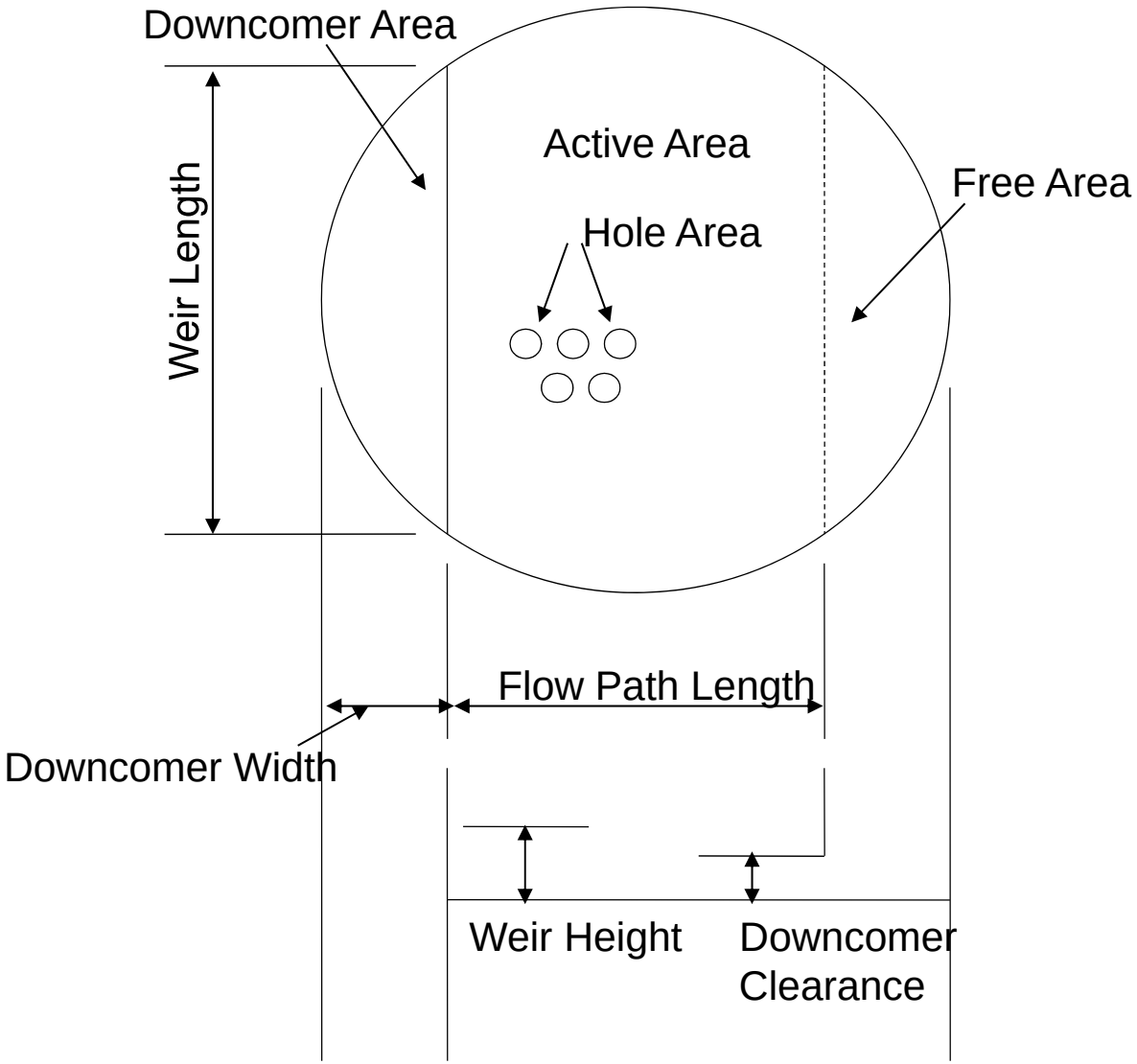
Tray Sizing & Rating

2001년 10월 9일 (화)
동양대학교 화학공학과
조 정 호

Tray

- Mass Transfer Operation에 최초로 이용된 Fractionation Equipment
- 1813년에 프랑스의 Cellier-Blumenthal에 의해 최초로
  제작
- Distillation, Absorption, Extraction에 이용
- 1950년대 이전: Sieve, Bubble-cap Tray 사용
- 현재: Valve Tray를 많이 사용
- 그 밖의 Special Tray Type

Tray Components



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Tray Components – Tray Deck (Tray Floor)

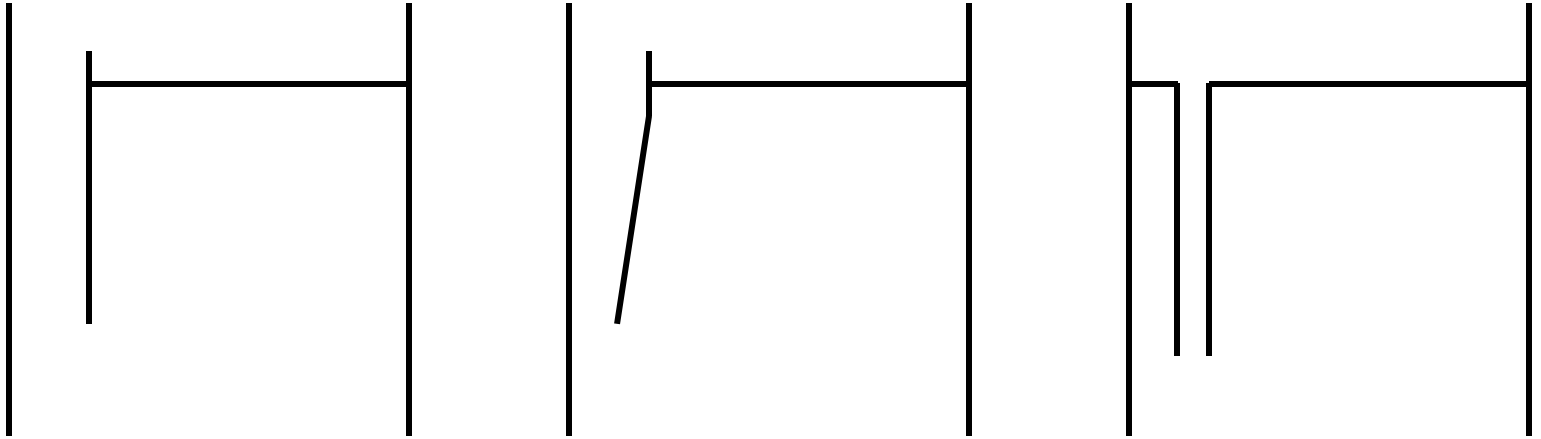
- Tray Deck : Active Area + Downcomer Inlet Area

- Active Area:
  - Vapor와 Liquid가 Cross Flow로 서로 접촉하여 Mass Transfer가 일어나는 부분

- Downcomer Inlet Area:
  - 윗 단의 Liquid가 내려오는 통로

Tray Components – Downcomer

Downcomer는 Tray Deck를 통과한 Liquid를 아랫단의 Tray Deck로 보내기 위한 통로로서, 다음 그림과 같이 여러 형태로 분류된다.



(a)
Straight downcomer

(b)
Slopped downcomer

(c)
Pipe downcomer

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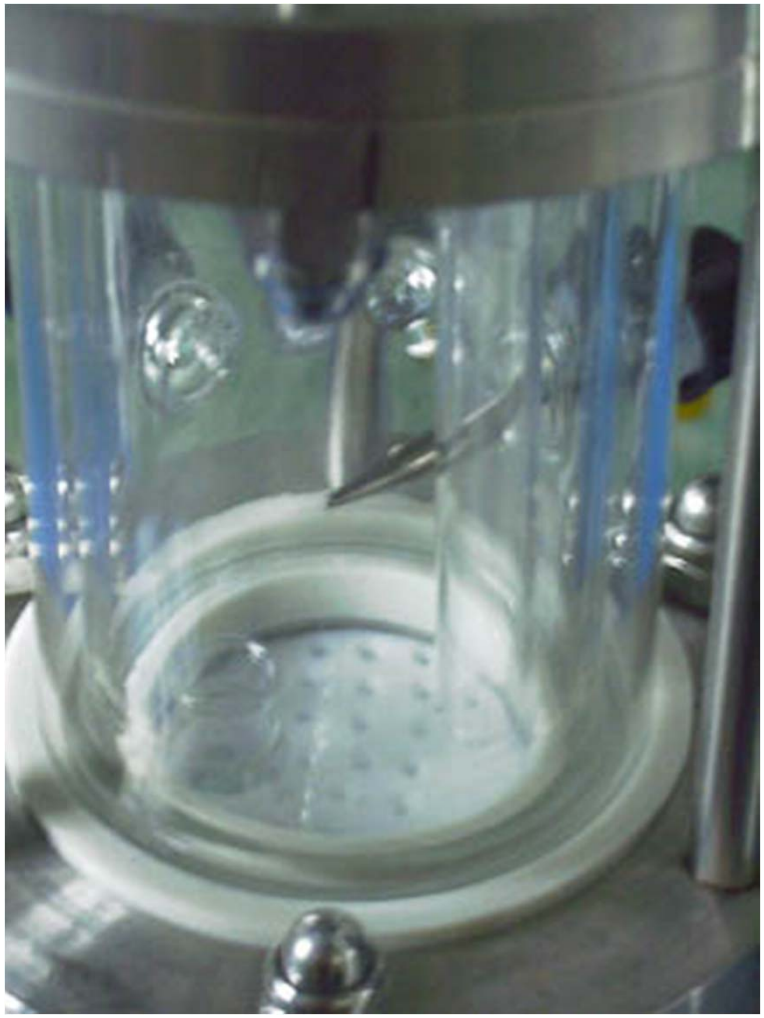
Pipe Downcomer의 예



Tray Components *- Continued*

- Outlet Weir

  Outlet Weir는 Tray Deck에서 Dwoncomer로 떨어지는 Liquid를 정체 시켜서 접촉시간을 늘리기 위한 역할을 하는 것으로 Tray의 Pressure Drop에 가장 큰 영향을 미친다.

- Inlet Weir

  Inlet Weir는 Downcomer 로부터 Tray Deck의 Active Area로 유입되는 와류 상태의 Liquid를 Steady하게 바꾸고자 할 때와 Vapor의 양이 많고 Liquid의 양이 적을 때 Sealing을 위하여 사용한다.

- Recessed Sump

  Tray Deck의 Inlet Area를 Tray Deck보다 낮게 하는 것으로 Column Dia.가 고정되어 있고 Downcomer Flood가 너무 클 경우 사용되며, Inlet Weir와 같은 용도로 사용되기도 한다.

Tray Components *- Continued*

- Tray Spacing

Tray Spacing은 Tray Deck와 Deck 사이의 간격으로 Maintenance를 고려하여 300 mm에서 900 mm로 정한다.

Column Diameter	Tray Spacing
– 1,200 mm	– 450 mm
1,200 – 7,200 mm	600 mm – 900 mm

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Tray Layout

- Active Area:

  Active Area는 Tray 한단의 전체 면적에서 Outlet, Inlet Downcomer Area를 뺀 면적으로 실질적인 기-액 접촉이 일어나는 Area이다.

- Downcomer Area:

  Downcomer Area 는 Tray에서 Liquid가 내려가는 부분의 Area로, Multi-pass Tray 에서는 전제 Downcomer Area를 더한 Area이다.

- Hole Area:

  Hole Area는 Active Area에 있는 Hole의 전체 면적으로 Tray의 종류에 관계 없이 전체 Hole Area를 말한다.

- Flow Path Length:

  Flow Path Length는 Tray Deck에서 Liquid가 흐르는 거리이다. Multi-path일 때는 전체 Flow Path Length를 더한 값이다.

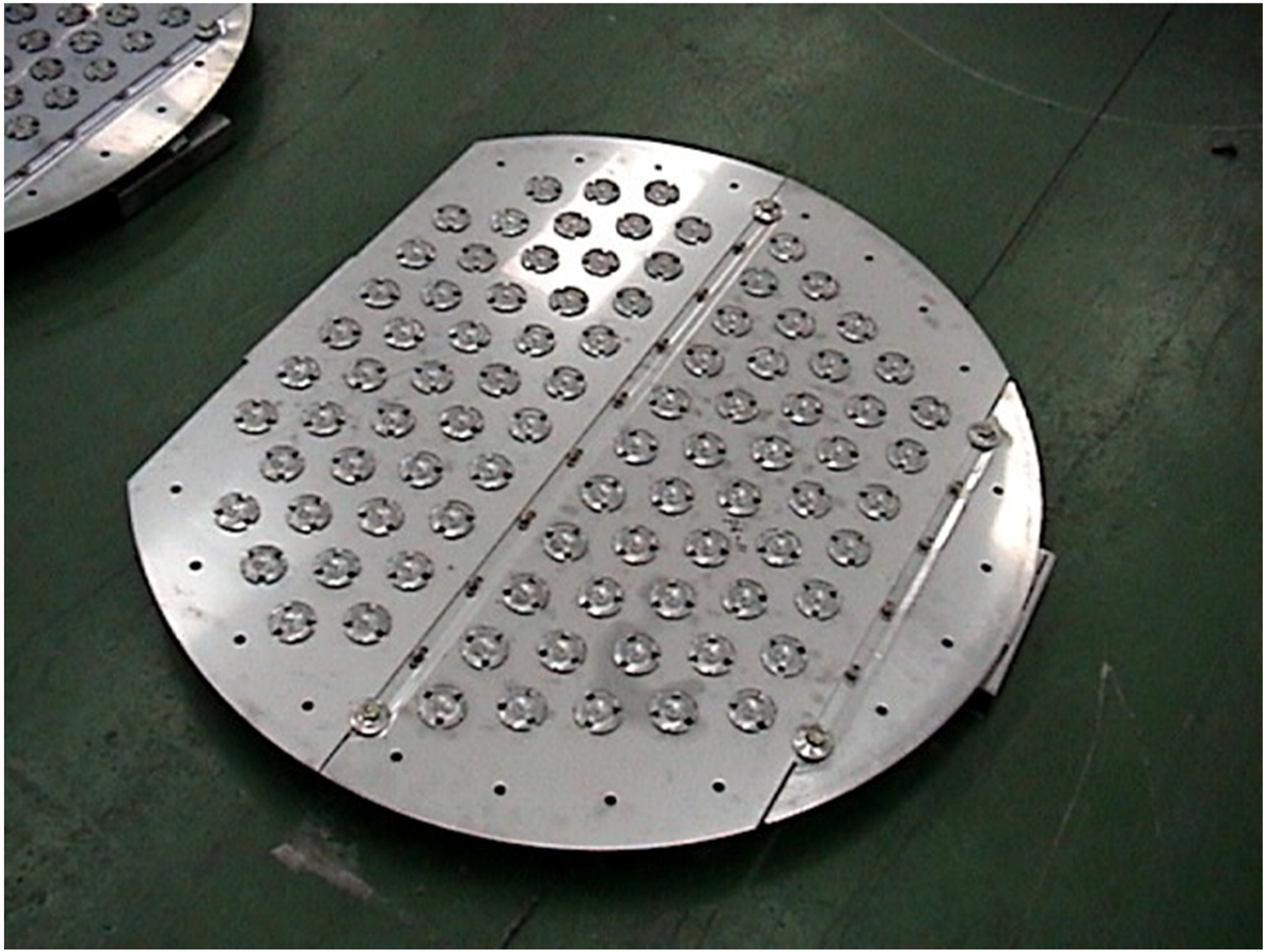
Tray Layout - *Continued*

- Downcomer Width:
  Downcomer Width는 Tower Wall 에서 Downcomer 까지의 길이이다.

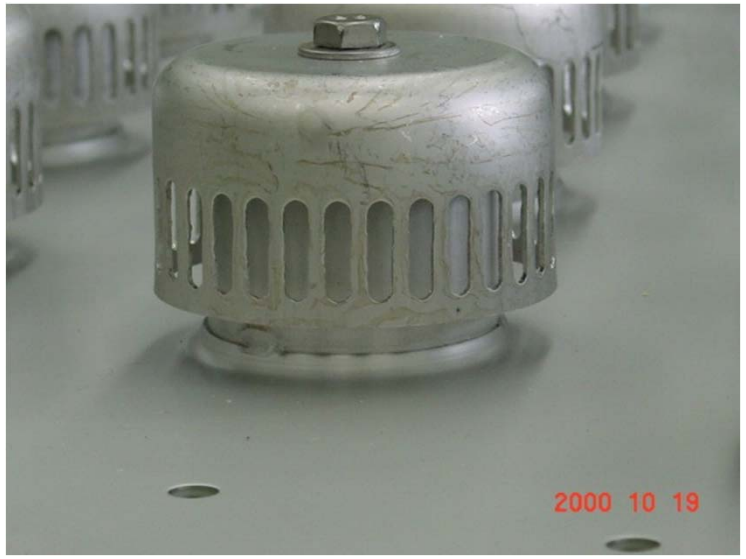
- Downcomer Clearance:
  Downcomer 와 Tray Deck 사이의 간격으로 Weir Height보다 항상 작다. Dwoncomer Flood가 크고, Liquid Flow를 조정하기 위하여 Downcomer Clearance는 Zero로 하고 Recessed Sump를 설치하는 경우도 있다.

Tray 종류 (1) – *Sieve Tray*

Tray 종류 (2) – *Valve Tray*



Tray 종류 (3) – *Bubble Cap Tray*



Tray 종류 (4) – *Dual Flow Tray*

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Process Requirements for Tray Design

항목	Description
Flow rate	Feed나 Product를 기준으로 해서 증류탑을 몇 개의 Group으로 나누어 그 Group에서는 유량이 일정하다고 가정하고 Tray를 계산한다.
Density	Vapor와 Liquid의 Density를 필요로 한다.
Viscosity/Surface Tension	이 물성치는 Liquid Phase 만의 물성치를 필요로 한다.
Foaming Factor	Foaming on trays is taken into account by using a so-called “system factor”.

