

PRO/II 화학공정모사기를 이용한
LPG 저장을 위한
냉동기설계

5

냉동기란 ?

가

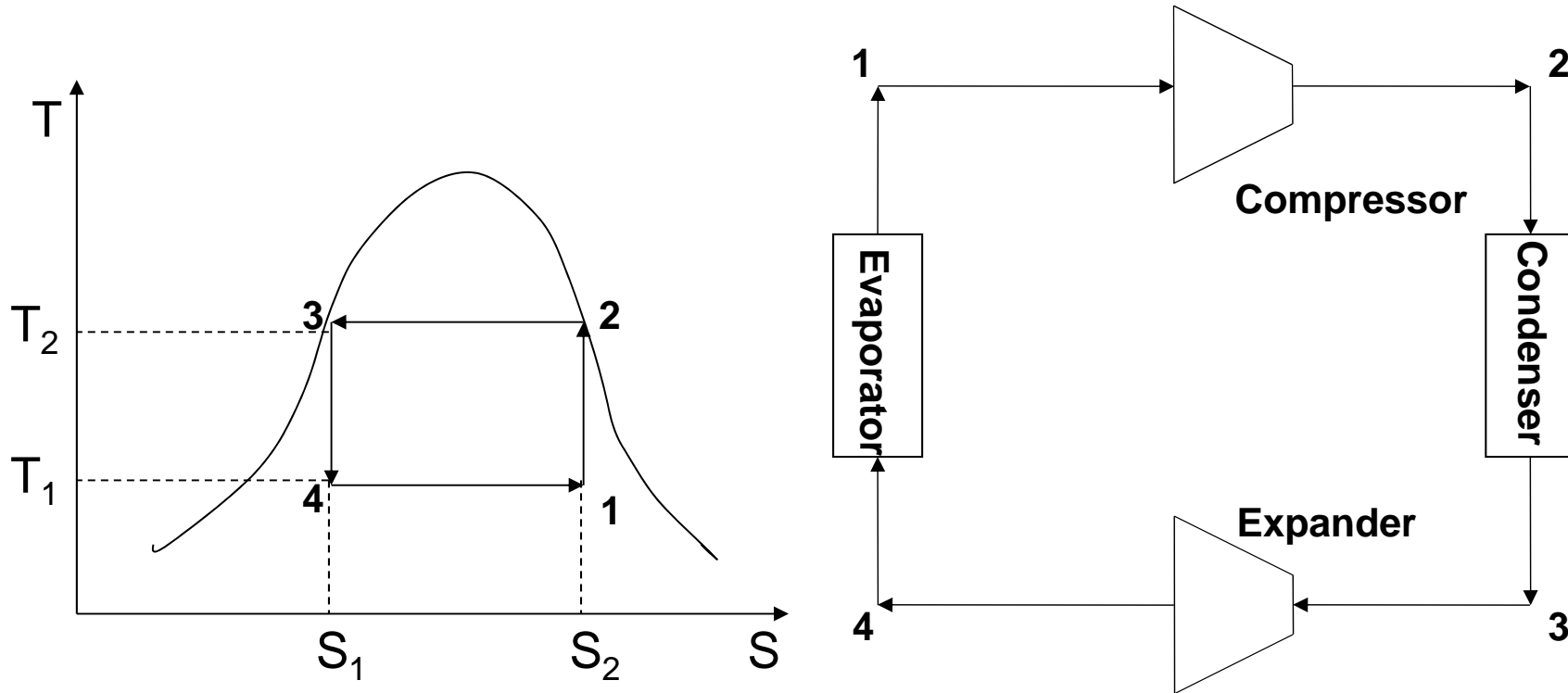
,
Joule-Thomson

,

▪

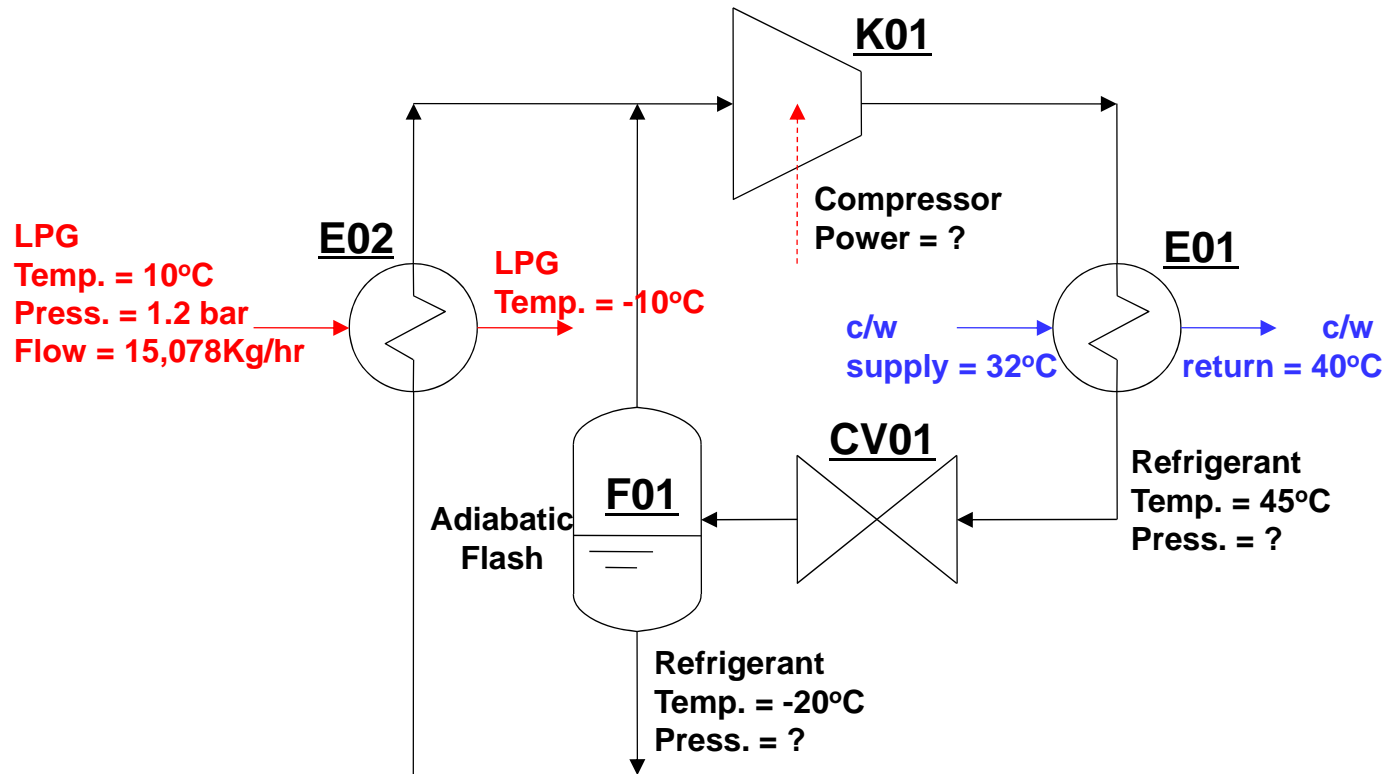
▪

이상적인 냉동사이클의 구성



- Step 1: Compression stage ($P_1 \rightarrow P_2$ & $T_1 \rightarrow T_2$) where $P_2 > P_1$ & $T_2 > T_1$.
- Step 2: Condensing stage ($S_2 > S_1$)
- Step 3: Expansion stage ($P_2 \rightarrow P_1$ & $T_2 \rightarrow T_1$) where $P_2 > P_1$ & $T_2 > T_1$.
- Step 4: Evaporation stage ($S_1 > S_2$)

실제적인 냉동사이클의 구성



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

