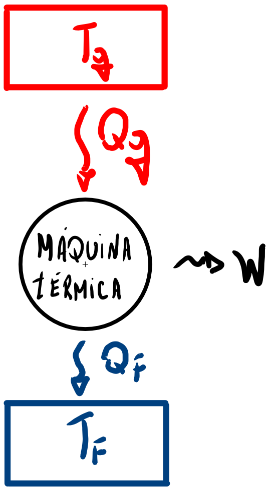
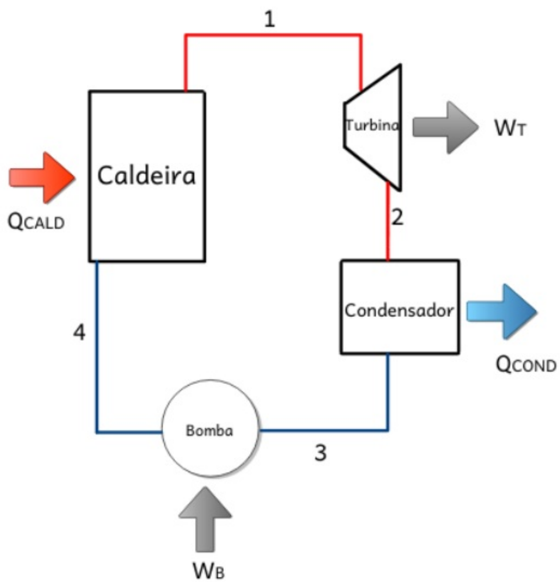
CICLO DE CARNOT

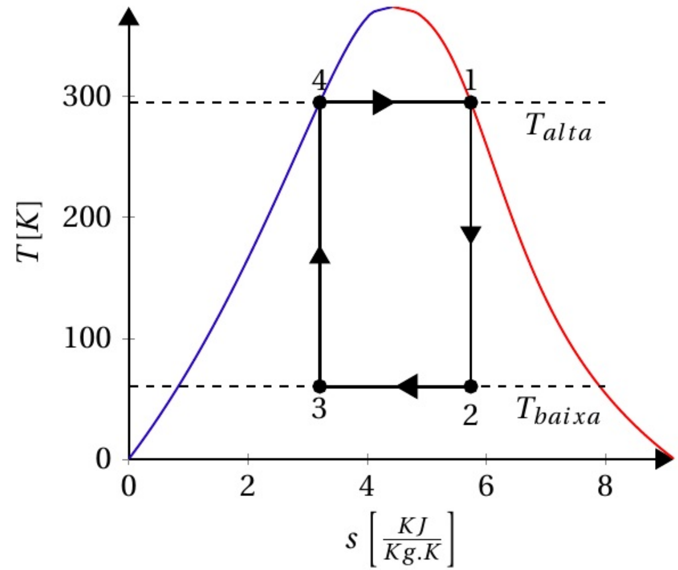
TEORIA & EXERCÍCIO

Fonte de Calor



Fonte Fria
(Ambiente ou Sumidouro)





Ciclo de geração de Potência a Vapor de Carnot

OBJETIVOS

Identificar os componentes do ciclo de Carnot & Hipóteses

Desenhar o diagrama Temperatura-Entropia

Balanço de energia em cada componente para cálculo dos trabalhos e calores

Cálculo do rendimento

Procedimento de solução

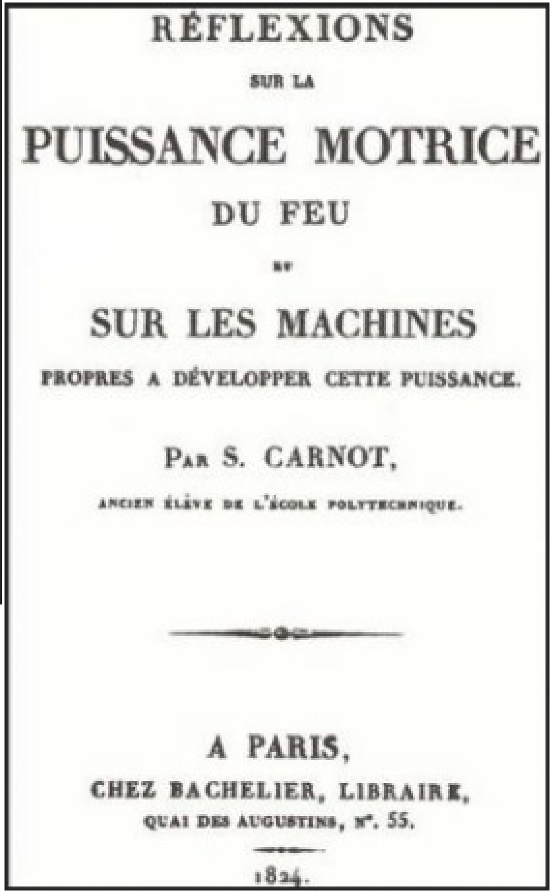
Pŕe-Requisitos:

1ª e 2ª Leis das Termodinâmica;

Estados Termodinâmicos;

SLIDES no Site (Ciclos Termodinâmicos)

Dúvidas e sugestões: email: rodrigo@cienciastermicas.com ou comentários



RÉFLEXIONS

SUR LA

PUISSANCE MOTRICE

DU FEU

ET

SUR LES MACHINES

PROPRES A DÉVELOPPER CETTE PUISSANCE.

PAR S. CARNOT,

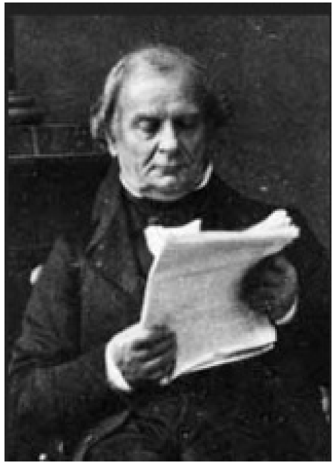
ANCIEN ÉLÈVE DE L'ÉCOLE POLYTECHNIQUE.

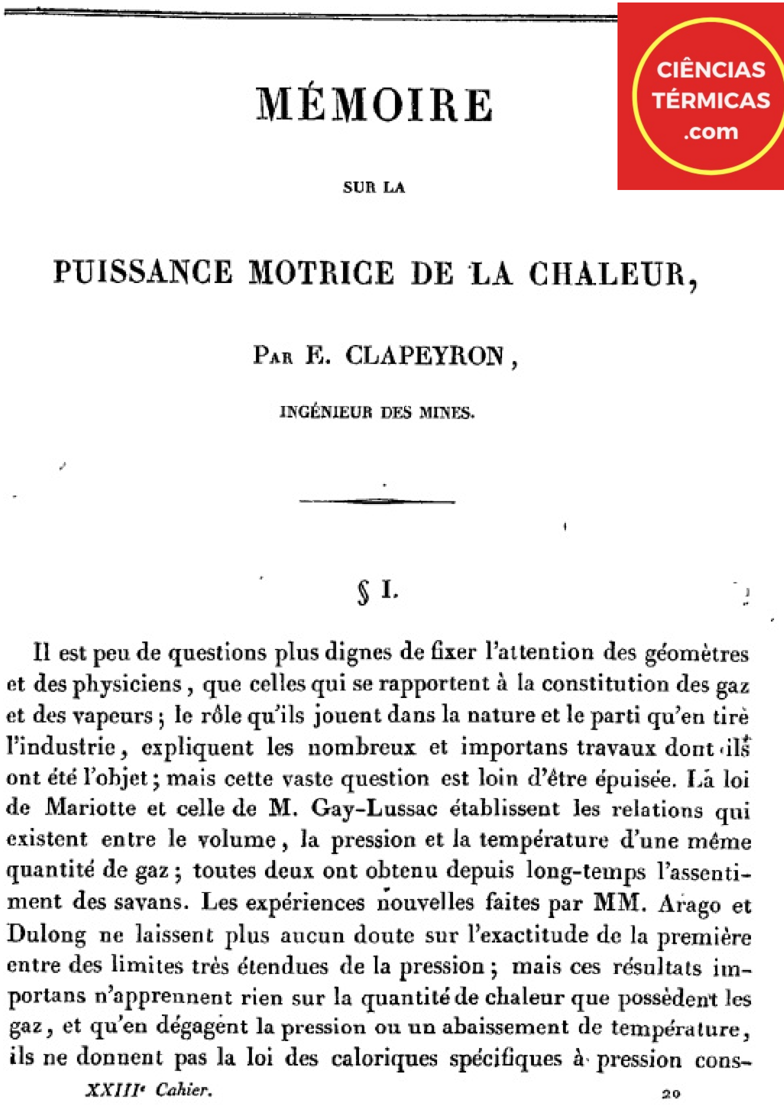
A PARIS,

CHEZ BACHELIER, LIBRAIRE,

QUAI DES AUGUSTINS, N°. 55.

1824.





MÉMOIRE

SUR LA

PUISSANCE MOTRICE DE LA CHALEUR,

PAR E. CLAPEYRON,

INGÉNIEUR DES MINES.

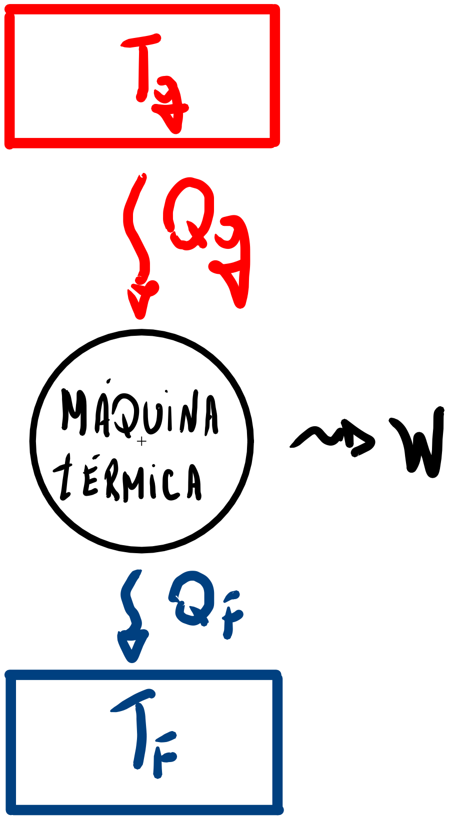
§ I.

