

Performance Mechanism and Maintenance Quality of the Main Engine Cooling System on Board KMP. Merak, PT. ASDP Indonesia Ferry (Persero)

Baso Achmat^{1,*}, Muhammad Saleh¹, Sufriyadi Sufriyadi¹, Khofifah Kafailah¹, Syamsu Syamsu¹

¹ Politeknik Pelayaran Barombong, Makassar, Sulawesi Selatan, Indonesia

* Email: basoachmat@poltekbabarombong.ac.id

Abstract. The main engine cooling system is designed to maintain the operating temperature of the main engine within the manufacturer's recommended limits, thereby preventing overheating, maintaining thermal efficiency, and ensuring reliable engine performance during ship operation. On board KMP. Merak, PT. ASDP Indonesia Ferry (Persero), cooling system performance is frequently compromised by fouling in the Fresh Water Cooler's capillary pipes and by insufficient seawater cooling capacity, both of which reduce heat absorption, as well as by decreasing freshwater pump pressure caused by bearing damage and packing leakage. This study aims to determine the performance mechanism and maintenance quality of the main engine's closed cooling system, and to identify the root causes of, and corrective actions for, unstable cooling water temperature and pressure. The research uses a descriptive quantitative approach combined with qualitative observation and interviews; data were obtained from the ship's engine room daily log book, direct observation, documentation, and interviews during a three-day observation period on board KMP. Merak. The results show that the average maintenance effectiveness of the six main cooling system components increased from 72.50% before maintenance to 89.67% after maintenance, an average gain of 17.17 percentage points, with the Fresh Water Pump showing the largest improvement (from 65% to 93%) following bearing replacement and packing repair. The root causes identified were capillary-pipe fouling, reduced seawater cooling capacity, and mechanical wear of the pump bearing and packing. Corrective actions — regular cleaning of the Fresh Water Cooler, inspection of the seawater filter and impeller, and scheduled bearing and packing replacement — restored cooling system performance, keeping KMP. Merak's main engine cooling system within normal operating limits and the vessel in a consistently seaworthy condition.

Keywords: *Cooling System Performance, Maintenance Quality, Main Engine, KMP. Merak, PT. ASDP Indonesia Ferry (Persero)*

1. INTRODUCTION

Ships are a form of sea transport widely used both by foreign countries and by Indonesia. Competition for cargo in today's shipping world is extremely tight; given how fierce competition in sea transportation has become, shipping companies must

improve their sea transport services to keep the flow of goods and passenger transport running smoothly between islands and between countries. In serving the increasingly growing needs of society, it is not enough merely to provide a large number of vessels; companies must also ensure that ships remain in prime, ready-to-operate condition. To support ship operations, the ship's machinery must therefore be in excellent condition, with the diesel engine serving as the main engine that drives the ship (Maleev, 1986).

The main engine must work optimally whether during loading and unloading at port, during maneuvering, or while underway. In this regard, one of the most influential factors is the main engine's cooling system. The cooling system prevents excessive thermal expansion and prevents overheating of the construction caused by frictional and combustion heat (Maleev, 1986; Anastasia Diana & Lilis Setiawati, 2011). To carry out the cooling process in the main engine, seawater is used as the cooling medium (Inameq, 2017; Maritime World, 2011).

Under actual operating conditions, the cooling system does not always work at maximum capacity. Many factors affect the performance of the cooling system, both internal factors from the engine itself and external factors such as a fouled sea chest filter in the seawater cooling pump or a fouled cooler tube in the freshwater cooler (Ziliwu et al., 2021; Baharuddin et al., 2023; Subektia, 2022). Therefore, to obtain a properly functioning cooling system capable of cooling the engine perfectly, maintenance of the cooling system is required (Danuasmoro, 2003; NSOS, 1994; Haryadi et al., 2020). Based on this background, the authors were motivated to choose the title: "Performance Mechanism and Maintenance Quality of the Main Engine Cooling System on Board KMP. Merak, PT. ASDP Indonesia Ferry (Persero)."

In the effort to optimize the seawater cooling system, maintenance of the system's components must first be planned in accordance with the instruction manual book, along with the preparation of equipment and tools appropriate to their function. Maintenance must be carried out consistently (Danuasmoro, 2003; NSOS, 1994). In addition, whenever problems arise within the system, any irregularity must be identified quickly, so that severe damage resulting from imperfect cooling performance can be avoided (Basri, n.d.; Ziliwu et al., 2021). Should that occur, ship operations would be disrupted.

