

Simulation of Vapor Recompression Refrigeration Cycle

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조 정 호

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7

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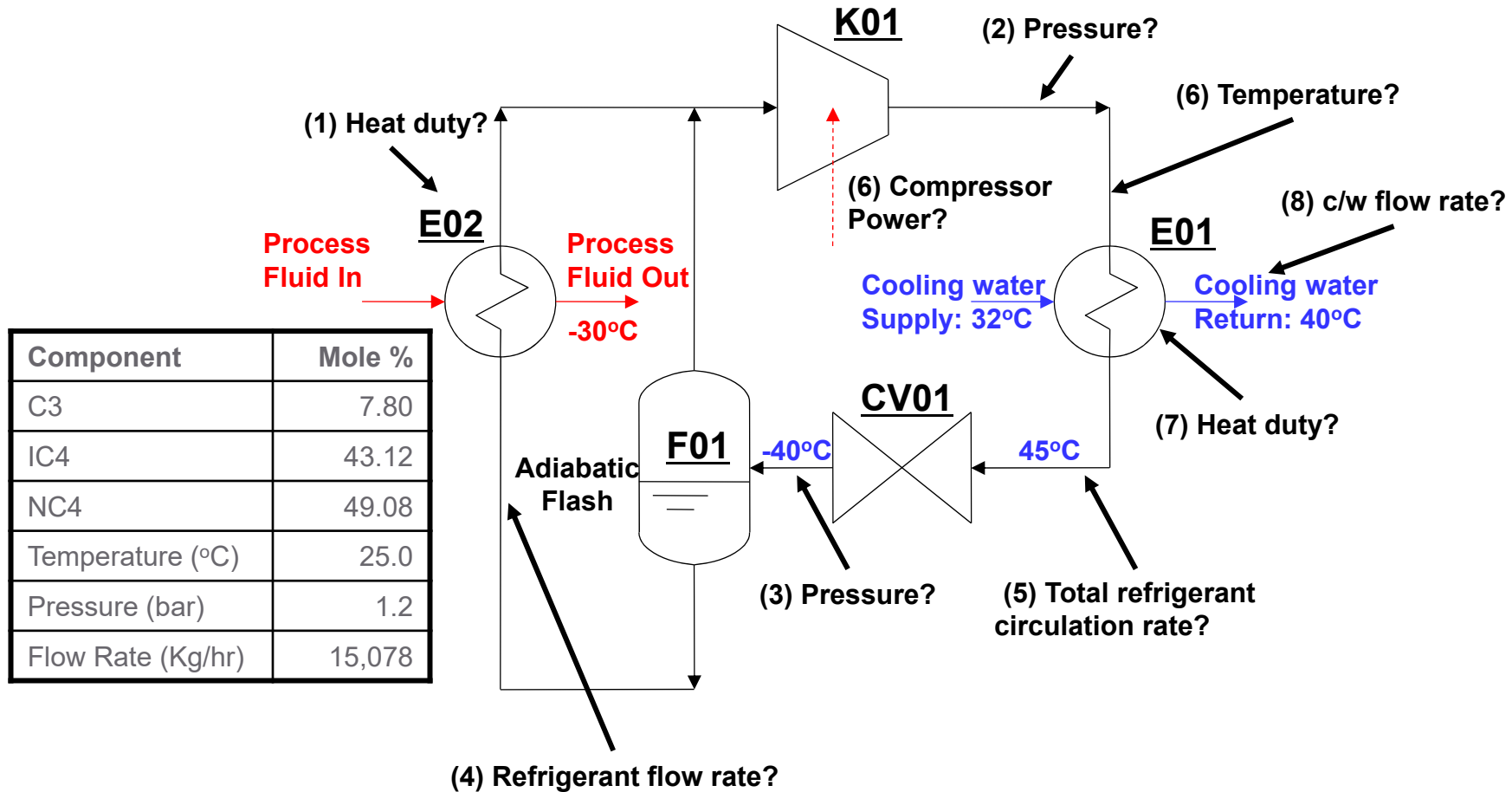
10

다른 종류의 냉동사이클에 대한 예시

1

Estimation of the Evaporator Heat Duty

Refrigeration Cycle Example:

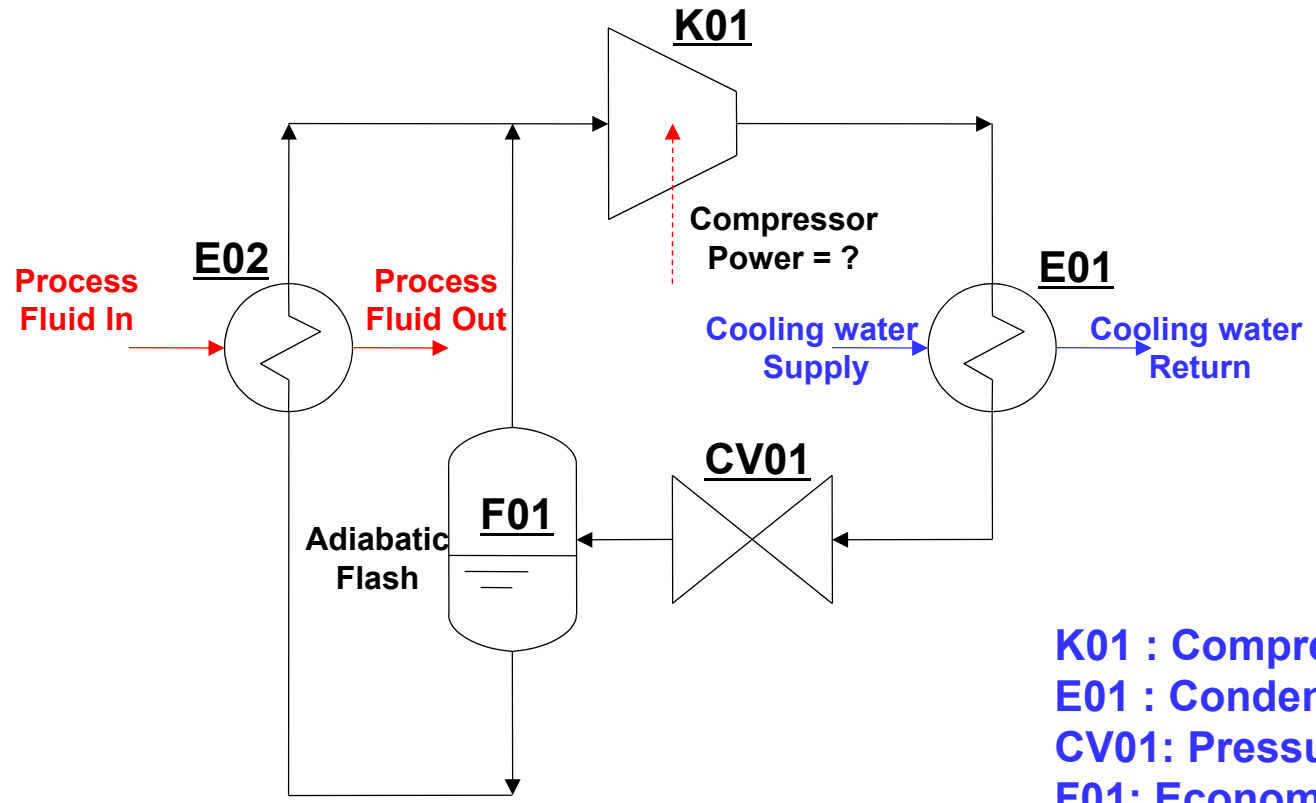


Use Peng-Robinson Equation of State.

Refrigeration Cycle Example:

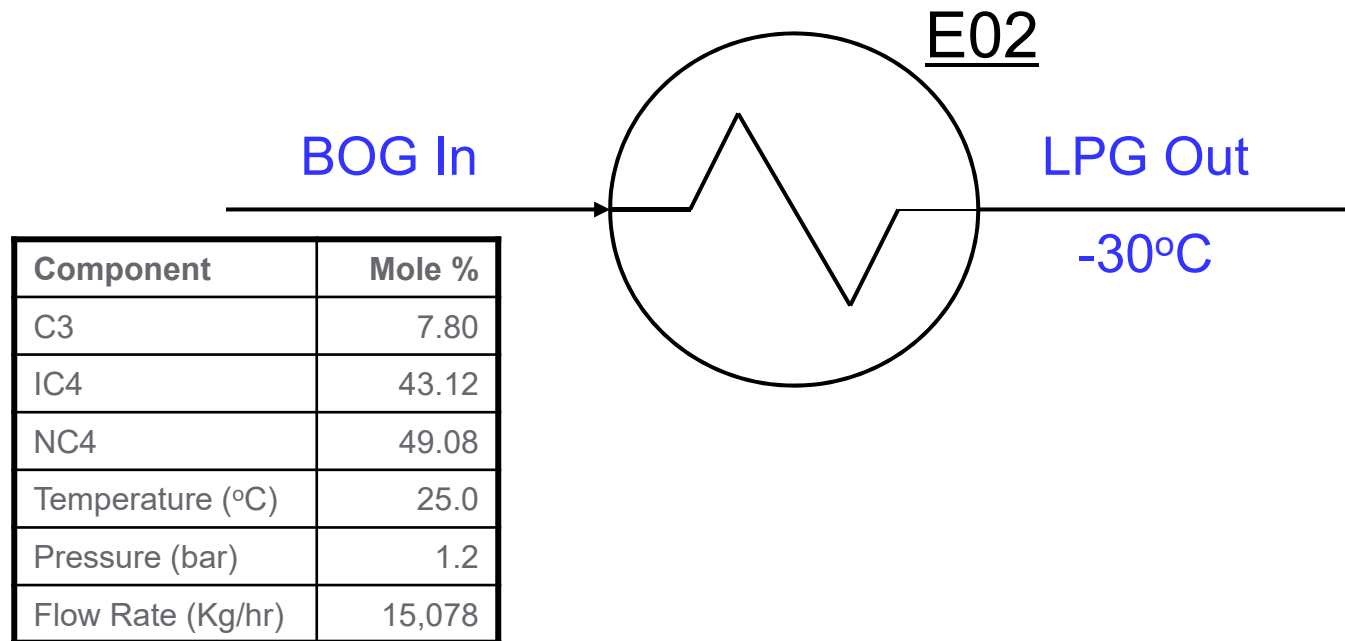
Step	Contents
0	<ul style="list-style-type: none">• Draw a schematic diagram for vapor recompression refrigeration cycle• Explain the principles of the propane refrigeration cycle
1	<ul style="list-style-type: none">• Estimate the heat duty of the evaporator in 10^6 Kcal/hr.
2	<ul style="list-style-type: none">• Determine the discharge pressure of the compressor.
3	<ul style="list-style-type: none">• Determine the outlet pressure of the expansion valve.
4	<ul style="list-style-type: none">• Determine the refrigerant mass flow rate feeding to the evaporator.
5	<ul style="list-style-type: none">• Determine the total refrigerant circulation rate.
6	<ul style="list-style-type: none">• Estimate the compressor power. Assume that that adiabatic efficiency of the compressor is 70%.• Estimate the compressor discharge temperature.
7	<ul style="list-style-type: none">• Determine the heat duty of the condenser.
8	<ul style="list-style-type: none">• Determine the cooling water consumptions in tons per hour.
9	<ul style="list-style-type: none">• Complete the overall refrigeration cycle in one PRO/II file and compare its results with each step-by-step simulation results.
10	<ul style="list-style-type: none">• Complete the overall refrigeration cycle for mixed refrigerants and compare their results with a single refrigerant simulation results.

Step 0: Draw a Schematic Diagram of the Vapor Refrigeration Cycle Using Propane

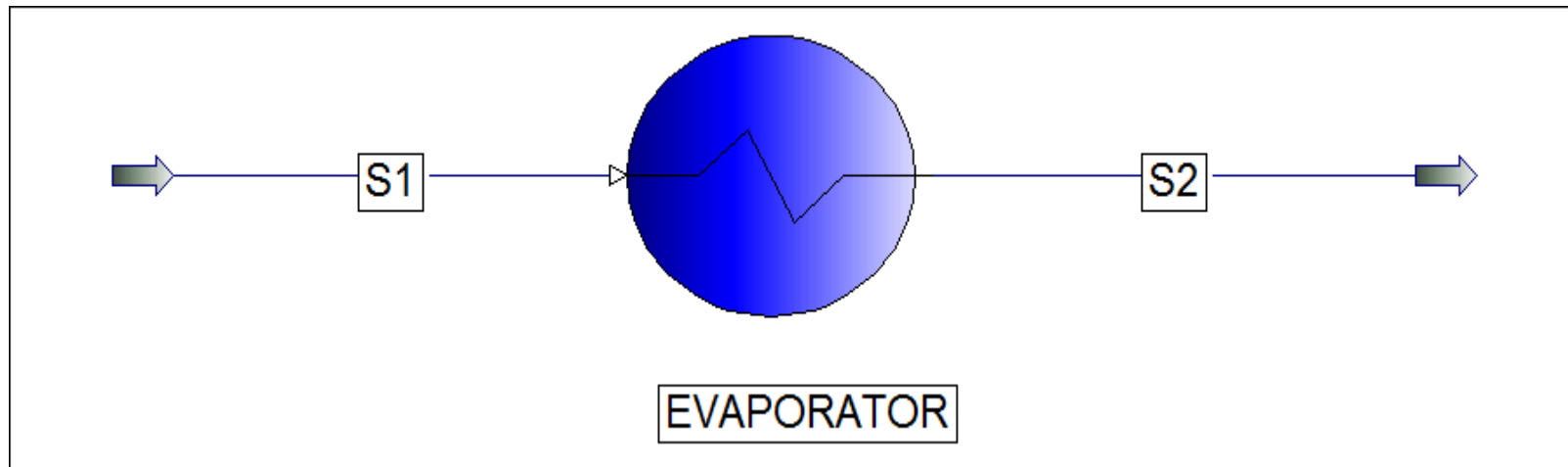


- K01 : Compressor**
- E01 : Condenser**
- CV01: Pressure Let-down Valve**
- F01: Economizer**
- E02: Evaporator**

Step 1: Evaporator Heat Duty?