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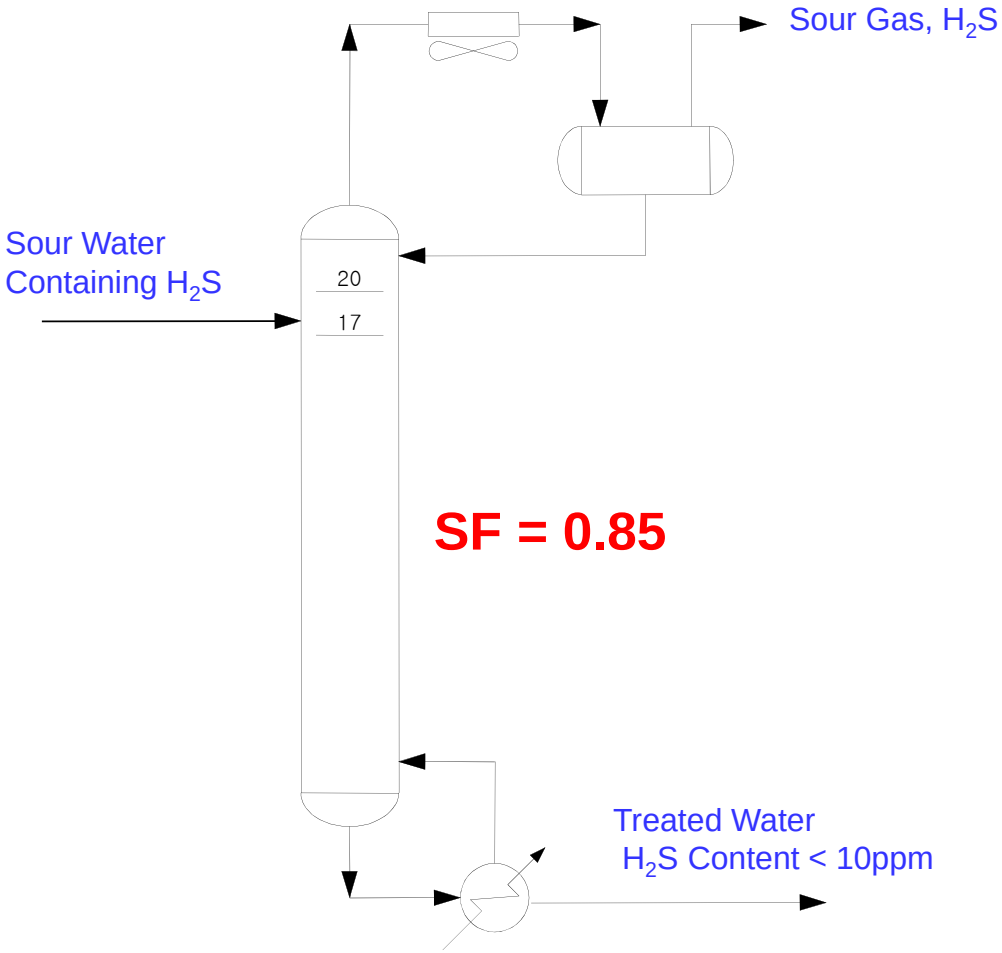
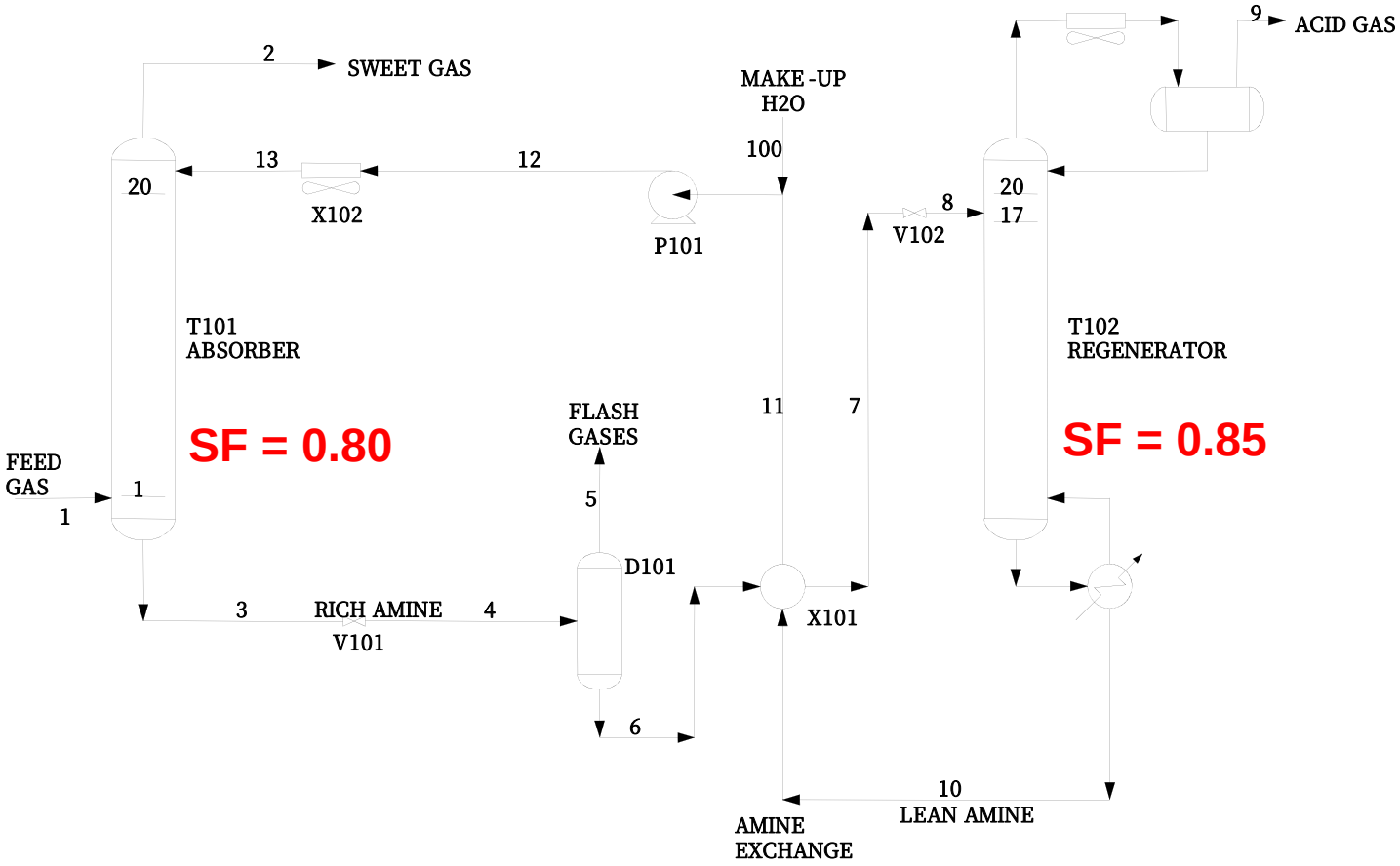
System Factors for Foaming Applications

System	Factor
Sour Water Stripper	0.85
Amine Contactor	0.80
CO_2 Absorber	0.80
CO_2 Regenerator	0.85
Vacuum Towers	0.85
Glycol Contactors	0.50

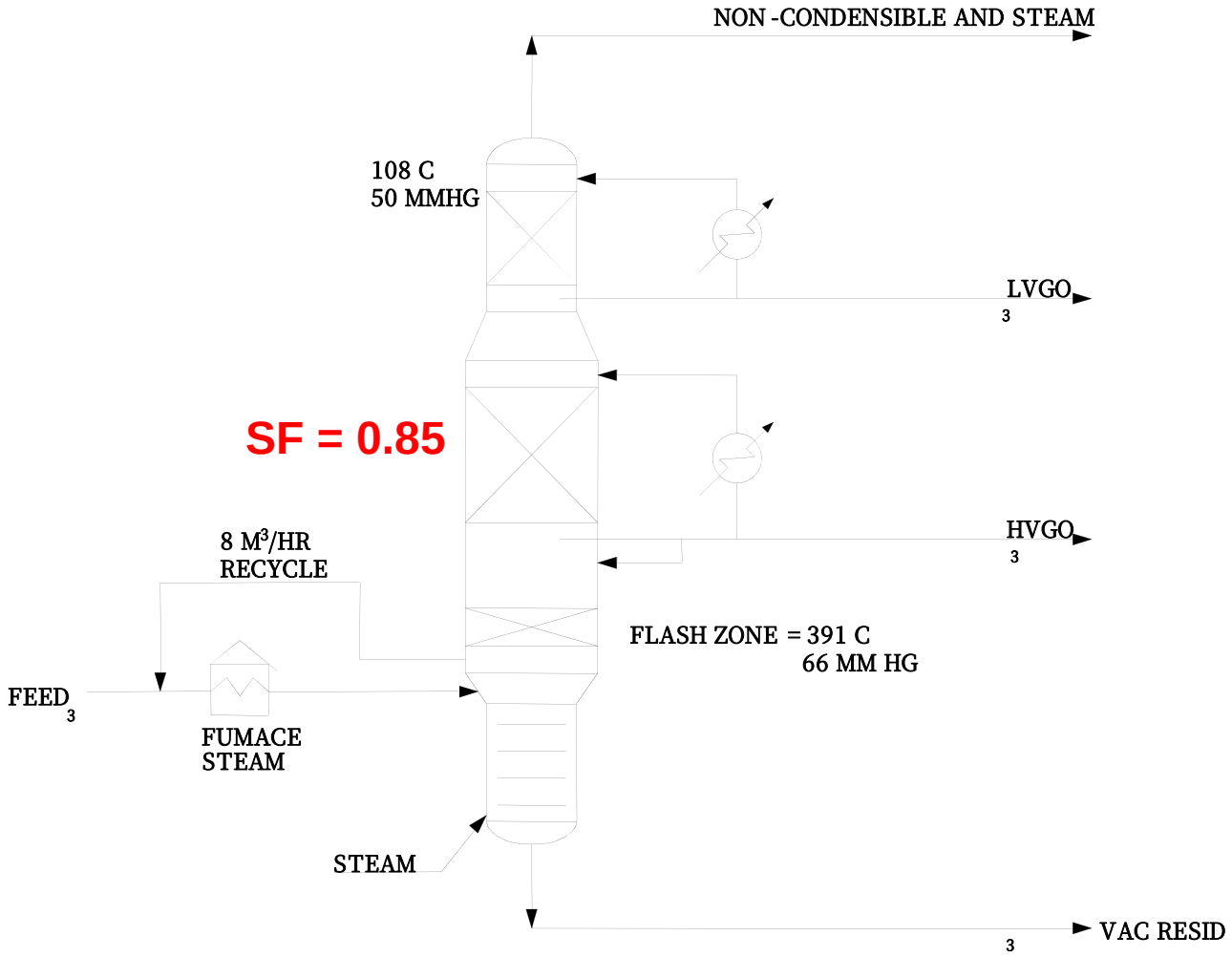
System Factor for Sour Water Stripper



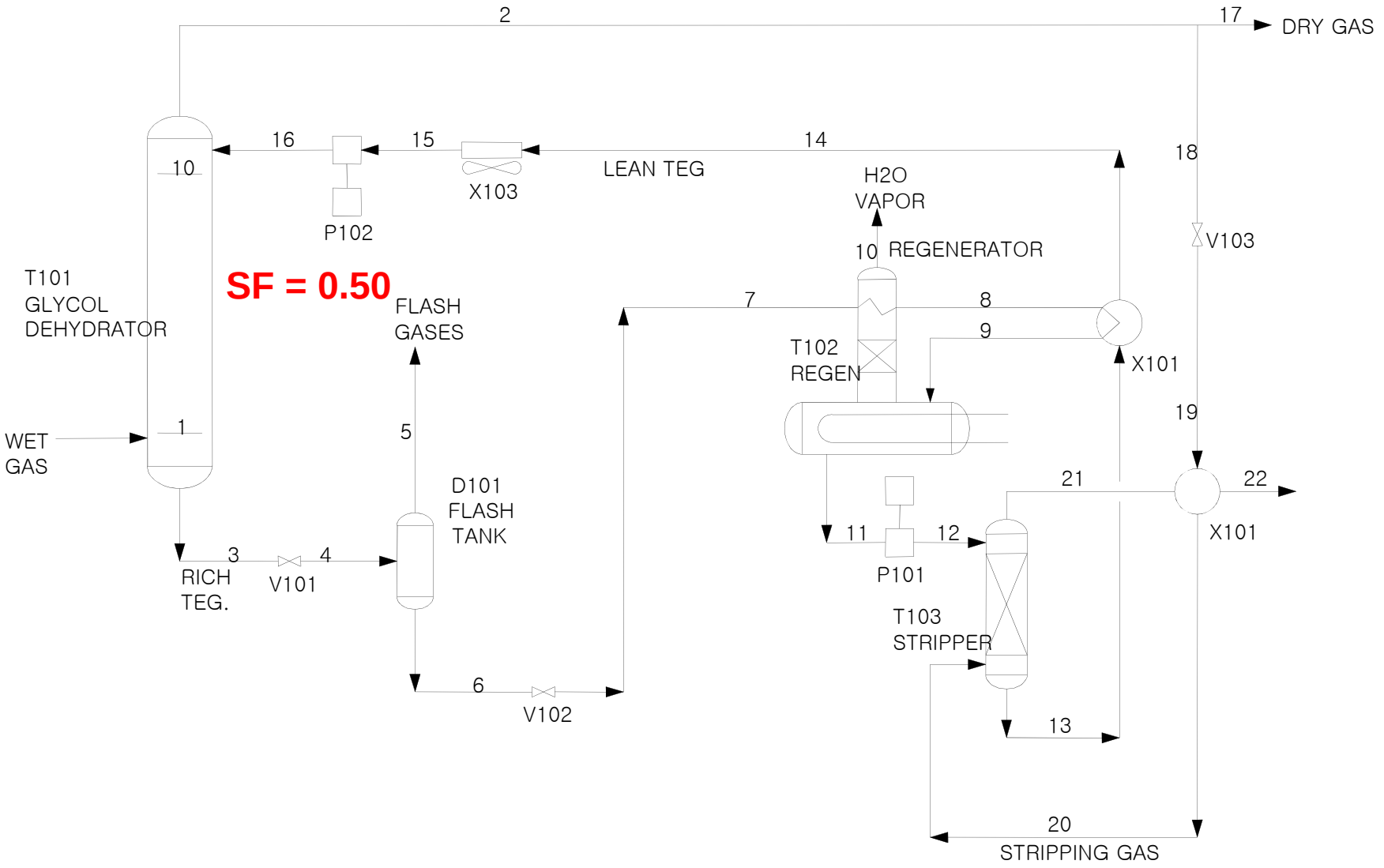
System Factors
for CO_2 Absorber and Regenerator



System Factor for Vacuum Tower



System Factor for Glycol Dehydrator

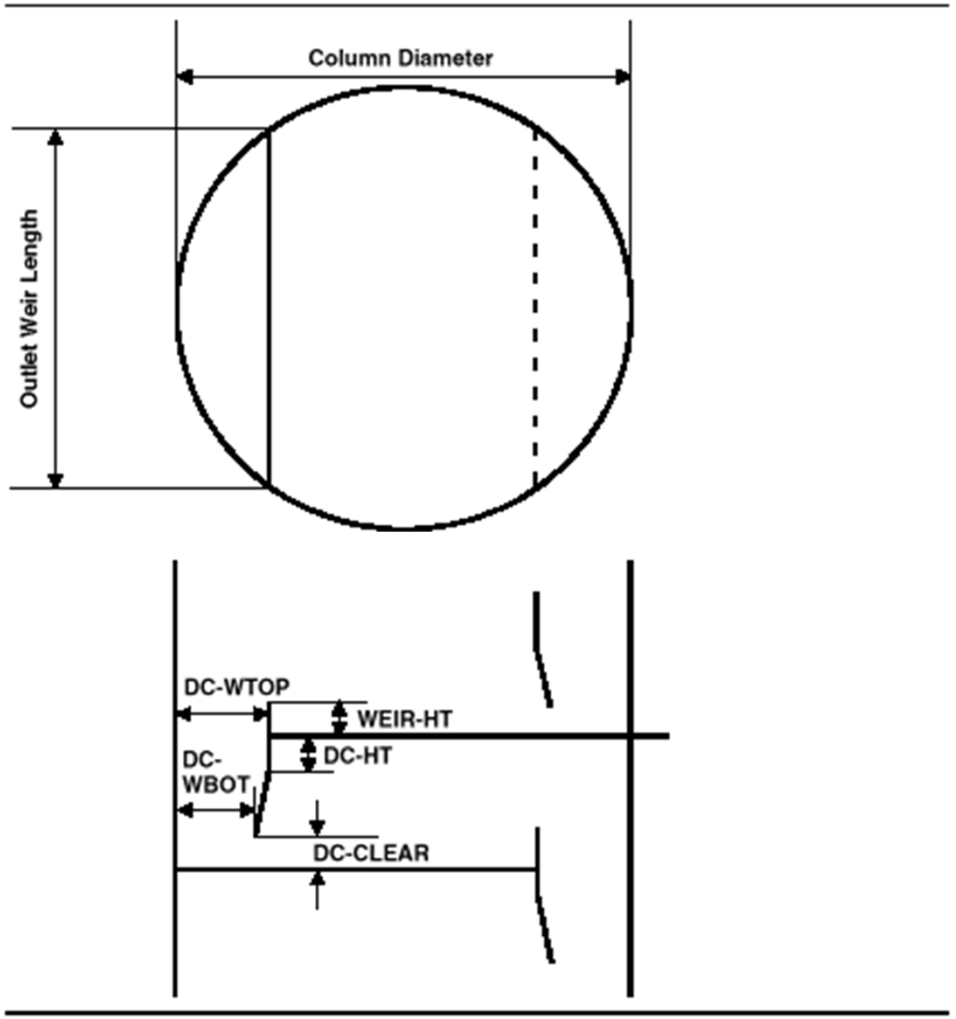


Tray Number of Passes

Column 의 Diameter 가 클 경우에 1 Pass로 설계하게 되면, Active Area에 Dead Zone이 생기며, Outlet Weir를 통과하는 Liquid의 양이 커서 Tray의 Performance가 낮아지므로 아래와 같이 Multi Pass Tray로 설계한다.

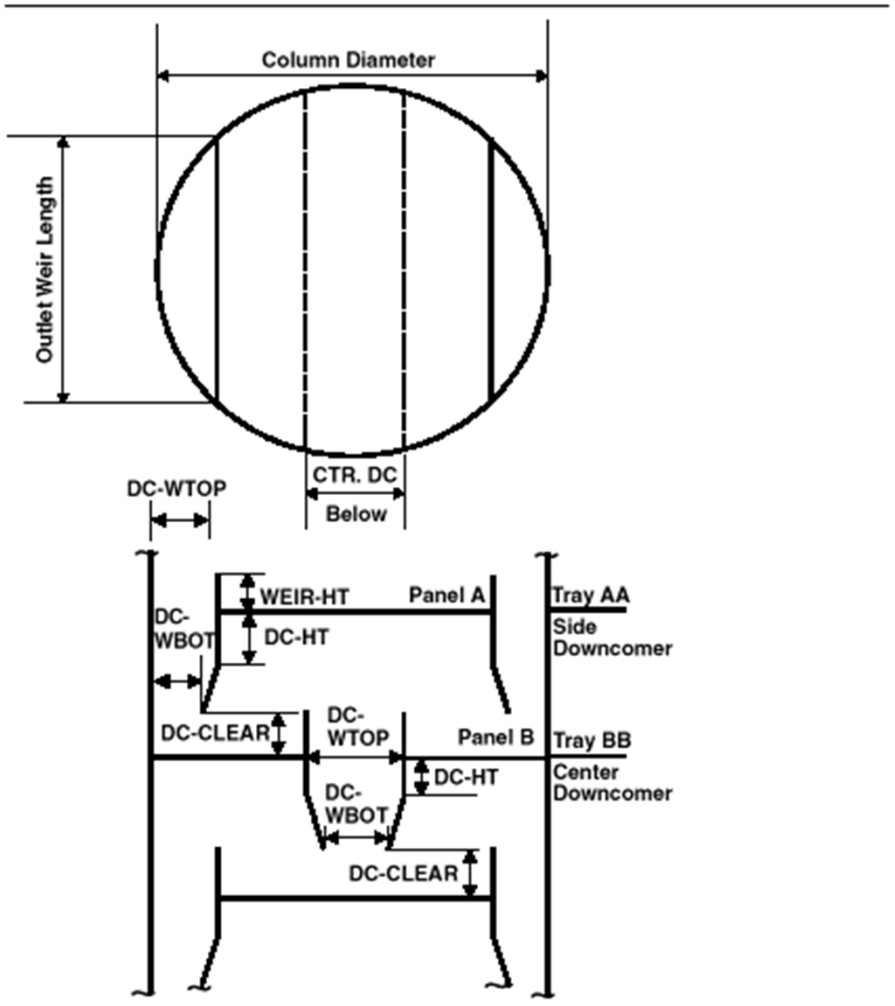
Column Diameter	Number of Passes
– 1,500 mm	1
1,500 mm – 2,400 mm	2
2,400 mm – 3,000 mm	3
3,000 mm – 4,000 mm	4
4,000 mm –	5

