LAMPIRAN

A. Perhitungan Neraca Massa & Energi

Perhitungan Kapasitas Rancangan

1. Kapasitas produksi : 600.000 ton/tahun
2. Waktu operasi : 330 hari/tahun
3. 1 hari kerja : 24 jam
4. Waktu operasi : 1 jam
5. Basis perhitungan : 1.000 kg/jam
6. Kapasitas produksi dalam 1 jam operasi :

   $= \frac{600.000\ ton}{1} \times \frac{1.000\ kg}{1\ ton} \times \frac{1\ tahun}{330\ hari} \times \frac{1\ hari}{24\ jam}$

   = 75.757.8 kg/jam (4.448,4 kmol / jam)
7. Kebutuhan bahan baku :

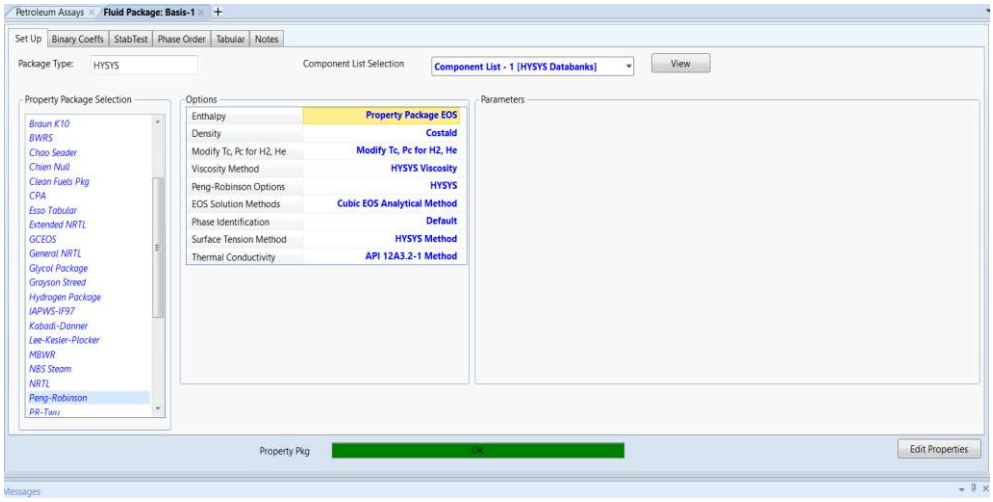
   Reaksi keseluruhan :

   $N_2 + 3H_2 \leftrightarrow 2NH_3$

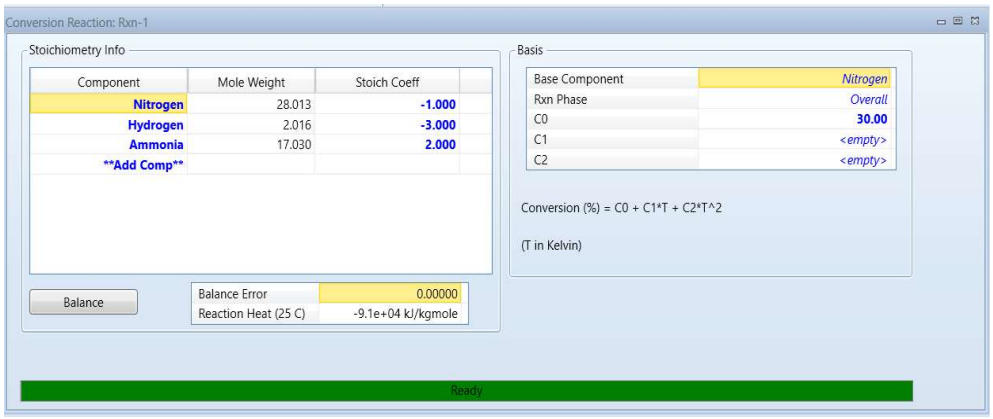
Pra Rancangan Pabrik ini menggunakan perhitungan software ASPEN HYSYS Versi 14. (https://drive.google.com/drive/folders/1unBHfEsz2ZWTFkXTfFXbtnnIK-L5VZnC?usp=sharing)

1. Komponen input :
   - Nitrogen (N_2)
   - Hidrogen (H_2)
   - Oksigen (O_2)
   - Air (H_2O)
   - Argon (Ar)
   - Karbon dioksida (CO_2)
   - Amonia (NH_3)

2. Property package menggunakan Peng-Robinson → dipilih karena hasil perhitungan lebih akuran dan sederhana.

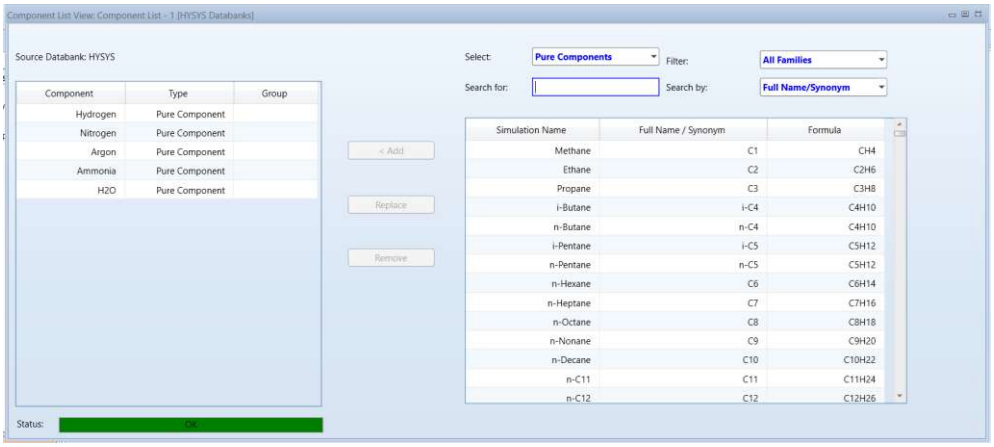


Reaksi stoikometri :

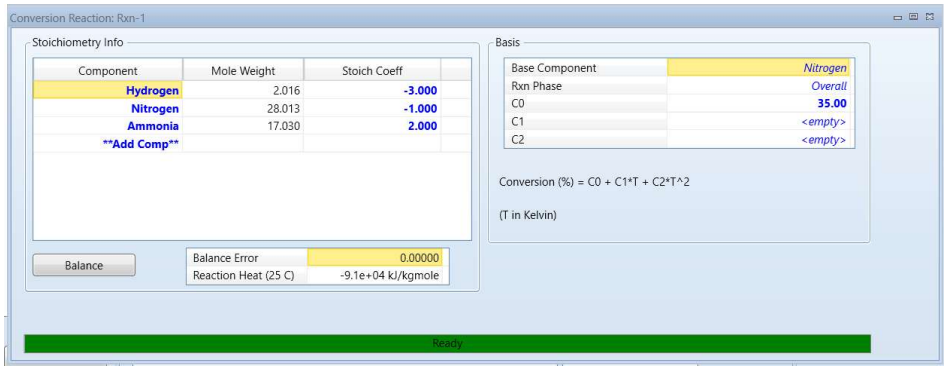


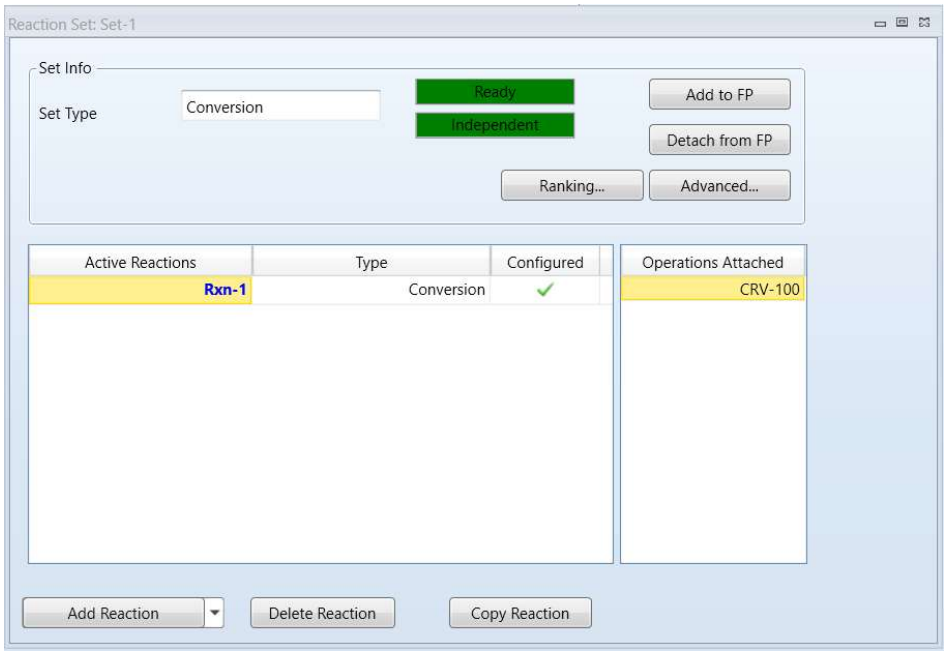
3. Produksi Amonia

Daftar komponen :



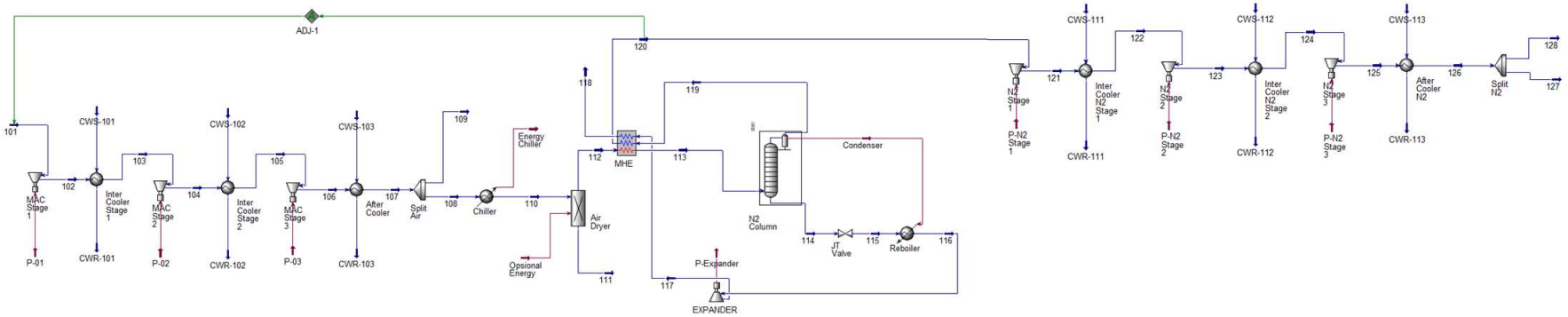
Reaction set :





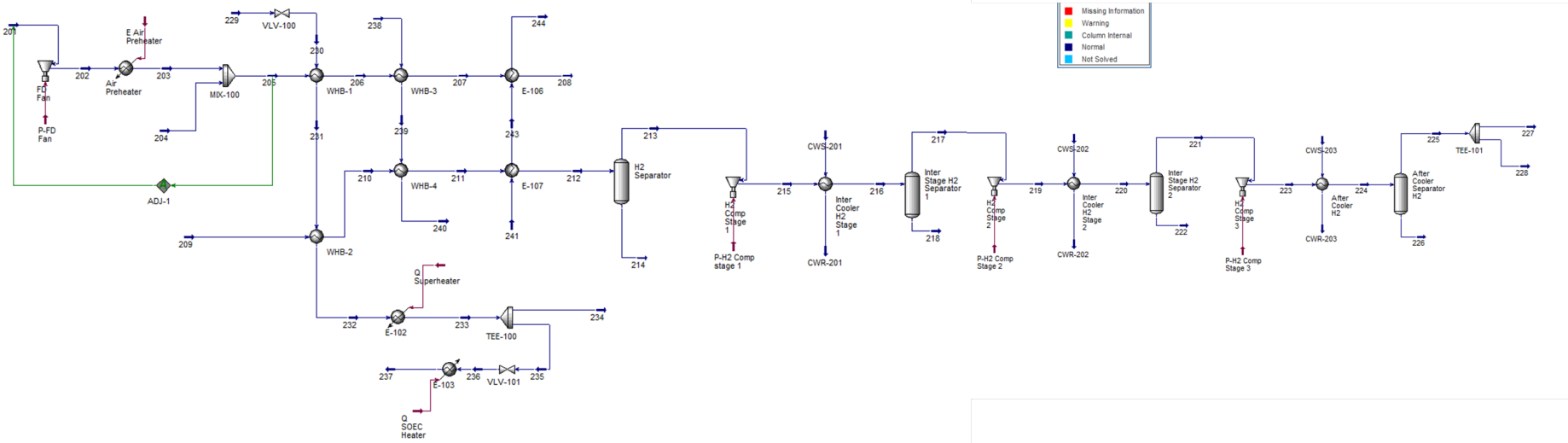
4. Flowsheet :

a) Pemisahan Udara (ASU) dan Nitrogen



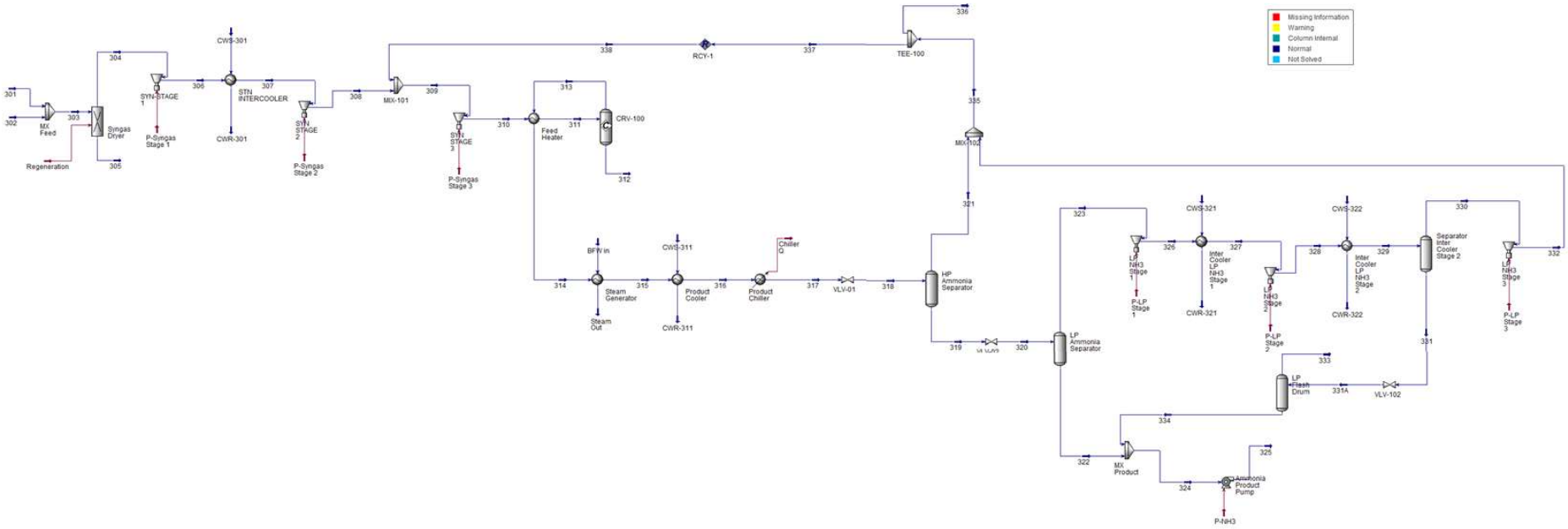
Gambar Lampiran 1 Flowsheet Simulasi HYSYS - Pemisahan Udara

b) Hidrogen dan Kompresi Hidrogen



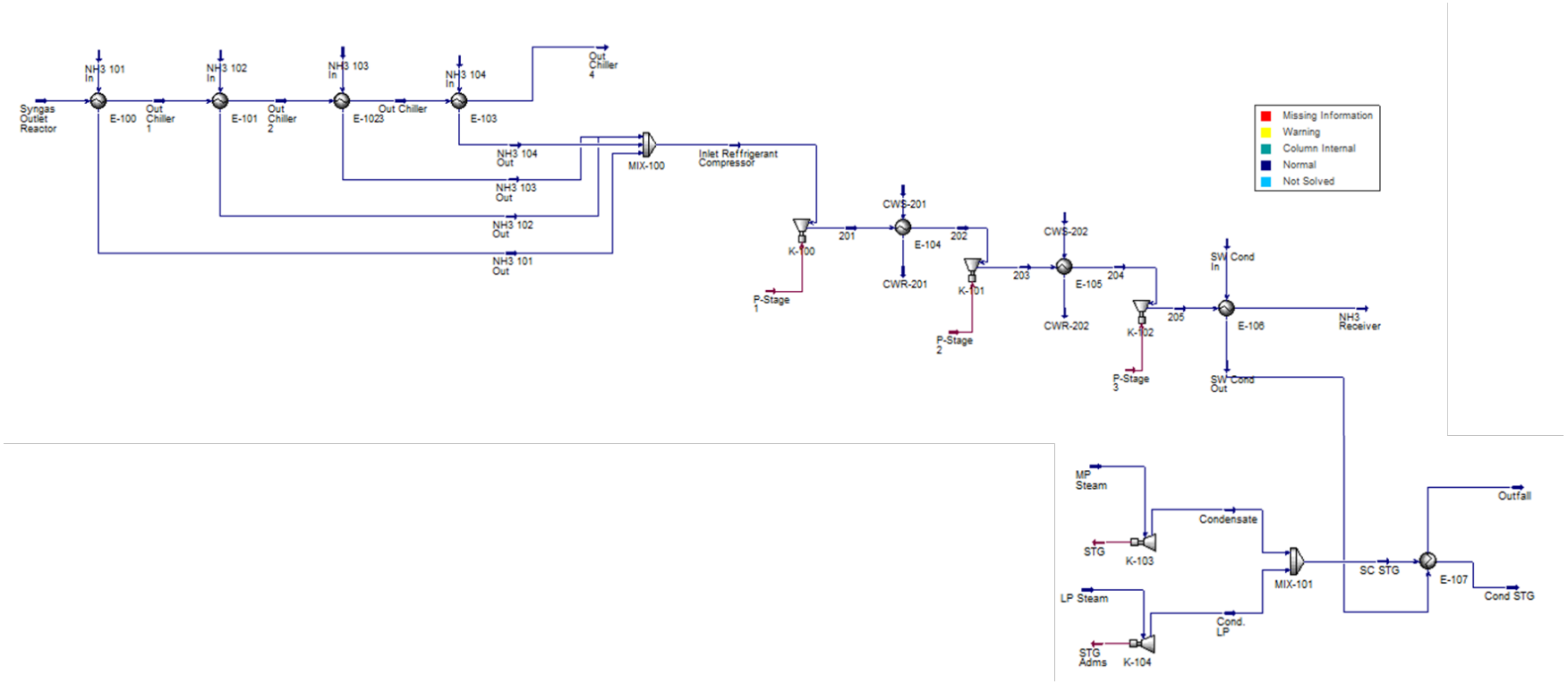
Gambar Lampiran 2 Flowsheet Simulasi HYSYS Hidrogen

c) Sintesis Amonia *Loop* Dan Recovery



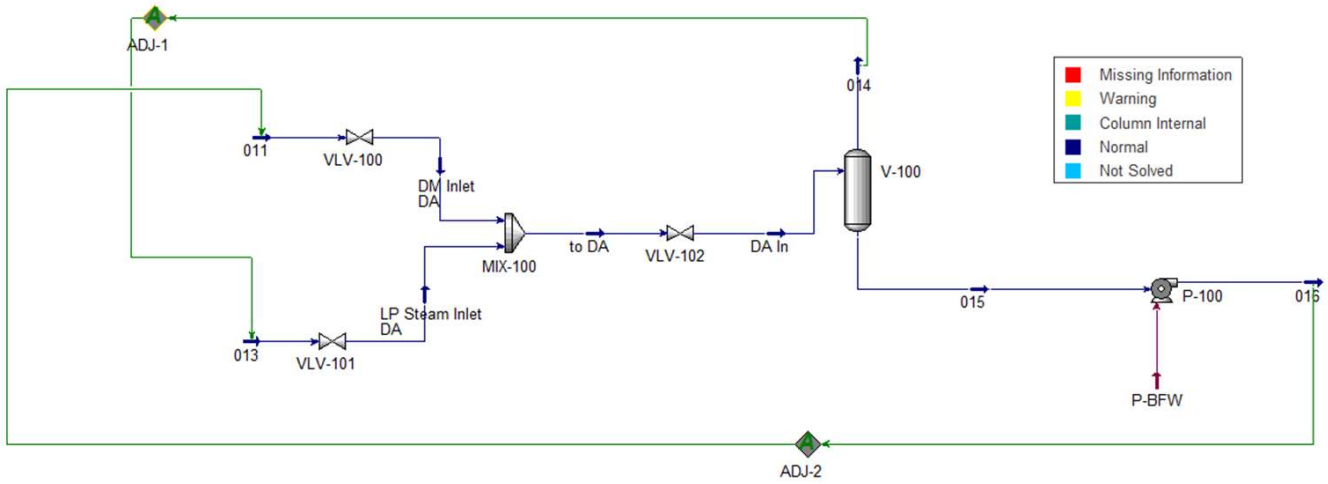
Gambar Lampiran 3 Sintesis NH3 *loop* dan *Recovery*

d) Refrigerasi Amonia Dan Steam *Recovery*



Gambar Lampiran 4 Flowsheet Simulasi HYSYS Refrigerasi NH3 dan Steam *Recovery*

e) Demin Water & BFW



Gambar Lampiran 5 Flosheet Simulasi HYSYS Demin Water dan BFW

5. Hasil Perhitungan HYSYS :

a) Pemisahan Udara

Tabel Lampiran 1 Perhitungan Neraca Massa & Energi HYSYS Pemisahan Udara

Stream No	*Unit*	101	102	CWS-101	CWR-101	103	104	105	CWS-102	CWR-102
Stream Name		Udara Inlet	Discharge Kompresor Stage 1	Cooling Water Inlet Inter stage Cooler 1	Cooling Water Outlet Inter stage Cooler 1	Outlet Intercooler Stage 1	Discharge Kompresor Stage 2	Outlet Intercooler Stage 2	Cooling Water Inlet Inter stage Cooler 2	Cooling Water Outlet Inter stage Cooler 2
Fraksi mol (Hidrogen)		-	-	-	-	-	-	-	-	-
Fraksi mol (Nitrogen)		0.7810	0.7810	-	-	0.7810	0.7810	0.7810	-	-
Fraksi mol (Oksigen)		0.2093	0.2093	-	-	0.2093	0.2093	0.2093	-	-
Fraksi mol (CO2)		0.0003	0.0003	-	-	0.0003	0.0003	0.0003	-	-
Fraksi mol (H2O)		0.0001	0.0001	1.0000	1.0000	0.0001	0.0001	0.0001	1.0000	1.0000
Fraksi mol (Argon)		0.0093	0.0093	-	-	0.0093	0.0093	0.0093	-	-
Fraksi mol (Amonia)		-	-	-	-	-	-	-	-	-
Fraksi uap		1.0000	1.0000	-	-	1.0000	1.0000	1.0000	-	-
Suhu	*C*	35.00	143.92	33.00	43.00	45.00	129.31	45.00	33.00	43.00
Tekanan	*kg/cm2_g*	-0.00	1.34	4.50	3.00	1.34	3.48	3.48	4.50	3.00
Molar Flow	*kgmole/h*	12,238.3	12,238.3	46,223.3	46,223.3	12,238.3	12,238.3	12,238.3	39,438.2	39,438.2
Hidrogen		-	-	-	-	-	-	-	-	-
Nitrogen		9,558.1	9,558.1	-	-	9,558.1	9,558.1	9,558.1	-	-
Oksigen		2,561.5	2,561.5	-	-	2,561.5	2,561.5	2,561.5	-	-
CO2		3.7	3.7	-	-	3.7	3.7	3.7	-	-
H2O		1.2	1.2	46,223.3	46,223.3	1.2	1.2	1.2	39,438.2	39,438.2
Argon		113.8	113.8	-	-	113.8	113.8	113.8	-	-
Amonia		-	-	-	-	-	-	-	-	-
Massa Aliran	*kg/h*	354,447.9	354,447.9	832,717.0	832,717.0	354,447.9	354,447.9	354,447.9	710,483.3	710,483.3
Liquid Volume Flow	*m3/h*	407.6	407.6	834.4	834.4	407.6	407.6	407.6	711.9	711.9
Heat Flow	*kJ/h*	1,725,766.0	41,002,536.9	(13,200,978,805.4)	(13,165,163,350.6)	5,187,082.2	35,564,795.2	5,006,654.4	(11,263,220,669.3)	(11,232,662,528.4)

Tabel Lampiran 2 Perhitungan Neraca Massa & Energi HYSYS Pemisahan Udara

Stream No	*Unit*	109	106	107	CWS-103	CWR-103	108	110	112	111	113
Stream Name		Udara untuk kebutuhan IA	Discharge Kompresor Stage 3	Outlet After Cooler	Cooling Water Inlet After Cooler	Cooling WaterOutlet After Cooler	Udara inlet Chiller	Udara Outlet Chiller	Udara Inlet MHE	Moisture yang tertangkap oleh Dryer	Udara Outlet MHE menuju ke N2 Column
Fraksi mol (Hidrogen)		-	-	-	-	-	-	-	-	-	-
Fraksi mol (Nitrogen)		0.7810	0.7810	0.7810	-	-	0.7810	0.7810	0.7813	-	0.7813

Stream No	*Unit*	109	106	107	CWS-103	CWR-103	108	110	112	111	113
Stream Name		Udara untuk kebutuhan IA	Discharge Kompresor Stage 3	Outlet After Cooler	Cooling Water Inlet After Cooler	Cooling WaterOutlet After Cooler	Udara inlet Chiller	Udara Outlet Chiller	Udara Inlet MHE	Moisture yang tertangkap oleh Dryer	Udara Outlet MHE menuju ke N2 Column
Fraksi mol (Oksigen)		0.2093	0.2093	0.2093	-	-	0.2093	0.2093	0.2094	-	0.2094
Fraksi mol (CO2)		0.0003	0.0003	0.0003	-	-	0.0003	0.0003	-	0.7500	-
Fraksi mol (H2O)		0.0001	0.0001	0.0001	1.0000	1.0000	0.0001	0.0001	-	0.2500	-
Fraksi mol (Argon)		0.0093	0.0093	0.0093	-	-	0.0093	0.0093	0.0093	-	0.0093
Fraksi mol (Amonia)		-	-	-	-	-	-	-	-	-	-
Fraksi uap		1.0000	1.0000	1.0000	-	-	1.0000	1.0000	1.0000	0.7508	1.0000
Suhu	*C*	45.00	120.04	45.00	33.00	43.00	45.00	15.00	15.00	15.00	-170.00
Tekanan	*kg/cm2_g*	7.00	7.00	7.00	4.50	3.00	7.00	6.50	6.50	6.50	6.00
Molar Flow	*kgmole/h*	50.0	12,238.3	12,238.3	35,224.9	35,224.9	12,188.3	12,188.3	12,183.4	4.9	12,183.4
Hidrogen		-	-	-	-	-	-	-	-	-	-
Nitrogen		39.1	9,558.1	9,558.1	-	-	9,519.0	9,519.0	9,519.0	-	9,519.0
Oksigen		10.5	2,561.5	2,561.5	-	-	2,551.0	2,551.0	2,551.0	-	2,551.0
CO2		0.0	3.7	3.7	-	-	3.7	3.7	-	3.7	-
H2O		0.0	1.2	1.2	35,224.9	35,224.9	1.2	1.2	-	1.2	-
Argon		0.5	113.8	113.8	-	-	113.4	113.4	113.4	-	113.4
Amonia		-	-	-	-	-	-	-	-	-	-
Massa Aliran	*kg/h*	1,448.1	354,447.9	354,447.9	634,580.0	634,580.0	352,999.8	352,999.8	352,816.9	182.9	352,816.9
Liquid Volume Flow	*m3/h*	1.7	407.6	407.6	635.9	635.9	406.0	406.0	405.7	0.2	405.7
Heat Flow	*kJ/h*	19,252.6	32,005,879.0	4,712,367.4	(10,059,932,779.1)	(10,032,639,267.6)	4,693,114.8	(6,048,071.6)	(4,310,013.7)	(1,791,903.3)	(71,681,447.0)

Tabel Lampiran 3 Perhitungan Neraca Massa & Energi HYSYS Pemisahan Udara

Stream No	*Unit*	119	114	115	116	117	120	118	121	122
Stream Name		Gas N2 outlet N2 Column	C-LOX product Bawah N2 Column	C-LOX product Bawah outlet Expansion Valve	C-LOX outlet Reboiler-Condenser	C-LOX outlet Expander	Gas N2 Outlet MHE	Waste Gas Outlet MHE	Discharge Stage 1 Kompresor N2	Outlet Intercooler stage 1 Kompresor N2
Fraksi mol (Hidrogen)		-	-	-	-	-	-	-	-	-
Fraksi mol (Nitrogen)		0.9998	0.6617	0.6617	0.6617	0.6617	0.9998	0.6617	0.9998	0.9998
Fraksi mol (Oksigen)		0.0000	0.3240	0.3240	0.3240	0.3240	0.0000	0.3240	0.0000	0.0000
Fraksi mol (CO2)		-	-	-	-	-	-	-	-	-
Fraksi mol (H2O)		-	-	-	-	-	-	-	-	-
Fraksi mol (Argon)		0.0002	0.0143	0.0143	0.0143	0.0143	0.0002	0.0143	0.0002	0.0002
Fraksi mol (Amonia)		-	-	-	-	-	-	-	-	-

Stream No	*Unit*	119	114	115	116	117	120	118	121	122
Stream Name		Gas N2 outlet N2 Column	C-LOX product Bawah N2 Column	C-LOX product Bawah outlet Expansion Valve	C-LOX outlet Reboiler-Condenser	C-LOX outlet Expander	Gas N2 Outlet MHE	Waste Gas Outlet MHE	Discharge Stage 1 Kompresor N2	Outlet Intercooler stage 1 Kompresor N2
Fraksi uap		1.0000	-	0.1826	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Suhu	*C*	-176.92	-171.27	-189.22	-176.19	-182.80	7.00	11.50	98.41	45.00
Tekanan	*kg/cm2_g*	5.00	6.00	0.50	0.50	0.10	5.00	0.10	12.00	12.00
Molar Flow	*kgmole/h*	4,310.0	7,873.4	7,873.4	7,873.4	7,873.4	4,310.0	7,873.4	4,310.0	4,310.0
Hidrogen		-	-	-	-	-	-	-	-	-
Nitrogen		4,309.2	5,209.9	5,209.9	5,209.9	5,209.9	4,309.2	5,209.9	4,309.2	4,309.2
Oksigen		0.1	2,550.9	2,550.9	2,550.9	2,550.9	0.1	2,550.9	0.1	0.1
CO2		-	-	-	-	-	-	-	-	-
H2O		-	-	-	-	-	-	-	-	-
Argon		0.7	112.7	112.7	112.7	112.7	0.7	112.7	0.7	0.7
Amonia		-	-	-	-	-	-	-	-	-
Massa Aliran	*kg/h*	120,744.7	232,072.2	232,072.2	232,072.2	232,072.2	120,744.7	232,072.2	120,744.7	120,744.7
Liquid Volume Flow	*m3/h*	149.7	256.0	256.0	256.0	256.0	149.7	256.0	149.7	149.7
Heat Flow	*kJ/h*	(26,234,878.2)	(86,394,767.1)	(86,394,767.1)	(45,447,732.5)	(46,774,531.7)	(2,477,314.1)	(3,160,662.5)	9,033,410.7	2,156,189.7

Tabel Lampiran 4 Perhitungan Neraca Massa & Energi HYSYS Pemisahan Udara

Stream No	*Unit*	CWS-111	CWR-111	123	124	CWS-112	CWR-112	125	126	CWS-113
Stream Name		Cooling Water Supply	Cooling Water Return	Discharge Stage 2 Kompresor N2	Outlet Intercooler stage 2 Kompresor N2	Cooling Water Supply	Cooling Water Return	Discharge Stage 3 Kompresor N2	Outlet After Cooler Kompresor N2	Cooling Water Supply
Fraksi mol (Hidrogen)		-	-	-	-	-	-	-	-	-
Fraksi mol (Nitrogen)		-	-	0.9998	0.9998	-	-	0.9998	0.9998	-
Fraksi mol (Oksigen)		-	-	0.0000	0.0000	-	-	0.0000	0.0000	-
Fraksi mol (CO2)		-	-	-	-	-	-	-	-	-
Fraksi mol (H2O)		1.0000	1.0000	-	-	1.0000	1.0000	-	-	1.0000
Fraksi mol (Argon)		-	-	0.0002	0.0002	-	-	0.0002	0.0002	-
Fraksi mol (Amonia)		-	-	-	-	-	-	-	-	-
Fraksi uap		-	-	1.0000	1.0000	-	-	1.0000	1.0000	-
Suhu	*C*	33.00	43.00	99.91	45.00	33.00	43.00	82.62	45.00	33.00
Tekanan	*kg/cm2_g*	4.50	3.00	19.00	19.00	4.50	3.00	26.00	26.00	4.50
Molar Flow	*kgmole/h*	8,875.7	8,875.7	4,310.0	4,310.0	9,203.4	9,203.4	4,310.0	4,310.0	6,359.7
Hidrogen		-	-	-	-	-	-	-	-	-

Stream No	*Unit*	CWS-111	CWR-111	123	124	CWS-112	CWR-112	125	126	CWS-113
Stream Name		Cooling Water Supply	Cooling Water Return	Discharge Stage 2 Kompresor N2	Outlet Intercooler stage 2 Kompresor N2	Cooling Water Supply	Cooling Water Return	Discharge Stage 3 Kompresor N2	Outlet After Cooler Kompresor N2	Cooling Water Supply
Nitrogen		-	-	4,309.2	4,309.2	-	-	4,309.2	4,309.2	-
Oksigen		-	-	0.1	0.1	-	-	0.1	0.1	-
CO2		-	-	-	-	-	-	-	-	-
H2O		8,875.7	8,875.7	-	-	9,203.4	9,203.4	-	-	6,359.7
Argon		-	-	0.7	0.7	-	-	0.7	0.7	-
Amonia		-	-	-	-	-	-	-	-	-
Massa Aliran	*kg/h*	159,896.9	159,896.9	120,744.7	120,744.7	165,800.4	165,800.4	120,744.7	120,744.7	114,570.9
Liquid Volume Flow	*m3/h*	160.2	160.2	149.7	149.7	166.1	166.1	149.7	149.7	114.8
Heat Flow	*kJ/h*	(2,534,828,856.8)	(2,527,951,635.9)	9,100,742.9	1,969,607.3	(2,628,417,558.7)	(2,621,286,423.1)	6,715,550.0	1,787,815.1	(1,816,280,809.3)

Tabel Lampiran 1 Perhitungan Neraca Massa & Energi HYSYS Pemisahan Udara

Stream No	*Unit*	CWR-113	128	127
Stream Name		Cooling Water Return	Nitrogen untuk Purging	Nitrogen ke Inlet Dryer (Feed)
Fraksi mol (Hidrogen)		-	-	-
Fraksi mol (Nitrogen)		-	0.9998	0.9998
Fraksi mol (Oksigen)		-	0.0000	0.0000
Fraksi mol (CO2)		-	-	-
Fraksi mol (H2O)		1.0000	-	-
Fraksi mol (Argon)		-	0.0002	0.0002
Fraksi mol (Amonia)		-	-	-
Fraksi uap		-	1.0000	1.0000
Suhu	*C*	43.00	45.00	45.00
Tekanan	*kg/cm2_g*	3.00	26.00	26.00
Molar Flow	*kgmole/h*	6,359.7	2,000.0	2,310.0
Hidrogen		-	-	-
Nitrogen		-	1,999.6	2,309.6
Oksigen		-	0.1	0.1
CO2		-	-	-
H2O		6,359.7	-	-
Argon		-	0.3	0.4
Amonia		-	-	-

Stream No	*Unit*	CWR-113	128	127
Stream Name		Cooling Water Return	Nitrogen untuk Purging	Nitrogen ke Inlet Dryer (Feed)
Massa Aliran	*kg/h*	114,570.9	56,030.0	64,714.7
Liquid Volume Flow	*m3/h*	114.8	69.5	80.2
Heat Flow	*kJ/h*	(1,811,353,074.5)	829,612.6	958,202.5

Energy Stream

Tabel Lampiran 5 Perhitungan Neraca Massa & Energi HYSYS Pemisahan Udara

	Unit	P-01	P-02	P-03	Energy Chiller	Condenser	P-Expander	P-N2 Stage 1	P-N2 Stage 2	P-N2 Stage 3	Opsional Energy
Heat Flow	*kJ/h*	39,276,770.9	30,377,713.0	26,999,224.6	10,741,186.5	40,947,034.5	1,326,799.2	11,510,724.8	6,944,553.2	4,745,942.7	(53,845.4)
	kW	10,910.2	8,438.3	7,499.8	2,983.7	11,374.2	368.6	3,197.4	1,929.0	1,318.3	(15.0)
	MW	10.91	8.44	7.50	2.98	11.37	0.37	3.20	1.93	1.32	- 0.01

b) Pemisahan Hidrogen

Tabel Lampiran 6 Perhitungan HYSYS Pemisahan Hidrogen dan WHB

	Unit	204	209	201	202	203	205	241	206	229
		O2 Product SOEC (Hasil Reaksi)	H2 Product SOEC (Hasil Reaksi)	Udara Untuk Mixing O2 Produk SOEC	Udara Outlet FD Fan	Udara Inlet SOEC (Outlet Preheater)	Mixing O2 Hasil Reaksi dengan Udara	SW Outlet	Demin Preheater	BFW
Fraksi mol (Hidrogen)		-	0.9980	-	-	-	-	-	-	-
Fraksi mol (Nitrogen)		-	-	0.7810	0.7810	0.7810	0.6428	-	0.6428	-
Fraksi mol (Oksigen)		1.0000	-	0.2093	0.2093	0.2093	0.3492	-	0.3492	-
Fraksi mol (H2O)		-	0.0020	0.0001	0.0001	0.0001	0.0001	1.0000	0.0001	1.0000
Fraksi mol (Argon)		-	-	0.0093	0.0093	0.0093	0.0077	-	0.0077	-
Fraksi mol (CO2)		-	-	0.0003	0.0003	0.0003	0.0002	-	0.0002	-
Fraksi uap		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	-	1.0000	-
Suhu	*C*	800.00	800.00	35.00	128.47	800.00	800.00	30.00	455.16	241.00
Tekanan	*kg/cm2_g*	0.90	2.50	-0.00	1.10	1.00	0.90	4.00	0.90	75.00
Molar Flow	*kgmole/h*	4,500.0	6,890.0	20,935.7	20,935.7	20,935.7	25,435.7	614,061.9	25,435.7	8,827.3
Hidrogen		-	6,876.2	-	-	-	-	-	-	-
Nitrogen		-	-	16,350.8	16,350.8	16,350.8	16,350.8	-	16,350.8	-
Oksigen		4,500.0	-	4,381.8	4,381.8	4,381.8	8,881.8	-	8,881.8	-
H2O		-	13.8	2.1	2.1	2.1	2.1	614,061.9	2.1	8,827.3

	Unit	204	209	201	202	203	205	241	206	229
		O2 Product SOEC (Hasil Reaksi)	H2 Product SOEC (Hasil Reaksi)	Udara Untuk Mixing O2 Produk SOEC	Udara Outlet FD Fan	Udara Inlet SOEC (Outlet Preheater)	Mixing O2 Hasil Reaksi dengan Udara	SW Outlet	Demin Preheater	BFW
Argon		-	-	194.7	194.7	194.7	194.7	-	194.7	-
CO2		-	-	6.3	6.3	6.3	6.3	-	6.3	-
Massa Aliran	*kg/h*	144,000.0	14,110.7	606,345.1	606,345.1	606,345.1	750,345.1	11,062,387.7	750,345.1	159,024.7
Liquid Volume Flow	*m3/h*	126.6	198.7	697.3	697.3	697.3	823.9	11,084.7	823.9	159.3
Heat Flow	*kJ/h*	113,626,366.9	154,358,132.4	2,952,224.4	60,512,934.5	505,123,680.8	618,750,047.7	(175,514,574,109.3)	331,007,801.1	(2,368,391,726.8)

Tabel Lampiran 7 Perhitungan HYSYS Pemisahan Hidrogen dan WHB

	Unit	230	231	210	232	233	234	235	237	236
		ke WHB-1	ke WHB-2	H2 Separator	ke Steam	Superheater Out	Steam System	SOEC	SOEC Inlet Feed	Steam Inlet Steam Heater
Fraksi mol (Hidrogen)		-	-	0.9980	-	-	-	-	-	-
Fraksi mol (Nitrogen)		-	-	-	-	-	-	-	-	-
Fraksi mol (Oksigen)		-	-	-	-	-	-	-	-	-
Fraksi mol (H2O)		1.0000	1.0000	0.0020	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Fraksi mol (Argon)		-	-	-	-	-	-	-	-	-
Fraksi mol (CO2)		-	-	-	-	-	-	-	-	-
Fraksi uap		-	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Suhu	*C*	240.94	265.00	576.11	390.00	390.00	390.00	390.00	800.00	356.34
Tekanan	*kg/cm2_g*	46.90	46.90	2.50	46.90	46.90	46.90	46.90	5.00	5.00
Molar Flow	*kgmole/h*	8,827.3	8,827.3	6,890.0	8,827.3	8,827.3	1,923.5	6,903.8	6,903.8	6,903.8
Hidrogen		-	-	6,876.2	-	-	-	-	-	-
Nitrogen		-	-	-	-	-	-	-	-	-
Oksigen		-	-	-	-	-	-	-	-	-
H2O		8,827.3	8,827.3	13.8	8,827.3	8,827.3	1,923.5	6,903.8	6,903.8	6,903.8
Argon		-	-	-	-	-	-	-	-	-
CO2		-	-	-	-	-	-	-	-	-
Massa Aliran	*kg/h*	159,024.7	159,024.7	14,110.7	159,024.7	159,024.7	34,651.2	124,373.5	124,373.5	124,373.5
Liquid Volume Flow	*m3/h*	159.3	159.3	198.7	159.3	159.3	34.7	124.6	124.6	124.6
Heat Flow	*kJ/h*	(2,368,391,726.8)	(2,080,649,480.2)	107,482,578.9	(2,033,773,926.7)	(2,033,773,926.7)	(443,156,078.7)	(1,590,617,848.0)	(1,468,705,319.4)	(1,590,617,848.0)

,

Tabel Lampiran 8 Perhitungan HYSYS Pemisahan Hidrogen dan WHB

	Unit	238	239	207	240	211	243	208	244	212
		Demin Feed	Out 02	O2 Vent to Atm	LP Steam Header	H2 inlet Cooler	Cooling Water outlet	O2 Vent ke atmosfer	Cooling water outlet ke Outfall	H2 inlet separator
Fraksi mol (Hidrogen)		-	-	-	-	0.9980	-	-	-	0.9980
Fraksi mol (Nitrogen)		-	-	0.6428	-	-	-	0.6428	-	-
Fraksi mol (Oksigen)		-	-	0.3492	-	-	-	0.3492	-	-
Fraksi mol (H2O)		1.0000	1.0000	0.0001	1.0000	0.0020	1.0000	0.0001	1.0000	0.0020
Fraksi mol (Argon)		-	-	0.0077	-	-	-	0.0077	-	-
Fraksi mol (CO2)		-	-	0.0002	-	-	-	0.0002	-	-
Fraksi uap		-	1.0000	1.0000	1.0000	1.0000	-	1.0000	-	1.0000
Suhu	*C*	115.00	170.00	170.00	180.00	566.79	32.20	47.00	34.15	45.00
Tekanan	*kg/cm2_g*	5.00	5.00	0.90	5.00	2.50	4.00	0.90	4.00	2.50
Molar Flow	*kgmole/h*	5,362.9	5,362.9	25,435.7	5,362.9	6,890.0	614,061.9	25,435.7	614,061.9	6,890.0
Hidrogen		-	-	-	-	6,876.2	-	-	-	6,876.2
Nitrogen		-	-	16,350.8	-	-	-	16,350.8	-	-
Oksigen		-	-	8,881.8	-	-	-	8,881.8	-	-
H2O		5,362.9	5,362.9	2.1	5,362.9	13.8	614,061.9	2.1	614,061.9	13.8
Argon		-	-	194.7	-	-	-	194.7	-	-
CO2		-	-	6.3	-	-	-	6.3	-	-
Massa Aliran	*kg/h*	96,613.3	96,613.3	750,345.1	96,613.3	14,110.7	11,062,387.7	750,345.1	11,062,387.7	14,110.7
Liquid Volume Flow	*m3/h*	96.8	96.8	823.9	96.8	198.7	11,084.7	823.9	11,084.7	198.7
Heat Flow	*kJ/h*	(1,497,088,523.3)	(1,272,068,052.8)	105,987,330.7	(1,270,143,251.8)	105,557,777.9	(175,409,605,002.7)	12,990,890.7	(175,316,608,562.7)	588,671.2

Tabel Lampiran 9 Perhitungan HYSYS Pemisahan Hidrogen dan WHB

	Unit	213	214	215	216	CWS-201	CWR-201	217	218	219
		H2 ke Suction Kompresor H2	H2 Drain Separator Inlet	Discharge stage 1 kompresor H2	H2 Outlet Intercooler stage 1	Cooling Water Supply	Cooling Water Return	H2 Outlet Separator Stage 1	H2 Drain Separator Stage 1	Discharge Stage 2 kompresor H2
Fraksi mol (Hidrogen)		0.9980	0.0001	0.9980	0.9980	-	-	0.9980	0.0001	0.9980
Fraksi mol (Nitrogen)		-	-	-	-	-	-	-	-	-
Fraksi mol (Oksigen)		-	-	-	-	-	-	-	-	-
Fraksi mol (H2O)		0.0020	0.9999	0.0020	0.0020	1.0000	1.0000	0.0020	0.9999	0.0020
Fraksi mol (Argon)		-	-	-	-	-	-	-	-	-
Fraksi mol (CO2)		-	-	-	-	-	-	-	-	-
Fraksi uap		1.0000	-	1.0000	1.0000	-	-	1.0000	-	1.0000

	Unit	213	214	215	216	CWS-201	CWR-201	217	218	219
		H2 ke Suction Kompresor H2	H2 Drain Separator Inlet	Discharge stage 1 kompresor H2	H2 Outlet Intercooler stage 1	Cooling Water Supply	Cooling Water Return	H2 Outlet Separator Stage 1	H2 Drain Separator Stage 1	Discharge Stage 2 kompresor H2
Suhu	*C*	45.00	45.00	159.43	45.00	33.00	43.00	45.00	45.00	148.72
Tekanan	*kg/cm2_g*	2.50	2.50	7.00	7.00	4.50	3.00	7.00	7.00	16.00
Molar Flow	*kgmole/h*	6,890.0	-	6,890.0	6,890.0	29,156.2	29,156.2	6,890.0	-	6,890.0
Hidrogen		6,876.2	-	6,876.2	6,876.2	-	-	6,876.2	-	6,876.2
Nitrogen		-	-	-	-	-	-	-	-	-
Oksigen		-	-	-	-	-	-	-	-	-
H2O		13.8	-	13.8	13.8	29,156.2	29,156.2	13.8	-	13.8
Argon		-	-	-	-	-	-	-	-	-
CO2		-	-	-	-	-	-	-	-	-
Massa Aliran	*kg/h*	14,110.7	-	14,110.7	14,110.7	525,252.3	525,252.3	14,110.7	-	14,110.7
Liquid Volume Flow	*m3/h*	198.7	-	198.7	198.7	526.3	526.3	198.7	-	198.7
Heat Flow	*kJ/h*	588,671.2	-	23,179,891.6	588,603.9	(8,326,771,570.6)	(8,304,180,282.8)	588,603.9	-	21,088,367.5

Tabel Lampiran 10 Perhitungan HYSYS Pemisahan Hidrogen dan WHB

	Unit	220	CWS-202	CWR-202	221	222	223	224	CWS-203	CWR-203
		H2 Outlet Intercooler stage 2	Cooling Water Supply	Cooling Water Return	H2 Outlet Separator Stage 2	H2 Drain Separator Stage 2	Discharge Stage 3 kompresor H2	H2 Outlet after cooler	Cooling Water Supply	Cooling Water Return
Fraksi mol (Hidrogen)		0.9980	-	-	0.9980	0.0001	0.9980	0.9980	-	-
Fraksi mol (Nitrogen)		-	-	-	-	-	-	-	-	-
Fraksi mol (Oksigen)		-	-	-	-	-	-	-	-	-
Fraksi mol (H2O)		0.0020	1.0000	1.0000	0.0020	0.9999	0.0020	0.0020	1.0000	1.0000
Fraksi mol (Argon)		-	-	-	-	-	-	-	-	-
Fraksi mol (CO2)		-	-	-	-	-	-	-	-	-
Fraksi uap		1.0000	-	-	1.0000	-	1.0000	1.0000	-	-
Suhu	*C*	45.00	33.00	43.00	45.00	45.00	106.21	45.00	33.00	43.00
Tekanan	*kg/cm2_g*	16.00	4.50	3.00	16.00	16.00	26.00	26.00	4.50	3.00
Molar Flow	*kgmole/h*	6,890.0	26,455.2	26,455.2	6,890.0	-	6,890.0	6,890.0	15,615.6	15,615.6
Hidrogen		6,876.2	-	-	6,876.2	-	6,876.2	6,876.2	-	-
Nitrogen		-	-	-	-	-	-	-	-	-
Oksigen		-	-	-	-	-	-	-	-	-
H2O		13.8	26,455.2	26,455.2	13.8	-	13.8	13.8	15,615.6	15,615.6
Argon		-	-	-	-	-	-	-	-	-
CO2		-	-	-	-	-	-	-	-	-

	Unit	220	CWS-202	CWR-202	221	222	223	224	CWS-203	CWR-203
		H2 Outlet Intercooler stage 2	Cooling Water Supply	Cooling Water Return	H2 Outlet Separator Stage 2	H2 Drain Separator Stage 2	Discharge Stage 3 kompresor H2	H2 Outlet after cooler	Cooling Water Supply	Cooling Water Return
Massa Aliran	*kg/h*	14,110.7	476,593.6	476,593.6	14,110.7	-	14,110.7	14,110.7	281,316.9	281,316.9
Liquid Volume Flow	*m3/h*	198.7	477.6	477.6	198.7	-	198.7	198.7	281.9	281.9
Heat Flow	*kJ/h*	589,905.3	(7,555,391,010.6)	(7,534,892,548.4)	589,905.3	-	12,693,083.2	593,540.9	(4,459,689,337.2)	(4,447,589,794.9)

Tabel Lampiran 11 Perhitungan HYSYS Pemisahan Hidrogen dan WHB

	Unit	227	226	225	228
		Inlet Syngas Dryer	H2 Drain Separator Stage 3	H2 Outlet Separator Stage 3	H2 Fuel
Fraksi mol (Hidrogen)		0.9980	0.0001	0.9980	0.9980
Fraksi mol (Nitrogen)		-	-	-	-
Fraksi mol (Oksigen)		-	-	-	-
Fraksi mol (H2O)		0.0020	0.9999	0.0020	0.0020
Fraksi mol (Argon)		-	-	-	-
Fraksi mol (CO2)		-	-	-	-
Fraksi uap		1.0000	-	1.0000	1.0000
Suhu	*C*	45.00	45.00	45.00	45.00
Tekanan	*kg/cm2_g*	26.00	26.00	26.00	26.00
Molar Flow	*kgmole/h*	6,890.0	-	6,890.0	-
Hidrogen		6,876.2	-	6,876.2	-
Nitrogen		-	-	-	-
Oksigen		-	-	-	-
H2O		13.8	-	13.8	-
Argon		-	-	-	-
CO2		-	-	-	-
Massa Aliran	*kg/h*	14,110.7	-	14,110.7	-
Liquid Volume Flow	*m3/h*	198.7	-	198.7	-
Heat Flow	*kJ/h*	593,540.9	-	593,540.9	-

Energy Stream

Tabel Lampiran 12 Perhitungan HYSYS Pemisahan Hidrogen dan WHB

Heat Flow	*Unit*	**P-FD Fan**	**E Air Preheater**	**Q Superheater**	**Q SOEC Heater**	**P-H2 Comp stage 1**	**P-H2 Comp Stage 2**	**P-H2 Comp Stage 3**
	kJ/h	57,560,710.0	444,610,746.3	-	121,912,528.6	22,591,220.3	20,499,763.7	12,103,177.9
	KW	15,989.1	123,503.0	-	33,864.6	6,275.3	5,694.4	3,362.0
	MW	15.99	123.50	-	33.86	6.28	5.69	3.36

c) Perhitungan Energi SOEC :

Kebutuhan Hidrogen untuk reaktor

= 6890 kmol /jam

= 6890 kmol/jam x 22.414 Nm3/kmol

= 154432.68 Nm3/jam

Reaksi Elektrolisis :

