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Ships and marine technology — Ballast water management systems (BWMS) —

Part 2:
Risk assessment and risk reduction of BWMS using electrolytic methods

Navires et technologie maritime — Systèmes de gestion de l'eau de ballast (BWMS) —

Partie 2: Appréciation du risque et réduction du risque des BWMS qui utilisent des procédés électrolytiques

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 8, *Ships and marine technology.*

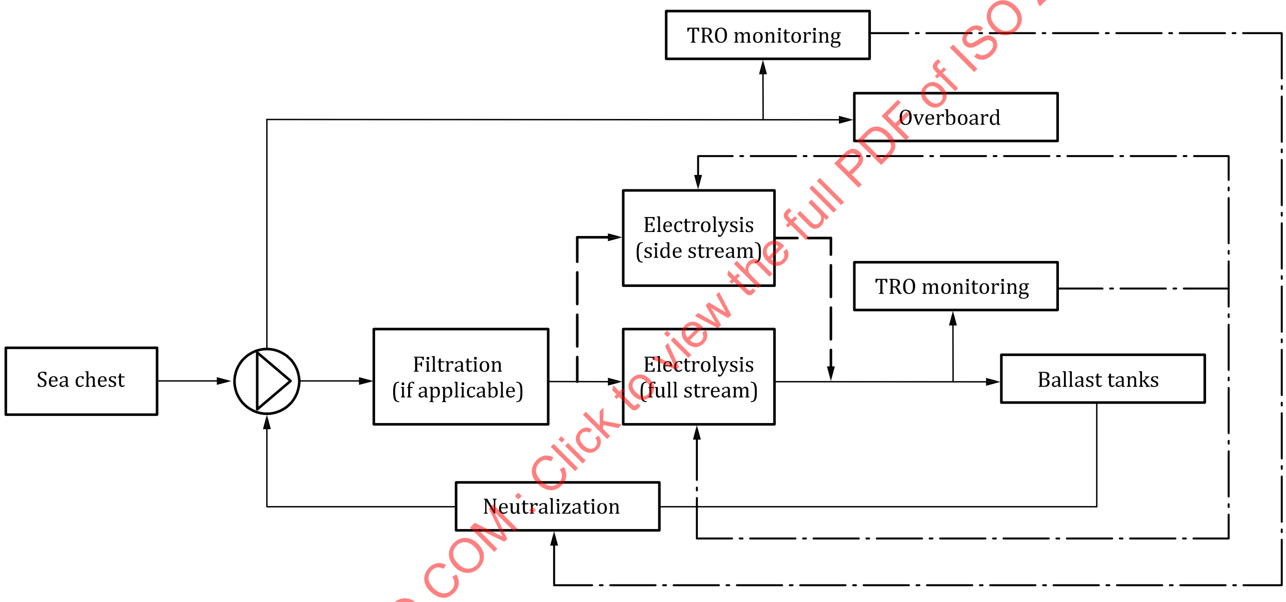
A list of all parts in the ISO 23314 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

A ballast water management system (BWMS) using the electrolytic method applies a combination of filtration (if applicable), electrolysis and a neutralization process to treat ballast water to meet Regulation D-2 of the International Maritime Organization (IMO) BWM Convention[19], or the ballast water discharge standard (BWDS) requirements of port state administrations, e.g. the U.S. Coast Guard (USCG)[31].

At the uptake of ballast water, the BWMS utilizes filtration (if applicable) and injection of active substances (e.g. sodium hypochlorite) generated by an electrolysis process. The active substance can be generated within the full flow of the ballast pipe (full stream) or generated from a smaller side stream (either extracted from the ballast pipe or sourced from a brine tank) and then mixed with the full ballast flow. The active substance in the ballast pipe is measured as total residual oxidants (TRO) and the BWMS regulates the TRO level to ensure ballast water is treated to the threshold level. During discharge, the residual TRO is monitored and neutralized prior to discharge overboard to ensure that the amount of residual active substance entering the receiving environment is acceptable. The treatment process is shown in Figure 1.



Key

——— or — — —	treatment flow
—— · ——	feedback signal

Figure 1 — Overview of BWMS using the electrolytic method

Ships and marine technology — Ballast water management systems (BWMS) —

Part 2: Risk assessment and risk reduction of BWMS using electrolytic methods

1 Scope

This document provides requirements and recommendations for designers of BWMS using electrolytic methods to document the risk assessment and risk reduction process over the lifecycle of the equipment, and to support its approval for use on ships by administrations and classification societies. Specifically, this document provides basic terminology, principles and a methodology to identify and subsequently minimize the risk of hazards in the design of BWMS using electrolytic methods. It specifies the procedures for risk assessment and risk reduction following the guidance in ISO 12100. Risks considered include: human health and safety; marine environment related to conditions on board; and ship installation, operation, maintenance and structural integrity.

This document does not address the methodology for the risk assessment of corrosion effects, toxicity and ecotoxicity of active substances, relevant chemicals and/or other chemicals generated or used by BWMS using electrolytic methods, which is evaluated by the IMO GESAMP-Ballast Water Working Group as prescribed in the document IMO GESAMP, Methodology for the Evaluation of Ballast Water Management Systems using Active Substances[26].

This document does not address risks associated with the end of life disposition of the BWMS.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12100 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
active substance
substance or organism, including a virus or fungus, that has a general or specific action on or against harmful organisms and pathogens

Note 1 to entry: For *BWMS* (3.3) using *electrolytic methods* (3.8), it means reaction products that are generated by the electrolytic method for the ballast water treatment.

[SOURCE: IMO G9]

3.2
ballast water
water with its suspended matter taken on board a ship to control trim, list, draught, stability or stresses of the ship

3.3
ballast water management system
BWMS
system that processes *ballast water* (3.2) such that it meets or exceeds the ballast water discharge performance standard in Regulation D-2 of the BWM Convention

Note 1 to entry: A BWMS includes ballast water treatment equipment, all associated control equipment, piping arrangements within the BWMS as specified by the manufacturer, control and monitoring equipment, and sampling devices.

Note 2 to entry: A BWMS does not include the ship's ballast water fittings, which can include piping, valves, pumps, etc. that would be required if the BWMS was not fitted.

