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Article

### Analysis of the Effectiveness of the Marine Growth Prevention System (MGPS) in Preventing Marine Organism Growth in the Engine Cooling System of MV Ever Clear

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#### ABSTRACT

The ship engine cooling system is critical for maintaining the operational stability of main and auxiliary machinery. However, biofouling within sea chests and seawater pipelines remains a prevalent issue, leading to flow obstruction, reduced heat transfer efficiency, and potential engine malfunction. While the Marine Growth Prevention System (MGPS) is designed to mitigate this via electrolysis, marine growth persisted on MV Ever Clear, indicating suboptimal system performance. This study evaluates the effectiveness of the MGPS, identifies root causes of performance degradation, and proposes a structured maintenance strategy. Using a qualitative descriptive method with a case study approach, data were collected through direct onboard observation, structured interviews, and logbook analysis. Results indicate that the system's effectiveness decreased due to a measured current deviation from the targeted 293 A down to 190 A (-35%) and a voltage drop from 8 V to 5.5 V. This degradation was primarily caused by electrode passivation (salt deposits), insufficient routine maintenance compliance, and inadequate operational monitoring. Corrective actions, including mechanical cleaning and system resets, successfully restored operational parameters. It is concluded that MGPS efficacy is strictly contingent upon stable electrical parameters, rigorous adherence to scheduled preventive maintenance, and continuous operational supervision.

## 1. Introduction

The operational capability of maritime transportation is intrinsically linked to the reliability of the ship's main engine, which serves as the primary propulsion unit. To ensure sustained performance and prevent overheating during voyages, the main engine requires a robust cooling system. Modern vessels utilize closed central cooling systems that employ freshwater cooled by seawater through heat exchangers, offering precise thermal control but with higher complexity. Despite these advantages, the direct intake of marine water introduces significant biological challenges.

The marine environment is populated by diverse microorganisms that can infiltrate the ship's piping network. The uncontrolled proliferation of these organisms, known as biofouling, leads to severe operational impediments. Biofouling accumulation significantly increases internal pipe frictional resistance and degrades hydrodynamic performance, manifesting as flow obstruction, increased seawater pump load, reduced heat transfer coefficient, and potential main engine derating. To mitigate these risks, vessels are equipped with a Marine Growth Prevention System (MGPS), an electrochemical device designed to inhibit the settlement of marine biota within the sea chests and internal piping.

However, the mere installation of an MGPS does not guarantee immunity from biofouling. Preliminary observations conducted onboard the MV Ever Clear revealed that despite an active MGPS, the system experienced a critical deviation—specifically, a current drop from the designed 293 A to 190 A—allowing marine organism growth to persist within the cooling infrastructure. This indicates suboptimal performance, posing a direct threat to the engine's thermal stability.

While previous studies have highlighted the general importance of MGPS, few have provided a granular, logbook-based operational analysis of electrochemical degradation combined with human-factor maintenance failures. Consequently, this research aims to:

1. Evaluate the operational effectiveness of the MGPS on the MV Ever Clear based on electrical parameter deviations.
2. Identify the root causes (mechanical, procedural, and human) contributing to the degradation of the system's performance.
3. Propose short-term corrective and long-

term preventive maintenance strategies to optimize system reliability.

## 2. Literature Review

### 2.1 The Criticality of Marine Cooling Systems

The internal combustion engine is thermodynamically limited, with a significant portion of fuel energy rejected as heat. If not removed, this heat compromises lubrication, induces thermal stress, and leads to structural failure. Modern vessels like MV Ever Clear employ a central cooling system (closed loop). Freshwater circulates through the engine and auxiliary machinery, which is then cooled in a central heat exchanger by a separate seawater circuit. This design confines the corrosive seawater to specific components—sea chests, seawater pumps, and central coolers—making the protection of this circuit paramount. Any obstruction in this circuit creates a severe bottleneck for the entire vessel's thermal management.

### 2.2 Marine Biofouling: Mechanisms and Impact

Biofouling is the accumulation of microorganisms, plants, and animals on submerged surfaces. The biological process begins with a conditioning film of organic molecules, facilitating the settlement of bacteria and diatoms to form a microbial biofilm. The final stage involves the settlement of macroorganisms such as barnacles and mussels, which secrete calcium carbonate shells. The engineering consequences are severe:

1. Flow Restriction: As barnacles grow, they occlude the flow path. A reduction in diameter leads to a quadratic increase in pressure drop according to the Darcy-Weisbach equation, forcing seawater pumps to operate inefficiently and reducing cooling flow.
2. Thermal Insulation: Biofilms have low thermal conductivity. Macro-fouling blocks the narrow passages of plate heat exchangers entirely, exponentially increasing fouling resistance and leading to rapid overheating.
3. Microbiologically Influenced Corrosion (MIC): Sulfate-Reducing Bacteria (SRB) thrive beneath fouling layers, producing hydrogen sulfide ( $H_2S$ ) that aggressively attacks steel and copper alloys

### 2.3 Marine Growth Prevention Systems (MGPS) and Farady's Law

To counteract these biological threats, vessels utilize MGPS. The most common and effective type for internal piping is the Impressed Current Electrolytic System.

