Analysis of The Influence of F.O Purifier Maintenance on The Performance of The Main Engine on The KM. Logistik Nusantara 2 Ship

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***Abstract*— Fuel oil (F.O) purifiers play a crucial role in ensuring the quality of fuel supplied to the main engine in marine vessels. Poor maintenance of the F.O purifier can reduce engine performance and increase the risk of damage. This study aims to analyze the influence of F.O purifier maintenance on the performance of the main engine on the KM. Logistik Nusantara 2 ship. The research method used is a descriptive quantitative approach by collecting operational data such as purifier condition, fuel cleanliness level, engine power, and fuel consumption before and after maintenance activities. The results show that proper and scheduled maintenance of the F.O purifier significantly improves fuel quality, reduces specific fuel consumption, and stabilizes the engine's power output. These findings highlight the importance of routine maintenance to enhance operational efficiency and engine reliability.**

Keywords— *Purifier, Fuel, Diesel Engine*

I. INTRODUCTION

Maritime transportation plays a vital role in supporting global and domestic trade by enabling the movement of goods across vast distances efficiently [1]. With continuous advancements in science and technology, particularly in maritime operations, sea transport has become increasingly dominant. Ships are capable of transporting large volumes of cargo, making them essential in modern logistics networks. Heavy Fuel Oil (HFO), a common fuel used in marine engines, contains various impurities such as water, sludge, and solid particles [2]. Due to its high viscosity and contaminant content, HFO cannot be directly used in marine engines without prior treatment .

These impurities, if not removed, can lead to blockages in fuel injectors and deterioration in engine performance. Thus, purification processes are necessary to ensure that the fuel is clean and suitable for combustion. A Fuel Oil (F.O) purifier is an essential piece of auxiliary machinery in marine vessels, responsible for separating water and solid contaminants from the fuel before it reaches the main engine [3]. The fuel treatment process typically includes sedimentation, heating, filtration, and centrifugal separation using the F.O purifier. To maintain fuel quality and ensure optimal combustion, engine room personnel must conduct routine inspections and maintenance of the purifier, including checking vital components such as the main seal ring, O-ring, and valve seat. The principle behind the F.O purifier is based on centrifugal force, which accelerates the separation process up to 6,000–7,000 times faster than gravitational sedimentation. This method enables efficient and rapid removal of contaminants from the fuel. However, during the researcher's sea training aboard KM. Logistik Nusantara 2, operational problems were identified with the F.O purifier system [4].

These included a malfunction in the water feed mechanism, which disrupted the separation process, and unstable pump pressure, which led to reduced fuel purification efficiency. These conditions threatened the reliability and performance of the ship's main engine, especially during long voyages. This study addresses a critical gap in maritime engineering literature by empirically analyzing the relationship between F.O purifier maintenance and the performance of the main engine [5]. While previous research has emphasized the function of purifiers in general terms, this study contributes a novel insight by focusing on real-world operational challenges and maintenance impacts observed onboard a specific vessel (KM. Logistik Nusantara 2). The findings are expected to offer practical recommendations for ship engineers to improve maintenance strategies and engine performance reliability [6].

Given the complexity and importance of fuel treatment systems in maritime operations, particularly

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the role of the F.O purifier, ensuring proper maintenance becomes a key factor in sustaining engine efficiency, reducing fuel consumption, and preventing unplanned downtimes. Despite the widespread use of F.O purifiers, there is a lack of detailed empirical studies that evaluate the direct impact of their maintenance on engine performance metrics [7]. Therefore, this study aims to fill this gap by examining how the condition and maintenance practices of the F.O purifier on KM. Logistik Nusantara 2 influence the performance of its main engine. The outcomes of this research are expected to support best practices in preventive maintenance and contribute to enhancing the operational reliability of marine vessels [8].

