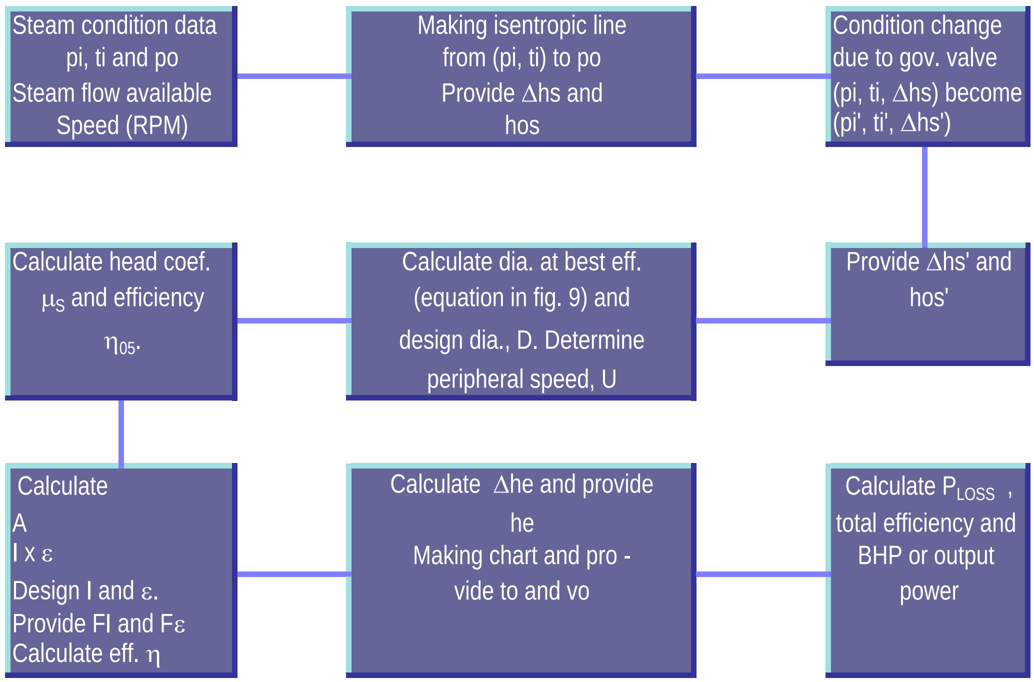
STEAM TURBINE CALCULATION SHEET, OUTPUT POWER

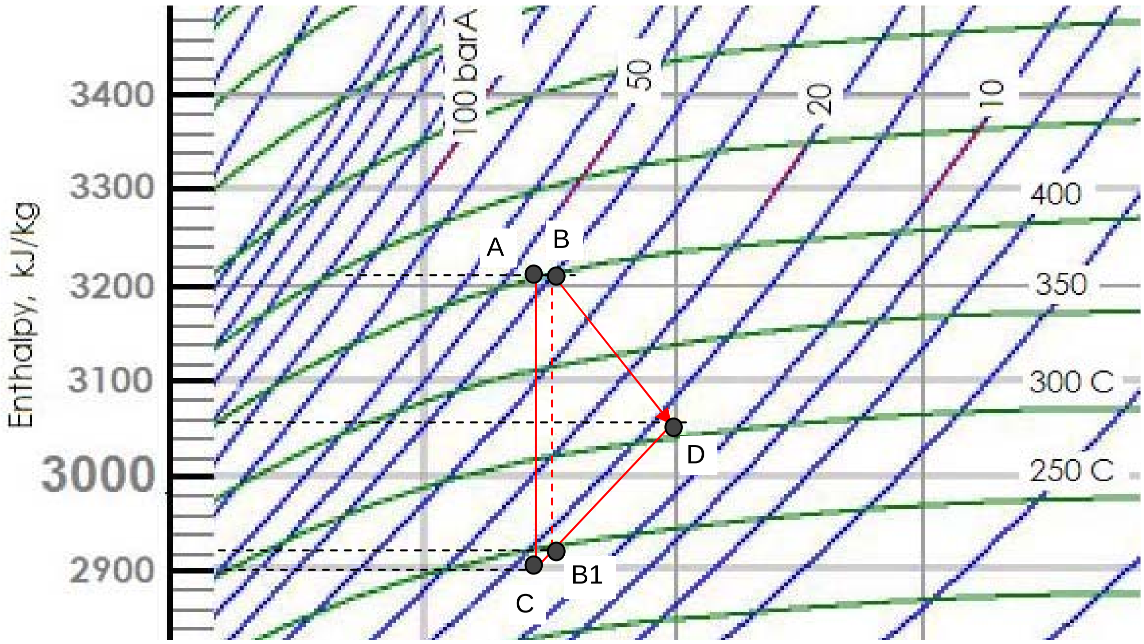
FOR IMPULSE TURBINE

FLOW CHART

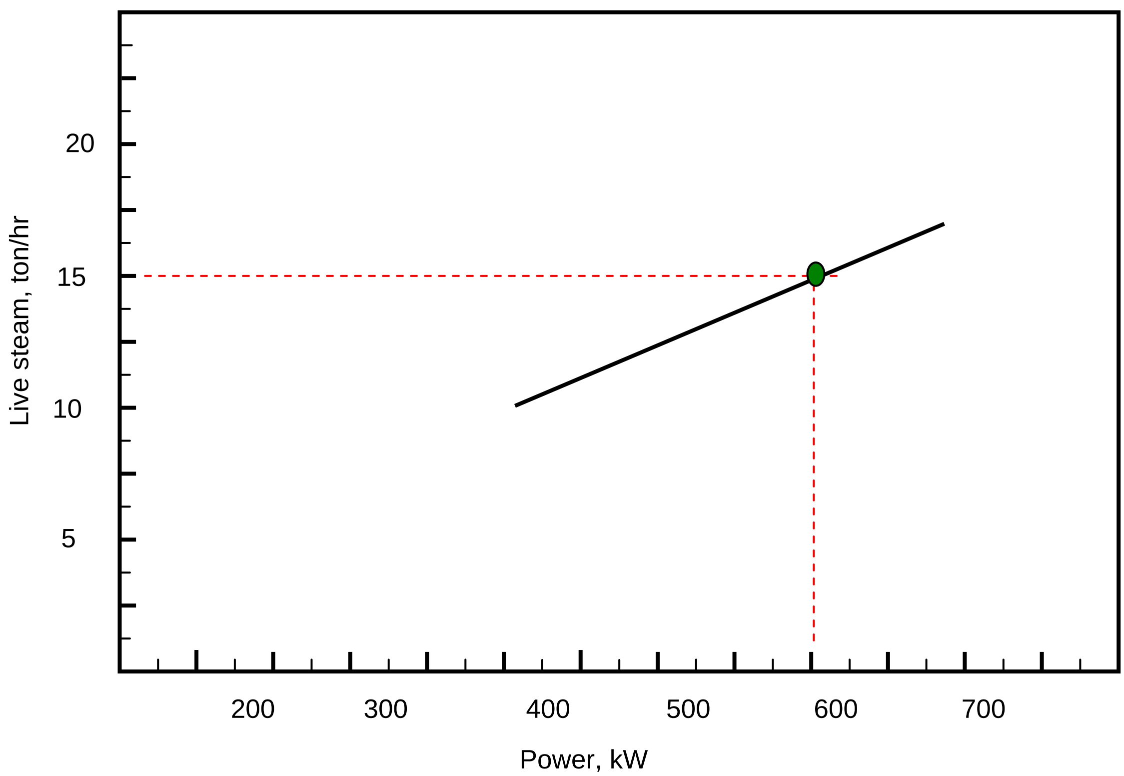


STEAM TURBINE CALCULATION SHEET

No.	Designation		Quantity		Note and additional information
1					
2	Turbine type, figure 3		CURTIS		
3			STAND ALONE		
4	REQUIRED CONDITION				
5			Normal	Rated	
6	Steam flow available, m	ton/hr	15		
7	Turbine speed, N	RPM	4000		Before reducing gear or without gear
8	Inlet pressure, pi	bar A	42		
9	Inlet temperature, ti	C	400		
10	Exhaust pressure, po	bar A	13		
11					
12	STEAM DATA				
13	hi	kJ/kg	3210		See steam Mollier diagram, point A
14	hos	kJ/kg	2900		Mollier diagram, isentropic proc., point C
15	Δhs	kJ/kg	310		= hi - hos (point A to C)
16	Governor valve factor		0.93		Multi valve 0.97, single valve 0.93
17	Δhs'	kJ/kg	288.3		= Gov. vlv. Factor x Δhs (equation 11)
18	hos'	kJ/kg	2921.7		Point B1
19	pi'	bar A	39		Point B for pressure
20	ti'	C	395		Point B for temperature
21	vi'	m^3/kg	0.075		See steam table at pi' and ti'
22	CALCULATION				
23	Nom. Diameter at best eff.,	mm	1004		Equation in figure 9. at μ_s = 6.5 (for Curtis)
