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Research Article

Situation awareness information requirement for marine engine room monitoring at the future shore control center

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Abstract

Information integration for explicit comprehension can be highly challenging in a large-scale system with interconnected equipment under the influence of the environment. This presents a great challenge in acquiring and maintaining situation awareness during the transition from traditional to remote and, eventually, to autonomous operation. However, the maritime industry appears to approach situation awareness in a highly restricted manner that focuses on visual and navigational awareness only, resulting in no support system for engine room monitoring. This research conducted a goal-directed task analysis with thirty-one subject matter experts, with an average sea experience of 9.78 years, to investigate situation awareness in the engine room. As a result, the situation awareness information requirements for nine machineries and twelve systems are developed. The findings reveal that numerous perception elements, and their complex combinations, for higher-level awareness comprise situation awareness, and situation awareness deterioration is highly likely, due to the replication or reproduction of ship sense and expanded system coverage to compensate for the lack of marine engineers on ships. This research proposes that presenting higher-level situation awareness information in consideration of schema instantiation could be a promising alternative to developing and optimising the situation awareness support system for engine room monitoring at the future shore control center.

1. Introduction

Maritime 4.0 is the pursuit of transforming the conventional maritime industry into a greener and smarter industry through vessel design, construction, operations, and shipping (Sullivan et al., 2020). It has become a main focus within the maritime research community, inspiring many publications that quadrupled within eight years after 2010 (Sanchez-Gonzalez et al., 2019). Due to the rapid technological advances, it is even envisioned as a disruptive opportunity, requiring a high level of cooperation of regulatory bodies, industrial partners, labor organisations and other stakeholders (Pribyl & Weigel, 2018).

One of the crucial fields in Maritime 4.0 is the Maritime Autonomous Surface Vessel (MASS), which shares many traits similar to self-driving land and unmanned aerial vehicles. The MASS is projected to be embedded with a self-navigating capability and automated operation assistant systems, such as a voyage planner, and located at the final phase of maritime autonomy, according to the International Maritime Organization (IMO), shown below (IMO, 2021). While none of the phases incorporates specific timeline projections, a mandatory goal-based MASS Code is expected to enter into force in 2028 for regulatory scoping, and the second and third degrees have been the targets of several MASS projects.

- Degree One: Ship with automated processes and decision support
- Degree Two: Remotely controlled ship with seafarers on board
- Degree Three: Remotely controlled ship without seafarers on board
- Degree Four: Fully autonomous ship

Remote operation in the second and third degrees is of particular importance within the maritime industry, as not only an intermediate step to bridge the gap between conventional and autonomous ships, but as a feasible alternative with promising economic and safety benefits. Remote operation eliminates the need to accommodate seafarers on each vessel and enables the monitoring of multiple vessels simultaneously with fewer people at the shore control center. This allows hull simplification and construction, maintenance and operation cost reduction, because cabins and auxiliary machinery for sea-life support are no longer needed. For instance, Allal et al. (2018) showed that removing auxiliary systems could save around 74 % of the total energy consumption in conventional vessels. Slow steaming becomes less economically demanding due to the increased cargo space. Monitoring multiple vessels simultaneously at the shore control center, instead of allocating seafarers on each vessel, helps reduce labor costs. In addition, remote operation eliminates traditional stressors, such as motion sickness, sleep deprivation, and the sense of isolation, known to contribute to performance decline, and may solve the problem of the significant shortfall of young seafarers in the future (Shenoi et al., 2015).

Conversely, past research has demonstrated that remote operation renders situation awareness a crucial challenge. For instance, Yanco and Drury (2004) examined the situation awareness of remote operators interacting with urban search and rescue robots, and discovered that all subjects reported a loss of robot orientation and spent an average of 30 % of the time gaining situation awareness. Similarly, Riley and Endsley (2004) reported immediate disorientation upon a sudden change of the environment, e.g., entering a smoke-filled space, and reorientation appeared to require substantial cognitive efforts, taking several minutes to regain awareness of the remote robots. Two autonomous ship projects showed this to be the case for future shipping. MUNIN (Maritime Unmanned Navigation through Intelligence in Networks), a collaborative research project co-funded by the European Commission, investigated the potential of autonomous vessels across autonomous navigation and autonomous engine monitoring capabilities at the shore control center. The project concluded that monitoring all measurements from the engine room was technically possible. However, the operator must maintain their situation awareness to understand their context, and take countermeasures when human intervention is required. They further suggested that a user-centered design will be a cornerstone in developing the shore control center (MacKinnon et al., 2015). Another project was AAWA (the Advanced Autonomous Waterborne Applications), a € 6.6 million project funded by Tekes, examining the economic, social, legal, and technical aspects to develop a preliminary design of the autonomous vessel. They emphasized that the lack of ship sense (e.g., visual, auditory, olfactory, and tactile senses) at the shore control center would be a critical challenge for operators in understanding the situation, and the absence of full comprehension of the ship's condition can lead to incidents (AAWA, 2016). Similarly, a recent focus group study reported that visibility was involved with a majority of perceptual information comprising navigational situation awareness, followed by body balance, thermal sense, sound, and smell (Yoshida et al., 2020).

The lessons learnt from two pioneer projects appear to have been appreciated in recent MASS initiatives since 2020, including a) Korea Autonomous Surface Ship Project (KASS, 2023) and b) Designing the Future of Full Autonomous Ship (NYKLINE, 2020). The projects are underway to develop a situation awareness system through automated object detection and 3D surrounding bird's eye view through virtual reality as a part of the intelligent navigation system. However, looking closer, the applications are limited to visual and navigational awareness, and attempt to address situation awareness issues through automation. Most importantly, no situation awareness support systems are found for engine room monitoring, albeit that ship maneuvering is not the sole task that demands situation awareness. This misinterpretation of situation awareness appears to result from a narrow and direct adoption of the term from particular domains, such as automobile and aviation, except for air traffic control.

In fact, situation awareness issues have been a focus of numerous sectors, including cyber defense (Kott et al., 2015), healthcare (Dekker, 2015), power plants (Burns et al., 2008) and offshore plants (Sneddon et al., 2017). Healthcare practitioners, cyber securities, and power plant operators do not drive any objects. Still, their awareness of patients, cyber systems, and power plants is vital in a similar fashion to monitoring in the engine room, which has, to date, been understood to be resolved by automation and, as a result, neglected. The situation awareness studies in the nuclear power plant explicitly indicate the criticality of situation awareness during system monitoring, and imply that engine room monitoring is not an exception (Reinerman-Jones et al., 2019; Wang et al., 2022; Zuo et al., 2020). For instance, upon investigating forty-one nuclear power plant incidents, Patrick et al. (2007) discovered that an action performed or omitted was the most prevalent problem, accounting for 19 incidents. This was followed by a lack of awareness of plant and subsystem status, found in 18 incidents. Similarly, Solberg et al. (2023) examined 58 incidents during the planned outage of nuclear power plants, and discovered that over half of incidents involved comprehension errors, such as lack of mental models and over-reliance on default values. This was followed by perception and projection errors, each accounting for 14 events.

Mental models, internal representations of an object or phenomenon, or schemata (i.e., prototypical mental models) provide a fundamental basis for acquiring situation awareness (Endsley, 1995b). They direct attention and assist information classification at the perceptual level, e.g., knowing where to look for desired information under a particular instance, and provide mental layouts to integrate information and form comprehension and projection of future states (Endsley & Jones, 2013). These mental layouts are compared to the environment to gain situation awareness through pattern matching, and often provide default values for missing information, explaining behavioral differences between experts and novices in highly uncertain environments (Endsley, 2016). This underlines the importance of investigating what information constitutes mental models and situation awareness in developing support systems.

However, situation awareness across engine room monitoring has received no attention in the maritime research community and industry, albeit with some effort being made to identify situation awareness information requirements for navigation (Haffaci et al., 2021; Sharma et al., 2019). The information requirement is vital for a deeper understanding of situation awareness in the target domain and for developing the domain-specific, objective assessment of situation awareness, the Situation Awareness Global Assessment Technique (SAGAT) (Endsley, 2017; Endsley & Rodgers, 1994). Hence, this research aims to develop the situation awareness requirements for engine room monitoring through a goal-directed task analysis, following a guideline (Endsley et al., 1998; Endsley & Rodgers, 1994).

2. Materials and methods

This research was approved by the University of Tasmania Human Research Ethics Committee. Informed consent was obtained from each participant.

2.1 Goal-directed task analysis

The goal-directed task analysis segments a mission into the overall goal, subgoals, and objectives, and discloses underlying information elements required to meet each objective. These elements are categorized into perception, comprehension, and projection levels to establish the situation awareness information requirement. The goal-directed task analysis has broadly been employed in multiple industries, including nuclear power plants (Ma et al., 2006), brigade operations

(Bolstad et al., 2002), fire response teams (Rezaeifam et al., 2023), ship navigation (Sharma et al., 2019), paramedics (Abd Hamid & Waterson, 2010) and aviation (Endsley et al., 1998).

According to (Endsley et al., 1998), a goal-directed task analysis is conducted in four steps: previous task analysis review, expert elicitation, initial review, and final review of the task analysis. Reviewing existing documents helps understand the task domain and allows the designing of questions to elicit expert knowledge. A preliminary goal structure and information elements are identified during expert elicitation, which are further developed in the last two review stages. This research conducted goal-directed task analysis in two phases: expert elicitation and final review. This was due to the unavailability of previous situation awareness studies in engine room monitoring and the difficulty of having consecutive interviews with experienced seafarers for an extended period.

2.2 Participants

Previous goal-directed task analysis was typically engaged between seven (e.g., navigators) and eighteen (e.g., paramedics) subject matter experts (Abd Hamid & Waterson, 2010; Sharma et al., 2019). In this study, thirty-one senior engineers (i.e., chief and second engineers), with an average sea experience of 9.78 years, were recruited through researchers' professional contacts. Before the interviews, participants were given an information sheet and consent form and were assigned to the elicitation or final review stage based on their availability for consecutive interview sessions. Also, they were informed of three levels of situation awareness, so as not to restrict their responses to certain types of information. Interviews were conducted online, except for three cases where participants were available onsite. All interviews were audio-recorded for post-analysis upon their agreement.

2.3 Expert elicitation

Two second engineers, with an average sea experience of 6.25 years, served as subject matter experts and participated in 30 one-to-one interview sessions. Each session lasted between 1.5 and 2 hours, and the total interview length was around 50 hours. Upon developing a basic goal structure, the following questions were developed to ascertain situation awareness information on each objective.

1. What reflects the main functionality of a system or machinery?
2. What reflects the overall system or machinery status?
3. If there are changes in system or machinery states, what are the causes of such changes?

A list of machinery types and systems for the analysis was selected through consultations with two experts, considering their general usage on commercial diesel-driven vessels. In this study, a system was understood as linkages between machinery, similar to the role of blood veins (system) and organs (machinery), instead of functionalities of each engine room compartment, such as propulsion or ventilation systems. Due to the difficulty in clearly separating machinery and systems, information elements were aggregated when the role of machinery within the system was crucial. This includes steam service systems for auxiliary boilers, compressed air systems for air compressors, fuel purification systems for purifiers, and bilge systems for oily water separators. The systems were further divided into subsystems when each subsystem played a unique role. This includes fuel oil, lubricating oil, and steam systems. As a result, nine types of machinery and twelve systems were included in the analysis.

Lastly, three types of questions on each type of machinery and system were developed to elicit a broad spectrum of situation awareness information involved in typical engine room monitoring tasks in practice. This included current status evaluation, intervention requirement, and future projection. Each type of machinery or system had at least one type of question. As a result, thirty-nine questions were developed, consisting of fifteen acceptability, fifteen interventions, and nine projection questions, as shown in **Table 1**.

2.4 Final review

Twenty-nine chief and second engineers, with an average sea experience of 10 years, participated in the one-to-one interview sessions. Ten participants were chief engineers, with an average experience of 17 years; the rest were second engineers, with an average experience of 6.36 years. Each session lasted between 20 minutes and 1.8 hours, and the total interview length was 28 hours. The participants were guided to answer three goal-directed task analysis questions, and monitoring task questions were developed from the expert elicitation phase. The typical monitoring task questions were randomly selected and employed until participants' responses on information elements appeared saturated due to the interview time constraint.

Table 1 List of typical monitoring task questions. Systems and machinery are denoted by S and M.

Machinery and System Type		Question Type	Question
M1	Main engine (2 Stroke)	Intervention	Q1. Is there a need to adjust the speed?
		Intervention	Q2. Do you need to change the fuel?
		Intervention	Q3. Is there a need to adjust the cylinder oil quantity?
		Acceptability	Q4. Is the sump tank level appropriate?
		Acceptability	Q5. Is cylinder compression appropriate?
M2	Generator (4 Stroke)	Projection	Q1. Will parallel operation be needed?
		Acceptability	Q2. Is cylinder compression appropriate?
M3	Auxiliary boiler	Intervention	Q1. Does leakage require immediate action?
		Acceptability	Q2. Is there a need to adjust the current boiler start and stop pressure?
		Intervention	Q3. Is blow-down needed?
		Acceptability	Q4. Do economizers generate sufficient steam?
M4	Freshwater generator	Projection	Q1. Will the freshwater production rate be acceptable?
M5	Air compressor	Acceptability	Q1. Is the running hour of the compressor acceptable?
M6	Purifier	Projection	Q1. Will the purification rate be sufficient to meet the fuel demand?
		Intervention	Q2. Is there a need to adjust the heater temperature setting?
M7	Oily water separator	Acceptability	Q1. Is the bilge discharge plan acceptable?
		Projection	Q2. Is there a need to arrange filter renewal?
M8	Air handling unit	Acceptability	Q1. Is the ratio of recirculation and fresh air appropriate?
		Projection	Q2. Will heating or cooling be required?
M9	Steering gear	Intervention	Q1. Is there a need to adjust the rudder response speed?
S1	Fuel oil transfer	Intervention	Q1. Is there a need to change the bunker tank?
		Intervention	Q2. Is heating required?
S2	Fuel oil service and overflow	Acceptability	Q1. Is a timer of auto-filter acceptable?
		Acceptability	Q2. Is the increase in the overflow tank level acceptable?
		Intervention	Q3. Is fuel transfer required from the overflow tank?
S3	Sludge	Intervention	Q1. Is there a need for sludge evaporation?
S4	Lube oil transfer	Projection	Q1. Will there be a need for replenishment or renewal?
S5	Lube oil service	Acceptability	Q1. Is a timer of auto-filter acceptable?
S6	Steam condensation	Acceptability	Q1. Is the change in cascade level acceptable?
S7	Steam feed water	Acceptability	Q1. Is chemical dosage acceptable?
S8	Seawater cooling and MGPS	Projection	Q1. Will the current flow rate provide sufficient cooling?
		Projection	Q2. Will an anode renewal be required?
		Intervention	Q3. Is there a need to adjust the anode current?
S9	Central cooling water	Acceptability	Q1. Is the chemical dosage rate acceptable?
		Projection	Q2. Will there be a need to increase cooling capacity?
S10	Jacket cooling water	Acceptability	Q1. Is the chemical dosage rate acceptable?
		Intervention	Q2. Is there a need for a cooling water temperature setting adjustment?
S11	Freshwater service	Intervention	Q1. Is there a need to change the freshwater tank?
S12	Stern tube	Intervention	Q1. Is there a need to change the air or lubricating oil pressure?

3. Results

The goal-directed task analysis revealed matches in respect of the overall goal, two subgoals, and six objectives. The overall goal of engine room monitoring is to "perform safe and efficient engine room monitoring”. The main goal comprises two subgoals corresponding to ensuring the performance of machinery or systems within the engine room. Three objectives were found on each subgoal, identical to both machinery and systems: a) check the main functionality, b) evaluate the overall status, and c) identify sources of influence on machinery (or system) performance. As a result, twenty-one situation awareness information requirements are developed across machinery types and systems in the engine room. Due to the large volume of this research, the goal-directed task analysis and situation awareness information requirement for the auxiliary boiler are presented in **Tables 2** and **3**, respectively. Situation awareness information requirements and goal-directed task analysis for other machinery types and systems can be found in **Appendixes A** and **B**.

Table 2 Goal-directed task analysis for auxiliary boiler. System and machinery are denoted by S and M in italics.