One Pass Tray



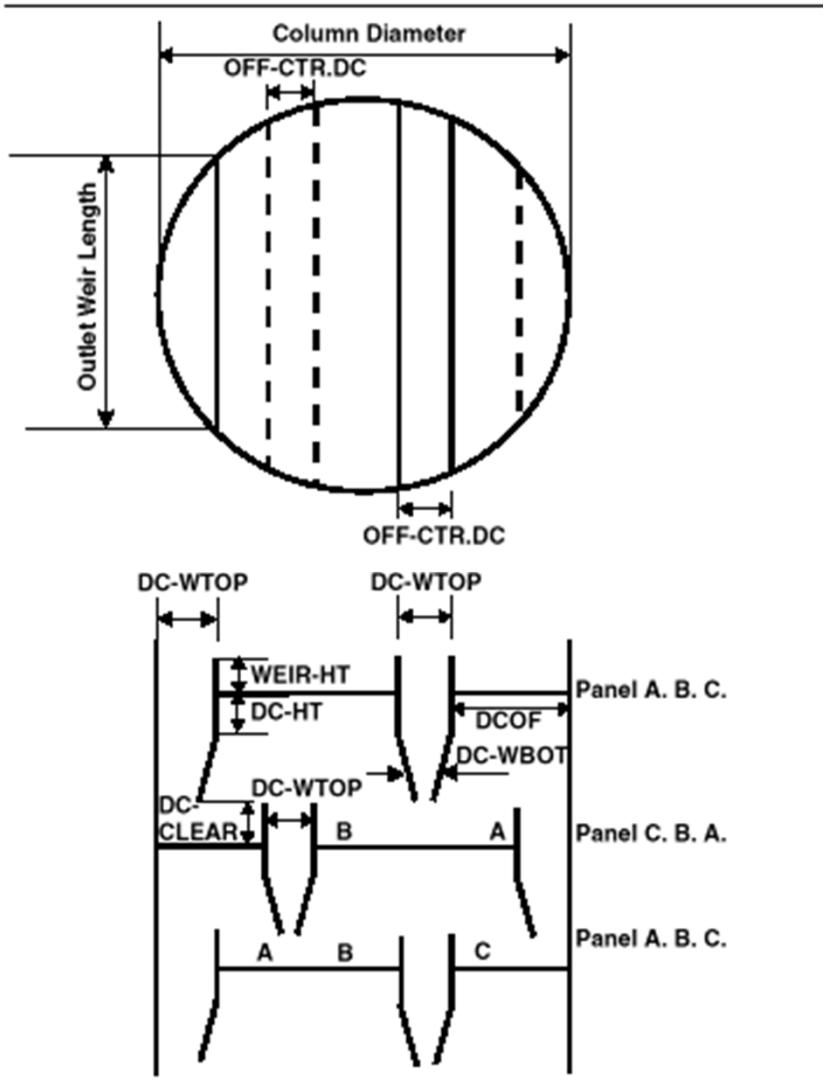
A One-Pass Tray

Two Pass Tray



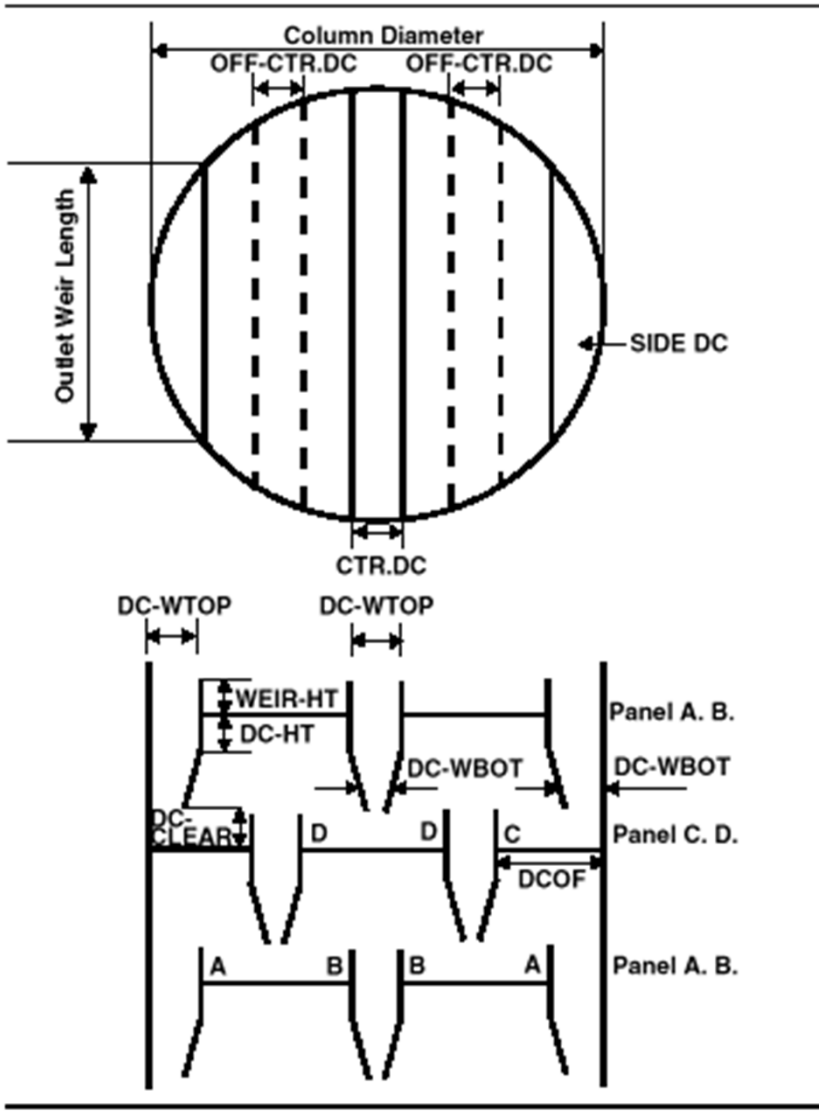
A Two-Pass Tray

Three Pass Tray



A Three-Pass Tray

Four Pass Tray



A Four-Pass Tray

Tower Diameter

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Initial estimation

$$D_t\,(feet) = \left[\frac{6.8(V - LOAD) + 10(L - LOAD)}{\sqrt{Tray\_Spacing\,(feet)}}\right]^{0.5}$$

where

$$V - LOAD = (Vapor\_Rate, CFS)\sqrt{\frac{\rho_v}{\rho_l - \rho_v}}$$

$$L - LOAD = (Liquid\_Rate, CFS)$$

Tray Sizing and Rating

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- Rating vs. Sizing:
  - Simulating a column with fixed operating conditions is called ***"rating"***.
  - Manipulating operating conditions to achieve some overall result is called ***"sizing"***.

- Sizing Mode:
  - Sizing Mode determines column diameter to satisfy the flooding approach specified for each stage. The largest diameter is selected.

- Rating Mode:
  - Rating Mode calculates performance and hydraulic information such as flooding approach, downcomer bakcup, and pressure drop.

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Tray Sizing and Rating

- ASPEN PLUS or PRO/II calculates sizing and performance parameters such as:
  - Column diameter
  - Flooding approach or approach to maximum capacity
  - Downcomer backup
  - Pressure drop

- These results are based on:
  - Column loadings (vapor and liquid traffic)
  - Tray geometry
  - Transport properties

Tray Performance

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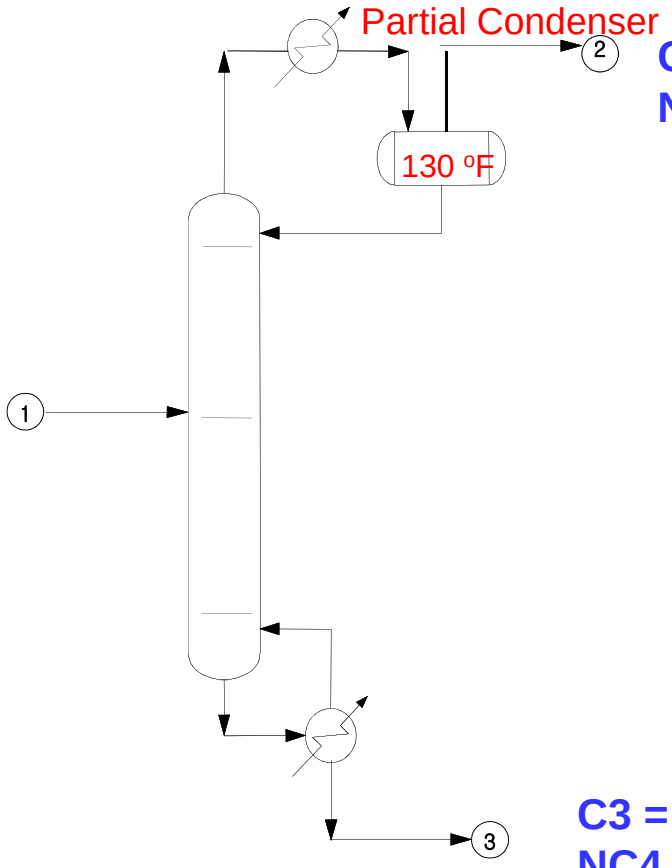
유형	현상
Flooding	• 정해진 Tower Size에서 Tray 용량의 한계를 의미 • Tray Type마다 차이는 있으나 % Flooding이 80보다 크고 20보다 작은 경우에는 Tray 효율이 급격히 저하된다.
Weeping	• Hole Area로 올라오는 Vapor의 양이 너무 적어 Liquid 중 일부분이 Hole Area를 통하여 떨어지는 현상
Blowing	• Liquid 양이 Vapor 양에 비해 너무 적어 Active Area 상의 Liquid의 일부분이 Vapor와 함께 위로 올라가는 현상
Entrainment	• Blowing과 유사한 현상으로 Active Area의 Liquid 중 많은 양이 Vapor 와 함께 올라오는 현상 • Tray에 Drying 현상을 유발시킬 수 있다.
Dumping	• Weeping 양이 많아져서 액유량과 같아지는 경우

Tray Sizing Example
– Depropanizer

Feed, lbmole/hr	
C2	30
C3	200
NC4	370
NC5	350
NC6	50
Total	1000
Press.	320 psia
Temp.	225 °F

LK

HK



C3 = 191 lbmole/hr
NC4 = 5 lbmole/hr

C3 = 9 lbmole/hr
NC4 = 365 lbmole/hr

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Tray Sizing for Depropanizer New Design

1. Determine the number of tray to obtain:
   a) C3 recovery at overhead : 95.5 %
   b) NC4 recovery at overhead : 1.35 %

2. Determine the column operating pressure, based on a dew point condenser temperature of 130^{o}F.

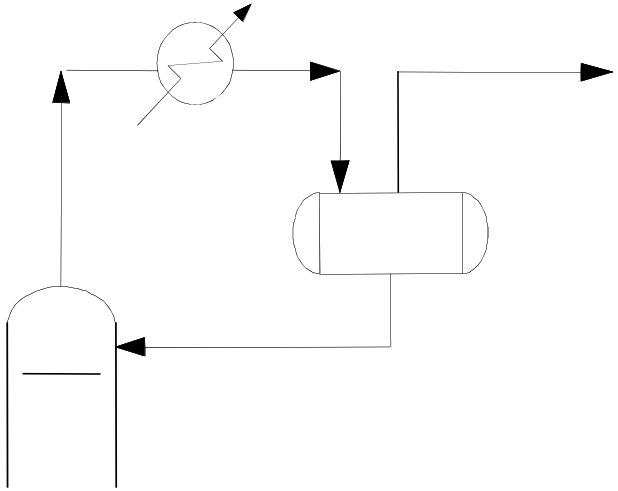
3. Use RK-Soave (in A+) (SRK in PRO/II) method for VLE calculation.

4. Find an actual reflux ratio which minimizes the summation of total utility consumptions *(operating costs)* and theoretical number of stages *(capital costs)*.

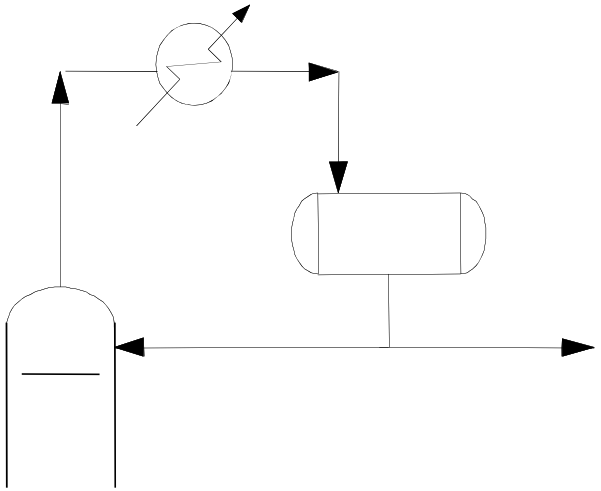
5. Use Sieve Tray Internal Type.

How we can determine the condenser type?
or How we can determine the column pressure?

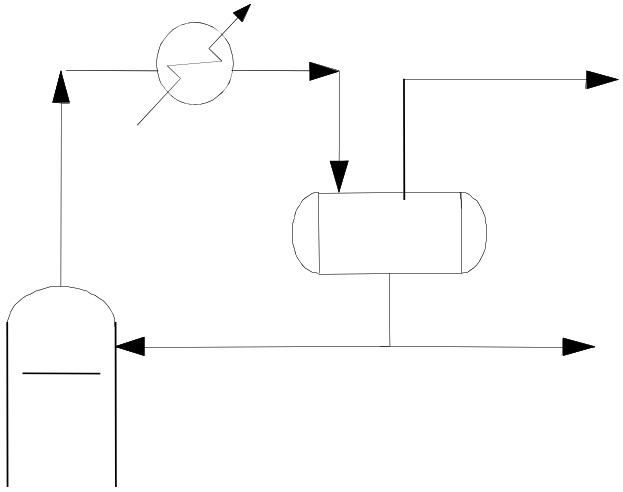
A. Partial



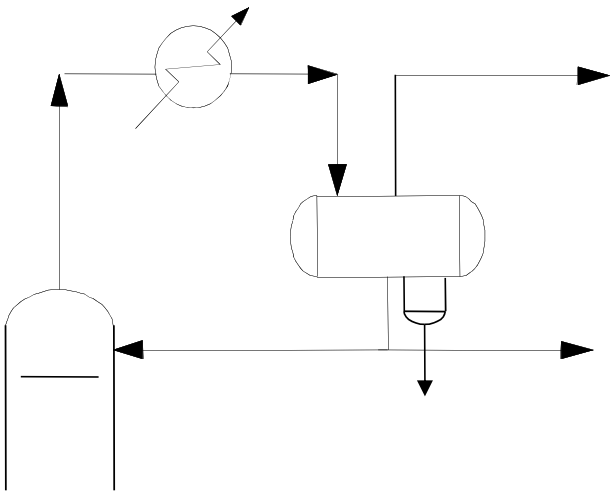
B. Bubble or sub-cooled



C. Mixed



D. Mixed with decanter



It depends on the refrigerant available and overhead compositions to be assumed.

- Overhead molar flow rate (assume)

  C2 = 30, C3 = 191, NC4 = 5, Total = 226

- Normalize ! (Component mole %)

  C2 = 13.27, C3 = 84.51, NC4 = 2.22

- First, we have to determine the dew point pressure !

Component	Mole %
C2	13.27
C3	84.51
NC4	2.22
Temperature (^{o}F)	130.00
Dew P at 130 ^{o}F	?

Component Specification in ASPEN PLUS

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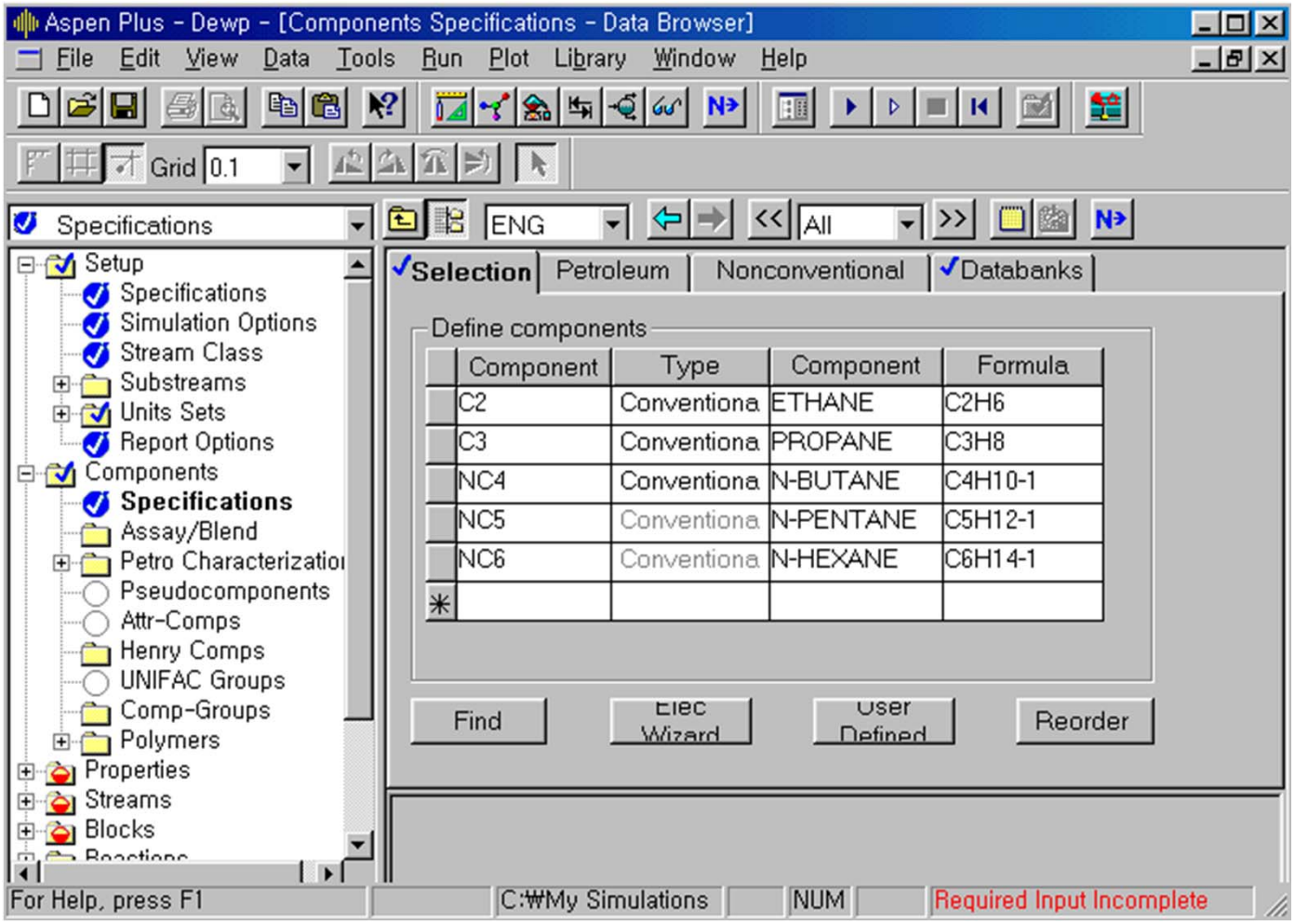
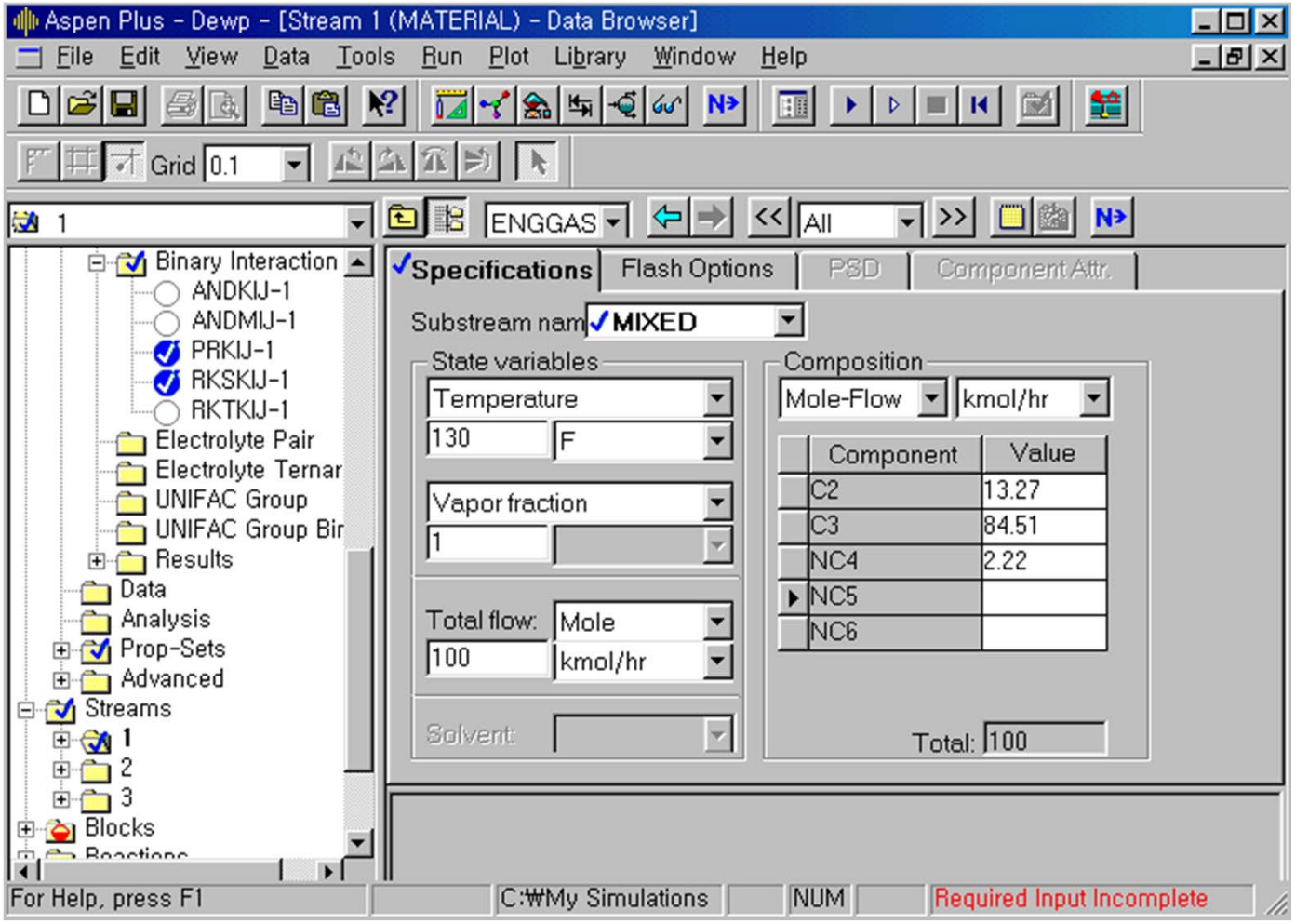


