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OPTIMIZATION OF INERT GAS SYSTEM MAINTENANCE TO PREVENT EXPLOSIONS IN THE CARGO TANKS OF THE MT. GRIYA CIREBON

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ABSTRACT

The MT. Griya Cirebon is a crude oil tanker whose loading and unloading operations rely heavily on the reliability of the Inert Gas System (IGS). The IGS serves to reduce the oxygen concentration inside the cargo tanks to prevent explosions caused by the mixing of hydrocarbon vapors with air. During the author's onboard project aboard the MT. Griya Cirebon between October 2021 and August 2022, two recurring failures disrupted unloading operations: the inert gas supply temperature rose to 60°C — far above the permissible limit of 5°C above seawater temperature — and an oxygen concentration in the inert gas reaching 6.54%, exceeding the maximum limit of 5% set by the IMO. This study employed a qualitative descriptive method using observation, interviews, and documentation to identify the root causes and formulate corrective actions. The results showed that the high inert gas temperature was caused by suboptimal scrubber unit performance due to inadequate maintenance of the seawater spray nozzles and the scrubber pump (impeller wear, clogged suction lines, and dirty filters). The high oxygen content was caused by a leak in the rubber flexible hose upstream of the inert gas blower, triggered by strong vibrations resulting from shaft/impeller misalignment and material fatigue in the rubber hose. Recommended solutions include scheduled maintenance in accordance with the manual, replacement of damaged impellers and rubber flexible hoses, realignment of the blower shaft, and calibration of the oxygen analyzer. Implementing these measures will restore IGS performance and ensure the safety and operational efficiency of the tanker's cargo operations.

Keywords: *inert gas system, scrubber unit, oxygen analyzer, flexible rubber hose, tanker safety, cargo tank explosion prevention. Six distinguishing characteristics set IoT systems apart from conventional network computing*

INTRODUCTION

Competition in the shipping industry today requires every company to maximize the operational efficiency of maritime transport services. Oil tankers play a strategic role in the distribution of fuel and petroleum products between regions. In addition to operational optimization, safety and damage prevention through the implementation of proper Standard Operating Procedures (SOPs) are also major concerns, particularly because oil cargoes produce flammable vapors and gases both during loading and while in transit.

If hydrocarbon vapors from the cargo mix with oxygen in the cargo tank atmosphere at a certain concentration, the potential for an explosion becomes very high and can result in property damage and loss of life. One incident that underscores the magnitude of this risk was the tanker explosion in Nigeria on December 23, 2020, which left six people dead and dozens injured. To prevent similar incidents, tankers are required to be equipped with an Inert Gas System (IGS), which serves to reduce the oxygen concentration in the cargo tank to below 5%, thereby rendering the tank's atmosphere non-flammable.

While conducting sea training aboard the MT. Griya Cirebon, the author discovered that the Inert Gas System—which is intended to be a safety measure—actually caused operational disruptions. On February 21, 2022, while the vessel was unloading at Jetty 2 of PHR Dumai, the IGS temperature alarm sounded and indicated a reading of up to

60°C, far above the normal limit of 5°C above seawater temperature. Furthermore, on December 7, 2021, at Jetty V B in Balikpapan, the oxygen analyzer alarm sounded and indicated an oxygen content of 6.54%, exceeding the maximum limit of 5%. Both incidents forced a temporary halt to unloading operations and required immediate corrective action by the engineer on watch.

Based on this background, the author formulates two main research questions: (1) what caused the high temperature of the inert gas to be supplied into the cargo tanks; and (2) what caused the high oxygen content in the inert gas. The objective of this study is to identify the causes of these two issues and to formulate optimal maintenance measures so that the Inert Gas System can operate in accordance with technical specifications and support the smooth and safe loading and unloading processes on tanker vessels.

LITERATURE REVIEW

An Inert Gas System is a system that uses flue gas from a boiler and feeds it into the cargo tank, thereby reducing the oxygen concentration inside the tank and preventing potential explosions or fires. This system is mandatory on crude oil tankers with a flash point above 60°C and a deadweight tonnage exceeding 20,000 metric tons [1]. The oxygen content in the inert gas permitted by the International Maritime Organization (IMO) must not exceed 5% by volume in the cargo tank atmosphere [2].