Il est peu de questions plus dignes de fixer l'attention des géomètres et des physiciens, que celles qui se rapportent à la constitution des gaz et des vapeurs; le rôle qu'ils jouent dans la nature et le parti qu'en tire l'industrie, expliquent les nombreux et importans travaux dont ils ont été l'objet; mais cette vaste question est loin d'être épuisée. La loi de Mariotte et celle de M. Gay-Lussac établissent les relations qui existent entre le volume, la pression et la température d'une même quantité de gaz; toutes deux ont obtenu depuis long-temps l'assentiment des savans. Les expériences nouvelles faites par MM. Arago et Dulong ne laissent plus aucun doute sur l'exactitude de la première entre des limites très étendues de la pression; mais ces résultats importans n'apprennent rien sur la quantité de chaleur que possèdent les gaz, et qu'en dégagent la pression ou un abaissement de température, ils ne donnent pas la loi des caloriques spécifiques à pression cons-

XXIII^e Cahier. 20

O Motor térmico idealizado

Fonte de Calor



Fonte Fria
(Ambiente ou Sumidouro)

Balanço de ENERGIA (1ª Lei)

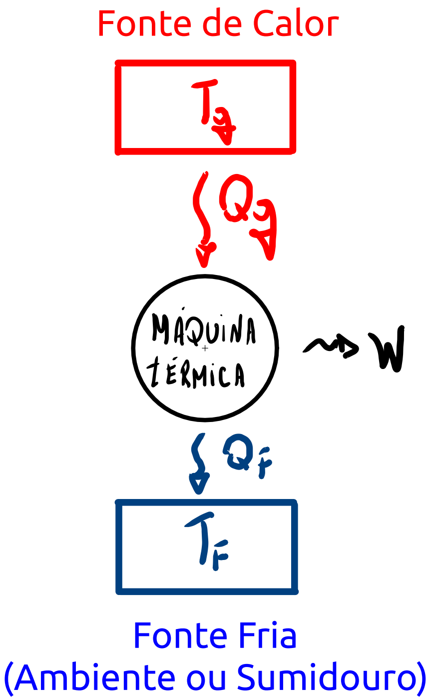
$$Q_q = W + Q_F$$

$$\rightsquigarrow W = Q_q - Q_F$$

Rendimento $= \dfrac{\text{O que quer}}{\text{O que gasta}}$

$$\eta = \frac{W}{Q_q} = \frac{Q_q - Q_F}{Q_q} \Rightarrow \eta = 1 - \frac{Q_F}{Q_q}$$

$$\eta_c = 1 - \frac{T_F}{T_q}$$



Processos reversíveis

MÁQUINA TÉRMICA → isentrópica! $\dot{Q} = 0$; $\dot{E}_d = 0$

trocas DE CALOR À TEMPERATURAS constantes

↳ processos DE MUDANÇA DE FASE → Calor latente

↳ Variação de temperatura = fonte de irreversibilidade

↳ Processos dissipativos

→ Pressão de SATURAÇÃO ∝ TEMPERATURA DE SATURAÇÃO

Ciclos

s

(Adiabático e Reversível)

Propriedades Termodinâmicas

CIÊNCIAS TÉRMICAS .com

The International Association for the Properties of Water and Steam

Educational Resources

It is intended that, in the future, IAPWS will provide a variety of educational materials about water and steam and their industrial and scientific uses. For now, we provide the following links to materials of educational interest:

FAQs about Water and Steam
Also see our list of Additional Resources for information about water, steam, and aqueous systems.

Online Water and Steam Property Calculator

Water and Steam Property Library for Excel

Water and Steam Property Library for MATLAB

Water and Steam Property Library for Mathcad

Water and Steam Property Library for iPhone, iPad, and iPod touch

Water and Steam Property Library for Android Smart Phones and Tablets

Steam Tables for Pocket Calculators

ASME Compact Steam Tables booklet

In addition, links to software and books for "steam tables" may be found here.

This page updated June 18, 2018

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http://www.iapws.org/index.html

Fluid Property Calculator

Fluid: Water and Steam IAPWS-IF97 - LibIF9

Function: Specific enthalpy h(p,t,x)

Unit System: SI

Enter given values:

Range of validity

Pressure p (bar)	0
Temperature t (°C)	0
Vapor fraction x	-1

Details on the vapor fraction x

Calculate / Recalculate

Result:

Specific enthalpy h = kJ/kg

For further information on property libraries available for Excel®, MATLAB®, Mathcad®, Engineering Equation Solver® EES, DYMOLA® (Modelica), SimulationX®, and LabView® click here.

Apps for calculating steam properties for iPhone, iPad, and iPod touch can be found here (description) and for Android phones and tablets here (description).

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Prof. Hans-Joachim Kretzschmar
Dr. Sebastian Herrmann
Dr. Matthias Kunick
Programmer: Joachim Posselt

Tel.: +49-172-7914607
E-mail: info@thermofluidprop.com

www.thermodynamic-property-libraries.com
www.international-steam-tables.com
www.thermodynamik-formelsammlung.de

https://web1.hszg.de/thermo_fpc/

Propriedades Termodinâmicas

https://www.steamtablesonline.com/

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1. General Properties | 2. Saturation Properties | 3. Steam Turbine | 4. Flash Evaporator | 5. T-S Diagram | 6. H-S Diagram | 7. H-S Diagram (vapor) | 8. Gas Tables

Input Data

Select function: 1. function (p, x)

1. Pressure (absolute): 8 bar

2. Quality: 1 %

Calculate

Register and Create Account

	Property Name	Property ID	*	Results (Liquid)	Results	Results (Vapor)	Units (SI)	Constants used in calculation
	1. Thermodynamic Properties - Main							
1	Pressure (absolute)	p		8.0000000000	8.0000000000	8.0000000000	bar	Specific gas constant: R = 0.461526 kJ/(kg·K)
2	Temperature	t		170.4135108136	170.4135108136	170.4135108136	°C	Molar gas constant: Rm = 8.31451 J/(mol·K)
3	Density	d		897.0316593695	285.1508906588	4.1609882209	kg/m³	Molar mass: M = 18.015257 g/mol
4	Specific volume	v		0.0011147879	0.0035069152	0.2403275248	m³/kg	Critical temperature: Tc = 647.096 K, (373.946 °C)
5	Specific enthalpy	h		721.0178484198	741.4906945822	2768.3024646637	kJ/kg	Critical pressure: pc = 22.064 MPa, (220.64 bar)
6	Specific entropy	s		2.0459891539	2.0921446862	6.6615423799	kJ/(kg·K)	Critical density: rhoc = 322 kg/m³
7	Specific exergy	ex		563.4766835695	580.3955537448	2255.3637014114	kJ/kg	Triple-point temperature: Tt = 273.16 K, (0.01 °C)
8	Specific internal energy	u		720.1260181352	738.6851624018	2576.0404447959	kJ/kg	Triple-point pressure: pt = 611.657 Pa, (0.00611657 bar)
9	Specific isobaric heat capacity	cp		4.3708962238	NA	2.6031637730	kJ/(kg·K)	
10	Specific isochoric heat capacity	cv		3.4364953290	NA	1.8700067769	kJ/(kg·K)	
11	Speed of sound	w		1417.1890676607	NA	498.8722362889	m/s	
	2. Thermodynamic Properties - Other (*, * registration required)							
12	Isentropic exponent	kapa		*	*	*	dimensionless	
13	Specific Helmholtz free energy	H		*	*	*	kJ/kg	
14	Specific Gibbs free energy	G		*	*	*	kJ/kg	
15	Compressibility factor	Z		*	*	*	dimensionless	
16	Quality (vapor mass fraction)	quality		*	*	*	%	

Output Pane (* registration required)

	*	p [bar]	t [°C]	v [m³/kg]	h [kJ/kg]	s [kJ/(kg·K)]	ex [kJ/kg]	u [kJ/kg]	cp [kJ/(kg·K)]	cv [kJ/(kg·K)]	w [m/s]
1		8.0000000000	170.4135108136	0.0035069152	741.4906945822	2.0921446862	580.3955537448	738.6851624018	NA	NA	NA

Pressão kPa	Temp. °C	Líquido sat.	Vapor sat.	Líquido sat.	Evap.	Vapor sat.	Líquido sat.	Evap.	Vapor sat.	Líquido sat.	Evap.	Vapor sat.
P	T	v_l	v_v	u_l	u_{lv}	u_v	h_l	h_{lv}	h_v	s_l	s_{lv}	s_v
0,6113	0,01	0,001000	206,132	0	2375,3	2375,3	0,00	2501,30	2501,30	0,0000	9,1562	9,1562
1	6,98	0,001000	129,20802	29,29	2355,69	2384,98	29,29	2484,89	2514,18	0,1059	8,8697	8,9756
1,5	13,03	0,001001	87,98013	54,70	2338,63	2393,32	54,70	2470,59	2525,30	0,1956	8,6322	8,8278
2	17,50	0,001001	67,00385	73,47	2326,02	2399,48	73,47	2460,02	2533,49	0,2607	8,4629	8,7236
2,5	21,08	0,001002	54,25385	88,47	2315,93	2404,40	88,47	2451,56	2540,03	0,3120	8,3311	8,6431
3	24,08	0,001003	45,66502	101,03	2307,48	2408,51	101,03	2444,47	2545,50	0,3545	8,2231	8,5775
4	28,96	0,001004	34,80015	121,44	2293,73	2415,17	121,44	2432,93	2554,37	0,4226	8,0520	8,4746
5	32,88	0,001005	28,19251	137,79	2282,70	2420,49	137,79	2423,66	2561,45	0,4763	7,9187	8,3950
7,5	40,29	0,001008	19,23775	168,76	2261,74	2430,50	168,77	2406,02	2574,79	0,5763	7,6751	8,2514
10	45,81	0,001010	14,67355	191,79	2246,10	2437,89	191,81	2392,82	2584,63	0,6492	7,5010	8,1501
15	53,97	0,001014	10,02218	225,90	2222,83	2448,73	225,91	2373,14	2599,06	0,7548	7,2536	8,0084
20	60,06	0,001017	7,64937	251,35	2205,36	2456,71	251,38	2358,33	2609,70	0,8319	7,0766	7,9085
25	64,97	0,001020	6,20424	271,88	2191,21	2463,08	271,90	2346,29	2618,19	0,8930	6,9383	7,8313

Temp. °C	Pressão kPa	Líquido sat.	Vapor sat.	Líquido sat.	Evap.	Vapor sat.	Líquido sat.	Evap.	Vapor sat.	Líquido sat.	Evap.	Vapor sat.
T	P	v_l	v_v	u_l	u_{lv}	u_v	h_l	h_{lv}	h_v	s_l	s_{lv}	s_v
0,01	0,6113	0,001000	206,132	0,00	2375,33	2375,33	0,00	2501,35	2501,35	0,0000	9,1562	9,1562
5	0,8721	0,001000	147,118	20,97	2361,27	2382,24	20,98	2489,57	2510,54	0,0761	8,9496	9,0257
10	1,2276	0,001000	106,377	41,99	2347,16	2389,15	41,99	2477,75	2519,74	0,1510	8,7498	8,9007
15	1,705	0,001001	77,925	62,98	2333,06	2396,04	62,98	2465,93	2528,91	0,2245	8,5569	8,7813
20	2,339	0,001002	57,7897	83,94	2318,98	2402,91	83,94	2454,12	2538,06	0,2966	8,3706	8,6671
25	3,169	0,001003	43,3593	104,86	2304,90	2409,76	104,87	2442,30	2547,17	0,3673	8,1905	8,5579
30	4,246	0,001004	32,8922	125,77	2290,81	2416,58	125,77	2430,48	2556,25	0,4369	8,0164	8,4533
35	5,628	0,001006	25,2158	146,65	2276,71	2423,36	146,66	2418,62	2565,28	0,5052	7,8478	8,3530
40	7,384	0,001008	19,5229	167,53	2262,57	2430,11	167,54	2406,72	2574,26	0,5724	7,6845	8,2569
45	9,593	0,001010	15,2581	188,41	2248,40	2436,81	188,42	2394,77	2583,19	0,6386	7,5261	8,1647
50	12,350	0,001012	12,0318	209,30	2234,17	2443,47	209,31	2382,75	2592,06	0,7037	7,3725	8,0762
55	15,758	0,001015	9,56835	230,19	2219,89	2450,08	230,20	2370,66	2600,86	0,7679	7,2234	7,9912
60	19,941	0,001017	7,67071	251,09	2205,54	2456,63	251,11	2358,48	2609,59	0,8311	7,0784	7,9095
65	25,03	0,001020	6,19656	272,00	2191,12	2463,12	272,03	2346,21	2618,24	0,8934	6,9375	7,8309

