

The Effect of Lo Cooler Temperature on Exhaust Gas from The Main Engine of the Logindo Overcomer

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Abstract:

The Indonesian maritime sector is highly dependent on main engine performance, where lubricant oil (LO) cooler temperature affects exhaust gas stability. This study analyzes the causal relationship between LO cooler temperature (X) and main engine exhaust gas (Y) on MV Logindo Overcomer. Using a quantitative causal-comparative approach, data were collected from 10 purposively selected engine room crew members during 12 months of Sailing Practice through Likert scale questionnaires, observations, and engine logbooks. SPSS v.27 analysis showed descriptive statistics (X: mean=52.50; Y: mean=37.70), highly valid/reliable instruments (Cronbach's $\alpha > 0.90$), regression equation $Y=8.423+0.558X$, coefficient of determination 71.6%, and Spearman correlation $r=0.894$ ($p=0.000$). The results prove a very strong influence of LO cooler temperature on exhaust gas stability. The conclusion recommends regular cleaning of the LO cooler, replacement of accurate thermometers, real-time monitoring, and crew training to prevent combustion inefficiency and overheating, similar to the case of KM Pratiwi Raya.

Keywords: Exhaust Gas; LO Cooler; Main Engine; Marine Diesel and Spearman Correlation.

I. INTRODUCTION

Indonesia, as a maritime nation with a water area far larger than its land area, possesses abundant marine resources and a crucial role for maritime transportation in supporting inter-island connectivity and the distribution of goods domestically and internationally (Dahuri et al., 2001; Priadi, 2024; Statista, 2025). Maritime transportation is the backbone of modern industry, where intense competition among shipping companies demands that the fleet be kept in prime condition to ensure smooth operations and customer satisfaction (Kotler & Keller, 2016; Haistar Marine, 2025). The main engine as the ship's main propulsion converts chemical energy from diesel fuel into mechanical power that is channeled to the propeller through the transmission system, but often experiences decreased performance due to maintenance problems (MAN Diesel & Turbo, 2011; Carlton, 2012; Kim et al., 2021). In the case of KM. Pratiwi Raya in 2020, routine monitoring every four hours showed a decrease in lubricating oil pressure from 3-4 MPa to 2-3 MPa, a temperature increase from 60-80°C to 75-90°C, and a cooling system disturbance with water pressure dropping from 0.05-0.15 MPa to 0.03-0.07 MPa and a temperature increase from 70-80°C to 78-85°C, which indicated problems with the filter and LO cooler due to non-compliance with manual procedures (Swedish Club, 2025; Ejournal Candela, 2023).

Fluctuations in these parameters not only reduce overall main engine performance but also affect exhaust gas, which is an indicator of combustion inefficiency, potentially causing asset damage, high economic costs, and hindering long-distance vessel operations (Haistar Marine, 2025; PIP Semarang Ejournal, 2023). Exhaust gas instability due to suboptimal LO cooler temperatures exacerbates competition in the shipping industry and poses risks to crews and companies (Fuel Journal, 2022; Maofu Power, 2025). This study aims to analyze the effect of LO cooler temperature on main engine exhaust gas and find solutions to maintain exhaust gas stability, with a focus on optimizing the lubricating oil cooling system. The urgency of this research lies in the urgent need to maintain ship performance amidst Indonesia's high dependence on maritime transportation, where LO cooler failure can cause significant financial losses and operational inefficiencies, as evidenced by real-life cases such as KM. Pratiwi Raya (Kotler & Keller, 2016; Swedish Club, 2025). The novelty of this study is the integration of empirical data analysis of LO cooler temperature fluctuations with exhaust gas parameters on Indonesian merchant vessels, which have not been widely explored specifically, thus providing a practical contribution to predictive maintenance and a reference for nautical cadets and crews (Ejournal Candela, 2023; Kim et al., 2021).