Feed Composition Specification in ASPEN PLUS



Thermo Option in ASPEN PLUS

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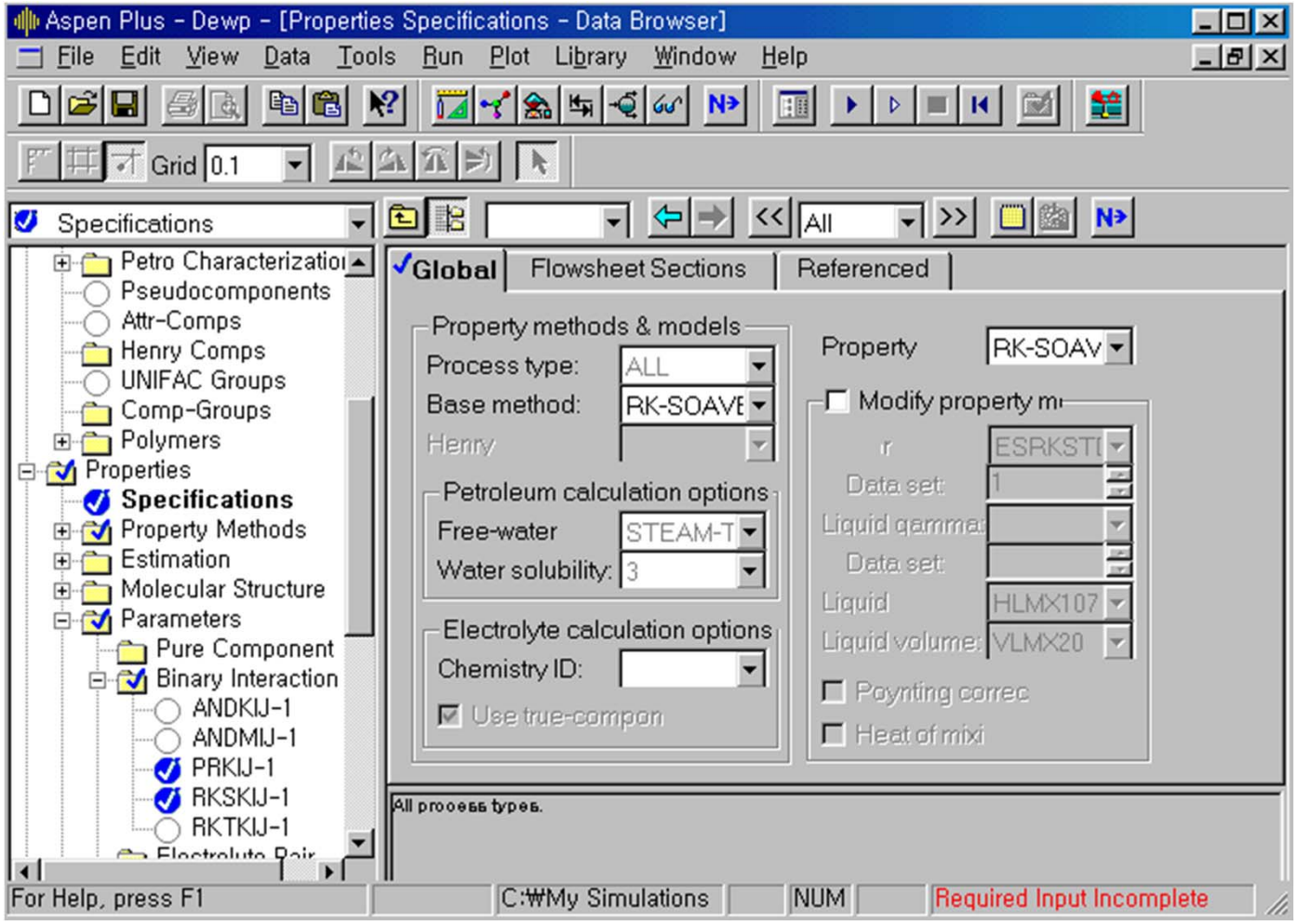

Dew Point Calculation in ASPEN PLUS

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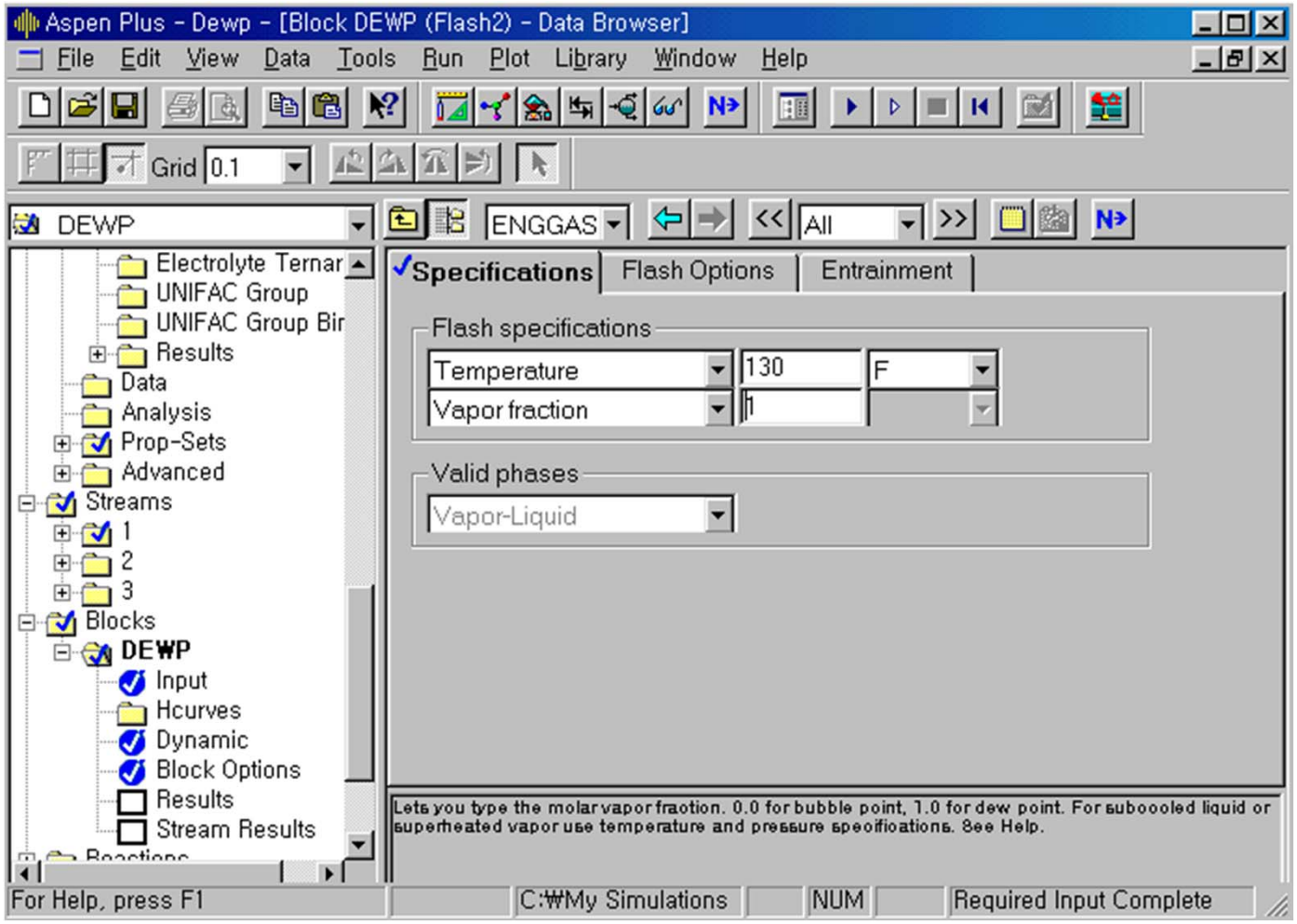

Examine Result ASPEN PLUS

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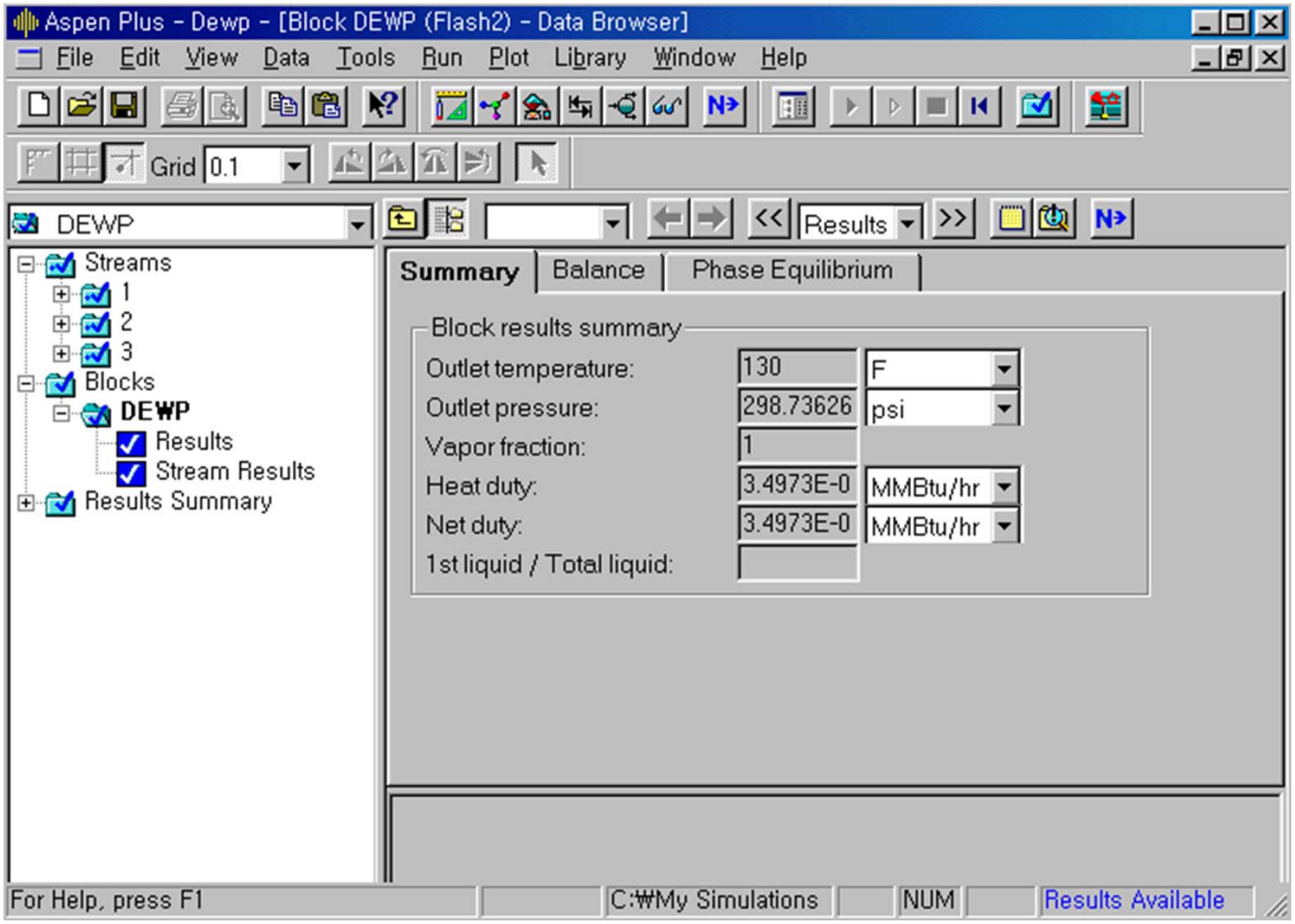

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How about using PRO/II ?

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  PRINT INPUT=ALL
  SEQUENCE PROCESS
COMPONENT DATA
  LIBID 1,C2/2,C3/3,NC4
THERMODYNAMIC DATA
  METHOD SYSTEM=SRK
STREAM DATA
  PROPERTY STREAM=1, TEMPERATURE=100, PRESSURE=300, PHASE=M, &
         RATE(M)=100, COMPOSITION(M)=1,13.27/2,84.51/3,2.22
UNIT OPERATIONS
  FLASH UID=F01
      FEED 1
      PROD V=1V, L=1L
      DEW  TEMP=130
END
```

ASPEN PLUS Keyword Input File

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```
TITLE 'Dew Pressure Calculation at the Condenser Pressure'
IN-UNITS ENG
DEF-STREAMS CONVEN ALL
DESCRIPTION "
    General Simulation with English Units :
    F, psi, lb/hr, lbmol/hr, Btu/hr, cuft/hr.
    Property Method: None
    Flow basis for input: Mole
    Stream report composition: Mole flow "
DATABANKS PURE10  / AQUEOUS  / SOLIDS  / INORGANIC  /  &
       NOASPENPCD
PROP-SOURCES PURE10  / AQUEOUS  / SOLIDS  / INORGANIC
COMPONENTS
    C2 C2H6 /
    C3 C3H8 /
    NC4 C4H10-1
FLOWSHEET
    BLOCK DEW IN=1 OUT=2 3
PROPERTIES RK-SOAVE
STREAM 1
    SUBSTREAM MIXED TEMP=130. VFRAC=0. MOLE-FLOW=1.
    MOLE-FRAC C2 0.1327 / C3 0.8451 / NC4 0.0222
BLOCK DEW FLASH2
    PARAM TEMP=130. VFRAC=1.
```

FLASH ID		F01
FEEDS		1
PRODUCTS	VAPOR	1V
	LIQUID	1L

TEMPERATURE, F	**130.000**
PRESSURE, PSIA	**298.857**
PRESSURE DROP, PSI	1.143
MOLE FRAC VAPOR	1.00000
MOLE FRAC LIQUID	.00000
DUTY, MM BTU/HR	.58994
FLASH TYPE	DEW-T

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Dew Pressure Calculation Results

	ASPEN PLUS	PRO/II
Condenser Type	Partial	Partial
Condenser Operating Temperature	130^{o}F	130^{o}F
Condenser Operating Pressure	298.736 psia	298.857 psia
Condenser Pressure Drop	4 psia (assumed)	4 psia (assumed)
Column Pressure Drop	5 psia (assumed)	5 psia (assumed)

- Next step is to determine the minimum number of stages & minimum reflux ratio for separation using “SHORTCUT” model.

