Effective alarm management in the maritime industry

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Abstract

This paper provides a high level summary of the research investigating the experiences of watchkeepers regarding alarm management on operational ships, highlighting best practices and challenges. The findings aim to enhance the safety and efficiency of maritime operations. The research involved interviews, questionnaires, and a literature review of related work, including standards and good practices of adjacent industries. Key recommendations include adopting design processes and objective performance criteria, which factor in human limitations and capabilities at the regulatory level. Something which will invariably result in improved system design, better training, officer well-being, and effective alarm systems.

Keywords

Alarm management; Time-critical actions; Maritime industry; Watchkeepers; Safety; Efficiency;

Introduction

The maritime industry faces significant challenges related to safety and operational efficiency, with alarm management being a critical aspect. Alarms are essential for alerting watchkeepers to potential issues, and effective management is crucial for maintaining safety. This paper summarises the research report on alarm management, providing insights into best practices and challenges.

Background

The research project aimed to survey alarm systems in the maritime industry. The focus was on the experiences and opinions of watchkeeping officers, juxtaposed with preliminary analysis of shipborne alarm data.

Methodology

The research involved engaging with personnel on board 15 ships, conducting semi-structured interviews, and collecting questionnaire responses from 65 watchkeeping seafarers. Field observations on bridge alarms were made on two modern technical sister ships. Over 12 years of engine room alarm/event log data were obtained for future work. Discussions were also held with more than 10 distinct ship owners and various technical executives.

Key Findings

Watchkeepers' experience

The research highlights the challenges faced by watchkeepers in managing the noise and rate of alarms, particularly in urgent or time-pressured situations. The interviews and questionnaires revealed a range of opinions and experiences, providing a rich narrative from the end users' perspectives.

Based on the watchkeepers' opinions and observed experiences, it is clear that the majority of alarms on both the bridge and within the ECR are perceived to be unnecessary in terms of requiring user action. With observed rates at times exceeding one alarm per minute, it is impossible to argue that a ship would be sufficiently resourced in terms of qualified manning to action such rates in any case.

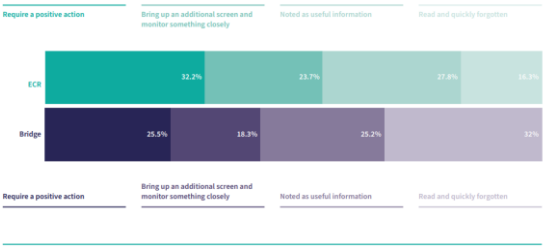

Figure 1: Survey responses when asked proportion of the 10 most typical alarms actually require an operator's response

On average, less than one third of the 10 most typical alarms were reported to require users to take positive action (Figure 1). This indicates missing steps within the alarm management lifecycle, in particular rationalisation.

For multiple engineers, the system provided invaluable information for system analysis after a critical piece of machinery had tripped, which typically generated an excessive number of alarms, causing an alarm flood—sometimes forcing the watchkeepers to accept alarms without time to read and understand them (Figure 2). The alarms would be muted and acknowledged until the alarm flood ended. From that point, the engineers would use the mimics to recover the ship's critical systems and later use the chronological alarm list on the HMI to investigate for the root causes.

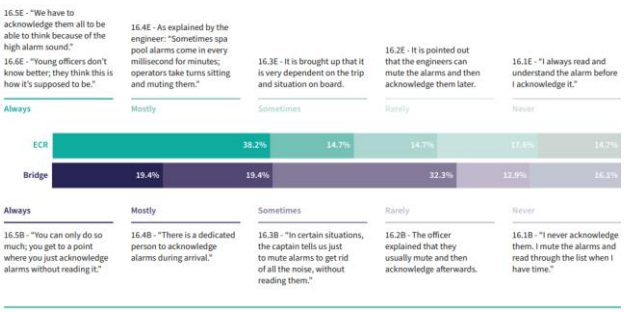

Figure 2: Survey responses when asked if they feel forced to accept alarms without time to read and understand them

A review of experiences of nuisance alarms, those acknowledged or silenced without subsequent operator action, also showed that the majority of watchkeepers believe they are often exposed to irrelevant alarms that chatter, are fleeting or happen for no rational reason.

Alarm data analysis

The preliminary analysis of alarm data from one of the sampled ships revealed significant insights into the operational challenges. In particular, high rates of nuisance alarms, overwhelm the watchkeepers and hinder their ability to respond effectively to real alarm situations. Such alarms systematically "break" the watchkeepers and change how these people think about and respond to alarms—leading to a dangerous normalisation of deviance.

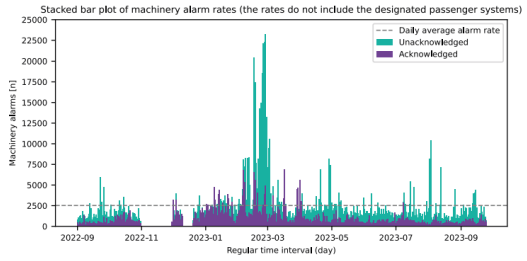

Figure 3: Daily alarm rates - Machinery (zero values for specific dates indicate missing data, not zero alarms)

Overall, the ship exhibited an alarm rate of ~2500 machinery alarms per day. Some alarms clear before being acknowledged (fleeting or chattering behaviour) or are muted instead of acknowledged to prevent reannunciation (Figure 3). This "mute only" strategy was observed to be adopted by multiple engineering and navigational watchkeepers on other ships as well.