24	Design dia., D	mm	1000		Fill with adjustment
25	Peripheral velocity, U	m/s	209.80		Equation 1
26	Head coefficient, μ_S		6.550		Equation 4
27	Efficiency, η_{05}		0.71		Figure 12
28	Entrance area factor, A		34		Page 16
29	l x ε	mm	0.541		Equation 15 but replace P by (Δhs' x m x η_{05})
30	Design nozzle height, l	mm	25.0		Fill so that ε within the range below
31	Degree of admission, ε		0.022		Half circle,0.015-0.45 for wld, min. 0.007 reaming
32	Efficiency factor Fl		0.95		Figure 13
33	Efficiency factor Fe		0.794		Equation in figure 13
34	Efficiency, η_1		0.54		= η_{05} x F_l x Fε
35	Δhe	kJ/kg	154.4		= η_l x Δhs'
36	he	kJ/kg	3055.6		= hi - Δhe, point D in Mollier diagram
37	Exhaust temperature, to	C	305		See steam Mollier diagram at point D
38	Exhaust specific volume, vo	m^3/kg	0.19936		See steam table
39	P_{LOSS}	kW	68.49		Equation 5
40	Mechanical efficiency, η_m		0.956		Figure 15
41	Turbine efficiency, η		0.51		= η_1 x η_m
42	Power	kW	546.54		Equation 9
43	*Note for cell and font color :*				
44	XXX.X	Input data or data taken from charts		XXX.X	Selected data or design where adjustment
45	XXX.X	Calculation result or from chart that has been converted in equation			is permitted



