CHAPTER IV
RESULTS AND DISCUSSION

In this chapter was distinguished in two parts, part 1 is the analysis in the exergetic efficiency of the over all plant and the second part is the analysis in topping unit and the main equipment of this unit.

4.1 Calculation of Exergetic Efficiency for Overall Plant

The calculation of exergetic efficiency can be determined by equation 3.1 which can be expressed in the simple form

$$\eta_B = \frac{\Delta B_{useful} + \Delta B_{credits} + \Delta B_{separation}}{\Delta B_{driving}} * 100 \qquad (4.1)$$

In order to clearly understand in the scheme of this plant the process flow diagram of plant and utilities diagram has been illustrated in Figure 4.1, 4.2, and 4.3 respectively. The result obtained from calculation for this plant was presented in Table 4.1.

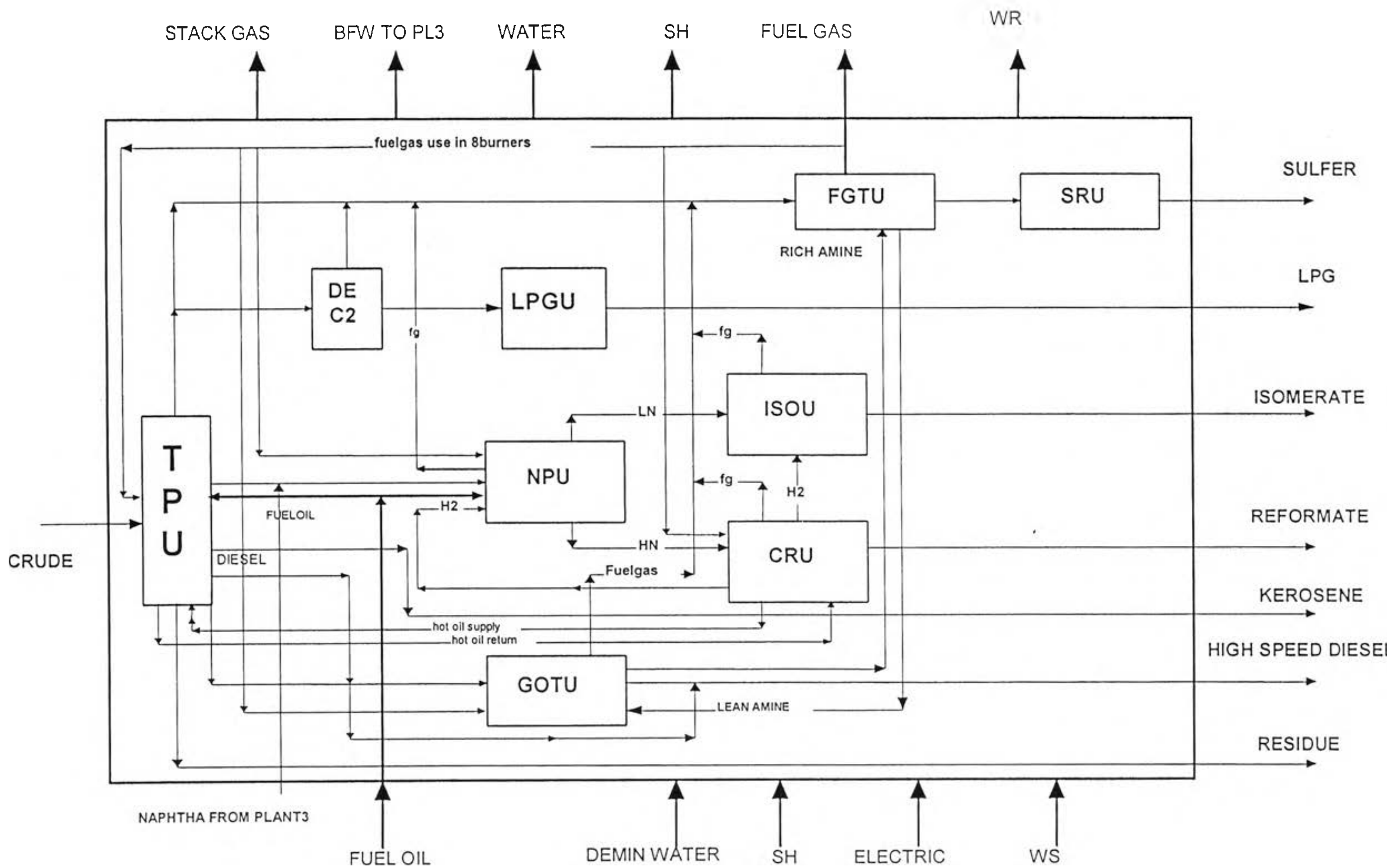

Figure 4.1 Simple process flow diagram of plant 2

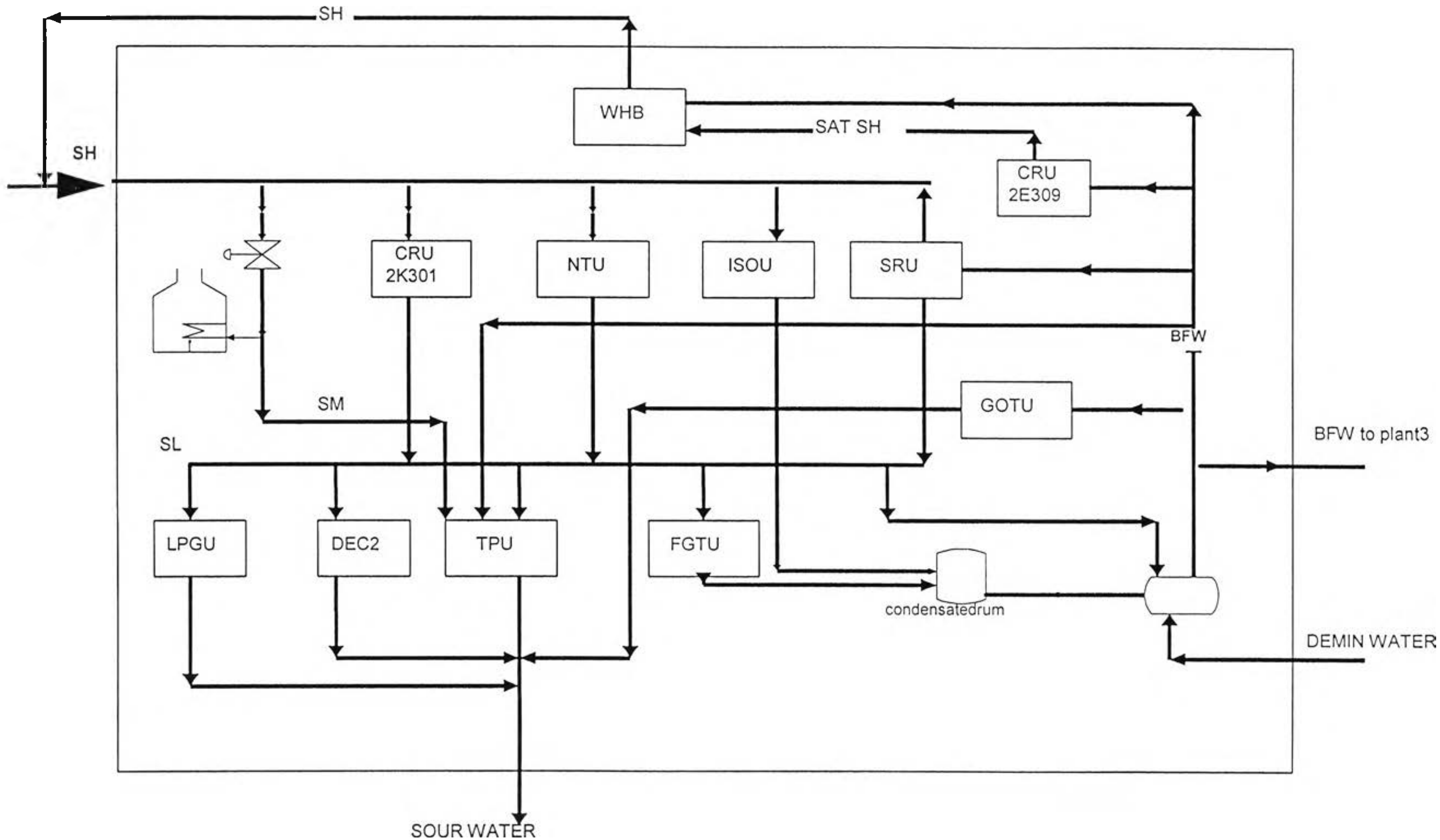

Figure 4.2 Simple process flow diagram of steam and water utility in plant 2

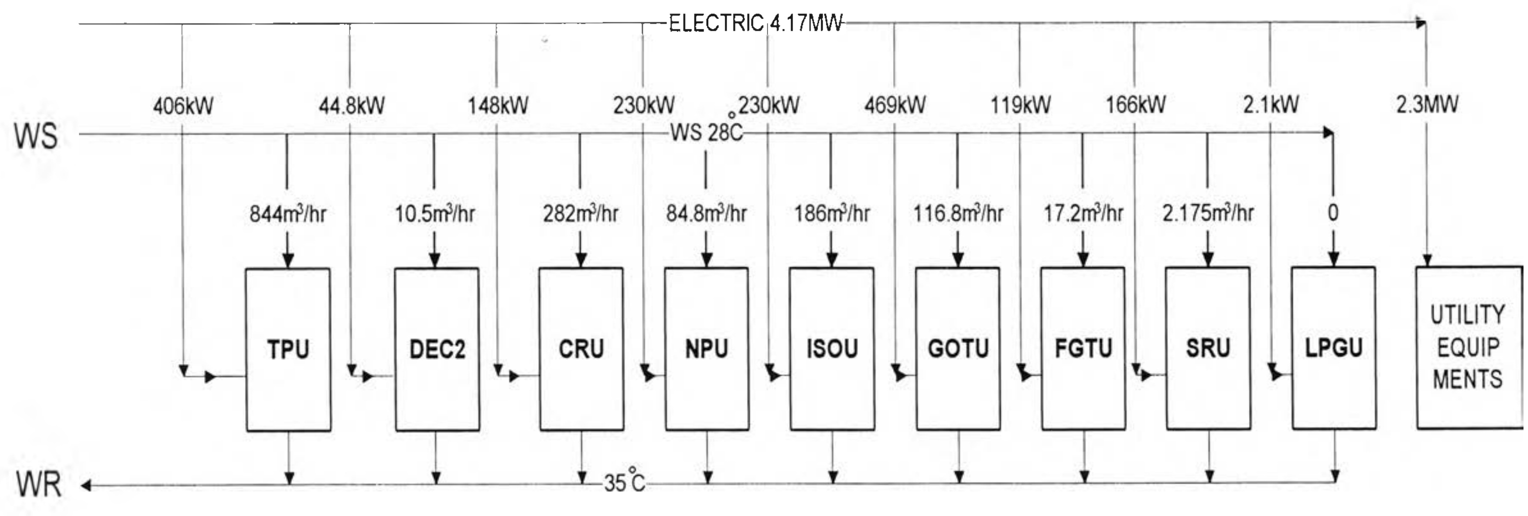

Figure 4.3 Simple process flow diagram of cooling water and electricity in plant 2

