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THESIS

MATERIAL BALANCE, SCHEDULING AND COST EVALUATION OF COMMERCIAL BIODIESEL PLANT FROM PALM OIL

SADUDEE BUNDITHUM

A Thesis Submitted in Partial Fulfillment of
the Requirements for the Degree of
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In this present work, four biodiesel production plants with capacities of 100,000; 300,000 and 500,000 kg/batch were investigated. The plants employed batch process with potassium hydroxide and palm stearin as catalyst and feedstock, respectively. Simulation of the belonging processes was performed under Aspen Batch Process Developer software. The condition of transesterification of palm stearin to methyl ester was as following; concentration of potassium hydroxide 0.5%, molar ratio of methanol to oil 6:1, reaction temperature at 60 ^{o}C and reaction time of 1 hour.

Additionally, settling time for 6 hours was pursued after the completion of reaction. The difference of each process model (plant A to D) was sizing and number of equipment was varies. Each process was simulated in order to optimize the operation time which had an effect on productivity of biodiesel production. After that, the economic cost was analyzed to evaluate the investment and operating cost.

From the results of schedule simulation, the plant A and 500,000 kg/batch feedstock capacity of fixed time revealed the suitable for schedule time, investment cost and operating cost.

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Lastly, and most importantly, I also extend my heartfelt thanks to my family for everything. They are the only one reason I fought/fight/will fight for. To them I dedicate this thesis.

Sadudee Bundithum

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LIST OF ABBREVIATIONS

FAME	=	Fatty acid methyl ester
TAG	=	Triacylglycerols
FFA	=	Free fatty acid
BD	=	Biodiesel
Min.	=	Minimum
Max.	=	Maximum
FCI	=	Fixed-capital investment
NPV	=	Net present value
IRR	=	Internal rate of return
PB	=	Payback period
CPO	=	Crude palm oil
CPS	=	Crude palm stearin

MATERIAL BALANCE, SCHEDULING AND COST EVALUATION OF COMMERCIAL BIODIESEL PLANT FROM PALM OIL

INTRODUCTION

With the negative environmental impacts, worldwide demands of fossil fuel like natural gas and oil are however exponentially increasing as nations develop into industrial countries and as the global population increases. Consequently, our need is soon going to outplace our ability to draw energy from traditional resources leading to its depletion in the near future. Therefore, discovering alternative energy sources is a pressing task nowadays not only to attain energy security but to protect the whole world as well. Fortunately, new and environmentally friendly energy supplies like water energy, wind energy, solar, fuel cell, electric power, hydrogen, biofuel and biodiesel are being developed. (Atadashi *et al*., 2011; Kasteren and Nisworo, 2007)

As an exciting member of alternative energy, original biodiesel was first introduced in 1900 at Paris World Exhibition by Dr. Rudolf Diesel with his internal combustion engine using peanut oil as fuel source. Currently, vegetable oil is replaced with alkyl ester as the second generation to improve cetane number, heat combustion value and viscosity. The major advantage of biodiesel is that it is a renewable energy because it is derived from vegetable oils that are chemically converted into diesel like fuel.

Biodiesel or fatty acid methyl ester (FAME) is produced from renewable feed stock of vegetable oils or animal fats and used cooking oil (Kasteren and Nisworo, 2007). It is produced through the reaction of a vegetable oil and methyl alcohol in the presence of a catalyst. Commonly used catalysts are strong caustic based substances such as sodium hydroxide and potassium hydroxide and strong acid such as sulfuric acid. However, the strong caustic catalysts are the most commonly used in industry, because they render faster process compared to that from the others (Berrios and

Skelton, 2008). The chemical process is called transesterification (if triglyceride is a raw material) or esterification (if fatty acid is used instead) which produces biodiesel and glycerin or water. Biodiesel is biodegradable and has a low emission of carbon dioxide, carbon monoxide and sulphur dioxide (Antolín *et al*., 2002; Bouaid *et al*., 2005). It has even a higher cetane number than petrodiesel (Paul, 2005).

In contrast with its plain reaction, design and construction of commercial biodiesel plant are complicated operations. Considering the technical, social, environmental and economic conditions, along with location and land suitability for raw material development, infrastructure, water supply and social facilities and availability of human resource, detailed production process is also directly critical to the feasibility of the project.

Typically, a process selection study will start with a design basis prepared by the plant owner that defines many of the design parameters to be in used in the study, for instance feed composition and condition, process equipment design assumption, fuel balance requirements, possible driver configurations and desired rate of production (Mark J. Roberts *et al*., 2004). After design basis is established, process simulation is performed to cope with unspecified equipment performance parameters. The result can be validated with the real data from laboratory scale process or pilot plant scale one. Such parameters should be calculated with a model embedded in the same process simulation rather than in other application. This approach can save time and result in a more optimum design, particularly if numerical optimization or numerical method are employed (Roberts *et al*., 2004).

To simplify this painstaking task, Aspen Process Developer was chosen for conceptual design optimization and performance monitoring of present biodiesel production process through engineering relationships such as mass and energy balance to assess the performance of a operation cycle. Results from the simulation were validated with the data from a laboratory process as well as from a real commercial plant to ensure the integrity of the simulation. Moreover the time schedule of the process in this work was also simulated. This approach involved the

design of model operation for biodiesel production plant, the purchase of materials and estimation of operation expenses, resulting in estimate of biodiesel production plant costs. The flexibility of model could aid in the comparison of alternate routes for reduction in production costs. A model could thus assist in determining the overall economy of operation, and choices feedstock, chemical process, plant capacity and design (Haas *et al*., 2006).

OBJECTIVES

1. To design biodiesel plants using Aspen Batch Process Developer.
2. To perform the scheduling of biodiesel production process at different capacities.
3. To optimize biodiesel plant capacity using fixed cost and operating cost criteria.

Scopes of thesis

The biodiesel production plant was simulated with feedstock capacity of 100,000; 300,000 and 500,000 kg. Reactor, setting and mixing tanks were batch operating units. The feedstock of biodiesel production plant was stearin; methanol was main reactant for transesterification and potassium hydroxide was used as catalyst. Aspen Batch Process Developer version 7.0 for production plant simulation. Biodiesel, glycerol, glycerides, potassium hydroxide, acid value, soap, methanol content and water content were analyzed from samples originated from lab-scale experiments as well as from a pilot plant. Finally, the life time of production plant was limited to 15 years.

LITERATURE REVIEW

1. Biodiesel

A diesel-equivalent, processed fuel derived from variety of feedstocks, was referred to Biodiesel (Greek, bio, life+diesel from Rudolf Diesel) (Demirbas, 2008; Knothe *et al.*, 2005). These feedstocks included most common vegetable oils (e.g., soybean, cottonseed, palm, peanut, rapeseed/canola, sunflower, safflower, coconut) and animal fats, usually tallow, as well as waste oils (e.g., used frying oils). The triacylglycerols (TAG; often also called triglycerides) were found as the major components in vegetable oils and animal fats. (Knothe *et al.*, 2005) Table 1 lists the fatty acid compositions of most promising current plant and animal sources for biodiesel production. (Drapcho *et al.*, 2008)

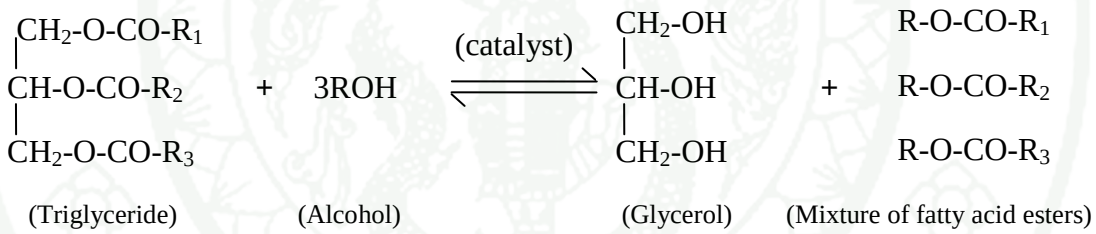


Figure 1 The transesterification reaction; R_1, R_2 and R_3 are mixture of various fatty acid chains. The alcohol used for producing biodiesel is usually methanol (R is CH_3).

Source: Knothe *et al.* (2005)

In the biodiesel production process, the vegetable oil or animal fat was undergone a chemical reaction termed transesterification reaction to obtain biodiesel. (Knothe *et al.*, 2005) Transesterification reaction was a chemical reaction between triglyceride and alcohol (commonly methanol) with the presence of a catalyst (typically a base) to yield biodiesel and glycerol. (Halek *et al.*, 2009) The general scheme of the transesterification reaction was already presented previously in the introduction and was given here again in Figure 1. Generally, Methanol was used as

the alcohol for biodiesel production since it was the least expensive alcohol, even if the other alcohols (e.g., ethanol, *iso*-propanol) may yield a biodiesel fuel with the better fuel properties. (Knothe *et al.*, 2005)

Figure 2 explained the transesterification reaction of oil with methanol and potassium hydroxide (KOH) as a catalyst by following three-step reaction sequence. When KOH was used with high-purity feedstocks, the optimum conditions of the transesterification were at 1 wt% KOH catalyst, 69^0C and 7:1 alcohol-vegetable oil molar ratio. These gave the 97.7% conversion in 18 min. (Nag, 2008)

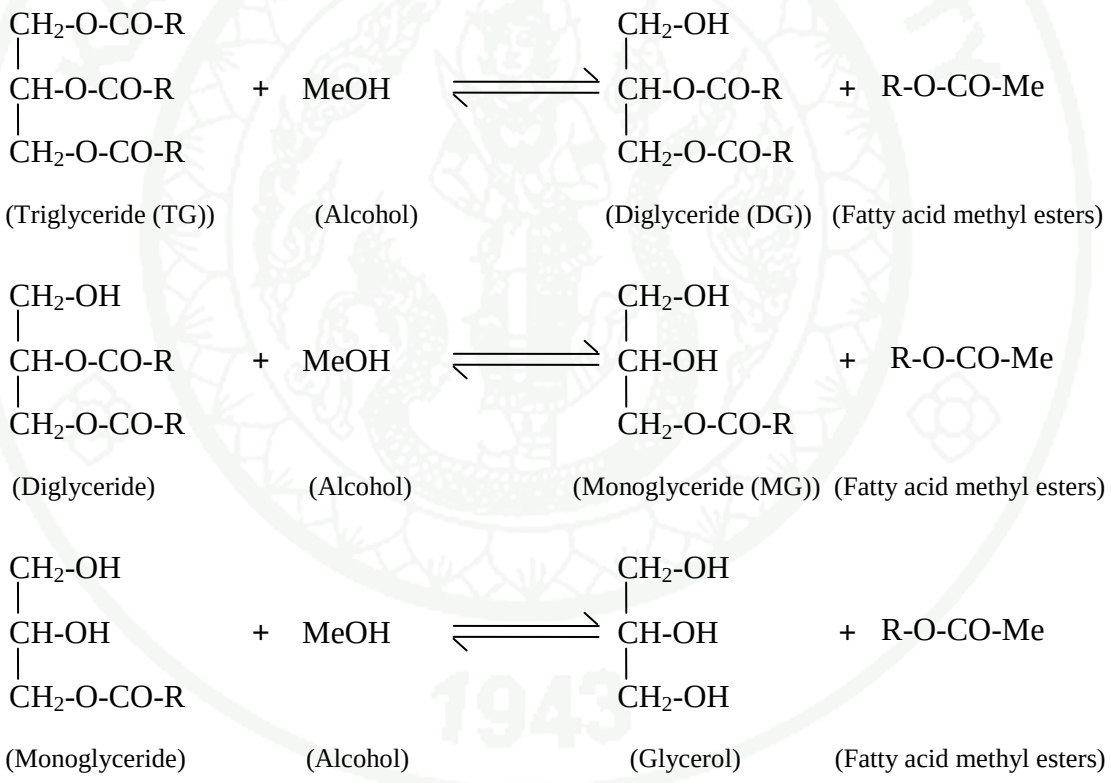


Figure 2 Scheme of three-step transesterification

Source: Nag (2008)

Table 1 Typical oil content and fatty acid compositions (% by wt. of total lipids) of plant and animal oils. Cetane and iodine values are also reported.

Source	Oil content	Iodine value (oil)	Cetane index (esters)	Palmitic 16:0	Palmitoleic 16:1	Stearic 18:0	Oleic 18:1	Linoleic 18:2	Linolenic 18:3
Vegetable-based oils									
Rape (canola) oil	30	98	55	3.5	-	0.9	64.4	22.3	8.2
Olive oil	20	81	60	9.2	0.8	3.4	80.4	4.5	0.6
Sunflower oil	47	125	52	6.0	-	4.2	18.7	69.3	-
Safflower oil	60			5.2	-	2.2	76.3	16.2	-
Soybean oil	18	130	53	10.6	-	4.8	22.5	52.3	8.2
Palm oil	35	54	65	47.9	-	4.2	37.0	9.1	0.3
Cottonseed oil	40	105	55	28.7	-	0.9	13.0	57.4	-
Poppyseed oil	-	-	-	12.6	0.1	4.0	22.3	60.2	0.5
Sesameseed oil	49	-	-	13.1	-	3.9	52.8	30.2	-
Linseed (flax) oil	35	178	-	5.1	0.3	2.5	18.9	18.1	55.1
Wheat grain oil	11	-	-	20.6	1.0	1.1	16.6	56.0	2.9
Corn oil	-	120	53	11.8	-	2.0	24.8	61.3	-

Table 1 (Continued)

Source	Oil content	Iodine value (oil)	Cetane index (esters)	Palmitic 16:0	Palmitoleic 16:1	Stearic 18:0	Oleic 18:1	Linoleic 18:2	Linolenic 18:3
Castor oil	-	-	-	25.9	0.3	3.1	10.8	11.3	17.6
Peanut oil	48	93	-	11.4		2.4	48.3	32.0	0.9
Hazelnut oil	62	-	-	4.9	0.2	2.6	83.6	8.5	0.2
Walnut oil	60	-	-	7.2	0.2	1.9	18.5	56.0	16.2
Almond oil	54	-	-	6.5	0.5	1.4	70.7	20.0	-
Coconut oil	35	10	70	9.7	0.1	3.0	6.9	2.2	-
Jatropha oil		185	-	13.3	1.0	4.9	32.0	45.0	0.2
Hempseed oil	35	-	-	6.0	-	2.0	12.0	60.0	20.0
Rice bran oil	10	-	-	21.5	-	2.9	38.4	34.4	2.2
Camelina oil		155	-	5.4	-	2.6	14.3	14.3	38.4
Seashore Mallow	22	102	-	24.1	0.6	1.0	13.7	55.2	0.8
Evening primrose	17	-	-	6.0	-	2.0	11.0	81.0	
Pumpkin seed	47	-	-	9.0	-	-	34.0	50.0	8.0

Table 1 (Continued)

Source	Oil content	Iodine value (oil)	Cetane index (esters)	Palmitic 16:0	Palmitoleic 16:1	Stearic 18:0	Oleic 18:1	Linoleic 18:2	Linolenic 18:3
Animal-based oils									
Poultry fat	-	-	-	22.2	8.4	5.1	42.3	19.3	1.0
Lard	-	65	65	17.3	1.9	15.6	42.5	9.2	0.4
Tallow	-	50	75	28.4	-	14.8	44.6	2.7	-
Waste oils									
Yellow grease	-	-	-	23.2	3.8	13.0	44.3	7.0	0.7
Brown grease	-	-	-	22.8	3.1	12.5	42.4	12.1	0.8
Brown grease ME	-	-	-		23.0	12.9	42.5	11.6	0.8
White grease	-	-	-	23.3	3.5	11.0	47.1	11.0	1.0

Source: Drapcho *et al*. (2008)

1.1 Biodiesel production process

Figure 3 represented a schematic diagram of the processes involved in biodiesel production, with the use of transesterification reaction, from feedstocks containing low levels of free fatty acid (FFA). The reactants (alcohol, catalyst, and oil) were fed into a reactor and the mixture was then agitated for about 1 hour at 60°C. Batch reactor was normally used in the smaller plants; while in the larger plants (>4 million l/yr), continuous flow processes involving continuous stirred-tank reactors (CSTR) or plug flow reactors were more preferable. After the reaction was carried out, glycerol was removed from the methyl esters phase. Due to the low solubility of glycerol in the esters phase, the separation generally occurred quickly and could be accomplished with either a settling tank or a centrifuge. The excess methanol was commonly not removed from the reaction stream until after the glycerol and methyl esters were separated. After glycerol separation, the methyl esters was transferred to a neutralization step and then passed through a methanol stripper, usually a vacuum flash process or a falling film evaporator, before the water washing step. Acid was also added to the biodiesel product to neutralize any residual catalyst and to split any soap formed during the reaction. Soaps may reacted with the acid to generate water-soluble salts and FFA according to the following equation: (Knothe, Gerpen and Krahl, 2005)

R-COONa	+	HAc	⟶	R-COOH	+	NaAc
Sodium soap		Acid		Fattty acid		Salt

The salts could be removed during the water washing step and the FFA could stay in the biodiesel. The water washing step was intended to eliminate any remaining catalyst, soap, salts, methanol and free glycerol from the biodiesel. Neutralization before washing could help reduce the amount of water required and minimize the potential for emulsions forming when the wash water is added to the biodiesel. After the wash process, any remaining water was removed from the biodiesel by a vacuum flash process. (Knothe *et al.*, 2005)

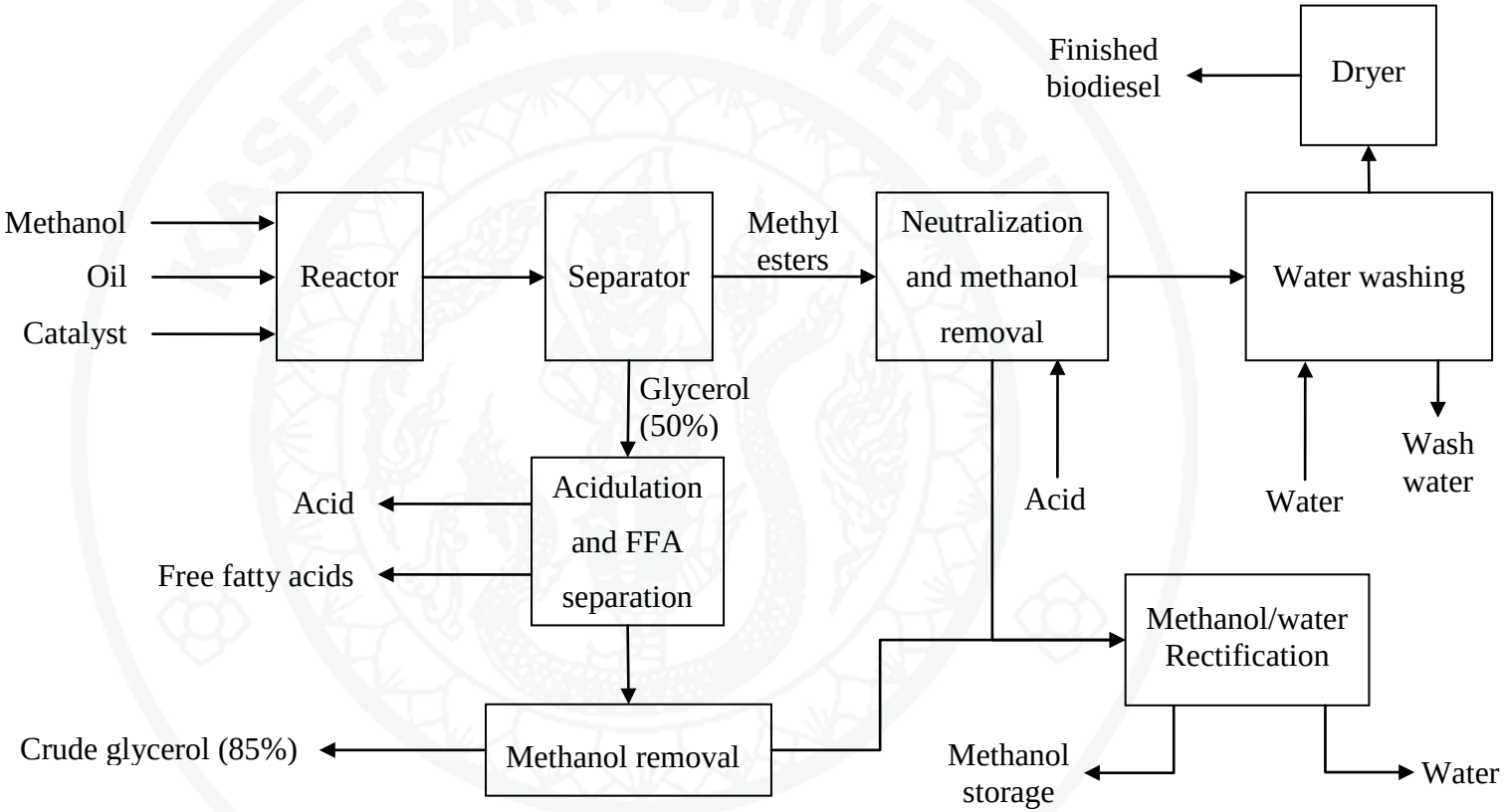


Figure 3 Process flow scheme for biodiesel production.

Source: Knothe *et al.* (2005)

The glycerol stream leaving the separator was only ~50% glycerol. It consisted of the excess methanol and most of the catalyst and soap. The glycerol has little value in this form and disposal may be difficult. The methanol content required the glycerol to be treated as hazardous waste. The first step in refining the glycerol was usually to add acid to split the soaps into FFA and salts. The FFAs were not soluble in the glycerol; and then it raised to the top where they can be removed and recycled. (Knothe *et al.*, 2005)

Methanol removed from the methyl ester and glycerol streams tended to collect any water that may enter the process. This water should be removed in a distillation column before the methanol was returned to the process. This step was more difficult, if an alcohol such as ethanol or isopropanol was used since they formed an azeotrope with water. Then, a molecular sieve was used to remove the water. (Knothe *et al.*, 2005)

1.2 Biodiesel properties

The purification stage was necessary. The untreated biodiesel contained several impurities such as free glycerol, soap, metals, methanol, free fatty acids (FFA), catalyst, water and glycerides. These caused the reduction of engine life, if the levels of impurities were high. Table 2 showed the effect of each impurity. (Berrios and Skelton, 2008)

The parameters according to standard of pure biodiesel (B100) must be met before it was used as a pure fuel or being blended with petroleum-based diesel fuel. Biodiesel, B100, specification was given in Table 3. (Demirbas, 2008) This method was used for examination properties of biodiesel complied with the Ministry of Energy standard of biodiesel.

Table 2 Effects of impurities on biodiesel and engines

Impurity	**Effect**
Free fatty acid (FFA)	Corrosion Low oxidation stability
Water	Hydrolysis (FFA formation) Corrosion Bacteriological growth (filter blockage)
Methanol	Low values of density and viscosity Low flash point (transport, storage and use problems) Corrosion of Al and Zn pieces
Glycerides	High viscosity Deposits in the injectors (carbon residue) Crystallization
Metals (soap, catalyst)	Deposits in the injectors (carbon residue) Filter blockage (sulphated ashes) Engine weakening
Glycerol	Settling problems Increase aldehydes and acrolein emissions

Source: Berrios and Skelton (2008)

Table 3 Standard of biodiesel followed by Ministry of Energy

Properties	**Methods**	**Limits**
Methyl ester (% wt.)	EN 14103	96.5 min.
Density @ 15^0C (kg/m^3)	ASTM D 1298	860-900
Viscosity @ 40^0C (cst)	ASTM D 445	3.5-5.0
Flash point (^{0}C)	ASTM D 93	120 min.
Sulphur (%wt.)	ASTM D 2662	0.0010 max.
Carbon residue @ 10% distillation residue (%wt.)	ASTM D 4530	0.30 max.

Table 3 (Continued)

Properties	**Methods**	**Limits**
Methyl ester (% wt.)	EN 14103	96.5 min.
Density @ 15^0C (kg/m^3)	ASTM D 1298	860-900
Viscosity @ 40^0C (cst)	ASTM D 445	3.5-5.0
Flash point (^{0}C)	ASTM D 93	120 min.
Sulphur (%wt.)	ASTM D 2662	0.0010 max.
Carbon residue @ 10% distillation residue (%wt.)	ASTM D 4530	0.30 max.
Cetane number	ASTM D 613	51 min
Suiphated ash (% wt.)	ASTM D 874	0.02 max.
Water content (% wt.)	EN ISO 12937	0.050 max.
Total contaminate (% wt.)	EN 12662	0.0024 max.
Copper strip corrosion	ASTM D 130	Class 1
Oxidation stability @ 100^0C (hours)	EN 14112	6 min.
Acid value (mg KOH/g)	ASTM D 664	0.5 max
Iodine value (g Iodine/100g)	EN14111	120 max.
Linolic Acid Methylester (% wt.)	EN 14103	12.0 max.
Methanol content (% wt.)	EN 14110	0.2 max.
Monoglyceride content (% wt.)	EN 14105	0.2 max.
Diglyceride content (% wt.)	EN 14105	0.2 max.
Triglyceride content (% wt.)	EN 14105	0.2 max.
Free Glycerine (% wt.)	EN 14105	0.2 max.
Total Glycerine (% wt.)	EN 14105	0.25 max.
Group I metals (Na+K) (mg/kg)	EN 14108,14109	5.0 max.
Group II metals (Ca+Mg) (mg/kg)	EN 14538	5.0 max.
Phosphorus content (% wt.)	ASTM D 4951	0.0010 max.

Source: Ministry of Energy (2007)

2. Material balance

Material balance was very important in an industry. It was the fundamental in the control of processing, particularly in the control of yields of the products. If the unit operation, whatever its nature, was seen as a whole, it may be represented diagrammatically as a box, as shown in Figure 4. The mass going into the box must be balanced with the mass coming out. (Bureau of Energy Efficiency, 2011)

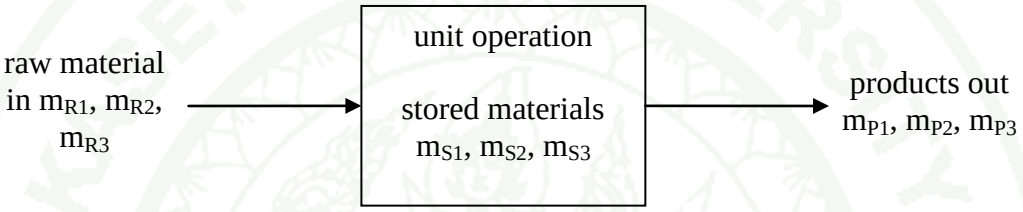


Figure 4 Mass balance

Source: Bureau of Energy Efficiency, 2011

2.1 The general balance equation

The system with no leaks - possibilities-generation or consumption in reaction and accumulation within the process unit - are all that can account for a difference between the input and output flow rates. A balance on a conserved quantity (total mass, mass of a particular species) in a system (a single process unit, a collection of units, or an entire process) may be written in the equation 1. (Felder and Rousseau, 2000)

$$\begin{pmatrix}\text{input}\\ \text{enters}\\ \text{through}\\ \text{system}\\ \text{boundaries}\end{pmatrix}+\begin{pmatrix}\text{generation}\\ \text{produced}\\ \text{within}\\ \text{system}\end{pmatrix}-\begin{pmatrix}\text{output}\\ \text{leaves}\\ \text{through}\\ \text{system}\\ \text{boundaries}\end{pmatrix}-\begin{pmatrix}\text{consumption}\\ \text{consumed}\\ \text{within system}\end{pmatrix}=\begin{pmatrix}\text{accumulation}\\ \text{buildup}\\ \text{within system}\end{pmatrix} \quad (1)$$

The following rules may be used to simplify the material balances equation:

- If the balance quantity is total mass, set equation = 0 and consumption = 0. Except in nuclear reactions mass can neither be created nor destroyed.
- If the balanced substance is a nonreactive species (neither a reactant nor a product), set generation = 0 and consumption = 0

If a system is at steady state, set accumulation = 0, regardless of what is being balanced. By definition, in steady-state system nothing can change with time, including the amount of the balanced quantity. (Felder and Rousseau, 2000)

2.2 Balance on continuous steady-state processes

For continuous processes at steady-state, the accumulation term in the general balance equation, equation (1), equaled to zero and the equation was simplified to equation 2. (Felder and Rousseau, 2000)

$$\text{input} + \text{generation} = \text{output} + \text{consumption} \qquad (2)$$

If the balance is on a nonreactive species or on total mass, the generation and consumption terms equal to zero and the equation was reduced to input = output. (Felder and Rousseau, 2000)

2.3 Integral balances on batch processes

Ammonia was produced from nitrogen and hydrogen in a batch reactor. At time t=0, there were n_0 mol of NH_3 in the reactor, and at a later time t_f the reaction terminated and the contents of the reactor, which include n_f mol of ammonia, were withdrawn. Between t_0 and t_f no ammonia entered or leaved through the reactor boundaries, so the general balance equation (equation (1)) was simply generation = accumulation. Moreover, the quantity of ammonia that built up (accumulated) in the

reactor between t_0 and t_f was simply n_f - n_0, the final amount minus the initial amount. (Felder and Rousseau, 2000)

The same reasoning may be applied to any substance participating in a batch process (Felder and Rousseau, 2000)

accumulation = final output - initial input (by definition)
=generation - consumption (from equation (1))

These two expressions for the accumulation yields

initial input + generation = final output + consumption (3)

This equation was identical to equation (2) for continuous steady-state processes, except that in this case of the input and output terms denote the initial and final amounts of the balanced substance rather than flow rates of the balanced substance in continuous feed and product streams. The word “initial” and “final” may be left out for brevity, as long as sight of what “input” and “output” mean in the context of batch processes is not loss. (Felder and Rousseau, 2000)

2.4 Integral balances on semi-batch and continuous processes

Integral balances can also be written for semi-batch and continuous processes. The procedure was to write a differential balance on the system and then to integrate it between two instants of time. In most cases the required calculations were more complex than those we have seen so far; however, some problems of this type were relatively straightforward. (Felder and Rousseau, 2000)

3. Batch planning and scheduling

Every plant was based on a production schedule. The schedule may come from a planning and it was usually produced on regular schedule such as monthly,

weekly or daily. The main objective of batch production planning and scheduling was to optimize capacity of batch manufacturing and customer order within time. Production scheduling was concerned with setting the sequence and quality of actual grade production. Specific shipment dates and current inventories are used to set these schedules. (Barke *et al.*, 2005)

3.1 Design of single-product processing sequences

The determination of optimal batch time at a given batch sizes was batch volume per unit mass of product. Since most processes, in practice, have recipes with numerous tasks and a comparable number of processing units. When preparing a schedule of tasks and equipment items, it was common to specific units, usually with batch sizes, and to optimize cycle times for a specific recipe. In some cases, using the rates of production and yields, the vessels are designed as well; that is, vessel sizes were determined to minimize the cost of the plant while determining the cycle times for a specific recipe. Batch process design begins with the specification of a recipe of tasks to produce a product. The tasks were assigned to equipment items, but over specific intervals of time, which vary with batch size, which was often determined by the available equipment sizes. (Seider *et al*., 2010)

3.2 Batch cycle time

In batch processes, it was common for a task to consist of a sequence of steps to be carried out in the same equipment unit. For example, Figure 5 showed a typical recipe with its task and steps. Each step involved a batch time, which was determined by the processing rates and the batch size, that is, the amount of the final product in one batch. Furthermore, a production line was a set of equipment items assigned to the tasks in a recipe to produce a product. When a production line was used to produce a sequence of identical batches, the cycle time was the time between the completions of batches. To better visualize the schedule of production, an equipment occupation diagram known as a Gantt chart was prepared to show the

period of batch time as shown in Figure 6 which indicated that unit U2 had the longest batch time implying that the unit was the bottle neck in the process. The second batch was begun in time to produce the feed to unit U2 when received after processing the first batch. In this diagram, the batches were transferred from unit-to-unit immediately (so-called zero-wait strategy, with no intermediate storage utilized). Clearly, the cycle time, 6 hr was the batch time of U2. (Seider *et al*., 2010)

In the schedule in Figure 6a, the serial process had a distinct task assigned to each equipment item. When the fourth task can be carried out in U1, this unit was better utilized and U4 can be released for production elsewhere in the batch plant, as shown in Figure 6b. Note that to achieve this schedule without adding intermediate storage; it was necessary to retain the batch within U3 until U1 became available. Furthermore, to increase the efficiency of the schedule, that is, to reduce the cycle time, it was common to add one or more units in parallel that shown in the figure 6c, the bottle neck was eliminated and cycle time was reduced to 4 hours. (Seider *et.al*., 2010)

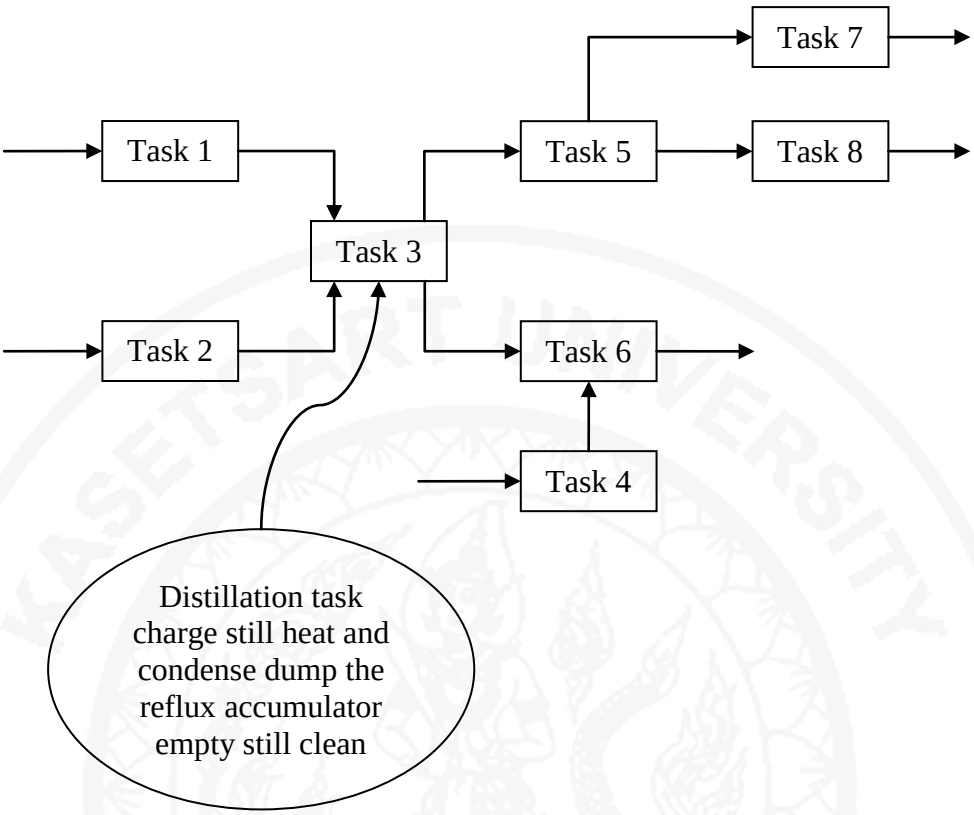


Figure 5 Recipes, task, and subtask.

Source: Seider *et al*. (2010)

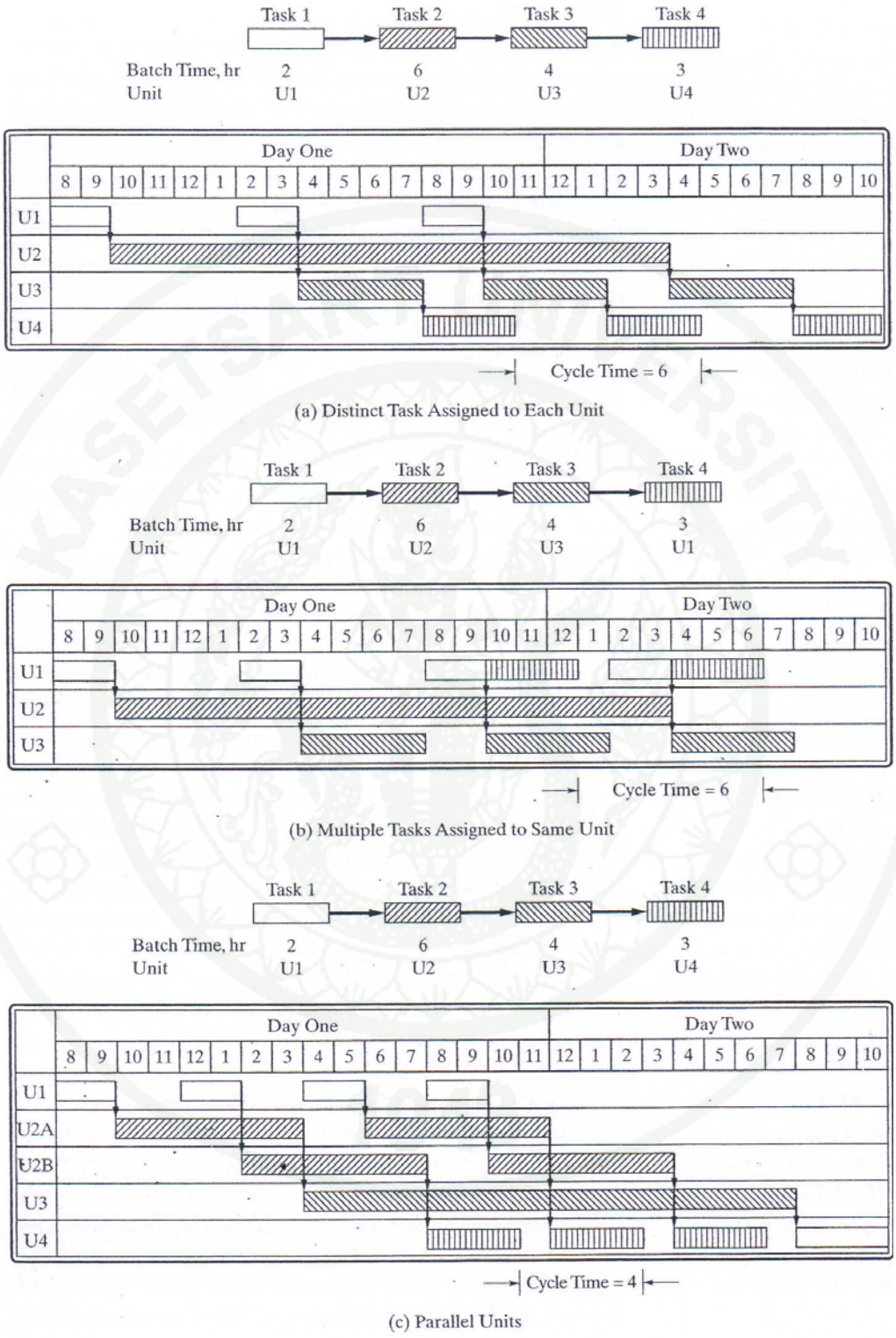


Figure 6 Serial recipe and Gantt charts.

Source: Seider *et al*. (2010)

4. Economical cost

A capital investment was required for any industrial process, and determination of the necessary investment was an important part of a plant-design project. The total investment for any process consisted of fixed-capital investment for physical equipment and facilities in the plant plus working capital. The working capital must be available to pay salaries, keep raw materials and products be convenient, and control other items which required a special direct cash. So, the analysis of cost in industrial processes, capital-investment costs, manufacturing costs, and general expenses including income taxes must be considered. (Peters *et al.*, 2004)

The total amount of money needed to supply the necessary plant and manufacturing facilities including the money required for operation of the facilities was the capital investment. Table 4 showed the summary of this typical variation in component costs as percentages of fixed-capital investment for multiprocess grass-roots plants or large *battery-limit* additions. A *grass-roots* plant was defined as a complete plant established on a new site. Investment consisted of site development, battery limit facilities, all costs of land, and auxiliary facilities. A geographical boundary defining as the coverage of a specific project was *battery limit.* Usually this encompasses the manufacturing area of a proposed plant or addition, including all process equipment but excluding provision of storage, utilities, administrative buildings, or auxiliary facilities unless so specified. Normally, this excluded site preparation and consequently, may be applied to the extension of an existing plant. (Peters *et al.*, 2004)

Table 4 Typical percentages of fixed-capital investment (FCI) values for direct and indirect cost segments for multipurpose plants or large additions to existing facilities

Component	**Range of FCI, %**
Direct cost	
Purchased equipment	15-40
Purchased-equipment installation	6-14
Instrumentation and controls (installed)	2-12
Piping (installed)	4-17
Electrical systems (installed)	2-10
Buildings (including services)	2-18
Yard improvements	2-5
Service facilities (installed)	8-30
Land	1-2
Indirect costs	
Engineering and supervision	4-20
Construction expenses	4-17
Legal expenses	1-3
Contractor's fee	2-6
Contingency	5-15

Source: Peters *et al.* (2004)

Total product cost consisted of three major components: selling the product, recovering the capital investment and contributing to corporate functions. The manufacturing costs and general expenses were generally taken into account later. Manufacturing costs were also known as operating or production costs. Further subdivision of the manufacturing costs was quite dependent upon the interpretation of variable, fixed, and overhead costs. (Peters *et al.*, 2004).

Table 5 and 6 summarized the pre-design estimation for capital investment cost and total product costs, respectively. The percentages indicated in both tables gave the ranges found in typical chemical plants. Due to the wide variations in different types of plants, the factors presented should be used only when more accurate data were not available.

Table 5 Estimation of capital investment cost (showing individual component)

The percentages indicated in the following summary of the various costs constituting the capital investment are approximations applicable to ordinary chemical processing plants. It should be realized that the values given vary depending on many factors, such as plant location, type of process, and complexity of instrumentation.

I. **Direct costs** = material and labor involved in actual installation of complete facility (65-85% of fixed-capital investment)

   A. Equipment + installation + instrumentation + piping + electrical + insulation + painting (50-60% of fixed-capital investment)

      1. Purchased equipment (15-40% of fixed-capital investment)
      2. Installation, including insulation and painting (25-55% of purchased-equipment cost)
      3. Instrumentation and controls, installed (8-50% of purchased-equipment cost)
      4. Piping, installed (10-80% of purchased-equipment cost)
      5. Electrical, installed (10-40% of purchased-equipment cost)

   B. Buildings, process, and auxiliary (10-70% of purchased-equipment cost)

   C. Service facilities and yard improvements (40-100% of purchased-equipment cost)

   D. Land (1-2% of fixed-capital investment or 4-8% of purchased-equipment cost)

Table 5 (Continued)

II. **Indirect cost** = expenses which are not directly involved with material and labor of actual installation of complete facility (15-35% of fixed-capital investment)
   A. Engineering and supervision (5-30% of direct cost)
   B. Legal expenses (1-3% of fixed-capital investment)
   C. Construction expense and contractor's fee (10-20% of fixed-capital investment)
   D. Contingency (5-15% of fixed-capital investment)

III. **Fixed-capital investment** = direct costs + indirect costs

IV. **Working capital** (10-20% of total capital investment)

V. **Total capital investment** = fixed-capital investment + working capital

Source: Peters *et al.* (2004)

Table 6 Estimation of total product cost (showing individual components)

The percentages indicated in the following summary of the various costs involved in the complete operation of manufacturing plants are approximations applicable to ordinary chemical processing plants. It should be realized that the values given vary depending on many factors, such as plant location, type of process, and company policies

I. **Manufacturing cost** = direct production cost + fixed charges + plant overhead costs

A. Direct production cost (about 66% of total product cost)

1. Raw materials (10-80% of total product cost)
2. Operating labor (10-20% of total product cost)
3. Direct supervisory and clerical labor (10-20% of operating labor)
4. Utilities (10-20% of total product cost)
5. Maintenance and repairs (2-10% of fixed-capital investment)
6. Operating supplies (10-20% of maintenance and repair costs, or 0.5-1% of fixed-capital investment)
7. Laboratory charges (10-20% of operating labor)
8. Patents and royalties (0-6% of total product cost)

B. Fixed charges (10-20% of total product cost)

1. Depreciation (depends on method of calculation)
2. Local taxes (1-4% of fixed-capital investment)
3. Insurance (0.4-1% of fixed-capital investment)
4. Rent (8-12% of value of rented land and buildings)
5. Financing (interest) (0-10% of fixed-capital investment)

C. Plant overhead costs (50-70% of cost for operating labor, supervision, and maintenance; or 5-15% of total product cost) include cost for the following: general plant upkeep and overhead, payroll overhead, packaging, medical services, safety and protection, restaurants, recreation, salvage, laboratories, and storage facilities

Table 6 (Continued)

II. **General expenses** = administrative cost + distribution and selling costs + research and development cost (15-25% of the total product cost)
   A. Administrative cost (about 20% of cost of operating labor, supervision, and maintenance; or 2-5% of total product cost) include costs for executive salaries, clerical eages, computer support, legal fees, office supplies, and communications
   B. Distribution and marketing costs (2-20% of total product cost) include costs for sales offices, salespeople, shipping, and advertising
   C. Research and development costs (2-5% of every sales dollar, or about 5% of total product cost)

III. **Total product cost** = manufacturing cost + general expenses

IV. **Gross earnings cost** (gross earning = total income – total product cost; amount of gross earnings cost depends on amount of gross earning for entire company and income tax regulations; a general range for gross earning cost is 15-40% of gross earning)

Source: Peters *et al.* (2004)

4.1 Net Present Value (NPV)

The net present value criterion indicated that the present value of benefits must equal or exceed the present value of costs if a project was to be selected. Equation 4 described the relation as the following below. (Steiner, 1996)

$$\sum_{j=0}^{N}\left(B_j - C_j\right)\left(P/F, i, j\right) \geq 0 \qquad (4)$$

Where i = opportunity cost of capital

B_j = benefits at the end of period j

C_j = costs at the end of period j

N = number of compounding periods; life of investment

P/F, i, j = single-payment present-worth factor for period j at discount rate i.

$$= \frac{1}{(1+i)^j}$$

4.2 Internal Rate of Return (IRR)

The internal rate of return was the percentage rate that caused the discounted present value of the benefits in a cash flow to be equal to the discounted present value of the costs which shown in equation 5. (Steiner, 1996)

$$\sum_{j=0}^{N} B_j\left(P/F, i^*, j\right) = \sum_{j=0}^{N} C_j\left(P/F, i^*, j\right) \quad (5)$$

Where IRR, i^* = internal rate of return

P/F, i^*, j = single-payment present-worth factor for period j at discount rate i^*

$$= \frac{1}{\left(1+i^*\right)^j}$$

The internal rate of return can also be defined as the discounted rate that resulted in the net present value (NPV) of a cash flow to equal zero which shown in equation 6. (Steiner, 1996)

$$NPV = \sum_{j=0}^{N} B_j \left(P/F, i^*, j\right) - \sum_{j=0}^{N} C_j \left(P/F, i^*, j\right) = 0 \quad (6)$$

4.3 Payback Period (PB)

The profitability measure of payback period, or payout period, was the length of time necessary for the total return to equal the capital investment. The initial fixed-capital investment and annual cash flow were usually used to calculate PB, displayed in equation 7. It was subjected to the fact that the cash flow usually changes from year to year. (Peters *et al.*, 2004)

$$PB = \frac{V + A_x}{A_j} \quad (7)$$

Where PB = payback period in years
V = manufacturing fixed-capital investment
A_x = annual cash flow
$V + A_x$ = fixed-capital investment
A_j = annual cash flow

5. Literature review

The process of methyl ester production for pilot plant using B. *carinata* oil as feedstock and potassium hydroxide as catalyst had been studied by Bouaid *et al.* (2005). It was found that the maximum yield of 98% can be obtained with 1.5% initial concentration of catalyst, 25 ^{0}C operating temperature and 6:1 molar ratio of methanol to oil. Through evaluation of biodiesel purity by the calculation of methyl ester concentration in the biodiesel phase after 1 hour of settling step and estimation of the biodiesel yield after reaction and separation stage by comparison between biodiesel weight yield and the initial amount of vegetable oil, they concluded that

saponification of triglycerides was the only side reaction. Furthermore, mass balance analyzing the methyl ester and glycerol phases indicated that the methyl ester dissolution in the glycerol phase was only 0.05% after the reaction step.

From that work of Kapilakarn and Peugtong (2005), transesterification of palm oil consisting of only 3-palmatic acid with less than 1% fatty acid was tha main reaction in CSTR reactor used in the simulation by means of HYSYS 3.2 software for the preliminary economic design to determine the optimal operating condition of the production process. It was found that the molar ratio of methanol to oil at 6:1, reaction temperature at 70 ^{0}C and reaction time of 20 minutes was optimal for minimizing the operating cost. Additionally, doubling size of reactor improved the product purity; stepping up from 96.62 to 98.21% at the same production rate. Two half-size reactors in series stimulated, moreover, better product purity and operating cost than those from the single reactor with equivalent size.

Six major economic cost factors including fixed capital cost (FCC), total capital investment cost (TCC), total manufacturing cost (TMC), net annual profit after tax (NNP), after tax rate of return (ARR) and break-even price (BBP) of biodiesel production of three plants in Taiwan with capacities of 8,000; 30,000 and 100,000 ton/year were analyzed and assessed in the work from You *et* a*l.* (2008). The plants in this work used continuous process with NaOH and virgin soybean oil as catalyst and feedstock respectively. The result exhibited that NNP and ARR of the plants with capacities of 8,000; 30,000; and 100,000 ton/year were US$ -24×10^{3}, US$ 1975×10^{3} and US$ 8879×10^{3}, and -10.44, 40.23 and 67.38%, respectively. Furthermore, BBP of those three plants were US$ 862, US$ 724 and US$ 678. It was also transparent that the plant with capacity of 100,000 ton/year provided comparatively higher NNP and more attractive ARR with lower BBP making it economically feasible. Finally, they conclude that plant capacity, price of feedstock oil and diesel yield of glycerin and biodiesel was the most significant variables affecting the economic viability of biodiesel production.

Cost of industrial scale biodiesel production from waste cooking oil had also been studied by Kasteren and Nisworo (2007). Simulation of the process was performed under Aspen Plus® version 11.1.1. In this work, Triolein ($C_{57}H_{104}O_6$) was chosen to represent the waste cooking oil and methyl oleate ($C_{19}H_{36}O_2$) was chosen to represent the biodiesel product. Transesterification was carried out under supercritical condition in adiabatic plug flow reactor (RPlug) with propane as co-solvent. Three plant capacities of 125,000; 80,000 and 8,000 ton/year operated continuously resulting in high purity of methyl esters at 99.8% and almost pure glycerol as by-product. The economic assessment of those plants indicated that biodiesel could be sold at US$ 0.17/l US$ 0.24/l and US$ 1.52/l for the plant capacities of 125,000; 80,000 and 8,000 ton/year respectively. They also suggested that the key factors for the economic feasibility of the plants were raw material price, plant capacity, glycerol price and capital cost.

A model of biodiesel production cost of continuous process of crude, degummed soybean oil as feedstock and sodium methoxide as catalyst was estimated in the work from Hass *et al.* (2006) with the helping of ASPEN PLUS (2001) to develop a process model of the production of 10×10^6 gal/year. The plant was designed to operated three shifts per day and 47 weeks per year with a depreciable life of 10 years. From the result, it was clear that the single greatest contributor to the production cost was the price of oil feedstock which accounted for 88% of total estimated production costs. Moreover, the cost of feedstock showed a direct linear relationship between the two. They also found that if the process recovered glycerol during production of biodiesel, the production cost would be decreased by 6%. Furthermore, the production cost of biodiesel was found to vary inversely with variation in the value of glycerol.

Mockus *et al. (*2002) presented a methodology that combined a production plan and daily operation schedule in a single model by means of VisTis scheduling tool. Pharmaceutical pilot plant with 2-year production plan had been conducted with several different schedules to test the proposed methodology. It was found that a

modest increase in the processing times or demands distributed base plan, implying that adding every detail throughout the planning horizon provided no benefit as long as total tardiness was concerned. They also advised that evolution of the palm over the course of several months might give a much better feeling for the uselessness of setting up campaign with full detail far into the further. In addition, stochastic simulation of the plan would help determine the quality of the schedule under unknown uncertainty.

Evolution of fuel properties of methyl ester, ethyl and isopropyl ester of crude palm oil (CPO) and crude palm stearin (CPS) had been carried out via the work of May *et al.* (2005). They found that densities at 40 ^{0}C methyl, ethyl and isopropyl ester of CPO and CPS were 0.855-0.858 kg/l. Sulfur content of these esters were low with only 0.04 wt% at maximum. The viscosities at 40 ^{0}C of the esters were in the range of 4.4×10^{-6}-5.2×10^{-6} m^2/s. The pour point ranged from 6-18 ^{0}C with the notice that ethyl and isopropyl esters outperformed methyl ester in this parameter as well as alkyl esters of CPO showed better result than that of CPS. Alkyl esters of both CPO and CPS exhibited cloud points ranging from 7-19 ^{0}C (maximal value was from methyl ester of CPS, minimal value was from isopropyl ester of CPO). Boiling range of alkyl esters of CPO and CPS was narrow compared to that of petroleum diesel. The widest boiling range was from isopropyl ester followed with ethyl ester and methyl ester. It was also found that alkyl ester of CPO had shorter boiling range than that from alkyl esters of CPS. Heat of combustion of CPO and CPS esters was around 39.7-49.4 MJ/kg. Flash point of methyl ester of both CPO and CPS was 178 and 165 ^{0}C respectively which so far higher than that of petroleum diesel.

MATERIALS AND METHODS

Materials

1. Samples from biodiesel production plant in Thailand were taking from

    1.1 Reactor output
    1.2 Settling tank output

2. Equipment and tools for experiment

    2.1 Balance (0.0001 g accuracy): BL2105, Sartorius, Germany
    2.2 Volumetric flask 100 ml
    2.3 Erlenmeyer flask 250 ml
    2.4 Beaker
    2.5 Burette 50 ml
    2.6 Auto pipette: Boeco, Germany
    2.7 Pipette
    2.8 Stirring bar
    2.9 Spatula

3. Chemicals

    3.1 Iso-propanol (AR grade, Merck, Germany)
    3.2 Phenolthalien (0.1%) (AR grade, Ajax finechem, Australia)
    3.3 Bromophenol blue (0.04%) (AR grade, Ajax finechem, Australia)
    3.4 Hydrochoric acid (0.1 N solution) (AR grade, J.T Baker, USA)
    3.5 Potassium hydroxide (0.1 N solution) (A.R. grad, Ajax finechem, Australia)

4. Computing machine

Acer laptop with Intel core™2 CPU T5500 running at 1.66 GHz, 2 GB of RAM running on Microsoft windows XP professional x86 (32-bit) version 2002 Service Pack 3

5. Software

5.1 Aspen Batch Process Developer version 7.0 (Aspen Technology, Inc)
5.2 Microsoft Office Visio 2007
5.3 Microsoft Office Excel 2007

Methods

This thesis consists of four parts; process design, mass balance calculation, schedule simulation and cost estimation. The process of biodiesel production plant was designed based on a real plant in Thailand. The mass balance was calculated by means of Aspen Batch Process Developer and the flow diagram was illustrated in Microsoft Office Visio. The schedule of biodiesel production plant was simulated inside the same software. The biodiesel production plant selection was using the cost criteria.

1. Process design

The production process of palm biodiesel was designed by Batch Process Developer as shown in Figure 7. Details of units and materials are as following:

Mixing of alcohol and catalyst (M-101)

The catalyst is potassium hydroxide. It is dissolved in the alcohol (methanol) using a standard agitator or mixer and the corresponding methoxide was obtained.

Excess alcohol was used to ensure total conversion of the oil to its alkyl ester. In the design, mole ratio of methanol to oil was 6:1 and 0.5% (wt. of oil) potassium hydroxide was used.

Reaction (R-101)

Heated palm stearin (around 67 °C) from stearin tank (TT-101) was charged simultaneously with the alcohol/catalyst solution into the closed reaction vessel. The system from here on is totally closed to the atmosphere to prevent the loss of methanol. The condition inside reactor was kept just above the boiling point of the alcohol (60 °C) to speed up the reaction and the reaction proceeded for 1 hour.

Separation (TT-103)

After the completion of reaction, two major products existed: glycerol and biodiesel. The glycerol phase was much denser than biodiesel phase and the two can be gravity separated in the settling tank at ambient temperature. The presence of alcohol in both phases might make separation difficult. If the sedimentation process took place at a higher temperature, separation of the phases may be optimized because a temperature increase caused a decrease in viscosity and an increase of separation speed. Separation process of biodiesel and glycerol phases was performed in laboratory. The result showed that after 6 hour of settling time at ambient temperature there was no any difference in separation in both phases so that the settling time in the settling tank in the designed process was set to be 6 hours.