Problem Description

LPG

가. Gas Composition

- 1) Propane : 7.80 mole%
- 2) N-butane : 49.08 mole%
- 3) I-butane : 43.12 mole%

나. Condition

- 1) In/Out Temperature : 10°C / -10°C
- 2) In/Out Pressure : 1.2 bar / 1.2 bar

다. Flow Rate

- 1) 15,078 Kg/hr

REFRIGERANT: Propane

Cooling Medium: Water

In/Out Temperature : 10°C / -10°C

냉동기 설계 Procedure

Step 1: (E02) Heat duty = ?

Step 2:

Step 3: Pressure Let-down Valve

Step 4:

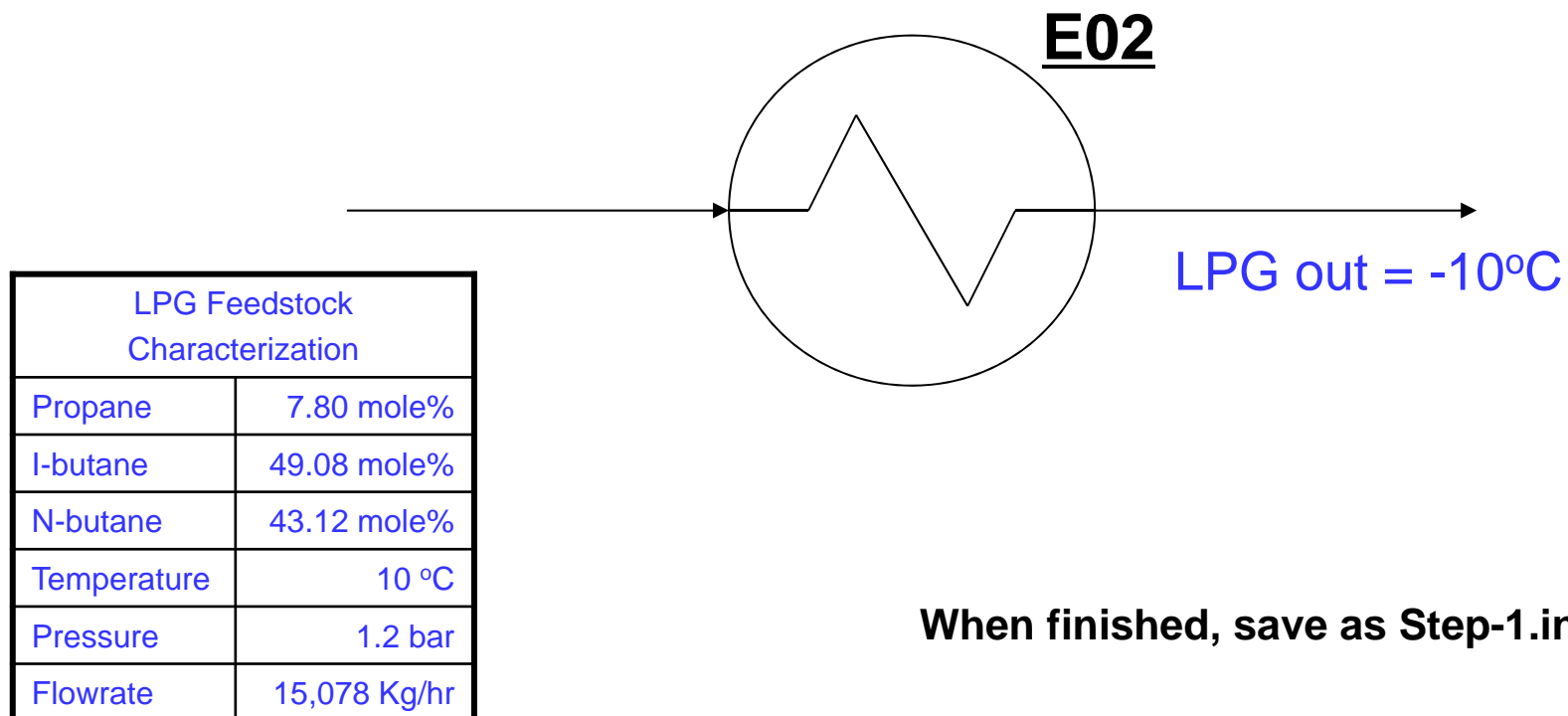
Step 5:

Step 6: (E01) Heat duty = ?

Step 7:

Step 8:

Step 1: 증발기(E02)의 Heat duty = ?