$2H_2O \rightarrow 2H_2 + O_2$

Dengan konsentrasi Hidrogen produk 99.8% maka diperlukan

Reaksi	$2H_2O$	→	$2H_2$	+	O_2
Mula-mula	6903.81		0		0
Reaksi	6890		6890.0		3445.0
Sisa	13.81		6890.0		3445.0

Sehingga diperlukan umpan Steam sebanyak : 6903.81 kmol/jam

Data Manufaktur SOEC (TOPSOE Datasheet)

Specific Energy : 3.1 kWh / Nm3 H2

Produk yang diharapkan H2 (Kebutuhan H2 untuk reaksi Amonia) : 154432.68 Nm3/jam

Efisiensi : 99% (Desain)

Kebutuhan Energi = Specific Energy x Produk H2 / Efisiensi

= 3.1 x 154432.68 / 0.99

= 482413.84 kW 3600

= 1737689818.7 kJ/jam

d) Reaksi Amonia dan *Recovery Loop*

Tabel Lampiran 13 Perhitungan HYSYS Reaksi Amonia dan *Recovery Loop*

No Aliran		127	227	303	304	305	306	307	CWS-301	CWR-301
Nama Aliran	*Unit*	Nitrogen Inlet Dryer	Hidrogen Inlet Dryer	Syngas Inlet Dryer (Total)	Syngas Outlet Dryer	Moisture yang tertangkap di Dryer	Discharge Kompresor Syngas Stage 1	Outlet After Cooler	CWS-301	CWR-301
Fraksi mol (Hidrogen)		-	0.9960	0.7459	0.7482	-	0.7482	0.7482	-	-
Fraksi mol (Nitrogen)		0.9998	-	0.2510	0.2518	-	0.2518	0.2518	-	-
Fraksi mol (Argon)		0.0002	-	0.0001	0.0001	-	0.0001	0.0001	-	-
Fraksi mol (Amonia)		-	-	-	-	-	-	-	-	-
Fraksi mol (H2O)		-	0.0040	0.0030	-	1.0000	-	-	1.0000	1.0000
Fraksi uap		1.0000	1.0000	1.0000	1.0000	-	1.0000	1.0000	-	-
Suhu	*C*	45.00	45.00	44.50	40.00	40.00	171.42	45.00	33.00	43.00
Tekanan	*kg/cm2_g*	26.00	26.00	26.00	25.00	2.50	66.00	66.00	4.50	3.00
Molar Flow	*kgmole/h*	2,310.0	6,890.0	9,200.0	9,172.4	27.6	9,172.4	9,172.4	43,996.3	43,996.3
Hidrogen		-	6,862.4	6,862.4	6,862.4	-	6,862.4	6,862.4	-	-
Nitrogen		2,309.5	-	2,309.5	2,309.5	-	2,309.5	2,309.5	-	-
Argon		0.5	-	0.5	0.5	-	0.5	0.5	-	-
Amonia		-	-	-	-	-	-	-	-	-
H2O		-	27.6	27.6	-	27.6	-	-	43,996.3	43,996.3
Massa Aliran	*kg/h*	64,715.5	14,331.2	79,046.7	78,550.2	496.5	78,550.2	78,550.2	792,596.9	792,596.9
Liquid Volume Flow	*m3/h*	80.2	198.5	278.8	278.3	0.5	278.3	278.3	794.2	794.2
Heat Flow	*kJ/h*	958,185.9	(2,751,417.3)	(1,793,231.4)	3,692,525.4	(7,856,000.8)	38,830,096.0	4,740,221.4	(12,564,958,770.2)	(12,530,868,895.6)

Tabel Lampiran 14 Perhitungan HYSYS Reaksi Amonia dan *Recovery Loop*

No Aliran		308	309	310	311	313	312	314	BFW in	Steam Out
Nama Aliran	*Unit*	Discharge Kompresor Syngas Stage 2	Inlet Kompresos Syngas setelah bercampur dengan Recycle	Discharge Kompresor Syngas stage 3	Inlet Reaktor NH3	Outlet Reaktor NH3	Produk Bawah Reaktor	Inlet BFW Heater	BFW in	BFW Outlet
Fraksi mol (Hidrogen)		0.7482	0.7346	0.7346	0.7346	0.5681	0.5672	0.5681	-	-
Fraksi mol (Nitrogen)		0.2518	0.2553	0.2553	0.2553	0.2020	0.2018	0.2020	-	-
Fraksi mol (Argon)		0.0001	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	-	-
Fraksi mol (Amonia)		-	0.0099	0.0099	0.0099	0.2297	0.2308	0.2297	-	-
Fraksi mol (H2O)		-	-	-	-	-	-	-	1.0000	1.0000

No Aliran		308	309	310	311	313	312	314	BFW in	Steam Out
Nama Aliran	*Unit*	Discharge Kompresor Syngas Stage 2	Inlet Kompresos Syngas setelah bercampur dengan Recycle	Discharge Kompresor Syngas stage 3	Inlet Reaktor NH3	Outlet Reaktor NH3	Produk Bawah Reaktor	Inlet BFW Heater	BFW in	BFW Outlet
Fraksi uap		1.0000	1.0000	1.0000	1.0000	1.0000	-	1.0000	-	-
Suhu	*C*	130.49	25.10	50.65	170.00	490.16	490.16	364.84	115.00	241.00
Tekanan	*kg/cm2_g*	125.00	125.00	155.00	155.00	155.00	155.00	155.00	75.00	74.00
Molar Flow	*kgmole/h*	9,172.4	25,124.8	25,124.8	25,124.8	20,635.1	-	20,635.1	8,827.3	8,827.3
Hidrogen		6,862.4	18,456.5	18,456.5	18,456.5	11,721.9	-	11,721.9	-	-
Nitrogen		2,309.5	6,413.8	6,413.8	6,413.8	4,169.0	-	4,169.0	-	-
Argon		0.5	5.1	5.1	5.1	5.1	-	5.1	-	-
Amonia		-	249.5	249.5	249.5	4,739.2	-	4,739.2	-	-
H2O		-	-	-	-	-	-	-	8,827.3	8,827.3
Massa Aliran	*kg/h*	78,550.2	221,329.1	221,329.1	221,329.1	221,326.9	-	221,326.9	159,024.9	159,024.9
Liquid Volume Flow	*m3/h*	278.3	762.5	762.5	762.5	614.3	-	614.3	159.3	159.3
Heat Flow	*kJ/h*	27,862,668.1	(14,670,954.9)	4,463,523.4	94,723,225.7	94,723,819.2	-	4,464,117.0	(2,463,336,109.0)	(2,368,393,032.5)

Tabel Lampiran 15 Perhitungan HYSYS Reaksi Amonia dan *Recovery Loop*

No Aliran		315	316	CWS-311	CWR-311	317	321	319	318	320
Nama Aliran	*Unit*	Inlet Cooler	Outlet Cooler	CWS-311	CWR-311	Outlet Chiller	HP Syngas outlet Separator (Vapor)	Liquid Produk Bawah HP Separator	Syngas Setelah *pressure Control* ke Inlet HP Separator	Liquid Produk Bawah HP Separator setelah *pressure control* (Inlet LP Separator)
Fraksi mol (Hidrogen)		0.5681	0.5681	-	-	0.5681	0.7264	0.0041	0.5681	0.0041
Fraksi mol (Nitrogen)		0.2020	0.2020	-	-	0.2020	0.2585	0.0008	0.2020	0.0008
Fraksi mol (Argon)		0.0002	0.0002	-	-	0.0002	0.0003	0.0001	0.0002	0.0001
Fraksi mol (Amonia)		0.2297	0.2297	-	-	0.2297	0.0148	0.9950	0.2297	0.9950
Fraksi mol (H2O)		-	-	1.0000	1.0000	-	-	-	-	-
Fraksi uap		1.0000	0.9481	-	-	0.7800	1.0000	-	0.7808	0.0145
Suhu	*C*	230.00	45.00	35.00	45.00	- 33.50	- 34.17	- 34.17	- 34.17	- 33.64
Tekanan	*kg/cm2_g*	155.00	155.00	10.00	10.00	154.00	125.00	125.00	125.00	0.50
Molar Flow	*kgmole/h*	20,635.1	20,635.1	189,327.4	189,327.4	20,635.1	16,111.9	4,523.2	20,635.1	4,523.2
Hidrogen		11,721.9	11,721.9	-	-	11,721.9	11,703.3	18.6	11,721.9	18.6

No Aliran		315	316	CWS-311	CWR-311	317	321	319	318	320
Nama Aliran	*Unit*	Inlet Cooler	Outlet Cooler	CWS-311	CWR-311	Outlet Chiller	HP Syngas outlet Separator (Vapor)	Liquid Produk Bawah HP Separator	Syngas Setelah *pressure Control* ke Inlet HP Separator	Liquid Produk Bawah HP Separator setelah *pressure control* (Inlet LP Separator)
Nitrogen		4,169.0	4,169.0	-	-	4,169.0	4,165.2	3.8	4,169.0	3.8
Argon		5.1	5.1	-	-	5.1	4.8	0.2	5.1	0.2
Amonia		4,739.2	4,739.2	-	-	4,739.2	238.6	4,500.5	4,739.2	4,500.5
H2O		-	-	189,327.4	189,327.4	-	-	-	-	-
Massa Aliran	*kg/h*	221,326.9	221,326.9	3,410,751.4	3,410,751.4	221,326.9	144,529.4	76,797.4	221,326.9	76,797.4
Liquid Volume Flow	*m3/h*	614.3	614.3	3,417.6	3,417.6	614.3	489.2	125.1	614.3	125.1
Heat Flow	*kJ/h*	(90,478,959.6)	(237,641,181.6)	(54,039,154,529.9)	(53,891,992,307.8)	(363,669,536.4)	(42,551,612.3)	(321,117,924.1)	(363,669,536.4)	(321,117,924.1)

Tabel Lampiran 16 Perhitungan HYSYS Reaksi Amonia dan *Recovery Loop*

No Aliran		320	323	322	325	326	327	CWS-321	CWR-321	328
Nama Aliran	*Unit*	Liquid Produk Bawah HP Separator setelah *pressure* control (Inlet LP Separator)	Vapor Outlet LP Separator	Liquid NH3 LP Separator	NH3 Produk Discharge Transfer Pump	Discharge LP Compresor Stage 1	Outlet Intercooler LP Compresor Stage 1	CWS-321	CWR-321	Discharge LP Compresor Stage 2
Fraksi mol (Hidrogen)		0.0041	0.2826	0.0000	0.0000	0.2826	0.2826	-	-	0.2826
Fraksi mol (Nitrogen)		0.0008	0.0576	0.0000	0.0000	0.0576	0.0576	-	-	0.0576
Fraksi mol (Argon)		0.0001	0.0031	0.0000	0.0000	0.0031	0.0031	-	-	0.0031
Fraksi mol (Amonia)		0.9950	0.6566	1.0000	1.0000	0.6566	0.6566	-	-	0.6566
Fraksi mol (H2O)		-	-	-	-	-	-	1.0000	1.0000	-
Fraksi uap		0.0145	1.0000	-	-	1.0000	1.0000	-	-	1.0000
Suhu	*C*	-33.64	-33.64	-33.64	-33.46	205.31	45.00	33.00	43.00	202.99
Tekanan	*kg/cm2_g*	0.50	0.50	0.50	7.00	14.00	14.00	4.50	3.00	55.00
Molar Flow	*kgmole/h*	4,523.2	65.6	4,457.6	4,479.2	65.6	65.6	493.2	493.2	65.6
Hidrogen		18.6	18.5	0.1	0.1	18.5	18.5	-	-	18.5
Nitrogen		3.8	3.8	0.0	0.0	3.8	3.8	-	-	3.8
Argon		0.2	0.2	0.0	0.0	0.2	0.2	-	-	0.2
Amonia		4,500.5	43.1	4,457.4	4,479.0	43.1	43.1	-	-	43.1

No Aliran		320	323	322	325	326	327	CWS-321	CWR-321	328
Nama Aliran	*Unit*	Liquid Produk Bawah HP Separator setelah *pressure* control (Inlet LP Separator)	Vapor Outlet LP Separator	Liquid NH3 LP Separator	NH3 Produk Discharge Transfer Pump	Discharge LP Compresor Stage 1	Outlet Intercooler LP Compresor Stage 1	CWS-321	CWR-321	Discharge LP Compresor Stage 2
H2O		-	-	-	-	-	-	493.2	493.2	-
Massa Aliran	*kg/h*	76,797.4	885.0	75,912.4	76,280.2	885.0	885.0	8,885.1	8,885.1	885.0
Liquid Volume Flow	*m3/h*	125.1	1.9	123.2	123.8	1.9	1.9	8.9	8.9	1.9
Heat Flow	*kJ/h*	(321,117,924.1)	(2,098,910.0)	(319,019,014.1)	(320,455,133.9)	(1,568,858.4)	(1,951,008.3)	(140,854,075.1)	(140,471,925.2)	(1,608,971.4)

Tabel Lampiran 17 Perhitungan HYSYS Reaksi Amonia dan *Recovery Loop*

No Aliran		328	329	CWS-322	CWR-322	330	331	331A	333	334
Nama Aliran	*Unit*	Discharge LP Compresor Stage 2	Outlet Intercooler LP Compresor Stage 2	CWS-322	CWR-322	Vapor Outlet Separator ke Inlet LP Kompresor Stage 3	NH3 Liquid LP Separator Stage 2	NH3 Liquid Outlet *Pressure control*	Vapor Flash drum ke Fuel System	Produk NH3 yang di gabung dengan Produk Utama
Fraksi mol (Hidrogen)		0.2826	0.2826	-	-	0.5046	0.0061	0.0061	0.0235	0.0000
Fraksi mol (Nitrogen)		0.0576	0.0576	-	-	0.1031	0.0010	0.0010	0.0040	0.0000
Fraksi mol (Argon)		0.0031	0.0031	-	-	0.0052	0.0005	0.0005	0.0018	0.0000
Fraksi mol (Amonia)		0.6566	0.6566	-	-	0.3871	0.9924	0.9924	0.9708	1.0000
Fraksi mol (H2O)		-	-	1.0000	1.0000	-	-	-	-	-
Fraksi uap		1.0000	0.5548	-	-	1.0000	-	0.2605	1.0000	-
Suhu	*C*	202.99	45.00	33.00	43.00	45.00	45.00	-25.48	-25.48	-25.48
Tekanan	*kg/cm2_g*	55.00	55.00	4.50	3.00	55.00	55.00	0.50	0.50	0.50
Molar Flow	*kgmole/h*	65.6	65.6	1,187.5	1,187.5	36.4	29.2	29.2	7.6	21.6
Hidrogen		18.5	18.5	-	-	18.4	0.2	0.2	0.2	0.0
Nitrogen		3.8	3.8	-	-	3.8	0.0	0.0	0.0	0.0
Argon		0.2	0.2	-	-	0.2	0.0	0.0	0.0	0.0
Amonia		43.1	43.1	-	-	14.1	29.0	29.0	7.4	21.6
H2O		-	-	1,187.5	1,187.5	-	-	-	-	-
Massa Aliran	*kg/h*	885.0	885.0	21,392.4	21,392.4	389.6	495.4	495.4	127.6	367.8
Liquid Volume Flow	*m3/h*	1.9	1.9	21.4	21.4	1.1	0.8	0.8	0.2	0.6
Heat Flow	*kJ/h*	(1,608,971.4)	(2,529,065.7)	(339,131,415.8)	(338,211,321.4)	(644,823.4)	(1,884,242.4)	(1,884,242.4)	(351,906.5)	(1,532,335.9)

Tabel Lampiran 18 Perhitungan HYSYS Reaksi Amonia dan *Recovery Loop*

No Aliran		324	332	335	336	337	338
Nama Aliran	*Unit*	Produk NH3 campuran dari Produk Utama dan dari LP Kompresor	Vapor outlet LP Kompresor stage 3	Campuran Vapor dari HP Separator dan LP Kompresor ke sistem *Recovery*	Purge	Recycle	Recycle Inlet Stage 3 Kompresor Syngas
Fraksi mol (Hidrogen)		0.0000	0.5046	0.7259	0.7259	0.7259	0.7268
Fraksi mol (Nitrogen)		0.0000	0.1031	0.2582	0.2582	0.2582	0.2573
Fraksi mol (Argon)		0.0000	0.0052	0.0003	0.0003	0.0003	0.0003
Fraksi mol (Amonia)		1.0000	0.3871	0.0157	0.0157	0.0157	0.0156
Fraksi mol (H2O)		-	-	-	-	-	-
Fraksi uap		-	1.0000	0.9996	0.9996	0.9996	0.9996
Suhu	*C*	-33.60	144.52	-33.49	-33.49	-33.49	-33.48
Tekanan	*kg/cm2_g*	0.50	125.00	125.00	125.00	125.00	125.00
Molar Flow	*kgmole/h*	4,479.2	36.4	16,148.3	201.9	15,946.5	15,952.4
Hidrogen		0.1	18.4	11,721.7	146.5	11,575.1	11,594.0
Nitrogen		0.0	3.8	4,168.9	52.1	4,116.8	4,104.3
Argon		0.0	0.2	5.0	0.1	4.9	4.6
Amonia		4,479.0	14.1	252.7	3.2	249.6	249.5
H2O		-	-	-	-	-	-
Massa Aliran	*kg/h*	76,280.2	389.6	144,919.1	1,811.5	143,107.6	142,778.9
Liquid Volume Flow	*m3/h*	123.8	1.1	490.2	6.1	484.1	484.2
Heat Flow	*kJ/h*	(320,551,350.0)	(534,638.8)	(43,086,251.1)	(538,578.1)	(42,547,672.9)	(42,533,623.0)

Energy Stream

Tabel Lampiran 19 Perhitungan HYSYS Reaksi Amonia dan *Recovery Loop*

	Unit	Regeneration	Chiller Q	P-NH3	P-LP Stage 1	P-LP Stage 2	P-LP Stage 3	P-Syngas Stage 1	P-Syngas Stage 2	P-Syngas Stage 3
Heat Flow	kJ/h	(2,370,244.1)	126,028,354.7	96,216.2	530,051.6	342,036.9	110,184.5	35,137,570.6	23,122,446.7	19,134,478.3
	kW	(658.4)	35,007.9	26.7	147.2	95.0	30.6	9,760.4	6,422.9	5,315.1
	MW	-0.66	35.01	0.03	0.15	0.10	0.03	9.76	6.42	5.32

e) Amonia Refrigerasi & Steam *Recovery*

Tabel Lampiran 20 Hasil Perhitungan HYSYS Refrigerasi Amonia dan Steam *Recovery*

No Aliran		*Syngas Outlet Reactor*	*Out Chiller 1*	*NH3 101 In*	*NH3 101 Out*	*Out Chiller 2*	*NH3 102 In*	*NH3 102 Out*	*Out Chiller 3*	*NH3 103 In*
Nama Aliran	*Unit*	*Syngas Outlet Reactor*	*Out Chiller 1*	*NH3 101 In*	*NH3 101 Out*	*Out Chiller 2*	*NH3 102 In*	*NH3 102 Out*	*Out Chiller 3*	*NH3 103 In*
Fraksi mol (Hidrogen)		0.5681	0.5681	-	-	0.5681	-	-	0.5681	-
Fraksi mol (Nitrogen)		0.2020	0.2020	-	-	0.2020	-	-	0.2020	-
Fraksi mol (Amonia)		0.2297	0.2297	1.0000	1.0000	0.2297	1.0000	1.0000	0.2297	1.0000
Fraksi mol (Argon)		0.0002	0.0002	-	-	0.0002	-	-	0.0002	-
Fraksi mol (H2O)		-	-	-	-	-	-	-	-	-
Fraksi uap		0.9480	0.8389	-	1.0000	0.8121	-	1.0000	0.7968	-
Suhu	*C*	45.00	16.00	- 35.00	- 35.00	2.00	- 35.00	- 35.00	- 10.00	- 35.00
Tekanan	*kg/cm2_g*	155.00	154.75	- 0.10	- 0.10	154.50	- 0.10	- 0.10	154.25	- 0.10
Molar Flow	*kgmole/h*	20,635.1	20,635.1	2,555.7	2,555.7	20,635.1	920.4	920.4	20,635.1	682.7
Hidrogen		11,722.8	11,722.8	-	-	11,722.8	-	-	11,722.8	-
Nitrogen		4,168.3	4,168.3	-	-	4,168.3	-	-	4,168.3	-
Amonia		4,739.9	4,739.9	2,555.7	2,555.7	4,739.9	920.4	920.4	4,739.9	682.7
Argon		4.1	4.1	-	-	4.1	-	-	4.1	-
H2O		-	-	-	-	-	-	-	-	-
Massa Aliran	*kg/h*	221,284.9	221,284.9	43,522.8	43,522.8	221,284.9	15,674.1	15,674.1	221,284.9	11,625.8
Liquid Volume Flow	*m3/h*	614.2	614.2	70.6	70.6	614.2	25.4	25.4	614.2	18.9
Heat Flow	*kJ/h*	(237,691,782.5)	(298,488,804.7)	(183,174,696.7)	(122,377,674.5)	(320,383,948.0)	(65,967,643.0)	(44,072,499.6)	(336,623,981.9)	(48,929,424.1)

Tabel Lampiran 21 Hasil Perhitungan HYSYS Refrigerasi Amonia dan Steam *Recovery*

No Aliran		*NH3 103 Out*	*Out Chiller 4*	*NH3 104 In*	*NH3 104 Out*	*Inlet Reffrigerant Compressor*	*201*	*202*	*CWS-201*	*CWR-201*
Nama Aliran	*Unit*	*NH3 103 Out*	*Out Chiller 4*	*NH3 104 In*	*NH3 104 Out*	*Inlet Reffrigerant Compressor*	*Discharge Kompresor refrigerant stage 1*	*Outlet Intercooler Kompresor refrigerant stage 1*	*CWS-201*	*CWR-201*
Fraksi mol (Hidrogen)		-	0.5681	-	-	-	-	-	-	-
Fraksi mol (Nitrogen)		-	0.2020	-	-	-	-	-	-	-
Fraksi mol (Amonia)		1.0000	0.2297	1.0000	1.0000	1.0000	1.0000	1.0000	-	-
Fraksi mol (Argon)		-	0.0002	-	-	-	-	-	-	-

No Aliran		*NH3 103 Out*	*Out Chiller 4*	*NH3 104 In*	*NH3 104 Out*	*Inlet Reffrigerant Compressor*	*201*	*202*	*CWS-201*	*CWR-201*
Nama Aliran	*Unit*	*NH3 103 Out*	*Out Chiller 4*	*NH3 104 In*	*NH3 104 Out*	*Inlet Reffrigerant Compressor*	*Discharge Kompresor refrigerant stage 1*	*Outlet Intercooler Kompresor refrigerant stage 1*	*CWS-201*	*CWR-201*
Fraksi mol (H2O)		-	-	-	-	-	-	-	1.0000	1.0000
Fraksi uap		1.0000	0.7799	-	1.0000	1.0000	1.0000	1.0000	-	-
Suhu	*C*	- 35.00	- 33.50	- 35.00	- 35.00	- 35.00	122.43	45.00	33.00	43.00
Tekanan	*kg/cm2_g*	- 0.10	154.00	- 0.10	- 0.10	- 0.10	4.28	4.28	4.50	3.00
Molar Flow	*kgmole/h*	682.7	20,635.1	1,139.0	1,139.0	5,297.7	5,297.7	5,297.7	20,244.2	20,244.2
Hidrogen		-	11,722.8	-	-	-	-	-	-	-
Nitrogen		-	4,168.3	-	-	-	-	-	-	-
Amonia		682.7	4,739.9	1,139.0	1,139.0	5,297.7	5,297.7	5,297.7	-	-
Argon		-	4.1	-	-	-	-	-	-	-
H2O		-	-	-	-	-	-	-	20,244.2	20,244.2
Massa Aliran	*kg/h*	11,625.8	221,284.9	19,396.8	19,396.8	90,219.5	90,219.5	90,219.5	364,700.9	364,700.9
Liquid Volume Flow	*m3/h*	18.9	614.2	31.5	31.5	146.4	146.4	146.4	365.4	365.4
Heat Flow	*kJ/h*	(32,689,390.2)	(363,719,351.5)	(81,635,348.8)	(54,539,979.2)	(253,679,543.5)	(224,123,693.5)	(239,809,607.8)	(5,781,566,196.6)	(5,765,880,282.3)

Tabel Lampiran 22 Hasil Perhitungan HYSYS Refrigerasi Amonia dan Steam *Recovery*

No Aliran		*203*	*204*	*CWS-202*	*CWR-202*	*205*	*NH3 Receiver*	*SW Cond In*	*SW Cond Out*	*MP Steam*
Nama Aliran	*Unit*	*Discharge Kompresor refrigerant stage 2*	*Outlet Intercooler Kompresor refrigerant stage 2*	*CWS-202*	*CWR-202*	*Discharge Kompresor refrigerant stage 3*	*NH3 Receiver*	*SW Cond In*	*SW Cond Out*	*MP Steam*
Fraksi mol (Hidrogen)		-	-	-	-	-	-	-	-	-
Fraksi mol (Nitrogen)		-	-	-	-	-	-	-	-	-
Fraksi mol (Amonia)		1.0000	1.0000	-	-	1.0000	1.0000	-	-	-
Fraksi mol (Argon)		-	-	-	-	-	-	-	-	-
Fraksi mol (H2O)		-	-	1.0000	1.0000	-	-	1.0000	1.0000	1.0000
Fraksi uap		1.0000	1.0000	-	-	1.0000	1.0000	-	-	1.0000
Suhu	*C*	121.24	45.00	33.00	43.00	95.63	44.94	30.00	31.10	390.00
Tekanan	*kg/cm2_g*	10.00	10.00	4.50	3.00	17.00	17.00	4.50	3.00	46.90
Molar Flow	*kgmole/h*	5,297.7	5,297.7	20,624.2	20,624.2	5,297.7	5,297.7	135,021.5	135,021.5	1,923.5
Hidrogen		-	-	-	-	-	-	-	-	-
Nitrogen		-	-	-	-	-	-	-	-	-
Amonia		5,297.7	5,297.7	-	-	5,297.7	5,297.7	-	-	-

No Aliran		*203*	*204*	*CWS-202*	*CWR-202*	*205*	*NH3 Receiver*	*SW Cond In*	*SW Cond Out*	*MP Steam*
Nama Aliran	*Unit*	*Discharge Kompresor refrigerant stage 2*	*Outlet Intercooler Kompresor refrigerant stage 2*	*CWS-202*	*CWR-202*	*Discharge Kompresor refrigerant stage 3*	*NH3 Receiver*	*SW Cond In*	*SW Cond Out*	*MP Steam*
Argon		-	-	-	-	-	-	-	-	-
H2O		-	-	20,624.2	20,624.2	-	-	135,021.5	135,021.5	1,923.5
Massa Aliran	*kg/h*	90,219.5	90,219.5	371,547.3	371,547.3	90,219.5	90,219.5	2,432,425.1	2,432,425.1	34,651.2
Liquid Volume Flow	*m3/h*	146.4	146.4	372.3	372.3	146.4	146.4	2,437.3	2,437.3	34.7
Heat Flow	*kJ/h*	(225,516,483.8)	(241,496,864.8)	(5,890,101,689.6)	(5,874,121,308.7)	(232,575,926.7)	(243,779,834.4)	(38,592,466,137.1)	(38,581,262,229.4)	(443,155,740.3)

Tabel Lampiran 23 Hasil Perhitungan HYSYS Refrigerasi Amonia dan Steam *Recovery*

No Aliran		*Condensate*	*LP Steam*	*Cond. LP*	*SC STG*	*Cond STG*	*Outfall*
Nama Aliran	*Unit*	*Condensate*	*LP Steam*	*Cond. LP*	*SC STG*	*Cond STG*	*Outfall*
Fraksi mol (Hidrogen)		-	-	-	-	-	-
Fraksi mol (Nitrogen)		-	-	-	-	-	-
Fraksi mol (Amonia)		-	-	-	-	-	-
Fraksi mol (Argon)		-	-	-	-	-	-
Fraksi mol (H2O)		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Fraksi uap		0.9184	1.0000	0.9072	0.9114	-	-
Suhu	*C*	51.31	180.00	51.31	51.31	51.31	50.45
Tekanan	*kg/cm2_g*	-0.90	5.00	-0.90	-0.90	-0.90	1.00
Molar Flow	*kgmole/h*	1,923.5	3,220.2	3,220.2	5,143.7	5,143.7	135,021.5
Hidrogen		-	-	-	-	-	-
Nitrogen		-	-	-	-	-	-
Amonia		-	-	-	-	-	-
Argon		-	-	-	-	-	-
H2O		1,923.5	3,220.2	3,220.2	5,143.7	5,143.7	135,021.5
Massa Aliran	*kg/h*	34,651.2	58,012.4	58,012.4	92,663.6	92,663.6	2,432,425.1
Liquid Volume Flow	*m3/h*	34.7	58.1	58.1	92.9	92.9	2,437.3
Heat Flow	*kJ/h*	(470,225,689.5)	(762,669,551.0)	(788,796,927.7)	(1,259,022,617.3)	(1,461,707,089.3)	(38,378,577,757.4)

Energy Stream

Tabel Lampiran 24 Hasil Perhitungan HYSYS Refrigerasi Amonia dan Steam *Recovery*

	Unit	*P-Stage 1*	*P-Stage 2*	*P-Stage 3*	*STG*	*STG Adms*
Heat Flow	*kJ/h*	29,555,850.0	14,293,124.0	8,920,938.1	27,069,949.2	26,127,376.8
	kW	8,210.0	3,970.3	2,478.0	7,519.4	7,257.6
	MW	8.21	3.97	2.48	7.52	7.26

f) Deaerator

Tabel Lampiran 25 Hasil Perhitungan HYSYS *Deaerator* & BFW

		011	013	014	015	LP Steam Inlet DA	DM Inlet DA	016	to DA	DA In
	Unit	*DM Inlet*	*LP Steam Inlet*	*Vent*	*Ke Pompa*	*LP Steam Inlet DA*	*DM Inlet DA*	*BFW Header*	*to DA*	*DA In*
Fraksi mol (H2O)		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Fraksi uap		-	1.0000	1.0000	-	1.0000	-	-	-	0.0154
Suhu	*C*	30.00	180.00	115.11	115.11	174.73	30.18	116.16	122.81	115.11
Tekanan	*kg/cm2_g*	10.00	5.00	0.70	0.70	1.50	1.50	75.00	1.50	0.70
Molar Flow	*kgmole/h*	12,271.4	2,142.7	221.3	14,192.8	2,142.7	12,271.4	14,192.8	14,414.1	14,414.1
Massa Aliran	*kg/h*	221,071.1	38,600.9	3,987.3	255,684.6	38,600.9	221,071.1	255,684.6	259,671.9	259,671.9
Liquid Volume Flow	*m3/h*	221.5	38.7	4.0	256.2	38.7	221.5	256.2	260.2	260.2
Heat Flow	*kJ/h*	(3,507,365,546.0)	(507,472,865.2)	(52,870,179.1)	(3,961,968,232.3)	(507,472,865.2)	(3,507,365,546.0)	(3,959,311,573.2)	(4,014,838,411.2)	(4,014,838,411.2)

Energy Stream

Tabel Lampiran 26 Hasil Perhitungan HYSYS *Deaerator* & BFW

	Unit	*P-BFW*
Heat Flow	*kJ/h*	2,656,659.1
	kW	738.0
	MW	0.74

B. Perhitungan Spesifikasi Alat

1. SOEC (Elektrolisis air)

Perhitungan kebutuhan elektrolyzer modul, menggunakan datasheet dari manufacturer yaitu Haldor Topsoe :

Get in touch today
Visit topsoe.com/contact for project-specific consumption figures and quotes

Technical data H_2 SOEC 100 MW SOEC 32,000 Nm^3/h	
Core capacity	
H_2 production capacity	32,000 Nm^3/h
Turn down ratio, at plant level	10-100%
Product conditions	
Pressure @ BL	2 bar g
Pressure H_2 product	Per customer requirement
Temperature H_2 @ BL	Ambient
H_2 purity	Up to 99.999% (dry basis after gas cleaning)
Feed conditions	
H_2O as DMW	27,000 kg/h
Power input	
Total stack power consumption	100 MW
Specific power consumption, stack level	3.1 kWh/Nm^3 H_2
Specific power consumption, plant level	Depending on heat integration and H_2 pressure
Steam supply (if available)	Flow rate depending on pressure level
Other specs	
Approximate footprint including BoP	8,400 m^2
Electricity supply at plant BL	24 kV (6-24 kV possible)

Haldor Topsoe A/S reserves the right to make changes at any time without notice, in materials, equipment, specifications and models shown in any document. Specifications are subject to technical changes. Images do not necessarily show the equipment that will be installed. All data are for reference only. Performance data are not to be used for guarantee purposes.

Sehingga didapat perhitungan :

Specific Energy	3.1	kWh / Nm3 H2	
Product Hidrogen	6890	Kmol/jam	
	154,432	Nm3 / jam	
Efficiency	99%		
Power Consumption	482,413.84	kW	
Individual Stack Production		100,000.0	kW
Jumlah Stack		5.0	Set

Spare	1.0	Set
Total	6.0	Set
Luas lahan per Stack 100 MW	8,400.0	m2
Total Luas lahan	50,400.0	m2
Hidrogen Untuk Fuel	871	kmol / jam
	19,530	Nm3 / jam
Power	60,542.92	kW
Jumlah Stack	1.0	Set
Spare	1.0	Set
Total	2.0	Set
Luas lahan per Stack 100 MW	8,400.0	m2
Total Luas lahan	16,800.0	m2
Total Luas Lahan SOEC	67,200.0	m2
Total Stack	8.0	Set

2. Tangki Amonia

Menghitung produksi NH_3

Desain pengapalan : 15 Hari sekali

Menentukan Massa Jenis NH_3 pada suhu penyimpanan : -33 ^oC

ρ = 0.682 kg/m^3 (Carl L, Yaws, 1999)

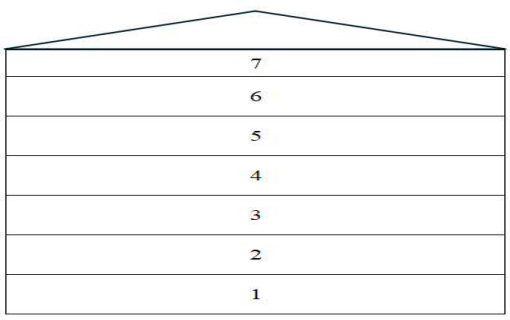
Produk = 600000 Ton / Tahun

= 1818.2 Ton / Hari

Allowance = 10%

Volume Tangki = $\frac{1818.2\ x\ 15}{0.682}$ x 1.1

= 43988.3 m^3



Menghitung tinggi tangki :

Tekanan Desain = 1 atm (101.325 kPa)

Tinggi tangki didapat :

$$H = \frac{P}{\rho.g}$$

$$= \frac{101.325}{0.682\ x\ 9.81}$$

$$= 15.145 \text{ m}$$

Dengan menggunakan rumus $V = \frac{1}{4}\pi D^2 H$

Diameter Tangki (D) = 60.83 m dan R = 30.42 m

= 30420 mm

Menghitung ketebalan plat tangki (API 650)

Tinggi plat standar 2.4 m

Desain CA (*Corrosion allowance*) = 1.7 mm

Material yang dipilih : SA-516 Gr.70 (*Carbon Steel*)

Stress allowable, S = 140

Efisiensi sambungan las = 0.85 (parsial Radiografi test)

$$T1 = \frac{P\ x\ R}{S\ x\ E}$$

$$= \frac{0.101325\ x\ 30.42}{140\ x\ 0.85}$$

$$= 0.0259 \text{ m}$$

$$= 25.9 \text{ mm}$$

Total tebal plat No. 1 = 25.9 + 1.7 = 27.6 mm

Dengan perhitungan yang sama didapat sesuai tabel berikut :

Plat no (Bawah ke Atas)	Tinggi	Tekanan hidrostatic	Tebal Plat	CA	Total Tebal Plat minimal
1	15.14	101,325.0	25.90	1.70	27.60
2	12.74	85,268.0	21.79	1.70	23.49
3	10.34	69,211.0	17.69	1.70	19.39
4	7.94	53,154.0	13.59	1.70	15.29
5	5.54	37,097.0	9.48	1.70	11.18
6	3.14	21,040.0	5.38	1.70	7.08
7	0.74	4,983.0	1.27	1.70	2.97

Menghitung beban penguapan di tangki:

Data :

Suhu Desain tangki = -33 ^{o}C

Suhu ambient = 35 ^{o}C

maka DT = 68 K

Kalor laten penguapan NH_3 = 1370 kJ/kg

Konduktivitas insulator perlit (tebal, δ = 0.6 m), λ = 0.035 W/(m.K) (sumber Engineering Toolbox)

Luas permukaan tangki secara keseluruhan :

- Luas Tangki sisi samping dan bawah = 3.14 x D x (D + H)
  = 3.14 x 60.83 (60.83 + 15.145)
  = 14510.7 m2
- Luas atap = 3.14 x R^2
  = 3.14 x 30.42^2
  = 2906.1 m2
- Total luas permukaan tangki = 17416.8 m2

Laju Penguapan tangki (margin 10%) = 1.1 x

$$= 1.1\ x\ \frac{\lambda\ .\ A.\ \Delta T}{\delta}\ \frac{5.8\ x\ 68}{}$$

= 75995.3 W

Konversi laju BOG = $\frac{Q\ Total}{H\ Vap}$

= $\frac{75995.3}{1370}$

= 0.05547 kg/s

= 199.7 kg/jam

3. Deaerator

Kondisi desain

Feed Umpan	=	221,071.1	kg/h
Steam Inlet	=	38,600.9	kg/h
Total BFW Out	=	255,684.6	kg/h
	=	71.024	Kg/s
Total Vent	=	3,987.3	kg/h
Tekanan Operasi	=	1.7	atm

	=	0.1723	MPa	
Tekanan Desain	=	3.0	atm	
	=	0.3040	MPa	
Holdup time design	=	15	menit	
	=	900	s	
Massa Jenis air pada P,T	=			(Steam table)
Desain		950	Kg/m3	

Volume liquid, V_l $= \frac{Flow\ rate\ x\ Hold\ time}{Density}$

$= \frac{71.024\ \left(\frac{kg}{s}\right) x\ 900(s)}{950\ (\frac{kg}{m3})}$

$= 67.29$ m3

Asumsi : Level liquid adalah 80%, maka total volume menjadi

$= \frac{67.29\ (m3)}{0.8}$

$= 84.11$ m3

Sehingga volume uap = 16.82 m3

Asumsi L/D = 3.5, dengan $V = \frac{\pi D^2}{4} \times L$ dan $L = 3.5\,D$

Diameter *vessel*, ID = 3.13 m → R = 1.565 m

Panjang *Vessel* T-T = 10.96 m

Tebal Shell (menggunakan standar ASME VIII Div.1 : $t = \frac{P \cdot R}{S\,E - 0.6P} + CA$

Dan *Head* 2:1 ellipsoidal : $t = \frac{P \cdot K \cdot D}{2S\,E - 0.2P} + CA, \quad K = 0.90$

Material yang di pilih : SA=516 Gr.70 (Carbon steel) dengan S= 138 MPa dan E (Join effisiensi) = 0.85 (Parsial radiografi test).

CA (*Corrosion allowance*) = 3 mm, maka :

t_{shell} $= \frac{P\ x\ R}{S.E - 0.6.P} + \text{CA}$

$= \frac{0.3040\ x\ 1.565}{138\ x\ 0.85\ -0.6\ x\ 0.3040} + 0.003$

$= \frac{0.47566}{117.1176} + 0.003$

$= 0.00706$ m

$= 7.06$ mm

t_{Head} $= \frac{P\ x\ K\ x\ D}{2S.E-0.2.P} + CA$

$= \frac{0.3040\ x\ 0.90\ x\ 3.13}{2\ x\ 138\ x\ 0.85-0.2\ x\ 0{,}3040} + 0.003$

$= \frac{0.8564}{234.539} + 0.003$

= 0.00665 m

= 6.65 mm

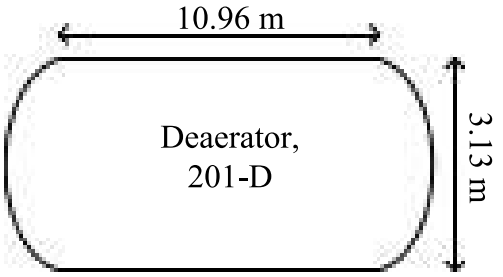
Tebal plat yang dipilih : 8 mm, sehingga MAWP nya :

MAWP $= \frac{SEt}{R+0.6t}$

$= \frac{138\ x\ 0.85\ x\ 0.008}{1.565+0.6x0.008}$

= 0.5978 MPa

= 5.9 Atm



4. *Pressure Vessel* (Bejana bertekanan)

a) Separator Hidrogen inlet Kompresor H2, 204-D

Pressure Vessel Design Calculation

(Sumber ASME VIII Div. 1)

Laju alir	=	14,110.71	kg/Jam =	3.92	kg/s
Tekanan Operasi	=	2.50	kg/cm2G		
	=	0.25	MPa Gauge		
	=	0.35	MPa		
Tekanan Desain	=	3.75	kg/cm2G		
	=	0.37	MPa Gauge		
	=	0.47	MPa		
Suhu Operasi	=	45.00	oC		
Suhu Desain	=	80.00	oC		
	=	353.15	K		

Komposisi		BM
H2	0.9980	2.01
H2O	0.0020	0.04
Total	1.0000	2.05

Mol campuran = 2.05 g/mol

= 0.00205 kg/mol

Asumsi faktor kompresibilitas, Z = 1

Densitas, ρ = $\frac{P\ x\ M}{Z\ R\ T}$

= $\frac{0.47\ x\ 0.00205}{1\ x\ 8.314\ x\ 353.15}$

= 3.2716 kg/m3

Densitas Liquid = 971.76 kg/m3 (Steam tabel)

Maksimal fraksi vapor = 0.9980

Maka laju alir massa cairan = 0.002 x 14110.71

= 28.22 kg/jam

= 0.0078 kg/s

Batas kecepatan Gas di (Sounders – Brown)

V_{maks} = $K \cdot \sqrt{\frac{\rho_l - \rho_v}{\rho_v}}$; Koefisien empiris, K = 0.25 m/s (dengan demister)

= 0.25 x $\sqrt{(971.76 - 3.2716)/3.2716}$

= 4.301 m/s

Margin Luas penampang ntuk mendapatkan L/D mendekati 2 = 112%

A_g = $\frac{\dot{m}_g}{\rho_v \cdot v_{max}}$

= $\frac{3.92}{3.2716\ x\ 4.301}$

= 0.59 m2

Diameter internal *vessel*:

= 0.867 m

Volume total = Volume liquid + Volume gas

Asumsi waktu tinggal cairan = 5 menit (300 detik)

Volume liquid $= \frac{Laju\ alir\ x\ waktu\ tinggal}{Density}$

$= \frac{0.0078\ x\ 300}{971.76}$

= 0.0024 m3

Dengan menggunakan formula yang sama, untuk bejana bertekanan (*pressure vessel*) dapat di lihat pada tabel

Komponen	Satuan	Inlet H2 Separator	H2 Dischaarge Kompressor	HP Amonia Separator	LP Amonia Separator	LP Amonia Flash Drum (Discharge LP Kompresor)	Perhitungan menggunakan standar ASME VIII Div. 1
		204-D	205-D	304-D	305-D	306-D	
Hidrogen		0.9980	0.9980	0.5681	0.0041	0.0061	
Nitrogen		-	-	0.2020	0.0008	0.0010	
Oksigen		-	-				
H2O		0.0020	0.0020				
Argon		-	-	0.0002	0.0001	0.0005	
NH3		-	-	0.2297	0.9950	0.9924	
BM, M	g/mol	2.0478	2.0478	10.7258	16.9790	16.9606	
	kg/mol	0.0020	0.0020	0.0107	0.0170	0.0170	
Laju alir	kg/jam	14,110.7	14,110.7	221,326.9	76,797.4	495.4	
	kg/s	3.9196	3.9196	61.4797	21.3326	0.1376	
Compresibility Factor, Z		1.00	1.00	1.20	1.00	1.00	
R	m^3 Pa K^{-1} mol^{-1}	8.314	8.314	8.314	8.314	8.314	Konstanta gas Molar
Tekanan Operasi	kg/cm2G	2.50	26.00	125.00	0.50	0.50	
Tekanan Desain	kg/cm2G	4.00	39.00	188.000	1.000	1.000	
	MPa	0.49	3.93	18.538	0.199	0.199	
Suhu Operasi	oC	45.00	45.00	- 34.17	- 33.64	- 25.48	
Suhu Desain	oC	80.00	80.00	80.00	1.36	9.52	
	K	353.15	353.15	353.15	274.51	282.67	
Material		SA-516 Gr.70					Carbon steel

Komponen	Satuan	Inlet H2 Separator	H2 Dischaarge Kompressor	HP Amonia Separator	LP Amonia Separator	LP Amonia Flash Drum (Discharge LP Kompresor)	Perhitungan menggunakan standar ASME VIII Div. 1
		204-D	205-D	304-D	305-D	306-D	
S	MPa	138.00	138.00	138.00	138.00	138.00	
E		1.00	1.00	1.00	1.00	1.00	
Massa Jenis Gas, ρ_v	kg/m3	0.3443	2.7382	56.4336	0.8900	0.8900	Untuk *vessel* 204-D, 205-D, 304 D menggunakan formula : Densitas gas $\rho_V = \frac{P \cdot MW}{R \cdot T}$ dan 305-D, 306-D menggunakan pendekatan *vapor density* amonia
Massa Jenis Liquid, ρ_l	kg/m3	971.8	971.8	600.0	682.0	682.0	
Laju Volumetrik Gas, V	m3/s	11.3857	1.4315	1.0894	0.2762	0.1546	$\dot{V} = \frac{\dot{m}}{\rho_V}$
K	m/s	0.11	0.11	0.03	0.10	0.10	Menggunakan wire mesh pad
$v_{s,\,maks}$	m/s	5.68	2.01	0.09	2.77	2.77	$v_{s,max} = K\sqrt{\frac{\rho_L - \rho_V}{\rho_V}}$
Kecepatan desain margin		15%	15%	15%	15%	15%	
$v_{s,\,des}$	m/s	4.83	1.71	0.07	2.35	2.35	Kecepatan desain (margin 15%): $v_{s,des} = 0.85 \cdot v_{s,max}$
Area Penampang, A	m2	2.36	0.84	14.75	0.12	0.07	$A = \dot{V} / v_{s,des}$

Komponen	Satuan	Inlet H2 Separator	H2 Dischaarge Kompressor	HP Amonia Separator	LP Amonia Separator	LP Amonia Flash Drum (Discharge LP Kompresor)	Perhitungan menggunakan standar ASME VIII Div. 1
		204-D	205-D	304-D	305-D	306-D	
Diameter dalam *Vessel*, D	m	1.73	1.03	4.33	1.59	1.49	L/D ~3–4.
Jari jari *vessel*, R	m	0.87	0.52	2.17	0.79	0.74	
Tinggi *vessel*	m	6.06	3.61	15.17	5.55	5.21	
Normal Liqud Level					50%	50%	
Hold up time	menit				3.00	3.00	
	detik				180.00	180.00	
Laju Liquid	m3/s				0.03	0.00	
V hold	m3				5.63	0.04	
Volume silinder (V/L)	m3				1.98	1.74	
Tinggi Liquid	m				2.85	0.02	
Total tinggi	m				4.85	2.02	
Corrosion Allowance, CA	mm	3.00	3.00	3.00	3.00	3.00	
	m	0.0030	0.0030	0.0030	0.0030	0.0030	
t (*vessel*)	m	0.0061	0.0179	0.3197	0.0041	0.0041	$t = \frac{P \cdot R}{S \cdot E - 0.6P} + \text{CA}$
	mm	6.11	17.94	319.66	4.15	4.08	
K untuk *head*		0.90	0.90	0.90	0.90	0.90	
t (*head* 2:1 ellipsoidal)	m	0.0058	0.0163	0.2686	0.0040	0.0040	$t = \frac{P \cdot K \cdot D_i}{2SE - 0.2P} + \text{CA}$
	mm	5.79	16.25	268.59	4.03	3.97	

Komponen	Satuan	Inlet H2 Separator	H2 Dischaarge Kompressor	HP Amonia Separator	LP Amonia Separator	LP Amonia Flash Drum (Discharge LP Kompresor)	Perhitungan menggunakan standar ASME VIII Div. 1
		204-D	205-D	304-D	305-D	306-D	
Plat yang di pilih	mm	8.0	18.0	350.0	6.0	6.0	
	m	0.0080	0.0180	0.3500	0.0060	0.0060	
MAWP	MPa	1.27	4.71	20.32	1.04	1.11	$P = \frac{SEt}{R + 0.6t}$
	kg/cm2G	14.0	49.1	208.2	11.6	12.3	

5. Reaktor Amonia

Komposisi gas inlet dan outlet dari neraca massa didapat :

Komponen	Satuan	Fraksi Mol		BM Campuran	
		Inlet	Outlet	Inlet	Outlet
H2	fraksi mol	0.7346	0.5681	1.481	1.145
N2	fraksi mol	0.2553	0.2020	7.151	5.660
Ar	fraksi mol	0.0002	0.0002	0.008	0.010
NH3	fraksi mol	0.0099	0.2297	0.169	3.911
Total		1.0000	1.0000	8.8091	10.7258

Total BM Campuran inlet	8.8091	gram/mol
	0.0088	kg/mol
Total BM Campuran Outlet	10.7258	gram/mol
	0.0107	kg/mol

		Inlet	Outlet
Total aliran	kmol/jam	25124.8	20635.1
	kg/jam	221329.1	221326.9
	kg/s	61.48	61.48
Tekanan Operasi	kg/cm2G	155.00	155.00
	MPa	15.30	15.30
Tekanan Desain	MPa	19.89	19.89
Suhu Operasi	oC	170.00	490.16
	K	443.15	763.31
Suhu Desain	oC	570.16	570.16
	K	843.31	843.31

Konversi :

DN_2 = Mol N_2 in – Mol N_2 Out

= (fraksi mol N_2 in x Flow in) – (fraksi mol N_2 out x Flow out)

= (0.2553 x 25124.8) – (0.2020 x 20635.1)

= 2244.84 kmol / jam

DNH_3 dihasilkan = Mol NH_3 out – Mol NH_3 in

= (fraksi mol NH_3 out x Flow out) – (fraksi mol NH_3 in x Flow in)

= (0.2297 x 20635.1) – (0.0099 x 25124.8)

= 4489.68 kmol / jam

Konversi Reaktor = $\left(1 - \frac{Total\ mol\ N2\ outlet}{Total\ mol\ N2\ Inlet}\right) x\ 100\%$

= $(1 - \frac{0.2020 \text{ x } 20635.1}{0.2553 \text{ x } 25124.8}) x\ 100\%$

= $\left(1 - \frac{4168.29}{6414.36}\right) x\ 100\%$

= 35.02 %

Pada tabel 8.3 Catalyst handbook M.V. Twigg didapat laju reaksi adalah :

Table 8.3. Variation of synthesis rates with catalyst granule size

Normal size range/mm	Rate/kmol N_2 h^{-1} m^{-3} of catalyst
0.6–1.2	300
3–4.5	112
6–9	61

Sehingga dengan ukuran granular katalis antara 6 – 9 mm, r = 61 kmol N_2/jam/m^3 katalis, sehingga volume reaktor :

$V_{katalis}$ = $\frac{jumlah\ selisih\ NH3}{rate\ reaksi}$

= $\frac{4489.68}{61}$

= 73.60 m^3

+ Margin 10% = 80.96 m^3

Vessel diameter (rujukan M. V. Twigg adalah 2.0 – 3.5 m dengan tinggi Bed 2 – 5 m / level sebagai best praktis di industri)

Diameter = 2.75 m (R = 1.375 m), luas penampang :

A = $0.25\pi D^2$

= 0.25 x 3.14 x 2.75^2

= 5.937 m^2

Tinggi Bed = $\frac{V}{A}$

= $\frac{80.96}{5.937}$

= 13.64 m

Tinggi masing-masing bed (dengan 3 bed reaktor) = 4.55 m

Dimensi reaktor

Dengan P, T desain material yang cocok (ASME VIII div. 1) adalah Incoloy 800H (untuk Suhu tinggi) dan dari tabel ASME Sec II, Part D, Subpart 3 didapat Stress allowable, S = 108 MPa

Efisiensi welding (100% RT) = 1

Corrosion allowance (CA) = 3 mm = 0.003 m

$t_{vessel} = \frac{P.R}{S.E-0.6P} + CA$

$= \frac{19.89\ x\ 1.375}{108x1\ -0.6x19.89} + 0.003$

$= \frac{27.349}{96.066} + 0.003$

= 0.2876 m

= 287.6 mm

$t_{head\ 2:1\ ellipsoidal} = \frac{P.K.D}{2S.E-0.2P} + CA$; K = 0.90

$= \frac{19.89\ x\ 0.90\ x\ 2.75}{2\ x\ 108\ x\ 1\ -0.2\ x\ 19.89} + 0.003$

$= \frac{49.22}{212.022} + 0.003$

= 0.2351 m

= 235.1 mm

6. Heat Exchanger

(https://drive.google.com/drive/folders/1dWUuAzQF9NjzuZRHOUya0ZC-TbEFlY41?usp=sharing)

Spesifikasi / desain dari penukar panas (*Heat exchanger)* akan menggunakan software HTRI Suite 9.0 dimana tahapan awal adalah sebagai berikut :

a. Penentuan HE yang akan di desain yaitu :

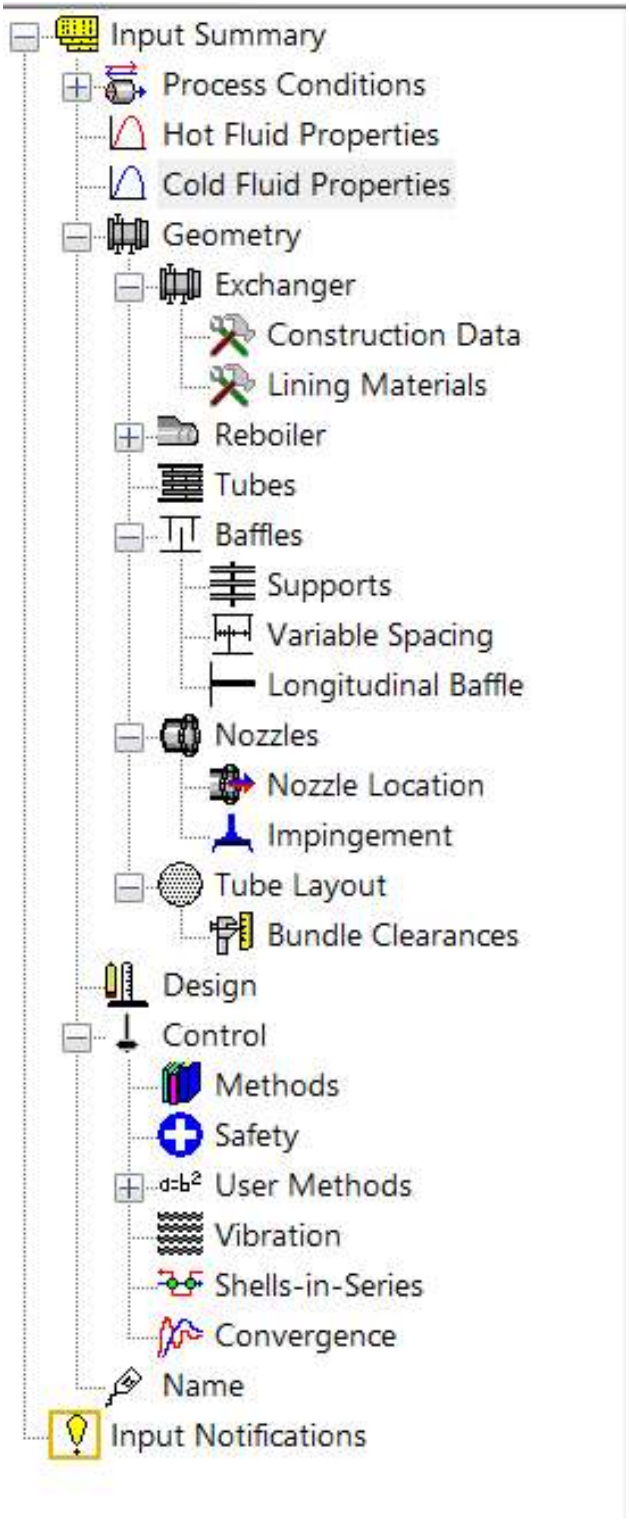
Peralatan utama untuk heat exchanger dalam proses amonia hijau adalah:

- Waste Heat Boiler (WHB), 201-C
- Hidrogen product Cooler, 204-C1
- Oksigen produk Cooler, 204-C2
- Feed Heater, 301-C
- BFW Heater. 302-C
- Syngas Cooler, 303-C
- Syngas Chiller, 304-C

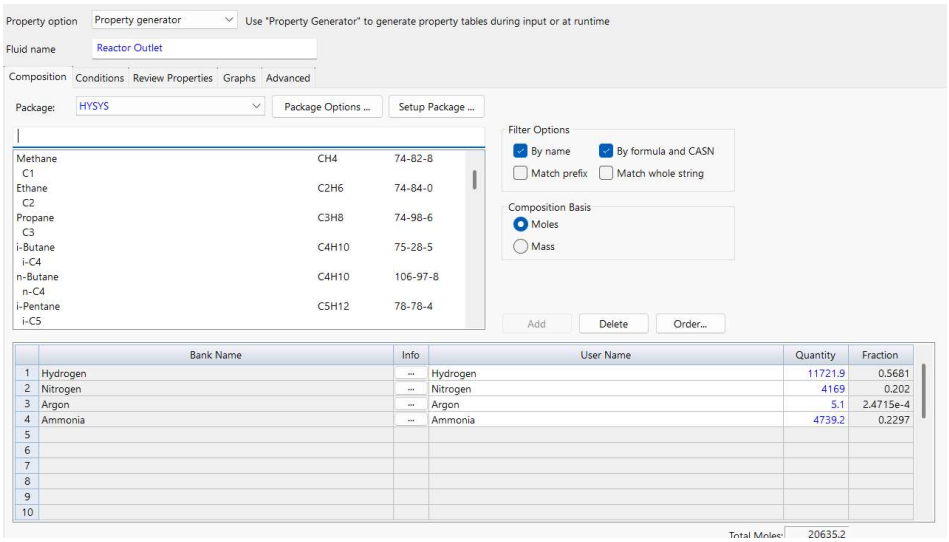
b. Input data di HTRI

Data komposisi material dari masing-masing aliran akan mengikuti komposisi sesai dengan neraca massa pada PFED di BAB IV.

