

Cost Optimization Analysis of Energy Efficiency During Compressor Shutdown at Platforming Unit I

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Abstrak

Kata Kunci:

Tinjauan Keselamatan
Pra-Startup, Manajemen
Keselamatan Proses,
Insiden Keselamatan
Proses.

Kompresor (C-100) yang terletak di unit Hydrobon & Platforming I dirancang untuk memenuhi kebutuhan gas daur ulang untuk menjaga rasio H₂/HC tetap optimal di bagian Platforming I dan meminimalisir laju pembentukan kokas di dalam reaktor. Selain itu, Kompresor (C-100) digunakan selama proses start-up unit Platforming I untuk memaksimalkan produksi LPG. Namun, PT X saat ini berfokus pada pemformatan ulang produksi untuk memenuhi permintaan pasar, yang mendorong pertimbangan untuk mengoperasikan Kompresor (C-100) untuk efisiensi energi dan penghematan biaya. Penghentian kompresor sebelumnya, yang mengkonsumsi 2400 kWh per hari dengan biaya listrik tahunan sebesar Rp 8.347.273.344,00, telah secara signifikan mengurangi konsumsi energi. Namun, biaya operasional lainnya, seperti pemeliharaan dan penggantian oli pelumas, tetap ada selama periode tersebut, dengan biaya tahunan masing-masing sebesar Rp 440.036.956,00 dan Rp 48.741.977,00. Selain itu, energi dari sumber alternatif seperti uap dan air pendingin juga meningkat untuk mempertahankan kinerja proses, dengan total biaya operasi tahunan masing-masing sebesar Rp 56.256.360.451,20 dan Rp 179.789.760,00. Secara keseluruhan, biaya operasi Kompresor (C-100), yang meliputi listrik, minyak pelumas, dan perawatan, mencapai Rp 8.836.052.276,80 setiap tahunnya. Peninjauan ulang terhadap operasi kompresor dapat memberikan solusi untuk optimalisasi biaya dan efisiensi energi bagi perusahaan.

Abstract

Key Word:

Compressor; Recycle
Gas; Energy Efficiency;
Operating Costs.

The compressor (C-100) located in the Hydrobon & Platforming I unit is designed to meet the need for recycled gas to keep the H₂/HC ratio optimal in the Platforming I section and minimise the rate of coke formation in the reactor. In addition, a Compressor (C-100) is used during the start-up process of the Platforming I unit to maximise LPG production. However, PT X is currently focusing on reformatting production to meet market demand, which prompts considering commissioning a Compressor (C-100) for energy efficiency and cost savings. The shutdown of the previous compressor, which consumed 2400 kWh per day at an annual electricity cost of IDR 8,347,273,344.00, has significantly reduced energy consumption. However, other operational costs, such as maintenance and lube oil make-up, remained during the period, with annual expenses of IDR 440,036,956.00 and IDR 48,741,977.00, respectively. In addition, energy from alternative sources such as steam and cooling water also increased to maintain process performance, with total annual operating costs of IDR 56,256,360,451.20 and IDR 179,789,760.00, respectively. Overall, the operating cost of the Compressor (C-100), which includes electricity, make-up lube oil, and maintenance, totalled IDR 8,836,052,276.80 each year. A review of the compressor operation could provide a solution for cost optimisation and energy efficiency for the company.

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INTRODUCTION

A petroleum refinery is a highly organized processing plant consisting of various physical and chemical processes to convert crude oil into products of the required quality and in the volumes demanded by the market (Abdul, M. 2015). PT X, which operates in the oil and gas industry, focuses on fuel oil (BBM) production using crude oil as the raw material. In the gasoline production process, a platforming process is required for naphtha products from the Crude Distillation Unit (CDU), Hydro Cracking Unit (HCU), and Delayed Coking Unit (DCU) with low octane values into high octane gasoline (HOMC). This process requires a platinum-based catalyst (Saleh, J. 2014).