Goal	**Perform safe and efficient engine room monitoring**
Subgoal 1.	Ensure machinery performance
Objective 1.1	Check the main functionality *Q1. What reflects the main functionality of the machinery?*
Situation awareness information	▪ Adequacy of steam production o Boiler auto stop and start pressure o Target steam pressure o Current steam pressure o Boiler load
Objective 1.2	Evaluate the overall status *Q2. What reflects the overall machinery status?*
Situation awareness information	▪ Adequacy of boiler operation mode o Boiler auto stop and start pressure o Target steam pressure o Current steam pressure o Dump steam setting pressure o Safety valve setting pressure ▪ Consistency of boiler water level o Deviation of current boiler water level fro m boiler setting water level ▪ Boiler setting water level ▪ Current boiler water level o Low alarm level o Low low alarm level o High alarm level ▪ Adequacy of boiler burner o Boiler load o Adequacy of fuel supply ▪ Boiler fuel pressure at nozzle ▪ Boiler fuel temperature at nozzle ▪ Ampere of rotary cup motor o Adequacy of boiler combustion air supply ▪ Boiler fan motor ampere ▪ Boiler fan damper position o Adequacy of boiler combustion status ▪ Colors of • Boiler exhaust gas • Flame o Boiler exhaust gas temperature ▪ Efficiency of heat exchange o Boiler ▪ Combustion chamber temperature ▪ Boiler exhaust gas temperature ▪ Boiler load o Exhaust gas boiler (economizer) ▪ Differential pressure of economizer gas side • Exhaust gas inlet pressure • Exhaust gas outlet pressure ▪ Temperature difference of economizer gas side • Exhaust gas inlet and outlet temperature ▪ Temperature difference of economizer waterside • Boiler water inlet and outlet temperature ▪ Adequacy of fuel consumption rate o Boiler daily fuel consumption rate ▪ Boiler fuel flowmeter o Boiler average fuel consumption rate during ▪ Sea-trial ▪ Past voyage under similar load o Boiler load
Objective 1.3	Identify sources of influence on machinery performance *Q3. If there are changes in machinery states, what are the causes of such changes?*
Situation awareness information	Within the system ▪ Performance degradation o Mechanical parts o Renewable or cleanable parts o Running hour o Maintenance interval ▪ Boiler load ▪ Operation of economizer ▪ Changes in heating demand ▪ Fuel type ▪ Fuel quality o Bacteria or micro-organisms Impact of relevant systems ▪ Impact on fuel supply *S2. FO Service & Overflow* ▪ Impact on fuel quality *M6. Purifier* ▪ Impact on freshwater quality *S11. Freshwater Service* Impact of environment ▪ Impact on system heat loss o Weather o Seasons o Seawater temperature ▪ Impact on combustion air o Engine room pressure ▪ Impact on steam production o Rolling and pitching

Table 3 Situation awareness information requirements for auxiliary boiler for four typical monitoring scenarios, denoted by Q and question numbers.

Level 1 Situation Awareness Information Element (Perception)

- Boiler
  - Load
  - Exhaust gas temperature
- Steam pressure
  - Current steam pressure **[Q1 & 2]**
  - Target steam pressure **[Q1 & 2]**
  - Auto stop and start pressure
  - Dump steam setting pressure **[Q2]**
  - Safety valve setting pressure
- Water level
  - Current boiler water level **[Q1 & 3]**
  - Boiler setting water level
    Low alarm level
  - Low low alarm level
  - High alarm level **[Q3]**
- Boiler burner
  - Fuel pressure at nozzle
  - Fuel temperature at nozzle
  - Ampere of rotary cup motor
  - Fan motor ampere
  - Fan damper position
- Combustion chamber
  - Temperature
  - Colors of
    - Flame
    - Exhaust gas
- Economizer
  - Exhaust gas inlet and outlet temperature **[Q4]**
  - Boiler water inlet and outlet temperature **[Q4]**
  - Exhaust gas inlet and outlet pressure **[Q4]**
- Fuel
  - Type
  - Quality
- Bacteria or micro-organisms
- Daily fuel consumption rate **[Q1]**
  - Boiler fuel flowmeter
- Average fuel consumption rate during
  - Sea-trial
  - Past voyage under similar load
- Boiler water quality **[Q3]**
  - Alkalinity **[Q3]**
  - Chloride **[Q3]**
  - Ph **[Q3]**
  - Phosphate **[Q3]**
  - Debris **[Q3]**
  - Blowdown interval **[Q3]**
- System heating
  - Target temperature of systems in use of steam **[Q1 & 2]**
  - Current systems temperature **[Q1 & 2]**
- Boiler operation
  - Running hour **[Q2]**
  - Running hour at given engine RPM **[Q4]**
  - Frequency of boiler cycle **[Q2 & 4]**
  - Operation of economizer **[Q2]**
- Types of fuel in use for **[Q2]**
  - Main engine **[Q2]**
  - Generator **[Q2]**
- Weather **[Q2]**
- Seasons **[Q2]**
- Seawater temperature **[Q2]**
- Engine room pressure
- Pitching and rolling
- Bilge accumulation rate **[Q1]**
- Bilge holding tank level **[Q1]**
- Freshwater consumption rate **[Q1]**
- Freshwater production rate **[Q1]**

Level 2 Situation Awareness Information Element (Comprehension)

- Adequacy of
  - Steam production
  - Boiler operation mode
  - Boiler burner
  - Fuel supply
  - Combustion air supply
  - Combustion status
  - Fuel consumption rate
- Efficiency of **[Q2 & 4]**
  - Heat exchange **[Q4]**
  - Boiler operation mode **[Q2]**
- Water level
  - Consistency of boiler water level
  - Surplus of boiler water level **[Q3]**
- Impact of steam leakage on **[Q1]**
  - Location **[Q1]**
    - Vulnerability to temperature **[Q1]**
    - Variation of systems temperature in use of steam **[Q1 & 2]**
    - Vulnerability to moisture **[Q1]**
  - Steam production **[Q1]**
  - System heating **[Q1]**
  - Boiler operational continuity **[Q1]**
- Impact of environment on **[Q2]**
  - System heat loss **[Q2]**
  - Combustion air
  - Steam production
- Deviation of current boiler water level from boiler setting water lev el
- Differential pressure of economizer gas side **[Q4]**
- Temperature difference of **[Q4]**
  - Economizer gas side **[Q4]**
  - Economizer water side **[Q4]**
- Changes in heating demand
- Status of engine load **[Q4]**
- Remaining freshwater quantity in tanks **[Q1]**

Level 3 Situation Awareness Information Element (Projection)

- Projected boiler load
- Projected deterioration of steam leakage **[Q2]**
- Projected steam demand **[Q2]**

At the perception level, information elements are mainly condition indicators such as temperature, pressure, and water level, forming a substantial portion of situation awareness information requirements, followed by comprehension and projection. The perception elements are intricately integrated to comprehend diverse monitoring aspects of machinery and systems. This includes the adequacy of the boiler burner, fuel supply, air supply, and heat exchange efficiency. Comprehension of machinery or systems with several subsets often requires sub-comprehension elements. This is the case for the adequacy of the boiler burner, which requires comprehension of fuel supply, air supply, and combustion status as sub-comprehension elements. In addition, the current values are often compared to default settings or previous records to form comprehension. This includes target steam pressure for the adequacy of boiler operation mode and fuel consumption rate during past voyages for the adequacy of fuel consumption rate. The volume of information that engineers contemplate often grows upon a change within a particular machinery type or system to isolate the cause, whether it arises from the machinery of interest or outside. For example, increased fuel consumption may not necessarily be due to a mechanical fault within the auxiliary boiler, but a low atmospheric temperature contributing to overall system heat loss or fuel mistreatment in purifiers. It shows that information integration for explicit comprehension can be highly challenging in a large-scale system with interconnected equipment under the influence of the environment. There are relatively few projection elements, most of which are disclosed under typical monitoring scenarios that demand decision-making. For example, the projected deterioration of steam leakage is one of the sources of information that helps determine whether or not to intervene immediately in case of steam leakage. This information is unavailable and unnecessary during normal operations. However, it becomes accessible and essential during abnormal events, suggesting that a wide range of decision-making scenarios should be involved to enrich the situation awareness information requirement.

4. Discussion

This research identifies that situation awareness in the engine room comprises numerous information elements, and information integration skills are essential for comprehension and projection. These findings demonstrate that situation awareness problems are not limited to navigation, but are expected to be much more severe during engine room monitoring due to the substantial volume of information. This is because innumerable system components and their dynamic interactions for possible interpretations inevitably complicate the system. The complicated system overloads the human's cognitive ability to find, sort, and integrate data, consequently increasing mental workload and reducing situation awareness (Endsley, 1995b). It should be noted that the current information requirements were based on a diesel-driven commercial ship sailing on international water, and only limited pages of the information requirements were uncovered. The actual information requirements for remote engine room monitoring will be dramatically elevated due to changes in the environment where humans interact with the system to acquire situation awareness.

Many scholars argue that situation awareness constitutes human involvement as an active participant, and situation awareness information is not limited to those directly available from the systems (Endsley & Garland, 2000; Porathe et al., 2014). This was found to be a strong case for engine room monitoring. The existing monitoring system often did not provide situation awareness information directly. Therefore, engineers had to integrate available sensor information to estimate the system status, or directly observe. For example, engineers developed an understanding of compressed air quality by examining the lubricating oil level, pressure, drain quantity, and frequency, or by visually inspecting water or oil content.

The sensor systems often provided the information but were insufficient without active participation. For instance, the bilge system comprises the holding tank and multiple bilge wells connected to a group of machinery or systems. Their levels and quality represent the amount and types of leakage or drainage. Typically, the bilge well, embedded with a high-level alarm, is located at the bottom of the engine room or in other areas with a high risk of water intrusion or leakage. While it is an efficient way of leakage detection, as fluid flows down eventually, a delay in early detection and difficulty in a root cause analysis exist, especially with the engine room of multiple decks. Minor steam leakage is barely noticeable by the change in bilge wells, but can deteriorate suddenly. Visual, auditory, olfactory and tactile senses, together with onsite human patrolling, have effectively addressed these shortcomings, as the leakage beyond the sensor coverage can be detected**.**

Some information is post-processed and recorded for prompt understanding. The tank levels and running hours of machinery are recorded to calculate daily changes, which provide a rapid perception of unusual changes within the systems. The daily running hours of air compressors represent air quantity withdrawn from the system, helping engineers quickly become aware of potential system leakage, performance degradation, and excessive air usage if running hours increase. The information is often recreated based on existing information. It includes the boiler on-off frequency in the given period and the speed of attaining the target air tank pressure in time, each reflecting the overall performance of economizers and air compressors.

The above findings indicate that the replication of conventional monitoring systems at the shore control center results in a loss of situation awareness information, as the conventional systems are designed to function in collaboration with human operators onsite. This means that, for remote operation, it is essential to expand the sensor coverage, reproduce or replicate the ship sense, and incorporate highly practical information to attain a similar level of situation awareness to that in traditional vessels (Ottesen, 2014). However, this eventually increases the amount of information, poses a risk of unbalanced information distribution across sensory modalities, and devastates situation awareness for remote engine room monitoring.

The perception of the environment becomes highly challenging with a flood of information that imposes a high mental workload on operators and negatively impacts their ability to remain focused and detect a change in system behaviour. This ability is known as vigilance and is mainly examined from the perspective of mental resources or mind-wandering. The resource depletion hypothesis emphasizes that individuals hold limited information-processing resources, and that tasks deplete their resources over time, which results in insufficient attention being paid toward the task and a gradual decrease in vigilance (Helton & Russell, 2011; Warm et al., 2018; Warm et al., 2008). On the contrary, mind-wandering advocates associate vigilance decrement with monotony, reduced arousal, underload, boredom, and under-stimulation in low-demand conditions (Malkovsky et al., 2012; Smallwood & Schooler, 2006) and frustration in high-demand conditions (Randall et al., 2019; Thomson et al., 2014). Attention is withdrawn from the primary task and shifted to task-unrelated thoughts, resulting in vigilance decrement and, therefore, performance impairment. (Smallwood & Schooler, 2006). While the two hypotheses differ in what causes vigilance decrement, mind-wandering or resource depletion, they concur on vigilance decrement during demanding conditions, either due to frustration or resource depletion.

Many studies have demonstrated that vigilance decrement, particularly on the lowest level of situation awareness information, is a leading cause of incidents in multiple domains. Jones and Endsley (1996) investigated 143 aviation incidents and discovered that the lowest level of situation awareness was associated with 76.3 % of the incidents, followed by comprehension at 20.3 % and projection problems at 3.4 %. A failure to attend to available data was the prevailing error, representing 35.1 % of the cases. The same trend was replicated in an air-carrier accident analysis (Endsley, 1995a), an offshore oil drilling incidents analysis (Sneddon et al., 2017) and most importantly, an analysis of 177 maritime accidents from 1987 and 2001 (Grech et al., 2002). A recent investigation of 535 maritime accidents revealed that attentional tunnelling, data overload, errant mental models, stress, and out-of-the-loop syndrome were found in over 60 % of incidents (Stratmann & Boll, 2016).

Information distribution is another issue. In the conventional engine room, situation awareness information is delivered through visual, olfactory, auditory, and tactile modalities. The problem is that it is challenging to replicate particular sensory cues with the same modality (e.g., heat and vibration), leaving visualisation as a convenient and economical alternative (e.g., heat map and amplitude). However, the visualisation of ship sense could lead to an excessive visual cognitive load, exacerbating vigilance decrement and restricting human potential in simultaneously dealing with information through multiple channels (Wickens, 2002).

Information overload also hinders the comprehension and projection process, which requires data integration from multiple sources for decision-making and performance evaluation. For instance, decision-making on auxiliary boiler steam leakage requires eighteen information elements, ranging from the system arrangement to relevant machinery information such as bilge and freshwater system. In addition, cross-checking information is often used to ensure that the task is commenced as intended, considering a potential system failure and mishandling. For example, the status of oil purification for purifiers is assessed not only by the discharge pressure and the oil feed rate, but also by settling and service tank levels. Other examples include the oily water separator, in which the bilge discharge rate and level change in the bilge holding tank are compared, and the fuel oil transfer system in which the pump functionality, sensor levels, and local tank levels are cross-checked.

The above examples demonstrate the intricacy of information integration for engine room monitoring and a strong need for situation awareness support systems. One support design principle is organising information around the goal and presenting comprehension and projection information (Endsley, 2016). This supports operators in finding, sorting, and integrating information, as a set of information is presented according to their mental model (Endsley & Garland, 2000). This can also be highly beneficial in the automated environment where human operators act as active supervisors to verify the system and react to potential system failures. Opaque system logic hinders comprehension, because operators are faced with ambiguous answers without any supporting clues; they are not aware of how information is integrated, and the opacity lowers the trustworthiness of the system (von Eschenbach, 2021). On the contrary, operators hold high situation awareness when provided with appropriate explanations of the system's behavior (Roth et al., 2020; Selkowitz et al., 2016; van de Merwe et al., 2022).

However, the presentation of higher-level information may increase visual cognitive load on operators, as a single perception element can be a part of more than two comprehension and projection information, e.g., steam pressure for adequacy for steam pressure and boiler operation mode. This dramatically increases the interface complexity of large-scale control systems that inevitably involve numerous amounts of information. In this respect, Porathe et al. (2020) emphasized the balance between system information and simplicity to provide operators with adequate explanations without overwhelming them for autonomous ship applications. The most important question, at this stage, is how to achieve this balance.

Schema provides great insight into optimising information presentation. In Endsley's theory, the schema is considered a prototypical mental model that provides a mental layout for integrating information that forms comprehension and projection (Endsley, 1995b). Schema becomes activated through pattern-matching between environmental cues and memory, and activation does not require a complete matching. This means that some cues might be more critical than others in comprehending and projecting the situation. In other words, perception information elements (e.g., simple readouts) may not contribute equally to forming mental models or schemata of comprehension information (e.g., combustion status), and only a few critical elements (e.g., max cylinder pressure) might be sufficient to reflect the environment. Similarly, Mutzenich et al. (2021) asserted that vehicle color may not be as important as vehicle trajectory for remote drivers, and a minimum situation awareness requirement would be critical for future training.

These characteristics offer a promising alternative to support situation awareness of remote operators in a large-scale system with minimal interface complexity. If comprehension and projection can be supported with fewer, but highly strong, perceptual cues, the amount of information on the display can be optimized, relieving the cognitive load for information processing. However, the current information requirement does not address the strength of each perception element in comprising higher-level information. Hence, following studies will aim to unveil strength differences and examine their empirical validity on engine room system monitoring through simulation experiments.

5. Conclusions

Numerous studies have shown that remoteness and automated systems lead to challenges in acquiring and maintaining situation awareness. The contemporary initiatives for autonomous ships appear to acknowledge the importance of situation awareness, but their applications are limited to visual and navigational awareness. Consequently, no research or industrial effort has so far been made to investigate situation awareness around the engine room, albeit situation awareness is not limited to physical maneuvering, but extends to knowing the status of distant systems. Hence, this research conducted a goal-directed task analysis through semi-structured interviews with thirty-one senior marine engineers and unveiled situation awareness information requirements for an ocean-going commercial vessel embedded with multiple machinery types and systems. Due to the existing variety of marine machinery, the information requirements are restricted to nine machinery types and twelve systems selected during the expert elicitation stage. The findings reveal that numerous perception elements and their intricate combinations for higher-level awareness construct situation awareness in the engine room. Perception elements often contribute to forming more than one comprehension and projection element, and comprehension is often composed of layers of sub-comprehension elements. Additionally, the volume of situation awareness information considered grows in the case of a change within the system or machinery to isolate the cause. These findings affirm a strong need to develop a situation awareness support system for engine room monitoring. This study suggests investigating cue strength differences in comprising higher-level situation awareness to address both system complexity and situation awareness. The outcome of the current research provides an in-depth understanding of situation awareness during engine room monitoring, serving as a basis for developing support systems for the future shore control center.