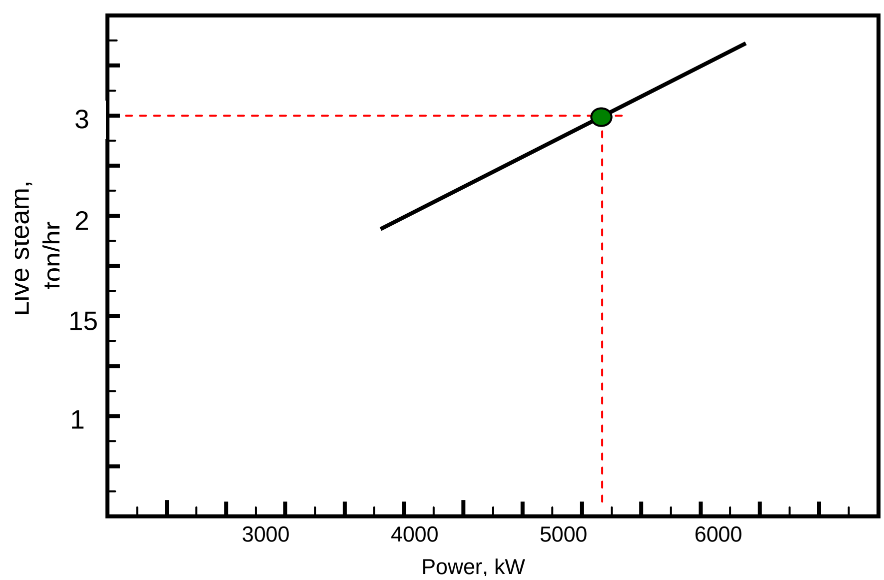
Steam Process in Mollier Diagram

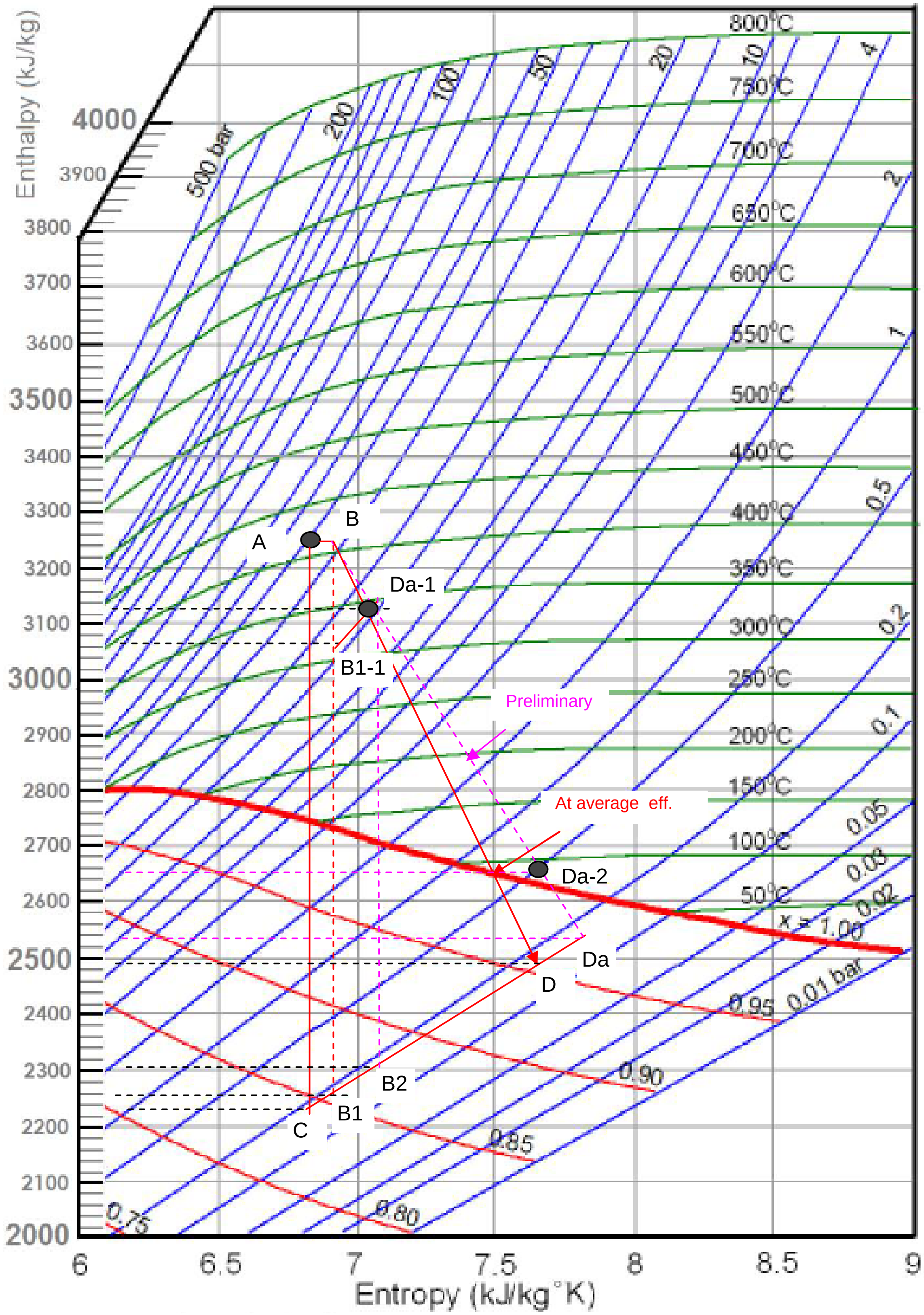


Live steam or steam consumption curve

No.	Designation		Quantity		Note and additional information
1					
2	Turbine type, figure 3		RATEAU STAGES		
3			CONDENSING TURBINE		
4	REQUIRED CONDITION				
5			Normal	Rated	
6	Driven equipment		Syngas Compressor		
7	Steam flow available	ton/hr	15		
8	N	RPM	10200		
9	pi	bar A	40		
10	ti	C	400		
11	po	bar A	0.12		
12	STEAM DATA				
13	hi	kJ/kg	3205		See steam Mollier diagram, point A
14	hos	kJ/kg	2160		Mollier diagram, isentropic proc., point C
15	Δhs	kJ/kg	1045		= hi - hos
16	Governor valve factor		0.97		Multi valve 0.97, single valve 0.93
17	Δhs'	kJ/kg	1013.65		= Gov. vlv. Factor x Δhs (equation 11)
18	hos'	kJ/kg	2191.35		Point B1
19	pi'	bar A	36		
20	ti'	C	395		At hi and pi'
21	vi'	m^3/kg	0.081		See steam table at pi' and ti'
22					
23	CALCULATION				
24	Min. no. of stages, zmin		5		
25	Design dia., D	mm	500		Fig. 10. Nearest cross point RPM vs red dot line
26	Calculated number of stages, z1		6.04		
27	Design no. of stages, z		6		Integer
28	Enthalpy per stage, Δh_{STG}	kJ/kg	168.9		= Δhs' / z