II. METHODS

This study uses a quantitative approach with a causal-comparative design to reveal the causal relationship between LO cooler temperature as the independent variable (X) and main engine exhaust gas as the dependent variable (Y), in accordance with the characteristics of systematic measurement and objective statistical analysis (Sugiyono, 2022; Makhrus Ali, 2022; Sudaryono, 2021). This approach emphasizes testing measurable variables through empirical data from instrument measurements during the Sailing Practice (Prala) on the Logindo Overcomer ship, with processing using SPSS version 27 for descriptive and inferential statistics to validate the effect of LO cooler temperature on exhaust gas fluctuations, as relevant to the case of decreased main engine performance on the KM. Pratiwi Raya (Emzir, 2021; Creswell & Creswell, 2023). This type of research ensures strong generalizability of the findings to the operational population of Indonesian merchant vessels (Dahuri et al., 2001; Kotler & Keller, 2016). Primary data collection instruments included direct observation of the LO cooler and exhaust gas operation for 12 months of Prala, a 5-point Likert questionnaire compiled based on variable functional indicators (scale: 1 = STS to 5 = SS), as well as documentation from the engine log book, monthly maintenance data, and the ship's particular MV.

Logindo Overcomer (two main engines Caterpillar 3516B 1920 kW @ 160 rpm, fuel MGO, consumption 12-19 m³ / 24 hours) (Sidik Priadana, 2021; Sugiyono, 2022). Secondary data were obtained from the crew list and literature related to diesel engine maintenance, with validity tests ($r_{count} \geq r_{table}$, $\alpha = 0.05$) and reliability (Cronbach's Alpha > 0.70) to ensure the quality of the instrument (Sudaryono, 2021; Emzir, 2021). The analysis techniques include descriptive (mean, median, distribution), inferential with Pearson/Spearman correlation (r : 0.00-0.199 very low to 0.80-1.000 very strong), coefficient of determination (R^2), and simple linear regression ($Y = a + bX + e$) to measure influence and prediction (Creswell & Creswell, 2023; MAN Diesel & Turbo, 2011; Carlton, 2012). The study population consisted of 19 crew members of the Logindo Overcomer ship responsible for main engine operations, as listed in the 2025 crew list, with a focus on the engine department for relevance to LO cooler and exhaust gas monitoring (Sugiyono, 2022). A sample of 10 respondents was selected through purposive sampling based on the following criteria: direct involvement in LO cooler maintenance, minimum one year of experience, and understanding of oil and exhaust gas temperatures, including KKM, Machinist II-III, ETO, oilers (MA, MAM, YH, I), and engine cadets (MR, F) (Sudaryono, 2021).

This selection ensured competent representation of the engine room, supporting the validity of empirical data related to temperature fluctuations as in the case of KM. Pratiwi Raya (Emzir, 2021; Swedish Club, 2025). The procedure began with observation and primary data collection during Prala on the MV. Logindo Overcomer (specifications: LOA 58.70 m, breadth 14.60 m, GRT 1674, class ABS), followed by distributing questionnaires to the sample and extracting secondary data from log books and maintenance records to measure LO cooler temperature parameters (target 60-80°C) and exhaust gas (Sidik Priadana, 2021; Creswell & Creswell, 2023). Data were entered into SPSS v.27 for assumption tests (normality), validity-reliability, correlation, determination, and regression, followed by interpretation of the results to conclude solutions for exhaust gas stabilization due to LO cooler temperature variations (Sugiyono, 2022; Makhrus Ali, 2022). All stages comply with research ethics with informed consent of respondents and triangulation of sources for reliability (Sudaryono, 2021; Emzir, 2021).