Table 4.1 Input and output exergy of plant 2

Input		Exergy (kW)	**Output**	Exergy (kW)
Feed			Products	
Crude	B_{phy}	483.7	Sulfur	171.3
	B_{che}	2598425.9		7694.9
Naphtha from plant3	B_{phy}	15.3	Kerosene	62.6
	B_{che}	326709.4		328086.5
	B_{phy}		Isomerate	6.0
	B_{che}			291614.8
	B_{phy}		HSD	56.8
	B_{che}			884589.2
	B_{phy}		LPG lig	0.3
	B_{che}			245.0
	B_{phy}		Reformate	8.1
	B_{che}			366659.1
	B_{phy}		Fuel oil	326.4
	B_{che}			1017654.9
	B_{phy}		Sourwater	2.5
	B_{che}			384.6
	B_{phy}		Fuel gas out	160.8
	B_{che}			29442.2
			B of mixing	1433.1
Input Utility			**Output Utility**	
SH	B_{tot}	7247.0	BFW to plant3	104.9
DEMIN	B_{tot}	299.1	water	363.4
			B credit	
			SH out from WHB	4992.5
Burner				
Fuel oil	B_{phy}	4.3	Stack	984.6
	B_{che}	15332.7		2945.2
Air	B_{phy}	12.0		
Cooling water in		21577.2	Cooling water out	21843.1
Electric		4173.3		
Total		2958314.1		2937012.2

4.1.1 Useful Exergy

In this plant useful exergy (ΔB_{useful}) is equal to the difference between the sum of total exergy of products and the sum of total exergy of feeds.

Product

Liq sulfur	B_{phy}	= 171.3	kW
	B_{che}	= 7694.9	kW
Kerosene	B_{phy}	= 62.6	kW
	B_{che}	= 328086.5	kW
Isomerate	B_{phy}	= 6.0	kW
	B_{che}	= 291614.7	kW
Hsd	B_{phy}	= 56.8	kW
	B_{che}	= 884589.2	kW
LPG	B_{phy}	= 0.34	kW
	B_{che}	= 245	kW
Reformate	B_{phy}	= 8.1	kW
	B_{che}	= 366659	kW
Fuel oil	B_{phy}	= 326.4	kW
	B_{che}	= 1017654.9	kW
Sourwater	B_{phy}	= 2.5	kW
	B_{che}	= 384.6	kW
	B_{che}	= 29442.2	kW
	Total	= 2927165.9	kW

Feed

Crude	B_{phy}	= 483.7	kW
	B_{che}	= 2598425.9	kW
Naphtha (Plant3)	B_{phy}	= 15.3	kW
	B_{che}	= 326709.4	kW
	Total	= 2925634.3	kW

$\therefore \Delta B$ useful = 2927165.9-2925634.3 kW

= 1531.6 kW

4.1.2 Credit Exergy

A credit exergy (ΔB_{credit}) is the heat that is generated from the process. In this plant it consist of a waste heat boiler to recovery heat from all of stack gas from seven burners in TPU, NTU, and CRU. The boiler feed water (BFW) was fed to the waste heat boiler to generate high-pressure steam (SH).

ΔB_{credit} = 4992.5-299.1= 4693.4 kW

4.1.3 Exergy Change due to Separation

In this plant the exergy change due to separation (ΔB_{mixing}) was calculated by equation 1.4 and the sum of

ΔB_{mixing} in every unit was accumulated to give ΔB_{mixing} of plant

ΔB_{mixing} = 1433.1 kW

4.1.4 Driving Exergy

The driving exergy ($\Delta B_{driving}$) of this plant is the summation of $(B_{fuel\ oil})+(B_{steam}-B_{condensate})+(B_{ws}-B_{wr})+B_{electric}$.

$B_{fuel\ oil}$ = (4.3+15332.6)

= 15336.9 kW

$B_{steam}-B_{condensate}$ = 7546.2-468.4

= 7077.8 kW

$B_{ws}-B_{wr}$ = 21577.2-21843.1

= -265.8 kW

$B_{electric}$ = 4173 kW

$\therefore$ The total of driving exergy = 15336.9+7077.8-265.8+4173

= 26035.1 kW

$$\therefore \text{Exergeticefficiency} = \frac{1531.6+1433.1+4693.4}{26035.1} * 100 = 29.4\%$$

The degree of perfection of this unit can be calculated by

$$\eta_P = \frac{B_{product} + B_{SHout} + B_{UTOUT}}{B_{feed} + B_{SH} + B_{demin} + B_{FO} + B_{elec}} * 100 \qquad (4.2)$$

$$\eta_P = \frac{2927165.9 + 4992.5 + 468.4}{2925634.3 + 7247 + 299.1 + 15349 + 4173.3} = 99.3\%$$

4.2 Calculation of Exergetic Efficiency for Topping Unit

The exergy efficiency of Topping unit can be calculated by equation 4.1 and the process schematic flow diagram was illustrated in Figure 4.4. The result obtained from calculation for this unit was presented in Table 4.2.

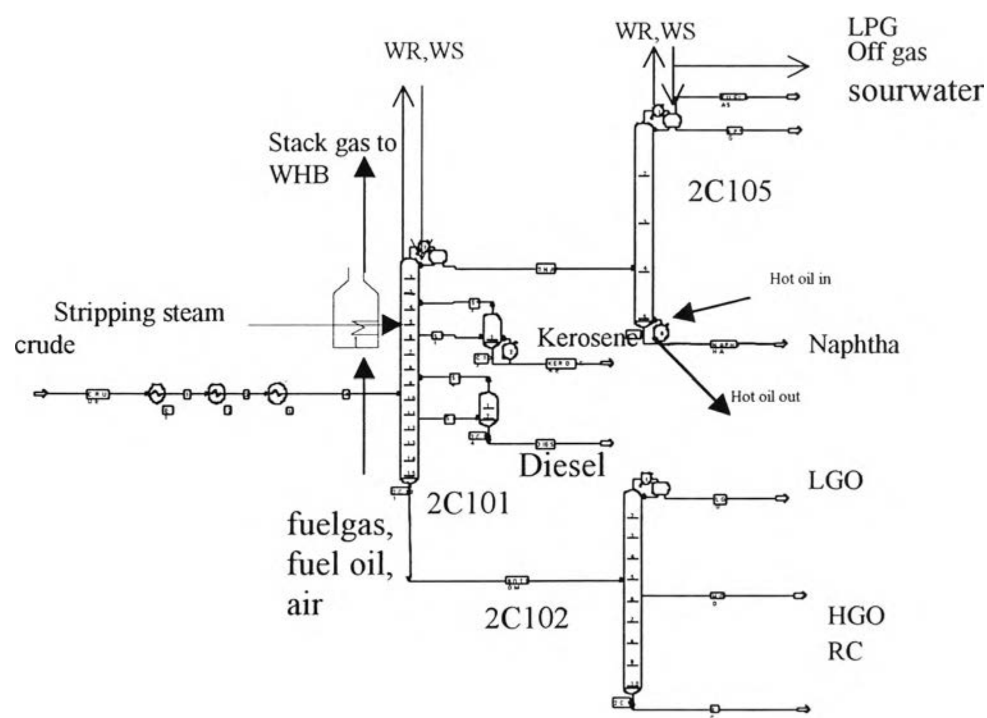

Figure 4.4 Simple process flow diagram of TPU

Table 4.2 Input and output exergy of TPU

Input		Exergy (kW)	**Output**	Exergy (kW)
Feed			Products	
B of crude	B_{phy}	484.3	Off gas	0.6
			LPG	27.9
			Naphtha	435.6
			Kerosene	89.0
			Diesel	854.6
			Gasoil	123.9
			RC	328.7
			Exergy of mixing	1027.6
Input Utilities			**Output Utilities**	
Desalt water in	B_{tot}	133.8	Desalt water out	189.5
BFW	B_{tot}	79.2	Condensate	63.2
B of hot oil in	B_{phy}	2097.1	B of hot oil out	1076.4
Low P steam	B_{tot}	177.5		
MED P steam	B_{tot}	103.4		
Burner				
B of fuel gas in 2F101	B_{phy}	60.5	Stack gas	1097.1
	B_{che}	11280.8		1212.5
B of fuel gas in F102	B_{phy}	40.4	Stack gas	2112.9
	B_{che}	10337.5		747.7
Fuel oil	B_{phy}	1.3		
	B_{che}	4372.0		
B of air in	B_{phy}	1.4		
Cooling water in	B_{tot}	69905.6	Cooling water out	69987.1
Electric		406.0		
total		96405.5	total	76486.4

4.2.1 Useful Exergy

In this unit the process is only separation and does not have any chemical reactions, so the chemical exergy does not change. The ΔB_{useful} is only the changing of the physical exergy.

Product

Off gas	B_{phy}	= 0.6	kW
Lpg	B_{phy}	= 27.9	kW
Naphtha	B_{phy}	= 435.6	kW
Diesel	B_{phy}	= 854.6	kW
Gas oil	B_{phy}	= 123.9	kW
Kerosene	B_{phy}	= 0.9	kW
Residue crude	B_{phy}	= 328.7	kW
	Total	= 1860.3	kW

Feed

Crude	B_{phy}	= 484.3	kW
	Total	= 484.3	kW

$\therefore \Delta B$ useful = 1860.3-484.3kW

= 1376 kW.