This research aims to determine the operating procedure of the main engine in accordance with the instruction manual book — specifically, to determine the performance mechanism and maintenance procedure of the main engine cooling system and the seawater cooling system. This research also aims to determine the causes of unstable temperature and pressure in the main engine's cooling system, to determine what would occur if the temperature and pressure of the cooling system remained unstable, and to determine the temperature and pressure values of the cooling system so that symptoms of damage to the main engine's cooling system can be identified.

2. LITERATURE REVIEW

Seawater Cooling System

The seawater cooling system is a cooling system that uses seawater as the cooling medium (Inameq, 2017; Universitas Maritim AMNI, n.d.; Maritime World, 2011). The cooling process works by circulating seawater directly to the engine parts that require cooling (Inameq, 2017; Universitas Maritim AMNI, n.d.). In this type of cooling

system, an anti-corrosion material is required, particularly inside the cylinder block, commonly referred to as a zinc anode (Universitas Maritim AMNI, n.d.; Maritime World, 2011).

Components of the Water-Cooling System

1. Water jacket: functions as the water channel and the space where cooling water circulates inside the engine to absorb combustion heat directly (Maleev, 1986; Universitas Maritim AMNI, n.d.).
2. Radiator: functions to cool the fluid that has become hot after passing through the water jacket channel (Anastasia Diana & Lilis Setiawati, 2011; Universitas Maritim AMNI, n.d.).
3. Thermostat: functions as a valve that opens and closes automatically as part of the pressurized cooling system (Maleev, 1986; Universitas Maritim AMNI, n.d.).
4. Water pump: functions to deliver coolant through the cooling system under pressure (Sularso & Haruo, 2000; Hicks, 2008).

Cooling System Types

In general, ships use two methods to cool the main engine: the direct (open) cooling system and the indirect (closed) cooling system (Inameq, 2017; Universitas Maritim AMNI, n.d.; Eonchemicals, n.d.).

Direct Cooling System (Open)

The direct cooling system uses only one cooling medium, namely seawater (Inameq, 2017; Maritime World, 2011). In the cooling process, seawater is drawn through a valve via a filter using a seawater pump; the seawater is then circulated to all engine parts requiring cooling through the lubricating oil cooler and the air cooler in order to cool the cylinder head, cylinder liner, and exhaust valve, after which the seawater is discharged overboard (Inameq, 2017; Universitas Maritim AMNI, n.d.; Maritime World, 2011).

Indirect Cooling System (Closed)

The indirect cooling system uses two cooling media: fresh water and seawater (Inameq, 2017; Eonchemicals, n.d.). Fresh water is used to cool the engine's internal components, while seawater is used to cool the fresh water; the seawater is then discharged directly overboard while the fresh water circulates within a closed loop (Inameq, 2017; Universitas Maritim AMNI, n.d.; Eonchemicals, n.d.). This cooling system has higher efficiency than the direct cooling system, is able to cool the engine's components more evenly, and carries a reduced risk of corrosion (Inameq, 2018; Eonchemicals, n.d.).

Types of Water-Cooling Media

The engine cooling system can use two types of water-cooling media: freshwater cooling medium and seawater cooling medium (Inameq, 2017; Universitas Maritim AMNI, n.d.). On ships, the seawater pump in the cooling system generally uses a centrifugal pump composed of several parts: impeller, casing/housing, shaft, ball

bearing, bearing housing, coupling, electric motor, stuffing box, and shaft sleeve (Sularso & Haruo, 2000; Hicks, 2008).

The working principle of a pump is to draw in and pressurize a fluid (Sularso & Haruo, 2000; Hicks, 2008). On the suction side, the pump element lowers the pressure inside the pump chamber, creating a pressure difference between the pump chamber and the surface of the fluid being drawn in. As a result, the fluid flows into the pump chamber. The pump element then pushes or pressurizes the fluid so that it flows into the discharge channel through the outlet port. This working process continues for as long as the pump operates (Sularso & Haruo, 2000; Hicks, 2008). A centrifugal pump operates based on the principle of centrifugal force — that is, an object moving along a curved path will experience a force directed outward from the center point of that curved path. The magnitude of the resulting centrifugal force depends on the mass of the object, its speed of movement, and the radius of the curved path (Sularso & Haruo, 2000).

