TE-Ch6_Cogen-Ex-6-1-to-6-6.xls
Ex. 6-1_elect. equivalent MWh_t

Item		Unit	Value		
Power output					
In condensing mode		MWh_e	135.7		
In cond.-extraction mode		MWh_e	125.6		
Lost electricity	ΔP	MWh_e	10.1		
Steam extraction:					
Mass flow m	50.00 t/h	kg /s	13.89		
Pressure		bar	12		
Temperature		°C	250		
Enthalpy		kJ/kg	2,936		
Condensate:					
Pressure		bar	1	1	1
Temperature		°C	95	70	0
Enthalpy		kJ/kg	398	293	0
Return rate *)		-	100%	70%	0%
Heat output	Q	MW_t	35.2	37.9	40.8
Electrical equivalent	ΔP/Q	MW_e/MW_t	0.287	0.266	0.248
	ΔP/m	MWh_e/t	0.202	0.202	0.202

*) Condensate may be consumed in industrial processes or lost in piping system or unclean for reuse

TE-Ch6_Cogen-Ex-6-1-to-6-6.xls

Ex 6-2_Electr.-to-heat ratio

Example calculated in the book directly, graph in PP file

Calculation tables only !

Item	Unit	Load 1	Load 2
Live steam	t /h	100	150
Steam extraction	t /h	75	125
Steam to condenser	t /h	25	25
Power output	MW	25	40

Annual Production		
Electricity production	MWh /a	50,000
Steam extraction	t /h	100,000
Cogen electri σ=0.30	MWh /a	30,000
Cond. Electricity	MWh /a	20,000

Example calculated in the book directly, graph in PP file

Calculation table only !

Item	Unit	Operation Mode	
		Power Only	Condensing-extraction
Power output	MW	600	548
Steam extraction	t / h	0	303
Fuel input	MJ / s	1,033	1,033

TE-Ch6_Cogen-Ex-6-1-to-6-6.xls

Ex. 6-4_PerformBackpressure CHP

Item	Formula	Unit	Case 1	Case 2
Given	type of plant	-	110bar no reheat	185bar reheat
Heat extraction at 6 bar	Q_{6bar}	MW_t	200	200
Heat extraction at 12 bar	Q_{12bar}	MW_t	150	150
Electricity-to-heat ratio, 6 bar steam *)	σ_{6bar}	kWh_e / kWh_t	0.392	0.457
Electrical equivalent, 6 bar steam	β_{6bar}	kWh_e / kWh_t	0.243	0.280
Electricity-to-heat ratio, 12 bar steam *)	σ_{12bar}	kWh_e / kWh_t	0.330	0.361
Electrical equivalent, 6 bar steam	β_{12bar}	kWh_e / kWh_t	0.277	0.327
Total efficiency	η_{tot}	-	84.6%	86.2%
Performance Parameters, in cogeneration, calculated				
Rated cogen electrical output, gross	$P_{cogen} = \Sigma\sigma_i \times Q_i$	MW_e	127.9	145.6
Fuel input	$Q_f = (P_{cogen} + \Sigma Q_i) / \eta_{tot}$	MJ/ s	565	575
Equivalent cond. power output	$P_{cond\_equ} = P_e + \Sigma\beta_i \times Q_i$	MW_e	**218.1**	**250.6**
Equivalent cond. Efficiency	$\eta_{cond\_equ.} = P_{cond\_equ.} + Q_f$	→	**38.6%**	**43.6%**