29	Peripheral velocity, U	m/s	267.5		Equation 1
30	Head coefficient, μ_S		2.36		Equation 4
31	Efficiency, η_{05}		0.81		Figure 12
32	Entrance area factor, A		34		
33	***First stage***				
34	l x ε	mm	1.527		Equation 15 but replace P by (Δhs' x m x η_{05})
35	Nozzle height, l	mm	25		Fill with adjustment
36	Degree of admission, ε		0.061		Max. 0.9 for Rateau turbine, fig. 16
37	Efficiency factor F_l		0.97		Figure 13
38	Efficiency factor Fε		0.905		Equation in figure 13
39	Efficiency, η_1		0.72		= η_{05} x F_l x Fε
40	hos_1	kJ/kg	3036.06		= hi - Δh_{STG} , point B1-1
41	Δhe_{STG-1}	kJ/kg	120.81		= η_{05} x Δh_{STG}
42	he_{STG-1}	kJ/kg	3084.19		= hi - Δhe_{STG-1} , point B1-2
43	po_1	bar A	16.0		See steam chart at point B1-2
44	to_1	C	325.0		
45	vo_1	m^3/kg	0.167		See steam table
46	P_{LOSS-1}	kW	74.42		Equation 5

1					
2	***Last stage***				
3	Δhe (preliminary)	kJ/kg	724.9		$= \eta_I \times \Delta hs'$ (preliminary eff. = 1'stg eff.)
4	he_Z (preliminary)	kJ/kg	2480.1		$=hi - \Delta he$, point Da
5	hi_{STG-Z} (preliminary)	kJ/kg	2600.9		$=he_Z + (\Delta he/z)$. Point Da-2
6	pi_1	bar A	0.49		Point Da-2
7	ti_1 for superheated, X for wet steam	C for ti	0.99		
