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Study on the Effect of Energy Losses on Diesel Power Plant Efficiency (Case Study at Diesel Power Plant at Human Resources Development Center for Electricity, New Renewable Energy and Energy Conservation)

Arief Indarto [1], Aspita D. Fajarsari [2]

[1,2]*Human Resources Development Center for Electricity, New Renewable Energy and Energy Conservation*
Ministry of Energy and Mineral Resources, Jakarta, Indonesia 13740
Corresponding Author: Aspita D. Fajarsari

ABSTRACT:*One of the key factor to sustain diesel power plant energy performance is control the criticalparameters. O_2 and flue gastemperatur on stack are criticalparameters towardenergylosses. By knowing O_2 and CO_2 parametersthroughmeasurementitcanbecalculated air ratio and excess air. Futherenergy lossescanbe determined by using air ratio and flue gastemperature data. Energylosses are a step to calculate diesel power plant efficiency.*

KEYWORDS: *energy losses, air ratio, excess air, diesel power plant efficiency.*

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I. INTRODUCTION

Paris Agreement in 2005 mandated that the Country of Parties maintain a rise in global average temperature below 2°C from pre-industrial condition, and try to limit be 1.5°C. Indonesia has ratified the Paris Agreement with Law 16/2016 and nationally committed to implement mitigation in 2030 amounting to 834 million tons of CO_2 (Commitment 1) and 1081 million tons of CO_2 (Commitment 2). National mitigation activities are carried out through the sectors: Energy, Waste, IPPU, Agriculture, and Forestry.

Mitigation of emissions in energy sector is carried out by taking steps:

- Transfer of fuel subsidies to the productive sector.
- Increased use of new renewable energy to 23% of national energy consumption in 2025.
- Waste management becomes an energy source.

Emission reduction targets by 2030:

- 314 million tons of CO_2 (Commitment 1).
- 398 million tons of CO_2 (Commitment 2).

The Greenhouse Gas (GHG) emissions reduction factors are caused by:

- Energy Diversification, increasing the share of new renewable energy.
- Use of Clean Coal Technology (CCT) for electricity generation.
- Substitution of energy used from fuel to natural gas.
- Implementation of the Energy Conservation program.

Diesel power plant is one type of thermal power plant that produces electricity using fossil fuels (oil fuel or gas) as its energy source. In Human Resources Development Center for Electricity, New Renewable Energy and Energy Conservation has a Diesel Power Plant is used for electricity back up and training program.

1.1. Identification of Problem

Human Resources Development Center for Electricity, New Renewable Energy and Energy Conservation has the task improve the competence of human resources in Electricity, New Renewable Energy and Energy Conservation, so there are several supporting facilities such as the installation of Solar Power Plant, Micro Hydro Power Plant, Diesel Power Plant, Boilers, Low Voltage Utilization Installation Laboratory, Main

Station and Medium and Low Voltage Distribution Networks and Electric Power Laboratory.On this occasion, energy conservation will be discussed in the combustion system of the diesel power plant.

Indicators of the combustion system efficiency used are air ratio and flue gas temperature. In practice, air ratio is indicated by the levels of O_2 or CO_2 in the combustion flue gases. Operating parameters changing in the combustion system such as O_2, CO_2, and exhaust gas temperatures affect combustion efficiency. Every excess air decreases by 5%, it will increase combustion efficiency by 1%.

1.2. Formulation of the Problem

By identifying operating parameters that change in the combustion system such as O_2, CO_2, and exhaust gas temperatures, the formulation of the problem is:

- Why are the air ratio and flue gas temperature is the main factor for combustion system efficiency the diesel power plant.
- How much the percentage of air ratio, excess air and flue gas temperature in a stack (flue gas losses in a stack).
- How much diesel power plants efficiency.
- How much energy input is utilized and output energy generated.

1.3. Objective and Benefits

The purpose of this study is to enrich teaching materials in the Energy Audit Training in Industry. And the benefit that can be taken is to increase the understanding of training participants in analyzing the performance of diesel power plant.

1.4. Diesel Power Plant

Human Resources Development Center for Electricity, New Renewable Energy and Energy Conservation has 2 units diesel power plant, with a capacity of 200 kVA and 220 kVA. The diesel power plants unit as shown in Fig. 1.