Note 3 to entry: A ballast water treatment system (BWTS) defined in Environmental Technology Verification (ETV) is considered the same as BWMS.

[SOURCE: IMO BWMS Code]

3.4
dangerous gas
gas that can develop an explosive and/or toxic atmosphere hazardous to the crew and/or the ship

EXAMPLE Hydrogen (H_2), hydrocarbon gas, ozone (O_3), chlorine (Cl_2), chlorine dioxide (ClO_2).

3.5
electrical distribution conductor
conductor intended for distributing the electricity, such as bus bars or conductors of insulated cables

3.6
electrolysis unit
unit that mainly consists of one or several chambers making use of an *electrolytic method* (3.8) to produce *active substances* (3.1) for the treatment of *ballast water* (3.2), including ventilation components for the safe handling of *dangerous gases* (3.4) if applicable, as well as relevant piping, valves, electrical and electronic components

3.7
electrolytic chamber
chamber that contains one or several sets of electrodes and associated power connections, and that makes use of the *electrolytic method* (3.8) for the production of *active substances* (3.1) when water flows through it

3.8
electrolytic method
treatment process in which water flows through a set of special electrodes, producing *active substances* (3.1) when an electric current is applied

3.9
flammable liquid
liquid having a flash point not exceeding 60 °C (closed cup test)

3.10
global integrated shipping information system
GISIS
public integrated information database developed by the IMO, which is composed of several modules that deal with ship particulars, maritime safety, chemicals associated with treated *ballast water* (3.2) and other shipping-related information

3.11
life cycle
entire lifespan from the design, manufacturing, storage, installation, to operation and disposal of a *BWMS* (3.3)

3.12
maximum allowable discharge concentration
MADC
maximum allowable concentration of *active substances* (3.1) during discharge of *ballast water* (3.2) as defined by port state control or local regulation

3.13
neutralization unit
unit that mainly consists of neutralizing agent preparation and dosing equipment for the purpose of neutralizing *active substances* (3.1) by adding neutralizing agent into the de-ballast pipe so as to reduce *TRO* (3.14) concentration to achieve compliance with the *MADC* (3.12)

3.14
total residual oxidant
TRO
sum of the effect of oxidizing chemicals, such as hypochlorous acid (HClO), hypochlorite (ClO), chlorine (Cl_2), hypobromous acid (HBrO), hypobromite (BrO), bromine (Br_2), chloramine compounds, bromine compound

4 Strategy for risk assessment and risk reduction

The process for risk assessment and risk reduction is based on guidance from ISO 12100 and is summarized in Figure 2.

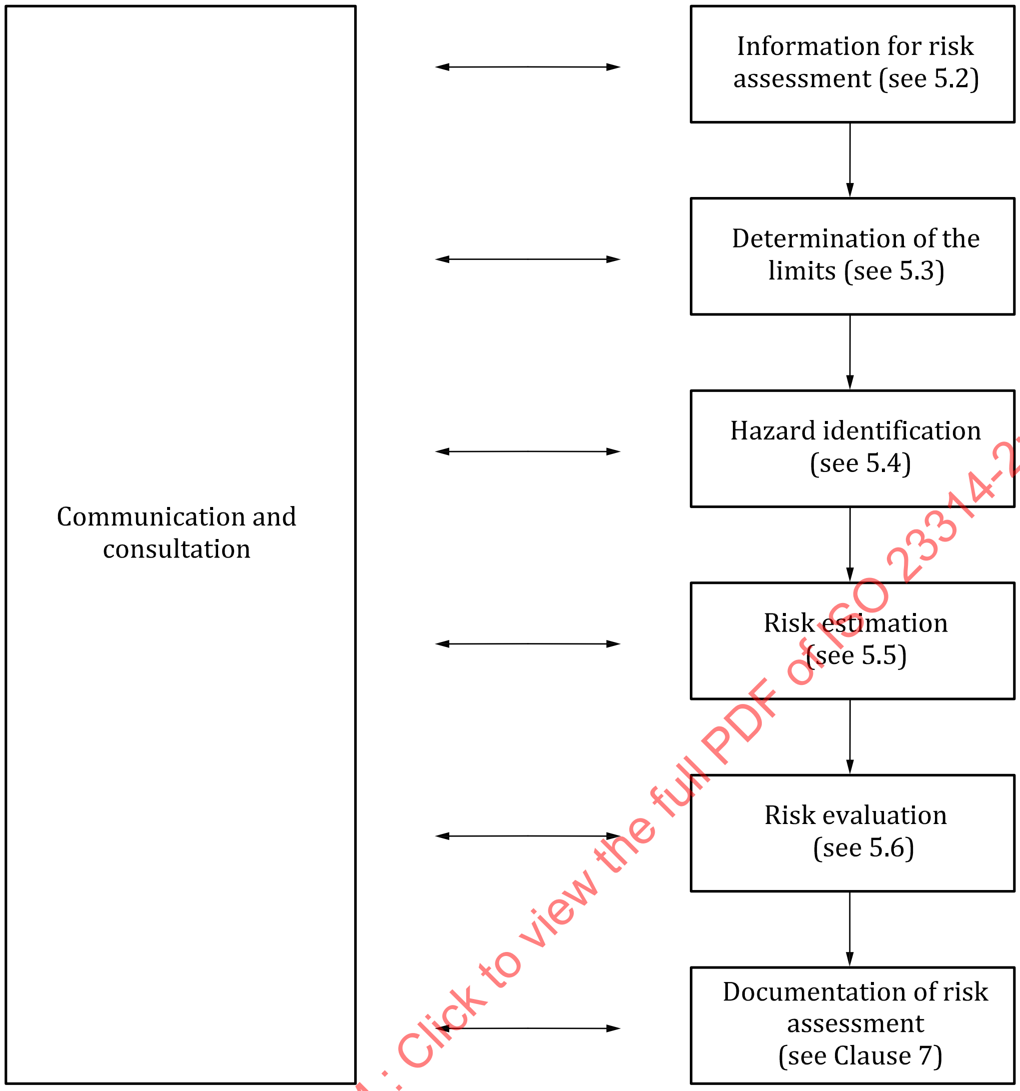


Figure 2 — General procedure of risk assessment and risk reduction for BWMS using the electrolytic method

5 Risk assessment process

5.1 General

The risk assessment for BWMS using the electrolytic method is comprised of risk analysis and risk evaluation.

