

Analysis of Energy and Exergoeconomic of Water Cleaning and Injection Facilities in the CPP Block, Indonesia

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ABSTRACT

One of the problems in the upstream oil and gas industry is that large quantities of produced water must go through a water cleaning and injection process in accordance with the Regulation of the State Minister of the Environment Number 19 of 2010 of the Republic of Indonesia concerning the quality standards of waste water for oil and gas and geothermal activities. A total of 224,257.1 barrels of water per day which is produced water in the CPP Block must go through a water management process which requires a large energy consumption of 269.47 MW/month. One effort to reduce the use of electrical energy is to conduct energy and exergy analysis to determine the point of highest energy use as a result of exergy destruction and convert it into economic costs as operating cost losses. From the research, it is known that the largest electrical energy consumption is at the injection pump 235.47 MW/month with exergy 67.72 kW, the largest exergy destruction is 31.04 kW at the charge filter pump with the efficiency of 54%. Energy and exergy analysis is used to identify changes in energy quality in a system.

KEYWORDS: Water Cleaning and Injection Plant, CPP Block, Energy Analysis, Energy Destruction, Exergy Economic.

NOMENCLATURE

WCP	Water Cleaning Plant
WIP	Water Injection Plant
GS	Gathering Station

BWPD	Barrel Water Per Day
MW	Mega-Watt
kW	Kilo-Watt
kW/h	Kilo-Watt Hour
PID	Piping Instrument Diagram
PFD	Process Flow Diagram
EP	Energy Potential
EK	Energy Kinetic
ROI	Return on Investment
η_{th}	Energy Efficiency (%)
$\dot{X}_{in}$	Input Exergy (kW)
$\dot{X}_{out}$	Output Exergy (kW)
$\dot{X}_{destroyed}$	Exergy Destruction (kW)
$\dot{X}_{heat}$	Heat Exergy (kW)
$\dot{X}_{work}$	Work Exergy (kW)
$\dot{X}_{mass,in}$	Mass Exergy In (kW)
$\dot{X}_{mass,out}$	Mass Exergy Out (kW)
$\Delta\dot{X}$	Exergy Balance (kW)
η_{II}	Exergy Efficiency (%)
E_{in}	Energy in (kW)
E_{out}	Energy out (kW)
$E_{mass,in}$	Mass Energy In (kW)
ΔE_{system}	Energy Balance System (kW)
$\dot{Q}_{in}$	Heat in (kW)
$\dot{Q}_{out}$	Heat out (kW)
$\dot{W}_{in}$	Work in (kW)
$\dot{W}_{out}$	Work out (kW)
COP_{sf}	Coefficient of Performance (%)
T_w	Environment Temperature (°C)
T_h	System Temperature (°C)
I_{in}	Irreversible Process (kW)
$\dot{W}_u$	Usefull Work (kW)
$\dot{W}_{rev,in}$	Reversible Work (kW)
$\Sigma_e(c_e\dot{E}_e)_t$	Increase in costs is associated with the transfer of energy, mass, power, or heat

1.0 INTRODUCTION

Coastal Plain Pekanbaru (CPP Block) is one of the old oil blocks in Riau which has been operating since 1982 where one of its production operating facilities is a water cleaning plant

(WCP) and a water injection plant (WIP), which function as water cleaning facilities and pumping clean water back into the earth reservoir. This water management production requires 279.46 MW/month of electrical energy or 54.6 % of the total energy use and absorbs 27.62 % of costs from the annual operating budget (source of company energy use data). Inefficient consumption of electrical energy at this facility is a waste of production costs, which will reduce the value of income and can cause losses that have an impact on the sustainability of the operation process in the CPP Block.

Along with the reduced energy reserves which will have an impact on the global energy crisis, causing the emergence of awareness of the importance of saving energy by utilizing the concept of work potential energy from a system known as exergy. This concept is very feasible to be applied to the upstream crude oil production operation process where in the operation there is a process of collecting, cleaning and re-injecting the produced water into the earth's reservoir where all these processes require very large energy consumption.

