A.5 Assessment on Turbine

Steam turbine is a mechanical device that extracts thermal energy from pressurized steam, and converts it to useful mechanical work.
The purpose of this assessment is to determine the efficiency of condensing extraction in the Cogen TK 3 and obtain the performance of Turbine TK 3.

Equipment spesification is as follows:

Turbin	
Type	Single casing extraction condensing type
Rated output	70.000 kW
Main steam pressure at main stop valve	95 kg/cm^2
Main steam temperature at main stop valve extraction pressure (at turbin outlet under guaranted point : Refer to HBD/V69023-T2/FUJ-001-1A)	
No.1 extraction	20.11 kg/cm^2
No.2 extraction	8.5 kg/cm^2
No.3 extraction	1.12 kg/cm^2
Exhaust pressure	0.083 kg/cm^2
Rated speed	3000 rpm
Direction of rotation	Clockwise (view from generator side)
Number of blading stages	Reaction stage 35
Auxiliary Equipment	
Capacity	$3m^3$
Number of set	1 for each turboset
Control oil tank	
Capacity	310 l
Number of set	1 for each turboset

Energy consumption data was obtained from overall efficiency steam turbine record from January to September 2014

Overall Plant Efficiency Steam Turbine

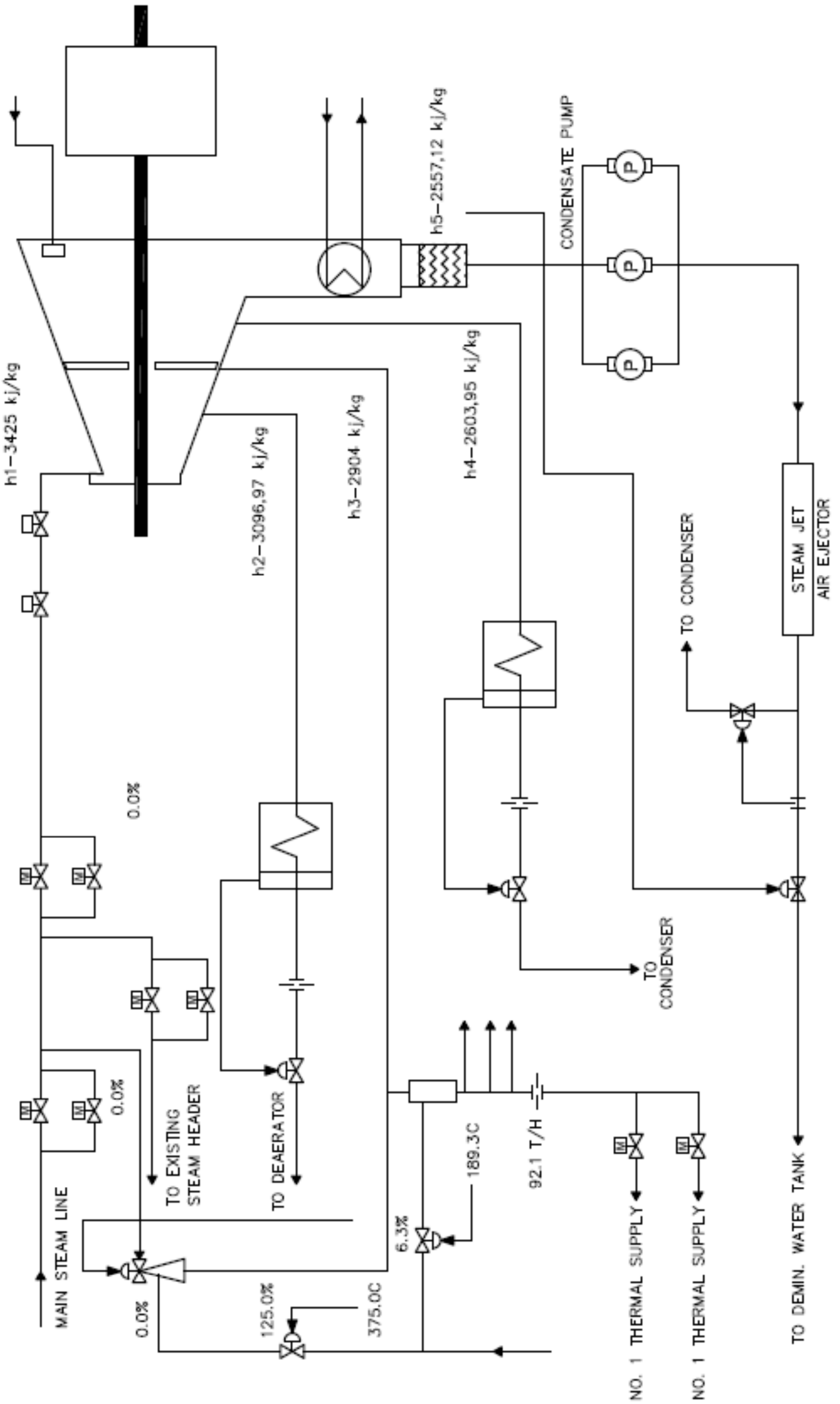
No	Item	Unit	2014,00									
			Jan	Feb	Maret	April	Mai	Juni	Juli	Agustus	Sept	Okt
1	Energy Input											
	- Coal Consumption	ton	26,06	22,91	23,97	23,98		23,63	24,56	24,72	24,20	
	- Average Calorie (ARB)	Kcal/Kg	6,21	6,27	6,30	6,30		6,10	6,19	6,13	6,10	
	Energy	GJ	676,89	599,98	630,95	631,43		602,94	635,65	633,75	616,85	
	- Solar Consumption	KL	18.50	21.43	53.04	0.00		51.05	13.71	72.02	0.00	