Figure 1. KM. Logistik Nusantara 2

TABLE 1.
SHIP PARTICULAR KM. LOGIISTIK NUSANTARA 2. (SOURCE : SHIP KM. LOGISTIK NUSANTARA 2)

Main Vessel Data	
Propulsion And Auxiliary Machines	
Main Engine	MAK 6M25 1980 Kw @750 rpm
Propeller	Controlled Pitch, Four Blades
Bow Thruster	Brunvoll 200 kw
Aux. Engine	2 x MAN Type D2840 LE 301, 443 kw @50 Hz 1500 rpm + E'Cy Gen 1x MAN, Type D 2866E, 99 kw @50 Hz
Main Vessel Data	
Flag	INDONESIA
Classification	BKI
Imo Number	9418470
Class Notation	I HULL MACH General cargo ship Equiped for Carriage Of Container- Heavy Cargo ((Cargo Hold Fr.(50-80) 180KN/m2)) Unrestricted Navigation – AUT – UMS ; MON-SHAFT; INWATERSURVEY
Type Of Vessel	STEEL GENERAL CARGO
Call Sign	YBVX2
Mmsi	525 105 002
Shipyard	ARKADAZ – TUZLA
Yearbuilt	2007
Owner	PT. PELNI

Figure. 2. F.O Purifire

II. METHOD

The research employed a qualitative method, which does not rely on statistical analysis but instead involves data collection, analysis, and interpretation. This approach is commonly associated with social and human-related issues. Qualitative research emphasizes understanding problems within social life as they occur in real-world settings. It adopts an inductive approach aimed at constructing theories or hypotheses through the exploration and disclosure of factual data.

1. Data Collection Technique

The research utilized a qualitative method, which, according to, does not involve statistical analysis but is conducted through data collection, analysis, and subsequent interpretation. This method is generally associated with social and human phenomena. Qualitative research emphasizes understanding issues within social life based on real conditions. It adopts an inductive approach aimed at constructing theories or hypotheses by uncovering empirical facts.

2. Data Analysis Technique

After collecting the necessary data, the next stage involves analyzing the data to transform it into accurate information. This study employed a descriptive qualitative data analysis technique, as defined by, which involves formulating guiding questions and then comparing field data with established theories to derive meaningful conclusions.

III. RESULTS AND DISCUSSION

According to, analysis is a crucial step in resolving a research problem, involving the presentation of data and a discussion related to the issues raised, as well as the techniques used to convey the data. To obtain analyzable data, the researcher collected information during the sea practice aboard KM. Logistik Nusantara 2. Based on the objectives of this study, the researcher was able to analyze various factors that contributed to the suboptimal performance of the main engine due to irregular maintenance of the F.O purifier, and to identify solutions to address these issues [9]

1. Observation Data

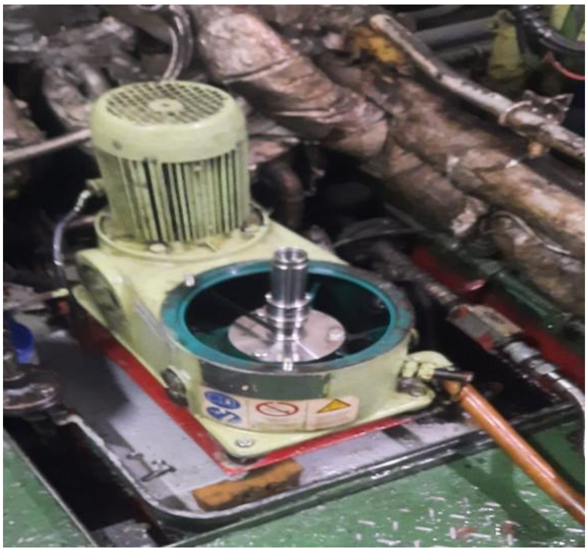

Figure. 3. F.O Purifier Gea Westfalia

2. Observation Results

Based on direct observations during the sea practice aboard KM. Logistik Nusantara 2, it was found that suboptimal engine performance is not only caused by mechanical failures in the engine itself but is more often the result of irregular maintenance of supporting systems, such as the Fuel Oil (F.O) Purifier. This condition became evident during an incident on December 15, 2023, when the vessel was en route from Makassar to Tahuna, North Sulawesi. Three hours after departure, a low fuel pressure alarm was triggered, followed by a sudden engine shutdown about ten minutes later. Initial inspections of the supply pump, transfer pump, and fuel pump showed no faults, indicating that the issue stemmed from another part of the fuel system. Further investigation by the Chief Engineer and First Engineer revealed that the cause of the engine failure was a clogged bowl disc in the F.O Purifier [10]. The clogging occurred due to the accumulation of sludge and contaminant particles that were not effectively removed, primarily due to a lack of regular cleaning and inspection. This incident highlighted that, even though the primary fuel system components were in good condition, a failure in the purification system could directly impact the operational continuity of the main engine. This finding reinforces the hypothesis of this study that the quality and consistency of F.O Purifier maintenance directly influence engine performance, particularly during long voyages that rely on continuous high-quality fuel. As part of the scientific documentation, the researcher recorded all inspection, cleaning, and evaluation procedures conducted during the incident [11]. This finding holds novelty as it provides empirical evidence of the cause-and-effect relationship between F.O Purifier maintenance and main engine stability, which has not been extensively explored in the context of national commercial vessel operations. By reconstructing the event based on direct observation, this study not only contributes to strengthening preventive maintenance practices but also provides real-world data that can serve as a reference for evaluating Standard Operating Procedures (SOPs) for auxiliary machinery maintenance in marine engineering systems [12].