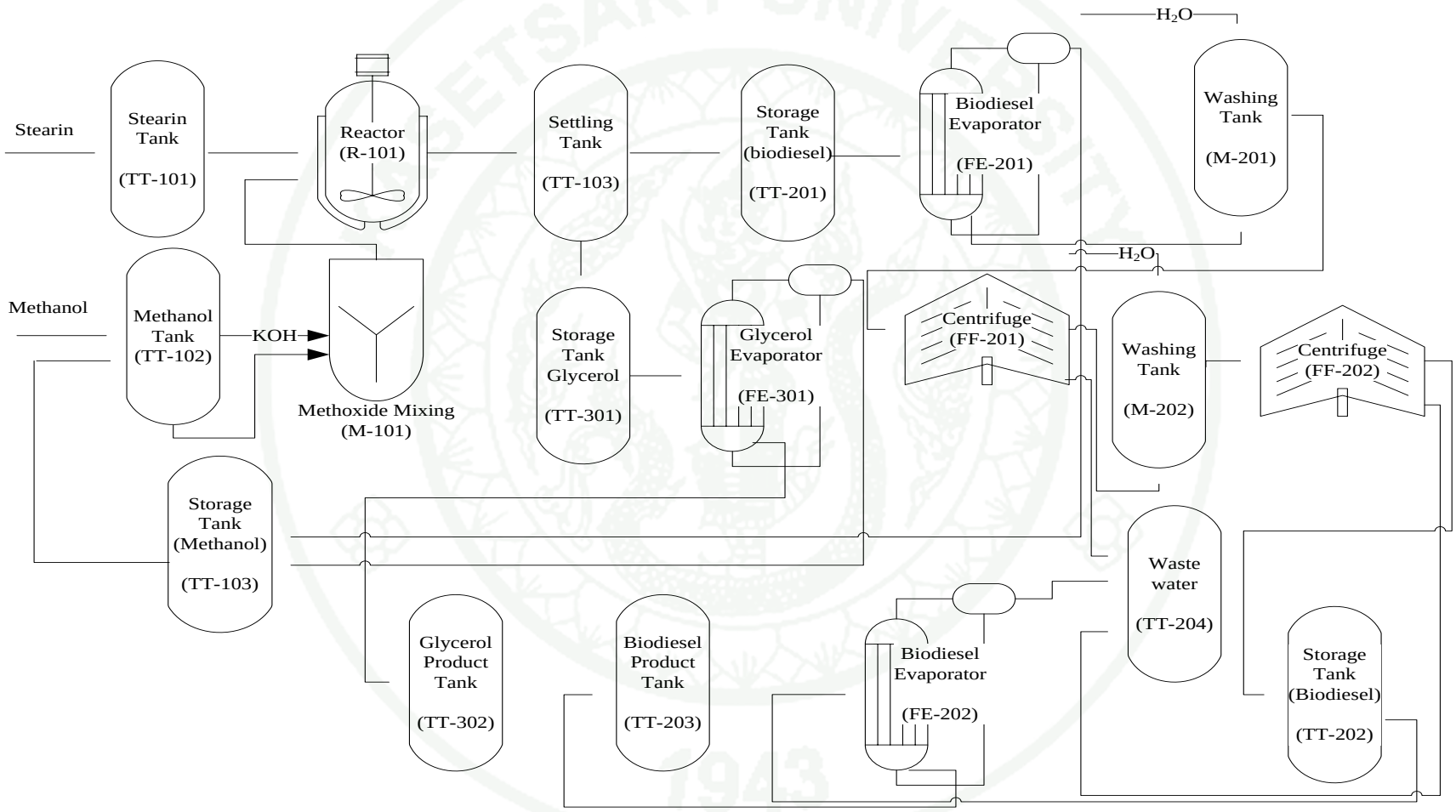


Figure 7 Biodiesel production process for mass balance calculation

Alcohol removal (FE-201 and FE-301)

Once the glycerin and biodiesel phases have been separated, each phase was fed into its buffer tank (TT-201 and TT-301) before excess alcohol in each phase was removed with a continuous flash evaporation process. The alcohol from both phases were recovered back to methanol storage tank (TT-103) and re-used together with a fresh one for the next batch.

Crude Glycerol (TT-302)

The glycerol from glycerol evaporator containing unused catalyst and soaps was sent to storage tank as crude glycerol. The concentration of this crude was around 70-80% pure glycerol that was ready to be sold as crude glycerol.

Biodiesel wash (M-201 and M-203)

The crude biodiesel was purified by washing gently with warm water to remove residual catalyst or soaps. Feed flow of water and crude biodiesel was countercurrent into the washing tank. The ratio of water to crude biodiesel was 0.5 and 0.3 in the first and second washing tank respectively. The mixture in both tanks was allowed to settle for 30 minutes. After that, centrifuges (FE-201 and FE-202) were used to separate water and impurities from crude biodiesel.

Biodiesel dry (FE-202)

Moist and cleaned biodiesel from separation unit (FE-202) was charged into buffer tank (TT-202) before diverted to continuous evaporation unit (TT-203) to remove any trace amount of moisture resulting in a clear amber-yellow liquid with a viscosity almost similar to petrodiesel and less than 200 ppm of water. The final product was then store in product storage tank (TT-302).

2. Mass balance

The most important step for setting-up a biodiesel plant is the evaluation of economic feasibility which must be based on reliable data. Mass balance can be utilized to collect the production data by analyzing composition of flow in the process in term of input and output to/from each unit. This flow and composition was related to mass of raw materials, biodiesel yield from transesterification, yield loss from side reaction (saponification), methyl ester dissolution in the glycerol phase in separation process, yield loss arising from carrying over with water in washing process and etc. Such information was mandatory to find utility requirements and sizing equipment. Performing the mass balance analysis of the full process was a key step to obtain economic cost data for performing the economic feasibility studies.

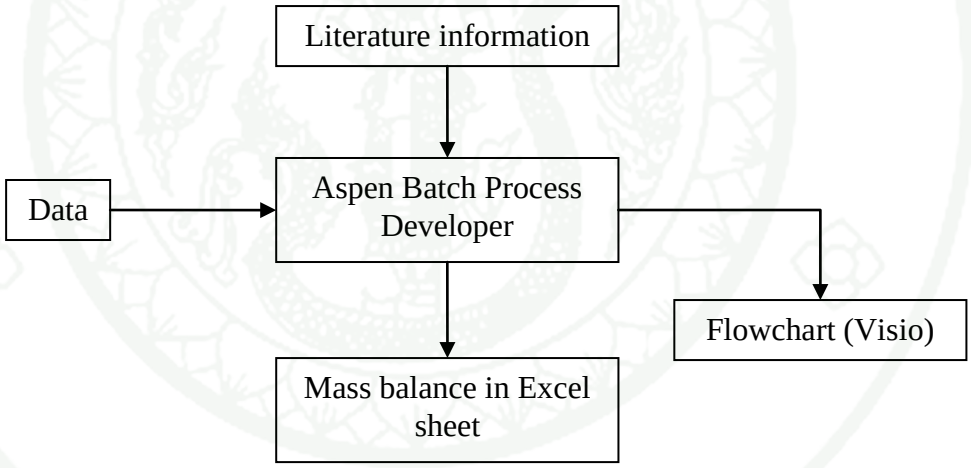


Figure 8 Diagram of mass balance simulation

The amount and ratio of raw materials was gathered from a biodiesel production plant in Thailand. The composition of materials like methyl ester, triglyceride, diglyceride, monoglyceride, soap, potassium hydroxide, free fatty acid, methanol and water content from reactor and settling tank was obtained from laboratory experiment at the same designed condition and the rest was specified based on literatures. These data were imported to Aspen Batch process Developer for mass balance calculation which was displayed in Figure 8. The results from Aspen Batch

Process Developer were flowchart of corresponding biodiesel plant and mass balance of each unit in the plant. Additionally, the flow chart of biodiesel plant and mass balance could be exported to Microsoft Office Visio 2007 and Microsoft Office Excel 2007, respectively.

Soap, potassium hydroxide and free fatty acid of the mixture in the reactor and settling tank were analyzed by titration method whose detail was demonstrated in appendix A. Gas Chromatography (GC) method was used to examined methyl ester, triglyceride, diglyceride, monoglyceride, glycerol, methanol content and water content.

Stearin, as a raw material of the process, was assumed to be the triglyceride consisting only stearic acid in its chains. The density of stearin and biodiesel was 891.53 and 860 kg/m^3, respestively. 97% of stearin was converted to biodiesel through transesterification and 3% was converted to soap by saponification. Therefore, after completion of reactions, there was no any remaining triglyceride in biodiesel and glycerol phases in the settling tank. The yield of biodiesel product was 90% after biodiesel pass through the washing units. The capacities of the plants were based on the feed rate of raw material (stearin) which was 100,000; 300,000 and 500,000 kg/batch.

3. Schedule of biodiesel production plant

The schedule simulation was summarized in a flow diagram as shown in Figure 9. The first step was to assign feedstock capacities, 100,000; 300,000 and 500,000 kg/batch, to the biodiesel production plant. Then, the size and number of units were varied to investigate the effect of cycle time. After that, this biodiesel production process was simulated by Aspen Batch Process Developer version 7.0.

Before performing the simulation, the equipment was examined for the suitability for this plant. Specific units were chosen for specific operating tasks as

following; the evaporator for methanol and water evaporation, the centrifuge for separating moisture out of washed biodiesel. Finally, the equipment was arranged for four different pattern to be plant A, B, C and D. After these plants were designed thoughtfully, they were assigned to operate in distinct patterns; fixed time and fixed flow rate. The fixed time pattern indicated that transferring time from each unit to the other had a unity value. Concurrently, the fixed flow rate pattern declared that stream flow rate from each unit to the other had a same value. The results of the schedule simulation were operation time and cycle time. The definition of operation time was the period of time to start feeding the substrate into the process until the product come out (overall operation time), which was called one batch. The cycle time was then defined as the time between the finishing time of product of the first batch and that of the second batch. The objective of designing biodiesel production separately in four plants was to compare the effect of different operations and cycle times.

From one raw material tank, the process of plant A consists of plant A define as from one material tank going to one reactor. While plant B, C and D define as from one raw material going to 2, 3 and 4 reactors as shown in Figure 10. 6The difference of plant A, B, C and D were size and amount of equipment. Size of units in the plants was A > B > C > D whereas number of the units was D > C > B > A.

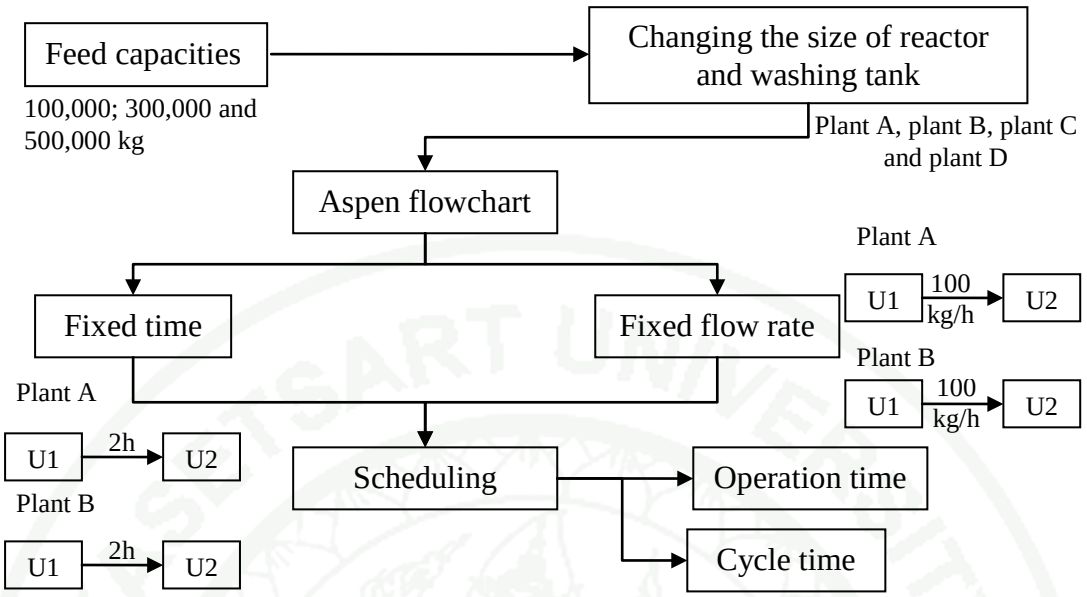


Figure 9 Scheme of schedule operation

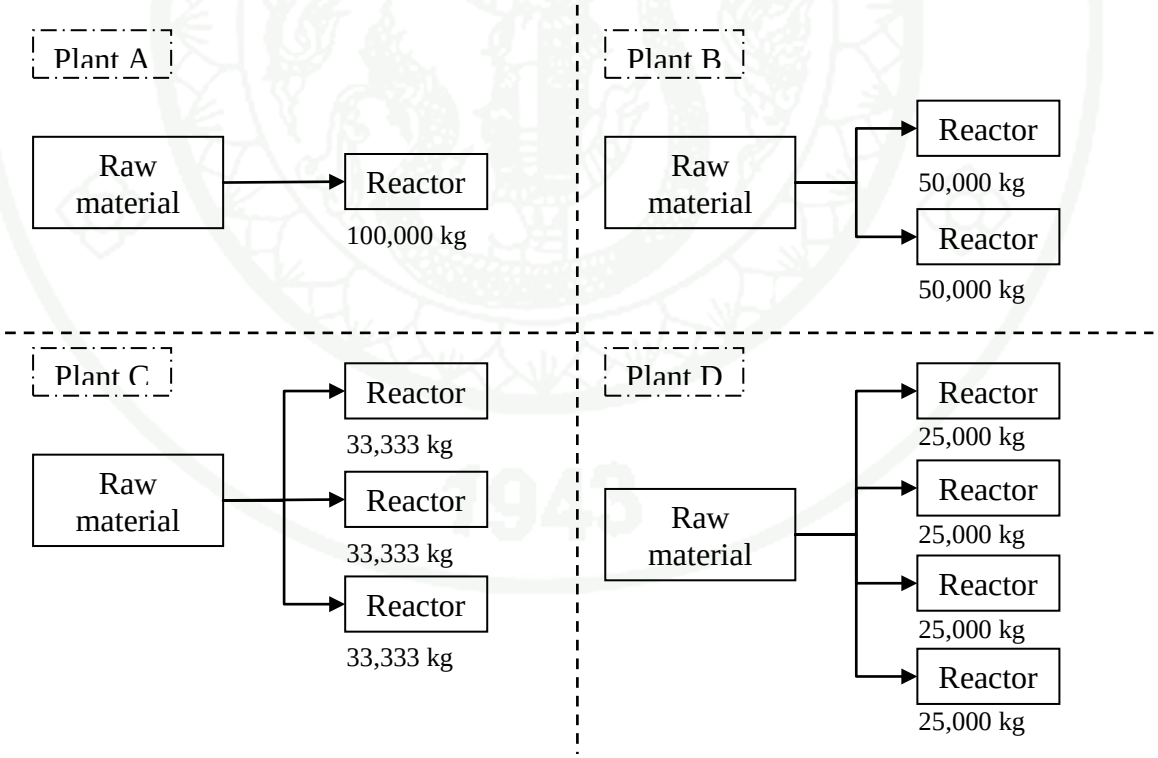


Figure 10 Sizing and number of reactor in plants

The biodiesel production plant A, B, C and D was designed to operate in two distinguish patterns, namely fixed time and fixed flow rate. For fixed flow rate, the flow rate of each stream all plant was 100, 300 and 500 m^3/h when the flow rate of feedstock was 100,000; 300,000 and 500,000 kg respectively.

The plant A had one reactor, one settling tank and two washing tanks, meanwhile plant B consisted of two reactors, two settling tanks and four washing tanks, plant C contained three reactors, three settling tanks and six washing tanks and plant D was composed of four reactors, four settling tanks and eight washing tanks as displayed in Figure 11.

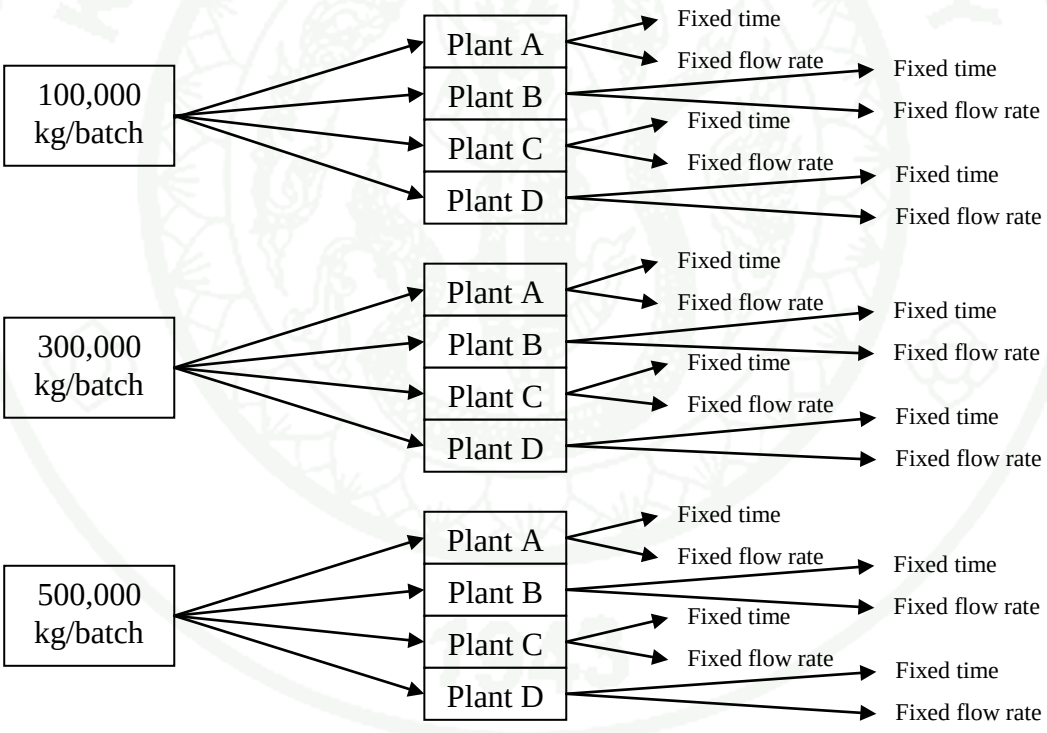


Figure 11 Load and operating pattern

4. Cost estimation

The cost estimation was described in a flow diagram as shown in Figure 12. The first step of cost evaluation was the calculation of tank volume and flow rate inside the process. The tank volume was calculated to estimate dimension of tank from which cost of equipment could be determined. After that, the investment cost and operating cost were calculated as the final result. The cost of equipment in the plants was the main cost of fixed-capital investment. The operating cost was calculated from the cost of raw materials and utilities. After that, biodiesel production plants were analyzed for their economic feasibility. The selection of biodiesel production plant in each capacity was considered on economic cost, schedule and design of plant.

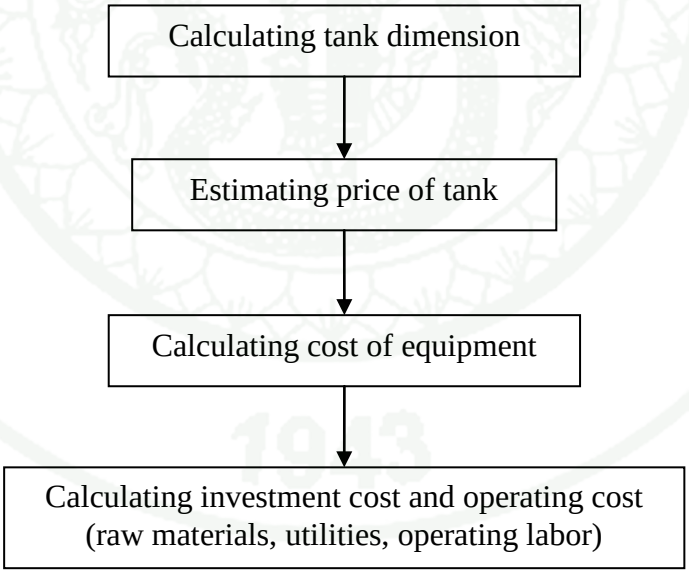


Figure 12 Scheme of estimate economic cost

The equipment in each plant was designed based on the palpable one in market as much as possible. If the raw data of equipment in the market were not

available, rules of thumb from various textbooks were applied. The example calculation of vessel dimension and motor of reactor and mixing vessel was showed in the appendix C and D, respectively. From appendix C, known dimension of tank was used to determine carbon steel cost. The material for storage tank was carbon steel SG 295 whose cost was 35 baht/kg (March, 2011). After that, the final storage tank cost was approximated to be 15 times over material cost coming from labor cost for tank production, welding cost and etc.

The fixed-capital investment consisted of the cost of equipment, installation, instrumentation and controls, piping, electrical systems, buildings (including services), yard improvement, service facilities, land, engineering, supervision, construction expenses, legal expenses, contingency which was 32%, 6%, 5%, 5%, 3%, 4%, 2%, 20%, 1%, 9%, 4%, 2%, 2% and 5% of fixed-capital investment, respectively.

The operating cost consisted of the cost of raw material, water, energy, operating labor and maintenance. The raw material comprised of stearin, methanol and potassium hydroxide which were 46.38, 10 and 18 baht/kg, respectively (March, 2011). The labor cost was 12,000 baht/month/shift (3 shifts/day). The biodiesel production plant A, B, C, D required 3, 4, 5 and 6 people/shift (8 hours), respectively. The maintenance cost was 5% of fixed-capital investment. Additionally, Income came from biodiesel and glycerol which were 46.09 baht/l and 5 baht/kg, respectively.

The last step was economic feasibility which was calculated from NPV and IRR. The equation for the calculation of NPV and IRR was demonstrated in the equation 4 and 5, respectively. Life cycle of all plants was assumed to be 15 years and the cost of raw materials, products and utilities were constant throughout the life cycle. However, labor cost was increased for 3% every year. Finally the plants operated 270 days per year.

RESULTS AND DISCUSSION

This section consists of results from experiments in laboratory, mass balance calculation, schedule simulation and cost estimation of the biodiesel production plant. Samples taking from experiments in laboratory were analyzed to determine composition of biodiesel and glycerol phases after the completion of reaction. With these results, mass balance in each unit of the process was calculated to examine capacity of biodiesel production per operation time. The operation time of biodiesel production process was simulated by Aspen Batch Developer version 7.0. Finally, the investment and operation cost in each biodiesel production plant was calculated in order to analyze cost of operation.

1. Experiments in laboratory to analysis composition of each stream line

The raw materials for biodiesel production in the proposed plants were palm stearin, methanol and potassium hydroxide. Palm stearin consisted mainly of triglyceride and free fatty acid at about 0.02 wt% according to titration. The purity of methanol and potassium hydroxide were 99.5 and 85% respectively.

The samples from a commercial plant were collected and washed in order to determine composition of biodiesel which shown in Table 7. Free glycerol was 0 wt% implying that glycerol totally dissolved into washing water. Therefore, water could remove glycerol contaminated in biodiesel phase effectively. The Table 7 also demonstrated that conversion of methyl ester was 97.9 wt%. This conversion was calculated in transesterification equation which 97% of triglyceride was converted to fatty acid methyl ester.

The samples from reactor and settling tank were also collected from units of biodiesel production plant in Thailand which produced biodiesel from palm stearin and potassium hydroxide as a catalyst. The sample from reactor was re-agitated and allowed to settle for 6, 27 and 48 hours before the composition of upper phase was

measured at corresponding time which can be illustrated in Table 8. It was clear that the settling time of 6 hours was suitable for the process because there was no any significant difference in glycerol concentration of the samples after 6 hours of settling time.

Table 7 The composition of biodiesel production

Test item	Test method	Result (wt. %)
Methyl ester	EN 14103	97.9
Monoglyceride	EN 14105	0.27
Diglyceride	EN 14105	0.10
Triglyceride	EN 14105	0.0
Free glycerin	EN 14105	0.0
Total glycerin	EN 14105	0.08

Table 8 The composition of biodiesel in upper phase in settling tank in each hour

Composition [wt%]	6 hours	27 hours	48 hours
Monoglyceride	0.28	0.28	0.26
Diglyceride	0.10	0.12	0.12
Triglyceride	0.0	0.0	0.0
Free glycerin	0.15	0.15	0.15
Total glycerin	0.23	0.24	0.23

Composition of the samples of upper and lower phases from settling tank was shown Table 9. In the commercial process, the stream line output from reactor was settled in the settling tank for 48 hours to allow glycerol and other impurity settle in the bottom of settling tank before both phases were transferred to other units. According to composition measurement, there was no potassium hydroxide in the upper phase (biodiesel phase). Therefore, this biodiesel production plant had actually no need for neutralization unit to neutralize remaining catalyst to salt before entering

evaporator. The remaining potassium hydroxide from reactor was in the lower phase (glycerol phase). The main contents in lower phase were glycerol and soap as can be noticed from Table 9.

Table 9 The composition of biodiesel production process in each unit

Composition [wt%]	**Output (R-101)**	**Input (TT-201)**	**Output (TT-301)**
Methyl ester	na.	na.	na.
Methanol content	na.	na.	na.
Water content	na.	na.	0.7000
Potassium hydroxide	0.0924	0	1.4800
Soap	1.8250	0.1014	6.1000
Acid value (mg KOH/g)	na.	0.0817	na.
Glycerol	na.	0.23	67.04

Note: na. = not available

The composition of glycerol phase in settling tank was dominated by glycerol which was demonstrated in Table 10. The stream line output TT-301 was the stream before entering evaporator and input TT-302 was the output from evaporator. Evaporator increased glycerol and water contents in stream because methanol and water were removed.

Table 10 Water content and glycerol in glycerol phase

Composition	**Output (TT-301)**	**Input (TT-302)**
Glycerol, % wt.	67.04	74.75
Water, %wt.	0.7	0.97

2. Mass balance

According to process designed as in Figure 13, mass balance in each unit whose capacity of biodiesel production and yield of fatty acid methyl ester were analyzed and optimized in Aspen Batch Process Developer, were presented in Table 11. The result of this simulation revealed that yield of fatty acid methyl ester (91.33%) could be obtained finally. The yield of biodiesel decreased due to carrying over of biodiesel with washing water. The conversion of triglyceride to biodiesel was 97.9%; the rest underwent saponification. The washing process to purify biodiesel phase employed water at about 80% of feed biodiesel in 2 consecutive washing steps; 50% in the first and 30% in the second. The results from mass balance declared that 91,329 kg biodiesel could be obtained from 100,000 kg stearin only if there was no sapoinification.

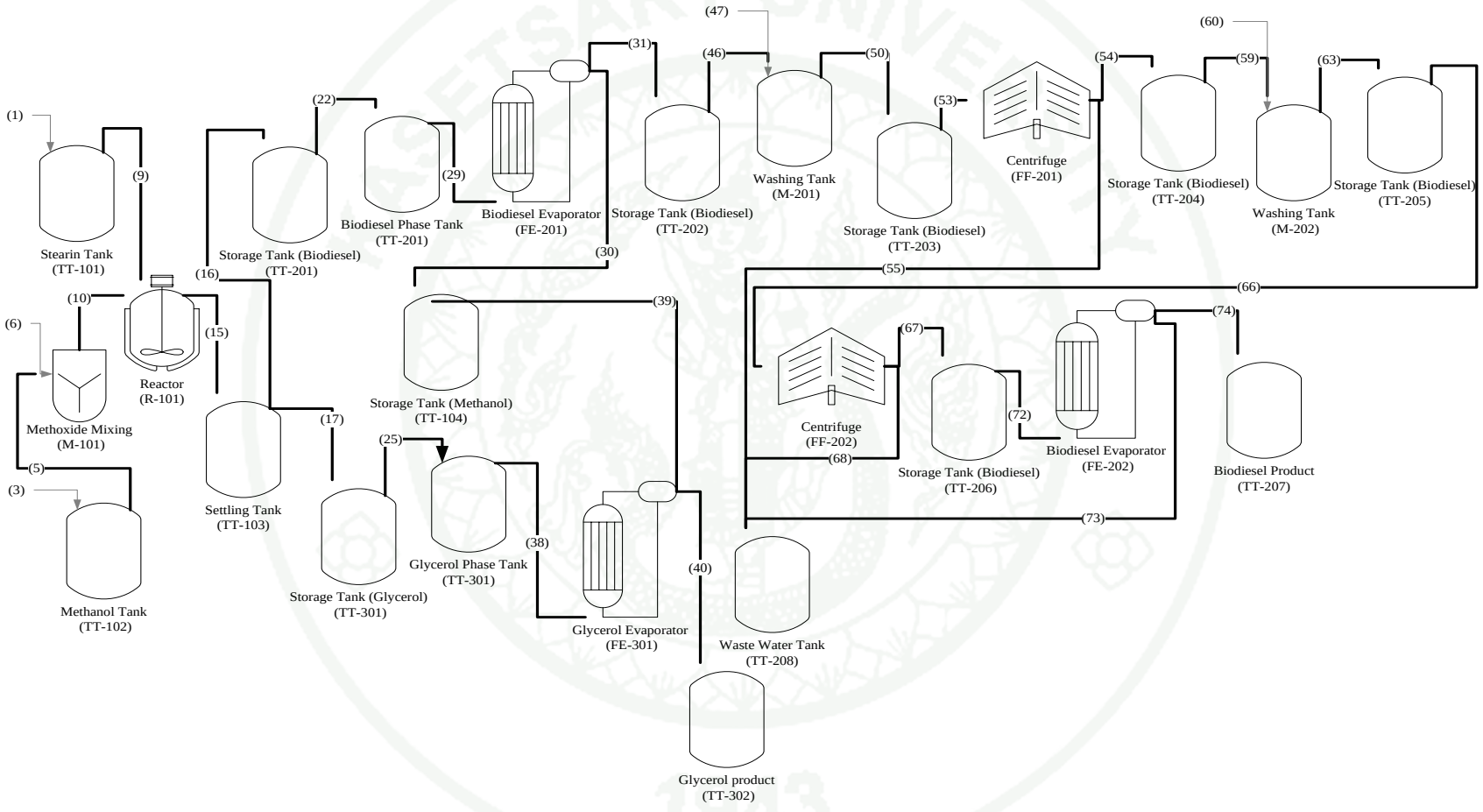


Figure 13 The process flow diagram of biodiesel production plant A at capacity of feedstock 100,000 kg from Aspen Batch Process Developer

Table 11 The result of mass balance from Aspen Batch Process Developer

Stream Line	Biodiosel (kg)	Triglyceride (kg)	Diglyceride (kg)	Monoglyceride (kg)	Glycerol (kg)	FFA (kg)	Methanol (kg)	Soap (kg)	Potassium hydroxide (kg)	Water (kg)	Total (kg)
1	0	99,721	na.	na.	0	279	0	0	0	0	100,000
3	0	0	0	0	0	0	20,049	0	0	101	20,150
5	0	0	0	0	0	0	20,049	0	0	101	20,150
6	0	0	0	0	0	0	0	0	476	0	476
9	0	99,721	na.	na.	0	279	0	0	0	0	100,000
10	0	0	0	0	0	0	20,049	0	476	101	20,626
15	97,814	0	343	392	10,151	3	9,549	2,161	102	118	120,633
16	96,836	0	309	381	233	3	4,011	972	0	0	102,745
17	978	0	34	12	9,917	0	5,539	1,188	102	118	17,888
29	96,836	0	309	381	233	3	4,011	972	0	0	102,745
30	0	0	0	0	0	0	3,289	0	0	0	3,289
38	978	0	34	12	9,917	0	5,539	1,188	102	118	17,888
39	0	0	0	0	0	0	4,542	0	0	0	4,542
40	978	0	34	12	9,917	0	997	1,188	102	118	13,346
46	96,836	0	309	381	233	3	723	972	0	0	99,456
47	0	0	0	0	0	0	0	0	0	49,728	49,728
53	96,836	0	309	381	233	3	722	972	0	49,728	149,184
55	4,842	0	155	190	117	1	361	486	0	49,231	55,383
59	91,994	0	155	190	117	1	361	486	0	497	93,801

Table 11 (Continued)

Stream Line	Biodiosel (kg)	Triglyceride (kg)	Diglyceride (kg)	Monoglyceride (kg)	Glycerol (kg)	FFA (kg)	Methanol (kg)	Soap (kg)	Potassium hydroxide (kg)	Water (kg)	Total (kg)
60	0	0	0	0	0	0	0	0	0	28,140	28,140
66	91,994	0	155	190	117	1	361	486	0	28,638	121,942
68	91,074	0	15	171	6	1	180	15	0	294	91,757
72	920	0	139	19	111	0.7	180	472	0	28,351	30,193
73	0	0	0	0	0	0	162	0	0	258	420
74	91,074	0	15	171	6	0.7	18	15	0	29	91,329

3 Schedule simulation

The schedule was simulated by Aspen Batch Process Developer program which was displayed in Table 12. The Table 12 was the arrangement which gave the shortest time for operation time and cycle time. If some equipment operated in parallel, the operation time decreased. This table was the result of biodiesel production plant A with capacity of 100,000 kg/batch stearin in fixed time pattern. The results from Table 12 were scheduling and the corresponding flowchart was shown in the Figure 14 and 15, respectively. The Figure 14 demonstrated operation time and cycle time which was 22.57 and 9 hours, respectively. The Figure 15 was the flowchart of biodiesel production process plant A.

Table 12 Description from Aspen Batch Process Developer in plant A which capacity of stearin 100,000 kg in fixed time

---

1. Preparation and Reaction

   Start Parallel

   Series

   1.1. Charge Stearin Tank (TT-101) with 100000 kg of STEARIN.

   Series

   1.2. Charge Methanol Tank (TT-102) with 20150 kg of 99.5% METHANOL.

   End Parallel

   1.3. Mix the contents of unit Methoxide Mixing (M-101). The mixing time is 111 min. Continuously add 20150 kg of the material from Methanol Tank (TT-102). The feed rate is 20.15 Cubic m/h. Continuously add 476.3989 kg of POTASSIUM-HYDROXIDE. Component distribution is as follows: 100% of POTASSIUM-HYDROXIDE from the Solid phase goes to the Liquid phase.

   1.4. React in unit Reactor (R-101) via Transesterification and Saponification. Reaction occurs over 136 min. Continuously add

100000 kg of the material from Stearin Tank (TT-101). The feed rate is 100 Cubic m/h. Continuously add 20626.3989 kg of the material from Methoxide Mixing (M-101). The feed rate is 20.62 Cubic m/h.

1.5. Separate the contents of unit Reactor (R-101) in separator Settling Tank (TT-103), into the following layers: Biodiesel phase and Glycerol phase. The feed time is 120.63 min. Biodiesel phase: 42% of METHANOL goes to Biodiesel phase, 99% of BIODIESEL goes to Biodiesel phase, 97% of MONOGLYCERIDE goes to Biodiesel phase, 90% of DIGLYCERIDE goes to Biodiesel phase, 100% of FFA goes to Biodiesel phase, 45% of SOAP goes to Biodiesel phase and 2.3% of GLYCEROL goes to Biodiesel phase. Unspecified components are sent to Glycerol phase. Biodiesel phase Transfer Stream: The stream, named Biodiesel, is sent to Storage Tank (Biodiesel) (TT-201). The transfer rate is 102.74 Cubic m/h. Glycerol phase Transfer Stream: The stream, named Glycerol phase, is sent to Storage Tank (Glycerol) (TT-301). The transfer rate is 17.89 Cubic m/h. The separation time is 360 min.

---

2. Purification

Start Parallel

Series

2.1. Mix the contents of unit Biodiesel Phase Tank (TT-201). Continuously add 1.027448e+5 kg of the material from Storage Tank (Biodiesel) (TT-201). The feed rate is 102.63 Cubic m/h.

2.2. Distill continuously the mixture from unit Biodiesel Phase Tank (TT-201) in unit Biodiesel Evaporator (FE-201). The mixture feed rate is 102.74 Cubic m/h. Separation is: 82% of METHANOL goes to Overhead. Unspecified materials go to Bottoms. The bottoms temperature is 110 C. Distillate Stream: The stream, named Methanol recovery, is sent to Storage Tank (Methanol) (TT-104). Bottoms

Stream: The stream, named Biodiesel, is sent to Storage Tank (Biodiesel) (TT-202).

Series

2.3. Mix the contents of unit Glycerol Phase Tank (TT-301). Continuously add 17888.33 kg of the material from Storage Tank (Glycerol) (TT-301). The feed rate is 17.89 Cubic m/h.

2.4. Distill continuously the mixture from unit Glycerol Phase Tank (TT-301) in unit Glycerol Evaporator (FE-301). The mixture feed rate is 17.89 Cubic m/h. Separation is: 82% of METHANOL goes to Overhead. Unspecified materials go to Bottoms. The bottoms temperature is 110 C. Distillate Stream: The stream, named Methanol recovery, is sent to Storage Tank (Methanol) (TT-104). Bottoms Stream: The stream, named Glycerol product, is sent to Glycerol product (TT-302).

2.5. Mix the contents of unit Washing Tank (M-201). Continuously add 99456.02 kg of the material from Storage Tank (Biodiesel) (TT-202). The feed rate is 99.46 Cubic m/h. Continuously add 49728.01 kg of WATER. The feed rate is 49.73 Cubic m/h.

2.6. Mix the contents of unit Storage Tank (Biodiesel) (TT-203). Continuously add 149184 kg of the material from Washing Tank (M-201). The feed rate is 149.18 Cubic m/h.

2.7. Centrifuge the contents of Storage Tank (Biodiesel) (TT-203) in centrifuge Centrifuge (FF-201). The transfer rate is 149.18 Cubic m/h. Components are separated as follows: 5% of BIODIESEL in Liquid goes to the Concentrate (Heavy), 99% of WATER in Liquid goes to the Concentrate (Heavy), 50% of MONOGLYCERIDE in Liquid goes to the Concentrate (Heavy), 50% of DIGLYCERIDE in Liquid goes to the Concentrate (Heavy), 50% of GLYCEROL in Liquid goes to the Concentrate (Heavy), 50% of SOAP in Liquid goes to the Concentrate (Heavy), 50% of FFA in Liquid goes to the Concentrate (Heavy) and 50% of METHANOL in Liquid goes to the Concentrate (Heavy).

100% of each unspecified component goes to Centrate (Light). The light fraction, named Biodiesel, is sent to Storage Tank (Biodiesel) (TT-204). The heavy fraction, named Waste water, is sent to Waste Water Tank (TT-208).

2.8. Mix the contents of unit Washing Tank (M-202). Continuously add 93801.39 kg of the material from Storage Tank (Biodiesel) (TT-204). The feed rate is 93.8 Cubic m/h. Continuously add 28140.417 kg of WATER. The feed rate is 28.14 Cubic m/h.

2.9. Mix the contents of unit Storage Tank (Biodiesel) (TT-205). Continuously add 1.219418e+5 kg of the material from Washing Tank (M-202). The feed rate is 121.94 Cubic m/h.

2.10. Centrifuge the contents of Storage Tank (Biodiesel) (TT-205) in centrifuge Centrifuge (FF-202). The transfer rate is 121.94 Cubic m/h. Components are separated as follows: 99% of BIODIESEL in Liquid goes to the Centrate (Light), 90% of MONOGLYCERIDE in Liquid goes to the Centrate (Light), 10% of DIGLYCERIDE in Liquid goes to the Centrate (Light), 50% of METHANOL in Liquid goes to the Centrate (Light), 1% of WATER in Liquid goes to the Centrate (Light), 5% of GLYCEROL in Liquid goes to the Centrate (Light), 50% of FFA in Liquid goes to the Centrate (Light) and 3% of SOAP in Liquid goes to the Centrate (Light). 100% of each unspecified component goes to Concentrate (Heavy). The light fraction, named Biodiesel, is sent to Storage Tank (Biodiesel) (TT-206). The heavy fraction, named Waste water, is sent to Waste Water Tank (TT-208).

2.11. Distill continuously the mixture from unit Storage Tank (Biodiesel) (TT-206) in unit Biodiesel Evaporator (FE-202). The mixture feed rate is 91.75 Cubic m/h. Separation is: 90% of WATER goes to Overhead and 90% of METHANOL goes to Overhead. Unspecified materials go to Bottoms. The bottoms temperature is 110 C. Distillate Stream: The stream, named Waste water, is sent to Waste Water Tank (TT-208).

Bottoms Stream: The stream, named Biodiesel Product, is sent to Biodiesel Product (TT-207).

End Parallel

The Figure 14 displayed operation time of equipment, time of material transfer in pipe, operation time and cycle time of biodiesel production process and number in rectangular solid corresponding with data in the Table 12. Operations in Figure 14 was shown in two types of sign; rectangular solid and rectangular mesh. The rectangular solid was separated into two parts; operation time of material transfer in pipe and operation time of material in equipment. The rectangular mesh was the resting period (no liquid in the tank) waiting for transferring to another tank or operating the next batch.

Biodiesel production plant A, B, C, and D simulated in Aspen Batch Process were displayed in Figure 15, 16, 17 and 18 respectively. The plant A had one reactor, one settling tank and two washing tanks, meanwhile plant B consisted of two reactors, two settling tanks and four washing tanks, plant C contained three reactors, three settling tanks and six washing tanks and plant D composed of four reactors, four settling tanks and eight washing tanks.

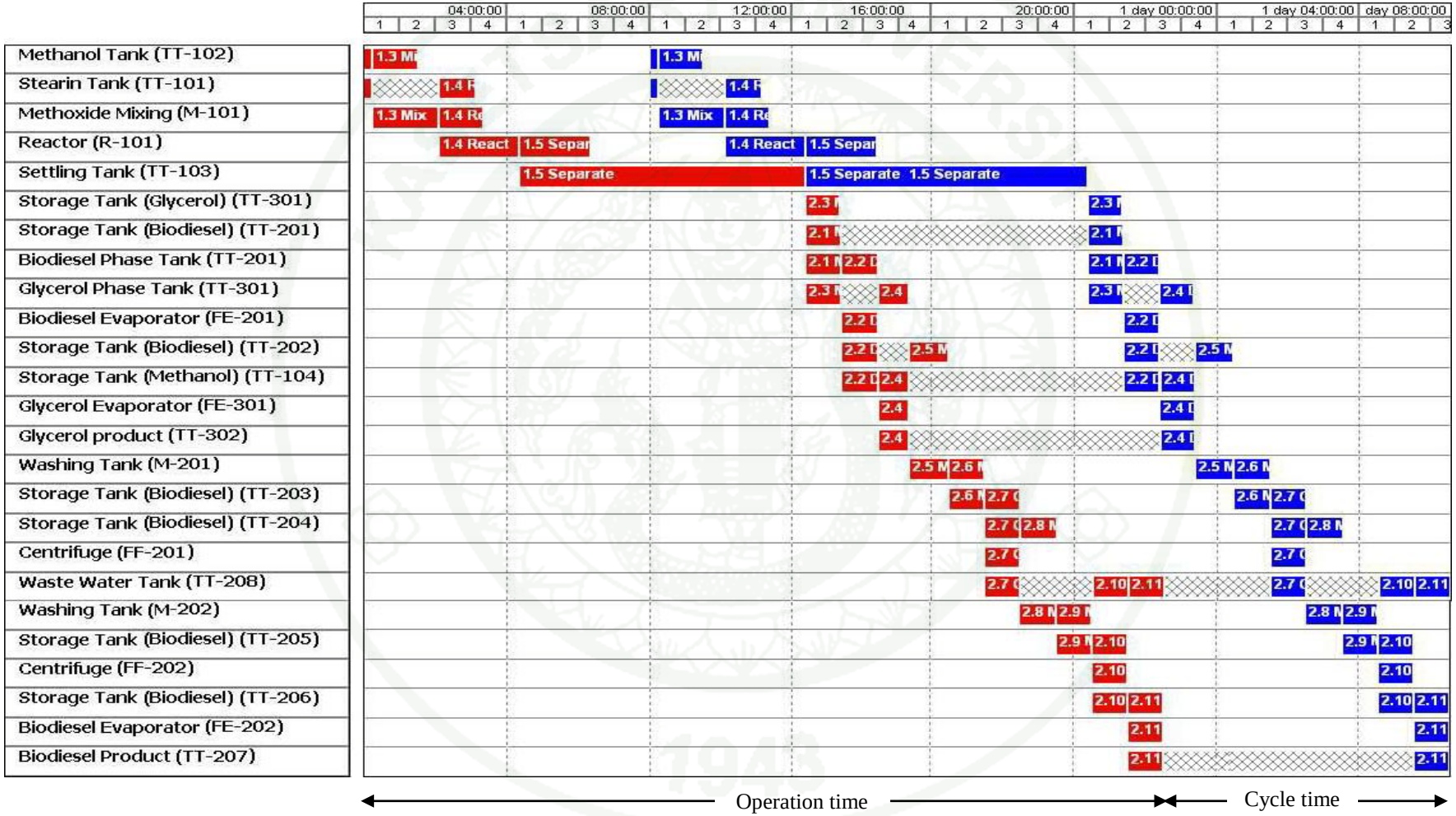


Figure 14 The schedule of biodiesel production plant A was fixed time at capacity of feedstock 100,000 kg

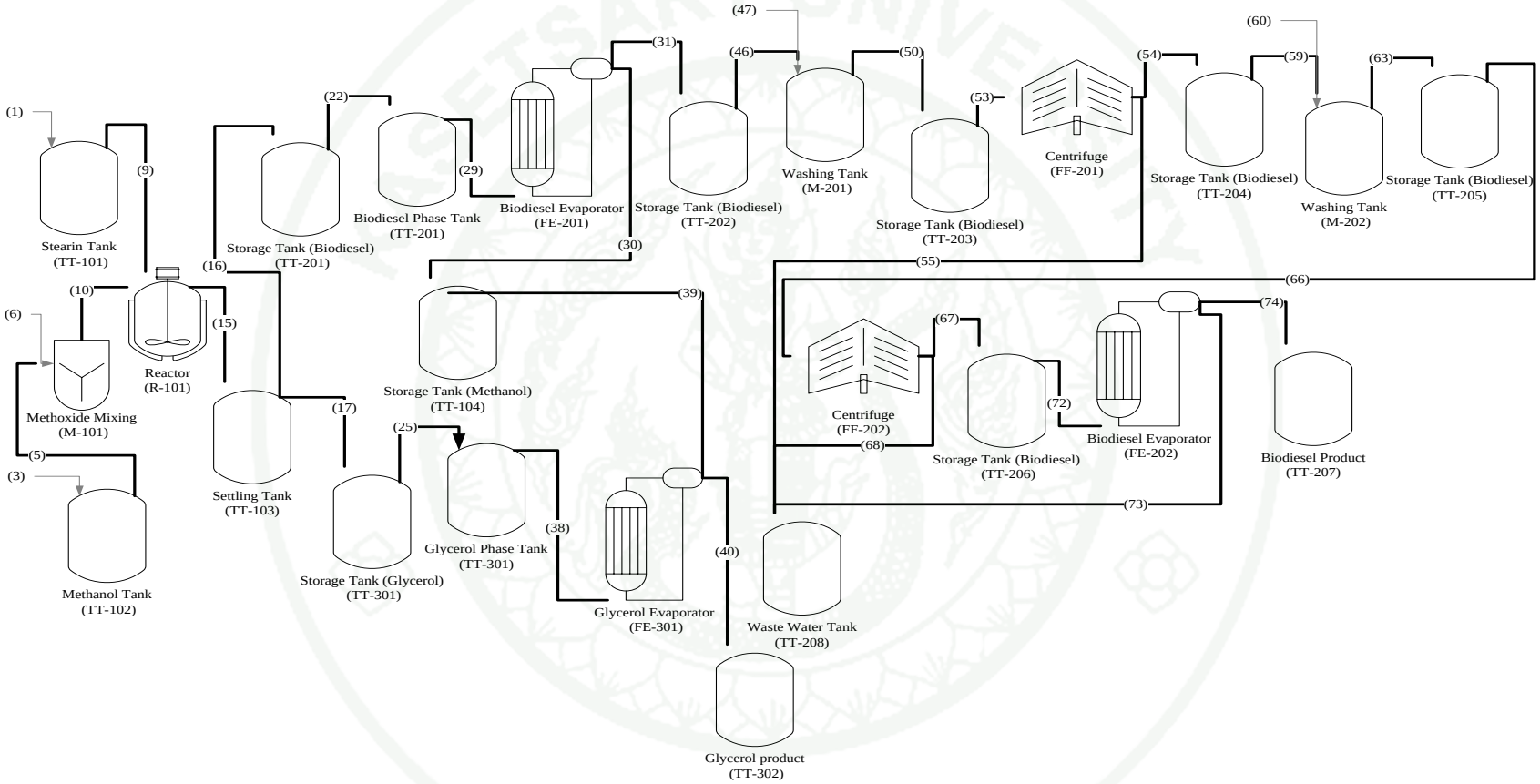


Figure 15 The process flow diagram of biodiesel production plant A at capacity of feedstock 100,000 kg from Aspen Batch Process Developer

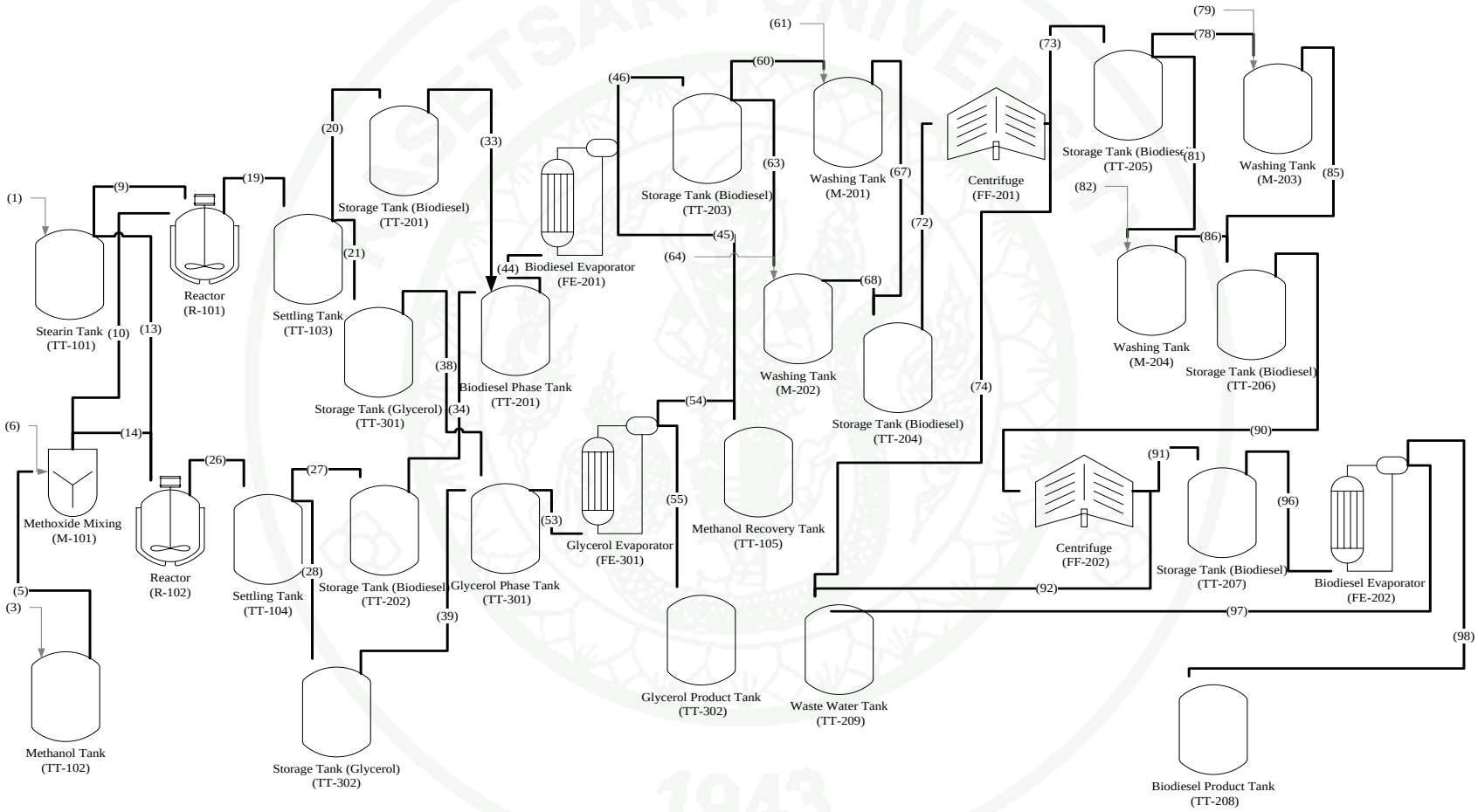


Figure 16 Biodiesel production plant B

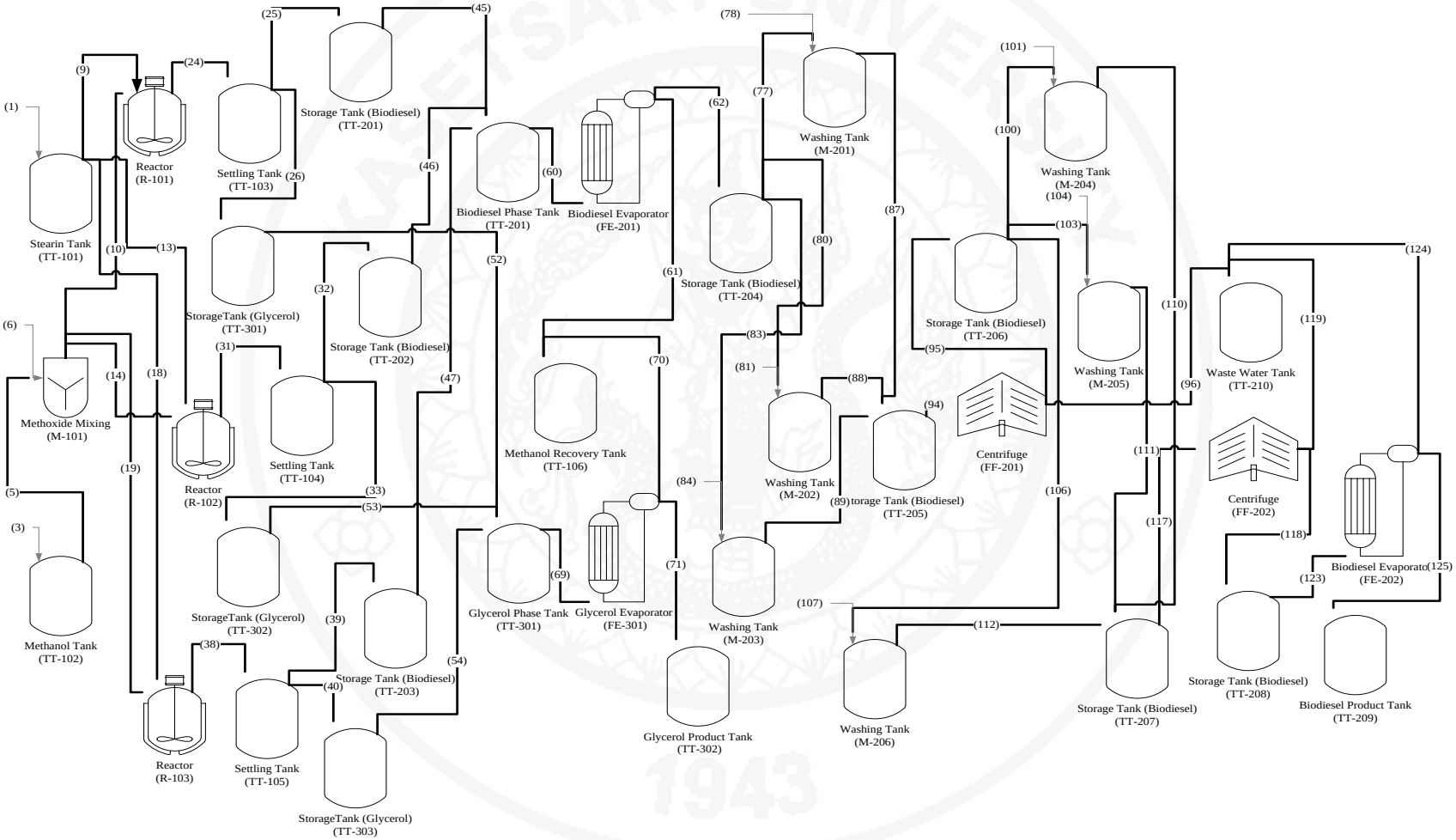


Figure 17 Biodiesel production plant C

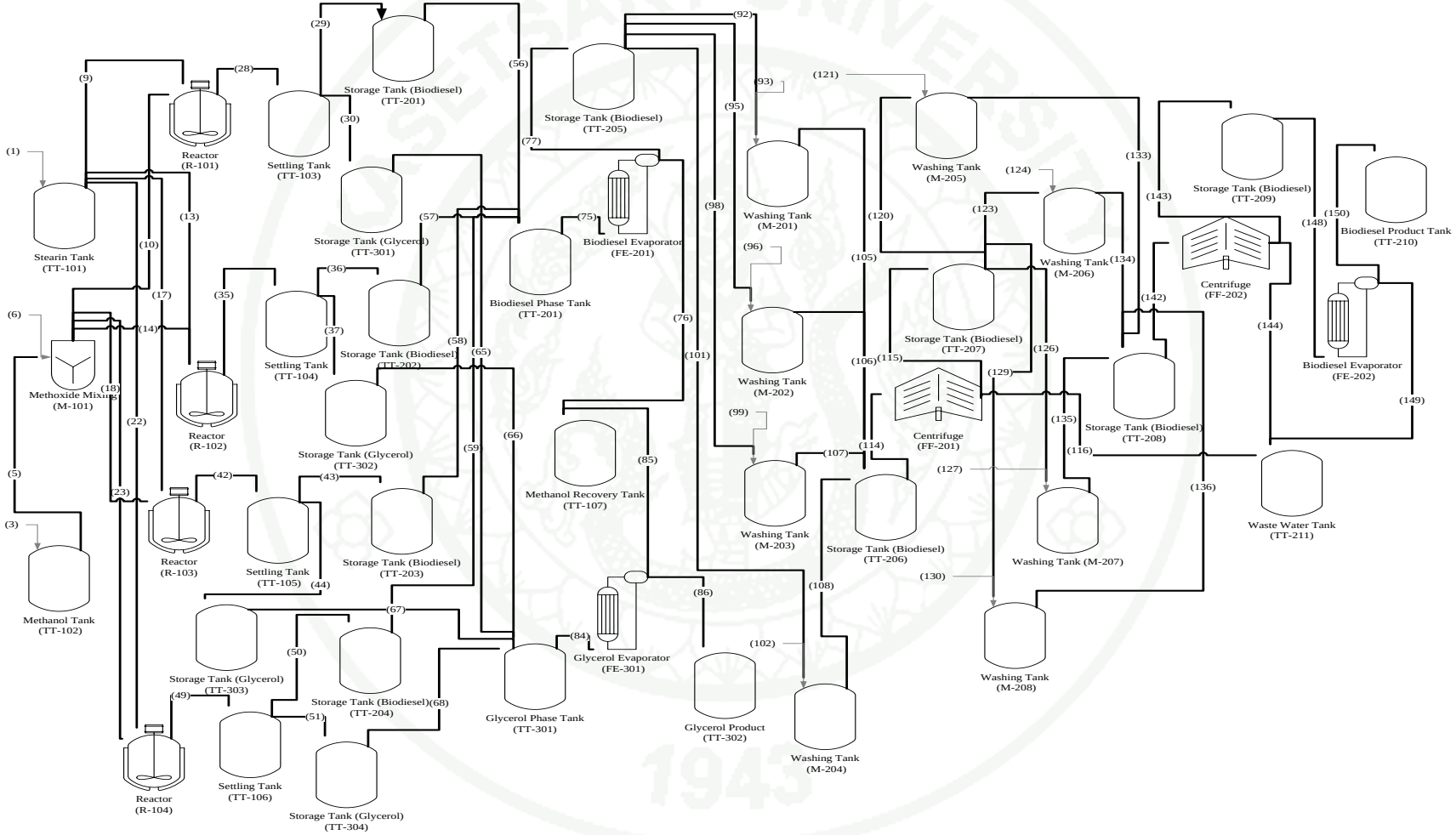


Figure 18 Biodiesel production plant D

The operation time and cycle time of each biodiesel production process was shown in Table 13. The result showed that operation time and cycle time of fixed flow rate were less than that of fixed time pattern. Furthermore, the capacity of biodiesel per batch in each plant was displayed in Table 14. The capacity of biodiesel of fixed time and fixed flow rate pattern gave the same capacity of biodiesel at the same capacity of feedstock.