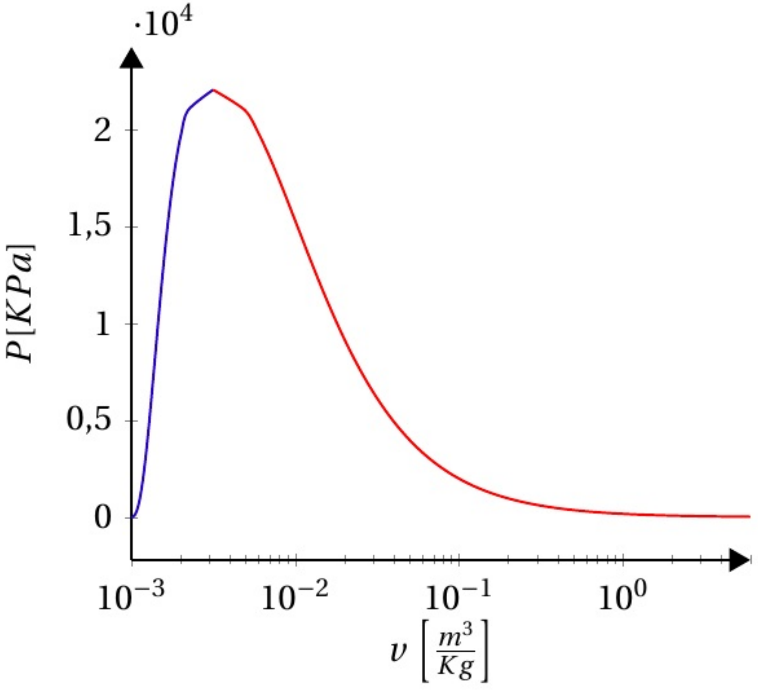


Diagrama P vs log(v) para água

titulo

$$x = \frac{m_v}{m}$$

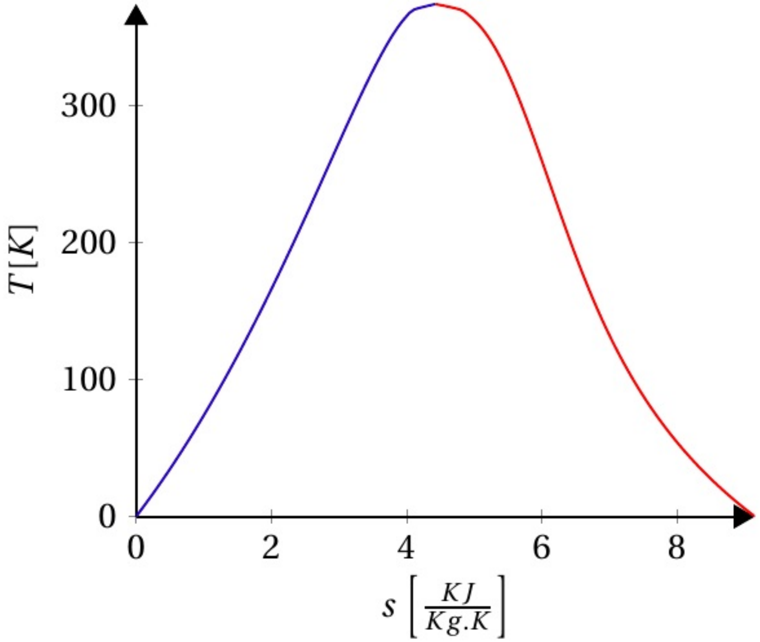


Diagrama temperatura entropia para água

Pressão kPa	Temp. °C	Líquido sat.	Vapor sat.	Líquido sat.	Evap.	Vapor sat.	Líquido sat.	Evap.	Vapor sat.	Líquido sat.	Evap.	Vapor sat.
P	T	v_l	v_v	u_l	u_{lv}	u_v	h_l	h_{lv}	h_v	s_l	s_{lv}	s_v
0,6113	0,01	0,001000	206,132	0	2375,3	2375,3	0,00	2501,30	2501,30	0,0000	9,1562	9,1562
1	6,98	0,001000	129,20802	29,29	2355,69	2384,98	29,29	2484,89	2514,18	0,1059	8,8697	8,9756
1,5	13,03	0,001001	87,98013	54,70	2338,63	2393,32	54,70	2470,59	2525,30	0,1956	8,6322	8,8278
2	17,50	0,001001	67,00385	73,47	2326,02	2399,48	73,47	2460,02	2533,49	0,2607	8,4629	8,7236
2,5	21,08	0,001002	54,25385	88,47	2315,93	2404,40	88,47	2451,56	2540,03	0,3120	8,3311	8,6431
3	24,08	0,001003	45,66502	101,03	2307,48	2408,51	101,03	2444,47	2545,50	0,3545	8,2231	8,5775
4	28,96	0,001004	34,80015	121,44	2293,73	2415,17	121,44	2432,93	2554,37	0,4226	8,0520	8,4746
5	32,88	0,001005	28,19251	137,79	2282,70	2420,49	137,79	2423,66	2561,45	0,4763	7,9187	8,3950
7,5	40,29	0,001008	19,23775	168,76	2261,74	2430,50	168,77	2406,02	2574,79	0,5763	7,6751	8,2514
10	45,81	0,001010	14,67355	191,79	2246,10	2437,89	191,81	2392,82	2584,63	0,6492	7,5010	8,1501
15	53,97	0,001014	10,02218	225,90	2222,83	2448,73	225,91	2373,14	2599,06	0,7548	7,2536	8,0084
20	60,06	0,001017	7,64937	251,35	2205,36	2456,71	251,38	2358,33	2609,70	0,8319	7,0766	7,9085
25	64,97	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7,8313

Temp. °C	Pressão kPa	Líquido sat.	Vapor sat.	Líquido sat.	Evap.	Vapor sat.	Líquido sat.	Evap.	Vapor sat.	Líquido sat.	Evap.	Vapor sat.
T	P	v_l	v_v	u_l	u_{lv}	u_v	h_l	h_{lv}	h_v	s_l	s_{lv}	s_v
0,01	0,6113	0,001000	206,132	0,00	2375,33	2375,33	0,00	2501,35	2501,35	0,0000	9,1562	9,1562
5	0,8721	0,001000	147,118	20,97	2361,27	2382,24	20,98	2489,57	2510,54	0,0761	8,9496	9,0257
10	1,2276	0,001000	106,377	41,99	2347,16	2389,15	41,99	2477,75	2519,74	0,1510	8,7498	8,9007
15	1,705	0,001001	77,925	62,98	2333,06	2396,04	62,98	2465,93	2528,91	0,2245	8,5569	8,7813
20	2,339	0,001002	57,7897	83,94	2318,98	2402,91	83,94	2454,12	2538,06	0,2966	8,3706	8,6671
25	3,169	0,001003	43,3593	104,86	2304,90	2409,76	104,87	2442,30	2547,17	0,3673	8,1905	8,5579
30	4,246	0,001004	32,8922	125,77	2290,81	2416,58	125,77	2430,48	2556,25	0,4369	8,0164	8,4533
35	5,628	0,001006	25,2158	146,65	2276,71	2423,36	146,66	2418,62	2565,28	0,5052	7,8478	8,3530
40	7,384	0,001008	19,5229	167,53	2262,57	2430,11	167,54	2406,72	2574,26	0,5724	7,6845	8,2569
45	9,593	0,001010	15,2581	188,41	2248,40	2436,81	188,42	2394,77	2583,19	0,6386	7,5261	8,1647
50	12,350	0,001012	12,0318	209,30	2234,17	2443,47	209,31	2382,75	2592,06	0,7037	7,3725	8,0762
55	15,758	0,001015	9,56835	230,19	2219,89	2450,08	230,20	2370,66	2600,86	0,7679	7,2234	7,9912
60	19,941	0,001017	7,67071	251,09	2205,54	2456,63	251,11	2358,48	2609,59	0,8311	7,0784	7,9095
65	25,03	0,001020	6,19656	272,00	2191,12	2463,12	272,03	2346,21	2618,24	0,8934	6,9375	7,8309

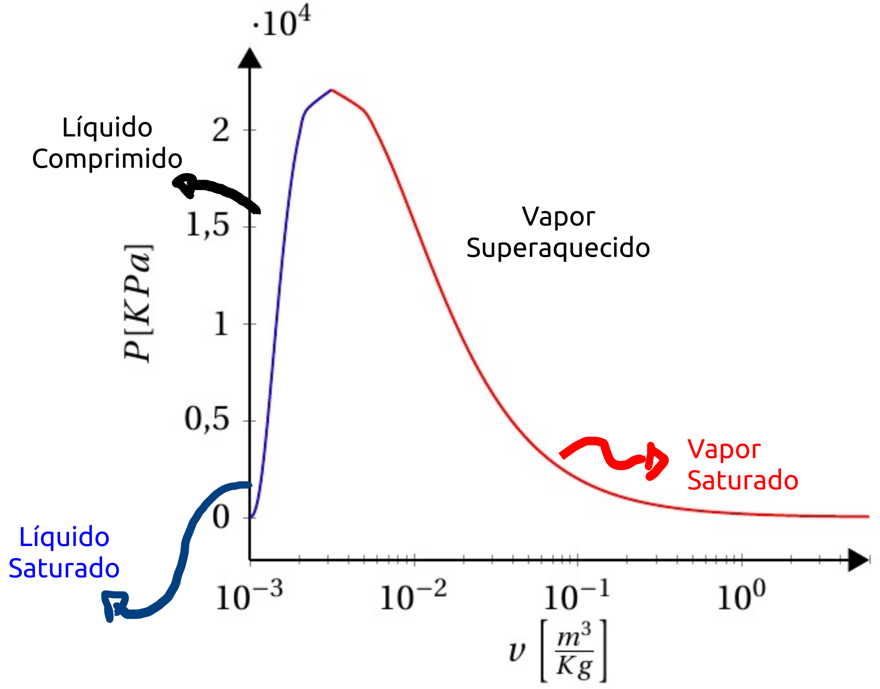


Diagrama P vs log(v) para água

titulo

$$X = \frac{m_v}{m}$$

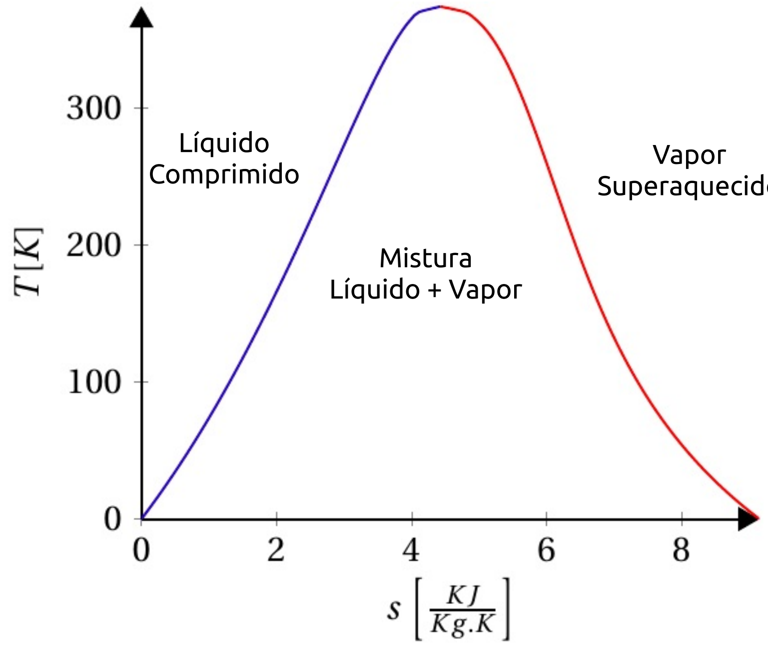
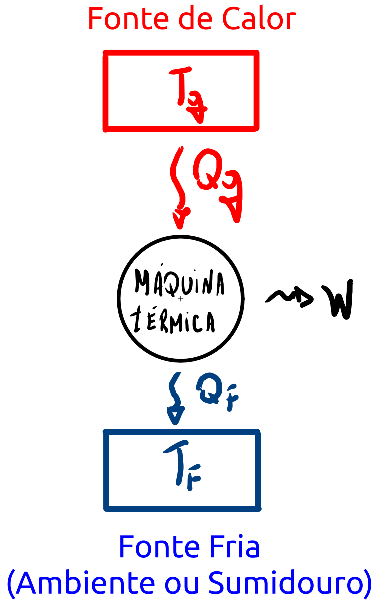


