No. 132 (Dec 2013)

Human Element Recommendations for structural design of lighting, ventilation, vibration, noise, access and egress arrangements

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Section 1 - Introduction

1.1 Scope and objectives

The objectives of this recommendation are to summarise information for human element and ergonomics during the structural design and arrangement of ships, including:

a) Stairs, vertical ladders, ramps, walkways and work platforms used for permanent means of access and/or for inspection and maintenance operations according to 9.2.1.1 and 9.3.1 of IMO Resolution MSC.296(87).

b) Structural arrangements to facilitate the provision of adequate lighting, ventilation, and to reduce noise and vibration in manned spaces according to 9.2.1.2, 9.3.2, and 9.3.3 of IMO Resolution MSC.296(87).

c) Structural arrangements to facilitate the provision of adequate lighting and ventilation in tanks or closed spaces for the purpose of inspection, survey and maintenance according to 9.2.1.3 and 9.3.4 of IMO Resolution MSC.296(87).

d) Structural arrangements to facilitate emergency egress of inspection personnel or ships' crew from tanks, holds, voids according to 9.2.1.4 and 9.3.5 of IMO Resolution MSC.296(87).

1.2 Application

This document is an IACS non mandatory recommendation on human element considerations during the structural design and arrangement of ships under the scope and objectives specified in 1.1 above. In addition, this document also provides information for industry best practices regarding human element considerations for design of lighting, ventilation, vibration, noise, access & egress.

1.3 Definitions

Ergonomics: 'Ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance.' (Source: International Ergonomics Association, 2013)

Human element: 'A complex multi-dimensional issue that affects maritime safety, security and marine environmental protection. It involves the entire spectrum of human activities performed by ships' crews, shore-based management, regulatory bodies, recognised organizations, shipyards, legislators, and other relevant parties, all of whom need to co-operate to address human element issues effectively.' (Source: IMO Resolution A.947(23))

1.4 Recommendation overview

This document is laid out in a number of sections and annexes with the purpose of presenting clear guidance on applying good ergonomic practice for design for lighting, ventilation, vibration, noise, access & egress.

- **Section 2** – The purpose of this section is to explain why the human element is increasingly seen as an important topic and how the regulations that govern shipping are increasingly putting more emphasis on the human element.

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- **Section 3** – The purpose of this section is to present a rationale for why the human element should be considered for the recommendation criteria – lighting, ventilation, vibration, noise, access and egress arrangements – and how this will have an implication for structures.

- **Section 4** – The purpose of this section is to present more detailed structural arrangement recommendations for each of the criteria – lighting, ventilation, vibration, noise, access and egress arrangements.

- **Annex A** – The Annex provides designers with measurement values for some of the criteria that can aid designers when applying design recommendations. They provide the designer with additional information that can assist in making design judgements.

- **Annex B** – The Annex presents a list of relevant standards that bear some relation to good ergonomic practice.

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Section 2 - The Human Element

2.1 Regulatory expectations

The regulations that govern the marine industry are gradually putting more emphasis on the human element. In general, the interest in the 'people aspects' of regulations is increasing due to the many rapid changes in the marine environment.

IMO Resolution A.947(23): Human Element Vision, Principles and Goals for the Organization

The IMO (according to Resolution A.947(23)) refers to the human element as:

"A complex multi-dimensional issue that affects maritime safety, security and marine environmental protection. It involves the entire spectrum of human activities performed by ships' crews, shore-based management, regulatory bodies, recognized organizations, shipyards, legislators, and other relevant parties, all of whom need to co-operate to address human element issues effectively."

In other words, anything that influences the interaction between a human and any other human, system or machine onboard ship, while accounting for the capabilities and limitations of the human, the system, and the environment.

IMO Resolution A.947(23) further states *"the need for increased focus on human-related activities in the safe operation of ships, and the need to achieve and maintain high standards of safety, security and environmental protection for the purpose of significantly reducing maritime casualties";* and that *"human element issues have been assigned high priority in the work program of the Organization because of the prominent role of the human element in the prevention of maritime casualties."*

ILO Maritime Labour Convention

The ILO's Maritime Labour Convention (MLC), 2006, provides comprehensive rights and protection at work for the world's seafarer population. It sets out new requirements specifically relating to the working and living conditions on board ships.

Aimed at seafarer health, personal safety and welfare in particular, the new MLC has specific requirements in Regulation 3.1 and Standard A3.1 for accommodation design and construction, especially in relation to living accommodation, sanitary facilities, lighting, noise, vibration, heating and ventilation.