Shortcut Modeling using ASPEN PLUS

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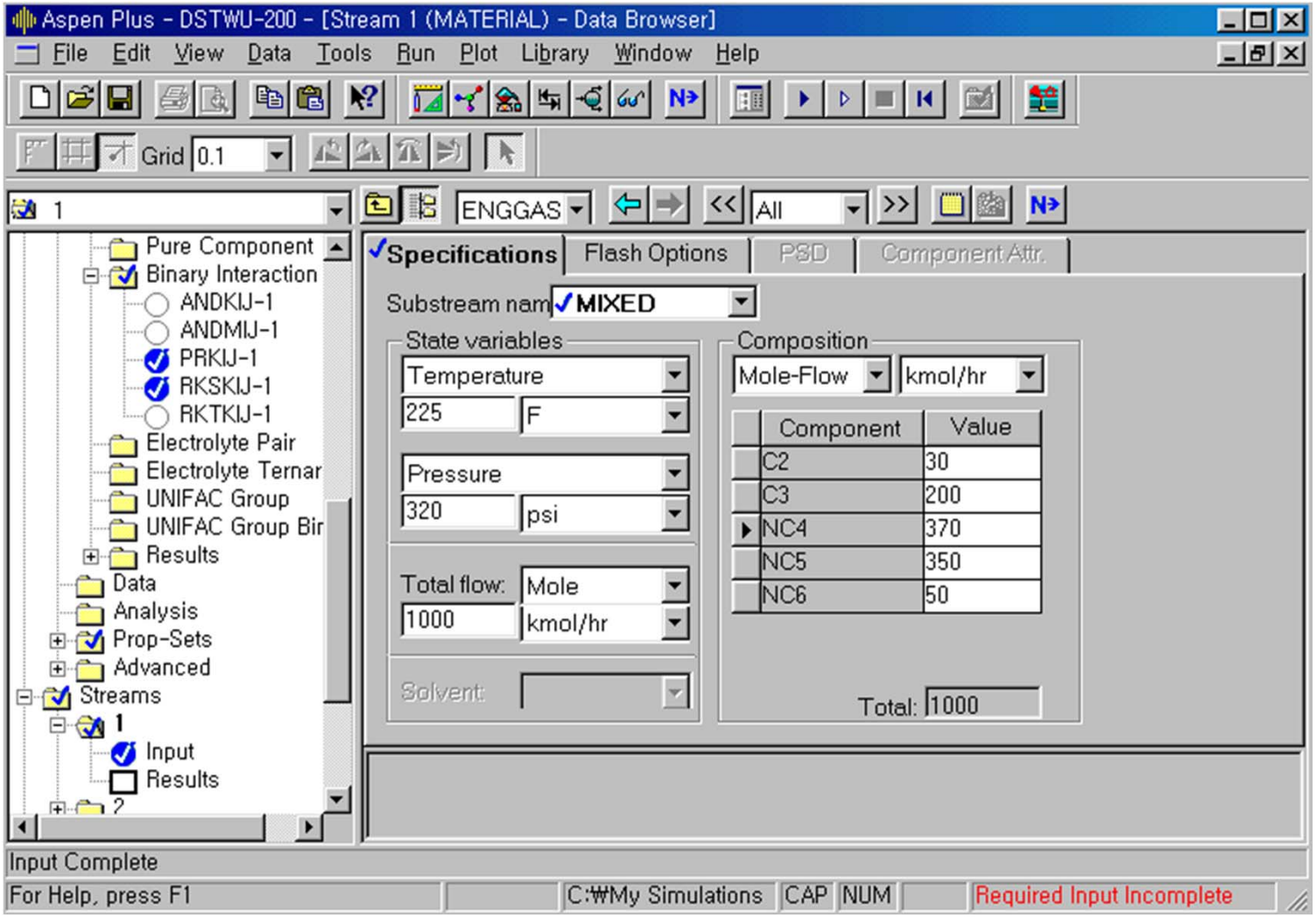

Shortcut Modeling using ASPEN PLUS

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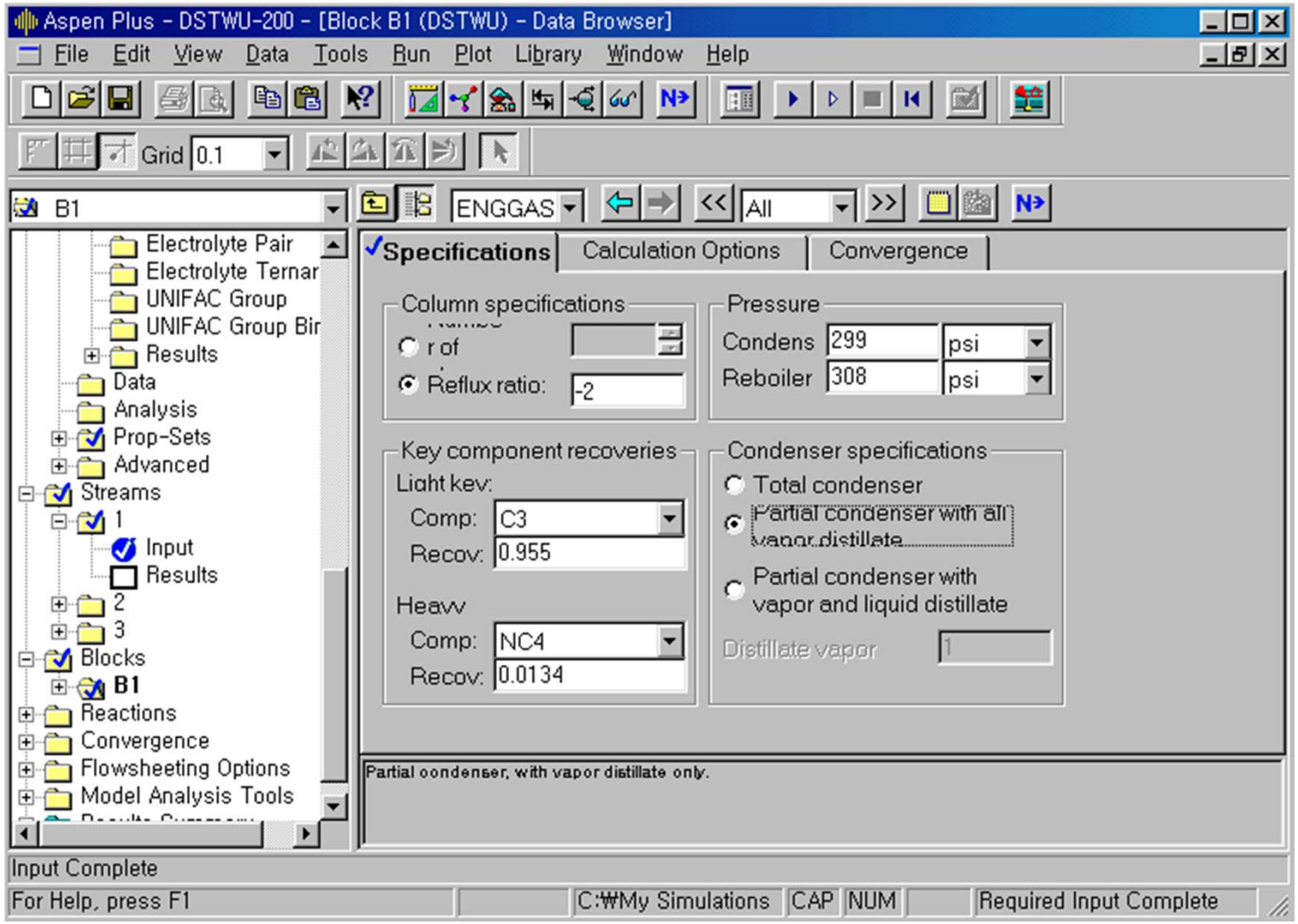

Shortcut Modeling using ASPEN PLUS

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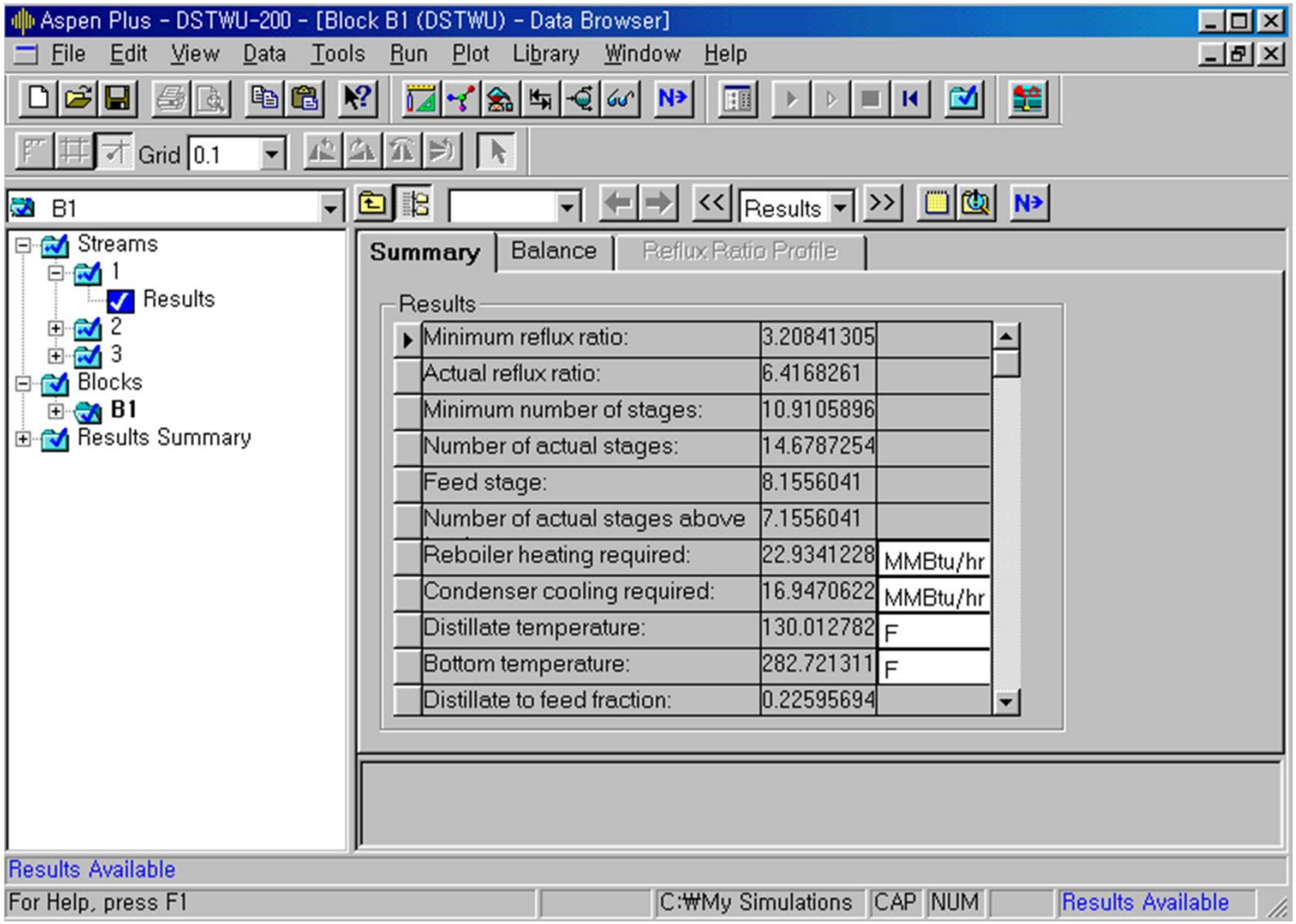

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DSTWU (Shortcut in Aspen Plus)modeling Case Study

R/R_{min}	Number of Tray	Reflux Ratio	Feed Tray	Condenser Duty	Reboiler Duty	Utility
1.00	**Infinitive**	**3.21**	-	-	-	-
1.05	38.3	3.37	19.7	3.82	6.54	10.36
1.10	26.1	3.53	13.7	4.06	6.77	10.83
1.50	17.9	4.81	9.7	5.67	8.39	14.06
2.00	14.7	6.42	8.0	7.69	10.40	18.09
2.50	13.8	8.02	7.7	9.67	12.39	22.06
5.00	12.1	16.04	6.9	19.60	22.32	41.92
Infinitive	**10.9**	**Infinitive**	-	-	-	-