4.2.2 Exergy Change due to Separation

In this unit there are three distillation columns. The sum of ΔB_{mixing} of the three column give ΔB_{mixing} of the unit as

ΔB_{mixing} = 1027.6 kW

4.2.3 Driving Exergy

The driving exergy of this unit are

B_{steam}-$B_{condensate}$	=	493.8-252.6	=241.2 kW
$B_{fuelgas}$+$B_{fueloil}$-B_{stack}	=	26093.9-5170.2	=20923.6kW
B_{ws}-B_{wr}	=	69905.6-69987.1	=-81.5 kW

$B_{electric}$ = 405.9 kW

$B_{hotoil\ (in-out)}$ = 2097.1-1076.4 =1020.7 kW

$\therefore \Delta B_{driving}$ = 241.2+20923.6-81.5+405.9+1020.7

= 22509.9 kW

4.2.4 Credit Exergy

In this unit does not has B_{credit}

$$\therefore \text{Exergetic efficiency} = \frac{(1027.6+1376)}{22510}*100 = 10.7\%$$

And the degree of perfection of TPU unit can be determined from

$$\eta_P = \frac{B_{products} + B_{hotoil}}{B_{feed} + B_{UTin} + B_{fuelgas} + B_{electric} + B_{hotoilin}}*100 \qquad (4.3)$$

$$\eta_P = \frac{2623406.9 + 457069.2}{2622030.9 + 495.2 + 26092.5 + 405.9 + 458089.9}*100 = 99.1\%$$

4.3 Calculation of Exergetic Efficiency for Naphtha Pretreating Unit

The exergetic efficiency of Topping unit can be calculated by equation 4.1 and the process schematic flow diagram was illustrated in Figure 4.5. The result obtained from calculation for this unit was presented in Table 4.3

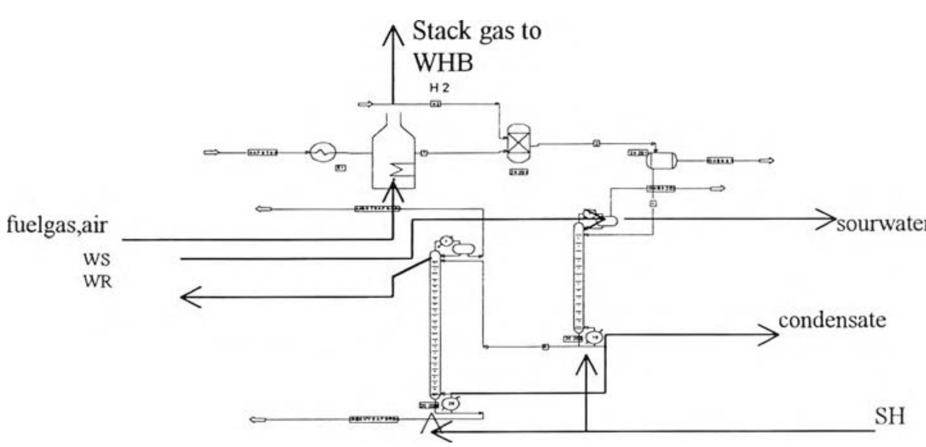

Figure 4.5 Simple process flow diagram of NTU

Table 4.3 Input and output exergy of NTU

Input		Exergy (kW)	Output	Exergy (kW)
Feed			Products	
H_2	B_{phy}	701.7	Gasout 2D201	629.1
	B_{che}	44646.6		31487.4
Naphtha from 2C105	B_{phy}	207.3	Gasout 2D202	32.6
	B_{che}	417559.7		11616.0
Naphtha from plant3	B_{phy}	11.7	Treated light naphtha	49.6
	B_{che}	251669.0		257302.5
	B_{phy}		Treated heavy naphtha	19.7
	B_{che}			418863.4
	B_{phy}		Sourwater	0.3
	B_{che}			27.5
			B of mixing	794.5
Input Utilities			**Output Utilities**	
SH to 2E207	B_{tot}	780.7	CPH out 2E207	53.5
SH to 2E208	B_{tot}	1757.7	CPH out 2E208	201.7
Burner				
Fuel	B_{phy}	11.3	Stack	636.4
	B_{che}	3856.3		200.3
Fuel oil	B_{phy}	3.1		
	B_{che}	10951.2		
Air	B_{phy}	0.4		
Cooling water in			**Cooling water out**	
2E203		414.6	2E203	419.9
2E206		190.1	2E206	192.5
2E209		587.5	2E209	594.9
Electric		230.1		
Total		734373.5	**Total**	721539.8

4.3.1 Useful Exergy

In this plant ΔB_{useful} is equal to the difference between the sum of total exergy of products and the sum of total exergy of feeds.

Feed

H2	B_{phy}	=	701.7
	B_{che}	=	44646.6
Naphtha(TPU)	B_{phy}	=	207.3
	B_{che}	=	417560
Naphtha(plant3)	B_{phy}	=	11.7
	B_{che}	=	257669.0
Total B feed		=	714796 kW

Product

Gas out from 2D201	B_{phy}	=	629.1
	B_{che}	=	31487.4
Gas out from 2D202	B_{phy}	=	32.6
	B_{che}	=	11616
Treated light naphtha	B_{phy}	=	7.4
	B_{che}	=	254907.2
Treated heavy naphtha	B_{phy}	=	19.7
	B_{che}	=	418863.4
Total B Product		=	720028 kW

$\therefore \Delta B$ useful =720028-714796 = 5202 kW.

4.3.2 Exergy Change due to Separation

In this unit it was the sum of ΔB_{mixing} from every distillation column in unit.

ΔB_{mixing} = 794.5 kW

4.3.3 Driving Exergy

In this unit the $\Delta B_{driving}$ was calculated by following detail.

B_{steam}-$B_{condensate}$ = 2538.3-225.3 = 2283 kW

$B_{fuelgas}$+$B_{fueloil}$-B_{stack} = 14822.4+10954-83673 = 24939.7kW

B_{ws}-B_{wr} = 1192.2-1207.2 = -15kW

$B_{electric}$ = 230.1 kW

$\therefore \Delta B_{driving}$ = 2283+24939.7-15+230.1 = 27438.8kW

$$\therefore \text{Exergy efficiency} = \frac{(5202 + 794.5)}{27438.8} * 100 = 21.85\%$$

And the degree of perfection of NTU unit can be determined from

$$\eta P = \frac{B_{products} + B_{UTout}}{B_{feed} + B_{UTin} + B_{fuelgas} + B_{electric}} * 100 \qquad (4.4)$$

$$\eta P = \frac{720028 + 53.5 + 201.7}{714796 + 2538.3 + 14822.3 + 230.1} = 98.4\%$$

4.4 Calculation of Exergetic Efficiency for Gasoil Pretreating Unit

The exergetic efficiency of Gasoil Pretreating Unit can be calculated by equation 4.1 and the process schematic flow diagram was illustrated in Figure 4.6. The result obtained from calculation for this unit was presented in Table 4.4.

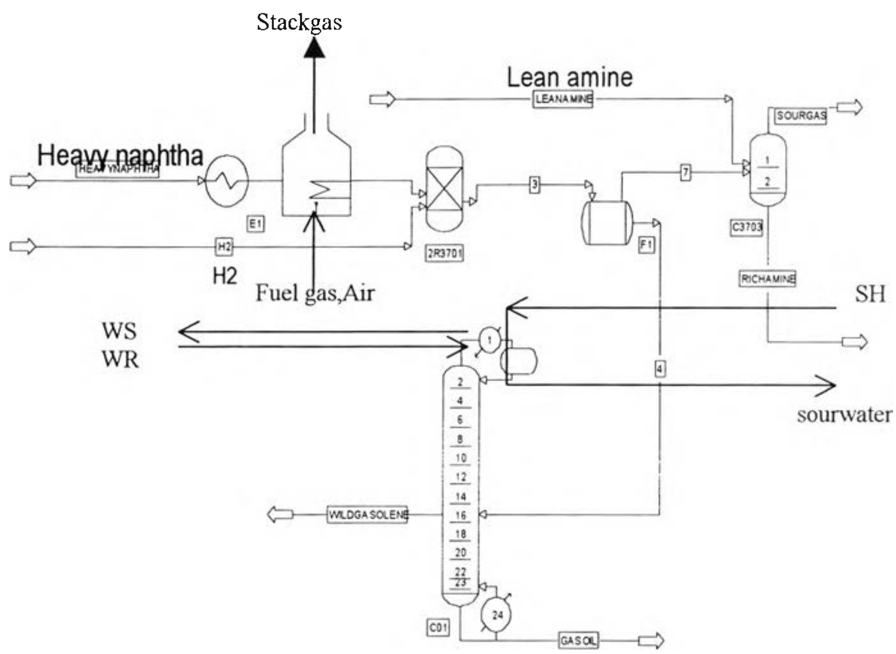

Figure 4.6 Simple process flow diagram of GOTU

Table 4.4 Input and output exergy of GOTU

Input		Exergy (kW)	**Output**	Exergy (kW)
Feed			Products	
Gasoil feed	B_{phy}	1103.0	Treated gas oil	76.2
	B_{che}	976780.3		948707.1
Poor amine	B_{phy}	28.1	Wild gasoline	0.6
	B_{che}	24298.3		18640.1
water	B_{phy}	1.2	Sour water	1.9
	B_{che}	34.8		289.5
H2 make up	B_{phy}	0.3	Rich amine	26.7
	B_{che}	41.9		27783.1
	B_{phy}		Sour gas	88.8
	B_{che}			7793.6
			B of mixing	274.3
Input Utilities			**Output Utilities**	
BFW		44.7		
SH to ejector		175.6		
Burner				
Fuel	B_{phy}	5.7	Stack	869.4
	B_{che}	7793.2		404.8
AIR	B_{phy}	0.8		
Cooling water in			**Cooling water out**	
2E3712		518.3	2E3712	524.8
2E3709		190.1	2E3709	192.1
2E3708		932.9	2E3708	944.7
Electric		469.0		
Total		1012692.5	**Total**	1005206.6

4.4.1 Useful Exergy

In this plant ΔB_{useful} is equal to the difference between the sum of total exergy of products and the sum of total exergy of feeds.

Product

Treated gasoil	$B_{phy}+B_{che}$	= 76.2+948707.1	kW
Wild gasoline	$B_{phy}+B_{che}$	= 0.6+18640.1	kW
Rich amine	$B_{phy}+B_{che}$	= 26.7+27783.1	kW
Sour water	$B_{phy}+B_{che}$	= 1.9+289.5	kW
Sour gas	$B_{phy}+B_{che}$	= 88.6+7793.6	kW
	Total	= 1003407.6	kW

Feed

Gasoil	$B_{phy}+B_{che}$	= 1103+976780.3	kW
Poor amine	$B_{phy}+B_{che}$	= 28.1+24298.3	kW
Water	$B_{phy}+B_{che}$	= 1.2+34.8	kW
H2make up	$B_{phy}+B_{che}$	= 0.3+41.9	kW
	Total	= 1002288	kW

$\therefore \Delta B$ useful = 1003407.6-1002288 kW

= 1119.6 kW

4.4.2 Exergy Change due to Separation

In this unit it was the sum of ΔB_{mixing} from every distillation column in unit.

ΔB_{mixing} = 274.3 kW

4.4.3 Driving Exergy

In this unit the $\Delta B_{driving}$ was calculated by following detail.