Fig 1. Unit Diesel Power Plant 220 kVA

The following are the specifications in nameplate generator:

Table 1. The Specifications in Nameplate Generator

Specification	Value
Ambient Temperature	27 °C
Standby Power Rate	220 kVA (176 kW)
Rate Voltage	400/230 V
Phase	3 Phase
Power Factor Rate	Cos phi = 0.8
Frequency Rate	50 Hz
Current Standby Rate	318 A
RPM Rate	1500 RPM
Altitude	152,4 m
Alternator Connection	S-STAR
Insulation Class	H
Excitation Voltage	38 V
Excitation Current	4 A

Fig. 2. Turbocharger System

II. DIESEL POWER PLANT SYSTEM

2.1. Fuel Characteristics

An understanding of fuel and its characteristics is necessary in selecting fuels for certain purposes and for the sake of energy efficiency. Fuel composition generally consists of carbon and hydrogen or a combination of both known as hydrocarbons. Types and characteristics of fuels (liquid, solid and gas) will be explained below.

Liquid fuels such as petroleum are the fuels most widely used in industrial processes. Some important properties related to storage, handling and preparation of liquid fuels will be discussed below.

Density is defined as the ratio between mass and volume of fuel at a reference temperature of 15°C. Density is measured by an instrument called a hydrometer. An understanding of density is useful both for quantitative calculations and for assessing ignition qualities. The unit of density is kg/m^3.

Specific heat is the amount of heat (kcals) needed to raise the temperature of 1 C from 1 kg of oil. The specific heat unit is kcal/kg°C. This value varies from 0.22 to 0.28 depending on specific gravity. Specific heat determines how much heat or energy is needed to heat the oil to reach a certain temperature. Light oils have low specific heat, whereas heavier oils have higher specific heat. The characteristics of liquid fuels as shown in Table 2.

Tabel 2. Characteristics of IDO Liquid Fuels[1]

No.	Characteristics	Unit	Boundary				Test Method
			Diesel 1		Diesel 2		
			Min.	Max	Min.	Max.	ASTM
1.	Density at 15^{0}C	kg/m^3	-	900	-	920	D 1298/4052
2.	Kinematic Viscocity at 40^{0}C	mm^2/dt	2.5	11.0	-	24.0	D 445
3.	Flash Point PMcc	^{0}C	60	-	60	-	D 93
4.	Pour Point	^{0}C	-	18	-	21	D 97
5.	Micro Carbon Residu	% m/m	-	0.50	-	3.0	D 4530
6.	Ash Cotent	% m/m	-	0.02	-	0.05	D 482
7.	Sediment by extraction	% m/m	-	0.02	-	-	D 473
8.	Water content	% v/v	-	0.25	-	0.3	D 95
9.	Setana number	-	35	-	-	-	D 613
10.	Sulfur content	% m/m	-	1.5	-	2.0	D 1552/2622
11.	Vanadium	mg/kg	-	100	-	100	AAS
12.	Aluminium + silikon	mg/kg	-	25	-	25	D 5184/AAS
13.	Colour	Class	6	-	6	-	D 1500

Some other fuel characteristics are specific gravity, viscosity, flash point, calorific value, sulfur, ash content, carbon residue, water content. This diesel power plant unit uses Industrial Diesel Oil (IDO), with the following data:

- High Heating Value (HHV)= 10.200 kkal/kg
- Density = 910 kg/m^3

2.2. Combustion Management

Combustion management is applied to obtain the optimum combustion process in a combustion system. Indicators of combustion system efficiency are the air ratio and flue gas temperature.

The air ratio is the ratio between actual combustion air and theoretical combustion air. In practice, the O_2 (%) content in the stack indicates the ratio of actual combustion air. The correlation between oxygen (O_2) content on the stack with combustion air ratios is shown the following formula:

$$\text{Air Ratio} = \frac{21}{21 - \%O_2}$$

Complete combustion can occur if the amount of combustion air supplied to the combustion chamber is more than the theoretical requirement (stoichiometric). But if excess air is made too much, the mass flow rate of the flue gas from the combustion becomes large. Excess air is the excess amount of combustion air supplied (%) of the theoretical combustion air amount. The amount of excess air can be calculated by the following formula.

$$\text{Excess Air (EA)} = \frac{378}{\left\{100 - \frac{(\alpha + \omega)}{\omega}\right\}} - 3.78$$

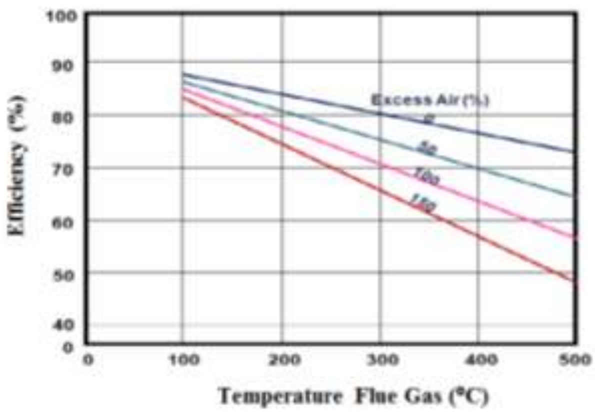
Where :

EA is excess air (%), α is the level of CO_2 in flue gas (%) measured, ω is the level of O_2 in flue gas (%) measured.