Diagrama temperatura entropia para água

O Ciclo de CARNOT



1->2: adição de calor
temperatura constante
Pressão constante
Caldeira

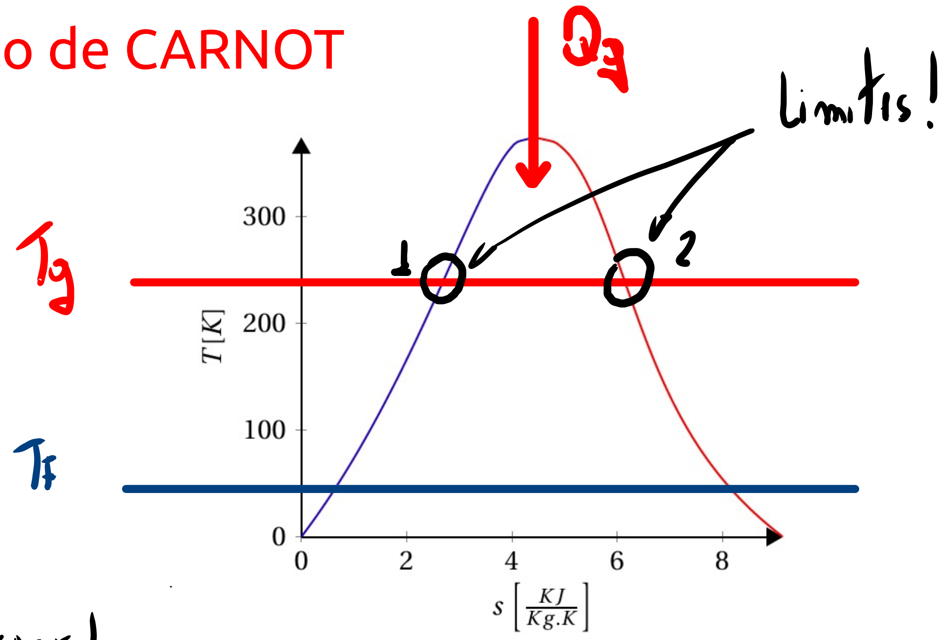
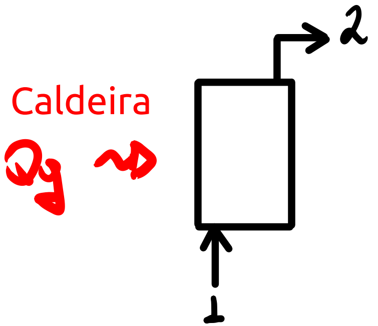
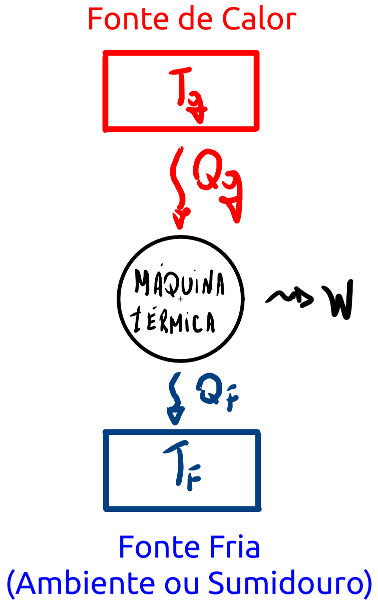


Diagrama temperatura entropia para água

MAIOR QUANTIDADE POSSÍVEL DE CALOR ADICIONADO SEM MUDAR DE FASE!



O Ciclo de CARNOT



1->2: adição de calor
T,P constante
Caldeira

2->3: expansão isoentrópica
Turbina

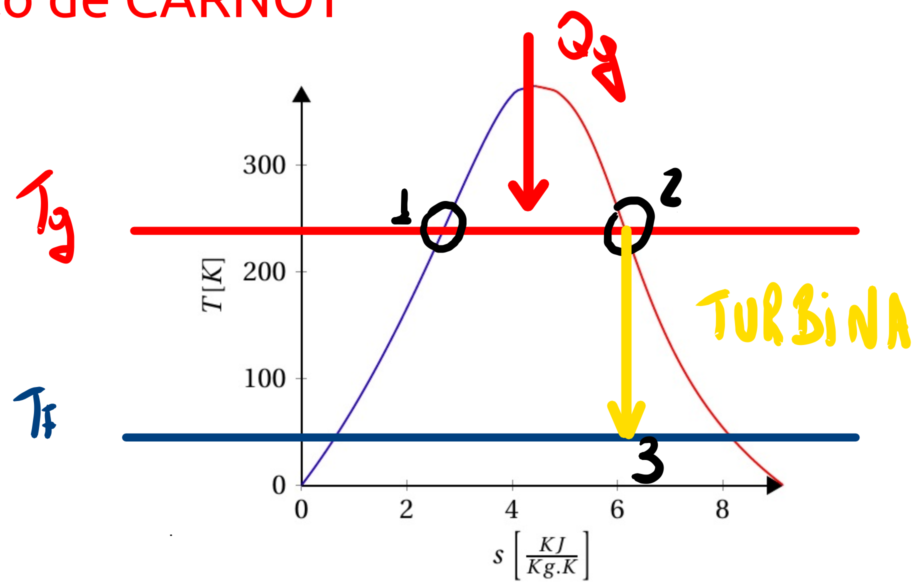
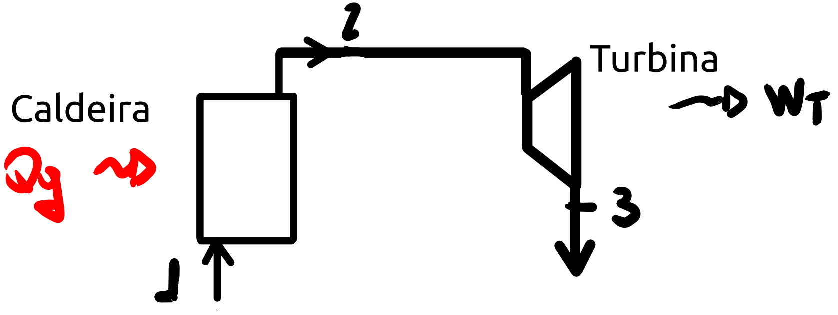
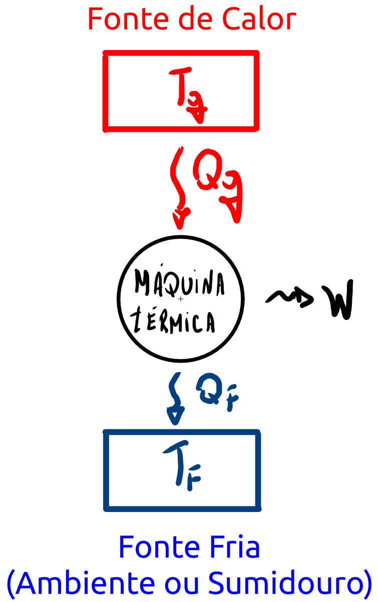


Diagrama temperatura entropia para água



O Ciclo de CARNOT



1->2: adição de calor
T,P constante
Caldeira

2->3: expansão isoentrópica
Turbina

3->4: Rejeição de Calor
Temperatura Constante
Pressão Constante
Condensador

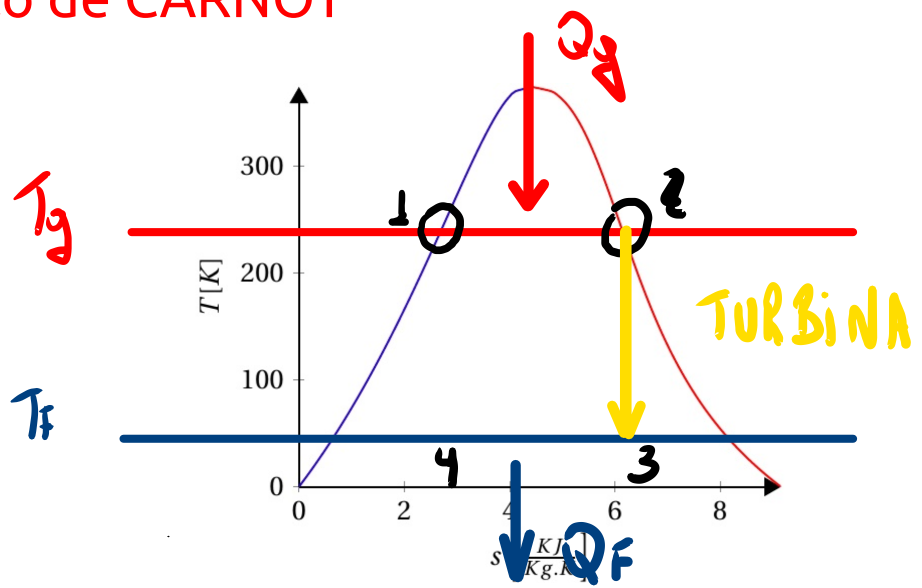
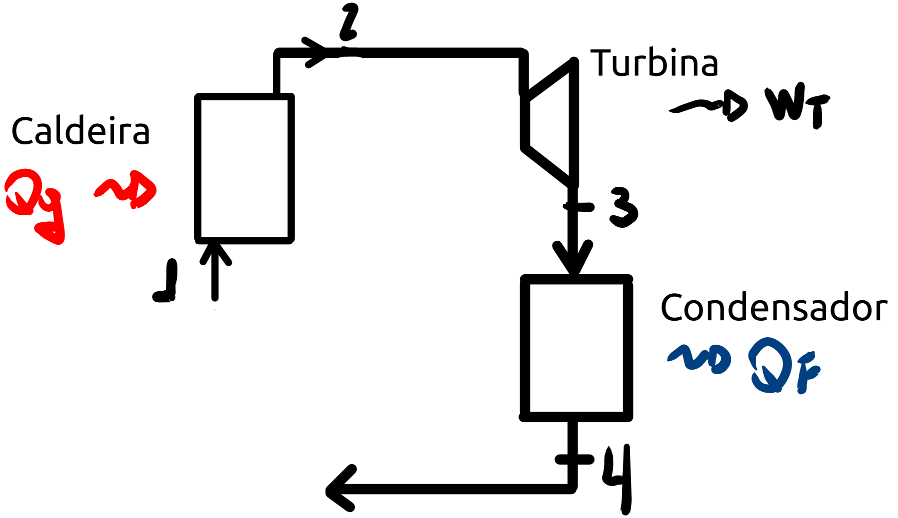
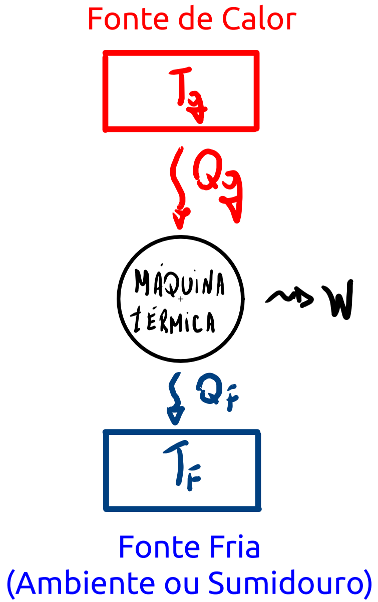