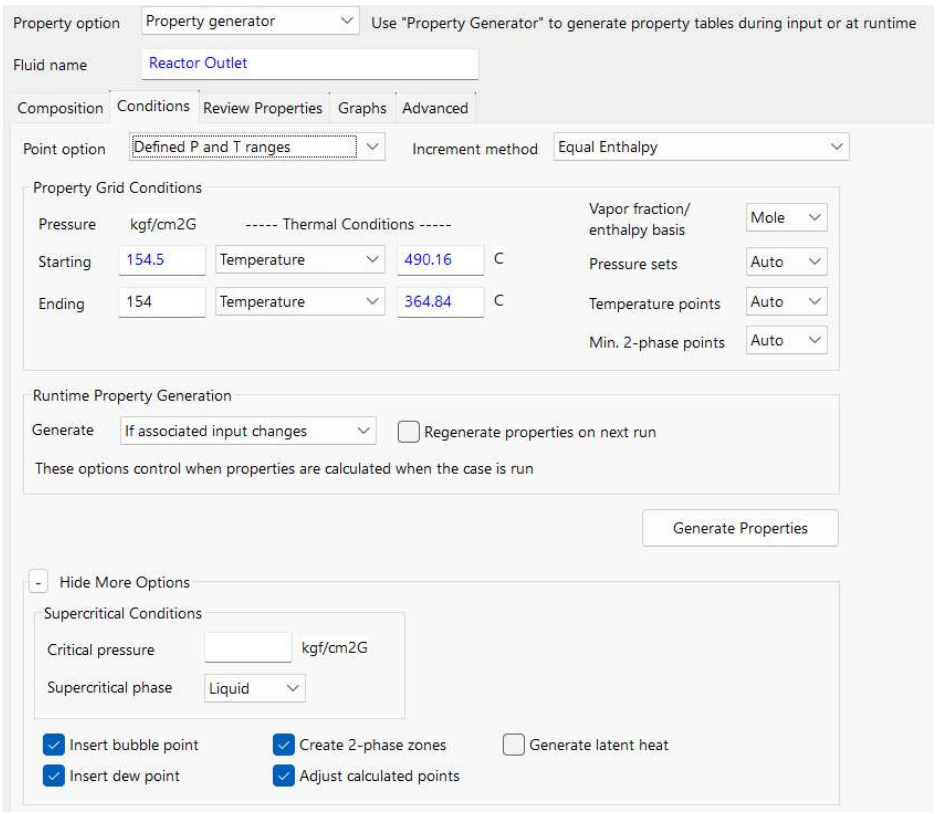
- Menu



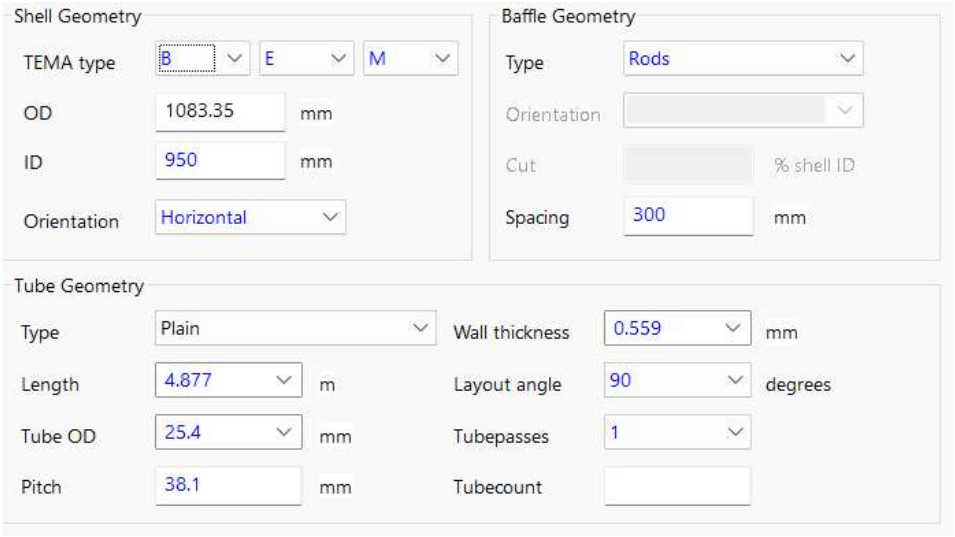
- Input komposisi Fluida (Hot & Cold side)

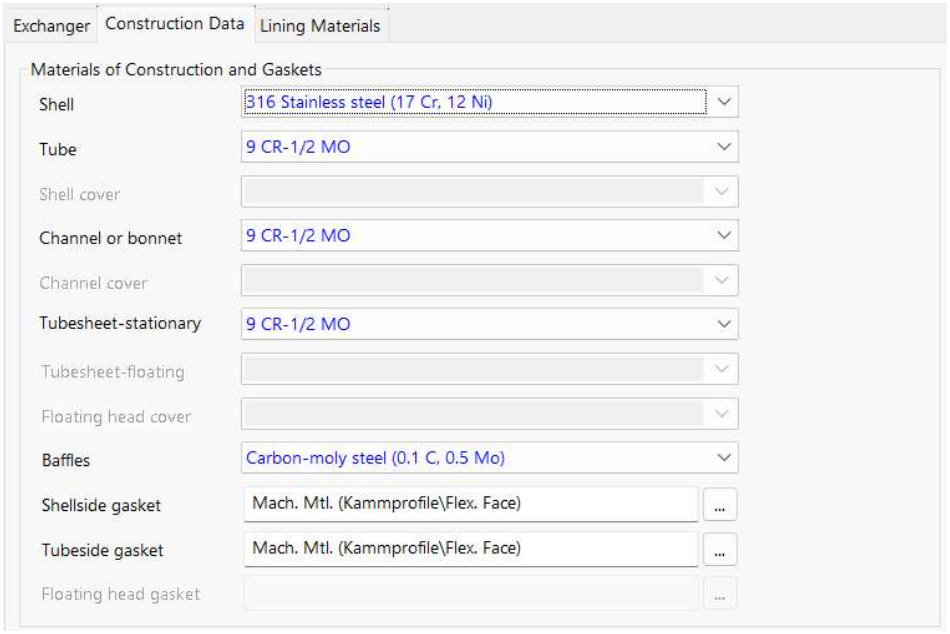


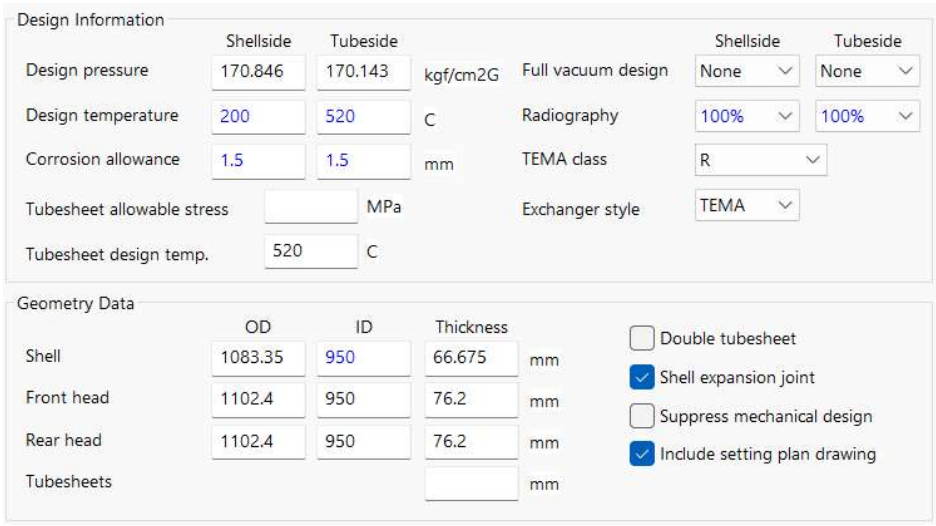
- Input Conditions

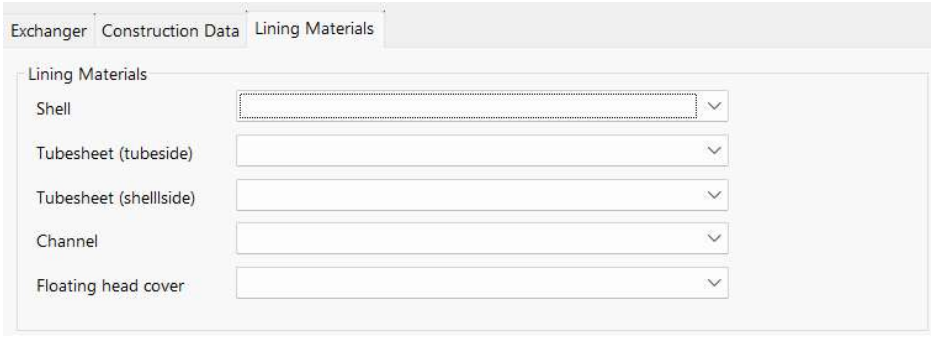


- Memilih geometri dari HE (Shell)

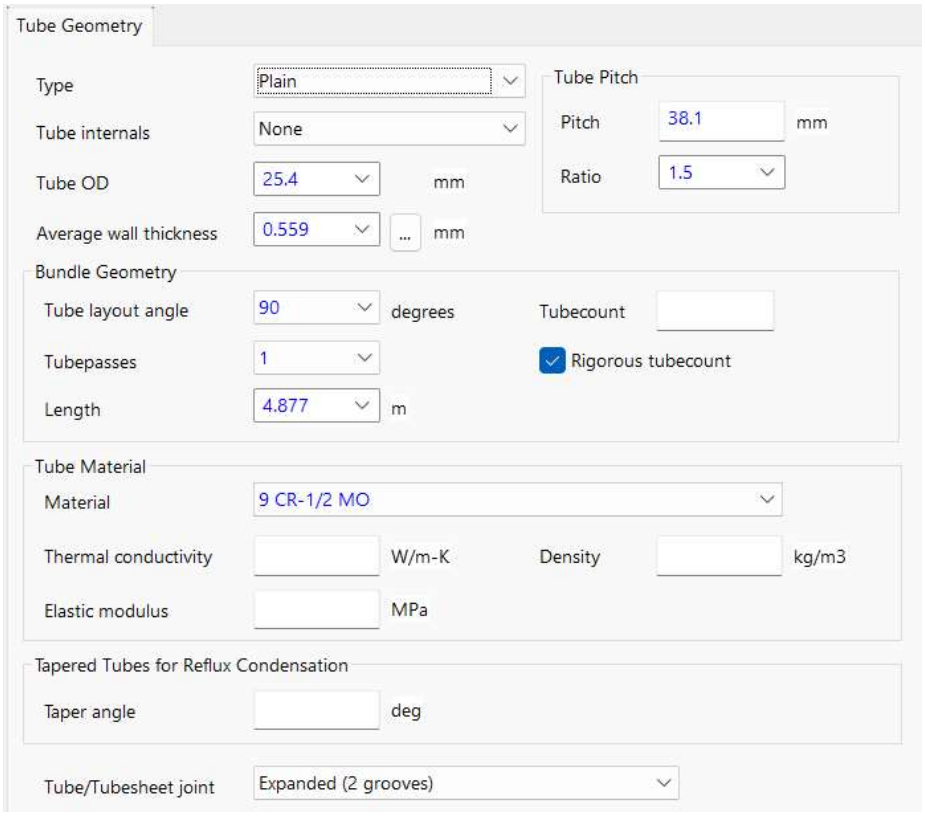




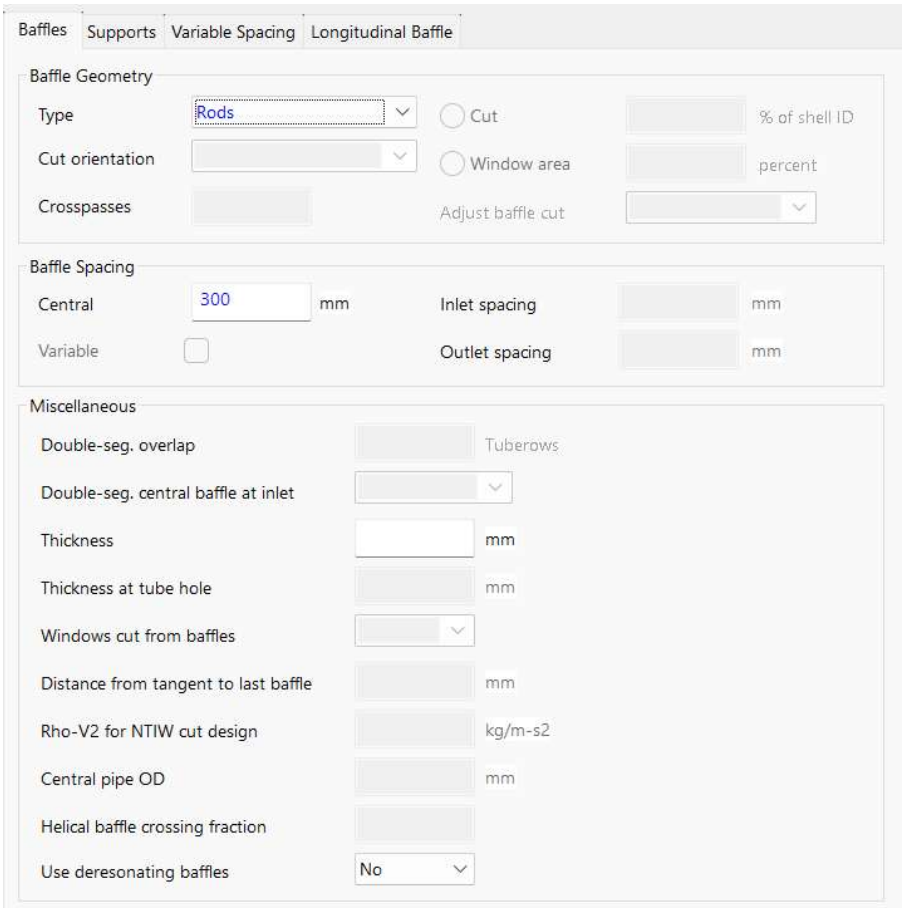


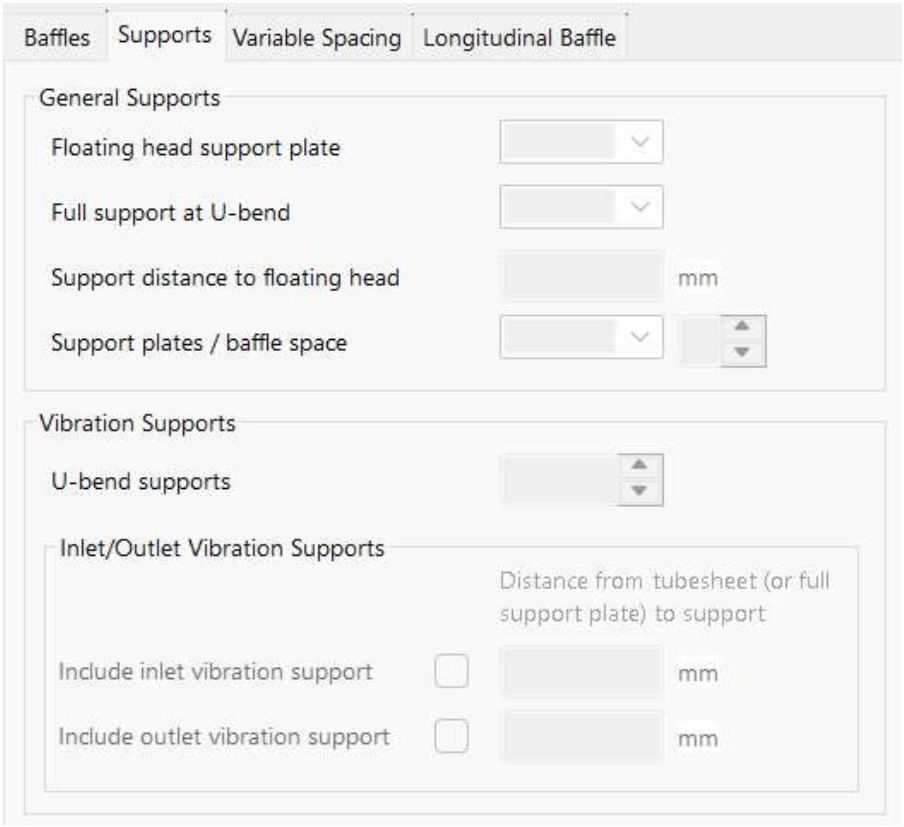


- Tube Geometri

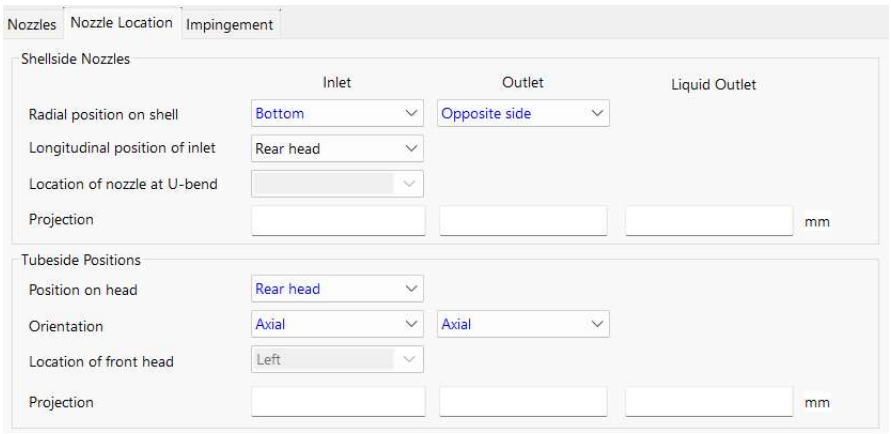


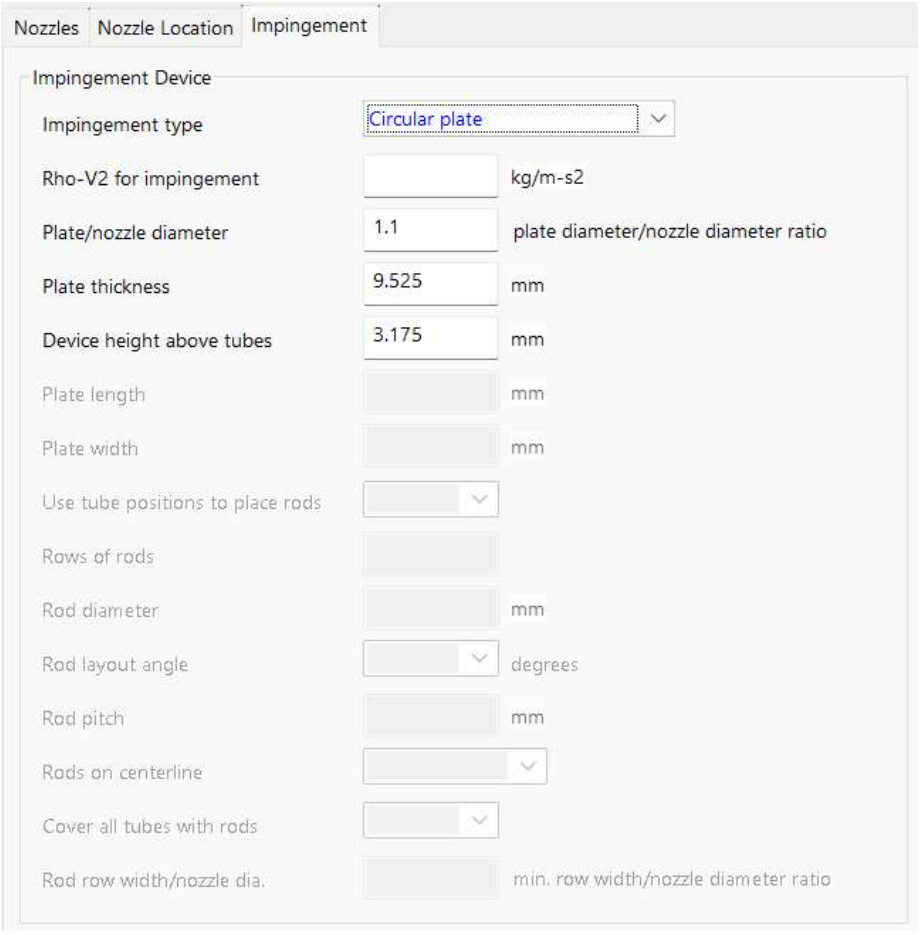
- Baffle


Baffles
Supports
Variable Spacing
Longitudinal Baffle
Baffle Geometry
Type
Rods
Cut
% of shell ID
Cut orientation
Window area
percent
Crosspasses
Adjust baffle cut
Baffle Spacing
Central
300
mm
Inlet spacing
mm
Variable
Outlet spacing
mm
Miscellaneous
Double-seg. overlap
Tuberows
Double-seg. central baffle at inlet
Thickness
mm
Thickness at tube hole
mm
Windows cut from baffles
Distance from tangent to last baffle
mm
Rho-V2 for NTIW cut design
kg/m-s2
Central pipe OD
mm
Helical baffle crossing fraction
Use deresonating baffles
No


Baffles
Supports
Variable Spacing
Longitudinal Baffle
General Supports
Floating head support plate
Full support at U-bend
Support distance to floating head
mm
Support plates / baffle space
Vibration Supports
U-bend supports
Inlet/Outlet Vibration Supports
Distance from tubesheet (or full support plate) to support
Include inlet vibration support
mm
Include outlet vibration support
mm




Nozzles
Nozzle Location
Impingement
Shellside Nozzles
Inlet
Outlet
Liquid Outlet
Radial position on shell
Bottom
Opposite side
Longitudinal position of inlet
Rear head
Location of nozzle at U-bend
Projection
mm
Tubeside Positions
Position on head
Rear head
Orientation
Axial
Axial
Location of front head
Left
Projection
mm



c. Rangkuman data input di HTRI adalah seperti pada tabel berikut

Adapun data input seperti tercantum dalam tabel dibawah ini:

Hasil simulasi HTRI adalah sebagai berikut :

- Waste Heat Boiler (WHB), 201-C

  WHB digunakan untuk memanfaatkan panas dari hasil reaksi elektrolisis dimana terdiri dari 4 bagian yaitu :

  - Pemanfaatan panas yang berasal dari produk Oksigen dan Hidrogen di SOEC yang menghasilkan Medium *Pressure* steam dengan tekanan 46.9 kg/cm2G dan Suhu 390 oC (201-C1, 201-C2).

201-C1 :

Output Summary

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:00 SN: 46639- **Customs Units**

Waste Heat Boiler (MP Steam - O2 side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

See Data Check Messages Report for Warning Messages.
See Runtime Message Report for Warning Messages.

Process Conditions		Hot Shellside		Cold Tubeside	
Fluid name		O2 Produk SOEC			BFW inlet
Total flow rate	(kg/hr)		750345		159025
Inlet/Outlet Y	(Wt. frac vap.)	1.0000	1.0000	0.0000	1.0000
Inlet/Outlet T	(Deg C)	800.00	455.17	240.94	265.00
Inlet P/Avg	(kgf/cm2G)	0.900	0.736	46.900	46.851
dP/Allow.	(kgf/cm2)	0.329	0.500	0.099	0.500
Fouling	(m2-K/W)		0.000100		0.000100

Exchanger Performance					
Shell h	(W/m2-K)	213.64	Actual U	(W/m2-K)	138.91
Tube h	(W/m2-K)	587.71	Required U	(W/m2-K)	125.37
Hot regime	(--)	Sens. Gas	Total duty	(MM kJ/hr)	287.91
Cold regime	(--)	Tran	Eff. area	(m2)	1872.7
EMTD	(Deg C)	340.7	Overdesign	(%)	10.80

Shell Geometry			Baffle Geometry		
TEMA type	(--)	BEM	Baffle type		None
Shell ID	(mm)	3600.0	Baffle cut	(Pct Dia.)	
Series	(--)	1	Baffle orientation	(--)	
Parallel	(--)	1	Central spacing	(mm)	4267.0
Orientation	(deg)	0.00	Crosspasses	(--)	1

Tube Geometry			Nozzles		
Tube type	(--)	Plain	Shell inlet	(mm)	3240.0
Tube OD	(mm)	25.400	Shell outlet	(mm)	3240.0
Length	(m)	8.534	Inlet height	(mm)	568.10
Pitch ratio	(--)	1.5000	Outlet height	(mm)	606.20
Layout	(deg)	90	Tube inlet	(mm)	154.05
Tubecount	(--)	5500	Tube outlet	(mm)	304.80
Tube Pass	(--)	1			

Thermal Resistance, %		Velocities, m/s	Min	Max	Flow Fractions	
Shell	65.02				A	
Tube	30.22	Tubeside	3.24e-2	1.12	B	0.989
Fouling	3.17	Crossflow	--	--	C	0.011
Metal	1.59	Longitudinal	36.87	45.35	E	
					F	

Final Results

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:00 SN: 46639- **Customs Units**

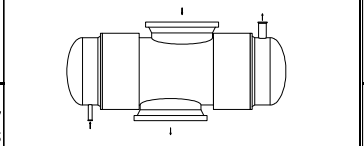
Waste Heat Boiler (MP Steam - O2 side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Process Data		Hot Shellside		Cold Tubeside	
Fluid name		O2 Produk SOEC		BFW inlet	
Fluid condition		Sens. Gas		Boil. Liquid	
Total flow rate	(kg/hr)	750345		159025	
Weight fraction vapor, In/Out	(--)	1.0000	1.0000	0.0000	1.0000
Temperature, In/Out	(Deg C)	800.00	455.17	240.94	265.00
Skin temperature, Min/Max	(Deg C)	279.06	621.32	266.32	607.97
Wall temperature, Min/Max	(Deg C)	275.34	617.42	271.08	612.96
Pressure, In/Average	(kgf/cm2G)	0.900	0.736	46.900	46.851
Pressure drop, Total/Allowed	(kgf/cm2)	0.329	0.500	0.099	0.500
Velocity, Mid/Max allow	(m/s)	42.13		0.56	
Mole fraction inert/Boiling rang	(Deg C)		0.0000		1.15e-3
Average film coef.	(W/m2-K)		213.64		587.71
Heat transfer safety factor	(--)		1.0000		1.0000
Fouling resistance	(m2-K/W)		0.000100		0.000100

Overall Performance Data

Overall coef., Reqd/Clean/Actual	(W/m2-K)	125.37 /	143.45 /	138.91
Total Duty, Calculated/Specified	(MM kJ/hr)	287.91 /		
Effective overall temperature difference	(Deg C)	340.7		
EMTD = (MTD) * (DELTA) * (F/G/H)	(Deg C)	340.8 *	0.9995 *	1.0000

See Runtime Messages Report for warnings.



Exchanger Fluid Volumes

Approximate shellside (L)	78557
Approximate tubeside (L)	77435

Shell Construction Information

TEMA shell type	BEM		Shell ID	(mm)	3600.0
Shells Series	1 Parallel	1	Total area	(m2)	3745.4
Passes Shell	1 Tube	1	Eff. area	(m2/shell)	1872.7
Shell orientation angle (deg)	0.00				
Impingement present	No				
Pairs seal strips	0		Passlane seal rods (mm)	0.000	No. 0
Shell expansion joint	No		Rear head support plate	No	
Weight estimation Wet/Dry/Bundle	1425155 /	1269234 /	165616 (kg/shell)		

Baffle Information

Type	None		Baffle cut (% dia)	
Crosspasses/shellpass	1		No. (Pct Area)	(mm) to C.L
Central spacing	(mm) 4267.0		1	
Inlet spacing	(mm) 0.000		2	
Outlet spacing	(mm) 0.000			
Baffle thickness	(mm) 0.000			
Use deresonating baffles	No			

Tube Information

Tube type	Plain		Tubecount per shell		5500
Overall length	(m) 8.534		Pct tubes removed (both)		21.14
Effective length	(m) 4.267		Outside diameter	(mm)	25.400
Total tubesheet	(mm) 4267.0		Wall thickness	(mm)	2.769
Area ratio	(out/in) 1.2788		Pitch (mm)	38.100 Ratio	1.5000
Tube metal	SA-214 Tube (W) K01807		Tube pattern (deg)		90

Shellside Performance

Nom vel, X-flow/window	0.00 / 41.99
Flow fractions for heat transfer	0.993
B=0.9893 C=0.0107	

Shellside Heat Transfer Corrections

Total	Beta	Gamma	End	Fin
0.982	0.920	1.067	1.000	1.000

Pressure Drops (Percent of Total)

Cross	Window	Ends	Nozzle	Shell	Tube
0.00	84.11	9.17	Inlet	3.76	39.52
MOMENTUM		0.00	Outlet	2.96	58.82

Two-Phase Parameters

Method	Inlet	Center	Outlet	Mix F
PP/TBR	Subcool	Tran	Mist	

H. T. Parameters		Shell	Tube
Overall wall correction			
Midpoint	Prandtl no.	0.80	
Midpoint	Reynolds no.	21046	7032
Bundle inlet	Reynolds no.	13792	4758
Bundle outlet	Reynolds no.	19346	28365
Fouling layer	(mm)		

Thermal Resistance, %

Shell	Tube	Fouling	Metal	Over Des
65.02	30.22	3.17	1.59	10.80

Total fouling resistance	(m2-K/W)	2.28e-4
Differential resistance	(m2-K/W)	7.78e-4

Shell Nozzles

Inlet at channel end: No

		Inlet	Outlet	Liquid Outlet
Number at each position		1	1	0
Diameter	(mm)	3240.0	3240.0	
Velocity	(m/s)	40.35	32.96	
Pressure drop	(kgf/cm2)	0.012	9.72e-3	
Height under nozzle	(mm)	568.10	606.20	
Nozzle R-V-SQ	(kg/m-s2)	1020.0	833.28	
Shell ent.	(kg/m-s2)	2099.3	1604.9	

Tube Nozzle		Inlet RADIAL	Outlet RADIAL	Liquid Outlet
Diameter	(mm)	154.05	304.80	
Velocity	(m/s)	2.93	26.84	
Pressure drop	(kgf/cm2)	0.039	0.058	
Nozzle R-V-SQ	(kg/m-s2)	6948.7	16251	

Annular Distributor		Inlet	Outlet
Length	(mm)		
Height	(mm)		
Slot area	(mm2)		

Diametral Clearances (mm)

Baffle-to-shell	Bundle-to-shell	Tube-to-baffle
11.113	18.215	0.0000

Supplementary Results

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:00 SN: 46639- **Customs Units**

Waste Heat Boiler (MP Steam - O2 side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Externally Enhanced Tube Geometry			Internally Enhanced Tube Geometry		
Type		Plain	Type		None
Fin density	(fin/meter)		Thickness	(mm)	
Fin height	(mm)		Pitch	(L/D)	
Fin thickness	(mm)				
Root diameter	(mm)				
Area/length	(m2/m)				

Mean Metal Temperatures

Mean shell temperature	634.64 (C)
Tubesheet temperature	832.22 (C)

Mean tube metal temperature in each tubepass, (C)

Tube Pass	Inside	Outside	Radial
1	404.90	410.32	407.83

Stream Properties

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:00 SN: 46639- **Customs Units**

Waste Heat Boiler (MP Steam - O2 side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Hot Shellside Fluid		**Inlet**	**Outlet**
Fluid name		O2 Produk SOEC	
Flow	(kg/hr)	750345	
Temperature	(C)	800.00	455.17
Pressure	(kgf/cm2G)	0.900	0.571
Weight fraction vapor	(--)	1.0000	1.0000
Vapor Properties			
Flow	(kg/hr)	750345	750345
Density	(kg/m3)	0.6265	0.7661
Viscosity	(cP)	0.0522	0.0372
Conductivity	(W/m-K)	0.0715	0.0530
Heat capacity	(kJ/kg-C)	1.1404	1.0809
Molecular weight	(--)	29.500	29.500
Liquid Properties			
Flow	(kg/hr)	0.0000	0.0000
Density	(kg/m3)	1055.7	1056.8
Viscosity	(cP)	5.5242	5.9059
Conductivity	(W/m-K)	0.4873	0.4835
Heat capacity	(kJ/kg-C)	4.3917	4.3958
Molecular weight	(--)	18.017	18.016
Latent heat	(kJ/kg)	2363.6	2412.8
Surface tension	(dyne/cm)	83.563	83.855

Molar Composition	**MW**	**Vapor**	**Liquid**	**K-Value**	**Vapor**	**Liquid**	**K-Value**
1 Nitrogen	28.01	0.6428	1.37e-4	4705.2	0.6428	1.25e-4	5152.7
2 Oxygen	32.00	0.3492	2.72e-7	1281720	0.3492	2.12e-7	1643652
3 Argon	39.95	0.0076	1.3e-11	6.12e+8	0.0076	9.1e-12	8.42e+8
4 CO2	44.01	2.48e-4	2.87e-6	86.433	2.48e-4	2.63e-6	94.131
5 H2O	18.02	8.26e-5	0.9999	8.26e-5	8.26e-5	0.9999	8.26e-5

Mass Composition	**Vapor**	**Liquid**	**Vapor**	**Liquid**
1 Nitrogen	0.6104	2.12e-4	0.6104	1.94e-4
2 Oxygen	0.3788	4.84e-7	0.3788	3.77e-7
3 Argon	0.0104	2.8e-11	0.0104	2.0e-11
4 CO2	3.70e-4	7.00e-6	3.70e-4	6.43e-6
5 H2O	5.04e-5	0.9998	5.04e-5	0.9998

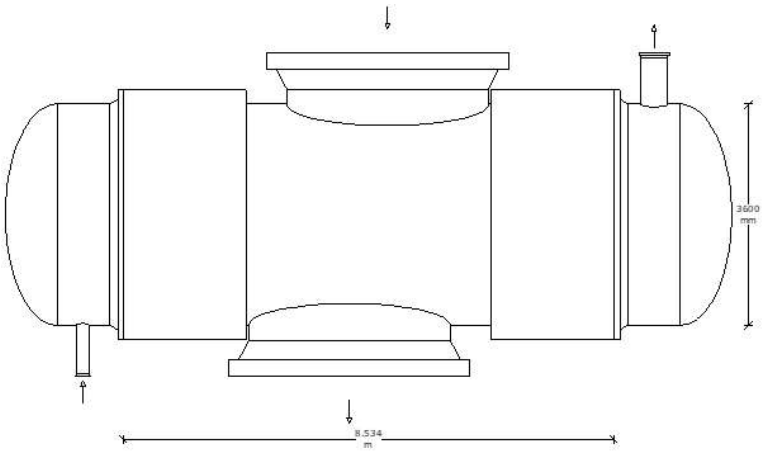
Stream Properties

Released to the following company:
-
Tugas Akhir

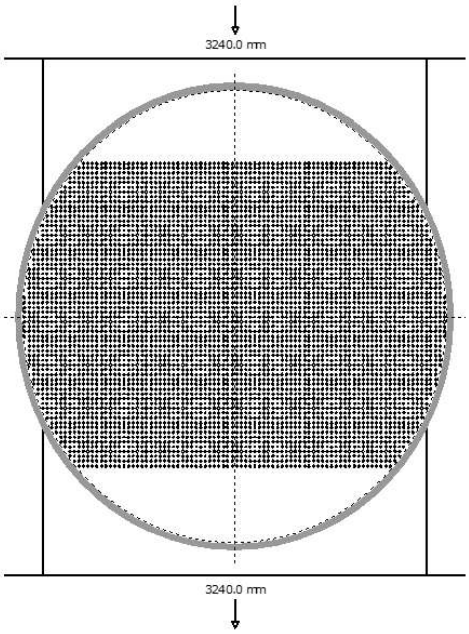
Xist 9 (32 bit) 24-Dec-25 22:00 SN: 46639- **Customs Units**

Waste Heat Boiler (MP Steam - O2 side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Cold Tubeside Fluid		**Inlet**			**Outlet**		
Fluid name		BFW inlet					
Flow	(kg/hr)	159025					
Temperature	(C)	240.94			265.00		
Pressure	(kgf/cm2G)	46.900			46.801		
Weight fraction vapor	(--)	0.0000			1.0000		
Vapor Properties							
Flow	(kg/hr)	0.0000			159025		
Density	(kg/m3)	22.888			22.552		
Viscosity	(cP)	0.0179			0.0181		
Conductivity	(W/m-K)	0.0527			0.0523		
Heat capacity	(kJ/kg-C)	2.4891			2.4780		
Molecular weight	(--)	18.015			18.015		
Liquid Properties							
Flow	(kg/hr)	159025			0.0000		
Density	(kg/m3)	808.32			780.14		
Viscosity	(cP)	0.1110			0.1026		
Conductivity	(W/m-K)	0.6269			0.6019		
Heat capacity	(kJ/kg-C)	5.3272			5.6987		
Molecular weight	(--)	18.015			18.015		
Latent heat	(kJ/kg)	1688.4			1689.1		
Surface tension	(dyne/cm)	28.292			23.482		
Molar Composition		**Vapor**	**Liquid**	**K-Value**	**Vapor**	**Liquid**	**K-Value**



Unit	201-C	Total tube inlet nozzles	1	StreamID	Shellside		Tubeside
Item no.	201-C1	Total tube outlet nozzles	1	Stream name	O2 Produk SOEC		BFW inlet
TEMA type	BEM	Total shell inlet nozzles	1	Flow (total), kg/hr	750345		159025
Shell diameter	3600 mm	Total shell outlet nozzles	1	Pressure drop, kgf/cm2	0.329		0.099
Tube length	8.534 m			Temperature, C	800.00	455.17	240.94 265.00
Dry weight	1269234 kg/shell			Wt. fraction vapor	1.0000	1.0000	0.0000 1.0000
Wet weight	1425155 kg/shell			Pressure, kgf/cm2G	0.900	0.571	46.900 46.801
Bundle weight	165616 kg/shell						



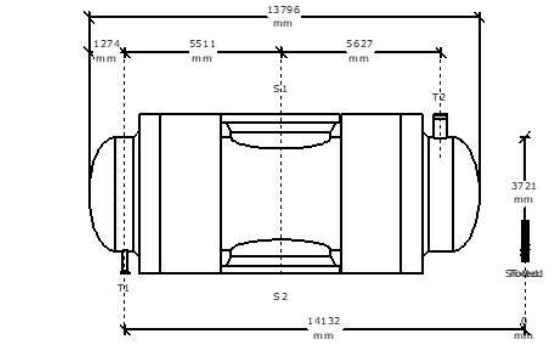
Unit	201-C
Item no.	201-C1
TEMA type	BEM
Shell ID	3600.0 mm
Actual OTL	3581.8 mm
Height under inlet nozzle	568.10 mm
Height under outlet nozzle	606.20 mm
Tube type	Plain
Tube OD	25.400 mm
Tube pitch	38.100 mm
Tube layout angle	90 deg
Tubes	5500
Tube positions available	5474
Tie rods	12
Seal strip pairs	0
Tube Passes	1

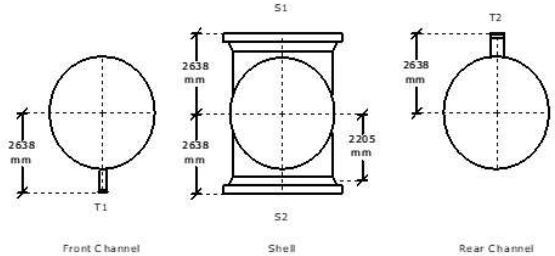
TUBEPASS DETAILS

Pass	Rows	Tubes
1	64	5474

SYMBOL LEGEND

- Tube
- Dummy Short Tube
- Dummy Long Tube
- Plugged Tube
- Tie Rod
- Seal Rod
- Impingement Rod





	Nozzles	OD, mm	Rating	Design	Shell	Tube	Weight	kg
S1	Inlet	3500.3		Pres (kgf/cm2G)	5.273	52.027	Bundle	165818
T1	Inlet	223.9		Temp (C)	832.22	293.33	Dry	1269234
S2	Outlet	3500.3		Passes	1	1	Wet	1425155
T2	Outlet	450.85		Thick (mm)	60.325	2.769		

Unit	201-C		
Company	-		
Customer		Ref	
Item No.	201-C1		
Service			
TEMA	BEM		Setting Plan
Date	24-Dec-25	By	
Diagram		Rev	

201-C2 :

Output Summary

Page 1

Released to the following company:

-

Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:01 SN: 46639- **Customs Units**

Waste Heat Boiler (MP Steam H2 Side) : 201-C

Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

See Data Check Messages Report for Warning Messages.

See Runtime Message Report for Warning Messages.

Process Conditions		Hot Shellside		Cold Tubeside	
Fluid name		H2 Produk SOEC			BFW inlet
Total flow rate	(kg/hr)		14111		159025
Inlet/Outlet Y	(Wt. frac vap.)	1.0000	1.0000	1.0000	1.0000
Inlet/Outlet T	(Deg C)	800.00	576.11	265.00	390.00
Inlet P/Avg	(kgf/cm2G)	2.500	2.477	46.900	46.843
dP/Allow.	(kgf/cm2)	0.046	0.500	0.115	0.500
Fouling	(m2-K/W)		0.000100		0.000100

Exchanger Performance					
Shell h	(W/m2-K)	183.09	Actual U	(W/m2-K)	66.13
Tube h	(W/m2-K)	137.23	Required U	(W/m2-K)	36.28
Hot regime	(--)	Sens. Gas	Total duty	(MM kJ/hr)	46.918
Cold regime	(--)	Sens. Gas	Eff. area	(m2)	999.41
EMTD	(Deg C)	359.5	Overdesign	(%)	82.28

Shell Geometry			Baffle Geometry		
TEMA type	(--)	BEM	Baffle type		None
Shell ID	(mm)	3600.0	Baffle cut	(Pct Dia.)	
Series	(--)	1	Baffle orientation	(--)	
Parallel	(--)	1	Central spacing	(mm)	1828.4
Orientation	(deg)	0.00	Crosspasses	(--)	1

Tube Geometry			Nozzles		
Tube type	(--)	Plain	Shell inlet	(mm)	742.95
Tube OD	(mm)	25.400	Shell outlet	(mm)	742.95
Length	(m)	2.438	Inlet height	(mm)	34.700
Pitch ratio	(--)	1.5000	Outlet height	(mm)	34.700
Layout	(deg)	90	Tube inlet	(mm)	336.55
Tubecount	(--)	6850	Tube outlet	(mm)	336.55
Tube Pass	(--)	1			

Thermal Resistance, %		Velocities, m/s	Min	Max	Flow Fractions	
Shell	36.12				A	
Tube	61.62	Tubeside	0.93	1.24	B	0.990
Fouling	1.51	Crossflow	--	--	C	0.010
Metal	0.76	Longitudinal	5.94	7.39	E	
					F	

Final Results

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:01 SN: 46639- **Customs Units**

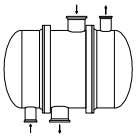
Waste Heat Boiler (MP Steam H2 Side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Process Data		Hot Shellside		Cold Tubeside	
Fluid name		H2 Produk SOEC		BFW inlet	
Fluid condition		Sens. Gas		Sens. Gas	
Total flow rate	(kg/hr)	14111		159025	
Weight fraction vapor, In/Out	(--)	1.0000	1.0000	1.0000	1.0000
Temperature, In/Out	(Deg C)	800.00	576.11	265.00	390.00
Skin temperature, Min/Max	(Deg C)	461.71	650.43	454.38	641.23
Wall temperature, Min/Max	(Deg C)	459.57	647.74	457.12	644.67
Pressure, In/Average	(kgf/cm2G)	2.500	2.477	46.900	46.843
Pressure drop, Total/Allowed	(kgf/cm2)	0.046	0.500	0.115	0.500
Velocity, Mid/Max allow	(m/s)	6.60		1.08	
Mole fraction inert/Boiling rang	(Deg C)		0.0000		0.0
Average film coef.	(W/m2-K)		183.09		137.23
Heat transfer safety factor	(--)		1.0000		1.0000
Fouling resistance	(m2-K/W)		0.000100		0.000100

Overall Performance Data

Overall coef., Reqd/Clean/Actual	(W/m2-K)	36.28	/	67.14	/	66.13
Total Duty, Calculated/Specified	(MM kJ/hr)	46.918	/			
Effective overall temperature difference	(Deg C)	359.5				
EMTD = (MTD) * (DELTA) * (F/G/H)	(Deg C)	359.6	*	0.9998	*	1.0000

See Runtime Messages Report for warnings.



