CHAPTER VII
DISCUSSION AND SUGGESTION

7.1 The Cumulative Degree of Perfection of the Bangchak Refinery's Products

The cumulative degrees of perfection of the Bangchak refinery's products are presented in the Table 7.1. Literature values are presented when available for comparison.

Table 7.1 The cumulative degrees of perfection of products from the literature and the Bangchak refinery

Products	Literature(1988)			Bangchak refinery's results		
	b^o_{ch} (MJ/kg)	CExC (MJ/kg)	CDP (%)	b^o_{ch} (MJ/kg)	CExC (MJ/kg)	CDP (%)
1. Fuel gas	-	-	-	60.92	73.44	82.95
2. LPG	-	-	-	48.46	56.51	85.74
3. Gasoline	35.60	42.40	84.00	47.34	56.38	83.96
4. IK (untreated)	-	-	-	49.34	53.02	93.07
5. Diesel	44.40	53.20	83.50	49.52	53.87	91.92
6. Fuel Oil	42.85	51.74	82.80	48.19	51.79	93.05

The cumulative degree of perfection can be indicated the energy consumption of the system under consideration. The higher degree of perfection, the lower amount of energy consumed in the system.

The reason why the cumulative degrees of perfection of the diesel oil and the fuel oil from the literature have lower values than those from the Bangchak refinery's results is due to the improvement of process refineries. However, the cumulative degrees of perfection of the gasoline from both results are almost the same. This is because the Bangchank refinery's process required more energy to produce the low-sulfur gasoline, which is much lower than sulfur content in the gasoline product from the literature.

7.2 The Production Efficiency of the Electricity and the Steam

In term of exergy analysis;

The production efficiency of the electricity was 38.53 percent.

The production efficiency of the steam was 43.20 percent.

In term of energy analysis;

The production efficiency of the electricity was 35.20 percent

The production efficiency of the steam was 37.60 percent.

From the results, it can be seen that the production efficiencies of the electricity and the steam on the basis of the energy analysis were lower than those on the basis of the exergy analysis. This is because the energy loss through the stack gas, mechanical equipment and the environment on the basis of the energy analysis was about 56 percent, whereas the exergy loss on the basis of the exergy analysis was about 52 percent. The energy analysis is based on the First Law of Thermodynamic which temperature is the main factor in the enthalpy term. The exergy analysis is based on the First and the Second Law of Thermodynamic which both temperature and pressure are concerned.

7.3 Losses

The main parts of the losses of the units which are Topping unit, Deethanizer unit, LPG Treating unit, Naphtha Pre-treating unit, Isomerization unit, Catalytic Reforming unit Gas Oil Hydrodesulfurization, Fuel Gas Treating unit, Sulfur Recovery unit and Energy complex were from furnaces and columns. The energy losses are from the temperature differences and combustion gas, while the exergy losses are not only from temperature difference and combustion gas but also from pressure differences and irreversibility. From the results from Table 7.2, it is shown that the most losses were occurred in Energy complex. The improvement in this unit will affect to all other units

Table 7.2 The losses in each unit

Process unit	Energy loss (kW)	% energy loss (%)	Exergy loss (kW)	% exergy loss (%)
TPU	9,519.881	0.305	51,063.764	1.553
Deethanizer unit	145.603	0.580	158.723	0.595
LPGU	152.548	0.204	138.350	0.175
NPU	46,696.821	6.093	45,053.425	5.555
Isomerization unit	1,960.956	0.767	2,380.274	0.878
CRU	470.736	0.051	14,402.575	1.468
GOHDU	16,195.663	1.375	12,571.295	1.018
FGTU	1,086.186	1.964	1,234.969	2.124
SRU	49.663	1.074	1,187.674	26.334
Energy complex	28,792.432	56.285	52,741.836	52.144

7.4 Preheating Combustion Reactants with Effluent Combustion Gas

The physical exergy of effluent combustion gases can be used to preheat combustion reactants because it not only lowers the specific physical exergy of the gases rejected into the environment but also reduces the flow rate of those gases, due to the reduction of fuel consumption. It is shown that the reduction of the fuel chemical exergy consumption is several times greater than the exergy increase of the preheated combustion reactants.