Here are the specifications data for the F.O Purifier on the ship KM. Logistik Nusantara 2:

TABLE 2.
F.O PURIFIER SPESIFICATIONS. (SOURCE : SHIP PARTICULAR & MANUAL BOOK GEAWESTFALIA PURIFIER)

Brand	Gea Westfalia
Type	OSD6-0136-067
Capacity	650 L/H, Temperature : In = 40^0 C, Out = 98^0 C. Heavy Liquid = 1,0 kg / dm^3 Solid = 1,4 kg / dm^3

Bowl		
Solids holding space (total)		0.9 dm^3
Speed · for densities of the product up to 1.05 kg/dm^3(at 15 °C) and · for densities of the separated solids up to 1.4 kg/dm^3		12 000 min^{-1}
Speed for higher densities		contact the factory
Starting time		approx. 2 - 4 min
Run-down time (without braking)		30 min
Run-down time (with braking)		6 min
Centripetal pump		
Output (depending on medium)		max. 4 000 l/h
Pressure head		1-1.5 bar
Operating water		
Quantity		min. 1 800 l/h
Pressure		2-3 bar
Standard operating water specification		
Suspended matter		max. 10 mg/l
Particle size		max. 50 µm
Hardness: - up to 55 °C separating temperature - above 55 °C separating temperature		< 12° dH < $6,^0$ dH
To Convert the hardness values stated use the following equation: 1° dH = 1.79° fH = 1.25° eH = 17.9 ppm $CaC0_3$		
Chlorine ions		<100 mg/I
Ph		6.5- 7.5
Nonnalseparating temperature of the product		
DO	20 ^{0}C	(68°F)
MDO	40 ^{0}C	(104°F)
LO	90 ^{0}C	(194°F)
LO HD	95 ^{0}C	(203°F)
HFO	98 ^{0}C	(208°F)
Due to the large number of products to be treated, it is not possible to specify an exact separating temperature of the product in this manual. The exact separating temperature of the product (in ^{0}C) is stated in The order-specific data sheet.		
Motor		
Power rating	50 Hz	4 kW
	60 Hz	4.8 kW
Speed	50 Hz	3000 RPM
	60 Hz	3600 RPM
Design		IM V1
Enclosure		IP55
Drive		50/60 Hz
Oil filling		approx. 2.5 I Oil quality, see section 4.2.3
Product pump		
Pump unit (gear or screw pump)		
Output		depending on plant rating
Suction height		max. 0.4 bar
Pressure head		2 bar
Weights		
Separator (with motor, without bowl)		160 kg
Bowl		42 kg
Motor		25 kg

Figure. 4. F.O Filter Supply

During the fuel purification process, contaminants settle within the purifier unit. The accumulation of sludge inside the bowl, resulting from fuel cleaning, may interfere with the efficiency of the purification process. The following image illustrates the presence of sediment resulting from fuel purification within the bowl of the F.O Purifier.

Figure. 5. Bowl F.O Purifier Condition Before Maintenanc

Therefore, regular maintenance is essential to ensure the efficient operation of the purifier itself. The maintenance procedures carried out include:

a. Cleaning the Bowl Body

Cleaning the bowl body is a critical maintenance task in ensuring the optimal performance of the Fuel Oil (F.O) purifier. As the core component responsible for separating contaminants from fuel through centrifugal force, the bowl body is subjected to continuous accumulation of sludge, carbon residues, sand, and water during purifier operation. These impurities are deposited along the inner wall of the bowl due to the intense rotational force up to thousands of revolutions per minute which causes heavier particles to migrate outward [13]. Over time, the presence of thick residual layers significantly reduces the separation capacity of the purifier and creates an imbalance that may affect the mechanical stability of the rotating parts. During the research aboard KM. Logistik Nusantara 2, it was observed that irregular cleaning of the bowl body resulted in a drastic decline in fuel quality, indicated by increasing fuel injector clogging and unstable combustion in the main engine. Sludge buildup inside the bowl chamber not only interfered with separation efficiency but also caused a rise in exhaust temperatures and black smoke emission due to unfiltered particles entering the combustion process.

