Energy Optimization of Crude Distillation Unit Through Pumparound Heat Duty Distribution

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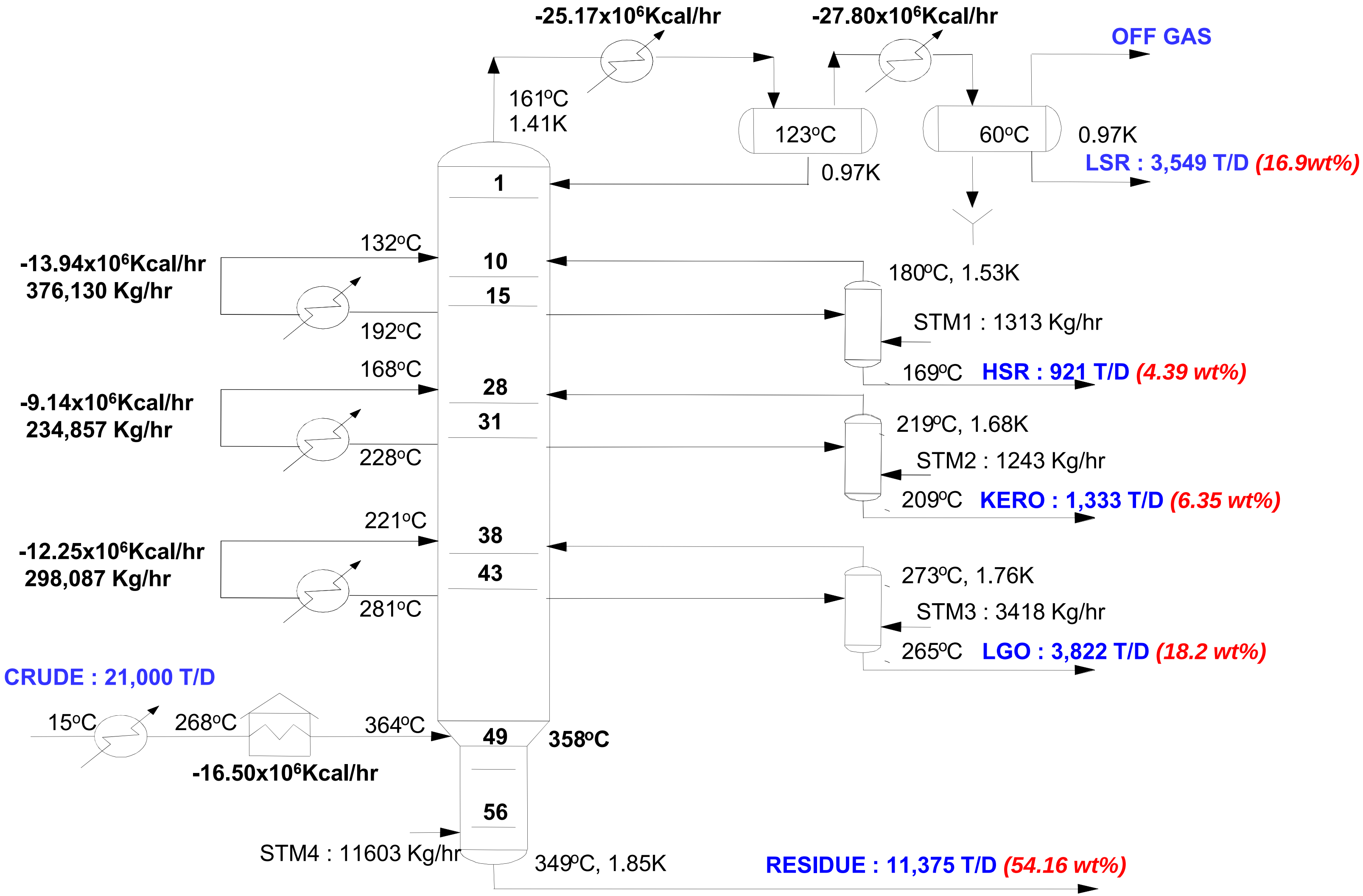
공주대학교 화학공학부

<u>조 정 호</u>

Minimum Information for CDU Simulation:

- Whole Crude TBP Data
- Whole Crude API Gravity
- Light Ends Analysis up to C5

Modeling an Atmospheric Crude Tower:



Problem Description:

- A crude unit is designed to process 21,000 tons per day of 50% Arabian heavy crude and 50% Arabian light crude. The desired products are shown in the next slide, with specifications in Table 1.

- 250^{o}C steam (assumed to be saturated) is available for stripping. The condenser is to operate at 123^{o}C and 0.97 Kg/cm^{2}G.

- An initial simulation model was constructed as shown in the above slide. ASTM D86 95% temperatures were used for HSR, Kerosene and LGO. The overflash (0.03) was set as a specification. A partial condenser was used to meet the desired temperature of 123^{o}C.

ASTM D86 Temperature for Sidecut Prodcuts:

Table 1 : Product Specification of Each Side Distillates					
	NAPHTHA	HSR	KEROSENE	LGO	RESIDUE
IBP	69	137	168	218	*319*
5 %	71	165 *(162)*	198 *(190)*	246 *(238)*	*368*
10 %	74	172 *(171)*	203 *(199)*	254 *(246)*	*381*
30 %	88	179 *(175)*	210 *(205)*	268 *(265)*	*454*
50 %	104 *(104)*	183 *(176)*	215 *(209)*	283 *(282)*	*533*
70 %	122 *(129)*	187 *(180)*	221 *(215)*	301 *(301)*	*684*
90 %	146 *(149)*	193 *(186)*	229 *(226)*	328 *(328)*	*874*
95 %	153 *(159)*	196 *(193)*	235 *(234)*	337 *(339)*	-
EP	162	204	251	378	-
					D1160