Risk analysis consists of determining the limits, identifying the hazards, and estimating risk over the whole lifespan of a BWMS, as considered in 5.3 to 5.5. Risk analysis provides the information required for the risk evaluation (see 5.6), which in turn allows judgment to be made about whether or not risk reduction (see Clause 6) is required.

5.2 Information for risk assessment

The information for the risk assessment of a BWMS using the electrolytic method shall consider the documentation described in the following list.

a) System description:

— documents related to installation guidance; the operation, maintenance and safety manual (OMSM); schematic diagrams; process flow diagrams; and applicable test reports.

b) Regulations, standards and other applicable documents:

— ISO and IEC standards (e.g. IEC 60079), IMO regulations or circulars (e.g. BWM Convention[19], BWMS Code[21], Procedure G9[20]), IACS Unified requirements (e.g. IACS UR M74[27]), port state administration rules (e.g. USCG 46 CFR 162.060[31]), and classification society rules;

— safety data sheets (SDSs) of the active substance, neutralizing agent, TRO measurement reagent, and dangerous gas (e.g. hydrogen);

— database of chemicals commonly associated with treated ballast water in the IMO GISIS.

c) Related to experience of use:

— known accidents, incidents or malfunction history of the actual or similar electrochlorination systems (from database of marine incidents, e.g. GISIS):

— the potential for adverse effects from human exposure (e.g. to active substances);

— the experience of users of similar system e.g. electrochlorination system in power plant, waterworks, etc.

The information used in the risk assessment shall be updated throughout the design process or when modifications to the BWMS are required.

5.3 Determination of the limits

5.3.1 General

Risk assessment begins with the determination of the limits of the BWMS, taking into account all the phases over the lifespan of the BWMS. This means considering the characteristics and performances of both subsystems and the overall system as an integrated process. Characteristics of the system, including its relationship with humans, the environment, and other products shall be identified in terms of the limits of the BWMS as given in 5.3.2 to 5.3.5.

The purpose of this step is to identify all key parameters and their associated performance limits. These parameters pertain to installation, operation, maintenance, personnel and the environment.

5.3.2 Use limits

Use limits include the intended use and the reasonably foreseeable misuse of the BWMS. Aspects to account for include the following.

— The anticipated levels of training, experience or ability of the people who carry out installation, commissioning, operation, and maintenance of the BWMS, e.g. unexpected system shutdown can be activated due to misuse by an operator who is improperly trained or unfamiliar with the BWMS.

— Exposure of other persons to the hazards associated with the system that can be reasonably be predicted, e.g. crew for other duties, administration officer or service personnel for other equipment adjacent to the BWMS.

5.3.3 Space limits

Aspects of space limits shall address the requirements for safe installation, operation, and maintenance of the BWMS. Considerations shall include:

— power supply and cabling;

— cooling water or ventilation air;

— operation and maintenance space;

— space for chemical storage (e.g. neutralizing agent, TRO measurement reagent);

— space for dangerous gas exhaust on open deck;

— installation location (e.g. hazardous area).

5.3.4 Time limits

Aspects of time limits shall consider specific operating and maintenance factors, including:

— life limit of parts that can wear due to corrosion, or life of critical components where a decline in efficiency affects performance capabilities (e.g. electrode);

— recommended service and calibration intervals;

— holding time (minimum for efficacy and maximum based on regrowth);

NOTE The holding time can be dependent on water salinity, water temperature and TRO concentration.

— TRO measurement reagent service life/neutralizing agent shelf life in both solid (if applicable) and aqueous forms (stored in ready to use form).

5.3.5 Environmental limits

Environmental limits shall consider the range of uptake water chemistries to be treated, operational limits of process variables within the BWMS, limitations imposed by the shipboard environment on the BWMS, hazardous by-products of the electrolytic process, and any environmental constraints on the storage and use of chemicals associated with the BWMS. At a minimum, the following limits shall be considered:

— recommended minimum salinity and temperature of the ballast water;

— recommended minimum salinity and minimum and maximum temperature of the electrolytic unit feed water;

— recommended minimum inlet pressure of the filtration unit (if applicable);

— treatment rated capacity (TRC);

— maximum allowable discharge concentration (MADC), related to potential toxicity to the receiving environment;

— lower TRO limit for treatment efficacy;

— upper TRO limit for the potential corrosive effects on ballast tanks;

— ambient marine environment related to locations on board;

— potential flammable and explosive atmospheres that can be created on board the vessel;

— potential health risks to personnel due to exposure to dangerous gas, and flammable and explosive environments;

— personnel exposure to active substances or other relevant chemicals;

— TRO measurement waste (if applicable).

NOTE The limits including water salinity, water temperature, holding time, and TRO concentration are also identified as representative system design limitations (SDL) for a BWMS using the electrolytic method as per the BWMS Code[21].

5.4 Hazard identification

5.4.1 General

After determination of the limits of the BWMS, the next essential step is to identify the reasonably foreseeable hazards (permanent hazards), unexpected hazards, hazardous situations, and hazardous events during all lifecycle phases of the system, including:

— design;

— transportation, storage and installation;

— commissioning;

— operation;

— maintenance.

Only when hazards have been identified can steps be taken to eliminate them or to reduce risks. Hazard identification shall identify the hazards associated with the operations to be performed by the BWMS and the tasks to be performed by persons who interact with it while considering the different components, mechanisms or functions of the system, and the environment in which the system can be operated.

In addition to general mechanical and electrical hazards, the designer of the BWMS shall identify hazards specific to the electrolytic method while considering the items in 5.4.2 to 5.4.4.