#### Principle of Operation:

The system functions as a miniature electrolysis plant. It consists of a control panel (rectifier) and an electrolytic cell (or sea chest-mounted anodes) containing Copper (Cu) and Aluminum (Al) or Iron (Fe) anodes. The rectifier converts the ship's AC power to a low-voltage, high-amperage DC output, which is driven through the anodes into the seawater electrolyte.

#### Anode Chemistry and Function:

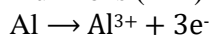
##### 1. Copper Anodes (Anti-Fouling):

The copper anode is the primary defense against marine life. When energized, the copper dissolves, releasing positive copper ions into the seawater stream.

These ions are toxic to marine invertebrates at the larval stage. They interfere with the enzymes necessary for the larvae to secrete their attachment cement and metamorphose. By maintaining a concentration of just 2 to 50 parts per billion (ppb) in the seawater intake, the system creates an environment where larvae remain suspended in the water column and pass through the system without settling.

##### 2. Aluminum Anodes (Anti-Corrosion):

Aluminum anodes are sacrificial in a different sense. They dissolve to release aluminum ions ( $Al^{3+}$ )



These ions react with the hydroxyl ions in seawater to form Aluminum Hydroxide ( $Al(OH)_3$ ), a gelatinous, flocculent precipitate. This floc spreads throughout the piping system, depositing a thin, film-like layer on the internal surfaces of pipes and coolers. This film serves two purposes: it suppresses corrosion by isolating the metal from the oxygenated seawater, and it helps to carry the copper ions further into the system, ensuring protection reaches the most remote pipework.

Operational Parameters: For the system to be effective, the rate of ion release must be constant. According to Faraday's First Law of Electrolysis, the mass of substance altered at an electrode is directly proportional to the quantity of electricity passed through that electrode. Therefore, maintaining the correct Current (Amperage) is the single most critical operational parameter. If

the current drops, the mass of copper released drops proportionally. If the copper concentration falls below the lethal threshold for the local marine species, biofouling will commence immediately.

### 2.4 Synthesis of Previous Studies

Previous studies have established the vulnerabilities of MGPS applications. Maulana (2024) identified physical fouling in reaction tanks and clogged injection nozzles from sediment as primary failure modes. Fachroini & Dwisetiono (2022) highlighted that MGPS effectiveness is strictly conditional on stable electrical current, corroborating the electrochemical degradation identified in this study. Simatupang et al. (2022) confirmed that salt crystal deposits causing electrode passivation are a major barrier to electrolysis. While these studies offer component-level insights, this research extends the literature by correlating continuous logbook parameter deviations with specific human maintenance practices, providing a holistic root cause analysis.

Maulana (2024) conducted a similar study on the *MT. Gas Dream*. His research identified that slow seawater flow was caused by physical fouling in the reaction tank and clogged injection nozzles. He highlighted that "lumpur" (mud/sediment) clogging the nozzles was a primary failure mode. This parallels the findings on *MV. Ever Clear* regarding sediment intake from low sea chests but differs in that *MV. Ever Clear's* failure was also heavily electrical (current drop).

Fachroini & Dwisetiono (2022) focused on the application of MGPS for hull protection. Their key finding was that MGPS effectiveness can reach 80%, but this performance is strictly conditional on stable electrical current and the physical condition of the electrodes. They noted that "performanya menurun jika arus listrik tidak stabil" (performance declines if electric current is unstable), which directly corroborates the root cause identified in this study.

Simatupang et al. (2022) analyzed the *LNG Ekaputra*, finding that "deposit kristal garam" (salt crystal deposits) on anodes was a major barrier to electrolysis. Their solution involved overhauling the electrolytic cell and replacing pipes. This study is highly relevant as it confirms that electrode passivation is a common failure mode in these systems and supports the

necessity of the "cleaning" maintenance protocol proposed for MV. Ever Clear.

Risdianto et al. (2023) emphasized the importance of "optimalisasi pemasangan" (installation optimization) and automated current adjustment on naval vessels (KRI). Their work suggests that manual systems (like those that might be on older commercial vessels) are more prone to operator error, whereas automated systems can better compensate for changing water conditions to maintain pipe integrity.