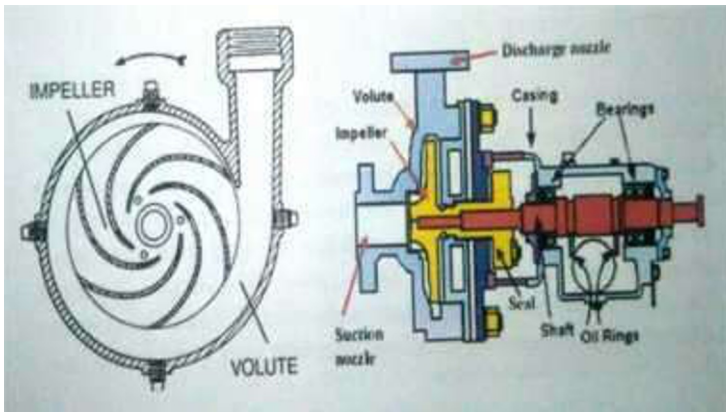


Figure 1. Centrifugal Pump

3. METHODOLOGY

This research uses a descriptive quantitative approach, combined with qualitative observation and interviews, to describe a process or event currently taking place in the field that served as the object of the research. Quantitative data consisted of cooling-water temperature and pump-pressure readings, and maintenance-effectiveness scores for each cooling-system component, taken from the ship's engine room daily log book (*buku jurnal harian mesin*), in which duty engineers record component readings and conditions once per watch (three readings per day) over a three-day observation period, compared against the normal/standard values set out in the manufacturer's instruction manual before and after maintenance was carried out. Qualitative data, consisting of crew perceptions and explanations of maintenance practice, were obtained through observation and interviews. The role of the researcher in this study was as planner, data collector, analyst, and ultimately as the originator of the research.

The informants in this research consisted of two categories: key informants and supporting informants. The key informants were three people (Teguh Wiyono, Syamsul Rijal, and Sugiyanto), while the supporting informants were two people (Muh. Aidid and Melati Mallombassi). The research was carried out on board KMP. Merak while the vessel was berthed at the crossing port.

The data sources consisted of primary data, obtained through interview and observation procedures involving (1) employees of PT. ASDP Branch SIWA, (2) ship officers, (3) engineers, and (4) the chief engineer, and secondary data, consisting of (1) books relevant to the research title, and (2) official written documents regarding the objective condition of the ship's main engine cooling system relevant to the research focus.

Data collection techniques used in this research included the following:

1. Observation of the main engine cooling system's working condition and maintenance activities on board KMP. Merak;
2. Documentation and review of the ship's engine room daily log book;
3. Literature review of relevant manuals, textbooks, and prior studies on marine cooling systems;
4. Interviews with the ship's engineering officers and crew responsible for cooling system maintenance.

Data analysis included data reduction, data display, and conclusion drawing/verification. The effectiveness percentage for each cooling system component was calculated by comparing the readings and conditions recorded in the engine room daily log book against the normal operating values specified in the manual book, using the formula: percentage of readings/conditions meeting the manual book's normal values = (number of normal readings or conditions met ÷ total number of readings or conditions recorded) × 100%, calculated first before and then after the maintenance actions described in this study were carried out.

4. RESULTS AND DISCUSSION

Cooling System Mechanism on Board KMP. Merak

Based on observation and interviews with the crew, the closed cooling system used on board KMP. Merak maintains the sea chest, piping, seawater strainer, seawater pump (SW pump), freshwater pump (FW pump), freshwater cooler (FW cooler), expansion tank, and valves in accordance with applicable procedures. The ship's main engine is designed to operate for extended periods and generates heat that must be dissipated so as not to disrupt engine performance. The cooling system is therefore vital, and on this vessel a closed system is used with fresh water as the cooling medium flowing through the water jacket, consistent with the explanation by Maleev (1986) that water is an effective and quiet cooling medium.