Exchanger Fluid Volumes

Approximate shellside(L)	16673
Approximate tubeside(L)	86055

Shell Construction Information

TEMA shell type	BEM		Shell ID	(mm)	3600.0
Shells Series	1	Parallel 1	Total area	(m2)	1332.6
Passes Shell	1	Tube 1	Eff. area	(m2/shell)	999.41
Shell orientation angle (deg)	0.00				
Impingement present	No				
Pairs seal strips	0		Passlane seal rods (mm)	0.000	No. 0
Shell expansion joint	No		Rear head support plate	No	
Weight estimation Wet/Dry/Bundle	1212026	/ 1109345	/ 35741	(kg/shell)	

Baffle Information

Type	None		Baffle cut (% dia)	
Crosspasses/shellpass	1		No.(Pct Area)	(mm) to C.L
Central spacing	(mm) 1828.4		1	
Inlet spacing	(mm) 0.000		2	
Outlet spacing	(mm) 0.000			
Baffle thickness	(mm) 0.000			
Use deresonating baffles	No			

Tube Information

Tube type	Plain		Tubecount per shell		6850
Overall length	(m)	2.438	Pct tubes removed (both)		0.2
Effective length	(m)	1.828	Outside diameter	(mm)	25.400
Total tubesheet	(mm)	609.60	Wall thickness	(mm)	2.769
Area ratio	(out/in)	1.2788	Pitch (mm)	38.100 Ratio	1.5000
Tube metal	SA-214 Tube (W) K01807		Tube pattern (deg)		90

Shellside Performance

Nom vel, X-flow/window 0.00 / 6.56

Flow fractions for heat transfer 0.993
B=0.9903 C=0.0097

Shellside Heat Transfer Corrections

Total	Beta	Gamma	End	Fin
0.983	0.920	1.069	1.000	1.000

Pressure Drops (Percent of Total)

Cross	Window	Ends	Nozzle	Shell	Tube
0.00	16.88	1.88	Inlet	45.67	53.24
MOMENTUM		0.00	Outlet	35.58	46.17

Two-Phase Parameters

Method	Inlet	Center	Outlet	Mix F

H. T. Parameters		Shell	Tube
Overall wall correction			0.849
Midpoint	Prandtl no.	0.82	0.95
Midpoint	Reynolds no.	900	19562
Bundle inlet	Reynolds no.	541	22583
Bundle outlet	Reynolds no.	795	16953
Fouling layer	(mm)		

Thermal Resistance, %

Shell	Tube	Fouling	Metal	Over Des
36.12	61.62	1.51	0.76	82.28

Total fouling resistance (m2-K/W) 2.28e-4
Differential resistance (m2-K/W) 0.0124

Shell Nozzles

Inlet at channel end No

		Inlet	Outlet	Liquid Outlet
Number at each position		1	1	0
Diameter	(mm)	742.95	742.95	
Velocity	(m/s)	113.74	91.20	
Pressure drop	(kgf/cm2)	0.021	0.016	
Height under nozzle	(mm)	34.700	34.700	
Nozzle R-V-SQ	(kg/m-s2)	1028.4	824.60	
Shell ent.	(kg/m-s2)	5037.9	4039.7	

Tube Nozzle		Inlet RADIAL	Outlet RADIAL	Liquid Outlet
Diameter	(mm)	336.55	336.55	
Velocity	(m/s)	21.96	29.91	
Pressure drop	(kgf/cm2)	0.061	0.053	
Nozzle R-V-SQ	(kg/m-s2)	10902	14855	

Annular Distributor		Inlet	Outlet
Length	(mm)		
Height	(mm)		
Slot area	(mm2)		

Diametral Clearances (mm)

Baffle-to-shell	Bundle-to-shell	Tube-to-baffle
11.113	18.215	0.0000

Supplementary Results

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:01 SN: 46639- **Customs Units**

Waste Heat Boiler (MP Steam H2 Side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Externally Enhanced Tube Geometry			Internally Enhanced Tube Geometry		
Type		Plain	Type		None
Fin density	(fin/meter)		Thickness	(mm)	
Fin height	(mm)		Pitch	(L/D)	
Fin thickness	(mm)				
Root diameter	(mm)				
Area/length	(m2/m)				

Mean Metal Temperatures

Mean shell temperature	684.67 (C)
Tubesheet temperature	832.22 (C)

Mean tube metal temperature in each tubepass, (C)

Tube Pass	Inside	Outside	Radial
1	549.84	552.56	551.31

Stream Properties

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:01 SN: 46639- **Customs Units**

Waste Heat Boiler (MP Steam H2 Side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Hot Shellside Fluid		**Inlet**	**Outlet**
Fluid name		H2 Produk SOEC	
Flow	(kg/hr)	14111	
Temperature	(C)	800.00	576.11
Pressure	(kgf/cm2G)	2.500	2.454
Weight fraction vapor	(--)	1.0000	1.0000
Vapor Properties			
Flow	(kg/hr)	14111	14111
Density	(kg/m3)	0.0795	0.0991
Viscosity	(cP)	0.0277	0.0188
Conductivity	(W/m-K)	0.4387	0.3708
Heat capacity	(kJ/kg-C)	15.021	14.655
Molecular weight	(--)	2.0480	2.0480
Liquid Properties			
Flow	(kg/hr)	0.0000	0.0000
Density	(kg/m3)	1024.5	1024.6
Viscosity	(cP)	1.6490	1.6585
Conductivity	(W/m-K)	0.5723	0.5720
Heat capacity	(kJ/kg-C)	4.3235	4.3237
Molecular weight	(--)	18.015	18.015
Latent heat	(kJ/kg)	2556.9	2556.9
Surface tension	(dyne/cm)	76.066	76.097

Molar Composition	**MW**	**Vapor**	**Liquid**	**K-Value**	**Vapor**	**Liquid**	**K-Value**
1 Hydrogen	2.02	0.9980	1.79e-6	557547	0.9980	1.76e-6	568336
2 H2O	18.02	0.0020	1.0000	0.0020	0.0020	1.0000	0.0020

Mass Composition	**Vapor**	**Liquid**	**Vapor**	**Liquid**
1 Hydrogen	0.9824	2.00e-7	0.9824	1.97e-7
2 H2O	0.0176	1.0000	0.0176	1.0000

Stream Properties

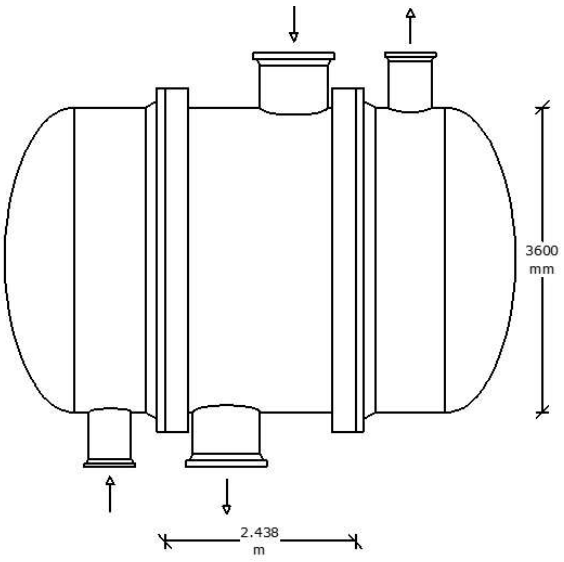
Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:01 SN: 46639- **Customs Units**

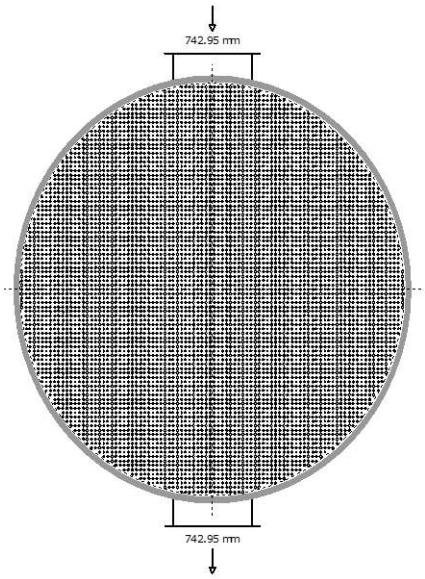
Waste Heat Boiler (MP Steam H2 Side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

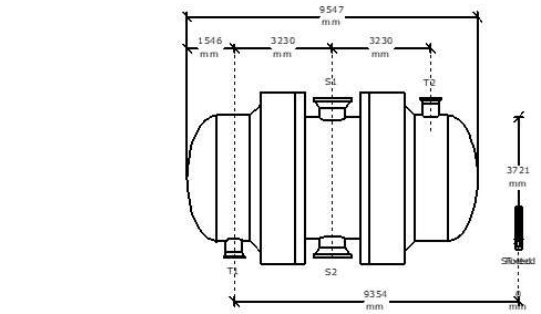
Cold Tubeside Fluid		Inlet	Outlet
Fluid name		BFW inlet	
Flow	(kg/hr)	159025	
Temperature	(C)	265.00	390.00
Pressure	(kgf/cm2G)	46.900	46.785
Weight fraction vapor	(--)	1.0000	1.0000
Vapor Properties			
Flow	(kg/hr)	159025	159025
Density	(kg/m3)	22.616	16.599
Viscosity	(cP)	0.0181	0.0245
Conductivity	(W/m-K)	0.0523	0.0587
Heat capacity	(kJ/kg-C)	2.4760	2.3056
Molecular weight	(--)	18.015	18.015
Liquid Properties			
Flow	(kg/hr)	--	--
Density	(kg/m3)	--	--
Viscosity	(cP)	--	--
Conductivity	(W/m-K)	--	--
Heat capacity	(kJ/kg-C)	--	--
Molecular weight	(--)	--	--
Latent heat	(kJ/kg)	--	--
Surface tension	(dyne/cm)	--	--

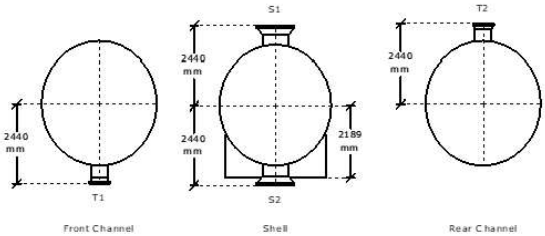
Molar Composition	Vapor	Liquid	K-Value	Vapor	Liquid	K-Value



					Shellside	Tubeside
Unit	201-C	Total tube inlet nozzles	1	Stream ID		
Item no.	201-C2	Total tube outlet nozzles	1	Stream name	H2 Produk SCB1	BFW inlet
TEMA type	BEM	Total shell inlet nozzles	1	Flow (total), kg/hr	14111	159025
Shell diameter	3600 mm	Total shell outlet nozzles	1	Pressure drop, kgf/cm2	0.046	0.115
Tube length	2.438 m			Temperature, C	800.00 576.11	265.00 390.00
Dry weight	1209345 kg/shell			Wt. fraction vapor	1.0000 1.0000	1.0000 1.0000
Wet weight	1212026 kg/shell			Pressure, kgf/cm2G	2.500 2.454	46.900 46.785
Bundle weight	35741 kg/shell					







	Nozzles	OD, mm	Rating	Design	Shell	Tube	Weight	kg
S1	Inlet	863.6		Pres (kgf/cm2G)	5.273	52.027	Bundle	35741
T1	Inlet	546.1		Temp (C)	832.22	421.11	Dry	1109345
S2	Outlet	863.6		Passes	1	1	Wet	1212026
T2	Outlet	546.1		Thick (mm)	60.325	2.769		

Unit	201-C		
Company	-		
Customer		Ref	
Item No.	201-C2		
Service			
TEMA	BEM		Setting Plan
Date	24-Dec-25	By	
Diagram		Rev	

- Pemanfaatan panas yang berasal dari produk Oksigen dan Hidrogen di SOEC yang menghasilkan Low *Pressure* steam dengan tekanan 5 kg/cm2G dan Suhu 180 oC (201-C3, 201-C4)

201-C3:

Output Summary

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 21:54 SN: 46639- **Customs Units**

Waste Heat Boiler (LP Steam - O2 side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

See Data Check Messages Report for Warning Messages.
See Runtime Message Report for Warning Messages.

Process Conditions		Hot Shellside		Cold Tubeside	
Fluid name		O2 Produk SOEC			BFW inlet
Total flow rate	(kg/hr)		750345		96613
Inlet/Outlet Y	(Wt. frac vap.)	1.0000	1.0000	0.0000	1.0000
Inlet/Outlet T	(Deg C)	455.16	169.96	115.00	170.00
Inlet P/Avg	(kgf/cm2G)	0.900	0.815	5.000	4.981
dP/Allow.	(kgf/cm2)	0.169	0.500	0.037	0.500
Fouling	(m2-K/W)		0.000100		0.000100

Exchanger Performance					
Shell h	(W/m2-K)	124.17	Actual U	(W/m2-K)	86.43
Tube h	(W/m2-K)	398.37	Required U	(W/m2-K)	83.22
Hot regime	(--)	Sens. Gas	Total duty	(MM kJ/hr)	225.17
Cold regime	(--)	Tran	Eff. area	(m2)	6911.5
EMTD	(Deg C)	108.7	Overdesign	(%)	3.86

Shell Geometry			Baffle Geometry		
TEMA type	(--)	BEM	Baffle type		None
Shell ID	(mm)	3600.0	Baffle cut	(Pct Dia.)	
Series	(--)	1	Baffle orientation	(--)	
Parallel	(--)	1	Central spacing	(mm)	12644
Orientation	(deg)	0.00	Crosspasses	(--)	1

Tube Geometry			Nozzles		
Tube type	(--)	Plain	Shell inlet	(mm)	3240.0
Tube OD	(mm)	25.400	Shell outlet	(mm)	2993.6
Length	(m)	13.000	Inlet height	(mm)	34.700
Pitch ratio	(--)	1.5000	Outlet height	(mm)	34.700
Layout	(deg)	90	Tube inlet	(mm)	128.19
Tubecount	(--)	6850	Tube outlet	(mm)	641.35
Tube Pass	(--)	1			

Thermal Resistance, %		Velocities, m/s	Min	Max	Flow Fractions	
Shell	69.61				A	
Tube	27.74	Tubeside	1.36e-2	3.96	B	0.987
Fouling	1.97	Crossflow	--	--	C	0.013
Metal	0.68	Longitudinal	22.48	33.39	E	
					F	

Final Results

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 21:54 SN: 46639- **Customs Units**

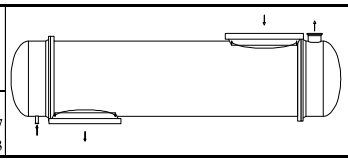
Waste Heat Boiler (LP Steam - O2 side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Process Data		Hot Shellside		Cold Tubeside	
Fluid name		O2 Produk SOEC		BFW inlet	
Fluid condition		Sens. Gas		Boil. Liquid	
Total flow rate	(kg/hr)	750345		96613	
Weight fraction vapor, In/Out	(--)	1.0000	1.0000	0.0000	1.0000
Temperature, In/Out	(Deg C)	455.16	169.96	115.00	170.00
Skin temperature, Min/Max	(Deg C)	131.92	343.71	130.40	340.69
Wall temperature, Min/Max	(Deg C)	131.42	342.73	131.03	341.95
Pressure, In/Average	(kgf/cm2G)	0.900	0.815	5.000	4.981
Pressure drop, Total/Allowed	(kgf/cm2)	0.169	0.500	0.037	0.500
Velocity, Mid/Max allow	(m/s)	25.50		0.87	
Mole fraction inert/Boiling rang	(Deg C)		0.0000		1.87e-3
Average film coef.	(W/m2-K)		124.17		398.37
Heat transfer safety factor	(--)		1.0000		1.0000
Fouling resistance	(m2-K/W)		0.000100		0.000100

Overall Performance Data

Overall coef., Reqd/Clean/Actual	(W/m2-K)	83.22	/	88.17	/	86.43
Total Duty, Calculated/Specified	(MM kJ/hr)	225.17	/			
Effective overall temperature difference	(Deg C)	108.7				
EMTD = (MTD) * (DELTA) * (F/G/H)	(Deg C)	109.0	*	0.9974	*	1.0000

See Runtime Messages Report for warnings.



Exchanger Fluid Volumes

Approximate shellside(L)	91617
Approximate tubeside(L)	79243

Shell Construction Information

TEMA shell type	BEM		Shell ID	(mm)	3600.0
Shells Series	1 Parallel	1	Total area	(m2)	7105.9
Passes Shell	1 Tube	1	Eff. area	(m2/shell)	6911.5
Shell orientation angle (deg)	0.00				
Impingement present	No				
Pairs seal strips	0		Passlane seal rods (mm)	0.000	No. 0
Shell expansion joint	No		Rear head support plate	No	
Weight estimation Wet/Dry/Bundle	405318	/ 234536	/ 155946	(kg/shell)	

Baffle Information

Type	None		Baffle cut (% dia)		
Crosspasses/shellpass	1		No.(Pct Area)	(mm)	to C.L
Central spacing	(mm)	12644	1		
Inlet spacing	(mm)	0.000	2		
Outlet spacing	(mm)	0.000			
Baffle thickness	(mm)	0.000			
Use deresonating baffles	No				

Tube Information

Tube type	Plain		Tubecount per shell		6850
Overall length	(m)	13.000	Pct tubes removed (both)		0.2
Effective length	(m)	12.644	Outside diameter	(mm)	25.400
Total tubesheet	(mm)	355.60	Wall thickness	(mm)	2.769
Area ratio	(out/in)	1.2788	Pitch (mm)	38.100 Ratio	1.5000
Tube metal	SA-214 Tube (W) K01807		Tube pattern (deg)		90

Shellside Performance

Nom vel, X-flow/window 0.00 / 25.43

Flow fractions for heat transfer 0.991
B=0.9874 C=0.0126

Shellside Heat Transfer Corrections

Total	Beta	Gamma	End	Fin
0.983	0.920	1.069	1.000	1.000

Pressure Drops (Percent of Total)

Cross	Window	Ends	Nozzle	Shell	Tube
0.00	74.15	8.63	Inlet	9.04	70.07
MOMENTUM		-0.00	Outlet	8.18	22.41

Two-Phase Parameters

Method	Inlet	Center	Outlet	Mix F
PP/TBR	Sens Liq	Tran	Tran	

H. T. Parameters		Shell	Tube
Overall wall correction			
Midpoint	Prandtl no.	0.73	
Midpoint	Reynolds no.	36118	1697
Bundle inlet	Reynolds no.	21320	1106
Bundle outlet	Reynolds no.	31009	17075
Fouling layer	(mm)		

Thermal Resistance, %

Shell	Tube	Fouling	Metal	Over Des
69.61	27.74	1.97	0.68	3.86

Total fouling resistance (m2-K/W) 2.28e-4
Differential resistance (m2-K/W) 4.46e-4

Shell Nozzles

Inlet at channel end No

		Inlet	Outlet	Liquid Outlet
Number at each position		1	1	0
Diameter	(mm)	3240.0	2993.6	
Velocity	(m/s)	27.39	21.37	
Pressure drop	(kgf/cm2)	0.015	0.014	
Height under nozzle	(mm)	34.700	34.700	
Nozzle R-V-SQ	(kg/m-s2)	692.31	632.78	
Shell ent.	(kg/m-s2)	5117.9	4684.4	

Tube Nozzle		Inlet RADIAL	Outlet RADIAL	Liquid Outlet
Diameter	(mm)	128.19	641.35	
Velocity	(m/s)	2.22	27.96	
Pressure drop	(kgf/cm2)	0.026	8.29e-3	
Nozzle R-V-SQ	(kg/m-s2)	4622.3	2323.1	

Annular Distributor		Inlet	Outlet
Length	(mm)		
Height	(mm)		
Slot area	(mm2)		

Diametral Clearances (mm)

Baffle-to-shell	Bundle-to-shell	Tube-to-baffle
11.113	18.215	0.0000

Stream Properties

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 21:54 SN: 46639- **Customs Units**

Waste Heat Boiler (LP Steam - O2 side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Hot Shellside Fluid		**Inlet**	**Outlet**
Fluid name		O2 Produk SOEC	
Flow	(kg/hr)	750345	
Temperature	(C)	455.16	169.96
Pressure	(kgf/cm2G)	0.900	0.731
Weight fraction vapor	(--)	1.0000	1.0000
Vapor Properties			
Flow	(kg/hr)	750345	750345
Density	(kg/m3)	0.9231	1.3850
Viscosity	(cP)	0.0373	0.0256
Conductivity	(W/m-K)	0.0530	0.0359
Heat capacity	(kJ/kg-C)	1.0809	1.0210
Molecular weight	(--)	29.500	29.500
Liquid Properties			
Flow	(kg/hr)	0.0000	0.0000
Density	(kg/m3)	1055.7	1056.3
Viscosity	(cP)	5.5242	5.7076
Conductivity	(W/m-K)	0.4873	0.4855
Heat capacity	(kJ/kg-C)	4.3917	4.3937
Molecular weight	(--)	18.017	18.016
Latent heat	(kJ/kg)	2363.6	2388.8
Surface tension	(dyne/cm)	83.563	83.707

Molar Composition	**MW**	**Vapor**	**Liquid**	**K-Value**	**Vapor**	**Liquid**	**K-Value**
1 Nitrogen	28.01	0.6428	1.37e-4	4705.2	0.6428	1.31e-4	4921.3
2 Oxygen	32.00	0.3492	2.72e-7	1281720	0.3492	2.41e-7	1447831
3 Argon	39.95	0.0076	1.3e-11	6.12e+8	0.0076	1.1e-11	7.15e+8
4 CO2	44.01	2.48e-4	2.87e-6	86.433	2.48e-4	2.75e-6	90.150
5 H2O	18.02	8.26e-5	0.9999	8.26e-5	8.26e-5	0.9999	8.26e-5

Mass Composition	**Vapor**	**Liquid**	**Vapor**	**Liquid**
1 Nitrogen	0.6104	2.12e-4	0.6104	2.03e-4
2 Oxygen	0.3788	4.84e-7	0.3788	4.28e-7
3 Argon	0.0104	2.8e-11	0.0104	2.4e-11
4 CO2	3.70e-4	7.00e-6	3.70e-4	6.71e-6
5 H2O	5.04e-5	0.9998	5.04e-5	0.9998

Stream Properties

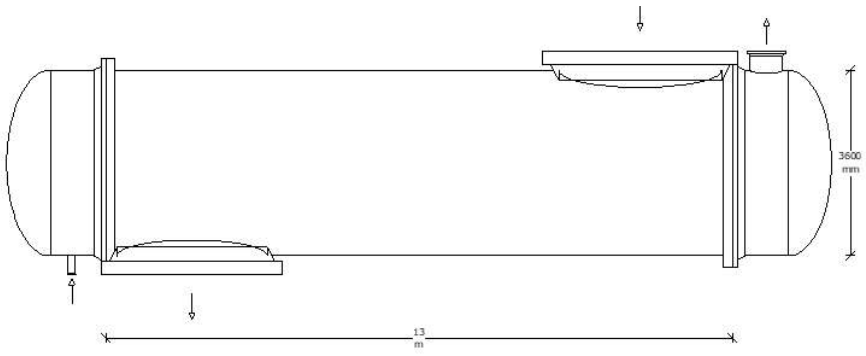
Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 21:54 SN: 46639- **Customs Units**

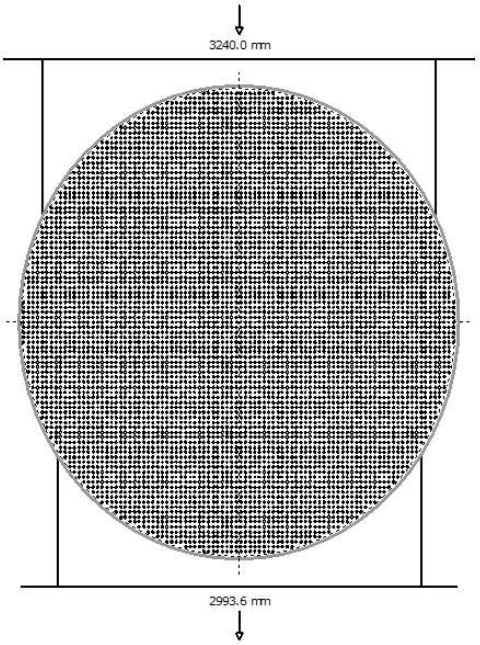
Waste Heat Boiler (LP Steam - O2 side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Cold Tubeside Fluid		**Inlet**	**Outlet**
Fluid name		BFW inlet	
Flow	(kg/hr)	96613	
Temperature	(C)	115.00	170.00
Pressure	(kgf/cm2G)	5.000	4.963
Weight fraction vapor	(--)	0.0000	1.0000
Vapor Properties			
Flow	(kg/hr)	0.0000	96613
Density	(kg/m3)	3.0785	2.9706
Viscosity	(cP)	0.0142	0.0147
Conductivity	(W/m-K)	0.0293	0.0317
Heat capacity	(kJ/kg-C)	1.9892	1.9908
Molecular weight	(--)	18.015	18.015
Liquid Properties			
Flow	(kg/hr)	96613	0.0000
Density	(kg/m3)	935.31	896.11
Viscosity	(cP)	0.2406	0.1712
Conductivity	(W/m-K)	0.6856	0.6849
Heat capacity	(kJ/kg-C)	4.4368	4.6106
Molecular weight	(--)	18.015	18.015
Latent heat	(kJ/kg)	2110.2	2111.0
Surface tension	(dyne/cm)	55.722	46.989

Molar Composition	**Vapor**	**Liquid**	**K-Value**	**Vapor**	**Liquid**	**K-Value**



Unit	201-C	Total tube inlet nozzles	1	Stream ID	Shellside		Tubeside	
Item no.	201-C3	Total tube outlet nozzles	1	Stream name	O2 Produk SOEC		BFW inlet	
TEMA type	BEM	Total shell inlet nozzles	1	Flow (total), kg/hr	750345		96613	
Shell diameter	3600 mm	Total shell outlet nozzles	1	Pressure drop, kgf/cm2	0.169		0.037	
Tube length	13 m			Temperature, C	455.16	169.96	115.00	170.00
Dry weight	234536 kg/shell			Wt. fraction vapor	1.0000	1.0000	0.0000	1.0000
Wet weight	405318 kg/shell			Pressure, kgf/cm2G	0.900	0.731	5.000	4.963
Bundle weight	155946 kg/shell							

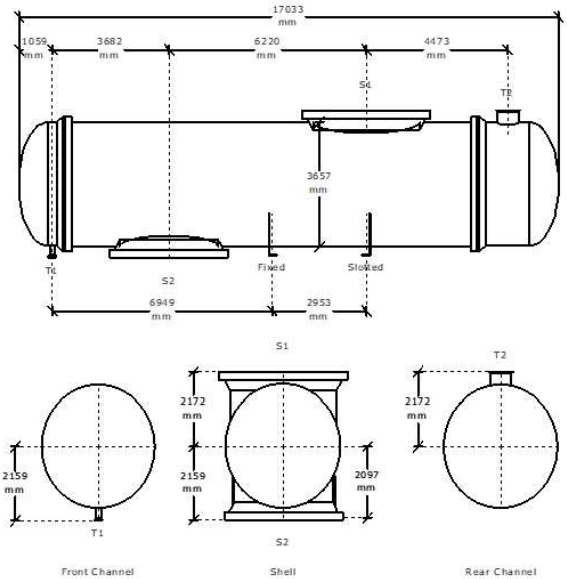


Unit	201-C
Item no.	201-C3
TEMA type	BEM
Shell ID	3600.0 mm
Actual OTL	3581.8 mm
Height under inlet nozzle	34.700 mm
Height under outlet nozzle	34.700 mm
Tube type	Plain
Tube OD	25.400 mm
Tube pitch	38.100 mm
Tube layout angle	90 deg
Tubes	6850
Tube positions available	6850
Tie rods	12
Seal strip pairs	0
Tube Passes	1

TUBEPASS DETAILS

Pass	Rows	Tubes
1	93	6850

SYMBOL LEGEND
- Tube
- Dummy Short Tube
- Dummy Long Tube
- Plugged Tube
- Tie Rod
- Seal Rod
- Impingement Rod



	Nozzles	OD, mm	Rating	Design	Shell	Tube	Weight	kg
S1	Inlet	3373.3		Pres (kgf/cm2G)	5.273	5.825	Bundle	155946
T1	Inlet	147.24		Temp (C)	487.78	198.89	Dry	234536
S2	Outlet	3120.6		Passes	1	1	Wet	405318
T2	Outlet	666.75		Thick (mm)	28.575	2.769		

Unit	201-C		
Company	-		
Customer		Ref	
Item No.	201-C3		
Service			
TEMA	BEM		Setting Plan
Date	24-Dec-25	By	
Diagram		Rev	

201-C4:

Output Summary

Page 1

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 21:57 SN: 46639- **Customs Units**

Waste Heat Boiler (LP Steam H2 Side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

See Data Check Messages Report for Warning Messages.
See Runtime Message Report for Warning Messages.

Process Conditions		Hot Shellside		Cold Tubeside	
Fluid name		H2 Produk SOEC			BFW inlet
Total flow rate	(kg/hr)		14111		159025
Inlet/Outlet Y	(Wt. frac vap.)	1.0000	1.0000	0.0000	0.0000
Inlet/Outlet T	(Deg C)	576.11	540.03	170.00	180.00
Inlet P/Avg	(kgf/cm2G)	2.500	2.451	46.900	46.846
dP/Allow.	(kgf/cm2)	0.099	0.500	0.108	0.500
Fouling	(m2-K/W)		0.000100		0.000100

Exchanger Performance					
Shell h	(W/m2-K)	772.28	Actual U	(W/m2-K)	585.52
Tube h	(W/m2-K)	13126	Required U	(W/m2-K)	535.48
Hot regime	(--)	Sens. Gas	Total duty	(MM kJ/hr)	7.4508
Cold regime	(--)	Sens. Liquid	Eff. area	(m2)	10.097
EMTD	(Deg C)	382.8	Overdesign	(%)	9.35

Shell Geometry			Baffle Geometry		
TEMA type	(--)	BEM	Baffle type		None
Shell ID	(mm)	600.00	Baffle cut	(Pct Dia.)	
Series	(--)	1	Baffle orientation	(--)	
Parallel	(--)	1	Central spacing	(mm)	1304.5
Orientation	(deg)	0.00	Crosspasses	(--)	1

Tube Geometry			Nozzles		
Tube type	(--)	Plain	Shell inlet	(mm)	540.00
Tube OD	(mm)	25.400	Shell outlet	(mm)	540.00
Length	(m)	2.438	Inlet height	(mm)	190.81
Pitch ratio	(--)	1.5000	Outlet height	(mm)	96.800
Layout	(deg)	90	Tube inlet	(mm)	154.05
Tubecount	(--)	97	Tube outlet	(mm)	154.05
Tube Pass	(--)	1			

Thermal Resistance, %		Velocities, m/s	Min	Max	Flow Fractions	
Shell	75.82				A	
Tube	5.70	Tubeside	1.66	1.67	B	0.945
Fouling	13.34	Crossflow	--	--	C	0.055
Metal	5.14	Longitudinal	167.44	172.44	E	
					F	

Final Results

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 21:57 SN: 46639- **Customs Units**

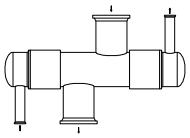
Waste Heat Boiler (LP Steam H2 Side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Process Data		Hot Shellside		Cold Tubeside	
Fluid name		H2 Produk SOEC		BFW inlet	
Fluid condition		Sens. Gas		Sens. Liquid	
Total flow rate	(kg/hr)	14111		159025	
Weight fraction vapor, In/Out	(–)	1.0000	1.0000	0.0000	0.0000
Temperature, In/Out	(Deg C)	576.11	540.03	170.00	180.00
Skin temperature, Min/Max	(Deg C)	259.93	275.30	191.58	202.09
Wall temperature, Min/Max	(Deg C)	238.27	252.11	219.28	231.76
Pressure, In/Average	(kgf/cm2G)	2.500	2.451	46.900	46.846
Pressure drop, Total/Allowed	(kgf/cm2)	0.099	0.500	0.108	0.500
Velocity, Mid/Max allow	(m/s)	169.79		1.66	
Mole fraction inert/Boiling rang	(Deg C)		0.0000		1.15e-3
Average film coef.	(W/m2-K)		772.28		13126
Heat transfer safety factor	(–)		1.0000		1.0000
Fouling resistance	(m2-K/W)		0.000100		0.000100

Overall Performance Data

Overall coef., Reqd/Clean/Actual	(W/m2-K)	535.48	/	675.68	/	585.52
Total Duty, Calculated/Specified	(MM kJ/hr)	7.4508	/			
Effective overall temperature difference	(Deg C)	382.8				
EMTD = (MTD) * (DELTA) * (F/G/H)	(Deg C)	383.0	*	0.9995	*	1.0000

See Runtime Messages Report for warnings.



Exchanger Fluid Volumes

Approximate shellside (L)	718.5
Approximate tubeside (L)	565.8

Shell Construction Information

TEMA shell type	BEM	Shell ID	(mm)	600.00	
Shells Series	1 Parallel	1	Total area	(m2)	18.871
Passes Shell	1 Tube	1	Eff. area	(m2/shell)	10.097
Shell orientation angle (deg)	0.00				
Impingement present	Rods	Impingement rod rows		2	
Pairs seal strips	1	Passlane seal rods (mm)	0.000	No. 0	
Shell expansion joint	No	Rear head support plate	No		
Weight estimation Wet/Dry/Bundle	10513	/ 9229.5	/ 2546.1	(kg/shell)	

Baffle Information

Type	None	Baffle cut (% dia)			
Crosspasses/shellpass	1	No. (Pct Area)	(mm)	to C.L	
Central spacing	(mm) 1304.5	1			
Inlet spacing	(mm) 0.000	2			
Outlet spacing	(mm) 0.000				
Baffle thickness	(mm) 0.000				
Use deresonating baffles	No				

Tube Information

Tube type	Plain	Tubecount per shell		97	
Overall length	(m) 2.438	Pct tubes removed (both)		40.12	
Effective length	(m) 1.305	Outside diameter	(mm)	25.400	
Total tubesheet	(mm) 1133.5	Wall thickness	(mm)	2.769	
Area ratio	(out/in) 1.2788	Pitch (mm)	38.100 Ratio	1.5000	
Tube metal	SA-214 Tube (W) K01807	Tube pattern (deg)		90	

Shellside Performance

Nom vel, X-flow/window 0.00 / 165.46

Flow fractions for heat transfer 0.973
B=0.9453 C=0.0547

Shellside Heat Transfer Corrections

Total	Beta	Gamma	End	Fin
0.945	0.920	1.028	1.000	1.000

Pressure Drops (Percent of Total)

Cross	Window	Ends	Nozzle	Shell	Tube
0.00	39.34	4.37	Inlet	23.62	32.91
MOMENTUM		0.00	Outlet	32.67	21.18

Two-Phase Parameters

Method	Inlet	Center	Outlet	Mix F

H. T. Parameters		Shell	Tube
Overall wall correction			
Midpoint	Prandtl no.	0.74	1.06
Midpoint	Reynolds no.	29857	189314
Bundle inlet	Reynolds no.	23882	184319
Bundle outlet	Reynolds no.	24965	194967
Fouling layer	(mm)		

Thermal Resistance, %

Shell	Tube	Fouling	Metal	Over Des
75.82	5.70	13.34	5.14	9.35

Total fouling resistance	(m2-K/W)	2.28e-4
Differential resistance	(m2-K/W)	1.6e-4

Shell Nozzles

Inlet at channel end No

		Inlet	Outlet	Liquid Outlet
Number at each position		1	1	0
Diameter	(mm)	540.00	540.00	
Velocity	(m/s)	170.40	167.82	
Pressure drop	(kgf/cm2)	0.023	0.032	
Height under nozzle	(mm)	190.81	96.800	
Nozzle R-V-SQ	(kg/m-s2)	2916.4	2872.2	
Shell ent.	(kg/m-s2)	1976.5	4679.1	

Tube Nozzle		Inlet RADIAL	Outlet RADIAL	Liquid Outlet
Diameter	(mm)	154.05	154.05	
Velocity	(m/s)	2.67	2.70	
Pressure drop	(kgf/cm2)	0.036	0.023	
Nozzle R-V-SQ	(kg/m-s2)	6329.2	6400.5	

Annular Distributor		Inlet	Outlet
Length	(mm)		
Height	(mm)		
Slot area	(mm2)		

Diametral Clearances (mm)

Baffle-to-shell	Bundle-to-shell	Tube-to-baffle
4.7625	19.856	0.0000

Supplementary Results

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 21:57 SN: 46639- **Customs Units**

Waste Heat Boiler (LP Steam H2 Side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Externally Enhanced Tube Geometry			Internally Enhanced Tube Geometry		
Type		Plain	Type		None
Fin density	(fin/meter)		Thickness	(mm)	
Fin height	(mm)		Pitch	(L/D)	
Fin thickness	(mm)				
Root diameter	(mm)				
Area/length	(m2/m)				

Mean Metal Temperatures

Mean shell temperature	557.92 (C)
Tubesheet temperature	604.44 (C)

Mean tube metal temperature in each tubepass, (C)

Tube Pass	Inside	Outside	Radial
1	225.48	245.15	236.12

Stream Properties

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 21:57 SN: 46639- **Customs Units**

Waste Heat Boiler (LP Steam H2 Side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Hot Shellside Fluid		**Inlet**	**Outlet**
Fluid name		H2 Produk SOEC	
Flow	(kg/hr)	14111	
Temperature	(C)	576.11	540.03
Pressure	(kgf/cm2G)	2.500	2.401
Weight fraction vapor	(--)	1.0000	1.0000
Vapor Properties			
Flow	(kg/hr)	14111	14111
Density	(kg/m3)	0.1004	0.1020
Viscosity	(cP)	0.0188	0.0180
Conductivity	(W/m-K)	0.3708	0.3599
Heat capacity	(kJ/kg-C)	14.655	14.598
Molecular weight	(--)	2.0480	2.0480
Liquid Properties			
Flow	(kg/hr)	0.0000	0.0000
Density	(kg/m3)	1024.5	1024.8
Viscosity	(cP)	1.6490	1.6694
Conductivity	(W/m-K)	0.5723	0.5716
Heat capacity	(kJ/kg-C)	4.3235	4.3238
Molecular weight	(--)	18.015	18.015
Latent heat	(kJ/kg)	2556.9	2556.9
Surface tension	(dyne/cm)	76.066	76.132

Molar Composition	**MW**	**Vapor**	**Liquid**	**K-Value**	**Vapor**	**Liquid**	**K-Value**
1 Hydrogen	2.02	0.9980	1.79e-6	557547	0.9980	1.72e-6	581286
2 H2O	18.02	0.0020	1.0000	0.0020	0.0020	1.0000	0.0020

Mass Composition	**Vapor**	**Liquid**	**Vapor**	**Liquid**
1 Hydrogen	0.9824	2.00e-7	0.9824	1.92e-7
2 H2O	0.0176	1.0000	0.0176	1.0000

Stream Properties

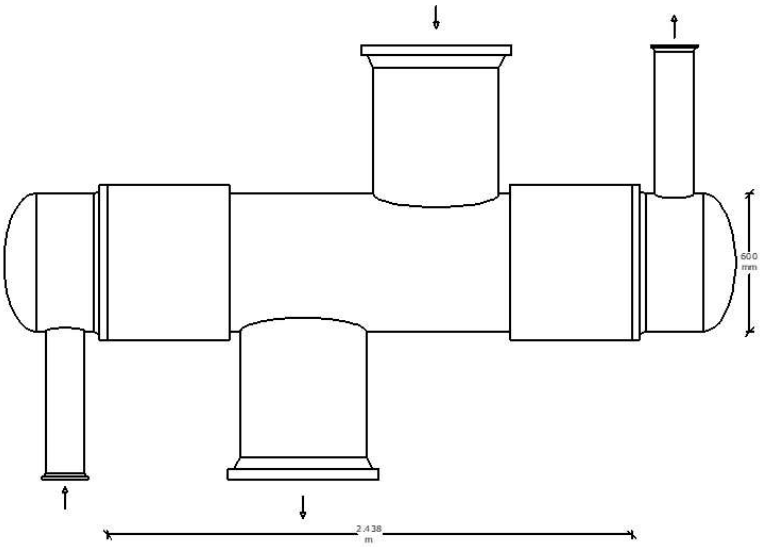
Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 21:57 SN: 46639- **Customs Units**

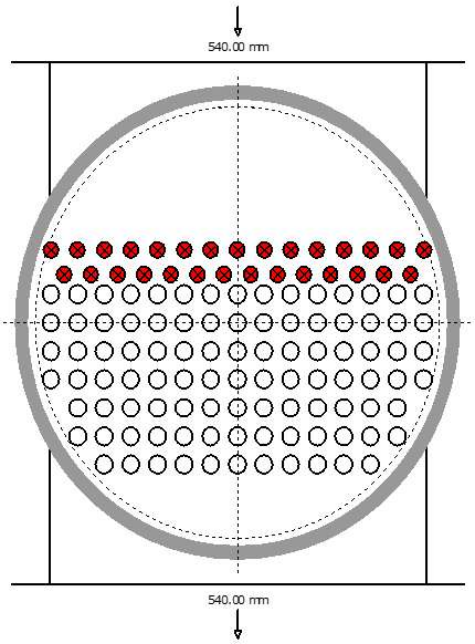
Waste Heat Boiler (LP Steam H2 Side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Cold Tubeside Fluid		Inlet	Outlet
Fluid name		BFW inlet	
Flow	(kg/hr)	159025	
Temperature	(C)	170.00	180.00
Pressure	(kgf/cm2G)	46.900	46.792
Weight fraction vapor	(--)	0.0000	0.0000
Vapor Properties			
Flow	(kg/hr)	0.0000	0.0000
Density	(kg/m3)	22.888	22.835
Viscosity	(cP)	0.0179	0.0179
Conductivity	(W/m-K)	0.0527	0.0526
Heat capacity	(kJ/kg-C)	2.4891	2.4876
Molecular weight	(--)	18.015	18.015
Liquid Properties			
Flow	(kg/hr)	159025	159025
Density	(kg/m3)	887.43	877.55
Viscosity	(cP)	0.1585	0.1494
Conductivity	(W/m-K)	0.6810	0.6766
Heat capacity	(kJ/kg-C)	4.6547	4.7157
Molecular weight	(--)	18.015	18.015
Latent heat	(kJ/kg)	1688.4	1689.2
Surface tension	(dyne/cm)	44.447	42.272

Molar Composition	Vapor	Liquid	K-Value	Vapor	Liquid	K-Value



				Stream ID	Shellside	Tubeside
Unit	201-C	Total tube inlet nozzles	1	Stream name	H2 Produk SOEC	BFW inlet
Item no.	201-C4	Total tube outlet nozzles	1	Flow (total), kg/hr	14111	159025
TEMA type	BEM	Total shell inlet nozzles	1	Pressure drop, kgf/cm2	0.099	0.108
Shell diameter	600 mm	Total shell outlet nozzles	1	Temperature, C	576.11 540.03	170.00 180.00
Tube length	2.438 m			Wt. fraction vapor	1.0000 1.0000	0.0000 0.0000
Dry weight	9229 kg/shell			Pressure, kgf/cm2G	2.500 2.401	46.900 46.792
Wet weight	10513 kg/shell					
Bundle weight	2546 kg/shell					

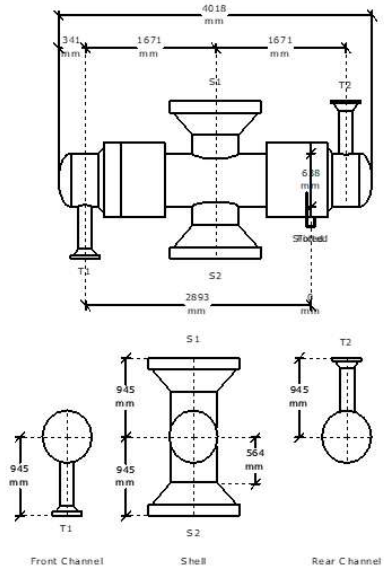


Unit	201-C
Itemno.	201-C4
TEMA type	BEM
Shell ID	600.00 mm
Actual OTL	580.14 mm
Height under inlet nozzle	190.81 mm
Rows of impingement rods	2
Impingement rod OD	22.225 mm
Height under outlet nozzle	96.800 mm
Tube type	Plain
Tube OD	25.400 mm
Tube pitch	38.100 mm
Tube layout angle	90 deg
Tubes	97
Tube positions available	97
Tie rods	6
Seal strip pairs	1
Tube Passes	1

TUBEPASS DETAILS

Pass	Rows	Tubes
1	7	97

SYMBOL LEGEND
- Tube
- Dummy Short Tube
- Dummy Long Tube
- Plugged Tube
- Tie Rod
- Seal Rod
- Impingement Rod



	Nozzles	OD, mm	Rating	Design	Shell	Tube	Weight	kg	Unit	201-C		
S1	Inlet	584.45		Pres (kgf/cm2G)	5.273	52.027	Bundle	2546	Company	-		
T1	Inlet	179.45		Temp (C)	604.44	210	Dry	9229	Customer		Ref	
S2	Outlet	584.45		Passes	1	1	Wet	10513	Item No.	201-C4		
T2	Outlet	179.45		Thick (mm)	19.05	2.769			Service			
									TEMA	BEM		Setting Plan
									Date	24-Dec-25	By	
									Diagram		Rev	

- Hidrogen produk Cooler, 204-C1

Output Summary Page 1

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:20 SN: 46639- **Customs Units**
Sebelum masuk sebagai Inlet Kompresor H2
Waste Heat Boiler (H2 Side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

See Data Check Messages Report for Warning Messages.
See Runtime Message Report for Warning Messages.

Process Conditions		Hot Shellside		Cold Tubeside	
Fluid name		H2 Produk SOEC		Sea Water Inlet	
Total flow rate	(kg/hr)	14111		1.11E+07	
Inlet/Outlet Y	(Wt. frac vap.)	1.0000	1.0000	0.0000	0.0000
Inlet/Outlet T	(Deg C)	566.79	45.00	30.00	32.21
Inlet P/Avg	(kgf/cm2G)	2.500	2.482	4.500	4.268
dP/Allow.	(kgf/cm2)	0.035	0.500	0.464	0.500
Fouling	(m2-K/W)		0.000100		0.000100

Exchanger Performance					
Shell h	(W/m2-K)	158.38	Actual U	(W/m2-K)	146.85
Tube h	(W/m2-K)	11537	Required U	(W/m2-K)	130.87
Hot regime	(--)	Sens. Gas	Total duty	(MM kJ/hr)	105.03
Cold regime	(--)	Sens. Liquid	Eff. area	(m2)	1531.1
EMTD	(Deg C)	145.6	Overdesign	(%)	12.21

Shell Geometry			Baffle Geometry		
TEMA type	(--)	BEM	Baffle type		None
Shell ID	(mm)	2500.0	Baffle cut	(Pct Dia.)	
Series	(--)	1	Baffle orientation	(--)	
Parallel	(--)	1	Central spacing	(mm)	5864.2
Orientation	(deg)	0.00	Crosspasses	(--)	1

Tube Geometry			Nozzles		
Tube type	(--)	Plain	Shell inlet	(mm)	742.95
Tube OD	(mm)	25.400	Shell outlet	(mm)	539.75
Length	(m)	6.096	Inlet height	(mm)	37.150
Pitch ratio	(--)	1.5000	Outlet height	(mm)	37.150
Layout	(deg)	90	Tube inlet	(mm)	1232.6
Tubecount	(--)	3272	Tube outlet	(mm)	1232.6
Tube Pass	(--)	1			

Thermal Resistance, %		Velocities, m/s	Min	Max	Flow Fractions	
Shell	92.72				A	
Tube	1.63	Tubeside	3.02	3.02	B	0.986
Fouling	3.35	Crossflow	--	--	C	0.014
Metal	2.30	Longitudinal	4.58	11.29	E	
					F	

Final Results

Released to the following company:
-
Tugas Akhir

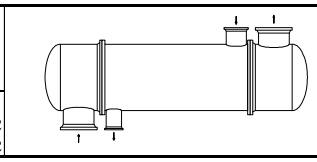
Xist 9 (32 bit) 24-Dec-25 22:20 SN: 46639-
Customs Units
Sebelum masuk sebagai Inlet Kompresor H2
Waste Heat Boiler (H2 Side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Process Data		Hot Shellside		Cold Tubeside	
Fluid name		H2 Produk SOEC		Sea Water Inlet	
Fluid condition		Sens. Gas		Sens. Liquid	
Total flow rate	(kg/hr)	14111		1.11e+7	
Weight fraction vapor, In/Out	(--)	1.0000	1.0000	0.0000	0.0000
Temperature, In/Out	(Deg C)	566.79	45.00	30.00	32.21
Skin temperature, Min/Max	(Deg C)	31.14	72.84	30.26	40.96
Wall temperature, Min/Max	(Deg C)	30.92	64.55	30.56	51.55
Pressure, In/Average	(kgf/cm2G)	2.500	2.482	4.500	4.268
Pressure drop, Total/Allowed	(kgf/cm2)	0.035	0.500	0.464	0.500
Velocity, Mid/Max allow	(m/s)	5.45		3.02	
Mole fraction inert/Boiling rang	(Deg C)		0.0000		1.07e-3
Average film coef.	(W/m2-K)		158.38		11537
Heat transfer safety factor	(--)		1.0000		1.0000
Fouling resistance	(m2-K/W)		0.000100		0.000100

Overall Performance Data

Overall coef., Reqd/Clean/Actual	(W/m2-K)	130.87	/	151.94	/	146.85
Total Duty, Calculated/Specified	(MM kJ/hr)	105.03	/			
Effective overall temperature difference	(Deg C)	145.6				
EMTD = (MTD) * (DELTA) * (F/G/H)	(Deg C)	147.1	*	0.9895	*	1.0000

See Runtime Messages Report for warnings.



