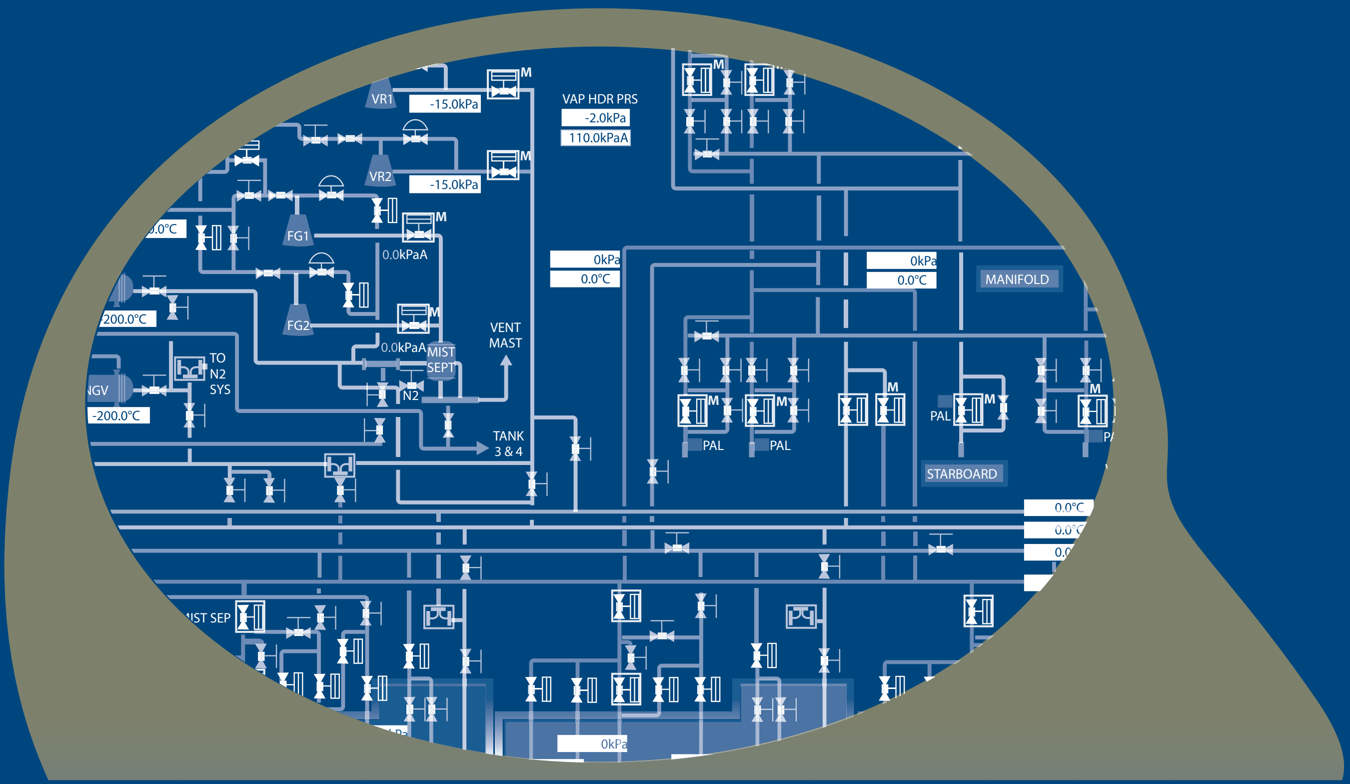

SIGTTO Society of International Gas Tanker & Terminal Operators Ltd

Recommendations for Management of Cargo Alarm Systems

First Edition

Human Element Series

Recommendations for Management of Cargo Alarm Systems

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SIGTTO

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info@witherbys.com
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Recommendations for Management of Cargo Alarm Systems

SIGTTO

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Part – 1

Introduction

1. Introduction

This publication recommends the implementation of *alarm management philosophies* for cargo alarm systems on gas carriers. The recommendation is for ship owners to work with system designers, Classification Societies and shipyards, to create a management system for cargo alarms on each ship. The information in this publication is based on existing philosophies in the ISM Code, the Code on Alerts and Indicators, the IGC Code and *IEC 62682* (Reference 1, Reference 2, Reference 3 and Reference 4). *Alarm management* is a good example of how *Human Element* considerations can lead to improved safety performance.

