
ISS (Isotope Separation System)

초저온증류 공정시물레이션

공주대학교 화학공학부

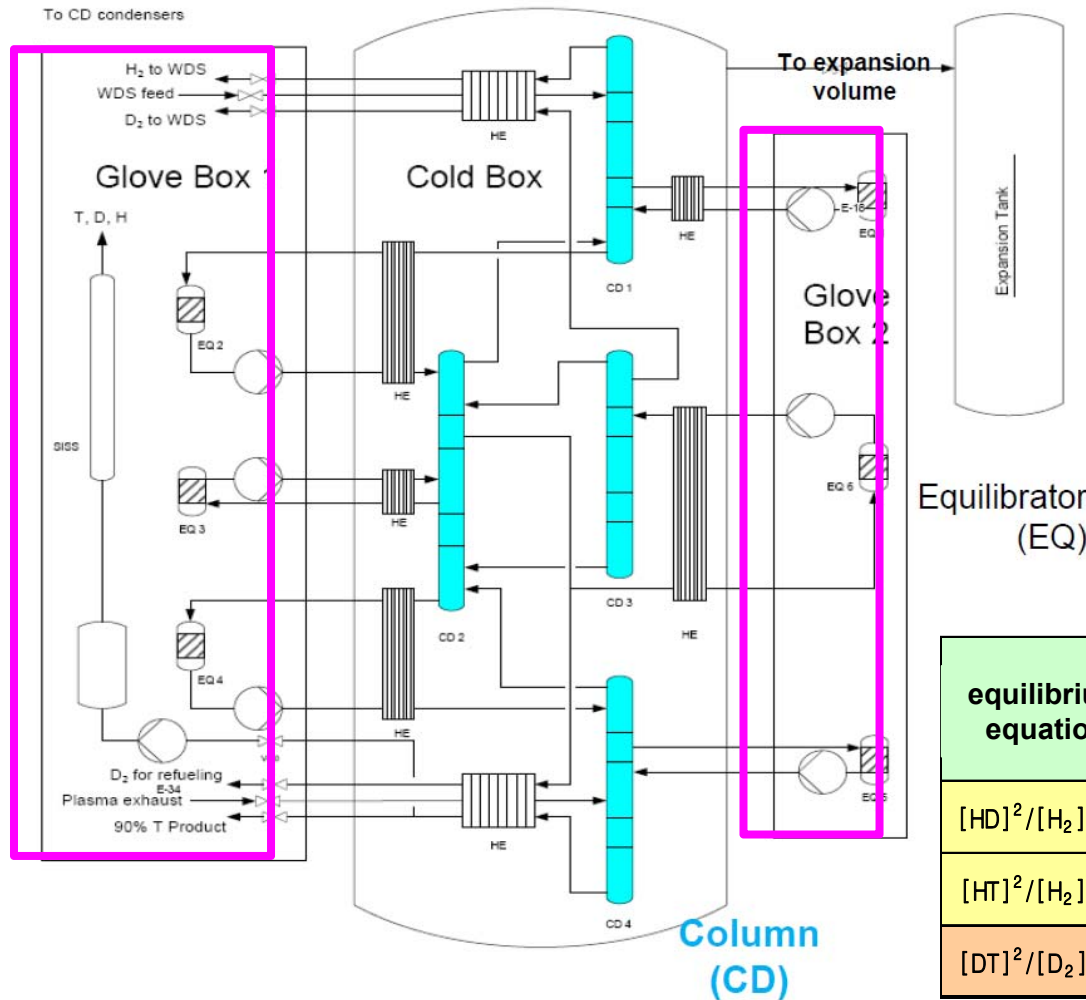
조 정 호

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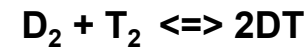
2. ITER ISS 평형 반응기

2. ITER ISS 평형 반응기



Equilibrator

목적: 최대한 원소단위로 재 분리하는 역할
 평형반응장치의 최적 배열과 위치가 존재



Equilibrium constant : $K_{DT} = [DT]^2 / [D_2][T_2]$

Reaction rate : $R_{DT} = r_{DT} f(P_{DT}, P_{D_2}, P_{T_2})$

Reactions in the equilibrators

- $HT + D_2 \leftrightarrow DT + HD$
- $2DT \leftrightarrow D_2 + T_2$

equilibrium equation	온도(K)					
	0	273.1	298.1	400	500	600
$[HD]^2/[H_2][D_2]$	0	3.18	3.25	3.48	3.62	3.72
$[HT]^2/[H_2][T_2]$	0	2.42	2.56	2.97	3.24	3.44
$[DT]^2/[D_2][T_2]$	0	3.79	3.82	3.88	3.92	3.94

EU Contribution to ITER Fuel Cycle, Alain Teissier, IBF 2013

2. ITER ISS 평형 반응기

수소동위원소와 기타 성분들의 물성 DB화

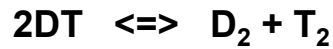
Properties of Hydrogen Isotopomers

종 류	H ₂	HD	HT	D ₂	DT	T ₂
끓는점 (K)	20.39	22.14	22.92	23.66	24.38	25.04
증기압 (mmHg) @25K	2483.19	1620.17	1346.05	1117.77	915.77	759.05

Relative volatility (@22K)