This unit, which is divided into two parts, Hydrobon and Platforming, plays a crucial role in gasoline production. Hydrobon, responsible for purifying heavy naphtha from the Naphtha Rerun Unit (NRU), achieves this by hydrogenation. This process, facilitated by a catalyst, removes contaminants such as olefin compounds

and other metals that can poison the catalyst. On the other hand, Platforming is tasked with rearranging the structure of hydrocarbon molecules using heat and a catalyst. The process in this sub-unit takes place in a 28-30 atm pressure reactor with a temperature of $\pm 487^{\circ}\text{C}$. The main reactions in the platforming unit are dehydrogenation, paraffin hydrocracking, isomerization, and paraffin dehydrocyclization. The following is the reaction equation: (Saleh, J. 2014) The process industries manage many hazardous, flammable and explosive substances, and the methodologies used to supervise these materials tend to be highly specialized (Abdul, M. 2015). The sector faces significant risks if safety is not effectively overseen. A process safety incident is one of the most dangerous threats, which can lead to catastrophic results. Such incidents involve releasing or losing hazardous substances that can result in extensive health and environmental impacts (Saleh, J. 2014).

- a. Dehydrogenation : $\text{C}_6\text{H}_{11}\text{CH}_3 \rightarrow \text{C}_6\text{H}_5\text{CH}_3 + \text{H}_2$
- b. Paraffin hydrocracking : $\text{C}_8\text{H}_{18} + \text{H}_2 \rightarrow \text{C}_5\text{H}_{12} + \text{C}_3\text{H}_8$
- c. Isomerisation : $\text{C}_6\text{H}_{12} \rightarrow \text{C}_2\text{H}_5 - \text{CH}(\text{CH}_3) - \text{C}_2\text{H}_5$
- d. Dehydrocyclisation of paraffin : $\text{C}_7\text{H}_{16} \rightarrow \text{C}_7\text{H}_{14} + \text{H}_2$

The Platforming reactor process, one of the critical processes in converting crude oil into high-value products such as petrol and recycled gas, plays a vital role in controlling the hydrogen-to-hydrocarbon (H_2/HC) ratio. Recycle gas in the oil and gas industry is a gas stream produced from a chemical reaction process and then returned to the reactor for reuse. The hydrogen gas (H_2) recycled into the reactor maintains an optimal balance between hydrogen and hydrocarbons during the catalytic reforming process, which ultimately affects the course of the reaction and the quality of the products produced (Saleh, J. 2014).

Applying recycled gas in platforming reactors is essential to controlling coke formation in the catalyst. Coke is a carbon deposit formed as a by-product of hydrocarbon reactions, which can decrease the activity of the catalyst and shorten its operational life. When the H_2/HC ratio is kept at an optimal level through recycled gas, hydrogen serves as a coke formation inhibiting agent by helping to remove carbon radicals before they form a coke layer. In addition, the recycled gas flow also helps to clean reaction products and condensation material from the catalyst surface, keeping the catalyst active and free of contaminants that could impair reactor performance (Saleh, J. 2014).

Increasing the H_2/HC ratio through recycled gas flow reduces the rate of coke formation and affects the flow rate of naphtha through the reactor and the temperature distribution therein. With a higher H_2/HC ratio, the reactor can run the reaction more efficiently, as the abundant hydrogen provides the necessary heat sink to absorb heat from the endothermic reaction. This helps maintain an optimal operating temperature, reduces the risk of overheating, and ensures that the reaction proceeds appropriately. The result is a reduction in the rate of coke formation, increased catalyst life, and improved end-product quality and yield, all of which contribute to the operational efficiency and profitability of production processes in the oil and gas industry. For the recycled gas in this platforming unit to be maintained, a booster device, namely a compressor, is needed as a support (Saleh, J. 2014).

A compressor is a mechanical device used to increase the pressure of a gas fluid. The pressure on the suction side of the pressure ranges from vacuum to high positive pressure. The discharge pressure can reach sub-atmospheric to thousands of lb/in² (psi), depending on the choice and configuration of the compressor. A reciprocating compressor is one type of positive displacement compressor, where the working principle moves gas/air by compressing gas/air volume by volume in the cylinder; because the volume decreases, the pressure increases. Compression of gas or air is done by a moving element that moves back and forth (reciprocating) in the cylinder. Element transfer was called the piston (Energy, P. 2016).

The specific heat ratio is the specific heat at constant pressure to the specific heat at constant volume. An important aspect in controlling this operating condition is understanding the heat ratio of the gases involved, especially when recycled gas is added to the system. The specific heat ratio is denoted by k , $k = C_p / C_v$, where for dry air, $k = 1.401$. This ratio plays a role in calculating gas compression. Table 1 gives the values of k , C_p , and C_v for several types of gases (Bhusari, A. 2020).