Modern cargo monitoring systems can be programmed with a virtually unlimited number of alarms. Such systems are then capable of generating a large number of alarms, almost simultaneously, in the event of an abnormal situation. This is generally referred to as *alarm flooding.* This effectively disables the alarm system as a source of information to the operator and may contribute to incident escalation.

C*hattering, fleeting* and *stale* alarms can reduce the efficiency of the cargo alarm system. It is vital that the operator can quickly check the status of the cargo system, including all safety critical elements, such as fire and gas detection, process and shutdown systems. The information presented to the operator should be grouped and presented in a manner that enables the operator to understand and react appropriately to a situation.

Alarm management is a systematic process that covers all typical issues found with modern alarm systems. A properly designed and implemented alarm management system can help to address the issue mentioned in the previous paragraphs. Alarm management is a comprehensive process that has been developed over many years. It addresses design, maintenance, training and audit aspects.

It is essential to recognise that the process of alarm management is not a one time event and that the procedures and settings will need to be reassessed over time. Audit review and management of change are important parts of this improvement process.

Part 1 of this publication provides a general introduction to this topic and Part 2 provides an overview of the alarm management lifecycle with relevant gas carrier references.

2. Scope

This document provides guidance for all types of gas carriers, from large LNG carriers to the smallest LPG carriers. All gas carriers will need to have alarm management processes, but less complex alarm systems will be easier to set up.

These recommendations are provided specifically for the cargo monitoring and safety systems on liquefied gas carriers. The recommendations have not considered the navigation, engine or any other monitoring systems.

These recommendations are for new ships only. These recommendations do not apply to existing ships and there is no suggestion that existing ships should be altered in any way. Owners of gas carriers may consider these recommendations if carrying out significant upgrades to alarm systems on an existing ship.

The purpose of these recommendations is to encourage owners to create an alarm management system that will address the design, management and operation of alarm systems. Owners may find valuable assistance from Classification Societies, alarm system designers and shipyards.

3. Introduction to Alarm Management

3.1 Background

Prior to the wide adoption of computer based systems, there were physical and economic limitations on the number of alarms that could be provided in a gas carrier's cargo system. Modern systems have improved and are now able to program in a large number of alarms. In addition, individual equipment manufacturers tend to request alarms for most deviations, which could result in a large number of cargo alarms being specified. If such a potentially complex system is not managed well it could be plagued with nuisance alarms and the operator is less likely to trust the alarm system.

In the event of a serious cargo incident, a system with a large number of alarms could cause *alarm flooding*. *Alarm flooding* interferes with the operator's ability to understand and respond correctly to the situation. The operator response speed, shown in the sub-system model below, consists of three stages: *Detect, Diagnose* and *Respond*.