When finished, save as Step-1.inp

PRO/II Keyword Input for Step 1

```
TITLE PROJECT=GAS_HAKHOI, PROBLEM=STEP-1, USER=JHCHO
  PRINT INPUT=ALL, FRACTION=M, PERCENT=M
  DIMENSION METRIC, PRES=BAR
  SEQUENCE PROCESS
COMPONENT DATA
  LIBID 1,C3/2,IC4/3,NC4
THERMODYNAMIC DATA
  METHOD SYSTEM=PR, SET=PR01
STREAM DATA
  PROPERTY STREAM=1, TEMP=10, PRES=1.2, RATE(WT)=15078, &
  COMP=1,7.8/2,49.08/3,43.12
UNIT OPERATIONS
  HX    UID=E02
  HOT   FEED=1, M=2
  OPER  HTEMP=-10
END
```


PRO/II Output Summary for Step 1

UNIT 1, 'E02'

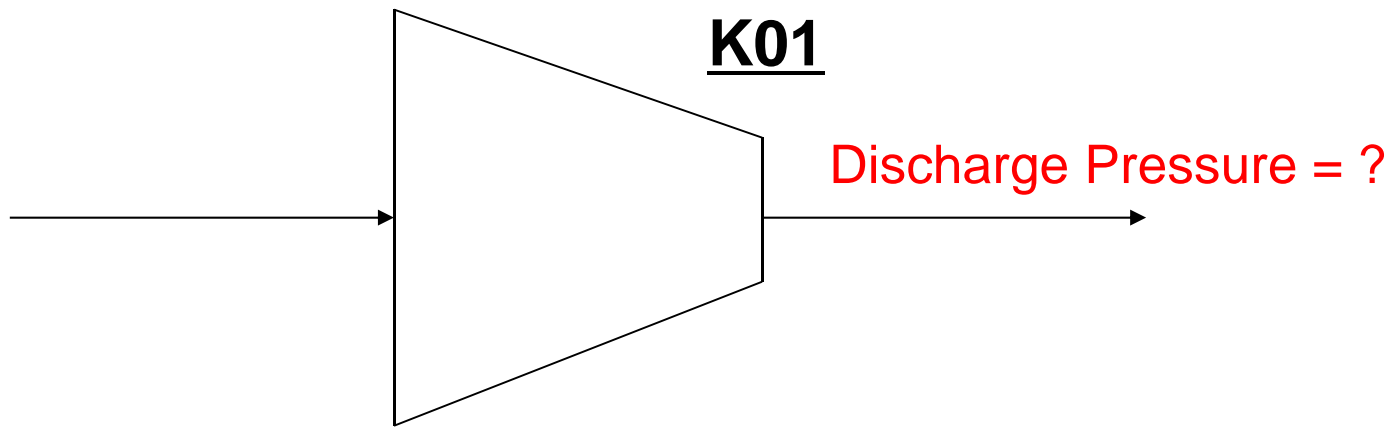
OPERATING CONDITIONS

DUTY, M*KCAL/HR 1.469

HOT SIDE CONDITIONS

	INLET	OUTLET
	-----	-----
FEED	1	
LIQUID PRODUCT		2
VAPOR, KG-MOL/HR	264.388	
K*KG/HR	15.078	
LIQUID, KG-MOL/HR		264.388
K*KG/HR		15.078
TOTAL, KG-MOL/HR	264.388	264.388
K*KG/HR	15.078	15.078
CONDENSATION, KG-MOL/HR		264.388
TEMPERATURE, C	<u>10.000</u>	<u>-10.000</u>
PRESSURE, BAR	1.200	1.200

Step 2: 압축기 출구에서의 압력의 결정



•

45°C

+ 0.5bar (?)

•

When finished, save as Step-2.inp

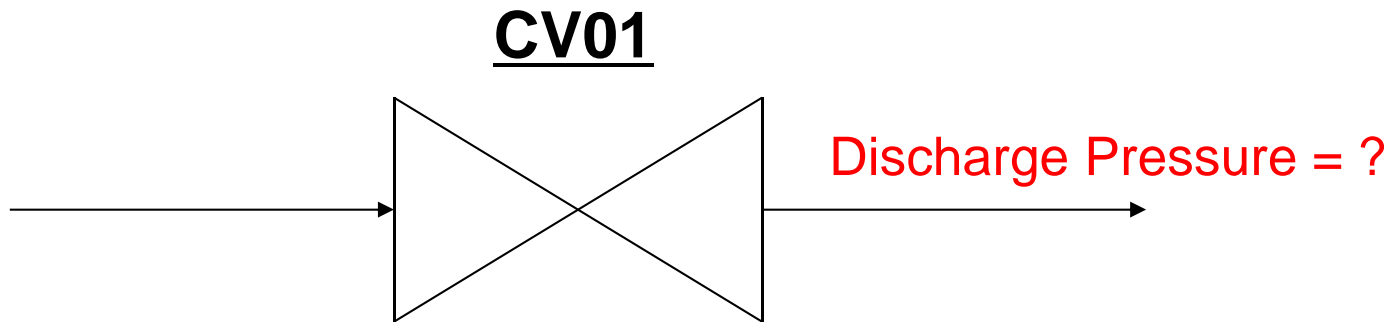
PRO/II Keyword Input for Step 2

```
TITLE PROJECT=GAS_HAKHOI, PROBLEM=STEP-2, USER=JHCHO
  PRINT INPUT=ALL, FRACTION=M, PERCENT=M
  DIMENSION METRIC, PRES=BAR
  SEQUENCE PROCESS
COMPONENT DATA
  LIBID 1,C3
THERMODYNAMIC DATA
  METHOD SYSTEM=PR, SET=PR01
STREAM DATA
  PROP STRM=1, TEMP=25, PRES=1, RATE(M)=100, COMP=1,100
UNIT OPERATIONS
  FLASH UID=F01
  FEED 1
  PRODUCT L=1L, V=1V
  BUBBLE TEMPERATURE=45
END
```

PRO/II Output Summary for Step 2

FLASH ID	F01
NAME	
FEEDS	1
PRODUCTS VAPOR	1V
LIQUID	1L
TEMPERATURE, C	<u>45.000</u>
PRESSURE, BAR	<u>15.386</u>
PRESSURE DROP, BAR	-14.386
MOLE FRAC VAPOR	0.00000
MOLE FRAC LIQUID	1.00000
DUTY, M*KCAL/HR	-0.31995
FLASH TYPE	<u>BUBBLE-T</u>