2.2 Human Element Considerations

The human element in a maritime sense can be thought of as including the following;

a) Design and Layout Considerations

Design and layout considers the integration of personnel with equipment, systems and interfaces. Examples of interfaces include: controls, displays, alarms, video-display units, computer workstations, labels, ladders, stairs, and overall workspace arrangement.

It is important for designers and engineers to consider personnel's social, psychological, and physiological capabilities, limitations and needs that may impact work performance. Hardware and software design, arrangement, and orientation should be compatible with personnel capabilities, limitations, and needs. Workplace design includes the physical design and arrangement of the workplace and its effect on safety and performance of personnel.

In addition, designers and engineers should be aware of the cultural and regional influences on personnel's behavioural patterns and expectations. This includes, for example, understanding that different cultural meanings with regard to colour exist, or that bulky clothing is needed when using equipment in cold weather. Awareness of potential physical differences (e.g., male/female, tall/short, North American versus South-East Asian) is needed so that the design, arrangement, and orientation of the work environment reflects the full range of personnel.

If these factors are not considered, the workplace design may increase the likelihood of human error. Additional training, operations, and maintenance manuals, and more detailed written procedures cannot adequately compensate for human errors induced by poor design.

b) Ambient Environmental Considerations

This addresses the habitability and occupational health characteristics related to human whole-body vibration, noise, indoor climate and lighting. Substandard physical working conditions undermine effective performance of duties, causing stress and fatigue. Examples of poor working conditions include poor voice communications due to high noise workplaces or physical exhaustion induced by high temperatures. Ambient environmental considerations also include appropriate design of living spaces that assist in avoidance of, and recovery from, fatigue.

c) Considerations Related to Human Capabilities and Limitations

Personnel readiness and fitness-for-duty are essential for vessel safety. This is particularly so as tasks and equipment increase in complexity, requiring ever-greater vigilance, skills, competency and experience. The following factors should be considered when selecting personnel for a task:

- Knowledge, skills, and abilities that stem from an individual's basic knowledge, general training, and experience
- Maritime-specific or craft-specific training and abilities (certifications and licenses) and vessel specific skills and abilities
- Bodily dimensions and characteristics of personnel such as stature, shoulder breadth, eye height, functional reach, overhead reach, weight, and strength
- Physical stamina; capabilities, and limitations, such as resistance to and freedom from fatigue; visual acuity; physical fitness and endurance; acute or chronic illness; and substance dependency
- Psychological characteristics, such as individual tendencies for risk taking, risk tolerance, and resistance to psychological stress.

d) Management and Organizational Considerations

This factor considers management and organizational considerations that impact safety throughout a system lifecycle. The effective implementation of a well-designed safety policy, that includes ergonomics, creates an environment that minimizes risks. Commitment of top management is essential if a safety policy is to succeed. Management's commitment can be demonstrated by:

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- Uniformly enforced management rules for employee conduct
- Easy-to-read and clear management policies
- Allocation of sufficient funds in the owner/operator's budget for operations and for safety programs, including ergonomics, to be properly integrated and implemented
- Work schedules arranged to minimize employee fatigue
- Creation of a high-level management safety position which includes the authority to enforce a safety policy that includes ergonomics
- Positive reinforcement of employees who follow company safety regulations
- Company commitment to vessel installation maintenance.

Section 3 - Rationale for considering the Human Element in the design of lighting, ventilation, vibration, noise, access and egress arrangements

3.1 General

3.1.1 The design of the on board working environment for the ship's crew should consider environmental factors such as lighting, ventilation, vibration and noise. Insufficient attention paid to the physical working conditions can have an effect on task performance, health and safety and well-being.

3.1.2 The design of stairs, vertical ladders, ramps, walkways and work platforms used for permanent means of access should facilitate safe movement within or among working or habitability areas. Insufficient attention paid to access arrangements can have an effect on task performance and safety. Insufficient attention paid to egress arrangements can have an effect on safe evacuation during an emergency.

3.1.3 The following headings are applied to each of the criteria addressed in this recommendation to give the rationale for what needs to be considered from a human element perspective;

- Task requirements
- Ergonomic design principles
- Conditions
- Implications for structures

3.2 Lighting

3.2.1 Task requirements

- The lighting of crew spaces should facilitate visual task performance as well as the movement of crew members within or between working or habitability areas. It should also aid in the creation of an appropriate aesthetic visual environment. Lighting design involves integrating these aspects to provide adequate illumination for the safety and well-being of crew as well as affording suitable task performance.