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Appendix A
SA Information Requirement

Perception
- Machinery -

Marine Diesel Engine (2 and 4 Stroke)

- Cylinder exhaust gas **[M1.5]**
  - P-max
  - P-comp
  - Temperature
  - Average P-max
  - Average P-comp
  - Average temperature
- Turbocharger
  - RPM
  - Exhaust gas inlet and outlet temperature
  - Exhaust gas inlet and outlet pressure
  - Blower outlet pressure
- Air cooler
  - Scavenging air inlet and outlet temperature
  - LTCW inlet and outlet temperature
  - Scavenging air inlet and outlet pressure
  - Drain quantity
- Fuel
  - Inlet pressure
  - Inlet temperature
  - Filter inlet pressure
  - Filter outlet pressure
  - Types of fuel in use **[M1.3]**
  - Quality
    - Bacteria or micro-organisms
- System lubricant temperature at
  - Turbocharger inlet
  - Engine inlet and outlet
- System lubricant pressure at
  - Turbocharger inlet
  - LO filter inlet and outlet
- System lubricant quantity **[M1.4] & [M2.2]**
  - Sump tank level
  - Sump tank low alarm level
  - Sump tank level rate of change
- System lubricant quality **[M2.2]**
  - Viscosity
  - Color
  - LO filter inlet and outlet pressure
- Compressed air
  - Starting air inlet pressure
  - Control air inlet pressure
  - Safety air inlet pressure
- HTCW
  - Inlet temperature
  - Outlet temperature
  - Inlet pressure
- Color of exhaust gas
- Leakage tank level
- Engine room
  - Temperature
  - Pressure
  - Humidity

Main Engine (2 Stroke)

- Power
  - Indicative power
  - Brake power
- Engine
  - RPM **[M1.1]**
  - Target RPM
  - Current fuel index **[M1.1]**
  - Current shaft torque **[M1.1]**
- Engine fuel index at **[M1.1]**
  - NCR
  - MCR
  - OR
- Engine shaft torque at **[M1.1]**
  - NCR
  - MCR
  - OR
- Torque-rich zone **[M1.1]**
- Fuel Quality
    - Sulfur content **[M1.3]**
    - Sludge content **[M1.2]**
- Daily fuel consumption rate
  - Main engine fuel flowmeter
- Average daily fuel consumption rate during
  - Sea-trial
  - Past voyage under similar operational environment
- Ship operational environment
  - Slip
  - Ship loading conditions
  - Ship speed
- System lubricant temperature at
  - Bearing
  - Piston
  - Crosshead
  - Cam
- System lubricant pressure at
  - Engine inlet
- Cylinder lubricant
  - Injection timing
  - Injection quantity
  - Pressure
  - Temperature
  - Type **[M1.3]**
- Renewal of **[M1.3]**
  - Piston
  - Piston ring
  - Cylinder liner
- Degradation level of **[M1.3]**

  - Piston ring
  - Cylinder liner
- Scavenging air tank
  - Pressure
  - Temperature **[M1.5]**
  - Residue quality **[M1.5]**
  - Water content **[M1.3]**
- Auxiliary blower auto stop and start pressure

- Operation state
  - Cylinder deactivation **[M1.1]**
  - Turbocharger dry cleaning **[M1.1]**
  - Engine pausing **[M1.2]**
  - Engine resting **[M1.2]**
- Rolling and pitching **[M1.4]**
- Weather
- Ocean depth

Generator (4 Stroke)
- Voltage
- Ampere
- Frequency
- Load **[M2.1]**
- Load capacity **[M2.1]**
- Power factors
- Three-phase wiring temperature
  - R(U)
  - S(V)
  - T(W)
- Alternator
  - Coolant temperature
  - Bearing lubricant

    - Temperature
    - Level
    - Color
- Daily fuel consumption rate
  - Generator fuel flowmeter
- Average daily fuel consumption rate during
  - Sea-trial
  - Past voyage under similar load
- Centrifugal LO filter sludge accumulation rate
  - Sludge thickness at the given time
- LO pump outlet pressure
- LO cooler
  - LTCW inlet and outlet temperature

Auxiliary Boiler
- Boiler
  - Load
  - Exhaust gas temperature
- Steam pressure
  - Current steam pressure **[M3.1] & [M3.2]**
  - Target steam pressure **[M3.1] & [M3.2]**
  - Auto stop and start pressure
  - Dump steam setting pressure **[M3.2]**
  - Safety valve setting pressure
- Water level
  - Current boiler water level **[M3.1] & [M3.3]**
  - Boiler setting water level
    Low alarm level
  - Low low alarm level
  - High alarm level **[M3.3]**
- Boiler burner
  - Fuel pressure at nozzle
  - Fuel temperature at nozzle
  - Ampere of rotary cup motor
  - Fan motor ampere
  - Fan damper position
- Combustion chamber
  - Temperature
  - Colors of
    - Flame
    - Exhaust gas
- Economizer **[M3.4]**
  - Exhaust gas inlet and outlet temperature
  - Boiler water inlet and outlet temperature
  - Exhaust gas inlet and outlet pressure
- Fuel

  - Type
  - Quality
    - Bacteria or micro-organisms
- Daily fuel consumption rate **[M3.1]**
  - Boiler fuel flowmeter
- Average fuel consumption rate during
  - Sea-trial
  - Past voyage under similar load
- Boiler water quality **[M3.3]**
  - Alkalinity
  - Chloride
  - pH
  - Phosphate
  - Debris
  - Blowdown interval
- System heating **[M3.1] & [M3.2]**
  - Target temperature of systems in use of steam
  - Current systems temperature
- Boiler operation
  - Running hour **[M3.2]**
  - Running hour at given engine RPM **[M3.4]**
  - Frequency of boiler cycle **[M3.2] & [M3.4]**
  - Operation of economizer **[M3.2]**
- Types of fuel in use for **[M3.2]**
  - Main engine
  - Generator
- Weather **[M3.2]**
- Seasons **[M3.2]**
- Seawater temperature **[M3.2]**
- Engine room pressure
- Pitching and rolling

Freshwater Generator

- Freshwater
  - Production rate **[M3.1] & [M4.1]**
  - Salinity level
  - Consumption rate **[M4.1] & [M3.1]**
- Feedwater flow rate
- Vacuum
  - Shell vacuum pressure
  - Speed of attaining target vacuum pressure
- Shell temperature
- Evaporator
  - JKCW inlet temperature
  - JKCW outlet temperature
- Condenser
  - CSW inlet temperature
  - CSW outlet temperature
- Distilled water
  - Discharge pressure
  - Target discharge pressure
  - Flow rate
- Ejector
  - Pressure
  - Brine level
    - Variance in freshwater salinity level
- Chemical
  - Dosing rate
  - Tank level
- Seawater temperature
- Freshwater tank
  - Dead freshwater quantity
  - Freshwater tank level
  - Corresponding freshwater tank level to freshwate r generator
- Voyage plan **[M4.1]**
  - Voyage length
  - Planned berthing date
  - Planned berthing length
  - Planned anchorage length
  - Availability of freshwater supply in the ports
  - Number of people onboard

Air Compressor

- Reservoir pressure
  - Main reservoir
  - Emergency reservoir
  - Service reservoir
- Compressor settings
  - Stop and start pressure of 1st compressor
  - Stop and start pressure of 2nd compressor
  - Safety valve setting pressure
- Temperature at
  - 1st stage air outlet
  - 2nd stage air outlet
  - Cooler LTCW inlet
  - Cooler LTCW outlet
- Pressure at
  - 1st stage air outlet (Air compressor LP) **[M5.1]**
  - 2nd stage air outlet (Air compressor HP) **[M5.1]**
  - LO pump outlet
- Speed of attaining stop pressure from start pressure **[M5.1]**
- Water drain
  - Drain quantity from air compressors
  - Drain quantity from air reservoirs
  - Drain frequency
- Oil drain
  - Drain quantity from air compressors
  - Drain frequency
- Lubrication
  - Color
  - LO level
  - Foam
  - Water
- Motor ampere
- Engine room
  - Temperature
  - Humidity
  - Pressure
- Air compressor operation **[M5.1]**
  - Daily running hour
  - Average daily running hour
  - Tasks requiring compressed air
- Quality of compressed air
  - Dryness
  - Oiliness

Purifier

- RPM
- Motor ampere
- Operating water pressure
- Fuel discharge
  - Pressure
  - Pressure deviations alarm pressure
  - Pressure low alarm pressure
- Sludge discharge
  - Partial discharge rate at the given time
  - Total discharge timer setting
  - Sludge tank level
  - Inspection through leakage hole
- Lubrication
  - Color
  - LO level
  - Foam
  - Water
- Fuel heater
  - Fuel outlet temperature
  - Target temperature
  - Steam inlet and outlet pressure
  - On-off percentage of steam regulating valve
- Fuel
  - Type **[M6.2]**

- Viscosity **[M6.2]**
- Specific gravity **[M6.2]**
- Quality
  - Sludge content
- Feed rate **[M6.1]**
- Total fuel consumption rate **[M6.1]**

- Gravity disc type in use **[M6.2]**
- Tank
  - Service tank level
  - Settling tank level
- Rolling and pitching

Oily Water Separator

- Bilge discharge **[M7.2]**
  - Rate **[M7.1]**
  - Pressure
  - PPM
- OWS filter **[M7.2]**
  - Inlet pressure
  - Outlet pressure
- Bilge heater
  - Bilge outlet temperature
  - Target temperature
- Bilge holding tank
  - Capacity **[M7.1]**
  - Level **[M3.1] & [M7.1]**
  - Bilge accumulation rate **[M3.1] & [M7.1]**
  - Oily content
  - Bilge temperature
- Bilge well
  - Capacity
  - Level
  - Bilge accumulation rate **[M3.1]**
  - Oily content
- Oily content in OWS tanks
- On-off positions of solenoid valves
- Bilge discharge period **[M7.1]**
- Bilge discharge area **[M7.1]**
- Engine room
  - Temperature
  - Humidity
- Seawater temperature
- Rolling and pitching

Air Handling Unit (AHU)

- Compressor
  - Refrigerant inlet pressure (AHU LP) **[M8.1]**
  - Refrigerant outlet pressure (AHU HP) **[M8.1]**
  - Running stage **[M8.1]**
  - Auto stop and start pressure
  - Trip pressure
  - Motor ampere
- Evaporator
  - Evaporator target air outlet temperature
  - Evaporator air outlet temperature
- Lubrication
  - Color
  - Foam
  - Water
  - LO level
  - LO pump outlet pressure
  - LO temperature
- Condenser
  - Cooling water inlet temperature
  - Cooling water outlet temperature
  - Cooling water inlet pressure
  - Cooling water outlet pressure
  - Refrigerant level
- Fan
  - RPM
  - Motor ampere
  - Fresh and recirculation air damper position **[M8.1]**
- Atmospheric air
  - Temperature **[M8.1]**
  - Humidity
  - Wind
  - Quality **[M8.1]**
    - Particulate matter (dust, dirt)
- Accommodation air quality **[M8.1]**
  - CO2 level
  - O2 level
  - Pressure
  - Particulate matter (dust, dirt)
- Accommodation
  - Temperature **[M8.2]**
  - Humidity **[M8.1]**
- Humidification
  - Humidifier target humidity
  - Humidifier steam or freshwater consumption rate
- Heating
  - Heater target temperature
  - Heater steam consumption rate
- AHU operation **[M8.1]**
  - Daily running hour
  - Average daily running hour
- Seawater temperature

Steering Gear

- Rudder
  - Angle **[M1.1]**
  - Command angle
  - Response speed
- Hydraulic
  - Tank level
  - Oil temperature
  - Oil pressure
- Grease
  - Injection timer setting
  - Manual injection interval
- Pitching and rolling

- Draft
- Ship speed

- System -

Fuel Oil Transfer

- Transfer pump
  - Discharge pressure **[S1.2]**
  - Auto start and stop level
  - Flow rate **[S1.2]**
- Bunker tank
  - Temperature **[S1.2]**
  - Target temperature **[S1.2]**
  - Level **[S1.1]**
  - Capacity **[S1.1]**
  - Corresponding bunker tank level to settling tank
  - Dead bunker quantity **[S1.1]**
  - Location **[S1.1]**
- Bunker
  - Pour point **[S1.2]**
  - Viscosity **[S1.2]**
  - Quality **[S1.1]**
    - Water content **[S1.2]**
    - Sludge content
- Settling tank
  - Quality
    - Drain quantity at the given time
  - Level
- Total fuel consumption rate **[S1.1]**
- Seawater temperature **[S1.2]**
- Bunker supply plan **[S1.1]**
- Rolling and pitching **[S1.1]**
- Heeling **[S1.1]**
- Trim **[S1.1]**

Fuel Oil Service & Overflow

- Fuel pressure at
  - Main engine inlet
  - Generator inlet
  - Boiler inlet
- Pump pressure at
  - Supply pump outlet
  - Desirable supply pump outlet
  - Circulating pump outlet
  - Desirable circulating pump outlet
- Fuel temperature at
  - Main engine inlet
  - Generator inlet
  - Boiler inlet
  - Fuel heater inlet
  - Fuel heater outlet
  - Service tank
- Fuel
  - Viscosity
  - Quality **[S2.1]**
    - Sludge content
  - Type **[S2.1]**
- Fuel flowmeter
  - Main engine
  - Generator
  - Boiler fuel
- Service tank
  - Level
  - Level rate of change
  - Low alarm level
- Overflow tank
  - Level **[S2.2] & [S2.3]**
  - Daily level increase **[S2.2]**
  - Average daily level increase **[S2.2]**
  - High level alarm setting **[S2.3]**
  - Capacity **[S2.3]**
  - 85 % of capacity **[S2.3]**
- Auto filter
  - Fuel inlet pressure
  - Fuel outlet pressure
  - Backflushing differential pressure setting
  - Backflushing timer setting
  - Backflushing count by differential pressure **[S2.1]**
- Quantity of fuel drained or overflowed **[S2.2]**
  - Service tank drain quantity at the given time **[S2.1]**
  - Settling tank drain quantity at the given time
  - Settling tank level
  - Total back flushing count
- Adjustments of system settings connected to overflow tank **[S2.2]**

Sludge

- Sludge tank **[S3.1]**
  - Level
  - Capacity
  - Accumulation rate
  - Temperature
  - Steam consumption rate
  - Water content
- Sludge discharge plan

Lube Oil Transfer

- System LO tanks
  - LO storage level
  - Sump tank levels **[S4.1]**
  - Corresponding sump tank level to LO storage tank
- Cylinder LO measuring tank
  - Level
  - Capacity
  - Low alarm level
  - High alarm level
  - Pump auto stop and start level
- LO transfer pump discharge pressure
- LO quality **[S4.1]**
  - TBN (total base number)
  - TAN (total acid number)

  - Water content
- LO renewal **[S4.1]**
  - LO running hour
  - LO renewal interval
  - Major overhaul of engines
- Rolling and pitching **[S4.1]**

Lube Oil Service
- Main LO pump
  - Inlet pressure
  - Outlet pressure
  - Desirable outlet pressure
- Main LO cooler
  - LO inlet temperature
  - LO outlet temperature
- Auto filter
  - LO inlet pressure
  - LO outlet pressure
  - Back flushing differential pressure setting
  - Backflushing timer setting
  - Backflushing count by differential pressure **[S5.1]**
- Sump tank
  - Level
  - Lubricant viscosity
  - Color
- Cylinder oil measuring tank
  - Level
  - Low alarm level
  - High alarm level
- Lubricant quality **[S5.1]**

Steam Condensation
- Cascade tank **[S6.1]**
  - Level
  - Desirable level
  - Low alarm level
  - High alarm level
  - Feedwater flow rate
- Quality of cascade tank condensed steam **[S6.1]**
  - Oily content
  - Debris
  - Salinity
  - Temperature
- Boiler
  - Steam outlet flow rate from boiler **[S6.1]**
  - Current steam pressure
  - Tube status **[S6.1]**
    - Color of exhaust gas
- Dump condenser or atmospheric condenser
  - Dump steam setting pressure
  - LTCW or cooling seawater inlet pressure
- Tank levels **[S6.1]**
  - Bilge well level
  - HTCW expansion tank level
  - HTCW temperature
  - LTCW expansion tank level
  - LTCW temperature
- Recent heating operations **[S6.1]**
  - List of tank heating
- Operation of economizer

Steam Feed Water
- Boiler water level
  - Current boiler water level
  - Boiler setting water level
  - Local boiler water gauge level
  - Boiler sensor water level
- Boiler water quality **[S7.1]**
  - Alkalinity
  - Chloride
  - pH
  - Phosphate
  - Debris
  - Blowdown interval
- Boiler feedwater flow rate **[S7.1]**
- Boiler chemical dosage rate **[S7.1]**