8	vi_1	m^3/kg	3.29		See steam table for specific volume
9	Entrance area factor, A		43		Page 16
10	$l \times \varepsilon$	mm	60.238		Equation 15 but replace P by ($\Delta hs' \times m \times \eta_{05}$)
11	Nozzle height, l	mm	75		Fill with adjustment.
12	ε		0.803		Max. 0.9 for Rateau turbine, fig. 16
13	Efficiency factor F_l		1.00		See fig. 13
14	Efficiency factor $F\varepsilon$		1.00		See fig. 13
15	Efficiency, η_Z		0.81		$= \eta_{05} \times F_l \times F\varepsilon$
16	Vapor partial, X		0.960		
17	Exhaust temperature, to	C	51		See steam Mollier diagram
18	Exhaust specific volume, vo	m^3/kg	12.74		See steam table
19	P_{LOSS-Z}	kW	0.65		Equation 5
20	***Average and Total***				
21	Total losses, P_{LOSS}	kW	225.20		$= z \times 0.5 \times (P_{LOSS-1} + P_{LOSS-Z})$
22	Average efficiency, η_{AVG}		0.76		$=(\eta_1 + \eta_Z) / 2$
23	h_{WET}	kJ/kg	2740		See Mollier diagram
24	Wet eficiency, η_{WET}		0.9989		h_{WET} = 2740 kJ/kg
25	Turbine efficiency, η		0.76		$= \eta_{AVG} \times \eta_{WET}$
26	Power output, P	kW	2998.2		Equation 9
27	Mechanical efficiency, η_m		0.963		Figure 15
28	BHP	kW	2887		$= \eta_m \times P$
29	he	kJ/kg	2431		$= hi - \Delta hs' \times \eta$