- In order to facilitate operation, inspection, and maintenance tasks in normally occupied spaces and inspection, survey and maintenance tasks in closed spaces, the design of lighting should promote;

- task performance, by providing adequate illumination for the performance of the range of tasks associated with the space
- safety, by allowing people enough light to detect hazards or potential hazards
- visual comfort and freedom from eye strain.

3.2.2 Ergonomic design principles

- In order to facilitate the task requirements identified above, the following design principles are identified as needing to be achieved for lighting design. These design principles are based on good ergonomic practice and will form the basis for the development of the structural arrangement recommendations.

- The design of lighting should;

- provide adequate illumination for the performance of the range of tasks associated with the space

- be suitable for normal conditions and any additional emergency conditions
- provide uniform illumination as far as practicable
- avoid glare and reflections
- avoid bright spots and shadows
- be free of perceived flicker
- be easily maintained and operated
- be durable under the expected area of deployment

3.2.3 Conditions

- The provision of adequate lighting is dependent on several factors which need to be taken into account. These include;

- Time of day and external light characteristics
- Differing proximity to deadlights, windows, doors

3.2.4 Implications for structures

- In order to address the design principles outlined above, there are several implications for the structural arrangements. These implications with regard to structures will address;

- Positioning of luminaires
- Overhead arrangements (stringers, pipes and ductwork, cable trays)
- Positioning of switches and controls
- Provision and position of windows providing natural light
- Control of natural and artificial sources of glare
- Supply of power
- Constrained space lighting (permanent or intrinsically safe portable lighting)

3.3 Ventilation

3.3.1 Task requirements

- In order to facilitate operation, inspection and maintenance tasks in manned spaces, the ventilation system is to be suitable to maintain operator vigilance, comfort, provide thermal protection (from heat and cold) and to aid safe and efficient operations.

- In order to facilitate periodic inspections, survey and maintenance in tanks or closed spaces the means of ventilation is to ensure the safety of personnel in enclosed spaces from poor or dangerous air quality.

3.3.2 Ergonomic design principles

- In order to facilitate the task requirements identified above, the following design principles are identified as needing to be achieved for ventilation / indoor climate design. These design principles are based on accepted ergonomic practice and will form the basis for the development of the structural arrangement recommendations.

- Indoor climate should be designed to;

- provide adequate heating and/or cooling for onboard personnel
- provide uniform temperatures (gradients)
- maintain comfortable zones of relative humidity
- provide fresh air (air exchange) as part of heated or cooled return air

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- provide clean filtered air, free of fumes, particles or airborne pathogens
- monitor gas concentration (CO, CO_2, O_2 etc.)
- be easily adjustable by onboard personnel
- minimise contribution of ventilation noise to living and work spaces
- provide sufficient velocity to maintain exchange rates whilst not being noisy or annoying
- provide means to use natural ventilation
- provide/assess safe air quality while working in enclosed spaces

• Additionally, the design of the ventilation system should give consideration to keep the structural integrity for purposes of fire insulation

3.3.3 Conditions

• Ventilation provisions should accommodate and take into account the following factors;

- extremes of external environmental conditions (highs and lows of temperature and humidity)
- expected human occupancy of work and living spaces
- operating components that contribute heat to a living or working space
- entry into confined spaces for the purpose of inspection

3.3.4 Implications for structures

• In order to address the design principles outlined above, there are several implications for the structural arrangements. These implications with regard to structures will include;

- exterior ambient conditions (sizing the HVAC system)
- indoor air quality (particulate, smoke, O_2, CO_2, other gases)
- Ventilation capacity and air flow
- Water stagnation
- Bio-organisms and toxins
- Pipe and ductwork condensate
- Inspection access, maintenance access
- Noise and vibration control
- Energy efficiency

3.4 Vibration

3.4.1 Task requirements

• In order to facilitate operation, inspection and maintenance tasks in manned spaces, the level of vibration is to be such that it does not introduce injury or health risks to shipboard personnel.

• Additionally, consideration will be made for the impact of vessel motion on human comfort.

• These considerations extend to living and work tasks occurring in habitability and work spaces as well as infrequently occupied spaces such as tanks and small holds entered for the purpose of maintenance or inspection.