Exchanger Fluid Volumes

Approximate shellside(L)	19882
Approximate tubeside(L)	43242

Shell Construction Information

TEMA shell type	BEM		Shell ID	(mm)	2500.0
Shells Series	1 Parallel	1	Total area	(m2)	1591.6
Passes Shell	1 Tube	1	Eff. area	(m2/shell)	1531.1
Shell orientation angle (deg)	0.00				
Impingement present	No				
Pairs seal strips	0		Passlane seal rods (mm)	0.000	No. 0
Shell expansion joint	No		Rear head support plate	No	
Weight estimation Wet/Dry/Bundle	125868	/	62773	/	21245 (kg/shell)

Baffle Information

Type	None		Baffle cut (% dia)	
Crosspasses/shellpass	1		No.(Pct Area)	(mm) to C.L
Central spacing	(mm)	5864.2	1	
Inlet spacing	(mm)	0.000	2	
Outlet spacing	(mm)	0.000		
Baffle thickness	(mm)	0.000		
Use deresonating baffles	No			

Tube Information

Tube type	Plain		Tubecount per shell		3272
Overall length	(m)	6.096	Pct tubes removed (both)		0.4
Effective length	(m)	5.864	Outside diameter	(mm)	25.400
Total tubesheet	(mm)	231.78	Wall thickness	(mm)	2.769
Area ratio	(out/in)	1.2788	Pitch (mm)	38.100 Ratio	1.5000
Tube metal	Titanium-grade 2 2		Tube pattern (deg)		90

Shellside Performance

Nom vel, X-flow/window 0.00 / 5.41

Flow fractions for heat transfer 0.990
B=0.9863 C=0.0137

Shellside Heat Transfer Corrections

Total	Beta	Gamma	End	Fin
0.982	0.920	1.067	1.000	1.000

Pressure Drops (Percent of Total)

Cross	Window	Ends	Nozzle	Shell	Tube
0.00	2.25	0.32	Inlet	44.65	7.99
MOMENTUM		0.00	Outlet	52.79	5.09

Two-Phase Parameters

Method	Inlet	Center	Outlet	Mix F

H. T. Parameters

		Shell	Tube
Overall wall correction			
Midpoint	Prandtl no.	0.72	5.54
Midpoint	Reynolds no.	3730	75893
Bundle inlet	Reynolds no.	1665	75494
Bundle outlet	Reynolds no.	3362	78419
Fouling layer	(mm)		

Thermal Resistance, %

Shell	Tube	Fouling	Metal	Over Des
92.72	1.63	3.35	2.30	12.21

Total fouling resistance (m2-K/W) 2.28e-4
Differential resistance (m2-K/W) 8.32e-4

Shell Nozzles

Inlet at channel end No

		Inlet	Outlet	Liquid Outlet
Number at each position		1	1	0
Diameter	(mm)	742.95	539.75	
Velocity	(m/s)	89.03	64.56	
Pressure drop	(kgf/cm2)	0.016	0.019	
Height under nozzle	(mm)	37.150	37.150	
Nozzle R-V-SQ	(kg/m-s2)	805.00	1106.0	
Shell ent.	(kg/m-s2)	3823.0	4330.8	

Tube Nozzle		Inlet RADIAL	Outlet RADIAL	Liquid Outlet
Diameter	(mm)	1232.6	1232.6	
Velocity	(m/s)	2.57	2.57	
Pressure drop	(kgf/cm2)	0.037	0.024	
Nozzle R-V-SQ	(kg/m-s2)	6607.1	6618.2	

Annular Distributor		Inlet	Outlet
Length	(mm)		
Height	(mm)		
Slot area	(mm2)		

Diametral Clearances (mm)

Baffle-to-shell	Bundle-to-shell	Tube-to-baffle
11.113	18.110	0.0000

Supplementary Results

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:20 SN: 46639- **Customs Units**
Sebelum masuk sebagai Inlet Kompresor H2
Waste Heat Boiler (H2 Side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Externally Enhanced Tube Geometry			Internally Enhanced Tube Geometry		
Type		Plain	Type		None
Fin density	(fin/meter)		Thickness	(mm)	
Fin height	(mm)		Pitch	(L/D)	
Fin thickness	(mm)				
Root diameter	(mm)				
Area/length	(m2/m)				

Mean Metal Temperatures

Mean shell temperature	170.38 (C)
Tubesheet temperature	598.89 (C)

Mean tube metal temperature in each tubepass, (C)

Tube Pass	Inside	Outside	Radial
1	35.68	39.08	37.52



Stream Properties

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:20 SN: 46639- **Customs Units**
Sebelum masuk sebagai Inlet Kompresor H2
Waste Heat Boiler (H2 Side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Hot Shellside Fluid		**Inlet**	**Outlet**
Fluid name		H2 Produk SOEC	
Flow	(kg/hr)	14111	
Temperature	(C)	566.79	45.00
Pressure	(kgf/cm2G)	2.500	2.465
Weight fraction vapor	(--)	1.0000	1.0000
Vapor Properties			
Flow	(kg/hr)	14111	14111
Density	(kg/m3)	0.1015	0.2653
Viscosity	(cP)	0.0186	0.0092
Conductivity	(W/m-K)	0.3680	0.1834
Heat capacity	(kJ/kg-C)	14.640	13.917
Molecular weight	(--)	2.0480	2.0480
Liquid Properties			
Flow	(kg/hr)	0.0000	0.0000
Density	(kg/m3)	1024.5	1024.6
Viscosity	(cP)	1.6490	1.6563
Conductivity	(W/m-K)	0.5723	0.5721
Heat capacity	(kJ/kg-C)	4.3235	4.3236
Molecular weight	(--)	18.015	18.015
Latent heat	(kJ/kg)	2556.9	2556.9
Surface tension	(dyne/cm)	76.066	76.089

Molar Composition	**MW**	**Vapor**	**Liquid**	**K-Value**	**Vapor**	**Liquid**	**K-Value**
1 Hydrogen	2.02	0.9980	1.79e-6	557547	0.9980	1.76e-6	565769
2 H2O	18.02	0.0020	1.0000	0.0020	0.0020	1.0000	0.0020

Mass Composition	**Vapor**	**Liquid**	**Vapor**	**Liquid**
1 Hydrogen	0.9824	2.00e-7	0.9824	1.97e-7
2 H2O	0.0176	1.0000	0.0176	1.0000

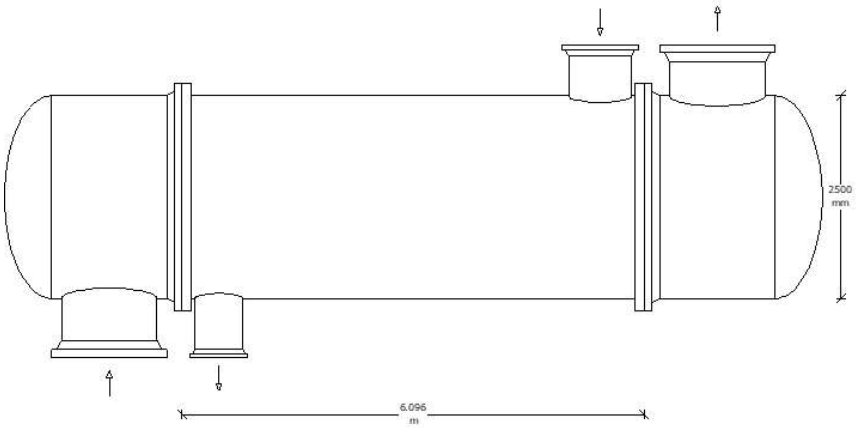
Stream Properties

Released to the following company:
-
Tugas Akhir

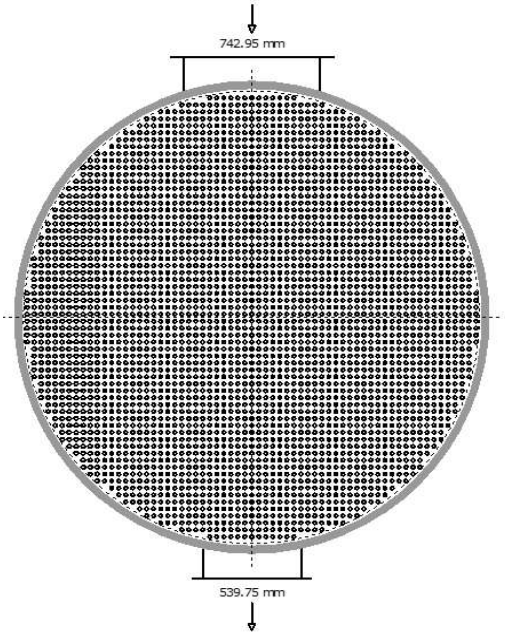
Xist 9 (32 bit) 24-Dec-25 22:20 SN: 46639- **Customs Units**
Sebelum masuk sebagai Inlet Kompresor H2
Waste Heat Boiler (H2 Side) : 201-C
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Cold Tubeside Fluid		Inlet	Outlet
Fluid name		Sea Water Inlet	
Flow	(kg/hr)	1.11e+7	
Temperature	(C)	30.00	32.21
Pressure	(kgf/cm2G)	4.500	4.036
Weight fraction vapor	(--)	0.0000	0.0000
Vapor Properties			
Flow	(kg/hr)	0.0000	0.0000
Density	(kg/m3)	2.8388	2.6154
Viscosity	(cP)	0.0141	0.0140
Conductivity	(W/m-K)	0.0290	0.0287
Heat capacity	(kJ/kg-C)	1.9824	1.9760
Molecular weight	(--)	18.015	18.015
Liquid Properties			
Flow	(kg/hr)	1.11e+7	1.11e+7
Density	(kg/m3)	1003.7	1002.0
Viscosity	(cP)	0.7972	0.7643
Conductivity	(W/m-K)	0.6182	0.6213
Heat capacity	(kJ/kg-C)	4.3129	4.3132
Molecular weight	(--)	18.015	18.015
Latent heat	(kJ/kg)	2120.6	2130.9
Surface tension	(dyne/cm)	71.234	70.851

Molar Composition	Vapor	Liquid	K-Value	Vapor	Liquid	K-Value



				Stream ID	Shellside		Tubeside	
Unit	201-C	Total tube inlet nozzles	1	Stream name	H2 Produk SOEC		Sea Water Inlet	
Item no.	201-C2	Total tube outlet nozzles	1	Flow (total), kg/hr	14111		1.11e+7	
TEMA type	BEM	Total shell inlet nozzles	1	Pressure drop, kgf/cm2	0.035		0.464	
Shell diameter	2500 mm	Total shell outlet nozzles	1	Temperature, C	566.79	45.00	30.00	32.21
Tube length	6.096 m			Wt. fraction vapor	1.0000	1.0000	0.0000	0.0000
Dry weight	62773 kg/shell			Pressure, kgf/cm2G	2.500	2.465	4.500	4.036
Wet weight	125868 kg/shell							
Bundle weight	21245 kg/shell							



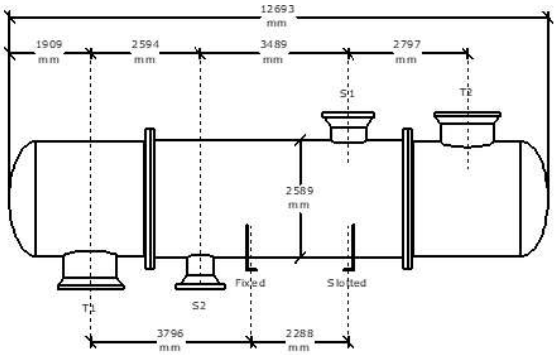
Unit	201-C
Item no.	201-C2
TEMA type	BEM
Shell ID	2500.0 mm
Actual OTL	2481.9 mm
Height under inlet nozzle	37.150 mm
Height under outlet nozzle	37.150 mm
Tube type	Plain
Tube OD	25.400 mm
Tube pitch	38.100 mm
Tube layout angle	90 deg
Tubes	3272
Tube positions available	3272
Tie rods	12
Seal strip pairs	0
Tube Passes	1

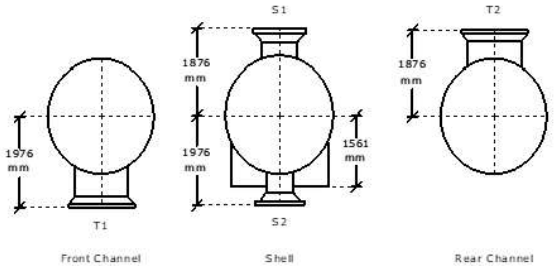
TUBEPASS DETAILS

Pass	Rows	Tubes
1	64	3272

SYMBOL LEGEND

- Tube
- Dummy Short Tube
- Dummy Long Tube
- Plugged Tube
- Tie Rod
- Seal Rod
- Impingement Rod





	Nozzles	OD, mm	Rating	Design	Shell	Tube	Weight	kg	Unit	201-C		
S1	Inlet	831.85		Pres (kgf/cm2G)	5.273	5.273	Bundle	21245	Company	-		
T1	Inlet	1264.4		Temp (C)	598.89	60	Dry	62773	Customer		Ref	
S2	Outlet	628.65		Passes	1	1	Wet	125868	Item No.	201-C2		
T2	Outlet	1264.4		Thick (mm)	44.45	2.769			Service			
									TEMA	BEM		Setting Plan
									Date	24-Dec-25	By	
									Diagram		Rev.	

- Oksigen produk Cooler, 204-C2

Output Summary Page 1

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:22 SN: 46639- **Customs Units**
O2 sebelum di Vent ke atmosfer
O2 Produk SOEC : 204-C2
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

See Data Check Messages Report for Warning Messages.
See Runtime Message Report for Warning Messages.

Process Conditions		Hot Shellside		Cold Tubeside	
Fluid name		O2 Produk SOEC		Sea Water	
Total flow rate	(kg/hr)	750345		1.11e+7	
Inlet/Outlet Y	(Wt. frac vap.)	1.0000	1.0000	0.0000	0.0000
Inlet/Outlet T	(Deg C)	170.00	47.00	32.10	34.07
Inlet P/Avg	(kgf/cm2G)	0.900	0.779	5.000	4.465
dP/Allow.	(kgf/cm2)	0.241	0.500	1.069	1.500
Fouling	(m2-K/W)		0.000100		0.000100

Exchanger Performance					
Shell h	(W/m2-K)	152.26	Actual U	(W/m2-K)	141.77
Tube h	(W/m2-K)	12505	Required U	(W/m2-K)	135.05
Hot regime	(--)	Sens. Gas	Total duty	(MM kJ/hr)	93.009
Cold regime	(--)	Sens. Liquid	Eff. area	(m2)	3488.1
EMTD	(Deg C)	54.8	Overdesign	(%)	4.98

Shell Geometry			Baffle Geometry		
TEMA type	(--)	BEM	Baffle type		None
Shell ID	(mm)	2500.0	Baffle cut	(Pct Dia.)	
Series	(--)	1	Baffle orientation	(--)	
Parallel	(--)	1	Central spacing	(mm)	14484
Orientation	(deg)	0.00	Crosspasses	(--)	1

Tube Geometry			Nozzles		
Tube type	(--)	Plain	Shell inlet	(mm)	2250.0
Tube OD	(mm)	25.400	Shell outlet	(mm)	2250.0
Length	(m)	14.630	Inlet height	(mm)	265.75
Pitch ratio	(--)	1.5000	Outlet height	(mm)	189.55
Layout	(deg)	90	Tube inlet	(mm)	1233.5
Tubecount	(--)	3018	Tube outlet	(mm)	1233.5
Tube Pass	(--)	1			

Thermal Resistance, %		Velocities, m/s	Min	Max	Flow Fractions	
Shell	93.11				A	
Tube	1.45	Tubeside	3.28	3.28	B	0.985
Fouling	3.23	Crossflow	--	--	C	0.015
Metal	2.21	Longitudinal	33.32	40.90	E	
					F	

Final Results

Released to the following company:
-
Tugas Akhir

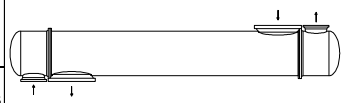
Xist 9 (32 bit) 24-Dec-25 22:22 SN: 46639- **Customs Units**
O2 sebelum di Vent ke atmosfer
O2 Produk SOEC : 204-C2
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Process Data		Hot Shellside		Cold Tubeside	
Fluid name		O2 Produk SOEC		Sea Water	
Fluid condition		Sens. Gas		Sens. Liquid	
Total flow rate	(kg/hr)	750345		1.11e+7	
Weight fraction vapor, In/Out	(—)	1.0000	1.0000	0.0000	0.0000
Temperature, In/Out	(Deg C)	170.00	47.00	32.10	34.07
Skin temperature, Min/Max	(Deg C)	33.18	43.18	32.34	35.87
Wall temperature, Min/Max	(Deg C)	32.96	41.28	32.62	38.31
Pressure, In/Average	(kgf/cm2G)	0.900	0.779	5.000	4.465
Pressure drop, Total/Allowed	(kgf/cm2)	0.241	0.500	1.069	1.500
Velocity, Mid/Max allow	(m/s)	34.48		3.28	
Mole fraction inert/Boiling rang	(Deg C)		0.0000		1.87e-3
Average film coef.	(W/m2-K)		152.26		12505
Heat transfer safety factor	(—)		1.0000		1.0000
Fouling resistance	(m2-K/W)		0.000100		0.000100

Overall Performance Data

Overall coef., Reqd/Clean/Actual	(W/m2-K)	135.05	/	146.50	/	141.77
Total Duty, Calculated/Specified	(MM kJ/hr)	93.009	/			
Effective overall temperature difference	(Deg C)	54.8				
EMTD = (MTD) * (DELTA) * (F/G/H)	(Deg C)	55.0	*	0.9964	*	1.0000

See Runtime Messages Report for warnings.



Exchanger Fluid Volumes

Approximate shellside(L)	51763
Approximate tubeside(L)	50210

Shell Construction Information

TEMA shell type	BEM		Shell ID	(mm)	2500.0
Shells Series	1 Parallel	1	Total area	(m2)	3523.3
Passes Shell	1 Tube	1	Eff. area	(m2/shell)	3488.1
Shell orientation angle (deg)	0.00				
Impingement present	No				
Pairs seal strips	0		Passlane seal rods (mm)	0.000	No. 0
Shell expansion joint	No		Rear head support plate	No	
Weight estimation Wet/Dry/Bundle	171435	/	69508	/ 43363	(kg/shell)

Baffle Information

Type	None		Baffle cut (% dia)	
Crosspasses/shellpass	1		No.(Pct Area)	(mm) to C.L
Central spacing	(mm)	14484	1	
Inlet spacing	(mm)	0.000	2	
Outlet spacing	(mm)	0.000		
Baffle thickness	(mm)	0.000		
Use deresonating baffles	No			

Tube Information

Tube type	Plain		Tubecount per shell		3018
Overall length	(m)	14.630	Pct tubes removed (both)		8.82
Effective length	(m)	14.484	Outside diameter	(mm)	25.400
Total tubesheet	(mm)	146.05	Wall thickness	(mm)	2.769
Area ratio	(out/in)	1.2788	Pitch (mm)	38.100 Ratio	1.5000
Tube metal	Titanium-grade 2 2		Tube pattern (deg)		90

Shellside Performance

Nom vel, X-flow/window 0.00 / 34.22

Flow fractions for heat transfer 0.990
B=0.9851 C=0.0149

Shellside Heat Transfer Corrections

Total	Beta	Gamma	End	Fin
0.981	0.920	1.066	1.000	1.000

Pressure Drops (Percent of Total)

	Cross	Window	Ends	Nozzle	Shell	Tube
	0.00	71.65	8.40	Inlet	10.39	3.46
MOMENTUM			-0.00	Outlet	9.56	2.21

Two-Phase Parameters

Method	Inlet	Center	Outlet	Mix F

H. T. Parameters		Shell	Tube
Overall wall correction			
Midpoint	Prandtl no.	0.73	5.25
Midpoint	Reynolds no.	96731	86367
Bundle inlet	Reynolds no.	61879	85583
Bundle outlet	Reynolds no.	78147	88826
Fouling layer	(mm)		

Thermal Resistance, %

Shell	Tube	Fouling	Metal	Over Des
93.11	1.45	3.23	2.21	4.98

Total fouling resistance (m2-K/W) 2.28e-4
Differential resistance (m2-K/W) 3.51e-4

Shell Nozzles

Inlet at channel end No

		Inlet	Outlet	Liquid Outlet
Number at each position		1	1	0
Diameter	(mm)	2250.0	2250.0	
Velocity	(m/s)	34.54	28.44	
Pressure drop	(kgf/cm2)	0.025	0.023	
Height under nozzle	(mm)	265.75	189.55	
Nozzle R-V-SQ	(kg/m-s2)	1810.8	1490.9	
Shell ent.	(kg/m-s2)	5209.5	5475.1	

Tube Nozzle		Inlet RADIAL	Outlet RADIAL	Liquid Outlet
Diameter	(mm)	1233.5	1233.5	
Velocity	(m/s)	2.57	2.57	
Pressure drop	(kgf/cm2)	0.037	0.024	
Nozzle R-V-SQ	(kg/m-s2)	6598.4	6608.5	

Annular Distributor		Inlet	Outlet
Length	(mm)		
Height	(mm)		
Slot area	(mm2)		

Diametral Clearances (mm)

Baffle-to-shell	Bundle-to-shell	Tube-to-baffle
11.113	19.292	0.0000

Supplementary Results

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:22 SN: 46639- **Customs Units**
O2 sebelum di Vent ke atmosfer
O2 Produk SOEC : 204-C2
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Externally Enhanced Tube Geometry			Internally Enhanced Tube Geometry		
Type		Plain	Type		None
Fin density	(fin/meter)		Thickness	(mm)	
Fin height	(mm)		Pitch	(L/D)	
Fin thickness	(mm)				
Root diameter	(mm)				
Area/length	(m2/m)				

Mean Metal Temperatures

Mean shell temperature	87.15 (C)
Tubesheet temperature	198.89 (C)

Mean tube metal temperature in each tubepass, (C)

Tube Pass	Inside	Outside	Radial
1	34.54	35.75	35.20



Stream Properties

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:22 SN: 46639- **Customs Units**
O2 sebelum di Vent ke atmosfer
O2 Produk SOEC : 204-C2
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

Hot Shellside Fluid		Inlet	Outlet
Fluid name		O2 Produk SOEC	
Flow	(kg/hr)	750345	
Temperature	(C)	170.00	47.00
Pressure	(kgf/cm2G)	0.900	0.659
Weight fraction vapor	(--)	1.0000	1.0000
Vapor Properties			
Flow	(kg/hr)	750345	750345
Density	(kg/m3)	1.5176	1.8400
Viscosity	(cP)	0.0256	0.0203
Conductivity	(W/m-K)	0.0359	0.0275
Heat capacity	(kJ/kg-C)	1.0212	0.9938
Molecular weight	(--)	29.500	29.500
Liquid Properties			
Flow	(kg/hr)	0.0000	0.0000
Density	(kg/m3)	1055.7	1056.5
Viscosity	(cP)	5.5242	5.7940
Conductivity	(W/m-K)	0.4873	0.4846
Heat capacity	(kJ/kg-C)	4.3917	4.3947
Molecular weight	(--)	18.017	18.016
Latent heat	(kJ/kg)	2363.6	2399.6
Surface tension	(dyne/cm)	83.563	83.772

Molar Composition	MW	Vapor	Liquid	K-Value	Vapor	Liquid	K-Value
1 Nitrogen	28.01	0.6428	1.37e-4	4705.2	0.6428	1.28e-4	5022.4
2 Oxygen	32.00	0.3492	2.72e-7	1281720	0.3492	2.28e-7	1530948
3 Argon	39.95	0.0076	1.3e-11	6.12e+8	0.0076	10e-12	7.68e+8
4 CO2	44.01	2.48e-4	2.87e-6	86.433	2.48e-4	2.70e-6	91.890
5 H2O	18.02	8.26e-5	0.9999	8.26e-5	8.26e-5	0.9999	8.26e-5

Mass Composition	Vapor	Liquid	Vapor	Liquid
1 Nitrogen	0.6104	2.12e-4	0.6104	1.99e-4
2 Oxygen	0.3788	4.84e-7	0.3788	4.05e-7
3 Argon	0.0104	2.8e-11	0.0104	2.2e-11
4 CO2	3.70e-4	7.00e-6	3.70e-4	6.58e-6
5 H2O	5.04e-5	0.9998	5.04e-5	0.9998

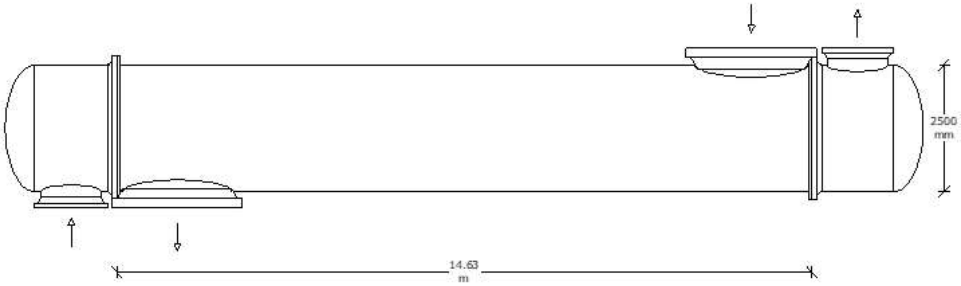
Stream Properties

Released to the following company:
-
Tugas Akhir

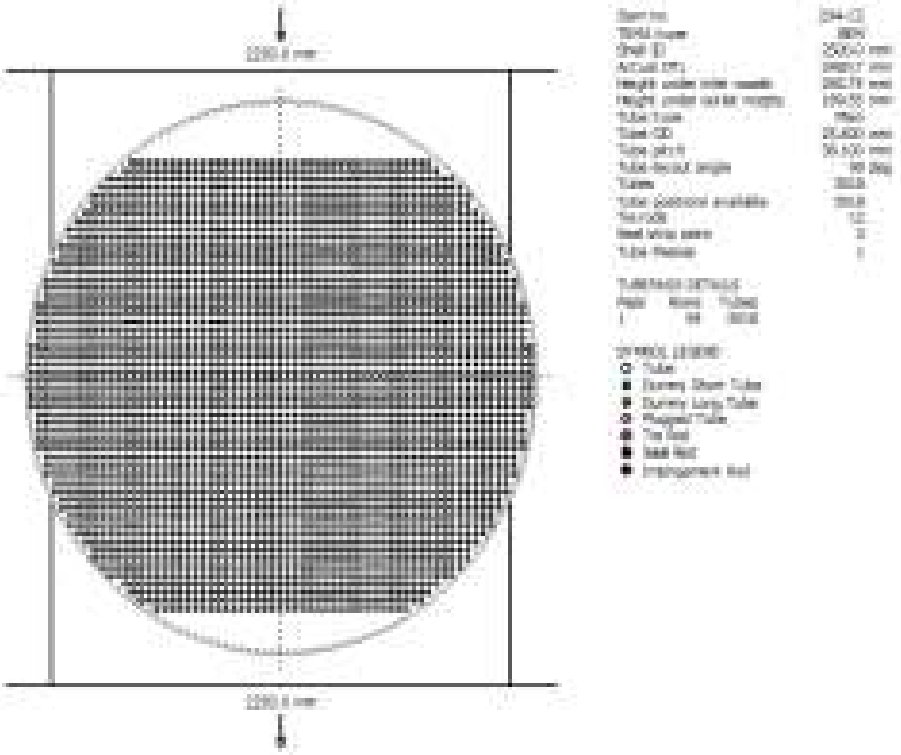
Xist 9 (32 bit) 24-Dec-25 22:22 SN: 46639- **Customs Units**
O2 sebelum di Vent ke atmosfer
O2 Produk SOEC : 204-C2
Rating - Horizontal Countercurrent Flow TEMA BEM Shell With No Baffles

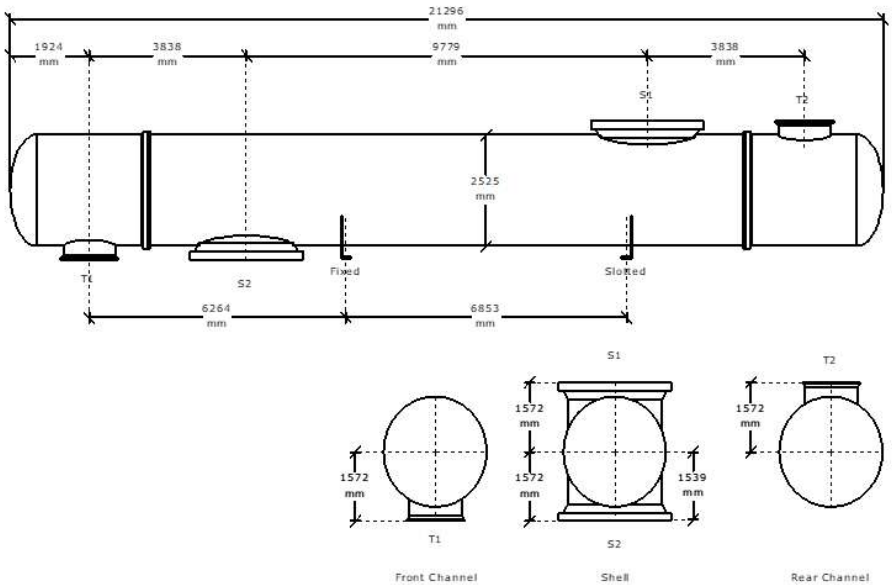
Cold Tubeside Fluid		**Inlet**	**Outlet**
Fluid name		Sea Water	
Flow	(kg/hr)	1.11e+7	
Temperature	(C)	32.10	34.07
Pressure	(kgf/cm2G)	5.000	3.931
Weight fraction vapor	(--)	0.0000	0.0000
Vapor Properties			
Flow	(kg/hr)	0.0000	0.0000
Density	(kg/m3)	3.0785	2.5647
Viscosity	(cP)	0.0142	0.0139
Conductivity	(W/m-K)	0.0293	0.0287
Heat capacity	(kJ/kg-C)	1.9892	1.9745
Molecular weight	(--)	18.015	18.015
Liquid Properties			
Flow	(kg/hr)	1.11e+7	1.11e+7
Density	(kg/m3)	1002.1	1000.6
Viscosity	(cP)	0.7626	0.7327
Conductivity	(W/m-K)	0.6212	0.6238
Heat capacity	(kJ/kg-C)	4.3131	4.3136
Molecular weight	(--)	18.015	18.015
Latent heat	(kJ/kg)	2110.2	2133.3
Surface tension	(dyne/cm)	70.869	70.527

Molar Composition	**Vapor**	**Liquid**	**K-Value**	**Vapor**	**Liquid**	**K-Value**



Item no.	204-C2	Total tube inlet nozzles	1	Stream ID	Shellside		Tubeside	
TEMA type	BEM	Total tube outlet nozzles	1	Stream name	O2 Produk SOEC		Sea Water	
Shell diameter	2500 mm	Total shell inlet nozzles	1	Flow (total), kg/hr	750345		1.11e+7	
Tube length	14.63 m	Total shell outlet nozzles	1	Pressure drop, kgf/cm2	0.241		1.069	
Dry weight	69508 kg/shell			Temperature, C	170.00	47.00	32.10	34.07
Wet weight	171435 kg/shell			Wt. fraction vapor	1.0000	1.0000	0.0000	0.0000
Bundle weight	43363 kg/shell			Pressure, kgf/cm2G	0.900	0.659	5.000	3.931





	Nozzles	OD, mm	Rating	Design	Shell	Tube	Weight	kg				
S1	Inlet	2294.4		Pres (kgf/cm2G)	5.273	5.825	Bundle	43363	Company	-		
T1	Inlet	1265.2		Temp (C)	198.89	60	Dry	69508	Customer		Ref	
S2	Outlet	2294.4		Passes	1	1	Wet	171435	Item No.	204-C2		
T2	Outlet	1265.2		Thick (mm)	12.7	2.769			Service			
									TEMA	BEM		Setting Plan
									Date	24-Dec-25	By	
									Diagram		Rev	

- Feed Heater, 301-C

Output Summary Page 1

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:15 SN: 46639- **Customs Units**

Feed Heater : 301-C
Rating - Horizontal Cocurrent Flow TEMA BEM Shell With Rod-type Baffles

No Data Check Messages.
See Runtime Message Report for Warning Messages.

Process Conditions		Cold Shellside		Hot Tubeside	
Fluid name			Syngas Inlet		Reactor Outlet
Total flow rate	(kg/hr)		221329		221327
Inlet/Outlet Y	(Wt. frac vap.)	1.0000	1.0000	1.0000	1.0000
Inlet/Outlet T	(Deg C)	50.65	170.00	490.16	364.83
Inlet P/Avg	(kgf/cm2G)	155.00	154.85	154.50	154.39
dP/Allow.	(kgf/cm2)	0.301	0.500	0.226	0.500
Fouling	(m2-K/W)		0.000100		0.000100

Exchanger Performance					
Shell h	(W/m2-K)	1593.8	Actual U	(W/m2-K)	792.08
Tube h	(W/m2-K)	2516.5	Required U	(W/m2-K)	694.38
Hot regime	(--)	Sens. Gas	Total duty	(MM kJ/hr)	90.314
Cold regime	(--)	Sens. Gas	Eff. area	(m2)	119.79
EMTD	(Deg C)	301.6	Overdesign	(%)	14.07

Shell Geometry			Baffle Geometry		
TEMA type	(--)	BEM	Baffle type		Rods
Shell ID	(mm)	1100.0	Baffle cut	(Pct Dia.)	
Series	(--)	1	Baffle orientation	(--)	
Parallel	(--)	1	Central spacing	(mm)	300.00
Orientation	(deg)	0.00	Crosspasses	(--)	9

Tube Geometry			Nozzles		
Tube type	(--)	Plain	Shell inlet	(mm)	387.35
Tube OD	(mm)	25.400	Shell outlet	(mm)	254.51
Length	(m)	4.877	Inlet height	(mm)	124.55
Pitch ratio	(--)	1.5000	Outlet height	(mm)	175.35
Layout	(deg)	90	Tube inlet	(mm)	387.35
Tubecount	(--)	510	Tube outlet	(mm)	254.51
Tube Pass	(--)	1			

Thermal Resistance, %		Velocities, m/s	Min	Max	Flow Fractions
Shell	49.70				A
Tube	32.92	Tubeside	8.76	10.38	B
Fouling	16.21	Crossflow	--	--	C
Metal	1.17	Longitudinal	2.10	2.82	E
					F

Final Results

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:15 SN: 46639- **Customs Units**

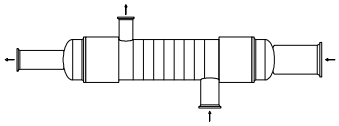
Feed Heater : 301-C
Rating - Horizontal Cocurrent Flow TEMA BEM Shell With Rod-type Baffles

Process Data		Cold Shellside		Hot Tubeside	
Fluid name		Syngas Inlet		Reactor Outlet	
Fluid condition		Sens. Gas		Sens. Gas	
Total flow rate	(kg/hr)	221329		221327	
Weight fraction vapor, In/Out	(—)	1.0000	1.0000	1.0000	1.0000
Temperature, In/Out	(Deg C)	50.65	170.00	490.16	364.83
Skin temperature, Min/Max	(Deg C)	265.89	271.88	300.47	346.64
Wall temperature, Min/Max	(Deg C)	281.65	305.95	283.98	310.99
Pressure, In/Average	(kgf/cm2G)	155.00	154.85	154.50	154.39
Pressure drop, Total/Allowed	(kgf/cm2)	0.301	0.500	0.226	0.500
Velocity, Mid/Max allow	(m/s)	2.51		9.47	
Mole fraction inert	(—)				0.0000
Average film coef.	(W/m2-K)		1593.8		2516.5
Heat transfer safety factor	(—)		1.0000		1.0000
Fouling resistance	(m2-K/W)		0.000100		0.000100

Overall Performance Data

Overall coef., Reqd/Clean/Actual	(W/m2-K)	694.38	/	945.27	/	792.08
Total Duty, Calculated/Specified	(MM kJ/hr)	90.314	/			
Effective overall temperature difference	(Deg C)	301.6				
EMTD = (MTD) * (DELTA) * (F/G/H)	(Deg C)	301.6	*	1.0000	*	1.0000

See Runtime Messages Report for warnings.



Exchanger Fluid Volumes

Approximate shellside(L)	2777.6
Approximate tubeside(L)	3593.7

Shell Construction Information

TEMA shell type	BEM		Shell ID	(mm)	1100.0
Shells Series	1 Parallel	1	Total area	(m2)	198.47
Passes Shell	1 Tube	1	Eff. area	(m2/shell)	119.79
Shell orientation angle (deg)	0.00				
Impingement present	Circular plate		Impingement diameter/nozzle		1.1000
Pairs seal strips	1		Passlane seal rods (mm)	0.000	No. 0
Shell expansion joint	Yes		Rear head support plate	No	
Weight estimation Wet/Dry/Bundle	120713	/	114344	/	11680 (kg/shell)

Baffle Information

Type	Rods		Baffle cut (% dia)	
Crosspasses/shellpass	9		No.(Pct Area)	(mm) to C.L
Central spacing	(mm) 300.00		1	
Ring ID	(mm) 1060.4		2	
ROD OD	(mm) 12.700			
Ring Thickness	(mm) 16.610			
Use deresonating baffles	No			

Tube Information

Tube type	Plain		Tubecount per shell		510
Overall length	(m)	4.877	Pct tubes removed (both)		15.42
Effective length	(m)	2.943	Outside diameter	(mm)	25.400
Total tubesheet	(mm)	1933.6	Wall thickness	(mm)	0.559
Area ratio	(out/in)	1.0460	Pitch (mm)	38.100 Ratio	1.5000
Tube metal	SA-214 Tube (W) K01807		Tube pattern (deg)		90

Shellside Performance

Nom vel, X-flow/window 0.00 / 2.51

Flow fractions for heat transfer

Shellside Heat Transfer Corrections

Total	Beta	Gamma	End	Fin
0.985	0.920	1.070	1.000	1.000

Pressure Drops (Percent of Total)

Cross	Window	Ends	Nozzle	Shell	Tube
0.00	2.34	0.26	Inlet	18.58	18.88
MOMENTUM		0.00	Outlet	78.83	52.29

Two-Phase Parameters

Method	Inlet	Center	Outlet	Mix F

H. T. Parameters		Shell	Tube
Overall wall correction		0.842	1.000
Midpoint	Prandtl no.	0.35	0.41
Midpoint	Reynolds no.	335256	301794
Bundle inlet	Reynolds no.	195774	279078
Bundle outlet	Reynolds no.	153455	321529
Fouling layer	(mm)		

Thermal Resistance, %

Shell	Tube	Fouling	Metal	Over Des
49.70	32.92	16.21	1.17	14.07

Total fouling resistance	(m2-K/W)	2.05e-4
Differential resistance	(m2-K/W)	1.78e-4

Shell Nozzles

Inlet at channel end No

		Inlet	Outlet	Liquid Outlet
Number at each position		1	1	0
Diameter	(mm)	387.35	254.51	
Velocity	(m/s)	10.98	34.80	
Pressure drop	(kgf/cm2)	0.056	0.237	
Height under nozzle	(mm)	124.55	175.35	
Nozzle R-V-SQ	(kg/m-s2)	5726.5	42060	
Shell ent.	(kg/m-s2)			

Tube Nozzle		Inlet AXIAL	Outlet AXIAL	Liquid Outlet
Diameter	(mm)	387.35	254.51	
Velocity	(m/s)	20.92	40.56	
Pressure drop	(kgf/cm2)	0.043	0.118	
Nozzle R-V-SQ	(kg/m-s2)	10913	49010	

Annular Distributor		Inlet	Outlet
Length	(mm)		
Height	(mm)		
Slot area	(mm2)		

Diametral Clearances (mm)

Baffle-to-shell	Bundle-to-shell	Tube-to-baffle
6.3500	39.569	0.0000

Supplementary Results

Released to the following company:

-

Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:15 SN: 46639- **Customs Units**

Feed Heater : 301-C

Rating - Horizontal Cocurrent Flow TEMA BEM Shell With Rod-type Baffles

Externally Enhanced Tube Geometry			Internally Enhanced Tube Geometry		
Type		Plain	Type		None
Fin density	(fin/meter)		Thickness	(mm)	
Fin height	(mm)		Pitch	(L/D)	
Fin thickness	(mm)				
Root diameter	(mm)				
Area/length	(m2/m)				

Mean Metal Temperatures

Mean shell temperature	117.94 (C)
Tubesheet temperature	520.00 (C)

Mean tube metal temperature in each tubepass, (C)

Tube Pass	Inside	Outside	Radial
1	295.55	292.02	293.76

Stream Properties

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:15 SN: 46639- **Customs Units**

Feed Heater : 301-C
Rating - Horizontal Cocurrent Flow TEMA BEM Shell With Rod-type Baffles

Hot Tubeside Fluid		**Inlet**	**Outlet**
Fluid name		Reactor Outlet	
Flow	(kg/hr)	221327	
Temperature	(C)	490.16	364.83
Pressure	(kgf/cm2G)	154.50	154.27
Weight fraction vapor	(--)	1.0000	1.0000
Vapor Properties			
Flow	(kg/hr)	221327	221327
Density	(kg/m3)	24.942	29.798
Viscosity	(cP)	0.0228	0.0196
Conductivity	(W/m-K)	0.1800	0.1572
Heat capacity	(kJ/kg-C)	3.2965	3.2144
Molecular weight	(--)	10.726	10.726
Liquid Properties			
Flow	(kg/hr)	--	--
Density	(kg/m3)	--	--
Viscosity	(cP)	--	--
Conductivity	(W/m-K)	--	--
Heat capacity	(kJ/kg-C)	--	--
Molecular weight	(--)	--	--
Latent heat	(kJ/kg)	--	--
Surface tension	(dyne/cm)	--	--

Molar Composition	**MW**	**Vapor**	**Liquid**	**K-Value**	**Vapor**	**Liquid**	**K-Value**
1 Hydrogen	2.02	0.5681	0.0000	--	0.5681	0.0000	--
2 Nitrogen	28.01	0.2020	0.0000	--	0.2020	0.0000	--
3 Argon	39.95	2.47e-4	0.0000	--	2.47e-4	0.0000	--
4 Ammonia	17.03	0.2297	0.0000	--	0.2297	0.0000	--

Mass Composition	**Vapor**	**Liquid**	**Vapor**	**Liquid**
1 Hydrogen	0.1068	0.0000	0.1068	0.0000
2 Nitrogen	0.5277	0.0000	0.5277	0.0000
3 Argon	9.21e-4	0.0000	9.21e-4	0.0000
4 Ammonia	0.3646	0.0000	0.3646	0.0000

Stream Properties

Released to the following company:
-
Tugas Akhir

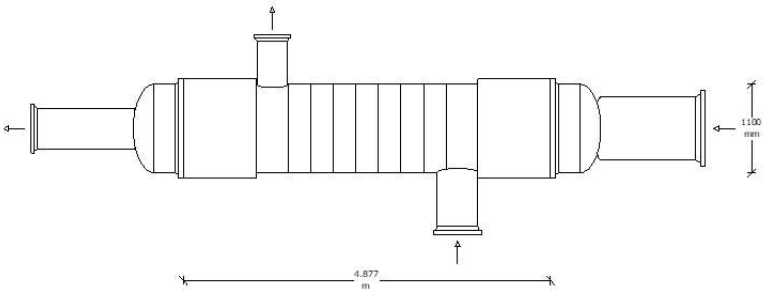
Xist 9 (32 bit) 24-Dec-25 22:15 SN: 46639- **Customs Units**

Feed Heater : 301-C
Rating - Horizontal Cocurrent Flow TEMA BEM Shell With Rod-type Baffles

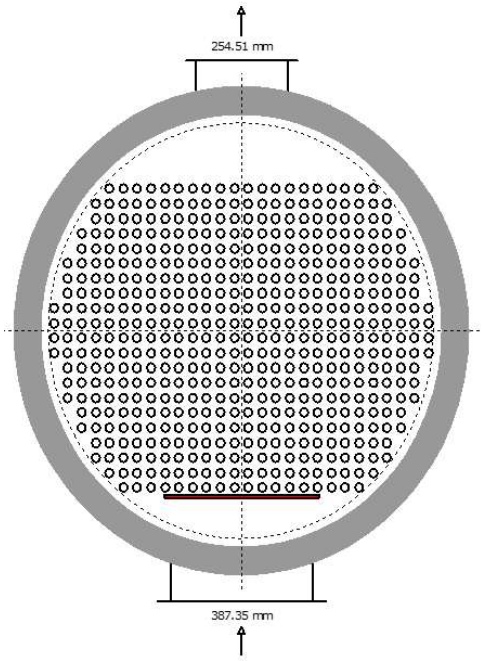
Cold Shellside Fluid		Inlet	Outlet
Fluid name		Syngas Inlet	
Flow	(kg/hr)	221329	
Temperature	(C)	50.65	170.00
Pressure	(kgf/cm2G)	155.00	154.70
Weight fraction vapor	(--)	1.0000	1.0000
Vapor Properties			
Flow	(kg/hr)	221329	221329
Density	(kg/m3)	47.532	34.723
Viscosity	(cP)	0.0120	0.0154
Conductivity	(W/m-K)	0.1193	0.1480
Heat capacity	(kJ/kg-C)	3.4475	3.4055
Molecular weight	(--)	8.8092	8.8092
Liquid Properties			
Flow	(kg/hr)	--	--
Density	(kg/m3)	--	--
Viscosity	(cP)	--	--
Conductivity	(W/m-K)	--	--
Heat capacity	(kJ/kg-C)	--	--
Molecular weight	(--)	--	--
Latent heat	(kJ/kg)	--	--
Surface tension	(dyne/cm)	--	--

Molar Composition	MW	Vapor	Liquid	K-Value	Vapor	Liquid	K-Value
1 Hydrogen	2.02	0.7346	0.0000	--	0.7346	0.0000	--
2 Nitrogen	28.01	0.2553	0.0000	--	0.2553	0.0000	--
3 Argon	39.95	2.03e-4	0.0000	--	2.03e-4	0.0000	--
4 Ammonia	17.03	0.0099	0.0000	--	0.0099	0.0000	--

Mass Composition	Vapor	Liquid	Vapor	Liquid
1 Hydrogen	0.1681	0.0000	0.1681	0.0000
2 Nitrogen	0.8118	0.0000	0.8118	0.0000
3 Argon	9.21e-4	0.0000	9.21e-4	0.0000
4 Ammonia	0.0192	0.0000	0.0192	0.0000



Item no.	301-C	Total tube inlet nozzles	1	Stream ID	Shellside		Tubeside	
TEMA type	BEM	Total tube outlet nozzles	1	Stream name	Syngas Inlet		Reactor Outlet	
Shell diameter	1100 mm	Total shell inlet nozzles	1	Flow (total), kg/hr	221329		221327	
Tube length	4.877 m	Total shell outlet nozzles	1	Pressure drop, kgf/cm2	0.301		0.226	
Dry weight	114344 kg/shell			Temperature, C	50.65	176.00	490.16	364.83
Wet weight	120713 kg/shell			Wt. fraction vapor	1.0000	1.0000	1.0000	1.0000
Bundle weight	11680 kg/shell			Pressure, kgf/cm2G	155.00	154.70	154.50	154.27

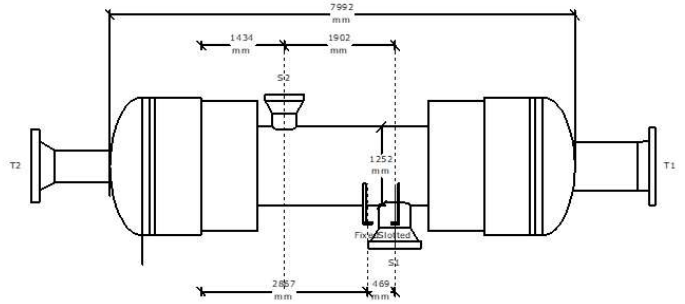


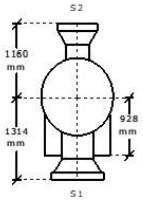
Item no.	301-C
TEMA type	BEM
Shell ID	1100.0 mm
Actual OTL	1060.4 mm
Height under inlet nozzle	124.55 mm
Height under outlet nozzle	175.35 mm
Tube type	Plain
Tube OD	25.400 mm
Tube pitch	38.100 mm
Tube layout angle	90 deg
Tubes	510
Tube positions available	510
Tie rods	8
Seal strip pairs	1
Tube Passes	1
Baffle cut % diameter	25

TUBEPASS DETAILS

Pass	Rows	Tubes
1	21	510

SYMBOL LEGEND
- Tube
- Dummy Short Tube
- Dummy Long Tube
- Plugged Tube
- Tie Rod
- Seal Rod
- Impingement Rod





Shell

	Nozzles	O.D, mm	Rating	Design	Shell	Tube	Weight	kg
S1	Inlet	539.75		Pres (kgf/cm2G)	170.85	170.14	Bundle	11680
T1	Inlet	781.05		Temp (C)	200	520	Dry	114344
S2	Outlet	406.91		Passes	1	1	Wet	120713
T2	Outlet	514.86		Thick (mm)	76.2	0.559		

Company	-		
Customer		Ref	
Item No.	301-C		
Service			
TEMA	BEM		Setting Plan
Date	24-Dec-25	By	
Diagram		Rev.	

- BFW Heater. 302-C

Output Summary Page 1

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:18 SN: 46639- **Customs Units**

BFW heater : 302-C
Rating - Horizontal Countercurrent Flow TEMA NEN Shell With No Baffles

See Data Check Messages Report for Warning Messages.
See Runtime Message Report for Warning Messages.

Process Conditions		Cold Shellside		Hot Tubeside	
Fluid name			BFW		Syngas Outlet Feed Heater
Total flow rate	(kg/hr)		159025		221327
Inlet/Outlet Y	(Wt. frac vap.)	0.0000	0.0000	1.0000	1.0000
Inlet/Outlet T	(Deg C)	115.00	331.47	490.16	230.00
Inlet P/Avg	(kgf/cm2G)	155.00	154.98	154.50	154.39
dP/Allow.	(kgf/cm2)	0.035	0.500	0.225	0.500
Fouling	(m2-K/W)		0.000100		0.000100

Exchanger Performance					
Shell h	(W/m2-K)	827.77	Actual U	(W/m2-K)	347.22
Tube h	(W/m2-K)	1828.9	Required U	(W/m2-K)	305.81
Hot regime	(--)	Sens. Gas	Total duty	(MM kJ/hr)	184.15
Cold regime	(--)	Sens. Liquid	Eff. area	(m2)	1337.1
EMTD	(Deg C)	125.1	Overdesign	(%)	13.54

Shell Geometry			Baffle Geometry		
TEMA type	(--)	NEN	Baffle type		None
Shell ID	(mm)	2400.0	Baffle cut	(Pct Dia.)	
Series	(--)	1	Baffle orientation	(--)	
Parallel	(--)	1	Central spacing	(mm)	4823.2
Orientation	(deg)	0.00	Crosspasses	(--)	1

Tube Geometry			Nozzles		
Tube type	(--)	Plain	Shell inlet	(mm)	254.51
Tube OD	(mm)	25.400	Shell outlet	(mm)	202.72
Length	(m)	6.706	Inlet height	(mm)	32.455
Pitch ratio	(--)	1.5000	Outlet height	(mm)	32.455
Layout	(deg)	30	Tube inlet	(mm)	438.15
Tubecount	(--)	3474	Tube outlet	(mm)	254.51
Tube Pass	(--)	1			

Thermal Resistance, %		Velocities, m/s	Min	Max	Flow Fractions	
Shell	41.95				A	
Tube	39.16	Tubeside	3.95	6.12	B	0.982
Fouling	10.63	Crossflow	--	--	C	0.018
Metal	8.26	Longitudinal	1.72e-2	2.38e-2	E	
					F	

Final Results

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:18 SN: 46639- **Customs Units**

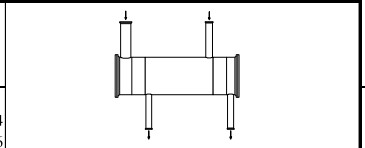
BFW heater : 302-C
Rating - Horizontal Countercurrent Flow TEMA NEN Shell With No Baffles

Process Data		Cold Shellside		Hot Tubeside	
Fluid name		BFW		ngas Outlet Feed Heater	
Fluid condition		Sens. Liquid		Sens. Gas	
Total flow rate	(kg/hr)	159025		221327	
Weight fraction vapor, In/Out	(—)	0.0000	0.0000	1.0000	1.0000
Temperature, In/Out	(Deg C)	115.00	331.47	490.16	230.00
Skin temperature, Min/Max	(Deg C)	172.99	387.24	192.87	418.73
Wall temperature, Min/Max	(Deg C)	176.65	393.03	185.33	406.79
Pressure, In/Average	(kgf/cm2G)	155.00	154.98	154.50	154.39
Pressure drop, Total/Allowed	(kgf/cm2)	0.035	0.500	0.225	0.500
Velocity, Mid/Max allow	(m/s)	1.94e-2		4.90	
Mole fraction inert	(—)				0.0000
Average film coef.	(W/m2-K)		827.77		1828.9
Heat transfer safety factor	(—)		1.0000		1.0000
Fouling resistance	(m2-K/W)		0.000100		0.000100

Overall Performance Data

Overall coef., Reqd/Clean/Actual	(W/m2-K)	305.81	/	388.54	/	347.22
Total Duty, Calculated/Specified	(MM kJ/hr)	184.15	/			
Effective overall temperature difference	(Deg C)	125.1				
EMTD = (MTD) * (DELTA) * (F/G/H)	(Deg C)	125.3	*	0.9987	*	1.0000

See Runtime Messages Report for warnings.