Operating facilities with long operating life can be modeled based on the reconciled data and their performance assessed by conducting energy and exergy analysis. According to T. Van Nguyen et al, 2014 [1], electrical energy is mostly consumed as motor power to rotate pumps and heaters operating where pressure drop and temperature loss occur in the operating system [1]. The energy analysis carried out is still using the principle of the 1st law of thermodynamics where energy is still seen as a quantitative form, so that a deeper energy analysis is still needed from a qualitative perspective by utilizing the 2nd law of thermodynamics in the form of energy analysis [2]. Energy consumption as a dominant indicator of a company's production operating costs greatly affects the company's total net profit, however, energy use so far has only been measured from the point of view of energy used in an operation optimization, but does not discuss energy quality, energy used and energy wasted is carried out [3]. By using energy and exergy analysis, the optimization method of production operation obtained a saving of 20.8% and the total energy loss decreased by 38.8% from 24,880.4 MJ/hour to 15,391.0 MJ/hour [3].

The production process of water treatment operations and water injection requires a large amount of energy accompanied by the loss of a certain amount of energy in the form of heat released to the environment. Benali et al., 2012 [4] analyzed the use of energy and economical exergy in the process of water treatment operations on Arab heavy oil platforms with the results obtained 21% reduction of the energy consumed [4]. Sun et al, 2000 [5] performed energy and exergy analyzes using closed-loop dynamic methods at a SaskEnergy/Transgas facility in North America where the analyzes performed pipeline optimization and water treatment pumping with a 10% reduction in operating energy consumption costs [5]. Each unit of equipment used in each process can be analyzed thermodynamically to obtain the highest exergy loss in the heat transfer process in the equipment system where 6.2% is caused by chemical exergy losses associated with the separation process and the remaining exergy losses are caused by physical loss of exergy, mainly due to temperature differences. The energy efficiency was 0.519 and the exergy efficiency was 0.233 for the whole system [6].

In energy and exergy analysis, the thermoeconomic approach is described from the resources required and the products produced and expressed as exergy flows. The concept

of exergy flow is used to diagnose and identify components that have decreased efficiency or intrinsically determine components that experience decreased performance. The identification results are used to measure the effect of the impact on energy consumption and the effect of a small impact on the performance of the equipment based on the concept of exergy and exergy costs [7].

Currently, the performance of a company's production operations is measured by indicators of energy demand and its impact on the environment, namely energy efficiency, which is defined as the ratio of energy used to wasted energy, energy intensity which is defined as the ratio of energy used to energy produced in the form of products produced and certain power consumption [8]. In energy and exergy analysis, the thermoeconomic approach is described from the resources required and the products produced and expressed as exergy flows. The concept of exergy flow is used to diagnose and identify components that have decreased efficiency or intrinsically determine components that experience decreased performance. The identification results are used to measure the effect of the impact on energy consumption and the effect of a small impact on the performance of the equipment based on the concept of exergy and exergy costs.

The quantitative analysis of energy carried out by the company so far is only based on the amount of energy, with the exergoeconomic analysis method it can be seen the balance of energy and exergy as well as the lost exergy during the WCP and WIP operation processes in the CPP Block where the lost exergy can be calculated as the value of energy waste and then converted into form of economic value into the company's operating costs that reduce revenue. From this research it is possible to determine the balance of energy and exergy during the operation process and calculate the flow rate of exergy destruction during the operation process and with the exergoeconomic method it is known the operating cost losses caused by exergy losses.

2.0 METHODOLOGY

This research was conducted to analyze abnormal energy losses during the operation process and can be used as a theoretical basis to apply energy efficiency and reduce energy losses that occur in water management subsystems that function to collect, clean and re-inject produced water, which includes piping and pumping equipment. The research approach is carried out descriptively quantitatively where the object or research subject is in accordance with actual conditions so that a factual picture of the characteristics of the research object is obtained, then quantitatively uses mathematical variables on each object quantitatively in sub-systems which include motors, pumps and piping and compared to the equipment performance output.

2.1 Data Collecting

Primary data collection is carried out every day from October 1, 2021 to December 15, 2021, on every operating equipment that has exergy flow and energy consumption. Primary data includes input and output operating parameters such as pressure, temperature, mass flow and fluid phase being flowed. Secondary data consists of official company data in the form of working drawings, PID and PFD, population of tools, data of tool specifications.

Data analysis begins with the planning stage in the form of literature study, problem formulation, research design and action plan, then the research stage is field data measurement, data comparison, data processing and final calculation of data results. The last stage is an analysis to determine the right

optimization method based on the results of calculations and research observations.

Average measurement data in the form of inflows and outflows of static equipment in October, November and December are depicted in Table 1.