The basic principle of the IGS is to maintain a low oxygen level inside the tank so that the hydrocarbon-air mixture remains below the lower flammable limit. In addition to its safety function, the IGS also helps facilitate the unloading process because the positive pressure of the inert gas prevents a vacuum from forming inside the tank as the cargo is pumped out [3]. The typical composition of flue gas, which serves as a source of inert gas, includes 12–15% carbon dioxide, a maximum of 0.5% oxygen, approximately 10 ppm sulfur dioxide, ±0.01% carbon monoxide, and the remainder nitrogen [4].

The main components of the IGS consist of a scrubber that cleans and cools the flue gas to 5°C above seawater temperature, a demister separator that separates particles and water droplets, an inert gas blower that draws in and pressurizes gas into the cargo tank with a total capacity of 125% of the cargo pump's capacity [2], an oxygen analyzer that monitors oxygen levels, and a control system that manages the operation of all equipment and triggers an alarm in the event of abnormal conditions [4]. In the hazardous area, there is a deck water seal that prevents the backflow of hydrocarbon gas, a deck mechanical non-return valve, a deck isolating valve, and a P/V breaker.

According to Marton [5], the IGS operation begins at the boiler; flue gas passes through the intake valve to the scrubber to be cooled and cleaned of ash and sulfur oxides, then passes through a demister to be separated from water particles, is drawn in by a blower, directed to the water seal deck, and distributed to the cargo tanks via the main pipe on the main deck. Some common causes of IGS malfunction include excessively high oxygen levels due to outside air leaking into the system, incomplete boiler combustion, and the inability to maintain positive inert gas pressure in the tank.

Previous research by Silvia et al. [6] on the performance of inert gas generators in achieving a 3% oxygen content confirmed that periodic maintenance of the cooling components, blower, and oxygen sensor has a significant effect on the stability of the system's oxygen output. Regulations regarding IGS on tankers are also strictly governed by SOLAS Chapter II-2 and IMO Resolution MSC.98(73) on the FSS Code, which emphasize the importance of periodic maintenance and testing of the system by the chief engineer.

RESEARCH METHOD

A. Time and Location of the Study

The research was conducted while the author was undergoing a sea internship for approximately ten months, from October 8, 2021, to August 24, 2022, aboard the MT. Griya Cirebon, owned by PT. Hutama Trans Kencana. Data collection was primarily carried out during the vessel's discharge operations, as the Inert Gas System was in operation at that time.

B. Research Type and Approach

This study employs a qualitative descriptive approach. According to Winartha [7], the qualitative descriptive method analyzes, describes, and summarizes various conditions and situations based on data collected through observations of issues occurring in the field. This study aims to provide an explanation of the events that occurred while the author was conducting his internship aboard the MT. Griya Cirebon and to systematically and accurately describe the facts regarding the relationships among the events under investigation.

C. Data Sources

The data sources in this study consist of primary and secondary data. Primary data were obtained directly from informants through observation and interviews regarding issues occurring in the Inert Gas System on the MT. Griya Cirebon. Secondary data were obtained from third-party sources, namely instruction manuals, literature, and previous research findings related to the subject of this study [8].

D. Data Collection Techniques

The data collection techniques used included direct observation of the performance of the Inert Gas System components during loading and unloading; interviews with the Second Engineer, who is the officer directly responsible for the operation and maintenance of the IGS; and a review of documentation, including the Kashiwa Inert Gas System instruction manual, piping diagrams, the inert gas blower shaft diagram, the ship's particulars, the crew list, and photographic documentation from the time of the incident.

E. Research Instruments

The population in this study consists of all machinery systems on board the MT. Griya Cirebon, while the sample selected is the Kashiwa Inert Gas System as the primary object of observation. Supporting instruments used include observation sheets, interview sheets, a documentation camera, and readings from measuring instruments on the IGS control panel, such as the scrubber pump pressure gauge, temperature indicator, and oxygen analyzer.

F. Data Analysis Techniques

The data obtained were analyzed using qualitative descriptive methods, involving the stages of data reduction, data presentation, and drawing conclusions. Each problem was analyzed using cause-and-effect diagrams to identify the contributing factors; alternative solutions were then formulated, evaluated, and the best solution was determined based on technical, cost, and safety considerations.