III. RESULT AND DISCUSSION

Data Presentation

1. Temperature LO Cooler (X)
 - a. Respondent Frequency Analysis

Table 1. Frequency Distribution of LO Cooler Temperature (X)

Res	X.1	X.2	X.3	X.4	X.5	X.6	X.7	X.8	X.9	X.10	X.11	X.12	X.13	X.14	XTOT
1.	2	2	3	2	3	3	2	3	4	2	3	2	3	3	37
2.	5	5	5	5	5	5	5	5	5	5	5	5	5	5	70
3.	2	3	4	3	2	3	2	2	3	2	3	2	4	3	38

4.	3	2	3	5	4	2	3	2	3	2	3	4	3	3	42
5.	5	3	3	5	3	3	3	3	3	2	2	3	5	5	48
6.	2	3	2	2	2	2	3	4	3	5	5	2	3	3	41
7.	3	4	5	4	5	4	4	5	5	5	5	5	5	5	64
8.	5	4	5	5	5	5	5	5	5	5	5	3	5	5	67
9.	4	5	4	5	4	3	4	5	5	5	5	5	4	5	63
10.	5	4	3	3	3	4	4	5	4	3	5	5	4	3	55
Total	36	35	37	39	36	34	35	39	40	36	41	36	41	40	525

Based on Table 1, respondents' answers to 14 statements regarding the Temperature LO Cooler (X) system were mostly in the score range of 3 to 5. This indicates that respondents assessed the condition of the lubricant cooling system on the main engine in the good category. The total score obtained of 525 from 10 respondents also showed a tendency towards positive assessment. In general, these results illustrate that the Temperature LO Cooler system on the Logindo Overcomer ship is in fairly good condition.

b. Descriptive Statistical Analysis

Table 2. Descriptive Statistical Analysis of LO Cooler Temperature (X)

N	Valid	10
	Missing	0
Mean		52.50
Median		51.50
Mode		37 ^a
Standard Deviation		12,817
Variance		164,278
Range		33
Minimum		37
Maximum		70
Sum		525

Descriptive analysis of the LO Cooler (X) temperature variable from 10 respondents showed a mean of 52.50, a median of 51.50, and a mode of 37, with a standard deviation of 12.817 and a variance of 164.278 reflecting a reasonable variation in assessment (range 37-70, total score 525). Overall, this system is considered quite good in supporting the main engine operations of the Logindo Overcomer ship.

2. Main Engine Exhaust Gas

a. Respondent Frequency Analysis

Table 3. Distribution of Main Engine Exhaust Gas Responses

Res	Y.1	Y.2	Y.3	Y.4	Y.5	Y.6	Y.7	Y.8	Y.9	Y.10	YTOT
1.	3	3	3	2	3	3	2	3	5	3	30
2.	5	5	5	5	5	5	5	5	5	5	50
3.	3	3	3	2	3	3	5	3	2	4	31
4.	3	4	3	3	3	5	5	3	3	3	35
5.	3	3	3	2	5	5	2	3	3	4	33
6.	3	3	2	3	2	3	2	3	3	3	27
7.	5	5	5	5	5	5	5	3	5	4	47
8.	5	5	5	3	5	5	5	5	5	5	48
9.	5	3	5	3	4	3	2	2	3	3	33
10.	4	4	5	4	3	3	5	5	5	5	43
Total	39	38	39	32	38	40	38	35	39	39	377

Based on Table 2, the distribution of respondents' answers to the statement regarding main engine exhaust gas mostly fell within the score range of 3 to 5. This indicates that respondents' perceptions of the condition of the main engine exhaust gas tended to be positive. A total score of 377 from 10 respondents indicated that the main engine exhaust gas was considered to be in fairly good and stable condition.

b. Descriptive Statistical Analysis

Table 4. Descriptive Statistical Analysis of Main Engine Exhaust Gas (Y)

N	Valid	10
	Missing	0
Mean		37.70
Median		34.00
Mode		33
Std. Deviation		8.447
Variance		71.344
Range		23
Minimum		27
Maximum		50
Sum		377
Percentiles	25	30.75
	50	34.00
	75	47.25

Descriptive analysis of the main engine exhaust gas (Y) variable from 10 respondents showed a mean of 37.70, a median of 34.00, and a mode of 33, with a standard deviation of 8.447 and a variance of 71.344 reflecting a reasonable variation in assessment (range 27-50, total score 377). Overall, the exhaust gas condition was assessed as quite good and relatively stable during the operation of the Logindo Overcomer vessel.