H₂/ HD : 1.6
 H₂/ HT : 2.1
 H₂/D₂ : 2.6
 H₂/DT : 3.4
 H₂/T₂ : 4.3

Equilibrator



$$\text{평형상수} : K_{DT} = [DT]^2 / [D_2][T_2]$$

$$\text{반응속도} : R_{DT} = r_{DT} f(P_{DT}, P_{D_2}, P_{T_2})$$

평형상수식	온도(K)					
	0	273.1	298.1	400	500	600
$[HD]^2/[H_2][D_2]$	0	3.18	3.25	3.48	3.62	3.72
$[HT]^2/[H_2][T_2]$	0	2.42	2.56	2.97	3.24	3.44
$[DT]^2/[D_2][T_2]$	0	3.79	3.82	3.88	3.92	3.94

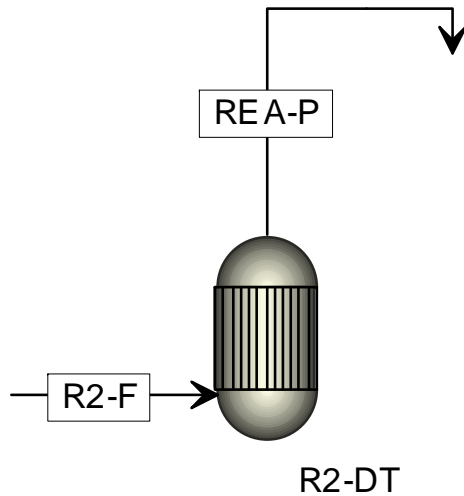
2. ITER ISS 평형 반응기

➤ Reactor 1:

$$K_2 = \frac{[DT]^2}{[D_2][T_2]} = 3.82$$

Reactions		
Rxn No.	Specification type	Stoichiometry
1	Temp. approach	T2 + D2 <-> 2DT

Calculated equilibrium constants		
Rxn No.	Equilibrium constant	Equilibrium temperature
1	3.8197968	298.15



Stream Number	R1-F		R1-P	
Stream Name	Feed		Product	
Temperature K	298.15		298.15	
Pressure atm	0.70		1.00	
Vapor Frac	1.00		1.00	
Mole Flow mol/min	1.17		1.17	
Mass Flow kg/hr	0.28		0.28	
	Flow rate (mol/min)	Percents (mol%)	Flow rate (mol/min)	Percents (mol%)
H ₂	0.00	0.00	0.00	0.00
HD	0.00	0.00	0.00	0.00
HT	0.01	0.85	0.01	0.85
D ₂	1.16	99.06	1.16	99.06
DT	0.00	0.09	0.00	0.09
T₂	<0.001	0.00	TRACE	0.00

T₂ Removal

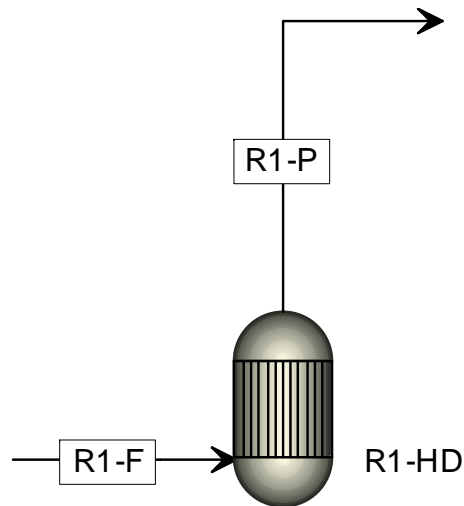
2. ITER ISS 평형 반응기

➤ Reactor 2:

Reactions		
Rxn No.	Specification type	Stoichiometry
1	Temp. approach	H2 + D2 <-> 2 HD

$$K_1 = \frac{[HD]^2}{[H_2][D_2]} = 3.26$$

Rxn No.	Equilibrium constant	Equilibrium temperature
▶	3.25771082	298.15 K



Stream Number	R1-F		R1-P	
Stream Name	Feed		Product	
Temperature K	298.00		298.15	
Pressure atm	0.90		1.00	
Vapor Frac	1.00		1.00	
Mole Flow kmol/hr	0.09		0.09	
Mass Flow kg/hr	0.34		0.34	
	Flow rate (kmol/hr)	Percents (mol%)	Flow rate (kmol/hr)	Percents (mol%)
H ₂	0.01	8.02	0.00	1.14
HD	0.00	3.34	0.02	17.09
HT	0.00	3.34	0.00	3.34
D ₂	0.08	85.23	0.07	78.35
DT	0.00	0.07	0.00	0.07
T ₂	0.00	0.00	0.00	0.00

PRO/II를 활용한 반응기 모델링

Reformer Modeling

➤ 개질 반응

- $r_1 : CH_4 + H_2O \rightarrow CO + 3H_2$: Reforming Reaction
- $r_2 : CO + H_2O \leftrightarrow CO_2 + H_2$: Shift Reaction

➤ Total Reaction: $r_{Total} : CH_4 + 2H_2O \leftrightarrow CO_2 + 4H_2$

➤ 반응기 형태

- Stoichiometric Reactor: 한계 반응물의 전환율을 지정
- Gibbs Reactor: 반응식을 알지 못하는 경우 Gibbs Free Energy Minimum 값으로부터 반응 평형을 계산
- Equilibrium Reactor: Gibbs Free Energy of Formation으로부터 반응 평형을 계산
- Kinetic Reactor: Kinetic Data(Pre-exponential Factor와 Activation Energy)를 활용하여 반응을 계산
 - ✓ Batch Reactor
 - ✓ PFR
 - ✓ CSTR