3.4.2 Ergonomic design principles

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- In order to facilitate the task requirements identified above, the following design principles were identified as needing to be considered in vibration control. Vessel design should;

- protect onboard personnel from harmful levels of vibration
- protect onboard personnel from levels of vibration impairing job performance
- protect onboard personnel from levels of vibration that interferes with sleep or comfort
- provide protection from both continuous exposure and shock (high peak values)

3.4.3 Conditions

- Vibration control provisions should accommodate and take into account the following factors;

- Continuous service output of prime mover(s)
- Equipment operation (such as thrusters, air compressors and auxiliary generators)
- Course, speed and water depth
- Rudder conditions
- Sea conditions
- Loading conditions

3.4.4 Implications for structures

- In order to meet the design principles outlined above, there are several implications for the structural arrangements to reduce vibration. The implications with regard to structures will address;

- Machinery excitation (main mover)
- Rotating components (turbines)
- Pumps
- Refrigeration
- Air compressors
- Shafting excitation
- Propeller blade tip/hull separation
- Cavitation
- Thrusters and azipods
- Hull and structure response to vibration.
- Resonance of structures
- Location of safety rails, hand holds, seating devices, means to secure loose stock or rolling stock in relation to ship motion

3.5 Noise

3.5.1 Task requirements

- Depending on the level and other considerations, noise can contribute to hearing loss, interfere with speech communications, mask audio signals, interfere with thought processes, disrupt sleep, distract from productive task performance, and induce or increase human fatigue.

- In order to facilitate operation, inspection and maintenance tasks in manned spaces, the level of noise should to be such that it;

- does not impair hearing either permanently or temporarily,
- is not at levels which interfere with verbal communication

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- is not at levels which interfere with the hearing of alarms and signals
- is not at levels that will cause stress, distract from task performance or increase the risk of errors
- does not interfere with the ability to sleep
- does not increase or induce fatigue
- does not reduce habitability or sense of comfort

3.5.2 Ergonomic design principles

• Noise control provisions should accommodate and take into account the following conditions. Vessel design should;

- ensure that onboard personnel are protected from harmful levels of noise (health hazards, hearing loss, cochlear damage)
- ensure that onboard personnel are protected from levels of noise impairing job performance
- ensure that onboard personnel are protected from levels of noise impairing verbal communication and the hearing of signals (such as alarms, bells, whistles, etc.)
- ensure that onboard personnel are protected from levels of noise that interfere with sleep or comfort

3.5.3 Conditions

• The development of provisions to reduce noise is dependent on several factors which need to be taken into account. These include;

- Equipment Operation
- Sea Conditions
- Loading Conditions and cargo operations
- Performance of maintenance or inspection tasks, including infrequently accessed areas.

3.5.4 Implications for structures

• In order to meet the design principles outlined above, there are implications for the structural arrangements to reduce noise, these include;

- Machinery excitation (main mover)
- Hull protrusions
- Rotating components (turbines)
- Pumps
- Refrigeration
- Air compressors, fans, ventilation ductwork, exhaust systems
- Shafting excitation
- Propeller blade tip/hull separation
- Cavitation
- Thrusters and azipods
- Noise abatement / shielding

3.6 Access & Egress

3.6.1 Task requirements

• The design of accesses and access structures of crew spaces should facilitate the safe movement of crew members within or among working or habitability areas. These include access structures such as passageways, ladders, ramps, stairs, work platforms, hatches, and doors. Also included are handrails, guard rails, and fall protection devices.

- In order to facilitate operation, inspection, and maintenance tasks in normally occupied spaces and inspection, survey and maintenance tasks in closed spaces, the design of accesses and access structures should promote;

- task performance, by providing adequate configurations and dimensions facilitating human access.
- safety, by providing barriers to falls or other types of injury.

3.6.2 Ergonomic design principles

- In order to facilitate the task requirements identified above, the following design principles are identified as needing to be achieved for access design. These design principles are based on good ergonomic practice and will form the basis for the development of the structural arrangement recommendations.