Table 13 The operation time and cycle time in each plant

Plant	Capacity of stearin (kg/batch)	Fixed time		Fixed flow rate	
		Operation time (h/batch)	Cycle time (h)	Operation time (h/batch)	Cycle time (h)
A	100,000	22.57	9.00	21.13	8.12
	300,000	22.57	8.00	21.13	8.12
	500,000	22.55	8.00	21.12	8.12
B	100,000	23.97	8.00	20.48	7.52
	300,000	23.97	8.00	20.47	7.52
	500,000	23.97	8.00	20.48	7.52
C	100,000	28.35	8.00	20.80	7.30
	300,000	28.33	8.08	20.80	7.30
	500,000	28.32	8.08	20.80	7.30
D	100,000	31.72	9.10	20.02	7.30
	300,000	31.73	9.10	20.87	7.30
	500,000	31.72	9.10	20.83	7.30

Table 14 The capacity of biodiesel per batch in each plant

Set	Capacity of stearin (kg)	Capacity of biodiesel in fixed time pattern (kg/batch)	Capacity of biodiesel in fixed flow rate pattern (kg/batch)
One	100,000	91,328.54	91,328.54
	300,000	273,985.66	273,985.66
	500,000	456,642.82	456,641.74
Two	100,000	91,328.55	91,328.34
	300,000	273,985.60	273,985.09
	500,000	456,642.69	456,641.71
Three	100,000	91,328.54	91,328.54
	300,000	273,985.56	273,985.56
	500,000	456,642.70	456,642.69
Four	100,000	91,328.56	91,328.56
	300,000	273,985.62	273,985.62
	500,000	456,638.80	456,638.65

Effect of operation time and cycle time on the capacity of biodiesel in each plant, at the capacity of 100,000; 300,000 and 500,000 kg/batch stearin was demonstrated in Table 15. The Table 15 displayed yield of biodiesel per operation time and annual biodiesel product in each plant at different patterns. Annual biodiesel product was the result from operation time with cycle times.

Fixed time and fixed flow rate patterns had an effect on operation time and cycle time. Therefore, both patterns had also an effect on capacity of biodiesel product. Therefore, if operation time and cycle time decreased, the capacity of biodiesel increased.

Table 15 The volume of biodiesel and annual biodiesel product in each plant

Plant	Capacity of stearin (kg)	Fixed time		Fixed flow rate	
		Volume of biodiesel per operation time (l/h)	Annual biodiesel product (l)	Volume of biodiesel per operation time (l/h)	Annual biodiesel product (l)
A	100,000	5,471	76,248,711	5,025	84,531,997
	300,000	16,413	257,419,085	15,077	253,596,029
	500,000	27,379	429,031,858	25,141	422,659,098
B	100,000	5,151	85,806,358	5,185	91,222,144
	300,000	15,454	257,419,028	15,563	273,666,502
	500,000	25,757	429,031,736	25,926	456,110,731
C	100,000	4,355	85,700,153	5,105	93,983,439
	300,000	13,076	254,551,700	15,316	281,950,256
	500,000	21,801	424,252,927	25,527	469,917,186
D	100,000	3,892	75,292,964	5,304	93,983,460
	300,000	11,675	225,878,842	15,265	281,950,318
	500,000	19,464	376,461,522	25,490	469,913,029

Note: density of biodiesel 860 kg/m^3

The effects of fixed time and fixed flow rate patterns on operation time in the biodiesel production plant A, B, C and D were displayed in Figure 19, 20, 21 and 22, respectively. In Figure 19, the biodiesel production of plant A with fixed time pattern had more yield of biodiesel per operation time than that of biodiesel production in fixed flow rate one. Therefore, the operation time with fixed time pattern was less than operation time with fixed flow rate one.

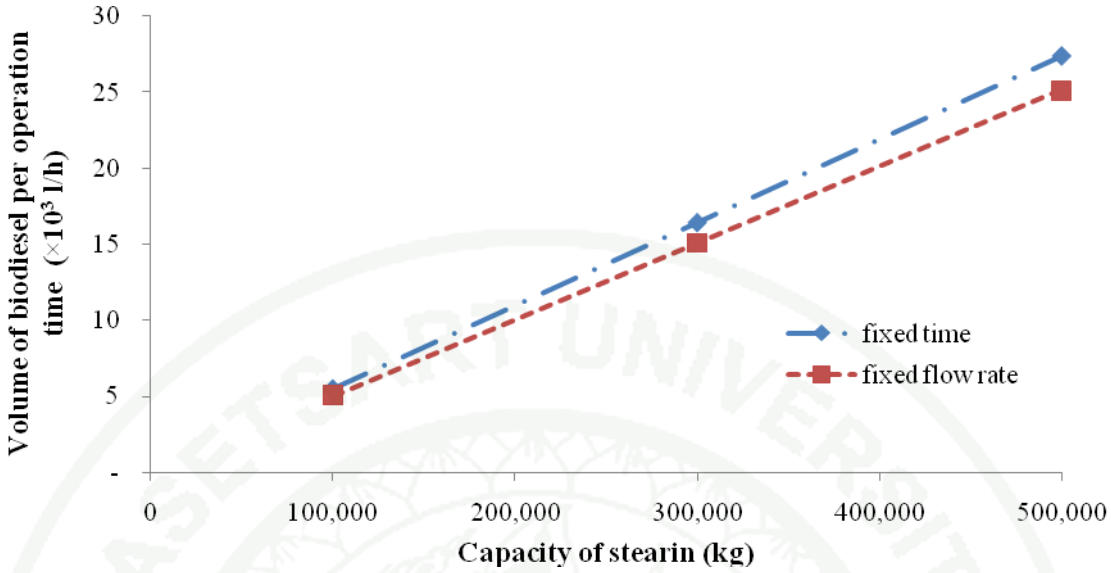


Figure 19 Comparison of volume of biodiesel per operation time between fixed time and fixed flow rate patterns in biodiesel production plant A

Figure 20 showed that the capacity of biodiesel in fixed time pattern was close to that in fixed flow rate one. The biodiesel production of plant B had the same operation time for both fixed time and fixed flow rate patterns. Figure 21 and 22 displayed a similar result; biodiesel yield per operation time of fixed flow rate pattern was more than that of fixed time one. Consequently, increasing number and reducing size of equipment could increase biodiesel yield in fixed flow rate pattern compared with fixed time one. Then, an increase in capacity of stearin showed the difference of biodiesel capacity between fixed flow pattern and fixed time one very clearly.

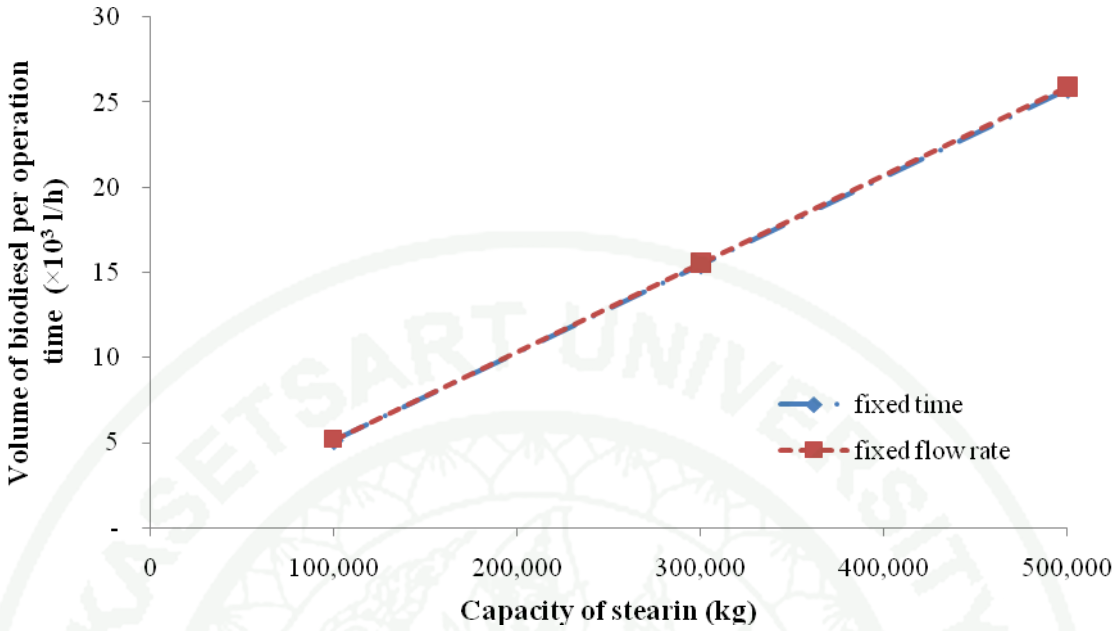


Figure 20 Comparison of volume of biodiesel per operation time between fixed time and fixed flow rate patterns in biodiesel production plant B

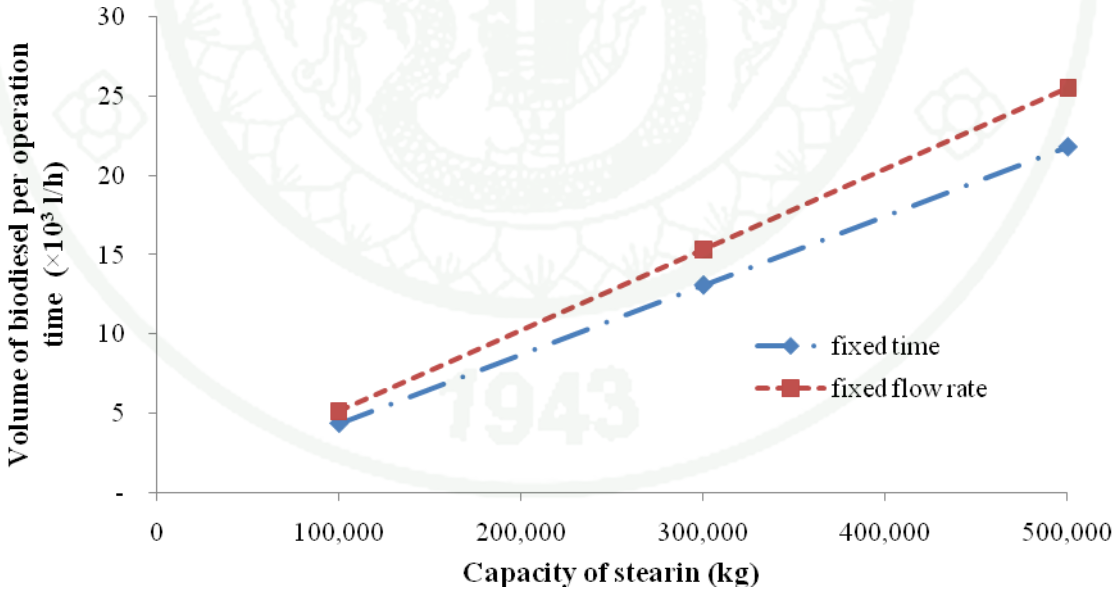


Figure 21 Comparison of volume of biodiesel per operation time between fixed time and fixed flow rate patterns in biodiesel production plant C

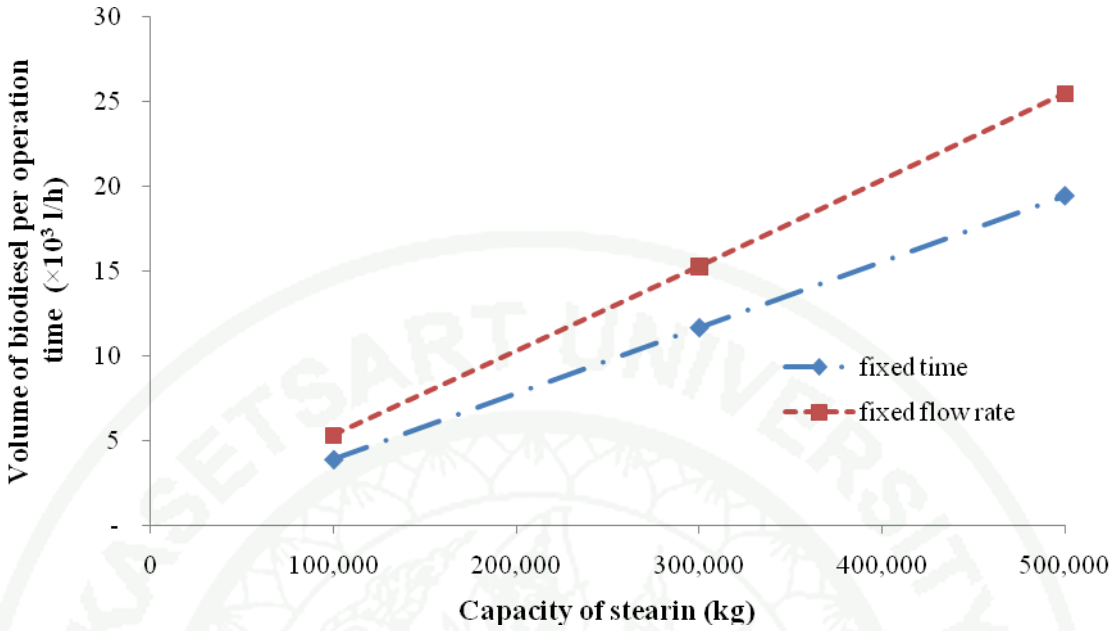


Figure 22 Comparison of volume of biodiesel per operation time between fixed time and fixed flow rate patterns in biodiesel production plant D

The influence of operation time included with cycle time was demonstrated in Figure 23, 24, 25 and 26 which were the comparison between an annual biodiesel product from fixed time pattern and fixed flow rate of each plant at capacity 100,000; 300,000 and 500,000 kg/batch stearin. The biodiesel production plant operated 270 days per year. Its number of batchs in each plant was not equal due to the difference in operation and cycle time; but additionally, cycle time had more effect than operation time did.

In Figure 23, an annual biodiesel product from fixed flow rate pattern was more than that from fixed time one until the capacity reached 100,000 kg/batch stearin, after that, the result was inversely. However, in the Figure 24, 25 and 26, the fixed flow rate pattern gave more annual biodiesel product than fixed time did for every capacity of stearin because cycle time of fixed flow rate pattern was less than that of fixed time one.

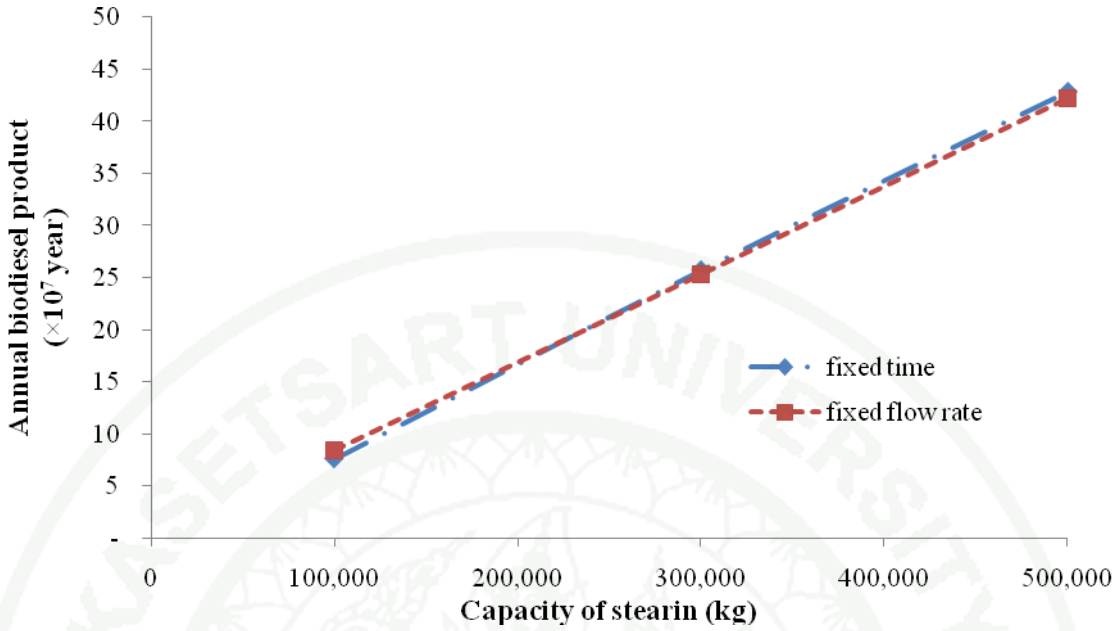


Figure 23 Comparison of annual biodiesel product between fixed time and fixed flow rate patterns in biodiesel production plant A

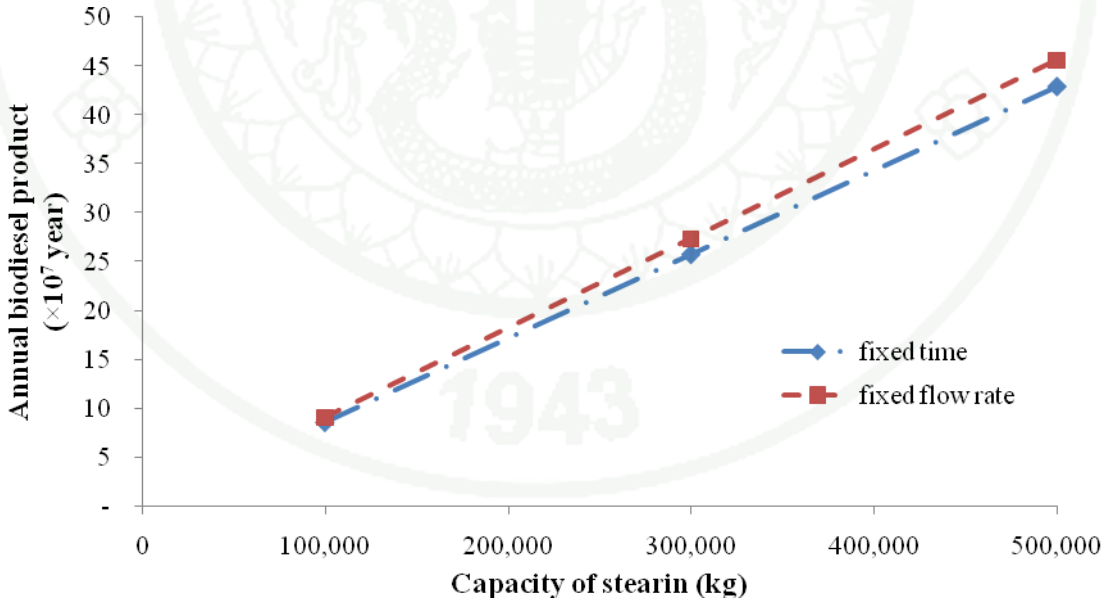


Figure 24 Comparison of annual biodiesel product between fixed time and fixed flow rate patterns in biodiesel production plant B

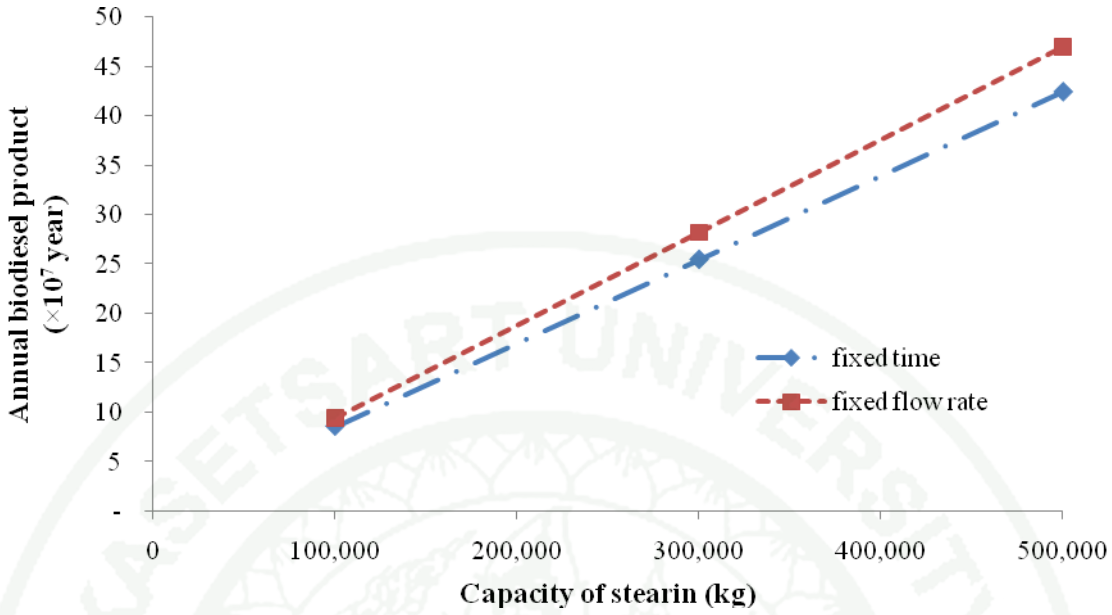


Figure 25 Comparison of annual biodiesel product between fixed time and fixed flow rate patterns in biodiesel production plant C

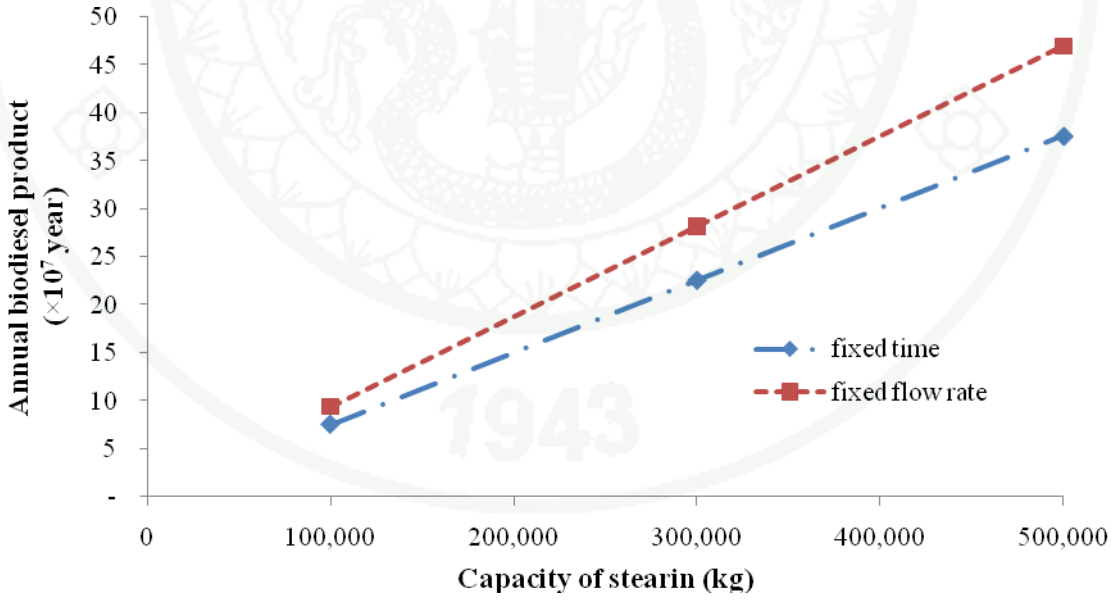


Figure 26 Comparison of annual biodiesel product between fixed time and fixed flow rate patterns in biodiesel production plant D

Effect of operation time and operation time with cycle time in fixed time pattern was shown in Figure 27 and 28. In Figure 27, the highest biodiesel yield per operation time obtained from plant A because plant A had the shortest operation time. In the Figure 28, too much increasing number and reducing size of equipment reduced annual biodiesel product because the biodiesel production plant D A had the most operation time with cycle time.

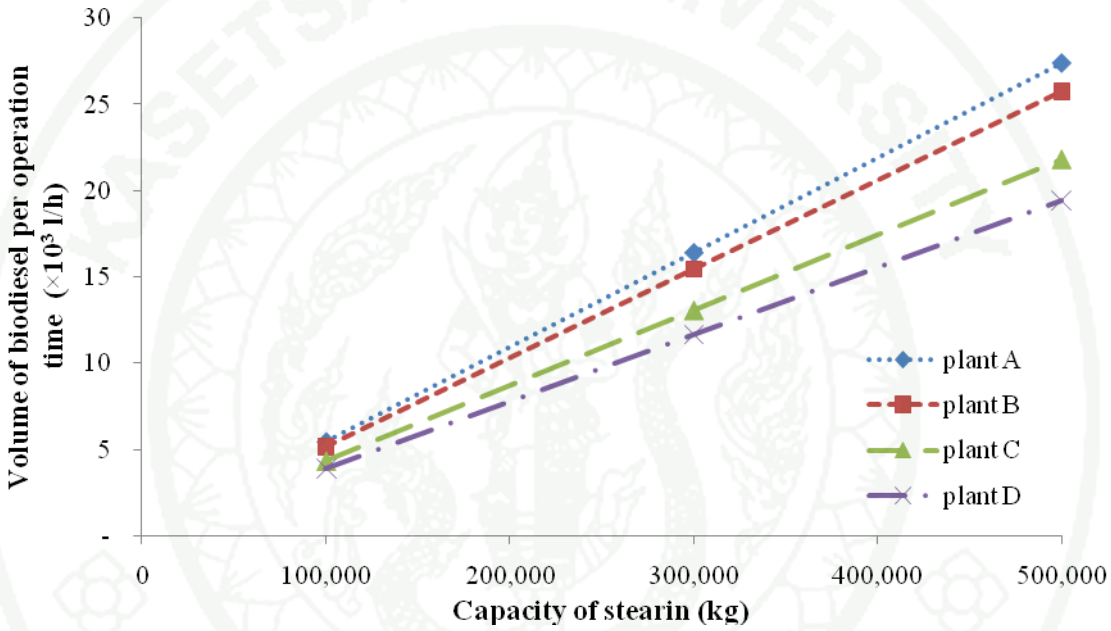


Figure 27 The volume of biodiesel per operation time in each plant of fixed time pattern

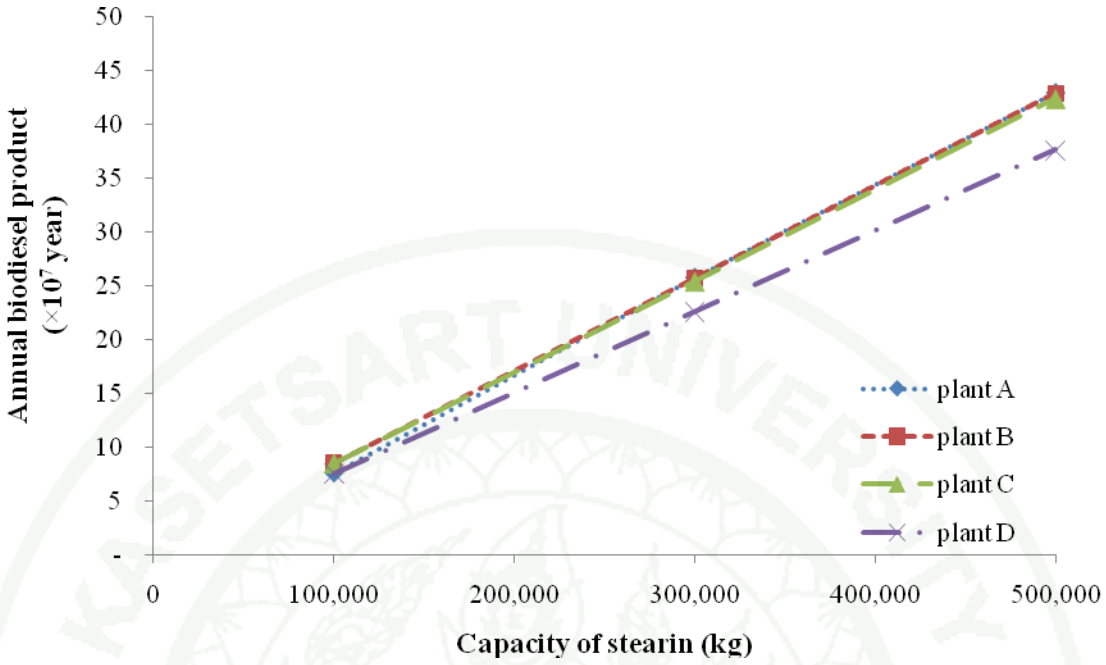


Figure 28 The annual biodiesel product in each plant of fixed time pattern

Figure 29 and 30 revealed biodiesel yield per operation time and annual biodiesel product in fixed flow rate pattern of each plant which displayed the influence of operation time and operation time with cycle time, respectively. In Figure 29, every plant had similar biodiesel yield per operation time. Annual biodiesel product in plant A was the lowest because of the effect of cycle time as shown in the Figure 30. For other plants, annual biodiesel product was increased and the cycle time was decreased by increasing amount of equipment and reducing the size of equipment.

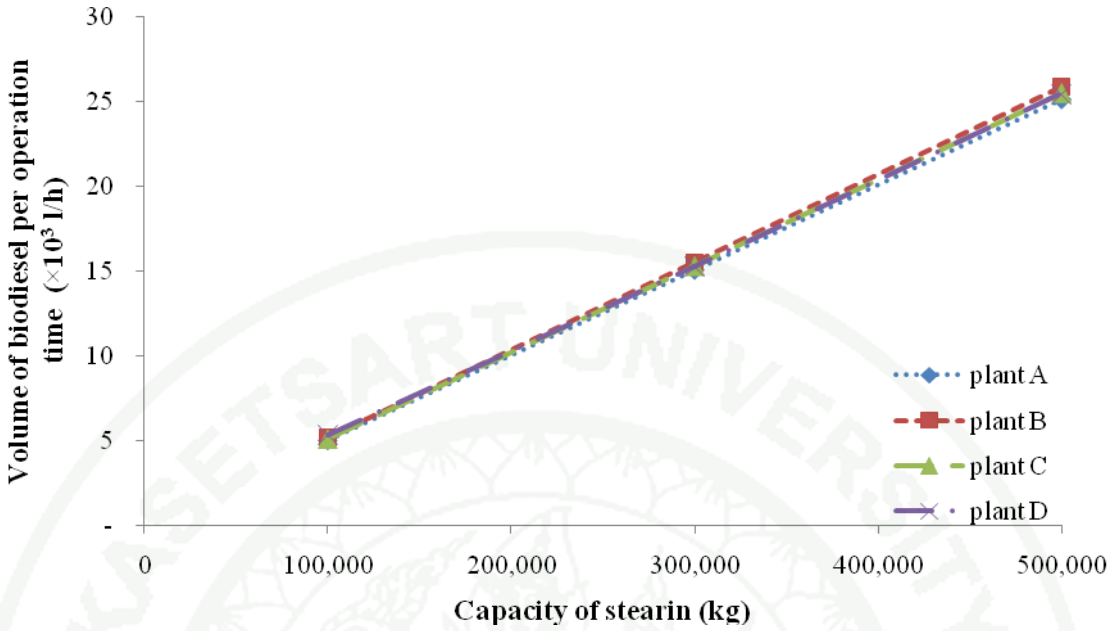


Figure 29 The volume of biodiesel per operation time in each plant of fixed flow rate pattern

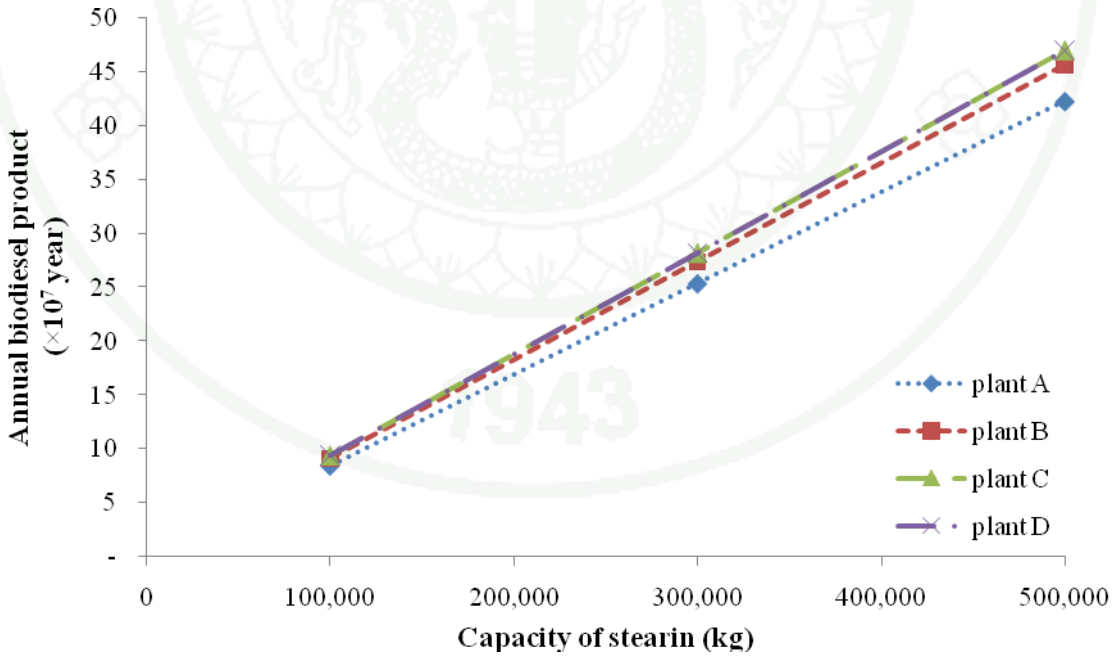


Figure 30 The annual biodiesel product in each plant of fixed flow rate pattern

Higher amount of annual biodiesel product could be obtained from the plant with fixed flow rate pattern in which the cycle time of fixed flow rate was shorter than that of fixed time one. The effect of fixed time and fixed flow rate patterns was very clear in high feed capacity of stearin and in the plant D which shown in the Figure 31.

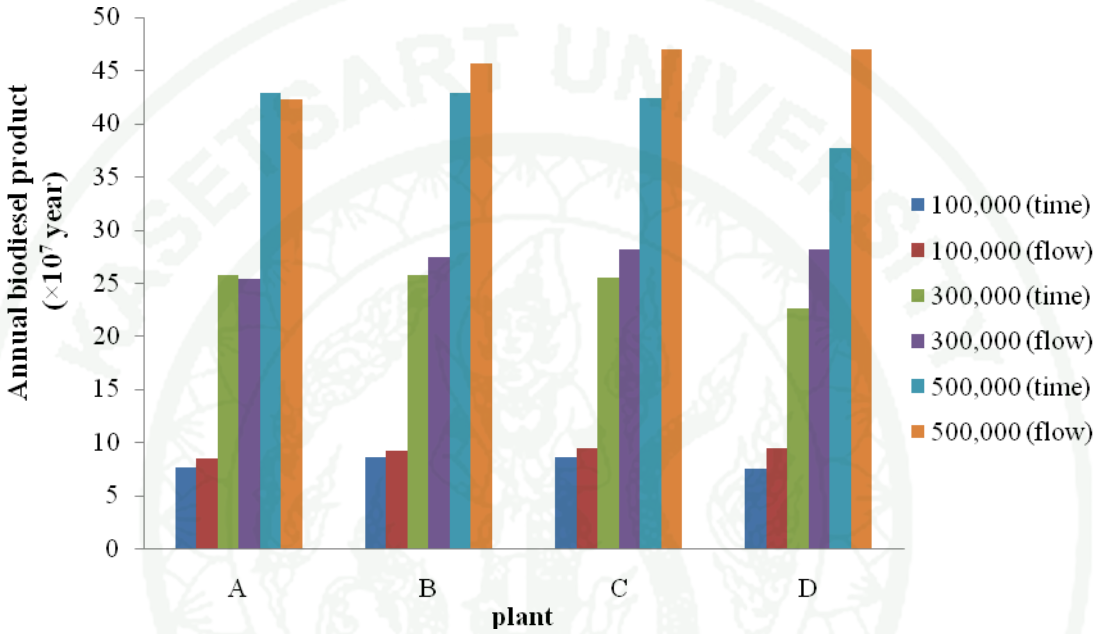


Figure 31 The annual biodiesel product in each plant of both fixed time and fixed flow rate pattern

4. Economic cost

The cost estimation consisted of two parts, fixed-capital investment and operating cost. The fixed-capital investment was the cost of equipment, land, construction expense and etc. The operating cost was the cost of operation in biodiesel production plant, for example, raw material, utility, operating labor and etc. The main fixed-capital investment of in each plant was cost of equipment which was shown in Table 17. However, the equipment in biodiesel production plant A, B, C and D was revealed in Table 16 which displayed different amount of equipment in each plant.

Table 16 The amount of equipment in each plant

Equipment	Amount of equipment in plant A	Amount of equipment in plant B	Amount of equipment in plant C	Amount of equipment in plant D
Stearin tank	1	1	1	1
Methanol tank	1	1	1	1
Methoxide mixing	1	1	1	1
Reactor	1	2	3	4
Settling tank	1	2	3	4
Storage tank (biodiesel)	1+1+1+1+1+1	2+1+1+1+1+1	3+1+1+1+1+1	4+1+1+1+1+1
Storage tank (glycerol)	1	2	3	4
Biodiesel phase tank	1	1	1	1
Glycerol phase tank	1	1	1	1
Biodiesel evaporator	1+1	1+1	1+1	1+1
Glycerol evaporator	1	1	1	1
Glycerol product	1	1	1	1
Storage tank (methanol)	1	1	1	1
Washing Tank	1+1	2+2	3+3	4+4
Centrifuge	1+1	1+1	1+1	1+1
Biodiesel product	1	1	1	1

Results from the Table 17 demonstrated cost of equipment of fixed time and fixed flow rate patterns. The cost of equipment of fixed flow rate pattern was more expensive than that of fixed time because fixed flow rate pattern used larger size of pump which was unnecessary because flow rate of stream in the fixed flow rate pattern was constant.

Table 17 The cost of equipment in each plant both fixed time and fixed flow rate pattern.

Type of plant	Capacity of stearin (kg)	Cost of equipment of fixed time (baht)	Cost of equipment of fixed flow rate (baht)
plant A	100,000	65,631,221	73,617,989
	300,000	176,953,237	214,786,820
	500,000	320,393,796	364,380,713
plant B	100,000	74,740,539	82,832,537
	300,000	217,440,968	244,846,805
	500,000	371,013,098	419,770,013
plant C	100,000	74,598,438	82,948,774
	300,000	215,063,860	243,372,518
	500,000	366,860,760	416,893,488
plant D	100,000	74,752,973	83,124,310
	300,000	206,570,527	243,517,998
	500,000	363,877,338	414,609,583

Detail of equipment cost in biodiesel production plant was explained in Table 18 which displayed both fixed-capital investment and operating cost of biodiesel production plant A at capacity of 100,000 kg/batch stearin in fixed time pattern. Details of other plants were displayed in appendix E.

Table 18 Detail of fixed-capital investment and operating cost in biodiesel production process of plant A at capacity of stearin 100,000 kg in fixed time pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		3,514,303,104	3,514,303,104	3,514,303,104	3,514,303,104	3,514,303,104	3,514,303,104	3,514,303,104
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		47,914,438	47,914,438	47,914,438	47,914,438	47,914,438	47,914,438	47,914,438
Total income		3,562,217,542	3,562,217,542	3,562,217,542	3,562,217,542	3,562,217,542	3,562,217,542	3,562,217,542
Investment cost								
Equipment cost								
1. ten storage tanks	28,331,422							
2. one reactor	2,496,598							
3. three mixing tanks	6,256,857							
4. two centrifuges	16,203,551							
5. three evaporators	10,261,693							
6. fourteen pumps	2,081,100							
Purchased equipment	65,631,221							
Purchased-equipment installation	12,306,000							
Instrumentation and controls (installed)	10,255,000							
Piping (installed)	10,255,000							
Electrical systems (installed)	6,153,000							
Buildings (including services)	8,204,000							
Yard improvement	4,102,000							
Service facilities (installed)	41,020,000							
Land	2,051,000							
Engineering and supervision	18,459,000							
Construction expenses	8,204,000							
Legal expenses	4,102,000							
Contractor's fee	4,102,000							
Contingency	10,255,000							
Total fixed-capital investment	205,099,221							
Manufacturing cost								
Raw materials								
1. stearin		3,330,084,000	3,330,084,000	3,330,084,000	3,330,084,000	3,330,084,000	3,330,084,000	3,330,084,000
2. methanol		150,319,403	150,319,403	150,319,403	150,319,403	150,319,403	150,319,403	150,319,403

Table 18 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	3,514,303,104	3,514,303,104	3,514,303,104	3,514,303,104	3,514,303,104	3,514,303,104	3,514,303,104	3,514,303,104
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	47,914,438	47,914,438	47,914,438	47,914,438	47,914,438	47,914,438	47,914,438	47,914,438
Total income	3,562,217,542	3,562,217,542	3,562,217,542	3,562,217,542	3,562,217,542	3,562,217,542	3,562,217,542	3,562,217,542
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	3,330,084,000	3,330,084,000	3,330,084,000	3,330,084,000	3,330,084,000	3,330,084,000	3,330,084,000	3,330,084,000
2. methanol	150,319,403	150,319,403	150,319,403	150,319,403	150,319,403	150,319,403	150,319,403	150,319,403
3. potassium hydroxide	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979

Table 18 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			782,735	782,735	782,735	782,735	782,735	782,735	782,735
Cost of energy			32,676,034	32,676,034	32,676,034	32,676,034	32,676,034	32,676,034	32,676,034
Depreciation			4,922,348	4,922,348	4,922,348	4,922,348	4,922,348	4,922,348	4,922,348
Operating labor			1,296,000	1,334,880	1,374,926	1,416,174	1,458,659	1,502,419	1,547,492
Maintenance and repairs			10,254,961	10,254,961	10,254,961	10,254,961	10,254,961	10,254,961	10,254,961
Total operating cost			3,531,570,112	3,531,608,992	3,531,649,039	3,531,690,286	3,531,732,772	3,531,776,531	3,531,821,604
EBIT			30,647,429	30,608,549	30,568,503	30,527,255	30,484,770	30,441,010	30,395,938
Tax			9,194,229	9,182,565	9,170,551	9,158,177	9,145,431	9,132,303	9,118,781
Net income			21,453,200.57	21,425,984.57	21,397,952.09	21,369,078.63	21,339,338.98	21,308,707.13	21,277,156.33
Net cash flow from operating activities			26,375,548.66	26,348,332.66	26,320,300.18	26,291,426.73	26,261,687.07	26,231,055.22	26,199,504.42
Change in Gross fixed Asset		205,099,221							
Net Cashflow		-205,099,221	26,375,549	26,348,333	26,320,300	26,291,427	26,261,687	26,231,055	26,199,504
Add: Beginning Cashflow			-205,099,221	-178,723,673	-152,375,340	-126,055,040	-99,763,613	-73,501,926	-47,270,871
Ending cashflow		-205,099,221	-178,723,673	-152,375,340	-126,055,040	-99,763,613	-73,501,926	-47,270,871	-21,071,366
NPV	฿63,542,448								
IRR	9.51%								

Table 18 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	782,735	782,735	782,735	782,735	782,735	782,735	782,735	782,735
Cost of energy	32,676,034	32,676,034	32,676,034	32,676,034	32,676,034	32,676,034	32,676,034	32,676,034
Depreciation	4,922,348	4,922,348	4,922,348	4,922,348	4,922,348	4,922,348	4,922,348	4,922,348
Operating labor	1,593,917	1,641,734	1,690,986	1,741,716	1,793,967	1,847,786	1,903,220	1,960,316
Maintenance and repairs	10,254,961	10,254,961	10,254,961	10,254,961	10,254,961	10,254,961	10,254,961	10,254,961
Total operating cost	3,531,868,029	3,531,915,846	3,531,965,098	3,532,015,828	3,532,068,079	3,532,121,898	3,532,177,332	3,532,234,428
EBIT	30,349,513	30,301,695	30,252,443	30,201,714	30,149,462	30,095,643	30,040,210	29,983,113
Tax	9,104,854	9,090,509	9,075,733	9,060,514	9,044,839	9,028,693	9,012,063	8,994,934
Net income	21,244,659.00	21,211,186.75	21,176,710.34	21,141,199.63	21,104,623.60	21,066,950.29	21,028,146.78	20,988,179.17
Net cash flow from operating activities	26,167,007.09	26,133,534.85	26,099,058.43	26,063,547.72	26,026,971.70	25,989,298.39	25,950,494.88	25,910,527.27
Change in Gross fixed Asset								
Net Cashflow	26,167,007	26,133,535	26,099,058	26,063,548	26,026,972	25,989,298	25,950,495	25,910,527
Add: Beginning Cashflow	-21,071,366	5,095,641	31,229,175	57,328,234	83,391,782	109,418,753	135,408,052	161,358,547
Ending cashflow	5,095,641	31,229,175	57,328,234	83,391,782	109,418,753	135,408,052	161,358,547	187,269,074

The results of fixed-capital investment and operating cost were concluded in Table 19 for fixed time pattern and fixed flow rate. From The Table 19, the operating cost of fixed flow rate was expensive than that of fixed time pattern because fixed flow rate yield more biodiesel than fixed time did. Both investment and operating costs had an effect on the selected operating pattern of biodiesel production plant. In the economic point of view, the investment and should be low, in order to gave the maximum benefit.

Table 19 The fixed-capital investment, operation cost in 15 years and total cost of fixed time and fixed flow rate patterns

plant	Capacity of feedstock	Fixed time			Fixed flow rate		
		fixed-capital investment	Operating cost in 15 years	Total cost	fixed-capital investment	Operating cost in 15 years	Total cost
Plant A	100,000	205,099,221	52,973,551,680	53,178,650,901	230,055,989	58,906,040,220	59,136,096,209
	300,000	552,980,237	178,347,724,845	178,900,705,082	671,206,820	176,669,116,020	177,340,322,840
	500,000	1,001,232,796	296,969,522,355	297,970,755,151	1,138,689,713	294,120,180,330	295,258,870,043
Plant B	100,000	233,564,539	59,605,044,480	59,838,609,019	258,853,537	63,543,580,650	63,802,434,187
	300,000	679,501,968	178,477,476,285	179,156,978,253	765,144,805	190,574,403,885	191,339,548,690
	500,000	1,159,415,098	297,143,870,445	298,303,285,543	1,311,780,013	317,307,673,305	318,619,453,318
Plant C	100,000	233,119,438	59,374,493,685	59,607,613,123	259,214,774	65,470,037,160	65,729,251,934
	300,000	672,073,860	176,515,613,085	177,187,686,945	760,540,518	196,336,595,115	197,097,135,633
	500,000	1,146,440,760	293,875,076,295	295,021,517,055	1,302,794,488	326,896,381,815	328,199,176,303
Plant D	100,000	233,601,973	52,377,957,825	52,611,559,798	259,764,310	65,488,952,550	65,748,716,860
	300,000	645,534,527	156,326,507,400	156,972,041,927	760,995,998	196,376,906,520	197,137,902,518
	500,000	1,137,117,338	260,998,877,775	262,135,995,113	1,295,655,583	326,949,415,560	328,245,071,143

The fixed-capital investment between fixed time and fixed flow rate patterns was compared with each other as shown in Figure 32, 33, 34 and 35 for plant A, B, C and D, respectively. In the plant A, B, C and D at high capacity of stearin, the fixed-capital investment of fixed flow rate pattern was higher than that of fixed time one due to the effect of pump cost which was larger than necessary. Then, the effect of fixed time and fixed flow rate patterns were very clear in the high feed capacity of stearin.

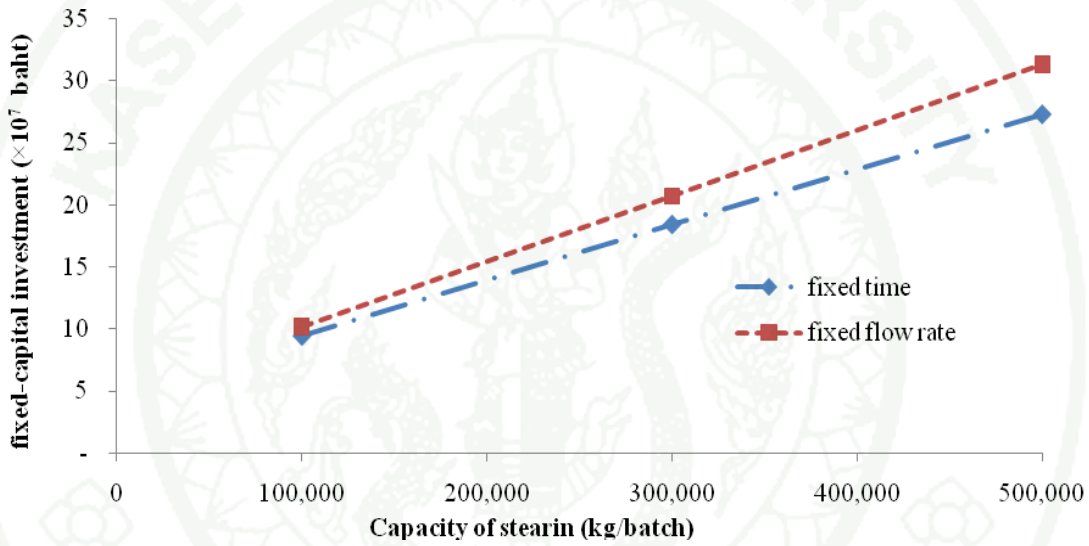


Figure 32 Comparison of fixed-capital investment between fixed time and fix flow rate patterns in biodiesel production of plant A

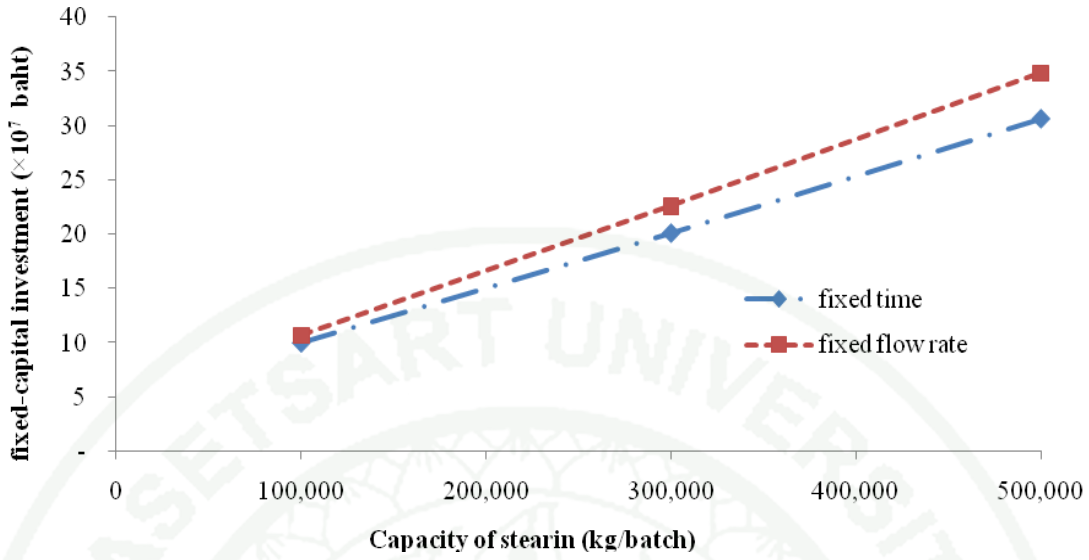


Figure 33 Comparison of fixed-capital investment between fixed time and fix flow rate patterns in biodiesel production of plant B

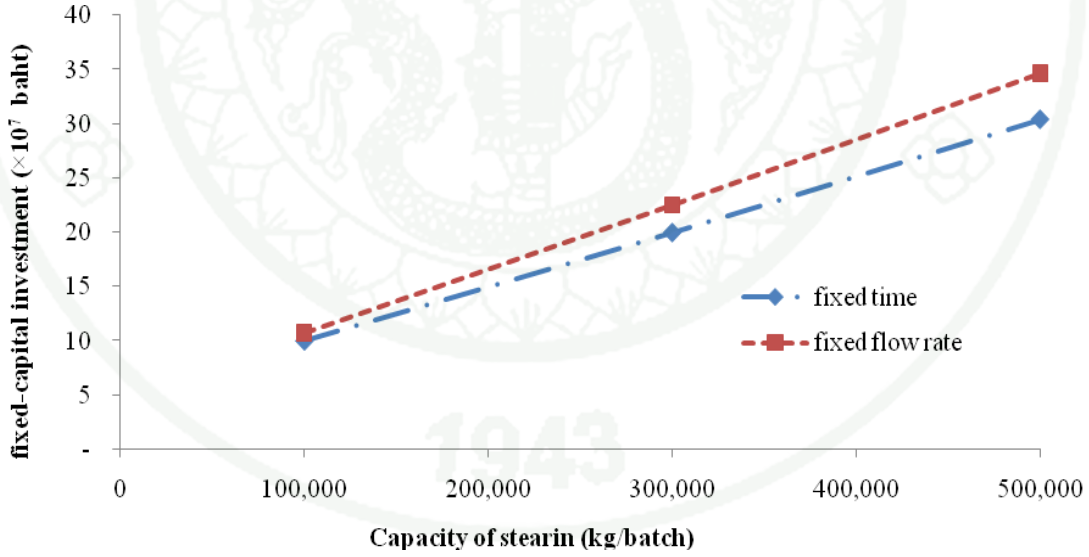


Figure 34 Comparison of fixed-capital investment between fixed time and fix flow rate patterns in biodiesel production of plant C

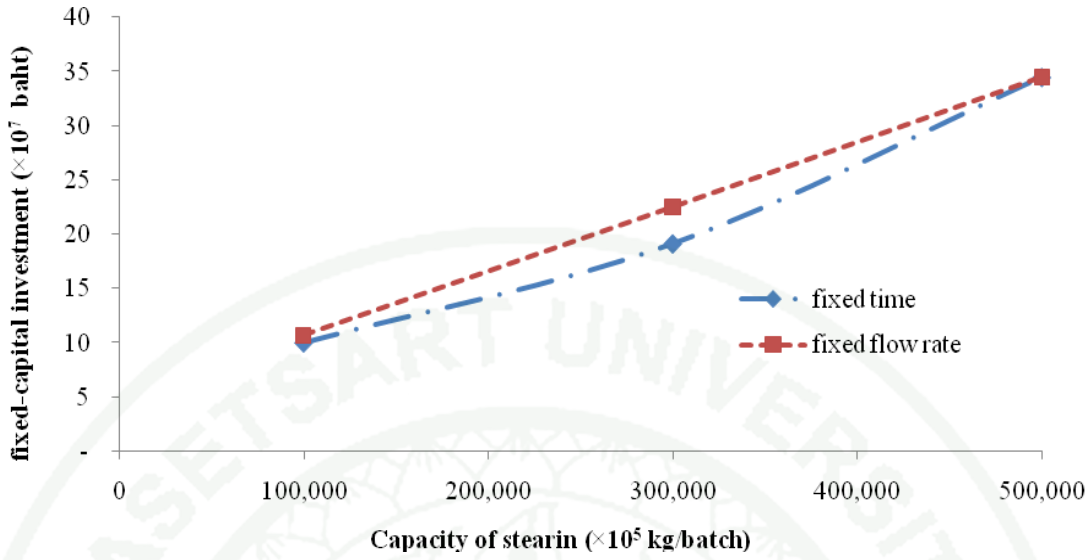


Figure 35 Comparison of fixed-capital investment between fixed time and fix flow rate patterns in biodiesel production of plant D

The operating cost in 15 years of each plant was displayed in Figure 36, 37, 38 and 39. For every plant, increasing capacity of stearin increased operating cost. Fixed flow rate pattern had higher operating cost than that of fixed time one at the capacity of 500,000 kg/batch stearin because fixed flow rate could produce more biodiesel product than fixed time did.