Step 1: Flow Sheet Drawing



Step_01_Evaporator heat duty.prz

Step 1: Evaporator Heat Duty

Data Review Window - Simple HX - 'EVAPORATOR'

Property	Value	Units
Hx Name	EVAPORATOR	
Hx Description		
Duty	1.7115	$\times 10^6$ Kcal/hr
MTD	n/a	

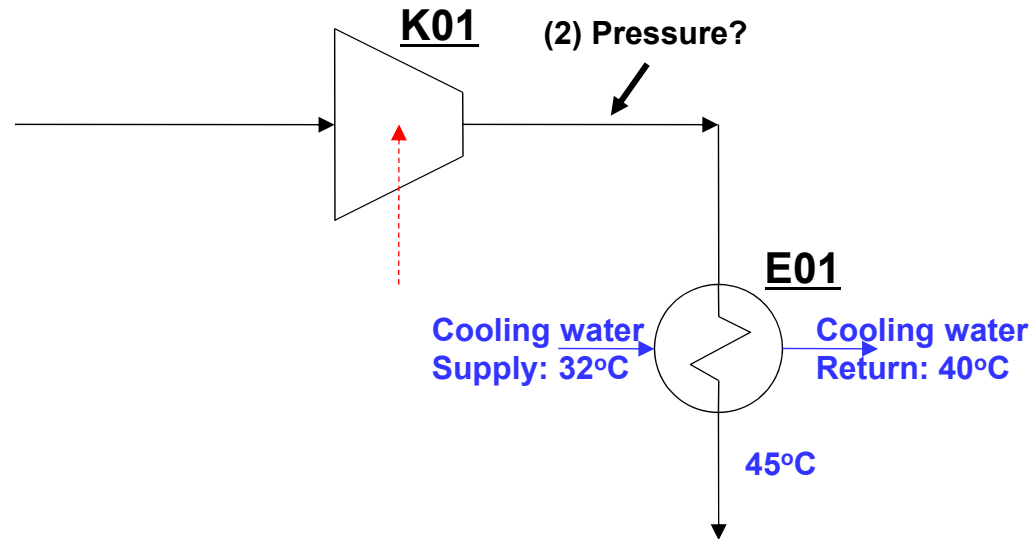
Heat Exchanger Unit

Exit the window without saving any data

2

Determination of the Compressor Discharge Pressure

Step 2: Compressor Discharge Pressure Determination

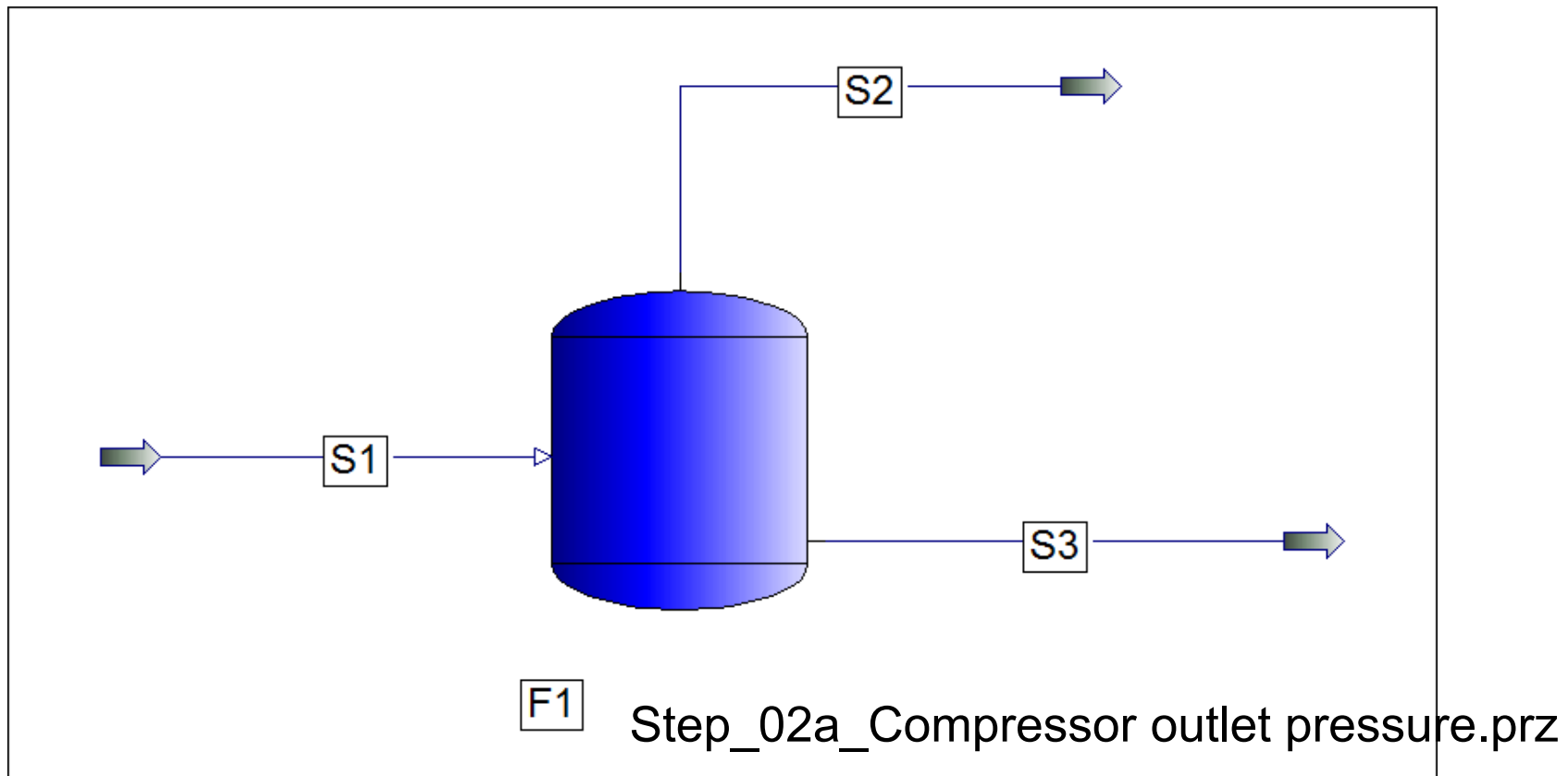


- Compressor discharge pressure is equal to....
 - When the propane refrigerant is cooled down to 45°C, it should be condensed and liquefied to saturate liquid state.
 - In principle, compressor discharge pressure is equal to the bubble point pressure of propane at 45°C using Peng-Robinson equation of state.

Step 2a: Compressor Discharge Pressure: Flash Calculation

➤ Step 2a: Using Flash module

- Bubble pressure calculation of propane at 45°C using Peng-Robinson equation of state.



Step 2a: Compressor Discharge Pressure: Flash Calculation

PRO/II - Flash Drum

UOM Define Range Help Overview Status Notes

Unit: F1 Description:

First Specification: Temperature 45.00 C Thermodynamic System: Default (PR01)

Second Specification: Unit Specification: Bubble Point Product Specification:

Parameter = value within the default tolerance

Temperature Estimate: C Pressure Estimate: bar Pseudostream Flowrate: 0.00000 kg-mol/hr Phase Assignment: Default

Product Phases... Print Options... Entrainment...

OK Cancel

Exit the window after saving all data

Step 2a: Compressor Discharge Pressure: Flash Calculation

Data Review Window - Flash (Water on Bottom) - 'F1'

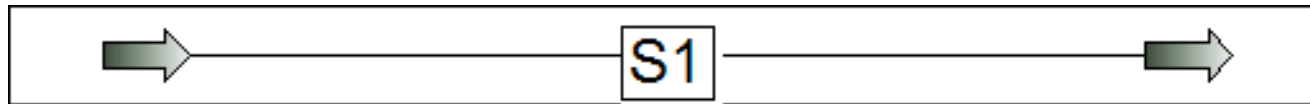
Property	Value	Units
Flash Name	F1	
Flash Description		
Temperature	45.0000	C
Pressure	15.3845	bar
DP	-14.3845	bar
Duty	-0.3204	$\times 10^6$ Kcal/hr

Flash Unit Copy Close

Exit the window without saving any data

Step 2b: Compressor Discharge Pressure: Feed Calculation

- Step 2b: Using Feed stream only
 - Feed stream thermal condition: Bubble point at 45°C using Peng-Robinson equation of state.



Step_02b_Compressor outlet pressure.prz

Step 2b: Compressor Discharge Pressure: Feed Calculation

PRO/II - Stream Data

UOM Range Help Tag Overview Status Notes

Stream: S1 Description:

To Unit: (Product Stream)

Stream Type

- Composition Defined
- Petroleum Assay
- Referenced to Stream
- Solids Only Stream

Thermal Condition

First Specification:

Temperature 45.00 C

Second Specification:

Bubble Point

Thermodynamic System: Determined From Connectivity

Exit the window after saving all data

Step 2b: Compressor Discharge Pressure: Feed Calculation

Data Review Window - Stream - 'S1'

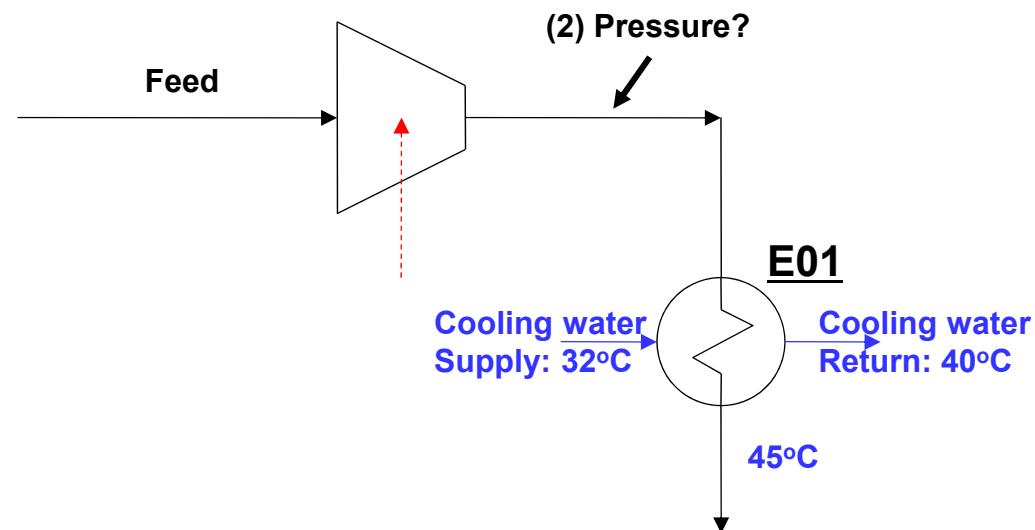
Property	Value	Units
Stream Name	S1	
Temperature	45.000	C
Pressure	15.385	bar
Flowrate	100.000	kg-mol/hr

Property Label List

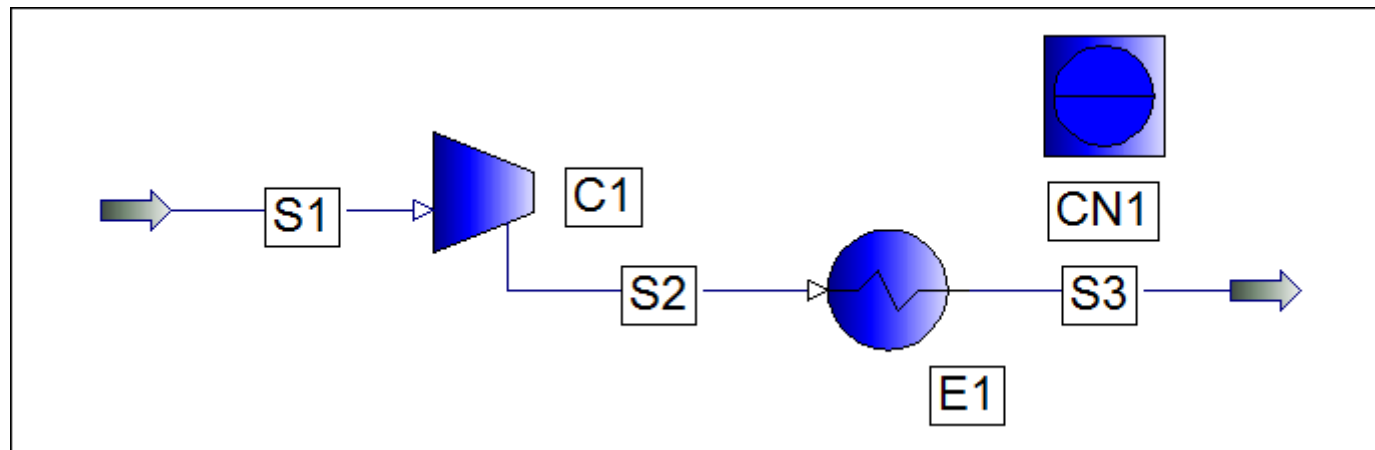
Exit the window without saving any data

Step 2c: Compressor Discharge Pressure: Using Controller

- Step 2c: Compressor and condenser system with controller
 - Feed stream thermal condition: Dew point at -40°C
 - Condenser outlet condition: saturated liquid state
 - Controller: Specify E01 outlet stream temperature as 45°C by varying the compressor discharge pressure.