Diagrama temperatura entropia para água



O Ciclo de CARNOT



1->2: adição de calor
T,P constante
Caldeira

2->3: expansão isoentrópica
Turbina

3->4: Rejeição de Calor
T,P constante
Condensador

4-> Aumento da pressão
Isoentrópico
Bomba

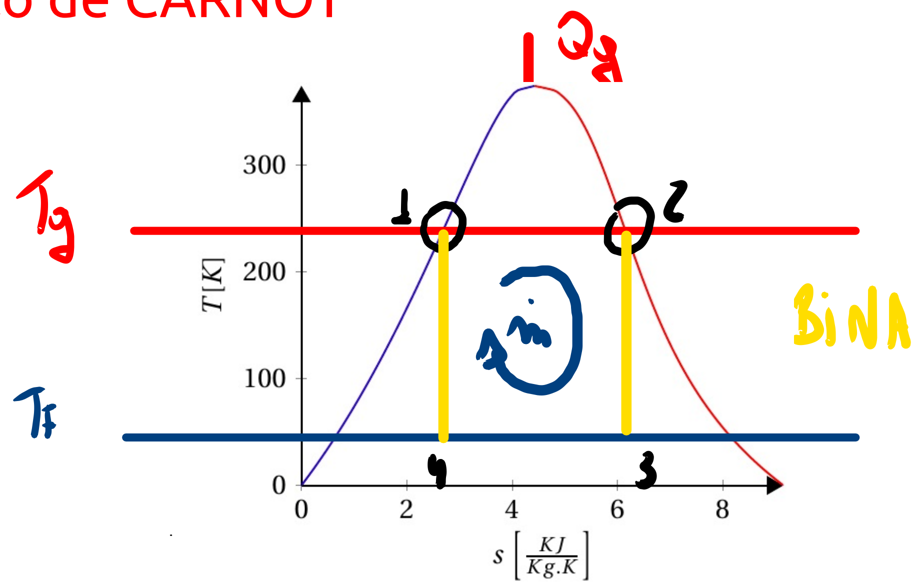
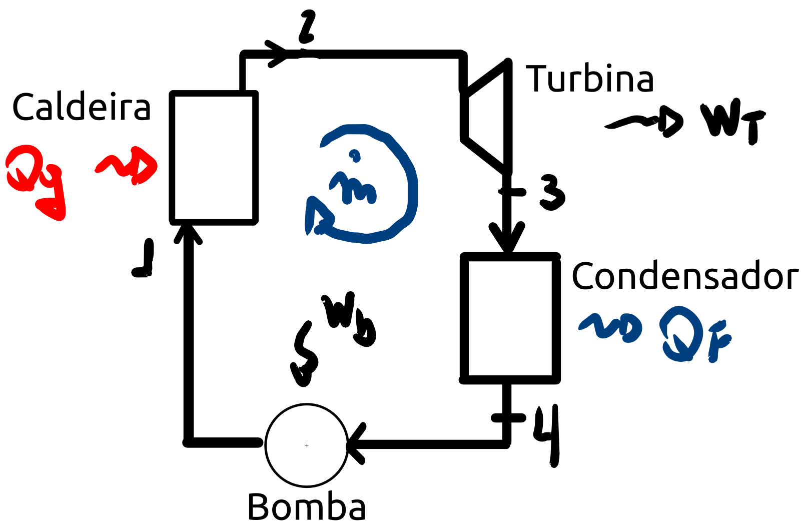
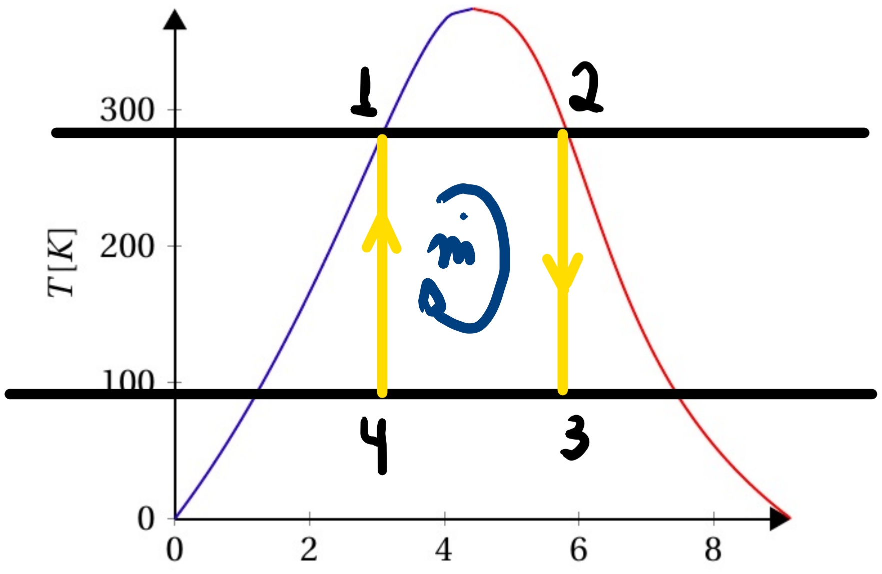
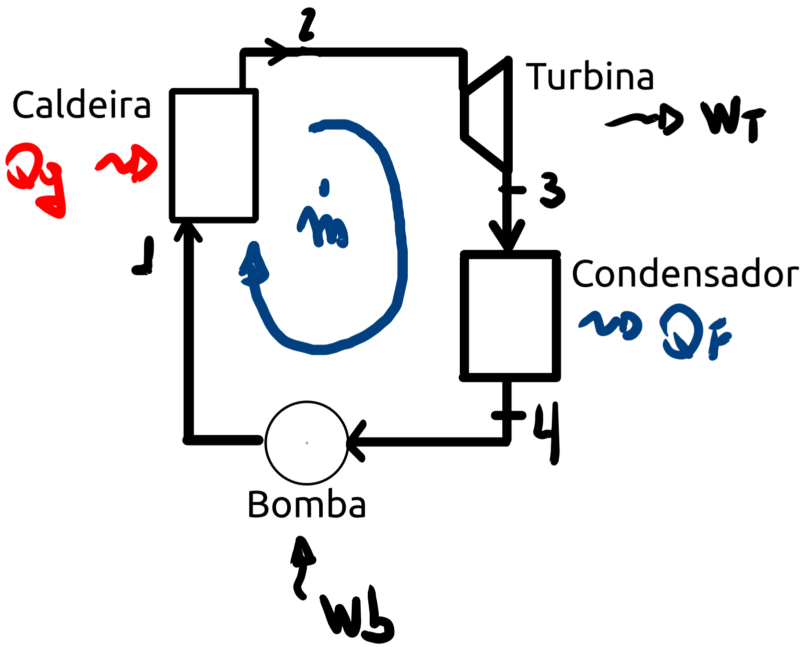


Diagrama temperatura entropia para água



O Ciclo de CARNOT

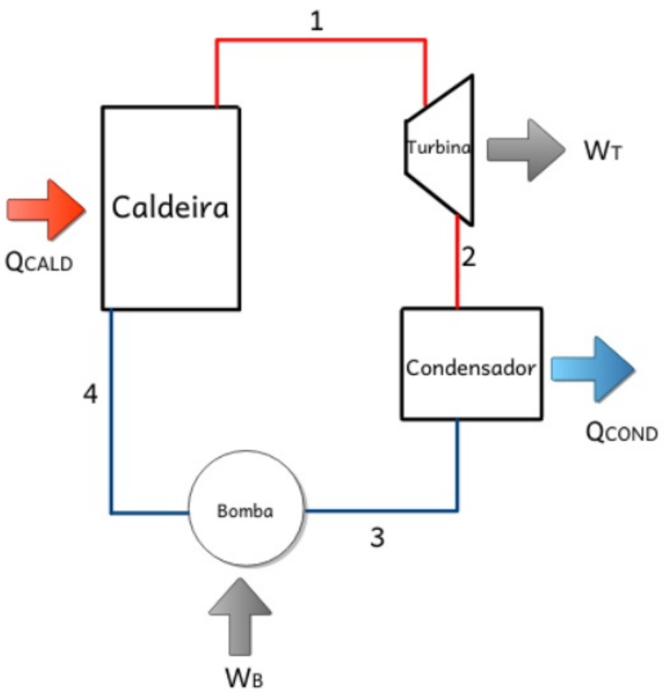


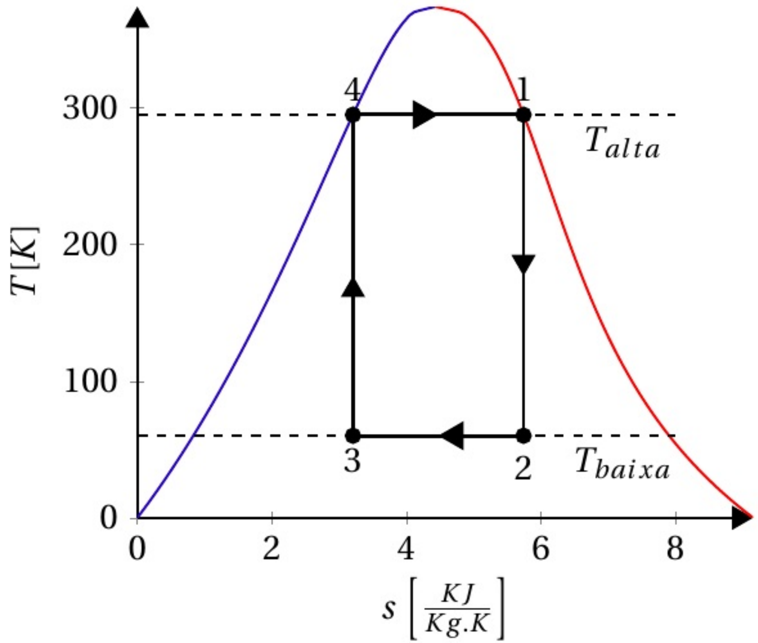


Ciclo Teórico

Não existe na prática

Referência para análise de desempenho dos demais ciclos





- 4 estados termodinâmicos
  - Caldeira
  - Turbina
  - Condensador
  - Bomba
- 4 Componentes
- Considera componentes perfeitos $\dot{\sigma_T} = 0$, $\dot{\sigma_B} = 0$

1ª Lei

$$\frac{DE}{Dt} = \frac{d}{dt}\int_{\forall} e\,(\rho\, d\forall) + \int_{SC} e\,(\rho\,\vec{V}\cdot d\vec{A}) = \dot{Q} + \dot{W}$$