Step 3: Pressure Let-down Valve



•

-20°C

▪

When finished, save as Step-3.inp

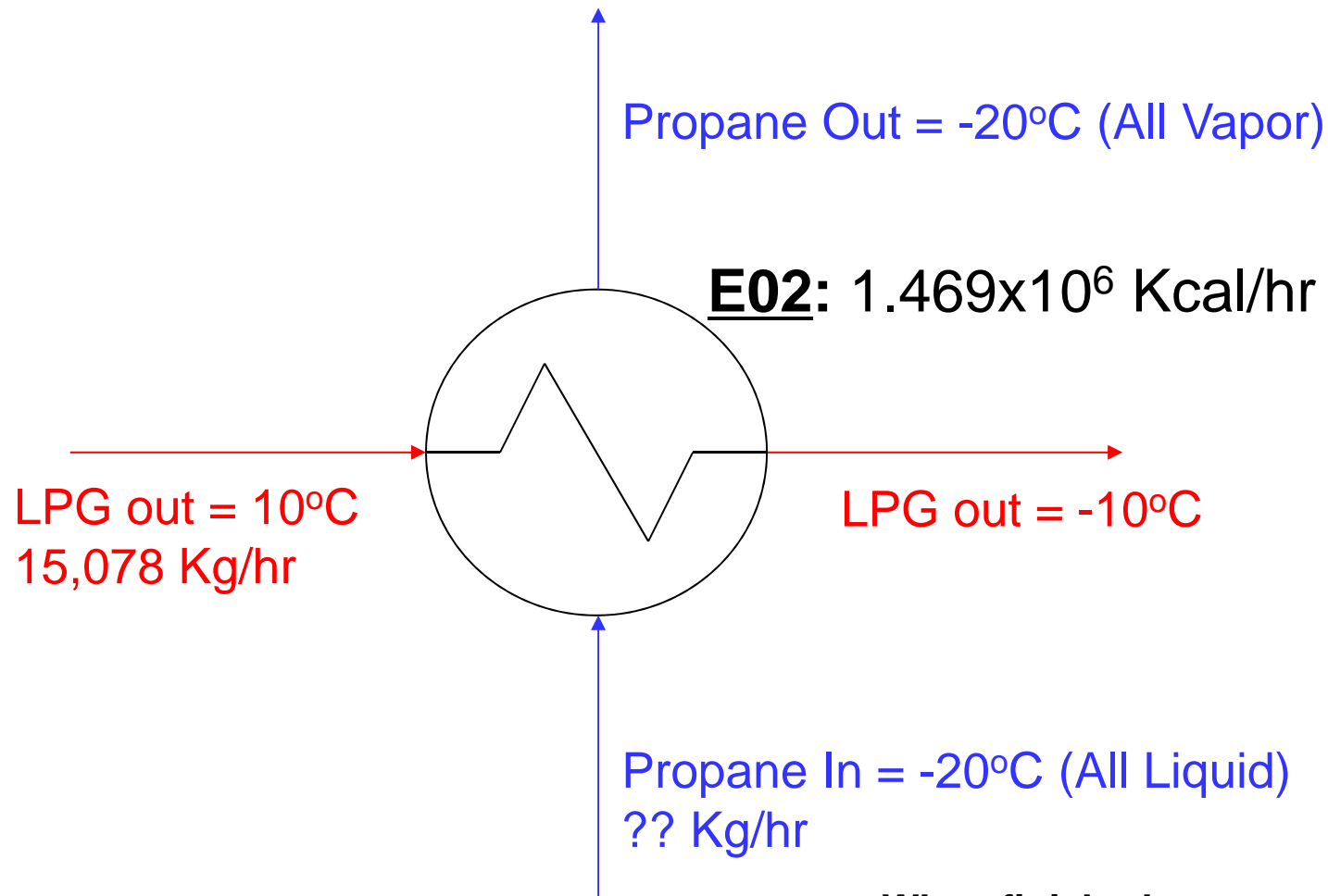
PRO/II Keyword Input for Step 3

```
TITLE PROJECT=GAS_HAKHOI, PROBLEM=STEP-3, USER=JHCHO
  PRINT INPUT=ALL, FRACTION=M, PERCENT=M
  DIMENSION METRIC, PRES=BAR
COMPONENT DATA
  LIBID 1,C3
THERMODYNAMIC DATA
  METHOD SYSTEM=PR, SET=PR01
STREAM DATA
  PROP STREAM=1, TEMP=25, PRES=1, RATE(M)=100, COMP=1,100
UNIT OPERATIONS
  FLASH UID=F01
  FEED 1
  PRODUCT V=1V, L=1L
  DEW TEMPERATURE=-20
END
```

PRO/II Output Summary for Step 3

FLASH ID	F01
NAME	
FEEDS	1
PRODUCTS VAPOR	1V
LIQUID	1L
TEMPERATURE, C	<u>-20.000</u>
PRESSURE, BAR	<u>2.439</u>
PRESSURE DROP, BAR	-1.439
MOLE FRAC VAPOR	1.00000
MOLE FRAC LIQUID	0.00000
DUTY, M*KCAL/HR	-0.08167
FLASH TYPE	<u>DEW-T</u>

Step 4: 냉매의 순환유량의 결정



When finished, save as Step-4.inp

PRO/II Keyword Input for Step 4

```
TITLE PROJECT=GAS_HAKHOI, PROBLEM=STEP-4, USER=JHCHO
  PRINT INPUT=ALL, FRACTION=M, PERCENT=M
  DIMENSION METRIC, PRES=BAR
  SEQUENCE PROCESS
COMPONENT DATA
  LIBID 1,C3
THERMODYNAMIC DATA
  METHOD SYSTEM=PR, SET=PR01
STREAM DATA
  PROP STREAM=C1, TEMP=-20, RATE(WT)=10000, COMP=1,100
UNIT OPERATIONS
  HX  UID=E02, NAME=EVAPORATOR
    COLD FEED=C1, M=C2
    OPER CLFRAC=0
  CONTROLLER UID=CON1
    SPEC HX=E02, DUTY, VALUE=1.469
    VARY STREAM=C1, RATE
END
```

PRO/II Output Summary for Step 4

UNIT 1, 'E02', 'EVAPORATOR'