Step 2c: Compressor Discharge Pressure: Using Controller



Step_02c_Compressor outlet pressure with controller.prz

Step 2c: Compressor Discharge Pressure: Using Controller

Data Review Window - Stream - 'S2'

Property	Value	Units
Stream Name	S2	
Temperature	84.901	C
Pressure	15.384	bar
Flowrate	100.000	kg-mol/hr

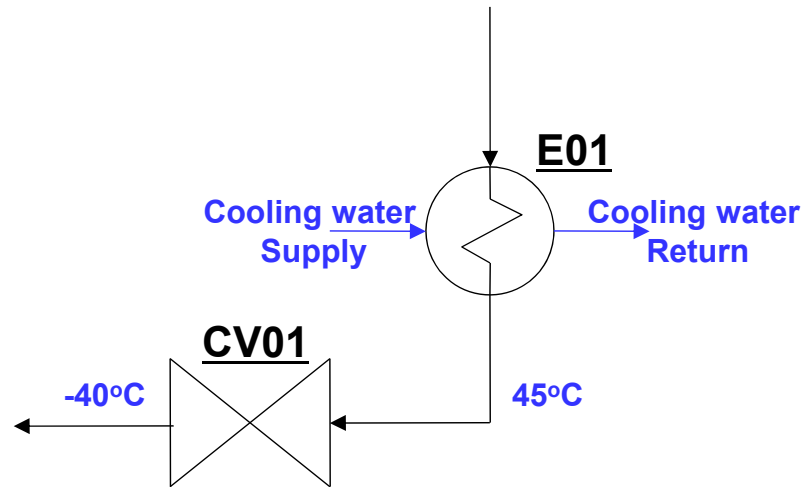
Property Label List

Exit the window without saving any data

3

Determination of the Valve Outlet Pressure

Step 3: Expansion Valve Outlet Pressure

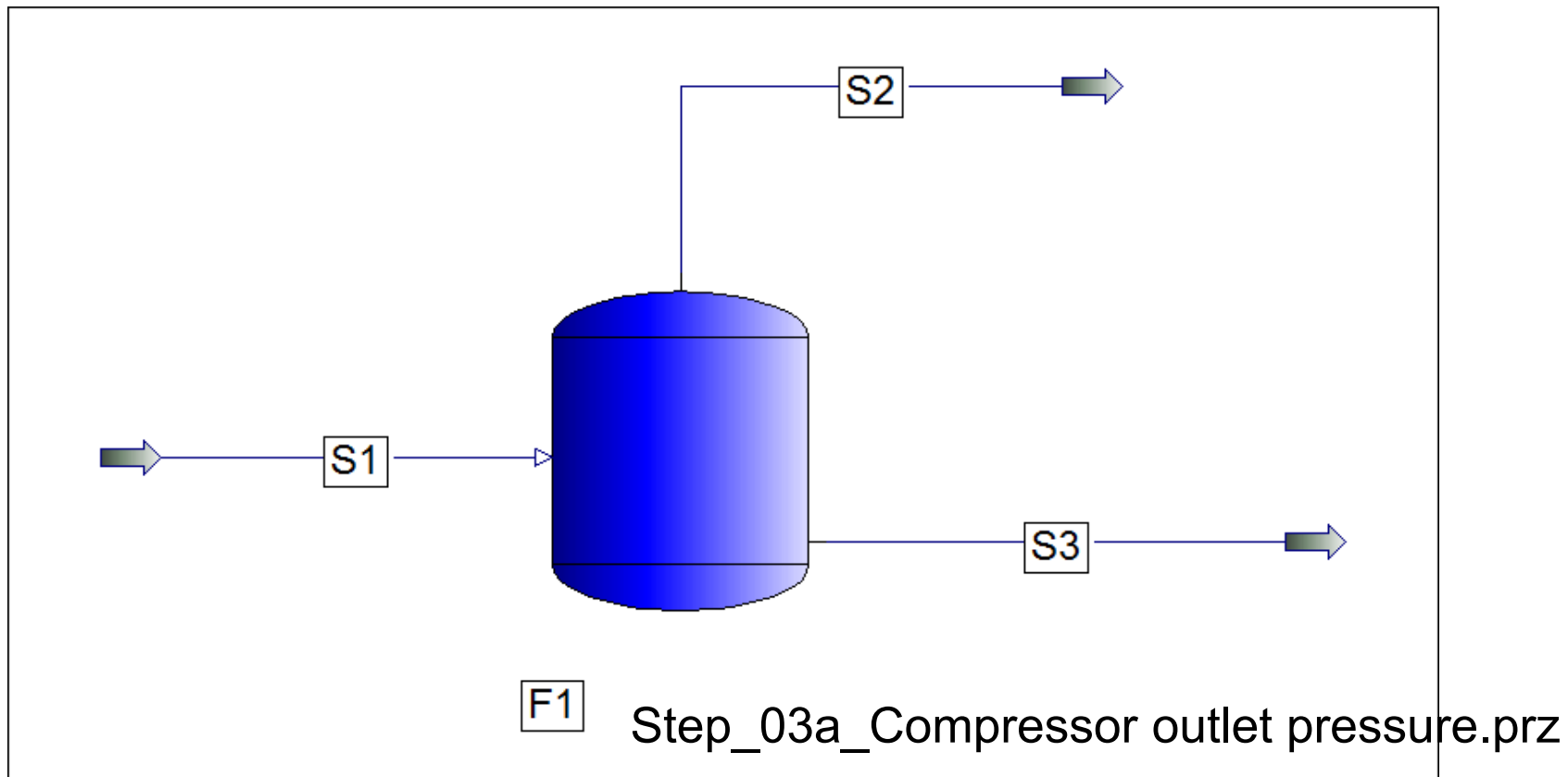


- Expansion valve outlet pressure is equal to....
- When the propane refrigerant is expanded to a lower pressure from the saturated liquid state at 45°C, propane temperature should be lowered to -40°C.
 - In principle, expansion valve outlet pressure is equal to the dew point pressure of propane at -40°C using Peng-Robinson equation of state.

Step 3a: Expansion Valve Outlet Pressure: Flash Calculation

➤ Step 3a: Using Flash module

- Dew pressure calculation of propane at -40°C using Peng-Robinson equation of state.



Step 3a: Expansion Valve Outlet Pressure: Flash Calculation

PRO/II - Flash Drum

UOM Define Range Help Overview Status Notes

Unit: Description:

First Specification

C

Thermodynamic System:

Second Specification

Unit Specification:

Product Specification:

Parameter = value within the default tolerance

Temperature Estimate: C

Pressure Estimate: bar

Pseudostream Flowrate: kg-mol/hr

Phase Assignment:

Exit the window after saving all data

Step 3a: Expansion Valve Outlet Pressure: Flash Calculation

Data Review Window - Flash (Water on Bottom) - 'F1'

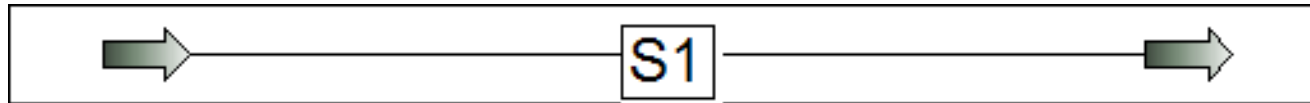
Property	Value	Units
Flash Name	F1	
Flash Description		
Temperature	-40.0000	C
Pressure	1.1143	bar
DP	-0.1143	bar
Duty	-0.1056	$\times 10^6$ Kcal/hr

Flash Unit Copy Close

Exit the window without saving any data

Step 3b: Expansion Valve Outlet Pressure: Feed Flash

- Step 3b: Using Feed stream only
 - Feed stream thermal condition: Bubble point at 45°C using Peng-Robinson equation of state.



Step_03b_Compressor outlet pressure.prz

Step 3b: Expansion Valve Outlet Pressure: Feed Flash

PRO/II - Stream Data

UOM Range Help Tag Overview Status Notes

Stream: S1 Description:

To Unit: (Product Stream)

Stream Type

- Composition Defined
- Petroleum Assay
- Referenced to Stream
- Solids Only Stream

Thermal Condition

First Specification:

Temperature -40.00 C

Second Specification:

Dew Point

Thermodynamic System: Determined From Connectivity

Exit the window after saving all data

Step 3b: Expansion Valve Outlet Pressure: Feed Flash

Data Review Window - Stream - 'S1'

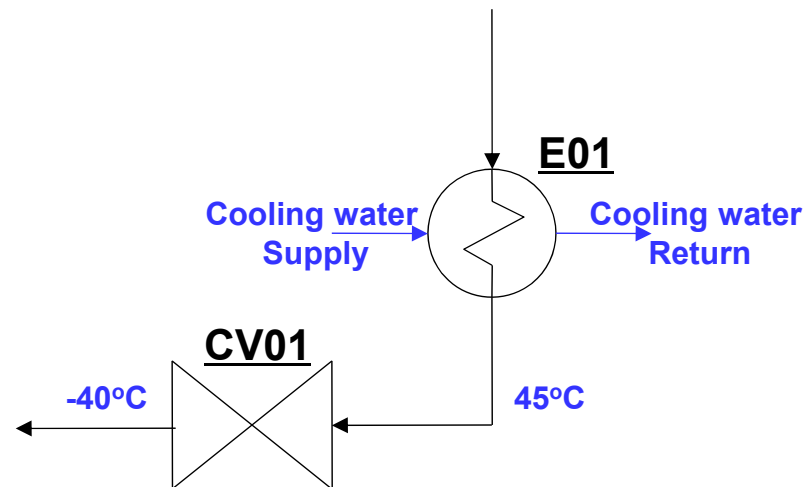
Property	Value	Units
Stream Name	S1	
Temperature	-40.000	C
Pressure	1.114	bar
Flowrate	100.000	kg-mol/hr

Property Label List

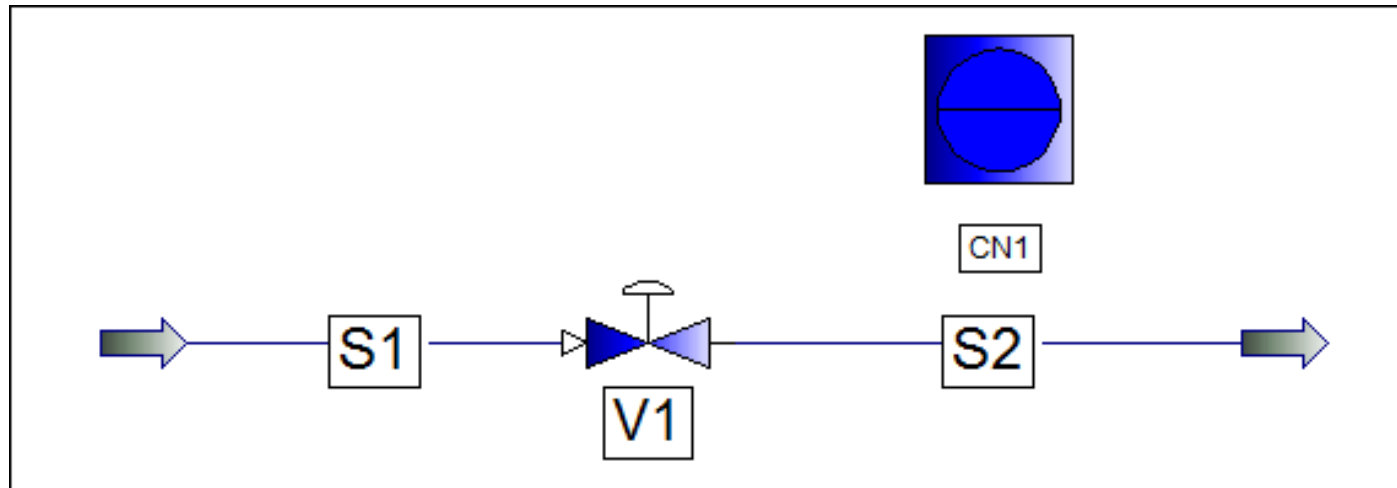
Exit the window without saving any data

Step 3c: Expansion Valve Outlet Pressure: Using Controller

- Step 3c: Compressor and condenser system with controller
 - Feed stream thermal condition: Bubble point at 45°C
 - Controller: Specify CV01 outlet stream temperature as -40°C by varying the expansion valve outlet pressure.



Step 3c: Expansion Valve Outlet Pressure: Using Controller



Step_03c_Expansion valve outlet pressure with controller.prz

Step 3c: Expansion Valve Outlet Pressure: Using Controller

PRO/II - Stream Data

UOM	Range	Help	Tag	Overview	Status	Notes
-----	-------	------	-----	----------	--------	-------

Stream: S1 Description:

To Unit: V1

Stream Type

- Composition Defined
- Petroleum Assay
- Referenced to Stream
- Solids Only Stream

Flowrate and Composition...

Stream Solids Data...

Stream Polymer Data...

Thermal Condition

First Specification:

Temperature 45.00 C

Second Specification:

Bubble Point

Thermodynamic System: Determined From Connectivity

OK Cancel

Exit the window after saving all data

Step 3c: Expansion Valve Outlet Pressure: Using Controller

PRO/II - Valve

UOM Define Range Help Overview Status Notes

Unit: V1 Description:

Product Phases...

Operating Parameter

Pressure Drop: bar

Outlet Pressure: 1.3000 bar

Thermodynamic System:
Default (PR01)

OK Cancel

Exit the window after saving all data

Step 3c: Expansion Valve Outlet Pressure: Using Controller

PRO/II - Feedback Controller

UOM Range Help Overview Status Notes

Unit: Description:

Specification
[Stream S2 Temperature in C = -40.000](#) within [the default tolerance](#)

Variable
[Valve V1 Pressure in bar](#)

Parameters
Maximum Number of Iterations: Print Results for Each Iteration

Action if Minimum/Maximum Limits are reached

- Accept as Solved if Limits are Reached
- Fail Unit and Stop Calculations if Limits are Reached
- Fail Unit and Continue Calculations if Limits are Reached

Next Unit Calculated after Control Variable is Changed:

Exit the window after saving all data

Step 3c: Expansion Valve Outlet Pressure: Using Controller

Data Review Window - Stream - 'S2'

Property	Value	Units
Stream Name	S2	
Temperature	-40.000	C
Pressure	1.114	bar
Flowrate	100.000	kg-mol/hr