The recommended air ratio for some types of fuel is as in the following table.

Table 3. The Recommended Air Ratio and Optimum O_2 on Stack[3]

Fuel	Air Ratio (%)	O_2 on Stack (%)
Coal	1.20 – 1.25	4 – 4.5
Biomass	1.20 – 1.40	4 – 6
Stoker firing	1.25 – 1.40	4.5 – 6.5
Fuel Oil	1.05 – 1.15	1 – 3
Gas/LPG	1.05 – 1.10	1 – 2
Black Liquor	1.05 – 1.10	1 – 2

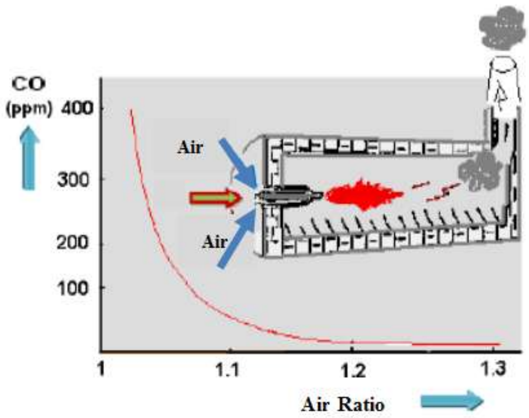


Graph 1. Excess Air Graph[3]

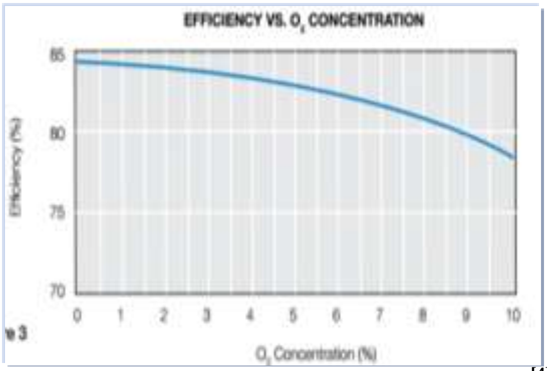
2.3. Factors Affecting Combustion Efficiency

One indicator of combustion efficiency is air ratio. Air ratio in practice is indicated by the levels of O_2 or CO_2 in the flue gas. So, O_2 and CO_2 are operating parameters of air ratio. The O_2 content in flue gases is a parameter of the combustion system operation.

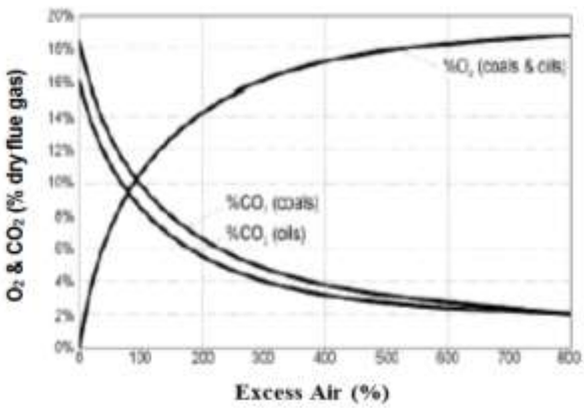
If the operating parameters (air ratio and flue gas temperature) are controlled, the combustion efficiency is well controlled. Non-combustible fuel is characterized by the appearance of CO and or black smoke in the flue gases.



Graph 2. Incomplete Combustion[4]

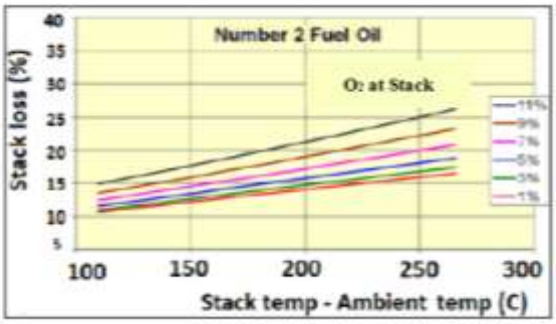


Graph 3. Efficiency vs O_2 Concentration Graph[4]



Graph 4. CO_2, O_2 vs excess air (ekstreme) coal & petroleum fuels[3]

