STEAM TURBINE CALCULATION SHEET, OUTPUT POWER

FOR IMPULSE + REACTION TURBINE

FLOW CHART

Steam condition data
pi, ti and po
Steam flow available
Speed (RPM)

Making isentropic line
from (pi, ti) to po
Provide Δhs and
hos

Condition change
due to gov. valve
(pi, ti, Δhs) become
(pi', ti', Δhs')

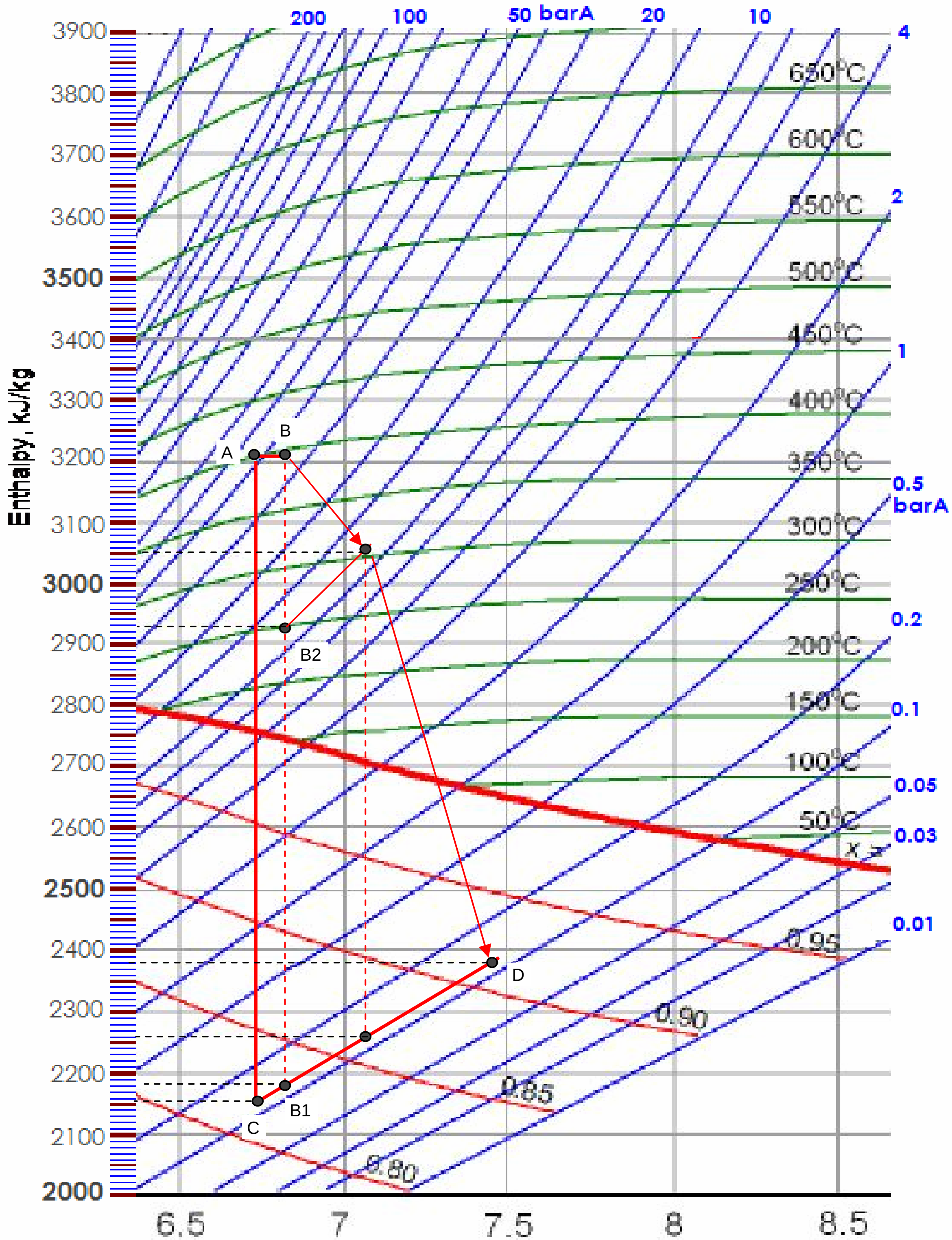
Provide Δhs' and
hos'

