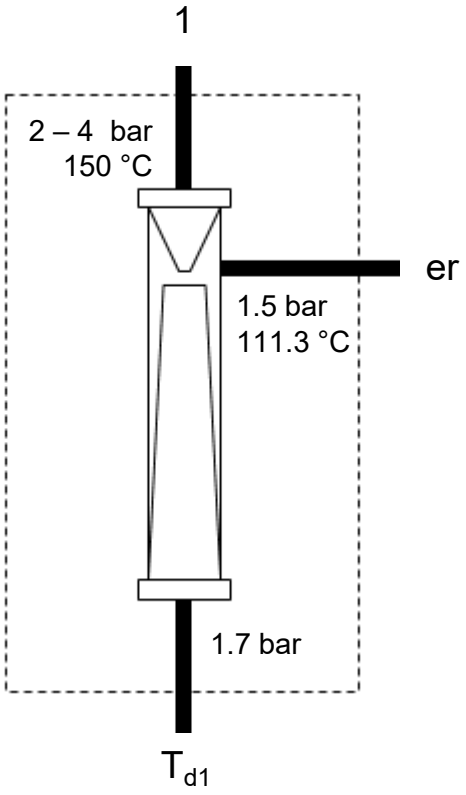

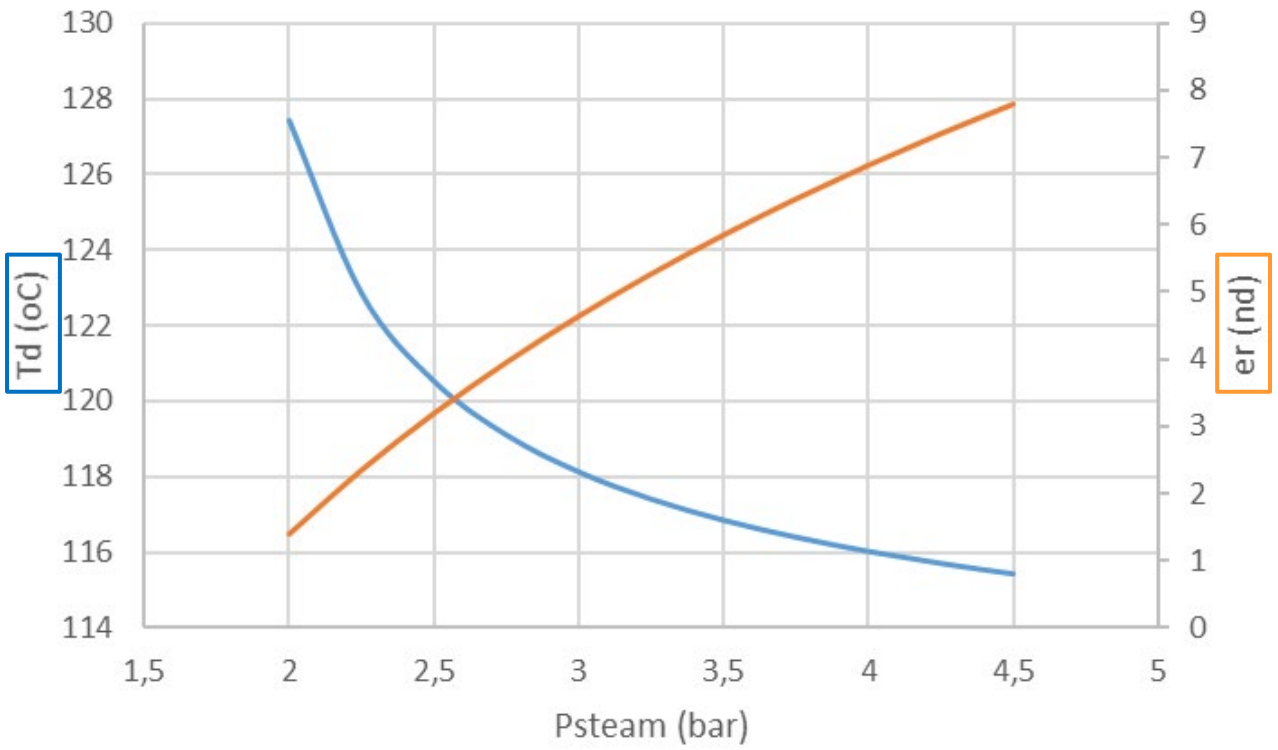

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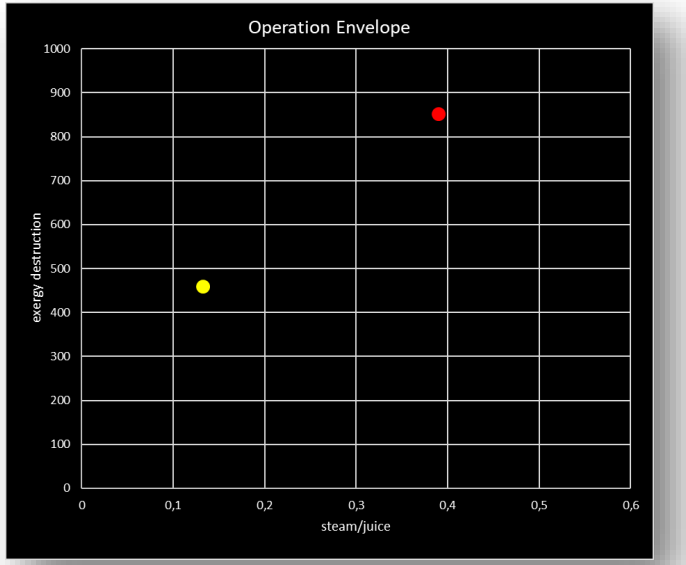