RESULTS AND DISCUSSION

MT. Griya Cirebon is a crude oil tanker that routinely conducts crude oil loading and unloading operations between domestic ports. The smooth operation of loading and unloading is closely related to the optimal operation of the Inert Gas System, as outlined in the instruction manual. The ship's specifications are presented in Table 1.

Table 1. Ship's Particulars: MT. Griya Cirebon

Parameter	Specifications
Vessel Name	MT. Griya Cirebon
Vessel Type	Oil Tanker (Crude Oil)
Flag	Indonesia
IMO Number	9279587
Year Built	2003 (Imabari Shipbuilding Co., Ltd., Japan)
GRT / NRT	28,828 / 12,962 metric tons
DWT	34,993 metric tons
Length Overall (LOA)	179.99 m
Sailing Route	Inter-island (Domestic)
IGS System	Kashiwa Inert Gas System

Source: Ship's Particulars MT. Griya Cirebon (2022)

During my sea training, I encountered two major issues with the Inert Gas System that hindered the efficiency of loading and unloading operations. These two issues are described below.

A. High Temperature of the Inert Gas to Be Supplied to the Tanks

On February 21, 2022, at 07:00 LT, while the MT Griya Cirebon was unloading cargo at Jetty 2 of PHR Dumai, the temperature alarm on the Inert Gas System sounded and the monitor indicated that the temperature had reached 60°C. This value far exceeded the normal limit of 5°C above seawater temperature, as specified by the Kashiwa Inert Gas System [4]. An investigation by the author and the Second Engineer revealed that the flue gas temperature exiting the scrubber tank remained high because the cooling water supply from the scrubber pump did not reach the required pressure. The pump's operating pressure was recorded at 1.6 bar, whereas the normal required pressure is 2.0 bar. A summary of the contributing factors is presented in Table 2.

Table 2. Analysis of Causes of High Inert Gas Temperature

Causes	Field Conditions	Impact on the System
Scrubber unit temperature sensor	The sensor is in good condition and the readings reflect the actual conditions	Not the primary cause
Seawater spray nozzle	Nozzle is dirty due to missed maintenance	Cooling water spray is uneven; heat absorption is reduced
Scrubber pump — impeller	The impeller is experiencing abrasion and corrosion (scouring) due to seawater	Pump pressure drops to 1.6 bar (normal 2.0 bar)
Scrubber pump — suction line	Blockage caused by debris, mussels, and barnacles	Cooling water flow to the scrubber is reduced
Scrubber pump — filter/strainer	Filter is clogged with debris	Pump suction is suboptimal; pressure drops

Source: Field observations at MT. Griya Cirebon (2022)

Further inspection revealed three concurrent causes affecting the scrubber pump: impeller damage due to abrasion-corrosion (scouring) from seawater impact; blockage of the suction line by debris and marine life such as clams and barnacles; and a filter clogged with debris. All three issues reduced the flow rate and pressure of the cooling water, preventing the seawater spray nozzles on the scrubber unit from producing an optimal spray pattern. Compounded by dirty nozzles resulting from infrequent scheduled maintenance, heat absorption from the flue gas was significantly reduced.

The impeller damage was resolved by replacing it with a new part; the option to recondition it was not chosen because it could potentially cause the pump to run out of balance and damage other components. The suction line and filter were cleaned according to the instruction manual, with the frequency increased to every time the pump is started. Maintenance of the seawater spray nozzle, which was previously performed once a year, was increased to once every six months to keep the nozzle clean even though the scrubber pump was not yet operating at full capacity. Following these measures, the pump pressure stabilized at 2.0 bar, and the temperature of the inert gas dropped to the normal range.

B. High Oxygen Levels in Inert Gas

On December 7, 2021, at 5:00 a.m. local time, while the vessel was unloading cargo at Jetty V B in Balikpapan, the oxygen analyzer alarm sounded and indicated an oxygen level of 6.54%. This value exceeded the maximum limit of 5% as stipulated in IMO Resolution A.567(14) and SOLAS Chapter II-2 [1], [2]. Because high oxygen levels have the potential to trigger an explosion, the system had to be shut down and unloading operations were interrupted. A summary of the contributing factors is presented in Table 3.

