METEOR STIP MARUNDA

pISSN : 1979 – 4746
eISSN : 2685 - 4775

Maritime Institute of Jakarta

ANALYSIS OF FRESH WATER GENERATOR OPERATION ON BOARD LNG/C SS. EKAPUTRA 1

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Submitted: 20/09/2023 ***Revised:*** 17/11/2023 ***Accepted:*** 07/12/2023 ***Published:*** 17/12/2023

Abstract

Fresh water is an essential commodity on board vessels, particularly on LNG/C SS. Ekaputra 1, where it is used as feed water for the main boiler to support high-pressure steam production. The vessel is equipped with a Fresh Water Generator (FWG), an auxiliary device that converts seawater into fresh water through evaporation and condensation processes. Following observation and interviews with the engineer responsible for the equipment, a decline in fresh water production from the FWG was identified. The research findings revealed two principal causes of the production decrease: leakage of the cooling tube in the condenser and the accumulation of salt deposits on the mesh separator. The cooling tube leakage was attributed to operational errors during the startup procedure, specifically the excessively rapid opening interval of the steam inlet valve for the air ejector, which caused rapid pressure changes and thermal differentials that compromised the material integrity of the cooling tube, leading to cracking and leakage. The salt deposits on the mesh separator were caused by the mineral salt content in seawater; under vacuum conditions in the flash chamber, the boiling point decreases and the temperature rises, causing the water to evaporate while the salt remains and accumulates on the mesh separator. Consequently, repairs to the leaking cooling tube and chemical cleaning of the mesh separator are necessary to restore optimal FWG production capacity.

Keywords: *fresh water generator, cooling tube, condenser leakage, mesh separator, salt deposit, vacuum distillation*

I. INTRODUCTION

The provision of fresh water on board ships is of fundamental importance for both crew welfare and vessel operations. Fresh water serves multiple critical functions, including supply of feed water for main boiler steam production, cooling medium for auxiliary machinery, and fulfillment of domestic consumption requirements for crew members. Under conventional circumstances, fresh water is obtained through shore-based bunkering operations; however, this process involves considerable time and cost, and the onboard storage tank capacity may not be sufficient to sustain the vessel's requirements throughout extended ocean voyages. Consequently, vessels engaged in long-distance or transoceanic routes are generally equipped with auxiliary equipment capable of producing fresh water from seawater through the process of distillation.

The Fresh Water Generator (FWG) is an auxiliary shipboard system designed to convert seawater into potable fresh water through evaporation and condensation processes. On board LNG/C SS. Ekaputra 1, the installed FWG operates on the two-stage flash distillation principle manufactured by Sasakura (Mitsubishi Heavy Industries). In this system, seawater is preheated in the feed water heater using steam at a pressure of 2.7 kgf until it reaches a temperature of 70–75°C. The heated seawater then enters the flash chamber under vacuum conditions of –590 mmHg at the first-stage flash chamber and –650 mmHg at the second-stage flash chamber. Under these reduced pressure conditions, the seawater boils at a lower temperature, producing water vapor that subsequently undergoes condensation to yield distillate water. The

distillate is then pumped into the distillate tank by the distillate pump for distribution throughout the vessel.

Under normal operating conditions, the FWG on LNG/C SS. Ekaputra 1 is designed to produce approximately 42 tons of fresh water per day. However, during the author's sea practice period, the fresh water production had declined to approximately 25 tons per day, which was insufficient to meet the vessel's daily consumption requirement of 30 tons. This production deficit posed a significant risk of fresh water shortage during the voyage. The investigation identified several operational problems, most critically the leakage of the cooling tube in the condenser unit, which occurred on June 28, 2022, while the vessel was sailing from Jakarta to Bintuni (Papua), and the accumulation of salt deposits on the mesh separator discovered on June 29, 2022.

Based on these operational challenges, this research was conducted to analyze the causes of the cooling tube leakage and the salt deposit accumulation on the mesh separator, and to identify appropriate corrective measures to restore the FWG to its optimal production capacity. The study addresses four primary research questions: (1) What causes the cooling tube leakage in the condenser? (2) How should the leaking cooling tube be repaired? (3) What causes salt deposits to accumulate on the mesh separator? (4) How should the salt deposit problem on the mesh separator be resolved?