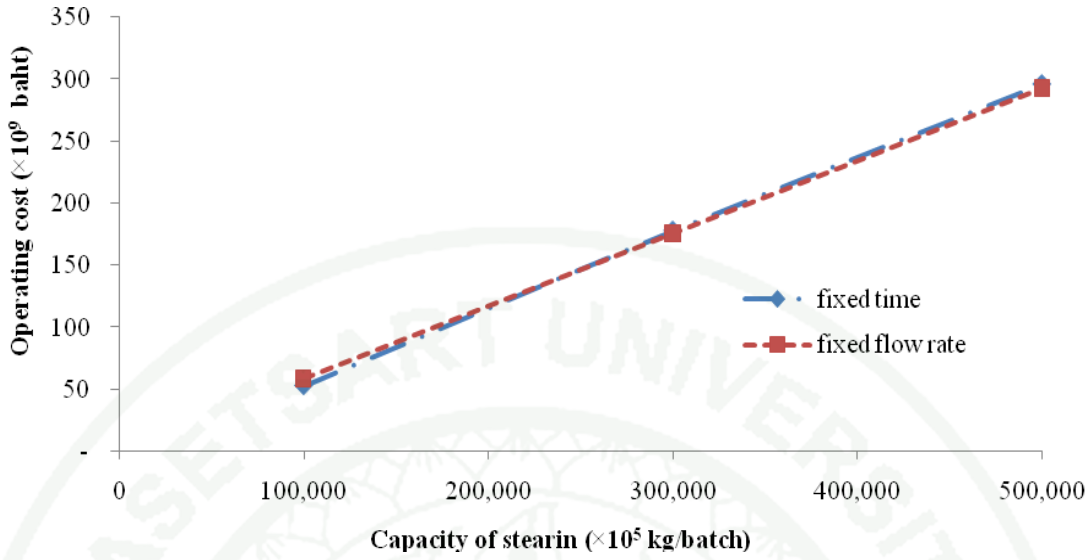


Figure 36 Comparison of operating cost in 15 years between fixed time and fixed flow rate patterns in biodiesel production of plant A

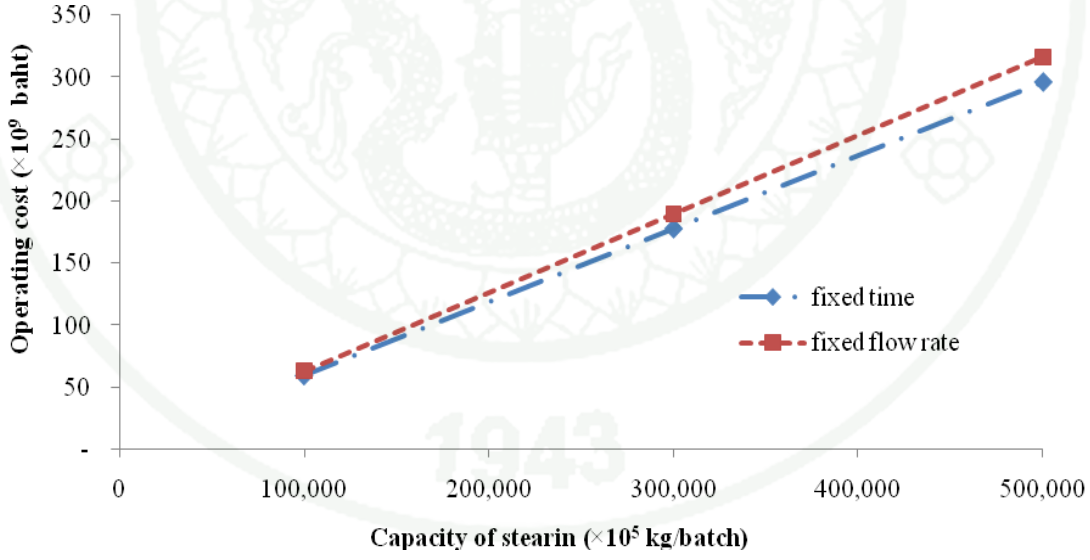


Figure 37 Comparison of operating cost in 15 years between time and fixed flow rate patterns in biodiesel production of plant B

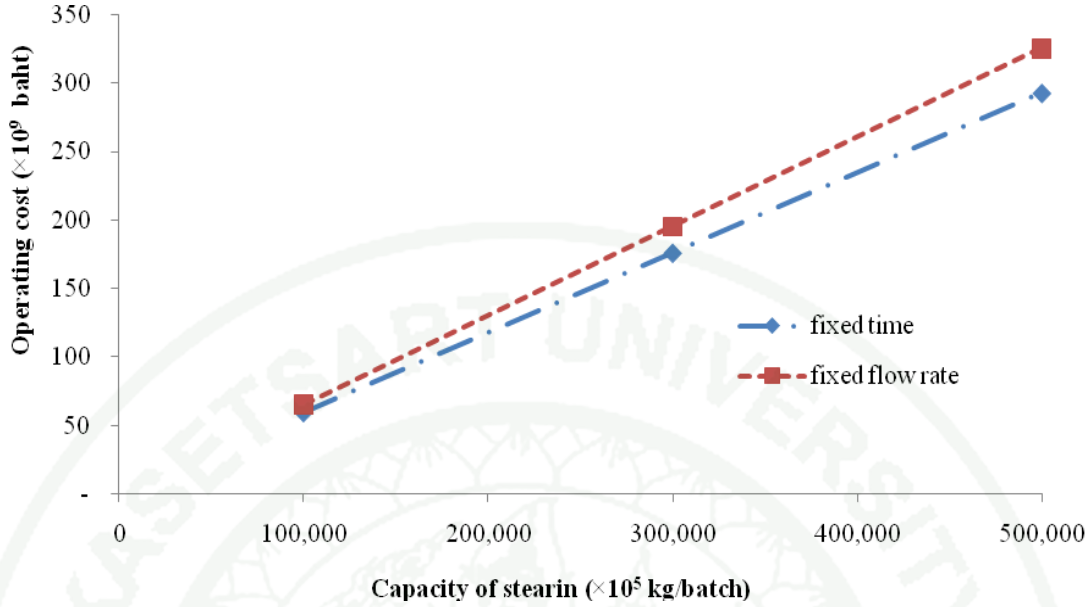


Figure 38 Comparison of operating cost in 15 years between time and fixed flow rate patterns in biodiesel production of plant C

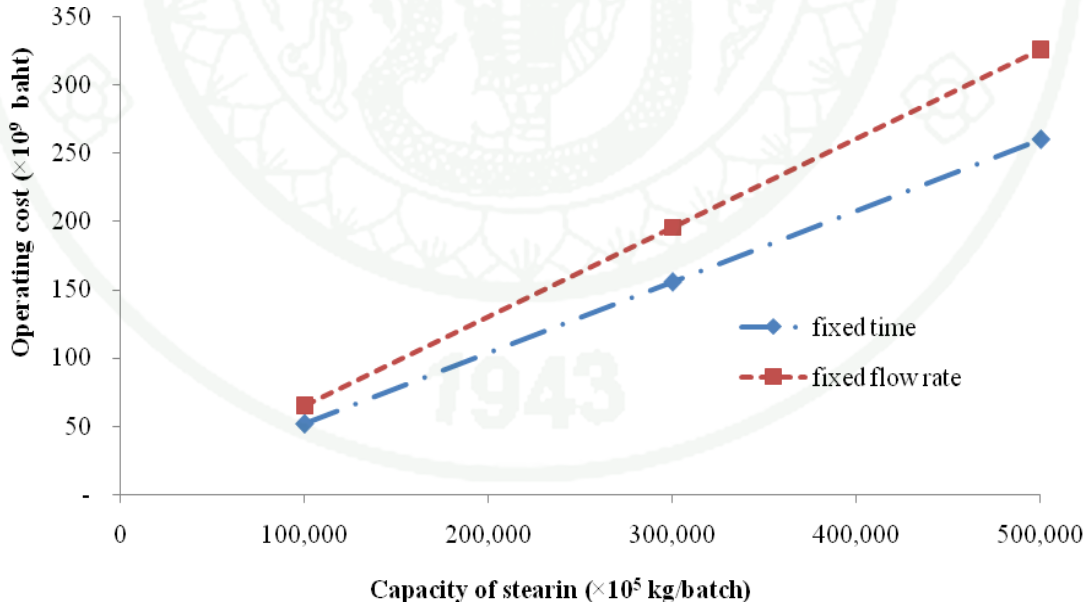


Figure 39 Comparison of operating cost in 15 years between time and fixed flow rate patterns in biodiesel production of plant D

Comparison of the fixed-capital investment of each plant was shown in Figure 40 and 41 for fixed time and fixed flow rate patterns, respectively. In the Figure 40, plant A, B and C had the same trend of fixed-capital investment but not plant D. The investment cost of plant D was the highest at capacity of 500,000 kg/batch stearin. This result might be due to the effect of equipment cost. In the Figure 41, the graphs of plant B, C and D were similar but plant A was different. This Figure showed the high fixed-capital investment due to an increase in amount of equipment and the reduced of equipment size.

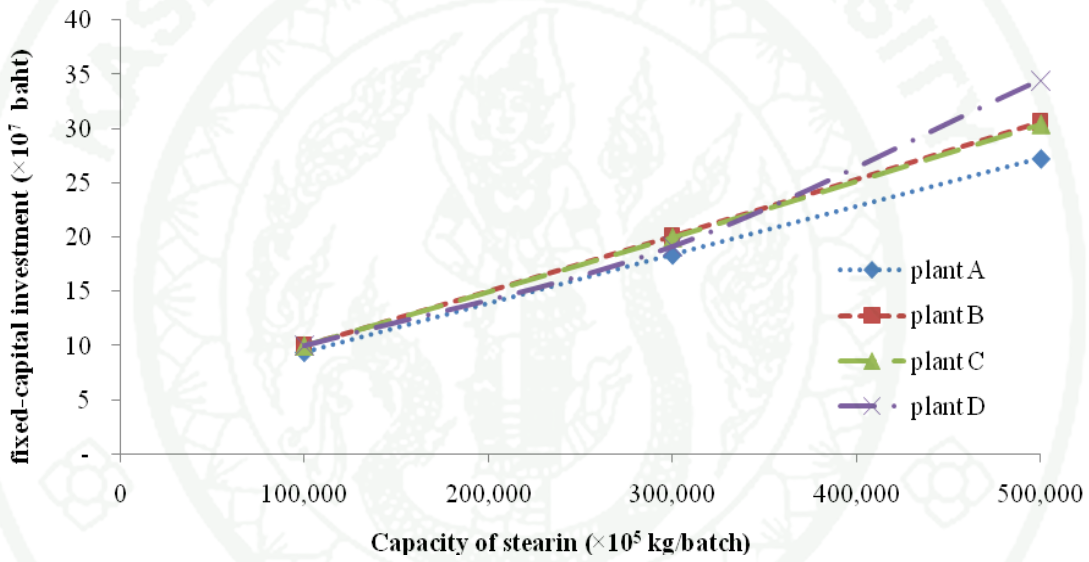


Figure 40 The fixed-capital investment of biodiesel in each plant from fixed time pattern

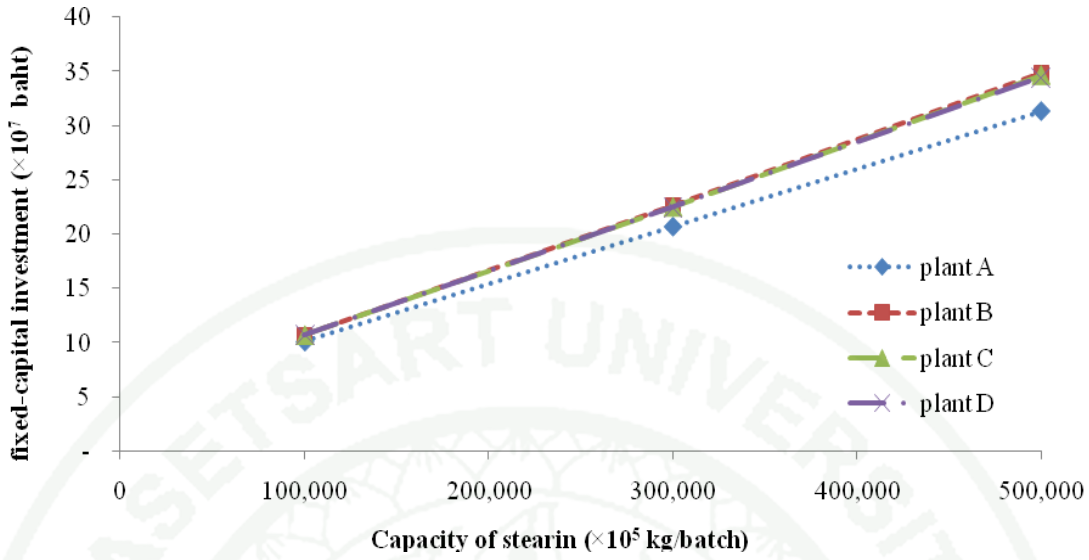


Figure 41 The fixed-capital investment of biodiesel in each plant from fixed flow rate pattern

In the Figure 42, the plant A, B, C had almost the same result but plant D had different one with lowest operating cost. Because plant D produced less biodiesel than other plant did and it had the most operation time and cycle time. On the other hand, the fixed flow rate pattern in the Figure 43 of plant A required the lowest operating cost. Therefore, the operating cost was the lowest for fixed time pattern but the operating cost was highest for fixed flow rate pattern when amount of equipment was increased and sized of equipment was reduced. These results was showed the effect of operation time and cycle time which the annual biodiesel product was the lowest for fixed time pattern but the annual biodiesel product was the highest for fixed flow rate pattern when amount of equipment was increased and sized of equipment was reduced.

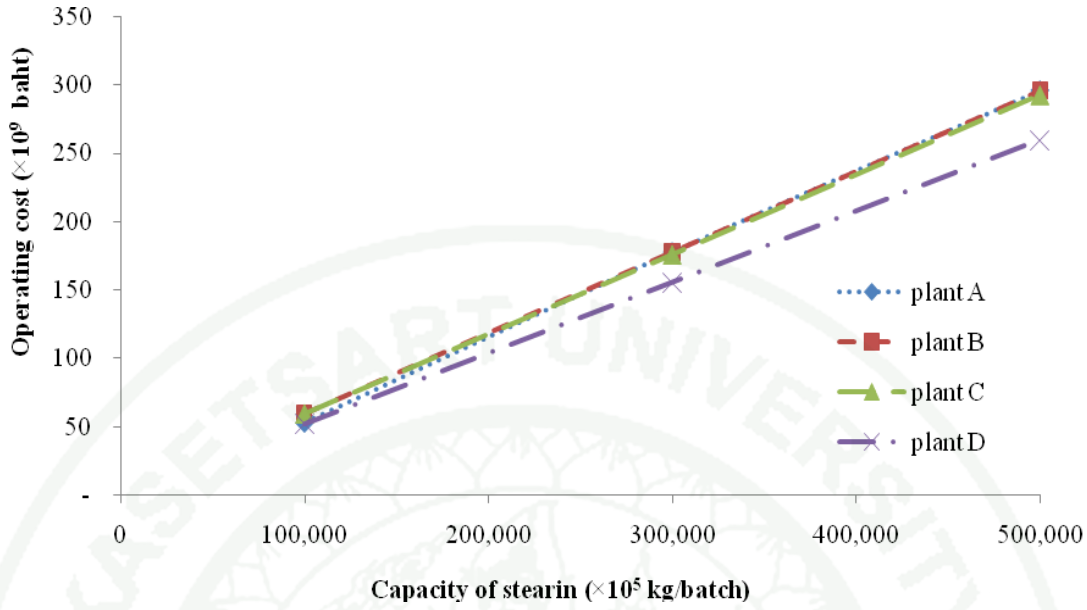


Figure 42 The operating cost of biodiesel in each plant from fixed time pattern

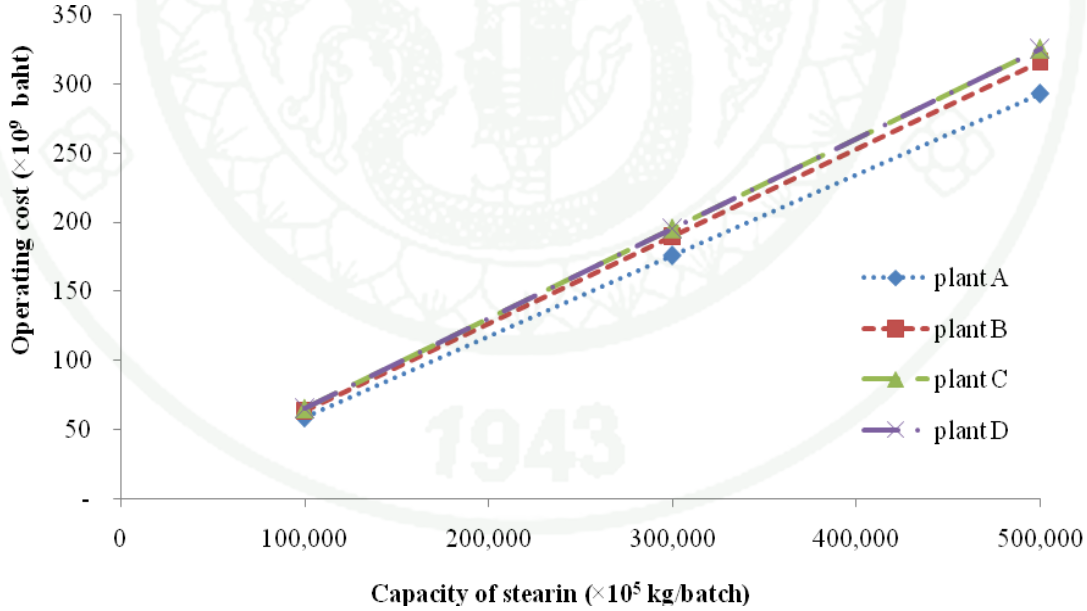


Figure 43 The operating cost of biodiesel in each plant from fixed flow rated pattern

From the sensitivity analysis, the selected plant must have the lowest of total cost per capacity of biodiesel which was displayed in Table 20. The biodiesel production plant plant D at capacity of 300,000 kg/batch stearin in fixed time pattern of operation for this reason. From the result of sensitivity analysis, the price of biodiesel and stearin had an immense effect on the selection of project which was showed in Figure 50.

Table 20 Total cost per capacity of biodiesel in fixed time and fixed flow rate patterns

Plant	Capacity of stearin (kg/batch)	Total cost/capacity of biodiesel (baht/l) changed flow rate	Total cost/capacity of biodiesel (baht/l) fixed flow rate
A	100,000	46.3125	46.4533
	300,000	46.1070	46.3461
	500,000	46.0474	46.2857
B	100,000	46.1838	46.4123
	300,000	46.1145	46.3139
	500,000	46.0566	46.2593
C	100,000	46.1775	46.3988
	300,000	46.1172	46.3029
	500,000	46.0587	46.2490
D	100,000	46.3303	46.3997
	300,000	46.0451	46.3031
	500,000	46.0998	46.2488

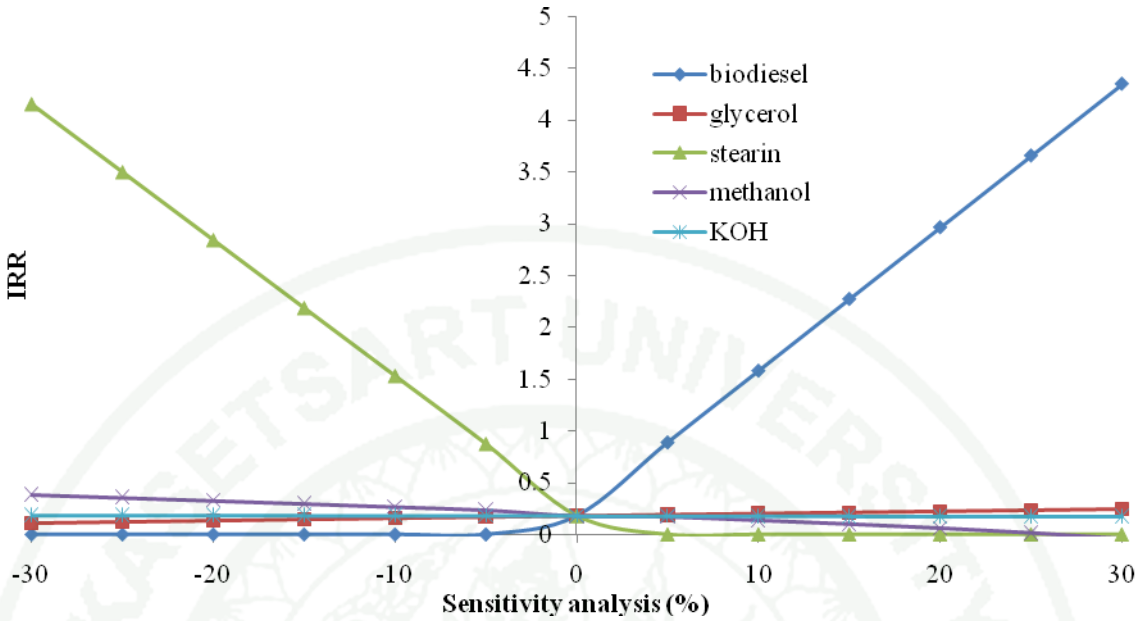


Figure 44 The sensitivity analysis of plant A at capacity of stearin 500,000 kg of fixed time pattern

CONCLUSION AND RECOMMENDATION

Conclusion

In this proposed work, the simulation and design of biodiesel production were studied in terms of time schedule and cost estimation. The biodiesel production in plant A, B, C, and D could be designed in 2 distinct patterns in Aspen Batch Process Developer. The cycle time has more effect on volume of biodiesel than operation time did. From the results, the fixed flow rate pattern of operation gave the higher annual of biodiesel product than that of fixed time one but fixed flow rate pattern yield higher total cost that than of fixed time pattern. For fixed time pattern, increasing amount of equipment and reducing size of equipment increased annual biodiesel product, but it was not be too much. On the other hand, for fixed flow rate, increasing amount of equipment and reducing size of equipment increased annual biodiesel product. For cost estimation of fixed time pattern, increasing amount of equipment and reducing size of equipment reduced total cost because it produced less. However, the fixed flow rate pattern, increasing amount of equipment and reducing size of equipment increased total cost. Therefore, the chosen biodiesel production process should have low cost meanwhile it produced high amount of biodiesel. From Table 20, the ratio of total cost per capacity of biodiesel was the lowest, that plant should be selected. Consequently, the biodiesel production of plant A at capacity 500,000 kg of stearin in fixed time pattern of operation was suitable for investment.

Recommendation

1. In the washing unit, the composition should be analysis for correctly in mass balance calculation.
2. The cost of equipment had an effect on investment cost so that price of equipment should be known exactly.

LITERATURE CITED

Antolín, G., F.V. Tinaut and Y. Briceño. 2002. Optimisation of biodiesel production by sunflower oil transesterification. **Bioresource Technology**. 83: 111-124.

Atadashi, I.M., M.K. Aroua and A.A. Aziz. 2011. Biodiesel separation and purification: A review. **Renewable Energy** 36: 437-443.

Barker, M., J. Rawtani and S. mackay. 2005. **Practical Batch Process Management**. Elsevier, Netherlands.

Berrios, M. and R.L. Skelton. 2008. Comparison of purification methods for biodiesel. **Chemical Engineering Journal**. 144: 459-465.

Bouaid, A, Y. Diaz, M. Martinez and J. Aracil. 2005. Pilot plant studies of biodiesel production using *Brassica carinata* as raw material. **Catalysis Today**. 106: 193-196.

Branan, C. 2005. **Rules of Thumb for Chemical Engineers**. Fourth edition. Elsevier, United Kingdom.

Bureau of Energy Efficiency. 2011. **Material and Energy Balance**. Available Source: http://www.em-ea.org/Guide%20Books/Book-1/1.4%20MATERIAL%20%20AND%20ENERGY%20BALANCE.pdf, February 01, 2011.

Couper, J.R. 2005. **Chemical Process Equipment Selection and design**. Second edition. Elsevier, United Kingdom.

Demirbas, A. 2008. **Biodiesel: A realistic Fuel Alternative for Diesel Engines**. Springer, Spain.

Drapcho, C.M., N.P. Nhuan and T.H. Walker. 2008. **Biofuels Engineering Process Technology**. McGraw-Hill, United States of America.

Richard, M.F. and R.W. Rousseau. 2000. **Elementary Principles of Chemical Processes**. Third edition. John Wiley & Sons, New Jersey.

GreenerPor. 2009. **EN 14214**. Available Source: http://www.greenerpro.com/EN14214.html, February 01, 2011.

Halek, F., A. Kavousi and M. Banifatemi. 2009. Biodiesel as an alternative fuel for diesel engines. **Engineering and Technology**. 57: 460-462.

Hass, M.J., A.J. McAloon, W.C. Yee and T.A. Foglia. 2006. A process model to estimate biodiesel production costs. **Bioresource Technology**. 97: 671-678.

Kapilakarn, K. and A. Peugtong. 2007. A comparison of costs of biodiesel production from transesterification. **International Energy Journal**. 8: 1-6.

Kasteren, J.M.N. and A.P. Nisworo. 2007. A process model to estimate the cost of industrial scale biodiesel production from waste cooking oil by supercritical transesterification. **Resources, Conservation and Recycling**. 50: 442-458.

Knothe, G., J.V. Gerpen and J. Krahl. 2005. **The Biodiesel Handbook**. AOCS PRESS, United States of America.

McCabe, W.L., C.S. Julian and P. Harriott. 2005. **Unit Operations of Chemical Engineering**. Seventh edition. MaGraw Hill, New York.

Ministry of Energy. 2007. **Properties of Biodiesel**. Available Source: http://www.pttplc.com/Files/Product/B5_Plus/standard_BioDiesel.pdf, February 01, 2011.

Mockus, L., J.M. Vinsion and K.Luo. 2002. The integration of production plan and operating schedule in a pharmaceutical pilot plant. **Computer & Chemical Engineering**. 26: 697-702.

Nag, A. 2008. **Biofuels Refining and Performance**. McGraw-Hill, United States of America.

Paul., G. 2005. **Biodiesel Growing a New Energy Economy.** Chelsea Green Publishing Company, United States.

Peters, M.S., K.D. Timmerhaus and R.E. West. 2004. **Plant Design and Economics for Chemical Engineers**. Fifth edition. McGraw-Hill, United States of America.

Roberts, M.J., Y.N. Liu, J.C. Bronfenbrebber and J. Solomon. 2004. Technology selection. **Hydrocarbon Engineering**. 81-84.

Seider, W.D., S. widagdo, D.R. Lewin and J.D. Seader. 2010. **Product and Process Design Principles**. Third edition. John Wiley & Sons, New Jersey.

Steiner, H.M. 1996. **Engineering Economic Principles**. Second edition. McGraw-Hill, United States of America.

Sustainable produced plantoils. 2010. **Palm Oil**. Available Source: http://www.plantoils.eu/palm_oil.html, December 19, 2010

Vinson, J. 2008. **The Value of Batch Process Design in a Chemical Engineering Education**. Aspen Technolgy.

You, Y.D., J.L. Shie, C.Y. Chang, S.H. Huang, C.Y. Pai, Y.H. Yu and C.H. Chang. 2008. Economic cost analysis of biodiesel production: case in soybean oil. **Energy & Fuel**. 22: 182-189.

APPENDICES

Appendix A

The method for analysis soap, potassium hydroxide and free fatty acid

Appendix A The method for analysis soap, potassium hydroxide and free fatty acid

1.1 Residual catalyst and soap titration

Weigh sample about 5 g into the Erlenmeyer flask and add isopropanol about 30 ml and phenolthalien (0.1%) about 2 drops to the flask. If solution turns pink, this represents the residual catalyst in esters. Then, add hydrochloric acid (0.1 N solutions) until solution losses pink color. Record amount of HCl required changing solution color as "A". After that, add bromophenol blue (0.04%) about 3-4 drops (blue solution) and add HCl to solution until it turns bright yellow and holds color. Record amount of HCl required changing solution color as "B". (Courtesy of CCCC BioFuels Program, n.d.)

Catalyst content: $$\frac{A \times C \times 56.1}{1{,}000 \times W} = \text{grams of KOH / grams of sample}$$

Soap content: $$\frac{B \times C \times 306}{1{,}000 \times W} = \text{grams of soap / grams of sample}$$

Where A = volume of hydrochloric acid for titration (pink to clear) (ml)

B = volume of hydrochloric acid for titration (blue to yellow) (ml)

C = concentration of HCL (mol/l)

W = weight of sample (g)

1.2 Analysis amount of acid value (FFA)

Weigh sample about 15 g into the Erlenmeyer flask and add isopropanol about 30 ml and phenolthalien (0.1%) amount 2 drops. Then using burette, add potassium hydroxide (0.1 N solutions) drop by drop to the oil-alcohol-phenolphthalein mixture, stirring all the time. It might turn a bit cloudy, keep stirring. Keep on carefully adding the KOH solution until the mixture just starts to turn pink

(magenta) and stays that way for 15 seconds. Record amount of KOH required changing solution color as “B”. (Addison, n.d.)

$$\frac{B \times C \times 306}{1{,}000 \times W} = \text{grams of soap / grams of sample}$$

Where B = volume of potassium hydroxide for titration (clear to pink) (ml)

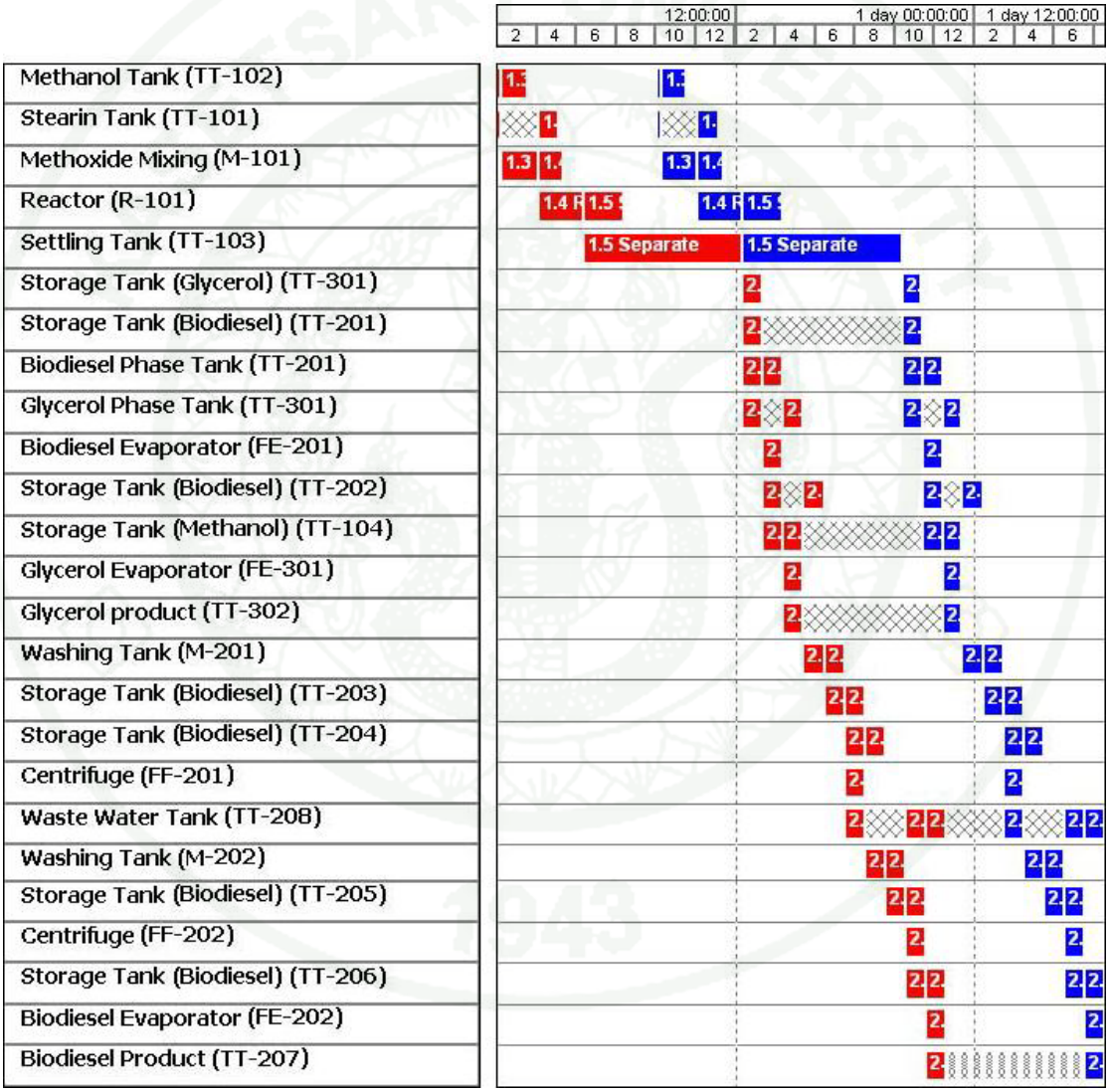
C = concentration of HCL (mol/l)

Appendix B

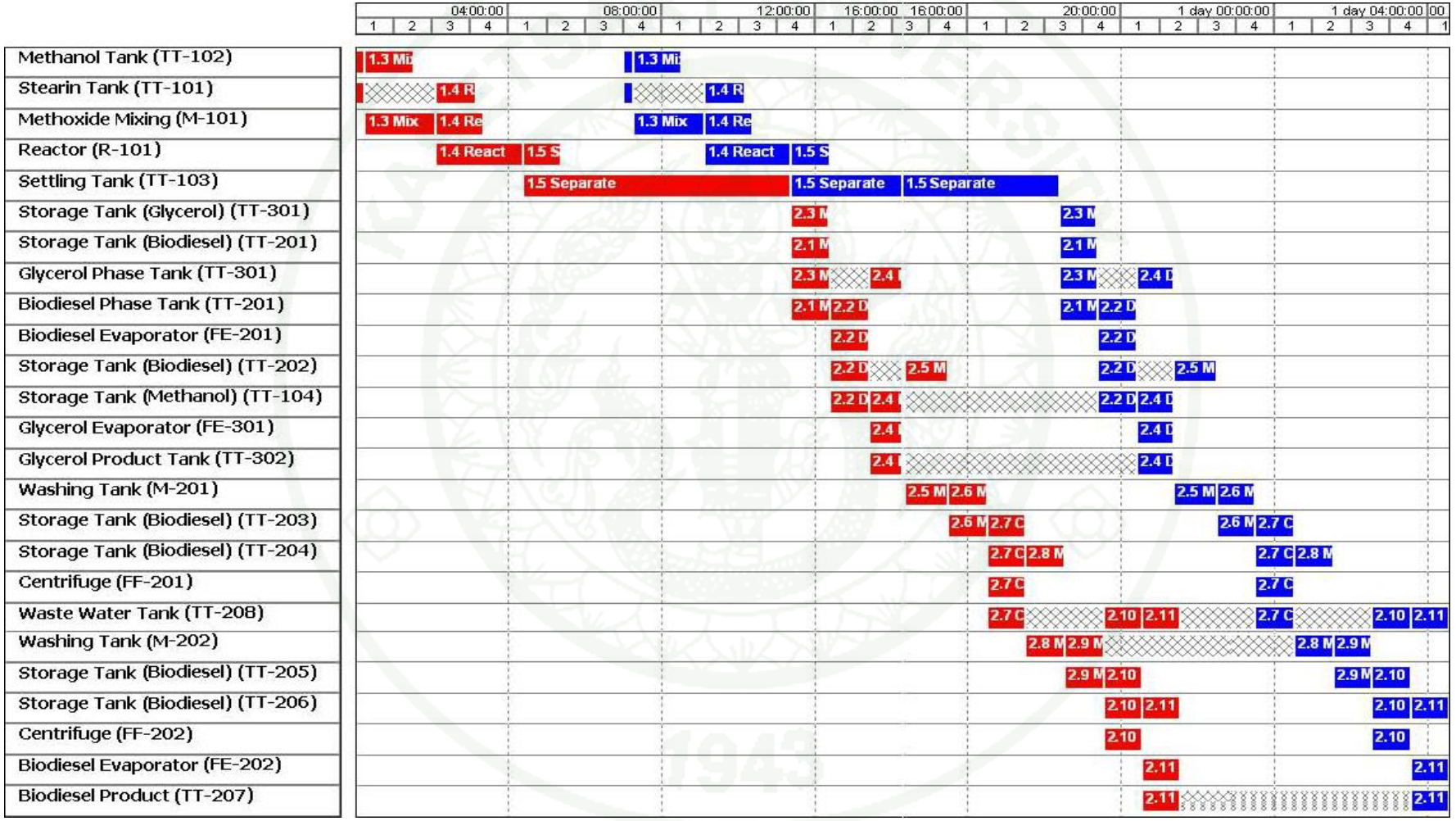
Schedule of biodiesel production plant from Aspen Batch Process Developer

Appendix B Schedule of biodiesel production plant from Aspen Batch Process Developer

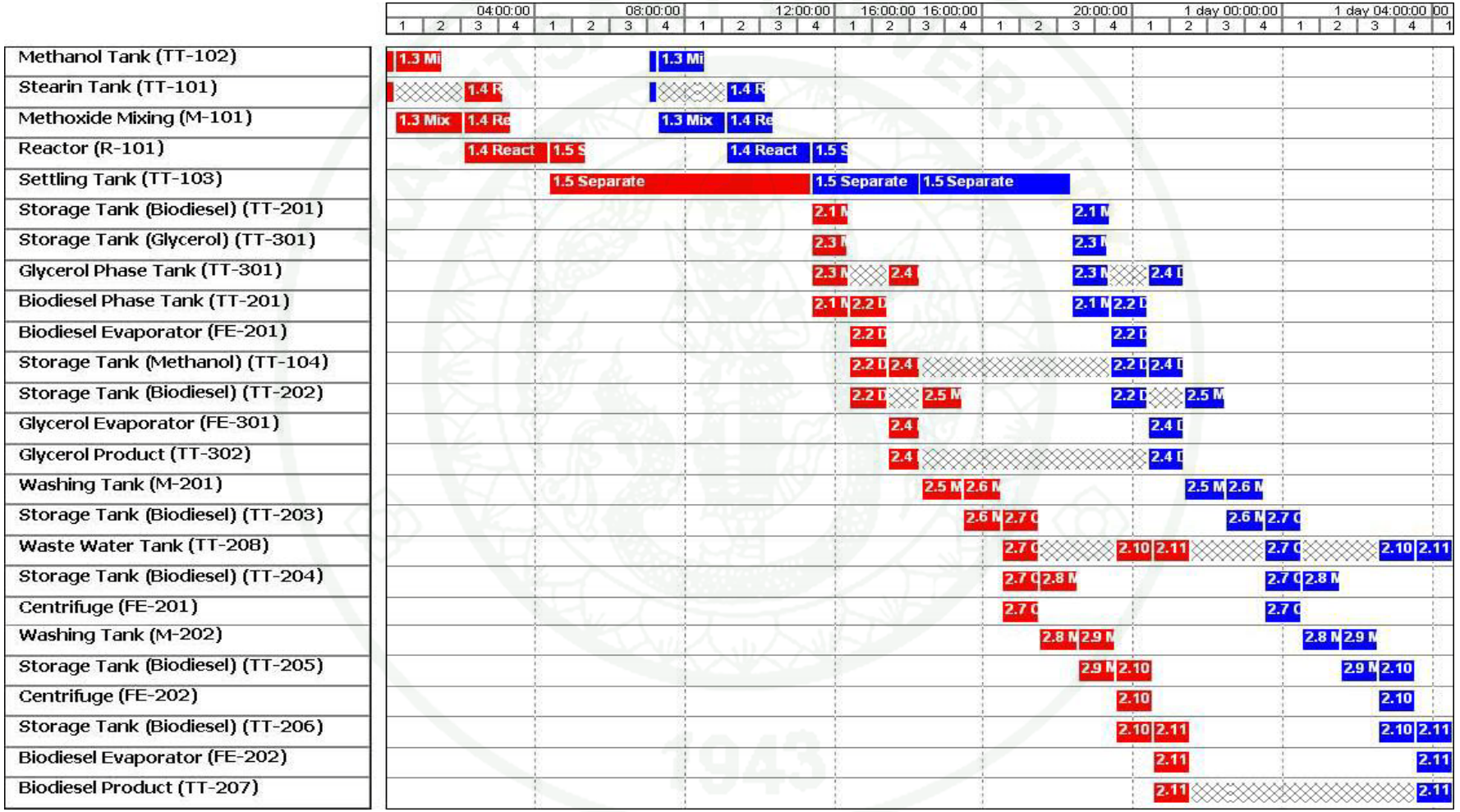
1. Schedule for changed flowrate in each plant for capacity of feedstock 100,000; 300,000 and 500,000 kg



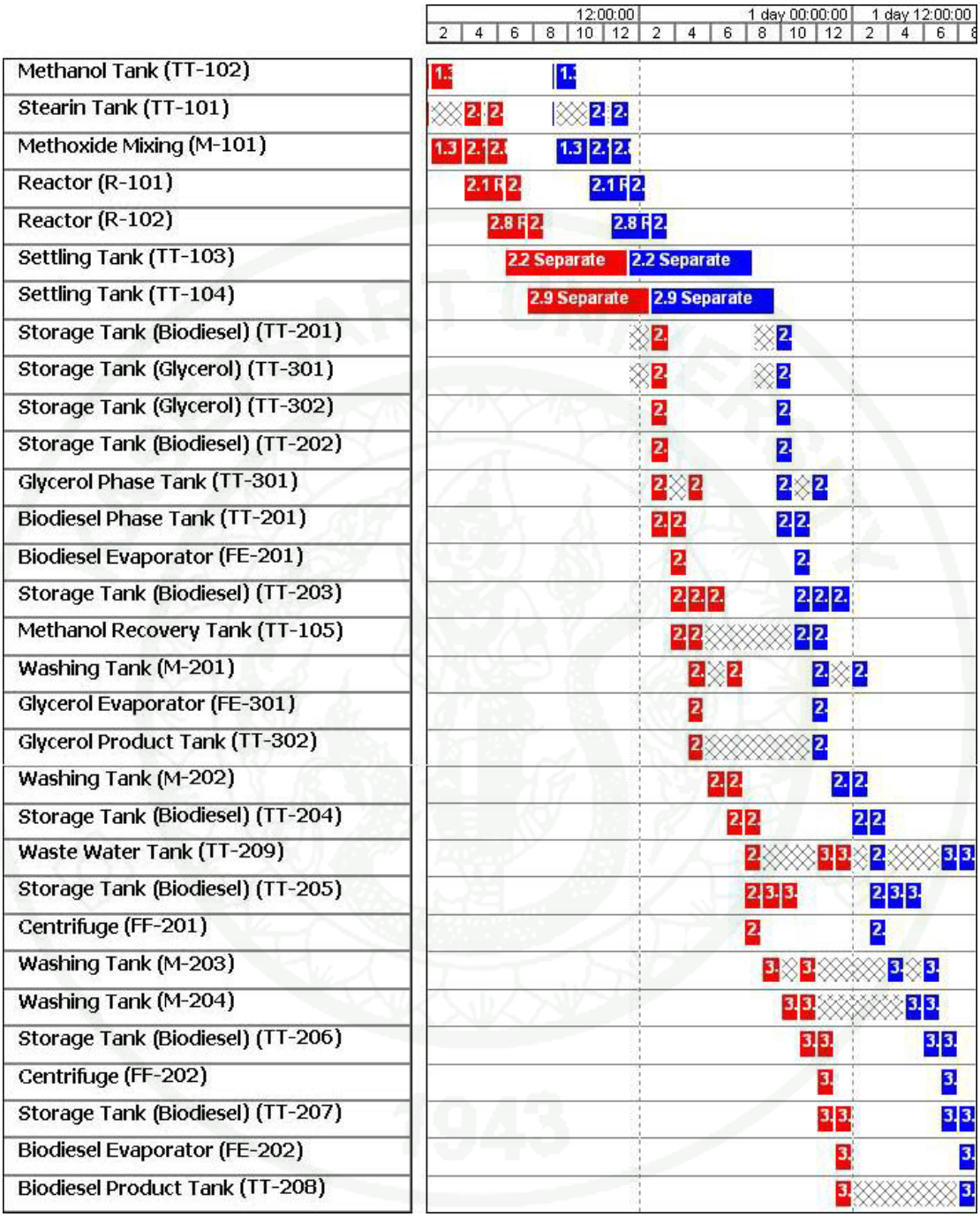
Appendix Figure B1 The schedule of biodiesel production plant A was fixed time at capacity of feedstock 100,000 kg.



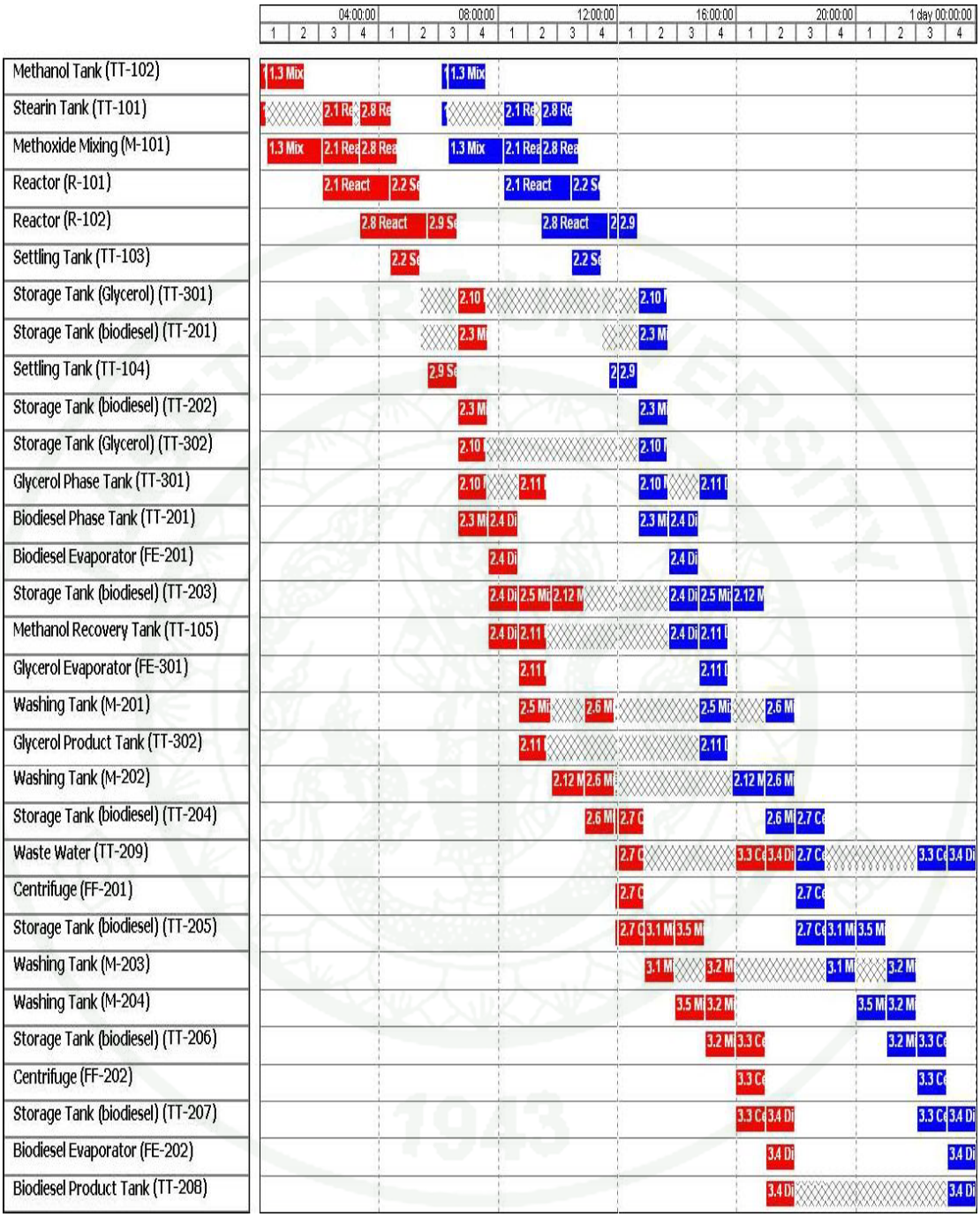
Appendix Figure B2 The schedule of biodiesel production plant A was fixed time at capacity of feedstock 300,000 kg.



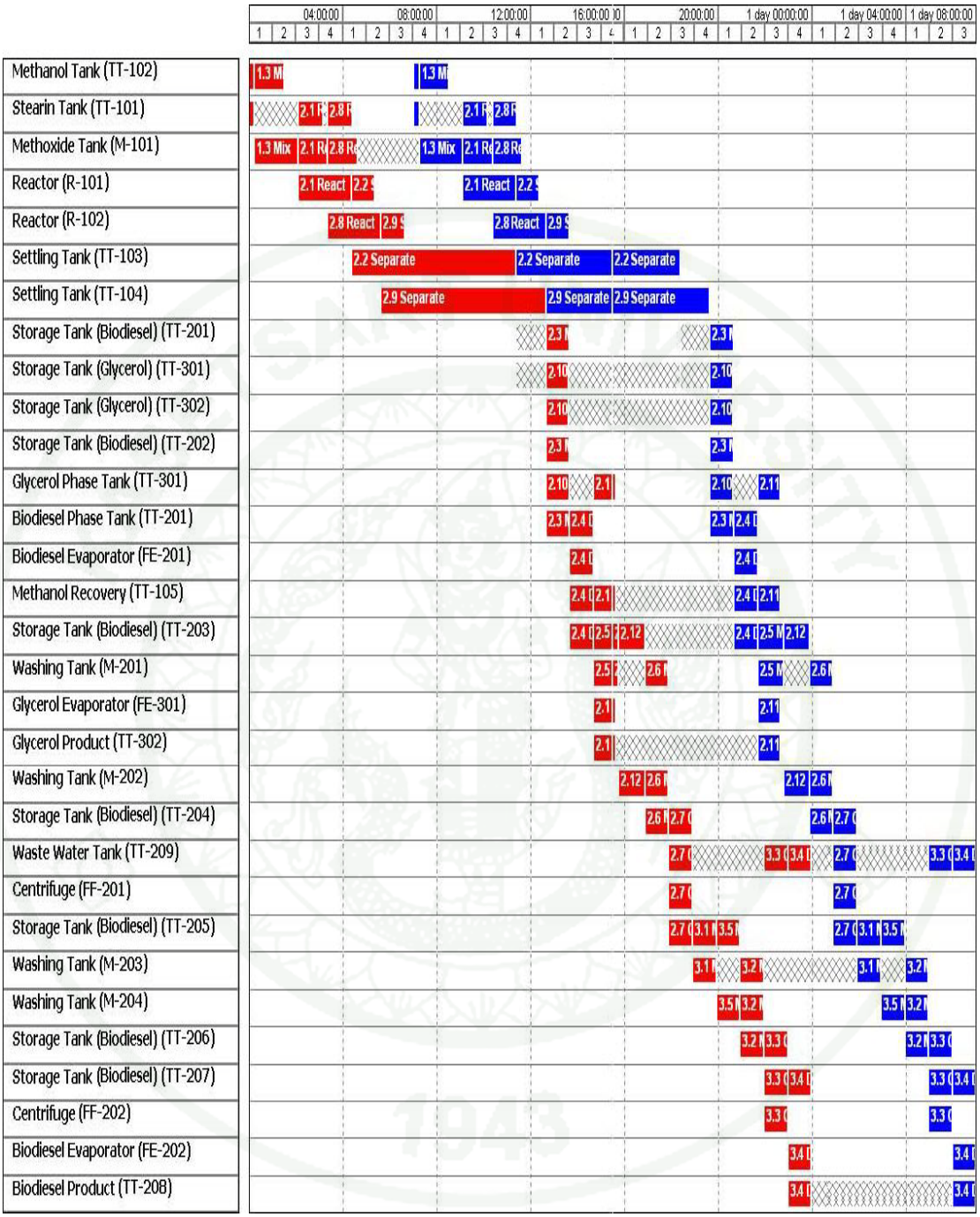
Appendix Figure B3 The schedule of biodiesel production plant A was fixed time at capacity of feedstock 500,000 kg.