Seawater Cooling & MPGS
- Cooling seawater pump
  - Inlet pressure
  - Outlet pressure
- Cooling seawater flow rate **[S8.1] & [S8.3]**
  - A number of running CSW pumps
- Seawater
  - Temperature **[S8.1]**
  - Chemical dosage rate
- Sea chest filter **[S8.1]**
  - Inlet pressure
  - Outlet pressure
- LT cooler seawater
  - Inlet temperature
  - Outlet temperature
  - Inlet pressure **[S8.3]**
  - Outlet pressure **[S8.3]**
  - Filter running hour **[S8.3]**
- LT cooler LTCW **[S8.1]**
  - Outlet temperature
  - Target temperature
  - Three-way valve position
- MGPS **[S8.2]**
  - Anode current
  - Anode sacrificial rate **[S8.3]**
  - Anode renewal interval
- Usage of low or high sea chest **[S8.3]**
- Presence of
  - Marine organisms, mud and floatage in the area
  - Marine growth in seawater cooling system **[S8.3]**
- Salinity level in voyage area **[S8.3]**
- Voyage type
  - Ocean sailing
  - Freshwater sailing

Central Cooling Water (LTCW System)
- LT cooler seawater **[S9.2]**
  - Inlet pressure
  - Outlet pressure

- Filter running hour
- LT cooler LTCW
  - Inlet temperature
  - Outlet temperature **[S9.2]**
  - Inlet pressure
  - Outlet pressure
  - Flow rate **[S9.2]**
    - Three-way valve position
- A number of LT coolers in use **[S9.2]**
- LTCW
  - Pump outlet pressure
  - Temperature
  - Target temperature **[S9.2]**
  - Chemical dosage rate **[S9.1]**
  - Quality **[S9.1]**
    - CaCO3 (Total hardness)
    - Chloride
    - Ph
    - Nitrite (NO2)
- LTCW expansion tank
  - Level
  - Desirable level
  - Freshwater feed quantity **[S9.1]**
- Past voyage data under similar conditions **[S9.2]**
  - Past seawater temperature
  - Past LTCW temperature
  - A number of LT cooler in use in the past

Jacket Cooling Water (HTCW System)

- HT cooler HTCW
  - Inlet temperature
  - Outlet temperature
  - Inlet pressure
  - Outlet pressure
  - Flow rate
    - Three-way valve position
- HTCW
  - Pump outlet pressure
  - Temperature
  - Target temperature
  - Chemical dosage rate **[S10.2]**
  - Quality **[S10.2]**
    - CaCO3
    - Chloride
    - Ph
    - Nitrite
- HTCW expansion tank
  - Level
  - Desirable level
  - Freshwater feed quantity **[S10.2]**
- HTCW heater steam consumption rate **[S10.1]**
- Speed of main engine load variation **[S10.1]**
- Main engine load
- Fuel **[S10.1]**
  - Type
  - Sulfur content
- Climate **[S10.1]**

Freshwater Service

- Freshwater pressure tank
  - Pressure
  - Level
  - Water and air ratio at given pressure
- Freshwater tank
  - Level **[M4.1] & [S11.1]**
  - Dead freshwater quantity **[M4.1] & [S11.1]**
  - Quality of freshwater **[S11.1]**
    - Chloride
    - Mud content
- Freshwater filter
  - Inlet pressure
  - Outlet pressure
- Freshwater pump
  - Auto start and stop pressure
  - Daily running hour **[S11.1]**
- Freshwater **[S11.1]**
  - Production rate
  - Consumption rate
- Disuse hours of the freshwater tanks **[S11.1]**
- Freshwater tank cleaning plan **[S11.1]**
- Rolling and pitching **[S11.1]**

Stern Tube

- Sealing pressure
  - Air pressure
  - LO pressure
- LO tank
  - Levels
  - Variance in levels
- Drain
  - Quantity
  - Accumulation rate
- Lubricant
  - Flow rate
  - Temperature
  - Pressure
  - Quality
    - Salinity
    - Water content
- Ship
  - Loading condition **[S12.1]**
  - Ballast condition **[S12.1]**
  - Draft
- Rolling and pitching

Comprehension
- Machinery -

Marine Diesel Engine (2 and 4 Stroke)
- Adequacy of
  - Combustion
  - Combustion air supply
  - Turbocharger
  - Air cooler
  - Fuel supply
  - Compressed air
  - Cylinder cooling
- Impact of environment on diesel engine
- Deviation of
  - Shut down parameters from alarm limit **[M1.1]**
  - Slow down parameters from alarm limits **[M1.1]**
  - Sump tank level from low level alarm **[M1.4]**
  - P-max from average P-max
  - P-comp from average P-comp
  - Exhaust gas temperature from average exhaust gas temperature
- Differential pressure
  - Turbocharger turbine
  - Fuel filter
  - LO filter
  - LO filter differential pressure rate of change
  - Air cooler scavenging air
- Pressure distribution of cylinders **[M1.5] & [M2.2]**
  - P-max
  - P-comp
  - Average P-max
  - Average P-comp
- Exhaust gas temperature distribution of cylinders **[M1.5] & [M2.2]**
  - Exhaust gas temperature
  - Exhaust gas average temperature

Main Engine (2 Stroke)
- Status of
  - Power generation
  - Engine load **[M1.1] & [M3.4]**
- Adequacy of
  - Auxiliary blowers
  - Fuel consumption rate
  - Cylinder lubrication
  - System lubrication and cooling
- Potential risk of engine operation **[M1.1]**
- Operation state of main engine **[M1.1] & [M1.2]**
- Impact of weather on sump tank suction **[M1.4]**
- Compliance with local and international regulations **[M1.2]**
  - Local regulations **[M1.2]**
  - International regulations **[M1.2]**

Generator (4 Stroke)
- Status of
  - Electricity generation
  - Generator load
- Adequacy of
  - Three-phase wiring
  - Alternator bearing lubrication
  - Fuel consumption rate
  - System lubrication and cooling
- Load **[M2.1]**
  - Available generator load
  - Allowable maximum load capacity
  - Current generator performance
- Redundancy requirement **[M2.1] & [M9.1]**
  - High risk ship maneuver
    - Docking
    - Narrow passage
    - Cargo loading and unloading
    - Berthing and unberthing
    - Bunkering
    - Congested passage
    - Rough weather
- Estimated inrush current of machinery **[M2.1]**

Auxiliary Boiler
- Adequacy of
  - Steam production
  - Boiler operation mode
  - Boiler burner
  - Fuel supply
  - Combustion air supply
  - Combustion status
  - Fuel consumption rate
- Efficiency of
  - Heat exchange **[M3.4]**
  - Boiler operation mode **[M3.2]**
- Water level
  - Consistency of boiler water level
  - Surplus of boiler water level **[M3.3]**
- Impact of steam leakage on **[M3.1]**
  - Location
    - Vulnerability to temperature
    - Vulnerability to moisture
  - Steam production
  - System heating
    - Variation of systems temperature in use of steam **[M3.2]**
  - Boiler operational continuity
- Impact of environment on
  - System heat loss **[M3.2]**
  - Combustion air
  - Steam production
- Deviation of current boiler water level from boiler setting water level
- Differential pressure of economizer gas side **[M3.4]**
- Temperature difference of **[M3.4]**
  - Economizer gas side
  - Economizer water side
- Changes in heating demand

Freshwater Generator
- Status of production units
- Adequacy of
  - Freshwater production
  - Demister

  - Distilled water transfer
  - Vacuum forming
  - Chemical dosage
- Consistency of distilled water discharge pressure
- Efficiency of
  - Heat exchange
  - Ejector
- Impact of environment on vacuum forming
- Deviation of distilled water discharge pressure from distilled water target discharge pressure
- Temperature difference of
  - Evaporator JKCW side
  - Condenser CSW side
- Minimum freshwater requirement **[M4.1]**

Air Compressor
- Adequacy of
  - Compressed air production
  - Operation mode
  - Lubrication
  - Compressor motor
  - Running hour **[M5.1]**
- Efficiency of
  - Compression **[M5.1]**
  - Cooler
- Impact of environment on
  - Air dryness
  - Air supply
- Temperature difference of cooler LTCW side
- Functionality of drain traps
- Changes in compressed air demand

Purifier
- Status of
  - Oil purification
  - Bowl sealing
- Adequacy of
  - Sludge discharge
  - Motor
  - Lubrication
  - Heater
  - Steam supply
- Stability of fuel discharge pressure
- Sufficiency of oil feed rate **[M6.1]**
- Impact of environment on settling tank
- Deviation of heater fuel outlet temperature from heat er target outlet temperature

Oily Water Separator
- Adequacy of
  - Bilge discharge **[M7.2]**
  - Bilge treatment
  - Bilge filtering
  - Bilge heater
  - Bilge holding tank and bilge well
- Impact of environment on
  - Bilge tank mixing
  - Bilge accumulation rate
  - Bilge temperature
- Differential pressure of OWS filters **[M7.2]**
- Functionality of pollution prevention sequence
- Validity of bilge discharge plan **[M7.1]**
- Compliance with local and international regulations **[M7.1]**
  - MARPOL
  - Local regulations

Air Handling Unit (AHU)
- Adequacy of
  - Cooling **[M8.1]**
  - Heating
  - Humidification
  - Condenser
  - Compressor operation mode
  - Compressor lubrication
  - Atmospheric air control
- Impact of environment
- Deviation of
  - Evaporator air outlet temperature from evaporato r target air outlet temperature
  - Accommodation humidity from humidifier target humidity
  - Accommodation temperature from heater target t emperature
- Temperature difference of condenser coolant side
- Pressure difference of condenser coolant side
- Functionality of AHU fan
- AHU compressor load **[M8.1]**

Steering Gear
- Adequacy of
  - Rudder operation
  - Hydraulic oil system
  - Grease injection
- Impact of environment on steering
- Deviation of rudder angle from command angle
- Redundancy requirement
  - High risk ship maneuver
    - Docking
    - Narrow passage
    - Berthing and unberthing
    - Congested passage
    - Rough weather

- System -

Fuel Oil Transfer
- Adequacy of
  - Fuel transfer
  - Bunker oil storage
- Impact of bunker temperature on bunker transfer **[S1 .2]**
- Impact of environment on heat loss
- Deviation of bunker tank temperature from bunker t ank target temperature **[S1.2]**
- Smoothness of bunker tank suction **[S1.1]**
- Priority of bunker tank usage **[S1.1]**
- Compliance with local and international regulations **[S1.1]**

  - Local regulations
  - International regulations
- Bunker usage plan **[S1.2]**

Fuel Oil Service & Overflow
- Adequacy of
  - Service fuel delivery
  - Service fuel temperature
  - Service tank level
  - Auto filter filtering
- Consistency of service fuel discharge pressure
- Deviation of
  - Supply pump outlet pressure from desirable supp ly pump outlet pressure
  - Circulating pump outlet pressure from desirable circulating pump pressure
  - Overflow tank daily level increase from average overflow tank daily level increase **[S2.2]**
  - Overflow tank level from overflow tank high lev el alarm setting **[S2.3]**
- Differential pressure of auto filters

Sludge
- Adequacy of sludge storage

Lube Oil Transfer
- Adequacy of
  - System lubricant transfer
  - Cylinder lubricant transfer
- Impact of weather on sump tank suction **[S4.1]**
- System lubricant replenishment requirement **[S4.1]**
- System lubricant renewal requirement **[S4.1]**

Lube Oil Service
- Adequacy of
  - System oil circulation
  - System lubricant cooling
  - Auto filter filtering
  - Sump tank lubricant
  - Cylinder oil measuring tank
- Consistency of system oil discharge pressure
- Deviation of main LO pump outlet pressure from de sirable main LO pump outlet pressure
- Auto filter differential pressure

Steam Condensation
- Adequacy of dump condenser or/and atmospheric co ndenser
- Consistency of cascade tank level **[S6.1]**
- Deviation of cascade tank level from desirable casca de tank level **[S6.1]**

Steam Feed Water
- Stability of boiler water level
- Precision of water level
- Deviation of current boiler water level from boiler s etting water level

Seawater Cooling & MPGS
- Adequacy of
  - Cooling seawater supply
  - Cooling
  - Chemical dosage
  - Anode current **[S8.3]**
- Impact of environment on
  - Cooling performance
  - Cooling water supply
- Blockage of
  - Sea chest filter
  - LT cooler at the given period **[S8.3]**
- Seawater cooling **[S8.1]**
  - Capacity
  - Demand
- Differential pressure of sea chest filter **[S8.1]**

Central Cooling Water (LTCW System)
- Adequacy of
  - LTCW supply
  - LTCW temperature control
- Stability of LTCW expansion tank level
- Impact of LTCW temperature on LTCW expansion t ank level
- Blockage of LT cooler at the given period **[S9.2]**
- Deviation of
  - LTCW temperature from LTCW target temperat ure
  - LTCW expansion tank level from desirable LTC W expansion tank level
- LTCW cooling capacity **[S9.2]**

Jacket Cooling Water (HTCW System)
- Adequacy of
  - HTCW supply
  - HTCW temperature control
- Stability of HTCW expansion tank level
- Impact of HTCW temperature on HTCW expansion tank level
- Deviation of
  - HTCW temperature from HTCW target temperat ure
  - HTCW expansion tank level from desirable HTC W expansion tank level
- Pre-heating requirement of main engine **[S10.1]**

Freshwater Service
- Adequacy of
  - Freshwater supply
  - Freshwater quality control
  - Freshwater service system operation mode
- Impact of environment
- Differential pressure of freshwater filters
- Remaining freshwater quantity **[M3.1] & [M4.1] & [S11.1]**

Stern Tube
- Adequacy of
  - Stern tube sealing
  - Stern tube lubrication
- Impact of environment
- Efficiency of stern tube sealing

Projection

- Machinery -

Main Engine (2 Stroke)
- Projected main engine load

Generator (4 Stroke)
- Projected generator load
- Projected load requirement **[M2.1]**
  - Projected operation of **[M2.1]**
    - Bow thruster **[M2.1]**
    - Ballast pumps **[M2.1]**
    - Winch and windlass **[M2.1]**
    - Crane **[M2.1]**
    - Cargo pumps **[M2.1]**
    - Other machinery **[M2.1]**

Auxiliary Boiler
- Projected boiler load
- Projected deterioration of steam leakage **[M3.1]**
- Projected steam demand **[M3.2]**

Freshwater Generator
- Projected freshwater production requirement **[M4.1]**
- Projected freshwater generator operational period **[M4.1]**
- Projected freshwater production quantity **[M4.1]**
- Projected freshwater consumption rate **[M4.1]**
- Projected work plans involving with the usage of fre shwater **[M4.1]**

Purifier
- Projected total fuel demand **[M6.1]**
  - Projected main engine load
  - Projected generator load
  - Projected boiler load

Oily Water Separator
- Projected bilge quantity **[M7.1]**

Air Handling Unit (AHU)
- Projected accommodation cooling demand **[M8.2]**
- Projected accommodation heating demand **[M8.2]**
- Projected atmospheric temperature **[M8.2]**
- Projected climate **[M8.2]**
- Projected weather **[M8.2]**
- Projected vessel location

- System -

Fuel Oil Transfer
- Projected bunker tank level **[S1.1]**
- Projected heat loss in pipelines **[S1.1]**
- Projected time to reach the bunker tank target tempe rature **[S1.2]**
- Projected usage of bunker tanks **[S1.2]**
- Projected climate **[S1.1]**

Sludge
- Projected sludge quantity **[S3.1]**
- Projected operation of incinerator

Seawater Cooling + MPGS
- Projected environment factors **[S8.1]**
  - Projected seawater temperature **[S9.2]**
  - Projected marine organisms in the area **[S8.3]**
- Projected engine room system cooling demand **[S8.1]**
  - Projected main engine load
  - Projected generator load
  - Projected boiler load
  - Projected auxiliary machinery load
- Projected remaining life of anode **[S8.2]**

Central Cooling Water (LTCW System)
- Projected engine room system cooling demand **[S9.2]**
- Projected environmental factors
  - Projected seawater temperature

Freshwater Service
- Projected remaining freshwater quantity in tanks **[S1 1.1]**

Stern Tube
- Projected draft **[S12.1]**

Appendix B
The goal-directed task analysis

The outcomes from the goal-directed task analysis are presented as follows, with typical mo nitoring questions for each item. The first three questions (Q1, Q2 and Q3) inquire about three objec tives; the fourth and sub-queries are typical monitoring questions.

1. Main Engine (2 Stroke MC)

Q1. What reflects the main functionality of the machinery?

1.1. Status of power generation
1.1.1. Indicative power
1.1.2. Brake power
1.1.3. Engine RPM
1.1.4. Target engine RPM

Q2. What reflects the overall machinery status?