Salvamento Automático | Ferramentas de Formata

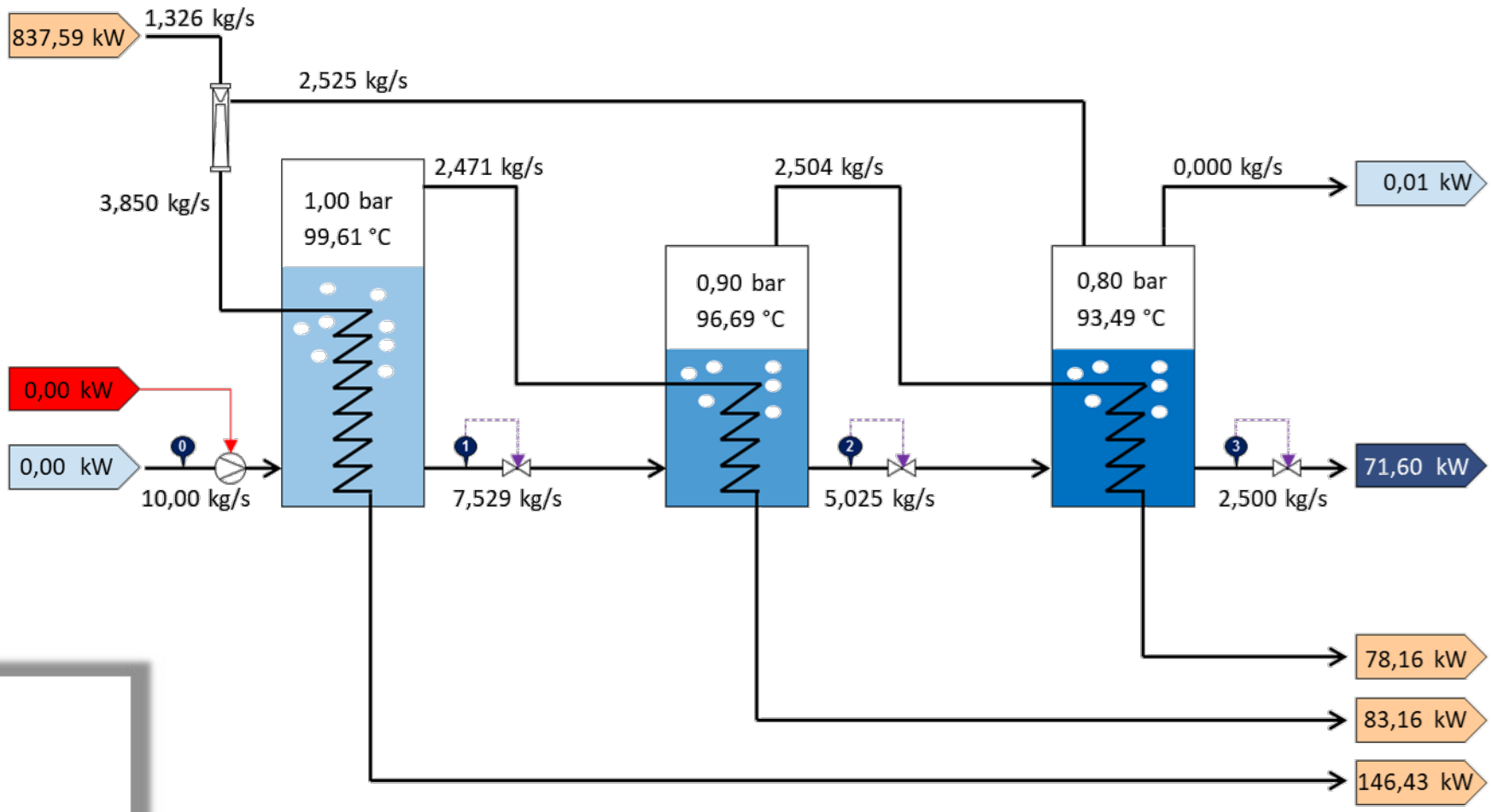
Arquivo | Página Inicial | Inserir | Layout da Página | Fórmulas | Dados | Revisão | Exibir