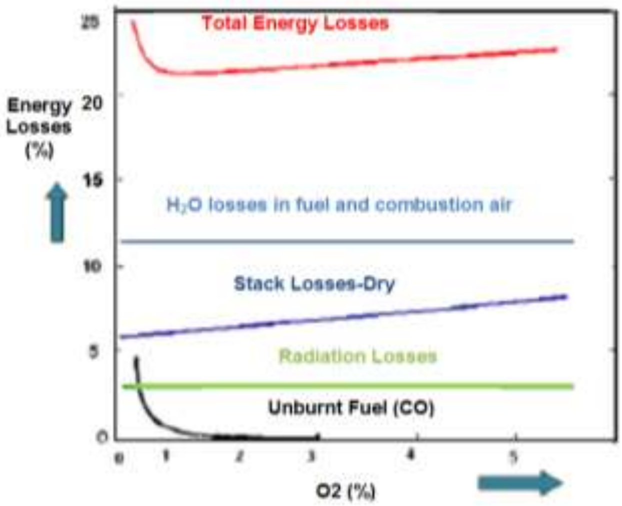
In addition to the air ratio as described above, another operating parameter that indicates combustion efficiency is exhaust gas temperature of the. The flue gas temperature is an important operating parameter that needs to be monitored related combustion efficiency. The lower the flue gas temperature more effective use of heat or in other words the less energy is wasted into the stack. Combustion efficiency related to the sensible heat of flue gas that come out through the stack.



Graph 5. Stack Loss vs. Stack Temperature for Fuel Oil[3]

The energy losses to the stack are determined by temperature and mass of flue gas flow. High temperatures and large mass of flue gas flow (too much air) make the amount of sensible energy of the flue gas lost to the stack become large. The sensible energy of flue gas lost to the stack is known as stack energy losses. The parameters that influence the amount of sensible energy of the flue gas of a combustion system are flue gas temperature and excess air. The lower the flue gas temperature and the lower the excess air (more air) according to the type of fuel used the less energy losses to the stack (see graph)

The following graph shows the relationship between flue gas losses to the stack. The vertical axis indicates the percentage of stack energy loss, while the horizontal axis is the amount of O_2 (excess air) content in combustion air.



Graph 6. Total Energy Lost to Stack vs O_2 (%)[4]

Stack energy losses can be calculated using the following formula.

Seigerts Formula

If the percentage of CO_2 or O_2 in the flue gas has been measured, then using the Seigert formula, the flue gas losses (gross - HHV) can be calculated as follows :

$$\text{Flue Gas Losses (\%)} = \frac{\text{K x } \Delta\text{T}}{\%\text{CO}_2} + \text{c}$$

where :

K and C : Seigert Constants (for various types of fuels see table).

ΔT : Different temperature of flue gas and combustion air (C).

% CO_2 : percentage of dry volume of CO_2 in the flue gas.

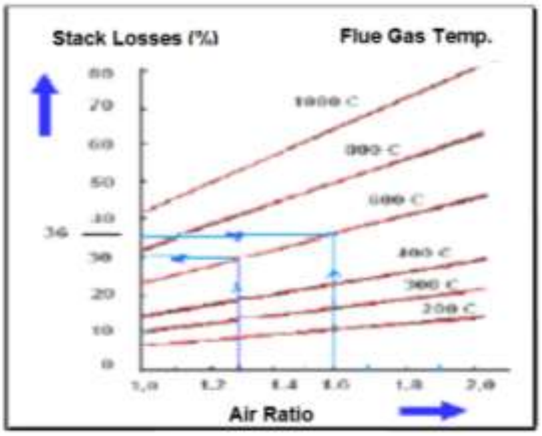
Table 4. Seigert Constant[4]

Type of Fuels	k	c
Gas	0.38	11.0
Fuel Oil	0.56	6.5
Coal	0.63	5.0

Example: Calculating the Effect of Air and Flue Gas Ratio on Energy Losses

The results of measurement of flue gas temperature on gas stack showed 600^{0}C. And the results of measurements of composition of the flue gas (O_2& CO_2) produce an air ratio of 1.6.
By knowing the operating parameters of CO_2 or O_2 and temperature of flue gas, flue gas energy losses can be calculated.

With the air ratio 1.6 above in the graph (the following figure), sensible energy losses in the flue gas can be known that is 36% of the input energy. If the air ratio is reduced to 1.3 then the amount of energy lost through the flue gas will drop to 30%. It means reducing the air ratio from 1.6 to 1.3, making energy losses to the stack reduced by 6% (from 36 to 30%).