Table 1: Average operating static equipment at WCP and WIP

MONTH 2021 (AVERAGE)	WATER (BARREL PER DAY)	ENVIRONMENT TEMP. (°F)	AVERAGE MEASUREMENT STATIC EQUIPMENT WATER CLEANING PLANT (WCP)					
			RAW WATER TANK			SHELL FILTER		
			TEMP (°F)	RATE (BWPD)	INCOMING- PRESSURE (Psi)	TEMP. (°F)	RATE (BWPD)	OUTGOING- PRESSURE (Psi)
OCTOBER 2021	226088,35	82,66	176,15	191290,90	35,10	175,15	5493,10	32,10
NOVEMBER 2021	223429,27	88,00	174,77	193531,27	35,00	173,77	5407,16	32,00
DECEMBER 2021	223790,73	86,60	174,87	193426,87	35,00	173,87	5353,78	32,00
AVERAGE	224436,12	85,75	175,26	192749,68	35,03	174,26	5418,01	32,03

Table 1 contains actual average measurement data during October 2021 until December 2021 on static equipment at a water cleaning plant where the liquid water is first collected in the raw water tank and then through the process of separating a

thin layer of oil and water on a shell filter containing shell media. The filtered water will be sent to the balance tank at the water injection plant facility with the average measurement data per month, it can be seen in Table 2.

Table 2: Average operating static equipment at WIP

MONTH 2021 (AVERAGE)	WATER (BARREL PER DAY)	AVERAGE MEASUREMENT STATIC EQUIPMENT							
		BALANCE TANK				SKIMMING TANK			
		INCOMING- PRESSURE (Psi)	TEMP (°F)	INCOMING (BWPD)	OUTGOING- PRESSURE (Psi)	INCOMING- PRESSURE (Psi)	TEMP (°F)	INCOMMIN G (BWPD)	OUTGOING- PRESSURE (Psi)
OCTOBER 2021	226088,35	31,10	173,65	189.906,32	34,06	3,00	176,15	1.384,58	4,90
NOVEMBER 2021	223429,27	31,00	172,27	191.925,73	34,00	3,00	174,77	1.605,53	5,00
DECEMBER 2021	223790,73	31,00	172,37	191.750,60	34,00	3,00	174,87	1.676,27	5,00
AVERAGE	224436,12	31,03	172,76	191194,22	34,02	3,00	175,26	1555,46	4,97

Table 2 is the actual average measurement data during October 2021 until December 2021 on static equipment located at the water injection plant where clean water is collected in the balance tank and then pumped using a transfer pump to an injection pump with a pressure of 1300 Psi to the earth reservoir. While the skimming tank serves to collect water that

still contains a layer of oil and is pumped back to the filter shell. There is no use of electrical energy on static equipment in WCP and WIP.

In Table 3 is depicted the average measurement data for rotary equipment on WCP where there is a large use of electrical energy to rotate the motor with long operating hours.

Table 3: Average operating rotating equipment at WCP

MONTH 2021 (AVERAGE)	AVERAGE MEASUREMENT ROTATING EQUIPMENT									
	FILTER CHARGE PUMP					SKIMMING RECYLCE PUMP				
	PRESSURE (Psi)	TEMP. (°F)		RATE (GPM)	ELECTRICAL POWER (KW)	PRESSUR E (Psi)	TEMP. (°F)		RATE (GPM)	ELECTRICAL POWER (KW)
		SUCTION	DISCHARGE				SUCTION	DISCHARGE		
OCTOBER 2021	36,10	175,15	177,15	5.493,10	4.942,00	50,00	169,77	175,77	39,70	779,88
NOVEMBER 2021	36,00	173,77	175,77	5.407,16	4.942,00	50,00	169,77	175,77	41,97	779,88
DECEMBER 2021	36,00	173,87	175,87	5.353,78	4.942,00	50,00	169,90	175,90	41,20	779,88
AVERAGE	36,03	174,26	176,26	5.418,01	4.942,00	50,00	169,81	175,81	40,96	779,88