The most significant energy used in compressor operation comes from electricity. The power provided by the power source drives the electric motor, pushing the compressor piston to move (Ramadhani, S. 2022). Some opportunities to save energy consumption on compressors include reducing output pressure, eliminating or reducing compressed air leaks, replacing high-efficiency electric motors, and reducing maintenance costs (Young, M. 1998). The cost incurred or used for maintenance of the equipment depends on how long the equipment has been used and the maintenance required for the equipment (Gunawan, W. 2020).

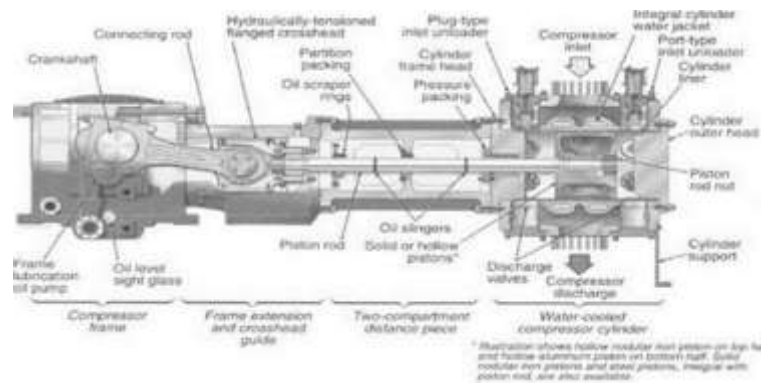


Figure 1: Alternating Compressor

Table 1. Specific Heat of Gases

Molecular Formula	Gas Name	Number of atoms	Specific Pressure (A)	Heat at Steady	Specific Volume (B)	Heat At Fixed	Specific Ratio (A/B)	Heat
Ar	Argon	1	0,1233		0,0746		1,667	
He	Helium	1	1,2425		0,746		1,666	
-	Air	2	0,24		0,17		1,401	
H ₂	Hydrogen	2	3,402		2,402		1,408	
N ₂	Nitrogen	2	0,2350		0,175		1,41	
O ₂	Oxygen	2	0,2419		0,173		1,40	
H ₂ O	Water vapour	3	0,4765		0,340		1,305	
CO ₂	Carbon dioxide	3	0,211		0,163		1,30	
C ₂ H ₂	Acetilin	4	0,402		0,323		1,24	
C ₂ H ₅ OH	Alcohol	9	0,435		0,400		1,13	

Before maintenance work is carried out, equipment is generally in two main conditions: regular operation or abnormal due to certain anomalies, such as decreased performance or component damage. Various factors, including equipment age, material wear, or operation beyond technical limits, can cause these abnormal conditions. After maintenance is carried out, the equipment is expected to return to operating at optimal performance. However, in some cases, maintenance failures can occur, requiring equipment rework or even component replacement. The uncertainty of maintenance results is a challenge in ensuring the operational reliability of the equipment (Nekhwevha, R. 2019).

The maintenance scheduling process is often plagued by delays triggered by a number of factors. Effective spare parts management and optimal Bill of Materials (BOM) management are crucial to avoid material shortages and reduce repair times. Time constraints due to production demands, as well as inadequate personnel competencies, also play a role in delaying maintenance. The need to obtain additional resources from third parties can worsen the situation. These delays not only impact repair times, but also increase maintenance costs, which depend on the frequency of maintenance and the duration of equipment operation. Therefore, effective maintenance scheduling is essential to avoid delays and reduce costs (Penn, S. 2014).

The C-100 compressor at Platforming Unit I plays a crucial role in the production process, so its operation and shutdown must be well managed to minimize costs and optimize energy use. The potential energy savings through improved compressor system performance are significant, ranging from 20 to 50 percent or more of total electrical energy usage (Sutton, I. 2015). However, compressor shutdown often poses its own challenges regarding energy efficiency and costs incurred. Therefore, it is important to analyze the cost optimization of the C-100 compressor shutdown. This study aims to analyze the various factors that affect the cost and energy used, and find an optimal solution to achieve a balance between the two.