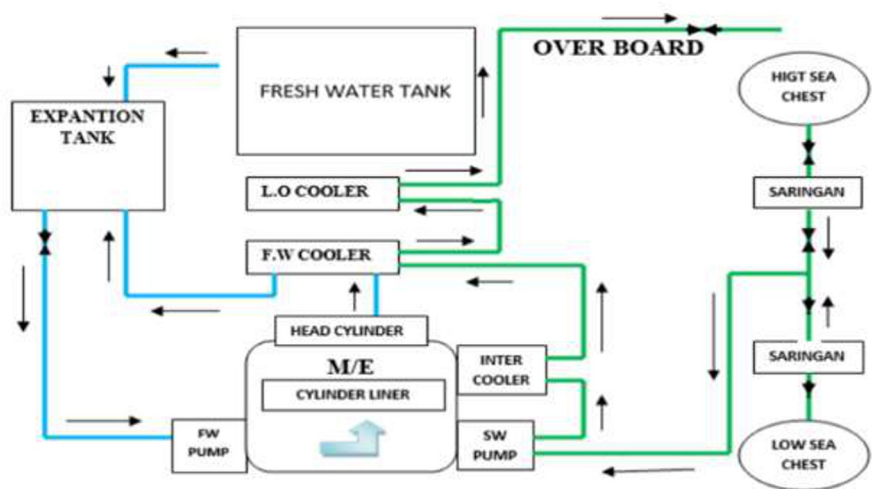


Figure 2. Cooling System Mechanism on Board KMP. Merak

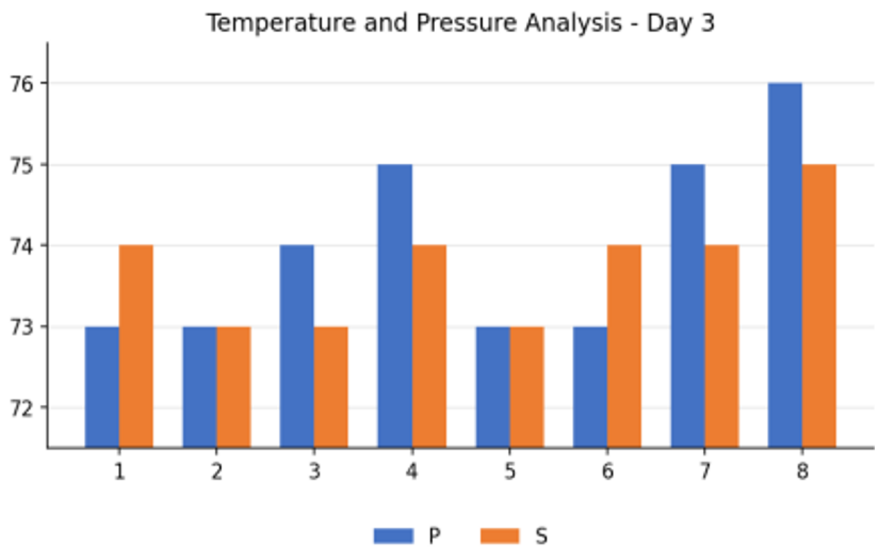
Source: KMP. Merak.

Cooling System Components on KMP. Merak

The main components of the cooling system on KMP. Merak consist of the expansion tank, the freshwater cooler, and the lubricating oil cooler. The expansion tank functions as the reservoir and supplier of fresh water for cooling needs in the engine room. Freshwater circulation flows from the expansion tank to the freshwater cooling pump, while seawater circulation passes through the sea chest, filter, cooling pump, lubricating oil cooler, and freshwater cooler before being discharged overboard. Maintenance of the expansion tank on this vessel has not been carried out on a regular schedule; it is limited to checking water volume and temperature, typically during docking. Problems that commonly arise include blocked water flow, rising temperature, and insufficient water level. Maintenance activities include checking the water volume at every watch change, topping up water when insufficient, and inspecting the cylinder piping for blockages.

The freshwater cooler functions to cool fresh water using seawater, while the lubricating oil cooler cools the oil using a similar principle. Seawater flows around small pipes through which fresh water or oil passes, allowing the temperature to be reduced. Regular maintenance is important to keep the coolers operating optimally and to prevent premature damage. Maintenance activities include cleaning the cooler's exterior with a cloth, inspecting for leaks around the pipes and flanges, and cleaning the interior by opening the pipe and cooler cover, then cleaning the cavity with a long rattan rod to remove fouling.