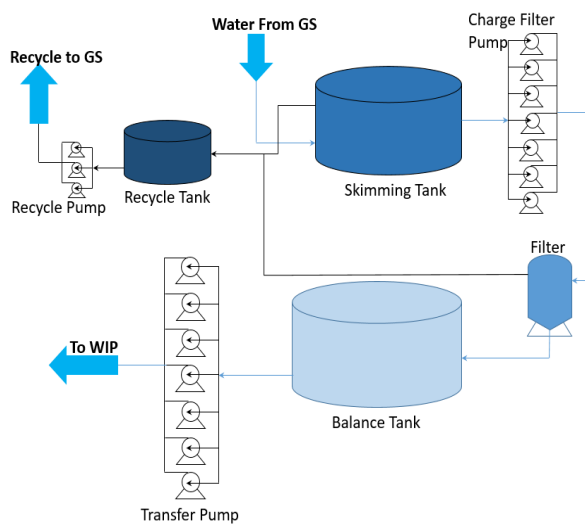


Figure 1: Flow diagram of WCP & WIP

The final product at the water cleaning plant facility is clean water without oil content which is then pumped from the balance tank to the water injection pump to be pumped directly at high pressure (average 1300 psi) to the injection well (Figure 2).

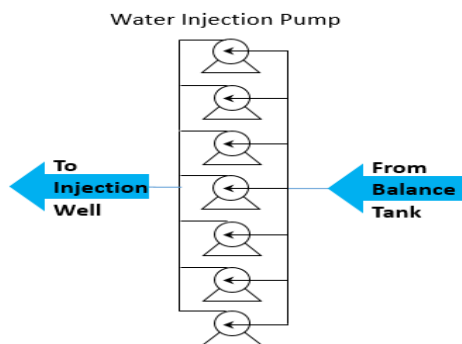


Figure 2: Flow diagram water injection pump

The input parameters for the WCP and WIP subsystems are pressure, temperature, fluid, and electric power. While the output parameters are pressure and temperature. The process that occurs in this subsystem is an irreversible process where each equipment loses a certain amount of energy in the form of heat loss and pressure drops that occur.

Each stage of the operation process requires a large amount of electrical energy so that this system is a thermal process that undergoes an irreversible process so that exergy losses occur at some of the weakest points in some equipment in each sub-process so that by using the first and second laws of thermodynamics it is known how much energy is used by each sub-process and points of energy loss can be determined and then this information can be used to improve the performance of facilities and equipment by closing the points of loss.

Energy analysis based on energy balance for each equipment in the WCP and WIP subsystems is calculated using equations (1) and (2). The exergy analysis is calculated by first determining the inflow and outflow exergy using equations that are calculated per equipment in each sub-system by checking the inflow and outflow exergy using equation (3). The first exergy flow at the WCP facility is in the skimming tank equipment which is the starting point for exergy that enters the equipment sub-system. Before calculating the parameters, the properties of the fluid entering this system are as depicted in Table 5.

Table 5: Fluid properties

TEMP (°C)	FLUID	DENSITY (KG/M ³)	ENTROPY s (kJ/kg.K)	SPEC.VOLUME v (m ³ /kg)	INT. ENERGY u (kJ/kg)	ENTHALPY h (kJ/kg)
80,08	Air/Water	1000	1,0756	0,001029	334,97	335,02
78,53	Air/Water	1000	1,0580	0,001028	328,80	328,87

The operating conditions of the static equipment are assumed to be a stationary system with a negative heat transfer direction or a certain amount of heat loss, a constant volume of static equipment, and no energy transfer in the form of work ($\Delta Q = W=0$), no input of electrical energy use and no form of others work. For rotating equipment, a number of incoming and outgoing energy flows occur, that can be seen in Table 6.

Table 6: Energy analysis of the rotating equipment

MONTH 2021 (AVERAGE)	ENERGY ANALYSIS ROTATING EQUIPMENT							
	FILTER CHARGE PUMP		SKIMMING RECYLCE PUMP		TRANSFER PUMP		WATER INJECTION PUMP	
	MASS FLOW (KG/S)	ΔW (kW)	MASS FLOW (KG/S)	ΔW (kW)	MASS FLOW (KG/S)	ΔW (kW)	MASS FLOW (KG/S)	ΔW (kW)
OCTOBER 2021	284,750	33,496	1548,239	861,086	284,068	55,132	294,493	70,9420
NOVEMBER 2021	283,746	33,279	1549,848	862,846	284,366	55,243	294,222	70,8166
DECEMBER 2021	175,931	14,050	1540,799	852,968	284,160	55,166	294,621	71,0012
AVERAGE	248,142	26,942	1546,295	858,966	284,198	55,180	294,445	70,9199

Table 6 is the result of calculation and analysis of energy in the form of work (kW) and mass flow rate (Kg/s) on rotating

equipment which is calculated based on daily monthly average data (from October 2021 to December 2021).