Material Balance for Reformer In & Out

ID	Stream Component	165		170	
		lbmol/hr	mole%	lbmol/hr	mole%
1	H2	1.36	7.26	11.11	45.97
2	CH4	5.83	31.13	3.11	12.87
3	CO	0.00	0.00	1.12	4.63
4	CO2	0.50	2.67	2.10	8.69
5	H2O	10.97	58.57	6.66	27.55
6	N2	0.07	0.37	0.07	0.29
7	O2	0.00	0.00	0.00	0.00
Total Flow		18.73	100.00	24.17	100.00
Temperature, F		1,129		1,060	
Pressure, psia		16.8		15.92	

Thermodynamic Model Selection: SRK

The screenshot displays the 'Properties - Data Browser' window. The left sidebar shows a tree view with 'Properties' expanded, containing sub-items like 'Specifications', 'Property Methods', 'Estimation', 'Molecular Structure', 'Parameters', 'Data', 'Analysis', 'Prop-Sets', 'Advanced', and 'CAPE-OPEN Packages'. Under 'Streams', items 5, 6, 165, 170, 171, and 172 are listed, with 'Input', 'Results', 'EO Variables', and 'Custom Stream Resu' checked.

The main panel is titled 'Global' and contains the following settings:

- Property methods & models:**
 - Process type: ALL
 - Base method: RK-SOAVE
 - Henry components: (empty)
- Petroleum calculation options:**
 - Free-water method: STEAM-TA
 - Water solubility: 3
- Electrolyte calculation options:**
 - Chemistry ID: (empty)
 - Use true-components
- Property method:** RK-SOAVE
- Modify property models:**
 - Modify property models
 - EDS: ESRKSTD
 - Data set: 1
 - Liquid gamma: (empty)
 - Data set: (empty)
 - Liquid enthalpy: HLMX107
 - Liquid volume: VLMX20
 - Heat of mixing
 - Poynting correction
 - Use liq. reference-state enthalpy

A note at the bottom states: 'All process types. Use the Property Method Selection Assistant for help.'

The status bar at the bottom left indicates 'Input Complete'.

Reformer: Reformer Temperature & Pressure

The screenshot displays the 'Block REFORMER (RStoic) - Data Browser' window. The left-hand tree view shows the hierarchy of the block, with 'REFORMER' expanded to show sub-items like 'Setup', 'Convergence', 'Dynamic', 'Block Options', 'Results', 'EO Variables', 'EO Input', 'Spec Groups', 'Ports', 'Stream Results', and 'Custom Stream Resu'. The right-hand pane is titled 'Specifications' and contains the following data:

Section	Parameter	Value	Units
Operating conditions	Pressure	15.92	psia
	Temperature	1060	F
Valid phases		Vapor-Liquid	

At the bottom of the window, a status bar indicates 'Results Available'.

Reactions: Reactions in Reformer

Block REFORMER (RStoic) - Data Browser

REFORMER ENG

Specifications Reactions Combustion Heat of Reaction Selectivity PSD Co

Rxn No.	Specification type	Stoichiometry
1	Frac. conversion	$\text{CH}_4 + \text{H}_2\text{O} \rightarrow 3 \text{H}_2 + \text{CO}$
2	Frac. conversion	$\text{CO} + \text{H}_2\text{O} \rightarrow \text{H}_2 + \text{CO}_2$

New... Edit Delete Copy Paste

Reactions occur in series

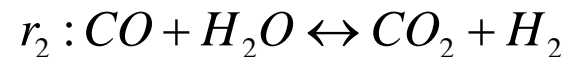
Results Available

Fractional Conversion: For CH₄ & CO

ID	Stream Component	165		170	
		lbmol/hr	mole%	lbmol/hr	mole%
1	H ₂	1.36	7.26	11.11	45.97
2	CH ₄	5.83	31.13	3.11	12.87
3	CO	0.00	0.00	1.12	4.63
4	CO ₂	0.50	2.67	2.10	8.69
5	H ₂ O	10.97	58.57	6.66	27.55
6	N ₂	0.07	0.37	0.07	0.29
7	O ₂	0.00	0.00	0.00	0.00
Total Flow		18.73	100.00	24.17	100.00
Temperature, F		1,129		1,060	
Pressure, psia		16.8		15.92	



$$CH_4 : \frac{5.83 - 3.11}{5.83} = 0.46655$$



$$CO : \frac{2.72 - 1.12}{2.72} = 0.58824$$

Fractional Conversion: For CH4 & CO

Edit Stoichiometry

Reaction No.: 1

Reactants

Component	Coefficient
CH4	-1
H2O	-1
*	

Products

Component	Coefficient
H2	3
CO	1
*	

Products generation

Molar extent: lbmol/hr

Fractional conversion: of component

Edit Stoichiometry

Reaction No.: 2

Reactants

Component	Coefficient
CO	-1
H2O	-1
*	

Products

Component	Coefficient
H2	1
CO2	1
*	

Products generation

Molar extent: lbmol/hr

Fractional conversion: of component

Reformer Result:

The screenshot shows the 'Block REFORMER (RStoic) - Data Browser' window. The left sidebar displays a tree view of the process components: Streams, Blocks (ANODE, B2, B4, CATHODE, REFORMER), and REFORMIN. The REFORMER block is expanded to show 'Results', 'EO Variables', 'Stream Results', and 'Custom Stream Results'. The main panel shows the 'Summary' tab with the following data:

Parameter	Value	Unit
Outlet temperature:	1060	F
Outlet pressure:	15.92	psia
Heat duty:	221165.215	Btu/hr
Net heat duty:	221165.215	Btu/hr
Vapor fraction:	1	
1st liquid / Total liquid:		

Results Available

Stream Reformer

The screenshot shows the 'Block REFORMER (RStoic) Stream Results - Data Browser' window. The left pane shows a tree view with 'Stream Results' selected. The main pane displays a table of material stream data. The table has columns for 'Mole Flow lbmol/hr' and 'Mole Frac'. The 'Mole Flow lbmol/hr' column is further divided into two sub-columns, with values 165 and 170. The 'Mole Frac' column is also divided into two sub-columns, with values 0.070 and 0.100. The table lists various chemical species: H2, CH4, CO, CO2, H2O, N2, O2, and H2.

	165	170	
Mole Flow lbmol/hr			
H2	1.360	11.120	
CH4	5.830	3.110	
CO		1.120	
CO2	0.500	2.100	
H2O	10.970	6.650	
N2	0.070	0.070	
O2			
Mole Frac			
H2	0.070	0.100	

Results Available

Stream Result: Comparison between Design & Aspen Plus

ID	Stream Component	165		170		<i>170</i>	
		lbmol/hr	mole%	lbmol/hr	mole%	<i>lbmol/hr</i>	<i>mole%</i>
1	H2	1.36	7.26	11.11	45.97	<i>11.12</i>	<i>46.01</i>
2	CH4	5.83	31.13	3.11	12.87	<i>3.11</i>	<i>12.87</i>
3	CO	0.00	0.00	1.12	4.63	<i>1.12</i>	<i>4.63</i>
4	CO2	0.50	2.67	2.10	8.69	<i>2.10</i>	<i>8.69</i>
5	H2O	10.97	58.57	6.66	27.55	<i>6.65</i>	<i>27.51</i>
6	N2	0.07	0.37	0.07	0.29	<i>0.07</i>	<i>0.29</i>
7	O2	0.00	0.00	0.00	0.00	<i>0.00</i>	<i>0.00</i>
Total Flow		18.73	100.00	24.17	100.00	<i>24.17</i>	<i>100.00</i>
Temperature, F		1,129		1,060		<i>1,060</i>	
Pressure, psia		16.8		15.92		<i>15.92</i>	

Cathode Modeling:

Stream	Reformer Out		Leak		To Anode		Reforming In		Cathode In		Cathode Out	
Stream Name	170		171		172		173		250		255	
Component	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%
H2	11.11	45.97	5.5161E-02	45.97	0.00	0.00	11.05	45.97	0.00	0.00	0.06	0.04
CH4	3.11	12.87	1.5441E-02	12.87	0.00	0.00	3.09	12.87	0.00	0.00	0.02	0.01
CO	1.12	4.63	5.5608E-03	4.63	0.00	0.00	1.11	4.63	0.00	0.00	0.01	0.01
CO2	2.10	8.69	1.0427E-02	8.69	17.50	66.67	2.09	8.69	24.03	14.08	6.54	4.52
H2O	6.66	27.55	3.3067E-02	27.55	0.00	0.00	6.63	27.55	25.99	15.23	26.03	18.00
N2	0.07	0.29	3.4755E-04	0.29	0.00	0.00	0.07	0.29	98.54	57.73	98.55	68.15
O2	0.00	0.00	0.0000E+00	0.00	8.75	33.33	0.00	0.00	22.14	12.97	13.39	9.26
Total Flow, lbmol/hr	24.17	100.00	0.12	100.00	26.25	100.00	24.05	100.00	170.70	100.00	144.60	100.00
Total Flow, lb/hr	317.9		1.6						4,995.1		3,946.1	
Temperature, F	1,129		1,129		1,129		1,129		1,042		1,140	
Pressure, psia	16.80		16.80		16.80		16.80		15.73		15.67	

Stream Result:

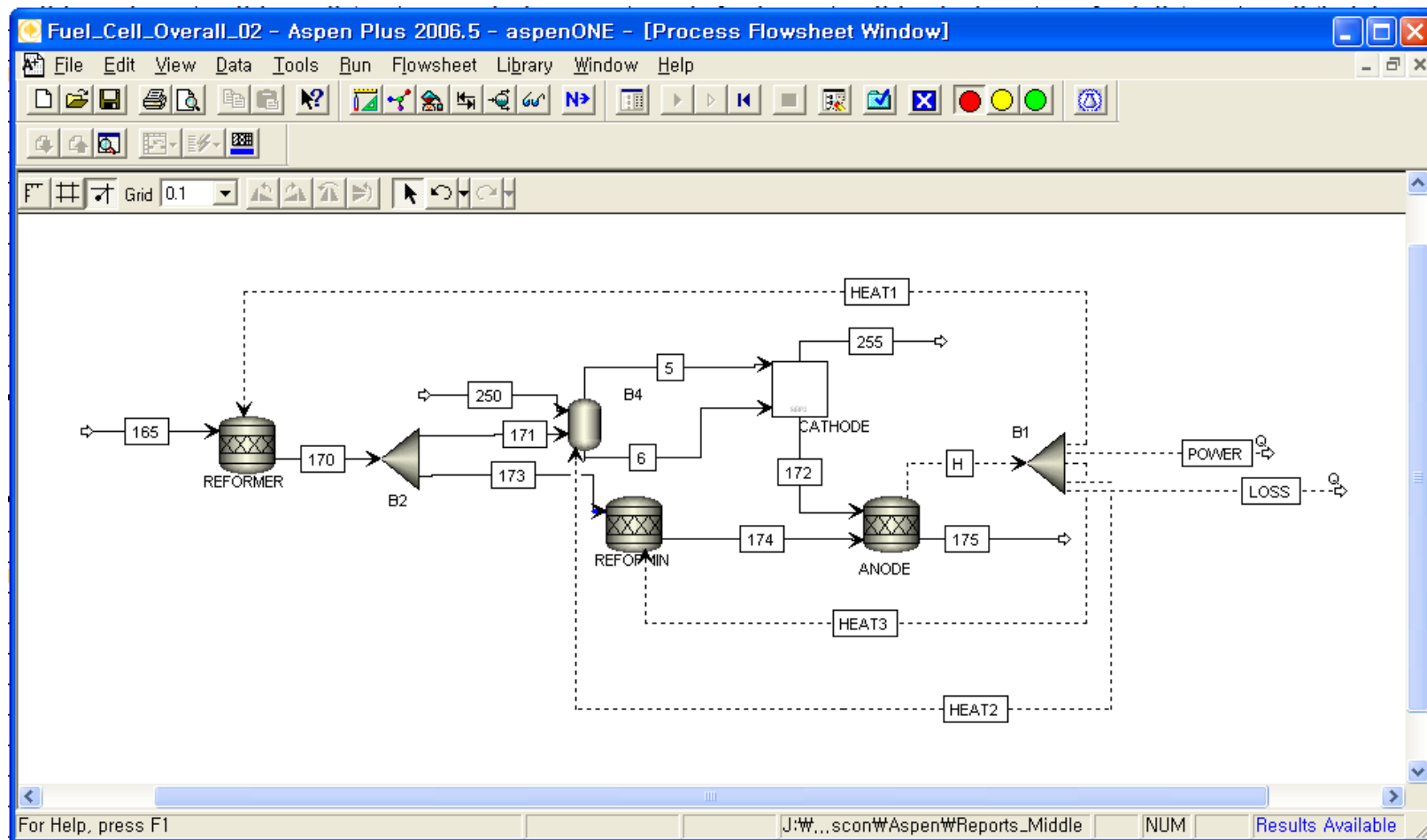
Design Case

Stream	Reformer In		Reformer Out		Leak		To Anode		Reforming In		Anode Out		Cathode In		Cathode Out	
Stream Name	165		170		171		172		173		175		250		255	
Component	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%
H2	1.36	7.26	11.11	45.97	5.5161E-02	45.97	0.00	0.00	11.05	45.97	4.53	9.49	0.00	0.00	0.06	0.04
CH4	5.83	31.13	3.11	12.87	1.5441E-02	12.87	0.00	0.00	3.09	12.87	0.02	0.04	0.00	0.00	0.02	0.01
CO	0.00	0.00	1.12	4.63	5.5608E-03	4.63	0.00	0.00	1.11	4.63	2.45	5.13	0.00	0.00	0.01	0.01
CO2	0.50	2.67	2.10	8.69	1.0427E-02	8.69	17.50	66.67	2.09	8.69	21.35	44.74	24.03	14.08	6.54	4.52
H2O	10.97	58.57	6.66	27.55	3.3067E-02	27.55	0.00	0.00	6.63	27.55	19.30	40.44	25.99	15.23	26.03	18.00
N2	0.07	0.37	0.07	0.29	3.4755E-04	0.29	0.00	0.00	0.07	0.29	0.07	0.15	98.54	57.73	98.55	68.15
O2	0.00	0.00	0.00	0.00	0.0000E+00	0.00	8.75	33.33	0.00	0.00	0.00	0.00	22.14	12.97	13.39	9.26
Total Flow, lbmol/hr	18.73	100.00	24.17	100.00	0.12	100.00	26.25	100.00	24.05	100.00	47.72	100.00	170.70	100.00	144.60	100.00
Temperature, F	1,129		1,060		1,060		1,140		1,060		1,139		1,042		1,140	
Pressure, psia	16.80		15.92		15.92		15.67		15.92		15.84		15.73		15.67	

Aspen Modeling

Stream	Reformer In		Reformer Out		Leak		To Anode		Reforming In		Anode Out		Cathode In		Cathode Out	
Stream Name	165		170		171		172		173		175		250		255	
Component	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%
H2	1.36	7.26	11.12	46.01	5.5211E-02	46.01	0.00	0.00	11.07	46.02	4.53	9.37	0.00	0.00	0.06	0.04
CH4	5.83	31.13	3.11	12.87	1.5441E-02	12.87	0.00	0.00	3.10	12.87	0.02	0.04	0.00	0.00	0.02	0.01
CO	0.00	0.00	1.12	4.63	5.5608E-03	4.63	0.00	0.00	1.11	4.63	3.73	7.71	0.00	0.00	0.01	0.00
CO2	0.50	2.67	2.10	8.69	1.0427E-02	8.69	17.50	66.67	2.09	8.69	20.05	41.48	24.03	14.08	6.54	4.52
H2O	10.97	58.57	6.65	27.51	3.3017E-02	27.51	0.00	0.00	6.62	27.51	19.30	39.93	25.99	15.23	26.02	18.00
N2	0.07	0.37	0.07	0.29	3.4755E-04	0.29	0.00	0.00	0.07	0.29	0.07	0.14	98.54	57.73	98.54	68.15
O2	0.00	0.00	0.00	0.00	0.0000E+00	0.00	8.75	33.33	0.00	0.00	0.64	1.32	22.14	12.97	13.39	9.26
Total Flow, lbmol/hr	18.73	100.00	24.17	100.00	0.12	100.00	26.25	100.00	24.06	100.00	48.34	100.00	170.70	100.00	144.57	99.98
Temperature, F	1,129		1,060		1,060		1,140		1,060		1,139		1,042		1,140	
Pressure, psia	16.80		15.92		15.92		15.67		15.92		15.84		15.73		15.67	