1.2. Status of engine load
1.2.1. Current engine load
1.2.1.1. Engine RPM
1.2.1.2. Engine fuel index
1.2.1.3. Engine shaft torque
1.2.2. Normal continuous rating (NCR)
1.2.2.1. Engine fuel index at NCR
1.2.2.2. Engine shaft torque at NCR
1.2.3. Maximum continuous rating (MCR)
1.2.3.1. Engine fuel index at NCR
1.2.3.2. Engine shaft torque at NCR
1.2.4. Overload rating (OR)
1.2.4.1. Engine fuel index at OR
1.2.4.2. Engine shaft torque at OR
1.2.5. Torque rich zone

1.3. Adequacy of combustion
1.3.1. Cylinders’
1.3.1.1. P-max distribution
1.3.1.1.1. P-max
1.3.1.1.2. Average P-max
1.3.1.1.3. Deviations from average P-max
1.3.1.2. P-comp distribution
1.3.1.2.1. P-comp
1.3.1.2.2. Average P-comp
1.3.1.2.3. Deviation from average P-comp
1.3.1.3. Exhaust gas temperature distribution
1.3.1.3.1. Exhaust gas temperature
1.3.1.3.2. Average exhaust gas temperature
1.3.1.3.3. Deviations from average exhaust gas temperature
1.3.2. Colors of exhaust gas

1.4. Adequacy of combustion air supply
1.4.1. Adequacy of auxiliary blowers
1.4.1.1. Auxiliary blower auto stop and start pressure
1.4.1.2. Scavenging air tank pressure

- 1.4.2. Adequacy of turbocharger
  - 1.4.2.1. Turbocharger RPM
  - 1.4.2.2. Turbocharger exhaust gas inlet and outlet temperature
  - 1.4.2.3. Turbine differential pressure
    - 1.4.2.3.1. Exhaust gas inlet pressure
    - 1.4.2.3.2. Exhaust gas outlet pressure
  - 1.4.2.4. Turbocharger blower outlet pressure
- 1.4.3. Adequacy of air cooler
  - 1.4.3.1. Air cooler scavenging air inlet and outlet temperature
  - 1.4.3.2. Air cooler LTCW inlet and outlet temperature
  - 1.4.3.3. Air cooler scavenging air differential pressure
    - 1.4.3.3.1. Scavenging air inlet pressure
    - 1.4.3.3.2. Scavenging air outlet pressure
  - 1.4.3.4. Air cooler drain quantity

1.5. Adequacy of fuel supply
- 1.5.1. Engine fuel inlet pressure
- 1.5.2. Engine fuel inlet temperature
- 1.5.3. Fuel filter differential pressure
  - 1.5.3.1. Fuel filter inlet pressure
  - 1.5.3.2. Fuel filter outlet pressure
- 1.5.4. Leakage tank level

1.6. Adequacy of main engine fuel consumption rate
- 1.6.1. Main engine daily fuel consumption rate
  - 1.6.1.1. Main engine fuel flowmeter
- 1.6.2. Ship operational environment
  - 1.6.2.1. Slip
  - 1.6.2.2. Ship loading conditions
  - 1.6.2.3. Ship speed
  - 1.6.2.4. Engine RPM
- 1.6.3. Main engine average daily fuel consumption rate during
  - 1.6.3.1. Sea-trial
  - 1.6.3.2. Past voyage under similar operational environments

1.7. Adequacy of system lubrication and cooling
- 1.7.1. System lubricant temperature at
  - 1.7.1.1. Bearing
  - 1.7.1.2. Piston
  - 1.7.1.3. Crosshead
  - 1.7.1.4. Cam
  - 1.7.1.5. Turbocharger inlet
  - 1.7.1.6. Engine inlet and outlet
- 1.7.2. System lubricant pressure at
  - 1.7.2.1. Turbocharger inlet
  - 1.7.2.2. Engine inlet
  - 1.7.2.3. LO filter inlet and outlet
- 1.7.3. System lubricant quantity
  - 1.7.3.1. Sump tank level
  - 1.7.3.2. Sump tank low alarm level
  - 1.7.3.3. Sump tank level rate of change
- 1.7.4. System lubricant quality
  - 1.7.4.1. Lubricant viscosity
  - 1.7.4.2. Lubricant color
  - 1.7.4.3. LO filter differential pressure

1.7.4.3.1. LO filter inlet pressure
1.7.4.3.2. LO filter outlet pressure
1.7.4.3.3. LO filter differential pressure rate of change

1.8. Adequacy of cylinder lubrication
1.8.1. Cylinder lubricant injection timing
1.8.2. Cylinder lubricant injection quantity
1.8.3. Cylinder lubricant pressure
1.8.4. Cylinder lubricant temperature
1.8.5. Engine RPM

1.9. Adequacy of compressed air
1.9.1. Starting air inlet pressure
1.9.2. Control air inlet pressure
1.9.3. Safety air inlet pressure

1.10. Adequacy of cylinder cooling
1.10.1. High Temperature Cooling Water (HTCW) engine inlet and outlet temperature
1.10.2. HTCW engine inlet pressure

1.11. Operation state of main engine
1.11.1. Cylinder deactivation
1.11.2. Turbocharger dry cleaning
1.11.3. Engine pausing
1.11.4. Engine resting

Q3. If there are changes in machinery states, what are the causes of such changes?

1.12. Within the system
1.12.1. Performance degradation
1.12.1.1. Mechanical parts
1.12.1.2. Renewable or cleanable parts
1.12.1.3. Running hour
1.12.1.4. Maintenance interval
1.12.2. Fuel type
1.12.3. Fuel quality
1.12.3.1. Bacteria or micro-organisms
1.12.4. Status of engine load

1.13. Impact of relevant systems
1.13.1. Impact on fuel
1.13.1.1. Circulation
- Refers to “System. 1.2. FO service + Overflow”
1.13.1.2. Purification
- Refers to “Machinery. 6. Purifier”
1.13.1.3. Heating
- Refers to “System. 1.2. FO service + Overflow”
1.13.1.4. Filtering
- Refers to “System. 1.2. FO service + Overflow”
1.13.2. Impact on lubricant
1.13.2.1. Circulation
- Refers to “System. 2.1 LO service”
1.13.2.2. Cooling
- Refers to “System. 2.1 LO service”
1.13.2.3. Filtering

- Refers to "System 2.1 LO service"

1.13.2.4. Replenishment
- Refers to "System 2.2 LO transfer"

1.13.2.5. Purification
- Refers to "Machinery. 6. Purifier"

1.13.3. Impact on coolant

1.13.3.1. Cooling of LTCW
- Refers to "System. 6. Central cooling"

1.13.3.2. Circulation of LTCW
- Refers to "System. 6. Central cooling"

1.13.3.3. Cooling of HTCW
- Refers to "System. 7. Jacket cooling water"

1.13.3.4. Circulation of HTCW
- Refers to "System. 7. Jacket cooling water"

1.13.3.5. Pre-heating of HTCW
- Refers to "System. 7. Jacket cooling water"

1.13.4. Impact on compressed air

1.13.4.1. Compressed air supply
- Refers to "Machinery. 5. Air compressor"

1.13.5. Impact of environment

1.13.5.1. Engine room temperature
1.13.5.2. Engine room pressure
1.13.5.3. Engine room humidity
1.13.5.4. Rolling and pitching
1.13.5.5. Weather
1.13.5.6. Ocean depth

Q4.1 Is there a need for adjusting speed?

1.14. Status of engine load

1.14.1. Current engine load
1.14.1.1. RPM
1.14.1.2. Fuel index
1.14.1.3. Shaft torque

1.14.2. NCR
1.14.2.1. Fuel index at NCR
1.14.2.2. Shaft torque at NCR

1.14.3. MCR
1.14.3.1. Fuel index at MCR
1.14.3.2. Shaft torque at MCR

1.14.4. OR
1.14.4.1. Fuel index at OR
1.14.4.2. Shaft torque at OR

1.14.5. Other references
1.14.5.1. Torque rich zone
1.14.5.2. Rudder angle

1.15. Potential risk of engine operation

1.15.1. Deviation of shut down parameters from alarm limits
1.15.2. Deviation of slow down parameters from alarm limits

1.16. Operation state of main engine

1.16.1. Cylinder deactivation

1.16.2. Turbocharger dry cleaning

Q4.2 Do you need to change the fuel?

1.17. Compliance with local and international regulations
1.17.1. Local regulations
1.17.2. International regulations

1.18. Operation state of main engine
1.18.1. Engine pausing
1.18.2. Engine resting

1.19. Fuel quality
1.19.1. Sludge content

Q4.3 Is there a need for adjusting cylinder oil quantity?

1.20. Renewal of items
1.20.1. Piston
1.20.2. Piston rings
1.20.3. Cylinder liner
1.21. Degradation of items
1.21.1. Cylinder liner
1.21.2. Piston rings
1.22. Water content in the combustion air
1.23. Fuel sulfur content
1.24. Fuel type
1.25. Cylinder lubricant type

Q4.4 Is sump tank level appropriate?

1.26. Deviation of sump tank level from low level alarm
1.26.1. Sump tank level
1.26.2. Low alarm level
1.27. Sump tank level rate of change
1.28. Impact of weather on sump tank suction
1.28.1. Rolling
1.28.2. Pitching

Q4.5 Is cylinder compression appropriate?

1.29. Scavenging air tank
1.29.1. Scavenging air tank temperature
1.29.2. Scavenging air tank residue quality
1.30. Pressure distribution of cylinders
1.31. Exhaust gas temperature distribution of cylinders

2. Generator (4 Stroke)

Q1. What reflects the main functionality of the machinery?

2.1. Status of electricity generation
2.1.1. Generator voltage
2.1.2. Generator ampere
2.1.3. Generator frequency
2.1.4. Generator load
2.1.5. Power factor

Q2. What reflects the overall machinery status?

2.2. Status of generator load
   2.2.1. Generator load
   2.2.2. Generator load capacity

2.3. Adequacy of three-phase wiring
   2.3.1. R(U) temperature
   2.3.2. S(V) temperature
   2.3.3. T(W) temperature
   2.3.4. Alternator cooling air or water temperature

2.4. Adequacy of alternator bearing lubrication
   2.4.1. Lubricant temperature
   2.4.2. Lubricant level
   2.4.3. Lubricant color

2.5. Adequacy of combustion
   2.5.1. Cylinders'
      2.5.1.1. P-max distribution
         2.5.1.1.1. P-max
         2.5.1.1.2. Average P-max
         2.5.1.1.3. Deviations from average P-max
      2.5.1.2. P-comp distribution
         2.5.1.2.1. P-comp
         2.5.1.2.2. Average P-comp
         2.5.1.2.3. Deviation from average P-comp
      2.5.1.3. Exhaust gas temperature distribution
         2.5.1.3.1. Exhaust gas temperature
         2.5.1.3.2. Average exhaust gas temperature
         2.5.1.3.3. Deviations from average exhaust gas temperature
   2.5.2. Colors of exhaust gas

2.6. Adequacy of combustion air supply
   2.6.1. Adequacy of turbocharger
      2.6.1.1. Turbocharger RPM
      2.6.1.2. Exhaust gas inlet and outlet temperature
      2.6.1.3. Turbine differential pressure
         2.6.1.3.1. Exhaust gas inlet pressure
         2.6.1.3.2. Exhaust gas outlet pressure
      2.6.1.4. Blower outlet pressure
   2.6.2. Adequacy of air cooler
      2.6.2.1. Scavenging air inlet and outlet temperature
      2.6.2.2. LTCW inlet and outlet temperature
      2.6.2.3. Air cooler scavenging air differential pressure
         2.6.2.3.1. Air inlet pressure
         2.6.2.3.2. Air outlet pressure
      2.6.2.4. Air cooler drain quantity

2.7. Adequacy of fuel supply
   2.7.1. Engine inlet fuel pressure
   2.7.2. Engine inlet fuel temperature
   2.7.3. Differential pressure of fuel filters
      2.7.3.1. Fuel filter inlet pressure
      2.7.3.2. Fuel filter outlet pressure
   2.7.4. Leakage tank level

2.8. Adequacy of fuel consumption rate
2.8.1. Generator daily fuel consumption rate
2.8.1.1. Generator fuel flow meter
2.8.1.2. Generator load
2.8.2. Generator average daily fuel consumption rate during
2.8.2.1. Sea-trial
2.8.2.2. Past voyage under similar load
2.8.2.2.1. Generator load

2.9. Adequacy of system lubrication and cooling
2.9.1. Lubricant temperature at
2.9.1.1. Turbocharger inlet
2.9.1.2. Engine inlet and outlet
2.9.2. Lubricant pressure at
2.9.2.1. Turbocharger inlet
2.9.2.2. LO pump outlet
2.9.2.3. LO filter inlet and outlet
2.9.3. System lubricant quantity
2.9.3.1. Sump tank level
2.9.3.2. Sump tank low alarm level
2.9.3.3. Sump tank level rate of change
2.9.4. System lubricant quality
2.9.4.1. Lubricant viscosity
2.9.4.2. Lubricant color
2.9.4.3. LO filter differential pressure
2.9.4.3.1. LO filter inlet pressure
2.9.4.3.2. LO filter outlet pressure
2.9.4.3.3. LO filter differential pressure rate of change
2.9.4.4. Centrifugal LO filter sludge accumulation rate
2.9.4.4.1. Sludge thickness in centrifugal LO filters at the given time
2.9.5. LTCW temperature at
2.9.5.1. LO cooler inlet and outlet

2.10. Adequacy of compressed air
2.10.1. Inlet air pressure of starting air motor
2.10.2. Starting air inlet pressure
2.10.3. Control air inlet pressure

2.11. Adequacy of cylinder cooling
2.11.1. HTCW engine inlet and outlet temperature
2.11.2. HTCW engine inlet pressure

Q3. If there are changes in machinery states, what are the causes of such changes?

2.12. Within the system
2.12.1. Performance degradation
2.12.1.1. Mechanical parts
2.12.1.2. Renewable or cleanable parts
2.12.1.3. Running hour
2.12.1.4. Maintenance interval
2.12.2. Fuel type
2.12.3. Fuel quality
2.12.3.1. Bacteria or micro-organisms
2.12.4. Generator load

2.13. Impact of relevant system

2.13.1. Impact on fuel
2.13.1.1. Circulation
- Refers to "System. 1.2. FO service + Overflow"
2.13.1.2. Purification
- Refers to "Machinery. 6. Purifier"
2.13.1.3. Heating
- Refers to "System. 1.2. FO service + Overflow"
2.13.1.4. Filtering
- Refers to "System. 1.2. FO service + Overflow"
2.13.2. Impact on lubricant
2.13.2.1. Replenishment
- Refers to "System 2.2 LO transfer"
2.13.3. Impact on coolant
2.13.3.1. Cooling of LTCW
- Refers to "System. 6. Central cooling"
2.13.3.2. Circulation of LTCW
- Refers to "System. 6. Central cooling"
2.13.4. Impact on compressed air
2.13.4.1. Supply
- Refers to "Machinery. 5. Air compressor"

2.14. Impact of environment
2.14.1. Engine room temperature
2.14.2. Engine room pressure
2.14.3. Engine room humidity

Q4. Is a change in the current operation mode needed to ensure the safety of environment, vessel, and human, and the on-time delivery of cargo?

Q4.1 Will a parallel operation be needed?

2.15. Estimated inrush current of machineries
2.16. Projected load requirement
2.16.1. Projected operation of
2.16.1.1. Bow thruster
2.16.1.2. Ballast pumps
2.16.1.3. Winch and windlass
2.16.1.4. Crane
2.16.1.5. Cargo pumps
2.16.1.6. Other machineries
2.17. Available generator load
2.17.1. Generator load
2.17.2. Allowable maximum load capacity
2.17.2.1. Current generator performance
2.17.2.2. Generator load capacity
2.18. Redundancy requirement
2.18.1. High risk ship maneuver
2.18.1.1. Docking
2.18.1.2. Narrow passage
2.18.1.3. Cargo loading and unloading
2.18.1.4. Berthing and unberthing
2.18.1.5. Bunkering
2.18.1.6. Congested passage
2.18.1.7. Rough weather

Q4.2. Is cylinder compression appropriate?

2.19. System lubricant quality
2.20. System lubricant quantity
2.21. P-max and P-comp distribution of cylinders
2.22. Exhaust gas temperature distribution of cylinders

3. Auxiliary Boiler

Q1. What reflects the main functionality of the machinery?

3.1. Adequacy of steam production
3.1.1. Boiler auto stop and start pressure
3.1.2. Target steam pressure
3.1.3. Current steam pressure
3.1.4. Boiler load

Q2. What reflects the overall machinery status?

3.2. Adequacy of boiler operation mode
3.2.1. Boiler auto stop and start pressure
3.2.2. Target steam pressure
3.2.3. Current steam pressure
3.2.4. Dump steam setting pressure
3.2.5. Safety valve setting pressure

3.3. Consistency of boiler water level
3.3.1. Deviation of current boiler water level from boiler setting water level
3.3.1.1. Boiler setting water level
3.3.1.2. Current boiler water level
3.3.2. Low alarm level
3.3.3. Low low alarm level
3.3.4. High alarm level

3.4. Adequacy of boiler burner
3.4.1. Boiler load
3.4.2. Adequacy of fuel supply
3.4.2.1. Boiler fuel pressure at nozzle
3.4.2.2. Boiler fuel temperature at nozzle
3.4.2.3. Ampere of rotary cup motor
3.4.3. Adequacy of boiler combustion air supply
3.4.3.1. Boiler fan motor ampere
3.4.3.2. Boiler fan damper position
3.4.4. Adequacy of boiler combustion status
3.4.4.1. Colors of
3.4.4.1.1. Boiler exhaust gas
3.4.4.1.2. Flame
3.4.4.2. Boiler exhaust gas temperature

3.5. Efficiency of heat exchange
3.5.1. Boiler
3.5.1.1. Combustion chamber temperature
3.5.1.2. Boiler exhaust gas temperature
3.5.1.3. Boiler load
3.5.2. Exhaust gas boiler (economizer)
3.5.2.1. Differential pressure of economizer gas side
3.5.2.1.1. Exhaust gas inlet pressure

3.5.2.1.2. Exhaust gas outlet pressure
3.5.2.2. Temperature difference of economizer gas side
3.5.2.2.1. Exhaust gas inlet and outlet temperature
3.5.2.3. Temperature difference of economizer water side
3.5.2.3.1. Boiler water inlet and outlet temperature

3.6. Adequacy of fuel consumption rate
3.6.1. Boiler daily fuel consumption rate
3.6.1.1. Boiler fuel flowmeter
3.6.2. Boiler average fuel consumption rate during
3.6.2.1. Sea-trial
3.6.2.2. Past voyage under similar load
3.6.3. Boiler load

Q3. If there are changes in machinery states, what are the causes of such changes?