Data analysis

1. Validity Test

Table 5. Results of the LO Cooler (X) Temperature Validity Test

Item	RCount	Rtable	Information
X.1	0.719	0.631	Valid
X.2	0.888	0.631	Valid
X.3	0.773	0.631	Valid
X.4	0.672	0.631	Valid
X.5	0.821	0.631	Valid
X.6	0.812	0.631	Valid
X.7	0.954	0.631	Valid
X.8	0.863	0.631	Valid
X.9	0.869	0.631	Valid
X.10	0.738	0.631	Valid
X.11	0.694	0.631	Valid
X.12	0.753	0.631	Valid
X.13	0.751	0.631	Valid
X.14	0.749	0.631	Valid

Table 5 shows that all question items in the Temperature LO Cooler (X) questionnaire have a calculated R value $<$ R Table (0.631). The calculated R value for each item ranges from 0.672 to 0.954. This indicates that all questions in the questionnaire are valid, meaning that each question is able to measure the Temperature LO Cooler variable well.

Table 6. Main Engine Validity Test Results

Item	RCount	Rtable	Information
Y.1	0.789	0.631	Valid
Y.2	0.950	0.631	Valid
Y.3	0.831	0.631	Valid
Y.4	0.783	0.631	Valid
Y.5	0.699	0.631	Valid

Y.6	0.665	0.631	Valid
Y.7	0.711	0.631	Valid
Y.8	0.730	0.631	Valid
Y.9	0.719	0.631	Valid
Y.10	0.806	0.631	Valid

Table 6 shows that all questions in the Main Engine Exhaust Gas (Y) questionnaire have a calculated R value < R Table (0.631). The calculated R value for each item ranges from 0.665 to 0.950. This indicates that all questions in the questionnaire are valid, meaning that each question is able to measure the main engine exhaust gas variable well.

2. Reliability Test

Table 7. Results of the LO Cooler (X) Temperature Reliability Test

Reliability Statistics	
Cronbach's Alpha	N of Items
.950	14

Table 7 shows the value *Cronbach's Alpha* for the LO Cooler variable (X) of 0.950 with a total of 14 question items, where the value is > 0.70. This value indicates that the LO Cooler temperature questionnaire is included in the very reliable category.

Table 8. Main Engine Reliability Test Results (Y)

Reliability Statistics	
Cronbach's Alpha	N of Items
.913	10

Table 8 shows the Cronbach's Alpha value for the LO Cooler (X) variable of 0.913 with 10 question items, which is > 0.70. This value indicates that the main engine exhaust gas questionnaire is in the highly reliable category.

3. Simple Linear Regression Analysis

Table 9. Simple Linear Regression Analysis

Coefficients ^a						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	8.423	6.690		1.259	.244
	LO COOLER	.558	.124	.846	4.492	.002

a. Dependent Variable: Gas Buang Main Engine

The simple linear regression equation $Y = 8.423 + 0.558X$ shows that when the LO cooler temperature (X) is zero, the main engine exhaust gas (Y) remains at 8.423 units (constant a). In addition, every one unit increase in the LO cooler temperature increases the exhaust gas by 0.558 units (regression coefficient b), confirming a positive and linear influence between the two variables.

4. Coefficient of Determination Test

Table 10. Results of the Determination Coefficient Test

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.846 ^a	.716	.681	4.774

a. Predictors: (Constant), LO COOLER

Based on Table 10, the coefficient of determination (R Square) value of 0.716 indicates that the LO Cooler temperature variable is able to explain 71.6% of the variation or change in the Main Engine Exhaust Gas variable. This means that approximately 71.6% of the main engine exhaust gas fluctuations can be explained by changes in the LO Cooler temperature condition, while the remaining 28.4% is influenced by other factors outside this model. The Adjusted R Square value of 0.681 indicates a fairly good level of model adjustment considering the number of variables and data used.