OPERATING CONDITIONS

DUTY, M*KCAL/HR 1.468

COLD SIDE CONDITIONS

INLET

OUTLET

FEED

C1

VAPOR PRODUCT

C2

VAPOR, KG-MOL/HR
K*KG/HR

346.939
15.299

LIQUID, KG-MOL/HR
K*KG/HR

346.939
15.299

TOTAL, KG-MOL/HR
K*KG/HR

346.939
15.299

VAPORIZATION, KG-MOL/HR

346.939

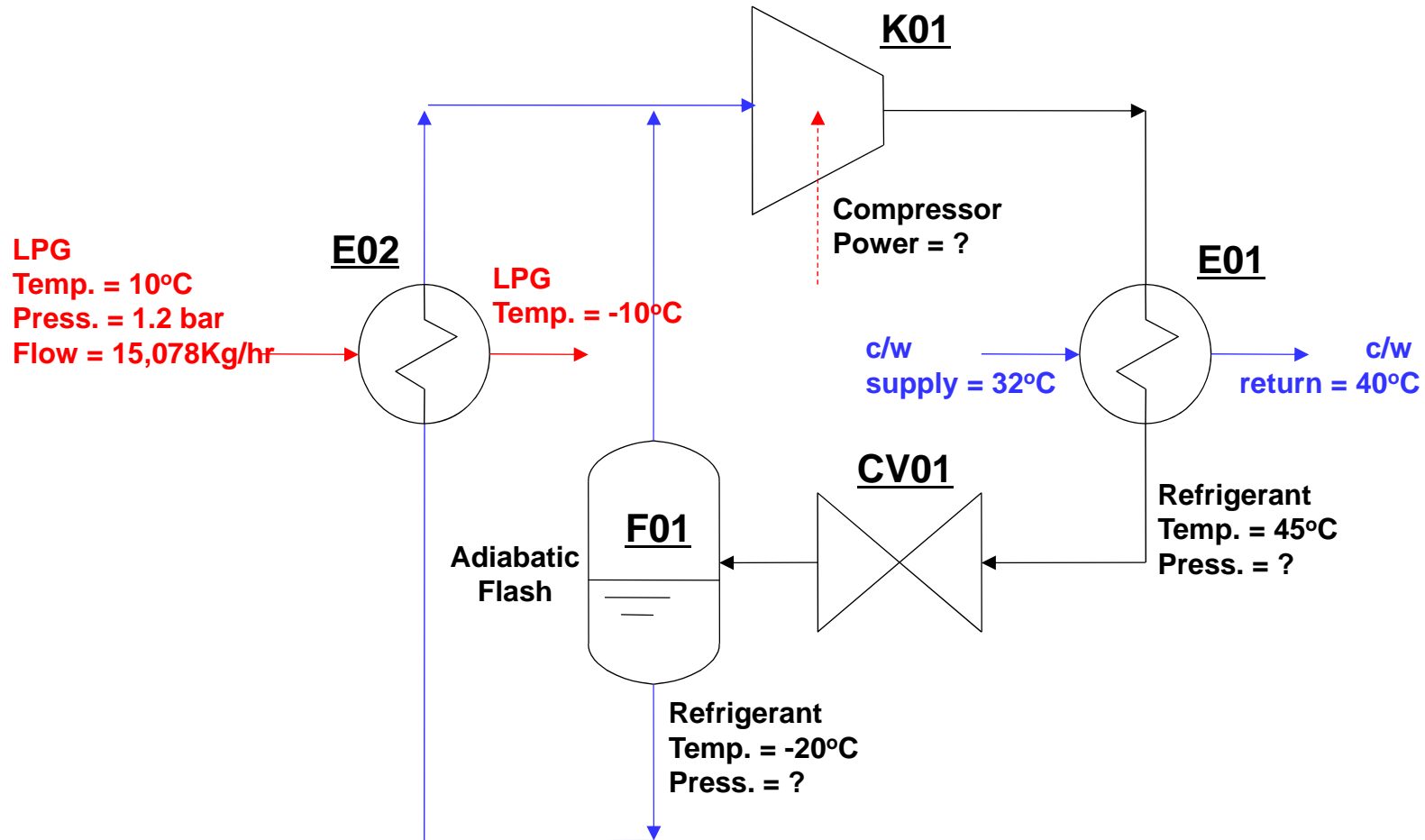
TEMPERATURE, C

-20.000 -20.000

PRESSURE, BAR

2.439 2.439

Step 5: 압축기 동력의 계산



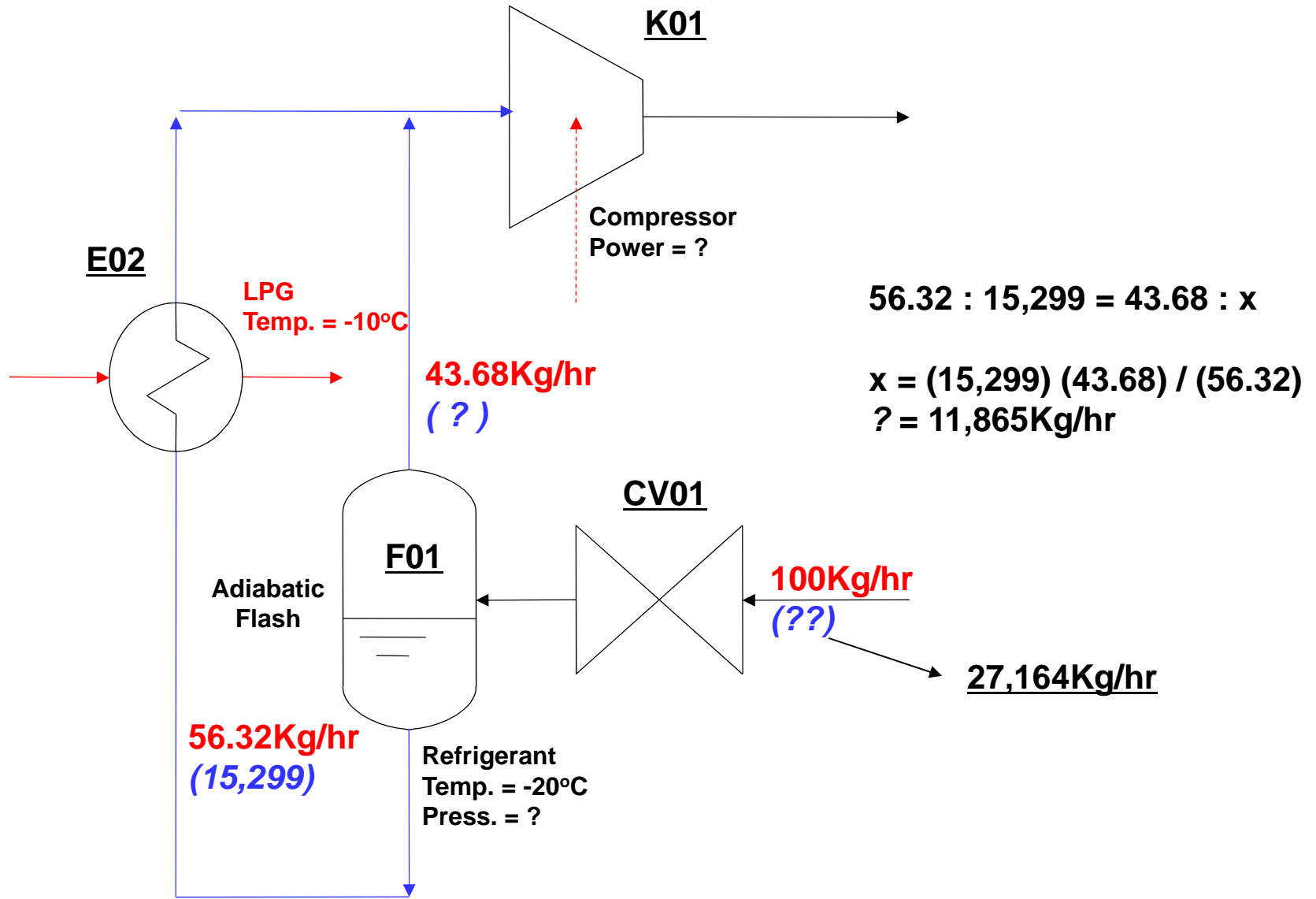
When finished, save as Step-5a.inp & Step-5b.inp