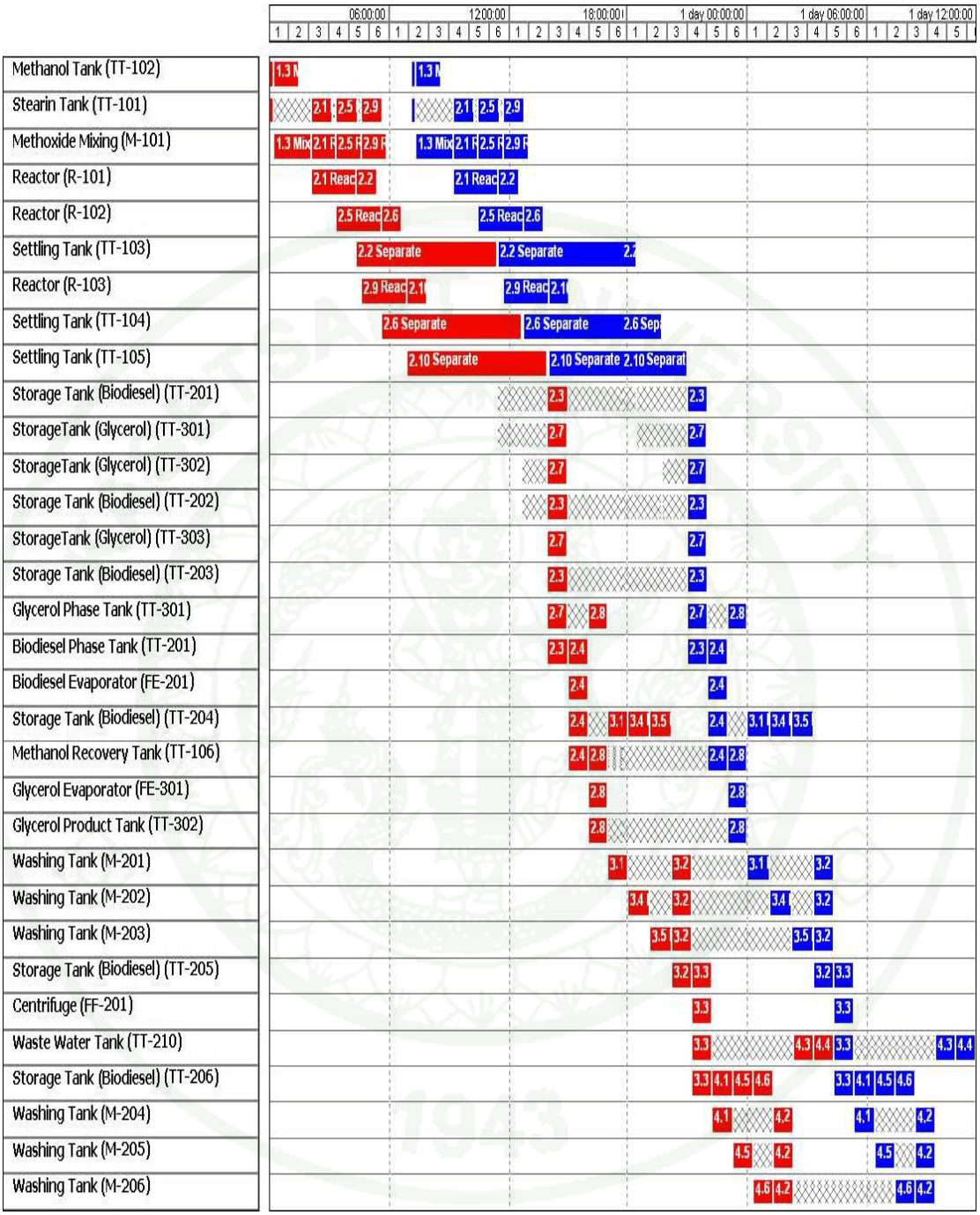
Appendix Figure B4 The schedule of biodiesel production plant B was fixed time at capacity of feedstock 100,000 kg.



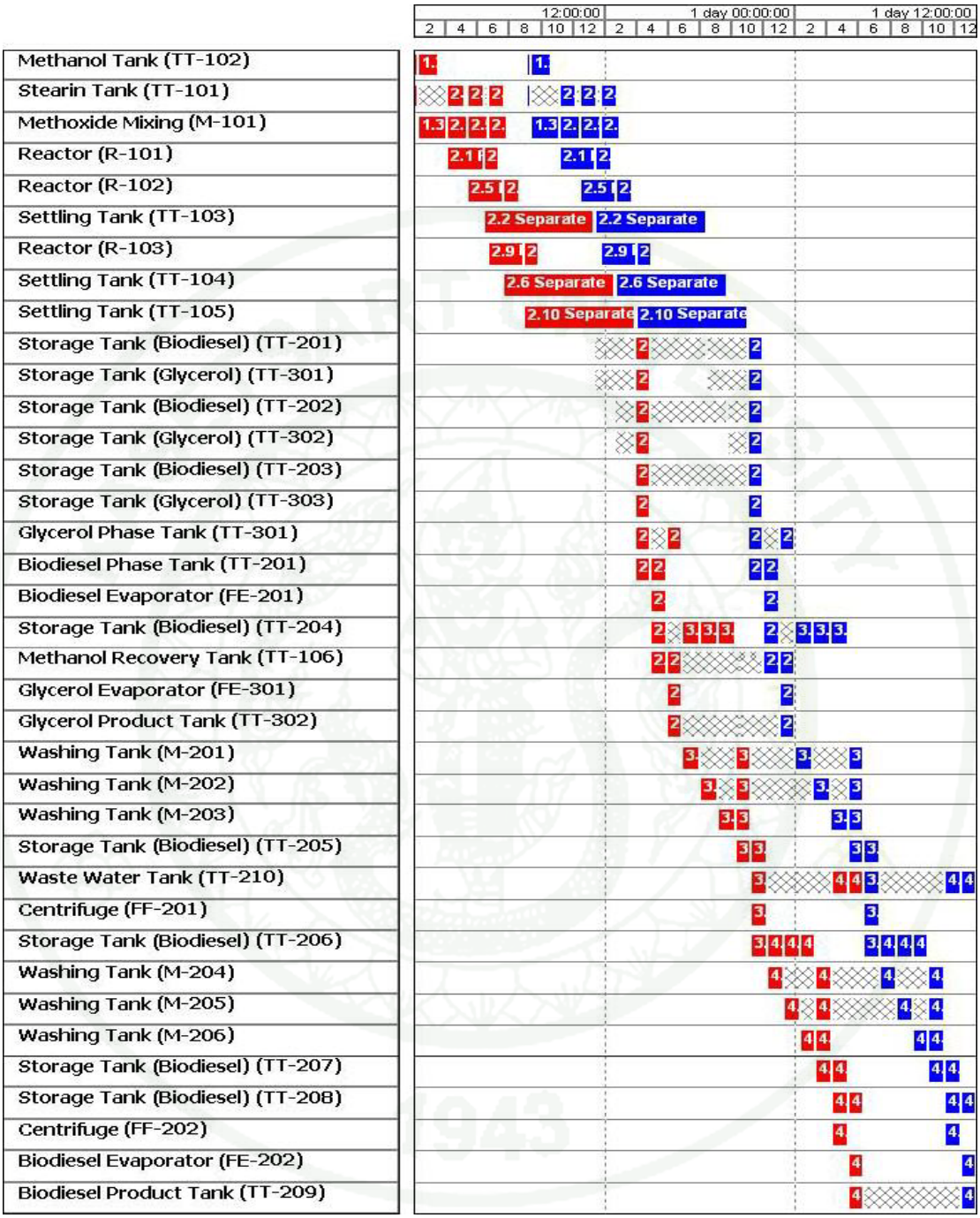
Appendix Figure B5 The schedule of biodiesel production plant B was fixed time at capacity of feedstock 300,000 kg.



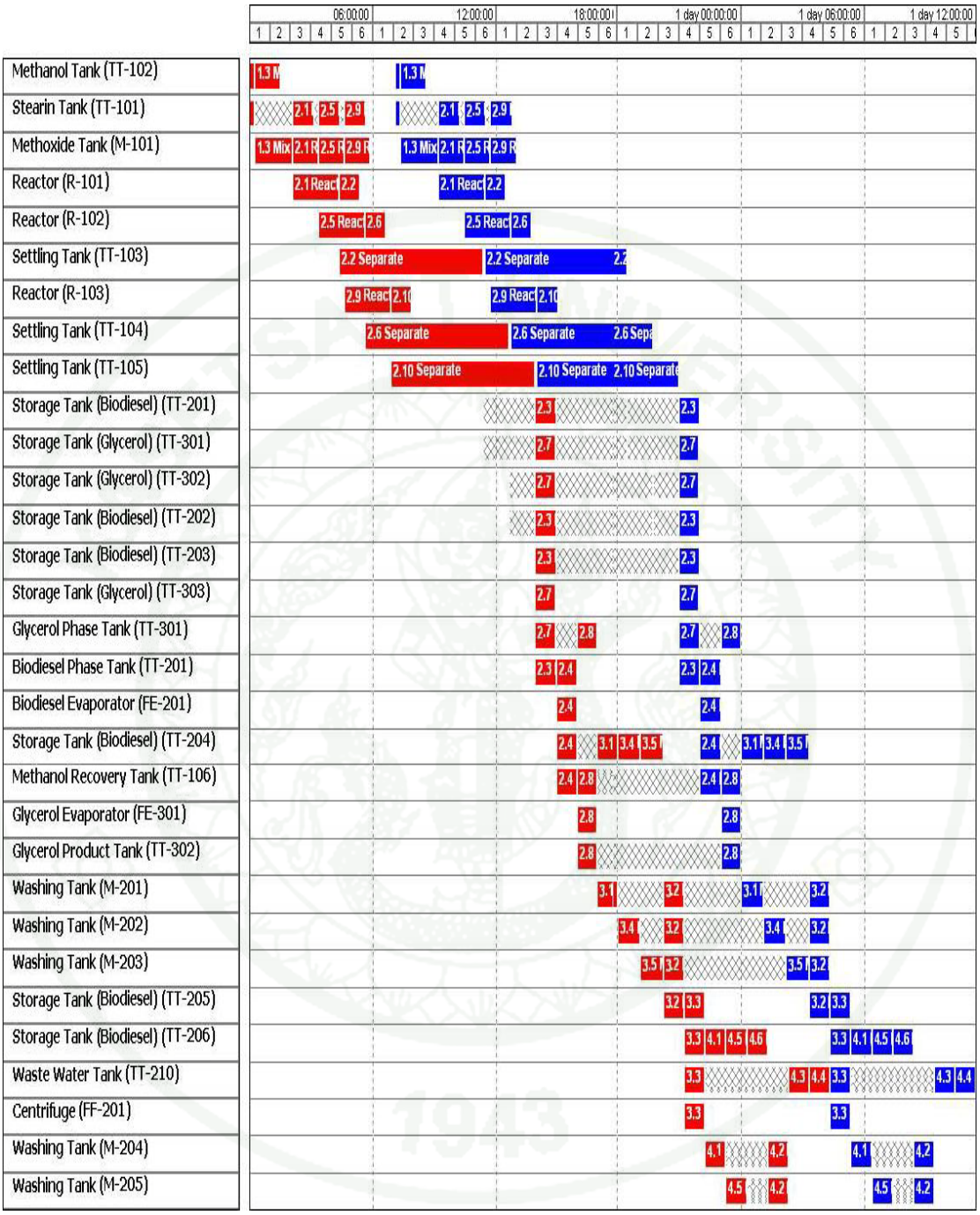
Appendix Figure B6 The schedule of biodiesel production plant B was fixed time at capacity of feedstock 500,000 kg.



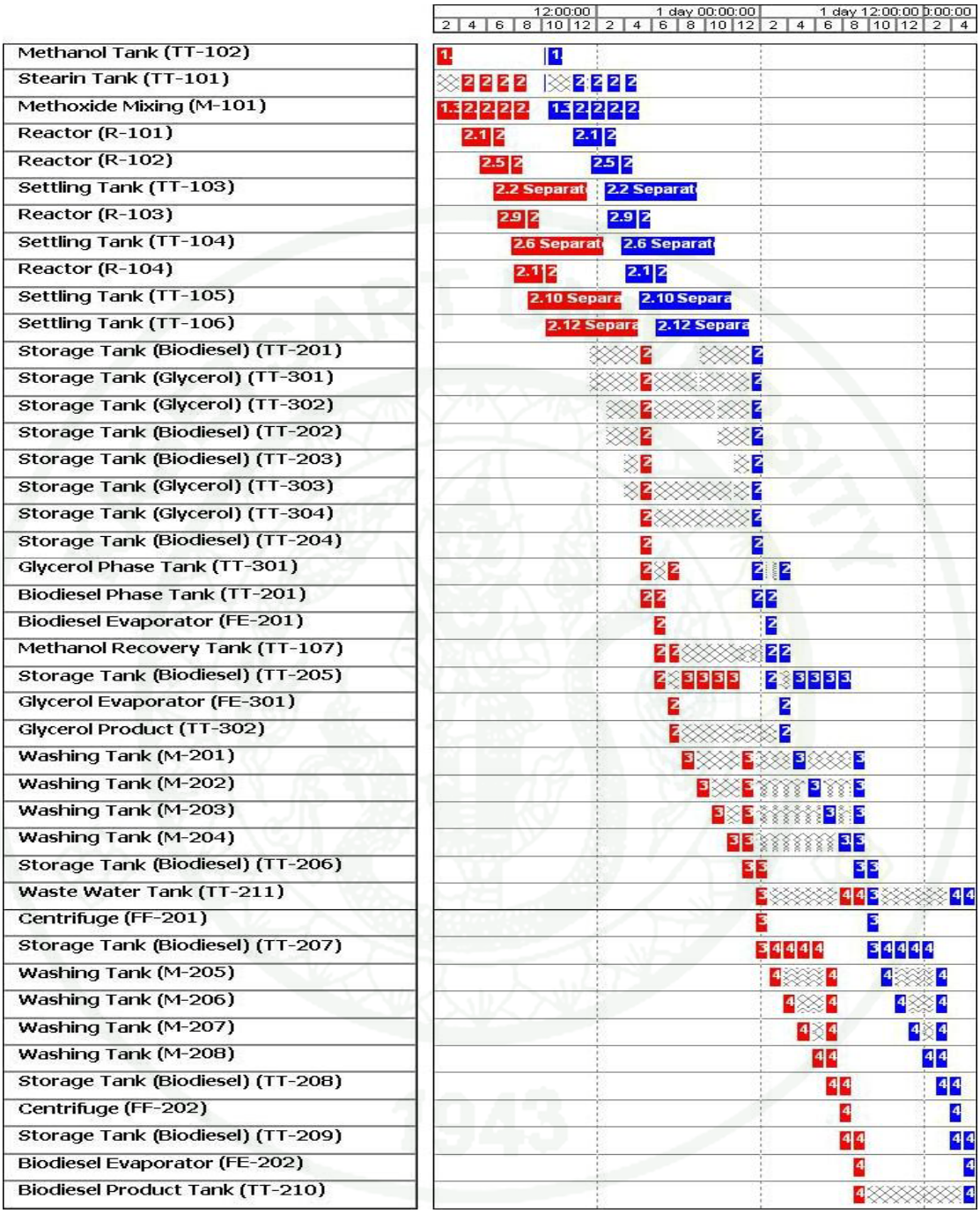
Appendix Figure B7 The schedule of biodiesel production plant C was fixed time at capacity of feedstock 100,000 kg.



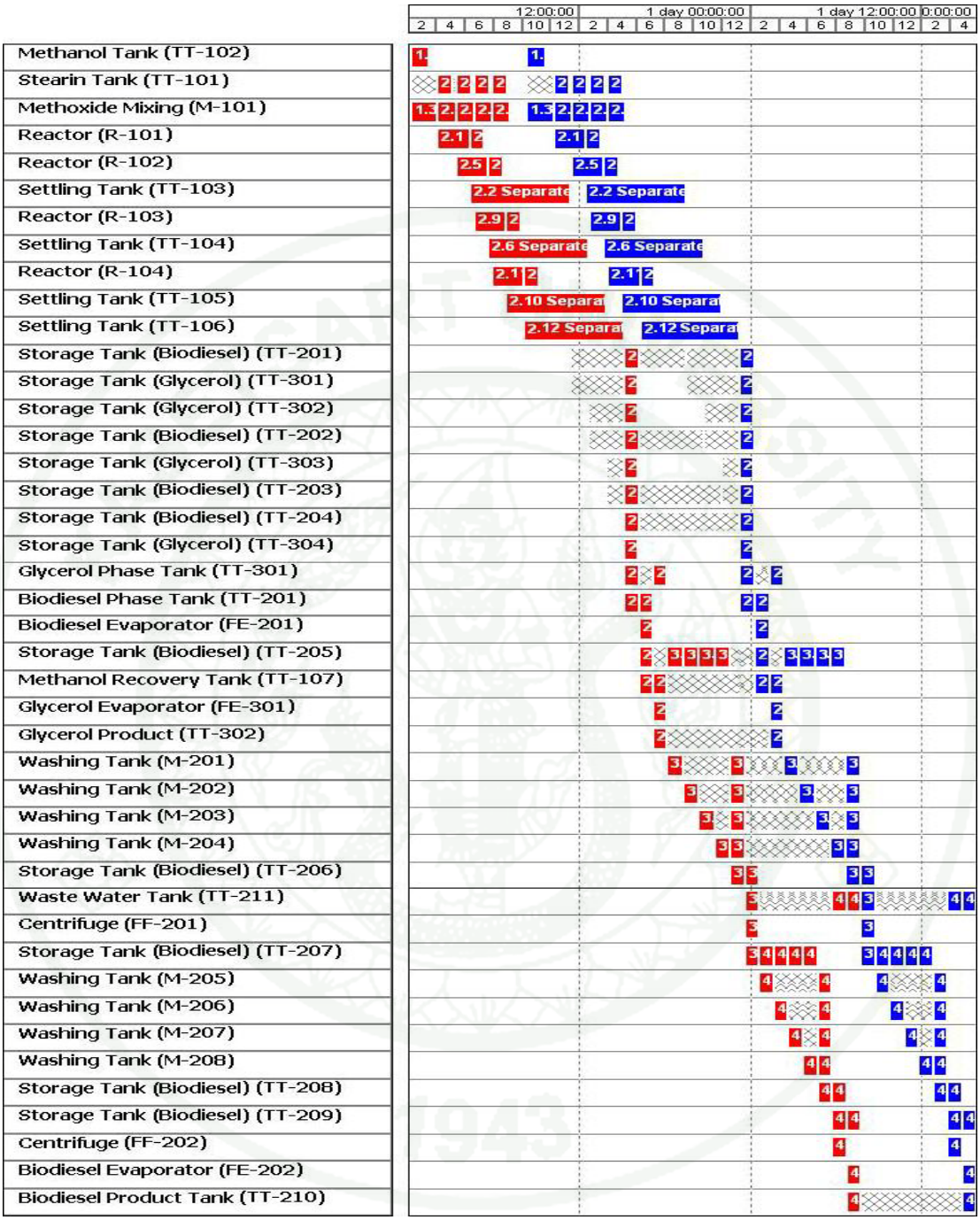
Appendix Figure B8 The schedule of biodiesel production plant C was fixed time at capacity of feedstock 300,000 kg.



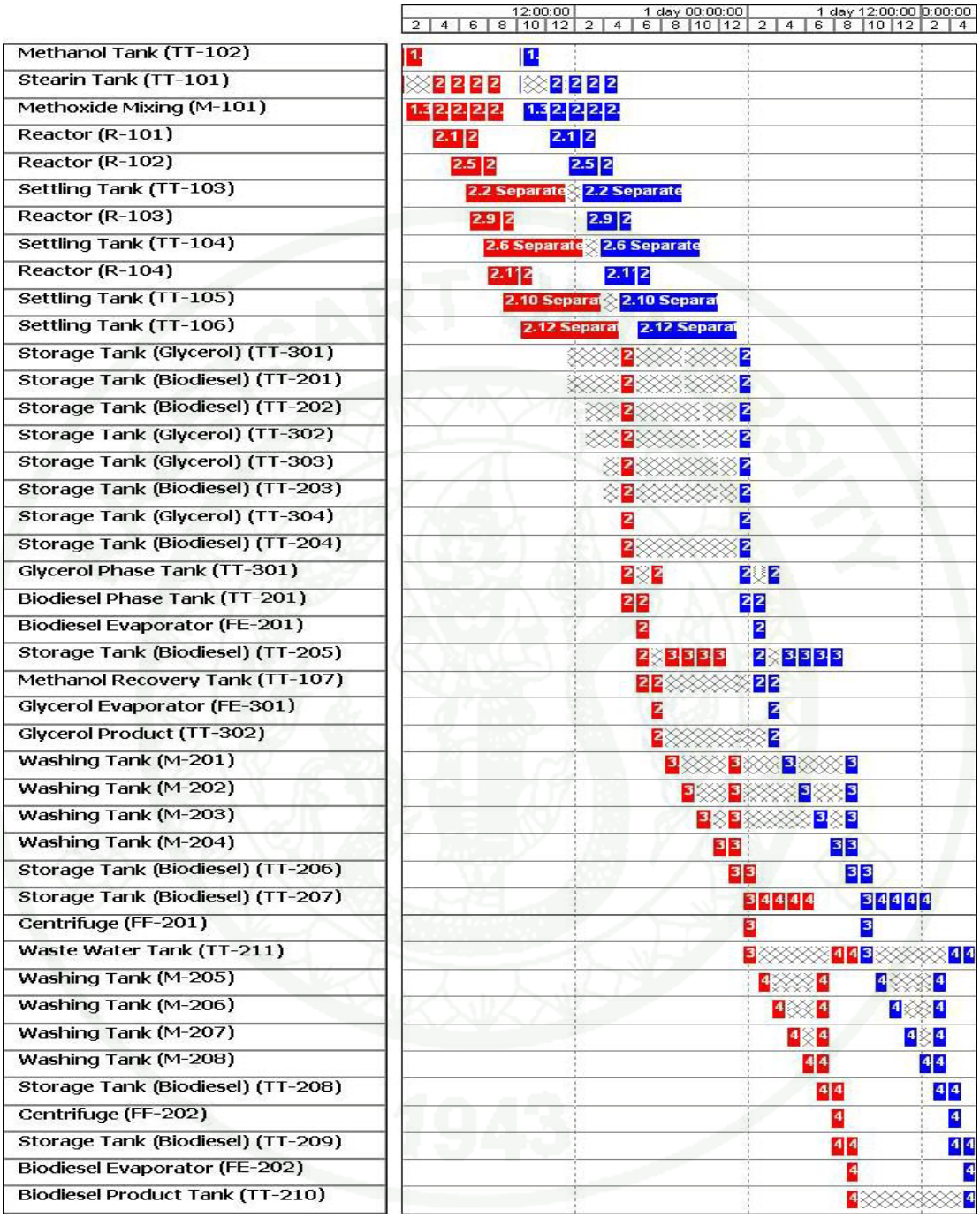
Appendix Figure B9 The schedule of biodiesel production plant C was fixed time at capacity of feedstock 500,000 kg.



Appendix Figure B10 The schedule of biodiesel production plant D was fixed time at capacity of feedstock 100,000 kg.

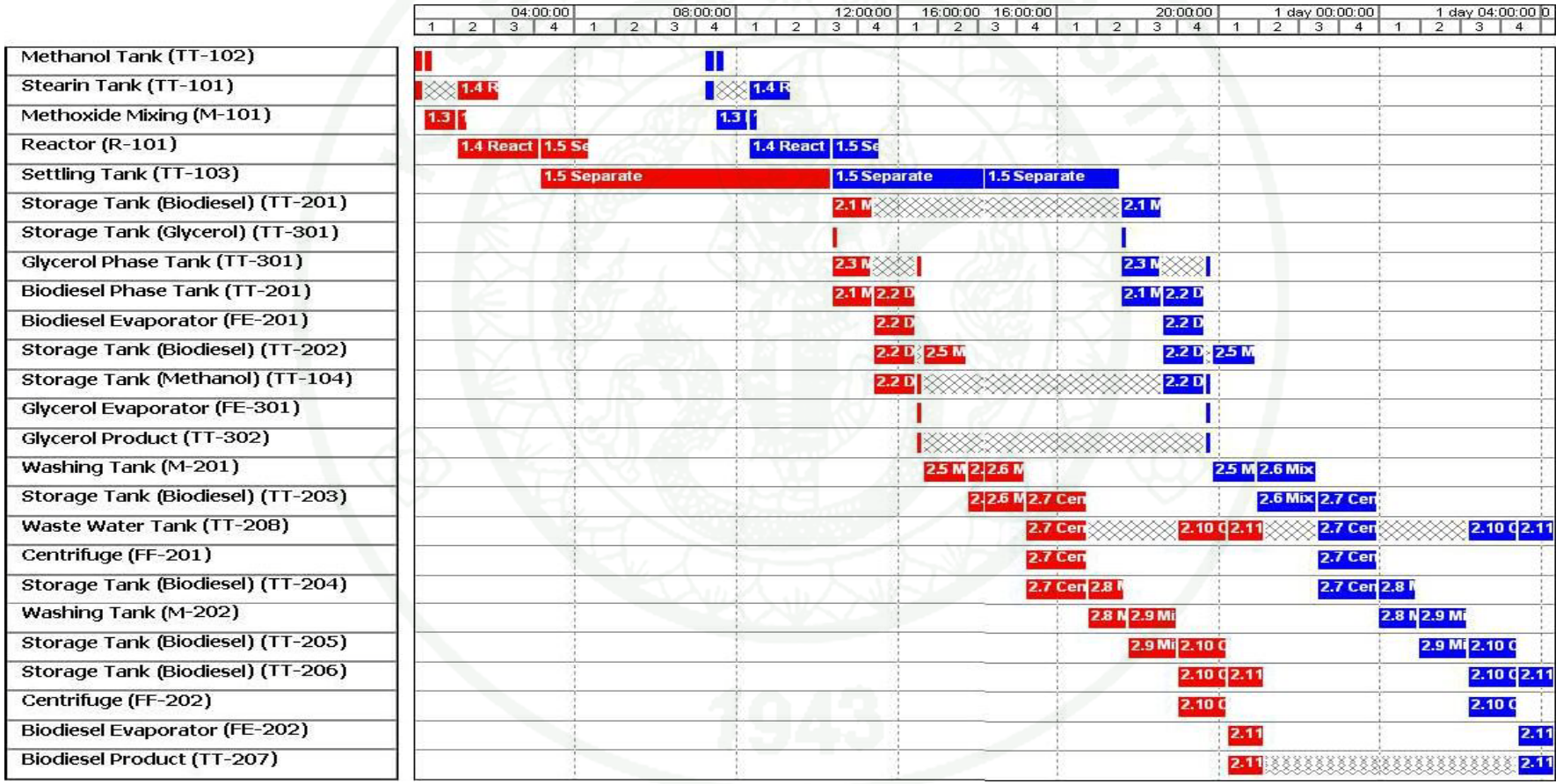


Appendix Figure B11 The schedule of biodiesel production plant D was fixed time at capacity of feedstock 300,000 kg.

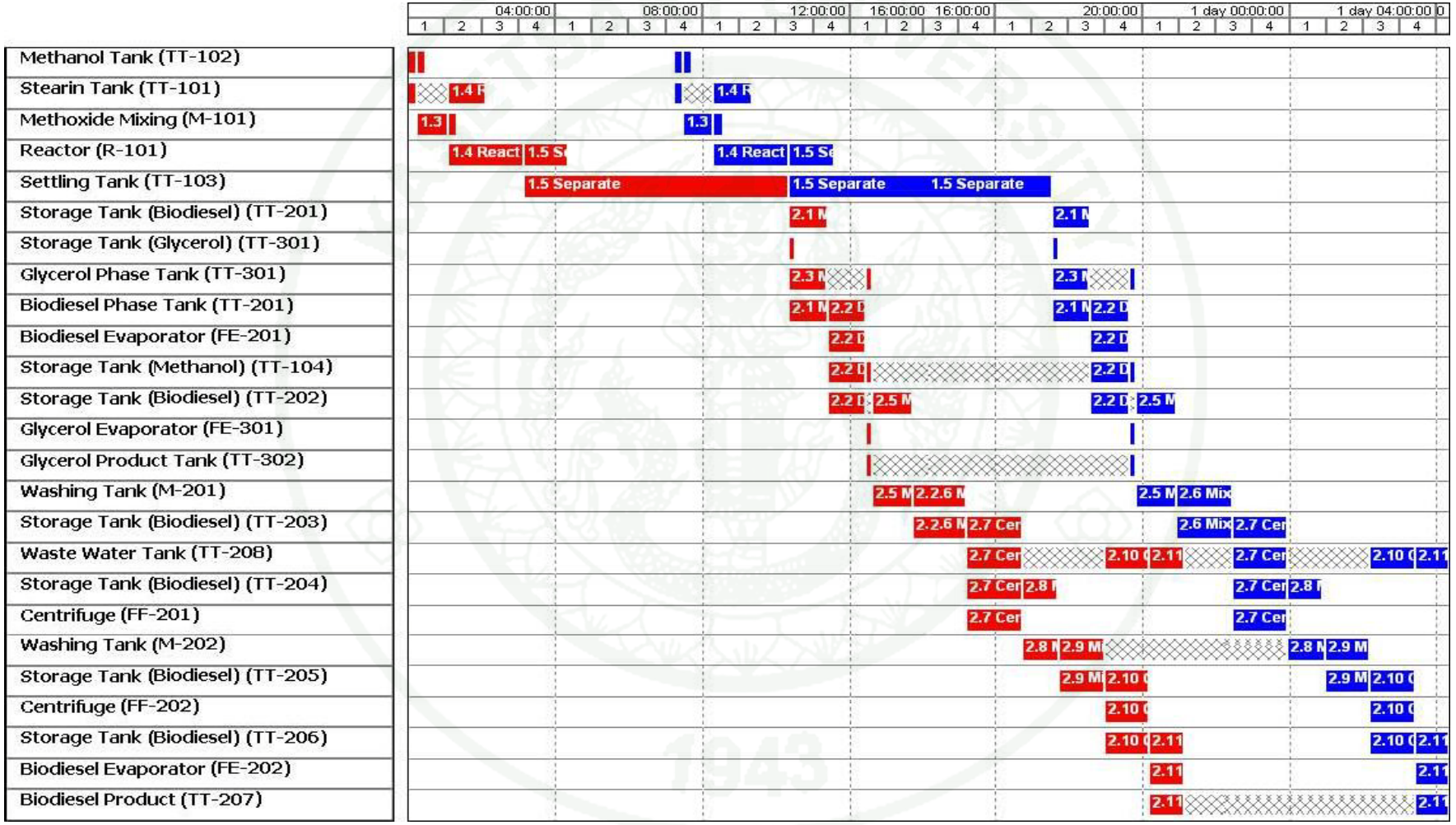


Appendix Figure B12 The schedule of biodiesel production plant D was fixed time at capacity of feedstock 500,000 kg.

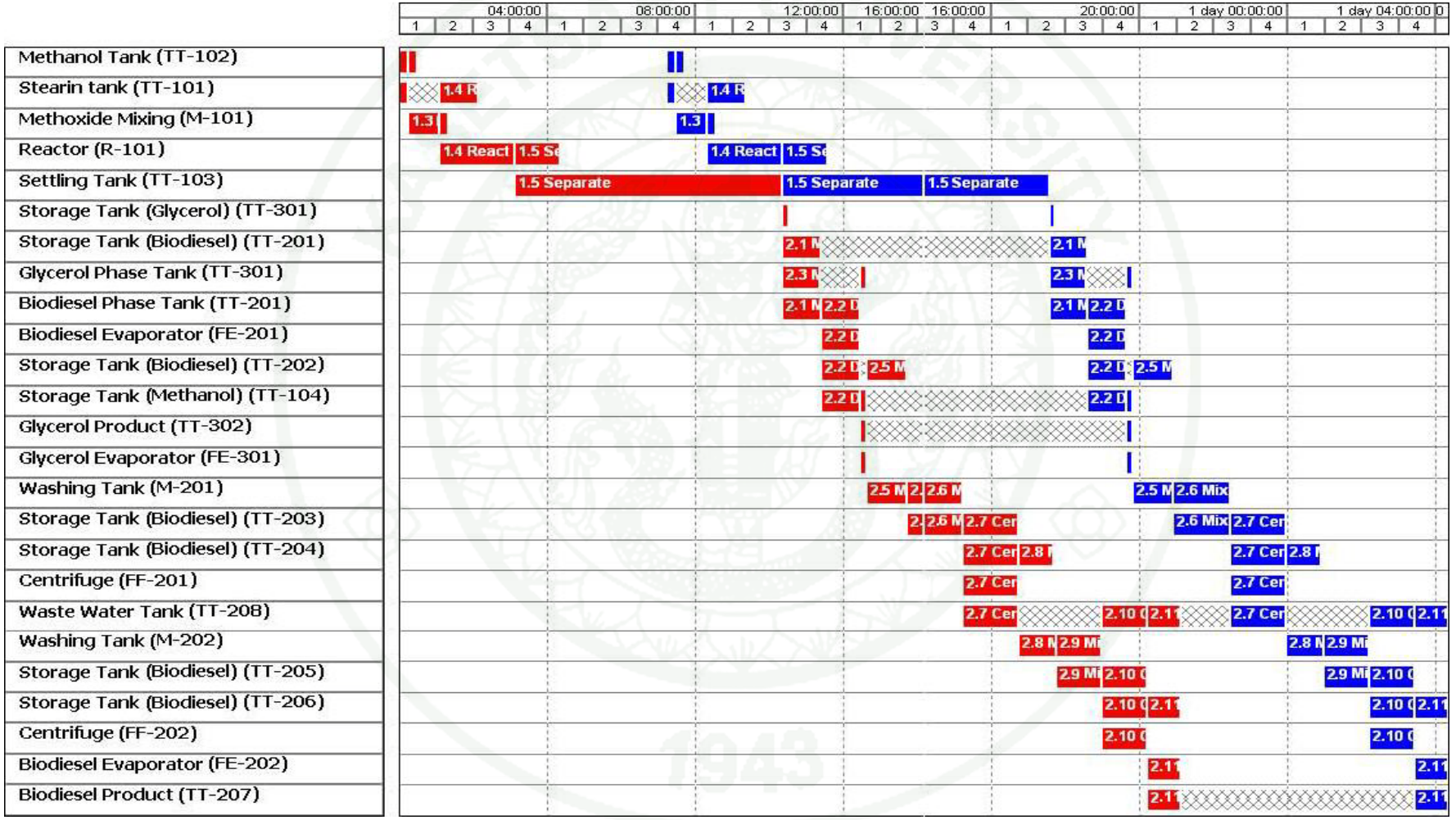
2. Schedule for fixed flowrate in each plant for capacity of feedstock 100,000; 300,000 and 500,000 kg



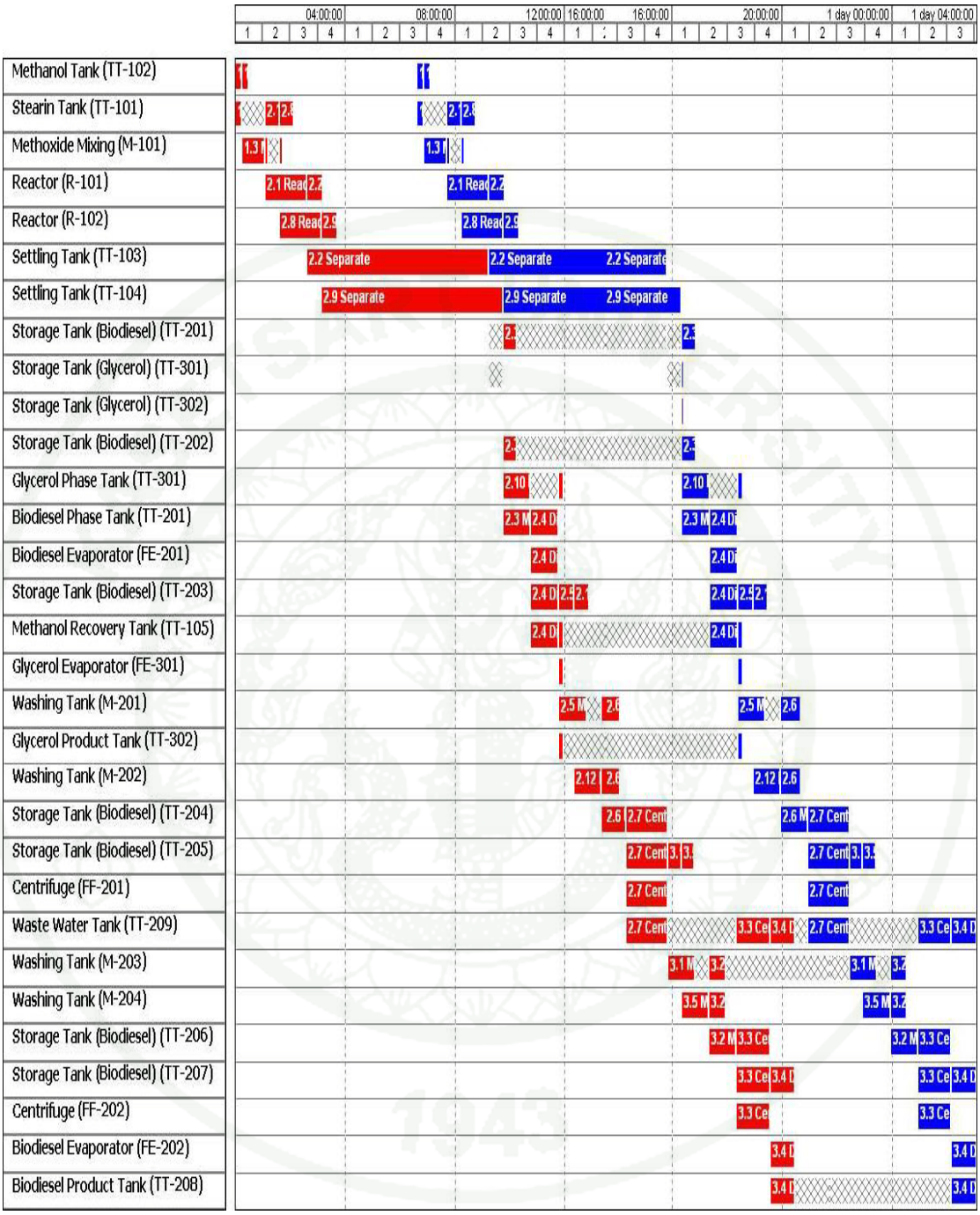
Appendix Figure B13 The schedule of biodiesel production plant A was fixed flowrate at capacity of feedstock 100,000 kg.



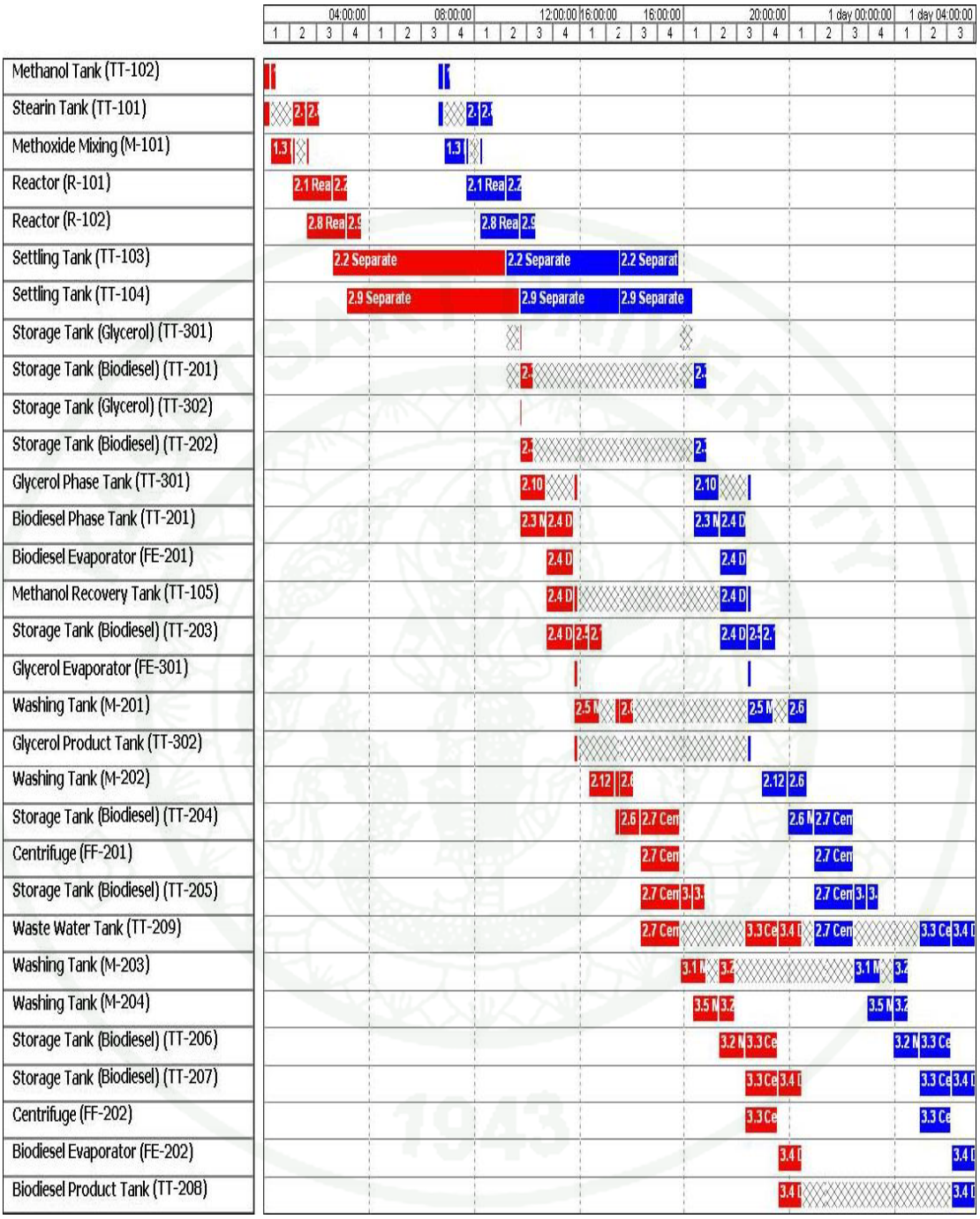
Appendix Figure B14 The schedule of biodiesel production plant A was fixed flowrate at capacity of feedstock 300,000 kg.



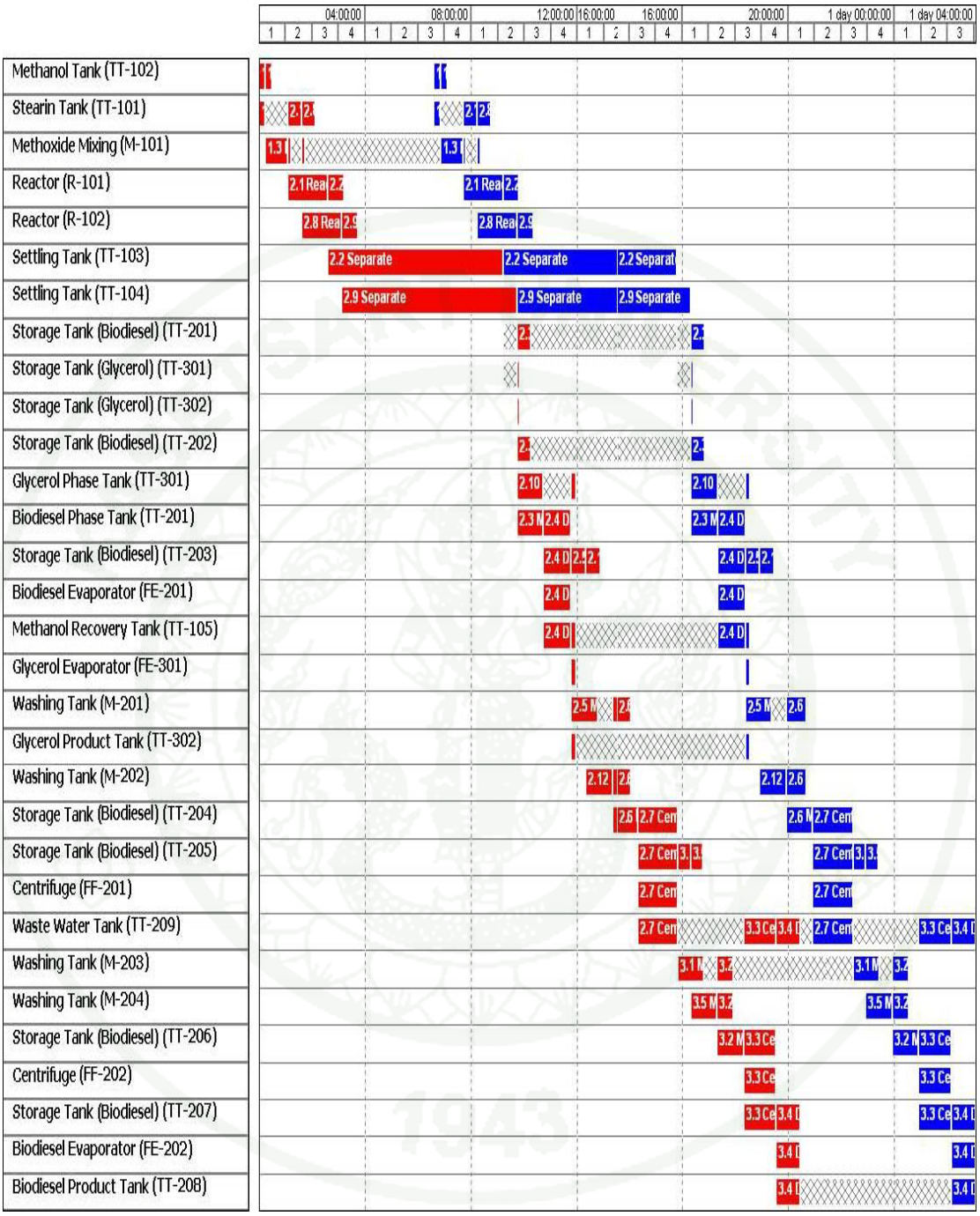
Appendix Figure B15 The schedule of biodiesel production plant A was fixed flowrate at capacity of feedstock 500,000 kg.



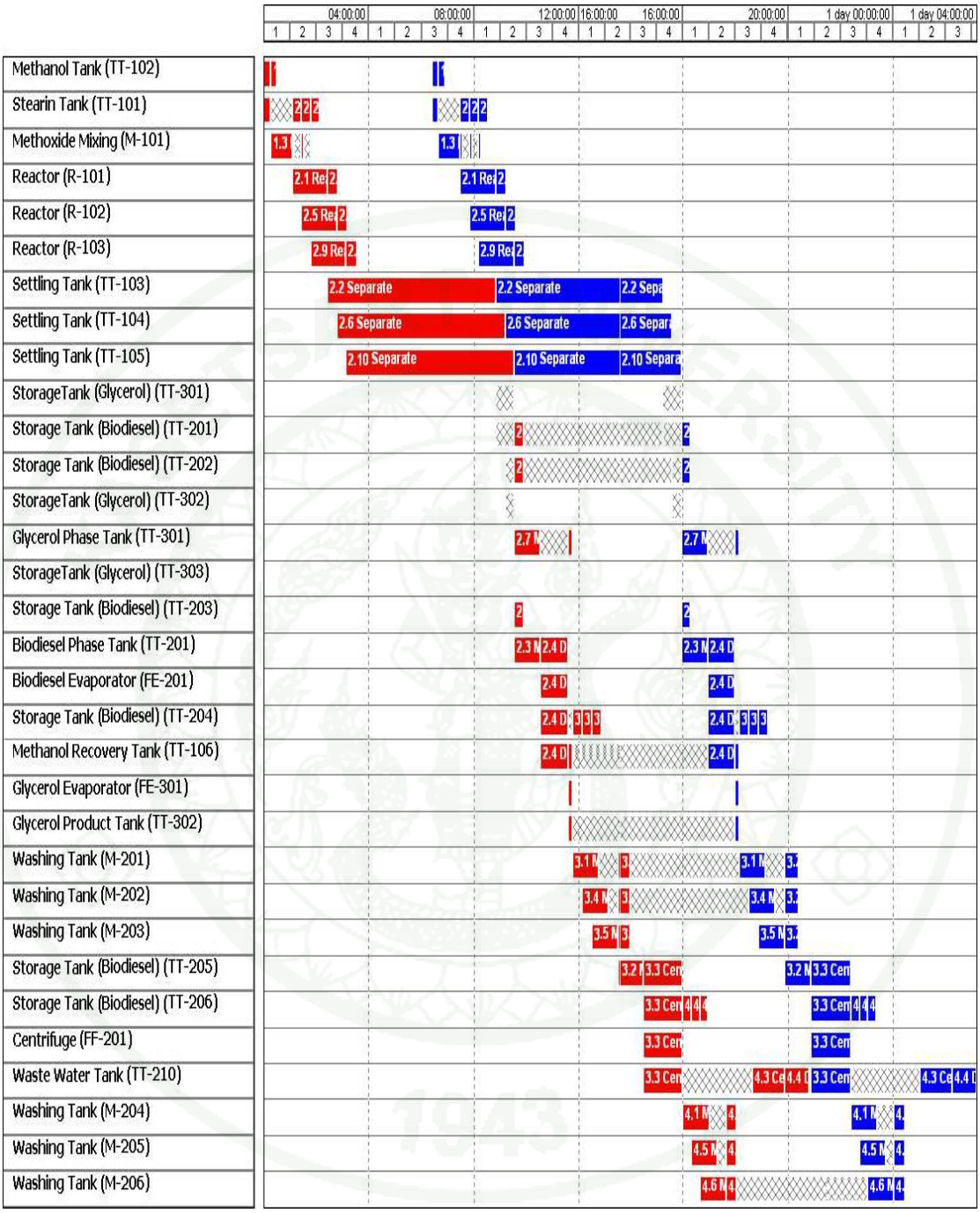
Appendix Figure B16 The schedule of biodiesel production plant B was fixed flowrate at capacity of feedstock 100,000 kg.



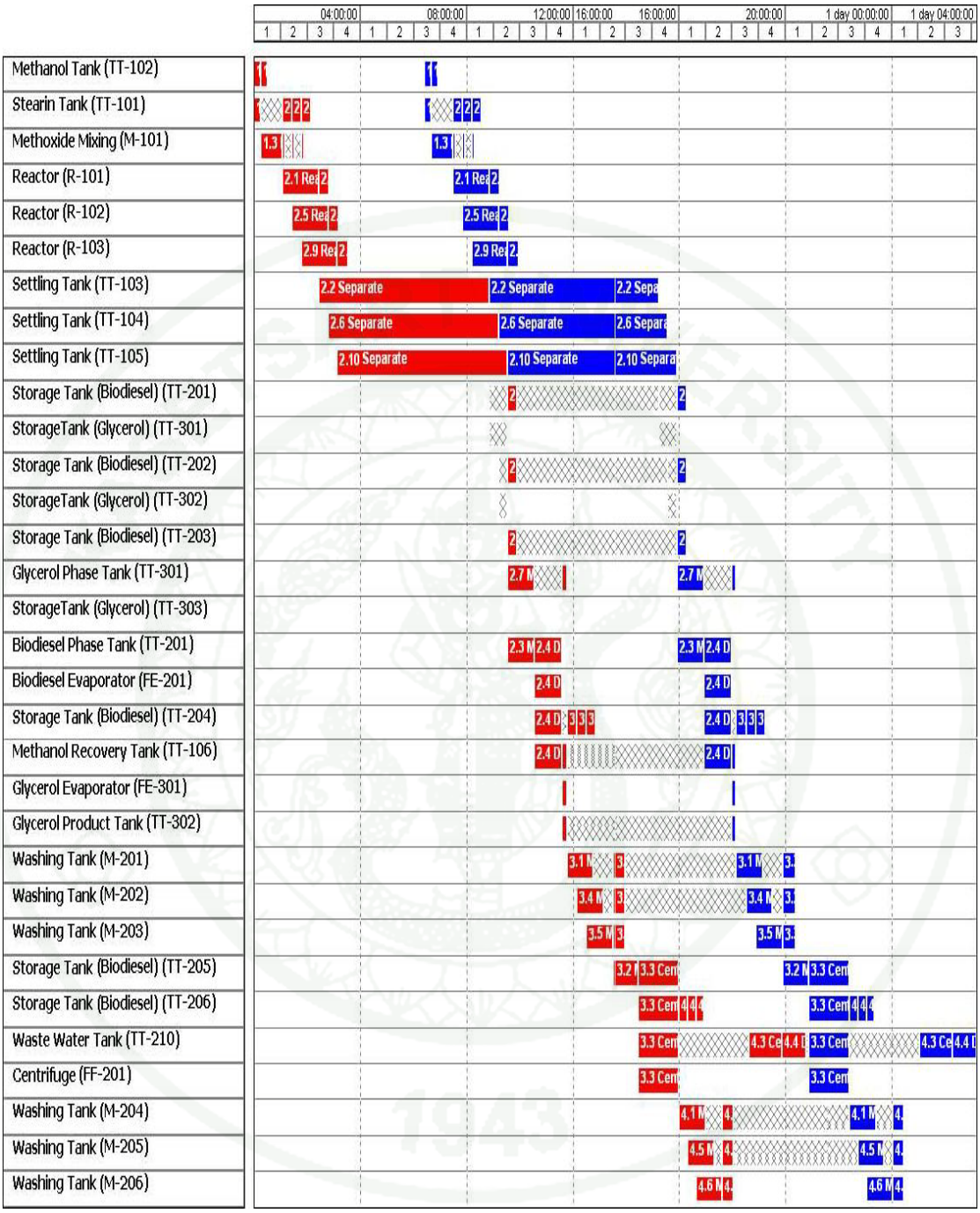
Appendix Figure B17 The schedule of biodiesel production plant B was fixed flowrate at capacity of feedstock 300,000 kg.



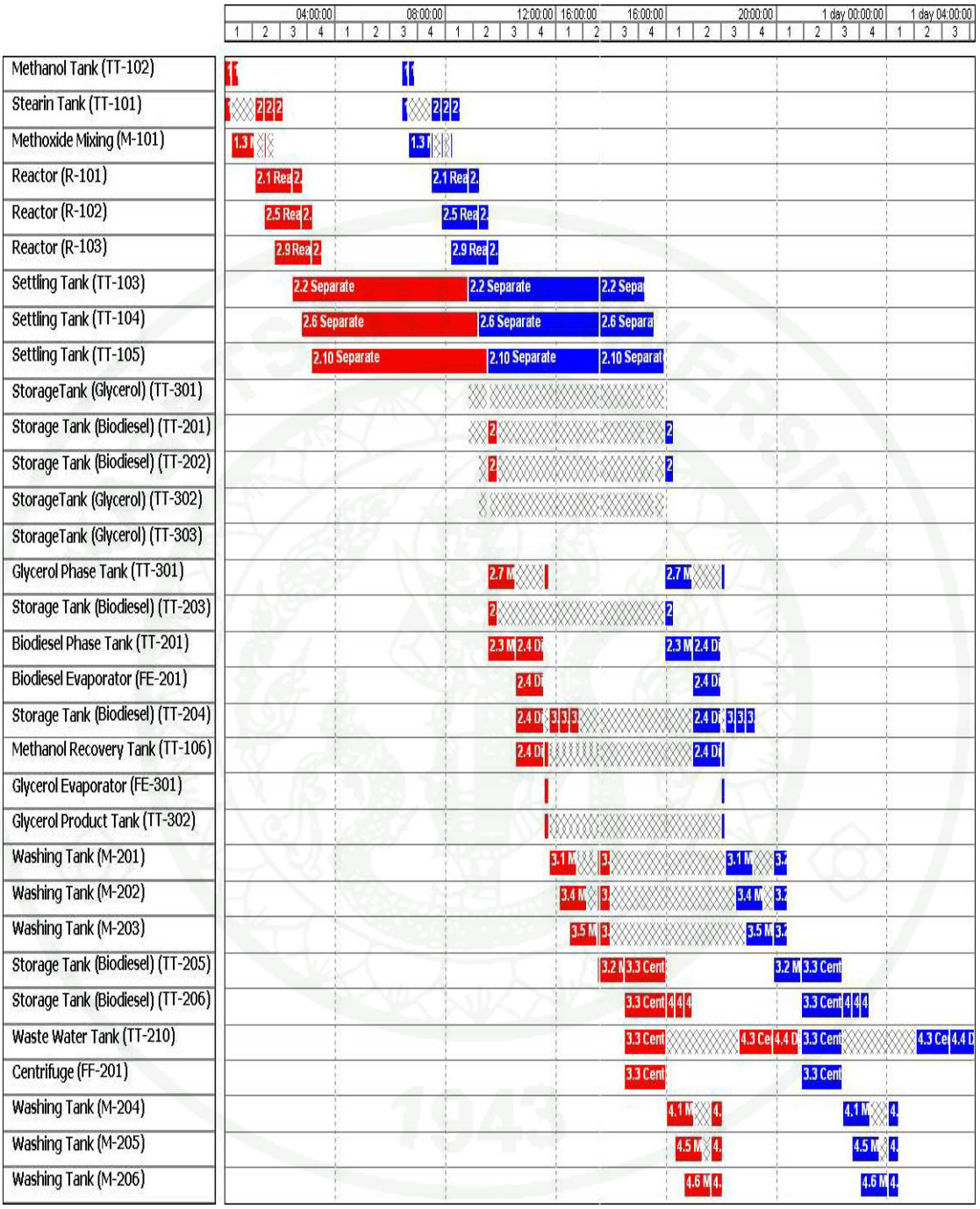
Appendix Figure B18 The schedule of biodiesel production plant B was fixed flowrate at capacity of feedstock 500,000 kg.