II. LITERATURE REVIEW

A. Principles of Flash Distillation

Flash distillation is a thermal desalination process that exploits the principle of reduced boiling point under vacuum conditions. When seawater is heated and introduced into a chamber maintained at a pressure significantly below atmospheric pressure, the water vaporizes at a temperature well below its normal boiling point of 100°C. According to Taylor (2014), this process is particularly advantageous in the marine environment because it can utilize low-grade waste heat from the engine cooling system or steam from the main boiler as the heating medium. The two-stage flash design employed in the Sasakura system provides improved thermal efficiency by utilizing the latent heat of condensation from the first stage to supplement the heating in the second stage.

B. Components of the Fresh Water Generator System

The FWG system comprises several critical components that work in coordination to achieve the distillation process. The feed water heater raises the seawater temperature using steam before it enters the flash chamber. The flash chamber, maintained under vacuum by the air ejector system, provides the low-pressure environment necessary for evaporation. The mesh separator, installed between the evaporation zone and the condenser, functions as a demister to remove entrained seawater droplets from the rising vapor, thereby preventing salt carryover into the distillate. The condenser cools the purified vapor back into liquid form through heat exchange with seawater flowing through the cooling tubes. The air ejector creates and maintains the vacuum within the flash chamber using motive steam, and the distillate pump transfers the produced fresh water to the storage tank.

C. Cooling Tube Function and Failure Modes

The cooling tubes within the condenser section serve as the heat exchange surface where water vapor is cooled and condensed back into liquid fresh water. These tubes are exposed to both the distillate on the shell side and seawater on the tube side, making them susceptible to various failure modes. Thermal stress caused by rapid temperature changes during startup or shutdown procedures can induce fatigue cracking in the tube material. Additionally, corrosion from seawater exposure and erosion from high-velocity flow can progressively thin the tube walls. A leak in any cooling tube allows seawater to contaminate the distillate, which is detected through elevated salinity readings. When the salinity exceeds acceptable limits, typically measured in parts per million (PPM), the FWG must be shut down to prevent contaminated water from entering the fresh water system.

D. Mesh Separator and Salt Deposition

The mesh separator is a wire mesh filter element positioned in the flash chamber above the seawater surface to intercept entrained water droplets carried upward by the rising steam. Under vacuum conditions, the reduced boiling point causes seawater to evaporate, but the dissolved mineral salts do not evaporate with the water and instead remain behind. Over time, these salts accumulate and deposit on the mesh separator surfaces, progressively reducing the effective passage area for vapor flow. When salt deposits become excessive, the restricted vapor path significantly reduces the volume of steam reaching the condenser, thereby directly decreasing fresh water production output. Regular cleaning of the mesh separator using chemical scale removers is essential for maintaining optimal FWG performance.

III. RESEARCH METHOD

This research was conducted during the sea practice (Prala) period on board LNG/C SS. Ekaputra 1 from September 18, 2021, to August 26, 2022, a duration of approximately 11 months. The study adopted a descriptive qualitative approach based on direct observation of events occurring during the operational period and information

gathered from the engineering personnel responsible for the FWG system.

A. Data Collection Techniques

Data collection was performed using three techniques. First, direct observation was conducted on the FWG system during normal operation and during the incidents that led to production decline. The author recorded operational parameters, observed the physical condition of components during maintenance activities, and documented the sequence of events during the cooling tube failure and mesh separator cleaning. Second, interviews were conducted with the Second Engineer of LNG/C SS. Ekaputra 1, who held direct responsibility for the FWG operation and maintenance. Both structured and unstructured interview techniques were employed to obtain comprehensive technical information. Third, a literature study was performed using the manufacturer's instruction manual (Sasakura/Mitsubishi), relevant maritime engineering textbooks, and company maintenance records to supplement the primary data.

B. Data Analysis Method

The collected data were analyzed using the root cause analysis technique with the why–why method. This systematic approach involves repeatedly asking "why" a problem occurred until the fundamental root cause is identified. The method was selected for its effectiveness in tracing the chain of causation from the observable symptom (decreased fresh water production) through intermediate causes (cooling tube leakage and salt deposit accumulation) to the root causes (operational procedural errors and inadequate maintenance scheduling). The analysis results were used to develop both immediate corrective actions and long-term preventive recommendations.