PRO/II Keyword Input for Step 5a

```
TITLE PROJECT=GAS_HAKHOI, PROBLEM=STEP-4, USER=JHCHO
  PRINT INPUT=ALL, RATE=WT, FRACTION=M, PERCENT=M
  DIMENSION METRIC, PRES=BAR
  SEQUENCE PROCESS
COMPONENT DATA
  LIBID 1,C3
THERMODYNAMIC DATA
  METHOD SYSTEM=PR, SET=PR01
STREAM DATA
  PROP STREAM=1, TEMP=45, PRES=15.886, RATE(WT)=100, COMP=1,100
UNIT OPERATIONS
  VALVE UID=CV01
  FEED 1
  PRODUCT V=1V, L=1L
  OPERATION PRESSURE=2.439
END
```

PRO/II Output Summary for Step 5a

STREAM ID	1	1L	1V
NAME			
PHASE	LIQUID	LIQUID	VAPOR
FLUID RATES, KG/HR			
1 C3	100.0000	56.3211	43.6789
TOTAL RATE, KG/HR	100.0000	56.3211	43.6789
TEMPERATURE, C	45.0000	-20.0025	-20.0025
PRESSURE, BAR	15.8860	2.4390	2.4390
ENTHALPY, M*KCAL/HR	2.9726E-03	-6.8700E-04	3.6596E-03
MOLECULAR WEIGHT	44.0970	44.0970	44.0970
WEIGHT FRAC VAPOR	0.0000	0.0000	1.0000
WEIGHT FRAC LIQUID	1.0000	1.0000	0.0000



PRO/II Keyword Input for Step 5b

```
TITLE PROJECT=GAS_HAKHOI, PROBLEM=STEP-4, USER=JHCHO
  PRINT INPUT=ALL, FRACTION=M, PERCENT=M
  DIMENSION METRIC, PRES=BAR
  SEQUENCE PROCESS
COMPONENT DATA
  LIBID 1,C3/2,IC4/3,NC4
THERMODYNAMIC DATA
  METHOD SYSTEM=PR, SET=PR01
STREAM DATA
  PROP STREAM=1, TEMP=-20, PHASE=V, RATE (WT) =27164, COMP=1,100
UNIT OPERATIONS
  COMPRESSOR UID=K01
    FEED 1
    PRODUCT V=2
    OPERATION PRES=15.886, EFF=70
END
```

PRO/II Output Summary for Step 5b

UNIT 1, 'K01'

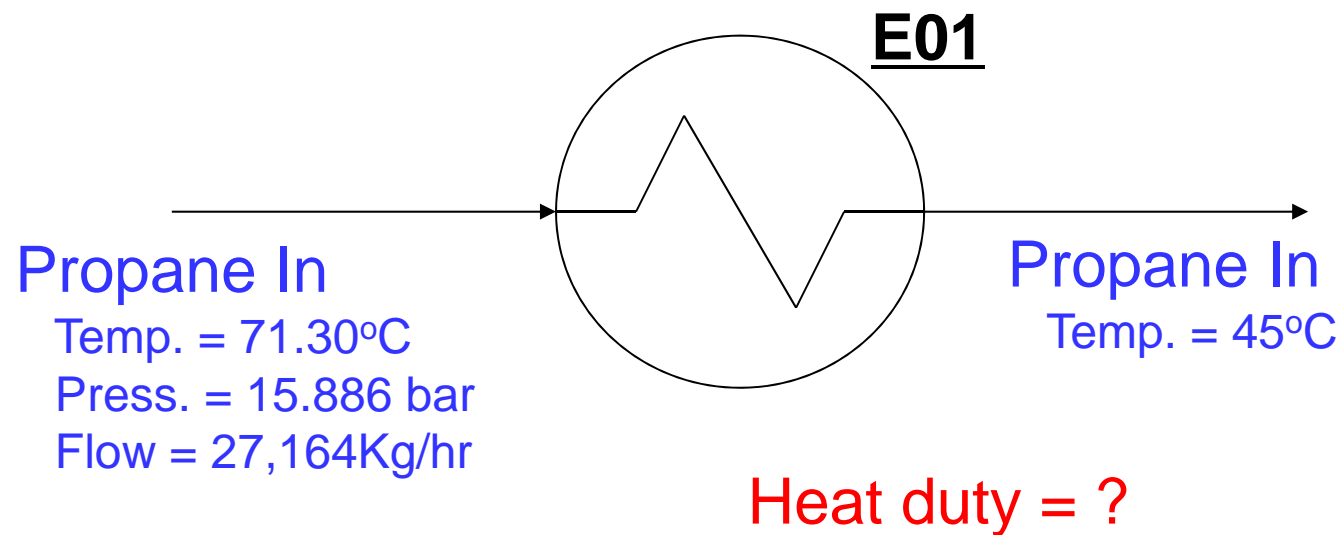
FEEDS 1

PRODUCTS VAPOR 2

OPERATING CONDITIONS

	INLET	ISENTROPIC	OUTLET
	-----	-----	-----
TEMPERATURE, C	-20.00	53.81	<u>71.30</u>
PRESSURE, BAR	2.44	15.89	15.89
ENTHALPY, M*KCAL/HR	2.2759	2.8458	3.0901
ENTROPY, KCAL/KG-MOL-C	51.6310	51.6310	52.8123
MOLE PERCENT VAPOR	100.0000	100.0000	100.0000
MOLE PERCENT LIQUID	0.0000	0.0000	0.0000
ADIABATIC EFF, PERCENT			70.0000
WORK, KW			
THEORETICAL			662.79
POLYTROPIC			699.44
ACTUAL			<u>946.84</u>

Step 6: (E01) Heat duty = ?