3.7. Within the system
3.7.1. Performance degradation
3.7.1.1. Mechanical parts
3.7.1.2. Renewable or cleanable parts
3.7.1.3. Running hour
3.7.1.4. Maintenance interval
3.7.2. Fuel type
3.7.3. Fuel quality
3.7.3.1. Bacteria or micro-organisms
3.7.4. Boiler load
3.7.5. Operation of economizer
3.7.6. Changes in heating demand

3.8. Impact of relevant systems
3.8.1. Impact on fuel supply
- Refers to "System. 1.2. FO service + Overflow"
3.8.2. Impact on fuel quality
- Refers to "Machinery. 6. Purifier"
3.8.3. Impact on freshwater quality
– Refers to "System. 8. Freshwater service"

3.9. Impact of environment
3.9.1. Impact on system heat loss
3.9.1.1. Weather
3.9.1.2. Seasons
3.9.1.3. Seawater temperature
3.9.2. Impact on combustion air
3.9.2.1. Engine room pressure
3.9.3. Impact on steam production
3.9.3.1. Rolling and pitching

Q4.1 Does leakage require immediate action?

3.10. Impact of steam leakage on location
3.10.1. Vulnerability to temperature
3.10.2. Vulnerability to moisture
3.11. Impact of steam leakage on steam production
3.11.1. Target steam pressure
3.11.2. Current steam pressure

3.12. Impact of steam leakage on heating
3.12.1. Variation of systems temperature in use of steam
3.12.1.1. Target temperature of systems in use of steam
3.12.1.2. Current systems temperature
3.13. Impact of steam leakage on boiler operational continuity
3.13.1. Current boiler water level
3.13.2. Bilge accumulation rate
3.13.3. Bilge holding tank level
3.13.4. Freshwater consumption rate
3.13.5. Remaining freshwater quantity in tanks
3.13.6. Freshwater production rate
3.13.7. Boiler daily fuel consumption rate
3.14. Projected deterioration of steam leakage

Q4.2 Is there a need for adjusting the current boiler start and stop pressure?

3.15. Projected steam demand
3.15.1. Types of fuel in use
3.15.1.1. Main engine
3.15.1.2. Generator
3.15.2. Operation of economizer
3.15.3. Impact of environment on system heat loss
3.15.3.1. Weather
3.15.3.2. Seasons
3.15.3.3. Seawater temperature
3.16. Efficiency of boiler operation mode
3.16.1. Dump steam setting pressure
3.16.2. Target steam pressure
3.16.3. Current steam pressure
3.16.4. Frequency of boiler cycle
3.16.5. Boiler running hour

3.17. Variation of systems temperature in use of steam
3.17.1. Current systems temperature
3.17.2. Target temperature of systems in use of steam

Q4.3 Is blow down needed?

3.18. Boiler water quality
3.18.1. Alkalinity
3.18.2. Chloride
3.18.3. pH
3.18.4. Phosphate
3.18.5. Debris
3.18.6. Blowdown interval

3.19. Surplus of boiler water level
3.19.1. Current boiler water level
3.19.2. High alarm level

Q4.4 Do economizers generate sufficient steam?

3.20. Efficiency of heat exchange (economizer)
3.20.1. Economizer
3.20.1.1. Differential pressure of economizer gas side
3.20.1.1.1. Exhaust gas inlet pressure
3.20.1.1.2. Exhaust gas outlet pressure

3.20.1.2. Temperature difference of economizer gas side
3.20.1.2.1. Exhaust gas inlet and gas outlet temperature
3.20.1.3. Temperature difference of economizer water side
3.20.1.3.1. Boiler water inlet and outlet temperature

3.21. Operation of auxiliary boiler
3.21.1. Status of engine load
3.21.2. Frequency of boiler cycle
3.21.3. Boiler running hour at given engine RPM

4. Freshwater generator

Q1. What reflects the main functionality of the machinery?

4.1. Adequacy of freshwater production
4.1.1. Freshwater production rate
4.1.2. Freshwater salinity level
4.1.3. Seawater temperature

Q2. What reflects the overall machinery status?

4.2. Adequacy of vacuum forming
4.2.1. Shell vacuum pressure
4.2.2. Shell temperature
4.2.3. Seawater temperature
4.2.4. Speed of attaining target vacuum pressure

4.3. Status of production units
4.3.1. Efficiency of heat exchange
4.3.1.1. Temperature difference of evaporator JKCW side
4.3.1.1.1. Evaporator JKCW inlet temperature
4.3.1.1.2. Evaporator JKCW outlet temperature
4.3.1.2. Temperature difference of condenser CSW side
4.3.1.2.1. Condenser CSW inlet temperature
4.3.1.2.2. Condenser CSW outlet temperature
4.3.2. Adequacy of demister
4.3.2.1. Freshwater salinity level
4.3.2.2. Freshwater production rate

4.4. Adequacy of distilled water transfer
4.4.1. Consistency of distilled water discharge pressure
4.4.1.1. Deviation of distilled water discharge pressure from distilled water target discharge pressure
4.4.1.1.1. Distilled water discharge pressure
4.4.1.1.2. Distilled water target discharge pressure
4.4.2. Corresponding freshwater tank level to freshwater generator
4.4.3. Distilled water flow rate

4.5. Efficiency of ejector
4.5.1. Ejector pressure
4.5.2. Shell vacuum pressure
4.5.3. Brine level
4.5.3.1. Variance in freshwater salinity level

4.6. Adequacy of chemical dosage
4.6.1. Feedwater flow rate

4.6.2. Chemical dosing rate
4.6.3. Chemical tank level

Q3. If there are changes in machinery states, what are the causes of such changes?

4.7. Within the system
4.7.1. Performance degradation
4.7.1.1. Mechanical parts
4.7.1.2. Renewable or cleanable parts
4.7.1.3. Running hour
4.7.1.4. Maintenance interval

4.8. Impact of relevant system
4.8.1. Changes in JKCW system load
- Refers to “Machinery. 1. Main engine”

4.8.2. Impact on seawater supply
- Refers to “System. 5. Seawater cooling + MGPS”

4.9. Impact of environment
4.9.1. Impact on vacuum forming
4.9.1.1. Seawater temperature

Q4. Is a change in the current operation mode needed to ensure the safety of environment, vessel, and human, and the on-time delivery of cargo?

Q4.1 Will freshwater production rate be acceptable?

4.10. Projected freshwater production requirement
4.10.1. Voyage plan
4.10.1.1. Voyage length
4.10.1.2. Planned berthing date
4.10.1.3. Planned berthing length
4.10.1.4. Planned anchorage length
4.10.1.5. Availability of freshwater supply in the ports
4.10.1.6. A number of people onboard
4.10.2. Remaining freshwater quantity in tanks
4.10.2.1. Dead freshwater quantity
4.10.2.2. Freshwater tank level
4.10.3. Projected
4.10.4. freshwater production quantity
4.10.4.1. Freshwater production rate
4.10.4.2. Projected freshwater generator operational period
4.10.4.2.1. Planned berthing length
4.10.4.2.2. Planned berthing date
4.10.5. Projected freshwater consumption rate
4.10.5.1. Freshwater consumption rate
4.10.5.2. Minimum freshwater requirement
4.10.5.3. Projected work plans involving with the usage of freshwater (e.g., tank cleaning)

5. Air compressor

Q1. What reflects the main functionality of the machinery?

5.1. Adequacy of compressed air production
5.1.1. Reservoir pressure
5.1.1.1. Main reservoir

5.1.1.2. Emergency reservoir
5.1.1.3. Service reservoir
5.1.2. Air compressor daily running hour

Q2. What reflects the overall machinery status?

5.2. Adequacy of air compressor running hour
5.2.1. Air compressor daily running hour
5.2.2. Air compressor average daily running hour
5.2.3. Tasks requiring compressed air

5.3. Adequacy of air compressor operation mode
5.3.1. Main reservoir pressure
5.3.2. Start and stop pressure of 1st compressor
5.3.3. Start and stop pressure of 2nd compressor
5.3.4. Safety valve setting pressure

5.4. Efficiency of air compressor compression
5.4.1. 1st stage air outlet pressure (Air compressor LP)
5.4.2. 2nd stage air outlet pressure (Air compressor HP)
5.4.3. Speed of attaining stop pressure from start pressure

5.5. Efficiency of air compressor cooler
5.5.1. Temperature difference of air compressor cooler LTCW side
5.5.1.1. Air compressor cooler LTCW inlet temperature
5.5.1.2. Air compressor cooler LTCW outlet temperature
5.5.2. 1st stage air outlet temperature
5.5.3. 2nd stage air outlet temperature

5.6. Functionality of drain traps
5.6.1. Drain quantity from air compressors
5.6.2. Drain quantity from air reservoirs

5.7. Quality of compressed air
5.7.1. Dryness
5.7.1.1. Water drain quantity from air reservoirs
5.7.1.2. Water drain frequency
5.7.2. Oiliness
5.7.2.1. Oil drain quantity from air compressors
5.7.2.2. Oil drain frequency
5.7.2.3. Air compressor LO level
5.7.2.4. LP
5.7.2.5. HP

5.8. Adequacy of air compressor lubrication
5.8.1. Color
5.8.2. Level
5.8.3. Foam
5.8.4. Water
5.8.5. LO pump outlet pressure
5.8.6. Oil drain quantity from air compressors

5.9. Adequacy of compressor motor
5.9.1. Compressor motor ampere

Q3. If there are changes in machinery states, what are the causes of such changes?

5.10. Within the system
5.10.1. Performance degradation
5.10.1.1. Mechanical parts
5.10.1.2. Renewable or cleanable parts
5.10.1.3. Running hour
5.10.1.4. Maintenance interval
5.10.2. Changes in compressed air demand

5.11. Impact of relevant systems
5.11.1. Changes in cooling water temperature and pressure
- Refers to "System. 6. Central cooling"

5.12. Impact of environment
5.12.1. Impact on air dryness
5.12.1.1. Engine room temperature
5.12.1.2. Engine room humidity
5.12.2. Impact on air supply
5.12.2.1. Engine room pressure

Q4.1 Is the running hour of the compressor acceptable?

5.13. Adequacy of air compressor running hour
5.13.1. Air compressor daily running hour
5.13.2. Air compressor average daily running hour
5.13.3. Tasks requiring compressed air

5.14. Efficiency of air compressor compression
5.14.1. LP
5.14.2. HP
5.14.3. Speed of attaining stop pressure from start pressure

6. Purifier

Q1. What reflects the main functionality of the machinery?

6.1. Status of oil purification
6.1.1. Oil feed rate
6.1.2. Purifier discharge pressure
6.1.3. Service tank level
6.1.4. Settling tank level

Q2. What reflects the overall machinery status?

6.2. Stability of fuel discharge pressure
6.2.1. Purifier discharge pressure
6.2.2. Purifier heater fuel outlet temperature
6.2.3. Discharge deviation alarm pressure
6.2.4. Discharge low alarm pressure

6.3. Adequacy of sludge discharge
6.3.1. Partial discharges rate at the given time
6.3.2. Total discharge timer setting
6.3.3. Sludge tank level
6.3.4. Status of bowl sealing
6.3.4.1. Inspection through leakage hole
6.3.4.2. Operating water pressure

6.4. Adequacy of purifier motor
6.4.1. Purifier motor ampere
6.4.2. Purifier RPM
6.4.3. Bodily information
6.4.3.1. Noise
6.4.3.2. Heat
6.4.3.3. Vibration

6.5. Adequacy of purifier lubrication
6.5.1. Color
6.5.2. Purifier LO level
6.5.3. Foam
6.5.4. Water

6.6. Adequacy of purifier heater
6.6.1. Deviation of purifier heater fuel outlet temperature from purifier heater target temperature
6.6.1.1. Purifier heater fuel outlet temperature
6.6.1.2. Purifier heater fuel target outlet temperature
6.6.2. Adequacy of steam supply
6.6.2.1. Steam inlet and outlet pressure
6.6.2.2. On-off percentage of steam regulating valve

Q3. If there are changes in machinery states, what are the causes of such changes?

6.7. Within the system
6.7.1. Performance degradation
6.7.1.1. Mechanical parts
6.7.1.2. Renewable or cleanable parts
6.7.1.3. Running hour
6.7.1.4. Maintenance interval
6.7.2. Fuel specification
6.7.2.1. Fuel type
6.7.2.2. Fuel oil viscosity
6.7.2.3. Specific gravity
6.7.2.4. Fuel quality
6.7.2.4.1. Sludge content

6.8. Impact of relevant systems
6.8.1. Impact on purifier operating water
– Refers to “System. 8. Freshwater service”
6.8.2. Impact on fuel temperature
- Refers to “Machinery. 3. Boiler”
6.8.3. Impact on fuel quality
- Refers to “System. 1.1. FO transfer”

6.9. Impact of environment
6.9.1. Impact on settling tank
6.9.1.1. Rolling
6.9.1.2. Pitching

Q4.1 Will purification rate be sufficient to meet the fuel demand?

6.10. Sufficiency of the oil feed rate
6.10.1. Projected total fuel demand
6.10.1.1. Projected main engine load
6.10.1.2. Projected generator load

6.10.1.3. Projected boiler load
6.10.2. Oil feed rate
6.10.3. Total fuel consumption rate

Q4.2. Is there a need for adjusting the heater temperature setting?

6.11. Fuel specification
6.11.1. Fuel type
6.11.2. Fuel oil viscosity
6.11.3. Specific gravity
6.12. Gravity disc type in use

Q4.3. Is there a need for adjusting a timer of total discharge?

6.12.1. Fuel quality
6.12.2. Partial discharge rate at the given time

7. Oily Water Separator

Q1. What reflects the main functionality of the machinery?

7.1. Adequacy of bilge discharge
7.1.1. Bilge PPM
7.1.2. Bilge discharge rate
7.1.3. Bilge discharge pressure

Q2. What reflects the overall machinery status?

7.2. Adequacy of bilge treatment
7.2.1. Adequacy of bilge filtering
7.2.1.1. Differential pressure of OWS filters
7.2.1.1.1. OWS filter inlet pressure
7.2.1.1.2. OWS filter outlet pressure
7.2.2. Adequacy of bilge heater
7.2.2.1. Bilge heater bilge outlet temperature
7.2.2.2. Bilge heater target temperature

7.3. Functionality of pollution prevention sequence
7.3.1. Bilge PPM
7.3.2. Oily content in OWS tanks
7.3.3. On-off positions of solenoid valves

7.4. Adequacy of bilge holding tank and bilge well
7.4.1. Bilge holding tank
7.4.1.1. Bilge holding tank capacity
7.4.1.2. Bilge holding tank level
7.4.1.3. Bilge holding tank bilge accumulation rate
7.4.1.4. Oily content in bilge holding tank
7.4.1.5. Bilge holding tank bilge temperature
7.4.2. Bilge well
7.4.2.1. Bilge well capacity
7.4.2.2. Bilge well level
7.4.2.3. Bilge well bilge accumulation rate
7.4.2.4. Oily content in bilge well

Q3. If there are changes in machinery states, what are the causes of such changes?

7.5. Within the system
7.5.1. Performance degradation

7.5.1.1. Mechanical parts
7.5.1.2. Renewable or cleanable parts
7.5.1.3. Running hour
7.5.1.4. Maintenance interval

7.6. Impact of relevant systems
7.6.1. Impact on water turbidity
- Refers to “System. 5. Cooling seawater + MGPS”
- Refers to “System. 8. Freshwater service”
7.6.2. Impact on bilge accumulation rate
- Refers to “Machinery. 1 Main engine”
- Refers to “Machinery. 2 Generator”
7.6.3. Impact on sequence control
- Refers to “Machinery. 5 Air Compressor”

7.7. Impact of environment
7.7.1. Impact on bilge tank mixing
7.7.1.1. Rolling and pitching
7.7.2. Impact on bilge accumulation rate
7.7.2.1. Engine room temperature
7.7.2.2. Engine room humidity
7.7.3. Impact on bilge temperature
7.7.3.1. Seawater temperature

Q4.1 Is bilge discharge plan acceptable?