Exchanger Fluid Volumes

Approximate shellside(L)	9334
Approximate tubeside(L)	87266

Shell Construction Information

TEMA shell type	NEN		Shell ID	(mm)	2400.0
Shells Series	1 Parallel	1	Total area	(m2)	1859.0
Passes Shell	1 Tube	1	Eff. area	(m2/shell)	1337.1
Shell orientation angle (deg)	0.00				
Impingement present	No				
Pairs seal strips	0		Passlane seal rods (mm)	0.000	No. 0
Shell expansion joint	No		Rear head support plate	No	
Weight estimation Wet/Dry/Bundle	3334914	/	3257017	/	224508 (kg/shell)

Baffle Information

Type	None		Baffle cut (% dia)		
Crosspasses/shellpass	1		No.(Pct Area)	(mm)	to C.L
Central spacing	(mm)	4823.2	1		
Inlet spacing	(mm)	0.000	2		
Outlet spacing	(mm)	0.000			
Baffle thickness	(mm)	0.000			
Use deresonating baffles	No				

Tube Information

Tube type	Plain		Tubecount per shell		3474
Overall length	(m)	6.706	Pct tubes removed (both)		0.32
Effective length	(m)	4.823	Outside diameter	(mm)	25.400
Total tubesheet	(mm)	1882.8	Wall thickness	(mm)	6.543
Area ratio	(out/in)	2.0627	Pitch (mm)	38.100 Ratio	1.5000
Tube metal	SA-214 Tube (W) K01807		Tube pattern (deg)		30

Shellside Performance

Nom vel, X-flow/window	0.00 / 1.92e-2
Flow fractions for heat transfer	0.987
B=0.9818 C=0.0182	

Shellside Heat Transfer Corrections

Total	Beta	Gamma	End	Fin
0.982	0.920	1.068	1.000	1.000

Pressure Drops (Percent of Total)

Cross	Window	Ends	Nozzle	Shell	Tube
0.00	0.13	0.02	Inlet	24.90	17.35
MOMENTUM		0.00	Outlet	74.95	60.94

Two-Phase Parameters

Method	Inlet	Center	Outlet	Mix F

H. T. Parameters		Shell	Tube
Overall wall correction		1.031	1.000
Midpoint	Prandtl no.	0.93	0.40
Midpoint	Reynolds no.	4024	94614
Bundle inlet	Reynolds no.	1709	81369
Bundle outlet	Reynolds no.	5155	110645
Fouling layer	(mm)		

Thermal Resistance, %

Shell	Tube	Fouling	Metal	Over Des
41.95	39.16	10.63	8.26	13.54

Total fouling resistance	(m2-K/W)	3.06e-4
Differential resistance	(m2-K/W)	3.9e-4

Shell Nozzles

Inlet at channel end: No

		Inlet	Outlet	Liquid Outlet
Number at each position		1	1	0
Diameter	(mm)	254.51	202.72	
Velocity	(m/s)	0.92	2.06	
Pressure drop	(kgf/cm2)	8.78e-3	0.026	
Height under nozzle	(mm)	32.455	32.455	
Nozzle R-V-SQ	(kg/m-s2)	800.08	2824.6	
Shell ent.	(kg/m-s2)	1281.2	3255.8	

Tube Nozzle		Inlet RADIAL	Outlet RADIAL	Liquid Outlet
Diameter	(mm)	438.15	254.51	
Velocity	(m/s)	17.07	31.80	
Pressure drop	(kgf/cm2)	0.039	0.137	
Nozzle R-V-SQ	(kg/m-s2)	6960.8	38427	

Annular Distributor		Inlet	Outlet
Length	(mm)		
Height	(mm)		
Slot area	(mm2)		

Diametral Clearances (mm)

Baffle-to-shell	Bundle-to-shell	Tube-to-baffle
11.113	18.861	0.0000

Supplementary Results

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:18 SN: 46639- **Customs Units**

BFW heater : 302-C
Rating - Horizontal Countercurrent Flow TEMA NEN Shell With No Baffles

Externally Enhanced Tube Geometry			Internally Enhanced Tube Geometry		
Type		Plain	Type		None
Fin density	(fin/meter)		Thickness	(mm)	
Fin height	(mm)		Pitch	(L/D)	
Fin thickness	(mm)				
Root diameter	(mm)				
Area/length	(m2/m)				

Mean Metal Temperatures

Mean shell temperature	226.90 (C)
Tubesheet temperature	500.00 (C)

Mean tube metal temperature in each tubepass, (C)

Tube Pass	Inside	Outside	Radial
1	293.66	283.32	287.29

Stream Properties

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:18 SN: 46639- **Customs Units**

BFW heater : 302-C
Rating - Horizontal Countercurrent Flow TEMA NEN Shell With No Baffles

Hot Tubeside Fluid		Inlet	Outlet
Fluid name		Syngas Outlet Feed Heater	
Flow	(kg/hr)	221327	
Temperature	(C)	490.16	230.00
Pressure	(kgf/cm2G)	154.50	154.28
Weight fraction vapor	(--)	1.0000	1.0000
Vapor Properties			
Flow	(kg/hr)	221327	221327
Density	(kg/m3)	23.885	38.005
Viscosity	(cP)	0.0227	0.0164
Conductivity	(W/m-K)	0.1802	0.1322
Heat capacity	(kJ/kg-C)	3.2877	3.1579
Molecular weight	(--)	10.726	10.726
Liquid Properties			
Flow	(kg/hr)	--	--
Density	(kg/m3)	--	--
Viscosity	(cP)	--	--
Conductivity	(W/m-K)	--	--
Heat capacity	(kJ/kg-C)	--	--
Molecular weight	(--)	--	--
Latent heat	(kJ/kg)	--	--
Surface tension	(dyne/cm)	--	--

Molar Composition	MW	Vapor	Liquid	K-Value	Vapor	Liquid	K-Value
1 Hydrogen	2.02	0.5681	0.0000	--	0.5681	0.0000	--
2 Nitrogen	28.01	0.2020	0.0000	--	0.2020	0.0000	--
3 Argon	39.95	2.47e-4	0.0000	--	2.47e-4	0.0000	--
4 Ammonia	17.03	0.2297	0.0000	--	0.2297	0.0000	--

Mass Composition	Vapor	Liquid	Vapor	Liquid
1 Hydrogen	0.1068	0.0000	0.1068	0.0000
2 Nitrogen	0.5277	0.0000	0.5277	0.0000
3 Argon	9.21e-4	0.0000	9.21e-4	0.0000
4 Ammonia	0.3646	0.0000	0.3646	0.0000



Stream Properties

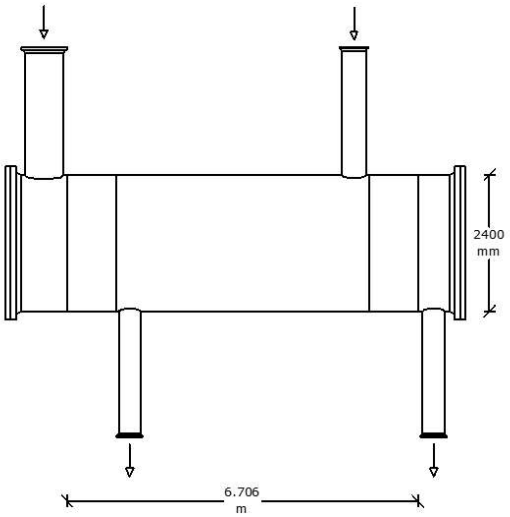
Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:18 SN: 46639- **Customs Units**

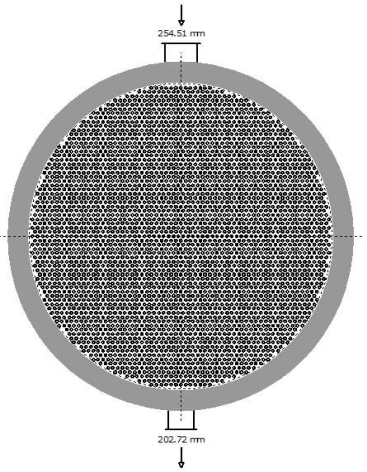
BFW heater : 302-C
Rating - Horizontal Countercurrent Flow TEMA NEN Shell With No Baffles

Cold Shellside Fluid		**Inlet**	**Outlet**
Fluid name		BFW	
Flow	(kg/hr)	159025	
Temperature	(C)	115.00	331.47
Pressure	(kgf/cm2G)	155.00	154.97
Weight fraction vapor	(--)	0.0000	0.0000
Vapor Properties			
Flow	(kg/hr)	--	--
Density	(kg/m3)	--	--
Viscosity	(cP)	--	--
Conductivity	(W/m-K)	--	--
Heat capacity	(kJ/kg-C)	--	--
Molecular weight	(--)	--	--
Liquid Properties			
Flow	(kg/hr)	159025	159025
Density	(kg/m3)	942.34	663.18
Viscosity	(cP)	0.2406	0.0798
Conductivity	(W/m-K)	0.6856	0.4790
Heat capacity	(kJ/kg-C)	4.3971	9.7006
Molecular weight	(--)	18.015	18.015
Latent heat	(kJ/kg)	--	--
Surface tension	(dyne/cm)	55.722	7.3136

Molar Composition	**Vapor**	**Liquid**	**K-Value**	**Vapor**	**Liquid**	**K-Value**



				Stream ID	Shell side	Tubeside
Item no.	302-C	Total tube inlet nozzles	1	Stream name	BFW	Gas Outlet Feed Heater
TEMA type	NEN	Total tube outlet nozzles	1	Flow (total), kg/hr	159025	221327
Shell diameter	2400 mm	Total shell inlet nozzles	1	Pressure drop, kgf/cm2	0.035	0.225
Tube length	6.706 m	Total shell outlet nozzles	1	Temperature, C	115.00 331.47	490.16 230.00
Dry weight	3257017 kg/shell			Wt. fraction vapor	0.0000 0.0000	1.0000 1.0000
Wet weight	3334914 kg/shell			Pressure, kgf/cm2G	159.0 154.97	154.50 138.28
Bundle weight	224508 kg/shell					

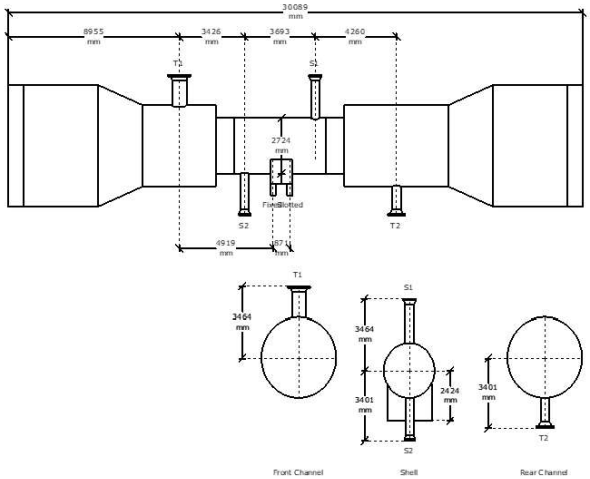


Item no.	302-C
TEMA type	NEN
Shell ID	2400.0 mm
Actual CTL	2381.1 mm
Height under inlet nozzle	32.455 mm
Height under outlet nozzle	32.455 mm
Tube type	Plain
Tube OD	25.400 mm
Tube pitch	38.100 mm
Tube layout angle	30 deg
Tubes	3474
Tube positions available	3474
Tie rods	12
Seal strip pairs	0
Tube Passes	1

TUBEPASS DETAILS

Pass	Rows	Tubes
1	71	3474

SYMBOL LEGEND
- Tube
- Dummy Short Tube
- Dummy Long Tube
- Plugged Tube
- Tie Rod
- Seal Rod
- Impingement Rod



	Nozzles	OD, mm	Rating	Design	Shell	Tube	Weight	kg	Company		Ref	
S1	Inlet	464.08		Pres (kgf/cm2G)	176.85	176.14	Bundle	224508	Customer			
T1	Inlet	730.25		Temp (C)	250	500	Dry	3257017	Item No.	302-C		
S2	Outlet	412.27		Passes	1	1	Wet	3334914	Service			
T2	Outlet	425.96		Thick (mm)	161.93	6.543			TEMA	NEN		Setting Plan
									Date	24-Dec-25	By	
									Diagram		Rev	

- Syngas Cooler, 303-C

Output Summary Page 1

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:24 SN: 46639- **Customs Units**

Syngas Cooler : 303-C
Rating - Horizontal Countercurrent Flow TEMA NEN Shell With No Baffles

See Data Check Messages Report for Warning Messages.
See Runtime Message Report for Warning Messages.

Process Conditions		Cold Shellside		Hot Tubeside	
Fluid name		Cooling Water		Product Inlet Cooler	
Total flow rate	(kg/hr)	3407833		221327	
Inlet/Outlet Y	(Wt. frac vap.)	0.0000	0.0000	1.0000	0.9194
Inlet/Outlet T	(Deg C)	33.00	43.00	230.00	45.00
Inlet P/Avg	(kgf/cm2G)	4.500	4.448	155.00	154.90
dP/Allow.	(kgf/cm2)	0.104	0.500	0.204	0.500
Fouling	(m2-K/W)		0.000100		0.000100

Exchanger Performance					
Shell h	(W/m2-K)	4594.6	Actual U	(W/m2-K)	609.18
Tube h	(W/m2-K)	1176.8	Required U	(W/m2-K)	541.68
Hot regime	(--)	Wet Wall	Total duty	(MM kJ/hr)	147.09
Cold regime	(--)	Sens. Liquid	Eff. area	(m2)	1637.2
EMTD	(Deg C)	46.1	Overdesign	(%)	12.46

Shell Geometry			Baffle Geometry		
TEMA type	(--)	NEN	Baffle type		None
Shell ID	(mm)	2150.0	Baffle cut	(Pct Dia.)	
Series	(--)	1	Baffle orientation	(--)	
Parallel	(--)	1	Central spacing	(mm)	5308.6
Orientation	(deg)	0.00	Crosspasses	(--)	1

Tube Geometry			Nozzles		
Tube type	(--)	Plain	Shell inlet	(mm)	1136.7
Tube OD	(mm)	25.400	Shell outlet	(mm)	1136.7
Length	(m)	6.096	Inlet height	(mm)	127.42
Pitch ratio	(--)	1.2500	Outlet height	(mm)	127.42
Layout	(deg)	30	Tube inlet	(mm)	336.55
Tubecount	(--)	3865	Tube outlet	(mm)	202.72
Tube Pass	(--)	1			

Thermal Resistance, %		Velocities, m/s	Min	Max	Flow Fractions	
Shell	13.26				A	
Tube	68.11	Tubeside	0.84	1.39	B	0.962
Fouling	14.11	Crossflow	--	--	C	0.038
Metal	4.52	Longitudinal	0.56	0.57	E	
					F	

Final Results

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:24 SN: 46639- **Customs Units**

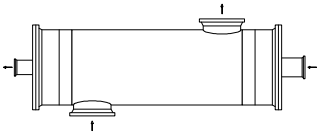
Syngas Cooler : 303-C
Rating - Horizontal Countercurrent Flow TEMA NEN Shell With No Baffles

Process Data		Cold Shellside		Hot Tubeside	
Fluid name		Cooling Water		Product Inlet Cooler	
Fluid condition		Sens. Liquid		Cond. Vapor	
Total flow rate	(kg/hr)		3407833		221327
Weight fraction vapor, In/Out	(—)	0.0000	0.0000	1.0000	0.9194
Temperature, In/Out	(Deg C)	33.00	43.00	230.00	45.00
Skin temperature, Min/Max	(Deg C)	35.39	57.75	38.56	80.48
Wall temperature, Min/Max	(Deg C)	36.43	65.18	37.19	70.70
Pressure, In/Average	(kgf/cm2G)	4.500	4.448	155.00	154.90
Pressure drop, Total/Allowed	(kgf/cm2)	0.104	0.500	0.204	0.500
Velocity, Mid/Max allow	(m/s)	0.57		0.97	
Mole fraction inert	(—)				0.0000
Average film coef.	(W/m2-K)		4594.6		1176.8
Heat transfer safety factor	(—)		1.0000		1.0000
Fouling resistance	(m2-K/W)		0.000100		0.000100

Overall Performance Data

Overall coef., Reqd/Clean/Actual	(W/m2-K)	541.68	/	709.24	/	609.18
Total Duty, Calculated/Specified	(MM kJ/hr)	147.09	/			
Effective overall temperature difference	(Deg C)	46.1				
EMTD = (MTD) * (DELTA) * (F/G/H)	(Deg C)	46.1	*	0.9998	*	1.0000

See Runtime Messages Report for warnings.



Exchanger Fluid Volumes

Approximate shellside(L)	6948.3
Approximate tubeside(L)	28048

Shell Construction Information

TEMA shell type	NEN		Shell ID	(mm)	2150.0
Shells Series	1 Parallel	1	Total area	(m2)	1880.1
Passes Shell	1 Tube	1	Eff. area	(m2/shell)	1637.2
Shell orientation angle (deg)	0.00				
Impingement present	No				
Pairs seal strips	0		Passlane seal rods (mm)	0.000	No. 0
Shell expansion joint	No		Rear head support plate	No	
Weight estimation Wet/Dry/Bundle	1109057	/	1074077	/	56088 (kg/shell)

Baffle Information

Type	None		Baffle cut (% dia)	
Crosspasses/shellpass	1		No.(Pct Area)	(mm) to C.L
Central spacing	(mm)	5308.6	1	
Inlet spacing	(mm)	0.000	2	
Outlet spacing	(mm)	0.000		
Baffle thickness	(mm)	0.000		
Use deresonating baffles	No			

Tube Information

Tube type	Plain		Tubecount per shell		3865
Overall length	(m)	6.096	Pct tubes removed (both)		4.45
Effective length	(m)	5.309	Outside diameter	(mm)	25.400
Total tubesheet	(mm)	787.40	Wall thickness	(mm)	3.048
Area ratio	(out/in)	1.3158	Pitch (mm)	31.750 Ratio	1.2500
Tube metal	SA-214 Tube (W) K01807		Tube pattern (deg)		30

Shellside Performance

Nom vel, X-flow/window	0.00 / 0.57
Flow fractions for heat transfer	0.974
B=0.9624 C=0.0376	

Shellside Heat Transfer Corrections

Total	Beta	Gamma	End	Fin
0.982	0.920	1.068	1.000	1.000

Pressure Drops (Percent of Total)

Cross	Window	Ends	Nozzle	Shell	Tube
0.00	55.87	6.14	Inlet	18.98	29.82
MOMENTUM		0.00	Outlet	19.00	68.84

Two-Phase Parameters

Method	Inlet	Center	Outlet	Mix F
RPM	Sens Gas	Wet Wall	Transition	0.1957

H. T. Parameters		Shell	Tube
Overall wall correction		1.012	
Midpoint	Prandtl no.	4.91	
Midpoint	Reynolds no.	16523	78964
Bundle inlet	Reynolds no.	19385	65143
Bundle outlet	Reynolds no.	23558	41194
Fouling layer	(mm)		

Thermal Resistance, %

Shell	Tube	Fouling	Metal	Over Des
13.26	68.11	14.11	4.52	12.46

Total fouling resistance	(m2-K/W)	2.32e-4
Differential resistance	(m2-K/W)	2.05e-4

Shell Nozzles

Inlet at channel end: Yes

		Inlet	Outlet	Liquid Outlet
Number at each position		1	1	0
Diameter	(mm)	1136.7	1136.7	
Velocity	(m/s)	0.93	0.94	
Pressure drop	(kgf/cm2)	0.020	0.020	
Height under nozzle	(mm)	127.42	127.42	
Nozzle R-V-SQ	(kg/m-s2)	869.04	875.72	
Shell ent.	(kg/m-s2)	4438.9	4473.0	

Tube Nozzle		Inlet AXIAL	Outlet AXIAL	Liquid Outlet
Diameter	(mm)	336.55	202.72	
Velocity	(m/s)	18.16	29.20	
Pressure drop	(kgf/cm2)	0.061	0.141	
Nozzle R-V-SQ	(kg/m-s2)	12550	55628	

Annular Distributor		Inlet	Outlet
Length	(mm)		
Height	(mm)		
Slot area	(mm2)		

Diametral Clearances (mm)

Baffle-to-shell	Bundle-to-shell	Tube-to-baffle
11.113	17.586	0.0000

Supplementary Results

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:24 SN: 46639- **Customs Units**

Syngas Cooler : 303-C
Rating - Horizontal Countercurrent Flow TEMA NEN Shell With No Baffles

Externally Enhanced Tube Geometry			Internally Enhanced Tube Geometry		
Type		Plain	Type		None
Fin density	(fin/meter)		Thickness	(mm)	
Fin height	(mm)		Pitch	(L/D)	
Fin thickness	(mm)				
Root diameter	(mm)				
Area/length	(m2/m)				

Mean Metal Temperatures

Mean shell temperature	36.32 (C)
Tubesheet temperature	255.00 (C)

Mean tube metal temperature in each tubepass, (C)

Tube Pass	Inside	Outside	Radial
1	47.24	45.15	46.10



Stream Properties

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:24 SN: 46639- **Customs Units**

Syngas Cooler : 303-C
Rating - Horizontal Countercurrent Flow TEMA NEN Shell With No Baffles

Hot Tubeside Fluid		**Inlet**	**Outlet**
Fluid name		Product Inlet Cooler	
Flow	(kg/hr)	221327	
Temperature	(C)	230.00	45.00
Pressure	(kgf/cm2G)	155.00	154.80
Weight fraction vapor	(--)	1.0000	0.9194
Vapor Properties			
Flow	(kg/hr)	221327	203478
Density	(kg/m3)	38.058	60.539
Viscosity	(cP)	0.0164	0.0124
Conductivity	(W/m-K)	0.1322	0.1006
Heat capacity	(kJ/kg-C)	3.1581	3.3153
Molecular weight	(--)	10.726	10.396
Liquid Properties			
Flow	(kg/hr)	0.0000	17849
Density	(kg/m3)	541.71	556.20
Viscosity	(cP)	0.0817	0.0912
Conductivity	(W/m-K)	0.4004	0.4192
Heat capacity	(kJ/kg-C)	5.2749	5.1203
Molecular weight	(--)	16.783	16.805
Latent heat	(kJ/kg)	879.96	919.73
Surface tension	(dyne/cm)	18.888	20.769

Molar Composition	**MW**	**Vapor**	**Liquid**	**K-Value**	**Vapor**	**Liquid**	**K-Value**
1 Hydrogen	2.02	0.5681	0.0209	27.204	0.5978	0.0189	31.577
2 Nitrogen	28.01	0.2020	0.0059	33.992	0.2127	0.0053	40.476
3 Argon	39.95	2.47e-4	5.32e-5	4.6420	2.57e-4	5.42e-5	4.7384
4 Ammonia	17.03	0.2297	0.9731	0.2360	0.1892	0.9758	0.1939

Mass Composition	**Vapor**	**Liquid**	**Vapor**	**Liquid**
1 Hydrogen	0.1068	0.0025	0.1159	0.0023
2 Nitrogen	0.5277	0.0099	0.5732	0.0088
3 Argon	9.21e-4	1.27e-4	9.87e-4	1.29e-4
4 Ammonia	0.3646	0.9874	0.3099	0.9888

Stream Properties

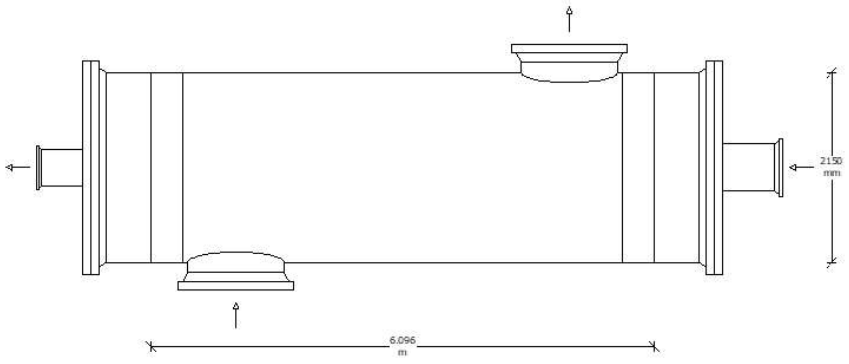
Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:24 SN: 46639- **Customs Units**

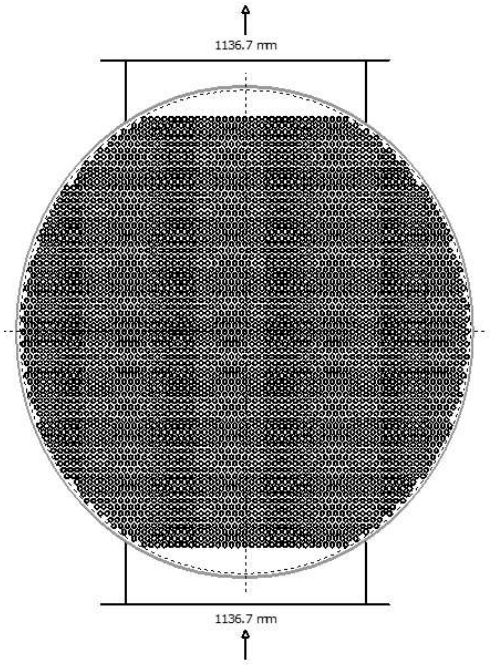
Syngas Cooler : 303-C
Rating - Horizontal Countercurrent Flow TEMA NEN Shell With No Baffles

Cold Shellside Fluid		Inlet	Outlet
Fluid name		Cooling Water	
Flow	(kg/hr)	3407833	
Temperature	(C)	33.00	43.00
Pressure	(kgf/cm2G)	4.500	4.396
Weight fraction vapor	(--)	0.0000	0.0000
Vapor Properties			
Flow	(kg/hr)	--	--
Density	(kg/m3)	--	--
Viscosity	(cP)	--	--
Conductivity	(W/m-K)	--	--
Heat capacity	(kJ/kg-C)	--	--
Molecular weight	(--)	--	--
Liquid Properties			
Flow	(kg/hr)	3407833	3407833
Density	(kg/m3)	1001.4	993.79
Viscosity	(cP)	0.7484	0.6159
Conductivity	(W/m-K)	0.6224	0.6352
Heat capacity	(kJ/kg-C)	4.3133	4.3165
Molecular weight	(--)	18.015	18.015
Latent heat	(kJ/kg)	--	--
Surface tension	(dyne/cm)	70.713	68.967

Molar Composition	Vapor	Liquid	K-Value	Vapor	Liquid	K-Value



Item no.	303-C	Total tube inlet nozzles	1	Stream ID	Shellside		Tubeside
TEMA type	NEN	Total tube outlet nozzles	1	Stream name	Cooling Water		Product Inlet Cooler
Shell diameter	2150 mm	Total shell inlet nozzles	1	Flow (total), kg/hr	3407833		221327
Tube length	6.096 m	Total shell outlet nozzles	1	Pressure drop, kgf/cm2	0.104		0.204
Dry weight	1074077 kg/shell			Temperature, C	33.00	43.00	230.00 45.00
Wet weight	1109057 kg/shell			Wt. fraction vapor	0.0000	0.0000	1.0000 0.9194
Bundle weight	56088 kg/shell			Pressure, kgf/cm2G	4.500	4.396	155.00 154.80



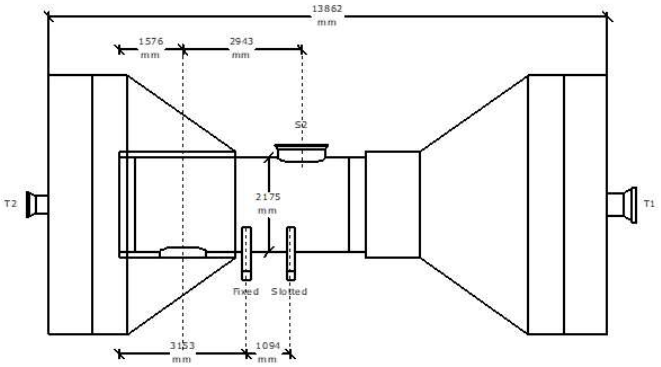
Item no.	303-C
TEMA type	NEN
Shell ID	2150.0 mm
Actual OTL	2132.4 mm
Height under inlet nozzle	127.42 mm
Height under outlet nozzle	127.42 mm
Tube type	Plain
Tube OD	25.400 mm
Tube pitch	31.750 mm
Tube layout angle	30 deg
Tubes	3865
Tube positions available	3865
Tie rods	12
Seal strip pairs	0
Tube Passes	1

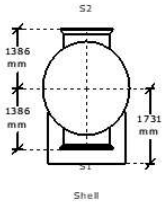
TUBEPASS DETAILS

Pass	Rows	Tubes
1	69	3865

SYMBOL LEGEND

- Tube
- Dummy Short Tube
- Dummy Long Tube
- Plugged Tube
- Tie Rod
- Seal Rod
- Impingement Rod





	Nozzles	OD, mm	Rating	Design	Shell	Tube	Weight	kg	Company	-		
S1	Inlet	1168.4		Pres (kgf/cm2G)	5.273	170.85	Bundle	56088	Customer		Ref	
T1	Inlet	546.1		Temp (C)	80	255	Dry	1074077	Item No.	303-C		
S2	Outlet	1168.4		Passes	1	1	Wet	1109057	Service			
T2	Outlet	412.27		Thick (mm)	12.7	3.048			TEMA	NEN		Setting Plan
									Date	24-Dec-25	By	
									Diagram		Rev	

- Syngas Chiller, 304-C

Output Summary Page 1

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:25 SN: 46639- **Customs Units**

Syngas Chiller produk NH3 : 304-C
Rating - Horizontal With No Baffles

No Data Check Messages.
No Runtime Messages.

Process Conditions		Cold Shellside		Hot Tubeside	
Fluid name		NH3 Refrigerant		Syngas ke Produk NH3	
Total flow rate	(kg/hr)		90220		221327
Inlet/Outlet Y	(Wt. frac vap.)	0.0000	1.0000	0.9186	0.6518
Inlet/Outlet T	(Deg C)	-35.00	-34.86	45.00	-33.50
Inlet P/Avg	(kgf/cm2G)	8.60e-3		155.00	154.56
dP/Allow.	(kgf/cm2)	0.401	0.500	0.888	1.500
Fouling	(m2-K/W)		0.000100		0.000100

Exchanger Performance					
Shell h	(W/m2-K)	3837.2	Actual U	(W/m2-K)	947.05
Tube h	(W/m2-K)	2650.2	Required U	(W/m2-K)	800.99
Hot regime	(--)		Total duty	(MM kJ/hr)	126.13
Cold regime	(--)		Eff. area	(m2)	1765.8
EMTD	(Deg C)	24.8	Overdesign	(%)	18.24

Shell Geometry			Baffle Geometry		
TEMA type	(--)	BKM	Baffle type		Support
Shell ID	(mm)	1800.0	Baffle cut	(Pct Dia.)	
Series	(--)	4	Baffle orientation	(--)	
Parallel	(--)	1	Central spacing	(mm)	1345.4
Orientation	(deg)	0.00	Crosspasses	(--)	1

Tube Geometry			Nozzles		
Tube type	(--)	Plain	Shell inlet	(mm)	
Tube OD	(mm)	25.400	Shell outlet	(mm)	
Length	(m)	6.096	Inlet height	(mm)	311.98
Pitch ratio	(--)	1.2500	Outlet height	(mm)	364.87
Layout	(deg)	30	Tube inlet	(mm)	254.51
Tubecount	(--)	1039	Tube outlet	(mm)	
Tube Pass	(--)	1			

Thermal Resistance, %		Velocities, m/s	Min	Max	Flow Fractions	
Shell	24.65				A	0.000
Tube	47.12	Tubeside	2.10	3.08	B	1.000
Fouling	21.87	Crossflow	6.33e-2	22.99	C	0.000
Metal	6.35	Longitudinal	--	--	E	0.000
					F	0.000

Stream Properties

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:25 SN: 46639- **Customs Units**

Syngas Chiller produk NH3 : 304-C
Rating - Horizontal Single Pass TEMA BKM Shell With No Baffles

Hot Tubeside Fluid For Unit 304-C		**Inlet**	**Outlet**
Fluid name		Syngas ke Produk NH3	
Flow	(kg/hr)	221327	
Temperature	(C)	45.00	-33.50
Pressure	(kgf/cm2G)	155.00	154.11
Weight fraction vapor	(--)	0.9186	0.6518
Vapor Properties			
Flow	(kg/hr)	203305	144260
Density	(kg/m3)	60.685	65.905
Viscosity	(cP)	0.0124	0.0101
Conductivity	(W/m-K)	0.1007	0.0967
Heat capacity	(kJ/kg-C)	3.3171	3.5306
Molecular weight	(--)	10.390	8.9621
Liquid Properties			
Flow	(kg/hr)	18022	77067
Density	(kg/m3)	556.16	673.08
Viscosity	(cP)	0.0912	0.2422
Conductivity	(W/m-K)	0.4192	0.6089
Heat capacity	(kJ/kg-C)	5.1194	4.3798
Molecular weight	(--)	16.804	16.966
Latent heat	(kJ/kg)	898.43	1231.1
Surface tension	(dyne/cm)	20.768	39.572

Molar Composition	**MW**	**Vapor**	**Liquid**	**K-Value**	**Vapor**	**Liquid**	**K-Value**
1 Hydrogen	2.02	0.5982	0.0190	31.486	0.7270	0.0051	143.64
2 Nitrogen	28.01	0.2128	0.0053	40.370	0.2587	9.98e-4	259.24
3 Argon	39.95	2.07e-4	4.38e-5	4.7347	2.40e-4	5.01e-5	4.7903
4 Ammonia	17.03	0.1888	0.9757	0.1935	0.0140	0.9939	0.0141

Mass Composition	**Vapor**	**Liquid**	**Vapor**	**Liquid**
1 Hydrogen	0.1161	0.0023	0.1635	6.01e-4
2 Nitrogen	0.5737	0.0088	0.8087	0.0016
3 Argon	7.97e-4	1.04e-4	0.0011	1.18e-4
4 Ammonia	0.3095	0.9888	0.0267	0.9976

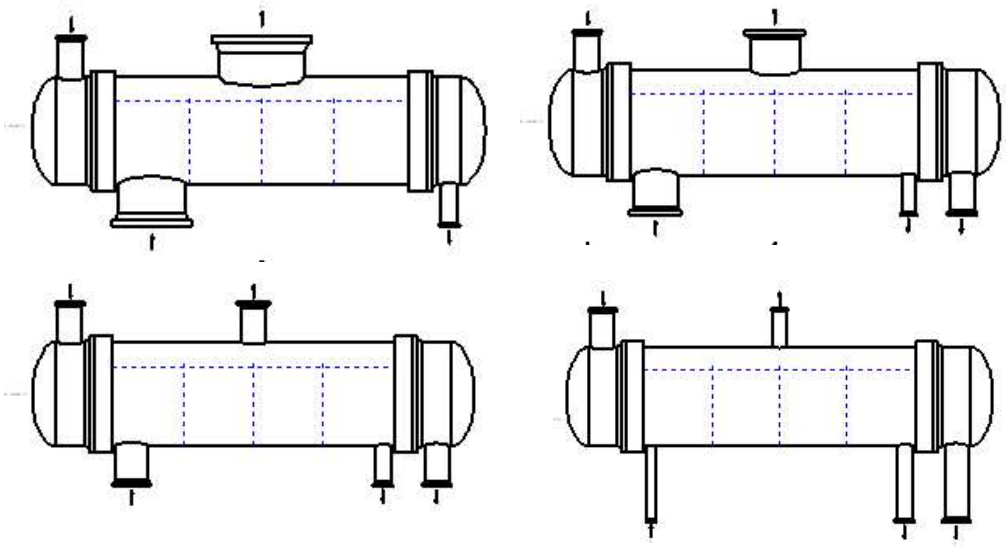
Stream Properties

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 24-Dec-25 22:25 SN: 46639- **Customs Units**

Syngas Chiller produk NH3 : 304-C
Rating - Horizontal Single Pass TEMA BKM Shell With No Baffles

Cold Shellside Fluid For Unit 304-C		**Inlet**			**Outlet**		
Fluid name		NH3 Refrigerant					
Flow	(kg/hr)	90220					
Temperature	(C)	-35.00			-34.86		
Pressure	(kgf/cm2G)	8.60e-3			-0.101		
Weight fraction vapor	(--)	0.0000			1.0000		
Vapor Properties							
Flow	(kg/hr)	0.0000			90220		
Density	(kg/m3)	0.7983			0.7978		
Viscosity	(cP)	0.0065			0.0065		
Conductivity	(W/m-K)	0.0199			0.0199		
Heat capacity	(kJ/kg-C)	2.0485			2.0487		
Molecular weight	(--)	17.030			17.030		
Liquid Properties							
Flow	(kg/hr)	90220			0.0000		
Density	(kg/m3)	675.45			675.44		
Viscosity	(cP)	0.2514			0.2514		
Conductivity	(W/m-K)	0.6179			0.6179		
Heat capacity	(kJ/kg-C)	4.4453			4.4453		
Molecular weight	(--)	17.030			17.030		
Latent heat	(kJ/kg)	1396.9			1396.9		
Surface tension	(dyne/cm)	40.167			40.166		
Molar Composition		**Vapor**	**Liquid**	**K-Value**	**Vapor**	**Liquid**	**K-Value**



7. Air Dryer, 101-DA/DB

Kondisi desain :

a) Komposisi :

Fraksi mol (Nitrogen)	0.7810
Fraksi mol (Oksigen)	0.2093
Fraksi mol (CO2)	0.0003
Fraksi mol (H2O)	0.0001
Fraksi mol (Argon)	0.0093

b) Perhitungan Kapasitas

Total Aliran	12,188.3	kmol/jam
	352,999.8	kg/jam
Tekanan	6.50	kg/cm2G
	7.39	Bar A
Tekanan Desain	11.08	Bar A
	1.11	MPa
Suhu	15.00	oC
	288.15	K
Suhu Desain	538.15	K

Menghitung Massa H2O	1.219	kmol/jam
	21.957	kg/jam
Menghitung massa CO2	3.656	kmol/jam
	160.914	kg/jam

Siklus (Estimasi)	12	Jam
Beban CO2	1,931.0	kg
Beban H2O	263.49	kg
Molsieve		
Equilibrium CO2 Capacity	18.5%	kg CO2 / kg Molsieve
Equilibrium H2O Capacity	27.0%	kg H2O / kg Molsieve
Active Alumina		
Equilibrium H2O Capacity	19.0%	kg H2O / kg Desiccant
Adsorbtion (Active Alimuna)		
Bulk density	760.0	kg/m3

Kebutuhan Desicant	1,386.8	kg Dessicant
	1.8	m3
Margin 20%	2.2	m3
Adsorbtion (Mol Sieve)		
Bulk Density	38.0	lb/ft3
	608.70	kg/m3
Kebutuhan Desicant	10,437.7	kg Dessicant
	17.1	m3
Margin 20%	20.6	m3
Total Volume desiccant (per *vessel*)	22.8	m3
Adsorbsion H2O	4,186.00	kJ/kg
Adsorbsion CO2	35.00	kJ/mol
Duty Regenerasi (Desorbsi)	2,638,685.17	kJ/siklus
Desorbsi H2O	1,102,964.07	kJ/siklus
Desorbsi CO2	1,535,721.10	kJ/siklus



13X-APG MOLSIV™ ADSORBENT

DESCRIPTION

13X-APG adsorbent is the sodium form of the Type X molecular sieve and an alkali metal aluminosilicate. 13X-APG adsorbent will adsorb molecules with critical diameters up to 8 angstroms.

APPLICATIONS

13X-APG adsorbent is specifically developed for air plant feed purification. It has a high capacity for carbon dioxide and water and maintains its capacity well above ambient conditions. It is available in a variety of shapes and sizes to suit your operating needs.

In addition, 13X-APG adsorbent can adsorb molecules, such as olefins, aromatics, straight and branch chain hydrocarbons, SO_x, and NO_x compounds.

CHEMICAL FORMULA

$Na_x [(AlO_2)_x(SiO_2)_y] \cdot z\ H_2O$

REGENERATION

13X-APG adsorbent can be regenerated for re-use by purging at elevated temperatures or at compressor waste heat temperatures.

SAFETY AND HANDLING

See the UOP brochure entitled "Precautions and Safe Practices for Handling Molecular Sieves in Process Units" or contact your UOP representative.

SHIPPING INFORMATION

13X-APG MOLSIV adsorbent is shipped in 55-gallon steel drums or quick load bags.

TYPICAL PHYSICAL PROPERTIES

13X-APG sieve is available in sphere or extrudate form. The diameters for the spheres or "beads" are shown below. The diameters for the extrudates or "pellets" are also shown; the length is approximately twice the diameter.

	1/16" Pellets	1/8" Pellets	TRISIV™ Pellets	8x12 Beads	6x8 Beads	4x8 Beads
Bulk density (lbs/ft³)	38	38	36	40	40	40
Particle diameter (mm)	1.6	3.2	3.2	2.0	3.0	4.0
Crush strength (lbs)	7	15	15	8	12	18
Equilibrium CO_2 capacity[1] (wt-%)	18.5	18.5	18.5	18.5	18.5	18.5
Equilibrium H_2O capacity[2] (wt-%)	27	27	27	27	27	27
Water content, as shipped (wt-%)	<1	<1	<1	<1	<1	<1

[1] Measured at 250 mm Hg and 25 °C
[2] Measured at 17.5 mm Hg and 25 °C

FOR MORE INFORMATION

For more information, contact your UOP representative or UOP's Adsorbents business at:

Telephone: 1-440-734-0086
Fax: 1-440-734-1688
E-mail: Adsorbents@uop.com

UOP LLC
25 East Algonquin Road
Des Plaines, IL 60017-5017
www.uop.com

© 2003 UOP LLC. All rights reserved.
This information is not to be taken as a warranty or representation for which UOP assumes legal responsibility nor as permission or recommendation to practice any patented invention without a license. It is offered solely for your consideration.

UOP 3102-90 0103A0Dv

Axens
IFP Group Technologies

TECHNICAL DATA SHEET

Procatalyse Catalysts & Adsorbents

A.A. 2-5 Grade A

Activated Alumina for Drying and Purification

The **high attrition resistance** and **static adsorption** gives **GRADE A** the optimized characteristics as **adsorbent** for purification or drying.

- Drying of organic liquids as LPG, aromatics, steam cracked liquids, gasoline, chloro and fluoro carbons.
- Drying of air and gases as steam cracked gases, catalytic reforming recycle gases, synthesis gases, methyl chloride, natural gas, LNG...
- Drying of hydrogen, oxygen, nitrogen, CO_2...
- Purification of gases and liquids (removal of metallic traces, BF_3, TBC, HCl, HF and fluorinated hydrocarbons).
- Catalyst for Claus conversion in Sub Dew Point Processes.

❑ ***Aspect***

High purity white Alumina beads

❑ ***Physical properties (*)***

	Min.	Max.	Units
Diameter	*2*	*5*	*mm*
Smaller than 2 mm		*2*	*wt%*
Larger than 5 mm		*2*	*wt%*
Loss on ignition (1000 °C-300 °C)		*7*	*wt%*
Tapped bulk density	*0.76*	*0.85*	*kg/l*
Surface area	*300*	*380*	*m2/g*
Particle crush strength	*12*		*daN*
Attrition resistance (AIF)	*97*		*wt%*
Static adsorption (at 60 % RH)	*19*	*23*	*wt%*

❑ ***Chemical analysis (*)***

Al2O3	*93.5*		*wt%*
Na2O		*5000*	*wtppm*

Shipping information

PACKAGING : 217 l. fiber drums (Net 160 kg)
or 80 l. (Net 50 kg)
or 1500 l. big bags (Net 1000 kg)

MANUFACTURING : Salindres plant
30340 SALINDRES (France)

(*) All figures are given within registered analytical methods, available upon request from our Technical Department

Axens se réserve le droit de modifier à sa seule discrétion et sans préavis tout ou partie des informations contenues dans cette fiche technique.
Les informations contenues dans la présente fiche technique n'ont qu'une valeur indicative et ne sauraient en aucun cas constituer un quelconque engagement contractuel de la part de Axens.

Axens reserves the right to change at its sole discretion, and without prior notice, all or part of the information contained in this Technical Data Sheet.
Technical information regarding the compositions, properties, or use of the product described in this Technical Data Sheet is believed to be reliable. However, no representation or warranty is made with respect thereto except as made by Axens in writing at the time of sale.

89, Boulevard Franklin Roosevelt - B.P. 50802 - F 92508 Rueil Malmaison - France
Tél. +33 (0)1 47 14 21 66 - Télécopieur +33 (0)1 47 01 67 95 - Télex 631091 F

c) Dimensi Dryer :

Dengan volume silinder 22.8 m3 dan dengan asumsi L/D antara 2 – 4, didapatkan :

Target H/D = 3

H = 3D

Sehingga dengan substitusi persamaan volume silinder :

$V = \frac{1}{4}\pi D^2 H$

$= \frac{3}{4}\pi D^3$

$D = \sqrt[3]{\frac{4.V}{3\pi}}$

$= \sqrt[3]{\frac{4\ x\ 22.8}{3\pi}}$

= 2.13 m

H = 3 x D

= 3 x 2.13

= 6.39 m

Material yang dipilih adalah carbon steel (SA-516 Grade 70)

Stress allowable, S: 138 MPa (ASME Section II-D)

Welding effisiensi, E = 1 (full Radiografi Test)

Coorision allowance (assumsi) = 3 mm

Sehingga didapat tebal shell :

$T_{shell} = \frac{P.R}{S.E-0.6P}$

$= \frac{1.11\ x\ 0.5\ x\ 2.13}{138\ x\ 1\ -0.6\ x\ 1.11}$

$= \frac{1.18215}{137.338}$

= 0.00862 m

= 8.62 mm

Total tebal shell + CA = 8.62 + 3 = 11.62 mm

Tebal *head* (2:1 ellipsoidal) :

K = 0.9 (asumsi dari referensi vendor Dryer)

$T_{Head} = \frac{P.K.D}{2S.E-0.2P}$

$= \frac{1.11\ x\ 0.9\ x\ 2.13}{2\ x\ 138\ x\ 1\ -0.2\ x\ 1.11}$

$= \frac{2.12787}{275.778}$

= 0.00772 m

= 7.72 mm

Total tebal *head* + CA = 7.72 + 3 = 10.72 mm

8. Air chiller, 101-C

Perhitungan chiller menggunakan program HTRI Exchanger suite 9.0 dengan input data sebagai berikut :

Komposisi :

Fraksi mol (Nitrogen)	0.7810
Fraksi mol (Oksigen)	0.2093
Fraksi mol (CO2)	0.0003
Fraksi mol (H2O)	0.0001
Fraksi mol (Argon)	0.0093

Laju alir = 12188.3 kmol/jam
= 352999.8 kg/jam
Tekanan operasi = 7.0 kg/cm^{2}G
DP toleransi = maksimal 0.5 kg/cm^2
Suhu operasi (Inlet / Outlet) = 45 / 15 ^{o}C
Hasil dapat dilihat sebagai berikut :

Output Summary

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 27-Dec-25 15:46 SN: 46639- **Customs Units**

Chiller Udara sebelum masuk ke ASU : 101-C
Rating - Horizontal Single Pass TEMA BKM Shell With No Baffles

See Data Check Messages Report for Informative Messages.
See Runtime Message Report for Warning Messages.

Process Conditions		Cold Shellside		Hot Tubeside	
Fluid name		NH3 Refrigerant			Udara
Total flow rate	(kg/hr)		7687.4		352999
Inlet/Outlet Y	(Wt. frac vap.)	0.0000	1.0000	1.0000	1.0000
Inlet/Outlet T	(Deg C)	-35.00	-33.00	45.00	15.00
Inlet P/Avg	(kgf/cm2G)	-0.018	-0.059	7.000	6.892
dP/Allow.	(kgf/cm2)	0.083	0.500	0.216	0.500
Fouling	(m2-K/W)		0.000100		0.000100

Exchanger Performance					
Shell h	(W/m2-K)	2290.5	Actual U	(W/m2-K)	380.48
Tube h	(W/m2-K)	610.48	Required U	(W/m2-K)	353.60
Hot regime	(--)	Sens. Gas	Total duty	(MM kJ/hr)	10.777
Cold regime	(--)	Flow	Eff. area	(m2)	139.04
EMTD	(Deg C)	60.9	Overdesign	(%)	7.60

Shell Geometry			Baffle Geometry		
TEMA type	(--)	BKM	Baffle type		Support
Shell ID	(mm)	1100.0	Baffle cut	(Pct Dia.)	
Series	(--)	1	Baffle orientation	(--)	
Parallel	(--)	1	Central spacing	(mm)	1599.2
Orientation	(deg)	0.00	Crosspasses	(--)	1

Tube Geometry			Nozzles		
Tube type	(--)	Plain	Shell inlet	(mm)	40.894
Tube OD	(mm)	38.100	Shell outlet	(mm)	438.15
Length	(m)	3.300	Inlet height	(mm)	39.163
Pitch ratio	(--)	1.2500	Outlet height	(mm)	77.261
Layout	(deg)	30	Tube inlet	(mm)	895.35
Tubecount	(--)	365	Tube outlet	(mm)	895.35
Tube Pass	(--)	1			

Thermal Resistance, %		Velocities, m/s			Flow Fractions	
Shell	16.61		Min	Max	A	0.000
Tube	72.93	Tubeside	34.32	37.48	B	1.000
Fouling	8.26	Crossflow	0.26	6.42	C	0.000
Metal	2.21	Longitudinal	--	--	E	0.000
					F	0.000

Final Results

Released to the following company:
-
Tugas Akhir

Xist 9 (32 bit) 27-Dec-25 15:46 SN: 46639- **Customs Units**

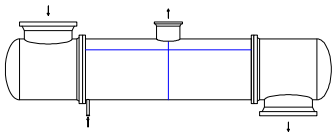
Chiller Udara sebelum masuk ke ASU : 101-C
Rating - Horizontal Single Pass TEMA BKM Shell With No Baffles

Process Data		Cold Shellside		Hot Tubeside	
Fluid name		NH3 Refrigerant		Udara	
Fluid condition		Boil. Liquid		Sens. Gas	
Total flow rate	(kg/hr)	7687.4		352999	
Weight fraction vapor, In/Out	(–)	0.0000	1.0000	1.0000	1.0000
Temperature, In/Out	(Deg C)	-35.00	-33.00	45.00	15.00
Skin temperature, Min/Max	(Deg C)	-28.53	32.41	-23.08	33.91
Wall temperature, Min/Max	(Deg C)	-26.55	32.96	-25.40	33.27
Pressure, In/Average	(kgf/cm2G)	-0.018	-0.059	7.000	6.892
Pressure drop, Total/Allowed	(kgf/cm2)	0.083	0.500	0.216	0.500
Velocity, Mid/Max allow	(m/s)	2.65		35.72	
Boiling range/Mole fraction ine	(Deg C)		2.00e-3		0.0000
Average film coef.	(W/m2-K)		2290.5		610.48
Heat transfer safety factor	(–)		1.0000		1.0000
Fouling resistance	(m2-K/W)		0.000100		0.000100

Overall Performance Data

Overall coef., Reqd/Clean/Actual	(W/m2-K)	353.60	/	414.72	/	380.48
Total Duty, Calculated/Specified	(MM kJ/hr)	10.777	/			
Effective overall temperature difference	(Deg C)	60.9				
EMTD = (MTD) * (DELTA) * (F/G/H)	(Deg C)	60.9	*	1.0000	*	1.0000

See Runtime Messages Report for warnings.



Exchanger Fluid Volumes

Approximate shellside(L)	1805.1
Approximate tubeside(L)	5916.9

Shell Construction Information

TEMA shell type	BKM	Shell ID	(mm)	1100.0	
Shells Series	1 Parallel	1	Total area	(m2)	144.17
Passes Shell	1 Tube	1	Eff. area	(m2/shell)	139.04
Shell orientation angle (deg)	0.00	Kettle ID	(mm)	1100.0	
Impingement present	Rods	Impingement rod rows		2	
Pairs seal strips	0	Passlane seal rods (mm)	0.000	No. 0	
Shell expansion joint	No	Rear head support plate	No		
Weight estimation Wet/Dry/Bundle	15098	/ 7379.1	/ 3319.2	(kg/shell)	

Baffle Information

Type	Support	Baffle cut (% dia)			
Crosspasses/shellpass	1	No. {Pct Area)	(mm) to C.L		
Central spacing	(mm) 1599.2	1			
Inlet spacing	(mm) 0.000	2			
Outlet spacing	(mm) 0.000	Support plates/baffle space		1	
Baffle thickness	(mm) 15.875				
Use deresonating baffles	No				

Tube Information

Tube type	Plain	Tubecount per shell		365	
Overall length	(m) 3.300	Pct tubes removed (both)		0.54	
Effective length	(m) 3.183	Outside diameter	(mm)	38.100	
Total tubesheet	(mm) 101.60	Wall thickness	(mm)	2.769	
Area ratio	(out/in) 1.1701	Pitch (mm)	47.625 Ratio	1.2500	
Tube metal	SA-214 Tube (W) K01807	Tube pattern (deg)		30	

Shellside Performance

Nom vel, X-flow/window	1.45 / 0.00
Kettle Recirculation Ratio (Internal/Feed)	12.58
Flow fractions for vapor phase	
A=0.0000 B=0.9999 C=5.31e-5 E=0.0000 F=0.0000	

Shellside Heat Transfer Corrections

Total	Beta	Gamma	End	Fin
1.038	1.000	1.038	1.000	1.000

Pressure Drops (Percent of Total)

Cross	Window	Ends	Nozzle	Shell	Tube
73.50	0.00	0.00	Inlet	25.73	7.28
MOMENTUM		0.00	Outlet	0.77	4.30

Two-Phase Parameters

Method	Inlet	Center	Outlet	Mix F
PP/TBR	Flow	Flow	Flow	

H. T. Parameters		**Shell**	**Tube**
Overall wall correction			
Midpoint	Prandtl no.		0.74
Midpoint	Reynolds no.	8288	549223
Bundle inlet	Reynolds no.	7999	531793
Bundle outlet	Reynolds no.	8475	564221
Fouling layer	(mm)		

Thermal Resistance, %

Shell	Tube	Fouling	Metal	Over Des
16.61	72.93	8.26	2.21	7.60

Total fouling resistance	(m2-K/W)	2.17e-4
Differential resistance	(m2-K/W)	2e-4

Shell Nozzles

Inlet at channel end Yes

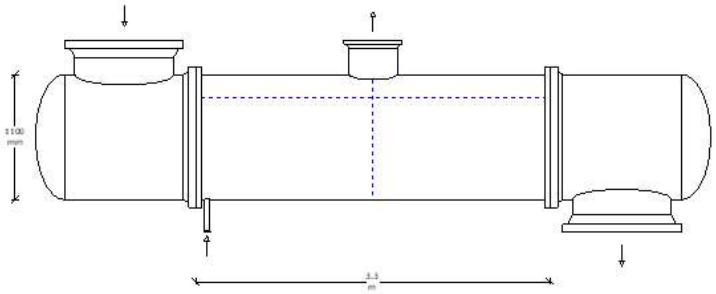
		Inlet	Outlet	Liquid Outlet
Number at each position		1	1	0
Diameter	(mm)	40.894	438.15	
Velocity	(m/s)	2.40	17.69	
Pressure drop	(kgf/cm2)	0.021	6.37e-4	
Height under nozzle	(mm)	39.163	77.261	
Nozzle R-V-SQ	(kg/m-s2)	3892.3	249.91	
Shell ent.	(kg/m-s2)	181.66	284.35	

Tube Nozzle		**Inlet** RADIAL	**Outlet** RADIAL	**Liquid Outlet**
Diameter	(mm)	895.35	895.35	
Velocity	(m/s)	18.01	16.72	
Pressure drop	(kgf/cm2)	0.016	9.30e-3	
Nozzle R-V-SQ	(kg/m-s2)	2804.3	2604.1	

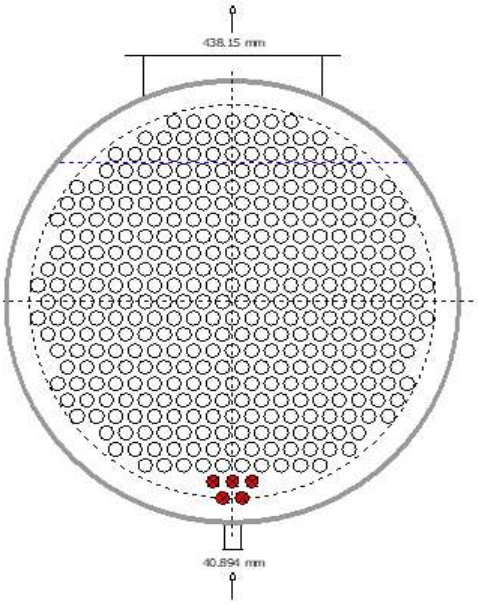
Annular Distributor		**Inlet**	**Outlet**
Length	(mm)		
Height	(mm)		
Slot area	(mm2)		

Diametral Clearances (mm)

Baffle-to-shell	Bundle-to-shell	Tube-to-baffle
6.3500	100.00	0.7937



Item no.	101-C	Total tube inlet nozzles	1	Stream ID	Shellside		Tubeside		
TEMA type	BKM	Total tube outlet nozzles	1	Stream name	NH3 Refrigerant		Ucara		
Shell diameter	1100 mm	Total shell inlet nozzles	1	Flow (total), kg/hr	7667.4		152999		
Kettle diameter	1100 mm	Total shell outlet nozzles	1	Pressure drop, kgf/cm2	0.083		0.236		
Tube length	3.3 m			Temperature, C	-35.00	-33.00	45.00	15.00	
Dry weight	7379 kg/shell			Wt. fraction vapor	0.0000	1.0000	1.0000	1.0000	
Wet weight	15098 kg/shell			Pressure, kgf/cm2G	-0.018	-0.103	7.000	6.784	
Bundle weight	3319 kg/shell								



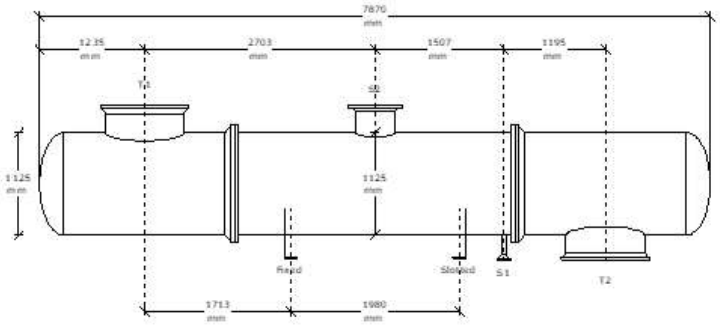
Item no.	101-C
TEMA type	BKM
Kettle ID	1100.0 mm
Shell ID	1100.0 mm
Actual OTL	994.16 mm
Height under inlet nozzle	39.163 mm
Rows of impingement rods	2
Impingement rod OD	34.925 mm
Height under outlet nozzle	77.261 mm
Tube type	Plain
Tube OD	38.100 mm
Tube pitch	47.625 mm
Tube layout angle	30 deg
Tubes	365
Tube positions available	365
Tie rods	8
Seal strip pairs	0
Tube Passes	1

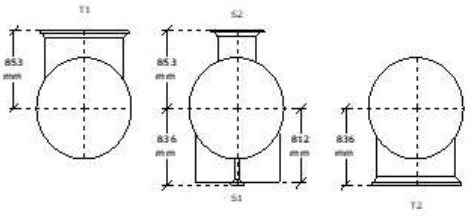
TUBEPASS DETAILS

Pass	Rows	Tubes
1	22	365

SYMBOL LEGEND

- Tube
- Dummy Short Tube
- Dummy Long Tube
- Plugged Tube
- Tie Rod
- Seal Rod
- Impingement Rod





	Nozzles	OD, mm	Rating	Design	Kettle	Tube	Weight	kg	Company		Ref	
S1	Inlet	80.415		Pres (kgf/cm2G)	5.273	7.734	Bundle	3319	Customer			
T1	Inlet	920.75		Temp (C)	-1.11	76.67	Dry	7379	Item No.	101-C		
S2	Outlet	450.85		Passes	1	1	Wet	15098	Service			Setting Plan
T2	Outlet	920.75		Thick (mm)	12.7	2.769			TEMA	BKM		
									Date	27-Dec-25	By	
									Diagram		Rev	

9. Syngas Dryer, 104-DA/DB

Komposisi inlet :

Fraksi mol (Hidrogen)	0.7459
Fraksi mol (Nitrogen)	0.2510
Fraksi mol (Argon)	0.0001
Fraksi mol (H2O)	0.0030

Total Aliran	9,200.0	kmol/jam
	79,046.7	kg/jam
Tekanan	26.00	kg/cm2G
	26.51	Bar A
Tekanan Desain	39.77	Bar A
	3.98	MPa
Suhu	44.50	oC
	317.65	K
Suhu Desain	567.65	K

Menghitung massa H2O = Fraksi mol H2O x Jumlah aliran

= 0.0030 x 9200 kmol /jam

= 27.6 kmol/jam

= 496.5 kg/jam

Desain siklus antara service dan regenerasi = 12 jam, jumlah total beban H2O adalah:

Beban = 12 jam x 496.5 kg/jam

= 5958 kg

UOP
A Honeywell Company



UOP MOLSIV™ 13X-PG Adsorbent

Adsorbents

Adsorbents

Description

UOP 13X-PG adsorbent, a sodium form of Type X molecular sieve, is an alkali metal aluminosilicate. 13X-PG adsorbent will adsorb molecules with critical diameters up to 10 angstroms.