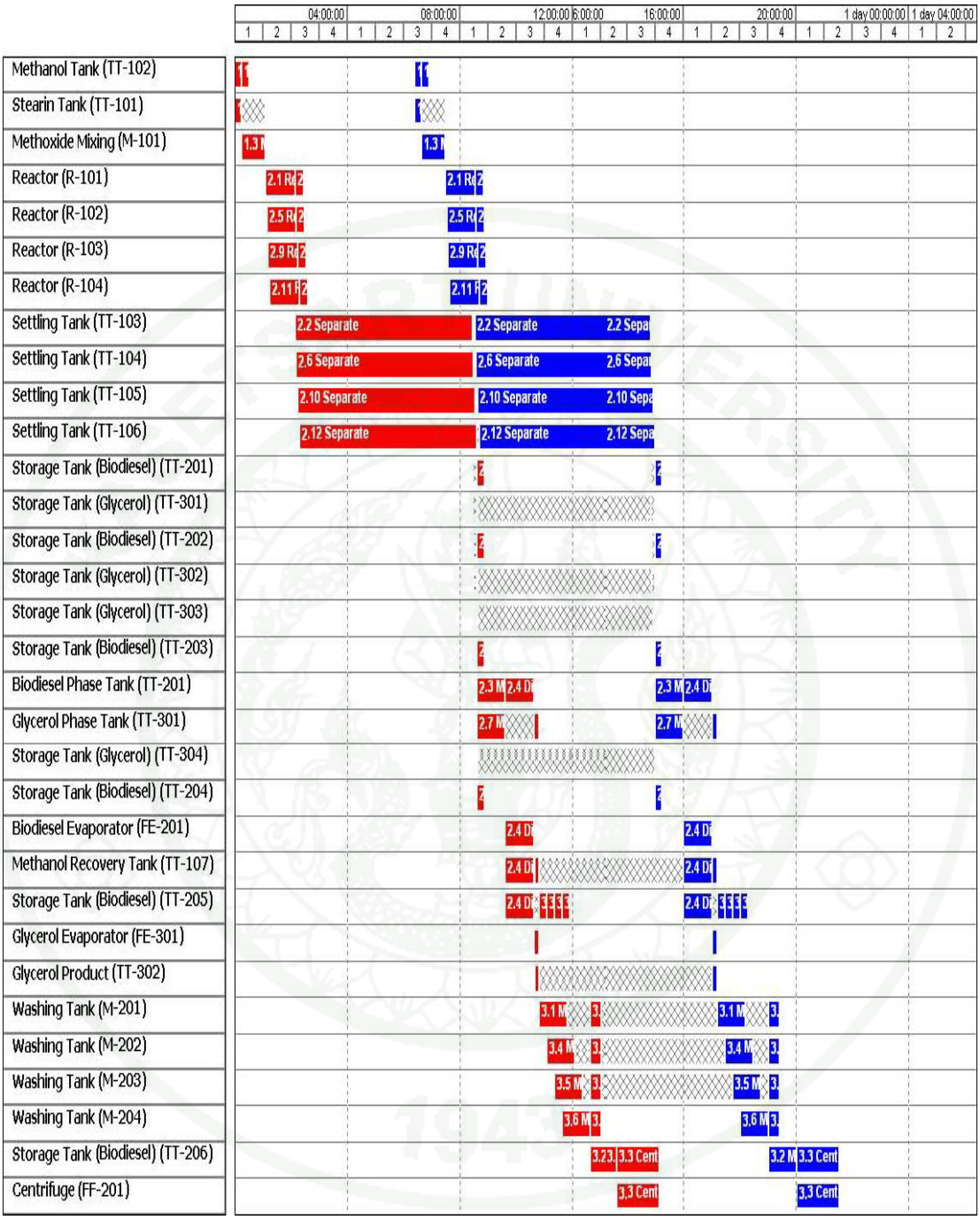
Appendix Figure B19 The schedule of biodiesel production plant C was fixed flowrate at capacity of feedstock 100,000 kg.



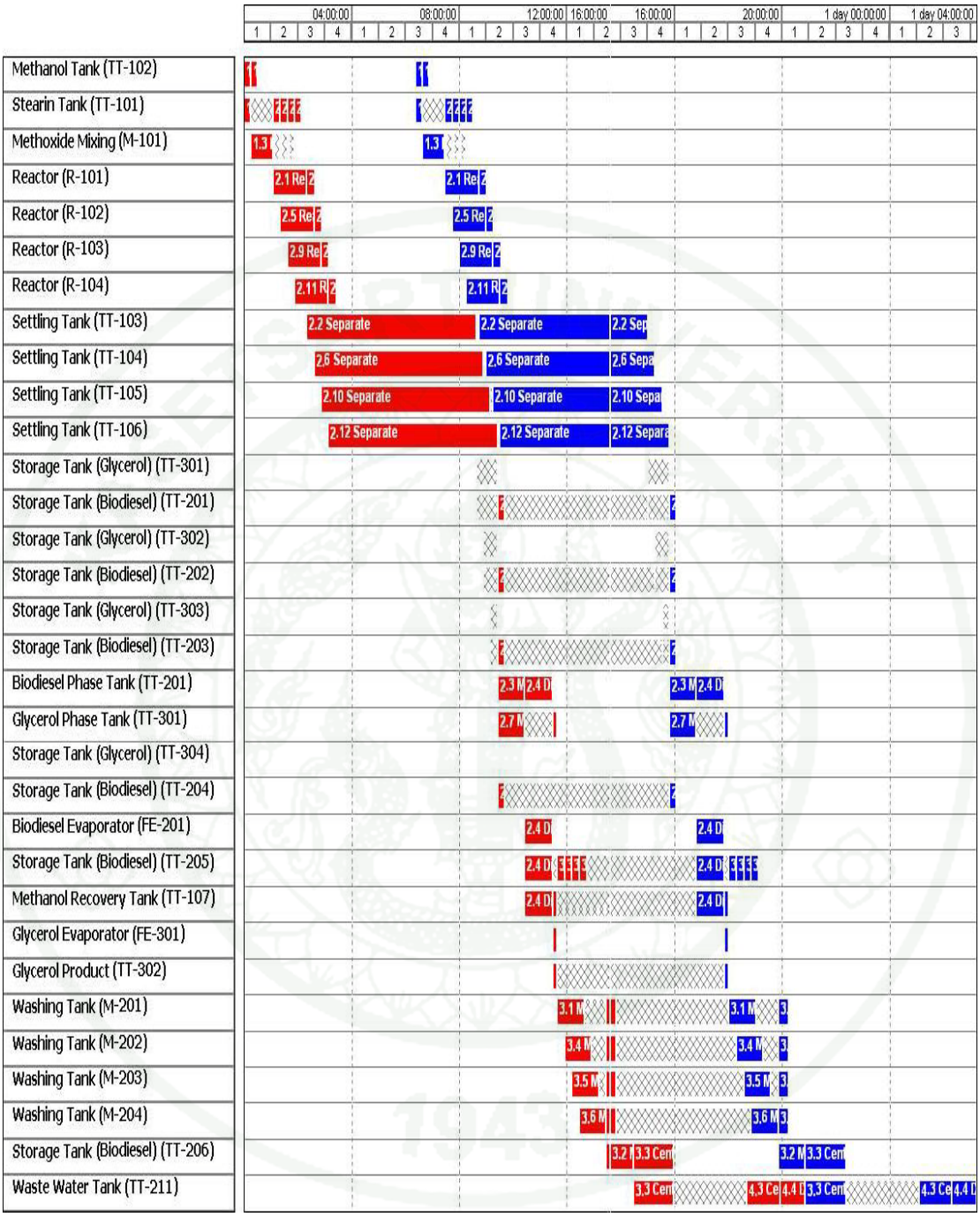
Appendix Figure B20 The schedule of biodiesel production plant C was fixed flowrate at capacity of feedstock 300,000 kg.



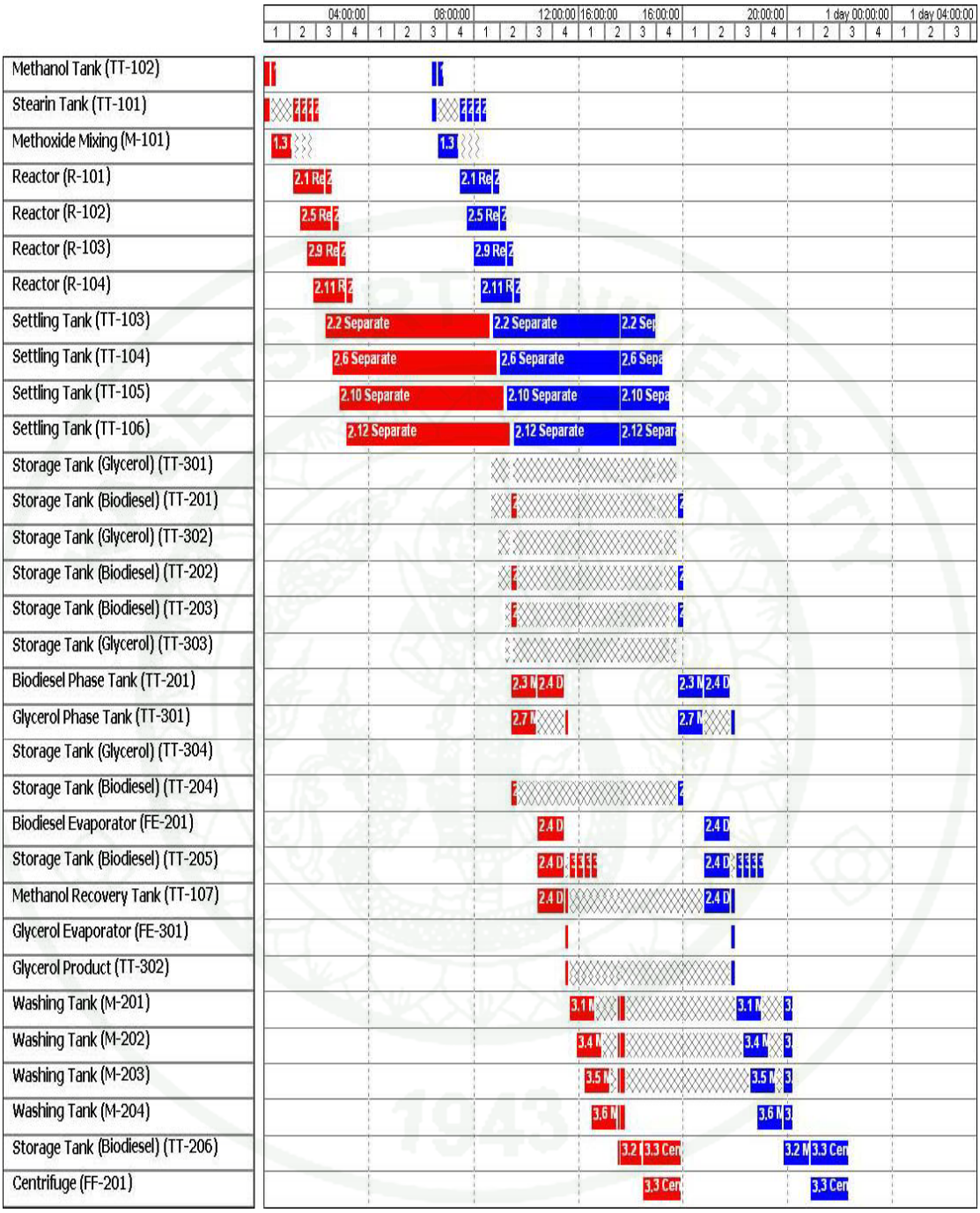
Appendix Figure B21 The schedule of biodiesel production plant C was fixed flowrate at capacity of feedstock 500,000 kg.



Appendix Figure B22 The schedule of biodiesel production plant D was fixed flowrate at capacity of feedstock 100,000 kg.



Appendix Figure B23 The schedule of biodiesel production plant D was fixed flowrate at capacity of feedstock 300,000 kg.

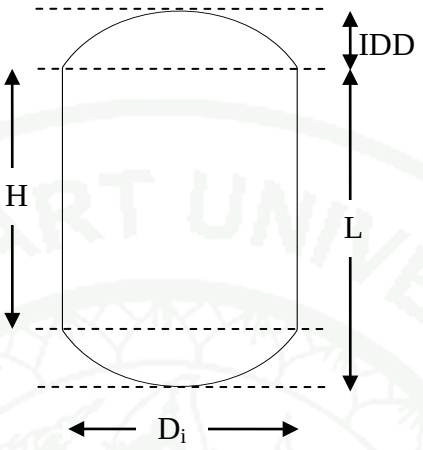


Appendix Figure B24 The schedule of biodiesel production plant D was fixed flowrate at capacity of feedstock 500,000 kg.

Appendix C

Tank design calculation

Appendix C Tank design calculation



Appendix Figure C1 Tank drawing 2 dimension

Volume of liquid in Stearin Tank; V = 526,676.80 L

Over design 20% ; V_{design} = 1.2×526,676.80 L = 632,012.16 L

≈ 632,000 L

Select head and bottom of tank is 2:1 Ellipsodal (Plant design and economies for chemical engineers; Table 12-10)

- Capacity as volume in head, m^3; $\frac{\pi D_a^3}{24}$
- IDD = inside depth of dish, m; $\frac{D_a}{4}$
- Approximate weight of dished portion of head, kg; $\rho_m \frac{\pi\left(nD_a+t\right)^2 t}{4}$

Volume of liquid in cylindrical shell = $\frac{\pi D_i^2 H}{4}$

Assumption: $L = 1.5D_i$

Find D_i of tank;

$$V_{cylinder} + V_{bottom} = V$$

$$\frac{\pi D_i^2 H}{4} + \frac{1}{2}\left(\frac{\pi D_i^3}{24}\right) = 632{,}000 \text{ L}$$

$$\frac{\pi D_i^2}{4}\left(L - \frac{D_i}{4}\right) + \frac{1}{2}\left(\frac{\pi D_i^3}{24}\right) = 632{,}000 \text{ L}$$

$$\frac{\pi D_i^2}{4}\left(1.5D_i - \frac{D_i}{4}\right) + \frac{1}{2}\left(\frac{\pi D_i^3}{24}\right) = 632{,}000 \text{ L}$$

$$\frac{16}{48}\pi D_i^3 = 632 \text{ m}^3$$

$$D_i = 8.45 \text{ m}$$

Find H of tank;

$$\frac{\pi D_i^2 H}{4} + \frac{1}{2}\left(\frac{\pi D_i^3}{24}\right) = 632 \text{ m}^3$$

$$\frac{\pi}{4}(8.45)^2 H + \frac{\pi}{48}(8.45)^3 = 632 \text{ m}^3$$

$$H = 10.57 \text{ m}$$

Find thickness of shell; $t = \dfrac{Pr}{SE - 0.6P}$

Selection carbon steel SG 295; S = 295,000 kPa, E = 0.6

Find pressure;

$$P = P_{atm} + \rho g h$$

$$= (101.325 \text{ kPa}) + \left(990.60 \text{ kg/m}^3\right)\left(9.81 \text{ m/s}^2\right)(12.68 \text{ m}) \times \frac{1 \text{ kPa}}{1{,}000 \text{ Pa}}$$

$$= 224.55 \text{ kPa}$$

Over design 10%; $P_{design} = 1.1 \times 224.55 \text{ kPa} = 247.01 \text{ kPa}$

$$t = \frac{(247.01 \text{ kPa})\left(8.45/2 \text{ m}\right)}{(0.6 \times 295{,}000 \text{ kPa}) - 0.6(247.01 \text{ kPa})}$$

$$= 0.0059 \text{ m} = 5.90 \text{ mm}$$

Appendix D

Motor of reactor and mixing calculation

Appendix D Motor of reactor and mixing calculation

Find power of agitator; from Rule of Thumb for Chemical Engineering

Assumption: liquid is slurrying; tip speed >20 ft/min, Power need 10 HP/1,000 gal

The liquid in tank 146,000 l

$$P = \frac{10\ \text{HP}}{1{,}000\ \text{gal}} \times 146{,}000\ \text{l} \times \frac{264.17\ \text{gal}}{1{,}000\ \text{l}}$$

$$P = 385.68\ \text{HP}$$

The power of agitator 385.68 HP

Find the cost of motor; from Chemical process equipment

Assumption: the type of motor is Open, drip-proof, tip speed 1,800 rpm

$$C = 1.46\exp\left[a_1 + a_2\left(\ln HP\right) + a_3\left(\ln HP\right)^2\right]$$

$$= 1.46\exp\left[4.2432 + 1.03251\left(\ln 385.68\right) - 0.03595\left(\ln 385.68\right)^2\right]$$

$$= 15{,}938.59\ \$$$

$$= 15{,}938.59\ \$ \times \frac{31\text{baht}}{\$}$$

$$= 494{,}096.29\ \text{baht}$$

The cost of motor 494,096.29 baht

Appendix E

Detail of fixed-capital investment and operating cost

Appendix Table E1 Fixed-capital investment and operating cost of plant A at capacity of stearin 100,000 kg in fixed time pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		3,514,303,104	3,514,303,104	3,514,303,104	3,514,303,104	3,514,303,104	3,514,303,104	3,514,303,104
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		47,914,438	47,914,438	47,914,438	47,914,438	47,914,438	47,914,438	47,914,438
Total income		3,562,217,542	3,562,217,542	3,562,217,542	3,562,217,542	3,562,217,542	3,562,217,542	3,562,217,542
Investment cost								
Equipment cost								
1. ten storage tanks	28,331,422							
2. one reactor	2,496,598							
3. three mixing tanks	6,256,857							
4. two centrifuges	16,203,551							
5. three evaporators	10,261,693							
6. fourteen pumps	2,081,100							
Purchased equipment	65,631,221							
Purchased-equipment installation	12,306,000							
Instrumentation and controls (installed)	10,255,000							
Piping (installed)	10,255,000							
Electrical systems (installed)	6,153,000							
Buildings (including services)	8,204,000							
Yard improvement	4,102,000							
Service facilities (installed)	41,020,000							
Land	2,051,000							
Engineering and supervision	18,459,000							
Construction expenses	8,204,000							
Legal expenses	4,102,000							
Contractor's fee	4,102,000							
Contingency	10,255,000							
Total fixed-capital investment	205,099,221							
Manufacturing cost								
Raw materials								
1. stearin		3,330,084,000	3,330,084,000	3,330,084,000	3,330,084,000	3,330,084,000	3,330,084,000	3,330,084,000
2. methanol		150,319,403	150,319,403	150,319,403	150,319,403	150,319,403	150,319,403	150,319,403

Appendix Table E1 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	3,514,303,104	3,514,303,104	3,514,303,104	3,514,303,104	3,514,303,104	3,514,303,104	3,514,303,104	3,514,303,104
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	47,914,438	47,914,438	47,914,438	47,914,438	47,914,438	47,914,438	47,914,438	47,914,438
Total income	3,562,217,542	3,562,217,542	3,562,217,542	3,562,217,542	3,562,217,542	3,562,217,542	3,562,217,542	3,562,217,542
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	3,330,084,000	3,330,084,000	3,330,084,000	3,330,084,000	3,330,084,000	3,330,084,000	3,330,084,000	3,330,084,000
2. methanol	150,319,403	150,319,403	150,319,403	150,319,403	150,319,403	150,319,403	150,319,403	150,319,403
3. potassium hydroxide	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979

Appendix Table E1 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			782,735	782,735	782,735	782,735	782,735	782,735	782,735
Cost of energy			32,676,034	32,676,034	32,676,034	32,676,034	32,676,034	32,676,034	32,676,034
Depreciation			4,922,348	4,922,348	4,922,348	4,922,348	4,922,348	4,922,348	4,922,348
Operating labor			1,296,000	1,334,880	1,374,926	1,416,174	1,458,659	1,502,419	1,547,492
Maintenance and repairs			10,254,961	10,254,961	10,254,961	10,254,961	10,254,961	10,254,961	10,254,961
Total operating cost			3,531,570,112	3,531,608,992	3,531,649,039	3,531,690,286	3,531,732,772	3,531,776,531	3,531,821,604
EBIT			30,647,429	30,608,549	30,568,503	30,527,255	30,484,770	30,441,010	30,395,938
Tax			9,194,229	9,182,565	9,170,551	9,158,177	9,145,431	9,132,303	9,118,781
Net income			21,453,200.57	21,425,984.57	21,397,952.09	21,369,078.63	21,339,338.98	21,308,707.13	21,277,156.33
Net cash flow from operating activities			26,375,548.66	26,348,332.66	26,320,300.18	26,291,426.73	26,261,687.07	26,231,055.22	26,199,504.42
Change in Gross fixed Asset		205,099,221							
Net Cashflow		-205,099,221	26,375,549	26,348,333	26,320,300	26,291,427	26,261,687	26,231,055	26,199,504
Add: Beginning Cashflow			-205,099,221	-178,723,673	-152,375,340	-126,055,040	-99,763,613	-73,501,926	-47,270,871
Ending cashflow		-205,099,221	-178,723,673	-152,375,340	-126,055,040	-99,763,613	-73,501,926	-47,270,871	-21,071,366
NPV	฿63,542,448								
IRR	9.51%								

Appendix Table E1 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	782,735	782,735	782,735	782,735	782,735	782,735	782,735	782,735
Cost of energy	32,676,034	32,676,034	32,676,034	32,676,034	32,676,034	32,676,034	32,676,034	32,676,034
Depreciation	4,922,348	4,922,348	4,922,348	4,922,348	4,922,348	4,922,348	4,922,348	4,922,348
Operating labor	1,593,917	1,641,734	1,690,986	1,741,716	1,793,967	1,847,786	1,903,220	1,960,316
Maintenance and repairs	10,254,961	10,254,961	10,254,961	10,254,961	10,254,961	10,254,961	10,254,961	10,254,961
Total operating cost	3,531,868,029	3,531,915,846	3,531,965,098	3,532,015,828	3,532,068,079	3,532,121,898	3,532,177,332	3,532,234,428
EBIT	30,349,513	30,301,695	30,252,443	30,201,714	30,149,462	30,095,643	30,040,210	29,983,113
Tax	9,104,854	9,090,509	9,075,733	9,060,514	9,044,839	9,028,693	9,012,063	8,994,934
Net income	21,244,659.00	21,211,186.75	21,176,710.34	21,141,199.63	21,104,623.60	21,066,950.29	21,028,146.78	20,988,179.17
Net cash flow from operating activities	26,167,007.09	26,133,534.85	26,099,058.43	26,063,547.72	26,026,971.70	25,989,298.39	25,950,494.88	25,910,527.27
Change in Gross fixed Asset								
Net Cashflow	26,167,007	26,133,535	26,099,058	26,063,548	26,026,972	25,989,298	25,950,495	25,910,527
Add: Beginning Cashflow	-21,071,366	5,095,641	31,229,175	57,328,234	83,391,782	109,418,753	135,408,052	161,358,547
Ending cashflow	5,095,641	31,229,175	57,328,234	83,391,782	109,418,753	135,408,052	161,358,547	187,269,074

Appendix Table E2 Fixed-capital investment and operating cost of plant A at capacity of stearin 300,000 kg in fixed time pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		11,864,445,637	11,864,445,637	11,864,445,637	11,864,445,637	11,864,445,637	11,864,445,637	11,864,445,637
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		161,761,236	161,761,236	161,761,236	161,761,236	161,761,236	161,761,236	161,761,236
Total income		12,026,206,874	12,026,206,874	12,026,206,874	12,026,206,874	12,026,206,874	12,026,206,874	12,026,206,874
Investment cost								
Equipment cost								
1. ten storage tanks	103,913,918							
2. one reactor	8,318,639							
3. three mixing tanks	20,731,474							
4. two centrifuges	28,689,613							
5. three evaporators	10,261,693							
6. fourteen pumps	5,037,900							
Purchased equipment	176,953,237							
Purchased-equipment installation	33,179,000							
Instrumentation and controls (installed)	27,649,000							
Piping (installed)	27,649,000							
Electrical systems (installed)	16,589,000							
Buildings (including services)	22,119,000							
Yard improvement	11,060,000							
Service facilities (installed)	110,596,000							
Land	5,530,000							
Engineering and supervision	49,768,000							
Construction expenses	22,119,000							
Legal expenses	11,060,000							
Contractor's fee	11,060,000							
Contingency	27,649,000							
Total fixed-capital investment	552,980,237							
Manufacturing cost								
Raw materials								
1. stearin		11,242,512,000	11,242,512,000	11,242,512,000	11,242,512,000	11,242,512,000	11,242,512,000	11,242,512,000
2. methanol		507,485,004	507,485,004	507,485,004	507,485,004	507,485,004	507,485,004	507,485,004

Appendix Table E2 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	11,864,445,637	11,864,445,637	11,864,445,637	11,864,445,637	11,864,445,637	11,864,445,637	11,864,445,637	11,864,445,637
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	161,761,236	161,761,236	161,761,236	161,761,236	161,761,236	161,761,236	161,761,236	161,761,236
Total income	12,026,206,874	12,026,206,874	12,026,206,874	12,026,206,874	12,026,206,874	12,026,206,874	12,026,206,874	12,026,206,874
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	11,242,512,000	11,242,512,000	11,242,512,000	11,242,512,000	11,242,512,000	11,242,512,000	11,242,512,000	11,242,512,000
2. methanol	507,485,004	507,485,004	507,485,004	507,485,004	507,485,004	507,485,004	507,485,004	507,485,004
3. potassium hydroxide	20,786,237	20,786,237	20,786,237	20,786,237	20,786,237	20,786,237	20,786,237	20,786,237

Appendix Table E2 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			2,642,540	2,642,540	2,642,540	2,642,540	2,642,540	2,642,540	2,642,540
Cost of energy			87,477,531	87,477,531	87,477,531	87,477,531	87,477,531	87,477,531	87,477,531
Depreciation			13,271,482	13,271,482	13,271,482	13,271,482	13,271,482	13,271,482	13,271,482
Operating labor			1,296,000	1,334,880	1,374,926	1,416,174	1,458,659	1,502,419	1,547,492
Maintenance and repairs			27,649,012	27,649,012	27,649,012	27,649,012	27,649,012	27,649,012	27,649,012
Total operating cost			11,889,848,323	11,889,887,203	11,889,927,250	11,889,968,497	11,890,010,983	11,890,054,742	11,890,099,815
EBIT			136,358,551	136,319,671	136,279,624	136,238,376	136,195,891	136,152,131	136,107,059
Tax			40,907,565	40,895,901	40,883,887	40,871,513	40,858,767	40,845,639	40,832,118
Net income			95,450,985.38	95,423,769.38	95,395,736.90	95,366,863.44	95,337,123.79	95,306,491.94	95,274,941.14
Net cash flow from operating activities			108,722,467.84	108,695,251.84	108,667,219.36	108,638,345.91	108,608,606.25	108,577,974.40	108,546,423.60
Change in Gross fixed Asset		552,980,237							
Net Cashflow		-552,980,237	108,722,468	108,695,252	108,667,219	108,638,346	108,608,606	108,577,974	108,546,424
Add: Beginning Cashflow			-552,980,237	-444,257,769	-335,562,517	-226,895,298	-118,256,952	-9,648,346	98,929,629
Ending cashflow		-552,980,237	-444,257,769	-335,562,517	-226,895,298	-118,256,952	-9,648,346	98,929,629	207,476,052
NPV	฿546,258,492								
IRR	18.00%								

Appendix Table E2 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	2,642,540	2,642,540	2,642,540	2,642,540	2,642,540	2,642,540	2,642,540	2,642,540
Cost of energy	87,477,531	87,477,531	87,477,531	87,477,531	87,477,531	87,477,531	87,477,531	87,477,531
Depreciation	13,271,482	13,271,482	13,271,482	13,271,482	13,271,482	13,271,482	13,271,482	13,271,482
Operating labor	1,593,917	1,641,734	1,690,986	1,741,716	1,793,967	1,847,786	1,903,220	1,960,316
Maintenance and repairs	27,649,012	27,649,012	27,649,012	27,649,012	27,649,012	27,649,012	27,649,012	27,649,012
Total operating cost	11,890,146,240	11,890,194,057	11,890,243,309	11,890,294,039	11,890,346,290	11,890,400,109	11,890,455,543	11,890,512,639
EBIT	136,060,634	136,012,817	135,963,564	135,912,835	135,860,583	135,806,764	135,751,331	135,694,234
Tax	40,818,190	40,803,845	40,789,069	40,773,850	40,758,175	40,742,029	40,725,399	40,708,270
Net income	95,242,443.81	95,208,971.56	95,174,495.15	95,138,984.44	95,102,408.41	95,064,735.10	95,025,931.59	94,985,963.98
Net cash flow from operating activities	108,513,926.27	108,480,454.03	108,445,977.61	108,410,466.90	108,373,890.88	108,336,217.57	108,297,414.06	108,257,446.45
Change in Gross fixed Asset								
Net Cashflow	108,513,926	108,480,454	108,445,978	108,410,467	108,373,891	108,336,218	108,297,414	108,257,446
Add: Beginning Cashflow	207,476,052	315,989,979	424,470,433	532,916,410	641,326,877	749,700,768	858,036,986	966,334,400
Ending cashflow	315,989,979	424,470,433	532,916,410	641,326,877	749,700,768	858,036,986	966,334,400	1,074,591,846

Appendix Table E3 Fixed-capital investment and operating cost of plant A at capacity of stearin 500,000 kg in fixed time pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		19,774,078,372	19,774,078,372	19,774,078,372	19,774,078,372	19,774,078,372	19,774,078,372	19,774,078,372
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		269,602,088	269,602,088	269,602,088	269,602,088	269,602,088	269,602,088	269,602,088
Total income		20,043,680,459	20,043,680,459	20,043,680,459	20,043,680,459	20,043,680,459	20,043,680,459	20,043,680,459
Investment cost								
Equipment cost								
1. ten storage tanks	192,291,787							
2. one reactor	15,038,664							
3. three mixing tanks	37,461,538							
4. two centrifuges	37,417,913							
5. three evaporators	30,016,695							
6. fourteen pumps	8,167,200							
Purchased equipment	320,393,796							
Purchased-equipment installation	60,074,000							
Instrumentation and controls (installed)	50,062,000							
Piping (installed)	50,062,000							
Electrical systems (installed)	30,037,000							
Buildings (including services)	40,049,000							
Yard improvement	20,025,000							
Service facilities (installed)	200,246,000							
Land	10,012,000							
Engineering and supervision	90,111,000							
Construction expenses	40,049,000							
Legal expenses	20,025,000							
Contractor's fee	20,025,000							
Contingency	50,062,000							
Total fixed-capital investment	1,001,232,796							
Manufacturing cost								
Raw materials								
1. stearin		18,737,520,000	18,737,520,000	18,737,520,000	18,737,520,000	18,737,520,000	18,737,520,000	18,737,520,000
2. methanol		845,808,340	845,808,340	845,808,340	845,808,340	845,808,340	845,808,340	845,808,340

Appendix Table E3 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	19,774,078,372	19,774,078,372	19,774,078,372	19,774,078,372	19,774,078,372	19,774,078,372	19,774,078,372	19,774,078,372
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	269,602,088	269,602,088	269,602,088	269,602,088	269,602,088	269,602,088	269,602,088	269,602,088
Total income	20,043,680,459	20,043,680,459	20,043,680,459	20,043,680,459	20,043,680,459	20,043,680,459	20,043,680,459	20,043,680,459
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	18,737,520,000	18,737,520,000	18,737,520,000	18,737,520,000	18,737,520,000	18,737,520,000	18,737,520,000	18,737,520,000
2. methanol	845,808,340	845,808,340	845,808,340	845,808,340	845,808,340	845,808,340	845,808,340	845,808,340
3. potassium hydroxide	34,643,728	34,643,728	34,643,728	34,643,728	34,643,728	34,643,728	34,643,728	34,643,728

Appendix Table E3 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			4,404,351	4,404,351	4,404,351	4,404,351	4,404,351	4,404,351	4,404,351
Cost of energy			124,234,098	124,234,098	124,234,098	124,234,098	124,234,098	124,234,098	124,234,098
Depreciation			24,029,520	24,029,520	24,029,520	24,029,520	24,029,520	24,029,520	24,029,520
Operating labor			1,296,000	1,334,880	1,374,926	1,416,174	1,458,659	1,502,419	1,547,492
Maintenance and repairs			50,061,640	50,061,640	50,061,640	50,061,640	50,061,640	50,061,640	50,061,640
Total operating cost			19,797,968,157	19,798,007,037	19,798,047,083	19,798,088,331	19,798,130,816	19,798,174,576	19,798,219,649
EBIT			245,712,302	245,673,422	245,633,376	245,592,128	245,549,643	245,505,883	245,460,810
Tax			73,713,691	73,702,027	73,690,013	73,677,638	73,664,893	73,651,765	73,638,243
Net income			171,998,611.56	171,971,395.56	171,943,363.08	171,914,489.62	171,884,749.96	171,854,118.12	171,822,567.31
Net cash flow from operating activities			196,028,131.32	196,000,915.32	195,972,882.84	195,944,009.38	195,914,269.72	195,883,637.88	195,852,087.07
Change in Gross fixed Asset		1,001,232,796							
Net Cashflow		-1,001,232,796	196,028,131	196,000,915	195,972,883	195,944,009	195,914,270	195,883,638	195,852,087
Add: Beginning Cashflow			-1,001,232,796	-805,204,665	-609,203,750	-413,230,867	-217,286,858	-21,372,588	174,511,050
Ending cashflow		-1,001,232,796	-805,204,665	-609,203,750	-413,230,867	-217,286,858	-21,372,588	174,511,050	370,363,137
NPV	฿982,401,704								
IRR	17.91%								

Appendix Table E3 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	4,404,351	4,404,351	4,404,351	4,404,351	4,404,351	4,404,351	4,404,351	4,404,351
Cost of energy	124,234,098	124,234,098	124,234,098	124,234,098	124,234,098	124,234,098	124,234,098	124,234,098
Depreciation	24,029,520	24,029,520	24,029,520	24,029,520	24,029,520	24,029,520	24,029,520	24,029,520
Operating labor	1,593,917	1,641,734	1,690,986	1,741,716	1,793,967	1,847,786	1,903,220	1,960,316
Maintenance and repairs	50,061,640	50,061,640	50,061,640	50,061,640	50,061,640	50,061,640	50,061,640	50,061,640
Total operating cost	19,798,266,074	19,798,313,891	19,798,363,143	19,798,413,873	19,798,466,124	19,798,519,943	19,798,575,377	19,798,632,473
EBIT	245,414,386	245,366,568	245,317,316	245,266,587	245,214,335	245,160,516	245,105,083	245,047,986
Tax	73,624,316	73,609,970	73,595,195	73,579,976	73,564,301	73,548,155	73,531,525	73,514,396
Net income	171,790,069.99	171,756,597.74	171,722,121.32	171,686,610.62	171,650,034.59	171,612,361.28	171,573,557.77	171,533,590.16
Net cash flow from operating activities	195,819,589.74	195,786,117.50	195,751,641.08	195,716,130.38	195,679,554.35	195,641,881.04	195,603,077.53	195,563,109.92
Change in Gross fixed Asset								
Net Cashflow	195,819,590	195,786,117	195,751,641	195,716,130	195,679,554	195,641,881	195,603,078	195,563,110
Add: Beginning Cashflow	370,363,137	566,182,727	761,968,844	957,720,485	1,153,436,616	1,349,116,170	1,544,758,051	1,740,361,129
Ending cashflow	566,182,727	761,968,844	957,720,485	1,153,436,616	1,349,116,170	1,544,758,051	1,740,361,129	1,935,924,239

Appendix Table E4 Fixed-capital investment and operating cost of plant B at capacity of stearin 100,000 kg in fixed time pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		3,954,815,068	3,954,815,068	3,954,815,068	3,954,815,068	3,954,815,068	3,954,815,068	3,954,815,068
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		53,920,426	53,920,426	53,920,426	53,920,426	53,920,426	53,920,426	53,920,426
Total income		4,008,735,494	4,008,735,494	4,008,735,494	4,008,735,494	4,008,735,494	4,008,735,494	4,008,735,494
Investment cost								
Equipment cost								
1. ten storage tanks	37,047,583							
2. one reactor	2,479,424							
3. three mixing tanks	6,163,785							
4. two centrifuges	16,203,551							
5. three evaporators	10,261,696							
6. fourteen pumps	2,584,500							
Purchased equipment	74,740,539							
Purchased-equipment installation	14,014,000							
Instrumentation and controls (installed)	11,678,000							
Piping (installed)	11,678,000							
Electrical systems (installed)	7,007,000							
Buildings (including services)	9,343,000							
Yard improvement	4,671,000							
Service facilities (installed)	46,713,000							
Land	2,336,000							
Engineering and supervision	21,021,000							
Construction expenses	9,343,000							
Legal expenses	4,671,000							
Contractor's fee	4,671,000							
Contingency	11,678,000							
Total fixed-capital investment	233,564,539							
Manufacturing cost								
Raw materials								
1. stearin		3,747,504,000	3,747,504,000	3,747,504,000	3,747,504,000	3,747,504,000	3,747,504,000	3,747,504,000
2. methanol		169,161,668	169,161,668	169,161,668	169,161,668	169,161,668	169,161,668	169,161,668

Appendix Table E4 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	3,954,815,068	3,954,815,068	3,954,815,068	3,954,815,068	3,954,815,068	3,954,815,068	3,954,815,068	3,954,815,068
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	53,920,426	53,920,426	53,920,426	53,920,426	53,920,426	53,920,426	53,920,426	53,920,426
Total income	4,008,735,494	4,008,735,494	4,008,735,494	4,008,735,494	4,008,735,494	4,008,735,494	4,008,735,494	4,008,735,494
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	3,747,504,000	3,747,504,000	3,747,504,000	3,747,504,000	3,747,504,000	3,747,504,000	3,747,504,000	3,747,504,000
2. methanol	169,161,668	169,161,668	169,161,668	169,161,668	169,161,668	169,161,668	169,161,668	169,161,668
3. potassium hydroxide	6,928,746	6,928,746	6,928,746	6,928,746	6,928,746	6,928,746	6,928,746	6,928,746

Appendix Table E4 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			880,849	880,849	880,849	880,849	880,849	880,849	880,849
Cost of energy			35,788,142	35,788,142	35,788,142	35,788,142	35,788,142	35,788,142	35,788,142
Depreciation			5,605,569	5,605,569	5,605,569	5,605,569	5,605,569	5,605,569	5,605,569
Operating labor			1,728,000	1,779,840	1,833,235	1,888,232	1,944,879	2,003,226	2,063,322
Maintenance and repairs			11,678,227	11,678,227	11,678,227	11,678,227	11,678,227	11,678,227	11,678,227
Total operating cost			3,973,669,632	3,973,721,472	3,973,774,867	3,973,829,864	3,973,886,511	3,973,944,857	3,974,004,954
EBIT			35,065,862	35,014,022	34,960,627	34,905,630	34,848,983	34,790,636	34,730,540
Tax			10,519,759	10,504,207	10,488,188	10,471,689	10,454,695	10,437,191	10,419,162
Net income			24,546,103.45	24,509,815.45	24,472,438.81	24,433,940.87	24,394,287.99	24,353,445.53	24,311,377.79
Net cash flow from operating activities			30,151,672.72	30,115,384.72	30,078,008.08	30,039,510.14	29,999,857.26	29,959,014.80	29,916,947.06
Change in Gross fixed Asset		233,564,539							
Net Cashflow		-233,564,539	30,151,673	30,115,385	30,078,008	30,039,510	29,999,857	29,959,015	29,916,947
Add: Beginning Cashflow			-233,564,539	-203,412,866	-173,297,482	-143,219,474	-113,179,963	-83,180,106	-53,221,091
Ending cashflow		-233,564,539	-203,412,866	-173,297,482	-143,219,474	-113,179,963	-83,180,106	-53,221,091	-23,304,144
NPV	฿73,141,906								
IRR	9.56%								

Appendix Table E4 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	880,849	880,849	880,849	880,849	880,849	880,849	880,849	880,849
Cost of energy	35,788,142	35,788,142	35,788,142	35,788,142	35,788,142	35,788,142	35,788,142	35,788,142
Depreciation	5,605,569	5,605,569	5,605,569	5,605,569	5,605,569	5,605,569	5,605,569	5,605,569
Operating labor	2,125,222	2,188,979	2,254,648	2,322,288	2,391,956	2,463,715	2,537,626	2,613,755
Maintenance and repairs	11,678,227	11,678,227	11,678,227	11,678,227	11,678,227	11,678,227	11,678,227	11,678,227
Total operating cost	3,974,066,854	3,974,130,610	3,974,196,280	3,974,263,919	3,974,333,588	3,974,405,346	3,974,479,258	3,974,555,387
EBIT	34,668,640	34,604,883	34,539,214	34,471,575	34,401,906	34,330,147	34,256,236	34,180,107
Tax	10,400,592	10,381,465	10,361,764	10,341,472	10,320,572	10,299,044	10,276,871	10,254,032
Net income	24,268,048.02	24,223,418.36	24,177,449.81	24,130,102.20	24,081,334.16	24,031,103.08	23,979,365.07	23,926,074.92
Net cash flow from operating activities	29,873,617.29	29,828,987.63	29,783,019.08	29,735,671.47	29,686,903.43	29,636,672.35	29,584,934.34	29,531,644.19
Change in Gross fixed Asset								
Net Cashflow	29,873,617	29,828,988	29,783,019	29,735,671	29,686,903	29,636,672	29,584,934	29,531,644
Add: Beginning Cashflow	-23,304,144	6,569,473	36,398,461	66,181,480	95,917,151	125,604,055	155,240,727	184,825,661
Ending cashflow	6,569,473	36,398,461	66,181,480	95,917,151	125,604,055	155,240,727	184,825,661	214,357,305

Appendix Table E5 Fixed-capital investment and operating cost of plant B at capacity of stearin 300,000 kg in fixed time pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		11,864,443,039	11,864,443,039	11,864,443,039	11,864,443,039	11,864,443,039	11,864,443,039	11,864,443,039
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		161,761,236	161,761,236	161,761,236	161,761,236	161,761,236	161,761,236	161,761,236
Total income		12,026,204,276	12,026,204,276	12,026,204,276	12,026,204,276	12,026,204,276	12,026,204,276	12,026,204,276
Investment cost								
Equipment cost								
1. ten storage tanks	134,191,442							
2. one reactor	7,693,497							
3. three mixing tanks	19,150,494							
4. two centrifuges	28,689,613							
5. three evaporators	22,259,522							
6. fourteen pumps	5,456,400							
Purchased equipment	217,440,968							
Purchased-equipment installation	40,770,000							
Instrumentation and controls (installed)	33,975,000							
Piping (installed)	33,975,000							
Electrical systems (installed)	20,385,000							
Buildings (including services)	27,180,000							
Yard improvement	13,590,000							
Service facilities (installed)	135,901,000							
Land	6,795,000							
Engineering and supervision	61,155,000							
Construction expenses	27,180,000							
Legal expenses	13,590,000							
Contractor's fee	13,590,000							
Contingency	33,975,000							
Total fixed-capital investment	679,501,968							
Manufacturing cost								
Raw materials								
1. stearin		11,242,512,000	11,242,512,000	11,242,512,000	11,242,512,000	11,242,512,000	11,242,512,000	11,242,512,000
2. methanol		507,485,004	507,485,004	507,485,004	507,485,004	507,485,004	507,485,004	507,485,004

Appendix Table E5 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	11,864,443,039	11,864,443,039	11,864,443,039	11,864,443,039	11,864,443,039	11,864,443,039	11,864,443,039	11,864,443,039
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	161,761,236	161,761,236	161,761,236	161,761,236	161,761,236	161,761,236	161,761,236	161,761,236
Total income	12,026,204,276	12,026,204,276	12,026,204,276	12,026,204,276	12,026,204,276	12,026,204,276	12,026,204,276	12,026,204,276
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	11,242,512,000	11,242,512,000	11,242,512,000	11,242,512,000	11,242,512,000	11,242,512,000	11,242,512,000	11,242,512,000
2. methanol	507,485,004	507,485,004	507,485,004	507,485,004	507,485,004	507,485,004	507,485,004	507,485,004
3. potassium hydroxide	20,786,237	20,786,237	20,786,237	20,786,237	20,786,237	20,786,237	20,786,237	20,786,237

Appendix Table E5 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			2,642,540	2,642,540	2,642,540	2,642,540	2,642,540	2,642,540	2,642,540
Cost of energy			89,369,540	89,369,540	89,369,540	89,369,540	89,369,540	89,369,540	89,369,540
Depreciation			16,308,065	16,308,065	16,308,065	16,308,065	16,308,065	16,308,065	16,308,065
Operating labor			1,728,000	1,779,840	1,833,235	1,888,232	1,944,879	2,003,226	2,063,322
Maintenance and repairs			33,975,098	33,975,098	33,975,098	33,975,098	33,975,098	33,975,098	33,975,098
Total operating cost			11,898,498,419	11,898,550,259	11,898,603,654	11,898,658,651	11,898,715,298	11,898,773,644	11,898,833,741
EBIT			127,705,857	127,654,017	127,600,622	127,545,624	127,488,978	127,430,631	127,370,534
Tax			38,311,757	38,296,205	38,280,186	38,263,687	38,246,693	38,229,189	38,211,160
Net income			89,394,099.72	89,357,811.72	89,320,435.08	89,281,937.14	89,242,284.26	89,201,441.80	89,159,374.06
Net cash flow from operating activities			105,702,164.23	105,665,876.23	105,628,499.59	105,590,001.65	105,550,348.78	105,509,506.31	105,467,438.58
Change in Gross fixed Asset		679,501,968							
Net Cashflow		-679,501,968	105,702,164	105,665,876	105,628,500	105,590,002	105,550,349	105,509,506	105,467,439
Add: Beginning Cashflow			-679,501,968	-573,799,803	-468,133,927	-362,505,428	-256,915,426	-151,365,077	-45,855,571
Ending cashflow		-679,501,968	-573,799,803	-468,133,927	-362,505,428	-256,915,426	-151,365,077	-45,855,571	59,611,868
NPV	฿395,285,561								
IRR	13.07%								

Appendix Table E5 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	2,642,540	2,642,540	2,642,540	2,642,540	2,642,540	2,642,540	2,642,540	2,642,540
Cost of energy	89,369,540	89,369,540	89,369,540	89,369,540	89,369,540	89,369,540	89,369,540	89,369,540
Depreciation	16,308,065	16,308,065	16,308,065	16,308,065	16,308,065	16,308,065	16,308,065	16,308,065
Operating labor	2,125,222	2,188,979	2,254,648	2,322,288	2,391,956	2,463,715	2,537,626	2,613,755
Maintenance and repairs	33,975,098	33,975,098	33,975,098	33,975,098	33,975,098	33,975,098	33,975,098	33,975,098
Total operating cost	11,898,895,641	11,898,959,397	11,899,025,067	11,899,092,706	11,899,162,375	11,899,234,134	11,899,308,045	11,899,384,174
EBIT	127,308,635	127,244,878	127,179,209	127,111,569	127,041,901	126,970,142	126,896,230	126,820,102
Tax	38,192,590	38,173,463	38,153,763	38,133,471	38,112,570	38,091,043	38,068,869	38,046,031
Net income	89,116,044.29	89,071,414.63	89,025,446.08	88,978,098.47	88,929,330.43	88,879,099.35	88,827,361.34	88,774,071.19
Net cash flow from operating activities	105,424,108.81	105,379,479.14	105,333,510.59	105,286,162.98	105,237,394.94	105,187,163.86	105,135,425.85	105,082,135.70
Change in Gross fixed Asset								
Net Cashflow	105,424,109	105,379,479	105,333,511	105,286,163	105,237,395	105,187,164	105,135,426	105,082,136
Add: Beginning Cashflow	59,611,868	165,035,976	270,415,456	375,748,966	481,035,129	586,272,524	691,459,688	796,595,114
Ending cashflow	165,035,976	270,415,456	375,748,966	481,035,129	586,272,524	691,459,688	796,595,114	901,677,250

Appendix Table E6 Fixed-capital investment and operating cost of plant B at capacity of stearin 500,000 kg in fixed time pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		19,774,072,742	19,774,072,742	19,774,072,742	19,774,072,742	19,774,072,742	19,774,072,742	19,774,072,742
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		269,602,088	269,602,088	269,602,088	269,602,088	269,602,088	269,602,088	269,602,088
Total income		20,043,674,830	20,043,674,830	20,043,674,830	20,043,674,830	20,043,674,830	20,043,674,830	20,043,674,830
Investment cost								
Equipment cost								
1. ten storage tanks	247,120,251							
2. one reactor	13,532,384							
3. three mixing tanks	33,770,454							
4. two centrifuges	37,417,913							
5. three evaporators	30,016,696							
6. fourteen pumps	9,155,400							
Purchased equipment	371,013,098							
Purchased-equipment installation	69,565,000							
Instrumentation and controls (installed)	57,971,000							
Piping (installed)	57,971,000							
Electrical systems (installed)	34,782,000							
Buildings (including services)	46,377,000							
Yard improvement	23,188,000							
Service facilities (installed)	231,883,000							
Land	11,594,000							
Engineering and supervision	104,347,000							
Construction expenses	46,377,000							
Legal expenses	23,188,000							
Contractor's fee	23,188,000							
Contingency	57,971,000							
Total fixed-capital investment	1,159,415,098							
Manufacturing cost								
Raw materials								
1. stearin		18,737,520,000	18,737,520,000	18,737,520,000	18,737,520,000	18,737,520,000	18,737,520,000	18,737,520,000
2. methanol		845,808,340	845,808,340	845,808,340	845,808,340	845,808,340	845,808,340	845,808,340

Appendix Table E6 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	19,774,072,742	19,774,072,742	19,774,072,742	19,774,072,742	19,774,072,742	19,774,072,742	19,774,072,742	19,774,072,742
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	269,602,088	269,602,088	269,602,088	269,602,088	269,602,088	269,602,088	269,602,088	269,602,088
Total income	20,043,674,830	20,043,674,830	20,043,674,830	20,043,674,830	20,043,674,830	20,043,674,830	20,043,674,830	20,043,674,830
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	18,737,520,000	18,737,520,000	18,737,520,000	18,737,520,000	18,737,520,000	18,737,520,000	18,737,520,000	18,737,520,000
2. methanol	845,808,340	845,808,340	845,808,340	845,808,340	845,808,340	845,808,340	845,808,340	845,808,340
3. potassium hydroxide	34,643,728	34,643,728	34,643,728	34,643,728	34,643,728	34,643,728	34,643,728	34,643,728

Appendix Table E6 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979
Cost of energy			127,516,189	127,516,189	127,516,189	127,516,189	127,516,189	127,516,189	127,516,189
Depreciation			27,826,007	27,826,007	27,826,007	27,826,007	27,826,007	27,826,007	27,826,007
Operating labor			1,728,000	1,779,840	1,833,235	1,888,232	1,944,879	2,003,226	2,063,322
Maintenance and repairs			57,970,755	57,970,755	57,970,755	57,970,755	57,970,755	57,970,755	57,970,755
Total operating cost			19,809,591,363	19,809,643,203	19,809,696,598	19,809,751,595	19,809,808,242	19,809,866,589	19,809,926,685
EBIT			234,083,467	234,031,627	233,978,232	233,923,235	233,866,588	233,808,241	233,748,144
Tax			70,225,040	70,209,488	70,193,469	70,176,970	70,159,976	70,142,472	70,124,443
Net income			163,858,426.76	163,822,138.76	163,784,762.12	163,746,264.18	163,706,611.30	163,665,768.84	163,623,701.10
Net cash flow from operating activities			191,684,433.27	191,648,145.27	191,610,768.63	191,572,270.69	191,532,617.82	191,491,775.35	191,449,707.62
Change in Gross fixed Asset		1,159,415,098							
Net Cashflow		-1,159,415,098	191,684,433	191,648,145	191,610,769	191,572,271	191,532,618	191,491,775	191,449,708
Add: Beginning Cashflow			-1,159,415,098	-967,730,664	-776,082,519	-584,471,751	-392,899,480	-201,366,862	-9,875,087
Ending cashflow		-1,159,415,098	-967,730,664	-776,082,519	-584,471,751	-392,899,480	-201,366,862	-9,875,087	181,574,621
NPV	฿788,193,580								
IRR	14.29%								

Appendix Table E6 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	4,404,351	4,404,351	4,404,351	4,404,351	4,404,351	4,404,351	4,404,351	4,404,351
Cost of energy	127,516,189	127,516,189	127,516,189	127,516,189	127,516,189	127,516,189	127,516,189	127,516,189
Depreciation	27,826,007	27,826,007	27,826,007	27,826,007	27,826,007	27,826,007	27,826,007	27,826,007
Operating labor	2,125,222	2,188,979	2,254,648	2,322,288	2,391,956	2,463,715	2,537,626	2,613,755
Maintenance and repairs	57,970,755	57,970,755	57,970,755	57,970,755	57,970,755	57,970,755	57,970,755	57,970,755
Total operating cost	19,809,988,585	19,810,052,342	19,810,118,011	19,810,185,651	19,810,255,319	19,810,327,078	19,810,400,989	19,810,477,118
EBIT	233,686,245	233,622,488	233,556,819	233,489,179	233,419,511	233,347,752	233,273,841	233,197,712
Tax	70,105,873	70,086,746	70,067,046	70,046,754	70,025,853	70,004,326	69,982,152	69,959,314
Net income	163,580,371.33	163,535,741.67	163,489,773.11	163,442,425.50	163,393,657.47	163,343,426.39	163,291,688.38	163,238,398.22
Net cash flow from operating activities	191,406,377.85	191,361,748.18	191,315,779.63	191,268,432.02	191,219,663.98	191,169,432.90	191,117,694.89	191,064,404.74
Change in Gross fixed Asset								
Net Cashflow	191,406,378	191,361,748	191,315,780	191,268,432	191,219,664	191,169,433	191,117,695	191,064,405
Add: Beginning Cashflow	181,574,621	372,980,999	564,342,747	755,658,527	946,926,959	1,138,146,623	1,329,316,055	1,520,433,750
Ending cashflow	372,980,999	564,342,747	755,658,527	946,926,959	1,138,146,623	1,329,316,055	1,520,433,750	1,711,498,155