Graph 7. Air Ratios, Flue Gas Temperatures and Energy Losses [3]

From the Graph 7. Above, it appears that the lower the temperature of flue gas the less energy is wasted. Likewise the air ratio, the lower the air ratio the less energy is wasted, or in other words the combustion efficiency is increasing. Theoretically, the maximum savings occur at an air ratio equal to 1. However, if the air ratio is made 1 in practice, the fuel does not burn completely, which is marked by the presence of CO and black smoke in the combustion gas (stack gas).

2.4. Efficiency of Diesel Power Plant

Efficiency of diesel power plants is related to the ability to absorb energy from fuel (input) into electrical energy (output). Increasing the combustion efficiency of a diesel power plants means increasing the energy produced or reducing the energy wasted or lost from the combustion process of diesel power plants. From the description above, efficiency can be interpreted as a comparison between the electrical energy produced (output) and the energy contained in the fuel (input).
According to the ASME (American Society of Mechanical Engineer) method, known as gross efficiency is calculated by:

- Direct (Input-Output method)
- Indirect (heat loss method)

Diesel power plants efficiency calculations by the direct method can be done if the respective output energy (steam) and input energy (fuel) are known. As explained above, efficiency is the ratio between energy output (output) and energy consumption (fuel input) with the units of each input & output made equal, and multiplied by 100%.

$$\text{Direct Efficiency} = \frac{\text{Output}}{\text{Input}} \text{x}100\%$$

where :

- Output is the energy generated
- Input is the net heating value of boiler fuel consumption

Calculation of the efficiency of indirect methods is often used in practice by knowing the input energy (input) and calculating energy losses in percent of fuel input. By using the principle of energy conservation law where the input energy (input) is equal to the energy output (output) plus energy losses. In other words, the output energy is equal to the input energy minus energy losses. And based on the previous definition of boiler efficiency, boiler efficiency based on indirect calculations can be written as follows:

$$\text{Indirect Efficiency} = \frac{\text{Output}}{\text{Input}} \text{x}100\%$$

$$\text{Indirect Efficiency} = \frac{\text{Input} - \text{Losses}}{\text{Input}} \text{x100\%}$$

Indirect Efficiency = 100 – Energy losses in % fuel input
Efficiency (%) = 100 – ∑ Energy Losses (%)
Each of the energy losses are:
- Loss of heat to the stack
- Heat loss due to incomplete combustion
- Radiation heat losses
- H2O latent heat losses in the flue gas

(Sources: Prosedur Standar dan Teknik Audit Energi di Industri, BPPT-Balai Besar Teknologi Industri, 2015)
Combustion efficiency is defined as the difference between the energy contained in a perfect combustion fuel reduced by stack energy losses.

The percentage of O_2 or CO_2 in the flue gas can be measured with portable gas-absorbing test kits. If the O2 operating parameters and the flue gas temperature are known, the flue gas losses can be calculated using the Seigert formula as described above (gross flue gas losses - HHV).
Combustion efficiency is (100 – Flue Gas Losses to the stack) %.
Stack Losses in this case are stated in % of fuel input.

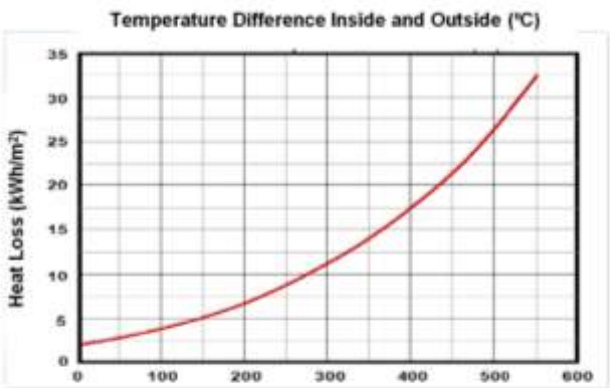
Water vapour latent heat energy losses is the energy contained in H_2O resulting from the combustion of the element hydrogen in the fuel with O_2 from the combustion air. The presence of water (H_2O) in the fuel or water formed from the combustion reaction H_2 from the fuel and O_2 from the combustion air, will increase the amount of energy losses to the stack, called the latent heat loss H_2O. The higher H_2 in fuel the greater the difference in gross heat value (HHV) and net heat value (LHV) as shown in the following table.