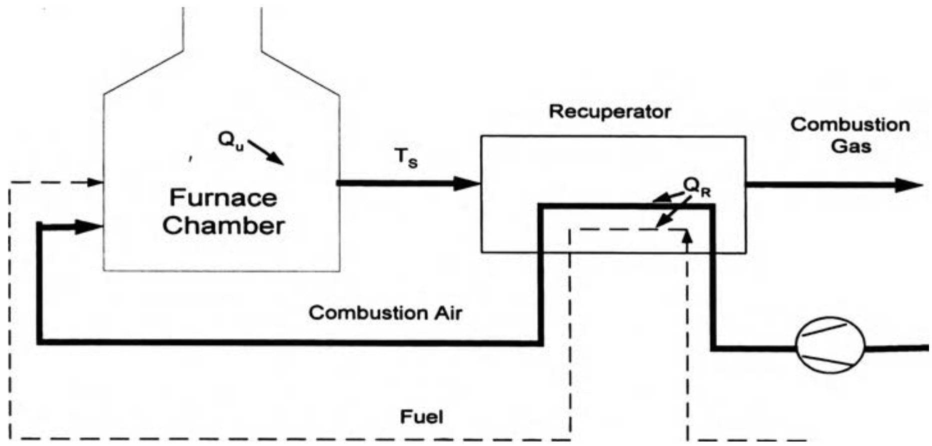


Figure 7.1 Scheme of furnace with recuperator

The energy balance for the comparative furnace operating without recuperation has the form

$$F_zC_l = Q_u + Q_w + H_l + F_z*(1 - \sigma - \alpha)*S*(T_{sz} - T_o) \qquad (7.1)$$

For the furnace equipped with a recuperator,

$$F_z*(1 - \omega)*(C_l + q_R) = Q_u + Q_w + H_l + F_z*(1 - \omega - \sigma + \alpha)*S*(T_x - T_o) \qquad (7.2)$$

where ;

F_z = fuel consumption in the comparative furnace

Q_u = the useful heat transferred inside the furnace chamber

Q_w = the heat rejected into the environment and to the cooling medium during the entire operation cycly

ω = fuel economy index due to recuperation

$$\omega = \frac{q_R[\chi' - (\sigma - \alpha)(\chi' - 1)]}{C_l + q_R - S(T_s - T_o)} \tag{7.3}$$

H_l = enthalpy of combustion gases leaking from the furnace chamber

q_R = recuperation heat per unit of fuel (J/mol, J/kg)

σ = relative heat capacity of the combustion gases leaking from the furnace chamber

α = relative heat capacity of the are penetrating into the furnace chamber through leaks

χ' = the coefficient of temperature distribution

C_l = the net calorific value(J/mol)

S = the mean heat capacity of combustion gas

T_s = the outlet combustion gases temperature

T_o = the environment temperature

μ_B = the multiplier of fuel exergy economy

$$\mu_B = \frac{\omega}{1 - \omega} \times \frac{b_F}{\Delta b_{ph}} \tag{7.4}$$

μ_r = the cumulative multiplier of exergy economy

$$\mu_r = \frac{1}{\eta_{rF}} \times \mu_B \tag{7.5}$$

The above concept can be applied to the Boiler A&B, the required data are presented as follows;

The preheated air temperature, t_A, was 210 °C.

The net calorific value, C_l, of the mixture of fuel gas and oil was 2,154.72 kmol/hr.

The mean heat capacity of combustion gases, S, was 200 kJ/(K*mol-fuel).

The outlet combustion gases temperature, t_s, was 350 °C.

The coefficient of temperature distribution, χ', was 1.4.

The leakage coefficient $\sigma - \alpha$ was 0.1.

The environmental temperature, t_o, was 25 °C

The mean heat capacity of air(dry basis), c_p, was $29.90*10^{-3}$ kJ/(K*mol air)

The air requirement for the combustion of fuel gas and fuel oil was 30.71 mol-air/mol-fuel.

Solution : The heat of recuperation, $q_R = (29.90*10^{-3})*(30.71)*(210 - 25)$

$= 169.87$ kJ/mol-fuel

The fuel economy index due to recuperation, ω, (Eq. 7.3)

$= (169.87)*[1.4 - (0.1)*0.4]/(2{,}154.72 + 169.87 - 0.200*(350 - 25))$

$= 0.10224$

The physical exergy increase of air in the recuperator

$= c_p*n_A*(t_A - t_o - t_o*\ln(t_o/t_A))$

$= (29.90*10^{-3})*(30.71)*(210 - 25 - 298*\ln(483/298))$

$= 37.73$ kJ/mol-fuel

With $b_F/C_l = 1.0289$, Eq. (7.4) yields

$\mu_B = (0.10224)*(1.0289)*(2{,}154.71)/(1 - 0.10224)/37.73$

$= 6.69169$

For the fuel under consideration, the cumulative degree of perfection, η_{rF},

= 0.84364 (from the mixture of fuel gas(86%) and fuel oil(14)).