	Energy	GJ	686,00	795,00	1,97	0,00		1,89	509,00	2,67	0,00	
	- Others Consumption (............)	KL										
	Energy	GJ										
	Total Energy Input	GJ	677,58	600,77	632,91	631,34		604,83	636,16	636,42	616,85	
2	Energy Output	KWH	43,934,000	40,186,000	43,114,000	43,639,000		44,512,000	44,966,000	45,841,000	44,744,000	
	- Generator Output (Gross Electricity)	GJ	157,93	144,46	154,99	156,87		160,01	161,64	164,79	160,85	
	- Off take steam LP	Ton	64,30	51,73	62,24	62,53		61,82	63,92	61,58	67,98	
	Pressure	Kg/cm^2	7,00	7,00	7,00	7,00		7,00	7,00	7,00	7,00	
	Temp	^0C	175,00	175,00	175,00	175,00		175,00	175,00	175,00	175,00	
	'Offtake steam LP	GJ	185,80	149,46	185,61	180,68		178,64	184,68	177,93	196,44	
	- Offtake steam MP	Ton										
	Pressure	Kg/cm^2										
	Temp	0C										
	- 'Offtake Steam MP	GJ										
	- Tot Condensate return	ton	94,45	90,08	89,43	94,25		96,25	97,11	98,74	93,03	
	Pressure	Kg/cm^2										
	Temp	^0C	45,00	45,00	45,00	45,00		45,00	45,00	45,00	45,00	
	- Tot Condensate return	GJ	33,63	32,07	31,84	33,56		34,27	34,58	35,16	33,12	
	- Demineralized make up	ton	81,75	62,75	72,36	68,28		73,87	75,87	76,90	79,89	
	Pressure	Kg/cm2	18,00	18,00	18,00	18,00		18,00	18,00	18,00	19,00	
	Temp	^0C	57,00	57,00	57,00	57,00		57,00	57,00	57,00	58,00	
	Demineralized make up	GJ	10,29	7,90	9,10	8,59		9,29	9,55	9,68	10,05	
	Total Energy Output	GJ	299,82	253,95	299,65	295,40		295,09	302,20	297,89	314,11	
3	**Energy Efficiency**	**%**	**44,25**	**42,27**	**47,34**	**46,79**		**48,79**	**47,50**	**46,81**	**50,92**	