This condition underlines the importance of routine cleaning, as even minor delays in maintenance could lead to long-term damage to both the purifier and the main engine system. According to manufacturer recommendations, the bowl should be dismantled and thoroughly cleaned every 200 to 300 operating hours, particularly when heavy fuel oil (HFO) with high impurity content is in use. The cleaning process involves mechanical scraping of sludge residues followed by chemical soaking to dissolve stubborn deposits without damaging the bowl’s structural integrity. Technicians must also inspect the inner surface for signs of corrosion or wear, which, if ignored, may compromise the purifier's ability to generate sufficient centrifugal force. A clean and well-maintained bowl body ensures that the F.O purifier operates within its designed specifications, producing cleaner fuel that supports efficient engine performance and reduces the risk of unscheduled repairs at sea. This preventive measure, though simple, is one of the most effective strategies to maintain engine reliability and operational safety on long voyages [14].

Figure. 6. Bowlbody Condition Before Cleaning

The image above shows the condition of the bowl body before cleaning, indicating the necessity of removing the accumulated deposits. Cleaning is performed by carefully brushing the areas with sludge buildup to avoid causing scratches on the surface of the bowl body

b. Cleaning the Bowl Disc.

The bowl disc area also contains a significant amount of sludge deposits. Therefore, cleaning is required for each of the disc components. The F.O Purifier contains thirty-two disc plates, which must be individually separated to allow thorough cleaning of each one. The cleaning process involves the use of diesel oil and a brush to facilitate the removal of dirt and deposits adhered to the discs. Once the bowl body and disc components have been thoroughly cleaned, the next step is to wipe each part using a clean cloth or rag to ensure that no residual diesel or dirt remains. It is essential to confirm that all disassembled components are clean and free of contaminants. Once the bowl body and disc components have been thoroughly cleaned, the next step is to wipe each part using a clean cloth or rag to ensure that no residual diesel or dirt remains. It is essential to confirm that all disassembled components are clean and free of contaminants [15].

The subsequent step involves reassembling the, a running test of the purifier unit is carried out. Finally, the condition of the HFO purifier filter is observed to identify any improvements resulting from the maintenance procedure. By performing maintenance on the purifier, the resulting fuel becomes noticeably cleaner, which can be observed in the fuel filter located downstream of the purifier. As the fuel exits the purifier and passes through the filter, it is evident that the filter remains cleaner following purifier maintenance [16].

Figure. 7. Disc Condition Before Treatment

This indicates that purifier maintenance significantly affects fuel cleanliness, with fuel processed through a well-maintained purifier being comparatively cleaner than that passing through a purifier lacking proper maintenance. The condition of the purifier directly impacts the quality of fuel used in diesel engine combustion. When the purifier has not undergone proper cleaning, residual impurities and sludge may still be present in the fuel, reducing its quality [17]

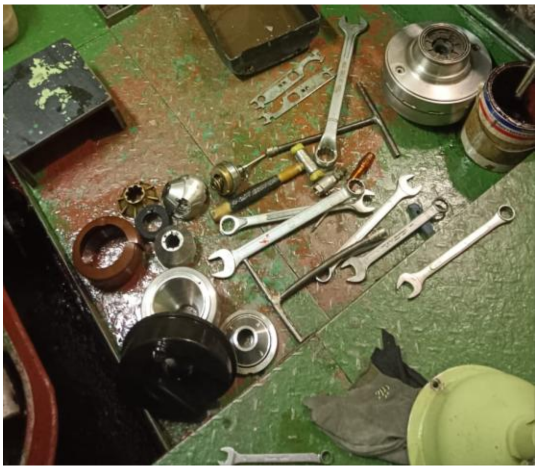

Figure. 8. Cleaned Components Of The F.O Purifie

Figure 9. Fuel Supply Filter Condition

The negative impacts of poor HFO purification include the following:

a. Suboptimal diesel engine performance due to dirty injectors, resulting in incomplete atomization of the fuel and increased exhaust gas temperatures.
b. Reduced engine power, as incomplete combustion caused by residual water and contaminants prevents the fuel from igniting properly within the combustion chamber.