METHOD

The methods used include research variables, working methods, and analysis methods. Research variables need to be determined first before starting the research. The variables include independent variables (x) and dependent variables (y) that are closely related. Independent variables are free to be regulated or controlled where these variables will affect the results. The independent variables used in this study are compressor pressure (kg/hour), compressor temperature (°C), and length of operation (days). Meanwhile, the dependent variable is a variable whose value depends on the independent variable being processed. The

dependent variables in this study are energy consumption (kWh) and operating costs (IDR).

This work method consists of preparation, implementation, and completion stages. In the implementation stage, a literature review of journals related to the research was conducted. Next, a field data search was conducted, and then the data was processed using Microsoft Excel and analysed to produce conclusions as part of the completion stage. This analysis method was used to review the energy efficiency value of this compressor (C-100) shutdown.

RESULT AND DISCUSSION

Base Line Data

The following presents the baseline data of the compressor (C-100) in Hydrobon and Platforming Unit I:

Table 2. Base Line Data Table

Base Line Data	
Specification Description	Stg 1.
Suction Temperature (°C)	37,81
Discharge Temperature (°C)	57,83
Suction Pressure (Kg/cm ²)	20,7267
Discharge Pressure (Kg/cm ²)	26,7035
Factor Compressibility (Z) in	1,007
Factor Compressibility (Z) exit	1,026
Capacity (Q) Nm ³ /h	286,1
Compressor Power (KW)	100
Drive Power (KW)	74,8

Based on the primary data obtained, it is known that the power required by the compressor is 100 kW, while the power supplied by the drive motor to drive the piston is 74.8 kW. The author can calculate the total electrical energy required to run the entire system with this information. This calculation considers the compressor's energy requirements and the drive motor's performance in its operation, thus allowing a more accurate analysis of total energy consumption.

Operating Condition Data

The following is data on the operational conditions of the C-100 compressor recorded from July 2 to August 3, 2024. This data includes important parameters affecting compressor performance, including inlet pressure (suction pressure), outlet pressure (discharge pressure), operating temperature, and gas flow rate passing through the compressor during the period. This data recording aims to monitor the condition of the compressor in real time.

Table 3. Table of Average Operating Conditions

No.	Average Operating Condition	First Week	Second Week	Third Week	Fourth Week
	Description				
1.	RPM Speed Motor	1500	1500	1500	1500
2.	RPM Compressor	1500	1500	1500	1500
3.	Suction Temperature (°C)	48,16	49,37	49,8	50,77
4.	Discharge Temperature (°C)	68,18	69,28	69,82	70,87
5.	Suction Pressure (Kg/cm ²)	21,5	21,5	21,5	21,5
6.	Discharge Pressure (Kg/cm ²)	26,76	26,77	26,74	26,83

Based on the average data of actual conditions for one month, the author can conclude that the compressor's performance is operating well. Observations on essential parameters such as discharge pressure, suction pressure, discharge temperature, and suction temperature support this. When this data is compared with the previously obtained baseline data, it is seen that all indicators are within the normal range, indicating that the compressor is operating according to optimal performance.

Electricity Cost Calculation

The electricity costs of the compressor and its drive were calculated to determine the total energy costs required to operate the compressor. The following is the calculation of electricity costs:

$$\begin{aligned}\text{Compressor Power} &= 100 \text{ kW} \\ &= 134,102 \text{ HP} \\ &= 2400 \text{ kWh}\end{aligned}$$

$$\begin{aligned}\text{Motion Power (Motor)} &= 74,8 \text{ kW} \\ &= 100, 3085 \text{ HP} \\ &= 1795,2 \text{ kWh}\end{aligned}$$

$$\text{Electricity Cost per kWh} = \text{IDR } 5.527,00 \text{ (F. Utilities PT X) Determining}$$

the Cost of a Power Compressor:

$$\begin{aligned}\text{Compressor Power Cost} &= \text{Compressor Power} \times \text{Electricity Cost/kWh} \\ &= 2400 \text{ kWh} \times \text{IDR } 5.527,- \\ &= \text{IDR } 13.264.800,- \text{ each day} \\ \text{Compressor Drive Cost} &= \text{Motion Power (Motor)} \times \text{Electricity Cost/kWh} \\ &= 1795,2 \text{ kWh} \times \text{IDR } 5.527,- \\ &= \text{IDR } 9.922.070,40 \text{ each day} \\ \text{Total} &= \text{IDR } 13.264.800,- + \text{IDR } 9.922.070,- \\ &= \text{IDR } 23.186.870,40 \text{ each day} \\ &= \text{IDR } 695.606.112,- \text{ each month} \\ &= \text{IDR } 8.347.273.344,- \text{ each year}\end{aligned}$$

The electricity costs for the compressor and its drives have been calculated, resulting in a total of IDR 8,347,273,344.00 each year. This figure reflects the annual energy cost required to run the compressor under current operational conditions. This calculation is essential in the overall operational cost analysis and can be used to identify energy-saving and cost-optimization opportunities.