5. Correlation Coefficient Test

Table 11. Spearman Rank Test Results

			Correlations	
			<i>Temperature</i> LO COOLER	<i>Gas Buang</i> Main Engine
Spearman's rho	<i>Temperature</i> LO COOLER	Correlation Coefficient	1.000	.894**
		Sig. (2-tailed)	.	.000
		N	10	10
	<i>Gas Buang</i> Main Engine	Correlation Coefficient	.894**	1.000
		Sig. (2-tailed)	.000	.
		N	10	10

** . Correlation is significant at the 0.01 level (2-tailed).

Spearman correlation analysis yielded a coefficient of 0.894 with a significance of 0.000 ($p < 0.01$), indicating a very strong and significant relationship between LO cooler temperature (X) and main engine exhaust gas (Y). This positive relationship indicates that optimizing LO cooler temperature contributes to exhaust gas stability, so the alternative hypothesis (H_a) regarding its effect is accepted.

Discussion

1. The Effect of LO Cooler Temperature on Main Engine Exhaust Gas

Based on the results of the Spearman rank correlation test, a correlation value of 0.894 was obtained with a significance value of 0.000. A significance value smaller than 0.01 confirms that the relationship is highly statistically significant, so it can be concluded that the LO Cooler Temperature has a close relationship with the performance of the main engine exhaust system on the Logindo Overcomer ship. This means that the performance of the LO Cooler has a significant impact on the condition of the exhaust gas produced by the ship's main engine. The results of the statistical analysis are consistent with direct observation data during the Sailing Practice (Prala) activities on the ship. Direct observations in the engine room showed that an increase in the temperature of the LO Cooler resulted in an increase in the temperature of the lube oil flowing to the main engine.

This condition resulted in the cooling process in the internal engine components, such as pistons, liners, and bearings, not taking place optimally. As a result, the combustion process in the cylinder became less efficient, resulting in exhaust gases with a higher temperature and a darker color. Conversely, when the LO Cooler was functioning properly and its temperature was maintained within the ideal operational limits (around 40–50°C), the main engine exhaust gas temperature remained stable within the normal range. The results of research by Suyuti, et al. (2024) also showed that the normal lubricant temperature ranged from 45–50°C, while increases above this limit were often caused by reduced cooling capacity of the LO Cooler. This confirms that the lubricant cooling system plays a crucial role in maintaining engine thermal efficiency and preventing exhaust overheating.

2. Efforts to Overcome Main Engine Exhaust Fluctuations

Fluctuations or unstable changes in the main engine exhaust gas on the Logindo Overcomer ship not only affect engine efficiency but can also negatively impact the surrounding environment. Exhaust gas with inconsistent temperatures and fluctuating components can increase levels of hazardous substances such as carbon monoxide (CO), nitrogen oxides (NO_x), and small particles that can potentially pollute the air. This not only endangers the health of the ship's crew but can also damage the marine ecosystem around the ship's shipping lane. The problem of fluctuating exhaust gas on the Logindo Overcomer ship is generally caused by various technical factors, primarily related to the lubricating oil cooling system (LO Cooler) which is not functioning optimally to maintain stable oil temperature within ideal limits. Based on observations, as the temperature in the LO Cooler increases, the oil cooling system's ability to decrease, resulting in less complete combustion in the main engine. This causes the exhaust gas temperature to become unstable and its color tends to be darker, indicating suboptimal combustion and potential damage to engine components. Some of the main causes of this condition include the LO Cooler inlet pipe being clogged by debris carried by seawater, thus impeding the flow of coolant.