7.8. Validity of bilge discharge plan
7.8.1. Projected bilge quantity
7.8.1.1. Bilge holding tank capacity
7.8.1.2. Bilge holding tank bilge level
7.8.1.3. Bilge holding tank accumulation rate
7.8.2. Bilge discharge rate
7.8.3. Bilge discharge period
7.8.4. Bilge discharge area
7.8.5. Compliance with local and international regulations
7.8.5.1. MARPOL
7.8.5.2. Local regulations

Q4.2. Is there a need for arranging filter renewal?

7.9. Differential pressure of OWS filters
7.9.1. OWS filter inlet pressure
7.9.2. OWS filter outlet pressure

7.10. Adequacy of bilge discharge
7.10.1. Bilge PPM
7.10.2. Bilge discharge rate
7.10.3. Bilge discharge pressure

8. Air handing unit (AHU)

Q1. What reflects the main functionality of the machinery?

8.1. Adequacy of accommodation cooling
8.1.1. Deviation of evaporator air outlet temperature from evaporator target air outlet temperature
8.1.1.1. Evaporator target air outlet temperature
8.1.1.2. Evaporator air outlet temperature

8.1.2. Atmospheric temperature
8.1.3. Accommodation temperature

Q2. What reflects the overall machinery status?

8.2. Adequacy of AHU compressor operation mode
8.2.1. AHU compressor auto stop and start pressure
8.2.2. AHU compressor trip pressure
8.2.3. AHU compressor refrigerant inlet pressure (AHU LP)
8.2.4. AHU compressor refrigerant outlet pressure (AHU HP)
8.2.5. AHU running stage
8.2.6. AHU compressor ampere

8.3. Adequacy of AHU condenser
8.3.1. Temperature difference of AHU condenser coolant side
8.3.1.1. Condenser cooling water inlet temperature
8.3.1.2. Condenser cooling water outlet temperature
8.3.2. Pressure difference of AHU condenser coolant side
8.3.2.1. Condenser cooling water inlet pressure
8.3.2.2. Condenser cooling water outlet pressure
8.3.3. AHU refrigerant level

8.4. Adequacy of AHU compressor lubrication
8.4.1. Color
8.4.2. Foam
8.4.3. Water
8.4.4. AHU compressor LO level
8.4.5. AHU compressor LO pump outlet pressure
8.4.6. AHU compressor LO temperature

8.5. Adequacy of atmospheric air control
8.5.1. Functionality of AHU fan
8.5.1.1. AHU fan RPM
8.5.1.2. AHU fan motor ampere
8.5.2. Adequacy of accommodation humidification
8.5.2.1. Deviation of accommodation humidity from humidifier target humidity
8.5.2.1.1. Accommodation humidity
8.5.2.1.2. Humidifier target humidity
8.5.2.2. Humidifier steam or freshwater consumption rate
8.5.3. Adequacy of accommodation heating
8.5.3.1. Deviation of accommodation temperature from heater target temperature
8.5.3.1.1. Accommodation temperature
8.5.3.1.2. AHU heater target temperature
8.5.3.2. AHU heater steam consumption rate

Q3. If there are changes in machinery states, what are the causes of such changes?

8.6. Within the system
8.6.1. Performance degradation
8.6.1.1. Mechanical parts
8.6.1.2. Renewable or cleanable parts
8.6.1.3. Running hour
8.6.1.4. Maintenance interval
8.6.2. AHU fresh and recirculation air damper position

8.7. Impact of relevant systems

8.7.1. Impact on condenser
- Refers to "System. 6. Central cooling"
- Refers to "System. 5. Cooling seawater + MGPS"

8.7.2. Impact on humidification or heating
- Refers to "Machinery. 3. Boiler"
- Refers to "System. 8. Fresh water service"

8.8. Impact of environment
8.8.1. Seawater temperature
8.8.2. Atmospheric humidity
8.8.3. Atmospheric temperature
8.8.4. Wind
8.8.5. Particulate matters (sand, dirt)

Q4.1 Is the ratio of recirculation and fresh air appropriate?

8.9. AHU compressor load
8.9.1. AHU LP
8.9.2. AHU HP
8.9.3. AHU running stage
8.9.4. Atmospheric temperature
8.9.5. AHU fresh and recirculation air damper position
8.9.6. AHU compressor daily running hour
8.9.7. AHU compressor average daily running hour
8.10. Adequacy of accommodation cooling
8.11. Accommodation air quality
8.11.1. Accommodation CO2 level
8.11.2. Accommodation O2 level
8.11.3. Accommodation air particulate matters (dust, dirt)
8.11.4. Accommodation humidity
8.11.5. Accommodation pressure
8.12. Atmospheric air quality
8.12.1. Atmospheric air particulate matters (dust, dirt)

Q4.2 Will heating or cooling be required?

8.13. Projected accommodation cooling or heating demand
8.13.1. Projected weather
8.13.1.1. Projected atmospheric temperature
8.13.2. Projected climate
8.13.2.1. Projected atmospheric temperature
8.14. Projected vessel location
8.15. Accommodation temperature

9. Steering gear

Q1. What reflects the main functionality of the machinery?

9.1. Adequacy of rudder operation
9.1.1. Deviation of rudder angle from command angle
9.1.1.1. Rudder angle
9.1.1.2. Command rudder angle
9.1.2. Rudder response speed

Q2. What reflects the overall machinery status?

9.2. Adequacy of steering gear hydraulic oil system
9.2.1. Steering gear hydraulic tank level

9.2.2. Steering gear hydraulic oil temperature
9.2.3. Steering gear hydraulic oil pressure

9.3. Adequacy of steering gear grease injection
9.3.1. Steering gear grease injection timer setting
9.3.2. Steering gear manual grease injection interval

Q3. If there are changes in machinery states, what are the causes of such changes?

9.4. Within the system
9.4.1. Performance degradation
9.4.1.1. Mechanical parts
9.4.1.2. Renewable or cleanable parts
9.4.1.3. Running hour
9.4.1.4. Maintenance interval

9.5. Impact of environment
9.5.1. Impact on steering
9.5.1.1. Pitching and rolling
9.5.1.2. Draft
9.5.1.3. Ship speed

Q4. Is there a need for adjusting the rudder response speed?

9.6. Redundancy requirement
9.6.1. High risk ship maneuver
9.6.1.1. Docking
9.6.1.2. Narrow passage
9.6.1.3. Berthing and unberthing
9.6.1.4. Congested passage
9.6.1.5. Rough weather

1. FO System
1.1. Transfer system

Q1. What reflects the main functionality of the system?

1.1.1. Adequacy of fuel transfer
- 1.1.1.1. Settling tank level
- 1.1.1.2. Corresponding bunker tank level to settling tank
- 1.1.1.3. Transfer pump discharge pressure
- 1.1.1.4. Transfer pump auto start and stop level

Q2. What reflects the overall system status?

1.1.2. Adequacy of bunker oil storage
- 1.1.2.1. Bunker tank temperature
- 1.1.2.2. Bunker tank level
- 1.1.2.3. Bunker tank capacity

1.1.3. Quality of settling tank fuel
- 1.1.3.1. Settling tank drain quantity at the given time

Q3. If there are changes in system states, what are the causes of such changes?

1.1.4. Within the system
- 1.1.4.1. Performance degradation
  - 1.1.4.1.1. Mechanical parts
  - 1.1.4.1.2. Renewable or cleanable parts
  - 1.1.4.1.3. Running hour
  - 1.1.4.1.4. Maintenance interval

1.1.5. Impact of relevant systems
- 1.1.5.1. Impact on bunker temperature
  - Refers to “System. 3.1 Steam service”

1.1.6. Impact of environment
- 1.1.6.1. Impact on heat loss
  - 1.1.6.1.1. Seawater temperature

Q4. Is a change in the current operation mode needed to ensure the safety of environment, system, and human, and the on-time delivery of cargo?

Q4.1 Is there a need to change a bunker tank?

1.1.7. Projected bunker tank level
- 1.1.7.1. Bunker tank level
- 1.1.7.2. Bunker tank capacity
- 1.1.7.3. Total fuel consumption rate

1.1.8. Smoothness of bunker tank suction
- 1.1.8.1. Dead bunker quantity
- 1.1.8.2. Rolling and pitching
- 1.1.8.3. Heeling
- 1.1.8.4. Trim

1.1.9. Compliance with local and international regulations
- 1.1.9.1. Local regulations
- 1.1.9.2. International regulations

1.1.10. Priority of bunker tank usage
- 1.1.10.1. Projected heat loss in pipelines

1.1.10.1.1. Location of bunker tank
1.1.10.1.2. Projected climate
1.1.10.2. Bunker supply plan
1.1.10.3. Bunker quality
1.1.10.3.1. Sludge content
1.1.10.3.2. Water content

Q4.2 Is heating required?

1.1.11. Deviation of bunker tank temperature from bunker tank target temperature
1.1.11.1. Bunker tank temperature
1.1.11.2. Bunker tank target temperature
1.1.11.3. Bunker pour point
1.1.11.4. Bunker viscosity
1.1.11.5. Seawater temperature
1.1.11.6. Water content
1.1.12. Bunker usage plan
1.1.12.1. Projected time to reach the bunker tank target temperature
1.1.12.2. Projected usage of bunker tanks
1.1.13. Impact of bunker temperature on bunker transfer
1.1.13.1. Transfer pump discharge pressure
1.1.13.2. Transfer pump flow rate

1.2. Service system + Overflow

- Service -

Q1. What reflects the main functionality of the system?

1.2.1.Adequacy of service fuel delivery
1.2.1.1. Fuel pressure at
1.2.1.1.1. Main engine inlet
1.2.1.1.2. Generator inlet
1.2.1.1.3. Boiler inlet
1.2.1.2. Fuel temperature at
1.2.1.2.1. Main engine inlet
1.2.1.2.2. Generator inlet
1.2.1.2.3. Boiler inlet
1.2.1.3. Flowmeter
1.2.1.3.1. Main engine fuel flowmeter
1.2.1.3.2. Generator fuel flowmeter
1.2.1.3.3. Boiler fuel flowmeter
1.2.1.4. Fuel oil viscosity

Q2. What reflects the overall system status?

1.2.2.Consistency of service fuel discharge pressure
1.2.2.1. Deviation of supply pump outlet pressure from desirable supply pump outlet pressur e
1.2.2.1.1. Supply pump outlet pressure
1.2.2.1.2. Desirable supply pump outlet pressure
1.2.2.2. Deviation of circulating pump outlet pressure from desirable circulating pump outle t pressure
1.2.2.2.1. Circulating pump outlet pressure
1.2.2.2.2. Desirable circulating pump outlet pressure

1.2.3.Adequacy of service fuel temperature

1.2.3.1. Service fuel tank temperature
1.2.3.2. Service fuel heater inlet temperature
1.2.3.3. Service fuel heater outlet temperature

1.2.4. Adequacy of service tank level
1.2.4.1. Service tank level
1.2.4.2. Service tank level rate of change
1.2.4.3. Service tank low alarm level

1.2.5. Adequacy of auto filter filtering
1.2.5.1. Auto filter differential pressure
1.2.5.1.1. Auto filter fuel inlet pressure
1.2.5.1.2. Auto filter fuel outlet pressure
1.2.5.2. Back flushing differential pressure setting
1.2.5.3. Back flushing timer setting

1.2.6. Quality of service tank fuel
1.2.6.1. Service tank drain quantity at the given time

Q3. If there are changes in system states, what are the causes of such changes?

1.2.7. Within the system
1.2.7.1. Performance degradation
1.2.7.1.1. Mechanical parts
1.2.7.1.2. Renewable or cleanable parts
1.2.7.1.3. Running hour
1.2.7.1.4. Maintenance interval
1.2.7.2. Fuel type

1.2.8. Impact of relevant systems
1.2.8.1. Impact on fuel oil viscosity
- Refers to “System. 3.1 Steam service”
1.2.8.2. Impact on fuel quality
- Refers to “Machinery. 6. Purifier”

Q4.1 Is a timer of auto-filter acceptable?

1.2.9. Back flushing count by differential pressure
1.2.10. Service tank drain quantity at the given time
1.2.11. Fuel quality
1.2.11.1. Sludge content
1.2.12. Fuel type

- Overflow -

Q4.2 Is the increase of the overflow tank level acceptable?

1.2.13. Deviation of overflow tank daily level increase from average overflow tank daily level increase
1.2.13.1. Overflow tank level
1.2.13.2. Overflow tank daily level increase
1.2.13.3. Overflow tank average daily level increase
1.2.14. Quantity of fuel overflowed or drained
1.2.14.1. Settling tank drain quantity at the given time
1.2.14.2. Service tank drain quantity at the given time
1.2.14.3. Total back flushing count
1.2.14.4. Settling tank level

1.2.15. Adjustments of system settings connected to overflow tank

Q4.3 Is fuel transfer required from the overflow tank?

1.2.16. Deviation of the overflow tank level from overflow tank high level alarm setting
1.2.16.1. Overflow tank level
1.2.16.2. Overflow tank high level alarm setting
1.2.16.3. Overflow tank capacity
1.2.16.4. 85 % of overflow tank capacity

1.3. Purification system + Sludge

- Purification -

Refer to “Machinery. 6. Purifier”

- Sludge System -

Q1. What reflects the main functionality of the system?

1.3.1. Adequacy of sludge storage
1.3.1.1. Sludge tank level
1.3.1.2. Sludge tank capacity
1.3.1.3. Sludge accumulation rate
1.3.1.4. Sludge tank temperature

Q3. If there are changes in system states, what are the causes of such changes?

1.3.2. Within the system
1.3.2.1. Performance degradation
1.3.2.1.1. Mechanical parts
1.3.2.1.2. Cleanable or renewable parts
1.3.2.1.3. Running hour
1.3.2.1.4. Maintenance interval
1.3.2.2. Impact of relevant systems
1.3.2.2.1. Impact on sludge accumulation rate
- Refers to “Machinery. 6. Purifier”

Q4.1 Is there a need for sludge evaporation?

1.3.3. Projected sludge quantity
1.3.3.1. Sludge tank capacity
1.3.3.2. Sludge tank level
1.3.3.3. Sludge accumulation rate
1.3.4. Water content in sludge tank
1.3.4.1. Sludge tank temperature
1.3.4.2. Sludge tank steam consumption rate
1.3.5. Sludge discharge plan
1.3.6. Projected operation of incinerator

2. LO System

2.1. LO transfer system

Q1. What reflects the main functionality of the system?

2.1.1. Adequacy of system lubricant transfer
2.1.1.1. LO storage tank level
2.1.1.2. Corresponding sump tank level to LO storage tank
2.1.1.3. LO transfer pump discharge pressure

Q2. What reflects the overall system status?

2.1.2. Adequacy of cylinder lubricant transfer
2.1.2.1. Cylinder oil pump auto stop and start level
2.1.2.2. Measuring tank level
2.1.2.3. Measuring tank low alarm level
2.1.2.4. Measuring tank high alarm level
2.1.2.5. Measuring tank capacity

Q3. If there are changes in system states, what are the causes of such changes?

2.1.3. Within the system
2.1.3.1. Performance degradation
2.1.3.1.1. Mechanical parts
2.1.3.1.2. Renewable or cleanable parts
2.1.3.1.3. Running hour
2.1.3.1.4. Maintenance interval

Q4.1 Will there be a need for replenishing or renewal?

2.1.4. System lubricant replenish requirement
2.1.4.1. Sump tank levels
2.1.4.2. Impact on weather on sump tank suction
2.1.4.2.1. Rolling
2.1.4.2.2. Pitching
2.1.5. System lubricant renewal requirements
2.1.5.1. LO quality
2.1.5.1.1. TBN (total base number)
2.1.5.1.2. TAN (total acid number)
2.1.5.1.3. Water content
2.1.5.2. Major overhaul of engines
2.1.5.3. LO running hour
2.1.5.4. LO renewal interval

2.2. LO service system

Q1. What reflects the main functionality of the system?

2.2.1. Adequacy of system oil circulation
2.2.1.1. Main LO pump inlet pressure
2.2.1.2. Main LO pump outlet pressure

Q2. What reflects the overall system status?

2.2.2. Consistency of system oil discharge pressure
2.2.2.1. Deviation of main LO pump outlet pressure from desirable main LO pump outlet pre ssure
2.2.2.1.1. Main LO pump outlet pressure
2.2.2.1.2. Desirable main LO pump outlet pressure

2.2.3. Adequacy of system lubricant cooling
2.2.3.1. Main LO cooler LO inlet temperature
2.2.3.2. Main LO cooler LO outlet temperature

2.2.4. Adequacy of auto filter filtering
2.2.4.1. Auto filter differential pressure
2.2.4.1.1. Auto filter LO inlet pressure
2.2.4.1.2. Auto filter LO outlet pressure

2.2.4.2. Back flushing differential pressure setting
2.2.4.3. Back flushing timer setting

2.2.5. Adequacy of sump tank lubricant
2.2.5.1. Sump tank level
2.2.5.2. Lubricant viscosity
2.2.5.3. Color

2.2.6. Adequacy of cylinder oil measuring tank
2.2.6.1. Measuring tank level
2.2.6.2. Measuring tank low alarm level
2.2.6.3. Measuring tank high alarm level

Q3. If there are changes in system states, what are the causes of such changes?