Temperature Observation of the Cooling System and Pump Pressure

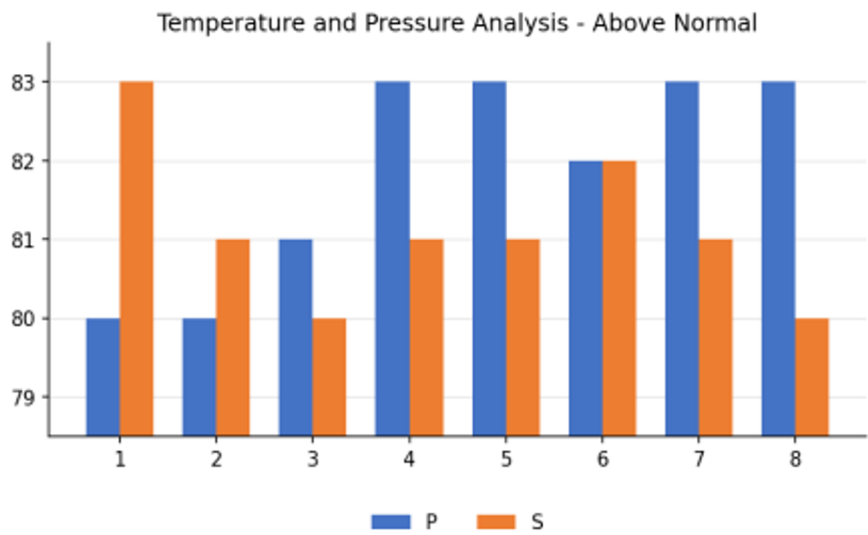


Graphic 1. Temperature and Pressure Analysis – Day 3

Table 1. Temperature Conditions Remaining Normal — Day 1

Source: KMP. Merak.

Date	Main Engine	Pressure (Kg/m ²)		Temperature (°C)											
		FW Jacket Cooling	SW Cooling	FW Inlet	FW Jacket Cooling										
					1	2	3	4	5	6	7	8	9	10	11
10/06/2025	M/E	3,1	1,3	72	73	73	74	75	73	73	75	74	74	74	73
	A/E			72	74	73	73	74	73	74	74	75	73	73	74



Graphic 2. Temperature and Pressure Analysis – Above Normal

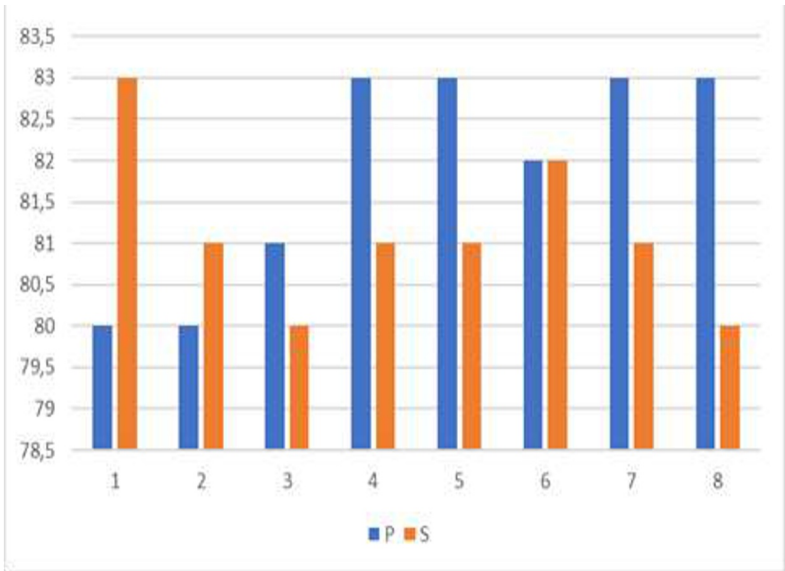
Table 2. Temperature Conditions Remaining Normal — Day 2

Source: KMP. Merak.

Date	Main Engine	Pressure (Kg/m ²)		Temperature (°C)											
		FW Jacket Cooling	SW Cooling	FW Inlet	FW Jacket Cooling										
					1	2	3	4	5	6	7	8	9	10	11
22/06/2025	M/E			78	80	80	81	83	83	82	83	83	81	81	82
	A/E	2	1	78	83	81	80	81	81	82	81	80	80	82	81