Control Stage :
Determine po_{IMP}, hs'_{IMP}, $\Delta hs'_{IMP}$
For Curtis, calculate diameter at best efficiency and
decide design diameter, D
For Rateau, provide D from Fig. 10
Calculate U, z and $\Delta h_{IMP\text{-}STG}$.
For Curtis or Rateau :
Recalculate μ_S . Calculate η_{05} and $l \times \varepsilon$
Decide l and calculate F_l, $F\varepsilon$.
Calculate efficiency of control stage, η_{IMP}
Calculate power loss of control stage, P_{LOSS}
Calculate output power of control stage, P_{IMP}
Calculate Δhe and he_{IMP}.
Determine to and vo

Reaction Stages :
$hi = he_{IMP}$., $ti = to_{IMP}$ and $vo=vi_{IMP}$
Provide hos_R and calculate Δhs_R
Provide pitch diameter, D and
base diameter from Fig. 11.
Calculate l and D/l. Decide S/l
Calculate z, $\Delta h_{R\text{-}STG}$, U, and U/C
Provide efficiency, η_R and
calculate Δhe and provide he_R.
Provide X, wet enthalpy h_{WET}
Calculate wet efficiency, η_W
Calculate reaction stage eff., h_R
Calculate output power of reaction
stages, P_R
Calculate output power of reaction +
control satge P. Calculate mechani-
cal eff., η_m
Calculate BHP

No.	Designation		Quantity		Note and additional information
1					
2	Turbine type		CURTIS+REACTION		
3			Control stage : Curtis		
4			CONDENSING TURBINE		
5	REQUIRED CONDITION				
6			Normal	Rated	
7	Steam flow available	ton/hr	32		
8	N	RPM	7500		
9	pi	bar A	42		
10	ti	C	400		
11	po	bar A	0.12		
12					
13	STEAM DATA				
14					
15	hi	kJ/kg	3210		See steam Mollier diagram, point A.
16	hos	kJ/kg	2155		See steam Mollier diagram, point C
17	Δhs	kJ/kg	1055		= hi - hos
18	Governor valve factor		0.97		Multi valve 0.97, single valve 0.93
19	Δhs'	kJ/kg	1023.4		= Gov. vlv. Factor x Δhs (equation 11)
20	hos'	kJ/kg	2186.7		See diagram, point B1
21	pi'	bar A	40		
22	ti'	C	395		
23	vi'	m^3/kg	0.074		See steam table at pi' and ti'
24					
25	CALCULATION				
26					
27	*Control Stage*				
28	Calculated po_{IMP}	bar A	12.00		Point B2 where po_{IMP} approx. = 0.3 x pi'
29	Designed po_{IMP}		12.0		
30	hos'_{IMP}	kJ/kg	2925.0		See diagram
31	$\Delta hs'_{IMP}$	kJ/kg	285.0		$=hi-hos'_{IMP}$
32	Calculated dia. At best eff.		532.3		Eq. 4 at μ_S = 6.5 for Curtis and = 2 for Rateau
33	Nominal diameter, D	mm	500		Fill with adjustment
34	Peripheral velocity, U	m/s	196.7		Equation 1
35	Head coefficient, μ_S		7.4		
36	Efficiency, η_{05}		0.71		Figure 12
37	Entrance area factor, A		34		
38	l x ε	mm	2.292		Equation 15 but replace P by (Δhs' x m x η_{05})
39	Nozzle height, l		25		Select l so that ε within the range below
40	ε		0.092		0.015-0.45 weld/half circle
41	Efficiency factor Fl		0.93		Figure 13
42	Efficiency factor Fe		0.834		Equation in figure 13
43	Efficiency, η_{IMP}		0.55		= η_{05} x F_l x Fε