Schultz (2007) provides the economic backdrop. His seminal work on the "Effects of coating roughness and biofouling" quantified the drag penalty of fouling. While focused on external hydrodynamics, the physics he describes—where biomass increases fluid resistance—is the exact mechanism causing the flow reduction in MV. Ever Clear's pipes. His data (up to 86% power penalty for heavy fouling) illustrates the massive energy cost of allowing fouling to occur.

#### **Synthesis:**

The literature confirms that while the *chemistry* of MGPS is sound, the *application* is fraught with vulnerability. The system relies on a continuous chain of events: stable power → clean electrode → electrolysis → ion transport. A break anywhere in this chain—specifically at the electrode surface due to scaling, or at the control panel due to crew negligence—results in total system failure. The research on MV. Ever Clear builds upon this by providing a granular analysis of how human factors (maintenance and monitoring) directly precipitate these technical failures.

### **3 Research Methodology**

#### **3.1 Research Design**

This study adopts a Qualitative Descriptive research design utilizing a Case Study approach. A qualitative methodology was selected because assessing MGPS failure requires understanding complex human-machine interactions—specifically how crew maintenance culture affects continuous electrochemical output—which cannot be captured by static quantitative performance tests alone. The descriptive aspect allows for detailing exact electrical log values, visual states of electrodes, and procedural shortcomings. As defined by Creswell and further elaborated for the Indonesian context by Nasution (2023) and Sugiyono (2016), qualitative methods are ideal for exploring

"how" and "why" a phenomenon occurs.

#### **3.2 Locus, Time and Operational Context**

The research was conducted onboard the MV Ever Clear (18,658.00 GT Container Ship; Main Engine: MAN B&W 6S60ME-C10.5) over 12 months (Dec 2023 - Dec 2024). The specific failure incident occurred while operating en route from Shekou to Tokyo. Operations in the Shekou port region involved shallow, sediment-rich waters, directly influencing the low sea chest intake quality.

#### **3.3 Data Sources and Collection Techniques**

Triangulation of data was achieved through three primary methods:

1. Direct Observation: Routine engine room rounds during the 08:00 and 16:00 watches monitored Voltage, Amperage, and Flow Rate. Visual inspections were documented whenever strainers were opened.
2. Semi-Structured Interviews: Conducted with three key personnel: The Chief Engineer (managerial perspective), Second Engineer, and Third Engineer (operational perspective). Interviews lasted 30-45 minutes and were transcribed for thematic analysis.
3. Documentation Study: Reviewed the Nippon Corrosion Engineering Co., Ltd. Instruction Manual, Planned Maintenance System (PMS) records, daily engine logbooks, and maintenance reports.

#### **3.4 Data Analysis Technique: Fishbone Analysis**

Data were analyzed using the Ishikawa (Fishbone) Root Cause Analysis method. Raw observational and interview data were coded into four categories: Man (human competency/compliance), Material (physical state of water and components), Method (procedures and schedules), and Machine (equipment limitations).

### **4 Results and Discussion**

#### **4.1 General Description of the MGPS on MV. Ever Clear**

The MV. Ever Clear is equipped with a Marine Growth Prevention System (MGPS) manufactured by Nippon Corrosion Engineering Co., Ltd. The system is designed to treat the seawater intakes for the central cooling system,

protecting the sea chests, strainers, pumps, and central coolers.

System Specifications:

Type: Electrolytic Anode System

Anodes: Copper (Anti-fouling) and Aluminum (Anti-corrosion)

Placement: Electrolytic Cell (Reaction Tank) injecting into Sea Chests

Operational Targets:

Current : 293 Amperes (A)

Voltage : 8 Volts (V)

Control : Constant Current (CC) regulation via Control Panel.

The system is critical because the vessel utilizes a central cooling system. If the seawater side (primary circuit) becomes fouled, the heat rejection capability of the entire plant is compromised, leading to high-temperature alarms on the freshwater side (secondary circuit).

#### 4.2 Findings: The Incident of Performance Failure

The investigation focuses on a specific operational failure observed on April 18, 2024, while the vessel was en route from Shekou to Tokyo.

Chronology of Failure:

During the 08:00–12:00 watch, the researcher and the Third Engineer detected abnormalities in the cooling system.

Flow Rate Drop: The flowmeter on the seawater outlet indicated a significant reduction in mass flow. This is a classic hydraulic symptom of increased pipe roughness or blockage.

MGPS Parameter Check: An immediate inspection of the MGPS control panel revealed a critical deviation. The system was operating at 190 A and 5.5 V.