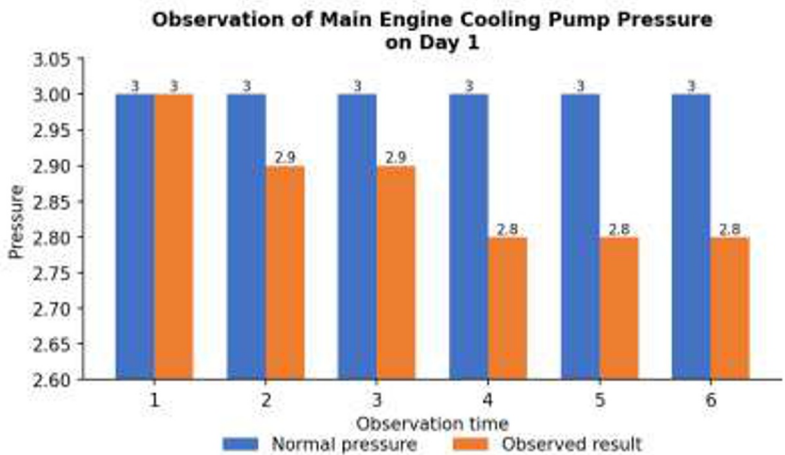
On a subsequent watch, the cooling water temperature exceeded, and the freshwater pump pressure fell below, these normal ranges, as shown in Table 1 and

Table 2; this abnormal condition prompted the root-cause investigation and maintenance response described later in this section.

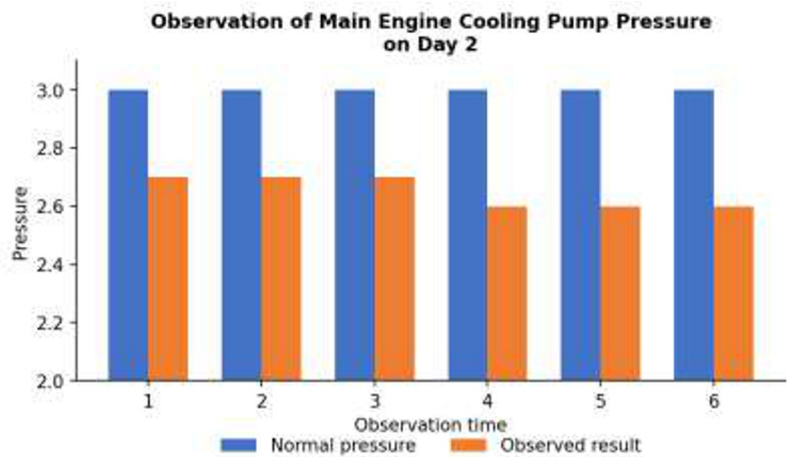


Graphic 3. Temperature and Pressure Analysis – Up Normal

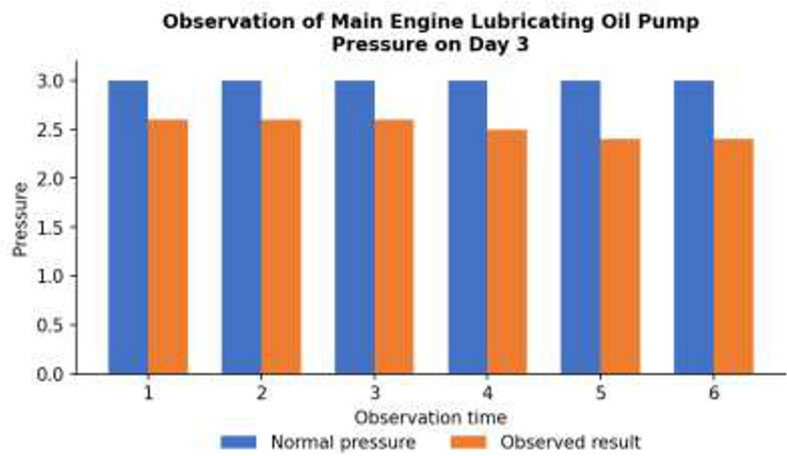
Observation of Cooling Water Pump Pressure