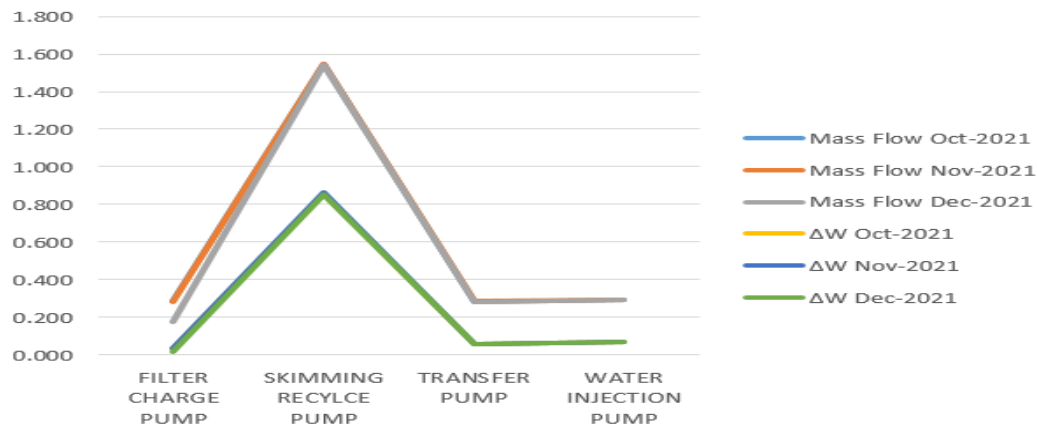


Figure 3: Energy analysis graph in the form of mass flow and work balance

The largest energy is found in the skimming recycle pump (Figure 3). This is caused by amount of mass flow pumped is greater than other pumps and with longer operating hours than other pumps. Skimming recycle pump serves to return liquid water with an oil layer back to the oil collection system so it requires a lot of energy to increase the pumping pressure so that it can penetrate the pressure at the collection station.

To calculate the exergy flow, it is assumed that the static equipment operating condition is a stationary system with negative heat transfer or heat loss direction, constant volume, and no energy transfer in the form of work ($\Delta W=0$) and without electricity and other forms of work/heat, so that by using equation 1-equation 3 the following results in Table 7 are obtained.

Table 7: Exergy analysis static equipment

MONTH 2021 (AVERAGE)	SKIMMING TANK		BALANCE TANK	
	ENERGY (Q_{out}) - kW	Exergy Destruction (X_{dest}) - kW	ENERGY (Q_{out}) - kW	Exergy Destruction (X_{dest}) - kW
OCTOBER 2021	2,13622E-06	39,30964392	122,9131088	1,112315848
NOVEMBER 2021	4,45046E-07	37,80607936	111,4154725	2,847600593
DECEMBER 2021	1,27087E-08	36,20028713	121,534696	3,176042509
AVERAGE	6,35822E-08	40,35305575	118,6210924	2,378652983

Table 7 is the result of calculation and analysis of potential maximum work in the form of energy out (kW) and exergy destruction (kW) on static equipment, which is calculated based on daily monthly average data (from October 2021 to December 2021). In Figure 4 shows the largest output energy that is found in the balance tank (average 118.62 kW). Because

the tank size is relatively large, so it takes a long time to collect ater. This causes a large loss of heat between the inlet and outlet temperatures and results in a large enthalpy difference and a large amount of internal energy contained in the fluid. In the skimming tank the average energy output is very small. In the initial process the water fluid from the collecting station is