Appendix Table E7 Fixed-capital investment and operating cost of plant C at capacity of stearin 100,000 kg in fixed time pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		3,949,920,062	3,949,920,062	3,949,920,062	3,949,920,062	3,949,920,062	3,949,920,062	3,949,920,062
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		49,861,463	49,861,463	49,861,463	49,861,463	49,861,463	49,861,463	49,861,463
Total income		3,999,781,526	3,999,781,526	3,999,781,526	3,999,781,526	3,999,781,526	3,999,781,526	3,999,781,526
Investment cost								
Equipment cost								
1. ten storage tanks	36,922,399							
2. one reactor	2,556,415							
3. three mixing tanks	6,260,943							
4. two centrifuges	16,203,551							
5. three evaporators	10,262,630							
6. fourteen pumps	2,392,500							
Purchased equipment	74,598,438							
Purchased-equipment installation	13,987,000							
Instrumentation and controls (installed)	11,656,000							
Piping (installed)	11,656,000							
Electrical systems (installed)	6,994,000							
Buildings (including services)	9,325,000							
Yard improvement	4,662,000							
Service facilities (installed)	46,624,000							
Land	2,331,000							
Engineering and supervision	20,981,000							
Construction expenses	9,325,000							
Legal expenses	4,662,000							
Contractor's fee	4,662,000							
Contingency	11,656,000							
Total fixed-capital investment	233,119,438							
Manufacturing cost								
Raw materials								
1. stearin		3,742,866,000	3,742,866,000	3,742,866,000	3,742,866,000	3,742,866,000	3,742,866,000	3,742,866,000
2. methanol		168,952,310	168,952,310	168,952,310	168,952,310	168,952,310	168,952,310	168,952,310

Appendix Table E7 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	3,949,920,062	3,949,920,062	3,949,920,062	3,949,920,062	3,949,920,062	3,949,920,062	3,949,920,062	3,949,920,062
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	49,861,463	49,861,463	49,861,463	49,861,463	49,861,463	49,861,463	49,861,463	49,861,463
Total income	3,999,781,526	3,999,781,526	3,999,781,526	3,999,781,526	3,999,781,526	3,999,781,526	3,999,781,526	3,999,781,526
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	3,742,866,000	3,742,866,000	3,742,866,000	3,742,866,000	3,742,866,000	3,742,866,000	3,742,866,000	3,742,866,000
2. methanol	168,952,310	168,952,310	168,952,310	168,952,310	168,952,310	168,952,310	168,952,310	168,952,310
3. potassium hydroxide	6,920,170	6,920,170	6,920,170	6,920,170	6,920,170	6,920,170	6,920,170	6,920,170

Appendix Table E7 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979
Cost of energy			24,865,368	24,865,368	24,865,368	24,865,368	24,865,368	24,865,368	24,865,368
Depreciation			5,594,896	5,594,896	5,594,896	5,594,896	5,594,896	5,594,896	5,594,896
Operating labor			2,160,000	2,224,800	2,291,544	2,360,290	2,431,099	2,504,032	2,579,153
Maintenance and repairs			11,655,972	11,655,972	11,655,972	11,655,972	11,655,972	11,655,972	11,655,972
Total operating cost			3,958,299,579	3,958,364,379	3,958,431,123	3,958,499,869	3,958,570,678	3,958,643,611	3,958,718,731
EBIT			41,481,947	41,417,147	41,350,403	41,281,657	41,210,848	41,137,915	41,062,794
Tax			12,444,584	12,425,144	12,405,121	12,384,497	12,363,255	12,341,375	12,318,838
Net income			29,037,363.15	28,992,003.15	28,945,282.35	28,897,159.93	28,847,593.83	28,796,540.75	28,743,956.08
Net cash flow from operating activities			34,632,259.01	34,586,899.01	34,540,178.21	34,492,055.79	34,442,489.69	34,391,436.61	34,338,851.94
Change in Gross fixed Asset		233,119,438							
Net Cashflow		-233,119,438	34,632,259	34,586,899	34,540,178	34,492,056	34,442,490	34,391,437	34,338,852
Add: Beginning Cashflow			-233,119,438	-198,487,179	-163,900,280	-129,360,102	-94,868,046	-60,425,556	-26,034,120
Ending cashflow		-233,119,438	-198,487,179	-163,900,280	-129,360,102	-94,868,046	-60,425,556	-26,034,120	8,304,732
NPV	฿117,238,980								
IRR	12.08%								

Appendix Table E7 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	879,759	879,759	879,759	879,759	879,759	879,759	879,759	879,759
Cost of energy	24,865,368	24,865,368	24,865,368	24,865,368	24,865,368	24,865,368	24,865,368	24,865,368
Depreciation	5,594,896	5,594,896	5,594,896	5,594,896	5,594,896	5,594,896	5,594,896	5,594,896
Operating labor	2,656,528	2,736,223	2,818,310	2,902,859	2,989,945	3,079,644	3,172,033	3,267,194
Maintenance and repairs	11,655,972	11,655,972	11,655,972	11,655,972	11,655,972	11,655,972	11,655,972	11,655,972
Total operating cost	3,958,796,106	3,958,875,802	3,958,957,889	3,959,042,438	3,959,129,524	3,959,219,222	3,959,311,611	3,959,406,772
EBIT	40,985,420	40,905,724	40,823,637	40,739,088	40,652,002	40,562,304	40,469,915	40,374,754
Tax	12,295,626	12,271,717	12,247,091	12,221,726	12,195,601	12,168,691	12,140,974	12,112,426
Net income	28,689,793.87	28,634,006.79	28,576,546.10	28,517,361.59	28,456,401.54	28,393,612.69	28,328,940.18	28,262,327.49
Net cash flow from operating activities	34,284,689.73	34,228,902.65	34,171,441.96	34,112,257.45	34,051,297.40	33,988,508.55	33,923,836.04	33,857,223.35
Change in Gross fixed Asset								
Net Cashflow	34,284,690	34,228,903	34,171,442	34,112,257	34,051,297	33,988,509	33,923,836	33,857,223
Add: Beginning Cashflow	8,304,732	42,589,422	76,818,325	110,989,767	145,102,024	179,153,322	213,141,830	247,065,666
Ending cashflow	42,589,422	76,818,325	110,989,767	145,102,024	179,153,322	213,141,830	247,065,666	280,922,890

Appendix Table E8 Fixed-capital investment and operating cost of plant C at capacity of stearin 300,000 kg in fixed time pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		11,732,287,877	11,732,287,877	11,732,287,877	11,732,287,877	11,732,287,877	11,732,287,877	11,732,287,877
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		159,959,440	159,959,440	159,959,440	159,959,440	159,959,440	159,959,440	159,959,440
Total income		11,892,247,317	11,892,247,317	11,892,247,317	11,892,247,317	11,892,247,317	11,892,247,317	11,892,247,317
Investment cost								
Equipment cost								
1. ten storage tanks	133,256,216							
2. one reactor	7,489,794							
3. three mixing tanks	18,643,713							
4. two centrifuges	28,689,613							
5. three evaporators	22,259,524							
6. fourteen pumps	4,725,000							
Purchased equipment	215,063,860							
Purchased-equipment installation	40,324,000							
Instrumentation and controls (installed)	33,604,000							
Piping (installed)	33,604,000							
Electrical systems (installed)	20,162,000							
Buildings (including services)	26,883,000							
Yard improvement	13,441,000							
Service facilities (installed)	134,415,000							
Land	6,721,000							
Engineering and supervision	60,487,000							
Construction expenses	26,883,000							
Legal expenses	13,441,000							
Contractor's fee	13,441,000							
Contingency	33,604,000							
Total fixed-capital investment	672,073,860							
Manufacturing cost								
Raw materials								
1. stearin		11,117,286,000	11,117,286,000	11,117,286,000	11,117,286,000	11,117,286,000	11,117,286,000	11,117,286,000
2. methanol		501,832,325	501,832,325	501,832,325	501,832,325	501,832,325	501,832,325	501,832,325

Appendix Table E8 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	11,732,287,877	11,732,287,877	11,732,287,877	11,732,287,877	11,732,287,877	11,732,287,877	11,732,287,877	11,732,287,877
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	159,959,440	159,959,440	159,959,440	159,959,440	159,959,440	159,959,440	159,959,440	159,959,440
Total income	11,892,247,317	11,892,247,317	11,892,247,317	11,892,247,317	11,892,247,317	11,892,247,317	11,892,247,317	11,892,247,317
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	11,117,286,000	11,117,286,000	11,117,286,000	11,117,286,000	11,117,286,000	11,117,286,000	11,117,286,000	11,117,286,000
2. methanol	501,832,325	501,832,325	501,832,325	501,832,325	501,832,325	501,832,325	501,832,325	501,832,325
3. potassium hydroxide	20,554,707	20,554,707	20,554,707	20,554,707	20,554,707	20,554,707	20,554,707	20,554,707

Appendix Table E8 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979
Cost of energy			89,657,709	89,657,709	89,657,709	89,657,709	89,657,709	89,657,709	89,657,709
Depreciation			16,129,791	16,129,791	16,129,791	16,129,791	16,129,791	16,129,791	16,129,791
Operating labor			2,160,000	2,224,800	2,291,544	2,360,290	2,431,099	2,504,032	2,579,153
Maintenance and repairs			33,603,693	33,603,693	33,603,693	33,603,693	33,603,693	33,603,693	33,603,693
Total operating cost			11,767,707,539	11,767,772,339	11,767,839,083	11,767,907,829	11,767,978,638	11,768,051,571	11,768,126,692
EBIT			124,539,778	124,474,978	124,408,234	124,339,488	124,268,679	124,195,746	124,120,625
Tax			37,361,934	37,342,494	37,322,470	37,301,846	37,280,604	37,258,724	37,236,188
Net income			87,177,844.91	87,132,484.91	87,085,764.11	87,037,641.69	86,988,075.59	86,937,022.51	86,884,437.84
Net cash flow from operating activities			103,307,635.58	103,262,275.58	103,215,554.78	103,167,432.36	103,117,866.26	103,066,813.18	103,014,228.51
Change in Gross fixed Asset		672,073,860							
Net Cashflow		-672,073,860	103,307,636	103,262,276	103,215,555	103,167,432	103,117,866	103,066,813	103,014,229
Add: Beginning Cashflow			-672,073,860	-568,766,224	-465,503,949	-362,288,394	-259,120,962	-156,003,095	-52,936,282
Ending cashflow		-672,073,860	-568,766,224	-465,503,949	-362,288,394	-259,120,962	-156,003,095	-52,936,282	50,077,946
NPV	฿378,069,934								
IRR	12.83%								

Appendix Table E8 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	2,613,106	2,613,106	2,613,106	2,613,106	2,613,106	2,613,106	2,613,106	2,613,106
Cost of energy	89,657,709	89,657,709	89,657,709	89,657,709	89,657,709	89,657,709	89,657,709	89,657,709
Depreciation	16,129,791	16,129,791	16,129,791	16,129,791	16,129,791	16,129,791	16,129,791	16,129,791
Operating labor	2,656,528	2,736,223	2,818,310	2,902,859	2,989,945	3,079,644	3,172,033	3,267,194
Maintenance and repairs	33,603,693	33,603,693	33,603,693	33,603,693	33,603,693	33,603,693	33,603,693	33,603,693
Total operating cost	11,768,204,066	11,768,283,762	11,768,365,849	11,768,450,398	11,768,537,484	11,768,627,182	11,768,719,571	11,768,814,732
EBIT	124,043,251	123,963,555	123,881,468	123,796,919	123,709,833	123,620,135	123,527,746	123,432,585
Tax	37,212,975	37,189,067	37,164,441	37,139,076	37,112,950	37,086,040	37,058,324	37,029,775
Net income	86,830,275.63	86,774,488.55	86,717,027.86	86,657,843.35	86,596,883.30	86,534,094.45	86,469,421.94	86,402,809.25
Net cash flow from operating activities	102,960,066.30	102,904,279.22	102,846,818.53	102,787,634.02	102,726,673.97	102,663,885.12	102,599,212.61	102,532,599.92
Change in Gross fixed Asset								
Net Cashflow	102,960,066	102,904,279	102,846,819	102,787,634	102,726,674	102,663,885	102,599,213	102,532,600
Add: Beginning Cashflow	50,077,946	153,038,013	255,942,292	358,789,110	461,576,744	564,303,418	666,967,303	769,566,516
Ending cashflow	153,038,013	255,942,292	358,789,110	461,576,744	564,303,418	666,967,303	769,566,516	872,099,116

Appendix Table E9 Fixed-capital investment and operating cost of plant C at capacity of stearin 500,000 kg in fixed time pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		19,553,817,410	19,553,817,410	19,553,817,410	19,553,817,410	19,553,817,410	19,553,817,410	19,553,817,410
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		266,599,054	266,599,054	266,599,054	266,599,054	266,599,054	266,599,054	266,599,054
Total income		19,820,416,464	19,820,416,464	19,820,416,464	19,820,416,464	19,820,416,464	19,820,416,464	19,820,416,464
Investment cost								
Equipment cost								
1. ten storage tanks	246,107,169							
2. one reactor	12,923,693							
3. three mixing tanks	32,275,486							
4. two centrifuges	37,417,913							
5. three evaporators	30,016,699							
6. fourteen pumps	8,119,800							
Purchased equipment	366,860,760							
Purchased-equipment installation	68,786,000							
Instrumentation and controls (installed)	57,322,000							
Piping (installed)	57,322,000							
Electrical systems (installed)	34,393,000							
Buildings (including services)	45,858,000							
Yard improvement	22,929,000							
Service facilities (installed)	229,288,000							
Land	11,464,000							
Engineering and supervision	103,180,000							
Construction expenses	45,858,000							
Legal expenses	22,929,000							
Contractor's fee	22,929,000							
Contingency	57,322,000							
Total fixed-capital investment	1,146,440,760							
Manufacturing cost								
Raw materials								
1. stearin		18,528,810,000	18,528,810,000	18,528,810,000	18,528,810,000	18,528,810,000	18,528,810,000	18,528,810,000
2. methanol		836,387,208	836,387,208	836,387,208	836,387,208	836,387,208	836,387,208	836,387,208

Appendix Table E9 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	19,553,817,410	19,553,817,410	19,553,817,410	19,553,817,410	19,553,817,410	19,553,817,410	19,553,817,410	19,553,817,410
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	266,599,054	266,599,054	266,599,054	266,599,054	266,599,054	266,599,054	266,599,054	266,599,054
Total income	19,820,416,464	19,820,416,464	19,820,416,464	19,820,416,464	19,820,416,464	19,820,416,464	19,820,416,464	19,820,416,464
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	18,528,810,000	18,528,810,000	18,528,810,000	18,528,810,000	18,528,810,000	18,528,810,000	18,528,810,000	18,528,810,000
2. methanol	836,387,208	836,387,208	836,387,208	836,387,208	836,387,208	836,387,208	836,387,208	836,387,208
3. potassium hydroxide	34,257,845	34,257,845	34,257,845	34,257,845	34,257,845	34,257,845	34,257,845	34,257,845

Appendix Table E9 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			4,355,293	4,355,293	4,355,293	4,355,293	4,355,293	4,355,293	4,355,293
Cost of energy			128,379,369	128,379,369	128,379,369	128,379,369	128,379,369	128,379,369	128,379,369
Depreciation			27,514,584	27,514,584	27,514,584	27,514,584	27,514,584	27,514,584	27,514,584
Operating labor			2,160,000	2,224,800	2,291,544	2,360,290	2,431,099	2,504,032	2,579,153
Maintenance and repairs			57,322,038	57,322,038	57,322,038	57,322,038	57,322,038	57,322,038	57,322,038
Total operating cost			19,591,671,753	19,591,736,553	19,591,803,297	19,591,872,043	19,591,942,852	19,592,015,785	19,592,090,906
EBIT			228,744,711	228,679,911	228,613,167	228,544,421	228,473,612	228,400,679	228,325,558
Tax			68,623,413	68,603,973	68,583,950	68,563,326	68,542,084	68,520,204	68,497,667
Net income			160,121,297.79	160,075,937.79	160,029,216.99	159,981,094.57	159,931,528.47	159,880,475.39	159,827,890.72
Net cash flow from operating activities			187,635,881.77	187,590,521.77	187,543,800.97	187,495,678.54	187,446,112.45	187,395,059.37	187,342,474.70
Change in Gross fixed Asset		1,146,440,760							
Net Cashflow		-1,146,440,760	187,635,882	187,590,522	187,543,801	187,495,679	187,446,112	187,395,059	187,342,475
Add: Beginning Cashflow			-1,146,440,760	-958,804,878	-771,214,356	-583,670,555	-396,174,877	-208,728,764	-21,333,705
Ending cashflow		-1,146,440,760	-958,804,878	-771,214,356	-583,670,555	-396,174,877	-208,728,764	-21,333,705	166,008,770
NPV	฿759,909,419								
IRR	14.08%								

Appendix Table E9 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	4,355,293	4,355,293	4,355,293	4,355,293	4,355,293	4,355,293	4,355,293	4,355,293
Cost of energy	128,379,369	128,379,369	128,379,369	128,379,369	128,379,369	128,379,369	128,379,369	128,379,369
Depreciation	27,514,584	27,514,584	27,514,584	27,514,584	27,514,584	27,514,584	27,514,584	27,514,584
Operating labor	2,656,528	2,736,223	2,818,310	2,902,859	2,989,945	3,079,644	3,172,033	3,267,194
Maintenance and repairs	57,322,038	57,322,038	57,322,038	57,322,038	57,322,038	57,322,038	57,322,038	57,322,038
Total operating cost	19,592,168,280	19,592,247,976	19,592,330,063	19,592,414,612	19,592,501,698	19,592,591,396	19,592,683,786	19,592,778,946
EBIT	228,248,184	228,168,488	228,086,401	228,001,852	227,914,766	227,825,068	227,732,678	227,637,517
Tax	68,474,455	68,450,546	68,425,920	68,400,556	68,374,430	68,347,520	68,319,803	68,291,255
Net income	159,773,728.50	159,717,941.43	159,660,480.74	159,601,296.22	159,540,336.18	159,477,547.33	159,412,874.81	159,346,262.13
Net cash flow from operating activities	187,288,312.48	187,232,525.40	187,175,064.71	187,115,880.20	187,054,920.16	186,992,131.31	186,927,458.79	186,860,846.10
Change in Gross fixed Asset								
Net Cashflow	187,288,312	187,232,525	187,175,065	187,115,880	187,054,920	186,992,131	186,927,459	186,860,846
Add: Beginning Cashflow	166,008,770	353,297,082	540,529,608	727,704,672	914,820,553	1,101,875,473	1,288,867,604	1,475,795,063
Ending cashflow	353,297,082	540,529,608	727,704,672	914,820,553	1,101,875,473	1,288,867,604	1,475,795,063	1,662,655,909

Appendix Table E10 Fixed-capital investment and operating cost of plant D at capacity of stearin 100,000 kg in fixed time pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		3,470,252,711	3,470,252,711	3,470,252,711	3,470,252,711	3,470,252,711	3,470,252,711	3,470,252,711
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		47,313,803	47,313,803	47,313,803	47,313,803	47,313,803	47,313,803	47,313,803
Total income		3,517,566,514	3,517,566,514	3,517,566,514	3,517,566,514	3,517,566,514	3,517,566,514	3,517,566,514
Investment cost								
Equipment cost								
1. ten storage tanks	36,808,476							
2. one reactor	2,657,648							
3. three mixing tanks	6,449,165							
4. two centrifuges	16,203,551							
5. three evaporators	10,262,632							
6. fourteen pumps	2,371,500							
Purchased equipment	74,752,973							
Purchased-equipment installation	14,016,000							
Instrumentation and controls (installed)	11,680,000							
Piping (installed)	11,680,000							
Electrical systems (installed)	7,008,000							
Buildings (including services)	9,344,000							
Yard improvement	4,672,000							
Service facilities (installed)	46,721,000							
Land	2,336,000							
Engineering and supervision	21,024,000							
Construction expenses	9,344,000							
Legal expenses	4,672,000							
Contractor's fee	4,672,000							
Contingency	11,680,000							
Total fixed-capital investment	233,601,973							
Manufacturing cost								
Raw materials								
1. stearin		3,288,342,000	3,288,342,000	3,288,342,000	3,288,342,000	3,288,342,000	3,288,342,000	3,288,342,000
2. methanol		148,435,177	148,435,177	148,435,177	148,435,177	148,435,177	148,435,177	148,435,177

Appendix Table E10 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	3,470,252,711	3,470,252,711	3,470,252,711	3,470,252,711	3,470,252,711	3,470,252,711	3,470,252,711	3,470,252,711
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	47,313,803	47,313,803	47,313,803	47,313,803	47,313,803	47,313,803	47,313,803	47,313,803
Total income	3,517,566,514	3,517,566,514	3,517,566,514	3,517,566,514	3,517,566,514	3,517,566,514	3,517,566,514	3,517,566,514
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	3,288,342,000	3,288,342,000	3,288,342,000	3,288,342,000	3,288,342,000	3,288,342,000	3,288,342,000	3,288,342,000
2. methanol	148,435,177	148,435,177	148,435,177	148,435,177	148,435,177	148,435,177	148,435,177	148,435,177
3. potassium hydroxide	6,079,803	6,079,803	6,079,803	6,079,803	6,079,803	6,079,803	6,079,803	6,079,803

Appendix Table E10 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			772,923	772,923	772,923	772,923	772,923	772,923	772,923
Cost of energy			33,961,854	33,961,854	33,961,854	33,961,854	33,961,854	33,961,854	33,961,854
Depreciation			5,606,465	5,606,465	5,606,465	5,606,465	5,606,465	5,606,465	5,606,465
Operating labor			2,592,000	2,669,760	2,749,853	2,832,348	2,917,319	3,004,838	3,094,984
Maintenance and repairs			11,680,099	11,680,099	11,680,099	11,680,099	11,680,099	11,680,099	11,680,099
Total operating cost			3,491,863,855	3,491,941,615	3,492,021,708	3,492,104,204	3,492,189,174	3,492,276,694	3,492,366,839
EBIT			25,702,659	25,624,899	25,544,806	25,462,310	25,377,340	25,289,820	25,199,675
Tax			7,710,798	7,687,470	7,663,442	7,638,693	7,613,202	7,586,946	7,559,903
Net income			17,991,861.05	17,937,429.05	17,881,364.09	17,823,617.18	17,764,137.87	17,702,874.17	17,639,772.56
Net cash flow from operating activities			23,598,325.91	23,543,893.91	23,487,828.95	23,430,082.04	23,370,602.72	23,309,339.03	23,246,237.42
Change in Gross fixed Asset		233,601,973							
Net Cashflow		-233,601,973	23,598,326	23,543,894	23,487,829	23,430,082	23,370,603	23,309,339	23,246,237
Add: Beginning Cashflow			-233,601,973	-210,003,647	-186,459,753	-162,971,924	-139,541,842	-116,171,239	-92,861,900
Ending cashflow		-233,601,973	-210,003,647	-186,459,753	-162,971,924	-139,541,842	-116,171,239	-92,861,900	-69,615,663
NPV	฿7,085,536								
IRR	5.47%								

Appendix Table E10 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	772,923	772,923	772,923	772,923	772,923	772,923	772,923	772,923
Cost of energy	33,961,854	33,961,854	33,961,854	33,961,854	33,961,854	33,961,854	33,961,854	33,961,854
Depreciation	5,606,465	5,606,465	5,606,465	5,606,465	5,606,465	5,606,465	5,606,465	5,606,465
Operating labor	3,187,833	3,283,468	3,381,972	3,483,431	3,587,934	3,695,572	3,806,439	3,920,633
Maintenance and repairs	11,680,099	11,680,099	11,680,099	11,680,099	11,680,099	11,680,099	11,680,099	11,680,099
Total operating cost	3,492,459,689	3,492,555,324	3,492,653,828	3,492,755,287	3,492,859,790	3,492,967,428	3,493,078,295	3,493,192,488
EBIT	25,106,826	25,011,191	24,912,687	24,811,227	24,706,724	24,599,086	24,488,219	24,374,026
Tax	7,532,048	7,503,357	7,473,806	7,443,368	7,412,017	7,379,726	7,346,466	7,312,208
Net income	17,574,777.91	17,507,833.41	17,438,880.59	17,367,859.17	17,294,707.12	17,219,360.50	17,141,753.48	17,061,818.25
Net cash flow from operating activities	23,181,242.76	23,114,298.27	23,045,345.44	22,974,324.03	22,901,171.97	22,825,825.35	22,748,218.34	22,668,283.11
Change in Gross fixed Asset								
Net Cashflow	23,181,243	23,114,298	23,045,345	22,974,324	22,901,172	22,825,825	22,748,218	22,668,283
Add: Beginning Cashflow	-69,615,663	-46,434,420	-23,320,122	- 274,776	22,699,548	45,600,720	68,426,545	91,174,763
Ending cashflow	-46,434,420	-23,320,122	- 274,776	22,699,548	45,600,720	68,426,545	91,174,763	113,843,046

Appendix Table E11 Fixed-capital investment and operating cost of plant D at capacity of stearin 300,000 kg in fixed time pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		10,410,755,852	10,410,755,852	10,410,755,852	10,410,755,852	10,410,755,852	10,410,755,852	10,410,755,852
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		141,937,936	141,937,936	141,937,936	141,937,936	141,937,936	141,937,936	141,937,936
Total income		10,552,693,788	10,552,693,788	10,552,693,788	10,552,693,788	10,552,693,788	10,552,693,788	10,552,693,788
Investment cost								
Equipment cost								
1. ten storage tanks	133,622,439							
2. one reactor	7,454,275							
3. three mixing tanks	18,458,042							
4. two centrifuges	28,689,613							
5. three evaporators	14,059,757							
6. fourteen pumps	4,286,400							
Purchased equipment	206,570,527							
Purchased-equipment installation	38,732,000							
Instrumentation and controls (installed)	32,277,000							
Piping (installed)	32,277,000							
Electrical systems (installed)	19,366,000							
Buildings (including services)	25,821,000							
Yard improvement	12,911,000							
Service facilities (installed)	129,107,000							
Land	6,455,000							
Engineering and supervision	58,098,000							
Construction expenses	25,821,000							
Legal expenses	12,911,000							
Contractor's fee	12,911,000							
Contingency	32,277,000							
Total fixed-capital investment	645,534,527							
Manufacturing cost								
Raw materials								
1. stearin		9,865,026,000	9,865,026,000	9,865,026,000	9,865,026,000	9,865,026,000	9,865,026,000	9,865,026,000
2. methanol		445,305,530	445,305,530	445,305,530	445,305,530	445,305,530	445,305,530	445,305,530

Appendix Table E11 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	10,410,755,852	10,410,755,852	10,410,755,852	10,410,755,852	10,410,755,852	10,410,755,852	10,410,755,852	10,410,755,852
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	141,937,936	141,937,936	141,937,936	141,937,936	141,937,936	141,937,936	141,937,936	141,937,936
Total income	10,552,693,788	10,552,693,788	10,552,693,788	10,552,693,788	10,552,693,788	10,552,693,788	10,552,693,788	10,552,693,788
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	9,865,026,000	9,865,026,000	9,865,026,000	9,865,026,000	9,865,026,000	9,865,026,000	9,865,026,000	9,865,026,000
2. methanol	445,305,530	445,305,530	445,305,530	445,305,530	445,305,530	445,305,530	445,305,530	445,305,530
3. potassium hydroxide	18,239,408	18,239,408	18,239,408	18,239,408	18,239,408	18,239,408	18,239,408	18,239,408

Appendix Table E11 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979
Cost of energy			56,008,732	56,008,732	56,008,732	56,008,732	56,008,732	56,008,732	56,008,732
Depreciation			15,492,768	15,492,768	15,492,768	15,492,768	15,492,768	15,492,768	15,492,768
Operating labor			2,592,000	2,669,760	2,749,853	2,832,348	2,917,319	3,004,838	3,094,984
Maintenance and repairs			32,276,726	32,276,726	32,276,726	32,276,726	32,276,726	32,276,726	32,276,726
Total operating cost			10,421,767,160	10,421,844,920	10,421,925,012	10,422,007,508	10,422,092,478	10,422,179,998	10,422,270,143
EBIT			130,926,629	130,848,869	130,768,776	130,686,280	130,601,310	130,513,790	130,423,645
Tax			39,277,989	39,254,661	39,230,633	39,205,884	39,180,393	39,154,137	39,127,094
Net income			91,648,640.20	91,594,208.20	91,538,143.24	91,480,396.33	91,420,917.01	91,359,653.32	91,296,551.71
Net cash flow from operating activities			107,141,408.67	107,086,976.67	107,030,911.71	106,973,164.80	106,913,685.49	106,852,421.79	106,789,320.18
Change in Gross fixed Asset		645,534,527							
Net Cashflow		-645,534,527	107,141,409	107,086,977	107,030,912	106,973,165	106,913,685	106,852,422	106,789,320
Add: Beginning Cashflow			-645,534,527	-538,393,118	-431,306,142	-324,275,230	-217,302,065	-110,388,380	-3,535,958
Ending cashflow		-645,534,527	-538,393,118	-431,306,142	-324,275,230	-217,302,065	-110,388,380	-3,535,958	103,253,362
NPV	฿440,624,657								
IRR	14.33%								

Appendix Table E11 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	2,318,763	2,318,763	2,318,763	2,318,763	2,318,763	2,318,763	2,318,763	2,318,763
Cost of energy	56,008,732	56,008,732	56,008,732	56,008,732	56,008,732	56,008,732	56,008,732	56,008,732
Depreciation	15,492,768	15,492,768	15,492,768	15,492,768	15,492,768	15,492,768	15,492,768	15,492,768
Operating labor	3,187,833	3,283,468	3,381,972	3,483,431	3,587,934	3,695,572	3,806,439	3,920,633
Maintenance and repairs	32,276,726	32,276,726	32,276,726	32,276,726	32,276,726	32,276,726	32,276,726	32,276,726
Total operating cost	10,422,362,993	10,422,458,628	10,422,557,132	10,422,658,591	10,422,763,094	10,422,870,732	10,422,981,599	10,423,095,792
EBIT	130,330,796	130,235,161	130,136,657	130,035,198	129,930,695	129,823,057	129,712,189	129,597,996
Tax	39,099,239	39,070,548	39,040,997	39,010,559	38,979,208	38,946,917	38,913,657	38,879,399
Net income	91,231,557.05	91,164,612.56	91,095,659.73	91,024,638.32	90,951,486.26	90,876,139.64	90,798,532.63	90,718,597.40
Net cash flow from operating activities	106,724,325.53	106,657,381.04	106,588,428.21	106,517,406.79	106,444,254.74	106,368,908.12	106,291,301.10	106,211,365.87
Change in Gross fixed Asset								
Net Cashflow	106,724,326	106,657,381	106,588,428	106,517,407	106,444,255	106,368,908	106,291,301	106,211,366
Add: Beginning Cashflow	103,253,362	209,977,688	316,635,069	423,223,497	529,740,904	636,185,158	742,554,067	848,845,368
Ending cashflow	209,977,688	316,635,069	423,223,497	529,740,904	636,185,158	742,554,067	848,845,368	955,056,734

Appendix Table E12 Fixed-capital investment and operating cost of plant D at capacity of stearin 500,000 kg in fixed time pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		17,351,111,564	17,351,111,564	17,351,111,564	17,351,111,564	17,351,111,564	17,351,111,564	17,351,111,564
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		236,569,123	236,569,123	236,569,123	236,569,123	236,569,123	236,569,123	236,569,123
Total income		17,587,680,687	17,587,680,687	17,587,680,687	17,587,680,687	17,587,680,687	17,587,680,687	17,587,680,687
Investment cost								
Equipment cost								
1. ten storage tanks	244,947,149							
2. one reactor	12,682,236							
3. three mixing tanks	31,451,810							
4. two centrifuges	37,417,913							
5. three evaporators	29,961,631							
6. fourteen pumps	7,416,600							
Purchased equipment	363,877,338							
Purchased-equipment installation	68,227,000							
Instrumentation and controls (installed)	56,856,000							
Piping (installed)	56,856,000							
Electrical systems (installed)	34,114,000							
Buildings (including services)	45,485,000							
Yard improvement	22,742,000							
Service facilities (installed)	227,423,000							
Land	11,371,000							
Engineering and supervision	102,341,000							
Construction expenses	45,485,000							
Legal expenses	22,742,000							
Contractor's fee	22,742,000							
Contingency	56,856,000							
Total fixed-capital investment	1,137,117,338							
Manufacturing cost								
Raw materials								
1. stearin		16,441,710,000	16,441,710,000	16,441,710,000	16,441,710,000	16,441,710,000	16,441,710,000	16,441,710,000
2. methanol		742,175,883	742,175,883	742,175,883	742,175,883	742,175,883	742,175,883	742,175,883

Appendix Table E12 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	17,351,111,564	17,351,111,564	17,351,111,564	17,351,111,564	17,351,111,564	17,351,111,564	17,351,111,564	17,351,111,564
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	236,569,123	236,569,123	236,569,123	236,569,123	236,569,123	236,569,123	236,569,123	236,569,123
Total income	17,587,680,687	17,587,680,687	17,587,680,687	17,587,680,687	17,587,680,687	17,587,680,687	17,587,680,687	17,587,680,687
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	16,441,710,000	16,441,710,000	16,441,710,000	16,441,710,000	16,441,710,000	16,441,710,000	16,441,710,000	16,441,710,000
2. methanol	742,175,883	742,175,883	742,175,883	742,175,883	742,175,883	742,175,883	742,175,883	742,175,883
3. potassium hydroxide	30,399,014	30,399,014	30,399,014	30,399,014	30,399,014	30,399,014	30,399,014	30,399,014

Appendix Table E12 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979
Cost of energy			122,327,713	122,327,713	122,327,713	122,327,713	122,327,713	122,327,713	122,327,713
Depreciation			27,290,823	27,290,823	27,290,823	27,290,823	27,290,823	27,290,823	27,290,823
Operating labor			2,592,000	2,669,760	2,749,853	2,832,348	2,917,319	3,004,838	3,094,984
Maintenance and repairs			56,855,867	56,855,867	56,855,867	56,855,867	56,855,867	56,855,867	56,855,867
Total operating cost			17,399,925,185	17,400,002,945	17,400,083,038	17,400,165,534	17,400,250,504	17,400,338,024	17,400,428,169
EBIT			187,755,502	187,677,742	187,597,649	187,515,153	187,430,183	187,342,663	187,252,518
Tax			56,326,651	56,303,323	56,279,295	56,254,546	56,229,055	56,202,799	56,175,755
Net income			131,428,851.27	131,374,419.27	131,318,354.31	131,260,607.40	131,201,128.08	131,139,864.39	131,076,762.78
Net cash flow from operating activities			158,719,673.79	158,665,241.79	158,609,176.83	158,551,429.92	158,491,950.61	158,430,686.91	158,367,585.31
Change in Gross fixed Asset		1,137,117,338							
Net Cashflow		-1,137,117,338	158,719,674	158,665,242	158,609,177	158,551,430	158,491,951	158,430,687	158,367,585
Add: Beginning Cashflow			-1,137,117,338	-978,397,664	-819,732,422	-661,123,245	-502,571,816	-344,079,865	-185,649,178
Ending cashflow		-1,137,117,338	-978,397,664	-819,732,422	-661,123,245	-502,571,816	-344,079,865	-185,649,178	-27,281,593
NPV	฿482,321,746								
IRR	11.03%								

Appendix Table E12 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	3,864,709	3,864,709	3,864,709	3,864,709	3,864,709	3,864,709	3,864,709	3,864,709
Cost of energy	122,327,713	122,327,713	122,327,713	122,327,713	122,327,713	122,327,713	122,327,713	122,327,713
Depreciation	27,290,823	27,290,823	27,290,823	27,290,823	27,290,823	27,290,823	27,290,823	27,290,823
Operating labor	3,187,833	3,283,468	3,381,972	3,483,431	3,587,934	3,695,572	3,806,439	3,920,633
Maintenance and repairs	56,855,867	56,855,867	56,855,867	56,855,867	56,855,867	56,855,867	56,855,867	56,855,867
Total operating cost	17,400,521,018	17,400,616,653	17,400,715,157	17,400,816,617	17,400,921,119	17,401,028,757	17,401,139,625	17,401,253,818
EBIT	187,159,669	187,064,034	186,965,530	186,864,071	186,759,568	186,651,930	186,541,062	186,426,869
Tax	56,147,901	56,119,210	56,089,659	56,059,221	56,027,870	55,995,579	55,962,319	55,928,061
Net income	131,011,768.13	130,944,823.63	130,875,870.80	130,804,849.39	130,731,697.33	130,656,350.71	130,578,743.70	130,498,808.47
Net cash flow from operating activities	158,302,590.65	158,235,646.16	158,166,693.33	158,095,671.91	158,022,519.86	157,947,173.24	157,869,566.22	157,789,631.00
Change in Gross fixed Asset								
Net Cashflow	158,302,591	158,235,646	158,166,693	158,095,672	158,022,520	157,947,173	157,869,566	157,789,631
Add: Beginning Cashflow	-27,281,593	131,020,998	289,256,644	447,423,337	605,519,009	763,541,529	921,488,702	1,079,358,269
Ending cashflow	131,020,998	289,256,644	447,423,337	605,519,009	763,541,529	921,488,702	1,079,358,269	1,237,147,900

Appendix Table E13 Fixed-capital investment and operating cost of plant A at capacity of stearin 100,000 kg in fixed flow rate pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		3,896,079,764	3,896,079,764	3,896,079,764	3,896,079,764	3,896,079,764	3,896,079,764	3,896,079,764
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		53,119,627	53,119,627	53,119,627	53,119,627	53,119,627	53,119,627	53,119,627
Total income		3,949,199,391	3,949,199,391	3,949,199,391	3,949,199,391	3,949,199,391	3,949,199,391	3,949,199,391
Investment cost								
Equipment cost								
1. ten storage tanks	28,331,422							
2. one reactor	2,496,598							
3. three mixing tanks	6,256,857							
4. two centrifuges	13,850,038							
5. three evaporators	19,969,274							
6. fourteen pumps	2,713,800							
Purchased equipment	73,617,989							
Purchased-equipment installation	13,803,000							
Instrumentation and controls (installed)	11,503,000							
Piping (installed)	11,503,000							
Electrical systems (installed)	6,902,000							
Buildings (including services)	9,202,000							
Yard improvement	4,601,000							
Service facilities (installed)	46,011,000							
Land	2,301,000							
Engineering and supervision	20,705,000							
Construction expenses	9,202,000							
Legal expenses	4,601,000							
Contractor's fee	4,601,000							
Contingency	11,503,000							
Total fixed-capital investment	230,055,989							
Manufacturing cost								
Raw materials								
1. stearin		3,691,848,000	3,691,848,000	3,691,848,000	3,691,848,000	3,691,848,000	3,691,848,000	3,691,848,000
2. methanol		166,649,366	166,649,366	166,649,366	166,649,366	166,649,366	166,649,366	166,649,366

Appendix Table E13 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	3,896,079,764	3,896,079,764	3,896,079,764	3,896,079,764	3,896,079,764	3,896,079,764	3,896,079,764	3,896,079,764
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	53,119,627	53,119,627	53,119,627	53,119,627	53,119,627	53,119,627	53,119,627	53,119,627
Total income	3,949,199,391	3,949,199,391	3,949,199,391	3,949,199,391	3,949,199,391	3,949,199,391	3,949,199,391	3,949,199,391
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	3,691,848,000	3,691,848,000	3,691,848,000	3,691,848,000	3,691,848,000	3,691,848,000	3,691,848,000	3,691,848,000
2. methanol	166,649,366	166,649,366	166,649,366	166,649,366	166,649,366	166,649,366	166,649,366	166,649,366
3. potassium hydroxide	6,825,843	6,825,843	6,825,843	6,825,843	6,825,843	6,825,843	6,825,843	6,825,843

Appendix Table E13 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979
Cost of energy			48,079,571	48,079,571	48,079,571	48,079,571	48,079,571	48,079,571	48,079,571
Depreciation			5,521,333	5,521,333	5,521,333	5,521,333	5,521,333	5,521,333	5,521,333
Operating labor			1,296,000	1,334,880	1,374,926	1,416,174	1,458,659	1,502,419	1,547,492
Maintenance and repairs			11,502,799	11,502,799	11,502,799	11,502,799	11,502,799	11,502,799	11,502,799
Total operating cost			3,927,069,348	3,927,108,228	3,927,148,274	3,927,189,522	3,927,232,007	3,927,275,767	3,927,320,839
EBIT			22,130,044	22,091,164	22,051,117	22,009,870	21,967,384	21,923,625	21,878,552
Tax			6,639,013	6,627,349	6,615,335	6,602,961	6,590,215	6,577,087	6,563,566
Net income			15,491,030.70	15,463,814.70	15,435,782.22	15,406,908.76	15,377,169.10	15,346,537.26	15,314,986.45
Net cash flow from operating activities			21,012,363.31	20,985,147.31	20,957,114.83	20,928,241.38	20,898,501.72	20,867,869.87	20,836,319.07
Change in Gross fixed Asset		230,055,989							
Net Cashflow		-230,055,989	21,012,363	20,985,147	20,957,115	20,928,241	20,898,502	20,867,870	20,836,319
Add: Beginning Cashflow			-230,055,989	-209,043,626	-188,058,479	-167,101,364	-146,173,122	-125,274,621	-104,406,751
Ending cashflow		-230,055,989	-209,043,626	-188,058,479	-167,101,364	-146,173,122	-125,274,621	-104,406,751	-83,570,432
NPV	-฿13,243,073								
IRR	4.09%								

Appendix Table E13 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	867,767	867,767	867,767	867,767	867,767	867,767	867,767	867,767
Cost of energy	48,079,571	48,079,571	48,079,571	48,079,571	48,079,571	48,079,571	48,079,571	48,079,571
Depreciation	5,521,333	5,521,333	5,521,333	5,521,333	5,521,333	5,521,333	5,521,333	5,521,333
Operating labor	1,593,917	1,641,734	1,690,986	1,741,716	1,793,967	1,847,786	1,903,220	1,960,316
Maintenance and repairs	11,502,799	11,502,799	11,502,799	11,502,799	11,502,799	11,502,799	11,502,799	11,502,799
Total operating cost	3,927,367,264	3,927,415,082	3,927,464,334	3,927,515,063	3,927,567,315	3,927,621,134	3,927,676,567	3,927,733,664
EBIT	21,832,127	21,784,310	21,735,058	21,684,328	21,632,077	21,578,258	21,522,824	21,465,728
Tax	6,549,638	6,535,293	6,520,517	6,505,298	6,489,623	6,473,477	6,456,847	6,439,718
Net income	15,282,489.13	15,249,016.88	15,214,540.46	15,179,029.76	15,142,453.73	15,104,780.42	15,065,976.91	15,026,009.30
Net cash flow from operating activities	20,803,821.74	20,770,349.49	20,735,873.08	20,700,362.37	20,663,786.34	20,626,113.03	20,587,309.53	20,547,341.91
Change in Gross fixed Asset								
Net Cashflow	20,803,822	20,770,349	20,735,873	20,700,362	20,663,786	20,626,113	20,587,310	20,547,342
Add: Beginning Cashflow	-83,570,432	-62,766,610	-41,996,260	-21,260,387	-560,025	20,103,761	40,729,874	61,317,184
Ending cashflow	-62,766,610	-41,996,260	-21,260,387	-560,025	20,103,761	40,729,874	61,317,184	81,864,526

Appendix Table E14 Fixed-capital investment and operating cost of plant A at capacity of stearin 300,000 kg in fixed flow rate pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		11,688,240,999	11,688,240,999	11,688,240,999	11,688,240,999	11,688,240,999	11,688,240,999	11,688,240,999
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		159,358,842	159,358,842	159,358,842	159,358,842	159,358,842	159,358,842	159,358,842
Total income		11,847,599,841	11,847,599,841	11,847,599,841	11,847,599,841	11,847,599,841	11,847,599,841	11,847,599,841
Investment cost								
Equipment cost								
1. ten storage tanks	103,913,918							
2. one reactor	8,318,639							
3. three mixing tanks	20,731,474							
4. two centrifuges	24,521,895							
5. three evaporators	50,934,595							
6. fourteen pumps	6,366,300							
Purchased equipment	214,786,820							
Purchased-equipment installation	40,273,000							
Instrumentation and controls (installed)	33,560,000							
Piping (installed)	33,560,000							
Electrical systems (installed)	20,136,000							
Buildings (including services)	26,848,000							
Yard improvement	13,424,000							
Service facilities (installed)	134,242,000							
Land	6,712,000							
Engineering and supervision	60,409,000							
Construction expenses	26,848,000							
Legal expenses	13,424,000							
Contractor's fee	13,424,000							
Contingency	33,560,000							
Total fixed-capital investment	671,206,820							
Manufacturing cost								
Raw materials								
1. stearin		11,075,544,000	11,075,544,000	11,075,544,000	11,075,544,000	11,075,544,000	11,075,544,000	11,075,544,000
2. methanol		499,948,098	499,948,098	499,948,098	499,948,098	499,948,098	499,948,098	499,948,098

Appendix Table E14 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	11,688,240,999	11,688,240,999	11,688,240,999	11,688,240,999	11,688,240,999	11,688,240,999	11,688,240,999	11,688,240,999
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	159,358,842	159,358,842	159,358,842	159,358,842	159,358,842	159,358,842	159,358,842	159,358,842
Total income	11,847,599,841	11,847,599,841	11,847,599,841	11,847,599,841	11,847,599,841	11,847,599,841	11,847,599,841	11,847,599,841
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	11,075,544,000	11,075,544,000	11,075,544,000	11,075,544,000	11,075,544,000	11,075,544,000	11,075,544,000	11,075,544,000
2. methanol	499,948,098	499,948,098	499,948,098	499,948,098	499,948,098	499,948,098	499,948,098	499,948,098
3. potassium hydroxide	20,477,530	20,477,530	20,477,530	20,477,530	20,477,530	20,477,530	20,477,530	20,477,530

Appendix Table E14 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979
Cost of energy			144,511,805	144,511,805	144,511,805	144,511,805	144,511,805	144,511,805	144,511,805
Depreciation			16,108,988	16,108,988	16,108,988	16,108,988	16,108,988	16,108,988	16,108,988
Operating labor			1,296,000	1,334,880	1,374,926	1,416,174	1,458,659	1,502,419	1,547,492
Maintenance and repairs			33,560,341	33,560,341	33,560,341	33,560,341	33,560,341	33,560,341	33,560,341
Total operating cost			11,777,941,068	11,777,979,948	11,778,019,995	11,778,061,243	11,778,103,728	11,778,147,488	11,778,192,560
EBIT			69,658,772	69,619,892	69,579,846	69,538,598	69,496,113	69,452,353	69,407,281
Tax			20,897,632	20,885,968	20,873,954	20,861,579	20,848,834	20,835,706	20,822,184
Net income			48,761,140.74	48,733,924.74	48,705,892.26	48,677,018.80	48,647,279.14	48,616,647.30	48,585,096.49
Net cash flow from operating activities			64,870,128.77	64,842,912.77	64,814,880.29	64,786,006.83	64,756,267.18	64,725,635.33	64,694,084.53
Change in Gross fixed Asset		671,206,820							
Net Cashflow		-671,206,820	64,870,129	64,842,913	64,814,880	64,786,007	64,756,267	64,725,635	64,694,085
Add: Beginning Cashflow			-671,206,820	-606,336,692	-541,493,779	-476,678,899	-411,892,892	-347,136,625	-282,410,989
Ending cashflow		-671,206,820	-606,336,692	-541,493,779	-476,678,899	-411,892,892	-347,136,625	-282,410,989	-217,716,905
NPV	฿164,333								
IRR	5.00%								

Appendix Table E14 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	2,603,294	2,603,294	2,603,294	2,603,294	2,603,294	2,603,294	2,603,294	2,603,294
Cost of energy	144,511,805	144,511,805	144,511,805	144,511,805	144,511,805	144,511,805	144,511,805	144,511,805
Depreciation	16,108,988	16,108,988	16,108,988	16,108,988	16,108,988	16,108,988	16,108,988	16,108,988
Operating labor	1,593,917	1,641,734	1,690,986	1,741,716	1,793,967	1,847,786	1,903,220	1,960,316
Maintenance and repairs	33,560,341	33,560,341	33,560,341	33,560,341	33,560,341	33,560,341	33,560,341	33,560,341
Total operating cost	11,778,238,985	11,778,286,802	11,778,336,054	11,778,386,784	11,778,439,036	11,778,492,855	11,778,548,288	11,778,605,385
EBIT	69,360,856	69,313,038	69,263,786	69,213,057	69,160,805	69,106,986	69,051,553	68,994,456
Tax	20,808,257	20,793,912	20,779,136	20,763,917	20,748,242	20,732,096	20,715,466	20,698,337
Net income	48,552,599.17	48,519,126.92	48,484,650.51	48,449,139.80	48,412,563.77	48,374,890.46	48,336,086.95	48,296,119.34
Net cash flow from operating activities	64,661,587.20	64,628,114.95	64,593,638.54	64,558,127.83	64,521,551.80	64,483,878.49	64,445,074.98	64,405,107.37
Change in Gross fixed Asset								
Net Cashflow	64,661,587	64,628,115	64,593,639	64,558,128	64,521,552	64,483,878	64,445,075	64,405,107
Add: Beginning Cashflow	-217,716,905	-153,055,318	-88,427,203	-23,833,564	40,724,564	105,246,116	169,729,994	234,175,069
Ending cashflow	-153,055,318	-88,427,203	-23,833,564	40,724,564	105,246,116	169,729,994	234,175,069	298,580,176

Appendix Table E15 Fixed-capital investment and operating cost of plant A at capacity of stearin 500,000 kg in fixed flow rate pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		19,480,357,868	19,480,357,868	19,480,357,868	19,480,357,868	19,480,357,868	19,480,357,868	19,480,357,868
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		265,590,654	265,590,654	265,590,654	265,590,654	265,590,654	265,590,654	265,590,654
Total income		19,745,948,521	19,745,948,521	19,745,948,521	19,745,948,521	19,745,948,521	19,745,948,521	19,745,948,521
Investment cost								
Equipment cost								
1. ten storage tanks	192,291,787							
2. one reactor	15,038,664							
3. three mixing tanks	37,461,538							
4. two centrifuges	31,982,719							
5. three evaporators	74,170,205							
6. fourteen pumps	13,435,800							
Purchased equipment	364,380,713							
Purchased-equipment installation	68,321,000							
Instrumentation and controls (installed)	56,934,000							
Piping (installed)	56,934,000							
Electrical systems (installed)	34,161,000							
Buildings (including services)	45,548,000							
Yard improvement	22,774,000							
Service facilities (installed)	227,738,000							
Land	11,387,000							
Engineering and supervision	102,482,000							
Construction expenses	45,548,000							
Legal expenses	22,774,000							
Contractor's fee	22,774,000							
Contingency	56,934,000							
Total fixed-capital investment	1,138,689,713							
Manufacturing cost								
Raw materials								
1. stearin		18,459,240,000	18,459,240,000	18,459,240,000	18,459,240,000	18,459,240,000	18,459,240,000	18,459,240,000
2. methanol		833,246,830	833,246,830	833,246,830	833,246,830	833,246,830	833,246,830	833,246,830

Appendix Table E15 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	19,480,357,868	19,480,357,868	19,480,357,868	19,480,357,868	19,480,357,868	19,480,357,868	19,480,357,868	19,480,357,868
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	265,590,654	265,590,654	265,590,654	265,590,654	265,590,654	265,590,654	265,590,654	265,590,654
Total income	19,745,948,521	19,745,948,521	19,745,948,521	19,745,948,521	19,745,948,521	19,745,948,521	19,745,948,521	19,745,948,521
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	18,459,240,000	18,459,240,000	18,459,240,000	18,459,240,000	18,459,240,000	18,459,240,000	18,459,240,000	18,459,240,000
2. methanol	833,246,830	833,246,830	833,246,830	833,246,830	833,246,830	833,246,830	833,246,830	833,246,830
3. potassium hydroxide	34,129,217	34,129,217	34,129,217	34,129,217	34,129,217	34,129,217	34,129,217	34,129,217

Appendix Table E15 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979
Cost of energy			218,826,548	218,826,548	218,826,548	218,826,548	218,826,548	218,826,548	218,826,548
Depreciation			27,328,581	27,328,581	27,328,581	27,328,581	27,328,581	27,328,581	27,328,581
Operating labor			1,296,000	1,334,880	1,374,926	1,416,174	1,458,659	1,502,419	1,547,492
Maintenance and repairs			56,934,486	56,934,486	56,934,486	56,934,486	56,934,486	56,934,486	56,934,486
Total operating cost			19,608,012,022	19,608,050,902	19,608,090,948	19,608,132,196	19,608,174,681	19,608,218,441	19,608,263,513
EBIT			137,936,500	137,897,620	137,857,573	137,816,325	137,773,840	137,730,080	137,685,008
Tax			41,380,950	41,369,286	41,357,272	41,344,898	41,332,152	41,319,024	41,305,502
Net income			96,555,549.75	96,528,333.75	96,500,301.27	96,471,427.82	96,441,688.16	96,411,056.31	96,379,505.51
Net cash flow from operating activities			123,884,130.63	123,856,914.63	123,828,882.15	123,800,008.69	123,770,269.04	123,739,637.19	123,708,086.39
Change in Gross fixed Asset		1,138,689,713							
Net Cashflow		-1,138,689,713	123,884,131	123,856,915	123,828,882	123,800,009	123,770,269	123,739,637	123,708,086
Add: Beginning Cashflow			-1,138,689,713	-1,014,805,582	-890,948,668	-767,119,786	-643,319,777	-519,549,508	-395,809,871
Ending cashflow		-1,138,689,713	-1,014,805,582	-890,948,668	-767,119,786	-643,319,777	-519,549,508	-395,809,871	-272,101,784
NPV	฿138,318,872								
IRR	6.83%								

Appendix Table E15 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	4,338,940	4,338,940	4,338,940	4,338,940	4,338,940	4,338,940	4,338,940	4,338,940
Cost of energy	218,826,548	218,826,548	218,826,548	218,826,548	218,826,548	218,826,548	218,826,548	218,826,548
Depreciation	27,328,581	27,328,581	27,328,581	27,328,581	27,328,581	27,328,581	27,328,581	27,328,581
Operating labor	1,593,917	1,641,734	1,690,986	1,741,716	1,793,967	1,847,786	1,903,220	1,960,316
Maintenance and repairs	56,934,486	56,934,486	56,934,486	56,934,486	56,934,486	56,934,486	56,934,486	56,934,486
Total operating cost	19,608,309,938	19,608,357,756	19,608,407,008	19,608,457,737	19,608,509,989	19,608,563,808	19,608,619,241	19,608,676,338
EBIT	137,638,583	137,590,766	137,541,514	137,490,784	137,438,533	137,384,714	137,329,280	137,272,183
Tax	41,291,575	41,277,230	41,262,454	41,247,235	41,231,560	41,215,414	41,198,784	41,181,655
Net income	96,347,008.18	96,313,535.94	96,279,059.52	96,243,548.81	96,206,972.79	96,169,299.48	96,130,495.97	96,090,528.36
Net cash flow from operating activities	123,675,589.06	123,642,116.81	123,607,640.40	123,572,129.69	123,535,553.66	123,497,880.35	123,459,076.84	123,419,109.23
Change in Gross fixed Asset								
Net Cashflow	123,675,589	123,642,117	123,607,640	123,572,130	123,535,554	123,497,880	123,459,077	123,419,109
Add: Beginning Cashflow	-272,101,784	-148,426,195	-24,784,079	98,823,562	222,395,692	345,931,245	469,429,126	592,888,202
Ending cashflow	-148,426,195	-24,784,079	98,823,562	222,395,692	345,931,245	469,429,126	592,888,202	716,307,312

Appendix Table E16 Fixed-capital investment and operating cost of plant B at capacity of stearin 100,000 kg in fixed flow rate pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		4,204,428,629	4,204,428,629	4,204,428,629	4,204,428,629	4,204,428,629	4,204,428,629	4,204,428,629
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		57,322,187	57,322,187	57,322,187	57,322,187	57,322,187	57,322,187	57,322,187
Total income		4,261,750,815	4,261,750,815	4,261,750,815	4,261,750,815	4,261,750,815	4,261,750,815	4,261,750,815
Investment cost								
Equipment cost								
1. ten storage tanks	37,047,583							
2. one reactor	2,479,424							
3. three mixing tanks	6,163,785							
4. two centrifuges	13,850,038							
5. three evaporators	19,902,006							
6. fourteen pumps	3,389,700							
Purchased equipment	82,832,537							
Purchased-equipment installation	15,531,000							
Instrumentation and controls (installed)	12,943,000							
Piping (installed)	12,943,000							
Electrical systems (installed)	7,766,000							
Buildings (including services)	10,354,000							
Yard improvement	5,177,000							
Service facilities (installed)	51,770,000							
Land	2,589,000							
Engineering and supervision	23,297,000							
Construction expenses	10,354,000							
Legal expenses	5,177,000							
Contractor's fee	5,177,000							
Contingency	12,943,000							
Total fixed-capital investment	258,853,537							
Manufacturing cost								
Raw materials								
1. stearin		3,984,042,000	3,984,042,000	3,984,042,000	3,984,042,000	3,984,042,000	3,984,042,000	3,984,042,000
2. methanol		179,838,952	179,838,952	179,838,952	179,838,952	179,838,952	179,838,952	179,838,952