- **Minimum Reflux Ratio = 3.21**
- **Minimum Number of Stages = 10.9**

Shortcut Modeling using PRO/II

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THERMODYNAMIC DATA
  METHOD SYSTEM=SRK
STREAM DATA
  PROP STREAM=1,TEMP=225,PRES=320,RATE=1000,&
       COMP=1,30/2,200/3,370/4,350/5,50
UNIT OPERATION DATA
 SHORTCUT UID=S01
   FEED 1
   PROD STREAM=2,CUTP=0.3,PRES=299
   PROD STREAM=3,PRES=308
   COND TYPE=PART,TEMP=130
   EVAL MODEL=CONV,KEYL=2,KEYH=3,RRMIN=1.75
   SPEC STREAM=2,COMP=3,RATE,RATIO,STREAM=1,VALUE=0.0135
   SPEC STREAM=3,COMP=2,RATE,RATIO,STREAM=1,VALUE=0.0450
END
```

Shortcut Modeling using PRO/II

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		TOTAL STREAM RATES				
		MOLES	WEIGHT	LIQUID VOL	NORM VAPOR(1)	NUM
STREAM + PHASE		LB-MOL/HR	LB/HR	FT3/HR	FT3/HR	SECTION TRAYS
2	V	226.00	9615.25	314.56	85762.74	1 12.51
3	L	774.00	51173.86	1340.37	293720.69	
TOTALS		1000.00	60789.11	1654.93	379483.44	**12.51**

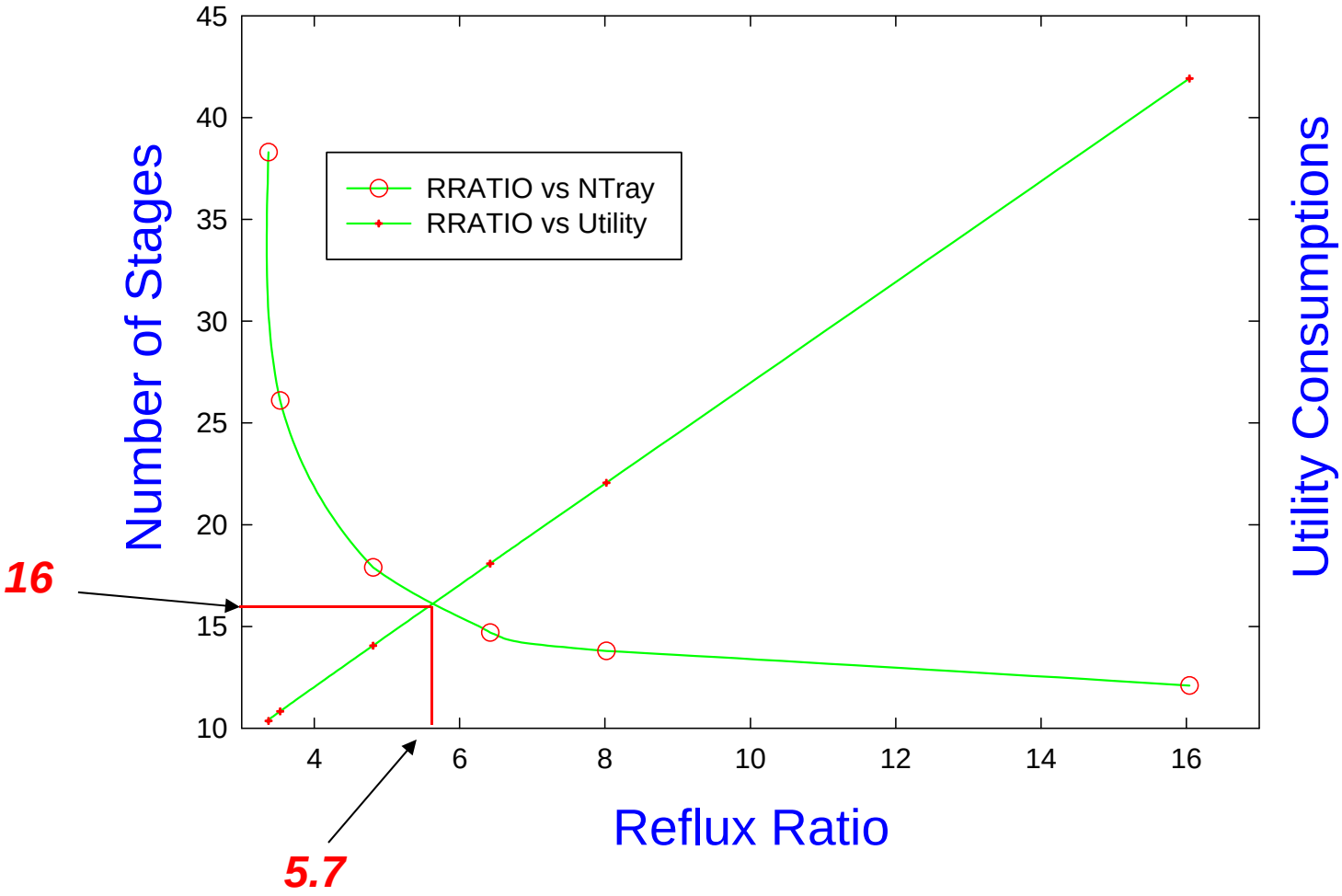
SPECIFICATIONS

PARAMETER TYPE	COMP. NUM	SPECIFICATION TYPE	SPECIFIED VALUE	CALCULATED VALUE
STRM 2	3	MOL RATIO	1.350E-02	1.350E-02
STRM 3	2	MOL RATIO	4.500E-02	4.500E-02

SUMMARY OF UNDERWOOD CALCULATIONS

MINIMUM REFLUX RATIO	**2.94575**
FEED CONDITION Q	**1.07172**
FENSKE MINIMUM TRAYS	**12.51173**

Reflux Ratio vs. # of Stages & Utility Consumptions



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Determination of Optimum Reflux Ratio & # of Stages

Feed rate	700 lb mole/hr
Feed thermal condition	Saturated liquid
Feed composition	45 % mol benzene, 55 % mol toluene
Column pressure	1 atm
Distillate composition	92 mole % benzene
Bottoms composition	95 mole % toluene
Average cooling-water temp in condenser	90 ^{o}F
Gain in cooling-water temp in condenser	50 ^{o}F
Steam to reboiler	Saturated, at 60 psia
Max allowable vapor velocity in tower	2.5 ft/sec
Stage efficiency	70% (overall)

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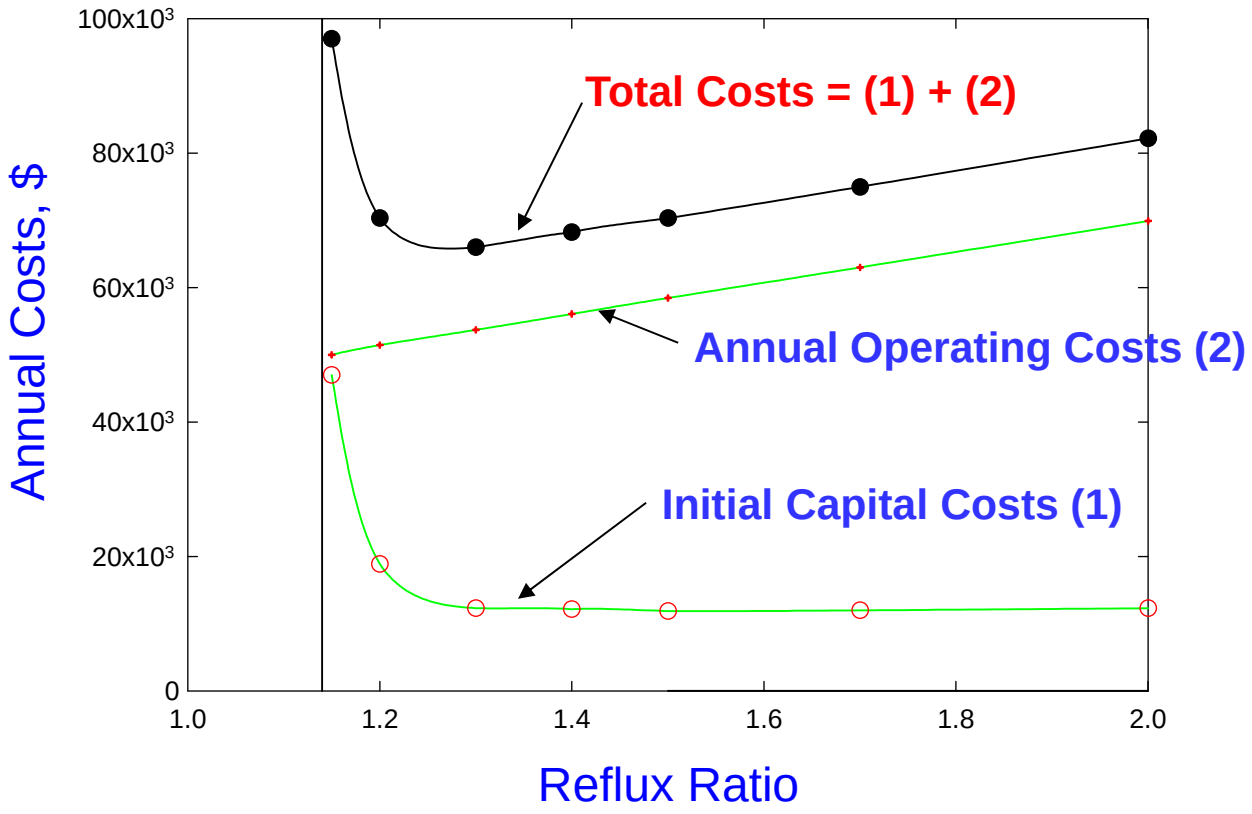
Determination of Optimum Reflux Ratio & Number of Stages

Reflux Ratio	No of Actual Stages	Column Diameter (feet)	Annual Cost					Total Annual Cost
			Fixed Charges			Operating		
			Column	Condenser	Reboiler	c/w	Steam	
1.14	Infinitive	6.7	$ Inf.	$ 1810	$ 3960	$ 5780	$ 44300	$ Infinitive
1.2	29	6.8	8930	1910	4040	5940	45500	66,320
1.3	21	7.0	6620	1950	4130	6200	47500	66,400
1.4	18	7.1	5920	2000	4240	6470	49600	68,230
1.5	16	7.3	5490	2050	4340	6740	51700	70,320
1.7	14	7.7	5290	2150	4540	7290	55700	74,970
2.0	13	8.0	5210	2280	4800	8100	61800	82,190

Total Variable Annual Cost for Benzene-toluene Distillation as a Function of Reflux Ratio



Overall Tray Efficiencies

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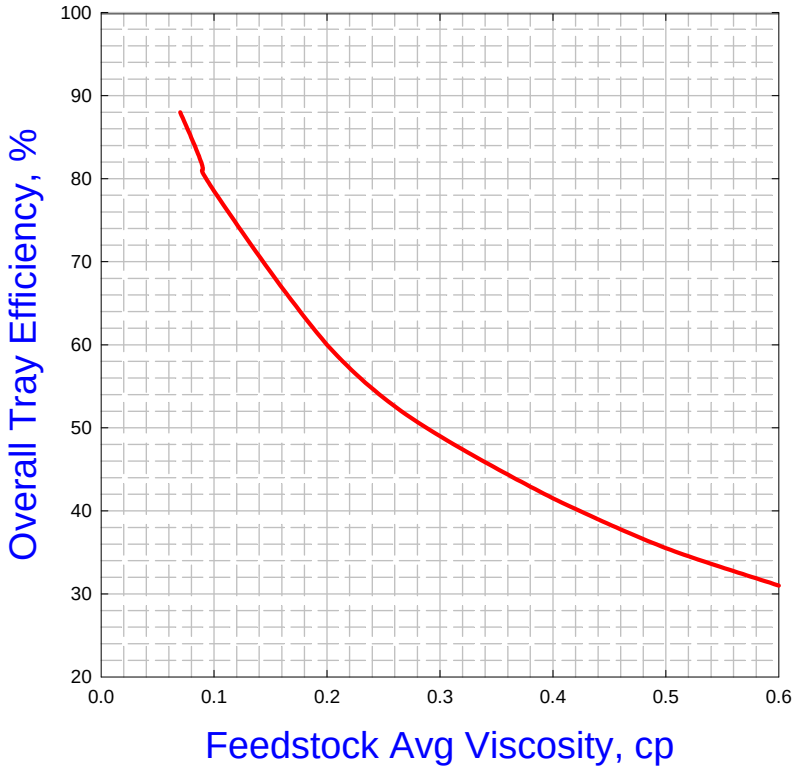
COLUMN TYPE	TYPICAL ACTUAL TRAYS	TYPICAL EFFICIENCY, % (THEOTICAL TRAYS)
ABSORBER/STRIPPER	15 – 25	20 – 30
SIDE STRIPPER(STEAM)	4 – 6	(2)
SIDE STRIPPER(REB)	6 – 8	(3 – 4)
REBOILED ABSORBER	25 – 40	45 – 55
DEETHANIZER	30 – 35	65 – 70
DEPROPANIZER	35 – 40	70 – 80
DEBUTANIZER	38 – 45	85 – 90
NAPHTHA SPLITTER	30 – 35	70 – 75
C2 SPLITTER	110 – 130	95 – 100
C3 SPLITTER	200 – 250	95 – 100
C4 SPLITTER	70 – 80	85 – 90
AMINE CONTACTOR	20 – 24	(4 – 5)
AMINE ABSORBER	20 – 24	(9 – 12)
CRUDE COLUMN	35 – 45	ABOUT 50 – 55

Overall Tray Efficiencies

Method of Drickamer & Bradford [1]

Notes:

1) Based on 54 refinery columns.