Regime Permanente

Desprezando forças de corpo

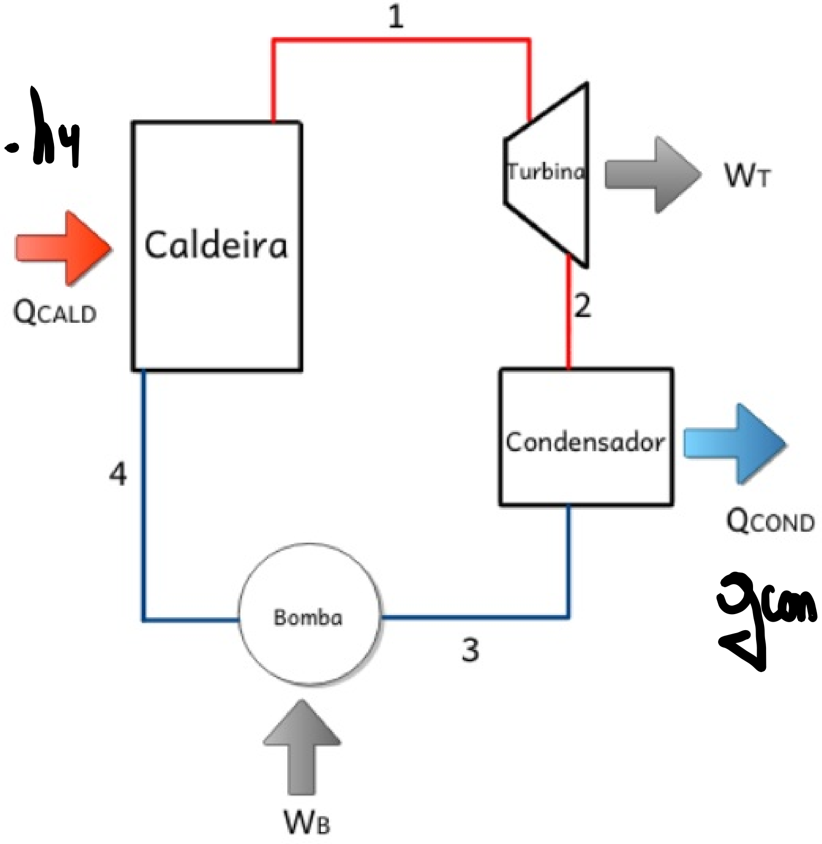
Força superficie → Pressão

$$du + d(P\cdot v) + d\left(\frac{V^2}{2}\right) + d(gz) = q + w$$

$$dh + \cancel{d\left(\frac{V^2}{2}\right)} + \cancel{d(gz)} = q + w$$

$$de = \delta q + \delta w \rightarrow dh = q + w$$

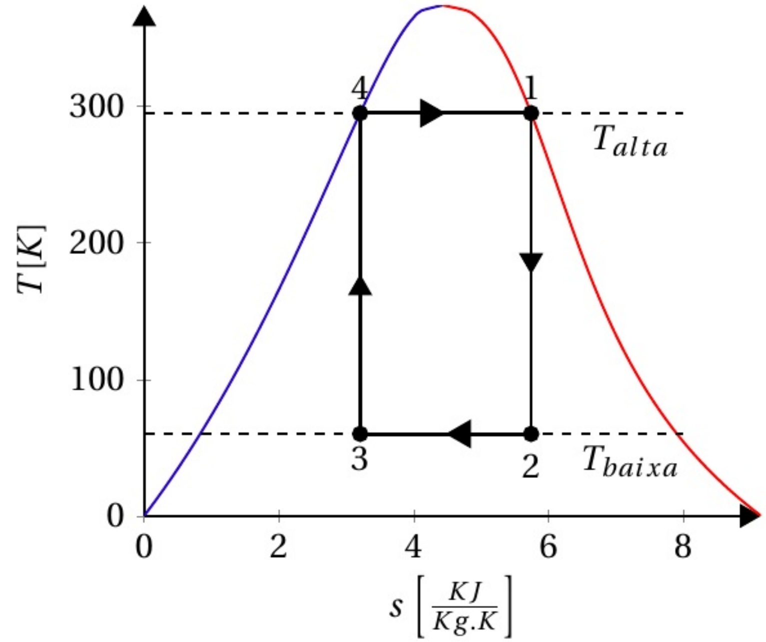
$$q_{CALD} = h_1 - h_4$$

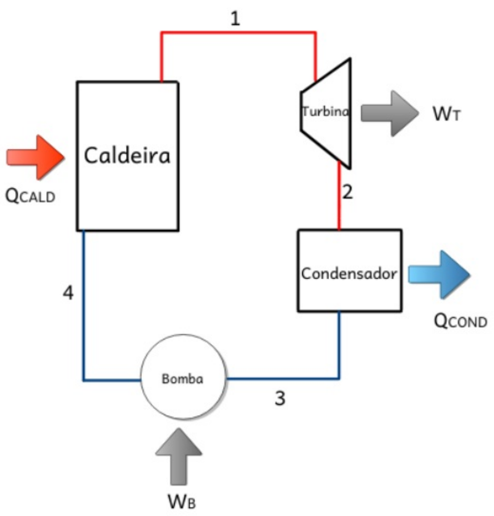


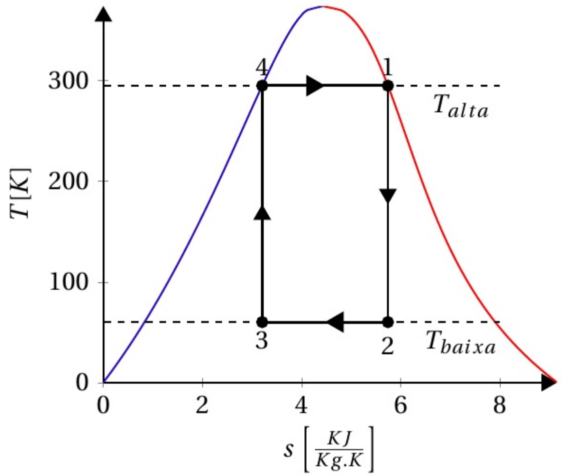
$$w_T = h_2 - h_1$$

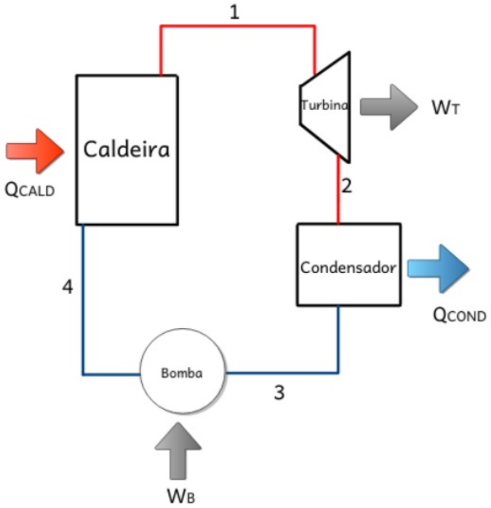
$$q_{cond} = h_3 - h_2$$

$$w_b = h_4 - h_3$$

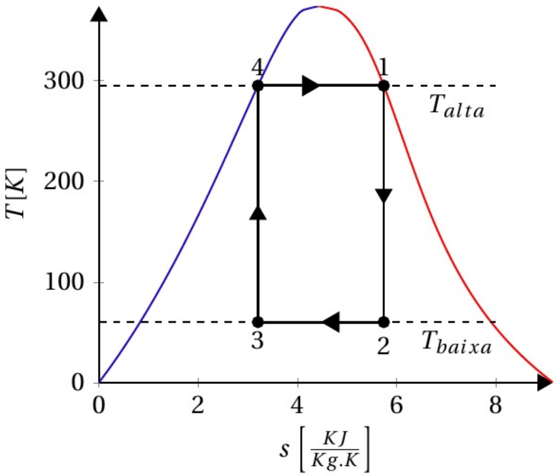


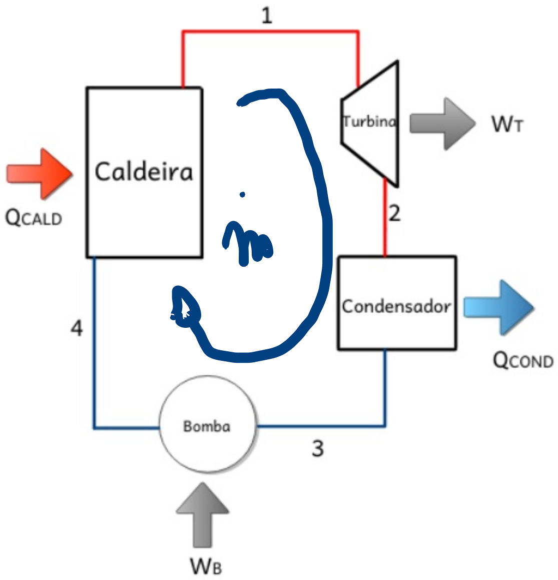

1
Caldeira
Turbina
W_T
Q_{CALD}
2
Condensador
4
Q_{COND}
Bomba
3
W_B

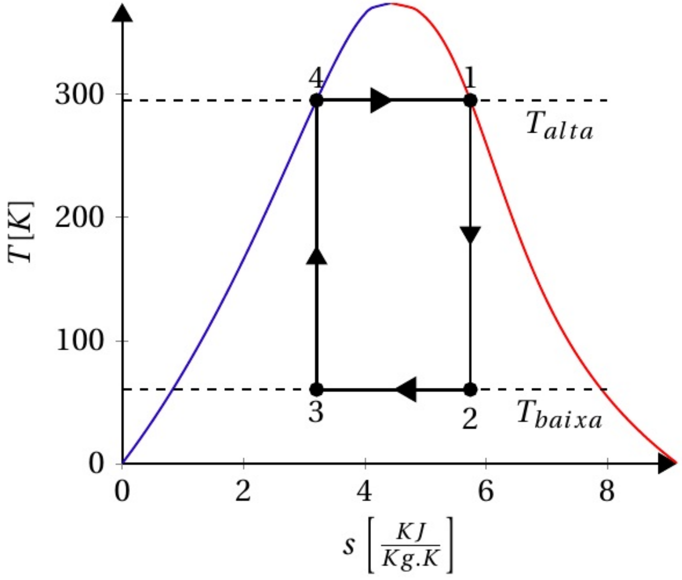

$T\,[K]$
300
200
100
0
4
1
T_{alta}
3
2
T_{baixa}
0
2
4
6
8
$s\left[\frac{KJ}{Kg.K}\right]$



Estado	P[KPa]	T[°C]	x	v[m^3/Kg]	h[KJ/Kg]	s[KJ/Kg.K]
1	PA	TSAT	1	v_v	h_v	s_v
2	PB		x_2	v	h	s_2
3	PB		x_3	v	h	s_4
4	PA	TSAT	0	v_L	h_L	s_L







Estado	P [KPa]	T [°C]	x	h [KJ/Kg]	s [KJ/Kg.K]
1	P_H	T_{sat1}	1	h_v	s_v
2	P_L	T_{sat2}	$x_2 = \frac{s_2 - s_L}{s_v - s_L}$	$h_2 = h_L + x_2(h_{LV})$	s_1
3	P_L	T_{sat2}	$x_3 = \frac{s_3 - s_L}{s_v - s_L}$	$h_3 = h_L + x_3(h_{LV})$	s_4
4	P_H	T_{sat1}	0	h_L	s_L

Componente	q [KJ/Kg]	w [KJ/Kg]
Turbina	0	$h_2 - h_1$
Condensador	$h_3 - h_2$	0
Bomba	0	$h_4 - h_3$
Caldeira	$h_1 - h_4$	0
$\sum$	q_{liq}	w_{liq}

$$\eta = \frac{|w_{liq}|}{q_{caldeira}} \qquad bwr = \frac{w_{bomba}}{|w_{turbina}|}$$

$$Pot = w \cdot \dot{m} \quad \left[\frac{kJ}{kg}\right] \cdot \left[\frac{kg}{s}\right] = \frac{kJ}{s} = kW$$

Componente	q [KJ/Kg]	w [KJ/Kg]
Turbina	0	$h_2 - h_1$
Condensador	$h_3 - h_2$	0
Bomba	0	$h_4 - h_3$
Caldeira	$h_1 - h_4$	0
$\sum$	q_{liq}	w_{liq}

Aspectos importantes a serem levados em consideração:

- $\mid q_{liq} \mid = \mid w_{liq} \mid$

  Todo ciclo os valores em módulo de todo o calor trocado devem ser iguais ao valor em módulo de todo o trabalho realizado e recebido.

- $q_{liq} = q_{condensador} + q_{caldeira}$

  $q_{caldeira} > 0$: calor adicionado ao sistema

  $q_{condensador} < 0$: calor rejeitado pelo sistema

- $w_{liq} = w_{turbina} + w_{bomba}$

  neste caso estamos considerando a primeira lei na forma: $de = \delta q + \delta w$. O sinal virá naturalmente dos cálculos realizados.