5.4.2 Human interaction with the equipment over the entire life cycle of a BWMS using the electrolytic method

Over the course of building, installation, operation, maintenance and removal of a BWMS, personnel can be exposed to a number of hazards. These can be a result of normal operation, or consequences of maintenance or repair activities. Hazards shall be considered for the following conditions or activities.

a) Health effects due to contact with active substances or other relevant chemicals.

b) Start-up/shutdown of systems (i.e. electrical shock, water hammer, etc.).

c) In the case of an operator initiating emergency shutdown, hazards can be dependent on the reason for the shutdown and the ballasting stage. Potential hazards include:

— explosion, fire, smoke, or ruptured piping due to dangerous gas accumulation;

— treatment failure;

— potential toxicity to the environment;

— fire or smoke generation;

— stored energy (i.e. electric or hydraulic).

d) Preparation of the neutralizing agent solution or TRO measurement reagent, if applicable (e.g. injury due to direct contact with chemicals such as neutralizing agents or TRO measurement reagents).

e) Incorrect mechanical connection or electrical wiring during installation and commissioning.

f) Incorrect operating sequences in manual/override and maintenance modes that can override computer-based control safety devices and shutdowns.

g) Inappropriate maintenance or troubleshooting of the BWMS.

5.4.3 Possible states of BWMS using the electrolytic method

Both normal and abnormal states of equipment conditions should be considered during the identification of reasonably foreseeable hazards. At a minimum, the following conditions should be considered.

a) Flooding from burst components due to water hammer or fire.

b) Potential respiratory hazards due to inhalation of toxic compounds from plastic components and other materials involved in fires.

c) Potential respiratory hazards due to inhalation of active substances.

d) Blockage in filtration unit due to dirty load of ballast water or insufficient filter cleaning.

e) Corrosion due to incorrect material selection.

f) Dangerous gas leakage from electrolysis unit and the piping where dangerous gas can be present due to welding joint breaking or sealing failure, e.g. improper gasket sealing between the flanges.

g) High temperature arcing or sparking conditions created by improper or loose electrical connections.

h) Explosion or fire due to non-rated hazardous electrical equipment installed in designated hazardous zones.

i) Inoperability of the BWMS due to environmental conditions outside of the intended operation ranges, including salinity, temperature, ballast pump capacity, etc.

j) Potential release of dangerous gas into the ballast tank.

NOTE 1 A hazardous condition exists any time the concentration of dangerous gas inside the ballast tank (or other potential gas release locations) exceeds the lower explosive limit (LEL).

k) Electrical and electronic component failure due to shipboard environment (e.g. vibration, temperature).

l) Excessive electrical harmonics reflected to the ship's electrical distribution system.

NOTE 2 See IACS UR E24[28] and vessel-specific requirements by classification societies.

m) In the case of interruptions in ship's power supply (e.g. loss of power, electrical fault), potential hazards include:

— treatment failure;

— residual dangerous gas in electrolysis unit and associated piping or duct;

— stored energy (i.e. electric or hydraulic) after shutdown of BWMS;

— seized valves allowing inadvertent discharge of non-compliant ballast water to the environment (exceeding D-2 performance standard or excessive TRO);

— failure of performance of critical components for the handling of dangerous gas.

n) In the case of an automated shutdown, hazards can be dependent on the reason for shutdown and the ballasting stage. Potential hazards include:

— explosion, fire, smoke, or ruptured piping due to dangerous gas accumulation;

— treatment failure;

— potential toxicity to the environment;

— fire, smoke, or electric short due to water intrusion into the electric control or power supply;

— stored energy (i.e. electric or hydraulic) after automated shutdown;

— operator awareness to respond;

— effect on active cargo operations and to stresses on ship.

o) Treatment capacity decreasing due to low salinity or low water temperature or excessively aged electrode conditions.

p) Potential ingress of a flammable liquid into a non-hazardous space from a hazardous location.

5.4.4 Unintended behaviour of the operator or reasonably foreseeable misuse

Operator controls include provisions for maintenance and checkout of BWMS functions, which can have unintended consequences if the operator conducts actions that fall outside the expected sequence of commands. Hazards resulting from such actions shall be considered, including the following.

a) Dangerous gas accumulation due to faulty operation, safeguard failure or poor maintenance of danger gas removal module (if applicable) in the electrolysis unit.

b) Loss of treatment performance due to bypass or overriding of the BWMS.

c) Loss of treatment performance due to improper maintenance of the filter elements (if applicable).

d) Loss of instrument's utility due to improper maintenance or calibration (e.g. TRO analyser maintenance, calibration and maintenance of dangerous gas monitoring equipment).

e) Improper valve line up during ballast system operations that cause:

— low flow rate through the electrolytic chamber;

— high pressure in the electrolytic chamber or other relevant equipment (e.g. TRO analyser);

— high temperature in the electrolytic chamber.

f) Fire/explosion at the dangerous gas exhaust outlet at open deck.

5.5 Risk estimation

5.5.1 General

Following the identification of specific hazards, an estimation of the risk associated with each hazardous situation shall be determined by assessing the elements of risk as defined in 5.5.2. When assessing each element of risk, the aspects given in 5.5.3 shall be considered for each element. These aspects consider potential protective measures and risk mediation strategies that can be available.

NOTE See ISO 12100:2010, 5.5.1.

The purpose of this step is to determine the severity of harm and its probability occurrence for a BWMS using the electrolytic method. The goal of the estimation is to evaluate possible scenarios, from low risk and low severity of harm to high risk and high severity of harm.

Methods for risk estimation can be qualitative (defining the level of risk such as "high", "medium" and "low") and can incorporate consequence and probability to evaluate the resultant level of risk against qualitative criteria. Several tools or models are available for risk estimation. An example of a risk estimation tool is shown in Annex A.

5.5.2 Elements of risk

The risk associated with a particular hazardous situation depends on the following elements, as defined in ISO 12100:2010, 5.5.2.

a) Severity of harm.

b) Probability of occurrence of that harm, which is a function of:

— persons exposed to the hazard,

— occurrence of a hazardous event, and

— technical and human possibilities to avoid or limit the harm.

5.5.3 Aspects to be considered during risk estimation

5.5.3.1 Persons exposed

Risk estimation shall account for reasonably foreseeable hazards during installation, commissioning, operation and maintenance of a BWMS to all personnel (operators and others) that use this equipment.

5.5.3.2 Type, frequency and duration of exposure

A BWMS utilizing the electrolytic method provides the potential for exposure to chemicals used for disinfection treatment and neutralization, as well as electrical and hydraulic energy hazards. Exposure to any of these can result in injury. Estimation of exposure to each of these hazards shall be evaluated for a) all modes of operation, and b) during maintenance to the BWMS. In particular, the analysis shall account for the need for access during ballasting or de-ballasting treatment, maintenance, troubleshooting and chemical handling. When estimating risk of exposure to dangerous gases, time weighted average and short-term exposure limits shall be considered for both normal operating conditions and in the case of an emergency.