- The design of access and egress arrangements should;

- provide adequate access for the performance of the range of tasks associated (general access, accommodations access, maintenance and other work access) with the space
- be suitable for normal and emergency conditions
- be sized according to the access (or related) task required
- be sized according to the expected user population
- be easily maintained and operated
- be durable under the expected area of deployment
- accommodate ship motions

3.6.3 Conditions

- The identification of access requirements is dependent on several factors which need to be taken into account when developing recommendations. These include;

- Expected extent of vessel motion and potential interference with walking, standing, or climbing due to instability
- Exposure to external areas that may experience rain, snow, ice, spray, wind or other environmental conditions that may influence the usability and safety of accesses or access aids
- Potential for slips, trips, or falls and provision and design of accesses and access aids preventing their occurrence.

3.6.4 Implications for structures

- In order to address the design principles outlined above, there are several implications for the structural arrangements. These implications with regard to structures will address;

- Provision and size of access structures (based on frequency of use and numbers of crew)
- Locations of accesses
- Exposure to the external elements
- Safety in access to, and use of, access structures

Section 4 - Ergonomic Structural Arrangement Recommendations

4.1 General

4.1.1 The guidance presented in this section provides detailed structural arrangement recommendations for each of the criteria – lighting, ventilation, vibration, noise, access and egress arrangements.

4.2 Lighting Design

4.2.1 Aims

- Following a review of IMO Resolution MSC.296(87), the structural arrangements to facilitate the provision of adequate lighting in spaces normally occupied or manned by shipboard personnel should be considered.

- A space may be considered as being 'normally occupied' or 'manned' when it is routinely occupied for a period of 20 minutes or more.

- Following a review of IMO Resolution MSC.296(87), the structural arrangements to facilitate the provision of adequate lighting in areas infrequently manned such tanks or closed spaces for periodic inspections, survey and maintenance should be considered.

4.2.2 Application

- The recommendations presented in this section are applicable to vessels covered in SOLAS Regulation II-1/3-10.

4.2.3 Locations

- Locations for lighting in manned spaces should be provided permanently and include the following;

- Living quarters (accommodation, recreation, offices, dining)
- Work Areas (control rooms, bridge, machinery spaces, workshops, offices, and spaces entered on a daily basis)
- Access Areas (corridors, stairways, ramps and the like)

- Lighting in infrequently manned spaces may be temporary and include the following;

- Tanks, small holds, infrequently occupied closed spaces

4.2.4 Structural Arrangements

Allowance should be made for the following ergonomic recommendations during structural design and construction as appropriate.

A) Positioning of Lighting

- Natural lighting through the use of windows and doors should be provided as far as practicable.

- Lights should be positioned, as far as practicable, in the same horizontal plane and arranged symmetrically to produce a uniform level of illumination.

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- Lights should be positioned taking account of air conditioning vents or fans, fire detectors, water sprinklers etc. so the lighting is not blocked by these items.

- Lights should be positioned so as to reduce as far as possible bright spots and shadows.

- Fluorescent tubes should be positioned at right angles to an operator’s line of sight while the operator is located at their typical duty station as far as practicable.

- Any physical hazards that provide a risk to operator safety should be appropriately illuminated.

- Lights should be positioned to consider the transfer of heat to adjacent surfaces.

- Lights should not to be positioned in locations which would result in a significant reduction in illumination.

- Lights should not to be positioned in locations that are difficult to reach for bulb replacement or maintenance.

B) Illuminance distribution

- Illumination of the operator task area should be adequate for the type of task, i.e. it should consider the variation in the working plane.

- Sharp contrasts in illumination across an operator task area or working plane should be reduced, as far as possible.

- Sharp contrasts in illumination between an operator task area and the immediate surround and general background should be reduced, as far as possible.

- Where necessary for operational tasks, local illumination should be provided in addition to general lighting.

- Lights should not flicker or produce stroboscopic effects.

C) Obstruction and glare

- Lights should be positioned so as to reduce as far as possible glare or high brightness reflections from working and display surfaces.

- Where necessary, suitable blinds and shading devices may be used to prevent glare.

- Lighting should not to be obstructed by structures such as beams and columns.

- The placement of controls, displays and indicators should consider the position of the lights relative to the operator in their normal working position, with respect to reflections and evenness of lighting.

- Surfaces should have a non-reflective or matt finish in order to reduce the likelihood of indirect glare.

D) Location and installation of lighting controls

- Light switches should be fitted in convenient and safe positions for operators.

- The mounting height of switches should be such that personnel can reach switches with ease.

E) Location and installation of electrical outlets

- Outlets should be installed where local lighting is provided, for e.g. in accommodation areas, work spaces and internal and external walkways.

- Provision is to be made for temporary lighting where necessary for inspection, survey and maintenance.