  $w_{turbina} < 0$: trabalho realizado pelo sistema na vizinhança

  $w_{bomba} > 0$: trabalho realizado pela vizinhança no sistema

$de = \delta q + \delta w$

$de = \delta q - \delta w$

Ciclo

processo cujo estado final = inicial

$de = 0$

Água é o fluido de trabalho em um ciclo de potência a vapor de Carnot. A caldeira opera a 8 [MPa] e o condensador a 20 [KPa]. Determine:

a) Trabalho desenvolvido pela turbina e bomba
b) Transferência de calor na caldeira e no condensador
c) bwr
d) Eficiência térmica
e) Eficiência de Carnot

1. Desenhar os componentes do ciclo

2. Fazer os diagramas $P - v$ e $T - s$

3. Fazer uma tabela das propriedades

4. Fazer uma tabela dos calores e trabalhos de cada componente

5. Calcular rendimento e bwr

Água é o fluido de trabalho em um ciclo de potência a vapor de Carnot. A caldeira opera a 8 [MPa] e o condensador a 20 [KPa]. Determine:

a) Trabalho desenvolvido pela turbina e bomba
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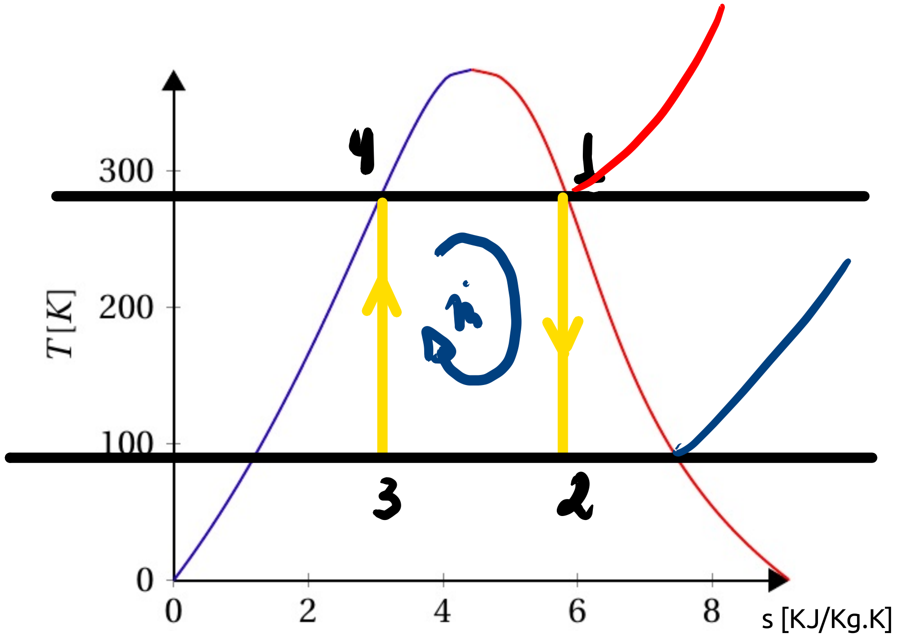
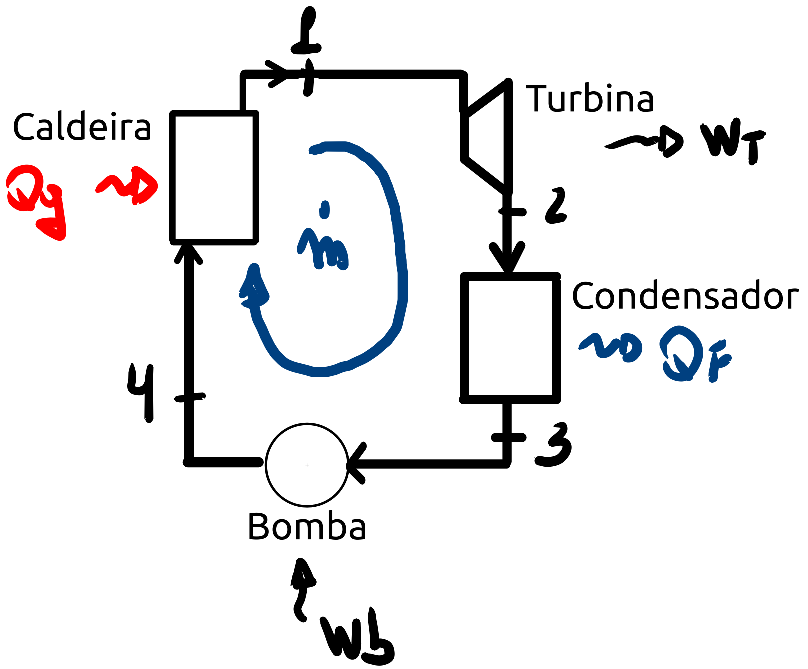
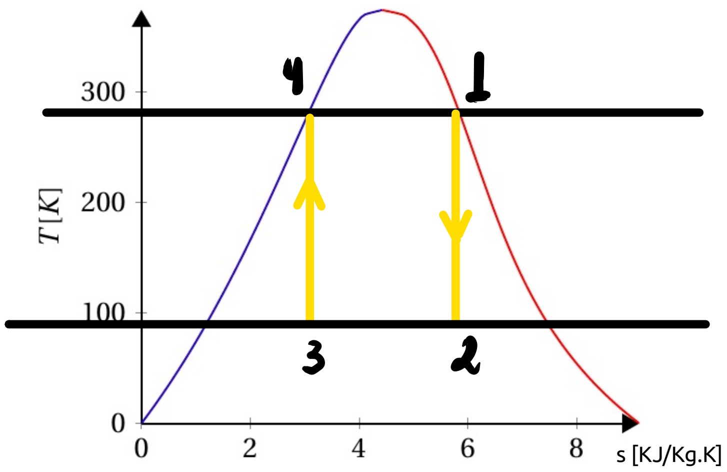
5. Calcular rendimento e *bwr*







Água é o fluido de trabalho em um ciclo de potência a vapor de Carnot. A caldeira opera a 8 [MPa] e o condensador a 20 [KPa]. Determine:

a) Trabalho desenvolvido pela turbina e bomba
b) Transferência de calor na caldeira e no condensador
c) bwr
d) Eficiência térmica
e) Eficiência de Carnot

1. Desenhar os componentes do ciclo
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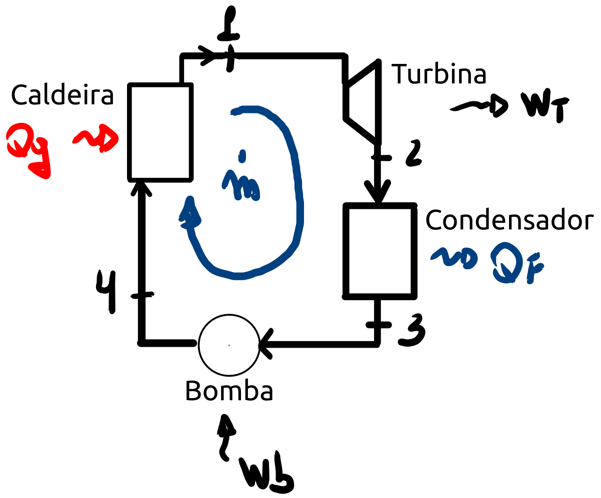
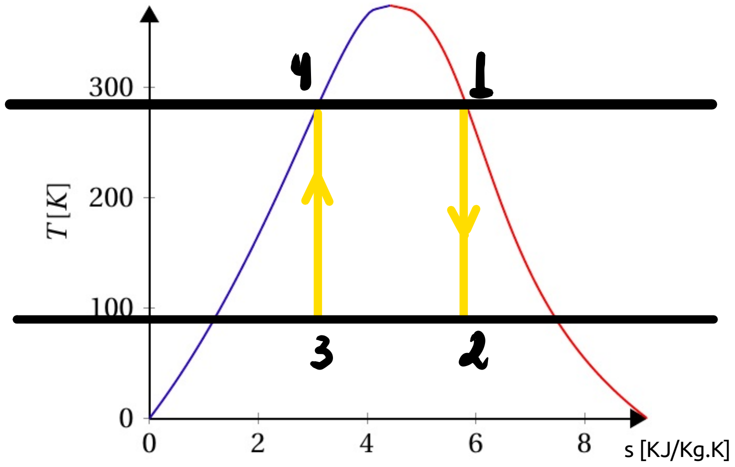
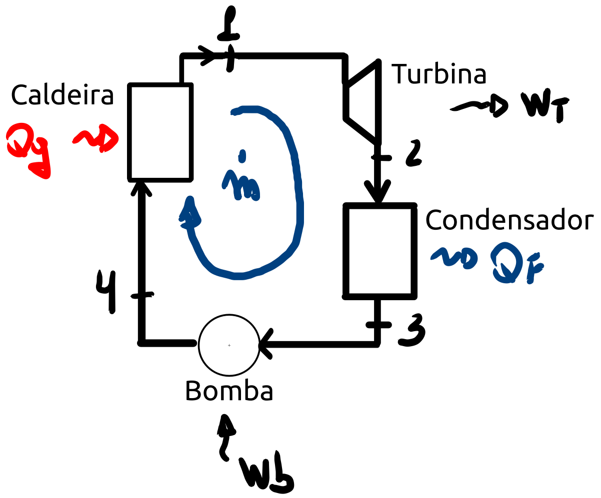


Estado	P [KPa]	T[°C]	x	h[KJ/Kg]	s[kJ/Kg.K]
1	8000		1		
2	20				
3	20				
4	8000		0		



Estado	P [KPa]	T[°C]	x	h[KJ/Kg]	s[kJ/Kg.K]
1	8000	295,06	1	2757,94	5,7431
2	20				
3	20				
4	8000	295,06	0	1316,61	3,2067

Pressão kPa	Temp. °C	Líquido sat. (m³/kg)	Vapor sat. (m³/kg)	Líquido sat. (kJ/kg)	Evap. (kJ/kg)	Vapor sat. (kJ/kg)	Líquido sat. (kJ/kg)	Evap. (kJ/kg)	Vapor sat. (kJ/kg)	Líquido sat. (kJ/kg K)	Evap. (kJ/kg K)	Vapor sat. (kJ/kg K)
P	T	v_l	v_v	u_l	u_{lv}	u_v	h_l	h_{lv}	h_v	s_l	s_{lv}	s_v
6000	275,64	0,001319	0,03244	1205,41	1384,27	2589,69	1213,32	1571,00	2784,33	3,0266	2,8625	5,8891
7000	285,88	0,001351	0,02737	1257,51	1322,97	2580,48	1266,97	1505,10	2772,07	3,1210	2,6922	5,8132
8000	295,06	0,001384	0,02352	1305,54	1264,25	2569,79	1316,61	1441,33	2757,94	3,2067	2,5365	5,7431
9000	303,40	0,001418	0,02048	1350,47	1207,28	2557,75	1363,23	1378,88	2742,11	3,2857	2,3915	5,6771



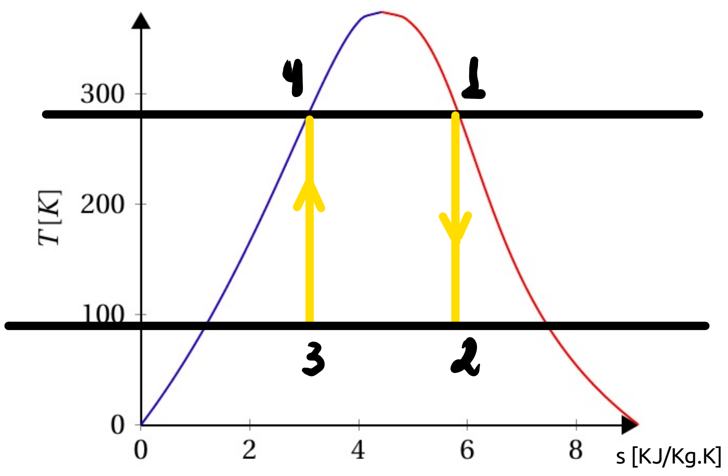
Estado {1, 4 $P = 8000$ kPa

$x_1 = 1$ VAPOR SATURADO

$x_4 = 0$ Líquido SATURADO

$T_1 = T_{SAT}(P_1)$; $h_1 = h_v(P_1)$; $s_1 = s_v(P_1)$

$T_4 = T_{SAT}(P_4)$; $h_4 = h_L(P_4)$; $s_4 = s_L(P_4)$



Estado	P [KPa]	T[°C]	x	h[KJ/Kg]	s[kJ/Kg.K]
1	8000	295,06	1	2757,94	5,7431
2	20	60,06	0,694	1888,067	5,7431
3	20				
4	8000	295,06	0	1316,61	3,2067