Applications

13X-PG adsorbent is used commercially for gas and liquid hydrocarbon dehydration and purification (removal of polar oxygenates and sulfur compounds). All molecules that can be adsorbed on molecular sieve Types 3A, 4A, and 5A can be adsorbed on 13X-PG adsorbent. In addition, it can adsorb molecules of larger critical diameters, such as aromatics and branched-chain hydrocarbons.

Chemical formula

$M_x[(AlO_2)_x(SiO_2)_y] \cdot z\ H_2O$ [M=Na]

Regeneration

13X-PG adsorbent can be regenerated for reuse by purging or evacuating at elevated temperatures.

Safety and handling

See the UOP brochure entitled "Precautions and Safe Practices for Handling Molecular Sieves in Process Units" or contact your UOP representative.

Shipping information

13X-PG adsorbent is shipped in steel drums and quick load bags.

Typical physical properties

	1/16" Pellets	1/8" Pellets	TRISIV™ Pellets
Nominal pore diameter (Å)	10	10	10
Nominal particle size diameter (mm)	1.9	3.7	3.4
Bulk density (lb/ft³)	39	38	37
(kg/m³)	625	610	595
Crush strength (lb)	7	14	14
(kg)	3	6	6
(N)	30	60	60
Heat of adsorption (Btu/lb H_2O)	1800	1800	1800
(kJ/kg H_2O)	4186	4186	4186
Equilibrium H_2O capacity* (wt-%)	26	26	26
Moisture content (wt-%)	1	1	1

*Measured at 17.5 mm Hg and 25 °C

For more information

For more information, contact your local UOP representative or our Des Plaines sales office:

e-mail: info@uop.com
fax: +1-847-391-2253
phone: +1-847-391-2000

UOP LLC
25 East Algonquin Road
Des Plaines, IL 60017-5017
U.S.A.
www.uop.com

© 2012 UOP LLC. All rights reserved.
The information in this document should not be construed as a representation for which UOP assumes legal responsibility, or an authorization or recommendation to practice a patented invention without a license.
UOP 4512-2 January, 2012

UOP
A Honeywell Company

Adsorbtion capacity = 26% kg H2O / kg mol sieve (Data UOP Molsiv 13X-PG), maka kebutuhan adsorbent adalah :

Total kebutuhan Ads. $= \dfrac{Beban\ H2O}{Adsorbent\ Capacity}$

$= \dfrac{5958\ kg}{26\%\ kg/kg\ adsoebent}$

= 22915.3 kg adsorbent

Dengan *bulk density* 595 kg/m3 (Data UOP Molsiv 13X-PG), volume adsorbent menjadi:

Volume $= \frac{kg\ Adsorbent}{Bulk\ density}$

$= \frac{22915.3}{595}$

$=$ 38.51 m3

Safety factor 1.2, Volume $=$ 38.51 x 1.2

$=$ 46.21 m3

dari GPSA Engineering Data Book : velocity yang direkomendasikan adalah 0.1 – 0.3 m/s, sehingga velocity yang dipakai : 0.2 m/s. Dengan demikian luas permukaan yang diperlukan adalah:

A $= \frac{Laju\ alir\ volumetrik\ (m3/s)}{Velocity}$,

Laju alir volumetrik, V $= \frac{n.R.T}{P}$ (gas ideal)

$= \frac{9200 \text{ x } 0.08134 \text{ x } 317.15}{26.51}$

$=$ 9164.95 m3/jam

$=$ 2.55 m3/s

A $= \frac{Laju\ alir\ volumetrik\ (m3/s)}{Velocity}$,

$= \frac{2.55}{0.2}$

$=$ 12.75 m2

D $= \sqrt{\frac{4A}{\pi}}$

$= \sqrt{\frac{4\ x\ 12.75}{\pi}}$

$=$ 4.03 m

Dengan diameter *vessel* 4.03 m, tinggi bed adalah:

H $= \frac{Volume\ Adsorbent}{A}$

$= \frac{46.21}{12.75}$

$=$ 3.62 m

Dengan perhitungan ketebalan plat (ASME VIII Div 1) diperoleh:

Material yang dipilih SA-516 Gr. 70, sehingga nilai S (allowable stress) = 138 MPa dan *vessel* dilakukan full Radiografi test, E = 1, CA = 3 mm

$T_{silinder}$ $= \frac{P\ desain\ x\ R}{S.E - 0.6\ P\ desain} + CA$

$= \frac{3.98\ x\ 2.015}{138\ x\ 1 - 0.6\ x\ 3.98} + 0.003$

$$= \frac{8.0197}{135.612} + 0.003$$

$$= 0.0621 \text{ m}$$

$$= 62.1 \text{ mm}$$

$$T_{\text{head 2:1}} = \frac{P\ desain\ x\ D}{2S.E - 0.2\ P\ desain} + CA$$

$$= \frac{3.98\ x\ 4.03}{2x138x1 - 0.2\ x\ 3.98} + 0.003$$

$$= \frac{16.0394}{275.204} + 0.003$$

$$= 0.0613 \text{ m}$$

$$= 61.3 \text{ mm}$$

10. Pompa dan Kompresor

Hasil simulasi lengkap (https://drive.google.com/drive/folders/1I43wTHeMuvumW0gSHnpnsGiBqsl-swYz?usp=sharing)

a. Pompa Boiler Feed Water

Dari simulasi HYSYS diperoleh hasil sebagai berikut:

Kondisi suction (015) dan discharge (016)

Name		015 @Main	016 @Main
Vapour		0.0000	0.0000 *
Temperature	(C)	115.1064	116.1582
Pressure	(kg/cm2_g)	0.7000 *	75.0000 *
Molar Flow	(kgmole/h)	14192.7957	14192.7957
Mass Flow	(kg/h)	255684.6398	255684.6398
Std Ideal Liq Vol Flow	(m3/h)	256.2006	256.2006
Molar Enthalpy	(kJ/kgmole)	-2.792e+005	-2.790e+005
Molar Entropy	(kJ/kgmole-C)	74.40	74.45
Heat Flow	(kJ/h)	-3.9620e+09	-3.9593e+09

Name		015 @Main	016 @Main
Molecular Weight		18.02	18.02
Molar Density	(kgmole/m3)	51.90	52.05
Mass Density	(kg/m3)	935.0	937.7
Act. Volume Flow	(m3/h)	273.5	272.7
Mass Enthalpy	(kJ/kg)	-1.550e+004	-1.549e+004
Mass Entropy	(kJ/kg-C)	4.130	4.133
Heat Capacity	(kJ/kgmole-C)	79.96	79.64
Mass Heat Capacity	(kJ/kg-C)	4.438	4.421

PARAMETERS							
Adiabatic Efficiency (%):	75.00	Delta P:	74.30 kg/cm2	Pressure Ratio:	43.87	Duty:	738.0 kW
Multiphase Pump							Not Active
CURVES							
Delta P:			74.30 kg/cm2	Duty:			738.0 kW
Coefficient A:	0.0000 *	Coefficient B:	0.0000 *	Coefficient C:	0.0000 *	Coefficient D:	0.0000 *
Coefficient E:	0.0000 *	Coefficient F:	0.0000 *				
Parameter Preferences		Units for Head:	m	Flow Basis	ActVolFlow	Units for Flow:	m3/h

PERFORMANCE			
Results			
Total Head	---	Velocity Head	-0.4330 m
Total Fluid Head	---	Delta P excluding Static Head Results	---
Pressure Head	794.6 m		
DYNAMICS			
Dynamic Specifications			

Head	(m)	---	Not Active	Power	(kJ/h)	2.657e+006	Not Active
Fluid Head	(kJ/kg)	---	Not Active	Capacity	(m3/h)	256.2	
Speed	(rpm)	---	Not Active	Use Characteristic Curves			Not Active
Efficiency	(%)	75.00	Active	Pump is Acting as a Turbine			Not Active
Pressure Increase	(kg/cm2)	74.30	Active				

b. Kompresor Udara (3 stage)

Dari simulasi HYSYS diperoleh hasil sebagai berikut:

Kondisi Suction (101) dan Discharge (102) di stage 1

Name		101 @Main	102 @Main
Vapour		1.0000	1.0000
Temperature	(C)	35.0000 *	143.9216
Pressure	(kg/cm2_g)	-0.0000 *	1.3432
Molar Flow	(kgmole/h)	12238.2627	12238.2627
Mass Flow	(kg/h)	354447.9207 *	354447.9207
Std Ideal Liq Vol Flow	(m3/h)	407.6264	407.6264
Molar Enthalpy	(kJ/kgmole)	141.0	3350
Molar Entropy	(kJ/kgmole-C)	152.8	154.8
Heat Flow	(kJ/h)	1.7258e+06	4.1003e+07

Properties

Name		101 @Main	102 @Main
Molecular Weight		28.96	28.96
Molar Density	(kgmole/m3)	3.957e-002	6.719e-002
Mass Density	(kg/m3)	1.146	1.946
Act. Volume Flow	(m3/h)	3.093e+005	1.822e+005
Mass Enthalpy	(kJ/kg)	4.869	115.7
Mass Entropy	(kJ/kg-C)	5.277	5.346
Heat Capacity	(kJ/kgmole-C)	29.18	29.87
Mass Heat Capacity	(kJ/kg-C)	1.008	1.031
LHV Molar Basis (Std)	(kJ/kgmole)	0.0000	0.0000
HHV Molar Basis (Std)	(kJ/kgmole)	4.101	4.101
HHV Mass Basis (Std)	(kJ/kg)	0.1416	0.1416

Act. Gas Flow	(ACT_m3/h)	3.093e+005	1.822e+005
Avg. Liq. Density	(kgmole/m3)	30.02	30.02
Specific Heat	(kJ/kgmole-C)	29.18	29.87
Std. Gas Flow	(STD_m3/h)	2.894e+005	2.894e+005
Std. Ideal Liq. Mass Density	(kg/m3)	869.5	869.5
Act. Liq. Flow	(m3/h)	---	---
Z Factor		0.9995	1.000
Watson K		6.013	6.013
Cp/(Cp - R)		1.398	1.386
Cp/Cv		1.401	1.389
Ideal Gas Cp/Cv		1.399	1.387
Ideal Gas Cp	(kJ/kgmole-C)	29.13	29.81
Mass Ideal Gas Cp	(kJ/kg-C)	1.006	1.029
Heat of Vap.	(kJ/kgmole)	1.007e+004	9833
Kinematic Viscosity	(cSt)	16.88	12.37
Liq. Mass Density (Std. Cond)	(kg/m3)	1.226	1.226
Liq. Vol. Flow (Std. Cond)	(m3/h)	2.892e+005	2.892e+005
Liquid Fraction		0.0000	0.0000
Molar Volume	(m3/kgmole)	25.27	14.88
Mass Heat of Vap.	(kJ/kg)	347.7	339.5
Phase Fraction [Molar Basis]		1.0000	1.0000
Surface Tension	(dyne/cm)	---	---
Thermal Conductivity	(W/m-K)	2.654e-002	3.393e-002
Bubble Point Pressure	(kg/cm2_g)	---	---
Viscosity	(cP)	1.934e-002	2.407e-002
Cv (Semi-Ideal)	(kJ/kgmole-C)	20.87	21.55
Mass Cv (Semi-Ideal)	(kJ/kg-C)	0.7206	0.7442
Cv	(kJ/kgmole-C)	20.83	21.51
Mass Cv	(kJ/kg-C)	0.7191	0.7426
Cv (Ent. Method)	(kJ/kgmole-C)	---	---
Mass Cv (Ent. Method)	(kJ/kg-C)	---	---
Cp/Cv (Ent. Method)		---	---
Reid VP at 37.8 C	(kg/cm2_g)	---	---
True VP at 37.8 C	(kg/cm2_g)	---	---
Liq. Vol. Flow - Sum(Std. Cond)	(m3/h)	2.892e+005	2.892e+005
Viscosity Index		-5.253	-5.967

Hasil

Results					
Adiabatic Head	(m)	8475	Power Consumed	(kW)	1.091e+004
Polytropic Head	(m)	8776	Polytropic Head Factor		1.000
Adiabatic Fluid Head	(kJ/kg)	83.11	Polytropic Exponent		1.573
Polytropic Fluid Head	(kJ/kg)	86.07	Isentropic Exponent		1.396
Adiabatic Efficiency		75 *	Speed	(rpm)	---
Polytropic Efficiency		78			---
Power/Torque					
Total Rotor Power	(kW)	1.091e+004	Total Rotor Torque	(N-m)	---
Transient Rotor Power	(kW)	0.0000	Transient Rotor Torque	(N-m)	---
Friction Power Loss	(kW)	0.0000	Friction Torque Loss	(N-m)	---
Fluid Power	(kW)	1.091e+004	Fluid Torque	(N-m)	---

Duty	(kJ/h)	3.928e+007	Active	Head	(m)	8776	Not Active
Adiabatic Efficiency		75 *	Not Active	Fluid Head	(kJ/kg)	86.07	Not Active
Polytropic Efficiency		78	Active	Capacity	(ACT_m3/h)	3.093e+005	Not Active
Pressure Increase	(kg/cm2)	1.343	Not Active	Speed	(rpm)	---	Not Active
		---		Use Characteristic Curves			No

Stage 2

Kondisi Suction (103) dan Discharge (104):

Name		103 @Main	104 @Main
Vapour		1.0000	1.0000
Temperature	(C)	45.0000 *	129.3065
Pressure	(kg/cm2_g)	1.3432	3.4820
Molar Flow	(kgmole/h)	12238.2627	12238.2627
Mass Flow	(kg/h)	354447.9207	354447.9207
Std Ideal Liq Vol Flow	(m3/h)	407.6264	407.6264
Molar Enthalpy	(kJ/kgmole)	423.8	2906
Molar Entropy	(kJ/kgmole-C)	146.8	148.4
Heat Flow	(kJ/h)	5.1871e+06	3.5565e+07

Properties:

Name		103 @Main	104 @Main
Molecular Weight		28.96	28.96
Molar Density	(kgmole/m3)	8.818e-002	0.1323
Mass Density	(kg/m3)	2.554	3.831
Act. Volume Flow	(m3/h)	1.388e+005	9.252e+004
Mass Enthalpy	(kJ/kg)	14.63	100.3
Mass Entropy	(kJ/kg-C)	5.070	5.124
Heat Capacity	(kJ/kgmole-C)	29.30	29.84
Mass Heat Capacity	(kJ/kg-C)	1.012	1.030
LHV Molar Basis (Std)	(kJ/kgmole)	0.0000	0.0000
HHV Molar Basis (Std)	(kJ/kgmole)	4.101	4.101
HHV Mass Basis (Std)	(kJ/kg)	0.1416	0.1416

Partial Pressure of CO2	(kg/cm2_g)	-1.033	-1.032
Cost Based on Flow	(Cost/s)	0.0000	0.0000
Act. Gas Flow	(ACT_m3/h)	1.388e+005	9.252e+004
Avg. Liq. Density	(kgmole/m3)	30.02	30.02
Specific Heat	(kJ/kgmole-C)	29.30	29.84
Std. Gas Flow	(STD_m3/h)	2.894e+005	2.894e+005
Std. Ideal Liq. Mass Density	(kg/m3)	869.5	869.5
Act. Liq. Flow	(m3/h)	---	---
Z Factor		0.9992	1.000
Watson K		6.013	6.013
Cp/(Cp - R)		1.396	1.386
Cp/Cv		1.402	1.392
Ideal Gas Cp/Cv		1.398	1.388
Ideal Gas Cp	(kJ/kgmole-C)	29.20	29.72
Mass Ideal Gas Cp	(kJ/kg-C)	1.008	1.026
Heat of Vap.	(kJ/kgmole)	9833	9552
Kinematic Viscosity	(cSt)	7.764	6.133
Liq. Mass Density (Std. Cond)	(kg/m3)	1.226	1.226
Liq. Vol. Flow (Std. Cond)	(m3/h)	2.892e+005	2.892e+005
Liquid Fraction		0.0000	0.0000
Molar Volume	(m3/kgmole)	11.34	7.560
Mass Heat of Vap.	(kJ/kg)	339.5	329.8
Phase Fraction [Molar Basis]		1.0000	1.0000
Surface Tension	(dyne/cm)	---	---
Thermal Conductivity	(W/m-K)	2.731e-002	3.306e-002
Bubble Point Pressure	(kg/cm2_g)	---	---
Viscosity	(cP)	1.983e-002	2.350e-002
Cv (Semi-Ideal)	(kJ/kgmole-C)	20.99	21.53
Mass Cv (Semi-Ideal)	(kJ/kg-C)	0.7248	0.7432
Cv	(kJ/kgmole-C)	20.90	21.43
Mass Cv	(kJ/kg-C)	0.7217	0.7400
Cv (Ent. Method)	(kJ/kgmole-C)	---	---
Mass Cv (Ent. Method)	(kJ/kg-C)	---	---
Cp/Cv (Ent. Method)		---	---
Reid VP at 37.8 C	(kg/cm2_g)	---	---
True VP at 37.8 C	(kg/cm2_g)	---	---
Liq. Vol. Flow - Sum(Std. Cond)	(m3/h)	2.892e+005	2.892e+005
Viscosity Index		-10.49	-11.13

Hasil:

Adiabatic Head	(m)	6555	Power Consumed	(kW)	8438
Polytropic Head	(m)	6738	Polytropic Head Factor		1.000
Adiabatic Fluid Head	(kJ/kg)	64.28	Polytropic Exponent		1.583
Polytropic Fluid Head	(kJ/kg)	66.08	Isentropic Exponent		1.398
Adiabatic Efficiency		75	Speed	(rpm)	---
Polytropic Efficiency		77			---
Power/Torque					
Total Rotor Power	(kW)	8438	Total Rotor Torque	(N-m)	---
Transient Rotor Power	(kW)	0.0000	Transient Rotor Torque	(N-m)	---
Friction Power Loss	(kW)	0.0000	Friction Torque Loss	(N-m)	---
Fluid Power	(kW)	8438	Fluid Torque	(N-m)	---

Duty	(kJ/h)	3.038e+007	Active	Head	(m)	6738	Not Active
Adiabatic Efficiency		75	Not Active	Fluid Head	(kJ/kg)	66.08	Not Active
Polytropic Efficiency		77	Active	Capacity	(ACT_m3/h)	1.388e+005	Not Active
Pressure Increase	(kg/cm2)	2.139	Not Active	Speed	(rpm)	---	Not Active
		---		Use Characteristic Curves			No

Speed:	---		Duty:		7.4998e+03 kW
Adiabatic Eff.:	75.00		PolyTropic Eff.:		76.91
Adiabatic Head:	5826 m		Polytropic Head:		5974 m
Adiabatic Fluid Head:	57.13 kJ/kg		Polytropic Fluid Head:		58.58 kJ/kg
Polytropic Exp.	1.590	Isentropic Exp.	1.402	Poly Head Factor	1.000

Stage 3

Kondisi Suction (105) dan Discharge (106)

Name		105 @Main	106 @Main
Vapour		1.0000	1.0000
Temperature	(C)	45.0000 *	120.0422
Pressure	(kg/cm2_g)	3.4820	7.0000 *
Molar Flow	(kgmole/h)	12238.2627	12238.2627
Mass Flow	(kg/h)	354447.9207	354447.9207
Std Ideal Liq Vol Flow	(m3/h)	407.6264	407.6264
Molar Enthalpy	(kJ/kgmole)	409.1	2615
Molar Entropy	(kJ/kgmole-C)	141.5	142.9
Heat Flow	(kJ/h)	5.0067e+06	3.2006e+07

Properties

Name		105 @Main	106 @Main
Molecular Weight		28.96	28.96
Molar Density	(kgmole/m3)	0.1677	0.2409
Mass Density	(kg/m3)	4.856	6.976
Act. Volume Flow	(m3/h)	7.300e+004	5.081e+004
Mass Enthalpy	(kJ/kg)	14.13	90.30
Mass Entropy	(kJ/kg-C)	4.884	4.934
Heat Capacity	(kJ/kgmole-C)	29.40	29.89
Mass Heat Capacity	(kJ/kg-C)	1.015	1.032
LHV Molar Basis (Std)	(kJ/kgmole)	0.0000	0.0000
HHV Molar Basis (Std)	(kJ/kgmole)	4.101	4.101
HHV Mass Basis (Std)	(kJ/kg)	0.1416	0.1416

Partial Pressure of CO2	(kg/cm2_g)	-1.032	-1.031
Cost Based on Flow	(Cost/s)	0.0000	0.0000
Act. Gas Flow	(ACT_m3/h)	7.300e+004	5.081e+004
Avg. Liq. Density	(kgmole/m3)	30.02	30.02
Specific Heat	(kJ/kgmole-C)	29.40	29.89
Std. Gas Flow	(STD_m3/h)	2.894e+005	2.894e+005
Std. Ideal Liq. Mass Density	(kg/m3)	869.5	869.5
Act. Liq. Flow	(m3/h)	---	---
Z Factor		0.9984	1.000
Watson K		6.013	6.013
User Property		---	---
Partial Pressure of H2S	(kg/cm2_g)	-1.033	-1.033
Cp/(Cp - R)		1.394	1.385
Cp/Cv		1.406	1.397
Ideal Gas Cp/Cv		1.398	1.389
Ideal Gas Cp	(kJ/kgmole-C)	29.20	29.66
Mass Ideal Gas Cp	(kJ/kg-C)	1.008	1.024
Heat of Vap.	(kJ/kgmole)	9552	9179
Kinematic Viscosity	(cSt)	4.090	3.320
Liq. Mass Density (Std. Cond)	(kg/m3)	1.226	1.226
Liq. Vol. Flow (Std. Cond)	(m3/h)	2.892e+005	2.892e+005
Liquid Fraction		0.0000	0.0000
Molar Volume	(m3/kgmole)	5.965	4.152
Mass Heat of Vap.	(kJ/kg)	329.8	316.9
Phase Fraction [Molar Basis]		1.0000	1.0000
Surface Tension	(dyne/cm)	---	---
Thermal Conductivity	(W/m-K)	2.740e-002	3.259e-002
Bubble Point Pressure	(kg/cm2_g)	---	---
Viscosity	(cP)	1.986e-002	2.316e-002
Cv (Semi-Ideal)	(kJ/kgmole-C)	21.09	21.57
Mass Cv (Semi-Ideal)	(kJ/kg-C)	0.7281	0.7449
Cv	(kJ/kgmole-C)	20.92	21.40
Mass Cv	(kJ/kg-C)	0.7223	0.7388
Cv (Ent. Method)	(kJ/kgmole-C)	---	---
Mass Cv (Ent. Method)	(kJ/kg-C)	---	---
Cp/Cv (Ent. Method)		---	---
Reid VP at 37.8 C	(kg/cm2_g)	---	---
True VP at 37.8 C	(kg/cm2_g)	---	---
Liq. Vol. Flow - Sum(Std. Cond)	(m3/h)	2.892e+005	2.892e+005
Viscosity Index		-16.05	-16.75

Hasil:

Adiabatic Head	(m)	5826	Power Consumed	(kW)	7500
Polytropic Head	(m)	5974	Polytropic Head Factor		1.000
Adiabatic Fluid Head	(kJ/kg)	57.13	Polytropic Exponent		1.590
Polytropic Fluid Head	(kJ/kg)	58.58	Isentropic Exponent		1.402
Adiabatic Efficiency		75	Speed	(rpm)	---
Polytropic Efficiency		77			---

Total Rotor Power	(kW)	7500	Total Rotor Torque	(N-m)	---
Transient Rotor Power	(kW)	0.0000	Transient Rotor Torque	(N-m)	---
Friction Power Loss	(kW)	0.0000	Friction Torque Loss	(N-m)	---
Fluid Power	(kW)	7500	Fluid Torque	(N-m)	---

Duty	(kJ/h)	2.700e+007	Active	Head	(m)	5974	Not Active
Adiabatic Efficiency		75	Not Active	Fluid Head	(kJ/kg)	58.58	Not Active
Polytropic Efficiency		77	Active	Capacity	(ACT_m3/h)	7.300e+004	Not Active
Pressure Increase	(kg/cm2)	3.518	Not Active	Speed	(rpm)	---	Not Active
		---		Use Characteristic Curves			No

Speed:		---	Duty:		7.4998e+03 kW
Adiabatic Eff.:		75.00	PolyTropic Eff.:		76.91
Adiabatic Head:		5826 m	Polytropic Head:		5974 m
Adiabatic Fluid Head:		57.13 kJ/kg	Polytropic Fluid Head:		58.58 kJ/kg
Polytropic Exp.	1.590	Isentropic Exp.	1.402	Poly Head Factor	1.000

c. Kompresor Nitrogen

Dari hasil simulasi HYSYS diperoleh:

Stage 1

Kondisi suction (120) & Discharge (121)

Name		120 @Main	121 @Main
Vapour		1.0000	1.0000
Temperature	(C)	7.0000 *	98.4117
Pressure	(kg/cm2_g)	5.0000	12.0000 *
Molar Flow	(kgmole/h)	4310.0000	4310.0000

Mass Flow	(kg/h)	120744.7158	120744.7158
Std Ideal Liq Vol Flow	(m3/h)	149.7224	149.7224
Molar Enthalpy	(kJ/kgmole)	-574.8	2096
Molar Entropy	(kJ/kgmole-C)	131.5	133.3
Heat Flow	(kJ/h)	-2.4773e+06	9.0334e+06

Properties

Name		120 @Main	121 @Main
Molecular Weight		28.02	28.02
Molar Density	(kgmole/m3)	0.2550	0.4134
Mass Density	(kg/m3)	7.143	11.58
Act. Volume Flow	(m3/h)	1.690e+004	1.043e+004
Mass Enthalpy	(kJ/kg)	-20.52	74.81
Mass Entropy	(kJ/kg-C)	4.693	4.759
Heat Capacity	(kJ/kgmole-C)	29.41	29.93
Mass Heat Capacity	(kJ/kg-C)	1.050	1.068

Phase Fraction [Vol. Basis]		1.000	1.000
Phase Fraction [Mass Basis]		1.000	1.000
Phase Fraction [Act. Vol. Basis]		1.000	1.000
Mass Exergy	(kJ/kg)	156.5	232.2
Partial Pressure of CO2	(kg/cm2_g)	-1.033	-1.033
Cost Based on Flow	(Cost/s)	0.0000	0.0000
Act. Gas Flow	(ACT_m3/h)	1.690e+004	1.043e+004
Avg. Liq. Density	(kgmole/m3)	28.79	28.79
Specific Heat	(kJ/kgmole-C)	29.41	29.93
Std. Gas Flow	(STD_m3/h)	1.019e+005	1.019e+005
Std. Ideal Liq. Mass Density	(kg/m3)	806.5	806.5
Act. Liq. Flow	(m3/h)	---	---
Z Factor		0.9963	1.001
Watson K		6.414	6.414
Cp/(Cp - R)		1.394	1.385
Cp/Cv		1.415	1.405
Ideal Gas Cp/Cv		1.401	1.392
Ideal Gas Cp	(kJ/kgmole-C)	29.04	29.53
Mass Ideal Gas Cp	(kJ/kg-C)	1.037	1.054
Heat of Vap.	(kJ/kgmole)	4750	3947
Kinematic Viscosity	(cSt)	2.460	1.869
Liq. Mass Density (Std. Cond)	(kg/m3)	1.186	1.186
Liq. Vol. Flow (Std. Cond)	(m3/h)	1.019e+005	1.019e+005
Molar Volume	(m3/kgmole)	3.922	2.419
Mass Heat of Vap.	(kJ/kg)	169.6	140.9
Phase Fraction [Molar Basis]		1.0000	1.0000
Surface Tension	(dyne/cm)	---	---
Thermal Conductivity	(W/m-K)	2.479e-002	3.123e-002
Bubble Point Pressure	(kg/cm2_g)	---	---
Viscosity	(cP)	1.757e-002	2.165e-002
Cv (Semi-Ideal)	(kJ/kgmole-C)	21.09	21.62
Mass Cv (Semi-Ideal)	(kJ/kg-C)	0.7529	0.7717
Cv	(kJ/kgmole-C)	20.79	21.30
Mass Cv	(kJ/kg-C)	0.7421	0.7603
Cv (Ent. Method)	(kJ/kgmole-C)	---	---
Mass Cv (Ent. Method)	(kJ/kg-C)	---	---
Cp/Cv (Ent. Method)		---	---
Reid VP at 37.8 C	(kg/cm2_g)	---	---
True VP at 37.8 C	(kg/cm2_g)	---	---
Liq. Vol. Flow - Sum(Std. Cond)	(m3/h)	1.019e+005	1.019e+005
Viscosity Index		-22.22	-23.46

Hasil

Adiabatic Head	(m)	7291	Power Consumed	(kW)	3197
Polytropic Head	(m)	7535	Polytropic Head Factor		1.000
Adiabatic Fluid Head	(kJ/kg)	71.50	Polytropic Exponent		1.594
Polytropic Fluid Head	(kJ/kg)	73.89	Isentropic Exponent		1.409
Adiabatic Efficiency		75	Speed	(rpm)	---
Polytropic Efficiency		78			---

Total Rotor Power	(kW)	3197	Total Rotor Torque	(N-m)	---
Transient Rotor Power	(kW)	0.0000	Transient Rotor Torque	(N-m)	---
Friction Power Loss	(kW)	0.0000	Friction Torque Loss	(N-m)	---
Fluid Power	(kW)	3197	Fluid Torque	(N-m)	---

Duty	(kJ/h)	1.151e+007	Active	Head	(m)	7535	Not Active
Adiabatic Efficiency		75	Not Active	Fluid Head	(kJ/kg)	73.89	Not Active
Polytropic Efficiency		78	Active	Capacity	(ACT_m3/h)	1.690e+004	Not Active
Pressure Increase	(kg/cm2)	7.000	Not Active	Speed	(rpm)	---	Not Active
		---		Use Characteristic Curves			No

Speed:		---	Duty:		3.1974e+03 kW
Adiabatic Eff.:		75.00	PolyTropic Eff.:		77.51
Adiabatic Head:		7291 m	Polytropic Head:		7535 m
Adiabatic Fluid Head:		71.50 kJ/kg	Polytropic Fluid Head:		73.89 kJ/kg
Polytropic Exp.	1.594	Isentropic Exp.	1.409	Poly Head Factor	1.000

Stage 2

Kondisi suction (122) dan discharge (123)

Name		122 @Main	123 @Main
Vapour		1.0000	1.0000
Temperature	(C)	45.0000 *	99.9113
Pressure	(kg/cm2_g)	12.0000	19.0000 *
Molar Flow	(kgmole/h)	4310.0000	4310.0000

Mass Flow	(kg/h)	120744.7158	120744.7158
Std Ideal Liq Vol Flow	(m3/h)	149.7224	149.7224
Molar Enthalpy	(kJ/kgmole)	500.3	2112
Molar Entropy	(kJ/kgmole-C)	128.7	129.8
Heat Flow	(kJ/h)	2.1562e+06	9.1007e+06

Properties

Name		122 @Main	123 @Main
Molecular Weight		28.02	28.02
Molar Density	(kgmole/m3)	0.4846	0.6324
Mass Density	(kg/m3)	13.58	17.72
Act. Volume Flow	(m3/h)	8894	6816

Mass Enthalpy	(kJ/kg)	17.86	75.37
Mass Entropy	(kJ/kg-C)	4.593	4.633
Heat Capacity	(kJ/kgmole-C)	29.83	30.15
Mass Heat Capacity	(kJ/kg-C)	1.065	1.076

Partial Pressure of CO2	(kg/cm2_g)	-1.033	-1.033
Cost Based on Flow	(Cost/s)	0.0000	0.0000
Act. Gas Flow	(ACT_m3/h)	8894	6816
Avg. Liq. Density	(kgmole/m3)	28.79	28.79
Specific Heat	(kJ/kgmole-C)	29.83	30.15
Std. Gas Flow	(STD_m3/h)	1.019e+005	1.019e+005
Std. Ideal Liq. Mass Density	(kg/m3)	806.5	806.5
Act. Liq. Flow	(m3/h)	---	---
Z Factor		0.9971	1.002
Watson K		6.414	6.414
Cp/(Cp - R)		1.386	1.381
Cp/Cv		1.418	1.412
Ideal Gas Cp/Cv		1.397	1.392
Ideal Gas Cp	(kJ/kgmole-C)	29.24	29.53
Mass Ideal Gas Cp	(kJ/kg-C)	1.044	1.054
Heat of Vap.	(kJ/kgmole)	3947	3154
Kinematic Viscosity	(cSt)	1.430	1.231
Liq. Mass Density (Std. Cond)	(kg/m3)	1.186	1.186
Liq. Vol. Flow (Std. Cond)	(m3/h)	1.019e+005	1.019e+005
Liquid Fraction		0.0000	0.0000
Molar Volume	(m3/kgmole)	2.064	1.581
Mass Heat of Vap.	(kJ/kg)	140.9	112.6
Thermal Conductivity	(W/m-K)	2.775e-002	3.160e-002
Bubble Point Pressure	(kg/cm2_g)	---	---
Viscosity	(cP)	1.941e-002	2.180e-002
Cv (Semi-Ideal)	(kJ/kgmole-C)	21.52	21.83
Mass Cv (Semi-Ideal)	(kJ/kg-C)	0.7680	0.7794
Cv	(kJ/kgmole-C)	21.04	21.35
Mass Cv	(kJ/kg-C)	0.7510	0.7622
Cv (Ent. Method)	(kJ/kgmole-C)	---	---
Mass Cv (Ent. Method)	(kJ/kg-C)	---	---
Cp/Cv (Ent. Method)		---	---
Reid VP at 37.8 C	(kg/cm2_g)	---	---
True VP at 37.8 C	(kg/cm2_g)	---	---
Liq. Vol. Flow - Sum(Std. Cond)	(m3/h)	1.019e+005	1.019e+005
Viscosity Index		-29.57	-30.54

Hasil

Adiabatic Head	(m)	4399	Power Consumed	(kW)	1929
Polytropic Head	(m)	4484	Polytropic Head Factor		0.9999
Adiabatic Fluid Head	(kJ/kg)	43.14	Polytropic Exponent		1.615
Polytropic Fluid Head	(kJ/kg)	43.97	Isentropic Exponent		1.416
Adiabatic Efficiency		75	Speed	(rpm)	---
Polytropic Efficiency		76			---

Total Rotor Power	(kW)	1929	Total Rotor Torque	(N-m)	---
Transient Rotor Power	(kW)	0.0000	Transient Rotor Torque	(N-m)	---
Friction Power Loss	(kW)	0.0000	Friction Torque Loss	(N-m)	---
Fluid Power	(kW)	1929	Fluid Torque	(N-m)	---

Duty	(kJ/h)	6.945e+006	Active	Head	(m)	4484	Not Active
Adiabatic Efficiency		75	Not Active	Fluid Head	(kJ/kg)	43.97	Not Active
Polytropic Efficiency		76	Active	Capacity	(ACT_m3/h)	8894	Not Active
Pressure Increase	(kg/cm2)	7.000	Not Active	Speed	(rpm)	---	Not Active
		---		Use Characteristic Curves			No

Speed:	---		Duty:	1.9290e+03 kW	
Adiabatic Eff.:	75.00		PolyTropic Eff.:	76.45	
Adiabatic Head:	4399 m		Polytropic Head:	4484 m	
Adiabatic Fluid Head:	43.14 kJ/kg		Polytropic Fluid Head:	43.97 kJ/kg	
Polytropic Exp.	1.615	Isentropic Exp.	1.416	Poly Head Factor	0.9999

Stage 3

Kondisi suction (124) dan discharge (125):

Name		124 @Main	125 @Main
Vapour		1.0000	1.0000
Temperature	(C)	45.0000 *	82.6175
Pressure	(kg/cm2_g)	19.0000	26.0000 *
Molar Flow	(kgmole/h)	4310.0000	4310.0000
Mass Flow	(kg/h)	120744.7158	120744.7158
Std Ideal Liq Vol Flow	(m3/h)	149.7224	149.7224
Molar Enthalpy	(kJ/kgmole)	457.0	1558
Molar Entropy	(kJ/kgmole-C)	125.0	125.8
Heat Flow	(kJ/h)	1.9696e+06	6.7155e+06

Properties:

Name		124 @Main	125 @Main
Molecular Weight		28.02	28.02
Molar Density	(kgmole/m3)	0.7457	0.8956
Mass Density	(kg/m3)	20.89	25.09
Act. Volume Flow	(m3/h)	5780	4812
Mass Enthalpy	(kJ/kg)	16.31	55.62
Mass Entropy	(kJ/kg-C)	4.461	4.489
Heat Capacity	(kJ/kgmole-C)	30.14	30.36
Mass Heat Capacity	(kJ/kg-C)	1.076	1.084
Act. Gas Flow	(ACT_m3/h)	5780	4812
Avg. Liq. Density	(kgmole/m3)	28.79	28.79
Specific Heat	(kJ/kgmole-C)	30.14	30.36
Std. Gas Flow	(STD_m3/h)	1.019e+005	1.019e+005
Std. Ideal Liq. Mass Density	(kg/m3)	806.5	806.5
Z Factor		0.9959	1.001
Watson K		6.414	6.414

Cp/(Cp - R)		1.381	1.377
Cp/Cv		1.428	1.424
Ideal Gas Cp/Cv		1.397	1.394
Ideal Gas Cp	(kJ/kgmole-C)	29.24	29.44
Mass Ideal Gas Cp	(kJ/kg-C)	1.044	1.051
Heat of Vap.	(kJ/kgmole)	3154	2228
Kinematic Viscosity	(cSt)	0.9348	0.8453
Liq. Mass Density (Std. Cond)	(kg/m3)	1.186	1.186
Liq. Vol. Flow (Std. Cond)	(m3/h)	1.019e+005	1.019e+005
Liquid Fraction		0.0000	0.0000
Molar Volume	(m3/kgmole)	1.341	1.117
Mass Heat of Vap.	(kJ/kg)	112.6	79.54
Phase Fraction [Molar Basis]		1.0000	1.0000
Thermal Conductivity	(W/m-K)	2.807e-002	3.080e-002
Bubble Point Pressure	(kg/cm2_g)	---	---
Viscosity	(cP)	1.953e-002	2.121e-002
Cv (Semi-Ideal)	(kJ/kgmole-C)	21.82	22.05
Mass Cv (Semi-Ideal)	(kJ/kg-C)	0.7790	0.7870
Cv	(kJ/kgmole-C)	21.10	21.32
Mass Cv	(kJ/kg-C)	0.7531	0.7610
Cv (Ent. Method)	(kJ/kgmole-C)	---	---
Mass Cv (Ent. Method)	(kJ/kg-C)	---	---
Cp/Cv (Ent. Method)		---	---
Reid VP at 37.8 C	(kg/cm2_g)	---	---
True VP at 37.8 C	(kg/cm2_g)	---	---
Liq. Vol. Flow - Sum(Std. Cond)	(m3/h)	1.019e+005	1.019e+005
Viscosity Index		-41.13	-42.33

Hasil:

Adiabatic Head	(m)	3006	Power Consumed	(kW)	1318
Polytropic Head	(m)	3047	Polytropic Head Factor		0.9999
Adiabatic Fluid Head	(kJ/kg)	29.48	Polytropic Exponent		1.636
Polytropic Fluid Head	(kJ/kg)	29.89	Isentropic Exponent		1.426
Adiabatic Efficiency		75	Speed	(rpm)	---
Polytropic Efficiency		76			---

Total Rotor Power	(kW)	1318	Total Rotor Torque	(N-m)	---
Transient Rotor Power	(kW)	0.0000	Transient Rotor Torque	(N-m)	---
Friction Power Loss	(kW)	0.0000	Friction Torque Loss	(N-m)	---
Fluid Power	(kW)	1318	Fluid Torque	(N-m)	---

Duty	(kJ/h)	4.746e+006	Active	Head	(m)	3047	Not Active
Adiabatic Efficiency		75	Not Active	Fluid Head	(kJ/kg)	29.89	Not Active
Polytropic Efficiency		76	Active	Capacity	(ACT_m3/h)	5780	Not Active
Pressure Increase	(kg/cm2)	7.000	Not Active	Speed	(rpm)	---	Not Active
		---		Use Characteristic Curves			No

Speed:		---	Duty:		1.3183e+03 kW
Adiabatic Eff.:		75.00	PolyTropic Eff.:		76.03
Adiabatic Head:		3006 m	Polytropic Head:		3047 m
Adiabatic Fluid Head:		29.48 kJ/kg	Polytropic Fluid Head:		29.89 kJ/kg
Polytropic Exp.	1.636	Isentropic Exp.	1.426	Poly Head Factor	0.9999

d. Kompresor Hidrogen

Dari simulasi HYSYS diperoleh:

Stage 1

Kondisi suction (213) dan discharge (215):

Name		213 @Main	215 @Main
Vapour		1.0000	1.0000
Temperature	(C)	45.0000	159.4267
Pressure	(kg/cm2_g)	2.5000	7.0000 *
Molar Flow	(kgmole/h)	6890.0000	6890.0000
Mass Flow	(kg/h)	14110.7078	14110.7078
Std Ideal Liq Vol Flow	(m3/h)	198.6833	198.6833
Molar Enthalpy	(kJ/kgmole)	85.44	3364
Molar Entropy	(kJ/kgmole-C)	114.8	116.8
Heat Flow	(kJ/h)	5.8867e+05	2.3180e+07

Properties

Molecular Weight		2.048	2.048
Molar Density	(kgmole/m3)	0.1308	0.2185
Mass Density	(kg/m3)	0.2679	0.4475
Act. Volume Flow	(m3/h)	5.266e+004	3.153e+004
Mass Enthalpy	(kJ/kg)	41.72	1643
Mass Entropy	(kJ/kg-C)	56.08	57.03
Heat Capacity	(kJ/kgmole-C)	28.50	28.79
Mass Heat Capacity	(kJ/kg-C)	13.92	14.06
LHV Molar Basis (Std)	(kJ/kgmole)	2.415e+005	2.415e+005
HHV Molar Basis (Std)	(kJ/kgmole)	2.825e+005	2.825e+005
HHV Mass Basis (Std)	(kJ/kg)	1.379e+005	1.379e+005
LHV Mass Basis (Std)	(kJ/kg)	1.179e+005	1.179e+005
Phase Fraction [Vol. Basis]		1.000	1.000
Phase Fraction [Mass Basis]		1.000	1.000
Phase Fraction [Act. Vol. Basis]		1.000	1.000
Mass Exergy	(kJ/kg)	1498	2814
Partial Pressure of CO2	(kg/cm2_g)	-1.033	-1.033
Cost Based on Flow	(Cost/s)	0.0000	0.0000
Act. Gas Flow	(ACT_m3/h)	5.266e+004	3.153e+004
Avg. Liq. Density	(kgmole/m3)	34.68	34.68
Specific Heat	(kJ/kgmole-C)	28.50	28.79
Std. Gas Flow	(STD_m3/h)	1.629e+005	1.629e+005
Std. Ideal Liq. Mass Density	(kg/m3)	71.02	71.02
Act. Liq. Flow	(m3/h)	0.0000	---
Z Factor		---	1.002
Watson K		47.60	47.60

Cp/(Cp - R)		1.412	1.406
Cp/Cv		1.413	1.407
Ideal Gas Cp/Cv		1.412	1.407
Ideal Gas Cp	(kJ/kgmole-C)	28.48	28.76
Mass Ideal Gas Cp	(kJ/kg-C)	13.91	14.04
Heat of Vap.	(kJ/kgmole)	8112	8210
Kinematic Viscosity	(cSt)	34.41	26.47
Liq. Mass Density (Std. Cond)	(kg/m3)	8.659e-002	8.659e-002
Liq. Vol. Flow (Std. Cond)	(m3/h)	1.630e+005	1.630e+005
Liquid Fraction		0.0000	0.0000
Molar Volume	(m3/kgmole)	7.643	4.577
Mass Heat of Vap.	(kJ/kg)	3961	4009
Phase Fraction [Molar Basis]		1.0000	1.0000
Surface Tension	(dyne/cm)	---	---
Thermal Conductivity	(W/m-K)	0.1834	0.2318
Viscosity	(cP)	9.220e-003	1.185e-002
Cv (Semi-Ideal)	(kJ/kgmole-C)	20.19	20.47
Mass Cv (Semi-Ideal)	(kJ/kg-C)	9.858	9.997
Cv	(kJ/kgmole-C)	20.17	20.45
Mass Cv	(kJ/kg-C)	9.849	9.988

Hasil

Adiabatic Head	(m)	1.224e+005	Power Consumed	(kW)	6275
Polytropic Head	(m)	1.269e+005	Polytropic Head Factor		1.000
Adiabatic Fluid Head	(kJ/kg)	1201	Polytropic Exponent		1.602
Polytropic Fluid Head	(kJ/kg)	1244	Isentropic Exponent		1.414
Adiabatic Efficiency		75	Speed	(rpm)	---
Polytropic Efficiency		78			---

Total Rotor Power	(kW)	6275	Total Rotor Torque	(N-m)	---
Transient Rotor Power	(kW)	0.0000	Transient Rotor Torque	(N-m)	---
Friction Power Loss	(kW)	0.0000	Friction Torque Loss	(N-m)	---
Fluid Power	(kW)	6275	Fluid Torque	(N-m)	---

Duty	(kJ/h)	2.259e+007	Active	Head	(m)	1.269e+005	Not Active
Adiabatic Efficiency		75	Not Active	Fluid Head	(kJ/kg)	1244	Not Active
Polytropic Efficiency		78	Active	Capacity	(ACT_m3/h)	5.266e+004	Not Active
Pressure Increase	(kg/cm2)	4.500	Not Active	Speed	(rpm)	---	Not Active
		---		Use Characteristic Curves			No

Speed:		---	Duty:		6.2753e+03 kW
Adiabatic Eff.:		75.00	PolyTropic Eff.:		77.72
Adiabatic Head:		1.224e+005 m	Polytropic Head:		1.269e+005 m
Adiabatic Fluid Head:		1201 kJ/kg	Polytropic Fluid Head:		1244 kJ/kg
Polytropic Exp.	1.602	Isentropic Exp.	1.414	Poly Head Factor	1.000

Stage 2

Kondisi suction (217) dan discharge (219):

Name		217 @Main	219 @Main
Vapour		1.0000	1.0000
Temperature	(C)	45.0000	148.7230
Pressure	(kg/cm2_g)	7.0000	16.0000 *
Molar Flow	(kgmole/h)	6890.0000	6890.0000
Mass Flow	(kg/h)	14110.7078	14110.7078
Std Ideal Liq Vol Flow	(m3/h)	198.6833	198.6833
Molar Enthalpy	(kJ/kgmole)	85.43	3061
Molar Entropy	(kJ/kgmole-C)	108.0	109.8
Heat Flow	(kJ/h)	5.8860e+05	2.1088e+07

Properties

Molecular Weight		2.048	2.048
Molar Density	(kgmole/m3)	0.2970	0.4737
Mass Density	(kg/m3)	0.6083	0.9702
Act. Volume Flow	(m3/h)	2.320e+004	1.454e+004
Mass Enthalpy	(kJ/kg)	41.71	1494
Mass Entropy	(kJ/kg-C)	52.74	53.62
Heat Capacity	(kJ/kgmole-C)	28.53	28.79
Mass Heat Capacity	(kJ/kg-C)	13.93	14.06
LHV Molar Basis (Std)	(kJ/kgmole)	2.415e+005	2.415e+005
HHV Molar Basis (Std)	(kJ/kgmole)	2.825e+005	2.825e+005
HHV Mass Basis (Std)	(kJ/kg)	1.379e+005	1.379e+005
Act. Gas Flow	(ACT_m3/h)	2.320e+004	1.454e+004
Avg. Liq. Density	(kgmole/m3)	34.68	34.68
Specific Heat	(kJ/kgmole-C)	28.53	28.79
Std. Gas Flow	(STD_m3/h)	1.629e+005	1.629e+005
Std. Ideal Liq. Mass Density	(kg/m3)	71.02	71.02
Act. Liq. Flow	(m3/h)	0.0000	---
Z Factor		---	1.005
Watson K		47.60	47.60
Cp/(Cp - R)		1.411	1.406
Cp/Cv		1.414	1.409
Ideal Gas Cp/Cv		1.412	1.407
Ideal Gas Cp	(kJ/kgmole-C)	28.48	28.73
Mass Ideal Gas Cp	(kJ/kg-C)	13.91	14.03
Heat of Vap.	(kJ/kgmole)	8210	8237
Kinematic Viscosity	(cSt)	15.17	12.00
Liq. Mass Density (Std. Cond)	(kg/m3)	8.659e-002	8.659e-002
Liq. Vol. Flow (Std. Cond)	(m3/h)	1.630e+005	1.630e+005

Liquid Fraction		0.0000	0.0000
Molar Volume	(m3/kgmole)	3.367	2.111
Mass Heat of Vap.	(kJ/kg)	4009	4022
Phase Fraction [Molar Basis]		1.0000	1.0000
Surface Tension	(dyne/cm)	---	---
Thermal Conductivity	(W/m-K)	0.1836	0.2279
Viscosity	(cP)	9.227e-003	1.164e-002
Cv (Semi-Ideal)	(kJ/kgmole-C)	20.22	20.48
Mass Cv (Semi-Ideal)	(kJ/kg-C)	9.872	10.00
Cv	(kJ/kgmole-C)	20.18	20.44
Mass Cv	(kJ/kg-C)	9.852	9.978
Cv (Ent. Method)	(kJ/kgmole-C)	---	---
Mass Cv (Ent. Method)	(kJ/kg-C)	---	---
Cp/Cv (Ent. Method)		---	---
Reid VP at 37.8 C	(kg/cm2_g)	---	---
True VP at 37.8 C	(kg/cm2_g)	---	---
Liq. Vol. Flow - Sum(Std. Cond)	(m3/h)	1.630e+005	1.630e+005
Viscosity Index		6.195	6.524