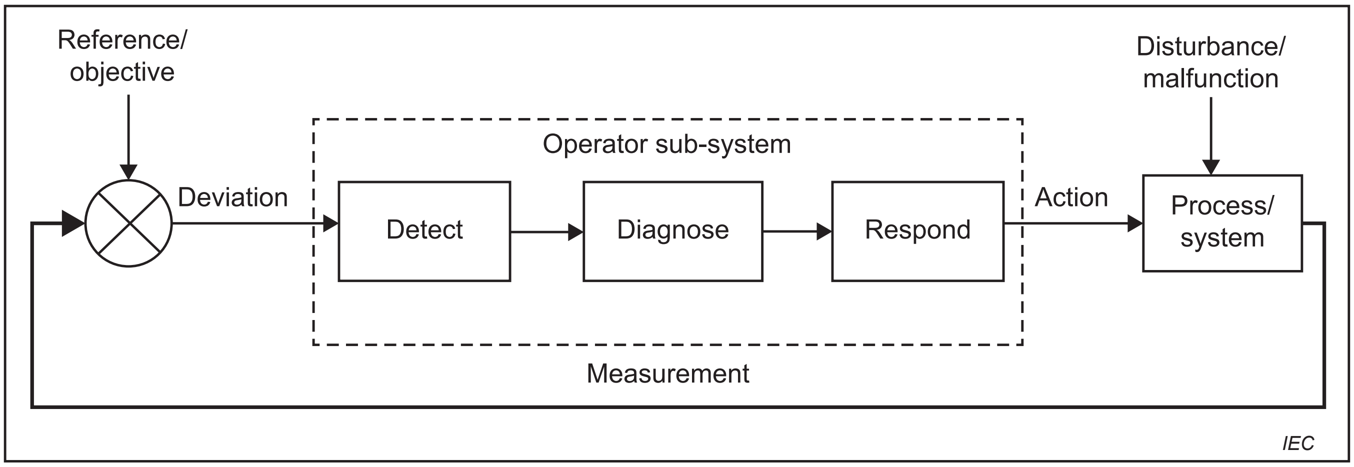

Figure 1: Feedback model of operator-process interaction (IEC 62682, Reference 4)

Alarm flooding interferes with the operator's ability to *Detect* accurately, and to *Diagnose* correctly. If the operator is confused or loses situational awareness, there may be a delayed or incorrect *Response*.

3.2 Alarm Management

Alarm management provides a structured method to create an effective alarm system that can help address the problems faced by highly automated systems.

This method can help to reduce the number of alarms to a minimum, which could reduce the possibility of the operator getting overwhelmed in an unfolding incident. The goal is to ensure that in an emergency the operator is only presented with information that is necessary to manage the situation. This is an example of how *Human Element* considerations at the design stage can lead to significant improvements in safety.

Alarm management also requires proper procedures to be in place to manage the many alarms that may be present in the system. An early stage is the collection of all relevant information relating to cargo alarms, which is then stored on a master alarm database. Procedures are created for managing change and specifying training requirements for operators and maintenance staff. Completing the process are audit requirements where the system is checked against ship specific alarm performance metrics.

3.3 Resources

The recommendations in this document are primarily based on creating a management system guided by the requirements in the ISM and IGC Codes, and the recommendations in the *Code on Alerts and Indicators* and *IEC 62682 – Management of alarm systems for the process industries* (Reference 1, Reference 3, Reference 2 and Reference 4). Each publication has information that is critical to setting up an effective alarm system. The next section provides a brief overview of relevant information contained in these publications.

4. Key Publications

Control room design and ergonomics is a vast subject. This document cannot, and does not attempt to, address all areas of this subject. There are many useful publications that the reader should consider, such as *ISO 17894 – General principles for the development and use of programmable electronic systems in marine applications, ISO 11064 – Ergonomic design of control centres* etc (Reference 5 and Reference 6).

The following documents are a useful starting point for implementing the process of alarm management:

- IMO – ISM Code (Reference 1)
- IMO – IGC Code (Reference 3)
- IMO – *Code on Alerts and Indicators (CAI)* (Reference 2)
- *IEC 62682 – Management of alarm systems for the process industries* (Reference 4).

4.1 ISM Code (Reference 1)

The ISM Code is an international standard for the safe management and operation of ships and for pollution prevention. The Code establishes safety management objectives and requires a safety management system (SMS) to be established by the ship owning/managing company. Alarm management procedures fall under the procedures required by the Code, which should be documented and compiled in a Safety Management Manual, a copy of which should be kept on board.

4.2 IGC Code (Reference 3)

The IGC Code is mandatory for gas carriers, so an initial list of mandatory cargo alarms and indicators can be compiled relatively easily. For example, in the IGC Code *Section 13.3 Overflow control,* there are the following requirements:

13.3.1 Except as provided in 13.3.4, each cargo tank shall be fitted with a high liquid level alarm operating independently of other liquid level indicators and giving an <u>audible and visual warning when activated</u>.