Table 1. FWG Production and Operational Parameter Comparison

Parameter	Normal Condition	Incident Condition	Remarks
FW Production (ton/day)	42	25	–40.5%
Distillate Salinity (PPM)	< 10	> 50	Exceeded limit
1st Stage Vacuum (mmHg)	–590	[measured]	Verify reading
2nd Stage Vacuum (mmHg)	–650	[measured]	Verify reading
Steam Inlet Pressure (MPa)	1.2	[measured]	—
FW Heater Outlet Temp. (°C)	70–75	[measured]	—

Source: Engine Control Room Log and Instruction Manual, LNG/C SS. Ekaputra 1 (2022)

IV. RESULTS AND DISCUSSION

A. Cooling Tube Leakage in the Condenser

On June 28, 2022, while LNG/C SS. Ekaputra 1 was sailing from Jakarta anchorage to Bintuni, Papua, following a bunkering operation, the fresh water generator experienced a critical failure. Although the FWG had been operating normally at startup, after approximately two days of continuous operation, a cooling tube leakage was detected in the condenser unit. The salinity of the distillate water rose to over 50 PPM, far exceeding the acceptable limit, which rendered the FWG incapable of producing usable fresh water.

The root cause analysis using the why–why method traced the leakage to an operational error during the FWG startup procedure. The investigation revealed that the steam inlet valve for the air ejector had been opened at an excessively rapid interval during the initial startup sequence. This rapid opening caused a sudden and severe pressure drop within the chamber, creating a significant temperature differential across the cooling tube surfaces. The rapid thermal change induced accelerated expansion and contraction stresses in the tube material, exceeding its fatigue limit and resulting in cracking and eventual leakage. The correct startup procedure requires the steam inlet valve to be opened gradually while monitoring three key parameters: the air flow at the ejector condenser (ensuring no wet steam, indicated by white-colored discharge, is visible before further opening), the pressure gauge on the steam inlet valve (maintaining stable pressure before incremental adjustments until reaching the normal operating pressure of 1.2 MPa), and the pressure gauge on the chamber (confirming stable vacuum conditions before each incremental valve opening).

To locate the specific position of the leaking tube, the Second Engineer conducted a pressure leak test on the condenser unit. The identified leaking cooling tube was marked and subsequently replaced with a new tube. During the replacement procedure, particular care was taken to remove the damaged tube slowly and completely to avoid leaving residual fragments that could obstruct flow or damage adjacent tubes. The installation of the replacement cooling tube restored the condenser's integrity, eliminating the seawater contamination path and enabling the FWG to resume producing fresh water with acceptable salinity levels.

B. Salt Deposit Accumulation on the Mesh Separator

Following the cooling tube repair on June 28, 2022, the FWG was restarted for a trial operation. However, on June

29, 2022, the fresh water production remained suboptimal at approximately 25 tons per day, significantly below the design capacity of 42 tons per day. A comprehensive inspection was conducted by opening the manhole on the flash chamber, which revealed extensive salt deposits accumulated on the mesh separator surfaces.

The salt deposit formation on the mesh separator is attributed to the physicochemical behavior of seawater under vacuum conditions. Seawater contains substantial concentrations of dissolved mineral salts. Inside the flash chamber, the vacuum environment lowers the boiling point of water, causing the liquid water to evaporate at reduced temperatures. However, the dissolved mineral salts do not undergo phase change and remain behind in solid form. As the evaporation process continues, these salts progressively crystallize and accumulate on the mesh separator surface. When the salt deposits cover a significant portion of the mesh separator area, they obstruct the passage of water vapor from the evaporation zone to the condenser. This restriction directly reduces the volume of vapor available for condensation, resulting in decreased fresh water production output.

The corrective action implemented by the responsible engineer involved removing the mesh separator from the flash chamber and performing a chemical cleaning procedure. The mesh separator was immersed in a solution prepared with SAF acid powder chemical scale remover at a mixing ratio of 1:10 (chemical to water, or 10% chemical concentration). The mesh separator was soaked in this solution until the salt deposits were completely dissolved and detached from the mesh surfaces. After thorough cleaning, the mesh separator was reinstalled in the flash chamber. Upon restarting the FWG, the fresh water production capacity was restored to its normal operating level of approximately 42 tons per day.