Property Label List

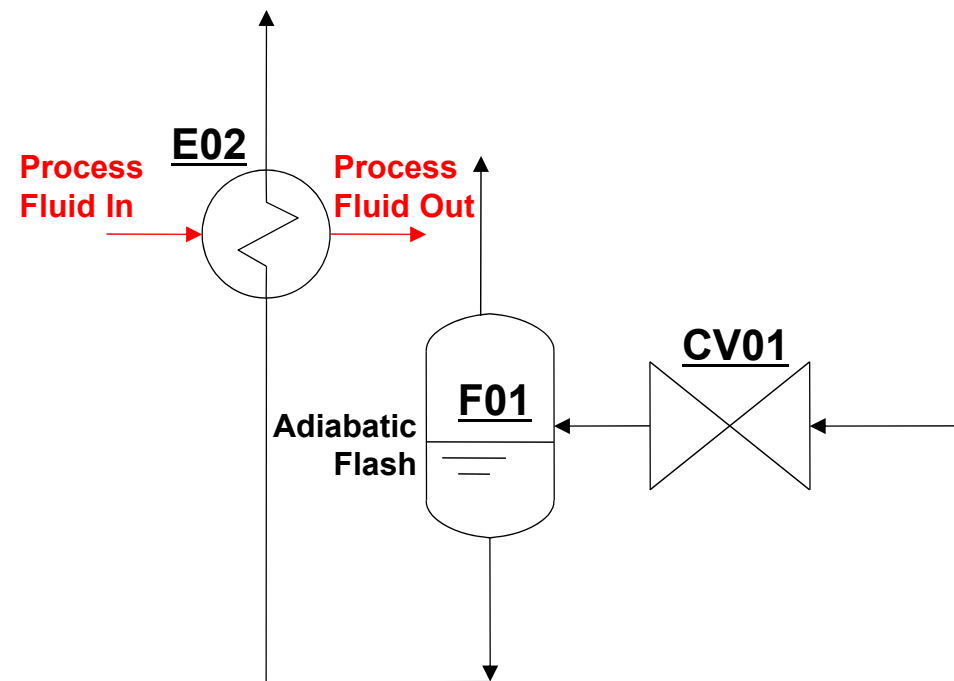
Exit the window without saving any data

4

Estimation of the Refrigerant Flow Rate to Evaporator

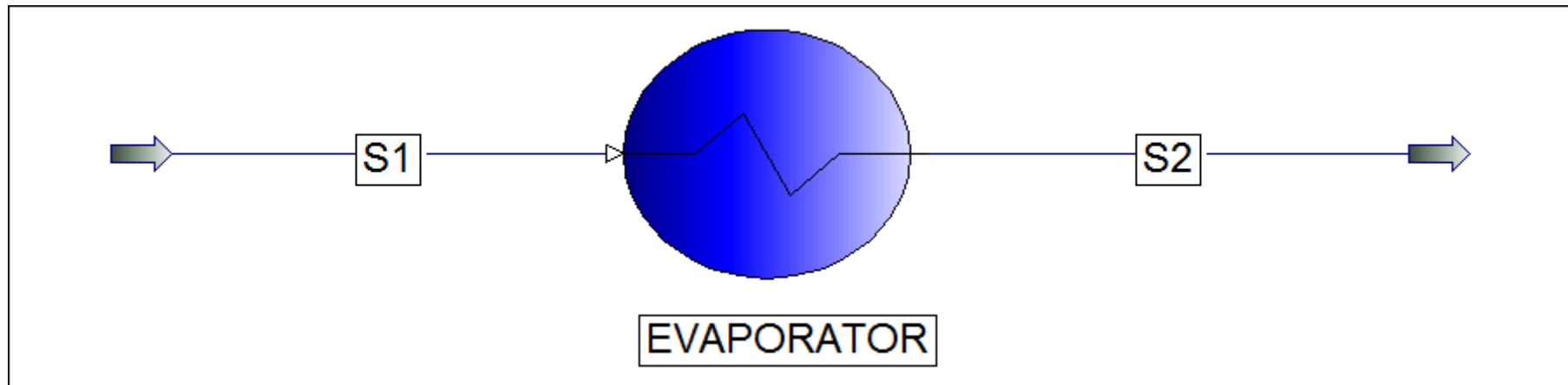
Step 4: Refrigerant Flow Rate to the Evaporator

- Refrigerant flow rate feeding the evaporator
 - Use utility option in evaporator simulation.
 - In principle, expansion valve outlet pressure is equal to the dew point pressure of propane at -40°C using Peng-Robinson equation of state.



Step 4a: Refrigerant Flow Rate to the Evaporator: Utility

- Step 4a: Use Utility option in HX
 - Choose propane as a refrigerant for cold side stream fluid.



Step_04a_Refrigerant flowrate to the evaporator.prz

Step 4a: Refrigerant Flow Rate to the Evaporator: Utility

PRO/II - Heat Exchanger

UOM Define Range Help Overview Status Notes

Unit: EVAPORATOR Description:

Hot Side

Process Stream...
Utility Stream...
Attach to Column...

Pressure Drop: 0.00000 bar

Thermodynamic System: Default (PR01)

Cold Side

Process Stream...
Utility Stream...
Attach to Column...

Pressure Drop: 0.00000 bar

Thermodynamic System: Default (PR01)

Specification...
Configuration...
Zones Analysis...
Print Options...

OK
Cancel

Exit the window after saving all data

Step 4a: Refrigerant Flow Rate to the Evaporator: Utility

Heat Exchanger - Cold Side Utility

UOM Define Range Help

Use Utility for Cold Side

Utility Type

Water

Air

Refrigerant

Water or Air Inlet and Outlet Conditions

Inlet Temperature: C

Outlet Temperature: C

Refrigerant Component Selection and Saturation Conditions

Component:

Saturation Conditions:

Pressure: bar

Temperature: C

Thermo Method for Air Cp Calculation

Ideal Thermo Method

Compatible with Simple HX Air Ver. 8.2 and earlier

Exit the window after saving all data

Step 4a: Refrigerant Flow Rate to the Evaporator: Utility

OPERATING CONDITIONS

DUTY, M*KCAL/HR 1.712
LMTD, C 29.383

HOT SIDE CONDITIONS

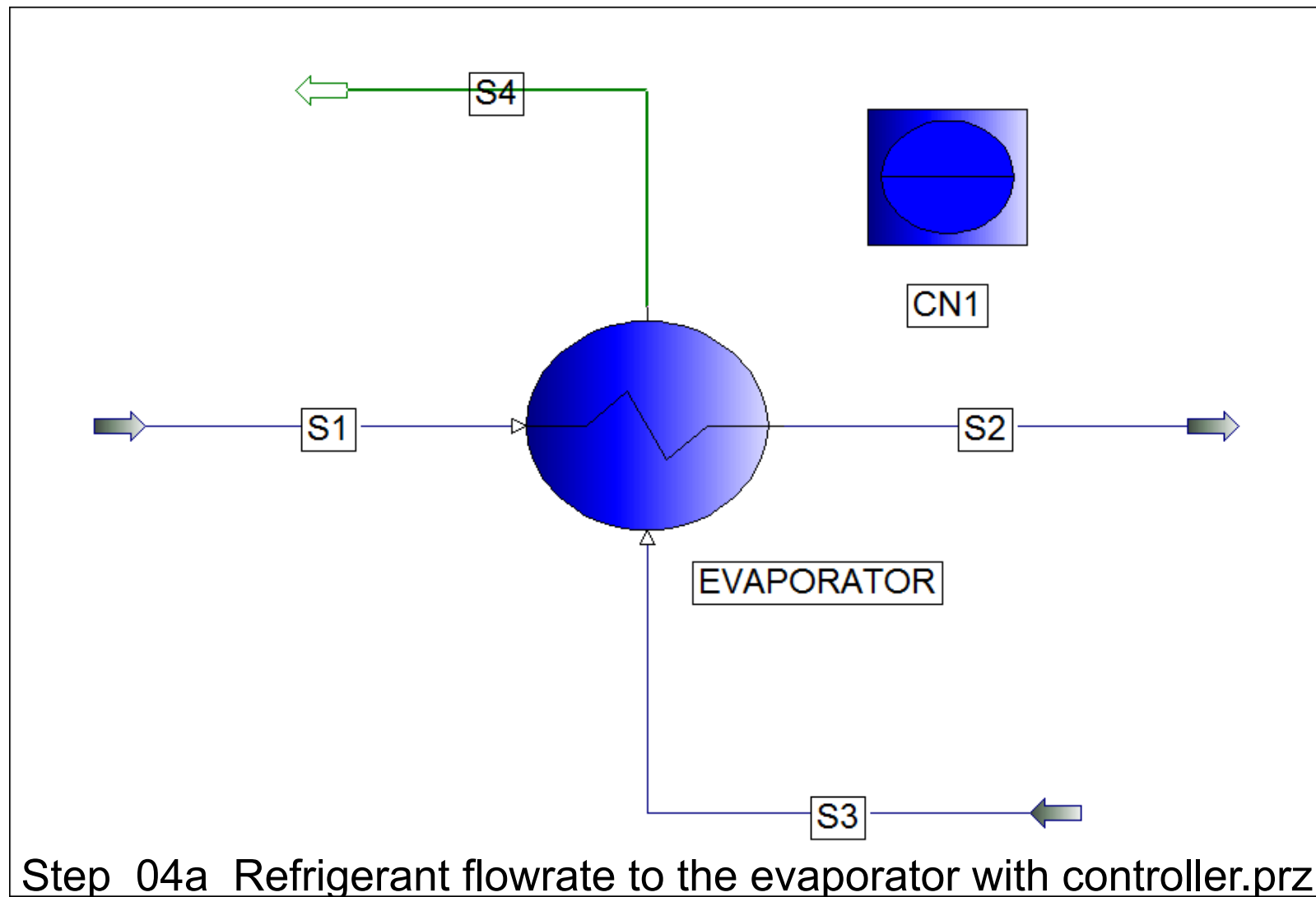
	INLET	OUTLET
	-----	-----
FEED	S1	
LIQUID PRODUCT		S2
VAPOR, KG-MOL/HR	264.390	
K*KG/HR	15.078	
CP, KCAL/KG-C	0.404	
LIQUID, KG-MOL/HR		264.390
K*KG/HR		15.078
CP, KCAL/KG-C		0.490
TOTAL, KG-MOL/HR	264.390	264.390
K*KG/HR	15.078	15.078
CONDENSATION, KG-MOL/HR		264.390
TEMPERATURE, C	25.000	-30.000
PRESSURE, BAR	1.200	1.200

COLD SIDE CONDITIONS

	INLET	OUTLET
	-----	-----
REFRIGERANT, KG/HR	16946.501	16946.501
SATURATION PRESSURE, BAR	<u>1.109</u>	
SATURATION TEMPERATURE, C	-40.000	

1.1143 bar

Step 4b: Refrigerant Flow Rate to the Evaporator: Controller



Step 4b: Refrigerant Flow Rate to the Evaporator: Controller

PRO/II - Stream Data

UOM Range Help Tag Overview Status Notes

Stream: S1 Description:

To Unit: EVAPORATOR

Stream Type

- Composition Defined
- Petroleum Assay
- Referenced to Stream
- Solids Only Stream

Flowrate and Composition...

Stream Solids Data...

Stream Polymer Data...

Thermal Condition

First Specification:

Temperature 25.00 C

Second Specification:

Pressure 1.2000 bar

Thermodynamic System: Determined From Connectivity

OK Cancel

Exit the window after saving all data

Step 4b: Refrigerant Flow Rate to the Evaporator: Controller

Stream Data - Flowrate and Composition

UOM Range Help Tag

Specify flowrate and composition for stream S1

Fluid Flowrate Specification

Total Fluid Flowrate: kg/hr Total LV or GV rate on an Adjusted Standard Basis

Individual Component Flowrates

Component Concentrations

Total Fluid Flowrate: kg-mol/hr

Copy	Component	Composition
Paste	C3	7.8000
	IC4	49.080
	NC4	43.120

Clear Compositions Total: 100.00

Normalize Component Flowrates Based on Specified Fluid Flowrate

Exit the window after saving all data

Step 4b: Refrigerant Flow Rate to the Evaporator: Controller

PRO/II - Stream Data

UOM Range Help Tag Overview Status Notes

Stream: S3 Description:

To Unit: EVAPORATOR

Stream Type

- Composition Defined
- Petroleum Assay
- Referenced to Stream
- Solids Only Stream

Flowrate and Composition...

Stream Solids Data...

Stream Polymer Data...

Thermal Condition

First Specification:

Temperature -40.00 C

Second Specification:

Bubble Point

Thermodynamic System: Determined From Connectivity

OK Cancel

Exit the window after saving all data

Step 4b: Refrigerant Flow Rate to the Evaporator: Controller

Stream Data - Flowrate and Composition

UOM Range Help Tag

Specify flowrate and composition for stream S3

Fluid Flowrate Specification

Total Fluid Flowrate: kg/hr Total LV or GV rate on an Adjusted Standard Basis

Individual Component Flowrates

Component Concentrations

Total Fluid Flowrate: kg-mol/hr

Copy	Component	Composition
Paste		Mole
	C3	<input type="text" value="100.00"/>
	IC4	<input type="text"/>
	NC4	<input type="text"/>

Total: 100.00

Normalize Component Flowrates Based on Specified Fluid Flowrate

Exit the window after saving all data

Step 4b: Refrigerant Flow Rate to the Evaporator: Controller

Heat Exchanger - Specifications

UOM Define Range Help

Specification: Cold Product Liquid Fraction

Value: 0.00000

Relative Tolerance: 0.000100

Area: m²

U-Value: kcal/hr-m²-K

Maximum Allowable U*A: kcal/hr-K

OK Cancel

Exit the window after saving all data

Step 4b: Refrigerant Flow Rate to the Evaporator: Controller

PRO/II - Feedback Controller

UOM Range Help Overview Status Notes

Unit: Description:

Specification
[Heat Exchanger EVAPORATOR Duty in x 10⁶ Kcal/hr = 1.7115](#) within [the default tolerance](#)

Variable
[Stream S3 Flowrate in kg/hr](#)

Parameters
Maximum Number of Iterations: Print Results for Each Iteration

Action if Minimum/Maximum Limits are reached

- Accept as Solved if Limits are Reached
- Fail Unit and Stop Calculations if Limits are Reached
- Fail Unit and Continue Calculations if Limits are Reached

Next Unit Calculated after Control Variable is Changed:

Exit the window after saving all data

Step 4b: Refrigerant Flow Rate to the Evaporator: Controller

OPERATING CONDITIONS

DUTY, M*KCAL/HR **1.712**

HOT SIDE CONDITIONS

	INLET	OUTLET
	-----	-----
FEED	S1	
TOTAL, KG-MOL/HR	264.390	264.390
K*KG/HR	15.078	15.078
CONDENSATION, KG-MOL/HR		264.390
TEMPERATURE, C	25.000	-30.000
PRESSURE, BAR	1.200	1.200

COLD SIDE CONDITIONS

	INLET	OUTLET
	-----	-----
FEED	S3	
VAPOR PRODUCT		S4
TOTAL, KG-MOL/HR	385.053	385.053
K*KG/HR	16.979	16.979
VAPORIZATION, KG-MOL/HR		385.053
TEMPERATURE, C	-40.000	-40.000
PRESSURE, BAR	1.114	1.114

Step 4b: Refrigerant Flow Rate to the Evaporator: Controller

STREAM ID		S1	S2	S3	S4
NAME					
PHASE		VAPOR	LIQUID	LIQUID	VAPOR
THERMO ID		PR01	PR01	PR01	PR01
FLUID RATES, KG/HR					
1	C3	909.3783	909.3783	16979.4860	16979.4860
2	IC4	7542.2557	7542.2557	0.0000	0.0000
3	NC4	6626.3660	6626.3660	0.0000	0.0000
TOTAL RATE, KG/HR		15078.0000	15078.0000	16979.4860	16979.4860
TEMPERATURE, C		25.0000	-29.9966	-40.0000	-40.0000
PRESSURE, BAR		1.2000	1.2000	1.1143	1.1143
ENTHALPY, M*KCAL/HR		1.5001	-0.2114	-0.3596	1.3519
MOLECULAR WEIGHT		57.0293	57.0293	44.0965	44.0965
WEIGHT FRAC VAPOR		1.0000	0.0000	0.0000	1.0000
WEIGHT FRAC LIQUID		0.0000	1.0000	1.0000	0.0000