Eq. (7.5) yields

$\mu_r = (6.69169)/(0.84364)$

$= 7.932$

The cumulative economy of fuel exergy is 7.932 times the exergy increase of the air preheated in the recuperator. The reduction of fuel consumption was 586 kg/hr (9.88 kmol/hr).

From the above calculation, it can be concluded that

1. The higher the ratio q_R/C_l, the greater the relative fuel economy.
2. At higher temperatures of effluent combustion gases, the relative fuel economy becomes greater.
3. If the temperature distribution approaches counterflow, the value of ω increases.
4. Leakage of combustion gases into the environment reduces the value of ω, especially in counterflow furnaces.

7.5 Application

The main application of the Cumulative Exergy Consumption (CExC) index are similar but broader in comparison with the Cumulative Energy Consumption (CEnC) index. These may be listed as follows;

A. Calculation of the necessary increase of raw materials and fuels extraction for a planned increase of production of the product under consideration. The following equation should be applied for calculating the necessary increase ΔR_k of the kth raw material extraction;

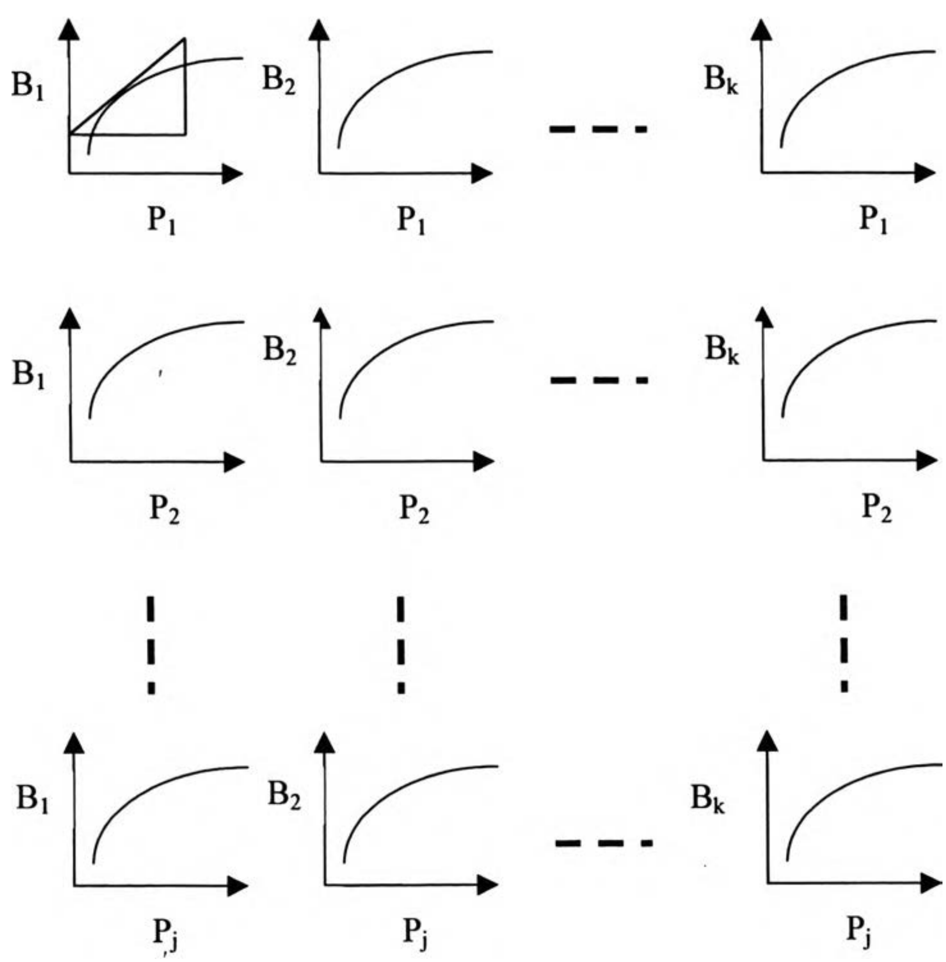
$$\Delta R_k = \frac{1}{b_k} \times \overline{r_k} \times \Delta P_j \qquad (7.6)$$

where ; b_k = specific exergy of the kth material

ΔP_j = planned increase of the net production of the jth product in the system under consideration

$$\bar{r}_{kj} = \left(\frac{\partial B_k}{\partial P_j} \right)_{opt} \tag{7.7}$$