C. Root Cause Analysis Summary

The root cause analysis revealed that both problems were interconnected through a common underlying factor: insufficient adherence to operational procedures and maintenance schedules. The cooling tube failure originated from improper startup technique, specifically the failure to follow the gradual valve opening procedure specified in the manufacturer's instruction manual. The salt deposit problem resulted from inadequate frequency of mesh separator inspection and cleaning. Both issues were exacerbated by insufficient monitoring of operational parameters and a lack of systematic documentation of maintenance activities within the Planned Maintenance System (PMS) framework. These findings underscore the critical importance of strict procedural compliance, regular preventive maintenance, and effective communication among engineering officers to ensure the reliable operation of shipboard auxiliary systems.

V. CONCLUSION

Based on the analysis and discussion presented in this study, the following conclusions are drawn regarding the decline in fresh water production from the Fresh Water Generator on board LNG/C SS. Ekaputra 1.

The cooling tube leakage in the condenser was caused by operational error during the FWG startup procedure, specifically the excessively rapid opening of the steam inlet valve for the air ejector. This rapid valve operation created sudden pressure drops and thermal differentials that induced material fatigue, cracking, and eventual leakage in the cooling tube. The leakage allowed seawater to contaminate the distillate, raising salinity above 50 PPM and halting fresh water production entirely. The corrective measure involved identifying the leaking tube through pressure testing and replacing it with a new component, while the preventive recommendation emphasizes strict adherence to the gradual valve opening procedure with continuous monitoring of air flow, steam pressure, and chamber vacuum parameters.

The accumulation of salt deposits on the mesh separator was caused by the crystallization of dissolved mineral salts from seawater under vacuum conditions in the flash chamber. As water evaporated at reduced boiling points, the salts remained in solid form and progressively covered the mesh separator surface, restricting vapor passage to the condenser and reducing production from 42 tons per day to 25 tons per day. The corrective measure involved chemical cleaning using SAF acid powder scale remover at a 10% concentration ratio, which successfully restored the mesh separator to its original condition.

Several recommendations are proposed to prevent recurrence of these issues. First, all engineering officers should adhere to the Planned Maintenance System and submit monthly maintenance reports documenting all scheduled and completed maintenance activities. Second, the engineer responsible for the FWG must regularly verify spare parts inventory against the spare part list and report the status to the Chief Engineer. Third, maintenance and repair activities must be conducted in accordance with the schedules prescribed in the manufacturer's instruction manual, with periodic inspection of all critical FWG components. Fourth, the correct operating procedure for the FWG should be posted at the local operating station to prevent operational errors during startup and shutdown sequences.

REFERENCES

[1] D. Taylor, Introduction to Marine Engineering, 4th ed. Oxford: Butterworth-Heinemann, 2014.

[2] P. A. Russell, Reeds General Engineering Knowledge for Marine Engineers, 3rd ed. London: Adlard Coles Nautical, 2014.
[3] Mitsubishi Heavy Industries Ltd., Instruction Manual for Sasakura Two-Stage Flash Type Distilling Plant. Nagasaki: MHI, 1989.
[4] D. Woodyard, Pounder's Marine Diesel Engines and Gas Turbines, 9th ed. Oxford: Butterworth-Heinemann, 2009.
[5] International Maritime Organization, International Safety Management Code (ISM Code), 4th ed. London: IMO Publishing, 2018.
[6] International Maritime Organization, SOLAS: International Convention for the Safety of Life at Sea, Consolidated ed. London: IMO Publishing, 2020.
[7] M. Arsyad and A. Z. Sultan, Manajemen Perawatan. Yogyakarta: CV Budi Utama, 2018.
[8] H. Kuiken, Diesel Engines for Ship Propulsion and Power Plants. Onnen: Target Global Energy Training, 2012.
[9] J. Sugiyono, Metode Penelitian Kuantitatif, Kualitatif, dan R&D. Bandung: Alfabeta, 2017.
[10] K. Ishikawa, Introduction to Quality Control. Tokyo: 3A Corporation, 1990.
[11] R. Harrington, Marine Engineering. Jersey City, NJ: SNAME, 1992.
[12] Badan Klasifikasi Indonesia, Rules for Classification and Construction of Seagoing Ships, Vol. III: Machinery Installations. Jakarta: BKI, 2019.
[13] A. Zainal, Ensiklopedia Manajemen, 5th ed. Jakarta: Bumi Aksara, 2018.
[14] T. Lamb, Ship Design and Construction, Vol. 2. Jersey City, NJ: SNAME, 2004.
[15] American Bureau of Shipping (ABS), Guidance Notes on Equipment Condition Monitoring Techniques. Houston: ABS, 2016.