Therefore, it is essential to carry out regular maintenance on the purifier to eliminate sludge buildup in its components. Proper cleaning of the purifier improves the cleanliness of the fuel used in the diesel engine combustion process. The following table presents the influence of purifier maintenance on diesel engine combustion results

.TABLE 3.
F.O PURIFIER MAINTENANCE AGAINST DIESEL COMBUSTION RESULTS

Purifier Maintenance	Maintenance Time	Diesel Engine		Remark
		RPM	Temperature Range After Maintenance	
Not Yet Maintenance	-	750 *rpm*	320ºC	Fair
First Maintenance	2154 Hours	750 *rpm*	342ºC	Good
Second Maintenance	2048 Hours	750 *rpm*	351ºC	Good
Third Maintenance	2006 Hours	750 *rpm*	360ºC	Good

Based on the maintenance results presented in the table above, the researcher concludes the following: In the case where the purifier had not yet undergone maintenance, the exhaust gas temperature was found to be below the expected threshold, with a recorded temperature of 320°C, whereas the minimum standard exhaust gas temperature for the main engine is 410°C. Following the first maintenance, an increase in exhaust temperature was observed, and further increases were noted during the second and third maintenance intervals. The highest exhaust temperature recorded reached 360°C, approaching the upper operational limit of 440°C.

These findings indicate that exhaust gas temperatures improved significantly after each purifier maintenance, suggesting more complete combustion and enhanced engine performance.Assupporting evidence, accurate exhaust gas temperature data for each cylinder was retrieved from the ship's engine room logbook, which had been officially signed by the vessel's Master and Chief Engineer. The following is the documented data:

3. Interview Results

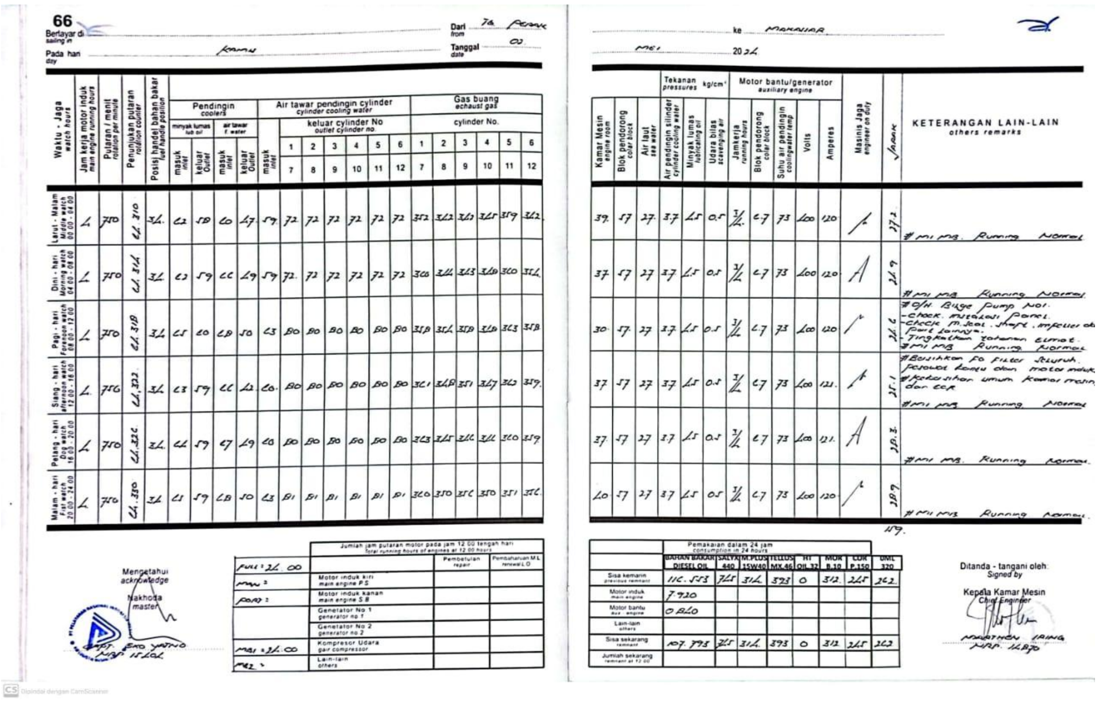

Figure. 10. Logbook Documentation Of KM. Logistik Nusantara 2

TABLE 4.
LIST OF RESPONDENTS

No	Name	Position
1	Ingram Pakpahan	Second Engineer
2	M. Fariz Ilmam	Third Engineer