Stack & Reformer Modeling: Adding Heat Balance



Stack & Reformer Modeling: Adding Heat Balance

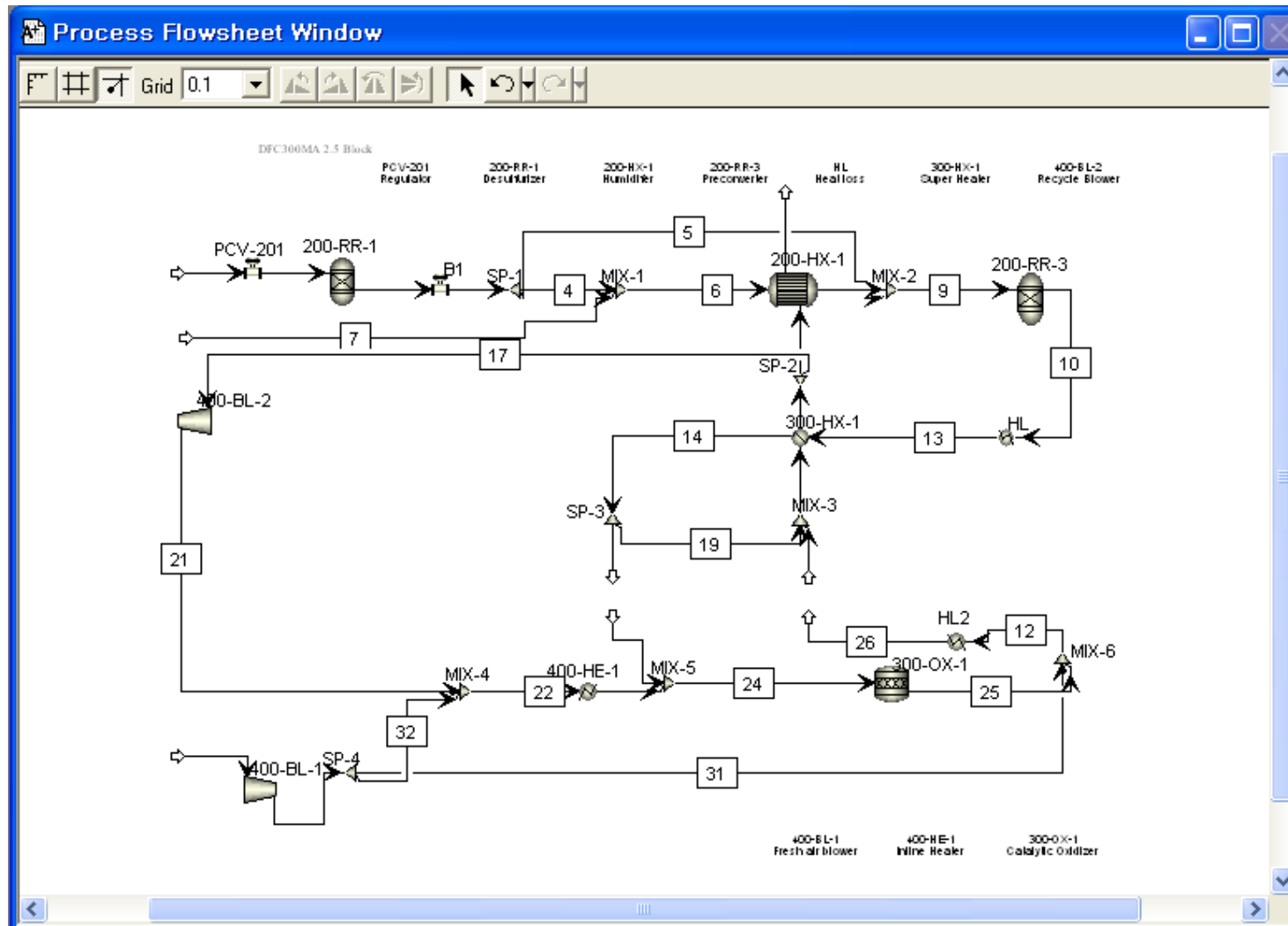
Design Case

Stream	Reformer In		Reformer Out		Leak		To Anode		Reforming In		Anode Out		Cathode In		Cathode Out	
Stream Name	165		170		171		172		173		175		250		255	
Component	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%
H2	1.36	7.26	11.11	45.97	5.5161E-02	45.97	0.00	0.00	11.05	45.97	4.53	9.49	0.00	0.00	0.06	0.04
CH4	5.83	31.13	3.11	12.87	1.5441E-02	12.87	0.00	0.00	3.09	12.87	0.02	0.04	0.00	0.00	0.02	0.01
CO	0.00	0.00	1.12	4.63	5.5608E-03	4.63	0.00	0.00	1.11	4.63	2.45	5.13	0.00	0.00	0.01	0.01
CO2	0.50	2.67	2.10	8.69	1.0427E-02	8.69	17.50	66.67	2.09	8.69	21.35	44.74	24.03	14.08	6.54	4.52
H2O	10.97	58.57	6.66	27.55	3.3067E-02	27.55	0.00	0.00	6.63	27.55	19.30	40.44	25.99	15.23	26.03	18.00
N2	0.07	0.37	0.07	0.29	3.4755E-04	0.29	0.00	0.00	0.07	0.29	0.07	0.15	98.54	57.73	98.55	68.15
O2	0.00	0.00	0.00	0.00	0.0000E+00	0.00	8.75	33.33	0.00	0.00	0.00	0.00	22.14	12.97	13.39	9.26
Total Flow, lbmol/hr	18.73	100.00	24.17	100.00	0.12	100.00	26.25	100.00	24.05	100.00	47.72	100.00	170.70	100.00	144.60	100.00
Temperature, F	1,129		1,060		1,060		1,140		1,060		1,139		1,042		1,140	
Pressure, psia	16.80		15.92		15.92		15.67		15.92		15.84		15.73		15.67	