No.	Designation		Quantity		Note and additional information
1	Δhe	kJ/kg	155.8		$= \eta_{IMP} \times \Delta h_{IMP}$
2	he_{IMP}	kJ/kg	3054.2		Than make steam process in Mollier diagr.
3	Exhaust temperature, to	C	300		See steam Mollier diagram
4	Exhaust specific volume, vo	m^3/kg	0.236		See steam table
5	P_{LOSS}	kW	20.32		Equation 5
6	Power output, P_{IMP}	kW	1364.9		
7					
8	*Reaction Stages*				
9	hi	kJ/kg	3054.2		
10	hos	kJ/kg	2260		
11	Δhs_R	kJ/kg	794.16		
12	Pitch diameter, D	mm	600		See fig. 11, at required speed, select pitch
13	Base diameter	mm	500		and base diameter
14	Average blade height, l	mm	100		
15	D/l		6		
16	S/l		0.40		=0.2 LP blade,=0.4 MP and =0.6 HP
17	Calculated number of stages		15		Eq. 12a (integer number)
18	Peripheral velocity, U	m/s	236.0		
19	Steam velocity, C	m/s	325.2		
20	Velocity ratio, U/C		0.73		
21	Δhs_{RSTG}	kJ/kg	52.9		
22	η_R		0.85		
23	Δhe_R	kJ/kg	675.03		
24	he_R	kJ/kg	2379.1		
25	X		0.915		
26	Wet enthalpy	kJ/kg	2700.0		
27	Wet eficiency, η_{WET}		0.980		Equation 7.
28	Turbine efficiency, η		0.83		$= \eta_R \times \eta_{WET}$
29	Reaction power output, P_R	kW	5879		
30	*Impulse + Reaction*				
31	Impulse+reactionl power output, P	kW	7244.03		$= P_R + P_{IMP}$
32	Mechanical efficiency, η_m		0.995		
33	Total power output (BHP)	kW	7208		$= \eta_m \times P$
34					
35					
36					
37					


Enthalpy, kJ/kg
3900
3800
3700
3600
3500
3400
3300
3200
3100
3000
2900
2800
2700
2600
2500
2400
2300
2200
2100
2000
6.5
7
7.5
8
8.5
200
100
50 barA
20
10
4
2
1
0.5 barA
0.2
0.1
0.05
0.03
0.01
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
0.95
0.90
0.85
0.80
A
B
B2
B1
C
D

Logo

STEAM TURBINE CALCULATION SHEET

STEAM CONSUMPTION

No.	Designation		Quantity		Note and additional information
1					
2	Turbine type		RATEAU+REACTION		
3			Control stage : Rateau		
4			CONDENSING TURBINE		
5	REQUIRED CONDITION				
6			Normal	Rated	
7	Steam flow available	ton/hr	51		
8	N	RPM	6000		
9	pi	bar A	42		
10	ti	C	400		
11	po	bar A	0.12		
12					
13	STEAM DATA				
14	hi	kJ/kg	3210		See steam Mollier diagram, point A.
15	hos	kJ/kg	2240		See steam Mollier diagram, point B
16	Δhs	kJ/kg	970		= hi - hos
17	Governor valve factor		0.97		Multi valve 0.97, single valve 0.93
18	Δhs'	kJ/kg	940.9		= Gov. vlv. Factor x Δhs (equation 11)
19	hos'	kJ/kg	2269.1		See diagram, point D
20	pi'	bar A	40		
21	ti'	C	395		
22	vi'	m^3/kg	0.074		See steam table at pi' and ti'
23					
24	CALCULATION				
25	*Control Stage*				
26	Calculated po_{IMP}	bar A	12.0		po_{IMP} approx. = 0.3 x pi'
27	Designed po_{IMP}	bar A	12		
28	hos'_{IMP}	kJ/kg	2930.0		See chart
29	$\Delta hs'_{IMP}$	kJ/kg	280.0		=hi - hos'_{IMP}
30	Nominal diameter, D	mm	600		See Fig.10. At near cross point N and red dot line
31	Peripheral velocity, U	m/s	188.8		Equation 1
32	Number of stage, z		3		
33	$\Delta hs'_{IMP-STG}$	kJ/kg	93		= $\Delta hs'_{IMP}$ / z
34	Head coefficient, μ_S		2.6		
35	Efficiency, η_{05}		0.80		
	First stage				
36	Entrance area factor, A_1		34		
37	l x ε	mm	5.319		Equation 15 but replace P by (Δhs' x m x η_{05})
38	Nozzle height, l_1		25		Select l so that ε within the range below
39	ε_1		0.213		0.015-0.45 weld/half circle, max. ≈ 0.8
40	Efficiency factor Fl		0.97		Figure 13
41	Efficiency factor Fe		0.951		Equation in figure 13
42	Efficiency, η_{IMP-1}		0.74		= η_{05} x F_l x Fε