Table 5. HHV and LHV for Various Types of Fuel[3]

Fuels	H_2 (%)	HHV/LHV
Gas	78	0.90
Fuel Oil	12	0.90
Coal	5	0.98

Fossil fuels generally consist of carbon (C) and hydrogen (H_2). Incomplete combustion carbon is oxidized to carbon dioxide (CO_2), and hydrogen is oxidized to H_2O by releasing some energy.
Incomplete combustion is characterized by the presence of C C C C C + CO CO CO. Incomplete combustion arises from:
- Supply of less air or surplus fuel
- Fuel deprivation/distribution is not good/uneven.

Energy lost through radiation and convection is energy loss from the surface of the diesel power plant insulation due to radiation and convection to the surrounding air. Radiation energy losses are determined by surface temperature and diesel power plant load factor. Radiation and Convection Energy Losses can be seen in Graph 8 below.



Graph 8. Radiation and Convection Energy Losses on Flat Surface[8]

2.5. Measurement data of flue gas diesel power plant in Human Resources Development Center of Electricity, New Renewable Energy and Energy Conservation with various load

Measurement data of flue gas with various load on October 23, 2018 as follows:

Table 6. Exhaust Gas Components of Diesel Power Plant with Various Load

Flue Gas Components	Load				
	Engine off	0 kW	45 kW	85 kW	125 kW
O_2	20,9 %	17,4 %	12,1 %	8,8 %	6,8 %
CO	-	-	-	-	-
Eff	-	-	75,1 %	73,3 %	71,4 %
CO_2	-	-	6,5 %	9,1 %	10,5 %
T-Stack	23°C	134° C	268° C	384° C	475° C
T-Air	24,6°C	25,3° C	25,5° C	26,1° C	26,2° C
EA*)	-	-	127,6 %	66,5 %	44,5 %

Note: EA is Excess Air

From the flue gas measurement there are no CO and H_2O components in the flue gas. Thus there are losses of incomplete combustion and water vapor latent heat losses.

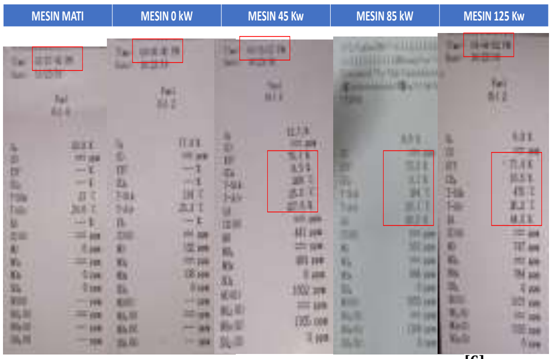


Fig 3. Flue Gas Measurement Data[6]

2.6. Cooling Losses

Cooling losses are the ratio between cooling losses and the energy input used.

$$\%\ \text{Cooling Losses} = \frac{\text{Cooling Losses}}{\text{Input}}$$

$$\%\ \text{Cooling Losses} = \frac{\text{A x v x } \rho \text{ x Cp x } \Delta\text{t}}{\text{Input}}$$

where:

A = Cooling Cross-sectional Area (m^2)
V = Air flow rate (m/s)
ρ = Air Density ($\frac{kg}{m^3}$)
Cp= Specific Isobar Heat (kJ/KgK)
Input = Energy (kWh)

Property	Value	Unit
Medium :	Air	
Pressure :	1	[bar]
Temperature :	41.2	[Celsius]
Density :	1.10968	[kg / m³]
Specific Enthalpy :	314.9296	[kJ / kg]
Specific Entropy :	6.918488	[kJ / kg K]
Specific isobar heat capacity : cp	1.007648	[kJ / kg K]

Fig 4. Ambient Air Condition, T=41,2°C[7]

Property	Value	Unit
Medium :	Air	
Pressure :	1	[bar]
Temperature :	63	[Celsius]
Density :	1.03744	[kg/m^3]
Specific Enthalpy :	336.904	[kJ / kg]
Specific Entropy :	6.986	[kJ / kg K]
Specific isobar heat capacity : cp	1.00904	[kJ / kg K]

Fig 5. Coolant Air Condition, T=63° C[7]

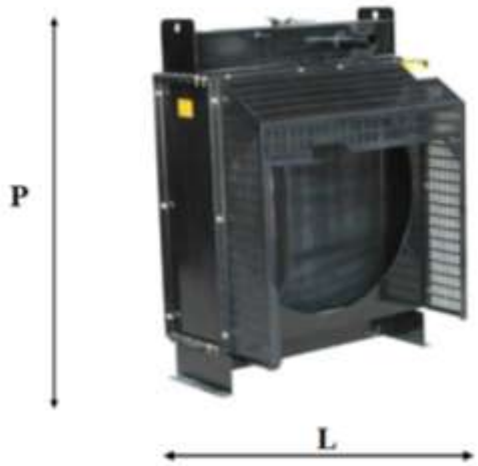


Fig 6. Cooling Typical

Dimention Area, A = p x l (1.2 x 1.2) m^2 .