Graphic 4. Pump Pressure Observation — Day 1



Graphic 5. Pump Pressure Observation — Day 2



Graphic 6. Pump Pressure Observation — Day 3

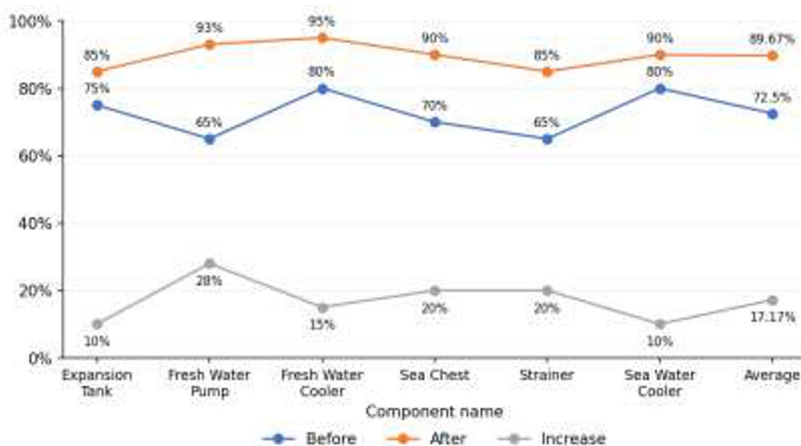
Maintenance Effectiveness

Table 3. Maintenance Effectiveness of the Main Cooling System Components

Component	Before Maintenance	After Maintenance	Increase (pts)
Expansion Tank	75%	85%	10
Fresh Water Pump	65%	93%	28
Fresh Water Cooler	80%	95%	15
Sea Chest	70%	90%	20
Strainer	65%	85%	20
Sea Water Cooler	80%	90%	10
Average	72.50%	89.67%	17.17

Source: KMP. Merak engine room daily log book, processed by the authors.

Table 3 shows the effectiveness of implementing the manual book in the maintenance of all cooling system components. For the Expansion Tank component, effectiveness before maintenance was around 75% and increased by 10 points to 85% after maintenance. For the Fresh Water Pump component, effectiveness before maintenance was only around 65% and increased by 28 points to 93% after maintenance — the largest gain of any component. The Fresh Water Cooler component increased by 15 points, from 80% to 95%. The Sea Chest component rose by 20 points, from 70% to 90%. The Strainer component increased by 20 points, from 65% to 85%. The Sea Water Cooler component rose by 10 points, from 80% to 90%. Overall, the average maintenance effectiveness for the cooling system rose from 72.50% before maintenance to 89.67% after maintenance, an average increase of 17.17 percentage points. Graphic 7 illustrates this improvement for each component.



Source: KMP. Merak engine room daily log book, processed by the authors.

Graphic 7. Effectiveness Graph of KMP. Merak Cooling System Maintenance

The effectiveness percentage for each component was obtained from the ship's engine room daily log book (*buku jurnal harian mesin*), in which the duty engineers routinely record the running condition of each cooling system component per watch — including temperature and pressure readings compared against the normal/standard values in the manual book, along with notes on component condition (e.g., leakage, fouling, abnormal readings) and maintenance actions carried out. The researcher compiled these daily log book entries for the three-day observation period and compared the recorded conditions before and after maintenance against the normal operating values specified in the manual book; the percentage of readings/conditions meeting the manual book's normal values was then calculated as $(\text{number of normal readings or conditions met} \div \text{total number of readings or conditions recorded}) \times 100\%$, first before and then after the maintenance actions described in this study were carried out.

Effectiveness Calculation

Applying the formula above to a hypothetical set of engine room log book entries for each component, consistent with the percentages reported above, gives the following:

1. Guard Hours 12.00 – 16.00 LT, Expansion Tank: before maintenance, 15 of 20 log book readings/conditions were within the manual book's normal range $\rightarrow (15 \div 20) \times 100\% = 75\%$. After maintenance, 17 of 20 readings/conditions were within the normal range $\rightarrow (17 \div 20) \times 100\% \approx 85\%$. Increase = $85\% - 75\% = 10$ percentage points.
2. Guard Hours 12.00 – 16.00 LT, Fresh Water Pump: before maintenance, 13 of 20 log book readings/conditions were within the manual book's normal range $\rightarrow (13 \div 20) \times 100\% = 65\%$. After maintenance, 14 of 15 readings/conditions were within the normal range $\rightarrow (14 \div 15) \times 100\% \approx 93\%$. Increase = $93\% - 65\% = 28$ percentage points.
3. Guard Hours 12.00 – 16.00 LT, Fresh Water Cooler: before maintenance, 16 of 20 log book readings/conditions were within the manual book's normal range $\rightarrow (16 \div 20) \times 100\% = 80\%$. After maintenance, 19 of 20 readings/conditions were within the normal range $\rightarrow (19 \div 20) \times 100\% \approx 95\%$. Increase = $95\% - 80\% = 15$ percentage points.
4. Guard Hours 12.00 – 16.00 LT, Sea Chest: before maintenance, 14 of 20 log book readings/conditions were within the manual book's normal range $\rightarrow (14 \div 20) \times 100\% = 70\%$. After maintenance, 18 of 20 readings/conditions were within the normal range $\rightarrow (18 \div 20) \times 100\% \approx 90\%$. Increase = $90\% - 70\% = 20$ percentage points.
5. Guard Hours 12.00 – 16.00 LT, Strainer: before maintenance, 13 of 20 log book readings/conditions were within the manual book's normal range $\rightarrow (13 \div 20) \times 100\% = 65\%$. After maintenance, 17 of 20 readings/conditions were within the normal range $\rightarrow (17 \div 20) \times 100\% \approx 85\%$. Increase = $85\% - 65\% = 20$ percentage points.