NOTE 1 The exposure limit to dangerous gas and chemicals can be found in relevant SDSs.

The risk estimation shall consider those tasks for which it is necessary to suspend protective measures, e.g. bypassing the BWMS in case of emergencies on board the ship to ensure the safety of the ship and crews.

NOTE 2 Five human exposure scenarios to active substances, relevant substances and by-products have been identified for BWMS in section 7.2.3 of IMO BWM.2/Circ.13/Rev.4.

5.5.3.3 Relationship between exposure and effects

The relationship between an exposure to a hazard and its effects shall be taken into account for each hazardous situation considered. The effects of accumulated exposure and combinations of hazards shall also be considered. When considering these effects, risk estimation shall, as far as practicable, be based on appropriate recognized data.

NOTE See ISO 12100:2010, 5.5.3.3.

5.5.3.4 Human factors

A BWMS using the electrolytic method is a complicated integrated system that is related to many human activities. Risk estimation from human factors shall consider the following:

— the interaction of a person(s) with the BWMS, e.g. operation, maintenance, troubleshooting and reagent preparation of the BWMS;

— interactions between persons, e.g. shift change during the operation and the maintenance of the BWMS;

— stress-related aspects, e.g. due to fire, bad weather, or other emergent situations;

— the capacity of persons to be aware of risks depending on their training, experience and ability;

— fatigue aspects (e.g. on duty for continuous long-time ballasting/de-ballasting treatment); and

— aspects of limited abilities (e.g. unfamiliarity with BWMS due to lack of experience or training).

NOTE See ISO 12100:2010, 5.5.3.4.

5.5.3.5 Suitability of protective measures

Risk estimation of BWMS using the electrolytic method shall take into account the suitability of protective measures and shall:

— identify the circumstances that can result in harm, e.g. using appropriate warning indication of dangerous gas or chemical, activation of an alarm with suitable settings for detection of dangerous gas and active substances;

— whenever appropriate, be carried out using quantitative methods to compare alternative protective measures, e.g. comparison rate of different materials that can be used in the BWMS, comparison of toxicity and corrosion characteristics of different neutralizing agents, which are used in the BWMS;

— provide information that can assist with the selection of appropriate protective measures, e.g. the SDSs of active substances, dangerous gases, and neutralizing agents, which are used or generated in the BWMS.

When estimating risk, special attention shall be paid to components that increase risk or directly affect treatment performance in case of failure, such as critical monitoring instruments, e.g. TRO measurement instrument, dangerous gas detectors, sensors for electrolysis reaction.

Protection to ship and crew can be improved by implementing inherently safe chemical handling and gas venting designs.

NOTE See ISO 12100:2010, 5.5.3.5.

5.5.3.6 Feasibility of protective measures

For the continued safe operation of the BWMS using the electrolytic method, the feasibility of the protective measures shall be considered. Protective measures that are inconvenient or difficult to implement can be overridden or ignored by the operators. For example, a protective measure (per the OMSM) to mitigate water hammers with slow opening or closing of manually operated valves can be overlooked by the crew during start-up or shutdown of the BWMS. This can be prevented by incorporating valves having an automated slow opening or closing function.

5.5.3.7 Sustainability of protective measures

The risk estimation shall take account of the sustainability of protective measures to ensure they are able to maintain the safe operation of the BWMS, e.g. automatic control to maintain the desired concentration of active substances during ballasting or de-ballasting treatment is required.

5.5.3.8 Information for use

Risk estimation shall consider the available information for use, e.g. installation guidance, commissioning procedures, and operating and maintenance procedures per the OMSM. See also 6.4.

5.6 Risk evaluation

After completion of the risk estimation, risk evaluation shall be performed to determine whether risk reduction is required.

Complete a risk evaluation according to ISO 12100:2010, 5.6.

6 Risk reduction

6.1 General

Risk reduction simultaneously reduces the severity of harm and the probability of occurrence, and shall follow protective measures as recommended by ISO 12100:

— incorporate inherently safe design measures;

— incorporate safeguards and complementary protective measures;

— provide information for use.

Standardized methods shall be used when applicable. Use existing information about a prototype or existing system to aid in risk reduction. This makes it possible for the designer to:

— estimate the risk associated with the potential hazards;

— evaluate the effectiveness of the protective measures implemented at the design stage;

— provide ship owners with quantitative information on potential hazards in the technical documentation;

— provide operators with quantitative information on potential hazard in the information for use.

6.2 Inherently safe design

6.2.1 General

Recognition and elimination of hazards during the design is the first and most important step in the risk reduction process, and offers an opportunity for an inherently safe design. Specific to BWMS using electrolytic methods, the designer shall address hazards following the guidance of ISO 12100 as listed in 6.2.2 to 6.2.4.

6.2.2 Considerations during the initial design

— Selection of materials and components that are resistant to corrosion including, but not limited to, filter elements, electrodes, piping to and from the electrolysis unit, and neutralizing pipeline.

— Selection of piping and materials that are suitable with respect to fire endurance and flammable spread requirements.

— Utilization of environmentally safe chemicals including, but not limited to, the neutralizer and TRO measurement reagent.

— Selection of electrode materials with a long service life based on test results, public information, or literature (e.g. per ISO 19097-2).

— Consideration of the expected dosage of the active substance and its effect on corrosion of materials and coatings used in ballast piping and ballast tanks in accordance with recognized methods (e.g. ISO 15711).

NOTE 1 An additional methodology for corrosion effect evaluation of active substances is prescribed in IMO G9 methodology (see BWM.2/Circ.13 and its revisions).

— Evaluation of active substances used or produced by the BWMS as they relate to toxicity and ecotoxicity.

NOTE 2 This is previously evaluated in accordance with Procedure (G9) adopted by resolution MEPC.169(57)[20] and the GESAMP BWWG Methodology (IMO technical circular BWM.2/Circ.13 and its revisions). Following a risk assessment by the GESAMP BWWG, basic and final approval of a BWMS that makes use of these chemicals can be approved by MEPC following a recommendation by the GESAMP BWWG.