2.7. Fuel Consumption

Fuel Data Consumption in accordance load as follows:

Table 7. Fuel Data Consumption in Various Load[7]

No.	Time	Load	RPM	Fuel Flow
1.	0	0	1405	2768
2.	15	45	1410	2810
3.	30	85	1405	2840
4.	45	125	1405	2869
5.	60	125	1410	2898

Table 8. Fuel Data Consumption[7]

Fuel Consumption
281,0 – 276,8 = 4,2 Liter
284,0 – 281,0 = 3,0 Liter
286,9 – 284,0 = 2,9 Liter
289,8 – 286,9 = 2,9 Liter

2.8. Output Energy
From measurement and calculation of energy output, the following data are obtained.

Table 9. Energy Output (kWh)[7]

Day (kW)	Time(hours)	Energy Count (kWh)	EnergyMeasure (kWh)
0	0	0	
0	0,25	0	0
45	0,25	11,25	11,11
85	0,25	21,25	20,44
125	0,25	31,25	30,1

III. RESULT AND DISCUSSION
From the theoretical basis above and by using field survey data collection discussion and results can be carried out as follows.

3.1. Air Ratio
From the measurement data in Fig. 3, the O_2 percentage is obtained:
- Load 45 kW = 12.1%
- Load 85 kW = 8.8 %
- Load 125 kW = 6.8 %

$$\text{Air Ratio} = \frac{21}{21 - \%O_2}$$

- AR 45 kW = 21/(21 – 12.1) = 2.36
- AR 85 kW = 21/(21 – 8.8) =1.72
- AR 125 kW = 21/(21 – 6.8) =1.48

3.2. Excess Air (EA)
From the measurement data in Fig. 3, the O_2 and CO_2 percentage is obtained:
- Load 45 kW = 12.1% O_2 dan 6.5% CO_2
- Load 85 kW = 8.8 % O_2 dan 9.1% CO_2
- Load 125 kW = 6.8 % O_2 dan 10.5% CO_2

$$\text{Excess Air (EA)} = \frac{378}{\left\{100 - \frac{(\alpha + \omega)}{\omega}\right\}} - 3.78$$

where:
α is the CO2 content in flue gas (%) measured, ω is the O_2 content in flue gas (%) measured.

EA 45 kW = 56.18919 atau 56.20%
EA 85 kW = 40.51644 atau 40.52%
EA125 kW = 31.08102 atau 31.08%

The result of the calculation of Air Ratio is in range 1.48% – 2.36% and Excess Air in range 31.08% – 56.20%. The results of Air Ratio calculation above when compared to standard air ratio (fuel) in Table 2 is 1.05% – 1.15%, the value is above the standard.
Whereas the measurement of the highest O_2 content was 12.1%, far above O_2 standard in Table 2, which was 3% or a difference of 3.03%.

3.3. Flue Gas
Measurements include the levels of O_2, CO_2 (in percent), CO (in ppm), and excess air (in percent). It also measured the temperature of flue gas (in ^{0}C).

The results of flue gas temperature measurement for various loading as follows:
- T Stack 45 kW = 268°C
- T Stack 85 kW = 384°C
- T Stack 125 kW = 475°C

By using the results of the air ratio and T-Stack calculation on each loading are:
Dengan menggunakan hasil perhitungan rasio udara dan T-Stack pada masing pembebanan, yaitu :
- AR 45 kW = 2,36 dan T-Stack = 268°C
- AR 85 kW = 1,72 dan T-Stack = 384°C
- AR 125 kW = 1,48 dan T-Stack = 475°C

And can be seen in Graph 7, it can be estimated stack losses ranging between 15% at 45 kW load and 25% at 125 kW.

3.4. Efficiency
Direct Efficiency

$$\text{Direct Efficiency} = \frac{\text{Output}}{\text{Input}}$$

where:
- Input = Fuel Mass (M) x Density (D) x High Heating Value (H)
- From Tabel 9, Output Load 45 kW = 11,25 kWh.
- From Tabel 2. Characteristics of IDO liquid fuel, Fuel Density 910 kg/m3 dan High Heating Value 10.500 Kcal/kg
- From Table 7. Fuel consumption are 3 liter, then: Direct Eff (load 45 kW) = 34% ; Eff Direct (load 85 kW) = 66% ; Eff Direct (load 125 kW) = 97%