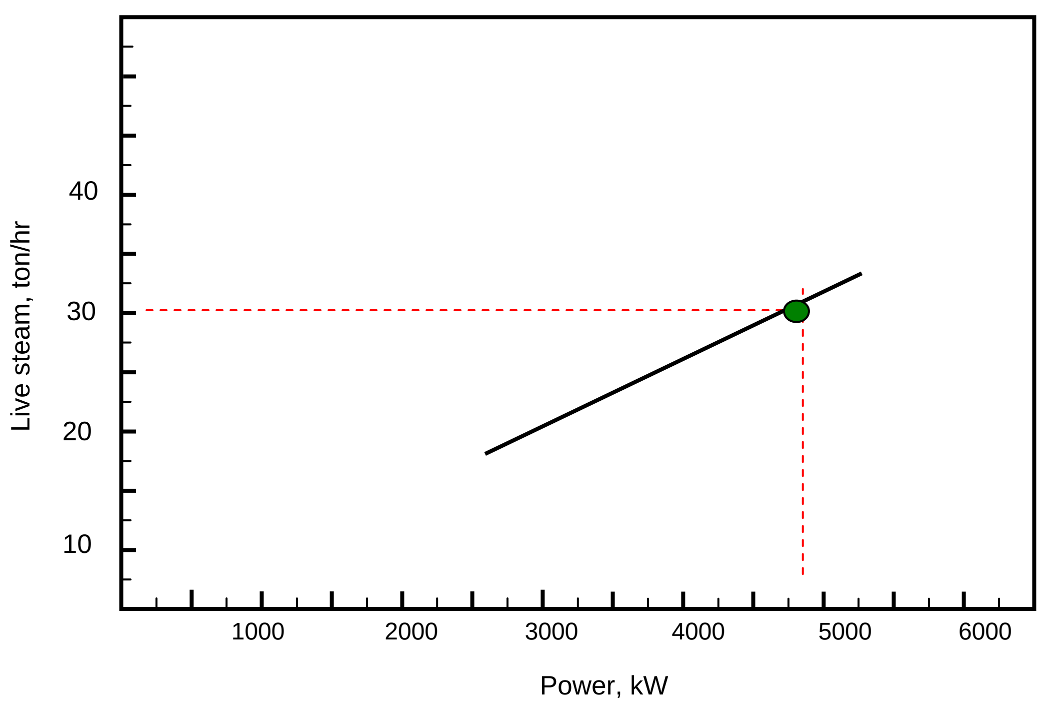

Enthalpy (kJ/kg)
Entropy (kJ/kg°K)
A
B
Da-1
B1-1
Preliminary
At average eff.
Da-2
Da
D
B2
B1
C
500 bar
200
100
50
20
10
4
2
1
0.5
0.2
0.1
0.05
0.03
0.02
0.01 bar
800°C
750°C
700°C
650°C
600°C
550°C
500°C
450°C
400°C
350°C
300°C
250°C
200°C
150°C
100°C
50°C
x = 1.00
0.95
0.90
0.85
0.80
0.75