*) taken from electricity-to -heat-ratio figures from text part

TE-Ch6_Cogen-Ex-6-1-to-6-6.xls

Example 6-5_Spliting_Cogen

Item	Symbol	Unit	Operation mode	
			cogen only	mixed cogen+bypass
Given rated output *)				
Gas turbine CHP	-	GT type	Mars 90	Mars 90
Rated electric output ISO	P_e	kW	9,111	9,111
Rated heat output (5 bar steam)	Q_t	kW_t	15,128	15,128
Rated firing capacity	Q_f	kW_t	29,352	29,352
Fuel load operating hours, plant	t_{FLH}	h /a	7,300	7,300
Performance parameters at rated conditions (calculated)				
Electric efficiency **)	$\eta_e = P_e / Q_f$	-	31.0%	31.0%
Total efficiency, cogen only	$\eta_{tot} = (P_e + Q_t) / Q_f$	-	82.6%	82.6%
Electricity-to-heat ratio	$\sigma = P_e / Q_t$	kW_e / KW_t	0.602	0.602
Electricity loss ratio	β	kW_e / KW_t	0	0
Annual performance (calculated)				
Annual elec. production, total **)	$W = P_e \times t_{FLH}$	MWh / a	66,510	66,510
Annual heat production, metered	Q_t	MWh_t / a	110,434	85,000
Cogenerated electricity	$W_{cogen} = \sigma \times Q_t$	MWh / a	66,510	51,192
		-	100%	77%
Fuel consumption, total	Q_f	MWh_t / a	214,270	214,270
contributed to cogeneration	$Q_f = (Pe+Qt) / \eta_{tot}$	MWh / a	214,270	164,921
Total efficiency, mixed mode		-	82.6%	70.7%

*) Source of capacity parameters: ASUE Gasturbinen-Kenndaten

**) the same in cogen and mixed mode operation as there is no electricity loss $\beta = 0$

TE-Ch6_Cogen-Ex-6-1-to-6-6.xls
Examle 6-6 Cond_equivalent

Item		Formula	Unit	Value
Rated power and heat output, given				
Electrical output, gross		P_{rated}	MW_e	87.6
Heat extraction at 6 bar	65 t / h	Q_{12bar}	MW_t	46.0
Heat extraction at 12 bar	100 t / h	Q_{6bar}	MW_t	67.3
Fuel input		Q_f	MW_t	305.4
Performance parameters, given				
Electricity-to-heat ratio, 12 bar steam		σ_{12bar}	kWh_e / kWh_t	0.335
Electrical equivalent, 12 bar steam		$\beta_{12\ bar}$	kWh_e / kWh_t	0.278
Electricity-to-heat ratio, 6 bar steam		σ_{6bar}	kWh_e / kWh_t	0.392
Electrical equivalent, 6 bar steam		$\beta_{6\ bar}$	kWh_e / kWh_t	0.243
Power balance				
Cogen power output		$P_{cogen} = \Sigma\sigma_i \times Q_i$	MW_e	41.8
Non-cogen power output		P_{non_cogen}	MW_e	45.8
Power loss		$\Delta P = \Sigma\beta_i \times Q_i$	MW_e	29.1
Equivalent condensing power		$P_{cond\text{-}equ} = P_m + \Delta P$	MW_e	116.7
Equivalent condensing efficiency		η_{cond_equ}	-	38.2%
Total efficiency cogeneration		η_{tot_cogen}	-	83.6%
Fuel input for non-cogen electricity		$Q_{f\_non\text{-}cogen} = P_{non\text{-}cogen} / \eta_{cond\_equ}$		119.8
Fuel input for cogen Heat and power		Q_{f_cogen}	MW_t	185.6
Annual Energy Balance				
Electricity generation, total	t=7,500 h/a	$W_{tot} = P_{mrated} \times t$	MWh / a	657,000
of which in cogeneration		$W_{cogem} = \Sigma\sigma \times Q_t$	MWh / a	218,882
Heat generation 12 bar	6,500 h/a	$Q_{t,\ 12\ bar}$	MWh / a	299,000
Heat generation 6 bar	4,500 h/a	$Q_{t,6\ bar}$	MWh / a	302,850
Fuel consumption	$Q_f = \frac{W_{cogen} + \Sigma Q_t}{\eta_{tot\_cogen}} + \frac{W_{cond.}}{\eta_{cond\_equ}}$ $[MWh_t / a]$		MWh/a	2,128,118

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