The above calculation requires a lot of backup information such as operating conditions for different capacities of operation. Results of this calculation can lead a prediction of the necessary increase of raw materials and fuels extraction for a planned increase of production of the product under consideration. The following matrix of graphs provides the exergy of natural resources delivered to the system in all the steps of the chain of production processes and the net production of products



The slope of each graph can be used to calculate the cumulative exergy consumption (local) CExC index, which is

$$\bar{r}_{kj} = \left(\frac{\partial B_k}{\partial P_j} \right)_{opt} \qquad (7.8)$$

B. Evaluation of the influence of price changes of raw materials and of fuels on the production costs of the product under consideration. The following equation expressing the increase Δk_j of the specific production cost of the j^{th} product caused by the increase Δk_k of the specific costs of raw materials;

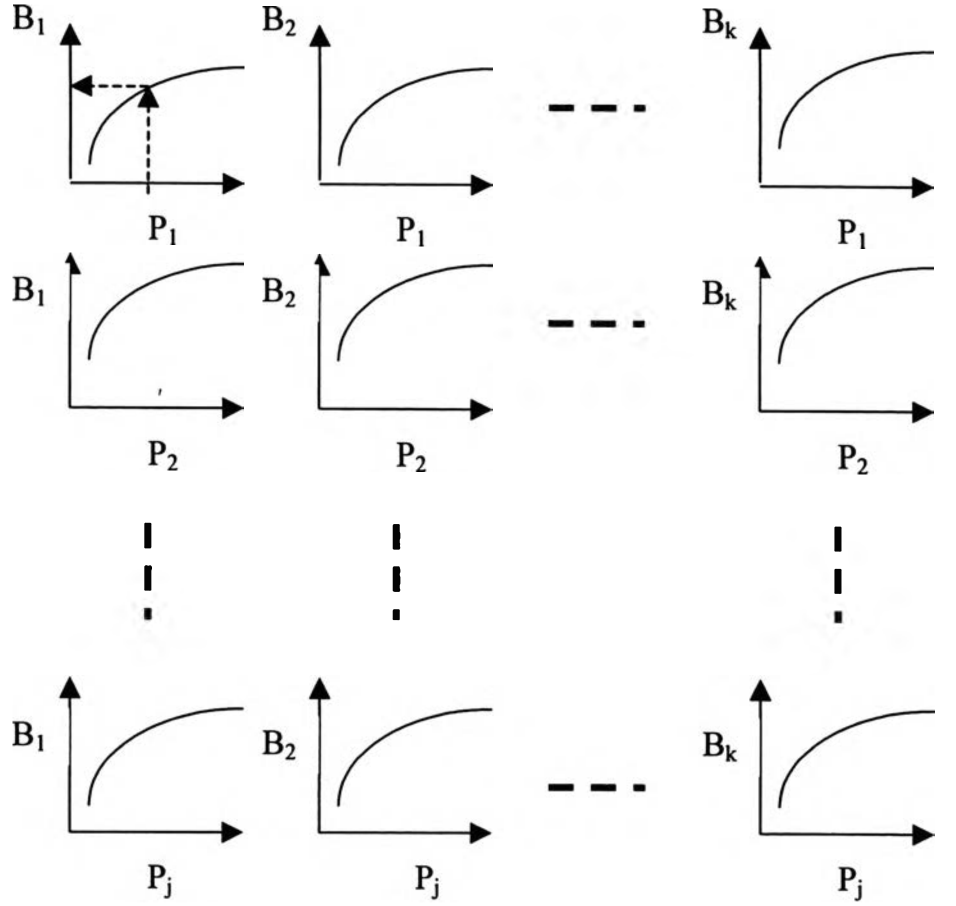
$$\Delta k_j = \sum_k \frac{1}{b_k} \times r_{kj} \times \Delta k_k \qquad (7.9)$$

where ; b_k = specific exergy of the k^{th} material

Δk_k = the increase of the specific costs of raw materials

$$r_{kj} = \frac{B_{kj}}{P_j} \qquad (7.10)$$

In order to evaluate the influence of price changes of raw materials and fuels on the production costs of the product under consideration, the backup information such as operating conditions and different capacities of operation must be set in a matrix as same as those of the application 7.5.1.



For calculating the cumulative exergy consumption index, r_{kj}, the slope of the graphs are required. The evaluation of the influence of the price changes of raw materials and fuels on the production costs can be calculated at any specified operation capacity of the plant.