13.3.7 Where arrangements are provided for overriding the overflow control system, they shall be such that inadvertent operation is prevented. When this override is operated, <u>continuous visual indication</u> shall be given at the relevant control station(s) and the navigation bridge.

4.3 Code on Alerts and Indicators, 2009 (Reference 2)

The *Code on Alerts and Indicators (CAI)* is an adopted but non-mandatory code published by the IMO. CAI provides specific information on a behavioural approach to the description and prioritisation of alarms for the marine industry and how this sits within the overall philosophy of alarms on a ship. In addition to other information, CAI divides alerts in four priorities based on the required response of the operator: emergency alarms, alarms, warnings and cautions.

.1 Emergency alarm: an alarm which indicates that immediate danger to human life or to the ship and its machinery exists and that immediate action should be taken.

.2 Alarm: an alarm is a high priority of an alert. Condition requiring immediate attention and action, to maintain the safe navigation and operation of the ship.

.3 Warning: condition requiring no immediate attention or action. Warnings are presented for precautionary reasons to bring awareness of changed conditions which are not immediately hazardous, but may become so if no action is taken.

.4 *Caution: the lowest priority of an alert. Awareness of a condition which does not warrant an alarm or warning condition, but still requires attention out of the ordinary consideration of the situation or of given information.*

The CAI provides a list of alert and indicator types and locations, but this should be checked against the latest IGC Code. It is worth noting that the 2009 edition of the CAI does not contain information from the IGC Code 2016 edition.

4.4 IEC 62682 – Management of Alarm Systems for the Process Industries (Reference 4)

IEC 62682 addresses the development, design, installation, and management of alarm systems in the process industries. This standard provides the latest philosophy and approach toward alarm management and was adapted from *ANSI/ISA 18.2 Management of alarm systems for the process industries.*

Although the standard provides comprehensive guidance on the management of the entire *alarm system lifecycle* for process industries, it is not specific to gas carriers. However, it contains useful information that can help the owner through the process of alarm management.

Part – 2

Recommendations

5. Alarm Management Lifecycle

The alarm management lifecycle diagram provides an overview of the recommended steps for the process of alarm management. This part of the document will briefly review each stage of the lifecycle and provide relevant references to the IGC Code and CAI (Reference 3 and Reference 2).

The information provided is a high level overview and more information is available in *IEC 62682* and in other publications (Reference 4). The ship owner should be able to carry out effective alarm management with the help of system designers, Classification Societies and shipyards.