2.2.7. Within the system
2.2.7.1. Performance degradation
2.2.7.1.1. Mechanical parts
2.2.7.1.2. Renewable or cleanable parts
2.2.7.1.3. Running hour
2.2.7.1.4. Maintenance interval

2.2.8. Impact of relevant systems
2.2.8.1. Impact on lubricant temperature and quality (water)
2.2.8.1.1. – Refers to "System. 6. Central cooling"
2.2.8.2. Impact on lubricant quality
2.2.8.2.1. – Refers to "Machinery. 6. Purifier"

Q4.1 Is a timer of auto-filter acceptable?

2.2.9. Back flushing count by differential pressure
2.2.10. Lubricant quality

2.3. **Purification system + Sludge**

- Purification & Sludge-

- Refer to "System. 1.3 Purification System + Sludge"

3. **Steam system**

- Steam service system -

- Refer to "Machinery. 3. Boiler"

3.1. **Steam condensation system**

Q1. What reflects the main functionality of the system?

3.1.1. Consistency of cascade tank level
3.1.1.1. Deviation of cascade tank level from desirable cascade tank level
3.1.1.1.1. Cascade tank level
3.1.1.1.2. Desirable cascade tank level
3.1.1.2. Cascade tank low alarm level
3.1.1.3. Cascade tank high alarm level

Q2. What reflects the overall system status?

3.1.2. Quality of cascade tank condensed steam

3.1.2.1. Condensed steam oily content
3.1.2.2. Debris in condensed steam
3.1.2.3. Condensed steam temperature
3.1.2.4. Condensed steam salinity

3.1.3. Adequacy of dump condenser or/and (atmospheric condenser)
3.1.3.1. Current steam pressure
3.1.3.2. Dump condenser dump steam setting pressure
3.1.3.3. Dump condenser LTCW or cooling seawater inlet pressure

Q3. If there are changes in system states, what are the causes of such changes?

3.1.4. Within the system
3.1.4.1. Performance degradation
3.1.4.1.1. Mechanical parts
3.1.4.1.2. Renewable or cleanable parts
3.1.4.1.3. Running hour
3.1.4.1.4. Maintenance interval
3.1.4.2. Operation of economizer
3.1.5. Impact of relevant system
3.1.5.1. Impact on steam condensation
- Refers to “System. 6. Central cooling”
- Refers to “System. 5. Cooling seawater + MGPS”

Q4.1. Is the change in cascade level acceptable?

3.1.6. Tank levels
3.1.6.1. Bilge well level
3.1.6.2. HTCW expansion tank level
3.1.6.3. HTCW temperature
3.1.6.4. LTCW expansion tank level
3.1.6.5. LTCW temperature
3.1.7. Consistency of cascade tank level
3.1.7.1. Deviation of cascade tank level from desirable cascade tank level
3.1.7.1.1. Cascade tank level
3.1.7.1.2. Desirable cascade tank level
3.1.7.2. Cascade tank high alarm level
3.1.7.3. Cascade tank low alarm level
3.1.8. Quality of cascade tank condensed steam
3.1.8.1. Condensed steam oily content
3.1.8.2. Debris in condensed steam
3.1.8.3. Condensed steam temperature
3.1.8.4. Condensed steam salinity
3.1.9. Steam and boiler water flow
3.1.9.1. Steam outlet flow rate from boiler
3.1.9.2. Cascade tank feedwater flow rate
3.1.10. Recent heating operations
3.1.10.1. A list of tank heating
3.1.11. Boiler tube status
3.1.11.1. Color of exhaust gas

3.2. **Steam feed water system**

Q1. What reflects the main functionality of the system?

3.2.1. Stability of boiler water level
3.2.1.1. Deviation of current boiler water level from boiler setting water level

3.2.1.1.1. Current boiler water level
3.2.1.1.2. Boiler setting water level

Q2. What reflects the overall system status?

3.2.2. Precision of water level
3.2.2.1. Local boiler water gauge level
3.2.2.2. Boiler sensor water level

Q3. If there are changes in system states, what are the causes of such changes?

3.2.3. Within the system
3.2.3.1. Performance degradation
3.2.3.1.1. Mechanical parts
3.2.3.1.2. Renewable or cleanable parts
3.2.3.1.3. Running hour
3.2.3.1.4. Maintenance interval
3.2.4. Impact of relevant system
- Refers to "System. 8. Freshwater service"

Q4.1. Is chemical dosage acceptable?

3.3. Boiler feedwater flow rate
3.4. Boiler chemical dosage rate
3.5. Boiler water quality
3.5.1. Alkalinity
3.5.2. Chloride
3.5.3. pH
3.5.4. Phosphate
3.5.5. Debris
3.5.6. Blowdown interval

4. Compressed air system

Refer to "Machinery. 5. Air Compressor"

5. Cooling seawater system + MGPS

- Cooling seawater -

Q1. What reflects the main functionality of the system?

5.1. Adequacy of cooling seawater supply
5.1.1. CSW pump inlet pressure
5.1.2. CSW pump outlet pressure

Q2. What reflects the overall system status?

5.2. Adequacy of cooling
5.2.1. LT cooler seawater inlet temperature
5.2.2. LT cooler seawater outlet temperature
5.2.3. Cooling seawater flow rate
5.2.3.1. A number of running CSW pumps

5.3. Adequacy of chemical dosage
5.3.1. Seawater chemical dosage rate
5.3.2. Cooling seawater flow rate
5.3.2.1. A number of running CSW pumps

5.4. Blockage of sea chest filter

5.4.1. Differential pressure of sea chest filter
5.4.1.1. Sea chest filter inlet pressure
5.4.1.2. Sea chest filter outlet pressure
5.4.2. CSW pump inlet pressure
5.4.3. CSW pump outlet pressure

Q3. If there are changes in system states, what are the causes of such changes?

5.5. Within the system
5.5.1. Performance degradation
5.5.1.1. Mechanical parts
5.5.1.2. Cleanable or renewable parts
5.5.1.3. Running hour
5.5.1.4. Maintenance interval
5.6. Impact of environment
5.6.1. Impact on cooling performance
5.6.1.1. Seawater temperature
5.6.2. Impact on cooling water supply
5.6.2.1. Presence of marine organisms, mud and floatage in the area

Q4.1. Will the current flow rate provide sufficient cooling?

5.7. Seawater cooling capacity
5.7.1. Seawater temperature
5.7.2. Cooling seawater flow rate
5.7.2.1. A number of running pumps
5.7.3. Differential pressure of the sea chest filter
5.7.3.1. Sea chest filter pressure
5.7.3.2. Sea chest filter pressure
5.8. Seawater cooling demand
5.8.1. LT cooler LTCW outlet temperature
5.8.2. LTCW target temperature
5.8.3. LT cooler three-way valve position
5.9. Projected environmental factors
5.9.1. Projected seawater temperature
5.9.2. Projected marine organism in the area
5.10. Projected engine room system cooling demand
5.10.1. Projected main engine load
5.10.2. Projected generator load
5.10.3. Projected boiler load
5.10.4. Projected auxiliary machinery load
5.10.5. LTCW target temperature

- MGPS -

Q1. What reflects the main functionality of the system?

5.11. Anode current

Q2. What reflects the overall system status?

5.12. Adequacy of anode current
5.12.1. Anode sacrificial rate
5.12.2. Presence of marine growth in seawater cooling system
5.12.3. Cooling seawater flow rate
5.12.3.1. A number of running CSW pumps

Q3. If there are changes in system states, what are the causes of such changes?

5.13. Within the system
5.13.1. Performance degradation
5.13.1.1. Mechanical parts
5.13.1.2. Renewable or cleanable parts
5.13.1.3. Running hour
5.13.1.4. Maintenance interval
5.14. Impact of relevant systems
5.14.1. Impact on seawater flow rate
- Refers to "System. 5. Cooling seawater + MGPS"
5.15. Impact of environment
5.15.1. Voyage type
5.15.1.1. Ocean sailing
5.15.1.2. Freshwater sailing

Q4.1 Will an anode renewal be required?

5.16. Projected remaining life of anode
5.16.1. Anode current
5.16.2. Anode sacrificial rate
5.16.3. Anode renewal interval

Q4.2 Is there a need for adjusting the anode current?

5.17. Blockage of LT cooler at the given period
5.17.1. LT cooler seawater inlet pressure
5.17.2. LT cooler seawater outlet pressure
5.17.3. LT cooler filter running hour
5.18. Adequacy of anode current
5.18.1. Presence of marine growth in the seawater cooling system
5.18.2. Cooling seawater flow rate
5.18.3. Anode sacrificial rate
5.19. Projected marine organism in area
5.20. Salinity level in voyage area
5.21. Usage of low or high sea chest

6. Central cooling system (Low Temperature Cooling Water; LTCW)

Q1. What reflects the main functionality of the system?

6.1. Adequacy of LTCW supply
6.1.1. LT cooler LTCW inlet and outlet temperature
6.1.2. LT cooler LTCW inlet and outlet pressure
6.1.3. LTCW pump outlet pressure

Q2. What reflects the overall system status?

6.2. Adequacy of LTCW temperature control
6.2.1. Deviation of LTCW temperature from LTCW target temperature
6.2.1.1. LTCW temperature
6.2.1.2. LTCW target temperature
6.2.2. LT cooler three-way valve position

6.3. LTCW quality
6.3.1. CaCO3 (Total hardness)
6.3.2. Chloride
6.3.3. Ph
6.3.4. Nitrite (NO2)

6.4. Stability of LTCW expansion tank level
6.4.1. Deviation of LTCW expansion tank level from desirable LTCW expansion tank level
6.4.1.1. LTCW expansion tank level
6.4.1.2. Desirable LTCW expansion tank level
6.4.2. Impact of LTCW temperature on LTCW expansion tank level

Q3. If there are changes in system states, what are the causes of such changes?

6.5. Within the system
6.5.1. Performance degradation
6.5.1.1. Mechanical parts
6.5.1.2. Cleanable or renewable parts
6.5.1.3. Running hour
6.5.1.4. Maintenance interval

6.6. Impact of relevant systems
6.6.1. Impact on LTCW temperature
- Refers to "System. 5. Cooling seawater + MGPS"
- Refers to "System. 7. Jacket cooling water"

Q4.1 Is chemical dosage rate acceptable?

6.7. LTCW chemical dosage rate
6.8. Quality of LTCW
6.8.1. CaCO3
6.8.2. Chloride
6.8.3. Ph
6.8.4. Nitrite
6.9. Freshwater feed quantity into LTCW expansion tank

Q4.2. Will there be the need for increasing cooling capacity?

6.10. LTCW cooling capacity
6.10.1. LT cooler LTCW outlet temperature
6.10.2. LTCW flow rate into LT coolers
6.10.2.1. LT cooler three-way valve position
6.10.3. Number of LT coolers in use
6.10.4. Blockage of LT cooler at the given period
6.10.4.1. LT cooler seawater inlet pressure
6.10.4.2. LT cooler seawater outlet pressure
6.10.4.3. LT cooler filter running hour
6.11. Projected engine room system cooling demand
6.11.1. Projected main engine load
6.11.2. Projected generator load
6.11.3. Projected boiler load
6.11.4. Projected auxiliary machinery load
6.11.5. LTCW target temperature
6.12. Projected environmental factors
6.12.1. Projected seawater temperature
6.13. Past voyage data under similar conditions
6.13.1. Past seawater temperature
6.13.2. Past LTCW temperature
6.13.3. Number of LT cooler in use in the past

7. Jacket Cooling Water System (High Temperature Cooling Water; HTCW)

Q1. What reflects the main functionality of the system?

7.1. Adequacy of HTCW supply
7.1.1. HT cooler HTCW inlet and outlet temperature
7.1.2. HT cooler HTCW inlet and outlet pressure
7.1.3. HTCW pump outlet pressure

Q2. What reflects the overall system status?

7.2. Adequacy of HTCW temperature control
7.2.1. Deviation of HTCW temperature from HTCW target temperature
7.2.1.1. HTCW temperature
7.2.1.2. HTCW target temperature
7.2.2. HTCW flow rate into HT cooler
7.2.2.1. HT cooler three-way valve position

7.3. Stability of HTCW expansion tank level
7.3.1. Deviation of HTCW expansion tank level from desirable HTCW expansion tank level
7.3.1.1. HTCW expansion tank level
7.3.1.2. Desirable HTCW expansion tank level
7.3.2. Impact of HTCW temperature on HTCW expansion tank level

7.4. Quality of HTCW
7.4.1. $CaCO_3$ (Total hardness)
7.4.2. Chloride
7.4.3. Ph
7.4.4. Nitrite (NO_2)

Q3. If there are changes in system states, what are the causes of such changes?

7.5. Within the system
7.5.1. Performance degradation
7.5.1.1. Mechanical parts
7.5.1.2. Cleanable or renewable parts
7.5.1.3. Running hour
7.5.1.4. Maintenance interval
7.5.2. Status of engine load

7.6. Impact of relevant systems
7.6.1. Impact on HTCW temperature
- Refers to “System. 6. Central cooling”
- Refers to “System. 3. Steam system”
- Refers to “Machinery. 4. Freshwater generator”

Q4.1. Is there a need for HTCW temperature setting adjustment?

7.7. Speed of main engine load variation
7.8. Pre-heating requirement of main engine
7.8.1. HTCW heater steam consumption rate
7.8.2. Climate
7.9. Fuel type
7.10. Fuel sulfur content

Q4.2 Is chemical dosage rate acceptable?

7.11. HTCW chemical dosage rate
7.12. Quality of HTCW
7.12.1. $CaCO_3$
7.12.2. Chloride
7.12.3. Ph

7.12.4. Nitrite
7.13. Freshwater feed quantity into HTCW expansion tank

8. Freshwater service system

Q1. What reflects the main functionality of the system?

8.1. Adequacy of freshwater supply
8.1.1. Freshwater pressure tank pressure
8.1.2. Freshwater pressure tank level

Q2. What reflects overall systems status?

8.2. Adequacy of freshwater quality control
8.2.1. Differential pressure of freshwater filters
8.2.1.1. Freshwater filter inlet pressure
8.2.1.2. Freshwater filter outlet pressure
8.2.2. Quality of freshwater in freshwater tank
8.2.2.1. Chloride
8.2.2.2. Mud content in freshwater tank

8.3. Adequacy of freshwater service system operation mode
8.3.1. Freshwater pump auto start and stop pressure
8.3.2. Water and air ratio at given pressure of freshwater pressure tank
8.3.3. Freshwater pressure tank level

Q3. If there are changes in system states, what are the causes of such changes?

8.4. Within the system
8.4.1. Performance degradation
8.4.1.1. Mechanical parts
8.4.1.2. Cleanable or renewable parts
8.4.1.3. Running hour
8.4.1.4. Maintenance interval
8.4.2. Quality of freshwater in the freshwater tank

8.5. Impact of relevant systems
8.5.1. Impact on heating
- Refers to "System. 3. Steam system"

8.6. Impact of environment
8.6.1. Rolling & pitching

Q4.1 Is there a need for changing freshwater tank?

8.7. Projected remaining freshwater quantity in tanks
8.7.1. Remaining freshwater quantity in tanks
8.7.1.1. Dead freshwater quantity
8.7.1.2. Freshwater tank level
8.7.1.3. Rolling and pitching
8.7.1.4. Freshwater pump daily running hour
8.7.2. Freshwater production rate
8.7.3. Freshwater consumption rate
8.8. Quality of freshwater in freshwater tank
8.8.1. Chloride
8.8.2. Mud content in freshwater tank
8.9. Disuse hours of freshwater tanks
8.10. Freshwater tank cleaning plan

9. **Bilge system**

- Refer to "Machinery. 7. Oily Water Separator"

10. Stern Tube System

Q1. What reflects the main functionality of the system?

10.1. Adequacy of stern tube sealing
- 10.1.1. Stern tube air pressure
- 10.1.2. Stern tube LO pressure
- 10.1.3. Stern tube LO tank levels
- 10.1.4. Draft

Q2. Is overall systems status acceptable?

10.2. Efficiency of stern tube sealing
- 10.2.1. Stern tube drain quantity
- 10.2.2. Stern tube drain accumulation rate
- 10.2.3. Variance in stern tube LO tank levels
- 10.2.4. Quality of stern tube lubricant
  - 10.2.4.1. Water content in stern tube lubricant
  - 10.2.4.2. Salinity in stern tube lubricant

10.3. Adequacy of stern tube lubrication
- 10.3.1. Stern tube lubricant flow rate
- 10.3.2. Stern tube lubricant temperature
- 10.3.3. Stern tube lubricant pressure

Q3. If there are changes in system states, what are the causes of such changes?

10.4. Within the system
- 10.4.1. Performance degradation
  - 10.4.1.1. Mechanical parts
  - 10.4.1.2. Cleanable or renewable parts
  - 10.4.1.3. Running hour
  - 10.4.1.4. Maintenance interval
- 10.4.2. Draft

10.5. Impact of relevant system
- 10.5.1. Impact on air pressure
  - Refers to "System. 4. Compressed air system"

10.6. Impact of environment
- 10.6.1. Rolling & Pitching

Q4.1 Is there a need for changing air or LO pressure?

10.7. Projected draft
- 10.7.1. Ship loading condition
- 10.7.2. Ship ballast condition