GAP = 12 *(3)*   GAP = 2 *(-3)*   GAP = 11 *(3)*

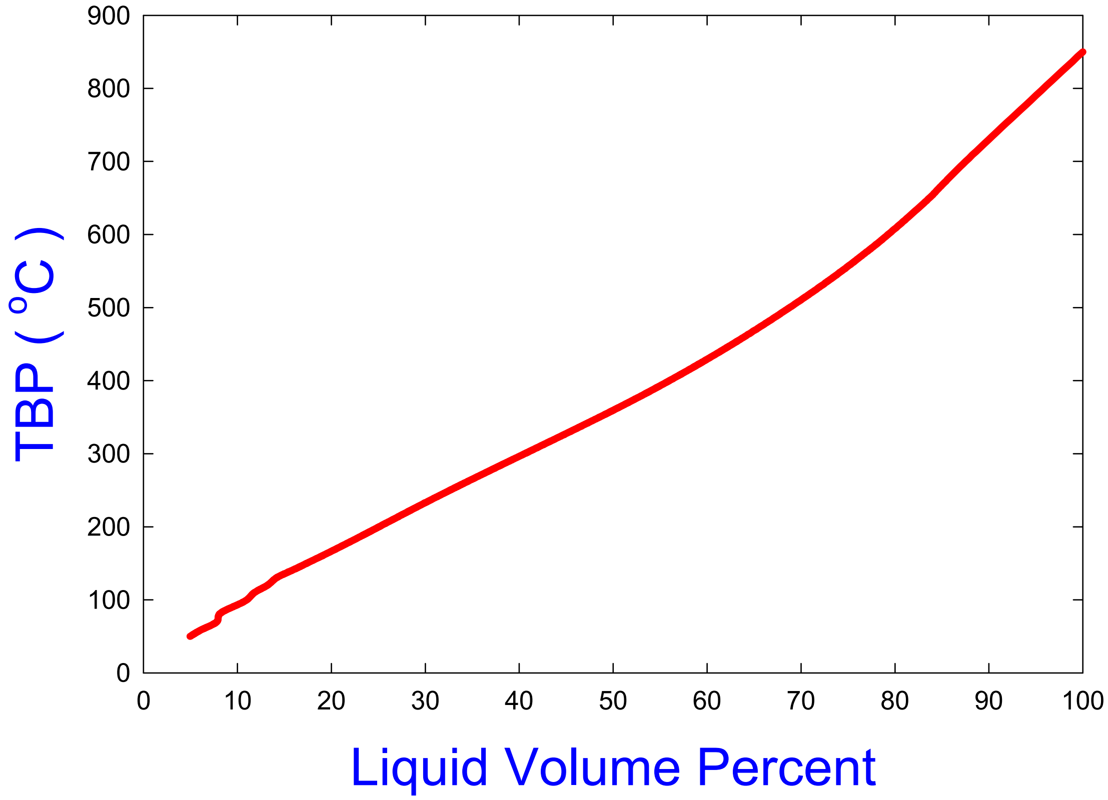
Feedstock Characterization for Crude Oil:

Table 2 : Oil 1 (Arabian Heavy Crude Oil : TBP)					
Liq. vol. %	Temp (C)	Liq. Vol. %	Temp (C)	Liq. vol. %	Temp (C)
4.9675	50	29.5540	230	57.3875	410
6.3165	60	31.0779	240	58.7564	420
7.8273	70	32.6249	250	60.0973	430
8.0584	80	34.1912	260	61.4113	440
9.4522	90	35.7731	270	62.6993	450
11.0033	100	37.3668	280	63.9624	460
11.8134	110	38.9686	290	66.4180	480
13.2141	120	40.5747	300	68.7861	500
14.1386	130	42.1813	310	71.0740	520
15.7578	140	43.7847	320	73.2721	540
17.3845	150	45.3812	330	75.3642	560
18.9837	160	46.9669	340	77.3657	580
20.5502	170	48.5379	350	79.2783	600
22.0844	180	50.0883	360	83.6724	650
23.5917	190	51.6115	370	87.5258	700
25.0820	200	53.1026	380	100.0000	850
26.5657	210	54.5616	390		
28.0529	220	55.9896	400		

Feedstock Characterization for Crude Oil:

Table 3 : Oil 1 (Arabian Heavy Crude Oil : Specific Gravity)					
Liq. vol. %	Sp. Gr.	Liq. Vol. %	Sp. Gr.	Liq. vol. %	Sp. Gr.
4.9675	0.6348	29.5540	0.8015	57.3875	0.9101
6.3165	0.7603	31.0779	0.8080	58.7564	0.9140
7.8273	0.6643	32.6249	0.8143	60.0973	0.9187
8.0584	0.6733	34.1912	0.8178	61.4113	0.9231
9.4522	0.7736	35.7731	0.8240	62.6993	0.9275
11.0033	0.6953	37.3668	0.8302	63.9624	0.9317
11.8134	0.7128	38.9686	0.8366	66.4180	0.9358
13.2141	0.7342	40.5747	0.8429	68.7861	0.9474
14.1386	0.7258	42.1813	0.8493	71.0740	0.9548
15.7578	0.7349	43.7847	0.8558	73.2721	0.9623
17.3845	0.7427	45.3812	0.9623	75.3642	0.9699
18.9837	0.7512	46.9669	0..8705	77.3657	0.9777
20.5502	0.7592	48.5379	0.8769	79.2783	0.9855
22.0844	0.7662	50.0883	0.8630	83.6724	0.9987
23.5917	0.7736	51.6115	0.8889	87.5258	1.0169
25.0820	0.7809	53.1026	0.8945	100.0000	1.1116
26.5657	0.7879	54.5616	0.9000		
28.0529	0.7948	55.9896	0.9052		

TBP vs. LV% for Arabian Heavy Crude Oil:



Lightend Analysis for Arabian Heavy Crude Oil:

Table 4: Lightends Analysis	
Component	**LV fraction**
C2	**0.0005**
C3	**0.0069**
IC4	**0.0031**
NC4	**0.0130**
Total	***0.0235***

Feedstock Characterization for Crude Oil:

Table 5 : Oil 2 (Arabian Light Crude Oil : TBP)					
Liq. vol. %	**Temp (C)**	**Liq. Vol. %**	**Temp (C)**	**Liq. vol. %**	**Temp (C)**
3.7904	40	32.4055	220	64.4796	400
4.5061	50	34.2644	230	66.0120	410
5.1447	60	36.1177	240	67.4992	420
7.0606	70	37.9654	250	68.9412	430
7.9677	80	39.8075	260	69.9615	440
8.7810	90	41.6440	270	71.3225	450
10.8900	100	43.4749	280	72.6537	460
11.8191	110	45.3662	290	75.2268	480
12.7902	120	47.1824	300	77.6808	500
15.3348	130	48.9886	310	80.0157	520
17.1090	140	50.7849	320	82.2399	540
18.8832	150	52.5712	330	84.1859	560
21.1010	160	54.3475	340	85.8773	580
23.1071	170	56.1138	350	87.4502	600
25.1326	180	57.8986	360	90.8971	650
26.9911	190	59.6116	370	93.7166	700
28.8573	200	61.2794	380	100.0000	850
30.5410	210	62.9021	390		

Feedstock Characterization for Crude Oil:

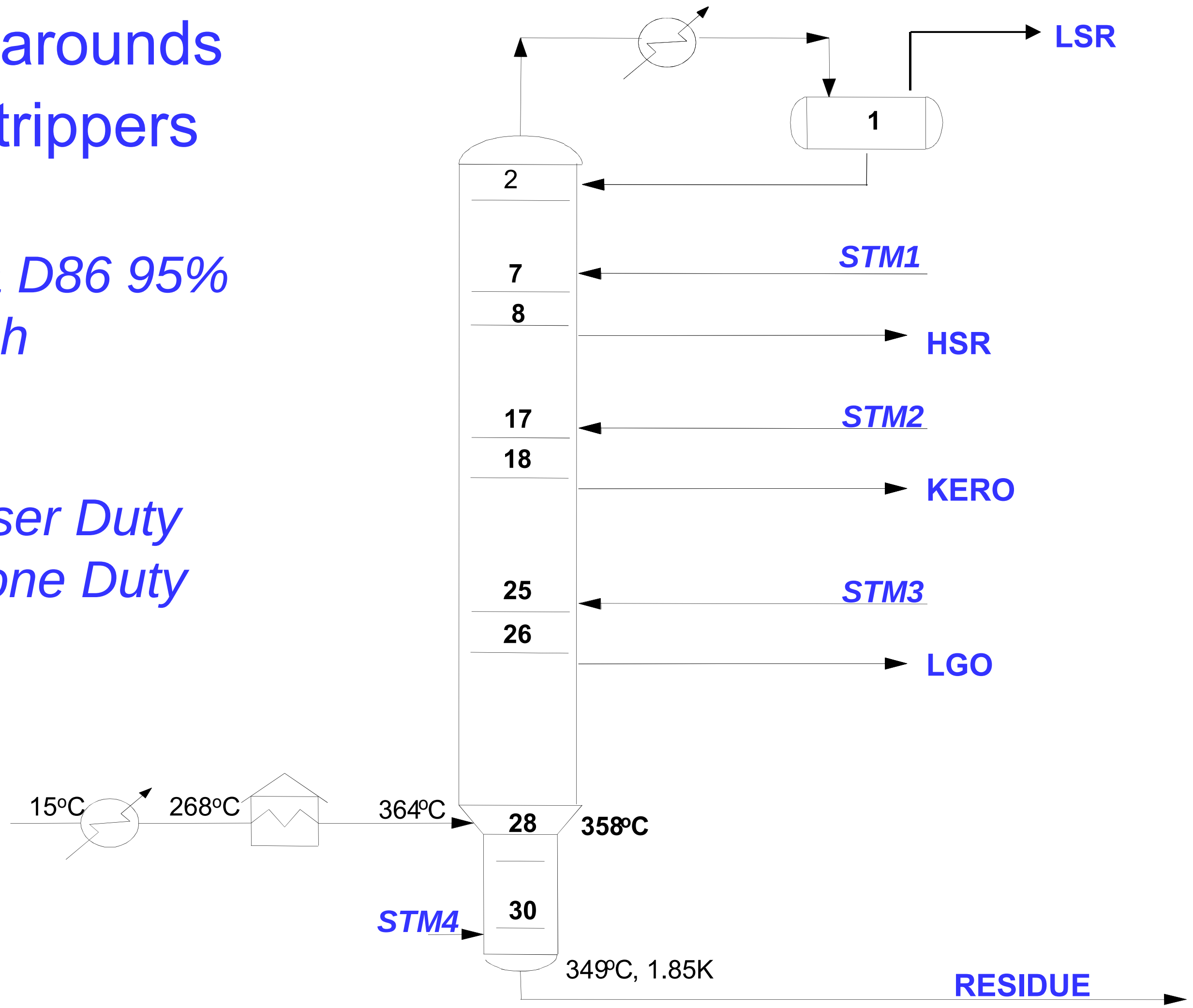
Table 6 : Oil 2 (Arabian Light Crude Oil : Specific Gravity)					
Liq. vol. %	Sp. Gr.	Liq. Vol. %	Sp. Gr.	Liq. vol. %	Sp. Gr.
3.7904	0.6341	32.4055	0.8023	64.4796	0.9075
4.5061	0.6541	34.2644	0.8083	66.0120	0.9104
5.1447	0.6527	36.1177	0.8142	67.4992	0.9147
7.0606	0.6627	37.9654	0.8163	68.9412	0.9188
7.9677	0.7156	39.8075	0.8221	69.9615	0.9228
8.7810	0.7044	41.6440	0.8281	71.3225	0.9267
10.8900	0.7018	43.4749	0.8342	72.6537	0.9304
11.8191	0.7242	45.3662	0.8404	75.2268	0.9358
12.7902	0.7664	47.1824	0.8467	77.6808	0.9406
15.3348	0.7326	48.9886	0.8532	80.0157	0.9476
17.1090	0.7594	50.7849	0.8598	82.2399	0.9549
18.8832	0.7647	52.5712	0.8690	84.1859	0.9624
21.1010	0.7634	54.3475	0.8754	85.8773	0.9702
23.1071	0.7707	56.1138	0.8815	87.4502	0.9784
25.1326	0.7770	57.8986	0.8873	90.8971	0.9914
26.9911	0.7852	59.6116	0.8928	93.7166	1.0095
28.8573	0.7919	61.2794	0.8980	100.0000	1.0982
30.5410	0.7961	62.9021	0.9029		

Lightend Analysis for Arabian Heavy Crude Oil:

Table 7: Lightends Analysis	
Component	**LV %**
C2	**0.0001**
C3	**0.0017**
IC4	**0.0018**
NC4	**0.0099**
Total	***0.0235***

Simplest Crude Column Model:

- No Pumparounds
- No Sidestrippers
- Specify
  - Naphtha D86 95%
  - Overflash
- Vary
  - Condenser Duty
  - Flash Zone Duty



Comparison btn Design, Shortcut & Rigorous(1) :

Design Shortcut *Rigorous (1)*	ASTM D86 5% Temp. (°C)	ASTM D86 50% Temp. (°C)	ASTM D86 95% Temp. (°C)
LSR	71.0	104.0	153
	2.2	111.5	155.0
	2.2	*111.0*	*157.9*
HSR	165.0	183.0	196
	165.0	178.5	196.0
	157.9	*179.5*	*197.2*
KERO	198.0	215.0	235
	198.0	211.1	234.0
	184.2	*215.7*	*239.8*
LGO	246.0	283.0	337
	245.0	281.7	337.0
	227.4	*285.4*	*362.0*
RESIDUE	D1160 5%	D1160 50%	D1160 90%
	368.0	533.0	874.0
	364.0	521.2	811.0
	179	*346*	*586*