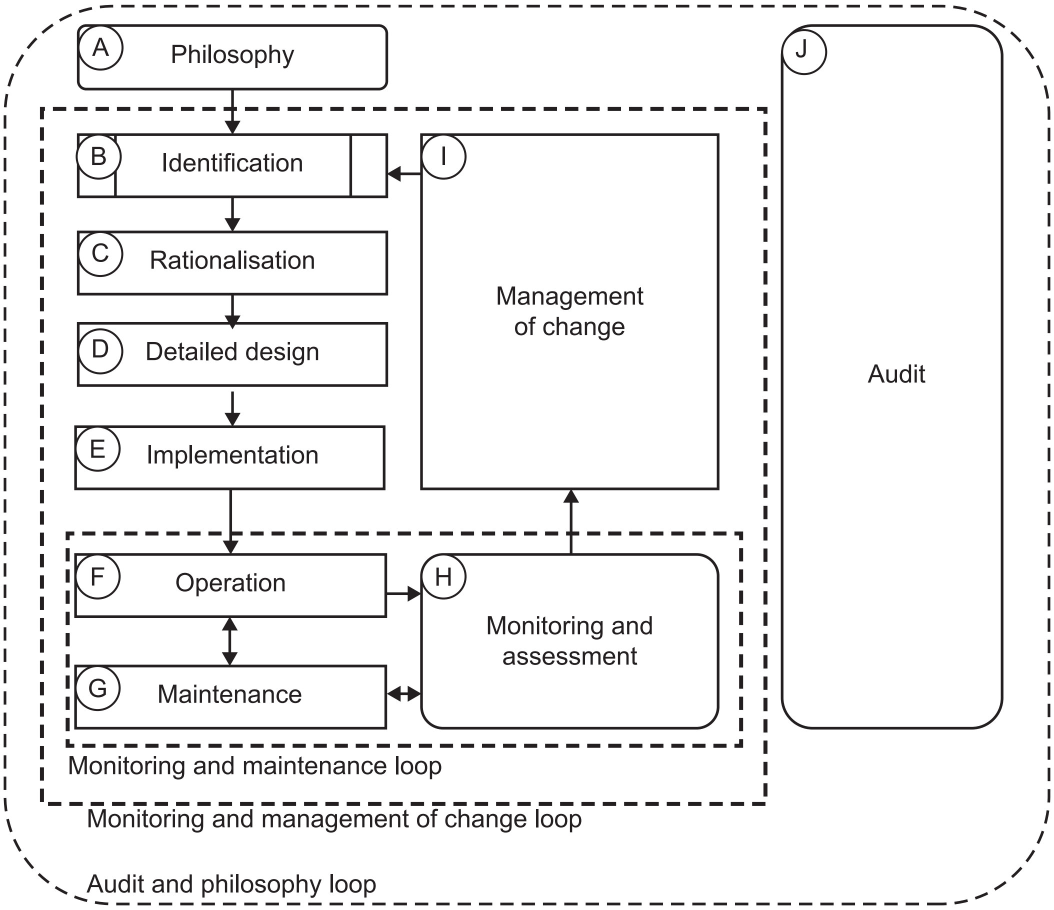

Figure 2: Alarm management lifecycle (IEC 62682, Reference 4)

6. Philosophy (A)

The recommended first step towards creating an *alarm management system* is to create a philosophy document. This document should contain the objectives of the system, ie how the ship-owner will address all aspects of alarm management. This document should contain information on the system design, operation and maintenance. It should also contain the philosophy that was used to classify and prioritise the alarms, colour code of alarms and performance standards. The roles and responsibilities should also be defined in the philosophy document.

The purpose of the philosophy document is to assist in creating consistency across the system and help with design and management. The recommended contents of an alarm philosophy document are available in *IEC 62682 – Table 3* (Reference 4).

Roles and responsibilities for alarm management should be defined in the philosophy document, including the identities of the personnel responsible for managing changes to the system, keeping proper records and carrying out maintenance. The philosophy document should be a 'controlled document' as defined by the ISM Code.

7. Identification (B)

Gas carriers are typically constructed and operated with a view to complying with international regulations, which are usually prescriptive by nature. Therefore, the initial stages of alarm identification are a straightforward process of identifying alarm requirements from relevant regulations.

For example, some of the alarms required at the cargo control station in CAI are listed in the table below (Reference 2).

Table 10.1.7 – Location: cargo control station				
IGC 13.4.2	High and low pressure in cargo tank	A	MI, AU, (V)	(2)
IGC 13.6.2 GC 13.6.4, 17.11	Gas detection equipment	A	AU, (V)	
GC 10.2.2 IGC 10.2.9	Shutdown of submerged cargo pumps	A	(AU, V)	
IGC 13.3.1 & 13.3.2 GC 13.3.1	High liquid level in cargo tank	A	AU, V	!, (2)
IGC 8.3.1.1 GC 8.4.2(a)	Vacuum protection of cargo tanks	A	(AU, V)	!, (2)
IGC 9.5.1, GC 9.5.2	Inert gas pressure monitoring	A	(AU, V)	!

Key: A-Alarm / AU-Audio / V-Visual / MI- Measuring Indicator

Table 1: Extracted alarms from CAI – Cargo control station (Reference 2)

Other potential alarms of the cargo system can be identified by analysing Piping and Instrumentation drawings, system mimic diagram workshops, and by reviewing experience of operators. If further analysis is required, and always in the case of special operations, specific hazard management studies such as HAZID / HAZOP / FMEA may be undertaken to identify additional alarms.