$B_{steam}-B_{condensate}$	= 220.3-1.9	= 218.4 kW
$B_{fuelgas}-B_{stack}$	= 7799.7-1274.2	= 6525.5kW
$B_{ws}-B_{wr}$	= 241.4-244.9	= -3.5 kW

$B_{electric}$ = 118.6 kW

$\therefore \Delta B_{driving}$ = 218.4+6525.5-3.5+118.6 =6859kW

$$\therefore \text{Exergetic efficiency} = \frac{(1119.6+274.3)}{6859} * 100 = 20.3\%$$

And the degree of perfection of GPU unit can be determined from

$$\eta_P = \frac{B_{products}}{B_{feed} + B_{UTin} + B_{fuelgas} + B_{electric}} * 100 \qquad (4.5)$$

$$\eta_P = \frac{1003407.6}{1002288 + 220.3 + 7799.7 + 469} * 100 = 99.3\%$$

4.5 Calculation of Exergetic Efficiency for Deethane Unit

The exergetic efficiency of Deethane Unit can be calculated by equation 4.1 and the process schematic flow diagram was illustrated in Figure 4.7. The result obtained from calculation for this unit was presented in Table 4.5.

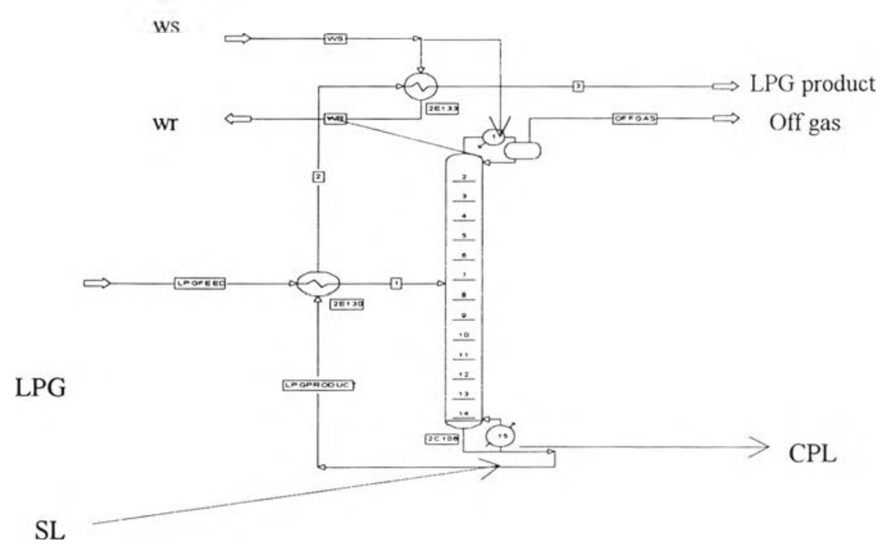

Figure 4.7 Simple process flow diagram of dethanizer unit

Table 4.5 Input and output exergy of deethanizer unit

Input		Exergy (kW)	**Output**	Exergy (kW)
Feed			Products	
LPG feed	B_{phy}	161.9	LPG product	145.6
	B_{che}	113726.3		108721.0
	B_{phy}		off gas	19.2
	B_{che}			4821.3
			B of mixing	26.2
Input Utility			**Output Utility**	
SL	B_{tot}	148.4	CPL	71.5
Cooling water in			**Cooling water out**	
2E131	B_{tot}	135.6	2E131	135.7
2E133	B_{tot}	419.0	2E133	424.3
Electric		44.8		
Total		114635.9	**Total**	114364.8

4.5.1 Useful Exergy

In this unit the process is only separation and does not have any chemical reaction ,so the chemical exergy does not change. The ΔB_{useful} is only changing due to physical exergy.

ΔB_{useful} $= B_{phy\ of\ products} - B_{feed}$

Product

Lpg product B_{phy} = 145.6 kW

Off gas B_{phy} = 19.2 kW

Feed

Lpg feed B_{phy} = 161.9 kW

$\therefore \Delta B$ useful = 164.8-161.9

= 2.9 kW

4.5.2 Exergy Change due to Separation

In this unit it was the sum of ΔB_{mixing} from every distillation column in unit.

ΔB_{mixing} = 26.2 kW

4.5.3 Driving Exergy

In this unit the $\Delta B_{driving}$ was calculated by following detail.

B_{steam}-$B_{condensate}$ = 148.4-71.5 = 76.8kW

B_{ws}-B_{wr} = 554.6-560 = -5.6 kW

$B_{electric}$ = 44.8 kW

$\therefore \Delta B_{driving}$ = 76.8-5.6+44.8 = 116.2kW

$$\therefore \text{Exergetic efficiency} = \frac{(2.9 + 26.2)}{116.2} * 100 = 25.03\%$$

And the degree of perfection of Dethanizer unit can be determined from

$$\eta_P = \frac{B_{products} + B_{utout}}{B_{feed} + B_{UTin} + B_{electric}} * 100 \quad (4.6)$$

$$\eta_P = \frac{113707.1 + 71.5}{113888.2 + 148.3 + 44.7} * 100 = 99.7\%$$

4.6 Calculation of Exergetic Efficiency for Isomerization Unit

The exergetic efficiency of Isomerization Unit can be calculated by equation 4.1 and the process schematic flow diagram was illustrated in Figure 4.8. The result obtained from calculation for this unit was presented in Table 4.6.

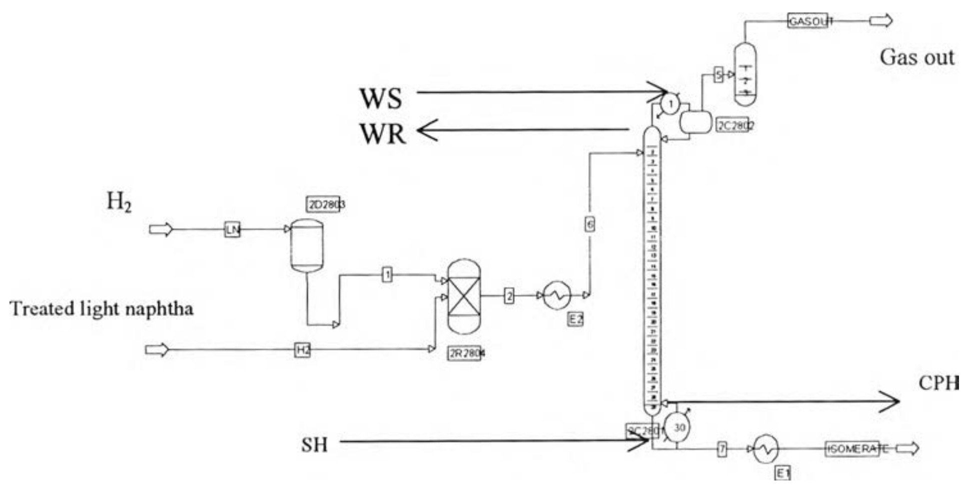

Figure 4.8 Simple process flow diagram of ISOU

Table 4.6 Input and output exergy of ISOU

		IN		OUT
Feed		kW	**Products**	kW
Treated light naphtha	B_{phy}	16.9	Isomerate	6.1
	B_{che}	323499.4		307217.6
H2	B_{phy}	167.4	Gas out	98.0
	B_{che}	20369.2		37035.9
			B of mixing	108.7
Input Utilities			**Output Utilities**	
SH to E2809	B_{tot}	719.8	CPH	450.4
SH to E2804	B_{tot}	34.8	CPH	1.9
SH toE2808	B_{tot}	231.7	CPH	15.1
Cooling water in			**Cooling water out**	
2E2801	B_{tot}	111.2		111.3
2E2810	B_{tot}	635.3		635.9
2E2811	B_{tot}	349.4		349.7
2E2812	B_{tot}	785.7		786.4
2E2813		524.1		524.6
Electric	B_{tot}	280.1		
Total		347724.8		347232.9

4.6.1 Useful Exergy

In this plant ΔB_{useful} is equal to the difference between the sum of total exergy of products and the sum of total exergy of feeds.

Product

Isomerate	B_{phy}	= 6.1 kW
	B_{che}	= 307217.6 kW
Gas out	B_{phy}	= 98 kW

	B_{che}	=	37035.9 kW
	Total	=	344357.6kW

Feed

Light naphtha	B_{phy}	=	16.9 kW
	B_{che}	=	323499.4 kW
H2	B_{phy}	=	167.4 kW
	B_{che}	=	20369.2 kW
	Total	=	344052.9 kW
$\therefore \Delta B$ useful		=	344357.6-344052.9 kW
		=	304.7 kW

4.6.2 Exergy Change due to Separation

In this unit it was the sum of ΔB_{mixing} from every distillation column in unit.

ΔB_{mixing} = 108.7 kW

4.6.3 Driving Exergy

In this unit the $\Delta B_{driving}$ was calculated by following detail.

B_{steam}-$B_{condensate}$	=	986.2-467.4	= 518.8kW
B_{ws}-B_{wr}	=	2405.6-2407.9	= -2.3 kW
$B_{electric}$	=	280.1 kW	
$\therefore \Delta B_{driving}$	=	518.8-2.3+280.1	= 796.6kW

$$\therefore \text{Exergetic efficiency} = \frac{304.7+108.7}{796.6} * 100 = 51.9\%$$

And the degree of perfection of the Isomeration unit can be determined from

$$\eta P = \frac{B_{products} + B_{utout}}{B_{feed} + B_{UTin} + B_{electric}} * 100 \qquad (4.7)$$

$$\eta P = \frac{344357.6+467.4}{344052.9+986.2+280.1} * 100 = 99.7\%$$

4.7 Calculation of Exergetic Efficiency for Catalytic Reforming Unit

The exergetic efficiency of catalytic reforming unit can be calculated by equation 4.1 and the process schematic flow diagram was illustrated in Figure 4.9. The result obtained from calculation for this unit was presented in Table 4.7.