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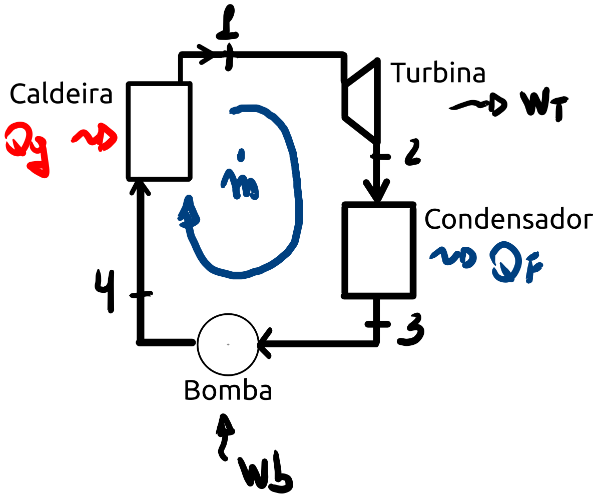
Pressão kPa	Temp. °C	(m^3/kg) Líquido sat.	Vapor sat.	(kJ/kg) Líquido sat.	Evap.	Vapor sat.	(kJ/kg) Líquido sat.	Evap.	Vapor sat.	(kJ/kg K) Líquido sat.	Evap.	Vapor sat.
P	T	v_l	v_v	u_l	u_{lv}	u_v	h_l	h_{lv}	h_v	s_l	s_{lv}	s_v
0,6113	0,01	0,001000	206,132	0	2375,3	2375,3	0,00	2501,30	2501,30	0,0000	9,1562	9,1562
15	53,97	0,001014	10,02218	225,90	2222,83	2448,73	225,91	2373,14	2599,06	0,7548	7,2536	8,0084
20	60,06	0,001017	7,64937	251,35	2205,36	2456,71	251,38	2358,33	2609,70	0,8319	7,0766	7,9085

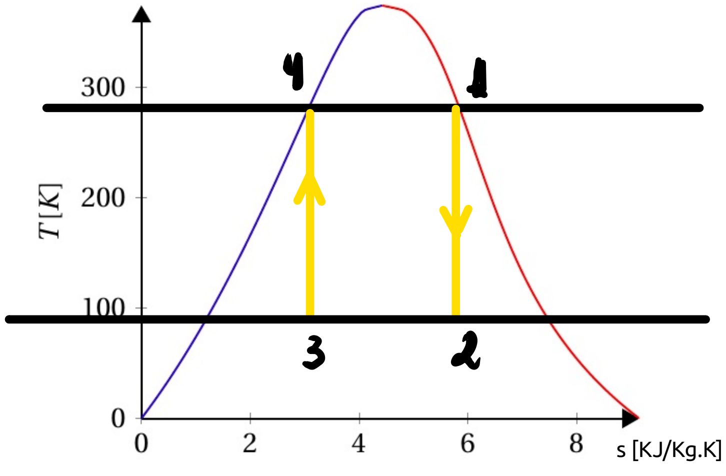


Estado 2: P = 20 kPa $\begin{cases} s_L = 0,8319 \\ s_V = 7,9085 \end{cases}$ s_2

$$x_2 = \frac{5,7431 - 0,8319}{7,9085 - 0,8319} \rightarrow x_2 = 0,694$$

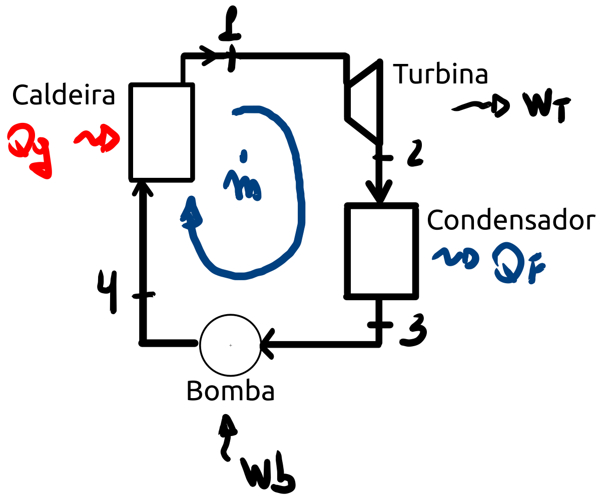
$$h_2 = 251,38 + 0,694(2609,7 - 251,38)$$

$$h_2 = 1888,067$$



Estado	P [KPa]	T[°C]	x	h[KJ/Kg]	s[kJ/Kg.K]
1	8000	295,06	1	2757,94	5,7431
2	20	60,06	0,694	1888,067	5,7431
3	20	60,06	0,3355	1042,796	3,2067
4	8000	295,06	0	1316,61	3,2067

Pressão kPa	Temp. °C	(m^3/kg) Líquido sat.	Vapor sat.	(kJ/kg) Líquido sat.	Evap.	Vapor sat.	(kJ/kg) Líquido sat.	Evap.	Vapor sat.	(kJ/kg K) Líquido sat.	Evap.	Vapor sat.
P	T	v_l	v_v	u_l	u_{lv}	u_v	h_l	h_{lv}	h_v	s_l	s_{lv}	s_v
0,6113	0,01	0,001000	206,132	0	2375,3	2375,3	0,00	2501,30	2501,30	0,0000	9,1562	9,1562
15	53,97	0,001014	10,02218	225,90	2222,83	2448,73	225,91	2373,14	2599,06	0,7548	7,2536	8,0084
20	60,06	0,001017	7,64937	251,35	2205,36	2456,71	251,38	2358,33	2609,70	0,8319	7,0766	7,9085

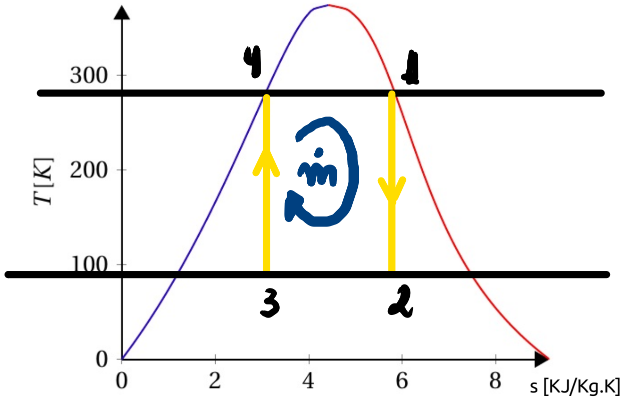


Estado 3: $P = 20\ kPa$ $\begin{cases} S_L = 0,8319 \\ S_V = 7,9085 \end{cases}$ $S_3 = 3,2067$

$$X_3 = \frac{3,2067 - 0,8319}{7,9085 - 0,8319} \rightarrow X_3 = 0,3355$$

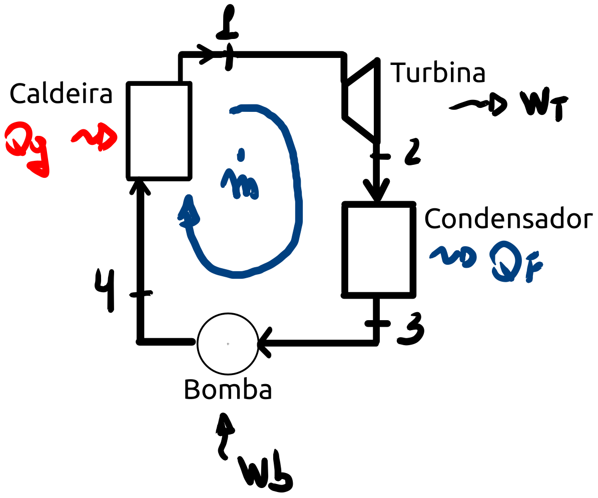
$$h_3 = 251,38 + 0,3355\,(2609,7 - 251,38)$$

$$h_3 = 1042,796$$



Ponto	P[KPa]	T[ºC]	x	$h[KJ/Kg]$	$s[KJ/Kg.K]$
1	8000	295,06	1	2757,94	5,7431
2	20	60,06	0,694	1888,067	5,7431
3	20	60,06	0,3355	1042,7965	3,2067
4	8000	295,06	0	1316,61	3,2067

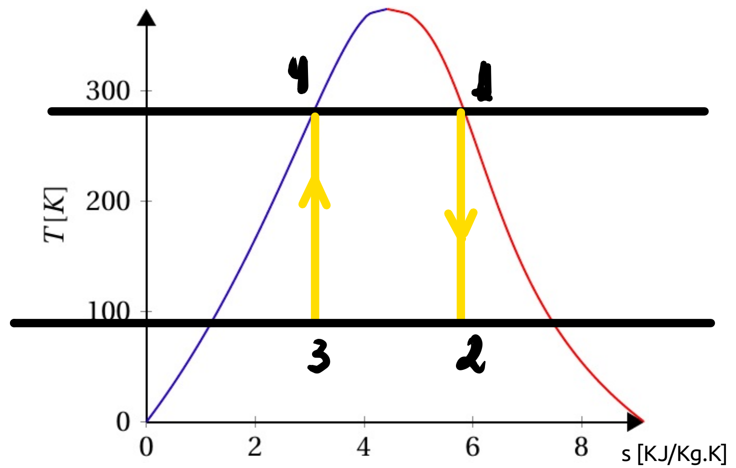
Componente	q[KJ/Kg]	w[KJ/Kg]
Caldeira	$h_1 - h_4 = 1441,33$	0
Turbina	0	$h_2 - h_1 = -869,873$
Condensador	$h_3 - h_2 = -845,2705$	0
Bomba	0	$h_4 - h_3 = 273,8135$
Σ	$q_{liq} = 596,0595$	$w_{liq} = -596,0595$



$$\eta = \frac{596,0595}{1441,33} = 0,4135$$

$$\eta_c = 1 - \frac{T_L}{T_H} = 1 - \frac{(60,06+273,16)}{(295,06+273,16)} = 0,4135$$

$$bwr = \frac{w_b}{w_T} = \frac{273,8135}{869,873} = 0,3148$$

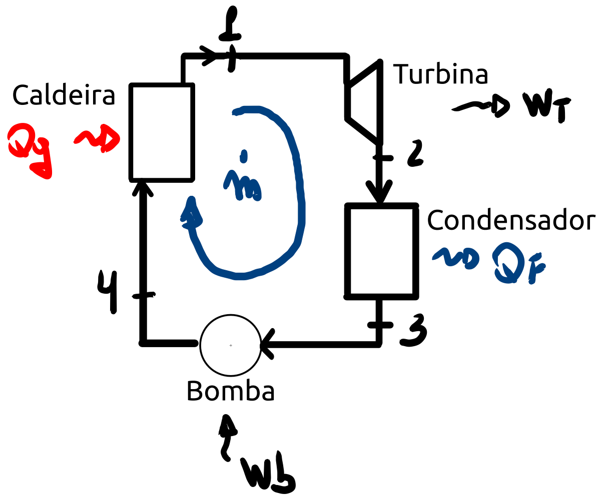


Ponto	P[KPa]	T[ºC]	x	$h[KJ/Kg]$	$s[KJ/Kg.K]$
1	8000	295,06	1	2757,94	5,7431
2	20	60,06	0,694	1888,067	5,7431
3	20	60,06	0,3355	1042,7965	3,2067
4	8000	295,06	0	1316,61	3,2067

$$\Delta s_g = s_1 - s_4 = 5,7431 - 3,2067 = 2,5364 \ \frac{kJ}{kg\,K}$$

$$\Delta s_F = s_3 - s_2 = 3,2067 - 5,7431 = -2,5364 \ \frac{kJ}{kg\,K}$$

$$\oint ds = 2,5364 + (-2,5364) = 0$$



$$ds_g = \int \frac{\delta Q}{T} \rightarrow T_g = \frac{h_1 - h_4}{s_1 - s_4} = 568,258\,K = 295\,°C$$

$$ds_F = \int \frac{\delta Q}{T} \rightarrow T_F = \frac{h_3 - h_2}{s_3 - s_2} = 333,25\,K = 60,09\,°C$$

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