8. Rationalisation (C)

The CAI divides alarms into four categories: *emergency alarm, alarm, warning* and *caution* (see Section 4.3) (Reference 2). Potential alarms should be rationalised according to the philosophy document into one of these categories.

It is important that the operator should only receive alarms that require an operator response, so all *potential alarms* need to be carefully evaluated to decide if they should be categorised as an alarm. The aim is to minimise the number of alarms that fall into the *alarm* category. After this stage, alarms are further reviewed to define their attributes, such as *limit, priority type* etc.

Individual equipment manufacturers and system designers may propose a large number of alarms. The success of the rationalisation stage is in identifying those alarms that are required to be presented and those that can be categorised into other priorities such as *warning* and *caution*. Some types of information from equipment can be presented on the display to indicate a state, this is informative and is not an alarm. The rationalisation should extend to system alarms as well, to ensure that these alarms do not distract the operator without good reason.

Emergency alarms (EM) have a higher priority than alarms (A) and it is recommended that these should only be used as defined by the CAI to avoid confusion with other ship emergency situations (Reference 2). An example of EM, flooding of a compartment with an extinguishing medium such as CO_2, is shown below.

Table 10.1.4 – Location: at the equipment or at the location being monitored				
IGC 11.5.2 GC 11.5.2	Inerting/extinguishing medium release	EM	AU	Gas-dangerous enclosed spaces

Table 2: Extracted alarms from CAI – Emergency alarm example (Reference 2)

The output of this stage is recorded into a master alarm database, which should be maintained as a controlled document and kept updated for the life of the system.

9. Detail Design (D)

At this stage, information in the master alarm database is used to configure the system. This stage is critical to resolving alarm management issues. Careful configuration of alarm deadbands and on-off delays can help to reduce nuisance alarms.

State-based alarm techniques can help to reduce irrelevant alarms. For example, a low flow alarm can be suppressed if a pump was tripped.

This stage also includes human machine interface (HMI) design, ie the display and annunciation of alarms, including the priority.

9.1 Human Machine Interface Design for Alarm Systems

HMI design is important to give the operator an instant overview of any critical situation and to help them take the correct action. The information presented should cover all safety systems and provide information on alarm conditions, suppressed alarms, overrides, faults etc.

Good HMI design can help the operator to understand situations more easily. It also makes it easier for the operator to access relevant information when needed. *Grouping* information can help the operator to understand the situation without undue difficulty. *Grouping* could be based on the type of situation, physical location or logical connection between components.

It is recommended that active situations should be displayed in the order they appear and remain visible to the operator. The design should be capable of showing which alarm came first (*first up alarm*). The design should allow the operator to change between different situations if more than one is active at the time.

The information presented on the HMI should be of sufficient quality to allow the operator to take the correct action. Ideally, both distinctive symbols and colours should be used so that the status can be clearly distinguished even by colour blind operators.

10. Implementation (E)

This stage of the lifecycle covers the implementation of the new alarm system, moving from design to operation. Important considerations include functional testing, verification of documentation and training.

Relevant personnel, on ships and in the office ashore, should be trained on alarm management. Operators should be trained on the appropriate response to relevant alarms, prior to assuming responsibility for responding to those alarms.

The trickle down method of training is not considered to be sufficient for this concept. It is not sufficient to train the initial delivery crew teams and rely on the knowledge being passed on during handover. Any person that joins a ship should ideally receive training and familiarisation prior to assuming a position of responsibility for alarm management.

11. Operation (F)

The operation stage comes after implementation and after a maintenance event.

This stage deals with alarm response procedure recommendations, alarm shelving, record keeping and refresher training for operators.

Documentation on specific alarm response procedures should be readily available to the operator. This information should include the alarm tag name and number, type, setpoint, potential causes, operator action etc.