Indirect Efficiency
To calculate the Indirect Efficiency the following formula is used:
IE = 100% – (A + B + C)
where:
A = Radiation and Conduction losses (R&C Losses)
B = Cooling Losses
C = Flue Gas losses

To calculate radiation and conduction losses, it is necessary to have temperature data of the body genset, turbo and flame flue gas as follows:

Tabel 10. Delta Temperature [7]

No.	T Machine	T Ambient	ΔT	AT
1.	178	35	143	
2.	204	35	169	**204**
3.	172	35	137	
4.	161	35	126	
5.	156	35	121	
6.	106	35	71	

Based on Graph 8.and calculation the difference in external and internal temperatures is 204°C, the radiation and conduction losses is around 7.5%

$$\text{Cooling Losses (CL)} = \frac{\text{Cooling Loss}}{\text{Input}}(\%)$$

$$\text{Cooling Losses (CL)} = \frac{\text{A x v x } \rho \text{ x Cp x } \Delta\text{T}}{\text{Energy Input}}$$

By using the data in Table 7 and data flow rate, air density and kWh input from calculation of direct efficiency, the cooling lossess is as follows:

Tabel 11. Calculation of the Cooling Loss Parameter

	p	l	A	v	ρ	Cp
Load	m	m	m2	m/s	kg/m^3	kJ/kgK
0	1,2	1,2	1,44	5,1	1,109	1,0076
45	1,2	1,2	1,44	5,1	1,109	1,0076
85	1,2	1,2	1,44	5,1	1,109	1,0076
125	1,2	1,2	1,44	5,1	1,109	1,0076

From the calculation results it can be seen that the CL for various loading is very small in value.
The various formulas used in calculating Flue gas losses are as follows:
(Sources: B2TKE Energy Audit Practice Materials)

$$\mathbf{Loss_{dry\ flue\ gas}} = \frac{\mathbf{K(T_{FG} - T_A)}}{\mathbf{CO_2}}$$

From the data in Table 6and the number of Seigert Constant, K in Table 4, we cancalculate Loss $_{\text{Dry Flue Gas}}$ and Loss $_{\text{Rad \& Con}}$ as follow :

Table 12. Calculation of Dry Flue Gas Losses[7]

No	Parameter	Unit	Load 0	Load 45	Load 85	Load 125
1.	O_2	%	17,4	12,1	8,8	6,8
2.	CO	ppm	0	0	0	0
3.	Efficiency	%	0	75,1	73,3	71,4
4.	CO_2	%	0	6,5	9,1	10,5
5.	T-Stack	C	134	268	384	475
6.	T-Ambient	C	25,3	25,5	26,1	26,2
7.	EA	%	0	127,6	66,5	44,5
8.	CO (0)	ppm	0	0	0	0
	K Liquid Petroliun		0,56	0,56	0,56	0,56
	Losses Dry Flue Gas	%	0	**20,892**	**22,024**	**23,936**
	Losses Unburn CO	%	0	0	0	0

From these formulas, losses due to non-combustion of CO and H_2O were not used because no CO and H_2O measurement data were obtained.
Using the calculation data above, then:
Indirect Efficiency (Load 45 kW) = 100 – (7,5+0,001+**20,892) =** 71.607**%**
Indirect Efficiency (Load 85 kW) = 70.475**%**
Indirect Efficiency (Load 125 kW) = 68.563**%**
From the results of indirect efficiency calculations above it appears that the highest efficiency is achieved at a lower load and Dry Flue Gas Losses.

IV. CONCLUSION

Study on the effect of energy losses on diesel power plant efficiency, case study at diesel power plant at human resources development center for electricity, new renewable energy and energy conservationwith the following results.

There is no CO levels in the measurement data indicates the complete combustion of diesel power plant is characterized by the amount of combustion air supplied to the combustion chamber more than the theoretical requirement (stoichiometric), ie excess air is more than 1% (stoichiometric 1%).

The lower the temperature of flue gas the less energy is wasted , the lower the air ratio percentage the less energy is wasted, or in other words the combustion efficiency increases at lower air and flue gases.
There is no H_2O levels in the measurement indicates there is no H_2O latent heat loss so it is not counted in the calculation of stack losses.
Losses from cooling is very small.

The results of indirect efficiency calculation are 71.6%, 70.5% and 68.6%, closer to the efficiency data of the measurement results are 75.1%, 73.3% and 71.4%.

The results of direct efficiency calculations are 34%, 66% and 97%, very significantly different from the efficiency data of 75.1%, 73.3% and 71.4%. This is because the calculation of direct efficiency is only determined by the efficiency of the input energy from the Fuel Oil used against the output energy produced, without taking into account losses.

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