Furthermore, inaccurate thermometers in measuring lubricating oil temperature can lead to errors in monitoring engine condition. Damage or leaks in the seawater pipe leading to the LO Cooler can also reduce the supply of coolant, thereby reducing cooling effectiveness. Another contributing factor is untimely maintenance schedules, resulting in poor cooling system maintenance. Environmental conditions such as the influence of waves when the ship is sailing at sea can also affect the stability of engine operation and coolant flow. Finally, the lack of knowledge and skills of engine crews in operating and maintaining the engine also exacerbates this condition, as operational errors can accelerate exhaust gas fluctuations. Efforts to address exhaust gas fluctuations in the Logindo Overcomer's main engine require comprehensive and continuous efforts to maintain optimal engine performance and minimize environmental impact. These efforts are as follows:

1. Regularly clean or flush the LO Cooler to remove dirt and deposits carried by seawater. Keeping this cooling system clean is crucial to ensure unobstructed coolant flow, maintain ideal lubricating oil temperatures, and maintain efficient combustion in the main engine.
2. Replacing the thermometer with a new, more accurate measuring device is also essential to accurately measure the lubricating oil temperature. Accurate measurements allow operators to monitor engine condition and take prompt corrective action if temperature increases that could potentially disrupt exhaust gas stability.
3. Replacing leaking or damaged seawater pipes is another important technical step. Damage to these pipes can reduce the flow of coolant to the LO Cooler, reducing the cooling system's performance and causing oil temperatures to rise. This can lead to incomplete combustion and fluctuating exhaust gas temperatures. Therefore, pipe replacement must be performed immediately upon detection of damage to ensure the cooling system continues to operate smoothly.
4. Improving the discipline of engine crews in following routine maintenance schedules also plays a significant role in preventing problems with the cooling and combustion systems. By performing maintenance consistently and on time, the potential for blockages, damage, and performance degradation can be significantly minimized.
5. Consistent real-time monitoring of oil temperature and pressure at the LO Cooler's input and output ports is essential. This effective monitoring allows operators to identify any anomalies or disturbances that could cause exhaust gas fluctuations early, allowing for prompt preventive or corrective action.
6. Regular education and training on main engine maintenance and repair is key to improving crew skills and knowledge. This training focuses not only on technical aspects but also emphasizes the importance of standard operating procedures and occupational safety.

Through consistent implementation, the Logindo Overcomer is able to reduce exhaust gas fluctuations, maintain engine efficiency, and minimize environmental impact. Improving crew skills through regular training and monitoring also ensures optimal cooling and combustion systems for smooth ship operations.

IV. CONCLUSION

This study concludes that the LO cooler temperature has a very strong and significant influence on the main engine exhaust gas on the Logindo Overcomer vessel, as evidenced by the Spearman correlation coefficient of 0.894 ($p=0.000 < 0.01$), the regression equation $Y=8.423 + 0.558X$, and the coefficient of determination of 71.6% which explains that the exhaust gas fluctuations are mostly caused by variations in the LO cooler temperature. This finding is in line with empirical observations during the Sailing Practice, where the increase in the LO cooler temperature disrupted the cooling of the lubricating oil, causing inefficient combustion and unstable exhaust gas, similar to the case of KM. Pratiwi Raya. The practical implications include recommendations for routine cleaning of the LO cooler, replacement of accurate thermometers, repair of leaking pipes, real-time monitoring, and crew training to prevent overheating and improve the operational efficiency of Indonesian merchant vessels. However, limitations of this study lie in the purposive sample of only 10 respondents from the engine department of one vessel, which limits generalizability to the wider fleet, and the reliance on a Likert questionnaire and logbook data without long-

term direct sensor measurements. Suggestions for future research include expanding the sample to multiple vessels, integrating IoT sensor data for real-time monitoring, multivariate analysis including environmental factors such as vessel load, and a mixed-methods approach with in-depth crew interviews for more comprehensive validation. This approach will enrich the holistic understanding of main engine optimization in the maritime sector.

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