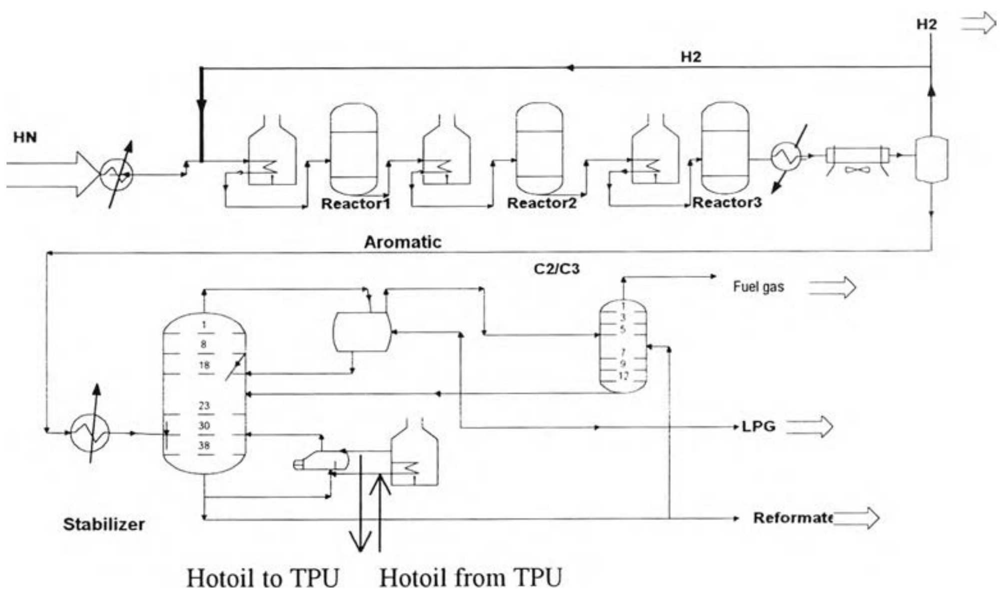

Figure 4.9 Simple process flow diagram of CRU

Table 4.7 Input and output exergy of CRU

Input		Exergy (kW)	Output	Exergy (kW)
Feed			**Products**	
Heavy naphtha	B_{phy}	51.5	Reformate	7.3
	B_{che}	329066.2		281009.2
	B_{phy}		H2 to ISOU	0.8
	B_{che}			42.7
	B_{phy}		H2 to NTU	81.8
	B_{che}			4910.8
	B_{phy}		LPG	61.6
	B_{che}			38164.1
	B_{phy}		Fuel gas from top2C302	23.8
	B_{che}			5186.6
	B_{phy}		Fuel gas from top2D302	0.2
	B_{che}			18.0
Credit				
Hot oil from TPU	B_{phy}	1076.4	Hot oil to TPU	2097.1
BFW	B_{tot}	54.4	SH(out)2E309	703.5
Cooling water in			**Cooling water out**	
E302	B_{tot}	1191.0	E302	1192.4
E303	B_{tot}	1016.4	E303	1017.5
E306	B_{tot}	1111.6	E306	1112.9
E307	B_{tot}	327.1	E307	327.5
Burner				
2F301	B_{phy}	9.6	Stack	205.1
	B_{che}	3556.0		257.0
2F302	B_{phy}	23.4	Stack	335.2
	B_{che}	5804.9		419.6
2F303	B_{phy}	9.3	Stack	158.9
	B_{che}	2752.3		199.0
2F304	B_{phy}	10.4	Stack	152.2
	B_{che}	3217.3		232.6
Air in	B_{phy}	9.0		
Input Utility			**Output Utility**	
SH(in) 2k301		2919.4	SL out (2k301)	2094.9
Electricity		147.7		
Total		352206.3	**Total**	340012.4

4.7.1 Useful Exergy

In this plant ΔB_{useful} is equal to the difference between the sum of total exergy of products and the sum of total exergy of feeds.

Product

Reformate	B_{phy}	= 7.3 kW
	B_{che}	= 281009.2 kW
H2out	B_{phy}	= 0.79+81.8kW
	B_{che}	= 42.74+4910.8 kW
LPG	B_{phy}	= 61.6 kW
	B_{che}	= 38164.1 kW
Fuel gas out(2C3C2)	B_{phy}	= 23.8 kW
	B_{che}	= 5186.6 kW
Fuel gas out(2D302)	B_{phy}	= 0.22 kW
	B_{che}	= 18 kW
	Total	= 329507 kW

Feed

heavynaphtha	B_{phy}	= 51.5 kW
	B_{che}	= 329066.2kW
	Total	= 329117.7kW
$\therefore \Delta B_{useful}$		= 329507-329117.7 kW
		= 389.3 kW

4.7.2 Exergy Change due to Separation

In this unit it was the sum of ΔB_{mixing} from every distillation column in unit.

ΔBmixing = 223.8 kW

4.7.3 Credit Exergy

This unit sends hotoil as a heat source in Debutanizer reboiler (2E126),therefore $\Delta B_{(hotoil\text{-}coldoil)}$ will be the B_{credit} for this unit.

$B_{hotoil\ to\ TPU} - B_{cold\ oil\ from\ TPU}$ = 2097.1-1076.4

= 1020.7 kW

Additional, high-pressure steam that was generated from 2E309 is also a credit

B_{credit}. B_{SH} -B_{BFW} = 703.5-54.4

= 649.2 kW

4.7.4 Driving Exergy

In this unit the $\Delta B_{driving}$ was calculated by following detail.

$B_{fuel\ gas}$-B_{stack} = 15383.3-1959.5 = 13423.7kW

B_{SH}-B_{SLout} = 2919.4-2094.9 = 824.6kW

B_{ws}-B_{wr} = 3646.2-3650.4 = -4.2 kW

$B_{electric}$ = 147.7 kW

$\therefore \Delta B_{driving}$ = 13423.7+824.6-4.2+147.7=14391.8kW

$$\therefore \text{Exergetic efficiency} = \frac{389.3+1020.7+649.2+223.8}{14391.8} * 100 = 15.9\%$$

And the degree of perfection of Catalytic Reforming unit can be determined from

$$\eta_P = \frac{B_{products} + B_{utout} + B_{SLout}}{B_{feed} + B_{fuel} + B_{UTin} + B_{electric}} * 100 \qquad (4.8)$$

$$\eta_P = \frac{329507 + 2800 + 2094}{29118 + 15392 + 4050 + 148} * 100 = 95.9\%$$

4.8 Calculation of Exergetic Efficiency for LPG Treating Unit

The exergetic efficiency of LPG treating Unit can be calculated by equation 4.1. And the process schematic flow diagram was illustrated in Figure 4.10. The result obtained from calculation for this unit was presented in Table 4.8.

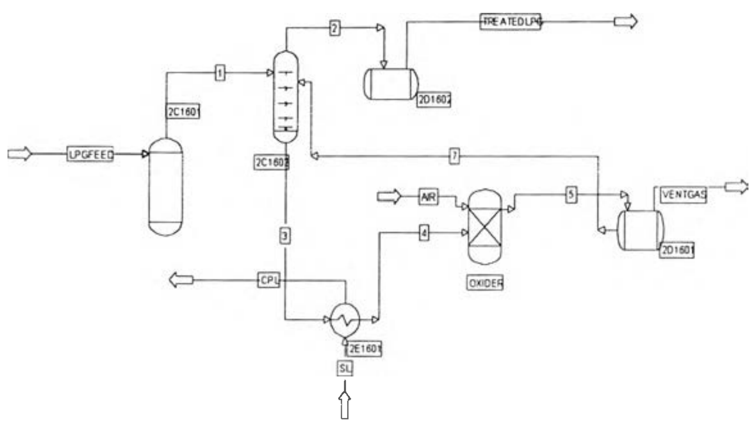

Figure 4.10 Simple process flow diagram of LPGU

Table 4.8 Input and output exergy of LPGU

Input		Exergy (kW)	**Output**	Exergy (kW)
Feed			Products	
LPG c105	B_{phy}	0.1	Treated LPG	0.6
	B_{che}	85.3		437.5
LPG c106	B_{phy}	0.02	Vent gas	0.1
	B_{che}	18.9		
LPG plant3	B_{phy}	0.5	Disulfide oil	0.0
	B_{che}	335.1		0.6
AIR	B_{phy}	0.2		
Utility in			Utility out	
B_{SL}	B_{tot}	32.4	B_{CPL}	5.8
Electric		2.1		
Total		442.2	**Total**	516.8

4.8.1 Useful Exergy

In this plant ΔB_{useful} is equal to the difference between the sum of total exergy of products and the sum of total exergy of feeds.

Product

Treated LPG	B_{phy}	= 0.6	kW
	B_{che}	= 437.5	kW
Vent gas	B_{phy}	= 0.1	kW
Disulfide oil	B_{phy}	= 0.00002	kW
	B_{che}	= 0.6	kW
	Total	= 438.9	kW

Feed

LPG from 2C105	B_{phy}	= 0.1	kW
	B_{che}	= 85.3	kW
LPG from 2C106	B_{phy}	= 0.02	kW
	B_{che}	= 18.9	kW
LPG from plant3	B_{phy}	= 0.5	kW
	B_{che}	= 335.1	kW
	Total	= 440.1	kW

$\therefore \Delta B$ useful = (438.9-440.1)kW

= -1.2 kW

4.8.2 Driving Exergy

In this unit the $\Delta B_{driving}$ was calculated by following detail.

B_{SL}-B_{CPL} = 26.6 kW

$B_{electric}$ = 2.1 kW

$\therefore \Delta B_{driving}$ = 26.6+2.1 kW

= 28.7 kW

$$\therefore \text{Exergetic efficiency} = \frac{-1.2}{28.7} * 100 = -4.63\%$$

Since ΔB useful is negative it means the exergy is used to carry out a process which does not actually require work and work is dissipated in the process. The degree of perfection is determined to express unit performance.

$$\therefore \eta_p = \frac{438.9}{(440.1+28.7)} * 100 = 93.6\% \qquad (4.9)$$

4.9 Calculation of Exergetic Efficiency for Fuel Gas Treating Unit

The exergetic efficiency of Fuel Gas treating Unit can be calculated by equation 4.1. and the process schematic flow diagram was illustrated in Figure 4.11. The result obtained from calculation for this unit was presented in Table 4.9.

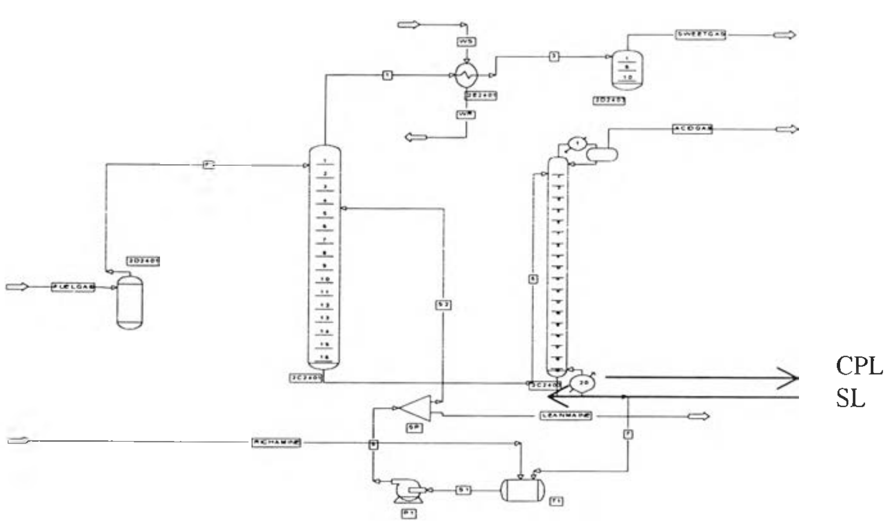

Figure 4.11 Simple process flow diagram of FGTU

Table 4.9 Input and output exergy of FGTU

Input		Exergy (kW)	**Output**	Exergy (kW)
Feed			Products	
Fuel gas	B_{phy}	430.2	Lean amine	22.8
	B_{che}	69730.8		25611.5
Rich amine	B_{phy}	33.0	Acid gas	3.6
	B_{che}	26668.6		2574.3
DEA fresh	B_{phy}	0.3	Sweet gas	327.5
	B_{che}			68481.3
			B mixing	31.9
Input Utility			**Output Utility**	
SL	B_{tot}	521.3	CPL	37.3
BFW		5.6		
Cooling tower in			**Cooling tower out**	
2E2401	B_{tot}	241.4	2E2401	244.9
Electric		118.6		
Total		98068.0	**Total**	97303.2

4.9.1 Useful Exergy

In this plant ΔB_{useful} is equal to the difference between the sum of total exergy of products and the sum of total exergy of feeds.