Make Up Lube Oil Cost Calculation

The following presents the calculation of make up lube oil costs for compressors (C-100) using the M-150 type:

$$\begin{aligned}\text{Lube Oil} &= 118 \text{ liter/month} \\ \text{Lube Oil Prices} &= \text{IDR } 34.422 / \text{liter (F. Utilities PT X)} \text{ Total} \\ &= 118 \text{ liter} \times \text{IDR } 34.422, - \\ &= \text{IDR } 4.061.831,00 \text{ each month} \\ &= \text{IDR } 48.741.977,00 \text{ each year}\end{aligned}$$

The lube oil make-up cost calculation for compressor C-100, which uses M-150, shows that the total cost required is IDR 48,741,977.00 annually. This figure includes all costs required to ensure an adequate supply of quality lube oil throughout the year to maintain the optimal performance of the compressor.

Maintenance Cost Calculation

The following presents data on compressor maintenance expenditure (C-100) from PT X years, which provides a historical overview as a basis for calculating and planning future costs:

Table 4. Maintenance Cost

Description	Year	Cost (IDR)	Total (IDR)
Unloader Valve Replacement	2020	650.871.091,-	
Upgrade Valve	2020	264.000.000,-	983.871.091,-
Main Bearing Fabrication	2020	69.000.000,-	
Compressor Repair	2021	260.075.472,-	260.075.472,-
Repair Motion Power (Motor)	2022	4.682.000,-	505.585.471, -
Pressure Switch Replacement	2022	500.903.471,-	
Repair Motion Power (Motor)	2023	10.615.790,-	10.615.790,-
		1.760.147.824,-	
Total		36.669.746,-	each month
		440.036.956,-	each year

The calculation above shows the details of maintenance and component replacement costs for various equipment during the period 2020 to 2023, including the cost of replacing the Unloader Valve, upgrading the valve, fabricating the main bearing, as well as repairing the compressor and motor with a total cost of IDR 1,760,147,824.00, which is equivalent to IDR 440,036,956.00 each year.

Steam Platforming I Cost Calculation

The calculation of steam costs aims to determine how much energy consumption is needed in Platforming Unit I so that it can be optimised for operational efficiency:

$$\begin{aligned}\text{Flow Steam} &= 8,33 \text{ ton/hour} \\ &= 199,92 \text{ ton/day} \\ \text{Steam Price} &= \text{IDR } 781.651,00/\text{ton (F. Utilities PT X)} \\ &= \text{IDR } 156.267.667,92 \text{ each day} \\ &= \text{IDR } 4.688.030.037,60 \text{ each month} \\ &= \text{IDR } 56.256.360.451,20 \text{ each year}\end{aligned}$$

A careful calculation of the Steam Platforming I process has been carried out, and the calculation results show that the total costs required are IDR 56,256,360,451.20 each year. This figure covers all aspects related to the operation of the Steam Platforming I process throughout the annual period.

Cooling Water Platforming I Cost Calculation

The calculation of cooling water costs in Platforming Unit I is carried out to analyze and measure the level of energy consumption required in Platforming Unit I. This analysis aims to ensure that energy use is carried out effectively to reduce operational costs while improving the overall performance of the platforming process. Thus, this step is essential to support the sustainability and effectiveness of operations in the industrial environment. The following is the calculation of cooling water costs in Platforming Unit I:

Flow Cooling Water = 149, 4 m³/hour
= 3585,6 m³/day
Cooling Water Price = IDR 20.809,00 m³ (F. Utilities PT X)
Total = IDR 499.416,00 each day
= IDR 14.982.480,00 each month
= IDR 179.789.760,00 each year

After performing detailed calculations, the total annual cost for the Cooling Water system at Platforming I was found to be IDR 179,789,760.-. This figure includes all necessary cost components, including operational costs, routine maintenance, and other expenses associated with using and maintaining the cooling water system for one year.