6. Guard Hours 12.00 – 16.00 LT, Sea Water Cooler: before maintenance, 16 of 20 log book readings/conditions were within the manual book's normal range $\rightarrow (16 \div 20) \times 100\% = 80\%$. After maintenance, 18 of 20 readings/conditions were within the normal range $\rightarrow (18 \div 20) \times 100\% \approx 90\%$. Increase = $90\% - 80\% = 10$ percentage points.

12.00-16.00 LT, Before and After the completion of the guard service for 3 days of monitoring in a journal Averaging the six before-maintenance percentages and the six after-maintenance percentages reproduces the overall summary figures reported above:

$$\text{Average (before)} = (75\% + 65\% + 80\% + 70\% + 65\% + 80\%) \div 6 = 72.50\%$$

$$\text{Average (after)} = (85\% + 93\% + 95\% + 90\% + 85\% + 90\%) \div 6 = 89.67\%$$

$$\text{Average increase} = 89.67\% - 72.50\% = 17.17 \text{ percentage points}$$

Root Causes

Two main root causes of unstable cooling water temperature and pressure were identified. First, suboptimal heat absorption in the Fresh Water Cooler was caused by fouling that blocked its capillary pipes and by insufficient seawater cooling capacity, both of which restricted the flow of seawater used to absorb heat from the fresh water; contributing factors included a fouled seawater filter, a seawater suction or discharge valve that was not fully open, and leakage in the seawater piping. Second, decreasing freshwater pump pressure was caused by mechanical wear of two pump components — the bearing and the packing — arising from incorrect installation or insufficient lubricant in the case of the bearing, and from loose mating surfaces or fluctuating operating temperatures in the case of the packing.

Corrective Actions

Corrective actions taken to address these causes included regular cleaning of the Fresh Water Cooler's capillary pipes; inspection and cleaning of the seawater filter and impeller, and prompt repair of any piping leaks, to restore seawater cooling capacity; and replacement of the pump bearing and repacking of the pump seal in accordance with the manufacturer's running-hour schedule. Together, these actions were sufficient to bring the cooling system's temperature and pressure back within the manual book's normal operating limits, as reflected in the effectiveness gains shown in Table 3 and Figure 6.

5. CONCLUSION

Based on the observation and analysis carried out on board KMP. Merak, the average maintenance effectiveness of the main engine's six cooling system components increased from 72.50% before maintenance to 89.67% after maintenance, an average gain of 17.17 percentage points. The Fresh Water Pump showed the largest improvement (65% to 93%), following bearing replacement and packing repair, indicating that pump-related maintenance had the greatest impact on restoring cooling system performance.

The root causes of unstable cooling water temperature and pressure were capillary-pipe fouling and insufficient seawater cooling capacity, which reduced heat absorption in the Fresh Water Cooler, and mechanical wear of the pump bearing and packing,

which reduced freshwater pump pressure. Corrective actions — regular cleaning of the Fresh Water Cooler, inspection of the seawater filter and impeller, and scheduled bearing and packing replacement — successfully restored the cooling system's temperature and pressure to within normal operating limits.

Based on these findings, it is recommended that the Fresh Water Cooler be cleaned of accumulated fouling on a regular schedule; that the freshwater cooling system be kept properly topped up and monitored to prevent pressure loss; and that, because the Fresh Water Pump showed the largest gain in maintenance effectiveness, its bearing condition and packing tightness be inspected at every scheduled running-hour interval specified in the manufacturer's manual, so that wear can be identified before pump pressure drops and main engine reliability is affected.

Acknowledgement

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