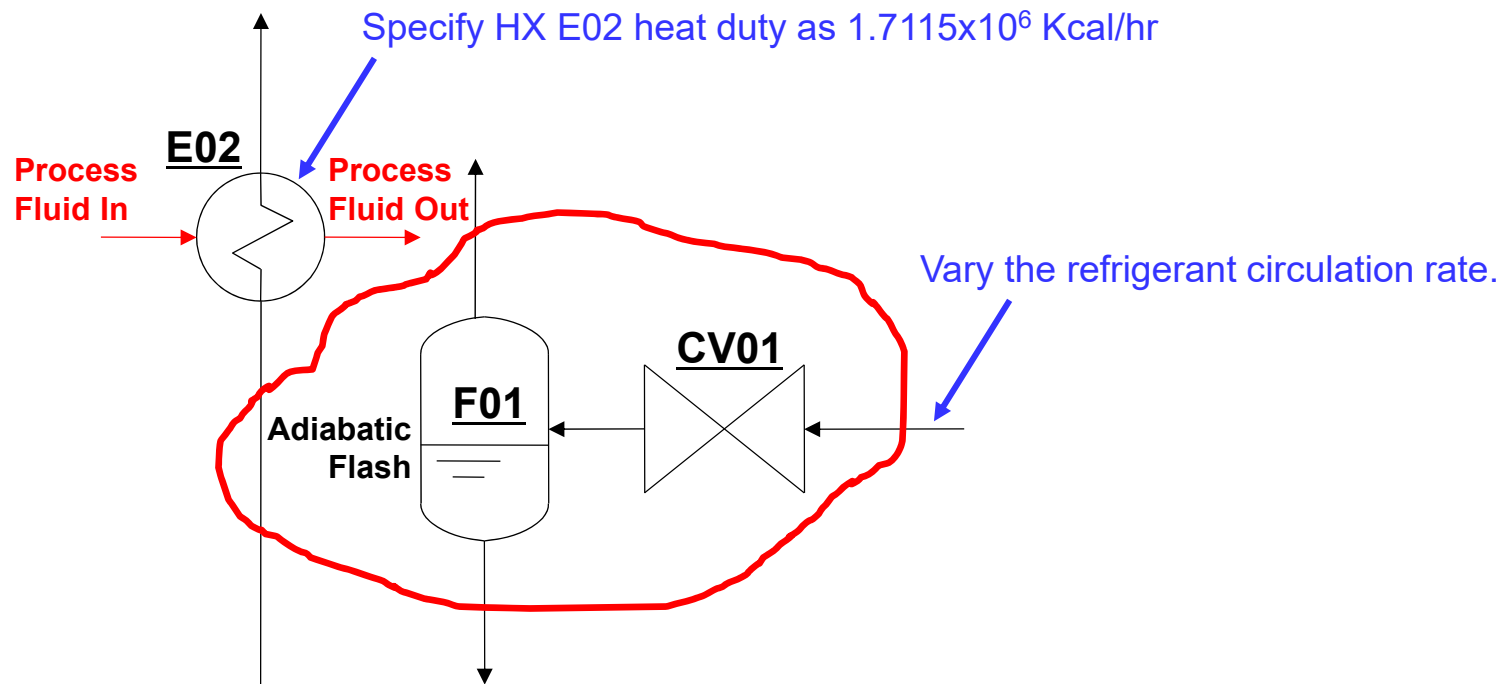
5

Estimation of the Total Refrigerant Circulation Rate

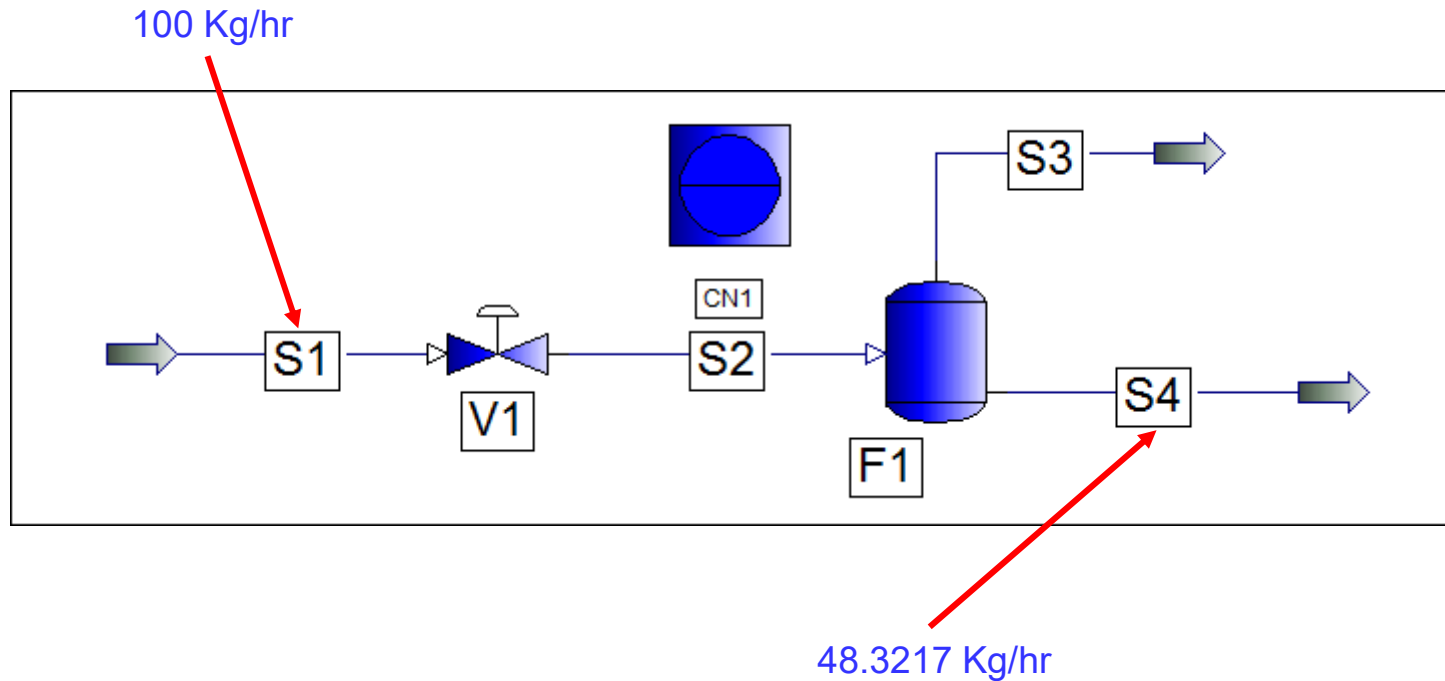
Step 5: Total Refrigerant Flow Rate

➤ Total refrigerant circulation rate

- A: Use proportional relation with valve and flash module
- B: Specify heat exchanger In principle, expansion valve outlet pressure is equal to the dew point pressure of propane at -40°C using Peng-Robinson equation of state.



Step 5a: Total Refrigerant Flow Rate



$$100 : 48.3217 = x : 16,979.486$$

$$x = 35,138.4285$$

Step_05a_Total refrigerant circulation rate.prz

Step 5a: Total Refrigerant Flow Rate

PRO/II - Feedback Controller

UOM Range Help Overview Status Notes

Unit: Description:

Specification
[Stream S2 Temperature in C = -40.000](#) within [an absolute tolerance of 1.0000e-006](#)

Variable
[Valve V1 Pressure in bar](#)

Parameters
Maximum Number of Iterations: Print Results for Each Iteration

Action if Minimum/Maximum Limits are reached

- Accept as Solved if Limits are Reached
- Fail Unit and Stop Calculations if Limits are Reached
- Fail Unit and Continue Calculations if Limits are Reached

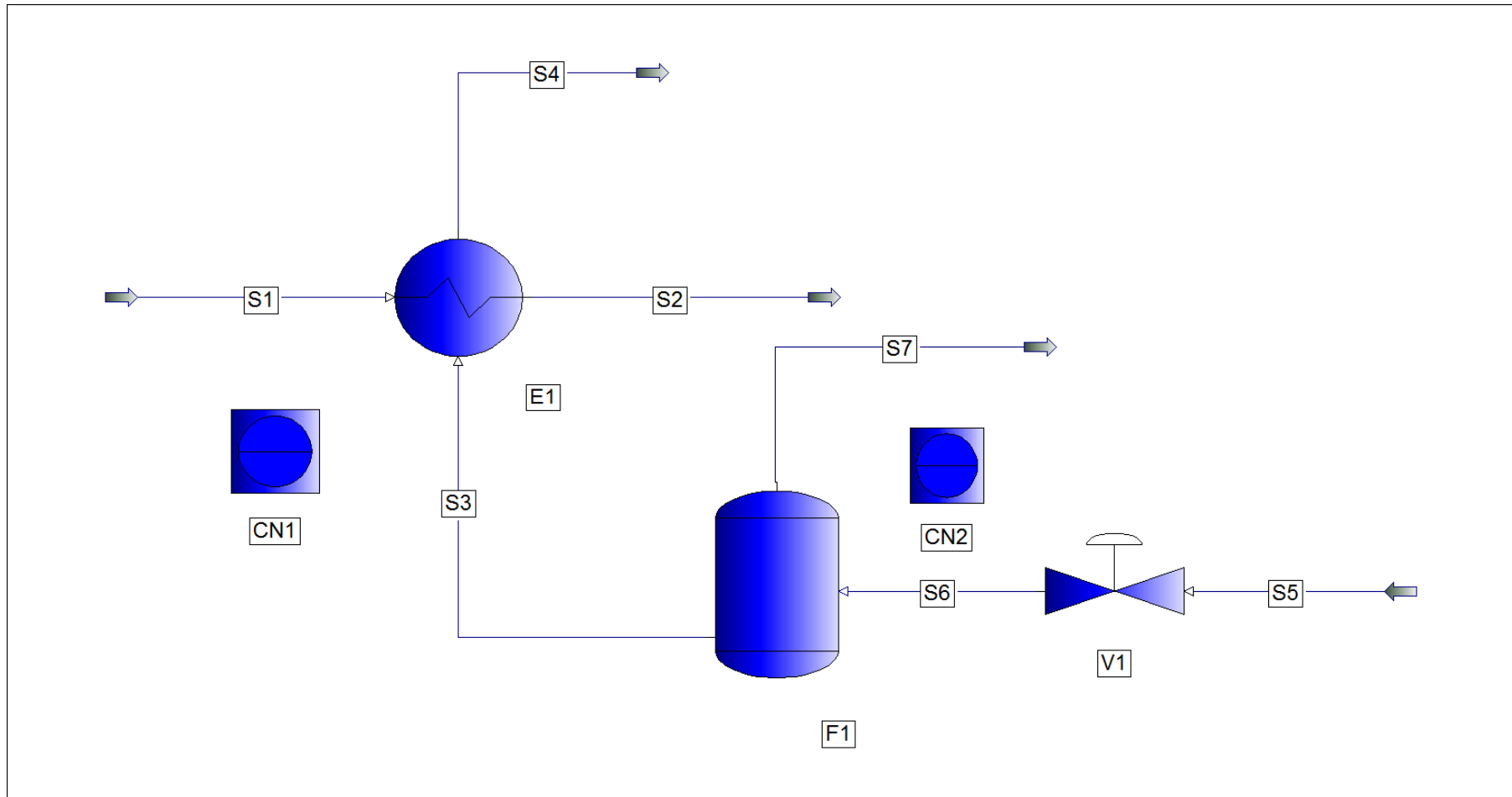
Next Unit Calculated after Control Variable is Changed:

Exit the window after saving all data

Step 5a: Total Refrigerant Flow Rate

STREAM ID		S1	S2	S3	S4
NAME					
PHASE		LIQUID	MIXED	VAPOR	LIQUID
THERMO ID		PR01	PR01	PR01	PR01
FLUID RATES, KG/HR					
1	C3	100.0000	100.0000	51.6783	48.3217
2	IC4	0.0000	0.0000	0.0000	0.0000
3	NC4	0.0000	0.0000	0.0000	0.0000
TOTAL RATE, KG/HR		100.0000	100.0000	51.6783	48.3217
TEMPERATURE, C		45.0000	-40.0000	-40.0000	-40.0000
PRESSURE, BAR		15.3845	1.1143	1.1143	1.1143
ENTHALPY, M*KCAL/HR		3.0915E-03	3.0915E-03	4.1148E-03	-1.0232E-03
MOLECULAR WEIGHT		44.0965	44.0965	44.0965	44.0965
WEIGHT FRAC VAPOR		0.0000	0.5168	1.0000	0.0000
WEIGHT FRAC LIQUID		1.0000	0.4832	0.0000	1.0000

Step 5b: Total Refrigerant Flow Rate: Controllers



Step_05b_Total refrigerant circulation rate with controller.prz

Step 5b: Total Refrigerant Flow Rate: Controllers

PRO/II - Stream Data

UOM	Range	Help	Tag	Overview	Status	Notes
-----	-------	------	-----	----------	--------	-------

Stream: S5 Description:

To Unit: V1

Stream Type

- Composition Defined
- Petroleum Assay
- Referenced to Stream
- Solids Only Stream

Thermal Condition

First Specification:

Temperature C

Second Specification:

Bubble Point

Thermodynamic System:

Exit the window after saving all data

Step 5b: Total Refrigerant Flow Rate: Controllers

Stream Data - Flowrate and Composition

UOM Range Help Tag

Specify flowrate and composition for stream S5

Fluid Flowrate Specification

Total Fluid Flowrate: kg/hr Total LV or GV rate on an Adjusted Standard Basis

Individual Component Flowrates

Component Concentrations

Total Fluid Flowrate: kg-mol/hr

Copy	Component	Composition
Paste	C3	100.00
	IC4	
	NC4	

Clear Compositions Total: 100.00

Normalize Component Flowrates Based on Specified Fluid Flowrate

Exit the window after saving all data

Step 5b: Total Refrigerant Flow Rate: Controllers

PRO/II - Feedback Controller

UOM Range Help Overview Status Notes

Unit: Description:

Specification
[Stream S6 Temperature in C = -40.000](#) within [an absolute tolerance of 1.0000e-006](#)

Variable
[Valve V1 Pressure in bar](#)

Parameters
Maximum Number of Iterations: Print Results for Each Iteration

Action if Minimum/Maximum Limits are reached

- Accept as Solved if Limits are Reached
- Fail Unit and Stop Calculations if Limits are Reached
- Fail Unit and Continue Calculations if Limits are Reached

Next Unit Calculated after Control Variable is Changed:

Exit the window after saving all data

Step 5b: Total Refrigerant Flow Rate: Controllers

PRO/II - Stream Data

UOM	Range	Help	Tag	Overview	Status	Notes
-----	-------	------	-----	----------	--------	-------

Stream: S1 Description:

To Unit: E1

Stream Type

- Composition Defined
- Petroleum Assay
- Referenced to Stream
- Solids Only Stream

Flowrate and Composition...