No.	Designation		Quantity		Note and additional information
1	Δhe	kJ/kg	206.8		$= \eta_{IMP} x \Delta hs'_{IMP}$
2	he_{IMP}	kJ/kg	3003.2		Make steam process in Mollier diagr.
3	P_{LOSS-1}	kW	29.55		Equation 5
4	***Last stage***				
5	Last stage of impulse, hi_z	kJ/kg	3072.1		
6	pi_Z		17.0		
7	ti_Z	C	320		See steam Mollier diagram
8	vi_Z	m^3/kg	0.155		See steam table
9	A_Z		34		
10	$l x \varepsilon$		11.142		
11	Nozzle height, l_Z		25		Select l so that ε within the range below
12	ε_Z		0.446		0.015-0.45 weld/half circle, max. ≈ 0.8
13	Efficiency factor Fl		0.97		
14	Efficiency factor Fe		0.989		
15	Efficiency, η_{IMP-Z}		0.77		$= \eta_{05} x F_l x F\varepsilon$
16	P_{LOSS-Z}	kW	21.97		Equation 5
17	***Average and Total***				
18	Average efficiency, η_{IMP}		0.75		
19	Average losses, P_{LOSS}	kW	77.28		
20	P_{IMP}	kW	2911.30		
21	he_{IMP}		2999.04		
22	to		275		
23	vo		0.204		
24	Power of control stage, P_{IMP}	kW	2911.3		
25	***Reaction Stages***				
26	hi	kJ/kg	2999.0		
27	hos	kJ/kg	2260		
28	Δhs_R	kJ/kg	739.04		
29	Pitch diameter, D	mm	600		See fig. 11, at required speed, select pitch
30	Base diameter	mm	500		and base diameter
31	Average blade height, l	mm	100		
32	D/l		6		
33	S/l		0.40		=0.2 LP blade,=0.4 MP and =0.6 HP
34	Calculated number of stages		22		Eq. 12a (integer number)
35	Peripheral velocity, U	m/s	188.8		
36	Steam velocity, C	m/s	259.1		
37	Velocity ratio, U/C		0.73		
38	Δhs_{RSTG}	kJ/kg	33.6		
39	η_R		0.883		
40	Δhe_R	kJ/kg	652.57		