It is recommended that operator access to shelve or modify alarms should be controlled and only allowed as specified in the philosophy document. Proper authorisation and reauthorisation procedures should be in place and all documentation should be maintained. Watch handover should include a list of shelved alarms, if any.

Depending on the requirements of the class of alarms in the system, refresher training may be required for operators. This should have been identified and documented in the alarm philosophy stage.

12. Maintenance (G)

The section on maintenance in alarm management covers the condition when an alarm is removed from service for testing and repair and subsequently returned to service. If any alarms are temporarily not in service then suitable interim procedures should be in place until the fault is rectified.

Periodic testing requirements for alarms, including intervals for each alarm, should be documented in the alarm philosophy document. Periodic testing records should contain as a minimum: the date, result of the test, test method, name of persons carrying out.

An example of an alarm testing requirement in the IGC Code:

18.6.2 Essential cargo handling controls and alarms shall be checked and tested prior to cargo transfer operations (Reference 3).

The philosophy document may identify refresher training for personnel involved in maintenance. This is dependent on the classification of the alarm.

13. Monitoring and Assessment (H)

At this stage, alarm system performance is checked to ensure that it is effective. *Monitoring* checks the quantitative aspects and *Assessment* checks the qualitative aspects of the alarm system. Monitoring and assessment is important as it checks the effectiveness of other parts of the lifecycle. Alarm system performance can degrade over time, as sensors age and process changes, so performance measurement is essential to ensure system integrity.

CAI specifies four priorities for alerts on a ship, it is suggested that the annunciated alarm priority distribution for the four priorities should be suitable for gas carriers (see *IEC 62682 Table 6* (Reference 2 and Reference 4)).

Alarm system performance metrics are summarised in *IEC 62682 Table 7 – Recommended alarm performance metric summary* (Reference 4). A few target values in this table may not be entirely suitable for a typical gas carrier due to infrequent cargo operations. However, the spirit and intent of the metrics should be taken into consideration when deciding the target values for a ship.

In the absence of any other ship specific information, the alarm flooding metric of less than ten alarms in a ten minute period is recommended. Metrics on chattering and fleeting alarms, and those on unauthorised suppression and unauthorised change, are examples of metrics that can be applied verbatim to a ship alarm system.

Performance metrics for different types of cargo operation should be included in the alarm philosophy document. It is possible that the alarm metrics for a typical gas carrier may need to be split up into separate operations, ie cargo loading/discharging, carriage at sea, an FSRU in regas mode, etc.

14. Management of Change (I)

Management of change is an important part of the lifecycle. This philosophy is in line with the ISM Code requirements for ships.

To preserve the integrity and effectiveness of the system, it is important that changes are properly authorised and are in accordance with the alarm philosophy document. There should be procedures in place to cover the addition, removal or modification of alarms and to ensure that changes have the desired effect. For example, a change in the setpoint of an alarm should be monitored to verify that it has the desired effect.

It is important to ensure that there is a proper technical basis for any change and that it is in line with the alarm philosophy document. If the change is temporary, then the time limit for the change should be clearly stated. Proper records should be kept of any permanent changes to the alarm system and these should be retained for the life of the system. The records should include the reason, date, type and person authorising the change. Any training requirements identified should be fed back to the operator training standard.

Management of change records should be stored on the ship, and ashore with the company, for the life of the alarm system. These records may be stored electronically but should be in a format appropriate for archiving and searching. Editable records are not appropriate for archiving.

15. Audit (J)

Alarm management is part of the safety management system (SMS) prescribed by the ISM Code.

An audit is a periodic review to assess the integrity of the alarm system and the alarm management processes. The frequency and requirements of an audit should be specified in the alarm philosophy document.

The audit should check the operation of the system and practices to ensure adherence to the alarm philosophy document. Personnel interviews should be carried out as part of the audit to check that relevant personnel have been given appropriate training, and to check that the alarm management system is performing as intended.