Note :

No	Item	Pressure	Temp	Enthalpi
1	LP Steam	7	220,00	2,889.46
2	MP Steam	18	240,00	2,886.57
3	Condensate return	1	85,00	356.05
4	Make Up Water	1	30,00	125.82
5	1 kWh = 3600.003 kj			
6	1 kCal = 4.187 kj			

Analysis:

Data obtained from the DCS is as follows:



Figure…. P&ID Extraction, Condensing, Steam Turbine TK-3 70 MW on actual condition

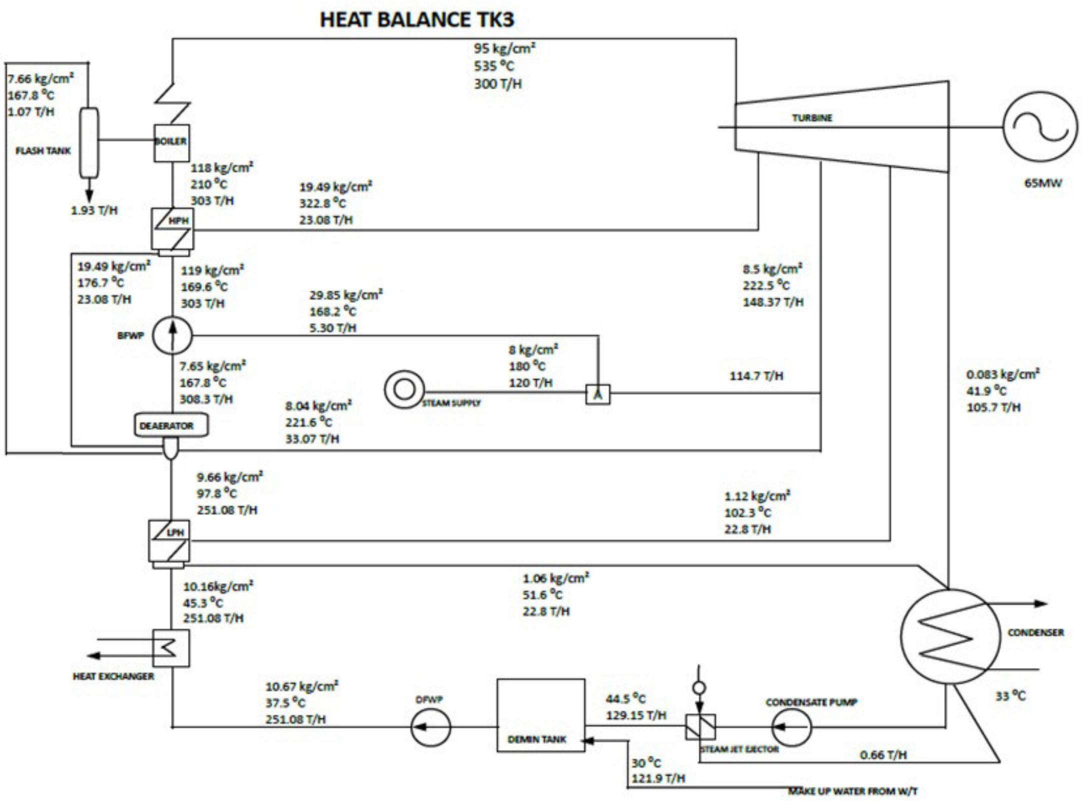
Based on DCS parameter, value of Enthalphy and Entrophy Turbin is as follows :