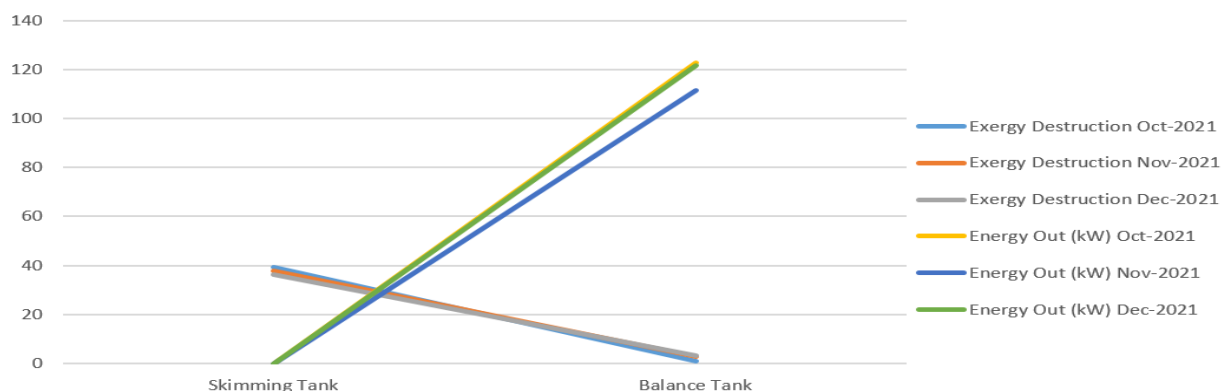


Figure 4: Energy analysis and exergy destruction chart of static equipment

first collected in the equipment. So, the process occurs quickly and only produces a small amount of internal energy contained. It can be concluded that irreversibility occurs due to large temperature differences, in line with Awaludin et al (2016) where irreversibility occurs due to large temperature differences [11].

The highest exergy destruction occurred in the skimming recycle tank (40.35 kW) due to the large amount of heat lost during the process due to damage to the tank insulation and corrosion on the tank walls as well as a large pressure drop due to pressure from gathering station, which is much larger than the tank outlet pressure, which only utilizes the flow of gravity [12]. So, the pressure difference between the inside and

outside is also relatively large.

The energy flow and exergy in the rotating equipment are calculated based on the useful potential work that occurs and the reversible work. Meanwhile, exergy annihilation is the difference between reversible work and potentially useful work. The second law efficiency (η_{II}) of a steady-flow pump is determined by the general definition where $EP = \Delta EK = 0$ so that the second law efficiency of an adiabatic equipment can be determined. Pump operation occurs at a constant temperature ($\Delta T = 0$) so $H = 0$ and there is no transfer of energy in the form of heat ($\Delta Q = 0$) so that the work done by the rotation of the motor shaft is negative. Where by using equation 3 is obtained the exergy analysis of the rotating equipment (Table 8).

Table 8: Exergy analysis rotating equipment

MONTH 2021 (AVERAGE)	CHARGE FILTER PUMP		SKIMMING RECYLCE PUMP		TRANSFER PUMP		INJECTION PUMP	
	W'(rev _{out,l}) (kW)	$\dot{X}_{destruction}$ (kW)	W'(rev _{out,l}) (kW)	$\dot{X}_{destruction}$ (kW)	W'(rev _{out,l}) (kW)	$\dot{X}_{destruction}$ (kW)	W'(rev _{out,l}) (kW)	$\dot{X}_{destruction}$ (kW)
OCTOBER 2021	65,4925742	31,99650598	356,0950427	504,99046	65,33564	10,20321	67,73339	3,2085846
NOVEMBER 2021	65,26158	31,98256298	356,465044	506,38054	65,40418	10,161626	67,67106	3,1454997
DECEMBER 2021	40,464073	26,41362547	354,3837371	498,58454	65,3568	10,190384	67,76283	3,2384197
AVERAGE	57,0727424	31,03589584	355,6479412	503,31851	65,36554	10,185073	67,72242667	3,1975013

Table 8 is the result of calculation and analysis of potential maximum work in the form of reversible work (kW) and exergy destruction (kW) on rotating equipment which is calculated based on daily monthly average data (from October 2021 to December 2021). Based on Figure 5, the reversible work on the skimming recycle pump is greater (355.65 kW) which is caused by the work of the motor on this pump being heavier than other pumps because the amount of fluid is much greater with fewer pumps. Hence, the amount of fluid is returned more to the collection station so that required pumping pressure to penetrate the perforation pressure in the GS. The work of the reversible injection pump is 67.72 kW because the injection pressure is very large (>1300 Psi) and the distance between the pump and the injection well is also very far. While

the lowest reversible workload is 57.07 kW because the pump load is very small only to pass through the filter media.

The biggest exergy damage to the skimming recycle pump (503.32 kW) was caused by a very large heat loss from the initial process to the process of pumping the fluid back to the GS due to the malfunction of the heater in the tank and pressure drop due to damage of check valve at pump discharge which caused back pressure from another pump.