2) Viscosity is average of feed as liquid at top & bottom temperatures of the column.
3) For Absorbers, use rich oil at exit temperature.
4) Efficiency is for key components.



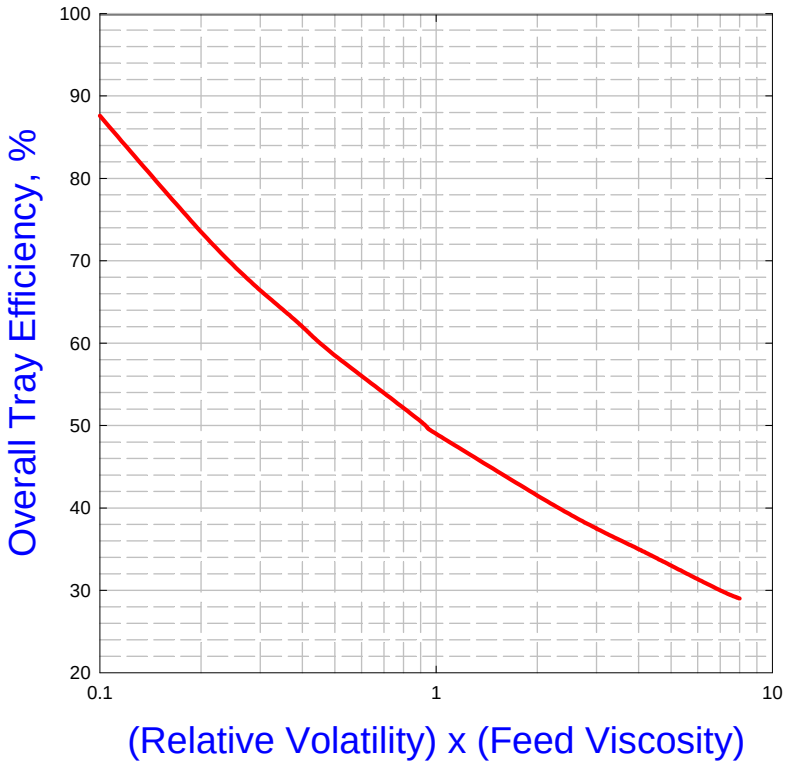
1 Tran. Am. Inst. Chem. Engrs, 39, 319 (1943).

Overall Tray Efficiencies

Method of O'Connel [1]

Notes:

1) Evaluate alpha and viscosity columns average conditions.
2) Better for columns with high alphas than Drickamer et al.
3) O'Connel states that efficiency may be different for different components in a mixture.
4) Based on commercial and laboratory column data.



1 Tran. Am. Inst. Chem. Engrs, 42, 741 (1946).

Determination of DeC3 Column Efficiency

Method I : From experience, 70 – 80% efficiency

- Typical DeC3 Column with condenser, reboiler and 40 trays
- At 75% (70 – 80%) efficiency, 30 theoretical stages
- Add stages for condenser and reboiler → 32 total

Method II : Method of Drickamer & Bradford

- Feed average viscosity is 0.09 cp, so tray efficiency is 80%.

Method III : Method of O'Connel

- Relative volatility between key components is 1.95 and feed viscosity is 0.09 cp, so tray efficiency is 76%.

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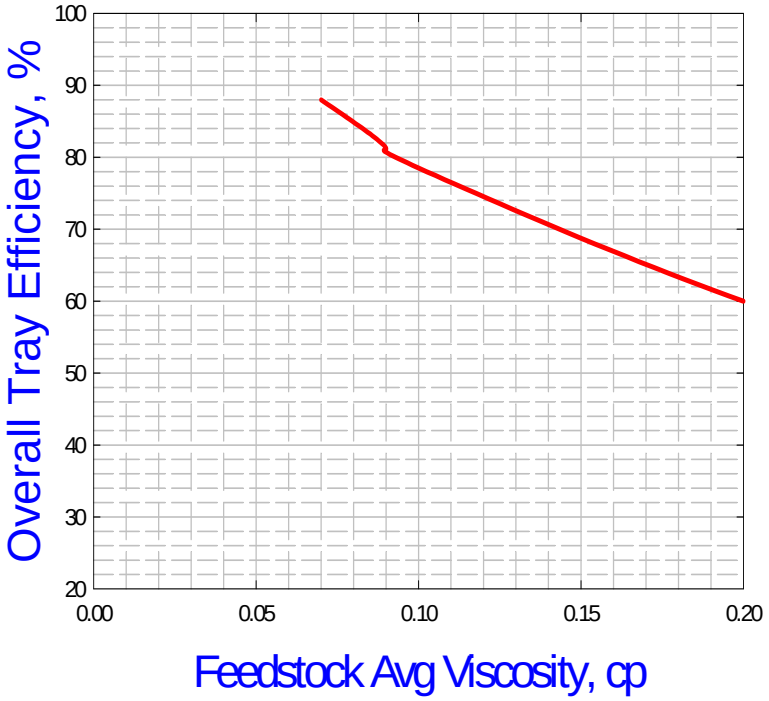
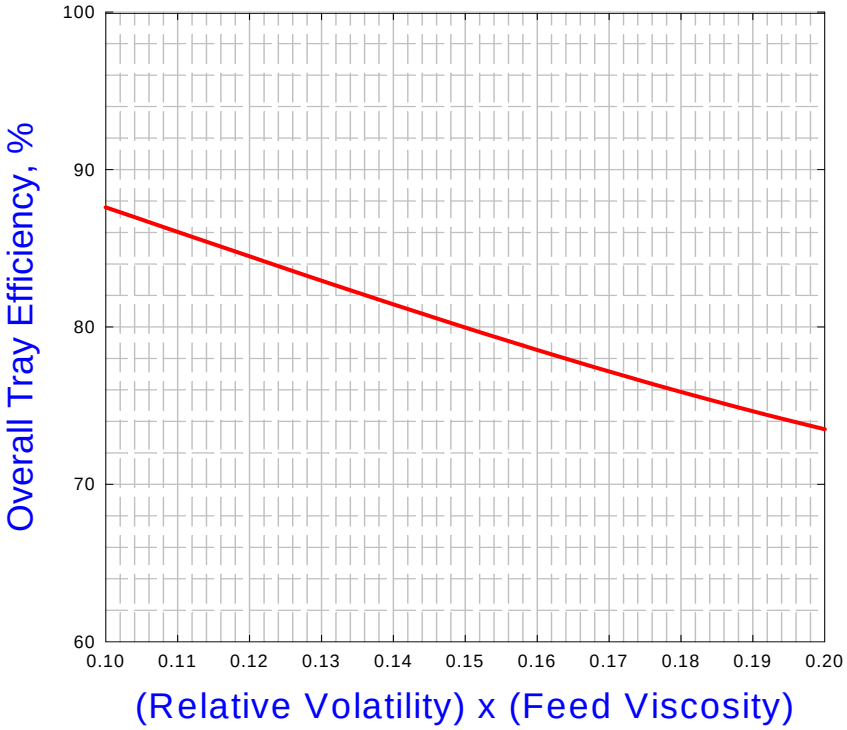
Method II



Method III



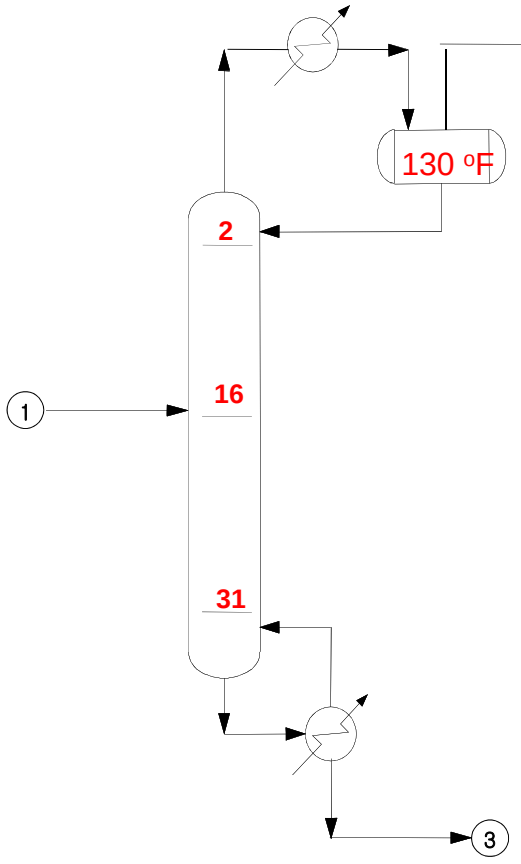
Rigorous Simulation of DeC3 Column

using ASPEN PLUS & PRO/II

LK

HK

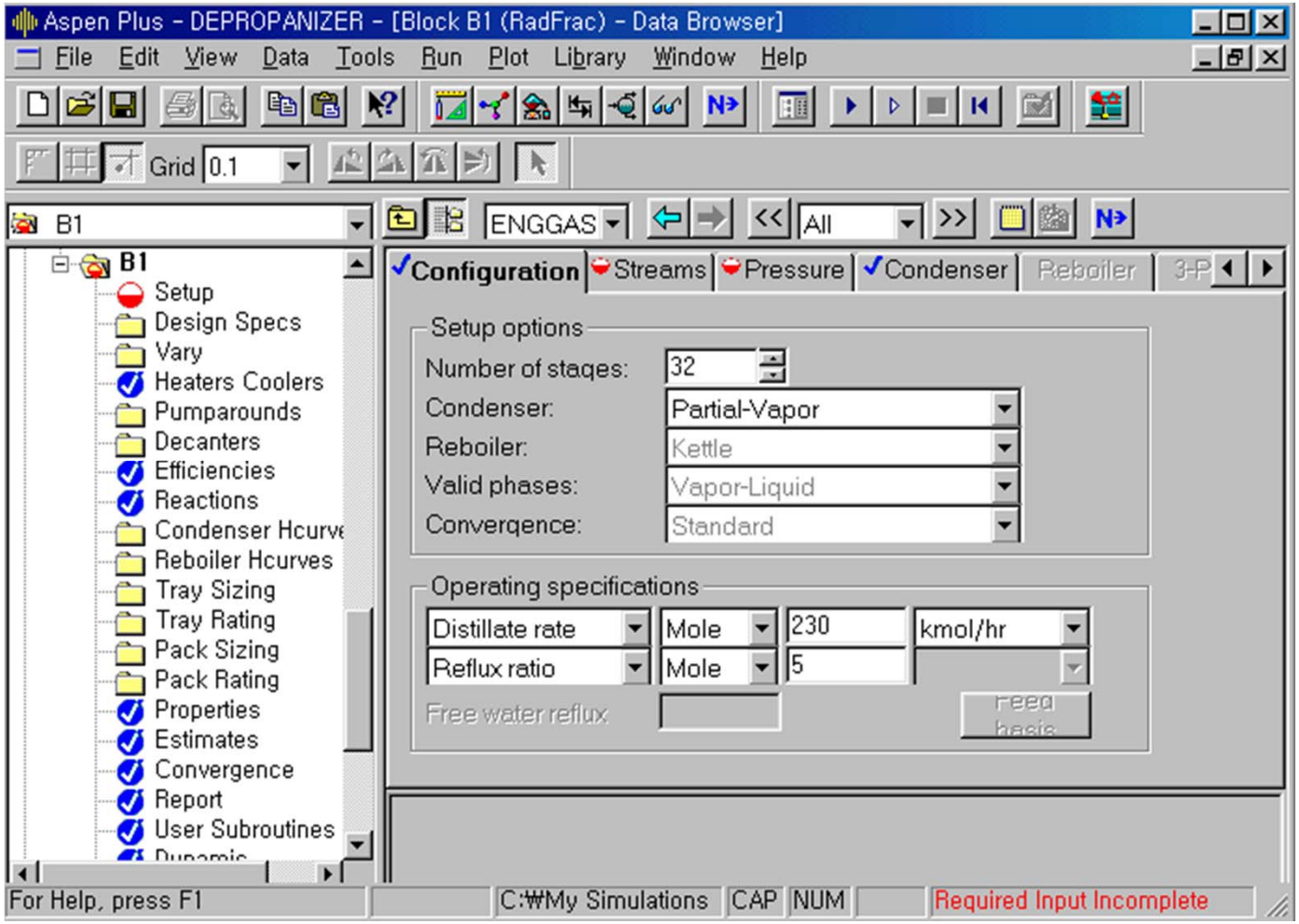
Feed, lbmole/hr	
C2	30
C3	200
NC4	370
NC5	350
NC6	50
Total	1000
Press.	320 psia
Temp.	225 °F



- 95.5 of C3 Recovery
- 98.6 of NC4 Recovery

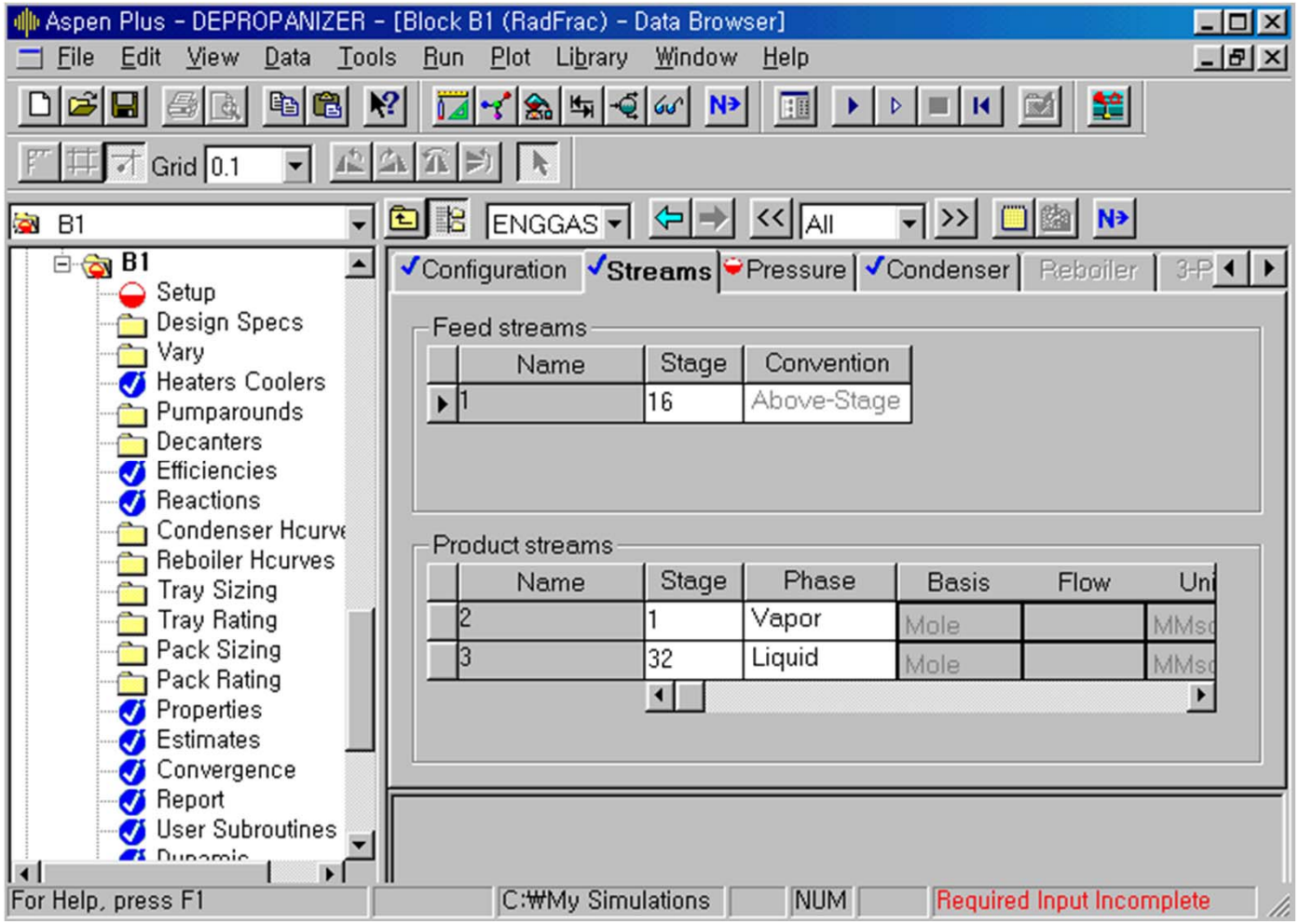
RadFrac Modeling using ASPEN PLUS

Configuration



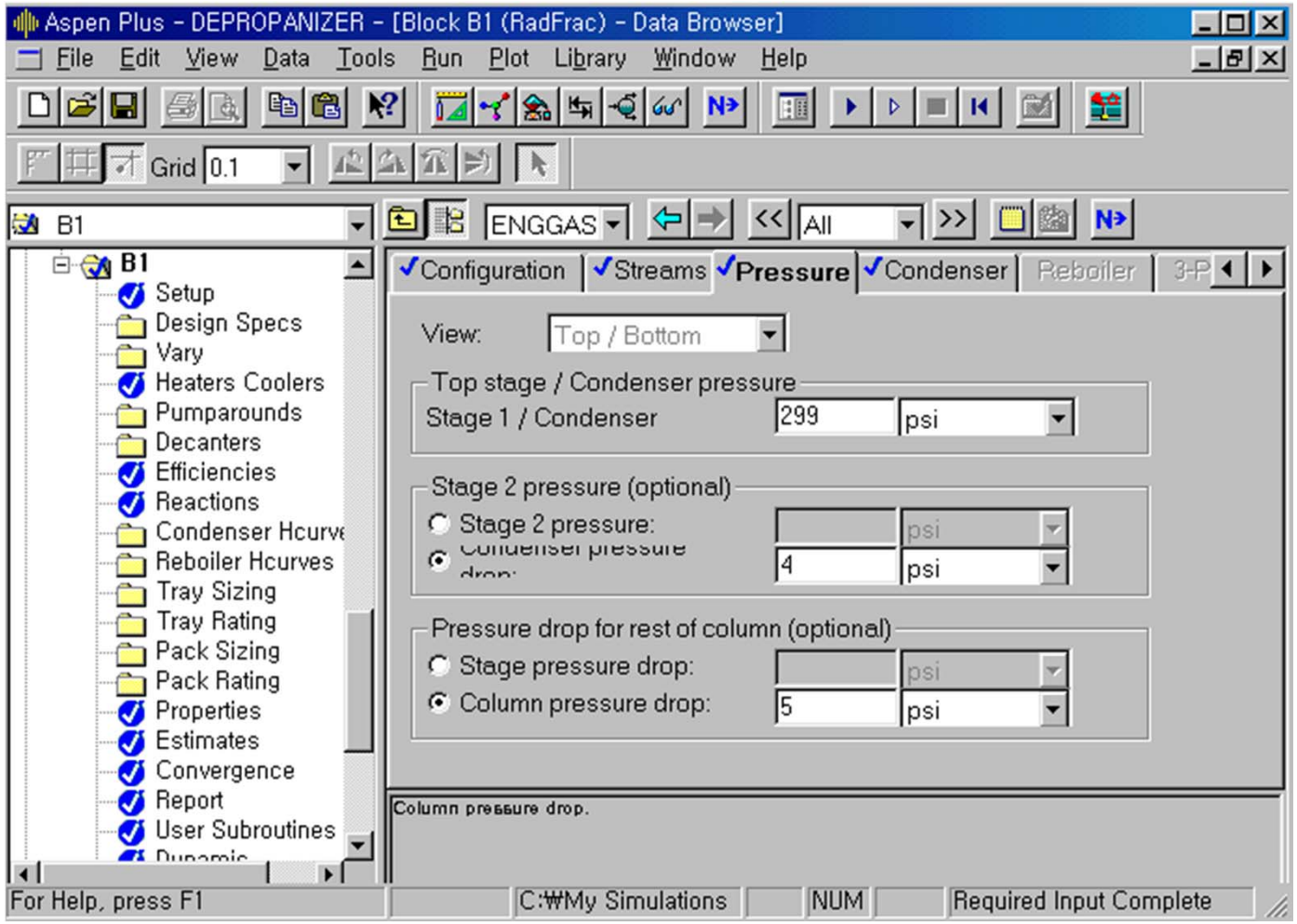
RadFrac Modeling using ASPEN PLUS

Streams



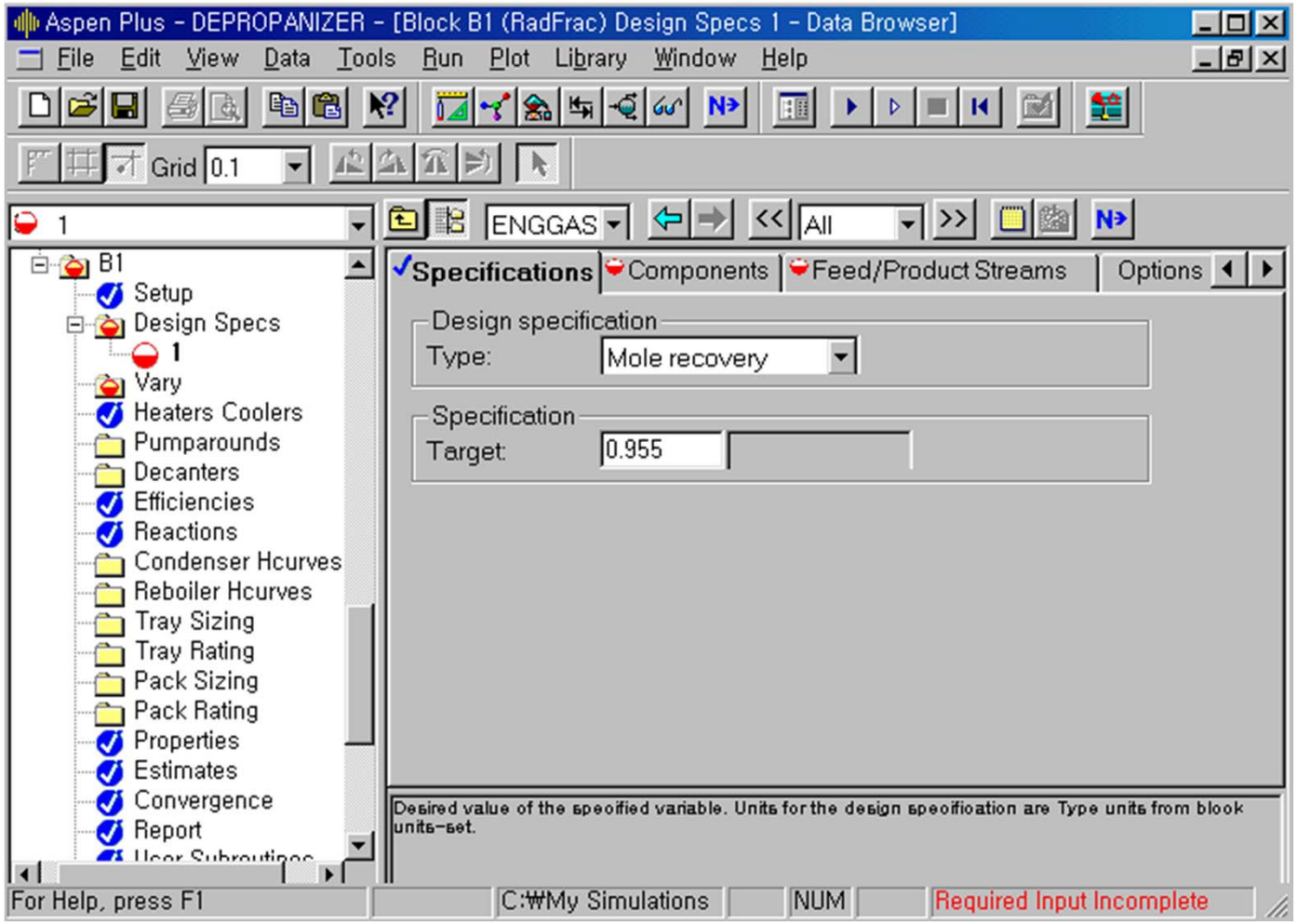
RadFrac Modeling using ASPEN PLUS

Pressure



RadFrac Modeling using ASPEN PLUS

Design Spec.1: Specifications



RadFrac Modeling using ASPEN PLUS

Design Spec.1: Components

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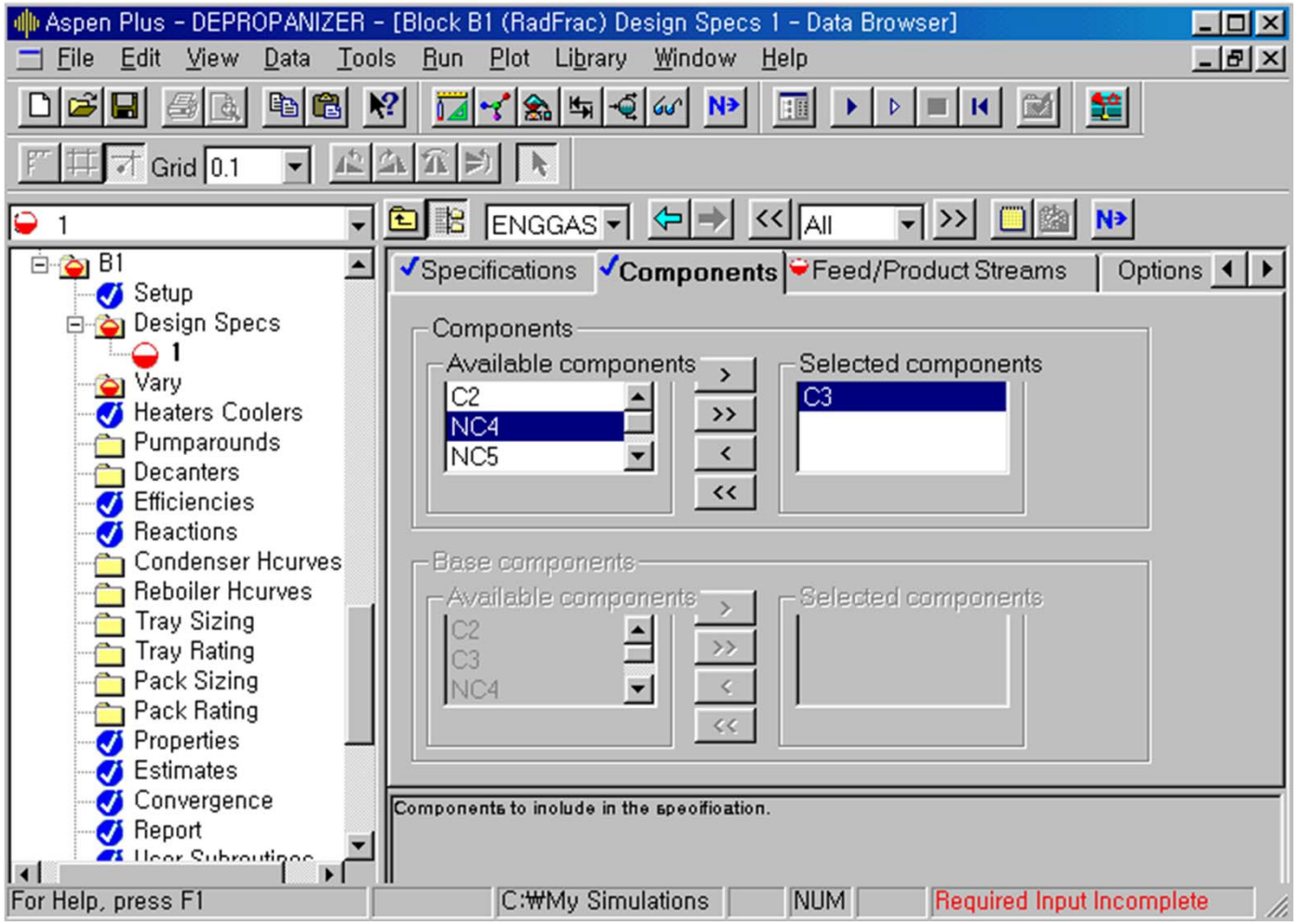
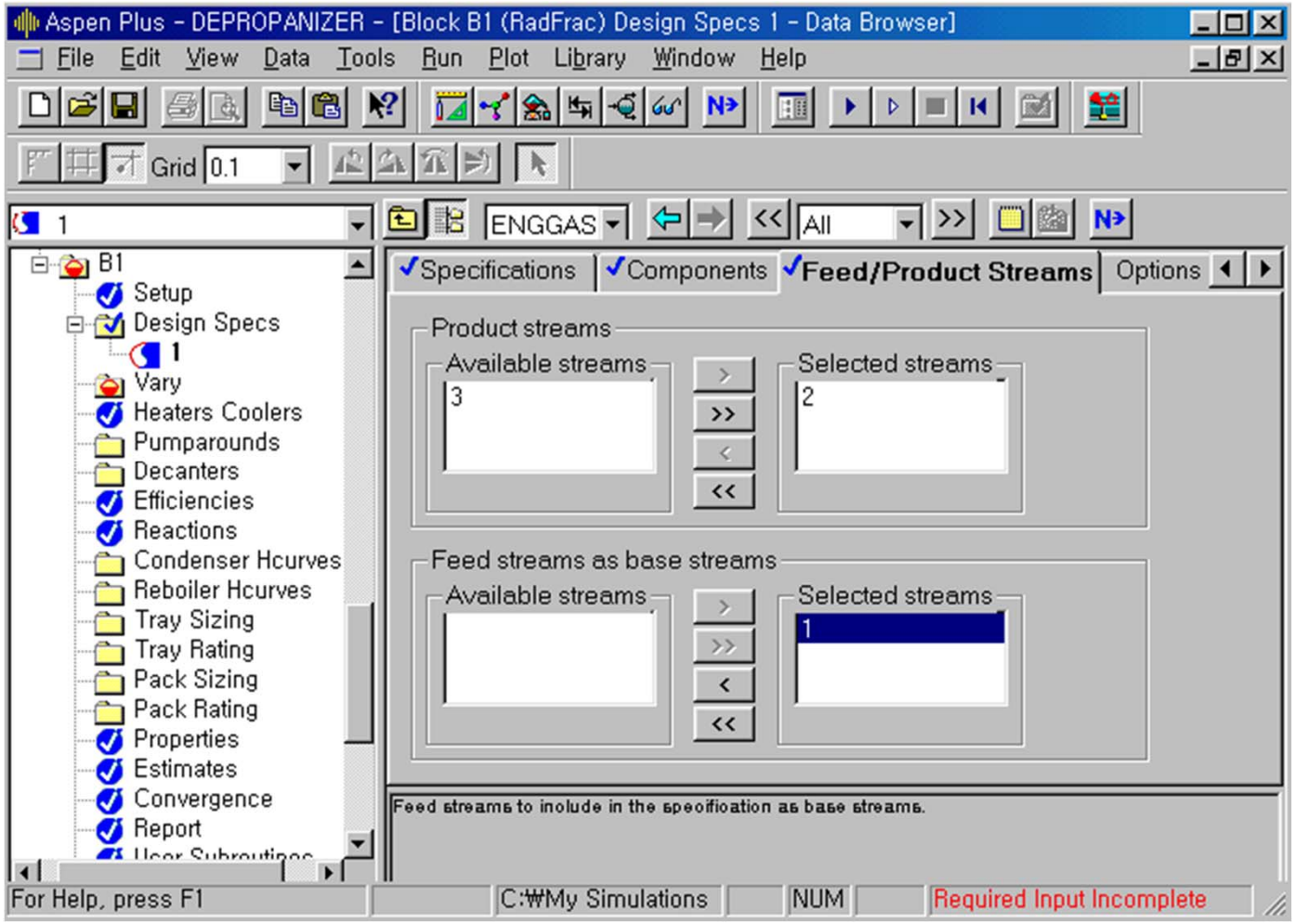


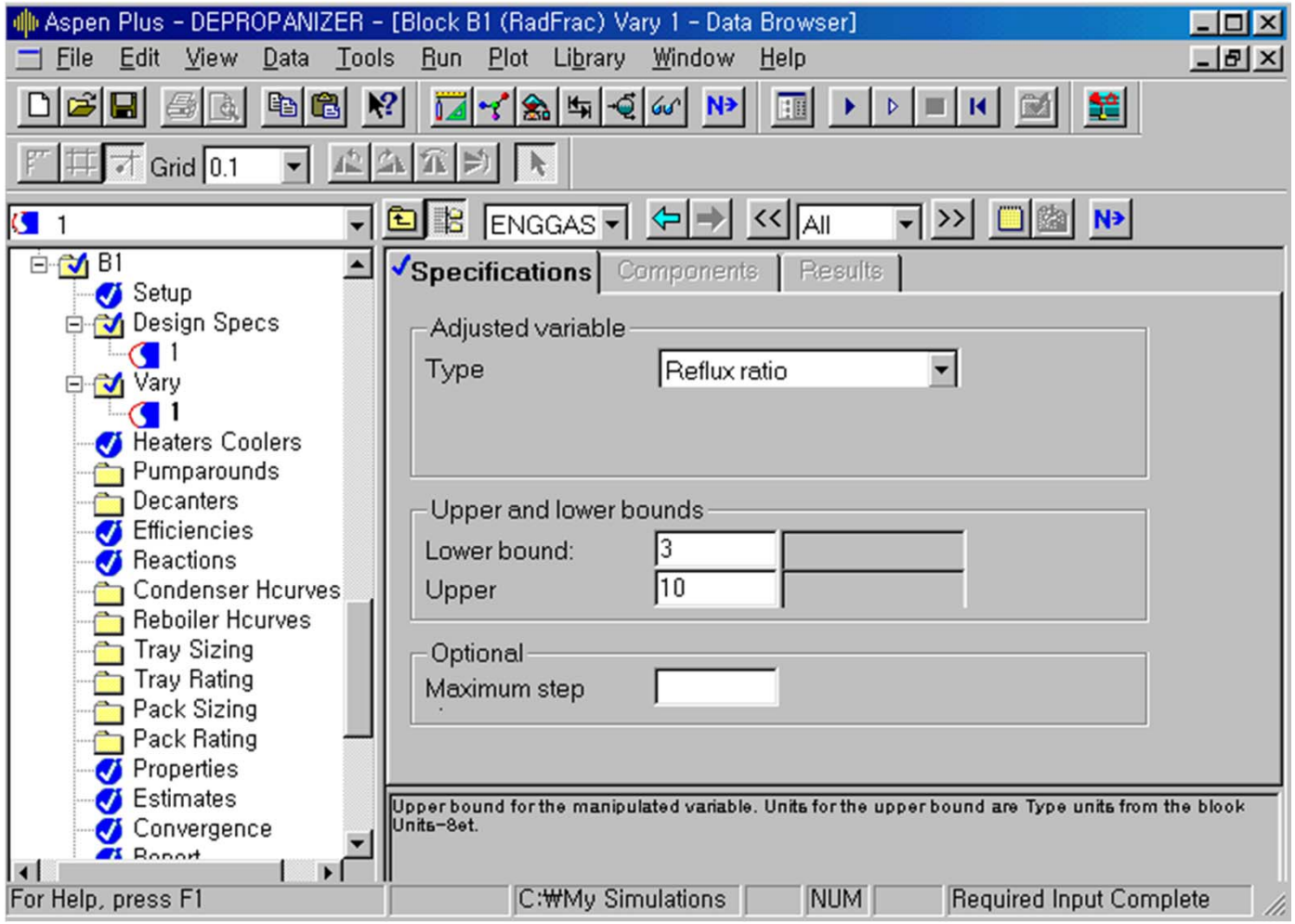
RadFrac Modeling using ASPEN PLUS

Design Spec.1: Feed/Product Streams



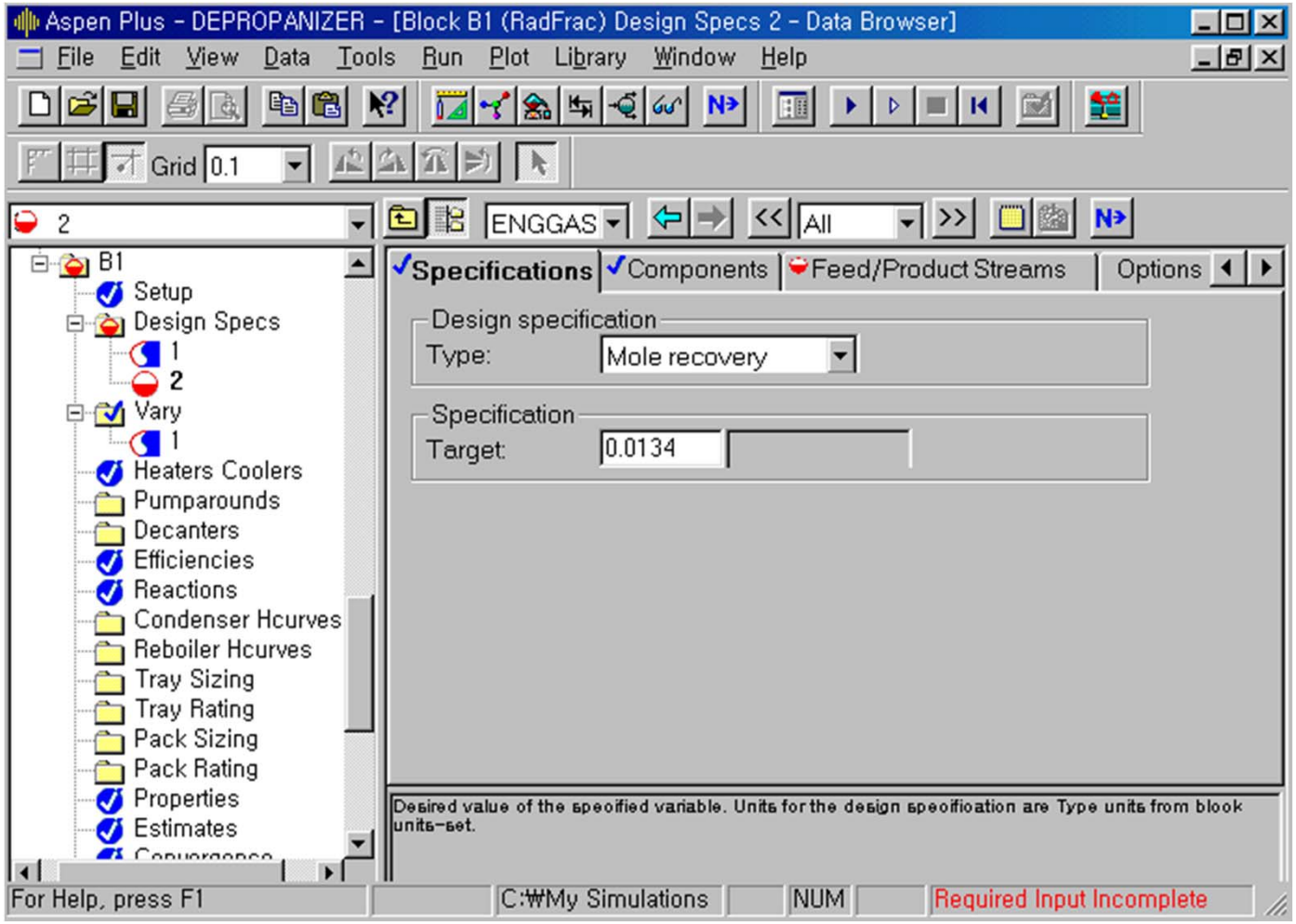
RadFrac Modeling using ASPEN PLUS

Vary1: Reflux Ratio



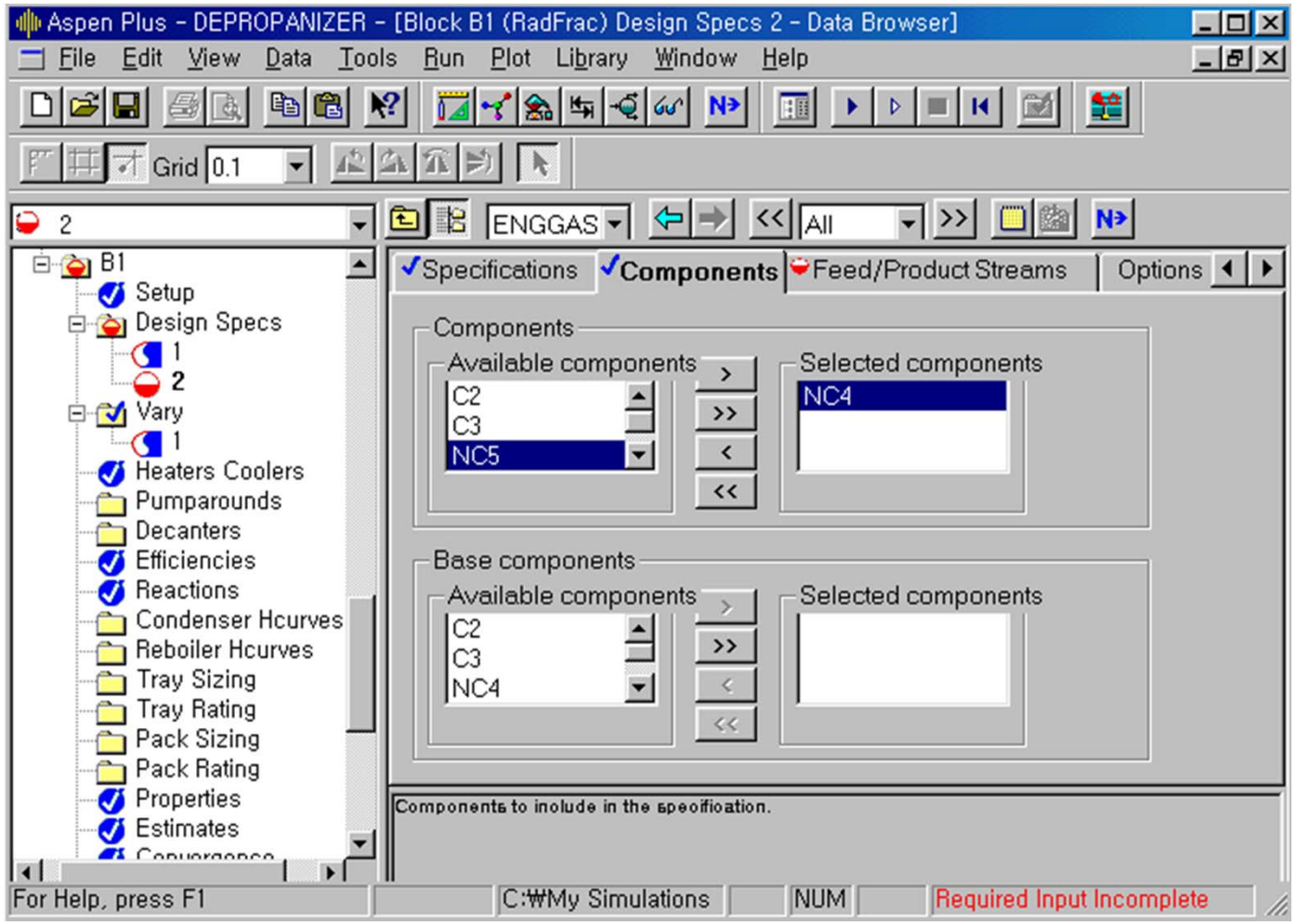
RadFrac Modeling using ASPEN PLUS

Design Spec.2: Specifications



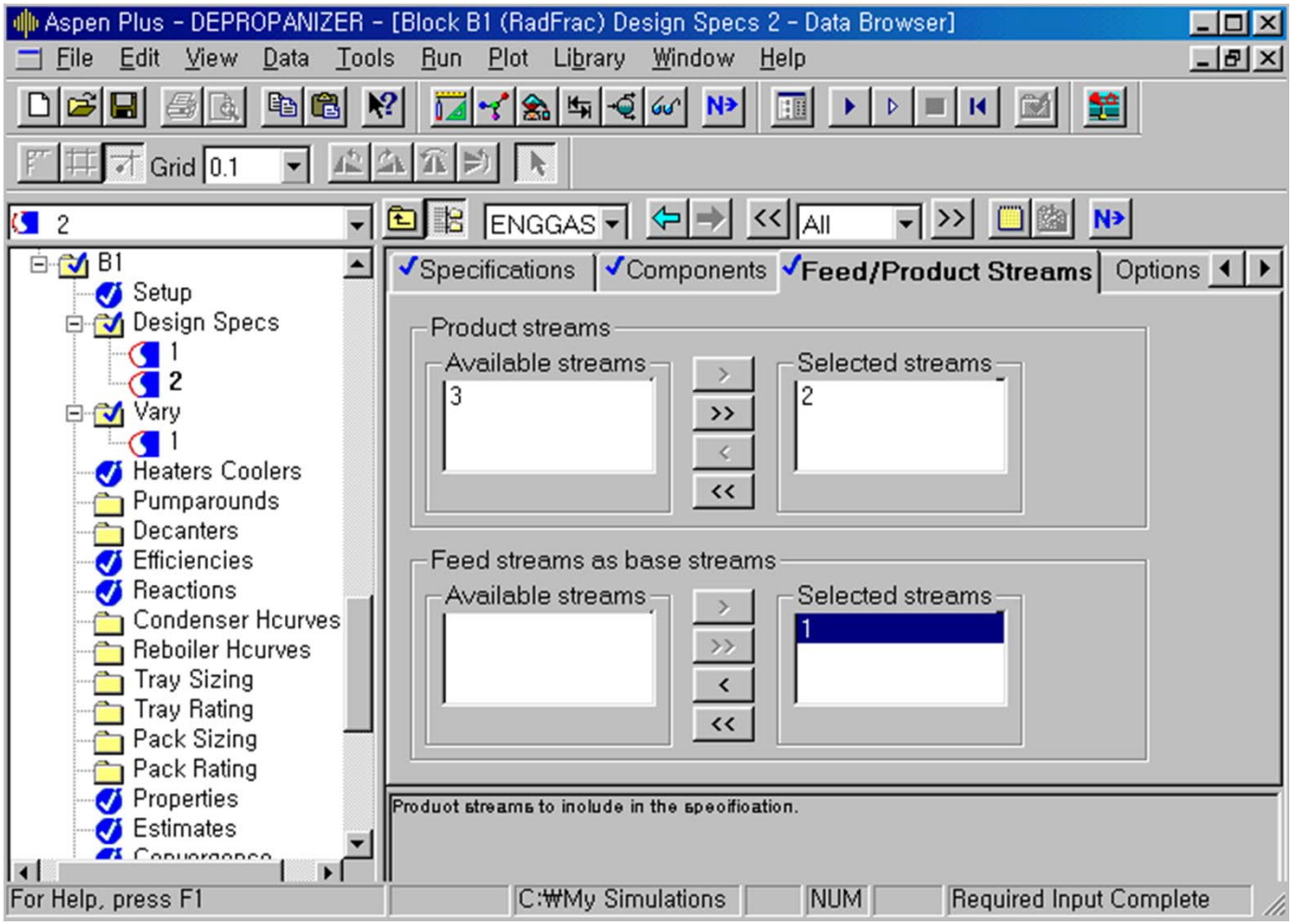
RadFrac Modeling using ASPEN PLUS

Design Spec.2: Components



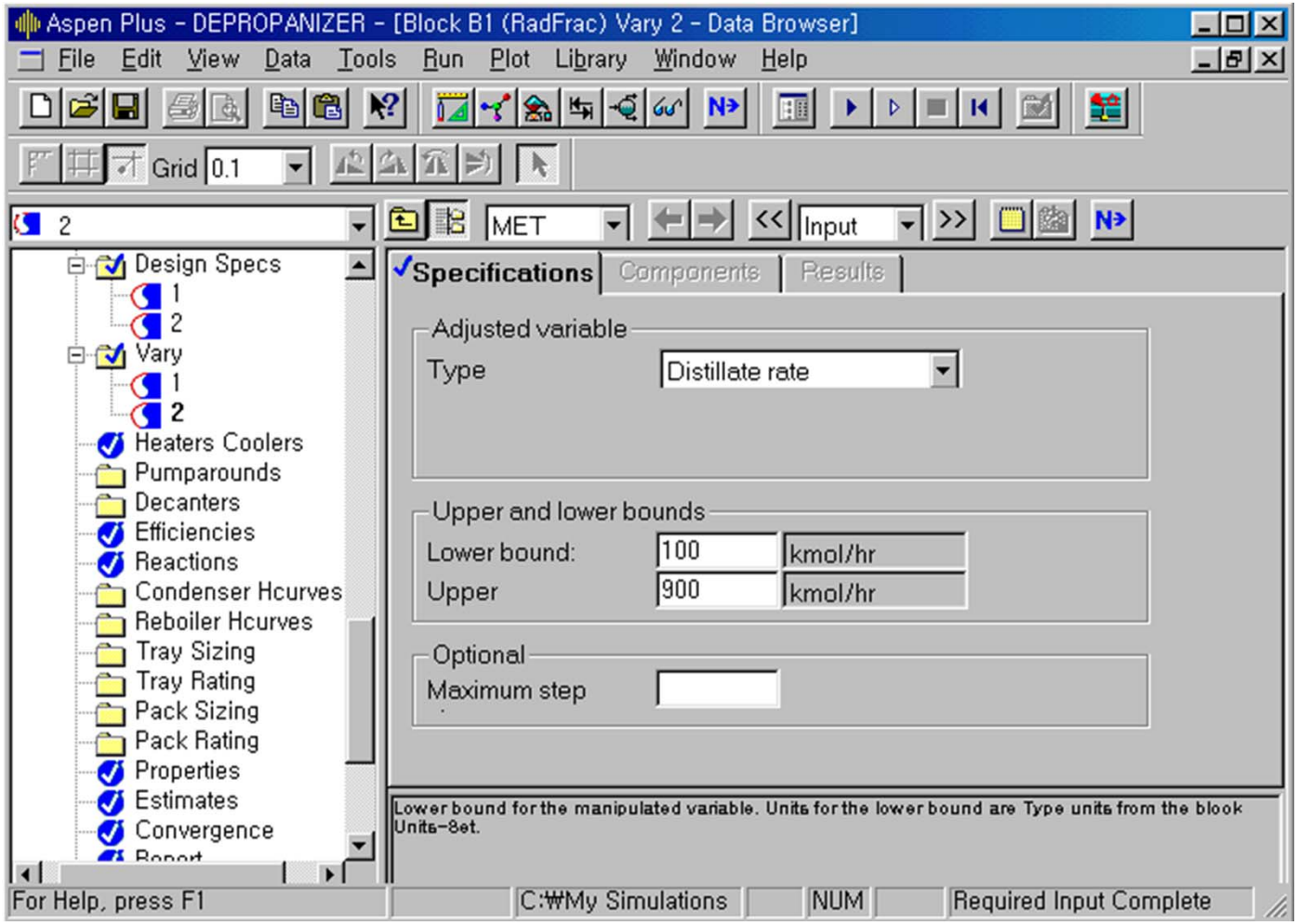
RadFrac Modeling using ASPEN PLUS

Design Spec.2: Feed/Product Streams



RadFrac Modeling using ASPEN PLUS

Vary 2: Distillate rate



PRO/II Keyword Input

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```
TITLE PROBLEM=DEWP,PROJECT=DISTILLATION,USER=JHCHO
 PRINT INPUT=ALL,PERC=M,RATE=M
COMPONENT DATA
  LIBID 1,C2/2,C3/3,NC4/4,NC5/5,NC6
THERMODYNAMIC DATA
  METHOD SYSTEM=SRK,TRANS=PURE
STREAM DATA
  PROP STREAM=1,TEMP=225,PRES=320,RATE=1000,&
       COMP=1,30/2,200/3,370/4,350/5,50
UNIT OPERATION DATA
 COLUMN UID=T01
  PARA TRAY=32,IO=100,DAMP=0.4
  FEED 1,16
  PROD OVHD=2,230,BTMS=3
  COND TYPE=PART,PRES=299
  PSPE TOP=303,DPCOL=5
  ESTI MODEL=CONV
  DUTY 1,1/2,32
  VARY DUTY=1,2
  SPEC STREAM=2,COMP=3,RATE,RATIO,STREAM=1,VALUE=0.0135
  SPEC STREAM=3,COMP=2,RATE,RATIO,STREAM=1,VALUE=0.0450
END
```