When finished, save as Step-6.inp

PRO/II Keyword Input for Step 6

```
TITLE PROJECT=GAS_HAKHOI, PROBLEM=STEP-4, USER=JHCHO
  PRINT INPUT=ALL, FRACTION=M, PERCENT=M
  DIMENSION METRIC, PRES=BAR
  SEQUENCE PROCESS
COMPONENT DATA
  LIBID 1,C3
THERMODYNAMIC DATA
  METHOD SYSTEM=PR, SET=PR01
STREAM DATA
  PROP STRM=1, TEMP=71.3, PRES=15.886, RATE(WT)=27164, COMP=1,100
UNIT OPERATIONS
  HX    UID=E01, NAME=CONDENSER
  HOT   FEED=1, M=2
  OPER  HTEMP=45
END
```

PRO/II Output Summary for Step 6

UNIT 1, 'E01', 'CONDENSER'

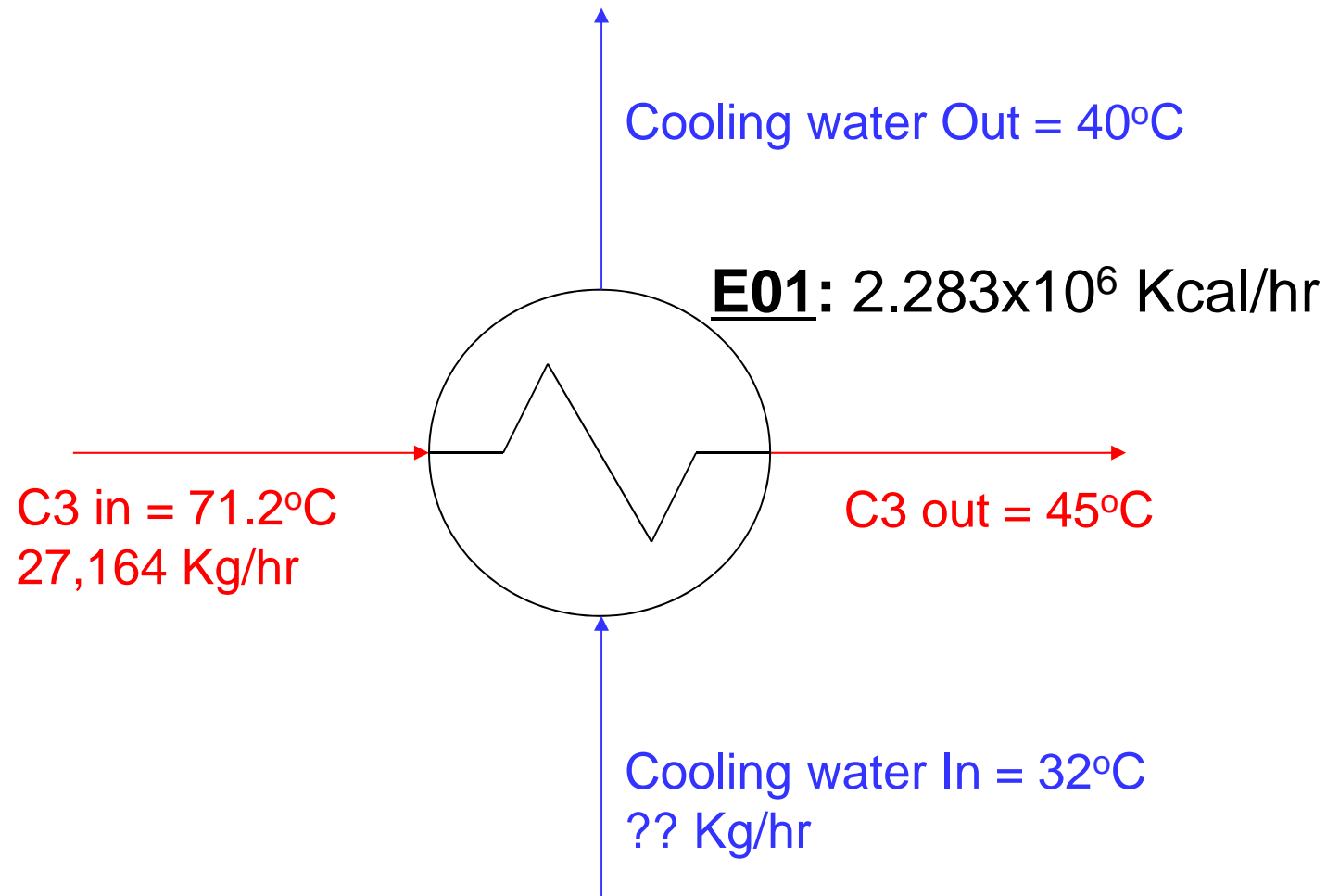
OPERATING CONDITIONS

DUTY, M*KCAL/HR 2.283

HOT SIDE CONDITIONS

	INLET	OUTLET
	-----	-----
FEED	1	
LIQUID PRODUCT		2
VAPOR, KG-MOL/HR	616.006	
K*KG/HR	27.164	
LIQUID, KG-MOL/HR		616.006
K*KG/HR		27.164
TOTAL, KG-MOL/HR	616.006	616.006
K*KG/HR	27.164	27.164
CONDENSATION, KG-MOL/HR		616.006
TEMPERATURE, C	<u>71.300</u>	<u>45.000</u>
PRESSURE, BAR	15.886	15.886

Step 7:



When finished, save as Step-7.inp

PRO/II Keyword Input for Step 7

```
TITLE PROJECT=GAS_HAKHOI, PROBLEM=STEP-4, USER=JHCHO
  PRINT INPUT=ALL, FRACTION=M, PERCENT=M
  DIMENSION METRIC, PRES=BAR
  SEQUENCE PROCESS
COMPONENT DATA
  LIBID 1,H2O
THERMODYNAMIC DATA
  METHOD SYSTEM=PR, SET=PR01
STREAM DATA
  PROPERTY STREAM=1, TEMPERATURE=32, PRESSURE=3.5, PHASE=M, &
    RATE(WT)=20000, COMPOSITION(M)=1,100, NORMALIZE
UNIT OPERATIONS
  HX  UID=E01, NAME=CONDENSER
    COLD FEED=1, M=2
    OPER CTEMP=40
  CONTROLLER UID=CON1
    SPEC HX=E01, DUTY, VALUE=2.283
    VARY STREAM=1, RATE
END
```