NOTE 3 The GESAMP BWWG Database of Chemicals provides physio-chemical, toxicological, and ecotoxicological information related to chemicals commonly associated with ballast water treated by active substances.

— Selection of piping and materials that are structurally suitable against hydraulic shock (i.e. water hammer) and physical damage (supports, expansion, etc.).

— Automated controls to reduce valve speed and minimize water hammer effects as systems are shut down (i.e. plastic piping components).

— Means to prevent water hammer effects during pump and valve operations.

— Sufficient treatment capacity margin of BWMS for challenging situations.

6.2.3 Choice of appropriate technology

— Selection of electrical equipment of suitable explosion-proof type intended for use in hazardous areas on board the ship such as the pump room, e.g. intrinsically safe type equipment in compliance with IEC 60079.

— Reliability of electrical and electronic components for the marine environment in compliance with relevant standards (see corresponding IEC standards such as IEC 60068, IEC 60092, IEC 61000, and IEC CISPR 16).

— Marinizing electrical distribution conductors (i.e. DC bus bars, moderate and high ampere cable connections, etc.) to eliminate hazards caused by loosening connecting hardware causing high impedance connections (i.e. overheating electrical connectors due to I^2R losses).

— Design considerations to avoid excessive electrical harmonics imposed on the vessel's electrical distribution system.

— Proper dilution method for dangerous gas to the level much less than the lower explosive limit (LEL) or threshold, if applicable.

— Seamless connections for piping leading dangerous gas out of spaces where it is generated or passes to avoid potential leakage of dangerous gas from the piping whenever possible.

— Means to prevent accumulation of dangerous gas (e.g. ascending of vent pipe).

6.2.4 Applying inherently safe design measures to control systems

— Safety alarms and shutdowns shall not be capable of being overridden, and control system self-checking shall be performed before resuming operations. For example, critical sensors (i.e. dangerous gas detector, pressure sensor) continue monitoring the parameters before the electrolysis process can be restarted during ballasting.

— Application software should not be reprogrammable by the user. Adequate evaluation and verification shall be carried out for the software and hardware design of the control system in compliance with recognized standards, e.g. ISO/IEC/IEEE 12207. The modification of software shall be traceable and significant modification shall be verified by surveys and submitted for approval by authorities, e.g. the modification of control for TRO dosing concentration in ballasting treatment.

— Ability to override system software or hardware functions during standard operation shall be minimized. For example, test and maintenance functions should limit run times to avoid leaving pumps, valves, etc. in manual override for extended periods.

— Automatic monitoring for critical operational parameters such as ballast water salinity and temperature, process water temperatures (i.e. power supply cooling water if provided, and electrolytic cell internal temperatures, etc.), pressures (i.e. electrolytic cell internal pressure, filter internal and differential pressures, etc.), dangerous gas leakage, and active substance leakage, etc. shall be used to ensure protective measures perform properly.

— Internal and external critical alarms shall be operational in all modes, including automatic, manual and stand-by modes.

— A redundant ventilation fan as a fail-safe for dilution of dangerous gas shall be included. This function shall provide automatic monitoring and switching due to failure of the primary ventilation fan if applicable.

— Sufficient extra running of the ventilation fan before the starting of electrolysis process and after finishing the operation of the electrolysis unit shall be considered on the basis of the electrolysis capacity and on-board installation if applicable.

— A ventilation fan shall be connected to the emergency power on board or an uninterrupted power supply (UPS) for safe ventilation of dangerous gas in case of loss of ship's power if applicable.

— Critical alarms for the electrolysis process shall have independent shutdown functions, e.g. high pressure or high temperature alarm.

— Critical alarms for dangerous gas handling shall have independent shutdown functions, e.g. dangerous gas high level alarm.

— A computer-based control system is recommended to be connected to a UPS with sufficient reserve power to keep the control system from operating beyond the automatic loss of power shutdown for monitoring and logging of events including closing of discharge valves if necessary.

— The ventilation fan in the space where the BWMS is located shall be interlocked with the BWMS so that the system cannot be operated unless the ventilation system is in operation.

6.3 Safeguarding and/or complementary protective measures

6.3.1 General

If it is not reasonably possible to eliminate the hazards or reduce the associated risk by the inherently safe design steps in 6.2, safeguarding and complementary protective measures shall be implemented. Several approaches are identified in 6.3.2 and 6.3.3.

6.3.2 Safeguarding measures

Personal protective equipment (PPE) specific to SDSs shall be identified as appropriate for preparing and handling the chemicals (e.g. neutralizer, electrolytic cell cleaning chemicals).

6.3.3 Complementary protective measures

— Emergency stop functions shall be provided and be independently wired to the computer-based controls. These shall be highly visible and clearly labelled.

— Isolation measures such as installing metallic isolation valves with fail-safe closing functions shall be provided between plastic piping components of the BWMS and vessel's ballast system if applicable (i.e. protection against flooding and ruptured plastic piping components).

— Means shall be provided to ground stray electrical current impressed in conductive water streams (i.e. electrolysis cell inlet and outlet piping systems).

— Means shall be provided to ground power supply equipment and the electrolytic chamber terminal in case that maximum output voltage of power supply equipment exceeds 42,4V peak or 60VDC in accordance with IEC 60950.

— Temperature control can be required for side stream electrolysis feed water. This should include safety features to prevent electrolytic chamber feed water from overheating. If electrical heaters are used, provide adequate electrical isolation to prevent electric shock to operators, and if steam heating is used, prevent over pressurization of the steam heater, etc.

— Safety guards to protect personnel shall be provided on all rotating machinery components (e.g. pump or motor shafts).

— Marine water or preparation of saline water shall be stored as a water source for the electrolysis unit under fresh water conditions, if necessary.

— For a system with multiple electrolytic chambers in parallel, each chamber should be fitted with suitable alarm functions (e.g. temperature, pressure, etc.). Any series configuration of electrolytic chambers shall be consistent with the approval conducted per the IMO G9 procedure. Any configuration that exceeds the TRC approved under the G9 process must be:

  1. tested according to BWM.2/Circ.13/Rev.4 (or above version) to demonstrate compliance with the previous approval;

  2. the configuration must be approved under G9.