The largest exergy damage occurred in rotary equipment was 547.74 kW and static equipment was 42.74 kW as shown in Table 9. The magnitude of the difference in exergy destruction between rotary equipment and static equipment was caused by rotating equipment, there was a very significant decrease in pump performance.

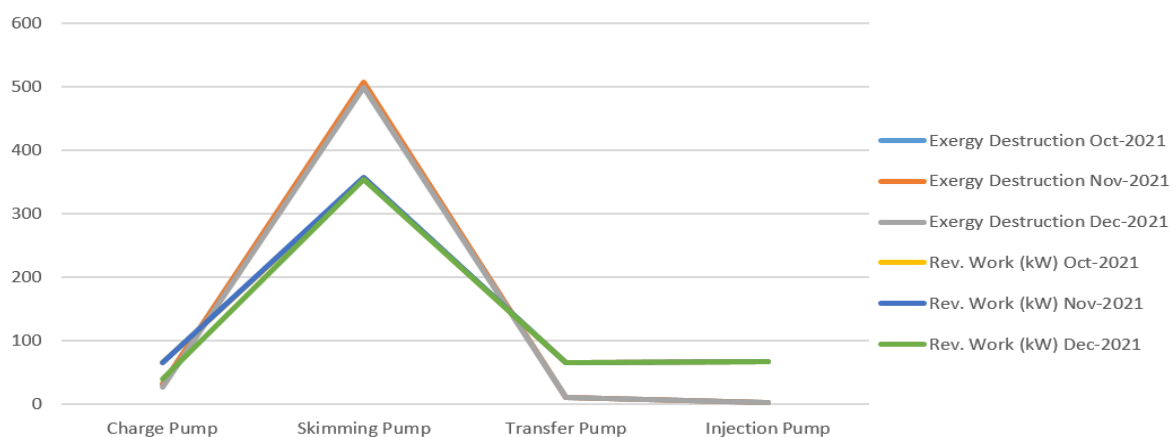


Figure 5: Reversible work and exergy destruction chart of rotating equipment

Table 9: Exergy analysis of rotating equipment

EQUIPMENT	$\dot{X}_{\text{destruction}}$ (kW)
Charge Filter Pump	31.035896
Skimming Recycle Pump	503.318514
Transfer Pump	10.185073
Injection Pump	3.197501
Skimming Tank	40.353056
Balance Tank	2.378653
TOTAL	590.468693

These results are almost the same as those obtained by Y. Liu (2019) [13] who investigated the energy and exergy losses in "North-East China", where the exergy damage to the pump system was 3397.1 MJ/h greater than that in the static equipment [13]. Also, approaching the research of Masoumi et al. (2015) who conducted research at Shazand-Arak Oil with the results of the analysis that 35% of energy loss occurred in the heater and 45% in the pumping system [14].

Lu, (2013) in [14] conducted a study on the pumping and piping system of Zhao II oil station in China's Daqing Oil Field where it was concluded that a large amount of exergy damage was caused by temperature and pressure drops in the delivery process and piping system. These results are in accordance with the results of research that has been carried out on the CPP block where exergy destruction occurs due to loss of temperature and pressure drop which causes changes in enthalpy and entropy of the flowing fluid. The analysis of the relationship between the exergy elimination process and flow is illustrated by the Grassman diagram (Figure 3).

The results of the exergy analysis are then combined with economic analysis in order to determine the total cost per year. The total value of expenditure is calculated from fixed operational maintenance costs, variable operational maintenance costs, and electricity costs. The initial investment costs are not taken into account because the facility's operating life has been for two periods of 40 years and is assumed to have reached ROI so that only actual operating and maintenance costs are taken into account.

Operational maintenance costs include the cost of salaries and employee benefits based on salary standards and direct costs issued by the Indonesian National Consultant Association (INKINDO, 2021) regarding the minimum conversion of direct labor costs where the direct cost index index of Riau Province is 0.894 [15]. By using a specific electricity price parameter of 0.09 \$/kWh, it can be calculated the economic cost of energy destruction, which is a production operation loss.

The exergy value obtained is calculated using the cost equation (equation 4) where the total cost of the total outflow rate is equal to the total expenditure to produce exergy. Hence, the cost of exergy destruction can be calculated. In Table 10 is showed the result of the calculation of exergy destruction for equipment in line of flow process. Total exergy destruction of water cleaning and water injection was 612,097 kW. The largest exergy destruction occurs in rotating equipment (skimming recycle pump of 503.318 kW), while the total value of losses due to exergy destruction is 465.517.08 USD/year or 1328.53 USD/year where the largest operating loss due to irreversible work also occurs in skimming recycle pump (Figure 7).