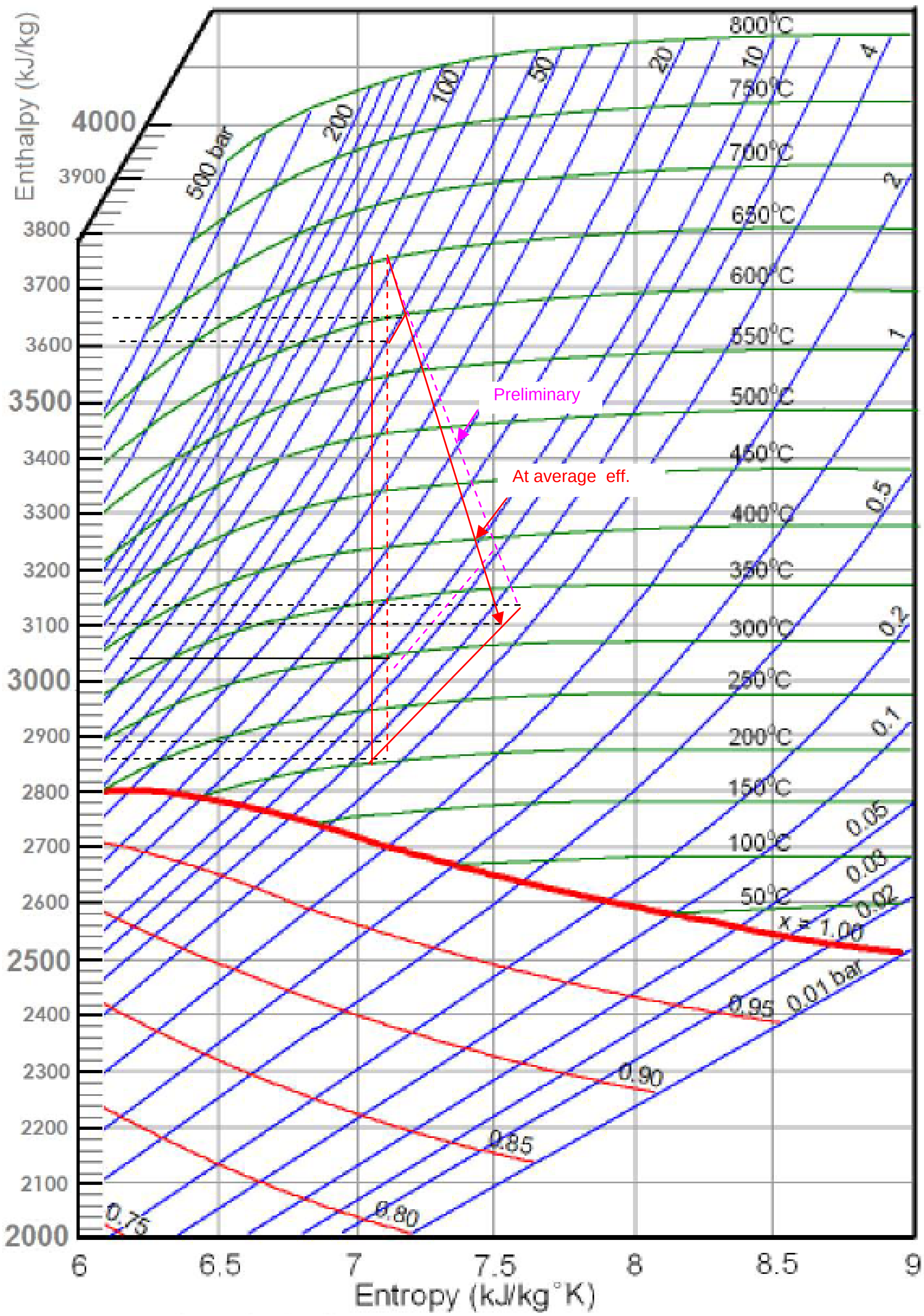
Logo

STEAM TURBINE CALCULATION SHEET

No.	Designation		Quantity		Note and additional information
1					
2	Turbine type, figure 3		RATEAU STAGES		
3			BACK PRESSURE TRUBINE		
4	REQUIRED CONDITION				
5			Normal	Rated	
6	Driven equipment		Air Compressor		
7	Steam flow available	ton/hr	30		
8	N	RPM	9000		
9	pi	bar A	110		
10	ti	C	650		
11	po	bar A	5		
12	STEAM DATA				
13	hi	kJ/kg	3737		See steam Mollier diagram
14	hos	kJ/kg	2820		See steam Mollier diagram
15	Δhs	kJ/kg	917		= hi - hos
16	Governor valve factor		0.97		Multi valve 0.97, single valve 0.93
17	Δhs'	kJ/kg	889.49		= Gov. vlv. Factor x Δhs (equation 11)
18	hos'	kJ/kg	2847.51		
19	pi'	bar A	100		
20	ti'	C	645		At hi and pi' (point B)
21	vi'	m^3/kg	0.0408		See steam table at pi' and ti' (point B) or
22					extrapolate in steam table
23	CALCULATION				
24	Min. no. of stages, zmin		3		
25	Design dia., D	mm	550		Fig. 10. Nearest cross point RPM vs red dot line
26	Calculated number of stages, z1		5.63		Eq. 12
27	Design no. of stages, z		6		Select with Integer number
28	Enthalpy per stage, Δh_{STG}	kJ/kg	148.2		= Δhs' / z
29	Peripheral velocity, U	m/s	259.6		Equation 1
30	Head coefficient, μ_S		2.20		Equation 4
31	Efficiency, η_{05}		0.83		Figure 12
32	Entrance area factor, A		34		
33	***First stage***				
34	l x ε	mm	1.493		Equation 15 but replace P by (Δhs' x m x η_{05})
35	Nozzle height, l	mm	25		Fill with adjustment
36	Degree of admission, ε		0.060		Max. 0.9 for Rateau turbine, fig. 16
37	Efficiency factor F_l		0.97		Figure 13
38	Efficiency factor $F\varepsilon$		0.905		Equation in figure 13
