CHAPTER V
PROCEDURE

5.1 Experiment

In order to evaluate the cumulative exergy consumption of products of plant no. 2 of the Bangchak refinery. There were 4 experiments, which were Gas Chromatography, ASTM 86, API and Elemental Analysis, need to be conducted as follows:

5.1.1 Gas Chromatography

Bangchak refinery provides this experiment for this thesis.

5.1.2 ASTM D86

The procedure to run the experiment is in the following;

Summary of Test Method (ASTM D86);

1. Based on its composition, vapor pressure, expected initial boiling point or its expected end point, or both, the sample is placed in one of five groups. The group in which the sample falls defines apparatus arrangement, condenser temperature, and other operational variables.

2. A 100 mL specimen of the sample is distilled under prescribed conditions for the group in which the sample falls. The distillation is performed in a laboratory batch distillation unit at ambient pressure under conditions that are designed to provide approximately one theoretical plate fractionation. Systematic observations of temperature readings and volumes

of condensate are made, depending on the needs of the user of the data. The volume of the residue and the losses are also recorded.

3. At the conclusion of the distillation, the observed vapor temperatures can be corrected for barometric pressure and the data are examined for conformance to procedural requirements, such as distillation rated. The test is repeated if any specified condition has not been met.

4. Test results are commonly expressed as percent evaporated or percent recovered versus corresponding temperature, either in a table or graphically, as a plot of the distillation curve.

5.1.3 Elemental Analysis

Liquid petroleum was examined by Science and Technological Research Equipment Center Chulalongkorn University.

5.1.4 API

For determining a specific gravity.

5.2 Calculation Method for Physical Exergy

The Physical exergy (B_{ph}) of each process stream was obtained from the Provision II computer simulation program which calculates the physical exergy by ($H-T_o*S$). In order to define B_{ph} , it was necessary to specify the component and condition of each stream (temperature, pressure) in order for calculating the enthalpy and entropy of each stream. In addition, a suitable thermodynamic method is required to determine the correct value.

Provision II computer simulation program recommends a suitable method for such calculations. For the light hydrocarbon stream the Solve-Redlich-Kwong (SRK) thermodynamic method has chosen to define the physical properties. For the water and steam system the physical properties can be calculated by the SRK thermodynamic method which specifies a steam table option. And the Grayson-Streed method was selected to calculate the physical properties of light oil and heavy oil. In this method it will use Curl-Pitzer method to calculate liquid enthalpy and entropy.

In order to specify the components of each stream in the process the gas chromatography has been used to define the component of light hydrocarbons. And for the heavy hydrocarbon components it is difficult to determine the exact composition and these are specified by a distillation curve. The ASTM D86 , TBP and API gravity were used as input to specify such streams.

In the exergy report from PRO Π program. There are 5 exergy functions which depend on the various applications of the user. The two significant outputs that is used in this study are $B_{(EXS)}$ which is the exergy at the existing state of the stream and $B_{(EVS)}$ which is the exergy at the environmental state at T_0 and P_0. The use of $B_{(EXS)} - B_{(EVS)}$ has been determined to denote the exergy of each stream.

5.3 Calculation Method for Chemical Exergy

Szargut *et al.* (1988) defined the standard chemical exergy of organic and inorganic substances at reference temperature (298.15 K) and reference pressure (101.325 kPa). In order to find the chemical exergy of each stream, the mole percent of each components has to be determined. However for heavy oil a calculation of the chemical exergy cannot be made directly because the composition is not defined. Therefore the elemental analysis of organic compound C,H,O,N,S,and H_2O were used to estimate the chemical exergy from the formula.

$$b_{ch} = \beta^*(C_l + L^*z_w) + b_{ch\,w}{}^*z_w \quad (5.1)$$

$$= \beta^*(C_f - 9^*L^*z_{h2}) + b_{ch\,w}{}^*z_w \quad (5.2)$$

where

C_f	=	gross calorific value of the moist fuel
C_l	=	net calorific value of the moist fuel
L	=	enthalpy of water vaporization
Z_{h2}	=	hydrogen mass fraction in moist fuel
Z_w	=	water mass fraction in moist fuel
B_{chw}	=	standard chemical exergy of water

$$\beta=1.041+0.1728\frac{Z_{H2}}{Z_c}+0.0432\frac{Z_{O2}}{Z_c}+0.2169\frac{Z_s}{Z_c}\left(1-2.028\frac{Z_{H2}}{Z_c}\right) \quad (5.3)$$

5.4 The Cumulative Exergy Consumption Equations

After calculating the physical and chemical energy/exergy in each unit, mass balance, energy balance and exergy balance must be set to be equal between influent and effluent streams in all units. Then, the cumulative exergy consumption equations for all boundary system referred to Chapter III have to be formulated for influent an effluent streams in each unit. By using Solver program in Microsoft Excel to solve equations, the 79 cumulative exergy consumption equations were solved simultaneously. The results will be shown in Chapter VI.

5.5 Exergetic Efficiency

For thermal processes, such as Topping unit, Deethanizer unit, steam generator, electrical power generating station and heating furnaces, the exergetic efficiency is the recommended measure of thermodynamic perfection. It can be expressed in the following mathematical form;

$$Exergetic \quad efficiency = \frac{\Delta B_{useful} + \Delta B_{separation} + \Delta B_{credit}}{\Delta B_{driving}} \tag{5.4}$$

where

ΔB_{useful} = the exergy change from feed to product

ΔB_{mixing} = the change in exergy for separation

$\Delta B_{driving}$ = the exergy change of all stream used to operate the process

ΔB_{credit} = the useful exergy deriving from process

5.6 Degree of Perfection

For chemical processes (e.g., LPG Treating unit, Naphtha Pretreating unit, Isomerization unit, Catalytic Reforming unit, Gas Oil Hydrodesulfurization unit, Fuel Gas Treating unit and Sulfur Removal unit), the degree of perfection is recommended as the measure of thermodynamic perfection, since for some processes the exergetic efficiency is negative, which is meaningless. It can be determined in the following mathematical form;

$$Degree \quad of \quad Perfection = \frac{Exergy \quad of \quad useful \quad product}{Feeding \quad exergy} \tag{5.5}$$