Appendix Table E16 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	4,204,428,629	4,204,428,629	4,204,428,629	4,204,428,629	4,204,428,629	4,204,428,629	4,204,428,629	4,204,428,629
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	57,322,187	57,322,187	57,322,187	57,322,187	57,322,187	57,322,187	57,322,187	57,322,187
Total income	4,261,750,815	4,261,750,815	4,261,750,815	4,261,750,815	4,261,750,815	4,261,750,815	4,261,750,815	4,261,750,815
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	3,984,042,000	3,984,042,000	3,984,042,000	3,984,042,000	3,984,042,000	3,984,042,000	3,984,042,000	3,984,042,000
2. methanol	179,838,952	179,838,952	179,838,952	179,838,952	179,838,952	179,838,952	179,838,952	179,838,952
3. potassium hydroxide	7,366,080	7,366,080	7,366,080	7,366,080	7,366,080	7,366,080	7,366,080	7,366,080

Appendix Table E16 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979
Cost of energy			49,384,554	49,384,554	49,384,554	49,384,554	49,384,554	49,384,554	49,384,554
Depreciation			6,212,436	6,212,436	6,212,436	6,212,436	6,212,436	6,212,436	6,212,436
Operating labor			1,728,000	1,779,840	1,833,235	1,888,232	1,944,879	2,003,226	2,063,322
Maintenance and repairs			12,942,677	12,942,677	12,942,677	12,942,677	12,942,677	12,942,677	12,942,677
Total operating cost			4,236,238,710	4,236,290,550	4,236,343,945	4,236,398,942	4,236,455,589	4,236,513,935	4,236,574,032
EBIT			25,512,106	25,460,266	25,406,870	25,351,873	25,295,226	25,236,880	25,176,783
Tax			7,653,632	7,638,080	7,622,061	7,605,562	7,588,568	7,571,064	7,553,035
Net income			17,858,473.94	17,822,185.94	17,784,809.30	17,746,311.36	17,706,658.48	17,665,816.01	17,623,748.28
Net cash flow from operating activities			24,070,909.72	24,034,621.72	23,997,245.08	23,958,747.14	23,919,094.26	23,878,251.80	23,836,184.06
Change in Gross fixed Asset		258,853,537							
Net Cashflow		-258,853,537	24,070,910	24,034,622	23,997,245	23,958,747	23,919,094	23,878,252	23,836,184
Add: Beginning Cashflow			-258,853,537	-234,782,627	-210,748,005	-186,750,760	-162,792,013	-138,872,919	-114,994,667
Ending cashflow		-258,853,537	-234,782,627	-210,748,005	-186,750,760	-162,792,013	-138,872,919	-114,994,667	-91,158,483
NPV	-฿11,053,559								
IRR	4.33%								

Appendix Table E16 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	936,447	936,447	936,447	936,447	936,447	936,447	936,447	936,447
Cost of energy	49,384,554	49,384,554	49,384,554	49,384,554	49,384,554	49,384,554	49,384,554	49,384,554
Depreciation	6,212,436	6,212,436	6,212,436	6,212,436	6,212,436	6,212,436	6,212,436	6,212,436
Operating labor	2,125,222	2,188,979	2,254,648	2,322,288	2,391,956	2,463,715	2,537,626	2,613,755
Maintenance and repairs	12,942,677	12,942,677	12,942,677	12,942,677	12,942,677	12,942,677	12,942,677	12,942,677
Total operating cost	4,236,635,932	4,236,699,689	4,236,765,358	4,236,832,997	4,236,902,666	4,236,974,425	4,237,048,336	4,237,124,465
EBIT	25,114,884	25,051,127	24,985,458	24,917,818	24,848,149	24,776,391	24,702,479	24,626,351
Tax	7,534,465	7,515,338	7,495,637	7,475,345	7,454,445	7,432,917	7,410,744	7,387,905
Net income	17,580,418.51	17,535,788.84	17,489,820.29	17,442,472.68	17,393,704.65	17,343,473.57	17,291,735.56	17,238,445.40
Net cash flow from operating activities	23,792,854.29	23,748,224.63	23,702,256.08	23,654,908.47	23,606,140.43	23,555,909.35	23,504,171.34	23,450,881.19
Change in Gross fixed Asset								
Net Cashflow	23,792,854	23,748,225	23,702,256	23,654,908	23,606,140	23,555,909	23,504,171	23,450,881
Add: Beginning Cashflow	-91,158,483	-67,365,629	-43,617,404	-19,915,148	3,739,760	27,345,901	50,901,810	74,405,982
Ending cashflow	-67,365,629	-43,617,404	-19,915,148	3,739,760	27,345,901	50,901,810	74,405,982	97,856,863

Appendix Table E17 Fixed-capital investment and operating cost of plant B at capacity of stearin 300,000 kg in fixed flow rate pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		12,613,289,109	12,613,289,109	12,613,289,109	12,613,289,109	12,613,289,109	12,613,289,109	12,613,289,109
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		171,966,603	171,966,603	171,966,603	171,966,603	171,966,603	171,966,603	171,966,603
Total income		12,785,255,712	12,785,255,712	12,785,255,712	12,785,255,712	12,785,255,712	12,785,255,712	12,785,255,712
Investment cost								
Equipment cost								
1. ten storage tanks	134,191,442							
2. one reactor	7,693,497							
3. three mixing tanks	19,150,494							
4. two centrifuges	24,521,895							
5. three evaporators	50,763,177							
6. fourteen pumps	8,526,300							
Purchased equipment	244,846,805							
Purchased-equipment installation	45,909,000							
Instrumentation and controls (installed)	38,257,000							
Piping (installed)	38,257,000							
Electrical systems (installed)	22,954,000							
Buildings (including services)	30,606,000							
Yard improvement	15,303,000							
Service facilities (installed)	153,029,000							
Land	7,651,000							
Engineering and supervision	68,863,000							
Construction expenses	30,606,000							
Legal expenses	15,303,000							
Contractor's fee	15,303,000							
Contingency	38,257,000							
Total fixed-capital investment	765,144,805							
Manufacturing cost								
Raw materials								
1. stearin		11,952,126,000	11,952,126,000	11,952,126,000	11,952,126,000	11,952,126,000	11,952,126,000	11,952,126,000
2. methanol		539,516,855	539,516,855	539,516,855	539,516,855	539,516,855	539,516,855	539,516,855

Appendix Table E17 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	12,613,289,109	12,613,289,109	12,613,289,109	12,613,289,109	12,613,289,109	12,613,289,109	12,613,289,109	12,613,289,109
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	171,966,603	171,966,603	171,966,603	171,966,603	171,966,603	171,966,603	171,966,603	171,966,603
Total income	12,785,255,712	12,785,255,712	12,785,255,712	12,785,255,712	12,785,255,712	12,785,255,712	12,785,255,712	12,785,255,712
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	11,952,126,000	11,952,126,000	11,952,126,000	11,952,126,000	11,952,126,000	11,952,126,000	11,952,126,000	11,952,126,000
2. methanol	539,516,855	539,516,855	539,516,855	539,516,855	539,516,855	539,516,855	539,516,855	539,516,855
3. potassium hydroxide	22,098,239	22,098,239	22,098,239	22,098,239	22,098,239	22,098,239	22,098,239	22,098,239

Appendix Table E17 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979
Cost of energy			148,424,592	148,424,592	148,424,592	148,424,592	148,424,592	148,424,592	148,424,592
Depreciation			18,363,520	18,363,520	18,363,520	18,363,520	18,363,520	18,363,520	18,363,520
Operating labor			1,728,000	1,779,840	1,833,235	1,888,232	1,944,879	2,003,226	2,063,322
Maintenance and repairs			38,257,240	38,257,240	38,257,240	38,257,240	38,257,240	38,257,240	38,257,240
Total operating cost			12,704,960,259	12,705,012,099	12,705,065,495	12,705,120,492	12,705,177,139	12,705,235,485	12,705,295,582
EBIT			80,295,452	80,243,612	80,190,217	80,135,220	80,078,573	80,020,227	79,960,130
Tax			24,088,636	24,073,084	24,057,065	24,040,566	24,023,572	24,006,068	23,988,039
Net income			56,206,816.72	56,170,528.72	56,133,152.08	56,094,654.14	56,055,001.26	56,014,158.80	55,972,091.06
Net cash flow from operating activities			74,570,337.06	74,534,049.06	74,496,672.42	74,458,174.48	74,418,521.60	74,377,679.14	74,335,611.40
Change in Gross fixed Asset		765,144,805							
Net Cashflow		-765,144,805	74,570,337	74,534,049	74,496,672	74,458,174	74,418,522	74,377,679	74,335,611
Add: Beginning Cashflow			-765,144,805	-690,574,468	-616,040,419	-541,543,747	-467,085,572	-392,667,051	-318,289,371
Ending cashflow		-765,144,805	-690,574,468	-616,040,419	-541,543,747	-467,085,572	-392,667,051	-318,289,371	-243,953,760
NPV	฿5,970,745								
IRR	5.12%								

Appendix Table E17 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	2,809,334	2,809,334	2,809,334	2,809,334	2,809,334	2,809,334	2,809,334	2,809,334
Cost of energy	148,424,592	148,424,592	148,424,592	148,424,592	148,424,592	148,424,592	148,424,592	148,424,592
Depreciation	18,363,520	18,363,520	18,363,520	18,363,520	18,363,520	18,363,520	18,363,520	18,363,520
Operating labor	2,125,222	2,188,979	2,254,648	2,322,288	2,391,956	2,463,715	2,537,626	2,613,755
Maintenance and repairs	38,257,240	38,257,240	38,257,240	38,257,240	38,257,240	38,257,240	38,257,240	38,257,240
Total operating cost	12,705,357,481	12,705,421,238	12,705,486,907	12,705,554,547	12,705,624,216	12,705,695,974	12,705,769,886	12,705,846,014
EBIT	79,898,230	79,834,474	79,768,804	79,701,165	79,631,496	79,559,738	79,485,826	79,409,697
Tax	23,969,469	23,950,342	23,930,641	23,910,349	23,889,449	23,867,921	23,845,748	23,822,909
Net income	55,928,761.29	55,884,131.63	55,838,163.07	55,790,815.46	55,742,047.43	55,691,816.35	55,640,078.34	55,586,788.19
Net cash flow from operating activities	74,292,281.63	74,247,651.97	74,201,683.42	74,154,335.81	74,105,567.77	74,055,336.69	74,003,598.68	73,950,308.53
Change in Gross fixed Asset								
Net Cashflow	74,292,282	74,247,652	74,201,683	74,154,336	74,105,568	74,055,337	74,003,599	73,950,309
Add: Beginning Cashflow	-243,953,760	-169,661,478	-95,413,826	-21,212,143	52,942,193	127,047,761	201,103,097	275,106,696
Ending cashflow	-169,661,478	-95,413,826	-21,212,143	52,942,193	127,047,761	201,103,097	275,106,696	349,057,005

Appendix Table E18 Fixed-capital investment and operating cost of plant B at capacity of stearin 500,000 kg in fixed flow rate pattern

List		0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)			46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel			21,022,143,604	21,022,143,604	21,022,143,604	21,022,143,604	21,022,143,604	21,022,143,604	21,022,143,604
Cost of glycerol (baht/kg)			5	5	5	5	5	5	5
Income from glycerol			286,611,019	286,611,019	286,611,019	286,611,019	286,611,019	286,611,019	286,611,019
Total income			21,308,754,624	21,308,754,624	21,308,754,624	21,308,754,624	21,308,754,624	21,308,754,624	21,308,754,624
Investment cost									
Equipment cost									
1. ten storage tanks		247,120,251							
2. one reactor		13,532,384							
3. three mixing tanks		33,770,454							
4. two centrifuges		31,982,719							
5. three evaporators		74,170,206							
6. fourteen pumps		19,194,000							
Purchased equipment	32	419,770,013	1,311,781,291	0.32					
Purchased-equipment installation	6	78,707,000	78,706,877	0.06					
Instrumentation and controls (installed)	5	65,589,000	65,589,065	0.05					
Piping (installed)	5	65,589,000	65,589,065	0.05					
Electrical systems (installed)	3	39,353,000	39,353,439	0.03					
Buildings (including services)	4	52,471,000	52,471,252	0.04					
Yard improvement	2	26,236,000	26,235,626	0.02					
Service facilities (installed)	20	262,356,000	262,356,258	0.20					
Land	1	13,118,000	13,117,813	0.01					
Engineering and supervision	9	118,060,000	118,060,316	0.09					
Construction expenses	4	52,470,000	52,471,252	0.04					
Legal expenses	2	26,236,000	26,235,626	0.02					
Contractor's fee	2	26,236,000	26,235,626	0.02					
Contingency	5	65,589,000	65,589,065	0.05					
Total fixed-capital investment	100	1,311,780,013	1,311,781,291	1					
Manufacturing cost									
Raw materials									
1. stearin			19,920,210,000	19,920,210,000	19,920,210,000	19,920,210,000	19,920,210,000	19,920,210,000	19,920,210,000
2. methanol			899,194,758	899,194,758	899,194,758	899,194,758	899,194,758	899,194,758	899,194,758

Appendix Table E18 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	21,022,143,604	21,022,143,604	21,022,143,604	21,022,143,604	21,022,143,604	21,022,143,604	21,022,143,604	21,022,143,604
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	286,611,019	286,611,019	286,611,019	286,611,019	286,611,019	286,611,019	286,611,019	286,611,019
Total income	21,308,754,624	21,308,754,624	21,308,754,624	21,308,754,624	21,308,754,624	21,308,754,624	21,308,754,624	21,308,754,624
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	19,920,210,000	19,920,210,000	19,920,210,000	19,920,210,000	19,920,210,000	19,920,210,000	19,920,210,000	19,920,210,000
2. methanol	899,194,758	899,194,758	899,194,758	899,194,758	899,194,758	899,194,758	899,194,758	899,194,758
3. potassium hydroxide	36,830,399	36,830,399	36,830,399	36,830,399	36,830,399	36,830,399	36,830,399	36,830,399

Appendix Table E18 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979
Cost of energy			225,610,381	225,610,381	225,610,381	225,610,381	225,610,381	225,610,381	225,610,381
Depreciation			31,482,668	31,482,668	31,482,668	31,482,668	31,482,668	31,482,668	31,482,668
Operating labor			1,728,000	1,779,840	1,833,235	1,888,232	1,944,879	2,003,226	2,063,322
Maintenance and repairs			65,589,001	65,589,001	65,589,001	65,589,001	65,589,001	65,589,001	65,589,001
Total operating cost			21,153,844,887	21,153,896,727	21,153,950,122	21,154,005,119	21,154,061,766	21,154,120,113	21,154,180,210
EBIT			154,909,736	154,857,896	154,804,501	154,749,504	154,692,857	154,634,511	154,574,414
Tax			46,472,921	46,457,369	46,441,350	46,424,851	46,407,857	46,390,353	46,372,324
Net income			108,436,815.43	108,400,527.43	108,363,150.79	108,324,652.85	108,284,999.97	108,244,157.51	108,202,089.77
Net cash flow from operating activities			139,919,482.97	139,883,194.97	139,845,818.33	139,807,320.39	139,767,667.52	139,726,825.05	139,684,757.32
Change in Gross fixed Asset		1,311,780,013							
Net Cashflow		-1,311,780,013	139,919,483	139,883,195	139,845,818	139,807,320	139,767,668	139,726,825	139,684,757
Add: Beginning Cashflow			-1,311,780,013	-1,171,860,530	-1,031,977,335	-892,131,517	-752,324,197	-612,556,529	-472,829,704
Ending cashflow		-1,311,780,013	-1,171,860,530	-1,031,977,335	-892,131,517	-752,324,197	-612,556,529	-472,829,704	-333,144,947
NPV	฿131,367,487								
IRR	6.52%								

Appendix Table E18 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	4,682,349	4,682,349	4,682,349	4,682,349	4,682,349	4,682,349	4,682,349	4,682,349
Cost of energy	225,610,381	225,610,381	225,610,381	225,610,381	225,610,381	225,610,381	225,610,381	225,610,381
Depreciation	31,482,668	31,482,668	31,482,668	31,482,668	31,482,668	31,482,668	31,482,668	31,482,668
Operating labor	2,125,222	2,188,979	2,254,648	2,322,288	2,391,956	2,463,715	2,537,626	2,613,755
Maintenance and repairs	65,589,001	65,589,001	65,589,001	65,589,001	65,589,001	65,589,001	65,589,001	65,589,001
Total operating cost	21,154,242,109	21,154,305,866	21,154,371,535	21,154,439,175	21,154,508,843	21,154,580,602	21,154,654,513	21,154,730,642
EBIT	154,512,514	154,448,758	154,383,088	154,315,449	154,245,780	154,174,022	154,100,110	154,023,981
Tax	46,353,754	46,334,627	46,314,926	46,294,635	46,273,734	46,252,206	46,230,033	46,207,194
Net income	108,158,760.00	108,114,130.34	108,068,161.78	108,020,814.17	107,972,046.14	107,921,815.06	107,870,077.05	107,816,786.90
Net cash flow from operating activities	139,641,427.55	139,596,797.88	139,550,829.33	139,503,481.72	139,454,713.68	139,404,482.60	139,352,744.59	139,299,454.44
Change in Gross fixed Asset								
Net Cashflow	139,641,428	139,596,798	139,550,829	139,503,482	139,454,714	139,404,483	139,352,745	139,299,454
Add: Beginning Cashflow	-333,144,947	-193,503,519	-53,906,721	85,644,108	225,147,590	364,602,304	504,006,786	643,359,531
Ending cashflow	-193,503,519	-53,906,721	85,644,108	225,147,590	364,602,304	504,006,786	643,359,531	782,658,985

Appendix Table E19 Fixed-capital investment and operating cost of plant C at capacity of stearin 100,000 kg in fixed flow rate pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		4,331,696,723	4,331,696,723	4,331,696,723	4,331,696,723	4,331,696,723	4,331,696,723	4,331,696,723
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		59,058,882	59,058,882	59,058,882	59,058,882	59,058,882	59,058,882	59,058,882
Total income		4,390,755,605	4,390,755,605	4,390,755,605	4,390,755,605	4,390,755,605	4,390,755,605	4,390,755,605
Investment cost								
Equipment cost								
1. ten storage tanks	36,922,399							
2. one reactor	2,556,415							
3. three mixing tanks	6,260,943							
4. two centrifuges	13,850,038							
5. three evaporators	19,969,279							
6. fourteen pumps	3,389,700							
Purchased equipment	82,948,774							
Purchased-equipment installation	15,553,000							
Instrumentation and controls (installed)	12,961,000							
Piping (installed)	12,961,000							
Electrical systems (installed)	7,776,000							
Buildings (including services)	10,369,000							
Yard improvement	5,184,000							
Service facilities (installed)	51,843,000							
Land	2,592,000							
Engineering and supervision	23,329,000							
Construction expenses	10,369,000							
Legal expenses	5,184,000							
Contractor's fee	5,184,000							
Contingency	12,961,000							
Total fixed-capital investment	259,214,774							
Manufacturing cost								
Raw materials								
1. stearin		4,104,630,000	4,104,630,000	4,104,630,000	4,104,630,000	4,104,630,000	4,104,630,000	4,104,630,000
2. methanol		185,282,273	185,282,273	185,282,273	185,282,273	185,282,273	185,282,273	185,282,273

Appendix Table E19 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	4,331,696,723	4,331,696,723	4,331,696,723	4,331,696,723	4,331,696,723	4,331,696,723	4,331,696,723	4,331,696,723
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	59,058,882	59,058,882	59,058,882	59,058,882	59,058,882	59,058,882	59,058,882	59,058,882
Total income	4,390,755,605	4,390,755,605	4,390,755,605	4,390,755,605	4,390,755,605	4,390,755,605	4,390,755,605	4,390,755,605
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	4,104,630,000	4,104,630,000	4,104,630,000	4,104,630,000	4,104,630,000	4,104,630,000	4,104,630,000	4,104,630,000
2. methanol	185,282,273	185,282,273	185,282,273	185,282,273	185,282,273	185,282,273	185,282,273	185,282,273
3. potassium hydroxide	7,589,034	7,589,034	7,589,034	7,589,034	7,589,034	7,589,034	7,589,034	7,589,034

Appendix Table E19 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979
Cost of energy			51,082,307	51,082,307	51,082,307	51,082,307	51,082,307	51,082,307	51,082,307
Depreciation			6,221,185	6,221,185	6,221,185	6,221,185	6,221,185	6,221,185	6,221,185
Operating labor			2,160,000	2,224,800	2,291,544	2,360,290	2,431,099	2,504,032	2,579,153
Maintenance and repairs			12,960,739	12,960,739	12,960,739	12,960,739	12,960,739	12,960,739	12,960,739
Total operating cost			4,364,669,144	4,364,733,944	4,364,800,688	4,364,869,435	4,364,940,243	4,365,013,176	4,365,088,297
EBIT			26,086,461	26,021,661	25,954,917	25,886,170	25,815,362	25,742,429	25,667,308
Tax			7,825,938	7,806,498	7,786,475	7,765,851	7,744,608	7,722,729	7,700,192
Net income			18,260,522.37	18,215,162.37	18,168,441.57	18,120,319.15	18,070,753.05	18,019,699.97	17,967,115.30
Net cash flow from operating activities			24,481,707.33	24,436,347.33	24,389,626.53	24,341,504.11	24,291,938.01	24,240,884.93	24,188,300.26
Change in Gross fixed Asset		259,214,774							
Net Cashflow		-259,214,774	24,481,707	24,436,347	24,389,627	24,341,504	24,291,938	24,240,885	24,188,300
Add: Beginning Cashflow			-259,214,774	-234,733,067	-210,296,720	-185,907,093	-161,565,589	-137,273,651	-113,032,766
Ending cashflow		-259,214,774	-234,733,067	-210,296,720	-185,907,093	-161,565,589	-137,273,651	-113,032,766	-88,844,466
NPV	-฿7,955,870								
IRR	4.52%								

Appendix Table E19 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	964,792	964,792	964,792	964,792	964,792	964,792	964,792	964,792
Cost of energy	51,082,307	51,082,307	51,082,307	51,082,307	51,082,307	51,082,307	51,082,307	51,082,307
Depreciation	6,221,185	6,221,185	6,221,185	6,221,185	6,221,185	6,221,185	6,221,185	6,221,185
Operating labor	2,656,528	2,736,223	2,818,310	2,902,859	2,989,945	3,079,644	3,172,033	3,267,194
Maintenance and repairs	12,960,739	12,960,739	12,960,739	12,960,739	12,960,739	12,960,739	12,960,739	12,960,739
Total operating cost	4,365,165,672	4,365,245,368	4,365,327,454	4,365,412,004	4,365,499,089	4,365,588,788	4,365,681,177	4,365,776,338
EBIT	25,589,933	25,510,237	25,428,150	25,343,601	25,256,515	25,166,817	25,074,428	24,979,267
Tax	7,676,980	7,653,071	7,628,445	7,603,080	7,576,955	7,550,045	7,522,328	7,493,780
Net income	17,912,953.09	17,857,166.01	17,799,705.32	17,740,520.81	17,679,560.76	17,616,771.91	17,552,099.40	17,485,486.71
Net cash flow from operating activities	24,134,138.05	24,078,350.97	24,020,890.28	23,961,705.77	23,900,745.72	23,837,956.87	23,773,284.36	23,706,671.67
Change in Gross fixed Asset								
Net Cashflow	24,134,138	24,078,351	24,020,890	23,961,706	23,900,746	23,837,957	23,773,284	23,706,672
Add: Beginning Cashflow	-88,844,466	-64,710,328	-40,631,977	-16,611,087	7,350,619	31,251,365	55,089,322	78,862,606
Ending cashflow	-64,710,328	-40,631,977	-16,611,087	7,350,619	31,251,365	55,089,322	78,862,606	102,569,278

Appendix Table E20 Fixed-capital investment and operating cost of plant C at capacity of stearin 300,000 kg in fixed flow rate pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		12,995,087,323	12,995,087,323	12,995,087,323	12,995,087,323	12,995,087,323	12,995,087,323	12,995,087,323
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		177,176,602	177,176,602	177,176,602	177,176,602	177,176,602	177,176,602	177,176,602
Total income		13,172,263,924	13,172,263,924	13,172,263,924	13,172,263,924	13,172,263,924	13,172,263,924	13,172,263,924
Investment cost								
Equipment cost								
1. ten storage tanks	133,256,216							
2. one reactor	7,489,794							
3. three mixing tanks	18,643,713							
4. two centrifuges	24,521,895							
5. three evaporators	50,934,600							
6. fourteen pumps	8,526,300							
Purchased equipment	243,372,518							
Purchased-equipment installation	45,632,000							
Instrumentation and controls (installed)	38,027,000							
Piping (installed)	38,027,000							
Electrical systems (installed)	22,816,000							
Buildings (including services)	30,422,000							
Yard improvement	15,211,000							
Service facilities (installed)	152,108,000							
Land	7,605,000							
Engineering and supervision	68,449,000							
Construction expenses	30,422,000							
Legal expenses	15,211,000							
Contractor's fee	15,211,000							
Contingency	38,027,000							
Total fixed-capital investment	760,540,518							
Manufacturing cost								
Raw materials								
1. stearin		12,313,890,000	12,313,890,000	12,313,890,000	12,313,890,000	12,313,890,000	12,313,890,000	12,313,890,000
2. methanol		555,846,818	555,846,818	555,846,818	555,846,818	555,846,818	555,846,818	555,846,818

Appendix Table E20 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	12,995,087,323	12,995,087,323	12,995,087,323	12,995,087,323	12,995,087,323	12,995,087,323	12,995,087,323	12,995,087,323
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	177,176,602	177,176,602	177,176,602	177,176,602	177,176,602	177,176,602	177,176,602	177,176,602
Total income	13,172,263,924	13,172,263,924	13,172,263,924	13,172,263,924	13,172,263,924	13,172,263,924	13,172,263,924	13,172,263,924
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	12,313,890,000	12,313,890,000	12,313,890,000	12,313,890,000	12,313,890,000	12,313,890,000	12,313,890,000	12,313,890,000
2. methanol	555,846,818	555,846,818	555,846,818	555,846,818	555,846,818	555,846,818	555,846,818	555,846,818
3. potassium hydroxide	22,767,103	22,767,103	22,767,103	22,767,103	22,767,103	22,767,103	22,767,103	22,767,103

Appendix Table E20 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979
Cost of energy			153,521,029	153,521,029	153,521,029	153,521,029	153,521,029	153,521,029	153,521,029
Depreciation			18,252,968	18,252,968	18,252,968	18,252,968	18,252,968	18,252,968	18,252,968
Operating labor			2,160,000	2,224,800	2,291,544	2,360,290	2,431,099	2,504,032	2,579,153
Maintenance and repairs			38,027,026	38,027,026	38,027,026	38,027,026	38,027,026	38,027,026	38,027,026
Total operating cost			13,089,106,341	13,089,171,141	13,089,237,885	13,089,306,632	13,089,377,440	13,089,450,373	13,089,525,494
EBIT			83,157,583	83,092,783	83,026,039	82,957,293	82,886,484	82,813,551	82,738,430
Tax			24,947,275	24,927,835	24,907,812	24,887,188	24,865,945	24,844,065	24,821,529
Net income			58,210,308.14	58,164,948.14	58,118,227.34	58,070,104.92	58,020,538.82	57,969,485.74	57,916,901.07
Net cash flow from operating activities			76,463,276.00	76,417,916.00	76,371,195.20	76,323,072.77	76,273,506.68	76,222,453.60	76,169,868.92
Change in Gross fixed Asset		760,540,518							
Net Cashflow		-760,540,518	76,463,276	76,417,916	76,371,195	76,323,073	76,273,507	76,222,454	76,169,869
Add: Beginning Cashflow			-760,540,518	-684,077,242	-607,659,326	-531,288,131	-454,965,058	-378,691,551	-302,469,098
Ending cashflow		-760,540,518	-684,077,242	-607,659,326	-531,288,131	-454,965,058	-378,691,551	-302,469,098	-226,299,229
NPV	฿28,449,048								
IRR	5.58%								

Appendix Table E20 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	2,894,366	2,894,366	2,894,366	2,894,366	2,894,366	2,894,366	2,894,366	2,894,366
Cost of energy	153,521,029	153,521,029	153,521,029	153,521,029	153,521,029	153,521,029	153,521,029	153,521,029
Depreciation	18,252,968	18,252,968	18,252,968	18,252,968	18,252,968	18,252,968	18,252,968	18,252,968
Operating labor	2,656,528	2,736,223	2,818,310	2,902,859	2,989,945	3,079,644	3,172,033	3,267,194
Maintenance and repairs	38,027,026	38,027,026	38,027,026	38,027,026	38,027,026	38,027,026	38,027,026	38,027,026
Total operating cost	13,089,602,869	13,089,682,565	13,089,764,651	13,089,849,201	13,089,936,286	13,090,025,985	13,090,118,374	13,090,213,535
EBIT	82,661,056	82,581,360	82,499,273	82,414,724	82,327,638	82,237,940	82,145,550	82,050,389
Tax	24,798,317	24,774,408	24,749,782	24,724,417	24,698,291	24,671,382	24,643,665	24,615,117
Net income	57,862,738.86	57,806,951.78	57,749,491.09	57,690,306.58	57,629,346.53	57,566,557.68	57,501,885.17	57,435,272.48
Net cash flow from operating activities	76,115,706.71	76,059,919.63	76,002,458.94	75,943,274.43	75,882,314.38	75,819,525.54	75,754,853.02	75,688,240.33
Change in Gross fixed Asset								
Net Cashflow	76,115,707	76,059,920	76,002,459	75,943,274	75,882,314	75,819,526	75,754,853	75,688,240
Add: Beginning Cashflow	-226,299,229	-150,183,522	-74,123,602	1,878,857	77,822,131	153,704,445	229,523,971	305,278,824
Ending cashflow	-150,183,522	-74,123,602	1,878,857	77,822,131	153,704,445	229,523,971	305,278,824	380,967,064

Appendix Table E21 Fixed-capital investment and operating cost of plant C at capacity of stearin 500,000 kg in fixed flow rate pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		21,658,483,140	21,658,483,140	21,658,483,140	21,658,483,140	21,658,483,140	21,658,483,140	21,658,483,140
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		295,294,322	295,294,322	295,294,322	295,294,322	295,294,322	295,294,322	295,294,322
Total income		21,953,777,461	21,953,777,461	21,953,777,461	21,953,777,461	21,953,777,461	21,953,777,461	21,953,777,461
Investment cost								
Equipment cost								
1. ten storage tanks	246,107,169							
2. one reactor	12,923,693							
3. three mixing tanks	32,275,486							
4. two centrifuges	31,982,719							
5. three evaporators	74,410,422							
6. fourteen pumps	19,194,000							
Purchased equipment	416,893,488							
Purchased-equipment installation	78,168,000							
Instrumentation and controls (installed)	65,140,000							
Piping (installed)	65,140,000							
Electrical systems (installed)	39,084,000							
Buildings (including services)	52,112,000							
Yard improvement	26,056,000							
Service facilities (installed)	260,558,000							
Land	13,028,000							
Engineering and supervision	117,251,000							
Construction expenses	52,112,000							
Legal expenses	26,056,000							
Contractor's fee	26,056,000							
Contingency	65,140,000							
Total fixed-capital investment	1,302,794,488							
Manufacturing cost								
Raw materials								
1. stearin		20,523,150,000	20,523,150,000	20,523,150,000	20,523,150,000	20,523,150,000	20,523,150,000	20,523,150,000
2. methanol		926,411,363	926,411,363	926,411,363	926,411,363	926,411,363	926,411,363	926,411,363

Appendix Table E21 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	21,658,483,140	21,658,483,140	21,658,483,140	21,658,483,140	21,658,483,140	21,658,483,140	21,658,483,140	21,658,483,140
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	295,294,322	295,294,322	295,294,322	295,294,322	295,294,322	295,294,322	295,294,322	295,294,322
Total income	21,953,777,461	21,953,777,461	21,953,777,461	21,953,777,461	21,953,777,461	21,953,777,461	21,953,777,461	21,953,777,461
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	20,523,150,000	20,523,150,000	20,523,150,000	20,523,150,000	20,523,150,000	20,523,150,000	20,523,150,000	20,523,150,000
2. methanol	926,411,363	926,411,363	926,411,363	926,411,363	926,411,363	926,411,363	926,411,363	926,411,363
3. potassium hydroxide	37,945,172	37,945,172	37,945,172	37,945,172	37,945,172	37,945,172	37,945,172	37,945,172

Appendix Table E21 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979
Cost of energy			233,461,788	233,461,788	233,461,788	233,461,788	233,461,788	233,461,788	233,461,788
Depreciation			31,267,033	31,267,033	31,267,033	31,267,033	31,267,033	31,267,033	31,267,033
Operating labor			2,160,000	2,224,800	2,291,544	2,360,290	2,431,099	2,504,032	2,579,153
Maintenance and repairs			65,139,724	65,139,724	65,139,724	65,139,724	65,139,724	65,139,724	65,139,724
Total operating cost			21,793,092,121	21,793,156,921	21,793,223,665	21,793,292,411	21,793,363,220	21,793,436,153	21,793,511,274
EBIT			160,685,341	160,620,541	160,553,797	160,485,050	160,414,242	160,341,309	160,266,188
Tax			48,205,602	48,186,162	48,166,139	48,145,515	48,124,272	48,102,393	48,079,856
Net income			112,479,738.40	112,434,378.40	112,387,657.60	112,339,535.18	112,289,969.08	112,238,916.00	112,186,331.33
Net cash flow from operating activities			143,746,770.95	143,701,410.95	143,654,690.15	143,606,567.72	143,557,001.63	143,505,948.55	143,453,363.87
Change in Gross fixed Asset		1,302,794,488							
Net Cashflow		-1,302,794,488	143,746,771	143,701,411	143,654,690	143,606,568	143,557,002	143,505,949	143,453,364
Add: Beginning Cashflow			-1,302,794,488	-1,159,047,717	-1,015,346,306	-871,691,616	-728,085,048	-584,528,047	-441,022,098
Ending cashflow		-1,302,794,488	-1,159,047,717	-1,015,346,306	-871,691,616	-728,085,048	-584,528,047	-441,022,098	-297,568,734
NPV	฿177,140,190								
IRR	7.05%								

Appendix Table E21 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	4,824,073	4,824,073	4,824,073	4,824,073	4,824,073	4,824,073	4,824,073	4,824,073
Cost of energy	233,461,788	233,461,788	233,461,788	233,461,788	233,461,788	233,461,788	233,461,788	233,461,788
Depreciation	31,267,033	31,267,033	31,267,033	31,267,033	31,267,033	31,267,033	31,267,033	31,267,033
Operating labor	2,656,528	2,736,223	2,818,310	2,902,859	2,989,945	3,079,644	3,172,033	3,267,194
Maintenance and repairs	65,139,724	65,139,724	65,139,724	65,139,724	65,139,724	65,139,724	65,139,724	65,139,724
Total operating cost	21,793,588,648	21,793,668,344	21,793,750,431	21,793,834,980	21,793,922,066	21,794,011,764	21,794,104,153	21,794,199,314
EBIT	160,188,813	160,109,117	160,027,030	159,942,481	159,855,395	159,765,697	159,673,308	159,578,147
Tax	48,056,644	48,032,735	48,008,109	47,982,744	47,956,619	47,929,709	47,901,992	47,873,444
Net income	112,132,169.12	112,076,382.04	112,018,921.35	111,959,736.83	111,898,776.79	111,835,987.94	111,771,315.43	111,704,702.74
Net cash flow from operating activities	143,399,201.66	143,343,414.58	143,285,953.89	143,226,769.38	143,165,809.33	143,103,020.49	143,038,347.97	142,971,735.28
Change in Gross fixed Asset								
Net Cashflow	143,399,202	143,343,415	143,285,954	143,226,769	143,165,809	143,103,020	143,038,348	142,971,735
Add: Beginning Cashflow	-297,568,734	-154,169,533	-10,826,118	132,459,836	275,686,605	418,852,414	561,955,435	704,993,783
Ending cashflow	-154,169,533	-10,826,118	132,459,836	275,686,605	418,852,414	561,955,435	704,993,783	847,965,518

Appendix Table E22 Fixed-capital investment and operating cost of plant D at capacity of stearin 100,000 kg in fixed flow rate pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		4,331,697,671	4,331,697,671	4,331,697,671	4,331,697,671	4,331,697,671	4,331,697,671	4,331,697,671
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		59,058,838	59,058,838	59,058,838	59,058,838	59,058,838	59,058,838	59,058,838
Total income		4,390,756,509	4,390,756,509	4,390,756,509	4,390,756,509	4,390,756,509	4,390,756,509	4,390,756,509
Investment cost								
Equipment cost								
1. ten storage tanks	36,808,476							
2. one reactor	2,657,648							
3. three mixing tanks	6,449,165							
4. two centrifuges	13,850,038							
5. three evaporators	19,969,282							
6. fourteen pumps	3,389,700							
Purchased equipment	83,124,310							
Purchased-equipment installation	15,586,000							
Instrumentation and controls (installed)	12,988,000							
Piping (installed)	12,988,000							
Electrical systems (installed)	7,793,000							
Buildings (including services)	10,391,000							
Yard improvement	5,195,000							
Service facilities (installed)	51,953,000							
Land	2,598,000							
Engineering and supervision	23,379,000							
Construction expenses	10,391,000							
Legal expenses	5,195,000							
Contractor's fee	5,195,000							
Contingency	12,988,000							
Total fixed-capital investment	259,764,310							
Manufacturing cost								
Raw materials								
1. stearin		4,104,630,000	4,104,630,000	4,104,630,000	4,104,630,000	4,104,630,000	4,104,630,000	4,104,630,000
2. methanol		185,282,273	185,282,273	185,282,273	185,282,273	185,282,273	185,282,273	185,282,273

Appendix Table E22 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	4,331,697,671	4,331,697,671	4,331,697,671	4,331,697,671	4,331,697,671	4,331,697,671	4,331,697,671	4,331,697,671
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	59,058,838	59,058,838	59,058,838	59,058,838	59,058,838	59,058,838	59,058,838	59,058,838
Total income	4,390,756,509	4,390,756,509	4,390,756,509	4,390,756,509	4,390,756,509	4,390,756,509	4,390,756,509	4,390,756,509
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	4,104,630,000	4,104,630,000	4,104,630,000	4,104,630,000	4,104,630,000	4,104,630,000	4,104,630,000	4,104,630,000
2. methanol	185,282,273	185,282,273	185,282,273	185,282,273	185,282,273	185,282,273	185,282,273	185,282,273
3. potassium hydroxide	7,589,034	7,589,034	7,589,034	7,589,034	7,589,034	7,589,034	7,589,034	7,589,034

Appendix Table E22 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979
Cost of energy			51,883,856	51,883,856	51,883,856	51,883,856	51,883,856	51,883,856	51,883,856
Depreciation			6,234,354	6,234,354	6,234,354	6,234,354	6,234,354	6,234,354	6,234,354
Operating labor			2,592,000	2,669,760	2,749,853	2,832,348	2,917,319	3,004,838	3,094,984
Maintenance and repairs			12,988,215	12,988,215	12,988,215	12,988,215	12,988,215	12,988,215	12,988,215
Total operating cost			4,365,930,170	4,366,007,930	4,366,088,023	4,366,170,519	4,366,255,489	4,366,343,009	4,366,433,154
EBIT			24,826,339	24,748,579	24,668,486	24,585,990	24,501,020	24,413,500	24,323,355
Tax			7,447,902	7,424,574	7,400,546	7,375,797	7,350,306	7,324,050	7,297,007
Net income			17,378,437.08	17,324,005.08	17,267,940.12	17,210,193.21	17,150,713.89	17,089,450.20	17,026,348.59
Net cash flow from operating activities			23,612,791.05	23,558,359.05	23,502,294.09	23,444,547.18	23,385,067.86	23,323,804.17	23,260,702.56
Change in Gross fixed Asset		259,764,310							
Net Cashflow		-259,764,310	23,612,791	23,558,359	23,502,294	23,444,547	23,385,068	23,323,804	23,260,703
Add: Beginning Cashflow			-259,764,310	-236,151,518	-212,593,159	-189,090,865	-165,646,318	-142,261,250	-118,937,446
Ending cashflow		-259,764,310	-236,151,518	-212,593,159	-189,090,865	-165,646,318	-142,261,250	-118,937,446	-95,676,744
NPV	-฿17,687,981								
IRR	3.91%								

Appendix Table E22 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	964,792	964,792	964,792	964,792	964,792	964,792	964,792	964,792
Cost of energy	51,883,856	51,883,856	51,883,856	51,883,856	51,883,856	51,883,856	51,883,856	51,883,856
Depreciation	6,234,354	6,234,354	6,234,354	6,234,354	6,234,354	6,234,354	6,234,354	6,234,354
Operating labor	3,187,833	3,283,468	3,381,972	3,483,431	3,587,934	3,695,572	3,806,439	3,920,633
Maintenance and repairs	12,988,215	12,988,215	12,988,215	12,988,215	12,988,215	12,988,215	12,988,215	12,988,215
Total operating cost	4,366,526,004	4,366,621,639	4,366,720,143	4,366,821,602	4,366,926,105	4,367,033,743	4,367,144,610	4,367,258,803
EBIT	24,230,506	24,134,871	24,036,367	23,934,907	23,830,404	23,722,766	23,611,899	23,497,706
Tax	7,269,152	7,240,461	7,210,910	7,180,472	7,149,121	7,116,830	7,083,570	7,049,312
Net income	16,961,353.94	16,894,409.44	16,825,456.61	16,754,435.20	16,681,283.14	16,605,936.53	16,528,329.51	16,448,394.28
Net cash flow from operating activities	23,195,707.90	23,128,763.41	23,059,810.58	22,988,789.17	22,915,637.11	22,840,290.49	22,762,683.48	22,682,748.25
Change in Gross fixed Asset								
Net Cashflow	23,195,708	23,128,763	23,059,811	22,988,789	22,915,637	22,840,290	22,762,683	22,682,748
Add: Beginning Cashflow	-95,676,744	-72,481,036	-49,352,272	-26,292,462	-3,303,672	19,611,965	42,452,255	65,214,939
Ending cashflow	-72,481,036	-49,352,272	-26,292,462	-3,303,672	19,611,965	42,452,255	65,214,939	87,897,687

Appendix Table E23 Fixed-capital investment and operating cost of plant D at capacity of stearin 300,000 kg in fixed flow rate pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		12,995,090,168	12,995,090,168	12,995,090,168	12,995,090,168	12,995,090,168	12,995,090,168	12,995,090,168
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		177,172,177	177,172,177	177,172,177	177,172,177	177,172,177	177,172,177	177,172,177
Total income		13,172,262,345	13,172,262,345	13,172,262,345	13,172,262,345	13,172,262,345	13,172,262,345	13,172,262,345
Investment cost								
Equipment cost								
1. ten storage tanks	133,622,439							
2. one reactor	7,454,275							
3. three mixing tanks	18,458,042							
4. two centrifuges	24,521,895							
5. three evaporators	50,935,046							
6. fourteen pumps	8,526,300							
Purchased equipment	243,517,998							
Purchased-equipment installation	45,660,000							
Instrumentation and controls (installed)	38,050,000							
Piping (installed)	38,050,000							
Electrical systems (installed)	22,830,000							
Buildings (including services)	30,440,000							
Yard improvement	15,220,000							
Service facilities (installed)	152,199,000							
Land	7,610,000							
Engineering and supervision	68,489,000							
Construction expenses	30,440,000							
Legal expenses	15,220,000							
Contractor's fee	15,220,000							
Contingency	38,050,000							
Total fixed-capital investment	760,995,998							
Manufacturing cost								
Raw materials								
1. stearin		12,313,890,000	12,313,890,000	12,313,890,000	12,313,890,000	12,313,890,000	12,313,890,000	12,313,890,000
2. methanol		555,846,818	555,846,818	555,846,818	555,846,818	555,846,818	555,846,818	555,846,818

Appendix Table E23 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	12,995,090,168	12,995,090,168	12,995,090,168	12,995,090,168	12,995,090,168	12,995,090,168	12,995,090,168	12,995,090,168
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	177,172,177	177,172,177	177,172,177	177,172,177	177,172,177	177,172,177	177,172,177	177,172,177
Total income	13,172,262,345	13,172,262,345	13,172,262,345	13,172,262,345	13,172,262,345	13,172,262,345	13,172,262,345	13,172,262,345
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	12,313,890,000	12,313,890,000	12,313,890,000	12,313,890,000	12,313,890,000	12,313,890,000	12,313,890,000	12,313,890,000
2. methanol	555,846,818	555,846,818	555,846,818	555,846,818	555,846,818	555,846,818	555,846,818	555,846,818
3. potassium hydroxide	22,767,103	22,767,103	22,767,103	22,767,103	22,767,103	22,767,103	22,767,103	22,767,103

Appendix Table E23 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979
Cost of energy			155,753,681	155,753,681	155,753,681	155,753,681	155,753,681	155,753,681	155,753,681
Depreciation			18,263,867	18,263,867	18,263,867	18,263,867	18,263,867	18,263,867	18,263,867
Operating labor			2,592,000	2,669,760	2,749,853	2,832,348	2,917,319	3,004,838	3,094,984
Maintenance and repairs			38,049,800	38,049,800	38,049,800	38,049,800	38,049,800	38,049,800	38,049,800
Total operating cost			13,091,793,768	13,091,871,528	13,091,951,621	13,092,034,116	13,092,119,087	13,092,206,606	13,092,296,752
EBIT			80,468,577	80,390,817	80,310,724	80,228,229	80,143,258	80,055,739	79,965,594
Tax			24,140,573	24,117,245	24,093,217	24,068,469	24,042,977	24,016,722	23,989,678
Net income			56,328,003.99	56,273,571.99	56,217,507.03	56,159,760.12	56,100,280.80	56,039,017.11	55,975,915.50
Net cash flow from operating activities			74,591,870.50	74,537,438.50	74,481,373.54	74,423,626.63	74,364,147.32	74,302,883.62	74,239,782.01
Change in Gross fixed Asset		760,995,998							
Net Cashflow		-760,995,998	74,591,871	74,537,439	74,481,374	74,423,627	74,364,147	74,302,884	74,239,782
Add: Beginning Cashflow			-760,995,998	-686,404,127	-611,866,689	-537,385,315	-462,961,689	-388,597,541	-314,294,658
Ending cashflow		-760,995,998	-686,404,127	-611,866,689	-537,385,315	-462,961,689	-388,597,541	-314,294,658	-240,054,876
NPV	฿8,896,518								
IRR	5.18%								

Appendix Table E23 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	2,894,366	2,894,366	2,894,366	2,894,366	2,894,366	2,894,366	2,894,366	2,894,366
Cost of energy	155,753,681	155,753,681	155,753,681	155,753,681	155,753,681	155,753,681	155,753,681	155,753,681
Depreciation	18,263,867	18,263,867	18,263,867	18,263,867	18,263,867	18,263,867	18,263,867	18,263,867
Operating labor	3,187,833	3,283,468	3,381,972	3,483,431	3,587,934	3,695,572	3,806,439	3,920,633
Maintenance and repairs	38,049,800	38,049,800	38,049,800	38,049,800	38,049,800	38,049,800	38,049,800	38,049,800
Total operating cost	13,092,389,601	13,092,485,236	13,092,583,740	13,092,685,199	13,092,789,702	13,092,897,340	13,093,008,207	13,093,122,401
EBIT	79,872,744	79,777,109	79,678,605	79,577,146	79,472,643	79,365,005	79,254,138	79,139,945
Tax	23,961,823	23,933,133	23,903,582	23,873,144	23,841,793	23,809,501	23,776,241	23,741,983
Net income	55,910,920.85	55,843,976.35	55,775,023.52	55,704,002.11	55,630,850.05	55,555,503.44	55,477,896.42	55,397,961.19
Net cash flow from operating activities	74,174,787.36	74,107,842.87	74,038,890.04	73,967,868.62	73,894,716.57	73,819,369.95	73,741,762.93	73,661,827.70
Change in Gross fixed Asset								
Net Cashflow	74,174,787	74,107,843	74,038,890	73,967,869	73,894,717	73,819,370	73,741,763	73,661,828
Add: Beginning Cashflow	-240,054,876	-165,880,088	-91,772,245	-17,733,355	56,234,513	130,129,230	203,948,600	277,690,363
Ending cashflow	-165,880,088	-91,772,245	-17,733,355	56,234,513	130,129,230	203,948,600	277,690,363	351,352,190

Appendix Table E24 Fixed-capital investment and operating cost of plant D at capacity of stearin 500,000 kg in fixed flow rate pattern

List	0	1	2	3	4	5	6	7
Cost of biodiesel (baht/l)		46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel		21,658,291,523	21,658,291,523	21,658,291,523	21,658,291,523	21,658,291,523	21,658,291,523	21,658,291,523
Cost of glycerol (baht/kg)		5	5	5	5	5	5	5
Income from glycerol		295,294,322	295,294,322	295,294,322	295,294,322	295,294,322	295,294,322	295,294,322
Total income		21,953,585,845	21,953,585,845	21,953,585,845	21,953,585,845	21,953,585,845	21,953,585,845	21,953,585,845
Investment cost								
Equipment cost								
1. ten storage tanks	244,947,149							
2. one reactor	12,682,236							
3. three mixing tanks	31,451,810							
4. two centrifuges	31,982,719							
5. three evaporators	74,351,670							
6. fourteen pumps	19,194,000							
Purchased equipment	414,609,583							
Purchased-equipment installation	77,739,000							
Instrumentation and controls (installed)	64,783,000							
Piping (installed)	64,783,000							
Electrical systems (installed)	38,870,000							
Buildings (including services)	51,826,000							
Yard improvement	25,913,000							
Service facilities (installed)	259,131,000							
Land	12,957,000							
Engineering and supervision	116,609,000							
Construction expenses	51,826,000							
Legal expenses	25,913,000							
Contractor's fee	25,913,000							
Contingency	64,783,000							
Total fixed-capital investment	1,295,655,583							
Manufacturing cost								
Raw materials								
1. stearin		20,523,150,000	20,523,150,000	20,523,150,000	20,523,150,000	20,523,150,000	20,523,150,000	20,523,150,000
2. methanol		926,411,363	926,411,363	926,411,363	926,411,363	926,411,363	926,411,363	926,411,363

Appendix Table E24 (Continued)

List	8	9	10	11	12	13	14	15
Cost of biodiesel (baht/l)	46.09	46.09	46.09	46.09	46.09	46.09	46.09	46.09
Income from biodiesel	21,658,291,523	21,658,291,523	21,658,291,523	21,658,291,523	21,658,291,523	21,658,291,523	21,658,291,523	21,658,291,523
Cost of glycerol (baht/kg)	5	5	5	5	5	5	5	5
Income from glycerol	295,294,322	295,294,322	295,294,322	295,294,322	295,294,322	295,294,322	295,294,322	295,294,322
Total income	21,953,585,845	21,953,585,845	21,953,585,845	21,953,585,845	21,953,585,845	21,953,585,845	21,953,585,845	21,953,585,845
Investment cost								
Equipment cost								
1. ten storage tanks								
2. one reactor								
3. three mixing tanks								
4. two centrifuges								
5. three evaporators								
6. fourteen pumps								
Purchased equipment								
Purchased-equipment installation								
Instrumentation and controls (installed)								
Piping (installed)								
Electrical systems (installed)								
Buildings (including services)								
Yard improvement								
Service facilities (installed)								
Land								
Engineering and supervision								
Construction expenses								
Legal expenses								
Contractor's fee								
Contingency								
Total fixed-capital investment								
Manufacturing cost								
Raw materials								
1. stearin	20,523,150,000	20,523,150,000	20,523,150,000	20,523,150,000	20,523,150,000	20,523,150,000	20,523,150,000	20,523,150,000
2. methanol	926,411,363	926,411,363	926,411,363	926,411,363	926,411,363	926,411,363	926,411,363	926,411,363
3. potassium hydroxide	37,945,172	37,945,172	37,945,172	37,945,172	37,945,172	37,945,172	37,945,172	37,945,172

Appendix Table E24 (Continued)

List		0	1	2	3	4	5	6	7
3. potassium hydroxide			6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979	6,156,979
Cost of energy			236,922,317	236,922,317	236,922,317	236,922,317	236,922,317	236,922,317	236,922,317
Depreciation			31,095,706	31,095,706	31,095,706	31,095,706	31,095,706	31,095,706	31,095,706
Operating labor			2,592,000	2,669,760	2,749,853	2,832,348	2,917,319	3,004,838	3,094,984
Maintenance and repairs			64,782,779	64,782,779	64,782,779	64,782,779	64,782,779	64,782,779	64,782,779
Total operating cost			21,796,627,704	21,796,705,464	21,796,785,557	21,796,868,052	21,796,953,023	21,797,040,542	21,797,130,687
EBIT			156,958,141	156,880,381	156,800,288	156,717,793	156,632,822	156,545,303	156,455,157
Tax			47,087,442	47,064,114	47,040,086	47,015,338	46,989,847	46,963,591	46,936,547
Net income			109,870,698.67	109,816,266.67	109,760,201.71	109,702,454.80	109,642,975.48	109,581,711.78	109,518,610.18
Net cash flow from operating activities			140,966,404.20	140,911,972.20	140,855,907.24	140,798,160.33	140,738,681.01	140,677,417.32	140,614,315.71
Change in Gross fixed Asset		1,295,655,583							
Net Cashflow		-1,295,655,583	140,966,404	140,911,972	140,855,907	140,798,160	140,738,681	140,677,417	140,614,316
Add: Beginning Cashflow			-1,295,655,583	-1,154,689,179	-1,013,777,207	-872,921,299	-732,123,139	-591,384,458	-450,707,041
Ending cashflow		-1,295,655,583	-1,154,689,179	-1,013,777,207	-872,921,299	-732,123,139	-591,384,458	-450,707,041	-310,092,725
NPV	฿155,834,972								
IRR	6.82%								

Appendix Table E24 (Continued)

List	8	9	10	11	12	13	14	15
Cost of water	4,824,073	4,824,073	4,824,073	4,824,073	4,824,073	4,824,073	4,824,073	4,824,073
Cost of energy	236,922,317	236,922,317	236,922,317	236,922,317	236,922,317	236,922,317	236,922,317	236,922,317
Depreciation	31,095,706	31,095,706	31,095,706	31,095,706	31,095,706	31,095,706	31,095,706	31,095,706
Operating labor	3,187,833	3,283,468	3,381,972	3,483,431	3,587,934	3,695,572	3,806,439	3,920,633
Maintenance and repairs	64,782,779	64,782,779	64,782,779	64,782,779	64,782,779	64,782,779	64,782,779	64,782,779
Total operating cost	21,797,223,537	21,797,319,172	21,797,417,676	21,797,519,135	21,797,623,638	21,797,731,276	21,797,842,143	21,797,956,336
EBIT	156,362,308	156,266,673	156,168,169	156,066,710	155,962,207	155,854,569	155,743,702	155,629,508
Tax	46,908,692	46,880,002	46,850,451	46,820,013	46,788,662	46,756,371	46,723,110	46,688,853
Net income	109,453,615.52	109,386,671.03	109,317,718.20	109,246,696.79	109,173,544.73	109,098,198.11	109,020,591.10	108,940,655.87
Net cash flow from operating activities	140,549,321.06	140,482,376.56	140,413,423.73	140,342,402.32	140,269,250.26	140,193,903.65	140,116,296.63	140,036,361.40
Change in Gross fixed Asset								
Net Cashflow	140,549,321	140,482,377	140,413,424	140,342,402	140,269,250	140,193,904	140,116,297	140,036,361
Add: Beginning Cashflow	-310,092,725	-169,543,404	-29,061,027	111,352,396	251,694,799	391,964,049	532,157,953	672,274,249
Ending cashflow	-169,543,404	-29,061,027	111,352,396	251,694,799	391,964,049	532,157,953	672,274,249	812,310,611

CURRICULUM VITAE

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EDUCATION :

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