Colar | Recortar | Copiar | Pincel de Formatação | Área de Transferência | Calibri | 11 | Fonte | Quebrar Texto Automaticar | Mesclar e Centralizar | Alinhamento

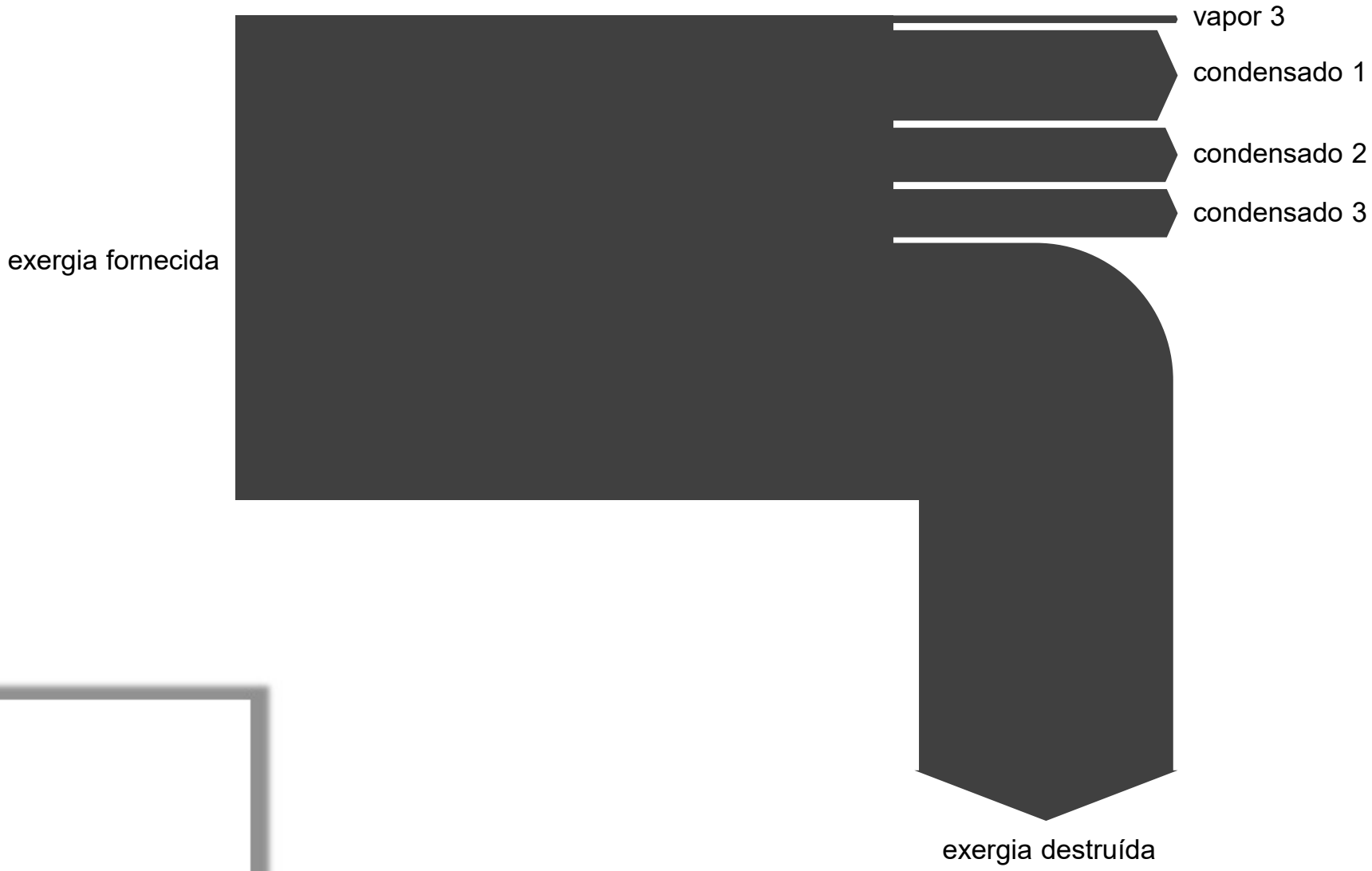
Agrupar 12

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	fluid and dead state				evaporator										
2															
3	fluid	water			evaps	Pref	P	T	hl	hv	sl	sv	xl	xv	
4	Pamb	1	bar		1	1	1,00	99,61	417,504	2674,95	1,30276	7,35885	33,6484	485,469	
5	Tamb	25	°C		2	0,9	0,90	96,69	405,198	2670,31	1,26964	7,39427	31,2157	470,273	
6	hamb	104,919	kJ/kg		3	0,8	0,80	93,49	391,71	2665,18	1,23304	7,43394	28,6403	453,312	
7	samb	0,3672	kJ/kg/K												
8	juice processing				performance										
9															
10	mlin	10	kg/s		ml0	10,00	kg/s	mst	1,326	kg/s	mrv3	2,525	kg/s		
11	P0	1	bar		ml1	7,529	kg/s	mv1	2,471	kg/s	mcond1	3,850	kg/s		
12	T0	25	°C		ml2	5,025	kg/s	mv2	2,504	kg/s					
13	h0	104,919	kJ/kg		ml3	2,500	kg/s	mv3	0,000	kg/s					
14	s0	0,3672	kJ/kg/K												
15	x0	0	kJ/kg												
16	Cin	15%	kg/kg												
17	Cout	60%	kg/kg												
18	mlout	2,5	kg/s												
19															