Nilai Enthalpy Berdasar Pengukuran

No			Temp [°C]	Pressure [Bar]	Flow [Ton/Hr]	Enthalpy [kjoule/kg]	Entrophy [kjoule/kg°C]
1	Inlet Turbine	h1	513,600	86,5340	296,000	3425,61	6,73
2	Extraction #1	h2	329,800	18,2280	19,600	3096,47	6,93
3	Extraction #2	h3	228,000	7,5460	22,000	2904,51	6,98
4	Extraction #2	h4	105,900	0,3626	19,700	2693,95	7,88
5	Vacum Condenser	h5	41,900	0,0813	131,200	175,48	8,23

* Value of Enthalphy and Entrophy was obtained from moiler graphic based on temperature and pressure measured on DCS.

Enthalphy theoretical value (refers to the turbine specification) is needed to calculate the efficiency of turbine. Based on data obtained, Enthalphy theoretical value is illustrated by the figure below:



Figure…. P&ID Extraction, Condensing, Steam Turbine TK-3 70 MW

Theoretical value of Enthalphy and Entrophy is as follows :

Nilai Enthalpy Berdasar Teory (Spesifikasi Turbin)							
No			Temp	Pressure	Flow	Enthalpy	Entrophy
			[°C]	[Bar]	[Ton/Hr]	[kjoule/kg]	[kjoule/kg°C]
2	Extraction #1	H1	322,80	18,81	28,08	3079,39	6,89
3	Extraction #2	H2	222,50	8,33	148,37	2888,96	6,90
4	Extraction #3	H3	102,30	1,10	22,80	2679,19	7,33
5	Vacum Condenser	H4	41,90	0,08	105,70	2576,96	8,23

Based on Enthalphy theoretical value and actual Enthalphy value, extraction efficiency and turbine condenser is calculated as follows:

- Extraction efficiency #1 stage :

$$Eff = \frac{Actual\ Heat\ Extacrion\ \#1\ Stage}{Theoritical\ Heat\ Extraction\ \#1\ Stage}\ x100\%$$

$$Eff = \frac{(h1 - h2)}{(h1 - H1)}\ x100\%$$

$$Eff = \frac{(3425{,}61 - 3096{,}47)}{(3425{,}61 - 3079{,}39)}\ x100\%$$

$$Eff = 95{,}07\%$$

- Extraction efficiency #2 stage :

$$Eff = \frac{Actual\ Heat\ Extacrion\ \#2\ Stage}{Theoritical\ Heat\ Extraction\ \#2\ Stage}\ x100\%$$

$$Eff = \frac{(h2 - h3)}{(H1 - H2)}\ x100\%$$

$$Eff = \frac{(3096{,}47 - 2904{,}51)}{(3079{,}39 - 2888{,}96)}\ x100\%$$

$$Eff = 100{,}81\%$$

- Extraction efficiency #3 stage :

$$Eff = \frac{Actual\ Heat\ Extacrion\ \#3\ Stage}{Theoritical\ Heat\ Extraction\ \#3\ Stage}\ x100\%$$