Stream Solids Data...

Stream Polymer Data...

Thermal Condition

First Specification:

Temperature 25.00 C

Second Specification:

Pressure 1.2000 bar

Thermodynamic System: Determined From Connectivity

OK Cancel

Exit the window after saving all data

Step 5b: Total Refrigerant Flow Rate: Controllers

Stream Data - Flowrate and Composition

UOM Range Help Tag

Specify flowrate and composition for stream S1

Fluid Flowrate Specification

Total Fluid Flowrate: kg/hr Total LV or GV rate on an Adjusted Standard Basis

Individual Component Flowrates

Component Concentrations
Total Fluid Flowrate: kg-mol/hr

Copy	Component	Composition
Paste	C3	7.8000
	IC4	49.080
	NC4	43.120

Clear Compositions Total: 100.00

Normalize Component Flowrates Based on Specified Fluid Flowrate

Exit the window after saving all data

Step 5b: Total Refrigerant Flow Rate: Controllers

Heat Exchanger - Specifications

UOM Define Range Help

Specification: Cold Product Liquid Fraction

Value: 0.00000

Relative Tolerance: 0.000100

Area: m²

U-Value: kcal/hr-m²-K

Maximum Allowable U*A: kcal/hr-K

OK Cancel

Exit the window after saving all data

Step 5b: Total Refrigerant Flow Rate: Controllers

PRO/II - Feedback Controller

UOM Range Help Overview Status Notes

Unit: Description:

Specification
[Heat Exchanger E1 Duty in x 10⁶ Kcal/hr = 1.7115](#) within [the default tolerance](#)

Variable
[Stream S5 Flowrate in kg/hr](#)

Parameters
Maximum Number of Iterations: Print Results for Each Iteration

Action if Minimum/Maximum Limits are reached

Accept as Solved if Limits are Reached

Fail Unit and Stop Calculations if Limits are Reached

Fail Unit and Continue Calculations if Limits are Reached

Next Unit Calculated after Control Variable is Changed:

Exit the window after saving all data

Step 5b: Total Refrigerant Flow Rate: Controllers

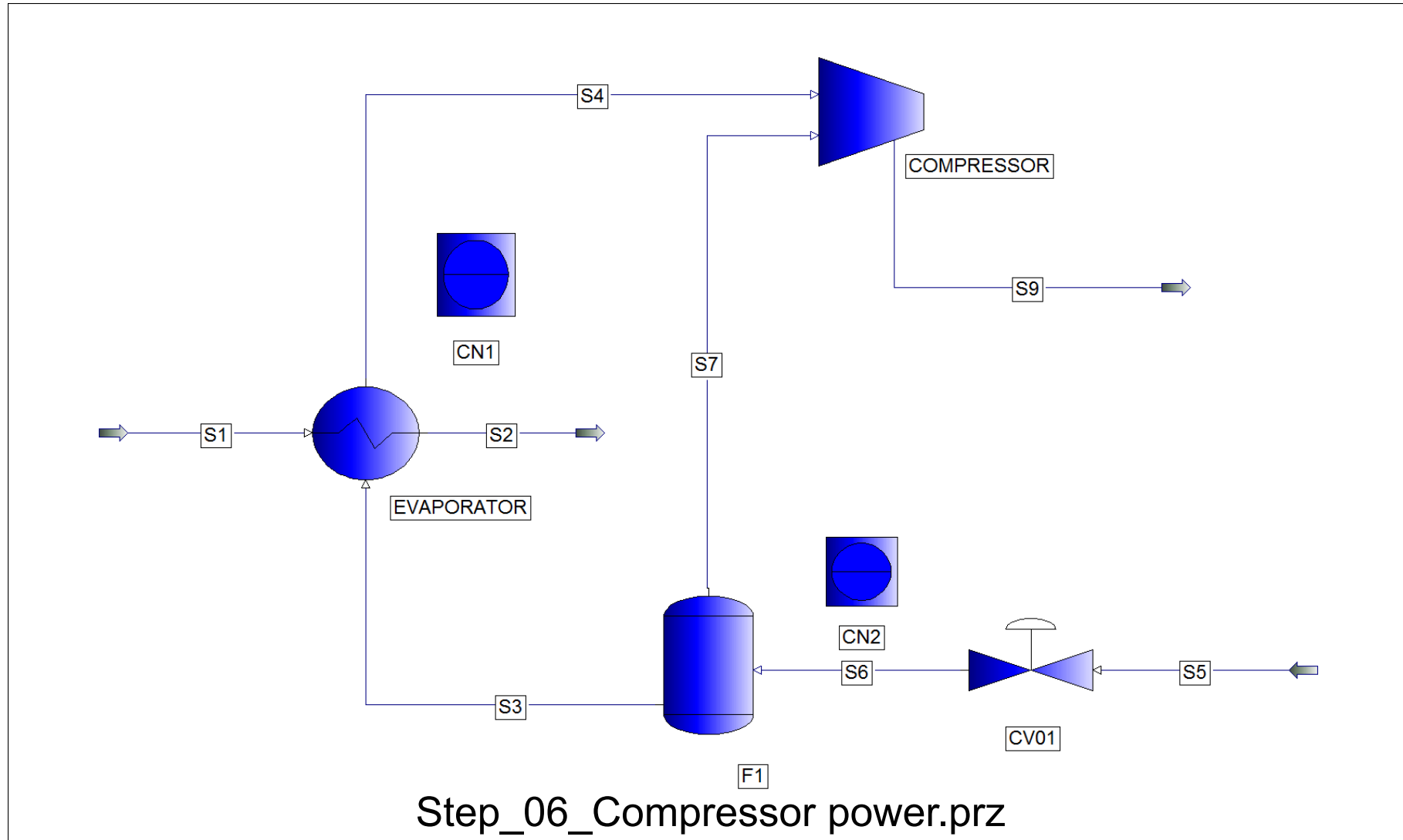
STREAM ID		<u>S5</u>	S6	S7
NAME				
PHASE		LIQUID	MIXED	VAPOR
THERMO ID		PR01	PR01	PR01
FLUID RATES, KG/HR				
1	C3	35138.3627	35138.3627	18158.9207
2	IC4	0.0000	0.0000	0.0000
3	NC4	0.0000	0.0000	0.0000
TOTAL RATE, KG/HR		35138.3627	35138.3627	18158.9207
TEMPERATURE, C		45.0000	-40.0000	-40.0000
PRESSURE, BAR		15.3845	1.1143	1.1143
ENTHALPY, M*KCAL/HR		1.0863	1.0863	1.4459
MOLECULAR WEIGHT		44.0965	44.0965	44.0965
WEIGHT FRAC VAPOR		0.0000	0.5168	1.0000
WEIGHT FRAC LIQUID		1.0000	0.4832	0.0000

A: 35,138.4285 Kg/hr

6

Compressor Power (Adiabatic efficiency: 70%), Compressor Discharge Temperature

Step 6: Compressor Power & Discharge Temperature



Step 6: Compressor Power & Discharge Temperature

PRO/II - Compressor

UOM Define Range Help Overview Status Notes

Unit: COMPRESSOR

Product Phases...
After-cooler...
Calculational Method...

Description:

Thermodynamic System: Default (PR01) ▾

Inlet Pressure: bar

Outlet Temperature Estimate: C

Machine Speed
Machine Speed Not Calculated ▾

Single Molecular Weight Curves

Performance Specification

Pressure, Work or Head Specification
Outlet Pressure ▾ bar

Efficiency or Temperature Specification
Adiabatic Efficiency ▾ Percent

Multiple Molecular Weight Curves

Performance Specification
Multiple Outlet Pressure Curves ▾ Head Basis Length Sp.Energy

Maximum Outlet Pressure: bar

Relative Convergence Tolerance:

Exit the window after saving all data

Step 6: Compressor Power & Discharge Temperature

UNIT 5, 'COMPRESSOR'

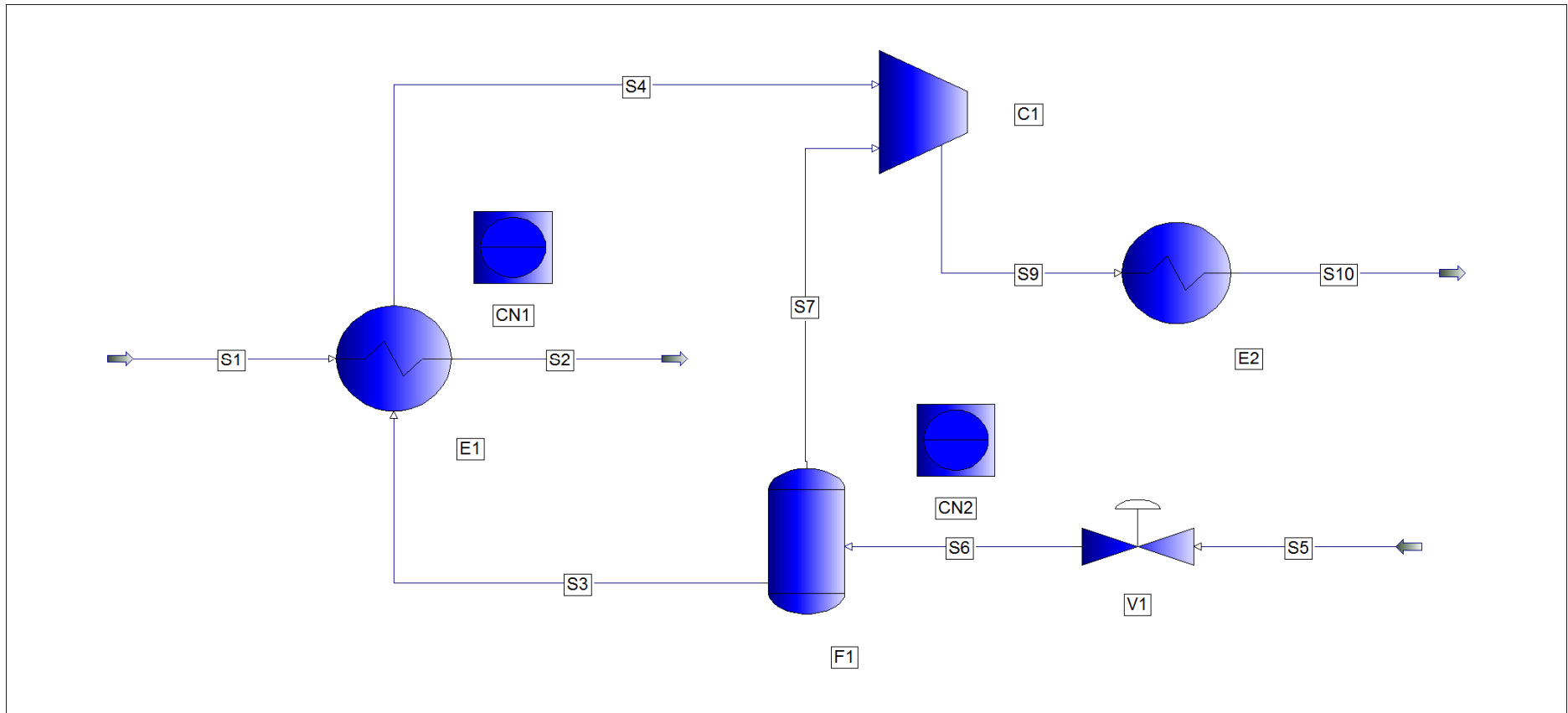
OPERATING CONDITIONS

	INLET	ISENTROPIC	OUTLET
	-----	-----	-----
TEMPERATURE, C	-40.00	59.87	<u>84.90</u>
PRESSURE, BAR	1.11	15.38	15.38
ENTHALPY, M*KCAL/HR	2.7978	3.8411	4.2882
ADIABATIC EFF, PERCENT			70.0000
POLYTROPIC EFF, PERCENT			74.9913
ISENTROPIC COEFFICIENT, K			1.0611
POLYTROPIC COEFFICIENT, N			1.1214
ASME "F" FACTOR			1.0349
HEAD, M			
ADIABATIC			12675.70
POLYTROPIC			13579.53
ACTUAL			18108.14
WORK, KW			
THEORETICAL			1213.31
POLYTROPIC			1299.82
ACTUAL			<u>1733.30</u>

7

Estimation of the Condenser Heat Duty & Cooling Water Consumptions

Step 7: Condenser Heat Duty



Step_07_Condenser duty.prz

Step 7: Condenser Heat Duty

Heat Exchanger - Specifications

UOM Define Range Help

Specification: Hot Product Liquid Fraction

Value: 1.0000

Relative Tolerance: 0.000100

Area: m²

U-Value: kcal/hr-m²-K

OK Cancel

Exit the window after saving all data

Step 7: Cooling Water Consumptions

Heat Exchanger - Cold Side Utility

UOM Define Range Help

Use Utility for Cold Side

Utility Type

Water
 Air
 Refrigerant

Water or Air Inlet and Outlet Conditions

Inlet Temperature: C
Outlet Temperature: C

Refrigerant Component Selection and Saturation Conditions

Component:
Saturation Conditions:
 Pressure: bar
 Temperature: C

Thermo Method for Air Cp Calculation

Ideal Thermo Method
 Compatible with Simple HX Air Ver. 8.2 and earlier

Exit the window after saving all data

Step 7: Cooling Water Consumptions

OPERATING CONDITIONS

DUTY, M*KCAL/HR	3.202
LMTD, C	25.737

HOT SIDE CONDITIONS

	INLET	OUTLET
	-----	-----
FEED	S9	
LIQUID PRODUCT		S10
VAPOR, KG-MOL/HR	796.851	
K*KG/HR	35.138	
CP, KCAL/KG-C	0.514	
LIQUID, KG-MOL/HR		796.851
K*KG/HR		35.138
CP, KCAL/KG-C		0.769
TOTAL, KG-MOL/HR	796.851	796.851
K*KG/HR	35.138	35.138
CONDENSATION, KG-MOL/HR		796.851
TEMPERATURE, C	84.901	45.000
PRESSURE, BAR	15.384	15.384