39	Efficiency, η_1		0.73		= η_{05} x F_l x $F\varepsilon$
40	hos_1	kJ/kg	3588.75		Make point at steam chart
41	Δhe_{STG-1}	kJ/kg	108.00		
42	he_{STG-1}	kJ/kg	3629.00		Make point at steam chart
43	po_1	bar A	65.0		See steam chart
44	to_1	C	590.0		
45	vo_1	m^3/kg	0.059		See steam table
46	P_{LOSS-1}	kW	213.09		Equation 5

1					
2	***Last stage***				
3	Δhe	kJ/kg	648.0		= η x $\Delta hs'$ (preliminary eff. = 1'stg eff.)
4	he_z	kJ/kg	3089.0		= hi-Δhe
5	hi_{STG-Z}	kJ/kg	3197.0		=he_Z + ($\Delta he/z$). Point Da-2
6	pi_1	bar A	9.0		See chart
7	ti_1	C	375.0		
8	vi_1	m^3/kg	0.33		
9	Entrance area factor, A		43		
10	l x ε	mm	11.506		Equation 15 but replace P by ($\Delta hs'$ x m x η_{05})
11	Nozzle height, l	mm	30		
12	ε		0.384		Max. 0.9 for Rateau turbine, fig. 16
13	Efficiency factor F_l		0.96		See fig. 13
14	Efficiency factor $F\varepsilon$		0.99		See fig. 13
15	Efficiency, η_Z		0.79		= η_{05} x F_l x $F\varepsilon$
16	P_{LOSS-Z}	kW	30.98		Equation 5
17	***Average and Total***				
18	Total losses, P_{LOSS}	kW	732.23		= z x 0.5 x (P_{LOSS-1} + P_{LOSS-Z})
19	Average efficiency, η_{AVG}		0.76		=(η_1 + η_Z) / 2
20	Power output	kW	4879		Equation 9
21	Mechanical efficiency, η_m		0.977		Figure 15
22	BHP	kW	4767		= η_m x P
23	he	kJ/kg	3064		




Enthalpy (kJ/kg)
Entropy (kJ/kg°K)
4000
3900
3800
3700
3600
3500
3400
3300
3200
3100
3000
2900
2800
2700
2600
2500
2400
2300
2200
2100
2000
6
6.5
7
7.5
8
8.5
9
500 bar
200
100
50
20
10
4
2
1
0.5
0.2
0.1
0.05
0.03
0.02
0.01 bar
800°C
750°C
700°C
650°C
600°C
550°C
500°C
450°C
400°C
350°C
300°C
250°C
200°C
150°C
100°C
50°C
x = 1.00
0.95
0.90
0.85
0.80
0.75
Preliminary
At average eff.