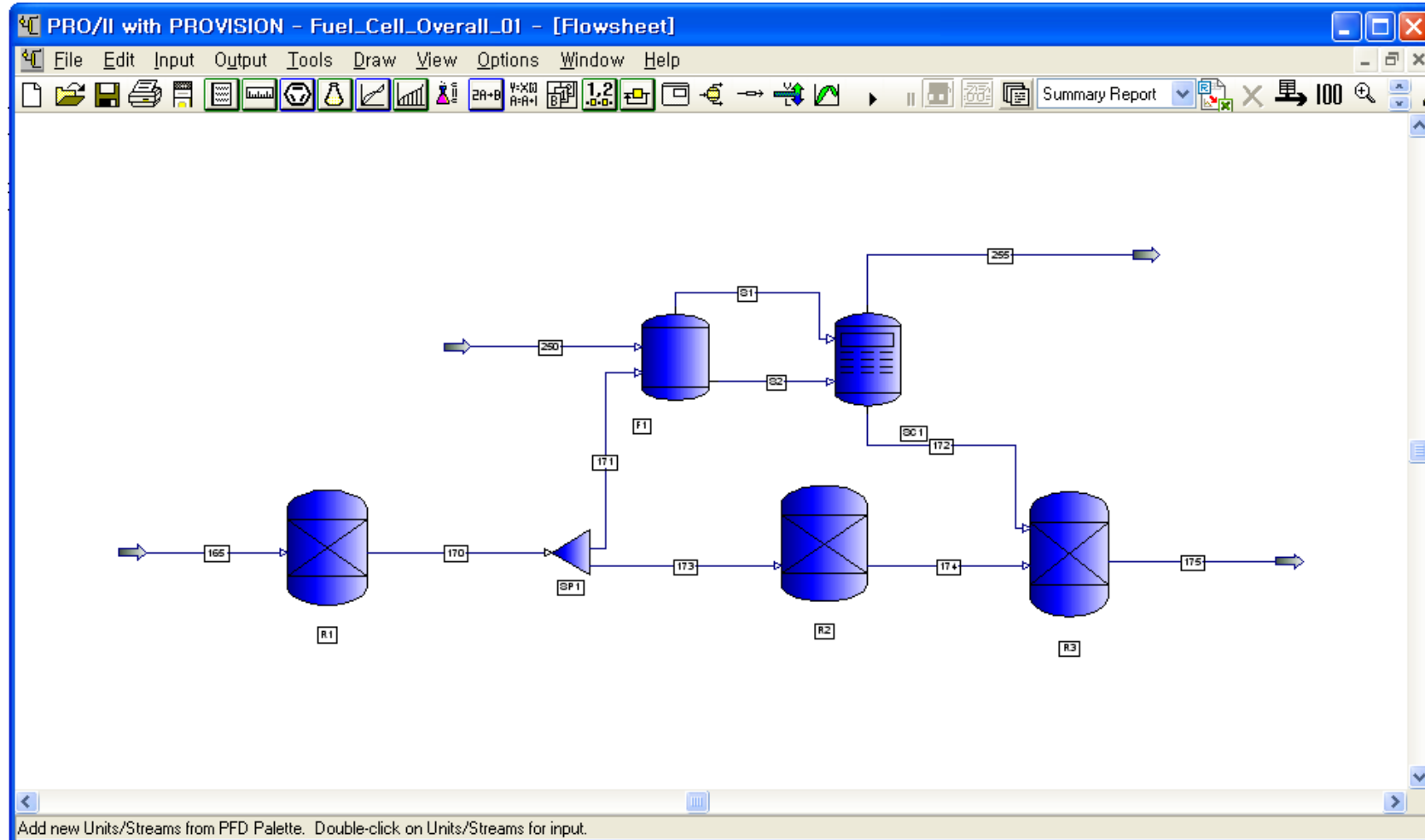
Aspen Modeling

Stream	Reformer In		Reformer Out		Leak		To Anode		Reforming In		Anode Out		Cathode In		Cathode Out	
Stream Name	165		170		171		172		173		175		250		255	
Component	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%
H2	1.36	7.26	11.12	46.01	5.5211E-02	46.01	0.00	0.00	11.07	46.02	4.53	9.37	0.00	0.00	0.06	0.04
CH4	5.83	31.13	3.11	12.87	1.5441E-02	12.87	0.00	0.00	3.10	12.87	0.02	0.04	0.00	0.00	0.02	0.01
CO	0.00	0.00	1.12	4.63	5.5608E-03	4.63	0.00	0.00	1.11	4.63	3.73	7.71	0.00	0.00	0.01	0.00
CO2	0.50	2.67	2.10	8.69	1.0427E-02	8.69	17.50	66.67	2.09	8.69	20.05	41.48	24.03	14.08	6.54	4.52
H2O	10.97	58.57	6.65	27.51	3.3017E-02	27.51	0.00	0.00	6.62	27.51	19.30	39.93	25.99	15.23	26.02	18.00
N2	0.07	0.37	0.07	0.29	3.4755E-04	0.29	0.00	0.00	0.07	0.29	0.07	0.14	98.54	57.73	98.54	68.15
O2	0.00	0.00	0.00	0.00	0.0000E+00	0.00	8.75	33.33	0.00	0.00	0.64	1.32	22.14	12.97	13.39	9.26
Total Flow, lbmol/hr	18.73	100.00	24.17	100.00	0.12	100.00	26.25	100.00	24.06	100.00	48.34	100.00	170.70	100.00	144.57	99.98
Temperature, F	1,129		1,060		1,060		1,140		1,060		1,139		1,042		1,140	
Pressure, psia	16.80		15.92		15.92		15.67		15.92		15.84		15.73		15.67	

Stack & Reformer 부분과의 연결:



Stack & Reformer 부분과의 연결: PRO/II with PROVISION



Stack & Reformer Modeling: PRO/II with PROVISION

Design Case

Stream	Reformer In		Reformer Out		Leak		To Anode		Reforming In		Anode Out		Cathode In		Cathode Out	
Stream Name	165		170		171		172		173		175		250		255	
Component	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%
H2	1.36	7.26	11.11	45.97	5.5161E-02	45.97	0.00	0.00	11.05	45.97	4.53	9.49	0.00	0.00	0.06	0.04
CH4	5.83	31.13	3.11	12.87	1.5441E-02	12.87	0.00	0.00	3.09	12.87	0.02	0.04	0.00	0.00	0.02	0.01
CO	0.00	0.00	1.12	4.63	5.5608E-03	4.63	0.00	0.00	1.11	4.63	2.45	5.13	0.00	0.00	0.01	0.01