Product

Sweet gas	B_{phy}	= 327.5	kW
	B_{che}	= 68481.3	kW
Lean amine	B_{phy}	= 22.8	kW
	B_{che}	= 25611.5	kW
Acid gas	B_{phy}	= 3.6	kW

	B_{che}	= 2574.3	kW
	Total	= 97021	kW

<u>Feed</u>

Fuel gas	B_{phy}	= 430.2	kW
	B_{che}	= 69730.8	kW
Rich amine	B_{phy}	= 33	kW
	B_{che}	= 26668.6	kW
	Total	= 96863	kW

$\therefore \Delta B$ useful = 97021-96863kW

= 158 kW

4.9.2 <u>Exergy Change due to Separation</u>

In this unit it was the sum of ΔB_{mixing} from every distillation column in unit.

ΔB_{mixing} = 31.9 kW

4.9.3 <u>Driving Exergy</u>

In this unit the $\Delta B_{driving}$ was calculated by following detail.

$B_{Steam}-B_{condensate}$	= 526.9-37.3	= 489.6kW
$B_{ws}-B_{wr}$	= 241.4-244.9	= -3.5 kW
$B_{electric}$	= 118.6kW	
$\therefore \Delta B_{driving}$	= 489.6-3.5+118.6	= 604.6kW

$$\therefore \text{Exergy efficiency} = \frac{158 + 31.9}{604.6} * 100 = 31.5\%$$

The degree of perfection of the Fuel Gas Treating unit can be determined from

$$\eta_P = \frac{B_{products} + B_{utout}}{B_{feed} + B_{UTin} + B_{electric}} * 100 \quad (4.10)$$

$$\eta_P = \frac{97021 + 37.3}{96863 + 527 + 118.6} * 100 = 99.5\%$$

4.10 Calculation of Exergetic Efficiency for Sulfur Recovery Unit

Because this unit uses a feed as acid gas to be reactant in a combustion reaction it serves as the driving exergy and the source of the principle component of the useful product. Therefore, the exergetic efficiency from equation 4.1 cannot be determined. Therefore, the Degree of perfection (ηp) given unit performance. Using with equation 3.5, ηp can be determined for this unit by equation 4.2. The process flow diagram was shown in Figure 4.12 and the result obtained from calculation for this unit was presented in Table 4.10.

$$\eta_P = \frac{B_{product} + B_{generated\ steam} + B_{cpl}}{B_{feed} + B_{fuel} + B_{electric} + B_{steam} + B_{BFW} + B_{AIR}} * 100 \quad (4.11)$$

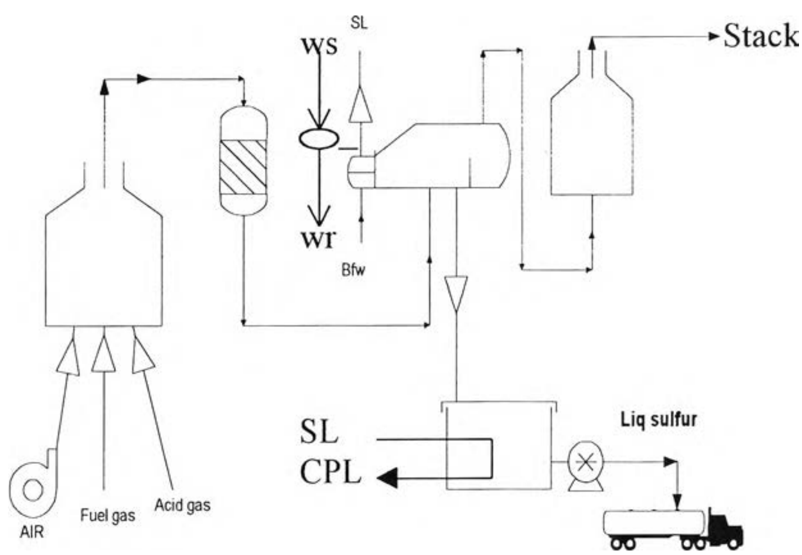

Figure 4.12 Simple process flow diagram of SRU

Table 4.10 Input and output exergy of SRU

Input		Exergy (kW)	**Output**	Exergy (kW)
Feed			Products	
Acid gas	B_{phy}	13.6	Sulfur	147.7
	B_{che}	9481.4		6844.5
Input Utilities			**Output Utilities**	
Fuel gas	B_{phy}	4.7	Stack gas	331.1
	B_{che}	1058.8		440.5
Air to burner	B_{phy}	44.9		
Credit				
BFW	B_{tot}	120.9	SL_3	633.8
	B_{tot}		SL_1	189.6
	B_{tot}		SL_2	6.3
Cooling water in			**Cooling water out**	
WS	B_{tot}	28.6	WR	31.5
SL_3	B_{tot}	32.1	CPL_3	26.5
Electric		165.9		
Total		10950.8	**Total**	8838.3

4.10.1 Useful Exergy

In this plant ΔB_{useful} is equal to the difference between the sum of total exergy of products and the sum of total exergy of feeds.

Product

Liquid sulfur	B_{phy}	=	147.7	kW
	B_{che}	=	6844.5	kW
	Total	=	6992.2	kW

Feed

Acid gas	B_{phy}	=	13.6	kW

	B_{che}	= 9481.4 kW
	Total	= 9495 kW
$\therefore \Delta B_{useful}$		= 6992.2-9495kW
		= -2502.8 kW

4.10.2 Credit Exergy

This unit generates low pressure steam from stack gas therefore the ΔB_{credit} is

$B_{SL}-B_{BFW}$ = (633.8+189.6+6.3)-120.9

= 708.8 kW

4.10.3 Driving Exergy

In this unit the $\Delta B_{driving}$ was calculated by following detail.

Fuelgas: B_{phy}	= 4.7	kW
B_{che}	= 1058.8	kW
Air: B_{phy}	= 44.9	kW
Steam-condensate: B_{tot}	= 32.1-26.5	kW
	= 5.6	kW
Cooling water	= 28.6-31.5	kW
	= -2.9	kW
$B_{electric}$	= 165.9	kW

$\therefore \Delta B_{driving}$ = 4.7+1058.8+44.9+5.6-2.9+165.9

= 1321.8 kW

$$\therefore \text{Exergetic efficiency} = \frac{-2502.8+708.8}{1321.8} * 100 = -140.3\%$$

This indicates that the acid gas supplies a large amount of the exergy driving the process and the exergetic efficiency and the exergetic efficiency does not adequately true. The degree of perfection has been defined by equation 4.2

$$\text{Degree of perfection} = \frac{B_{products} + B_{steam} + B_{CPL3}}{B_{feed} + B_{fuel} + B_{electric} + B_{steam} + B_{BFW} + B_{air}} * 100 \quad (4.12)$$

$$\therefore \text{Degree of perfection} = \frac{6992.2 + 829.8 + 26.5}{9495 + 1063.5 + 165.9 + 32.1 + 121 + 45} * 100 = 73.5\%$$

4.11 Calculation of Exergetic Efficiency of Waste Heat Boiler Unit

The waste heat boiler is the recovery equipment by use sum of stack gas from every burner in the plant to generate high-pressure steam (SH) from boiler feed water (BFW). It was shown in Figure 4.13 and the result obtained from calculation for this unit was presented in Table 4.11.

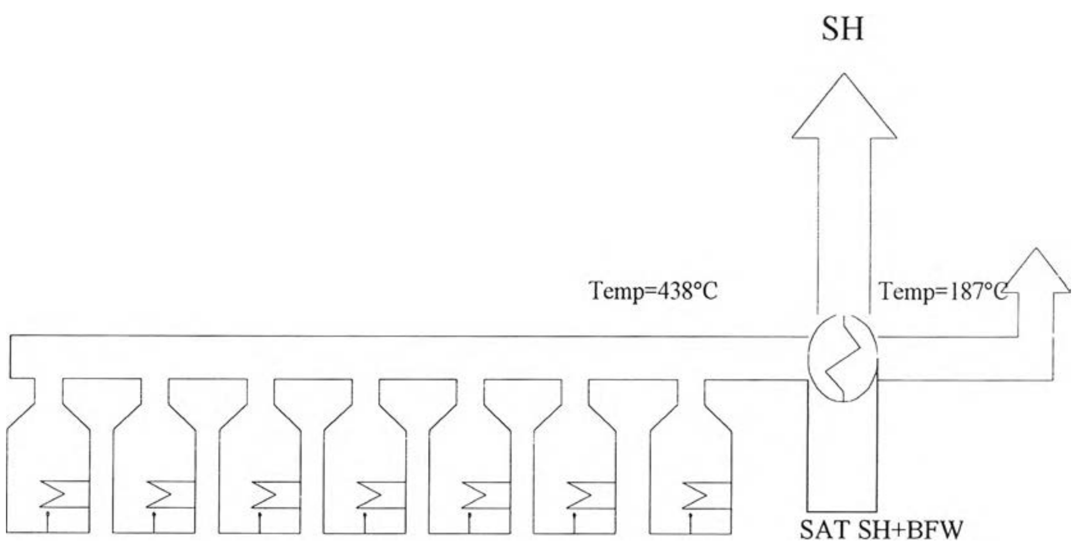

Figure 4.13 Simple process flow diagram of WHB

Table 4.11 Input and output exergy of overall furnace including waste heat boiler

Burners	B	Input (kW)	B of stack After WHB	B of stack Before WHB	ΔB useful kW
2F101	B_{phy}	60.5			8036.3
	B_{che}	11280.8			
2F102	B_{phy}	40.4			
	B_{che}	10337.5			
AIR	B_{phy}	1.4			
2F201	B_{phy}	11.3			1824.0
	B_{che}	3856.3			
AIR	B_{phy}	0.4			
Fuel oil	B_{phy}	4.3			
	B_{che}	15332.7			
AIR	B_{phy}	0.3			
2F301	B_{phy}	9.6			806.8
	B_{che}	3556.0			
2F302	B_{phy}	23.4			1025.8
	B_{che}	5804.9			
2F303	B_{phy}	9.3			514.9
	B_{che}	2752.3			
2F304	B_{phy}	10.4			388.6
	B_{che}	3217.3			
AIR to CRU burners	B_{phy}	9.0			
2F3701	B_{phy}	5.7			1115.0
	B_{che}	7793.2			
AIR	B_{phy}	0.8			
Electric to 2K303A/B		189.6			
ΔB BFW to steam					3916.1
Total		64307.39	4757.6	7104.9	17627.5

4.11.1 Useful Exergy

The ΔB_{useful} of waste heat boiler is the ΔB change between Boiler feed water and saturated steam from 2E309 to High pressure steam .

$$B_{SH} - B_{sat\ SH\ from\ 2E309} - B_{BFW} = 5608.7 - 1333.8 - 358.86$$

$$= 3916.1\ kW$$

4.11.2 Driving Exergy

The driving exergy of waste heat boiler is the exergy in the stack gas before WHB at 438 °C and the electric power of induced draft blower (2K303A/B) that forces the stack gas through the WHB.