Target Current : 293 A

Actual Current : 190 A

Deviation : -103 A (-35%)

Target Voltage : 8 V

Actual Voltage : 5.5 V

Physical Inspection: Upon opening the sea chest and strainers, the crew confirmed the presence of "pertumbuhan organisme laut" (marine organism growth). Barnacles and mussels had colonized the pipe walls, reducing the effective diameter and causing the flow restriction.

Component Analysis: Disassembly of the electrolytic cell revealed that the Copper and Aluminum electrodes were heavily coated with

"endapan garam" (salt deposits) and biological slime.

#### Analysis of the Data:

The log sheet data (Picture 1) confirms that this was not a sudden failure but a gradual degradation. The current of 190A represents a 35% reduction in the release rate of copper ions. According to Faraday's laws, the mass of copper released is linearly proportional to the current.

Date 日付	Ship's Location 船位	Power Supply Unit 電源機組設置		Sea Water Temp (°C) 海水 温度	Sea Water Flow 海水流量(m³/h)		Weekly Entry %[Residual Change] (ppm) 残留濃度変化		Remarks 備考	
		Ded No	D.C. (V)		D.C. (A)	m³	DAILY AVERAGE 日平均	%		DAILY AVERAGE 日平均
1	AT SEA	8	8 V	290 A	28	8	8			
2	HOCHIMEN	8								
3	AT SEA	8								
4	AT SEA	8	7.5 V	280 A	28	8	8			
5	AT SEA	8	7.5 V	280 A	28	8	8			
6	DA NANG	8	8 V	300 A	29	7	7			
7	AT SEA	8								
8	AT SEA	8	8 V	280 A	27	10	10			
9	AT SEA	8	8 V	280 A	27	8	8			
10	KAOHSIUNG	8								
11	AT SEA	8								
12	AT SEA	8								
13	TAPPEI	8	6 V	220 A	27	7	7			
14	AT SEA	8	6 V	220 A	26	8	8			
15	AT SEA	8	6 V	220 A	26	8	8			
16	HONGKONG	8								
17	SHIKOKU	8								
18	AT SEA	8	5.5 V	190 A	26	9	9			
19	AT SEA	8	-	-	-	-	-		MAINTENANCE	
20	AT SEA	8	-	-	-	-	-		MAINTENANCE	
21	YOKYO	8	-	-	-	-	-		MAINTENANCE	
22	YOKOHAMA	8	8 V	280 A	24	8	8			
23	SHIMIZU	8	8 V	280 A	23	8	8			
24	NAGOYA	8	7.5 V	280 A	24	8	8			
25	AT SEA	8	7.5 V	280 A	24	11	11			
26	YOKKAICHI	8	8 V	300 A	24	11	11			
27	AT SEA	8	8 V	280 A	23	10	10			
28	AT SEA	8	7.5 V	280 A	23	11	11			
29	AT SEA	8	7.5 V	280 A	23	10	10			
30	AT SEA	8	8 V	280 A	23	8	8			
31										

Note: Seawater flow rate into the Electrolytic Cell should be over 7 m³/h or 12m³/h (TD-12007, TD-1600P), and 20m³/h (TD-2400P)

1) With regard to Electrolytic Cell, check sea water off from the Cell by opening drain valve to the full in case of starting off the Power Supply for an extended period (for 24 hours or longer).

2) Operation Current of DC Output should be below 5A in case of the seawater temperature is below 5°C.

Figure 1. Log Sheet MGPS

However, the biological impact is non-linear. Marine larvae require a threshold concentration (e.g., 2-50 ppb) to be repelled. Once the ion concentration drops below this *Minimum Effective Concentration (MEC)*, the protection drops to near zero, allowing settlement to occur. The voltage drop to 5.5V indicates a change in the resistance of the cell, likely due to the insulating properties of the scale (passivation) on the anodes. This passivation layer prevents the seawater from contacting the metallic copper, effectively stopping the electrolysis process even if some current is still flowing through leak paths.

### 4.3 Discussion: Root Cause Analysis (Fishbone)

The application of the Fishbone analysis to the incident reveals a multi-dimensional failure.

#### 1. Man (Human Factor)

The "Man" factor was identified as a primary contributor. The decline in system performance was not sudden; it would have been visible on the control panel for days or weeks prior to the April 18th blockage.

**Lack of Monitoring:** The engine crew failed to conduct consistent "pengawasan dan pencatatan" (supervision and recording) of the parameters. The log sheets showed gaps, indicating that the MGPS was not being checked with the diligence applied to main engine parameters.