CO2	0.50	2.67	2.10	8.69	1.0427E-02	8.69	17.50	66.67	2.09	8.69	21.35	44.74	24.03	14.08	6.54	4.52
H2O	10.97	58.57	6.66	27.55	3.3067E-02	27.55	0.00	0.00	6.63	27.55	19.30	40.44	25.99	15.23	26.03	18.00
N2	0.07	0.37	0.07	0.29	3.4755E-04	0.29	0.00	0.00	0.07	0.29	0.07	0.15	98.54	57.73	98.55	68.15
O2	0.00	0.00	0.00	0.00	0.0000E+00	0.00	8.75	33.33	0.00	0.00	0.00	0.00	22.14	12.97	13.39	9.26
Total Flow, lbmol/hr	18.73	100.00	24.17	100.00	0.12	100.00	26.25	100.00	24.05	100.00	47.72	100.00	170.70	100.00	144.60	100.00
Temperature, F	1,129		1,060		1,060		1,140		1,060		1,139		1,042		1,140	
Pressure, psia	16.80		15.92		15.92		15.67		15.92		15.84		15.73		15.67	

PRO/II Modeling

Stream	Reformer In		Reformer Out		Leak		To Anode		Reforming In		Anode Out		Cathode In		Cathode Out	
Stream Name	165		170		171		172		173		175		250		255	
Component	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%	lbmol/hr	mole%
H2	1.36	7.26	11.12	46.01	5.5211E-02	46.01	0.00	0.00	11.07	46.03	4.53	9.50	0.00	0.00	0.06	0.04
CH4	5.83	31.13	3.11	12.87	1.5441E-02	12.87	0.00	0.00	3.09	12.85	0.02	0.04	0.00	0.00	0.02	0.01
CO	0.00	0.00	1.12	4.63	5.5608E-03	4.63	0.00	0.00	1.11	4.63	2.45	5.14	0.00	0.00	0.01	0.00
CO2	0.50	2.67	2.10	8.69	1.0427E-02	8.69	17.50	66.67	2.09	8.69	21.33	44.71	24.03	14.08	6.54	4.52
H2O	10.97	58.57	6.65	27.51	3.3017E-02	27.51	0.00	0.00	6.62	27.51	19.30	40.46	25.99	15.23	26.02	18.00
N2	0.07	0.37	0.07	0.29	3.4755E-04	0.29	0.00	0.00	0.07	0.29	0.07	0.15	98.54	57.73	98.54	68.15
O2	0.00	0.00	0.00	0.00	0.0000E+00	0.00	8.75	33.33	0.00	0.00	0.00	0.00	22.14	12.97	13.39	9.26
Total Flow, lbmol/hr	18.73	100.00	24.17	100.00	0.12	100.00	26.25	100.00	24.05	100.00	47.70	100.00	170.70	100.00	144.57	99.98
Temperature, F	1,129		1,060		1,060		1,140		1,060		1,139		1,042		1,140	
Pressure, psia	16.80		15.92		15.92		15.67		15.92		15.84		15.73		15.67	

감사합니다