$B_{stack\ before\ WHB}$ = 7104.9 kW

$B_{electric}$ in = 189.6 kW

$$\eta_B = \frac{3916.1}{7104.9+189.6} * 100 = 53.68\%$$

4.12 The Overall Furnace System

The ΔB useful of the overall furnace system is the sum of ΔB useful of each burner on each unit that is 2F101,2F102,2F201, 2F301,2F302, 2F303, 2F304 from TPU, NTU, and CRU and ΔB change between Boiler feed water to High pressure steam . Normally ΔB useful of a furnace is ΔB_{phy} of process fluid inlet and process fluid outlet by including both the radiation and convection zone.

4.12.1 Driving Exergy

The driving exergy of the waste heat boiler is the B of fuel and air from seven furnaces. From data in Table 4.11 the overall furnace system efficiency can be defined from equation. 4.1 and will be compared with no WHB.

$$\eta_B = \frac{17627.5}{(64307.4)} * 100 = 27.4\%$$

$$\eta_B(\text{no WHB}) = \frac{(17627.5 - 3916.1)}{(64307.4)} * 100 = 21.3\%$$

4.13 Discussion of Part 1

From the result of every unit the exergetic efficiency can be compared one another by the chart in Figure 4.14. And the comparison of exergetic efficiency and degree of perfection from every unit was shown in Table 4.12.

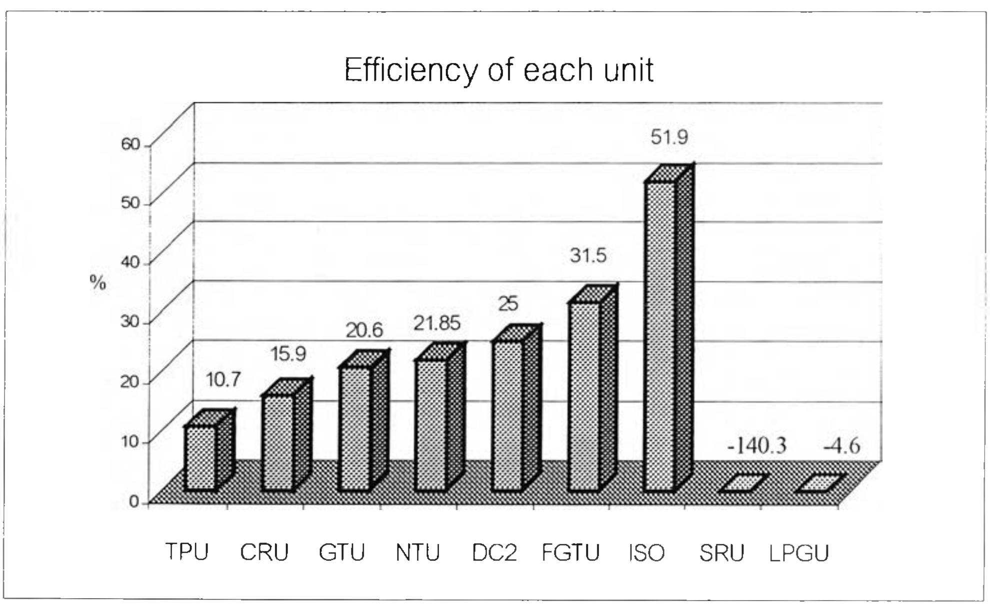

Figure 4.14 The exergetic efficiency of each unit in refinery

Table 4.12 The exergetic efficiency and degree of perfection for each unit

	Exergetic efficiency	Degree of perfection
Overall plant	29.4	99.3
TPU	10.7	99.1
NTU	21.8	98.4
GOTU	20.3	99.3
Dethanizer	25.1	99.7
ISOU	51.9	99.7
CRU	15.9	96
LPGU	-4.6	93.6
FGTU	31.5	99.5
SRU	-140.3	73.5

The exergetic efficiency of over all plant is 29.4%. The change in total exergy from crude to products is small compared with the driving exergy. Therefore, the exergetic efficiency is not high . However, this refinery had generated a credit of exergy from generating steam from waste heat boiler and used fuel gas derived from light gas for every unit in the plant. This replaces external driving exergy, and raises the efficiency of this refinery compared to other refineries (Dincer (1986) is 5.9%). In order to improve this figure air preheating should be considered because it will lead to a decrease in fuel gas at the furnaces and also reduce the amount of purchased fuel oil.

From Table 4.12 the TPU has the lowest exergetic efficiency (10.7%). The others low efficiencies are CRU, GOTU, and NTU . These units use a large amount of driving exergy, the chemical exergy of fuel gas. Consequently, the exergetic efficiency is low. The Dethanizer unit is a pure separation, and therefore the chemical exergy does not change. The condition (temperature, pressure) of feed and product are similar. Therefore, the exergetic efficiency is low . The ISOU and FGTU do not require high temperatures and therefore use only steam and electricity to drive the process. Hence, the exergetic efficiency of these units are high.

The LPGU gives a small negative change in exergy because it involves only the reaction of NaOH and a small amount of H_2S and other sulfur compound in LPG. Since the Na_2S that is derived from the reaction of NaOH and H_2S does not continue run down from this unit. It changes the new NaOH every 1 month, so it was neglected from analysis. Consequently, the ΔB_{useful} is negative. Moreover, it uses only small amount of steam to drive the process. Therefore, It this unit does not have a significant thermodynamic change.

The exergetic efficiency of SRU is also negative because the feed (acid gas) supplies a large amount of the exergy used to be drive the process. Therefore the degree of perfection was determined in order to assess thermodynamic efficiency of this unit.

The WHB increases the exergetic efficiency of the furnace system from 21.3% to be 27.4% because it recuperates exergy and uses it to generate high pressure steam.

Since the change in chemical exergy of the streams passing through the refinery is small the degree of perfection is very high. This indicated that the work required by the refinery to process crude is small compared to the work available in the product streams.

4.14 Results and Discussion of Part 2

From the result in part 1 the topping unit has the lowest exergetic efficiency. Therefore, the main effect in analyzing improvements has been directed to this unit. Consideration has been given to changes in the fire heater, the heat exchanger network and the distillation column itself.

4.14.1 Heat Exchanger Network

The HEN is the system of heat exchanger that is used to transfer heat from the product stream to the crude feed before entering to fire heater. The flow diagram of HEN was illustrated in Figure 4.15.

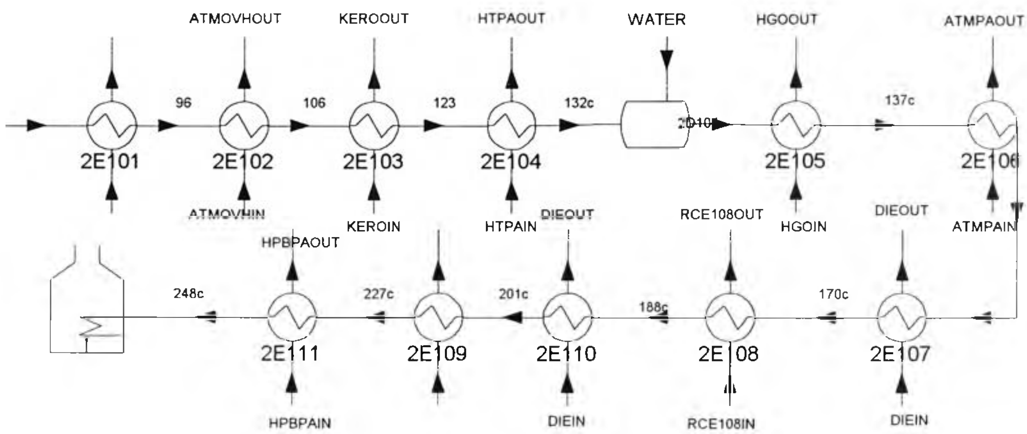

Figure 4.15 Simple process flow diagram of heat exchanger network

From the exergy balance of HEN in equation 3.6 this HEN will be

$$\sum_{1}^{n} B_{\text{crude in}} + \sum_{1}^{n} B_{\text{hotproduct in}} = \sum_{1}^{n} B_{\text{crude out}} + \sum_{1}^{n} B_{\text{hotproduct out}} + I \qquad (4.13)$$

ΔB_{useful} is $\sum_{i}^{n} B_{\text{crudeout}} - \sum_{i}^{n} B_{\text{crudein}} = B_{\text{heated crudeafter2E111}} - B_{\text{crude before 2E101}}$.