20	steam supply										steam consumption =		1,3257	kg/s	ok
21											steam/juice =		0,133	kg/kg	ok
22	mstin	?	kg/s												
23	Pst	2,5	bar								steam exergy input =		837,59	kW	ok
24	Tst	150	°C	ok							pump exergy input =		0,00	kW	ok
25	hst	2765,2	kJ/kg								juice exergy input =		0,00	kW	ok
26	sst	7,17077	kJ/kg/K								condensate @ evap#1 exergy output =		146,43	kW	ok
27	xst	631,794	kJ/kg								condensate @ evap#2 exergy output =		83,16	kW	ok
28											condensate @ evap#3 exergy output =		78,16	kW	ok
29	vapor supply										vapor @ evap#3 exergy output =		0,01	kW	ok
30											liquid @ evap#3 exergy output =		71,60	kW	ok
31	mvapin	0	kg/s		ideal										
32	Pcond	1,194	bar		1,194						overall exergy input =		837,59	kW	ok
33	Tcond	104,639	°C								overall exergy output =		379,36	kW	ok
34	hcond	438,749	kJ/kg								overall exergy destruction =		458,23	kW	ok
35	scond	1,35932	kJ/kg/K								everall exergy destructed to exergy input =		54,71%	kW/kW	ok
36	xcond	38,0303	kJ/kg								evaporation exergetic efficiency =		36,74%	kW/kW	ok
37															
38	parameters														
39															
40	eps	0,01													