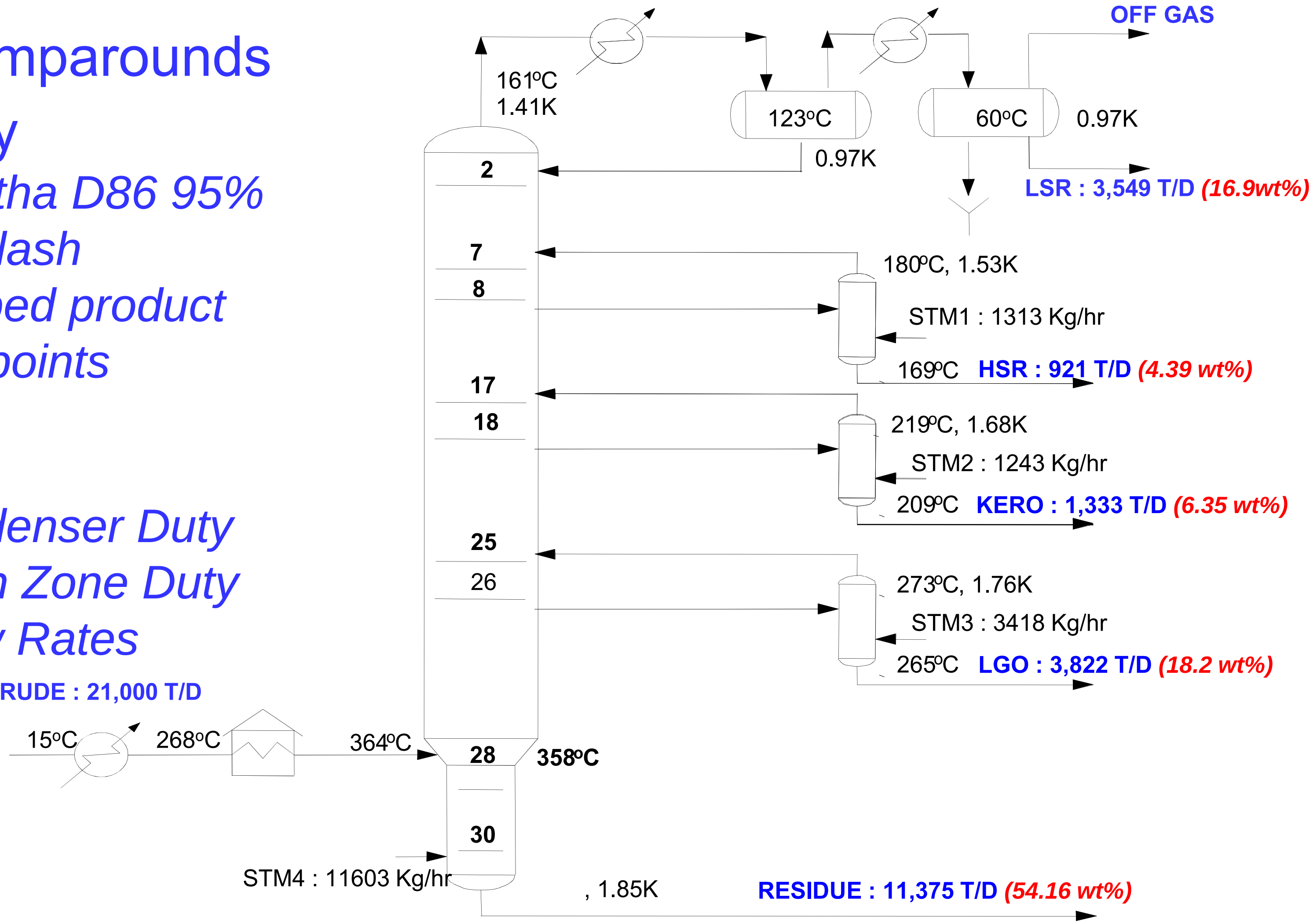
GAP : 12, 12, *0*

GAP : 2, 2, *-13*

GAP : 11, 11, *-12.4*

Add Side Strippers:

- No Pumparounds
- Specify
  - Naphtha D86 95%
  - Overflash
  - Stripped product 95% points
- Vary
  - Condenser Duty
  - Flash Zone Duty
  - Draw Rates



Examining Simulation Result: U-Type:

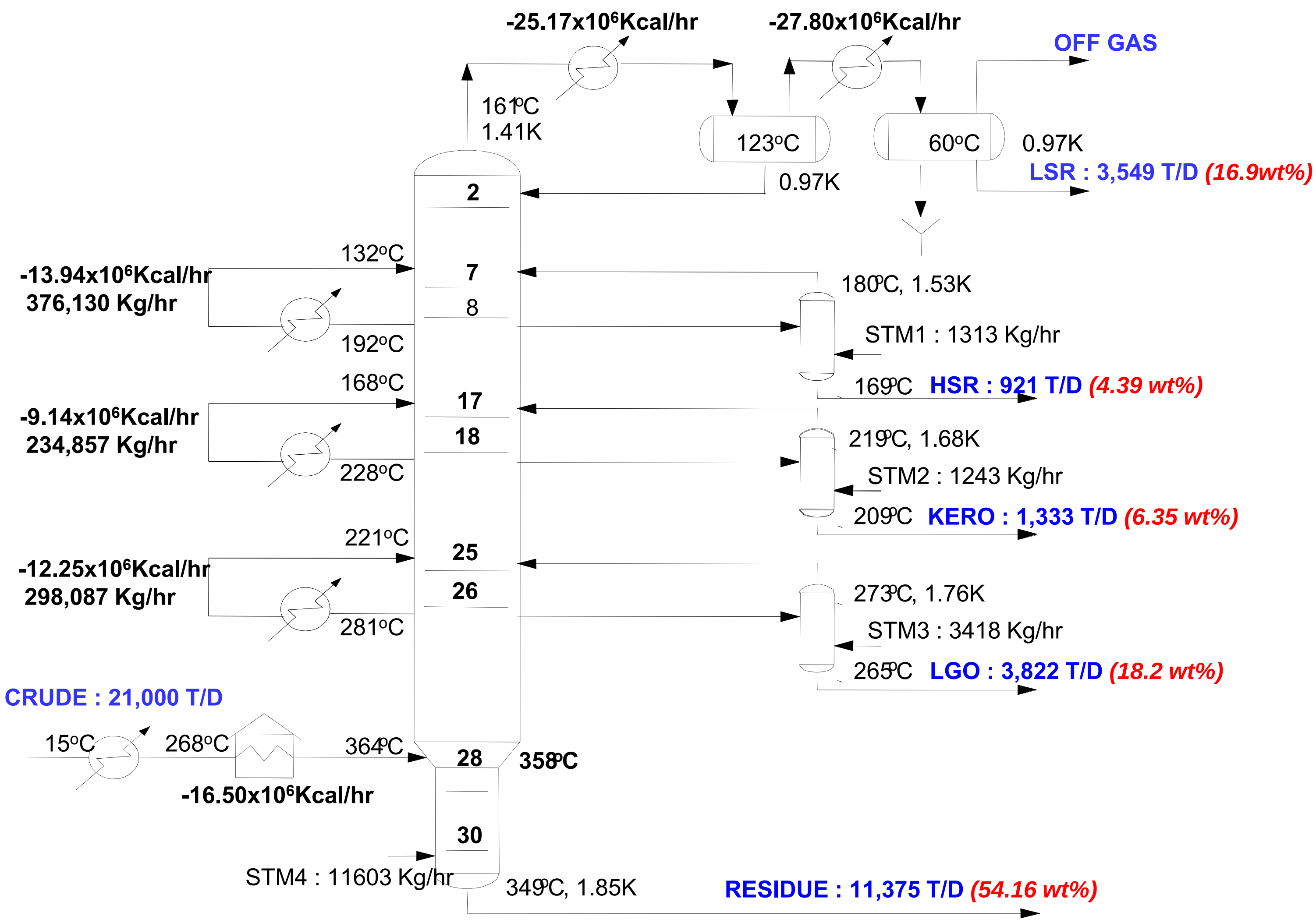
Design U-type-BK10 *U-type-GS*	ASTM D86 5% Temp. (°C)	ASTM D86 50% Temp. (°C)	ASTM D86 95% Temp. (°C)
LSR	71.0	104.0	153
	2.2	111.5	155.0
	24.6	*117.9*	*156.5*
HSR	165.0	183.0	196
	160.4	179.6	196
	161.8	*178.9*	*196*
KERO	198.0	215.0	235
	190.5	213.5	235
	188.0	*212.4*	*235*
LGO	246.0	283.0	337
	236.7	272.0	337
	233.8	*271.1*	*337*
RESIDUE	D1160 5%	D1160 50%	D1160 90%
	368.0	533.0	874.0