— Dangerous gas detectors shall be fitted at locations where dangerous gas can be present or accumulate. The relevant alarm shall be triggered with the proper value not exceeding the LEL and in accordance with classification society rules, and this triggering shall result in system shutdown.

— Suitable detection of active substances shall be fitted and relevant alarms shall be triggered with the proper value according to the exposure threshold and vessel classification society rules.

— An alarm shall activate when the TRO monitoring level is out of range during the uptake of ballast water.

— An alarm shall activate when the TRO monitoring level exceeds the MADC during ballast water discharge.

— An alarm shall activate when the flow rate is beyond the TRC or design limit range of the BWMS, (i.e. minimum or maximum).

— The position of the bypass valve shall be monitored by the BWMS to prevent untreated water from entering the ballast tank or being discharged overboard, and the bypass alarm shall activate and be recorded automatically by the control system.

  NOTE This can require hazardous area rated electric valve position sensors for use in hazardous areas when, for example, the pump room ventilation is off.

— A system shutdown function shall activate for any critical component failure which directly affects the treatment performance and safety of the BWMS, (e.g. TRO measurement instrument and dangerous gas detector).

— Clear audible and visual alarms shall be activated at suitable manned stations.

— Means shall be provided to prevent reverse flow of dangerous gases into the dilution stream if applicable (e.g. through use of dampers, all equipment explosion-proof type).

— Residual from the TRO measurement shall be treated or neutralized before discharge if applicable.

— Appropriate isolation shall be arranged for the interconnection of ballast piping between hazardous area and non-hazardous area (e.g. two screw down check valves in series with a spool piece).

6.4 Information for use

6.4.1 General

It is very important to convey sufficient information to the user as an integral part of the design of the BWMS using the electrolytic method. The information shall cover storage, transportation, installation, commissioning, operation, calibration and maintenance of the BWMS. The information shall also include essential warning indication and the training plan and documentation on how to use the system.

6.4.2 Installation guide

The purpose of installation guidance is to help the persons who install the BWMS to be acquainted with all the knowledge and specific information necessary for proper and correct installation of BWMS using the electrolytic method. In addition to generic installation information, the installation guide should also include, but not be limited to, the following items for the BWMS:

— BWMS location and space requirement;

— total power demand and energy consumption requirement of the BWMS;

— specific material requirement for piping for active substances of high concentration;

— specific connection requirements for piping of dangerous gases;

— ventilation piping routing requirement from the electrolysis unit to the open deck;

— dangerous gas ventilation outlet location requirements;

— cooling requirement for the power supply unit of the electrolysis unit;

— wiring requirements between the power supply unit and electrolysis unit;

— ventilation requirement for the BWMS;

— specific distance requirement for TRO measurement;

— piping interconnection requirements between safe and hazardous zones.

6.4.3 Commissioning procedure

The commissioning procedure specifies the necessary guidance to validate the installation and verify the BWMS functions properly. The commissioning documentation assumes procedures are carried out by qualified engineers from the BWMS manufacturer in accordance with its procedures after completing installation. The commissioning procedures consist of verification of readiness, function verification, and a method for demonstrating operation.

NOTE The discussion of commissioning in this document does not address the commissioning process under IMO BWM.2/Circ.70[24].

The verification of readiness should include, but not be limited to, the BWMS location, piping material, ventilation of the BWMS, piping routing and connection for dangerous gas, class type or product certificate, sensor reagent and chemical preparation validity, and control software version check.

The function verification should include, but not be limited to, the verification of critical alarm functions, e.g. low flow, high pressure, and high temperature for electrolysis, high level of dangerous gas, TRO high level during de-ballasting, TRO outside the controlled range in ballasting treatment, dilution failure of dangerous gas and system by-pass, independent shutdown function for dangerous gas ventilation and electrolysis, and emergency shutdown function.

The purpose of a demonstration operation test is to verify the BWMS is capable of automated, uninterrupted operation for both ballasting and de-ballasting processes. The BWMS should be operated automatically without activation of alarms in accordance with the commissioning procedure.

The vessel's flag administration or port state can require biological efficacy tests to validate compliance with regulation D-2 of the BWM Convention[19] or port state rules. These tests should be coordinated with all stakeholders (i.e. owner, operator, BWMS manufacturer, shipyard, flag, class society, and biological testing service provider, etc.). The testing is addressed in IMO Resolution A.1140(31)[22] and BWM.2/Circ.70[24].

6.4.4 Operation, maintenance and safety manual (OMSM)

The OMSM specifies the guidance for the persons involved in the operation and maintenance of the BWMS to carry out all the actions properly and safely. See ISO 12100 for the content of the OMSM. Relevant regulations and rules are also applicable for the compiling of OMSM, e.g. BWMS Code[21] or USCG 162.060-32[31] (as can be revised).

In addition to the description of the BWMS treatment technology, BWMS specification, and operation and maintenance procedures, the following should be highlighted in OMSM for BWMS using the electrolytic method:

— system design limitations, e.g. dosage of active substance, salinity, temperature, TRC, holding time, etc.;

— proper storage and safe handling of active substances, dangerous gas, chemical and reagent that are generated or used by the BWMS, in addition to the amount of substances to be held on board ship;

— procedures to be followed for leakage of dangerous gas or spillage of active substances and relevant chemicals, and in the case of shipboard emergencies, e.g. fire or flooding on board the ship;

— procedures for the management of wastes that can be generated during the operation of the BWMS.

6.4.5 Maintenance scheme

The maintenance scheme specifies the guidance for the persons who carry out periodic maintenance of the BWMS to keep it in good working condition, avoid malfunction, and prolong the service life. The maintenance scheme of BWMS can be integrated with shipboard planned maintenance system (PMS).

The maintenance scheme of BWMS should also include the following information in addition to the maintenance interval of generic marine components, e.g. piping, pumps, valves, and common sensors, e.g. pressure and temperature sensors:

— calibration schedule of critical sensors, e.g. the sensors for dangerous gas detection and ventilation, and sensors for TRO measurement;

— replacement schedule for the chemical or reagent, e.g. TRO measurement reagent (if applicable) and neutralizing agent;

— inspection schedule of the ventilation piping leading dangerous gas for corrosion and sealing condition.