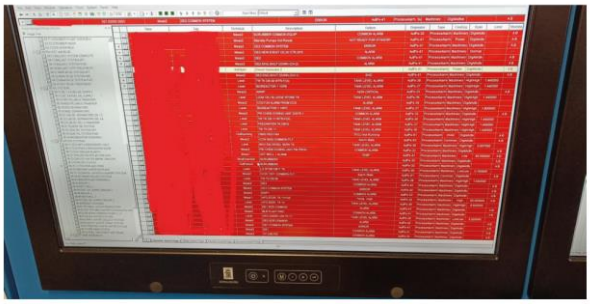

Figure 4: ECR HMI Alarm list on board the ship from bridge observation 1. Same situation on sister ship from observation 2

On the ship of the first bridge alarm load recording the authors noted that only a single engineering watchkeeper used the alarm list display in the ECR. It was also noted that no one used it on the sister vessel. Although no fewer than six large monitoring displays were available, the other watchkeepers preferred displaying other IAS mimics with various machinery P&IDs and sensor readings, such as the auxiliary boilers, the power management system, and the propulsion systems. This was common for other cruise ships and larger passenger vessels sampled in this report. This tendency is understandable, considering the substantial mental effort required to extract actionable information from these continuously growing collections of strings (text) printed onto the alarm HMI screen (Figure 4).

Best practices and recommendations

Extensive work in adjacent industries has addressed various aspects of the 'alarm problem', applying interdisciplinary methods from human factors/ ergonomics, control and instrumentation engineering, and systems thinking. These approaches emphasise the importance of usability of alarm systems under normal and abnormal conditions. In 1999, the Engineering Equipment and Materials Users Association (EEMUA) published its *Alarm Systems: A Guide to Design, Management and Procurement*, which has become a globally accepted source of good practices in alarm management. It is now coming into itsfourth edition and offers definitions and guidance for the principles of alarm system design, including general and specific assessments, how to implement an alarm management system in an organisation, and how to define an alarm philosophy.

One of the concepts presented by the publication is that of an Alarm Management Lifecycle, including sequential and iterative steps with multiple points of entry. Examining each individual step of the lifecycle would be too extensive, but it is worth describing some of its key concepts in relation to the work in this report.

The *Rationalisation stage (C)* is particularly important in moving from the design of an alarm system through to a set-up that is practically effective for its end users. This activity requires that each alarm justifies its value to the human operator who will later be expected to action it.

Rationalisation, in the context of the Alarm Management Lifecycle, imposes a set of key quality attributes that make an alarm fit for purpose, the three most prominent of which are:

1. Every alarm should have a defined purpose.

2. Every alarm should have a defined response.

3. Adequate time should be allowed for the operator to carry out this response.

If a signal from the system in question cannot satisfy these qualities, then the signal should not be an alarm.

A consolidated view of each lifecycle stage, its activities, inputs and outputs are depicted in the Table 1.

Table 1: Inputs and outputs of activities in the Alarm Management Lifecycle (taken from IEC 62682:2014)

Alarm management lifecycle stage		Activities	Clause number	Inputs	Outputs
Stage	Title				
A	Philosophy	Document the objectives, guidelines and work processes for alarm management, and ASRS.	6,7	Objectives and standards.	Alarm philosophy and ASRS.
B	Identification	Determine potential alarms.	8	PHA report, SRS, P&IDs, operating procedures, etc.	List of potential alarms.
C	Rationalization	Rationalization, classification, prioritization, and documentation.	9	Alarm philosophy, and list of potential alarms.	Master alarm database and alarm design requirements.
D	Detailed design	Basic alarm design, HMI design, and advanced alarming design.	10,11,12	Master alarm database and alarm design requirements.	Completed alarm design.
E	Implementation	Install alarms, implementation testing, and implementation training.	13	Completed alarm design and master alarm database.	Operational alarms and alarm response procedures.
F	Operation	Operator responds to alarms, and refresher training.	14	Operational alarms and alarm response procedures.	Alarm data.
G	Maintenance	Maintenance repair and replacement, and periodic testing.	15	Alarm monitoring reports and alarm philosophy.	Alarm data.
H	Monitoring & assessment	Monitoring alarm data and report performance.	16	Alarm data and alarm philosophy.	Alarm monitoring reports and proposed changes.
I	Management of change	Process to authorize additions,	17	Alarm philosophy and proposed	Authorized alarm changes.

The research outlines several recommendations, including the need for better system design and integration, improved training for watchkeepers, and the development of more effective alarm management policies.

Improved systems engineering and integration

One of the primary recommendations is to enhance the design and integration of alarm systems on ships. The report highlights the need for alarm systems that are intuitive and user-friendly, reducing the cognitive load on watchkeepers. But even more so on ensuring the quality of each alarm signal to be fit for purpose. Key suggestions include:

- Consolidation of alarms: Better integration of alarms from different packed systems can help watchkeepers manage alarms more effectively. This reduces the need to monitor multiple screens and allows for quicker identification and response to critical alarms.

- Prioritisation and filtering: Implementing mechanisms to prioritise and filter alarms based on their urgency and consequence of inaction can assist the operator where to allocate their time and resources during abnormal situations.

- Contextual information: Providing additional contextual information with alarms, such as the potential consequences of inaction and recommended actions, can help watchkeepers make informed decisions quickly, not to mention reduce the potential for operator errors or omissions of important safety actions.

Conclusion

The findings underscore the critical importance of effective alarm management in the maritime industry. By addressing the challenges identified and implementing the recommended best practices, the industry can improve the safety and efficiency of maritime operations. Continued research and collaboration are essential for further enhancing alarm management practices.

Future Work

Several areas for further research have been identified, including continued analysis of alarm data, development of maritime specific approaches to alarm rationalisation and objective performance assessments, which should be based on the recognition of human factors (human limitations and capabilities) in managing alarms. Pursuing these avenues can drastically improve the overall safety, efficiency, and well-being of the crew.

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