Table 3. Analysis of Causes of High Oxygen Levels in Inert Gas

Causes	Field Conditions	Impact on the System
Oxygen Analyzer Sensor	The sensor is in good condition, but requires calibration before each use	Accurate readings after recalibration
Vibration in the Inert Gas Blower	The shaft and impeller are not properly aligned; the fastening bolts on the bed plate are not tight	Significant vibration has caused cracks in the flexible rubber pipe
Fatigue of flexible rubber pipe material	Prolonged exposure to high temperatures of inert gas	Microscopic cracks appear and develop into leaks
Leaks in the flexible rubber pipe	Cracks in the pipe upstream of the inert gas blower	Outside air is drawn in by the blower; O_2 concentration rises to 6.54%

Source: Field observations at MT. Griya Cirebon (2021)

The investigation identified a leak in the flexible rubber pipe upstream of the inert gas blower, which allowed outside air to be drawn into the system by the blower's rotation. A root cause analysis revealed two mutually reinforcing factors. First, significant vibration from the inert gas blower due to an unbalanced shaft and impeller installation, as well as loose fastening bolts on the bed plate/housing. The second factor was material fatigue in the flexible rubber pipe caused by prolonged exposure to the high temperature of the inert gas. The combination of vibration and material fatigue accelerated the formation of microscopic cracks, which developed into macroscopic cracks.

The corrective actions taken were to replace the cracked flexible rubber pipe, then repair the mounting on the bed plate/housing, and reposition the shaft and impeller to restore rotational balance. After the leak was sealed, the oxygen level was reduced by venting the contaminated inert gas and recalibrating the oxygen analyzer. The calibration procedure followed the Kashiwa manual: set AIR V. (CVA) and ZERO GAS V. (CVZ) to the closed position, turn on the power switch and wait 3 minutes, select the 10% O_2 measurement range, set the filter pressure regulator to 1.5 kg/cm², open AIR V. to supply air to the sensor, and lock the reading once it stabilized.

Regular calibration of the oxygen analyzer is essential to maintain accuracy, as electrochemical sensors can degrade over time and be affected by environmental factors such as temperature, humidity, and pressure. Once all measures have been implemented, the oxygen analyzer's readings return to the normal range of less than 5%, and loading and unloading operations can safely resume.

C. Troubleshooting Evaluation

Scheduled maintenance in accordance with the instruction manual was chosen because it ensures the continued operational reliability of components and extends the service life of the equipment, although it requires additional attention and effort from the on-duty operator. For components that have experienced significant wear, such as the scrubber pump impeller and the rubber flexible pipe, replacement was chosen over reconditioning because it provides better operational reliability, even though it entails higher costs. Increasing the cleaning frequency of the seawater spray nozzle from once a year to once every six months, and cleaning the strainer every time the pump is used, has proven to restore the scrubber's performance to optimal conditions.

CONCLUSION

Based on an analysis of the two main issues with the Inert Gas System on the MT. Griya Cirebon, it can be concluded that the high temperature of the inert gas, which reached 60°C, was caused by suboptimal performance of the scrubber unit due to inadequate maintenance of the seawater spray nozzle and scrubber pump. The scrubber pump pressure dropped from 2.0 bar to 1.6 bar due to impeller damage caused by abrasion and corrosion, blockage of the suction line by marine organisms, and a filter clogged with debris. Repairs were carried out by replacing the impeller, cleaning the suction line and filter, and increasing the frequency of maintenance on the scrubber nozzles.

The high oxygen level in the inert gas—reaching 6.54%—was caused by a leak in the flexible rubber pipe upstream of the inert gas blower. The leak was triggered by significant vibration from the inert gas blower due to an unbalanced installation of the shaft and impeller, as well as material fatigue in the flexible rubber pipe caused by exposure to high temperatures. Repairs were carried out by replacing the rubber flexible pipe, repositioning the shaft and impeller, tightening the fasteners on the bed plate/housing, purging the contaminated inert gas, and recalibrating the oxygen analyzer.

It is recommended that all ship engineers implement the Planned Maintenance System (PMS) for the Inert Gas System in accordance with the instruction manual, adjusting the maintenance frequency based on usage intensity; ensure that all piping lines are free of leaks before the system is operated; and calibrate the oxygen analyzer before each use to ensure the accuracy of readings and the safety of loading and unloading operations.

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