6.4.6 Calibration manual

The calibration manual provides guidance to carry out the calibration of the essential sensors and meters. These devices can measure critical process parameters that are used to control and automate BWMS operations, therefore correct and accurate operations shall be ensured through periodic calibration. The manual shall include, but not be limited to, the calibration procedure and calibration interval, which can refer to sensor manuals or relevant regulations.

6.4.7 Warning indication

In addition to warning of malfunctions of mechanical, electrical, hydraulic, and pneumatic components, the BWMS should also include the following warning information.

— Warning signs shall be displayed near any location where a) the active substance is generated (e.g. by the electrolysis unit), and b) the neutralizer agent is stored or prepared (e.g. in the neutralizer unit). Signage shall indicate the chemical hazard, potential danger, and first aid information.

— The piping conveying dangerous gas should be marked with distinct colour if applicable.

NOTE ISO 14726 or other industry standard can be used for colour identification.

— Warning signs indicating that the possible emission of dangerous gas shall be permanently mounted at the ventilation outlet of the electrolysis unit (see ISO 24409-2).

6.4.8 Training plan and documentation

The training plan and documentation ensures the persons who perform BWMS operations and maintenance are acquainted with the knowledge and skills necessary for safe and correct operation and maintenance of the BWMS. The training plan shall include, but not be limited to, the system treatment process, BWMS operation, BWMS maintenance, instrument calibration, and chemical handling. The training can be carried out on board or in a workshop by qualified engineers. The training is recommended to be held in accordance with the manufacturers' specifications and training documentation shall be available on board the ship for crew reference. An example of a training plan is given in Annex E.

7 Documentation of risk assessment

The documentation shall contain a record of the procedure and results of the risk assessment and risk reduction and can help examine the decisions at a later time. Documentation shall be prepared in accordance with ISO 12100:2010, Clause 7.

Annexes B, C, and D give examples of risk assessment and corresponding protective measures to achieve risk reduction for the filtration unit (if applicable), electrolysis unit and neutralization unit, respectively.

NOTE See ISO/TR 14121-2 for information on documentation.

Annex A
(informative)

Example of a risk estimation matrix table in accordance with ISO/TR 14121-2

Table A.1 gives an example of the risk estimation tool in accordance with ISO/TR 14121-2. The risk matrix assists the persons performing the risk assessment in estimating the risk levels by scaling the severity of harm and probability of occurrence of harm. The severity level and probability level in Table A.1 are described is ISO/TR 14121-2:2012, 6.2.2.3 and 6.2.2.4. The risk level can be derived from Table A.1 after the severity and probability are estimated. The risk level ranking from L1 to L4 indicates the risk from lowest level to the highest level, which aligns with the risk level described in ISO/TR 14121-2:2012, Table 1.

Table A.1 — Example of a risk estimation matrix

Probability of occurrence of harm	Severity of harm			
	Catastrophic	Serious	Moderate	Minor
Very likely	L4	L4	L4	L3
Likely	L4	L4	L3	L2
Unlikely	L3	L3	L2	L1
Remote	L2	L2	L1	L1

Annex B
(informative)

Example of a risk assessment and risk reduction worksheet — Filtration unit

This annex provides examples of hazard events and the corresponding protective measures for the filtration unit (if applicable) employed by the BWMS using the electrolytic method, to assist the persons performing risk assessment to identify related hazards and achieve risk reduction, as shown in Table B.1.

The listed hazard events and the corresponding protective measures provided by this annex are not exhaustive. In addition, risk estimation is usually subjective and not performed per this annex; it is rather accomplished by the persons performing risk assessment based on empirical data and specification of the filtration unit (see 5.5).

Table B.1 — Example of a risk assessment and risk reduction worksheet — Filtration unit

ID	Hazard event	Cause	Risk estimation			Inherently safe design measures	Safeguarding and complementary protective measures	Remarks
			Probability	Severity	Risk level			
1	Leakage	Flange connection not properly secured	TBD	TBD	TBD		1. Regular visual inspection. 2. Pressure testing during commissioning.	
2	Leakage	Seal leaks	TBD				1. Periodic sealing replacement.	
3	Blockage	High dirt load on candles	TBD				1. Using pressure transmitter on filter outlet. 2. Reduce filtration flow when operating in entering high dirt load water voyage.	
4	Blockage	High pressure resistance on drain line	TBD				Choose suitable pipe size and piping arrangement to reduce the pressure loss after back-flushing line.	
5	Blockage	Screen lack of maintenance	TBD				Fresh water filling after each operation and periodic or emergent filter screen cleaning.	

Table B.1 *(continued)*

ID	Hazard event	Cause	Risk estimation			Inherently safe design measures	Safeguarding and complementary protective measures	Remarks
			Proba-bility	Sever-ity	Risk level			
6	Corrosion	Corrosion of the filter screen and filter body	TBD			1. Filter body is coated both inside and outside. 2. Provide sacrificial anode if possible. 3. Screen material should have excellent anti-corrosion characteristic.	Periodic inspection of filter internal and filter screen.	

Annex C
(informative)

Example of a risk assessment and risk reduction worksheet — Electrolysis unit

This annex provides examples of hazard events and the corresponding protective measures for the electrolysis unit employed by the BWMS using the electrolytic method, to assist the persons performing risk assessment to identify related hazards and achieve risk reduction, as shown in Table C.1.

The listed hazard events and the corresponding protective measures provided by this annex are not exhaustive. In addition, risk estimation is usually subjective and not performed per this annex; it is rather accomplished by the persons performing risk assessment based on empirical data and specification of the electrolysis unit (see 5.5).

Table C.1 — Example of a risk assessment and risk reduction worksheet — Electrolysis unit

ID	Hazard event	Cause	Risk estimation			Inherently safe design measures	Safeguarding and complementary protective measures	Remarks
			Probability	Severity	Risk level			
1	High level of dangerous gas	Leakage and/or accumulation of dangerous gas	TBD	TBD	TBD	1. Seamless connection for piping leading dangerous gas. 2. Proper dilution method for dangerous gas to the level much lower than LEL or threshold if applicable.	1. Dangerous gas detector is fitted with high level alarm.	