**Competency Gap:** There appeared to be a lack of understanding regarding the *implication* of a low current reading. The crew did not recognize that 190A was an alarm state indicating anode passivation. This suggests a need for better training on the specific operating principles of the MGPS.

**Negligence:** The maintenance was reactive. The crew only intervened when the *cooling system* failed (symptoms), rather than maintaining the MGPS to prevent the failure (cause).

#### 2. Material (Physical Components)

The "Material" aspect focused on the condition of the electrodes.

**Electrode Passivation:** The primary physical cause was the "penumpukan endapan garam" (accumulation of salt deposits) on the electrodes. In electrolytic systems, if the current density is incorrect or if the water flow through the cell is insufficient, hard scales (calcium carbonate/magnesium hydroxide) can form on the cathode and anode. This scale is an electrical insulator. It creates a barrier that prevents the release of ions.

**Corrosion/Wear:** The electrodes showed signs of wear. While consumable, uneven wear caused by scaling can reduce the surface area available for electrolysis, further driving down the current.

#### 3. Method (Procedures)

The "Method" analysis revealed a breakdown in the vessel's Planned Maintenance System (PMS).

**Maintenance Interval Violation:** The manufacturer's manual prescribes routine cleaning of the electrodes (e.g., every 2 months) to remove scale and restore conductivity. The investigation found that "kurangnya pelaksanaan perawatan... secara rutin" (lack of routine maintenance implementation) was a key factor. The maintenance was not performed according to the schedule, allowing the scale to build up to critical levels.

**SOP Deficiency:** There was a lack of a clear Standard Operating Procedure (SOP) for adjusting the system based on environmental conditions (e.g., entering port vs. open sea) or for responding to low amperage readings.

#### 4. Machine (Equipment Factors)

While the machine largely failed due to lack of maintenance, certain design aspects contributed.

**Sea Chest Selection:** The use of the "Low Sea Chest" in shallow or sediment-rich waters (like Shekou port) accelerated the fouling. Low sea chests ingest more sediment, silt, and bottom-dwelling larvae. The sediment can coat the electrodes, accelerating passivation. The corrective action taken—switching to the "High Sea Chest"—was effective but should have been a proactive procedural choice.

**Electrical Stability:** The drop in voltage suggests that the rectifier unit might struggle to maintain a Constant Current (CC) output when the load resistance (the cell) changes drastically due to fouling.

#### 4.4 Optimization and Corrective Actions

Following the failure, the crew executed targeted interventions:

1. **Mechanical Restoration:** Sea chest piping was mechanically cleared of macro-fouling. The electrolytic cell was dismantled, and electrodes were manually chipped to remove insulating salt deposits and scale.
2. **System Validation:** Upon restarting, the control panel immediately registered 293 A and 8 V. This confirmed the rectifier unit was healthy and the entire failure was localized to external electrode passivation.
3. **Operational Adjustment:** The vessel switched to the High Sea Chest for cleaner water intake in coastal zones. Post-maintenance flow rates returned to

optimal parameters, proving the system's efficacy is fully recoverable through rigorous maintenance.

## 5. Conclusion and Recommendations

Based on the logbook data and operational analysis of the MV Ever Clear, this study concludes:

1. Direct Parameter Dependency: MGPS effectiveness is entirely contingent upon electrical stability. The gradual current deviation to 190 A (-35%) directly reduced biocidal ion concentrations to sub-lethal levels, facilitating rapid biofouling.
2. Electrode Passivation: The primary mechanical failure point was the accumulation of insulating salt deposits on the electrodes, which stifled the electrolysis process.
3. Maintenance Compliance Deficits: The incident was a result of systematic shortcomings in maintenance management. Insufficient monitoring of daily logs and failure to execute the scheduled 2-month cleaning intervals allowed reversible passivation to escalate into full system blockage.

To ensure continuous thermal management reliability, the following phased actions are recommended:

Short-Term Operational Actions:

1. Enhanced Log Verification: Engine room logs detailing Voltage/Amperage must be audited daily by senior engineers. A sustained current drop of 10% must trigger immediate cell inspection.
2. Strategic Sea Chest Management: Implement Standard Operating Procedures (SOPs) mandating the use of the High Sea Chest in shallow, estuarine, or high-sediment ports to protect the electrodes from silt blanketing.

Long-Term Preventive & Managerial Actions:

1. Strict PMS Adherence: Enforce the manufacturer-mandated Planned Maintenance System (PMS), specifically the mandatory opening and mechanical cleaning of the electrolytic cell every two months, regardless of apparent system output.
2. Competency Development: Conduct routine onboard training for junior

engineers emphasizing the electrochemical relationship between electrical current readings and actual biological protection (Faraday's principle).

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