GAP : 12, 5.4, *5.3*

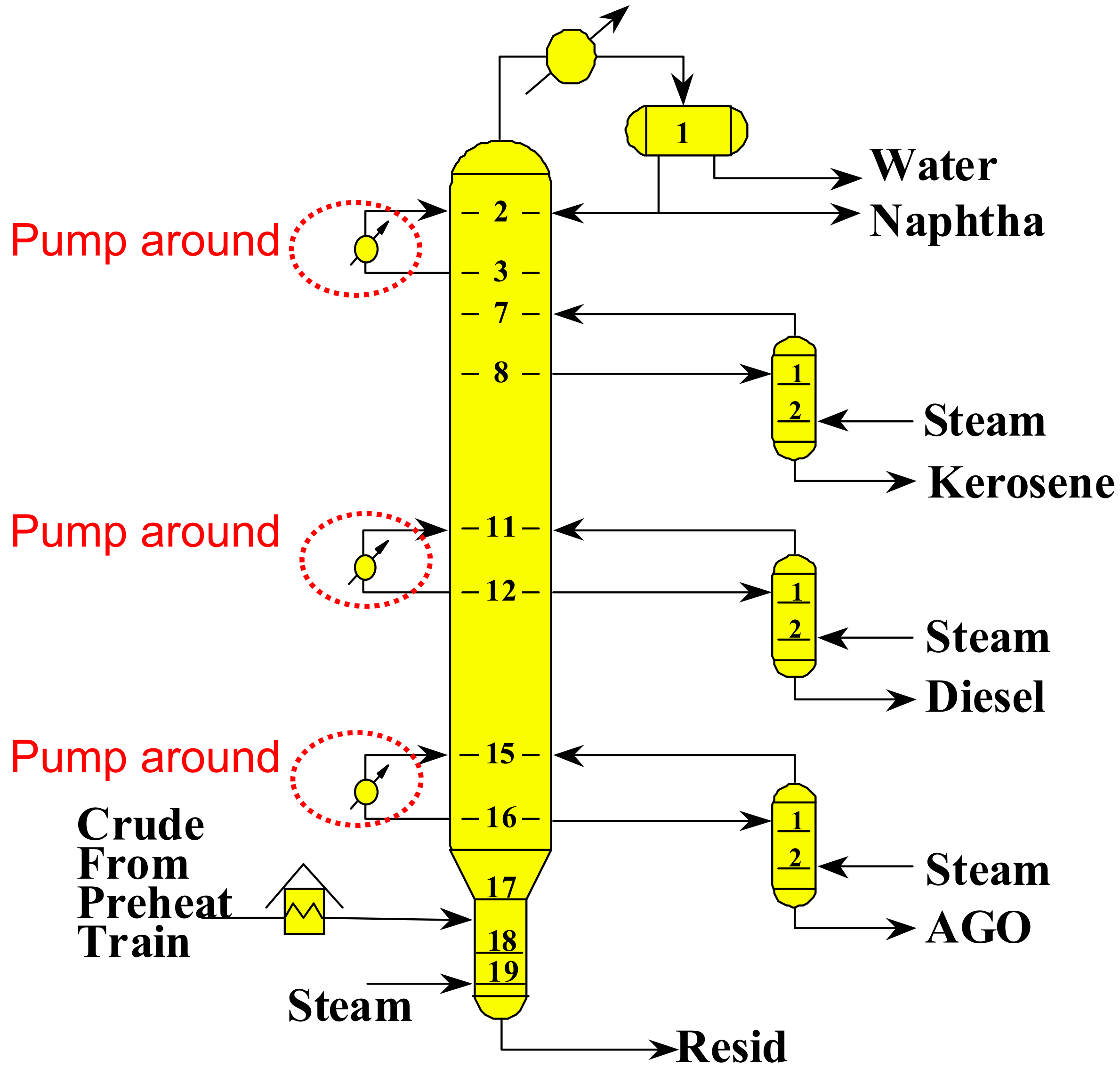
GAP : 2, -5.5, *-8*

GAP : 11, 1.7, -1.2

Add Pumparound Side-coolers:



CDU Column Overview:

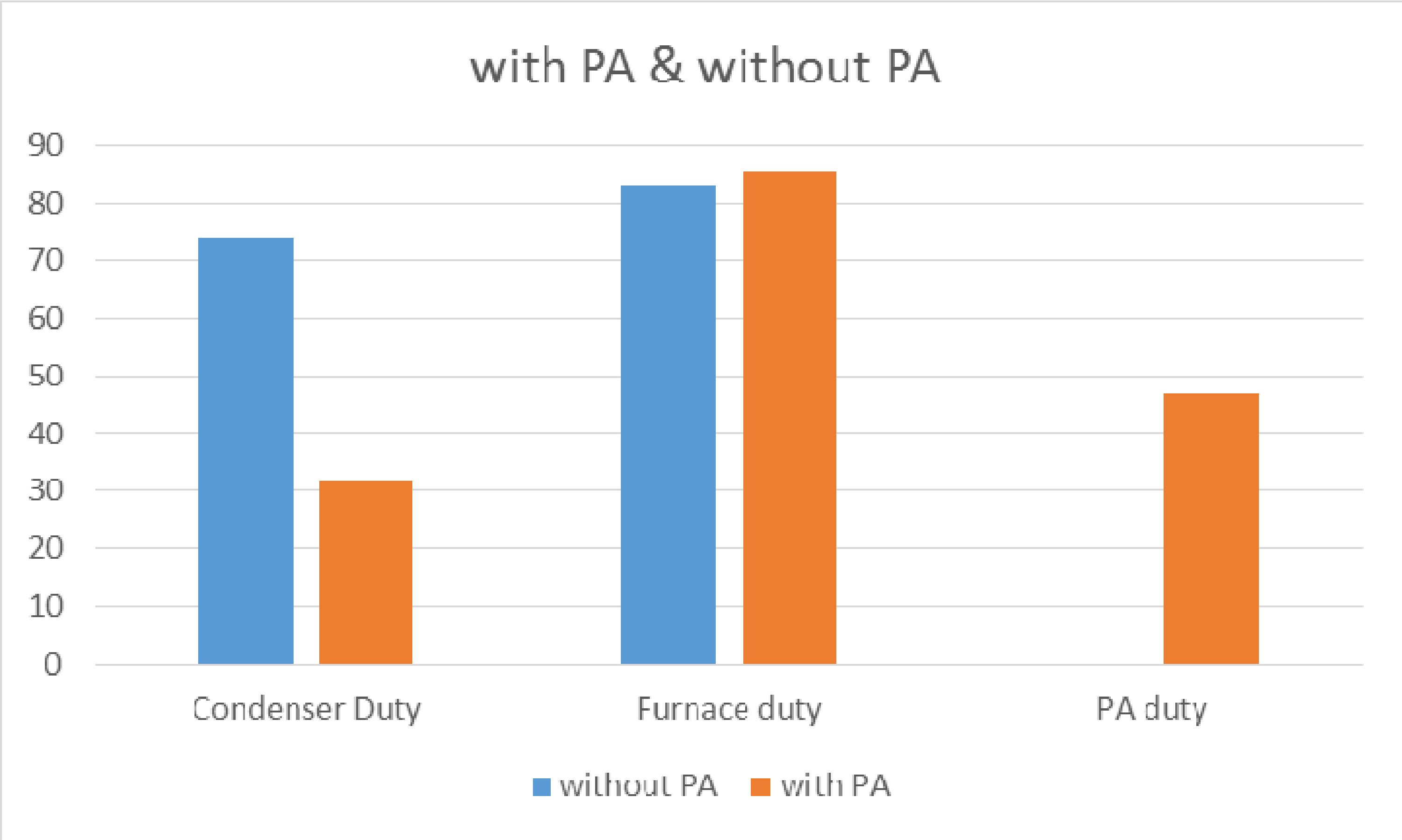


Pumparound Side-Cooler 설치 전과 후의 비교:

- **No Pumparound:**
  - Bigger condenser duty
  - Larger column diameter
- **Installing Pumparound:**
  - Smaller condenser duty
  - Smaller column diameter

Pumparound Side-Cooler 설치 전과 후의 비교:

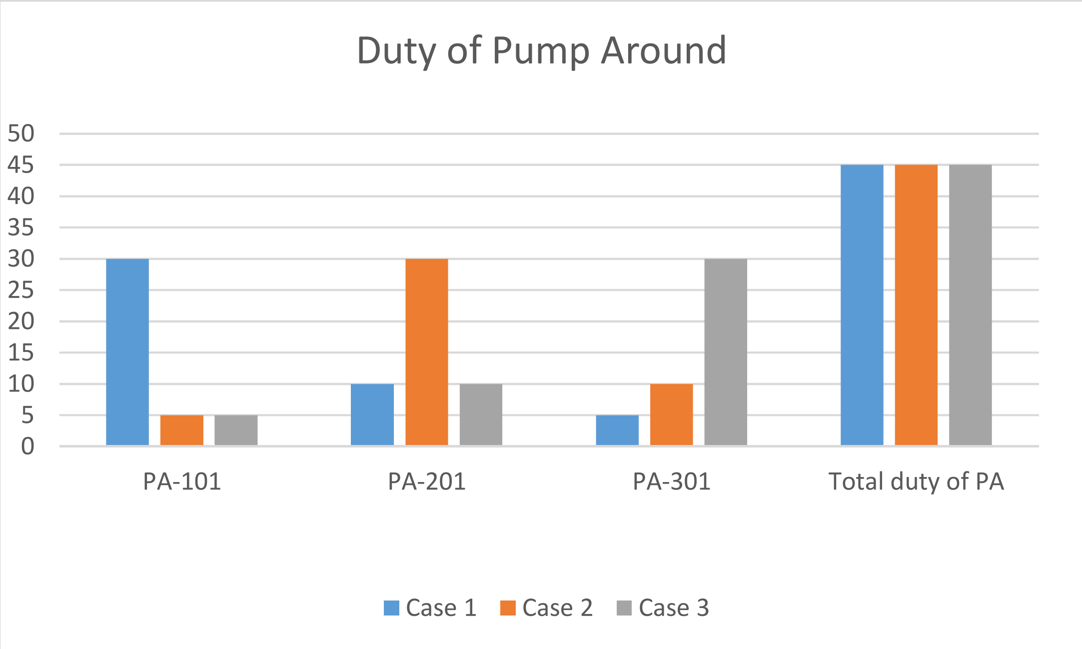
- Simulation Results:

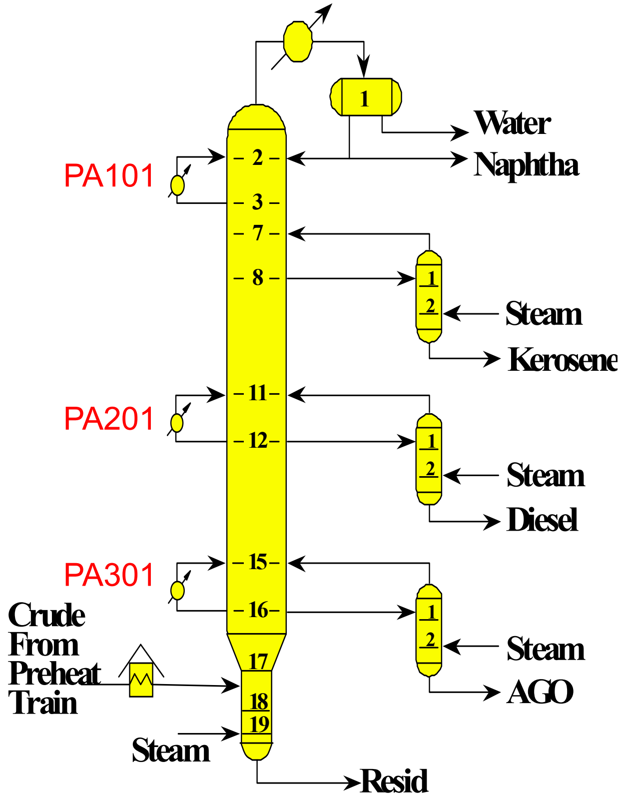


PA Case Studies:

➢ Case Studies for PA Duty Distributions:

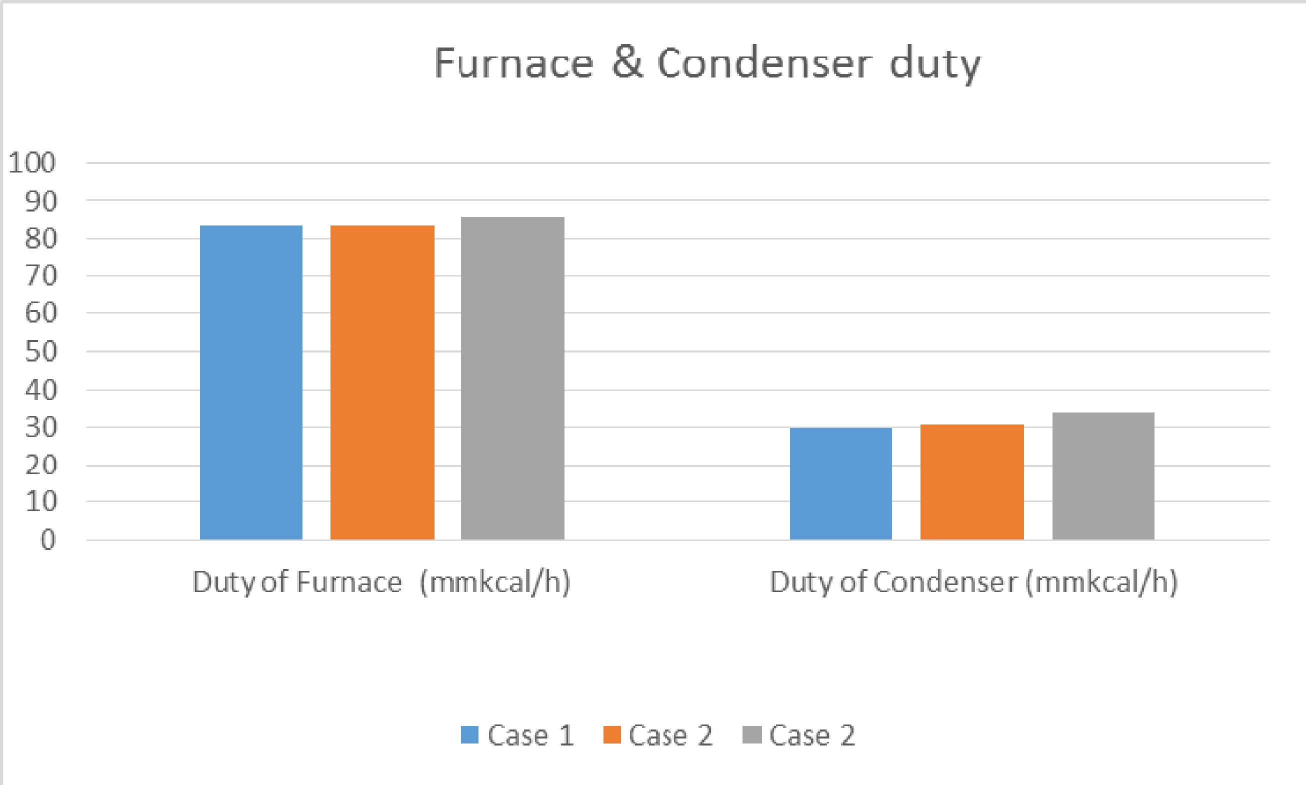
	Case 1	Case 2	Case 2
Duty of PA 101 (mmkcal/h)	30	5	5
Duty of PA 201 (mmkcal/h)	10	30	10
Duty of PA 301 (mmkcal/h)	5	10	30





Overall Case Study Results:

- Furnace and Condenser Duty on Different PA Cases:



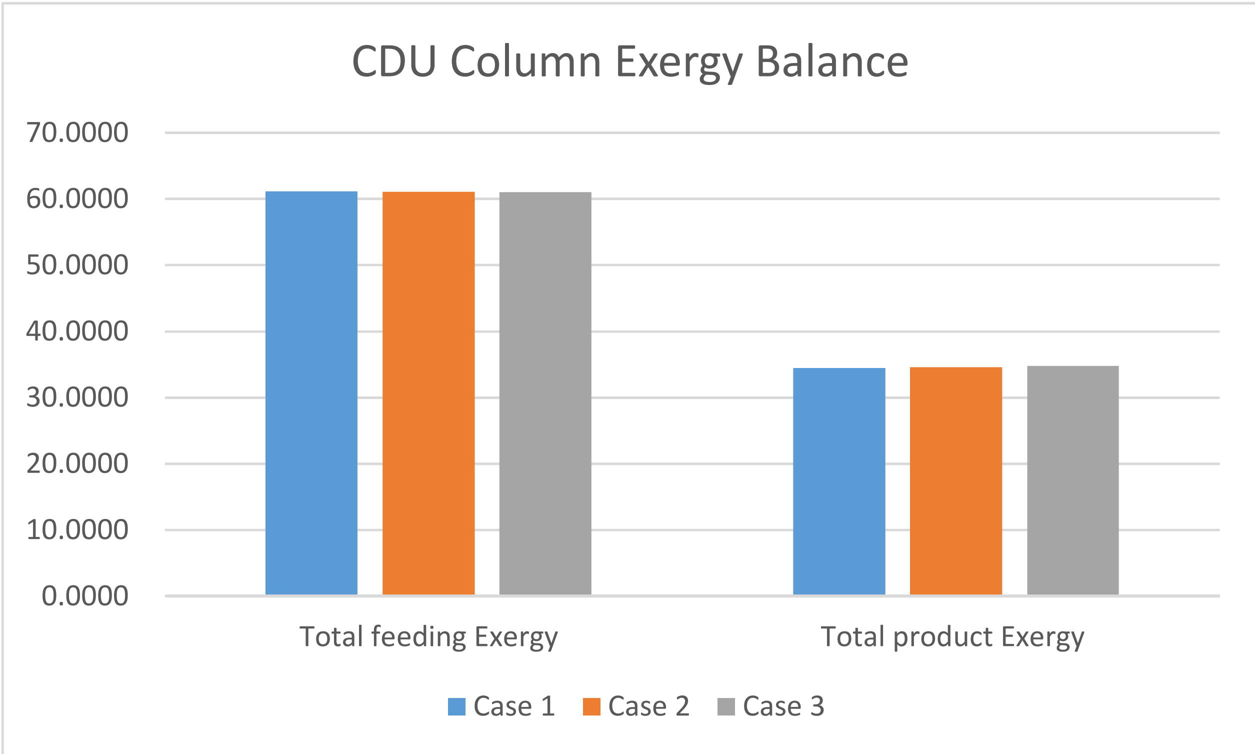
Overall Column Exergy Analysis:

➢ Calculated Exergy for each cases:

	Case 1	Case 2	Case 3
Total feeding Exergy	**61.1228**	**61.1149**	**61.0417**
CRUDE FEED	59.2627	59.2548	59.1816
MAIN STEAM	1.0098	1.0098	1.0098
KERO STEAM	0.3401	0.3401	0.3401
AGO STEAM	0.1277	0.1277	0.1277
DIESEL STEAM	0.3826	0.3826	0.3826
Total product Exergy	**34.4430**	**34.5871**	**34.8114**
NAPHTHA	-1.3749	-1.3759	-1.3760
DECANT	0.0169	0.0169	0.0169
KEROSENE	1.5795	1.6231	1.6397
DIESEL	3.0789	3.1369	3.2343
AGO	7.2104	7.2441	7.3364
RESID	23.9322	23.9420	23.9601

Overall Column Exergy Analysis:

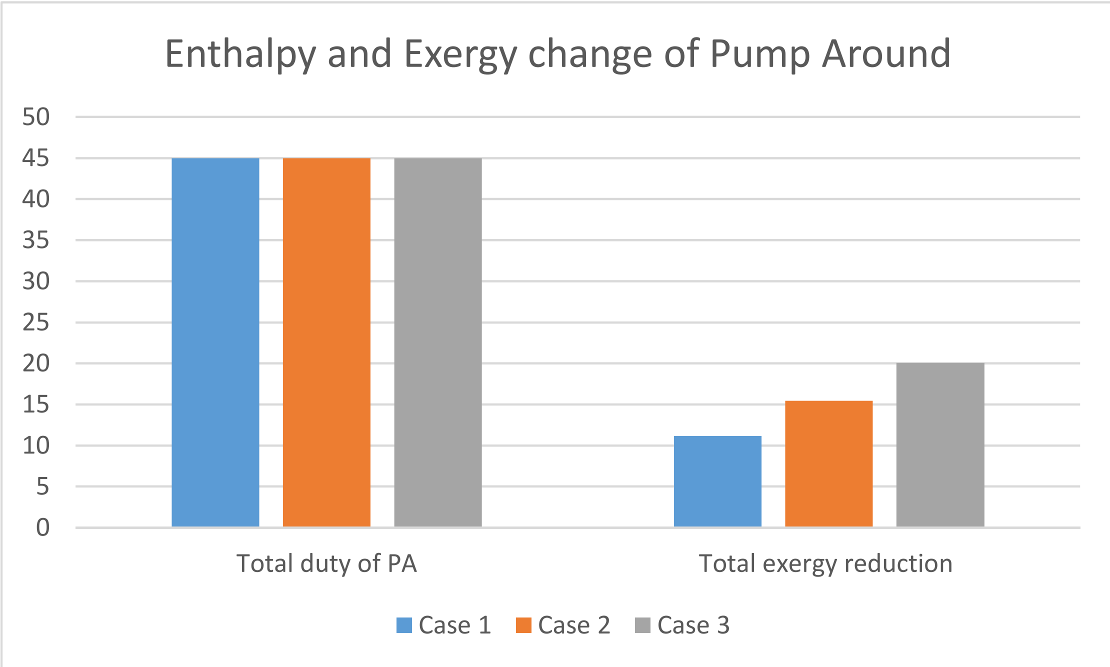
➢ Overall Exergy balance:



PA Enthalpy and Exergy Change:

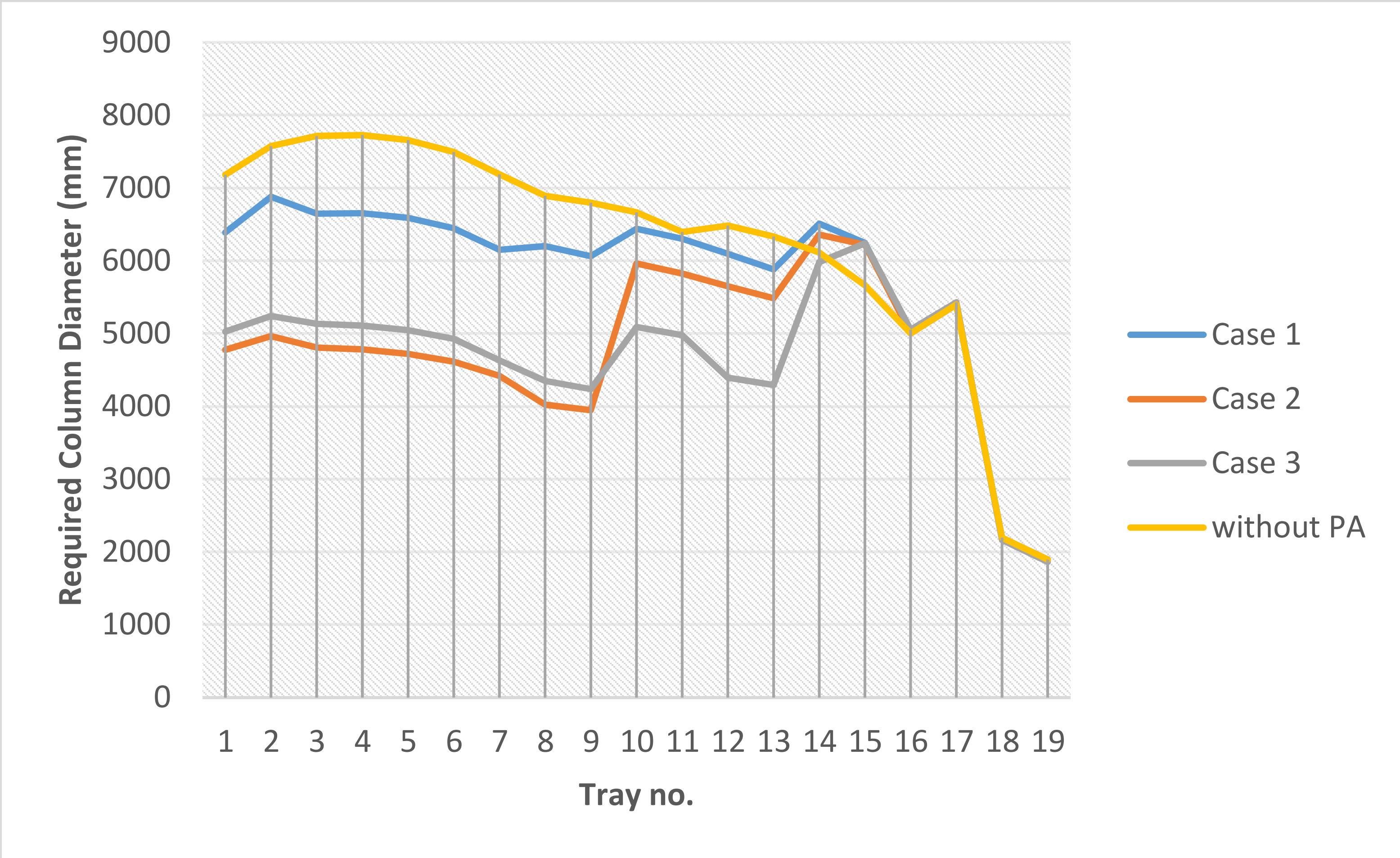
➢ Enthalpy and Exergy Change in Pumparound Part:

	Case 1	Case 2	Case 3
PA-101	30	5	5
PA-201	10	30	10
PA-301	5	10	30
Total duty of PA	45	45	45
PA 101 exergy reduction	4.24	1.50	1.52
PA 201 exergy reduction	4.35	8.88	4.08
PA 301 exergy reduction	2.58	5.08	14.44
Total exergy reduction	11.17	15.46	20.04



Required Column ID on the Several Cases:

- Required Column ID:



General Rules for Pumparound Side-Cooler:

General Rules:

- 전체 cooling duty의 60~70%를 pumparound side-cooler에서 담당할 수 있다.
- Column 아래 쪽의 pumparound cooler의 duty를 증가시킬수록 좀 더 고급에너지를 더욱 절감할 수 있다. 왜냐하면 열역학적으로 고온의 열일수록 더 고급에너지에 해당하므로

Conclusions:

- Pumparound Side-cooler의 설치목적은 전체 에너지 소모량을 줄이는 것이 아니라, 재생 가능한 에너지를 늘려주는 역할을 한다.
- Pumparound Side-cooler 설치 시 Column 내부의 Vapor loading을 줄여 줌으로써 Column의 Diameter를 줄일 수 있다.
- Pumparound Side-cooler의 Heat duty 분배를 고온부에서 많이 할수록, Column ID는 줄어들고 또한 Exergy 측면에서 유리하다. 즉, 더 많은 에너지를 이용할 수 있다.
- PA의 고온부의 열을 Column 전단부 Heat chain에서 사용하면, Furnace heater의 duty 감소를 통한 에너지 절감효과를 얻을 수 있다.
- PA의 Distribution은 Product Spec. 및 Column ID를 고려하여 결정한다.

THANK YOU