No.	Designation		Quantity		Note and additional information
1	he_R	kJ/kg	2346.5		
2	X		0.900		
3	Wet enthalpy	kJ/kg	2740		
4	Wet eficiency, η_{WET}		0.970		Equation 7.
5	Turbine efficiency, η		0.86		$= \eta_R \times \eta_{WET}$
6	Reaction power output, P_R	kW	8966		$= \eta \times \Delta hs_R \times m / 3.6$
7	*Impulse + Reaction*				
8	Impulse+reactionl power output,P	kW	11877.34		$= P_R + P_{IMP}$
9	Mechanical efficiency, η_m		0.995		See Fig. 15
10	Total power output (BHP)	kW	11818		
11					
12					
13					
14					
15					
16					
17					
18					
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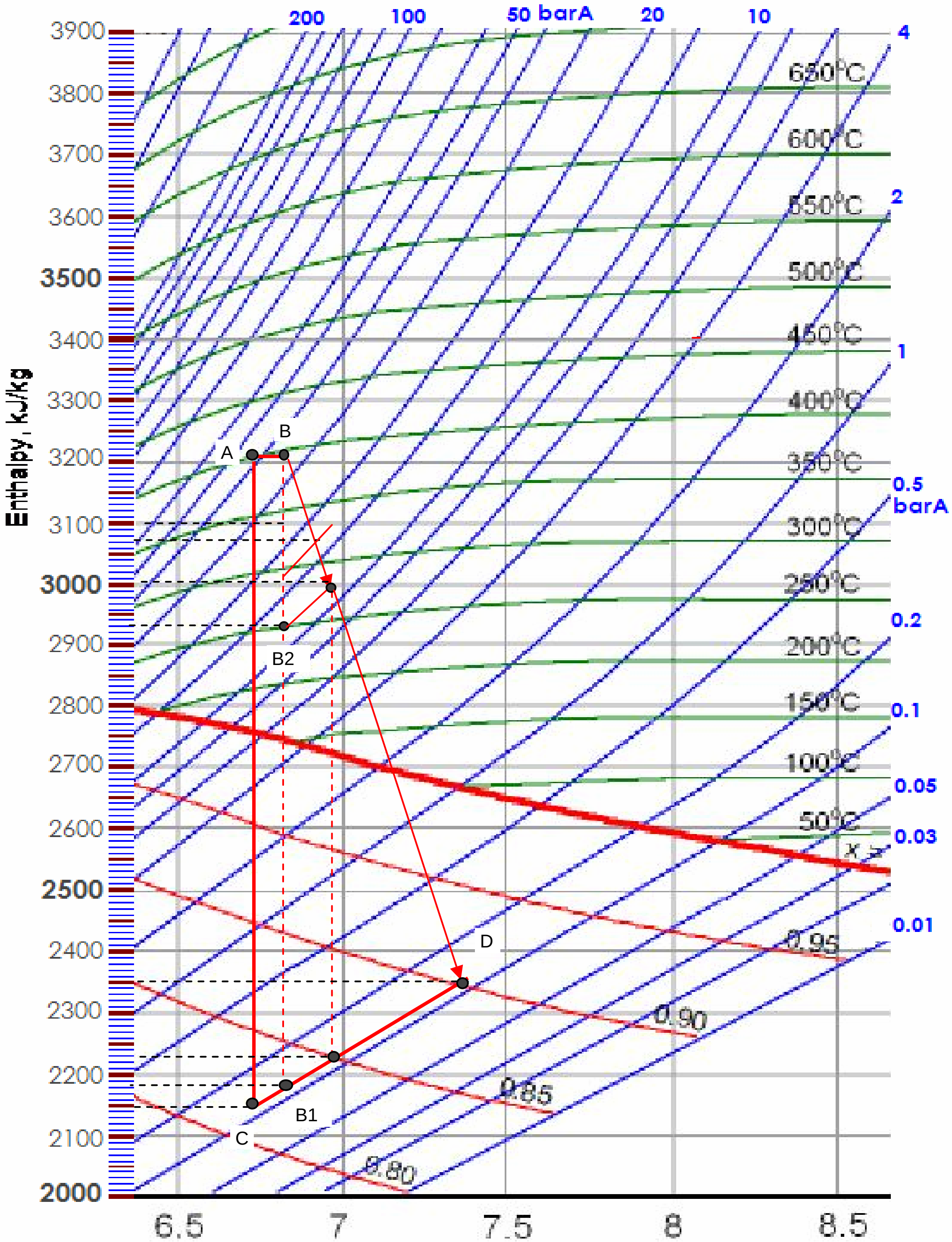
37					


200
100
50 barA
20
10
4
2
1
0.5
barA
0.2
0.1
0.05
0.03
0.01
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
0.95
0.90
0.85
0.80
A
B
B2
B1
C
D
Enthalpy, kJ/kg
3900
3800
3700
3600
3500
3400
3300
3200
3100
3000
2900
2800
2700
2600
2500
2400
2300
2200
2100
2000
6.5
7
7.5
8
8.5