Based on the respondent data presented in the table above, the researcher carefully selected participants by considering their expertise and responsibilities in managing the issues under investigation. This approach aimed to ensure the acquisition of relevant and reliable results. The following table summarizes the key questions posed by the researcher to the selected respondents.

TABLE 5.
SUMMARY OF INTERVIEW QUESTIONS

No	Question	Answer
1.	With your permission, Sir, based on your experience, how does regular purifier maintenance affect diesel engine combustion on board? Have you observed any differences in engine performance?	Yes, there is certainly a noticeable difference. When the F.O purifier is well-maintained and regularly serviced, the fuel entering the engine is significantly cleaner. This directly affects combustion, resulting in more complete burning and cleaner exhaust less black smoke. The engine becomes more responsive and less prone to overheating. Additionally, overall engine performance is more stable, especially during extended operations.
2.	If I may ask, Sir, what is your opinion on the effect of purifier maintenance on the quality of fuel used in marine diesel engines? Are there any impacts on engine performance or fuel efficiency?	The impact is considerable. When the purifier is properly maintained, the fuel becomes purer, as contaminants like water and sludge are filtered out before entering the engine. This leads to more efficient engine operation and better combustion, with less wasted fuel. We can also observe that fuel consumption improves after purifier maintenance due to the absence of residues that would otherwise interfere with combustion. As a result, the engine lifespan is extended, and mechanical failures are reduced.

4. Interview Summary and Discussion

Based on the interview results, the researcher concluded the following:

a. Regular maintenance of the purifier ensures cleaner fuel, free from sediment and impurities, resulting in more complete combustion compared to purifiers without maintenance. A lack of maintenance can prevent fuel from reaching the service tank.

b. The effect of purifier maintenance on fuel quality is significant. It is recommended that maintenance or overhaul be performed once a month or after every two voyages to clean the purifier bowl body from accumulated impurities.

5. Discussion

This section presents an in-depth analysis of data obtained over a 12-month and 25-day observation period during sea practice aboard KM. Logistik Nusantara 2. Data were collected through observation, interviews with engine room personnel, documentation, and literature review. According to, data analysis involves the processes of examination, filtration, and modeling to derive meaningful insights, support decision-making, and validate hypotheses [18]. The main finding from this research is that the performance of the main engine is closely and measurably affected by the maintenance condition of the F.O (Fuel Oil) purifier. Poor maintenance evident in the lack of scheduled cleaning, component degradation, and inadequate water supply led to a consistent pattern of performance degradation in the main engine [19].

This was reflected in unstable RPMs, increased exhaust temperatures, and decreased fuel efficiency. One of the notable contributions of this study is the identification of specific operational failures within the purifier unit, such as the malfunctioning water seal system and deteriorated O-rings, which are often overlooked in general maintenance routines. These technical faults, although minor in appearance, had compounded effects on fuel purity [20]. The research demonstrated that untreated or poorly purified Heavy Fuel Oil (HFO) results in incomplete combustion and, over time, in significant wear on engine components, including injector tips and piston heads.

The novelty of this study lies in its practical demonstration of the direct correlation between purifier maintenance and main engine reliability, using real operational data from a working vessel. Unlike previous studies that broadly discuss the importance of fuel purification, this research provides empirical evidence of the consequences when standard maintenance protocols are not followed [21]. Furthermore, it highlights targeted intervention strategies that significantly restored purifier efficiency and improved engine performance, such as:

- Precise inspection intervals for bowl and disc stack components;
- Scheduled replacement of critical seals;
- Adjustment of water supply pressure and temperature;
- Implementation of fuel quality control procedures aligned with ISO 8217 standards.