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DeC3 Column Simulation Results

	ASPEN PLUS	PRO/II
Theoretical Stage	32	32
Feed Stage	16	16
Tray Efficiency (%)	75	75
Condenser Duty (MM Btu/ Hr)	-5.1700	-5.1759
Reboiler Duty (MM Btu/ Hr)	7.8858	7.8767
Top Temperature (^{o}F)	139.3	139.3
Bottom Temperature (^{o}F)	273	273
Condenser Temperature (^{o}F)	130	130
C3 Recovery at OVHD (%)	95.50	95.50
NC4 Recovery at BTMS (%)	98.65	98.65

Tray Sizing for DeC3 Column

- For tray sizing, the diameter of each tray is adjusted to meet the flooding factor criterion (ex. FF = 85).

```
TSIZE SECTION(1)=2,15,SIEVE,FF=85
TSIZE SECTION(2)=16,31,SIEVE,FF=85
```

TRAY SIZING RESULTS

TRAY	VAPOR CFS	LIQUID HOTGPM	VLOAD CFS	-- DESIGN -- DIA, IN	FF	NP
2	5.042	199.2	1.749	41.5	85.0	1
3	5.003	197.6	1.737	41.3	85.0	1
23	5.586	534.5	2.084	57.0	85.0	1
24	5.658	542.2	2.124	57.5	85.0	1

Tray Sizing for DeC3 Column

- The entire section is then re-rated at the largest required diameter.

```
TSIZE SECTION(1)=2,15,SIEVE,FF=85
TSIZE SECTION(2)=16,31,SIEVE,FF=85

  TRAY RATING AT SELECTED DESIGN TRAYS
```

TRAY	VAPOR CFS	VLOAD CFS	DIAM IN	FF	NP	PRES DROP PSI
2	5.042	1.749	42.	83.4	1	.064
3	5.003	1.737	42.	82.8	1	.063
22	5.515	2.045	66.	60.3	1	.054
23	5.586	2.084	66.	61.4	1	.054

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Tray 와 Packing의 비교

Tray 의 장점	Packing 의 장점
• Feed Composition Variation	• Low Pressure Drop Tray에 비해 통상적으로 ¼ 정도의 작은 Pressure Drop을 갖는다.
• High Liquid Load Multi pass를 이용해서 High Liquid Load를 적절히 분배	• Small Diameter Tray : 750mm, Cartridge Type : 500mm Packing : 300mm까지 가능
• Fouling Service Fouling이 심한 유체는 Deposit이 생성되어 Packing의 경우는 Plugging에 의해 Performance 저하	• Low H.E.T.P. Tray를 Packing으로 교체할 경우 단수를 증가시키는 효과 H.E.T.P. < Tray Spacing

연락처

전화： **054-630-1148**
휴대폰 : **019-9166-2671**
홈페이지 : **http://www.edu.co.kr/jhcho65**
이메일 : **jhcho@phenix.dyu.ac.kr**
인터넷강의 : **http://infosys.korea.ac.kr**

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