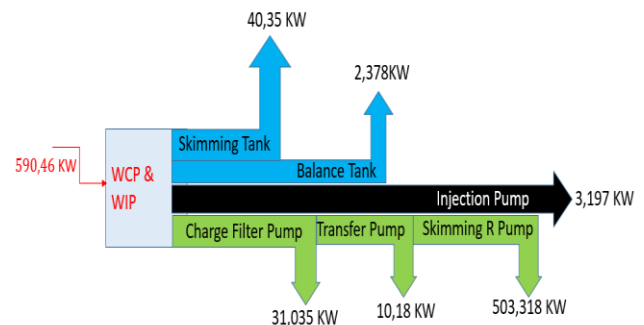


Figure 6: Grassman diagram for exergy flow

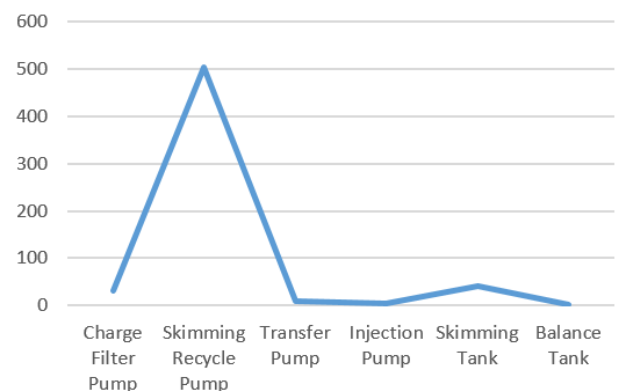


Figure 7: Exergy destruction rotating and static equipment

Table 10: Exergy-economic WCP and WIP

COMPONENTS	EXERGY DESTRUCTION (kW)	EXERGY DESTRUCTION COST PER HOURS (\$/H)	EXERGY DESTRUCTION PER DAY (\$/D)	EXERGY DESTRUCTION PER YEAR (\$/Y)
Charge Filter Pump	31,035	2,79315	67,0356	24467,994
Skimming Recycle Pump	503,318	45,29862	1087,16688	396815,9112
Transfer Pump	10,18	0,9162	21,9888	8025,912
Injection Pump	3,197	0,28773	6,90552	2520,5148
Skimming Tank	40,35	3,6315	87,156	31811,94
Balance Tank	2,378	0,21402	5,13648	1874,8152
TOTAL (\$)	612,0970367	1328,5305	466792,4765	465517,0872

Based on the measurements and calculations as well as the results obtained from previous studies, it is necessary to re-examine to analyze the causes of the temperature drop in the pressure loss on each equipment. Inspection and measurement of insulation need to be considered considering the age of use of insulation is 40 years. The loss of a certain amount of exergy in static equipment is caused by the loss of a certain amount of heat due to damage to the insulation and leakage of the insulation plate, while in rotating equipment it is caused by damage to the check valve on discharge position and gate valve in the suction position and pump design that is not comparable to current operating conditions (pump design is smaller than operation).

In general, the results of energy and exergy analysis can be used to identify weaknesses in each sub-process equipment and then it is recommended to repair equipment with a long operating life, replace equipment supporting components such as insulation, gate valves, and check valves. Furthermore, it is necessary to analyze the pump performance to determine the performance value and the efficiency value of rotary equipment.

4.0 CONCLUSION

The highest energy in static equipment was balance tank 118.621 kW, in rotating equipment was water injection pump 148,325.97 HP. The total value of losses due to exergy destruction was 590,468 kW wherein static equipment exergy destruction was skimming tank 40.35 kW and rotating equipment was skimming recycle pump 503.318 kW. Total exergy destruction cost was 465,517.09 \$/year. The highest exergy destruction cost was skimming recycle pump 396,815.911 \$/year and balance tank 1874.8152 \$/year. Energy analysis is carried out by comparing energy requirements with the energy used to run equipment, so that the performance of equipment can be known based on its efficiency value. Exergy analysis must first describe the exergy flow in a system and equipment so that it can be seen the flow and the exergy value used and the exergy destruction.

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