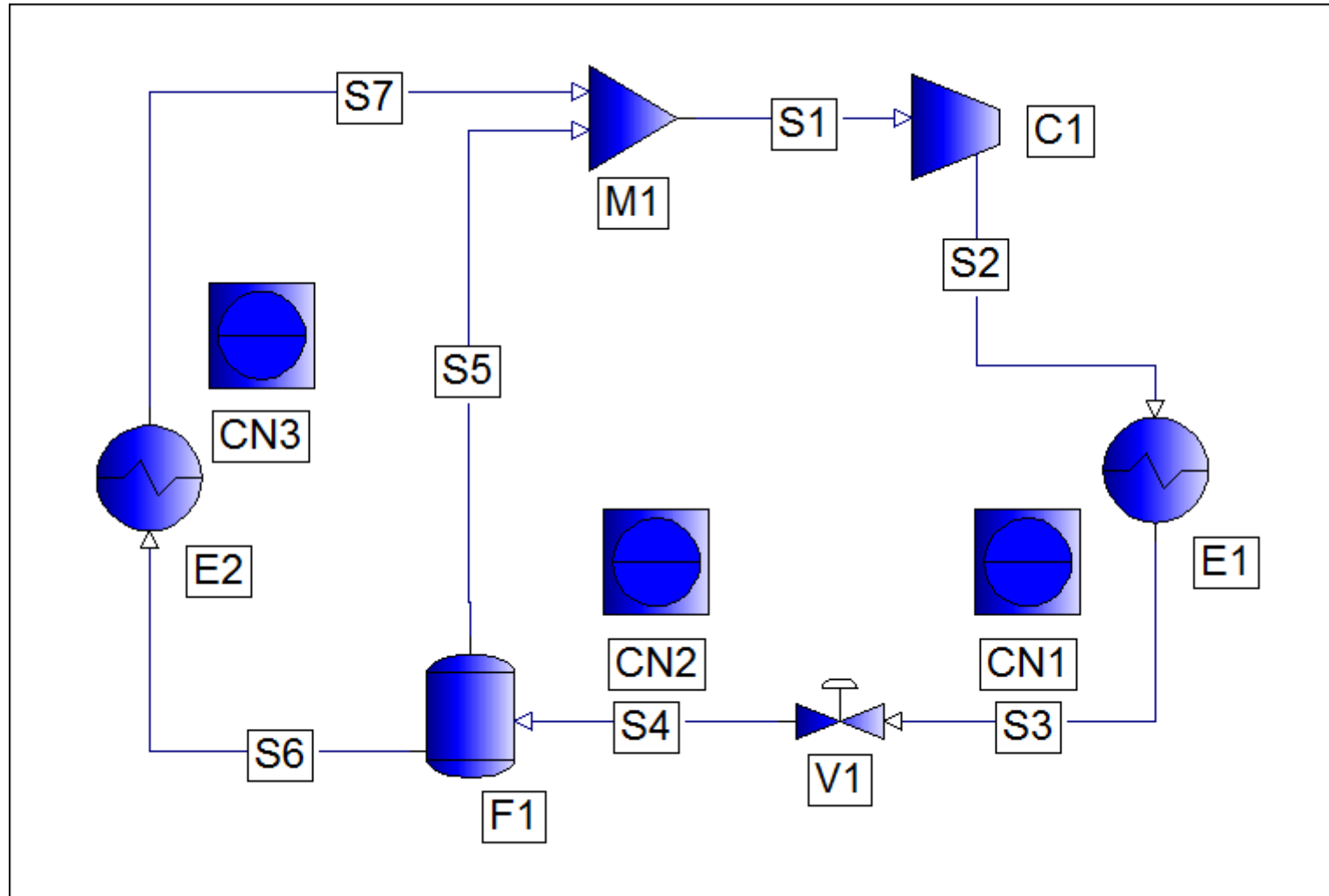
COLD SIDE CONDITIONS

	INLET	OUTLET
	-----	-----
COOLING WATER, KG/HR	400237.921	400237.921
TEMPERATURE, C	32.000	40.000

8

Overall Refrigeration Cycle Using Pure Propane

Step 8: Overall Refrigeration Cycle



Step_09_Overall refrigeration cycle.prz

Step 8: Overall Refrigeration Cycle

Step	Item	Stepwise Calculation	Overall Simulation
1	Evaporator heat duty (10^6 Kcal/hr)	1.7115	1.7115
2	Compressor discharge pressure (bar)	15.3845 (15.385) (15.384)	15.3845
3	Expansion valve outlet pressure (bar)	1.1143 (1.114) (1.114)	1.114
4	Refrigerant mass flow rate to the evaporator (kg/hr)	16,946.501 (16,979.486)	16,979.4872
5	Total refrigerant circulation rate (kg/hr)	35,138.4285 (35,138.3627)	35,138.4597
6	Compressor power (kW) & compressor outlet stream temperature ($^{\circ}$ C)	1733.30, 84.90	1,733.31, 84.901
7	Condenser heat duty (10^6 Kcal/hr)	3.202	3.2019
8	Cooling water consumptions (Ton/hr)	400.0	400.2

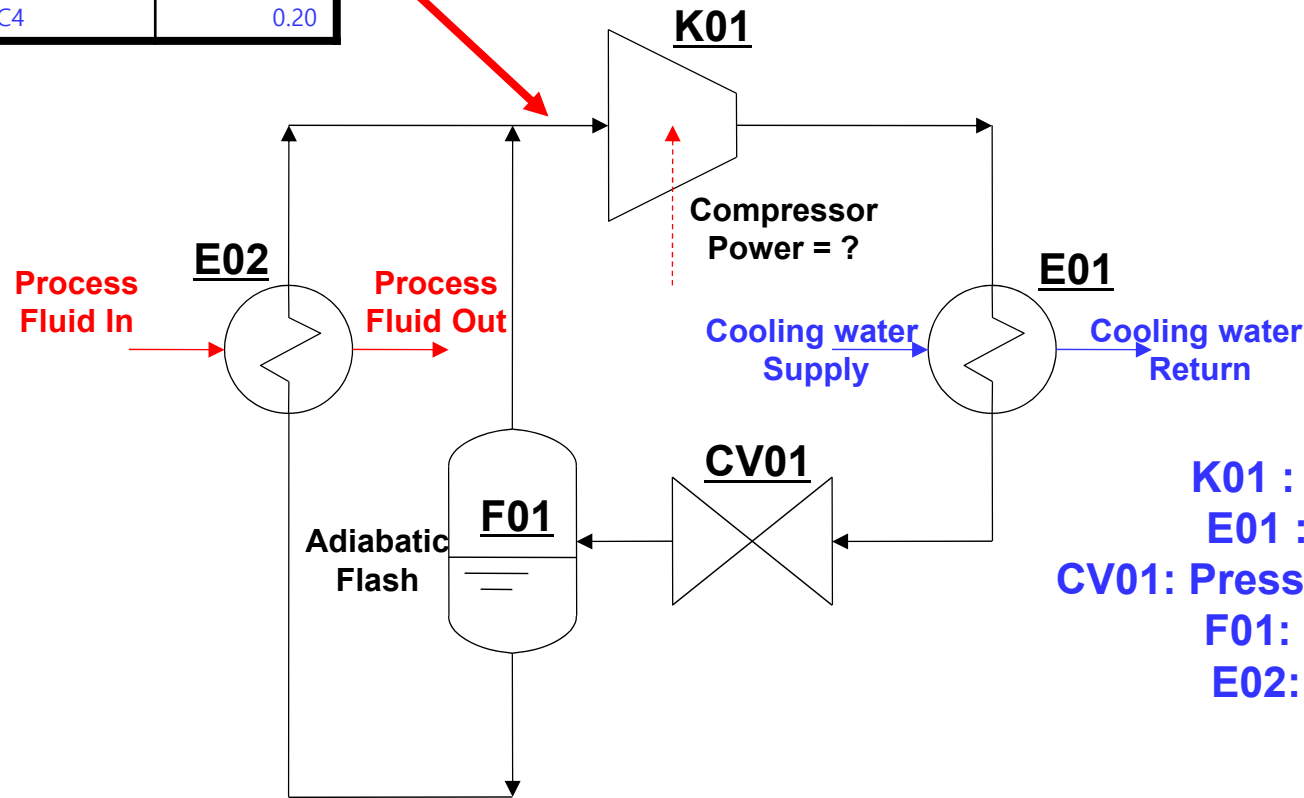
9

Pure Refrigerant vs. Mixed Refrigerants

Step 9: Pure Refrigerant vs. Mixed Refrigerants

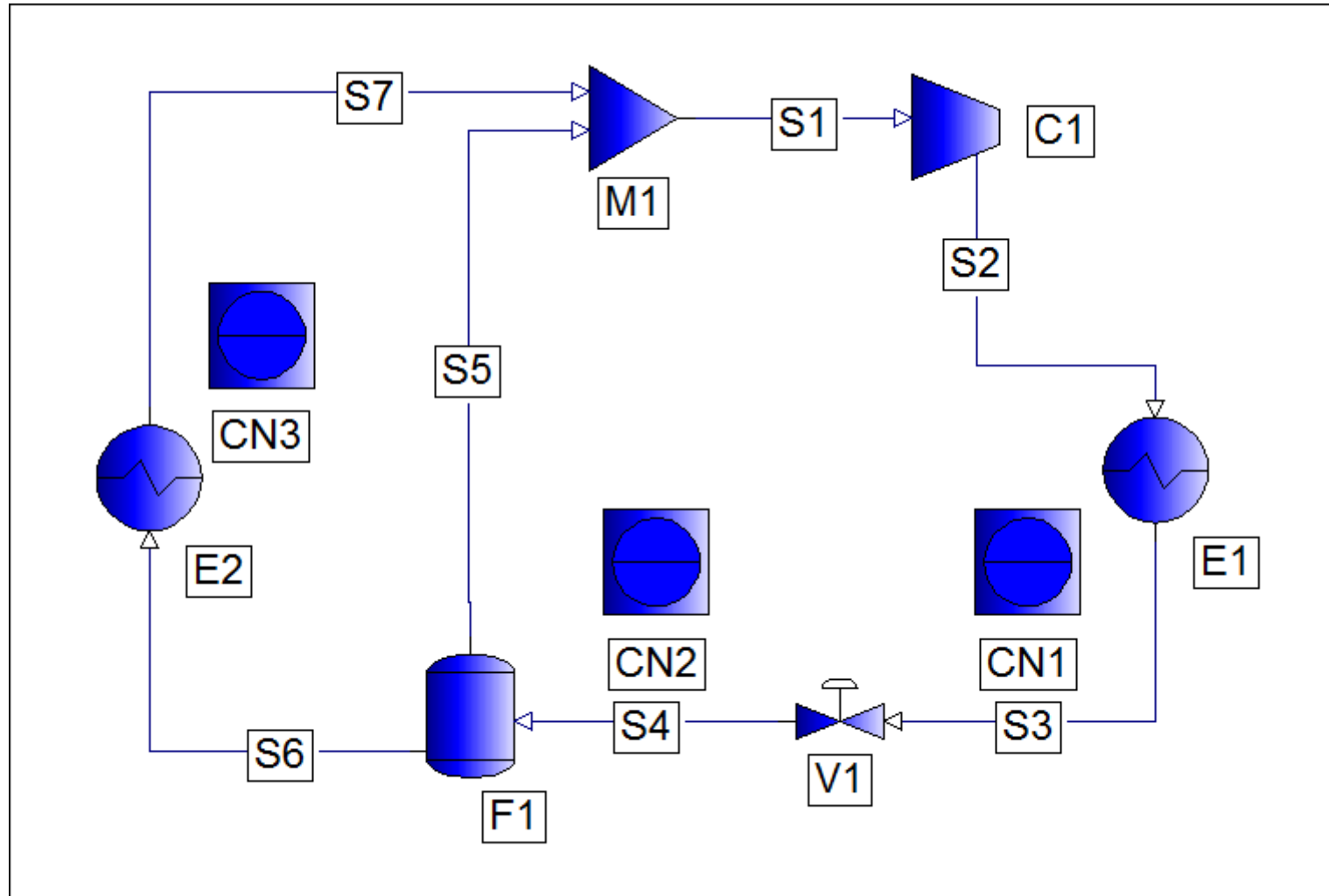
Component	Mole%
C2	0.50
C3	98.5
IC4	0.80
NC4	0.20

실제로는 약간의 혼합냉매임
따라서 순수성분 냉매일 때는 증발기 후단에서 온도
변화가 없으나 혼합냉매일 경우에는 약간의
온도증가가 발생함



K01 : Compressor
E01 : Condenser
CV01: Pressure Let-down Valve
F01: Economizer
E02: Evaporator

Step 9: Pure Refrigerant vs. Mixed Refrigerants



Step_10_Overall refrigeration cycle using mixed refrigerants .prz

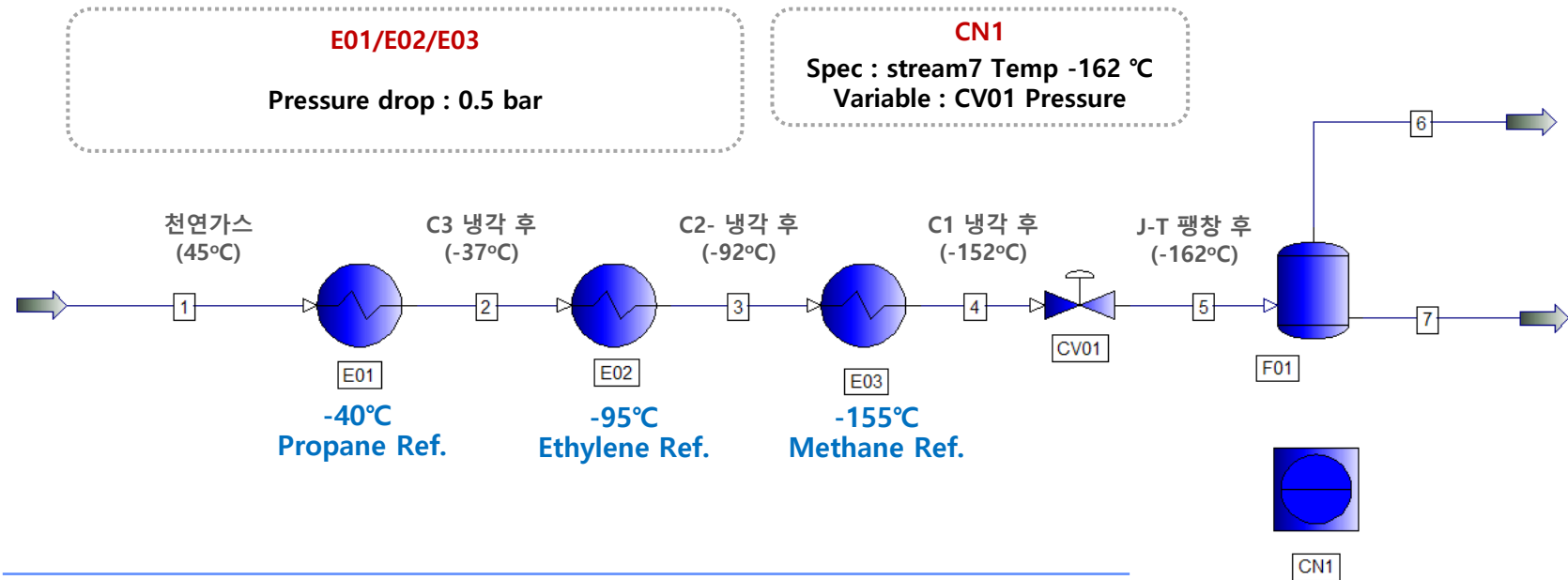
Step 9: Pure Refrigerant vs. Mixed Refrigerants