16. Critical Alarm and Action Panel

The Critical Alarm and Action Panel (CAAP) is used to present vital safety related information and to activate vital safety related functions independent of operator stations. This panel contains indicator lights and activation buttons that are independent of the HMI screens in a control room.

The HMI screen for the cargo control and safety systems is the main operating interface at the cargo control room. In addition to the HMI, a CAAP should be provided in the cargo control room of gas carriers. This allows anyone to see the status of cargo critical safety functions at any time. This panel may be used to comply with the IGC requirement for overflow control systems:

13.3.7 Where arrangements are provided for overriding the overflow control system, they shall be such that inadvertent operation is prevented. When this override is operated, continuous visual indication shall be given at the relevant control station(s) and the navigation bridge. (Reference 3)

In line with *ISO 2412*, the indicator light should show green to indicate that a system is healthy and available (Reference 7). If the system is switched off, bypassed, has an error or is in any state that it will not function as intended, then the indicator should show red colour. The size of the indication should be sufficient that is visible to anyone in the cargo control room.

In addition to indication, the CAAP should also allow manual activation of cargo critical safety functions. The panel should include the following systems:

- Overflow control system
- emergency shutdown system
- gas detection
- fire detection
- water spray system.

The design of the manual shutdown buttons should be such that cargo critical systems can be brought to a safe state without using the operator station. The CAAP should be independent of the visual display unit and data networks, ie all control signals should be connected to the relevant logic solvers. Failure to execute cargo critical safety functions on demand shall initiate an alarm at the relevant control station(s) or the navigation bridge.

Annexes

Annex 1 – Glossary of Terms and Abbreviations

Alarm flood: condition during which the alarm rate is greater than the operator can effectively manage (eg, more than 10 alarms per 10 minutes)

Alarm management: collection of processes and practices for determining, documenting, designing, operating, monitoring, and maintaining alarm systems

Alarm philosophy: document that establishes the basic definitions, principles, and processes to design, implement, and maintain an alarm system

Alarm priority: relative importance assigned to an alarm within the alarm system to indicate the urgency of response (eg, seriousness of consequences and allowable response time)

Allowable response time: maximum time between the annunciation of the alarm and when the operator takes corrective action to avoid the consequence

Chattering alarm: alarm that repeatedly transitions between the alarm state and the normal state in a short period of time

Critical Alarm and Action Panel (CAAP): panel used to present vital safety related information, and to activate vital safety related functions independent of operator stations

FMEA: Failure Mode and Effects Analysis

HAZID: Hazard Identification study

HAZOP: Hazard and Operability study

HMI – Human machine interface: collection of hardware and software used by the operator to monitor and interact with the control system and with the process via the control system

Master alarm database: list of alarms in a controlled document

Operator: person who monitors and makes changes to the process

Prioritisation: process of assigning a level of operational importance to an alarm

Rationalisation: process to review potential alarms using the principles of the alarm philosophy, to select alarms for design, and to document the rationale for each alarm

Reset: operator action that unlatches a latched alarm

Shelve: temporarily suppress an alarm, initiated by the operator, with engineering controls to unsuppress the alarm

Suppress: prevent the annunciation of the alarm to the operator when the alarm is active

Suppress by design: alarm annunciation to the operator prevented based on plant state or other conditions

It is worth noting that there are differences in definitions between IEC and CAI and these should be taken into account to avoid confusion. For example the different definitions of an alert are given below:

CAI – Alert: announce abnormal situations and conditions requiring attention

IEC – Alert: audible and/or visible means of indicating to the operator an equipment or process condition

Annex 2 – Reference List

1. IMO – ISM Code: International Safety Management Code
2. IMO – Code on Alerts and Indicators (CAI)
3. IMO – IGC Code: International Code of the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
4. IEC 62682 – Management of alarm systems for the process industries
5. ISO 17894 – Ships and marine technology – Computer applications – General principles for the development and use of programmable electronic systems in marine applications
6. ISO 11064 – Ergonomic design of control centres
7. ISO 2412 – Shipbuilding – Colours of indicator lights

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