$$Eff = \frac{(h3 - h4)}{(H2 - H3)}\ x100\%$$

$$Eff = \frac{(2904{,}51 - 2693{,}95)}{(2888{,}96 - 2679{,}19)}\ x100\%$$

$$Eff = 100{,}38\%$$

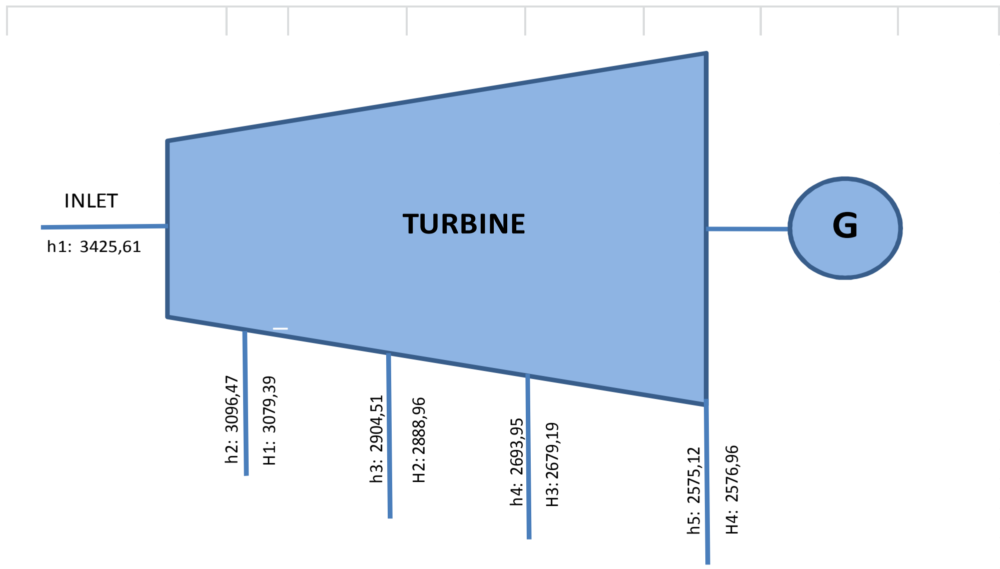
- Condenser efficiency stage :

$$Eff = \frac{Actual\ Heat\ Extacrion\ \#4\ Stage}{Theoritical\ Heat\ Extraction\ \#4\ Stage}\ x100\%$$

$$Eff = \frac{(h4 - h5)}{(H3 - H4)}\ x100\%$$

$$Eff = \frac{(2693{,}95 - 2575{,}12)}{(2679{,}19 - 2576{,}96)}\ x100\%$$

$$Eff = 116{,}24\%$$



No		Theoritical [kjoule/kg]	Actual [kjoule/kg]	Eff [%]
1	Inlet Turbine		3425,61	
2	Extraction #1	3079,39	3096,47	95,0667
3	Extraction #2	2888,96	2904,51	100,803
4	Extraction #3	2679,19	2693,95	100,377
5	Vacum Condenser	2576,96	2575,12	116,238

Turbine Efficiency based on Thermal Calculation is calculated as follows :

$$Eff\colon \frac{(kW\ x\ 860) + \left(\left((\mathrm{Q2\ x\ h2}) + (\mathrm{Q3\ x\ h3}) + (\mathrm{Q4\ x\ h4}) + (\mathrm{Q5\ x\ h5})\right)\mathrm{x\ 1000\ x\ 0{,}2388}\right)}{Q1\ \ x\ h1\ x0{,}2388}\ x\ 100\%$$

$$Eff: \frac{(kW\ x\ 860) + \left(\left((19{,}6 \text{ x } 3096{,}47) + (22{,}0 \text{ x } 2904{,}51) + (19{,}7 \text{ x } 2693{,}95) + (131{,}2\text{x}2575{,}12)\right)\text{x } 1000 \text{ x } 0{,}2388\right)}{296\ \ x\ 3425\ x1000\ x\ 0{,}2388} x\ 100\%$$

$$Eff: \frac{52202000}{242138557{,}7} x\ 100\%$$

$$Eff: 72{,}40\%$$

Vacum condensor is very important factor because little different value from the optimum value can make significant efficiency / vacuum condenser can be fluctuated from the optimum value, do the step bellows

- Make sure cold water temperature parameter not far from the manufacturing design , cold water temperature significantly is influented by weather such as ambient temperature and humidity,

  Hot weather and high humidity can make increasing of the cold water temperature, decreasing vacuum condenser can reduce ouput of the steam turbine, dry weather can make influence vise versa
- Keep clean the vacuum condenser pipe of dirty (so the vacuum can work optimum)
- Make sure no air leakage from the vacuum condenser
- Keep the Temperature & Pressure exit vacuum condenser as the manufacturing design, it can make more efficient steam turbine operation