Analysis of Results

Compressor (C-100) is located in the Hydrobon & Platforming I unit, which is designed as a tool to meet the needs of recycled gas so that the H₂/HC ratio in the platforming I section is maintained so that the rate of coke formation in the reactor can be minimised. The compressor is equipped with a motor as a driving device based on its type. Process variables must be maintained and influence the platforming unit process. The main variables in the platforming unit are divided into two independent variables: catalyst type, reactor temperature, space velocity, reactor pressure, H₂/HC ratio, feed properties, and feed additives. Meanwhile, the dependent variables are catalyst activity, reactor effluent yield, product quality, and catalyst stability. Compressor (C-100) is designed to assist the Platforming I unit start-up process; in this mode, the unit operates with the aim of maximising LPG (Liquified Petroleum Gas) production, which means that the C-100 system settings and optimisation are focused on producing LPG from the feedstock used. As for the current process, PT X is focused on maximising reformed products to meet market demand, so it is necessary to consider operating the C-100 because it can save costs and consider aspects of energy efficiency.

The discontinuation of the compressor, which previously consumed 2400 kWh of power per day, with electricity costs reaching IDR 8,347,273,344.00 each year, can reduce considerable energy consumption. During the period of compressor shutdown, some parameters that affect operational costs are maintenance and make-up lube oil, with average expenditure for maintenance reaching IDR 440,036,956.00 each year based on historical data and make-up lube oil amounting to IDR 48,741,977.00 each year. The use of energy from other sources, such as steam and cooling water, also has the potential to increase to ensure that operational processes remain optimal, which can cumulatively add to the operational cost burden during the period. Operating costs for the steam and cooling water energy systems are currently IDR 56,256,360,451.20 and IDR 179,789,760.00 annually. The overall operational cost of the C-100 compressor, calculated from several parameters such as electricity, make-up lube oil and maintenance, reaches IDR 8,836,052,276.80 each year.

To optimize costs and ensure efficient energy use during the C-100 compressor shutdown, several strategies can be implemented. First, adjust and optimize the energy consumption of other units by ensuring only essential equipment is operating and reducing energy use in non-critical sectors. Secondly, utilize this shutdown period to perform preventive maintenance and necessary repairs, thereby reducing the risk of breakdowns and higher maintenance costs in the future. In addition, strict monitoring and control of the use of resources such as steam and cooling water is crucial. This proactive approach can effectively reduce operational costs, as it ensures resources are used efficiently and wastage is minimized.

There are also several methods that can be applied to improve energy efficiency without increasing costs during compressor shutdowns. One of them is the implementation of a heat recovery system that utilises residual heat from other processes to meet energy needs, thereby reducing dependence on additional energy sources such as steam. In addition, the implementation of advanced monitoring and control technologies can help identify and eliminate energy wastage in real-time. Optimisation of operational parameters and production processes can also be done to ensure that all systems run at maximum efficiency with minimal energy

consumption. With the implementation of these strategies and methods, it is expected that energy efficiency during the shutdown of the C-100 compressor in Platforming Unit I can be significantly improved without increasing operational costs, thus supporting the effectiveness of the overall production process.

CONCLUSION

From the description in this study, several things can be concluded from the cost optimisation analysis of energy efficiency during compressor shutdown at Platforming Unit I as follows.

Firstly, the shutdown of the C-100 compressor reduces energy consumption considerably, with potential electricity cost savings reaching IDR 8,836,052,276.80 each year.

Secondly, to ensure cost-effectiveness during shutdown, it is crucial to conduct necessary maintenance and repairs, thereby mitigating the risk of future damage and higher maintenance expenses.

Third, a compressor shutdown can lead to increased load on the steam and cooling water systems, with annual operating costs of IDR 56,256,360,451.20 and IDR 179,789,760.00, respectively.

Fourth, with the right strategy, compressor shutdown can support energy efficiency and the overall effectiveness of the production process without increasing the operational cost burden.

Acknowledgment

The researcher would like to express his deepest gratitude to the Akamigas Energy and Mineral Polytechnic, as well as to the lecturers and field supervisors at the Dumai Oil and Gas Company for the support provided during this research. This support is precious for the smoothness and success of this research. The researcher hopes to work together again in the following collaborative project.

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