Hasil

Adiabatic Head	(m)	1.111e+005	Power Consumed	(kW)	5694
Polytropic Head	(m)	1.148e+005	Polytropic Head Factor		0.9999
Adiabatic Fluid Head	(kJ/kg)	1090	Polytropic Exponent		1.610
Polytropic Fluid Head	(kJ/kg)	1126	Isentropic Exponent		1.418
Adiabatic Efficiency		75	Speed	(rpm)	---
Polytropic Efficiency		78			---

Total Rotor Power	(kW)	5694	Total Rotor Torque	(N-m)	---
Transient Rotor Power	(kW)	0.0000	Transient Rotor Torque	(N-m)	---
Friction Power Loss	(kW)	0.0000	Friction Torque Loss	(N-m)	---
Fluid Power	(kW)	5694	Fluid Torque	(N-m)	---

Duty	(kJ/h)	2.050e+007	Active	Head	(m)	1.148e+005	Not Active
Adiabatic Efficiency		75	Not Active	Fluid Head	(kJ/kg)	1126	Not Active
Polytropic Efficiency		78	Active	Capacity	(ACT_m3/h)	2.320e+004	Not Active
Pressure Increase	(kg/cm2)	9.000	Not Active	Speed	(rpm)	---	Not Active
		---		Use Characteristic Curves			No

Speed:		---	Duty:		5.6944e+03 kW
Adiabatic Eff.:		75.00	PolyTropic Eff.:		77.51
Adiabatic Head:		1.111e+005 m	Polytropic Head:		1.148e+005 m
Adiabatic Fluid Head:		1090 kJ/kg	Polytropic Fluid Head:		1126 kJ/kg
Polytropic Exp.	1.610	Isentropic Exp.	1.418	Poly Head Factor	0.9999

Stage 3

Kondisi suction (221) dan discharge (223):

Name		221 @Main	223 @Main
Vapour		1.0000	1.0000
Temperature	(C)	45.0000	106.2099
Pressure	(kg/cm2_g)	16.0000	26.0000 *
Molar Flow	(kgmole/h)	6890.0000	6890.0000

Mass Flow	(kg/h)	14110.7078	14110.7078
Std Ideal Liq Vol Flow	(m3/h)	198.6833	198.6833
Molar Enthalpy	(kJ/kgmole)	85.62	1842
Molar Entropy	(kJ/kgmole-C)	101.7	102.9
Heat Flow	(kJ/h)	5.8991e+05	1.2693e+07

Properties

Molecular Weight		2.048	2.048
Molar Density	(kgmole/m3)	0.6279	0.8332
Mass Density	(kg/m3)	1.286	1.706
Act. Volume Flow	(m3/h)	1.097e+004	8270
Mass Enthalpy	(kJ/kg)	41.81	899.5
Mass Entropy	(kJ/kg-C)	49.67	50.25
Heat Capacity	(kJ/kgmole-C)	28.59	28.74
Mass Heat Capacity	(kJ/kg-C)	13.96	14.04
LHV Molar Basis (Std)	(kJ/kgmole)	2.415e+005	2.415e+005
HHV Molar Basis (Std)	(kJ/kgmole)	2.825e+005	2.825e+005
HHV Mass Basis (Std)	(kJ/kg)	1.379e+005	1.379e+005

Act. Gas Flow	(ACT_m3/h)	1.097e+004	8270
Avg. Liq. Density	(kgmole/m3)	34.68	34.68
Specific Heat	(kJ/kgmole-C)	28.59	28.74
Std. Gas Flow	(STD_m3/h)	1.629e+005	1.629e+005
Std. Ideal Liq. Mass Density	(kg/m3)	71.02	71.02
Act. Liq. Flow	(m3/h)	0.0000	---
Z Factor		---	1.009
Watson K		47.60	47.60

Cp/(Cp - R)		1.410	1.407
Cp/Cv		1.416	1.413
Ideal Gas Cp/Cv		1.412	1.409
Ideal Gas Cp	(kJ/kgmole-C)	28.48	28.63
Mass Ideal Gas Cp	(kJ/kg-C)	13.91	13.98
Heat of Vap.	(kJ/kgmole)	8237	8428
Kinematic Viscosity	(cSt)	7.187	6.288

Viscosity	(cP)	9.241e-003	1.073e-002
Cv (Semi-Ideal)	(kJ/kgmole-C)	20.28	20.43
Mass Cv (Semi-Ideal)	(kJ/kg-C)	9.900	9.975

Cv	(kJ/kgmole-C)	20.19	20.34
Mass Cv	(kJ/kg-C)	9.858	9.932
Cv (Ent. Method)	(kJ/kgmole-C)	---	---
Mass Cv (Ent. Method)	(kJ/kg-C)	---	---
Cp/Cv (Ent. Method)		---	---

Reid VP at 37.8 C	(kg/cm2_g)	---	---

True VP at 37.8 C	(kg/cm2_g)	---	---
Liq. Vol. Flow - Sum(Std. Cond)	(m3/h)	1.630e+005	1.630e+005
Viscosity Index		2.930	3.242

Hasil

Adiabatic Head	(m)	6.560e+004	Power Consumed	(kW)	3362
Polytropic Head	(m)	6.699e+004	Polytropic Head Factor		0.9998
Adiabatic Fluid Head	(kJ/kg)	643.3	Polytropic Exponent		1.633
Polytropic Fluid Head	(kJ/kg)	657.0	Isentropic Exponent		1.426
Adiabatic Efficiency		75	Speed	(rpm)	---
Polytropic Efficiency		77			---

Total Rotor Power	(kW)	3362	Total Rotor Torque	(N-m)	---
Transient Rotor Power	(kW)	0.0000	Transient Rotor Torque	(N-m)	---
Friction Power Loss	(kW)	0.0000	Friction Torque Loss	(N-m)	---
Fluid Power	(kW)	3362	Fluid Torque	(N-m)	---

Duty	(kJ/h)	1.210e+007	Active	Head	(m)	6.699e+004	Not Active
Adiabatic Efficiency		75	Not Active	Fluid Head	(kJ/kg)	657.0	Not Active
Polytropic Efficiency		77	Active	Capacity	(ACT_m3/h)	1.097e+004	Not Active
Pressure Increase	(kg/cm2)	10.00	Not Active	Speed	(rpm)	---	Not Active
		---		Use Characteristic Curves			No

Speed:		---	Duty:		3.3620e+03 kW
Adiabatic Eff.:		75.00	PolyTropic Eff.:		76.59
Adiabatic Head:		6.560e+004 m	Polytropic Head:		6.699e+004 m
Adiabatic Fluid Head:		643.3 kJ/kg	Polytropic Fluid Head:		657.0 kJ/kg
Polytropic Exp.	1.633	Isentropic Exp.	1.426	Poly Head Factor	0.9998

e. Kompresor Syngas

Dari simulasi HYSYS diperoleh:

Stage 1

Kondisi suction (304) dan discharge (306):

Name		304 @Main	306 @Main
Vapour		1.0000	1.0000
Temperature	(C)	40.0000 *	171.4238
Pressure	(kg/cm2_g)	25.0000 *	66.0000 *
Molar Flow	(kgmole/h)	9172.4400	9172.4400

Mass Flow	(kg/h)	78550.2244	78550.2244
Std Ideal Liq Vol Flow	(m3/h)	278.2825	278.2825
Molar Enthalpy	(kJ/kgmole)	402.6	4233
Molar Entropy	(kJ/kgmole-C)	108.5	110.7
Heat Flow	(kJ/h)	3.6925e+06	3.8830e+07

Properties

Name		304 @Main	306 @Main
Molecular Weight		8.564	8.564
Molar Density	(kgmole/m3)	0.9736	1.741
Mass Density	(kg/m3)	8.338	14.91
Act. Volume Flow	(m3/h)	9421	5269
Mass Enthalpy	(kJ/kg)	47.01	494.3
Mass Entropy	(kJ/kg-C)	12.66	12.93

Heat Capacity	(kJ/kgmole-C)	28.99	29.44
Mass Heat Capacity	(kJ/kg-C)	3.385	3.438

LHV Molar Basis (Std)	(kJ/kgmole)	1.810e+005	1.810e+005
HHV Molar Basis (Std)	(kJ/kgmole)	2.117e+005	2.117e+005
HHV Mass Basis (Std)	(kJ/kg)	2.472e+004	2.472e+004
LHV Mass Basis (Std)	(kJ/kg)	2.114e+004	2.114e+004
Phase Fraction [Vol. Basis]		1.000	1.000
Phase Fraction [Mass Basis]		1.000	1.000
Phase Fraction [Act. Vol. Basis]		1.000	1.000
Mass Exergy	(kJ/kg)	937.0	1306
Partial Pressure of CO2	(kg/cm2_g)	-1.033	-1.033
Cost Based on Flow	(Cost/s)	0.0000	0.0000
Act. Gas Flow	(ACT_m3/h)	9421	5269
Avg. Liq. Density	(kgmole/m3)	32.96	32.96
Specific Heat	(kJ/kgmole-C)	28.99	29.44
Std. Gas Flow	(STD_m3/h)	2.169e+005	2.169e+005
Std. Ideal Liq. Mass Density	(kg/m3)	282.3	282.3
Act. Liq. Flow	(m3/h)	---	---
Z Factor		1.007	1.022
Watson K		13.86	13.86
Cp/(Cp - R)		1.402	1.394
Cp/Cv		1.421	1.412
Ideal Gas Cp/Cv		1.409	1.401
Ideal Gas Cp	(kJ/kgmole-C)	28.65	29.07
Mass Ideal Gas Cp	(kJ/kg-C)	3.345	3.394
Heat of Vap.	(kJ/kgmole)	3606	3219
Kinematic Viscosity	(cSt)	1.325	1.012
Liq. Mass Density (Std. Cond)	(kg/m3)	0.3621	0.3621
Liq. Vol. Flow (Std. Cond)	(m3/h)	2.169e+005	2.169e+005
Liquid Fraction		0.0000	0.0000
Molar Volume	(m3/kgmole)	1.027	0.5744
Mass Heat of Vap.	(kJ/kg)	421.0	375.9
Thermal Conductivity	(W/m-K)	0.1134	0.1487
Bubble Point Pressure	(kg/cm2_g)	---	---
Viscosity	(cP)	1.105e-002	1.509e-002
Cv (Semi-Ideal)	(kJ/kgmole-C)	20.68	21.12
Mass Cv (Semi-Ideal)	(kJ/kg-C)	2.414	2.467
Cv	(kJ/kgmole-C)	20.40	20.85
Mass Cv	(kJ/kg-C)	2.382	2.435

Hasil

Adiabatic Head	(m)	3.421e+004	Power Consumed	(kW)	9760
Polytropic Head	(m)	3.560e+004	Polytropic Head Factor		0.9992
Adiabatic Fluid Head	(kJ/kg)	335.5	Polytropic Exponent		1.627
Polytropic Fluid Head	(kJ/kg)	349.2	Isentropic Exponent		1.440
Adiabatic Efficiency		75	Speed	(rpm)	---
Polytropic Efficiency		78			---

Total Rotor Power	(kW)	9760	Total Rotor Torque	(N-m)	---
Transient Rotor Power	(kW)	0.0000	Transient Rotor Torque	(N-m)	---
Friction Power Loss	(kW)	0.0000	Friction Torque Loss	(N-m)	---
Fluid Power	(kW)	9760	Fluid Torque	(N-m)	---

Duty	(kJ/h)	3.514e+007	Active	Head	(m)	3.560e+004	Not Active
Adiabatic Efficiency		75	Not Active	Fluid Head	(kJ/kg)	349.2	Not Active
Polytropic Efficiency		78	Active	Capacity	(ACT_m3/h)	9421	Not Active
Pressure Increase	(kg/cm2)	41.00	Not Active	Speed	(rpm)	---	Not Active
		---		Use Characteristic Curves			No

Speed:	---		Duty:		9.7604e+03 kW
Adiabatic Eff.:	75.00		PolyTropic Eff.:		78.06
Adiabatic Head:	3.421e+004 m		Polytropic Head:		3.560e+004 m
Adiabatic Fluid Head:	335.5 kJ/kg		Polytropic Fluid Head:		349.2 kJ/kg
Polytropic Exp.	1.627	Isentropic Exp.	1.440	Poly Head Factor	0.9992

Stage 2

Kondisi suction (307) dan discharge (308):

Name		307 @Main	308 @Main
Vapour		1.0000	1.0000 *
Temperature	(C)	45.0000 *	130.4867
Pressure	(kg/cm2_g)	66.0000	125.0000 *
Molar Flow	(kgmole/h)	9172.4400	9172.4400

Mass Flow	(kg/h)	78550.2244	78550.2244
Std Ideal Liq Vol Flow	(m3/h)	278.2825	278.2825
Molar Enthalpy	(kJ/kgmole)	516.8	3038
Molar Entropy	(kJ/kgmole-C)	100.9	102.5
Heat Flow	(kJ/h)	4.7402e+06	2.7863e+07

Properties

Molecular Weight		8.564	8.564
Molar Density	(kgmole/m3)	2.435	3.531
Mass Density	(kg/m3)	20.85	30.24
Act. Volume Flow	(m3/h)	3767	2598
Mass Enthalpy	(kJ/kg)	60.35	354.7
Mass Entropy	(kJ/kg-C)	11.78	11.96
Heat Capacity	(kJ/kgmole-C)	29.45	29.73
Mass Heat Capacity	(kJ/kg-C)	3.439	3.472
LHV Molar Basis (Std)	(kJ/kgmole)	1.810e+005	1.810e+005
HHV Molar Basis (Std)	(kJ/kgmole)	2.117e+005	2.117e+005
HHV Mass Basis (Std)	(kJ/kg)	2.472e+004	2.472e+004

LHV Mass Basis (Std)	(kJ/kg)	2.114e+004	2.114e+004
Phase Fraction [Vol. Basis]		1.000	1.000
Phase Fraction [Mass Basis]		1.000	1.000

Act. Gas Flow	(ACT_m3/h)	3767	2598
Avg. Liq. Density	(kgmole/m3)	32.96	32.96
Specific Heat	(kJ/kgmole-C)	29.45	29.73
Std. Gas Flow	(STD_m3/h)	2.169e+005	2.169e+005
Std. Ideal Liq. Mass Density	(kg/m3)	282.3	282.3
Act. Liq. Flow	(m3/h)	---	---
Z Factor		1.021	1.043
Watson K		13.86	13.86
Cp/(Cp - R)		1.393	1.388
Cp/Cv		1.436	1.428
Ideal Gas Cp/Cv		1.409	1.403
Ideal Gas Cp	(kJ/kgmole-C)	28.66	28.93
Mass Ideal Gas Cp	(kJ/kg-C)	3.347	3.378
Heat of Vap.	(kJ/kgmole)	3219	---
Kinematic Viscosity	(cSt)	0.5452	0.4659
Liq. Mass Density (Std. Cond)	(kg/m3)	0.3621	0.3621
Liq. Vol. Flow (Std. Cond)	(m3/h)	2.169e+005	2.169e+005
Thermal Conductivity	(W/m-K)	0.1165	0.1406
Bubble Point Pressure	(kg/cm2_g)	---	---
Viscosity	(cP)	1.137e-002	1.409e-002
Cv (Semi-Ideal)	(kJ/kgmole-C)	21.14	21.42
Mass Cv (Semi-Ideal)	(kJ/kg-C)	2.468	2.501
Cv	(kJ/kgmole-C)	20.51	20.82
Mass Cv	(kJ/kg-C)	2.396	2.432
Cv (Ent. Method)	(kJ/kgmole-C)	---	---
Mass Cv (Ent. Method)	(kJ/kg-C)	---	---
Cp/Cv (Ent. Method)		---	---
Reid VP at 37.8 C	(kg/cm2_g)	---	---
True VP at 37.8 C	(kg/cm2_g)	---	---
Liq. Vol. Flow - Sum(Std. Cond)	(m3/h)	2.169e+005	2.169e+005
Viscosity Index		-52.84	-47.54

Hasil

Adiabatic Head	(m)	2.251e+004	Power Consumed	(kW)	6423
Polytropic Head	(m)	2.315e+004	Polytropic Head Factor		0.9989
Adiabatic Fluid Head	(kJ/kg)	220.8	Polytropic Exponent		1.699
Polytropic Fluid Head	(kJ/kg)	227.0	Isentropic Exponent		1.485
Adiabatic Efficiency		75	Speed	(rpm)	---
Polytropic Efficiency		77			---

Total Rotor Power	(kW)	6423	Total Rotor Torque	(N-m)	---
Transient Rotor Power	(kW)	0.0000	Transient Rotor Torque	(N-m)	---
Friction Power Loss	(kW)	0.0000	Friction Torque Loss	(N-m)	---
Fluid Power	(kW)	6423	Fluid Torque	(N-m)	---

Duty	(kJ/h)	2.312e+007	Active	Head	(m)	2.315e+004	Not Active
Adiabatic Efficiency		75	Not Active	Fluid Head	(kJ/kg)	227.0	Not Active
Polytropic Efficiency		77	Active	Capacity	(ACT_m3/h)	3767	Not Active
Pressure Increase	(kg/cm2)	59.00	Not Active	Speed	(rpm)	---	Not Active
		---		Use Characteristic Curves			No

Speed:		---	Duty:		6.4229e+03 kW
Adiabatic Eff.:		75.00	PolyTropic Eff.:		77.11
Adiabatic Head:		2.251e+004 m	Polytropic Head:		2.315e+004 m
Adiabatic Fluid Head:		220.8 kJ/kg	Polytropic Fluid Head:		227.0 kJ/kg
Polytropic Exp.	1.699	Isentropic Exp.	1.485	Poly Head Factor	0.9989

Stage 3

Kondisi suction (309) dan discharge (310):

Name		309 @Main	310 @Main
Vapour		1.0000	1.0000
Temperature	(C)	25.1037	50.6531
Pressure	(kg/cm2_g)	125.0000	155.0000 *
Molar Flow	(kgmole/h)	25124.8115	25124.8115
Mass Flow	(kg/h)	221329.1029	221329.1029
Std Ideal Liq Vol Flow	(m3/h)	762.4744	762.4744
Molar Enthalpy	(kJ/kgmole)	-583.9	177.7
Molar Entropy	(kJ/kgmole-C)	94.41	95.00
Heat Flow	(kJ/h)	-1.4671e+07	4.4635e+06

Properties

Molecular Weight		8.809	8.809
Molar Density	(kgmole/m3)	4.796	5.396
Mass Density	(kg/m3)	42.25	47.53
Act. Volume Flow	(m3/h)	5239	4657
Mass Enthalpy	(kJ/kg)	-66.29	20.17
Mass Entropy	(kJ/kg-C)	10.72	10.78
Heat Capacity	(kJ/kgmole-C)	30.31	30.37
Mass Heat Capacity	(kJ/kg-C)	3.441	3.448
LHV Molar Basis (Std)	(kJ/kgmole)	1.809e+005	1.809e+005
HHV Molar Basis (Std)	(kJ/kgmole)	2.116e+005	2.116e+005
HHV Mass Basis (Std)	(kJ/kg)	2.402e+004	2.402e+004
Act. Gas Flow	(ACT_m3/h)	5239	4657
Avg. Liq. Density	(kgmole/m3)	32.95	32.95
Specific Heat	(kJ/kgmole-C)	30.31	30.37
Std. Gas Flow	(STD_m3/h)	5.941e+005	5.941e+005
Std. Ideal Liq. Mass Density	(kg/m3)	290.3	290.3
Act. Liq. Flow	(m3/h)	---	---
Z Factor		1.039	1.053
Watson K		13.71	13.71
Cp/(Cp - R)		1.378	1.377
Cp/Cv		1.463	1.459
Ideal Gas Cp/Cv		1.408	1.407
Ideal Gas Cp	(kJ/kgmole-C)	28.68	28.76
Heat of Vap.	(kJ/kgmole)	7617	7576
Kinematic Viscosity	(cSt)	0.2650	0.2533

Thermal Conductivity	(W/m-K)	0.1114	0.1193
Bubble Point Pressure	(kg/cm2_g)	---	---
Viscosity	(cP)	1.119e-002	1.204e-002
Cv (Semi-Ideal)	(kJ/kgmole-C)	22.00	22.06
Mass Cv (Semi-Ideal)	(kJ/kg-C)	2.497	2.504

Cv	(kJ/kgmole-C)	20.72	20.82
Mass Cv	(kJ/kg-C)	2.352	2.363
Cv (Ent. Method)	(kJ/kgmole-C)	20.68	20.74
Mass Cv (Ent. Method)	(kJ/kg-C)	2.347	2.354
Cp/Cv (Ent. Method)		1.466	1.464
Reid VP at 37.8 C	(kg/cm2_g)	---	---
True VP at 37.8 C	(kg/cm2_g)	---	---
Liq. Vol. Flow - Sum(Std. Cond)	(m3/h)	5.942e+005	5.942e+005
Viscosity Index		---	---

Hasil

Adiabatic Head	(m)	6612	Power Consumed	(kW)	5315
Polytropic Head	(m)	6679	Polytropic Head Factor		0.9991
Adiabatic Fluid Head	(kJ/kg)	64.84	Polytropic Exponent		1.811
Polytropic Fluid Head	(kJ/kg)	65.49	Isentropic Exponent		1.551
Adiabatic Efficiency		75	Speed	(rpm)	---
Polytropic Efficiency		76			---

Total Rotor Power	(kW)	5315	Total Rotor Torque	(N-m)	---
Transient Rotor Power	(kW)	0.0000	Transient Rotor Torque	(N-m)	---
Friction Power Loss	(kW)	0.0000	Friction Torque Loss	(N-m)	---
Fluid Power	(kW)	5315	Fluid Torque	(N-m)	---

Duty	(kJ/h)	1.913e+007	Active	Head	(m)	6679	Not Active
Adiabatic Efficiency		75	Not Active	Fluid Head	(kJ/kg)	65.49	Not Active
Polytropic Efficiency		76	Active	Capacity	(ACT_m3/h)	5239	Not Active
Pressure Increase	(kg/cm2)	30.00	Not Active	Speed	(rpm)	---	Not Active
		---		Use Characteristic Curves			No

Speed:	---		Duty:		5.3151e+03 kW
Adiabatic Eff.:	75.00		PolyTropic Eff.:		75.76
Adiabatic Head:	6612 m		Polytropic Head:		6679 m
Adiabatic Fluid Head:	64.84 kJ/kg		Polytropic Fluid Head:		65.49 kJ/kg
Polytropic Exp.	1.811	Isentropic Exp.	1.551	Poly Head Factor	0.9991

f. Kompresor Refrigerant

Dari simulasi HYSYS diperoleh:

Stage 1

Kondisi suction (Refrigerant Compresor) dan discharge (201):

Name		erant Compressor @Main	201 @Main
Vapour		1.0000	1.0000
Temperature	(C)	-34.9991	122.4315
Pressure	(kg/cm2_g)	-0.1000	4.2750 *
Molar Flow	(kgmole/h)	5297.6815	5297.6815

Mass Flow	(kg/h)	90219.5189	90219.5189
Std Ideal Liq Vol Flow	(m3/h)	146.4436	146.4436
Molar Enthalpy	(kJ/kgmole)	-4.789e+004	-4.231e+004
Molar Entropy	(kJ/kgmole-C)	163.4	167.1
Heat Flow	(kJ/h)	-2.5368e+08	-2.2412e+08

Properties

Molecular Weight		17.03	17.03
Molar Density	(kgmole/m3)	4.687e-002	0.1614
Mass Density	(kg/m3)	0.7983	2.748
Act. Volume Flow	(m3/h)	1.130e+005	3.283e+004
Mass Enthalpy	(kJ/kg)	-2812	-2484
Mass Entropy	(kJ/kg-C)	9.594	9.811
Heat Capacity	(kJ/kgmole-C)	34.89	39.06
Mass Heat Capacity	(kJ/kg-C)	2.049	2.294
LHV Molar Basis (Std)	(kJ/kgmole)	3.168e+005	3.168e+005
HHV Molar Basis (Std)	(kJ/kgmole)	3.783e+005	3.783e+005
HHV Mass Basis (Std)	(kJ/kg)	2.222e+004	2.222e+004

Act. Gas Flow	(ACT_m3/h)	1.130e+005	3.283e+004
Avg. Liq. Density	(kgmole/m3)	36.18	36.18
Specific Heat	(kJ/kgmole-C)	34.89	39.06
Std. Gas Flow	(STD_m3/h)	1.253e+005	1.253e+005
Std. Ideal Liq. Mass Density	(kg/m3)	616.1	616.1
Act. Liq. Flow	(m3/h)	---	---
Z Factor		0.9860	0.9809
Watson K		12.24	12.24

Cp/(Cp - R)		1.313	1.270
Cp/Cv		1.332	1.300
Ideal Gas Cp/Cv		1.318	1.278
Ideal Gas Cp	(kJ/kgmole-C)	34.46	38.25
Mass Ideal Gas Cp	(kJ/kg-C)	2.023	2.246
Heat of Vap.	(kJ/kgmole)	2.379e+004	2.176e+004
Kinematic Viscosity	(cSt)	8.177	4.176
Liq. Mass Density (Std. Cond)	(kg/m3)	612.3	612.3
Liq. Vol. Flow (Std. Cond)	(m3/h)	147.3	147.3
Liquid Fraction		0.0000	0.0000
Molar Volume	(m3/kgmole)	21.33	6.198
Mass Heat of Vap.	(kJ/kg)	1397	1278

Thermal Conductivity	(W/m-K)	1.986e-002	3.926e-002
Bubble Point Pressure	(kg/cm2_g)	-9.999e-002	95.74
Viscosity	(cP)	6.528e-003	1.148e-002
Cv (Semi-Ideal)	(kJ/kgmole-C)	26.57	30.74
Mass Cv (Semi-Ideal)	(kJ/kg-C)	1.560	1.805

Cv	(kJ/kgmole-C)	26.19	30.06
Mass Cv	(kJ/kg-C)	1.538	1.765
Cv (Ent. Method)	(kJ/kgmole-C)	---	---
Mass Cv (Ent. Method)	(kJ/kg-C)	---	---
Cp/Cv (Ent. Method)		---	---
Reid VP at 37.8 C	(kg/cm2_g)	13.76	13.76
True VP at 37.8 C	(kg/cm2_g)	13.76	13.76
Liq. Vol. Flow - Sum(Std. Cond)	(m3/h)	147.3	147.3
Viscosity Index		-15.76	-10.53

Hasil

Adiabatic Head	(m)	2.505e+004	Power Consumed	(kW)	8210
Polytropic Head	(m)	2.647e+004	Polytropic Head Factor		1.003
Adiabatic Fluid Head	(kJ/kg)	245.7	Polytropic Exponent		1.406
Polytropic Fluid Head	(kJ/kg)	259.6	Isentropic Exponent		1.299
Adiabatic Efficiency		75	Speed	(rpm)	---
Polytropic Efficiency		79			---

Total Rotor Power	(kW)	8210	Total Rotor Torque	(N-m)	---
Transient Rotor Power	(kW)	0.0000	Transient Rotor Torque	(N-m)	---
Friction Power Loss	(kW)	0.0000	Friction Torque Loss	(N-m)	---
Fluid Power	(kW)	8210	Fluid Torque	(N-m)	---

Duty	(kJ/h)	2.956e+007	Active	Head	(m)	2.647e+004	Not Active
Adiabatic Efficiency		75	Not Active	Fluid Head	(kJ/kg)	259.6	Not Active
Polytropic Efficiency		79	Active	Capacity	(ACT_m3/h)	1.130e+005	Not Active
Pressure Increase	(kg/cm2)	4.375	Not Active	Speed	(rpm)	---	Not Active
		---		Use Characteristic Curves			No

Speed:	---		Duty:		8.2100e+03 kW
Adiabatic Eff.:	75.00		PolyTropic Eff.:		79.24
Adiabatic Head:	2.505e+004 m		Polytropic Head:		2.647e+004 m
Adiabatic Fluid Head:	245.7 kJ/kg		Polytropic Fluid Head:		259.6 kJ/kg
Polytropic Exp.	1.406	Isentropic Exp.	1.299	Poly Head Factor	1.003

Stage 2

Kondisi suction (202) dan discharge (203):

Name		202 @Main	203 @Main
Vapour		1.0000	1.0000
Temperature	(C)	45.0000 *	121.2387
Pressure	(kg/cm2_g)	4.2750 *	10.0000 *
Molar Flow	(kgmole/h)	5297.6815	5297.6815

Mass Flow	(kg/h)	90219.5189	90219.5189
Std Ideal Liq Vol Flow	(m3/h)	146.4436	146.4436
Molar Enthalpy	(kJ/kgmole)	-4.527e+004	-4.257e+004
Molar Entropy	(kJ/kgmole-C)	158.8	160.5
Heat Flow	(kJ/h)	-2.3981e+08	-2.2552e+08

Properties

Molecular Weight		17.03	17.03
Molar Density	(kgmole/m3)	0.2043	0.3439
Mass Density	(kg/m3)	3.479	5.857
Act. Volume Flow	(m3/h)	2.593e+004	1.540e+004

Mass Enthalpy	(kJ/kg)	-2658	-2500
Mass Entropy	(kJ/kg-C)	9.322	9.425
Heat Capacity	(kJ/kgmole-C)	37.55	40.00
Mass Heat Capacity	(kJ/kg-C)	2.205	2.349
LHV Molar Basis (Std)	(kJ/kgmole)	3.168e+005	3.168e+005
HHV Molar Basis (Std)	(kJ/kgmole)	3.783e+005	3.783e+005
HHV Mass Basis (Std)	(kJ/kg)	2.222e+004	2.222e+004
Act. Gas Flow	(ACT_m3/h)	2.593e+004	1.540e+004
Avg. Liq. Density	(kgmole/m3)	36.18	36.18
Specific Heat	(kJ/kgmole-C)	37.55	40.00
Std. Gas Flow	(STD_m3/h)	1.253e+005	1.253e+005
Std. Ideal Liq. Mass Density	(kg/m3)	616.1	616.1
Act. Liq. Flow	(m3/h)	---	---
Z Factor		0.9632	0.9595
Watson K		12.24	12.24
Cp/(Cp - R)		1.284	1.262
Cp/Cv		1.340	1.326
Ideal Gas Cp/Cv		1.298	1.278
Ideal Gas Cp	(kJ/kgmole-C)	36.17	38.22
Mass Ideal Gas Cp	(kJ/kg-C)	2.124	2.244
Heat of Vap.	(kJ/kgmole)	2.176e+004	2.038e+004
Kinematic Viscosity	(cSt)	2.601	1.970
Liq. Mass Density (Std. Cond)	(kg/m3)	612.3	612.3
Liq. Vol. Flow (Std. Cond)	(m3/h)	147.3	147.3
Liquid Fraction		0.0000	0.0000
Molar Volume	(m3/kgmole)	4.894	2.908
Mass Heat of Vap.	(kJ/kg)	1278	1197
Thermal Conductivity	(W/m-K)	2.955e-002	3.980e-002
Bubble Point Pressure	(kg/cm2_g)	17.03	93.71
Viscosity	(cP)	9.051e-003	1.154e-002
Cv (Semi-Ideal)	(kJ/kgmole-C)	29.24	31.69
Mass Cv (Semi-Ideal)	(kJ/kg-C)	1.717	1.861
Cv	(kJ/kgmole-C)	28.03	30.16
Mass Cv	(kJ/kg-C)	1.646	1.771
Cv (Ent. Method)	(kJ/kgmole-C)	---	---
Mass Cv (Ent. Method)	(kJ/kg-C)	---	---
Cp/Cv (Ent. Method)		---	---
Reid VP at 37.8 C	(kg/cm2_g)	13.76	13.76
True VP at 37.8 C	(kg/cm2_g)	13.76	13.76
Liq. Vol. Flow - Sum(Std. Cond)	(m3/h)	147.3	147.3

Hasil

Adiabatic Head	(m)	1.212e+004	Power Consumed	(kW)	3970
Polytropic Head	(m)	1.243e+004	Polytropic Head Factor		1.001
Adiabatic Fluid Head	(kJ/kg)	118.8	Polytropic Exponent		1.405
Polytropic Fluid Head	(kJ/kg)	121.9	Isentropic Exponent		1.282
Adiabatic Efficiency		75	Speed	(rpm)	---
Polytropic Efficiency		77			---

Total Rotor Power	(kW)	3970	Total Rotor Torque	(N-m)	---
Transient Rotor Power	(kW)	0.0000	Transient Rotor Torque	(N-m)	---
Friction Power Loss	(kW)	0.0000	Friction Torque Loss	(N-m)	---
Fluid Power	(kW)	3970	Fluid Torque	(N-m)	---

Duty	(kJ/h)	1.429e+007	Active	Head	(m)	1.243e+004	Not Active
Adiabatic Efficiency		75	Not Active	Fluid Head	(kJ/kg)	121.9	Not Active
Polytropic Efficiency		77	Active	Capacity	(ACT_m3/h)	2.593e+004	Not Active
Pressure Increase	(kg/cm2)	5.725	Not Active	Speed	(rpm)	---	Not Active
		---		Use Characteristic Curves			No

Speed:	---		Duty:		3.9703e+03 kW
Adiabatic Eff.:	75.00		PolyTropic Eff.:		76.96
Adiabatic Head:	1.212e+004 m		Polytropic Head:		1.243e+004 m
Adiabatic Fluid Head:	118.8 kJ/kg		Polytropic Fluid Head:		121.9 kJ/kg
Polytropic Exp.	1.405	Isentropic Exp.	1.282	Poly Head Factor	1.001

Stage 3

Kondisi suction (204) dan discharge (205)

Name		204 @Main	205 @Main
Vapour		1.0000	1.0000
Temperature	(C)	45.0000 *	95.6335
Pressure	(kg/cm2_g)	10.0000	17.0000 *
Molar Flow	(kgmole/h)	5297.6815	5297.6815

Mass Flow	(kg/h)	90219.5189	90219.5189
Std Ideal Liq Vol Flow	(m3/h)	146.4436	146.4436
Molar Enthalpy	(kJ/kgmole)	-4.559e+004	-4.390e+004
Molar Entropy	(kJ/kgmole-C)	152.0	153.2
Heat Flow	(kJ/h)	-2.4150e+08	-2.3258e+08

Properties

Molecular Weight		17.03	17.03
Molar Density	(kgmole/m3)	0.4441	0.6294
Mass Density	(kg/m3)	7.563	10.72
Act. Volume Flow	(m3/h)	1.193e+004	8417
Mass Enthalpy	(kJ/kg)	-2677	-2578
Mass Entropy	(kJ/kg-C)	8.926	8.994
Heat Capacity	(kJ/kgmole-C)	39.40	41.33
Mass Heat Capacity	(kJ/kg-C)	2.314	2.427
LHV Molar Basis (Std)	(kJ/kgmole)	3.168e+005	3.168e+005
HHV Molar Basis (Std)	(kJ/kgmole)	3.783e+005	3.783e+005
HHV Mass Basis (Std)	(kJ/kg)	2.222e+004	2.222e+004

LHV Mass Basis (Std)	(kJ/kg)	1.860e+004	1.860e+004

Act. Gas Flow	(ACT_m3/h)	1.193e+004	8417
Avg. Liq. Density	(kgmole/m3)	36.18	36.18

Specific Heat	(kJ/kgmole-C)	39.40	41.33
Std. Gas Flow	(STD_m3/h)	1.253e+005	1.253e+005
Std. Ideal Liq. Mass Density	(kg/m3)	616.1	616.1
Act. Liq. Flow	(m3/h)	---	---
Z Factor		0.9210	0.9164
Watson K		12.24	12.24
User Property		---	---
Partial Pressure of H2S	(kg/cm2_g)	-1.033	-1.033
Cp/(Cp - R)		1.267	1.262
Cp/Cv		1.396	1.393
Ideal Gas Cp/Cv		1.298	1.285
Ideal Gas Cp	(kJ/kgmole-C)	36.17	37.49
Mass Ideal Gas Cp	(kJ/kg-C)	2.124	2.202
Heat of Vap.	(kJ/kgmole)	2.038e+004	1.910e+004
Kinematic Viscosity	(cSt)	1.213	1.015
Liq. Mass Density (Std. Cond)	(kg/m3)	612.3	612.3
Liq. Vol. Flow (Std. Cond)	(m3/h)	147.3	147.3
Liquid Fraction		0.0000	0.0000
Molar Volume	(m3/kgmole)	2.252	1.589
Mass Heat of Vap.	(kJ/kg)	1197	1121
Phase Fraction [Molar Basis]		1.0000	1.0000
Surface Tension	(dyne/cm)	---	---
Thermal Conductivity	(W/m-K)	3.047e-002	3.753e-002
Bubble Point Pressure	(kg/cm2_g)	17.03	37.41
Viscosity	(cP)	9.176e-003	1.087e-002
Cv (Semi-Ideal)	(kJ/kgmole-C)	31.09	33.02
Mass Cv (Semi-Ideal)	(kJ/kg-C)	1.826	1.939

Cv	(kJ/kgmole-C)	28.23	29.66
Mass Cv	(kJ/kg-C)	1.658	1.742
Cv (Ent. Method)	(kJ/kgmole-C)	---	---
Mass Cv (Ent. Method)	(kJ/kg-C)	---	---
Cp/Cv (Ent. Method)		---	---
Reid VP at 37.8 C	(kg/cm2_g)	13.76	13.76
True VP at 37.8 C	(kg/cm2_g)	13.76	13.76
Liq. Vol. Flow - Sum(Std. Cond)	(m3/h)	147.3	147.3

Hasil

Adiabatic Head	(m)	7562	Power Consumed	(kW)	2478
Polytropic Head	(m)	7705	Polytropic Head Factor		1.000
Adiabatic Fluid Head	(kJ/kg)	74.16	Polytropic Exponent		1.409
Polytropic Fluid Head	(kJ/kg)	75.56	Isentropic Exponent		1.275
Adiabatic Efficiency		75	Speed	(rpm)	---
Polytropic Efficiency		76			---

Total Rotor Power	(kW)	2478	Total Rotor Torque	(N-m)	---
Transient Rotor Power	(kW)	0.0000	Transient Rotor Torque	(N-m)	---
Friction Power Loss	(kW)	0.0000	Friction Torque Loss	(N-m)	---
Fluid Power	(kW)	2478	Fluid Torque	(N-m)	---

Duty	(kJ/h)	8.921e+006	Active	Head	(m)	7705	Not Active
Adiabatic Efficiency		75	Not Active	Fluid Head	(kJ/kg)	75.56	Not Active
Polytropic Efficiency		76	Active	Capacity	(ACT_m3/h)	1.193e+004	Not Active
Pressure Increase	(kg/cm2)	7.000	Not Active	Speed	(rpm)	---	Not Active
		---		Use Characteristic Curves			No

Speed:	---		Duty:	2.4780e+03 kW	
Adiabatic Eff.:	75.00		PolyTropic Eff.:	76.42	
Adiabatic Head:	7562 m		Polytropic Head:	7705 m	
Adiabatic Fluid Head:	74.16 kJ/kg		Polytropic Fluid Head:	75.56 kJ/kg	
Polytropic Exp.	1.409	Isentropic Exp.	1.275	Poly Head Factor	1.000

g. Kompresor LP syngas

Dari simulasi HYSYS diperoleh:

Stage 1

Kondisi suction (323) dan discharge (326):

Name		323 @Main	326 @Main
Vapour		1.0000	1.0000
Temperature	(C)	-33.6406	205.3147
Pressure	(kg/cm2_g)	0.5000	14.0000 *
Molar Flow	(kgmole/h)	65.6012	65.6012

Mass Flow	(kg/h)	885.0060	885.0060
Std Ideal Liq Vol Flow	(m3/h)	1.8631	1.8631
Molar Enthalpy	(kJ/kgmole)	-3.199e+004	-2.392e+004
Molar Entropy	(kJ/kgmole-C)	151.9	156.3
Heat Flow	(kJ/h)	-2.0989e+06	-1.5689e+06

Properties

Molecular Weight		13.49	13.49
Molar Density	(kgmole/m3)	7.635e-002	0.3749
Mass Density	(kg/m3)	1.030	5.057
Act. Volume Flow	(m3/h)	859.2	175.0
Mass Enthalpy	(kJ/kg)	-2372	-1773
Mass Entropy	(kJ/kg-C)	11.26	11.59
Heat Capacity	(kJ/kgmole-C)	32.73	37.48
Mass Heat Capacity	(kJ/kg-C)	2.426	2.779
LHV Molar Basis (Std)	(kJ/kgmole)	2.764e+005	2.764e+005
HHV Molar Basis (Std)	(kJ/kgmole)	3.284e+005	3.284e+005
HHV Mass Basis (Std)	(kJ/kg)	2.434e+004	2.434e+004

LHV Mass Basis (Std)	(kJ/kg)	2.049e+004	2.049e+004
Phase Fraction [Vol. Basis]		1.000	1.000
Phase Fraction [Mass Basis]		1.000	1.000
Phase Fraction [Act. Vol. Basis]		1.000	1.000
Mass Exergy	(kJ/kg)	88.41	588.3

Act. Gas Flow	(ACT_m3/h)	859.2	175.0
Avg. Liq. Density	(kgmole/m3)	35.21	35.21

Specific Heat	(kJ/kgmole-C)	32.73	37.48
Std. Gas Flow	(STD_m3/h)	1551	1551
Std. Ideal Liq. Mass Density	(kg/m3)	475.0	475.0

Z Factor	---	0.9886
Watson K	13.55	13.55

Cp/(Cp - R)		1.341	1.285
Cp/Cv		1.359	1.313
Ideal Gas Cp/Cv		1.346	1.293
Ideal Gas Cp	(kJ/kgmole-C)	32.36	36.72
Mass Ideal Gas Cp	(kJ/kg-C)	2.399	2.722
Heat of Vap.	(kJ/kgmole)	2.559e+004	3.032e+004
Kinematic Viscosity	(cSt)	7.666	3.131
Liq. Mass Density (Std. Cond)	(kg/m3)	0.5731	0.5731
Liq. Vol. Flow (Std. Cond)	(m3/h)	1544	1544
Liquid Fraction		0.0000	0.0000
Molar Volume	(m3/kgmole)	13.10	2.667
Mass Heat of Vap.	(kJ/kg)	1897	2247
Phase Fraction [Molar Basis]		1.0000	1.0000
Surface Tension	(dyne/cm)	---	---
Thermal Conductivity	(W/m-K)	4.043e-002	8.217e-002
Bubble Point Pressure	(kg/cm2_g)	---	---
Viscosity	(cP)	7.896e-003	1.583e-002
Cv (Semi-Ideal)	(kJ/kgmole-C)	24.41	29.17
Mass Cv (Semi-Ideal)	(kJ/kg-C)	1.810	2.162

Cv	(kJ/kgmole-C)	24.09	28.55
Mass Cv	(kJ/kg-C)	1.786	2.116
Cv (Ent. Method)	(kJ/kgmole-C)	---	---
Mass Cv (Ent. Method)	(kJ/kg-C)	---	---
Cp/Cv (Ent. Method)		---	---
Reid VP at 37.8 C	(kg/cm2_g)	---	---
True VP at 37.8 C	(kg/cm2_g)	---	---
Liq. Vol. Flow - Sum(Std. Cond)	(m3/h)	1544	1544

Hasil

Adiabatic Head	(m)	4.580e+004	Power Consumed	(kW)	147.2
Polytropic Head	(m)	4.916e+004	Polytropic Head Factor		1.004
Adiabatic Fluid Head	(kJ/kg)	449.2	Polytropic Exponent		1.435
Polytropic Fluid Head	(kJ/kg)	482.1	Isentropic Exponent		1.328
Adiabatic Efficiency		75	Speed	(rpm)	---
Polytropic Efficiency		80			---

Total Rotor Power	(kW)	147.2	Total Rotor Torque	(N-m)	---
Transient Rotor Power	(kW)	0.0000	Transient Rotor Torque	(N-m)	---
Friction Power Loss	(kW)	0.0000	Friction Torque Loss	(N-m)	---
Fluid Power	(kW)	147.2	Fluid Torque	(N-m)	---

Duty	(kJ/h)	5.301e+005	Active	Head	(m)	4.916e+004	Not Active
Adiabatic Efficiency		75	Not Active	Fluid Head	(kJ/kg)	482.1	Not Active
Polytropic Efficiency		80	Active	Capacity	(ACT_m3/h)	859.2	Not Active
Pressure Increase	(kg/cm2)	13.50	Not Active	Speed	(rpm)	---	Not Active
		---		Use Characteristic Curves			No

Speed:	---		Duty:		1.4724e+02 kW
Adiabatic Eff.:	75.00		PolyTropic Eff.:		80.50
Adiabatic Head:	4.580e+004 m		Polytropic Head:		4.916e+004 m
Adiabatic Fluid Head:	449.2 kJ/kg		Polytropic Fluid Head:		482.1 kJ/kg
Polytropic Exp.	1.435	Isentropic Exp.	1.328	Poly Head Factor	1.004

Stage 2

Kondisi suction (213) dan discharge (215)

Properties

Hasil

Speed:	---		Duty:		9.5010e+01 kW
Adiabatic Eff.:	75.00		PolyTropic Eff.:		78.53
Adiabatic Head:	2.956e+004 m		Polytropic Head:		3.095e+004 m
Adiabatic Fluid Head:	289.9 kJ/kg		Polytropic Fluid Head:		303.5 kJ/kg
Polytropic Exp.	1.455	Isentropic Exp.	1.327	Poly Head Factor	0.9998

Stage 3

Kondisi suction (330) dan discharge (332):

Name		330 @Main	332 @Main
Vapour		1.0000	1.0000
Temperature	(C)	45.0000	144.5232
Pressure	(kg/cm2_g)	55.0000	125.0000 *
Molar Flow	(kgmole/h)	36.3935	36.3935

Mass Flow	(kg/h)	389.6380	389.6380
Std Ideal Liq Vol Flow	(m3/h)	1.0552	1.0552
Molar Enthalpy	(kJ/kgmole)	-1.772e+004	-1.469e+004
Molar Entropy	(kJ/kgmole-C)	119.4	121.3
Heat Flow	(kJ/h)	-6.4482e+05	-5.3464e+05

Properties

Molecular Weight		10.71	10.71
Molar Density	(kgmole/m3)	2.217	3.673
Mass Density	(kg/m3)	23.73	39.33
Act. Volume Flow	(m3/h)	16.42	9.908
Mass Enthalpy	(kJ/kg)	-1655	-1372
Mass Entropy	(kJ/kg-C)	11.16	11.33
Heat Capacity	(kJ/kgmole-C)	35.33	36.84

Mass Heat Capacity	(kJ/kg-C)	3.300	3.441
LHV Molar Basis (Std)	(kJ/kgmole)	2.447e+005	2.447e+005
HHV Molar Basis (Std)	(kJ/kgmole)	2.892e+005	2.892e+005
HHV Mass Basis (Std)	(kJ/kg)	2.702e+004	2.702e+004

Act. Gas Flow	(ACT_m3/h)	16.42	9.908
Avg. Liq. Density	(kgmole/m3)	34.49	34.49
Specific Heat	(kJ/kgmole-C)	35.33	36.84
Std. Gas Flow	(STD_m3/h)	860.5	860.5
Std. Ideal Liq. Mass Density	(kg/m3)	369.2	369.2
Act. Liq. Flow	(m3/h)	---	---
Z Factor		---	0.9690
Watson K		14.91	14.91

Cp/(Cp - R)		1.308	1.291
Cp/Cv		1.491	1.466
Ideal Gas Cp/Cv		1.359	1.341
Ideal Gas Cp	(kJ/kgmole-C)	31.49	32.72
Mass Ideal Gas Cp	(kJ/kg-C)	2.941	3.056
Heat of Vap.	(kJ/kgmole)	2.188e+004	2.199e+004
Kinematic Viscosity	(cSt)	0.4837	0.3642
Liq. Mass Density (Std. Cond)	(kg/m3)	0.4536	0.4536
Liq. Vol. Flow (Std. Cond)	(m3/h)	859.0	859.0
Liquid Fraction		0.0000	0.0000
Molar Volume	(m3/kgmole)	0.4511	0.2722
Mass Heat of Vap.	(kJ/kg)	2044	2054
Phase Fraction [Molar Basis]		1.0000	1.0000
Surface Tension	(dyne/cm)	---	---
Thermal Conductivity	(W/m-K)	8.371e-002	0.1086
Bubble Point Pressure	(kg/cm2_g)	---	---
Viscosity	(cP)	1.148e-002	1.432e-002
Cv (Semi-Ideal)	(kJ/kgmole-C)	27.02	28.53
Mass Cv (Semi-Ideal)	(kJ/kg-C)	2.523	2.665

Cv	(kJ/kgmole-C)	23.70	25.14
Mass Cv	(kJ/kg-C)	2.213	2.348
Cv (Ent. Method)	(kJ/kgmole-C)	---	28.17
Mass Cv (Ent. Method)	(kJ/kg-C)	---	2.631
Cp/Cv (Ent. Method)		---	1.308
Reid VP at 37.8 C	(kg/cm2_g)	---	---
True VP at 37.8 C	(kg/cm2_g)	---	---
Liq. Vol. Flow - Sum(Std. Cond)	(m3/h)	859.0	859.0

Hasil

Adiabatic Head	(m)	2.163e+004	Power Consumed	(kW)	30.61
Polytropic Head	(m)	2.234e+004	Polytropic Head Factor		0.9980
Adiabatic Fluid Head	(kJ/kg)	212.1	Polytropic Exponent		1.605
Polytropic Fluid Head	(kJ/kg)	219.1	Isentropic Exponent		1.430
Adiabatic Efficiency		75	Speed	(rpm)	---
Polytropic Efficiency		77			---

Total Rotor Power	(kW)	30.61	Total Rotor Torque	(N-m)	---
Transient Rotor Power	(kW)	0.0000	Transient Rotor Torque	(N-m)	---
Friction Power Loss	(kW)	0.0000	Friction Torque Loss	(N-m)	---
Fluid Power	(kW)	30.61	Fluid Torque	(N-m)	---

Duty	(kJ/h)	1.102e+005	Active	Head	(m)	2.234e+004	Not Active
Adiabatic Efficiency		75	Not Active	Fluid Head	(kJ/kg)	219.1	Not Active
Polytropic Efficiency		77	Active	Capacity	(ACT_m3/h)	16.42	Not Active
Pressure Increase	(kg/cm2)	70.00	Not Active	Speed	(rpm)	---	Not Active
		---		Use Characteristic Curves			No

Speed:	---		Duty:	3.0607e+01 kW	
Adiabatic Eff.:	75.00		PolyTropic Eff.:	77.47	
Adiabatic Head:	2.163e+004 m		Polytropic Head:	2.234e+004 m	
Adiabatic Fluid Head:	212.1 kJ/kg		Polytropic Fluid Head:	219.1 kJ/kg	
Polytropic Exp.	1.605	Isentropic Exp.	1.430	Poly Head Factor	0.9980

h. Pompa NH3 produk

Dari simulasi HYSYS diperoleh:

Kondisi suction (324) & Discharge (325)

Name		324 @Main	325 @Main
Vapour		0.0000	0.0000
Temperature	(C)	-33.6010	-33.4638
Pressure	(kg/cm2_g)	0.5000	7.0000 *
Molar Flow	(kgmole/h)	4479.1888	4479.1888
Mass Flow	(kg/h)	76280.2392	76280.2392
Std Ideal Liq Vol Flow	(m3/h)	123.8183	123.8183
Molar Enthalpy	(kJ/kgmole)	-7.156e+004	-7.154e+004
Molar Entropy	(kJ/kgmole-C)	63.94	63.96
Heat Flow	(kJ/h)	-3.2055e+08	-3.2046e+08

Properties

Name		324 @Main	325 @Main
Molecular Weight		17.03	17.03
Molar Density	(kgmole/m3)	39.57	39.57
Mass Density	(kg/m3)	673.8	673.8
Act. Volume Flow	(m3/h)	113.2	113.2
Mass Enthalpy	(kJ/kg)	-4202	-4201
Mass Entropy	(kJ/kg-C)	3.755	3.755
Heat Capacity	(kJ/kgmole-C)	75.82	75.77
Mass Heat Capacity	(kJ/kg-C)	4.452	4.449

Hasil

PERFORMANCE			
Results			
Total Head	---	Velocity Head	-1.131e-003 m
Total Fluid Head	---	Delta P excluding Static Head Results	---
Pressure Head	96.47 m		

Head	(m)	---	Not Active	Power	(kJ/h)	9.622e+004	Not Active
Fluid Head	(kJ/kg)	---	Not Active	Capacity	(m3/h)	123.8	
Speed	(rpm)	---	Not Active	Use Characteristic Curves			Not Active
Efficiency	(%)	75.00 *	Active	Pump is Acting as a Turbine			Not Active
Pressure Increase	(kg/cm2)	6.500	Active				