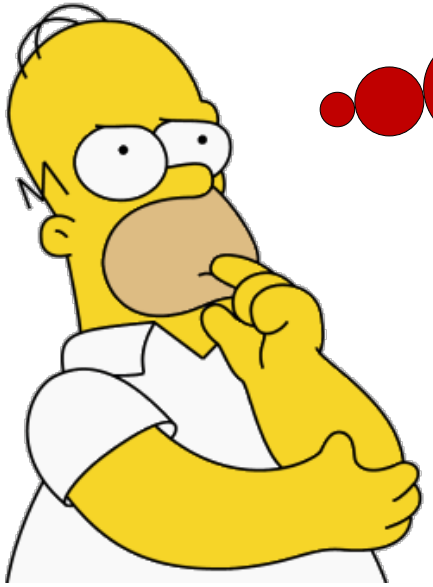
Inventário exergético global

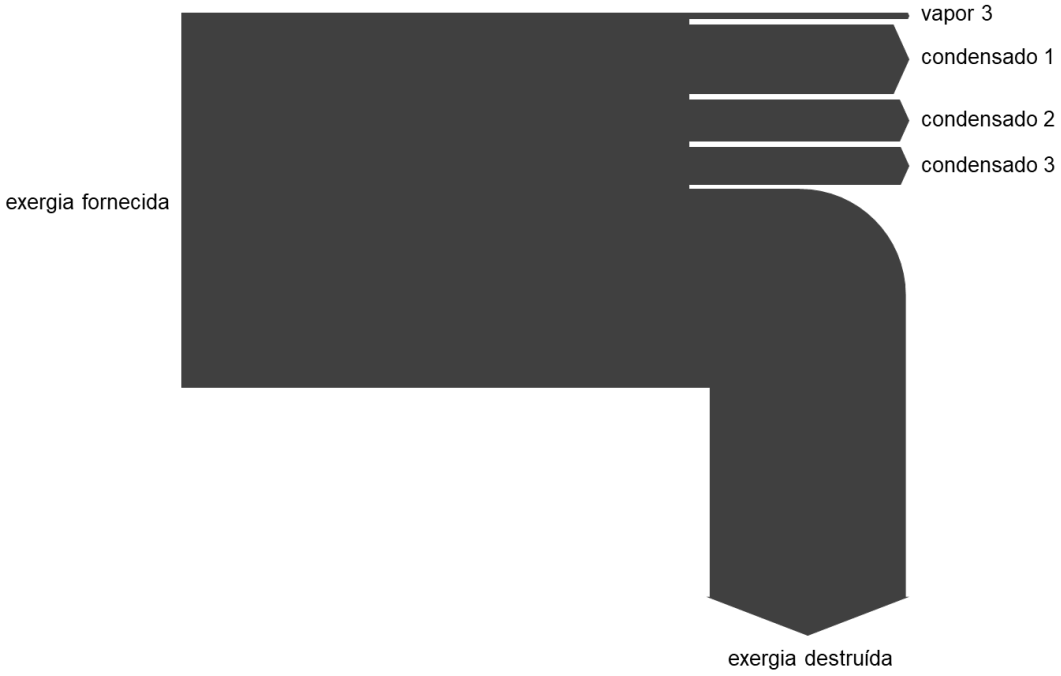


$$ex_{dest} = 458 \text{ kW}$$


vapor 3
condensado 1
condensado 2
condensado 3
exergia fornecida
exergia destruída

Mínima energia mecânica necessária para o processo de separação...
Manifestação da 2º Lei da Termodinâmica !!!





Curso de Termodinâmica

EXERGIA

parte 2/2

aula 14/20