These findings not only validate the hypothesis of this study but also offer a replicable model for maintenance optimization in similar maritime contexts. This study contributes to maritime engineering literature by bridging the gap between theoretical best practices and field-based operational realities aboard medium-range logistic vessels. In conclusion, this discussion affirms that effective maintenance of the F.O purifier is not merely a routine task but a strategic component in safeguarding main engine performance [22]. Through its emphasis on specific failure modes and recovery actions, this research introduces a novel framework for condition-based maintenance that can be adopted by engine room departments across the maritime industry [23].

6. Data Reduction.

According to [24], data reduction is the process of simplifying or summarizing data to facilitate analysis and interpretation without losing essential information. This approach increases analytical efficiency while preserving relevance.

The researcher posed three key questions to the Second and Third Engineers, yielding the following points:

a. Factors contributing to suboptimal fuel system performance included the lack of regular F.O Purifier maintenance, often due to limited time when docked [25].

b. One major impact of inadequate purifier performance was a drop in fuel pressure, which degraded main engine performance.

c. To improve purifier performance, maintenance must follow work-hour schedules with routine inspections of purifier components.

From the issues encountered during sea practice aboard KM. Logistik Nusantara 2, the researcher drew a general conclusion and clarified the research problem, focusing the applied research on analyzing the impact of proper F.O Purifier maintenance.

7. Answers to the Research Questions

1. What causes the F.O Purifier to perform suboptimally?

Several factors may contribute:

a. Poor Fuel Quality
   - High water and sludge content impairs separation.
   - Fuel viscosity does not meet purifier specifications.
   - Presence of heavy particulates or sludge.

b. Incorrect Settings or Operations
   - Bowl rotation speed below optimal level.
   - Inadequate fuel temperature.
   - Excessive flow rate, reducing separation time.

c. Component Failures
   - Blocked nozzle or bowl due to sludge.
   - Worn seals or gaskets leading to leakage.
   - Damaged disc stack impairing separation efficiency.

d. Heating System Issues
   - Inoperable heater keeps fuel viscosity too high.

- Faulty temperature sensors result in improper heating.

e. Poor Maintenance Practices
- Infrequent cleaning leads to sludge accumulation.
- Use of non-standard spare parts.
- Failure to inspect bearings and motors routinely.

2. What efforts can be made to optimize F.O Purifier performance?

a. Ensuring Fuel Quality
- Use a settling tank to reduce water and sludge before purification.
- Heat the fuel to 85–95°C (for HFO) for optimal viscosity.
- Regularly drain water and sludge from tanks.

b. Operational Adjustments
- Maintain correct bowl rotation speed (typically 7,000–9,000 rpm).
- Set an appropriate fuel flow rate within purifier capacity.
- Maintain optimal fuel temperature for efficient separation.

c. Routine Maintenance and Cleaning
- Clean the bowl, disc stack, and nozzle periodically.
- Ensure seals and gaskets are intact to prevent leaks.
- Service the sludge discharge system for proper function.
- Change oil and lubricate bearings according to schedule.

d. Regular Inspection and Testing
- Monitor vibration and sound levels for early fault detection [27].
- Check motor and heater conditions to ensure system stability.
- Conduct efficiency tests by analyzing the purified fuel.

e. Crew Training and Awareness
- Train crew members on purifier operation and maintenance.
- Emphasize correct procedures for start-up, shutdown, and emergencies.
- Implement routine performance monitoring via logbooks.

IV. CONCLUSION

This study aimed to analyze the influence of Fuel Oil (F.O) purifier maintenance on the performance of the main engine aboard the KM. Logistik Nusantara 2. The findings indicate that inadequate maintenance of the F.O purifier including irregular cleaning, neglected component inspection, and poor-quality fuel usage significantly reduces the efficiency of the fuel purification process. This results in higher impurity content in the fuel, which negatively impacts the engine's combustion efficiency, fuel consumption rate, and overall performance. To overcome these challenges, several optimization measures were implemented, such as increasing the frequency of routine maintenance, ensuring proper inspection and replacement of purifier components, and using fuel that meets the required specifications.

These improvements have led to better separation of water and contaminants, more stable engine performance, and enhanced operational reliability of the vessel. In conclusion, this study confirms that systematic and scheduled maintenance of the F.O purifier plays a critical role in maintaining engine efficiency and reliability. The research highlights the practical importance of fuel treatment systems in maritime operations and provides valuable insights for marine engineers seeking to improve fuel management and engine performance through preventive maintenance strategies.

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