$= 10.54 - 0.5$ mJ/sec $= 10.04$ mJ/sec

$\Delta B_{\text{driving}}$ is $\sum_{i}^{n} B_{\text{hotproductout}} - \sum_{i}^{n} B_{\text{hotproductin}} = 13.33$ mJ/sec

the exergetic efficiency of HEN is $= \frac{10.04}{13.33} * 100 = 75.2\%$

(the data of each number is in appendix)

4.14.2 Furnace

The furnace system of TPU was presented in Figure 4.16

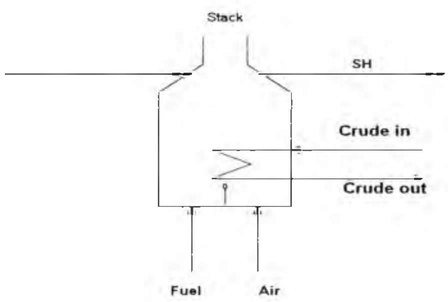

Figure 4.16 Simple process flow diagram of furnace

The topping unit has two parallel furnace, 2F101, 2F102. In this study the fire heaters were combined. This unit uses the furnace to heat the crude from 248°c to 349°c after it passes the heat exchanger network. The fire heaters also generate super heated high pressure steam which is used for stripping steam from the low pressure steam in the convection zone. The exergy balance of such a furnace is

$$B_{sl}+B_{crude\ in}+B_{fuel\ gas}+B_{air} = B_{crude\ out}+B_{stack}+B_{SH}+loss \qquad (4.14)$$

The efficiency of the combined fire heaters can be determined by

$$\eta_B = \frac{\Delta B_{useful}}{\Delta B_{driving}} * 100$$

$$\Delta B_{useful} = (B_{crude\ out}-B_{crude\ in})+(B_{SH}-B_{SL})$$

$$\Delta B_{driving} = B_{fuel}+B_{air}$$

$$\eta_B = \frac{(15778.2-7901.5)+(1549.2-1154.7)}{(26092.5+1.4)} = 31.7\%$$

(the data can see in appendix)

4.14.3 Distillation Column

The topping unit has three main distillation columns, (2C101, 2C102, 2C105) and also two side stripper columns (2C103, 2C104). This study includes the condensers and reboilers as part of the distillation columns. Figure 4.17 shows the main distillation column and side stripper of TPU.

4.14.3.1 2C101

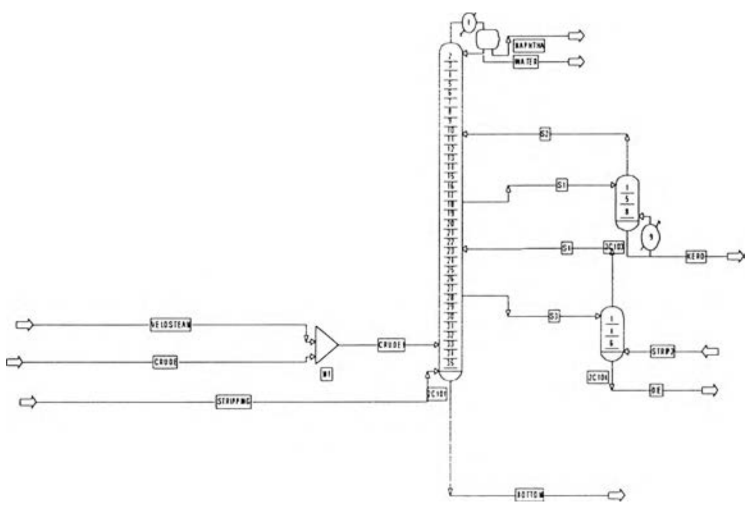

Figure 4.17 Simple process flow diagram of 2C101, 2C103, 2C104

In order to determine the exergetic efficiency of the column. It is necessary to determine the exergy flow into and out of the column. This is by making a simulation of the column and matching it with the existing column using the temperature, pressure, composition, and flow rate of crude feed and stripping steam. The product specification is the pinpoint of the running the program. The provision simulation program has been used for this study. The result from this program is used to calculate the exergy of each input and out put stream. And the result obtained from converged simulation for this column was presented in Table 4.13.

Table 4.13 Input and output exergy of each stream in 2C101

In put of 2C101	Exergy (kW)
Feed	16,046.80
Stripping steam	405.64
S2	2,055.60
S4	447.30
Total inlet	18,955.34
Exergy of condenser	774.27
Out put of 2C101	
Bottom	5,464.70
Condensate	0.02
Naphtha	302.20
S1	2,450.10
S3	3,123.70
Exergy of mixing	1,296.86
Total out let	12,637.58

The exergy of condenser is derived from the sum of removal of the exergy out to condense the overhead product from 2E101, 2A101, 2E112. These are $\Delta B_{(in-out)}$ of crude to 2E101, electric power of 2A101, and the ΔB change in cooling water supply and cooling water return in 2E112.

$\Delta B_{crude\,(in-out)}$ of 2E101 = 754.4 kW

Electric power of 2A101 = 18.95 kW

ΔB of WS and WR of2E112 = 0.91 kW

$\therefore$ Exergy of condenser is 754.4+18.95+0.91=774.27 kW

Table 4.12 indicates the total input exergy is greater than the output exergy and it cannot define the driving exergy. Therefore, the degree of perfection is appropriate to indicate the efficiency of this column.

$$\eta_p = \frac{\Sigma B_{\text{output stream}} + B_{\text{condenser}}}{\Sigma B_{\text{input stream}}} * 100$$

$$\eta_p = \frac{(12637.5 + 774.27)}{18955.34} * 100 = 70.75\%$$

4.14.3.2 2C103

Column 2C103 is the kerosene side stripper that is used to split the light component and return it to the main column. And the result obtained from converged simulation for this column was presented in Table 4.14.

Table 4.14 Input and output exergy of each stream in 2C103

Input of 2C103	Exergy (kW)
S1	2750.1
heat duty of reboiler	1699.7
Output of 2C103	
S2	2055.6
Kerosene	1796.7
Total outlet	3852.3
B of mixing	346.6

Again using the degree of perfection to determine performance of the column

$$\eta_p = \frac{\Sigma B_{\text{output stream}}}{\Sigma B_{\text{inputstream}} + B_{\text{reboiler}}} * 100$$

B of reboiler in this column can not be found in a direct way because it cannot be determined from component of the pump around stream. Consequently the indirect formula has been applied as $\Delta B = Q * \frac{(T - T_0)}{T}$ where T is the temperature of the heat source. In this case it is the temperature of the bottom pump around which is equal to 588.15°k from the output simulation.

where T_0 is the reference temperature =298.15°k

Q is the heat duty of the reboiler derived from the simulation which equals 3446.3 kW

$$\Delta B = 3446.3 * \frac{(588.15 - 298.15)}{298.15} = 1699.7 \text{ kW}$$

$$\eta_p = \frac{(3852.3+346.5)}{(2750+1699.7)} * 100 = 94.3\%$$

4.14.3.3 2C104

Column 2C104 is the diesel oil side stripper that is used to split the light component and return it to the main column. And the result obtained from converged simulation for this column was presented in Table 4.15.

Table 4.15 Input and output exergy of each stream in 2C104

Inlet of 2C104	Exergy (kW)
Striping steam S3	44.76 4123.70
Total inlet	4168.46
Output of 2C104	
DIE S4	2701.30 447.30
Total outlet	3148.60
B of mixing	62.95

This column does not have a reboiler and condenser . It uses stripping steam as its heat source. Thus the degree of perfection of this column is given by

$$\eta_p = \frac{\Sigma\ B_{outputstream}}{\Sigma B_{inputstream}} * 100$$

$$\eta p = \frac{(3148.6 + 62.9)}{4168.4} * 100 = 77\%$$

4.14.3.4 2C102

This column is the ATM fractionator which separates the bottoms of 2C101 in to LGO, HGO, and residue crude. This column has only a condenser. The degree of perfection will be the same as the 2C101. The inlet and outlet stream of this column shown in Figure 4.18 and the result obtained from converged simulation presented in Table 4.16.

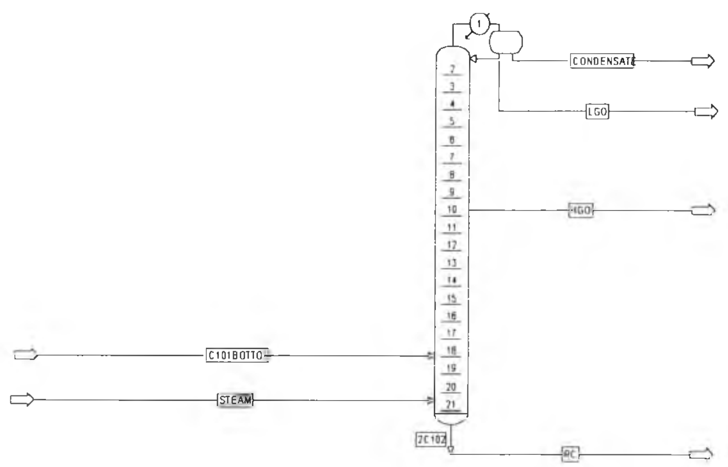

Figure 4.18 Simple process flow diagram of 2C102

Table 4.16 Input and output exergy of each stream in 2C102

Input of 2C102	Exergy (kW)
feed strippingsteam	5803.30 690.99
Total inlet	6494.29
Exergy duty of condenser	252.24
Output of 2C102	
HGO LGO	804.00 2.20
RC	4101.00
con B of mixing	1.22 261.48
Total outlet	5169.90

$$\eta p = \frac{(5169 + 252.24)}{6494.29} * 100 = 83.4\%$$

4.14.3.5 2C105

The duty of this column is split the LPG out of the naphtha The inlet and outlet stream of this column shown in Figure 4.19 and the result obtained from converged simulation presented in Table 4.17.

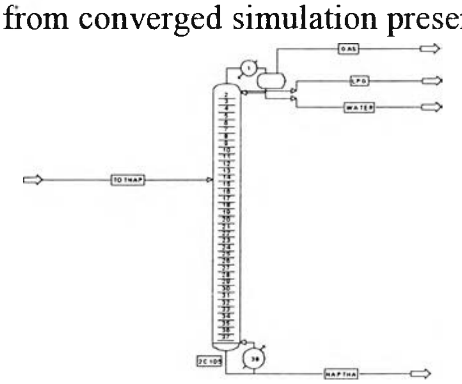

Figure 4.19 Simple process flow diagram of 2C105

Table 4.17 Input and output exergy of each stream in 2C105

Input of 2C105	Exergy (kW)
Tot nap	484.50
Hotoil in	2460.9
Hotoil out	953.9
Exergy of condenser	1.79
Output of 2C105	
Gasout	22.40
LPG	0.05
Naphtha	1483.20
Sour water	27.92
B of mixing	46.72
Total	1580.29

$$\eta_p = \frac{(1580.29+953.9+1.79)}{484+2460} * 100 = 86.1\%$$

4.15 Discussion of Part 2

For heat exchanger network, it has an exergetic efficiency of 75.2%. The HEN was designed to recovery heat from the product streams efficiently. The loss of exergy driving heat transfer increases as the temperature difference increases between the hot and cold streams.

The efficiency of burners, (2F101, 2F102) is low because the burner losses exergy in three ways; and stack gas, heat exchanger, and combustion process. Therefore, the recuperation of stack gas and recovery of heat with crude heated as high temperature as possible before entering the furnace will increase efficiency.

The column efficiency as determined by the degree of perfection was found to be between 70-80%. These columns need to be analyzed in more detail by another method to indicate the potential performance of the columns. In this study, a pinch technology will be applied to these columns in the next chapter.