Step	Item	Stepwise Calculation	Overall Simulation (Pure)	Overall Simulation (Mixed)
1	Evaporator heat duty (10 ⁶ Kcal/hr)	1.7115	1.7115	1.7115
2	Compressor discharge pressure (bar)	15.3845 (15.385) (15.384)	15.3845	15.434
3	Expansion valve outlet pressure (bar)	1.1143 (1.114) (1.114)	1.114	1.108
4	Refrigerant mass flow rate to the evaporator (kg/hr)	16,946.501 (16,979.486)	16,979.4872	16,939.8899
5	Total refrigerant circulation rate (kg/hr)	35,138.4285 (35,138.3627)	35,138.4597	35,026.3962
6	Compressor power (kW) & compressor outlet stream temperature (°C)	1733.30, 84.90	1,733.31, 84.901	1,736.0957, 85.7399
7	Condenser heat duty (10 ⁶ Kcal/hr)	3.202	3.2019	3.2044
8	Cooling water consumptions (Ton/hr)	400.0	400.2	400.6

10

다른 종류의 냉동 사이클에 대한 예시

천연가스 냉각을 위한 조건:

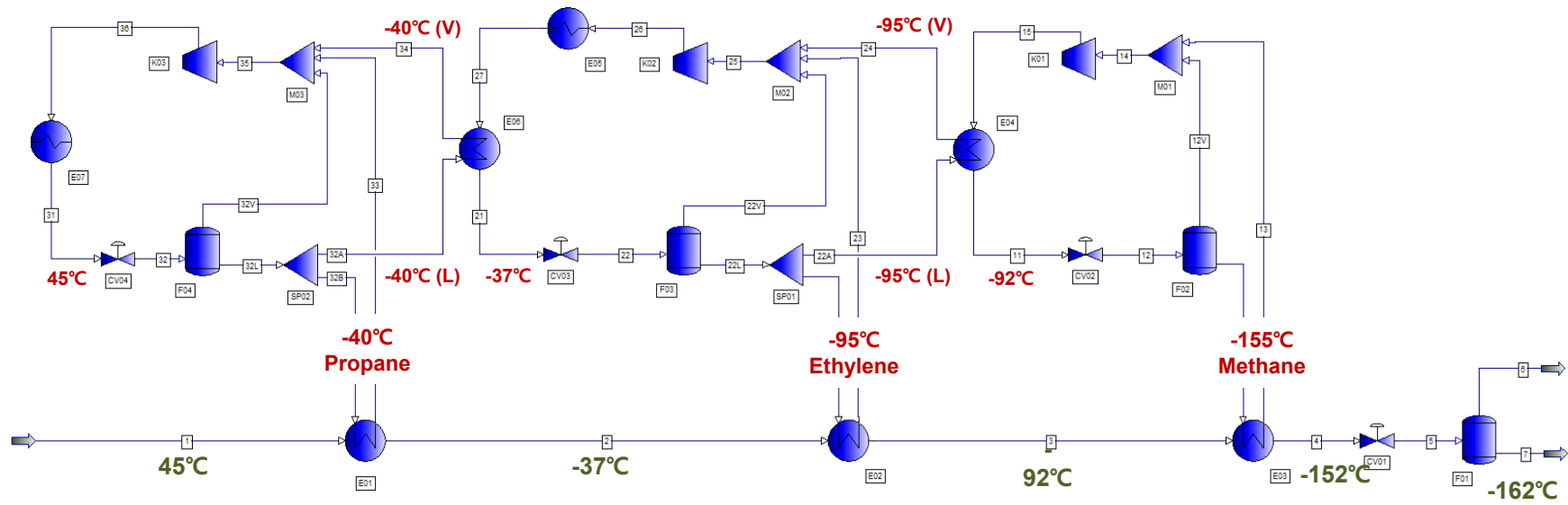


Hx name	E01	E02	E03
Duty (10 ⁶ Kcal/hr)	34.0145	58.5202	32.2301
Refrigerant Flow (kg/hr)	337,452	526,206	270,075

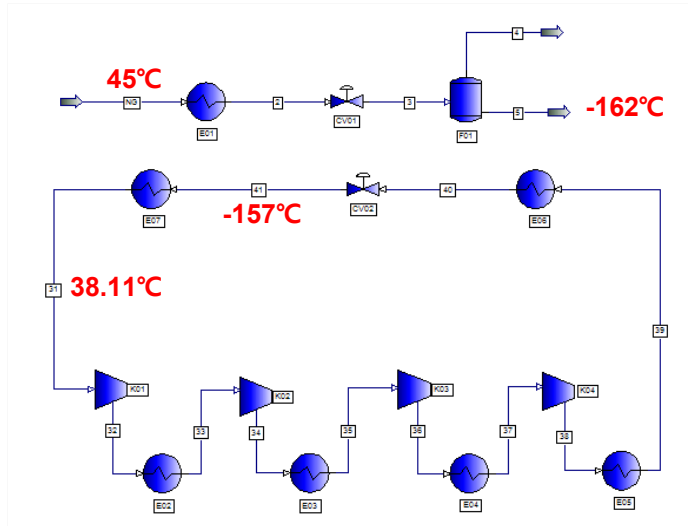
Stream name	1	2	3	4
Temperature	45°C	-37°C	-92°C	-152°C
Pressure	53 bar	52.5 bar	52 bar	51.5 bar

증발기로 들어가는 냉매의 유량을 알 수 있다. 이것을 이용하여 각 냉동사이클의 초기 냉매 유량을 구한다.

Cascade 냉동:



SMR 냉동:



SMR Composition

Component	Mole %
Nitrogen	7.14
Methane	11.91
Ethane	9.52
Propane	71.43
Total Flow (Kg/hr)	4.2E+06

SMR input Condition

Stream 31	Value
Temperature (°C)	38.11
Pressure (bar)	1.3

Cascade vs. SMR 냉동:

Cascade

Component	Compressor	Actual Work
C1	K01	65,915
C2	K02	114,073
C3	K03	262,446
Total Actual work (kW)		442,434

LNG	Flowrate (kg/hr)
Stream5	577,310

Actual Work
0.7700 kW/(kg/hr LNG)

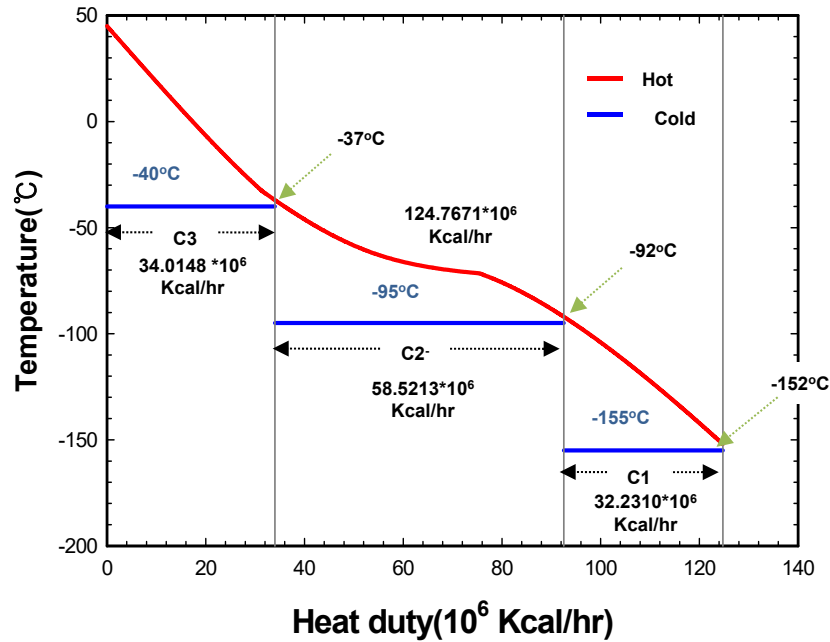
SMR

Component	Compressor	Actual Work
MR (C1, C2, C3, N2)	K01	99,255
	K02	98,265
	K03	94,661
	K04	86,503
Total Actual work (kW)		378,684

LNG	Flowrate (kg/hr)
Stream5	577,157

Actual Work
0.6561 kW/(kg/hr LNG)

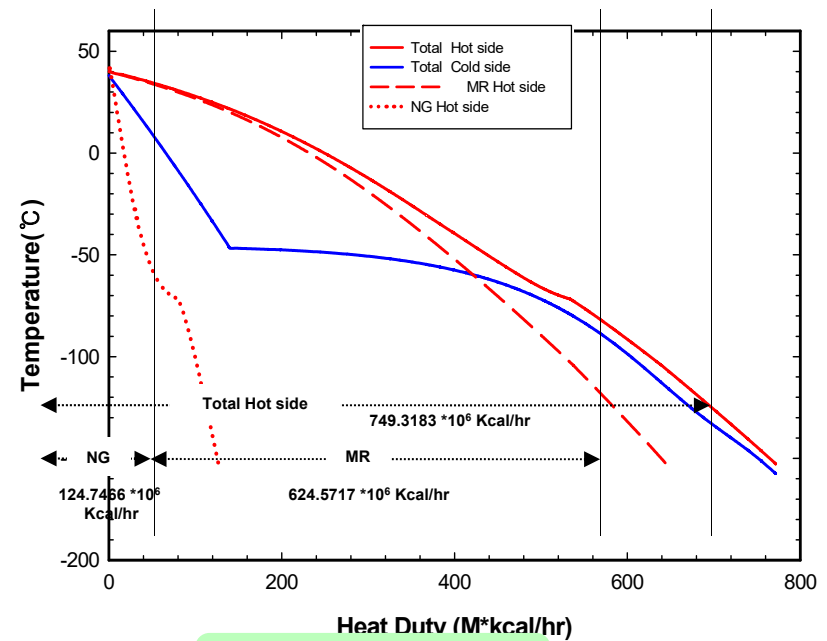
Cascade & SMR Heating Curve 비교:



Cascade Process

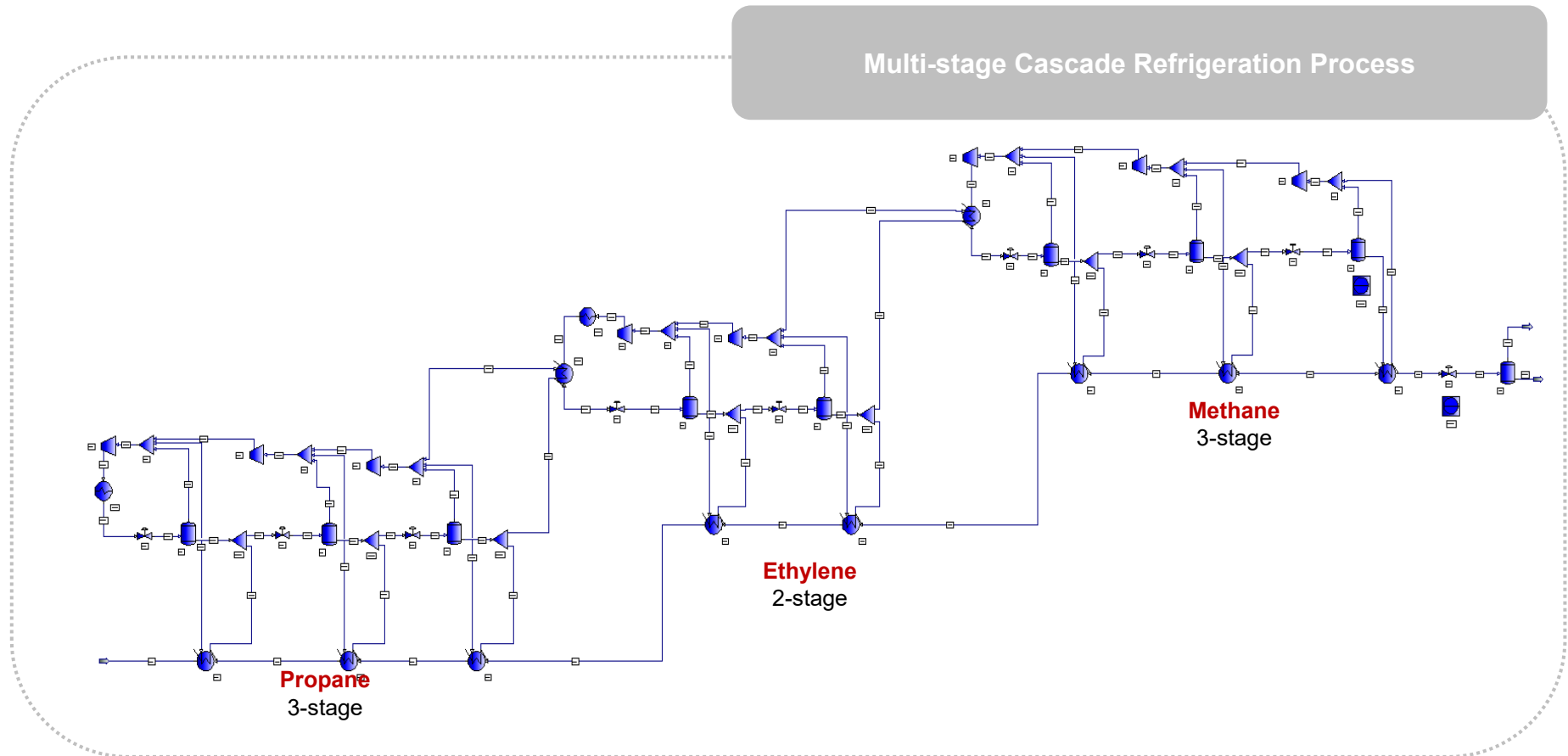
1단공정개요도.JNB
SigmaPlot 10.0 Notebook
63KB

SMR 완성.JNB
SigmaPlot 10.0 Notebook
62KB



SMR Process

다단 Cascade 냉동 사이클의 전산모사:



- ▶ 단순한 프로판 또는 프로필렌 냉동 사이클의 모사보다는 복잡한 냉동 사이클의 전산모사 능력 또한 매우 중요함



THANK YOU