PRO/II Output Summary for Step 7

UNIT 1, 'E01', 'CONDENSER'

OPERATING CONDITIONS

DUTY, M*KCAL/HR 2.283

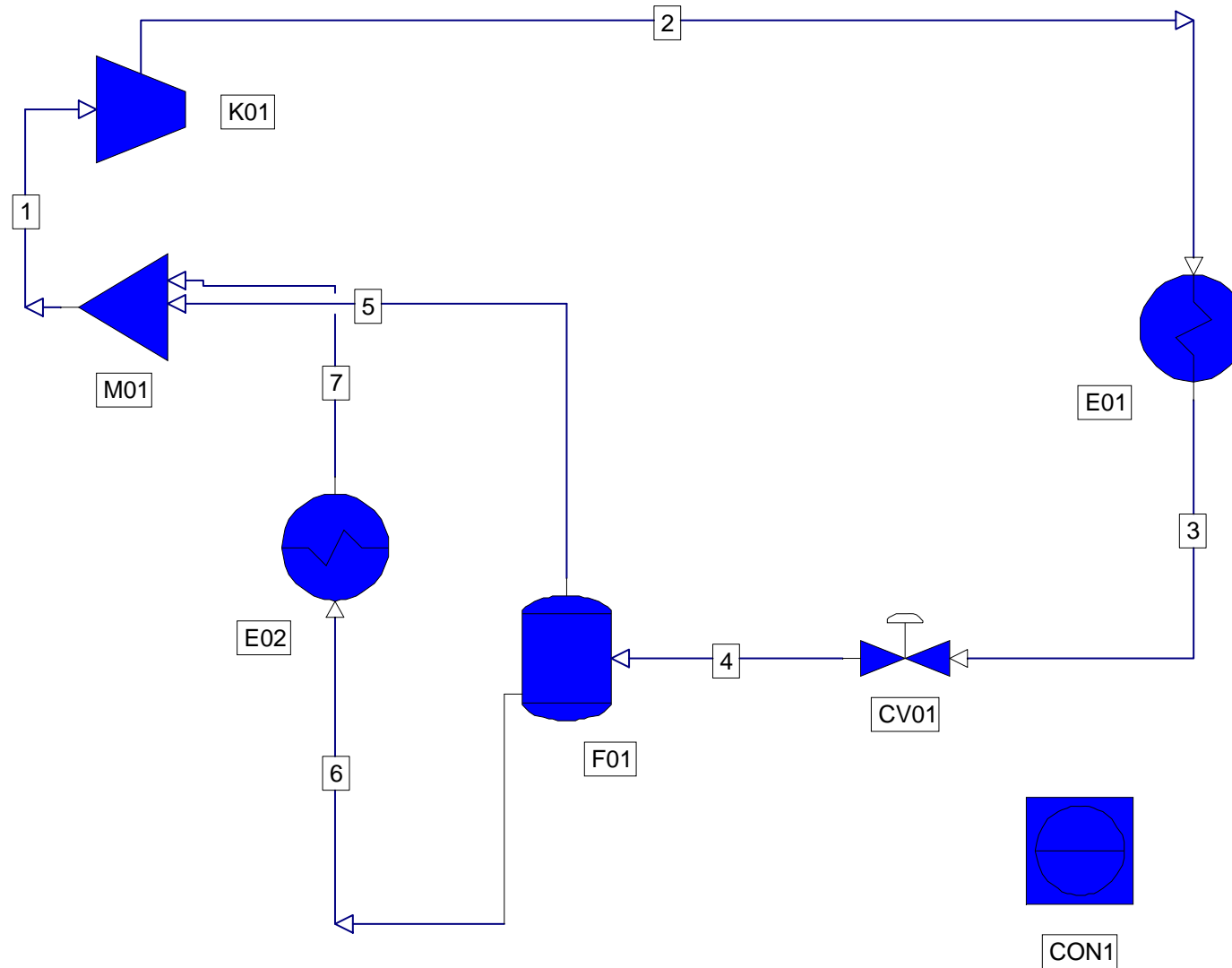
COLD SIDE CONDITIONS

	INLET	OUTLET
	-----	-----
FEED	1	
WATER PRODUCT		2
WATER, KG-MOL/HR	15881.168	15881.168
K*KG/HR	<u>286.099</u>	<u>286.099</u>
CP, KCAL/KG-C	0.998	0.997
TOTAL, KG-MOL/HR	15881.168	15881.168
K*KG/HR	286.099	286.099
CONDENSATION, KG-MOL/HR		0.000
TEMPERATURE, C	<u>32.000</u>	<u>40.000</u>
PRESSURE, BAR	3.500	3.500

각각의 Step별 모사 결과의 요약

Step	항목	모사 결과
1	(E02) Heat duty = ?	1.469x10 ⁶ Kcal/hr
2		15.886 bar
3	Pressure Let-down Valve	2.439 bar
4		15,299 Kg/hr
5		946.84 kW
6	(E01) Heat duty = ?	2.283x10 ⁶ Kcal/hr
7		286,099 Kg/hr

냉동사이클 전체의 공정모사



When finished, save as Refrigeration-cycle.inp

최종적인 물질 수지식

STRM NO.	1	2	3	4	5	6	7
C3 (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Temp. (°C)	-20.0	71.30	45.00	-20.00	11,865	15,299	15,299
Press. (bar)	2.439	15.886	15.886	2.439	2.439	2.439	2.439
Phase	V	V	L	M	V	L	V
Flow (Kg/hr)	27,164	27,164	27,164	27,164	11,865	15,299	15,299
Enthalpy (Kca/hr)	2,275,900	3,090,100	807,500	807,500	994,100	-186,600	1,281,800

STRM NO.	LPG1	LPG2	C/W-IN	C/W-OUT
Temp. (°C)	10.00	-10.00	32.00	40.00
Press. (bar)	2.439	15.886	15.886	2.439
Phase	V	V	L	M
Flow (Kg/hr)	15,078	15,078	286,099	286,099
Enthalpy (Kca/hr)	1,393,000	-75,990	9,155,000	11,438,000

최종 결과