4.3 Ventilation Design

4.3.1 Aims

- Following a review of IMO Resolution MSC.296(87), the structural arrangements to facilitate the provision of adequate ventilation in spaces normally occupied or manned by shipboard personnel should be considered.

- A space may be considered as being 'normally occupied' or 'manned' when it is routinely occupied for a period of 20 minutes or more.

- Following a review of IMO Resolution MSC.296(87), the structural arrangements to facilitate the provision of adequate ventilation in areas infrequently manned such tanks or closed spaces for periodic inspections, survey and maintenance should be considered.

4.3.2 Application

- The recommendations presented in this section are applicable to vessels covered in SOLAS Regulation II-1/3-10.

4.3.3 Locations

- Locations for ventilation in manned spaces should be provided permanently and include the following;

- Living quarters (accommodation, recreation, offices, dining)
- Work Areas (control rooms, bridge, machinery spaces, offices, spaces and voids entered)

- Locations for ventilation in infrequently manned spaces should be temporary and include the following;

- Tanks, small holds, infrequently occupied closed/enclosed spaces

4.3.4 Structural Arrangements

Allowance should be made for the following ergonomic recommendations during structural design and construction as appropriate.

A) Ship ventilation design

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- Natural ventilation design should be established by consideration of compartment layouts and specifications. Typical natural ventilation devices include mushroom ventilators, gooseneck ventilators, ventilators with weather proof covers etc.

- In general, HVAC (heating, ventilation and air conditioning) systems should be provided in spaces normally occupied during operation.

- For areas infrequently occupied (such as tanks or holds) means of air quality sampling (such as portable CO_2 densitometer) should be provided.

- Means to ventilate prior to entry of infrequently visited places should be provided.

- Adequate ventilation should be provided for inspection, survey, maintenance and repair within the voids of double-bottom and double-sided hulls.

B) Location and installation of ventilation

- The design of air ducts should facilitate reduced wind resistance and noise. Ductwork (particularly elbows and vents) should not contribute excess noise to a work or living space.

- Ductwork should not to interfere with the use of means of access such as stairs, ladders, walkways or platforms.

- Ductwork and vents should not be positioned to discharge directly on people occupying the room in their nominal working or living locations, for example, directed at a berth, work console, or work bench.

- Manholes and other accesses should be provided for accessibility and ventilation to points within.

- Fire dampers should be applied to contain the spread of fire, per statutory requirements.

- Ventilation penetrations through watertight subdivision bulkheads are not recommended unless accepted per statutory requirements. Ventilation dampers are to be visible (via inspection ports or other means).

- Ventilation fans for cargo spaces should have feeders separate from those for accommodations and machinery spaces.

- It is recommended that air Intakes for ventilation systems are located to minimise the introduction of contaminated air from sources such as for example, exhaust pipes and incinerators.

- Extractor grilles should be located to avoid short-circuits between inlets and outlets and to support even distribution of air throughout a work space.

4.4 Vibration Design

4.4.1 Aims

- Following a review of IMO Resolution MSC.296(87), the structural arrangements to minimize vibration in spaces normally occupied or manned by shipboard personnel should be considered.

- A space may be considered as being 'normally occupied' or 'manned' when it is routinely occupied for a period of 20 minutes or more.

4.4.2 Application

- The recommendations presented in this section are applicable to vessels covered in SOLAS Regulation II-1/3-10.

4.4.3 Locations

- Locations in which vibration should be minimized include the following;

- Living quarters (accommodation, recreation, offices, dining)
- Work Areas (such as control rooms, bridge, machinery spaces, offices, spaces and voids entered)

4.4.4 Structural Arrangements

Allowance should be made for the following ergonomic recommendations during structural design and construction as appropriate.

A) General

- Vibration levels should be at or below the acceptable ergonomic standards for spaces normally occupied by the crew. In general, ISO 6954:2000 may be used as a guideline to evaluate the vibration performance in the spaces normally occupied by the crew.

- Generally, many alternative measures are applicable to reduce vibration, including but not limited to:

  1 Resonance avoidance with a combination of appropriate selection of main engine and its revolution, number of propeller blades and structural natural frequencies;

  2 To avoid resonance, addition of mass or reduction in scantlings to achieve lower structural natural frequencies. Or conversely, reduction of mass or structural reinforcement to increase natural frequencies;

  3 Reduction of exciting force by for e.g. application of various kinds of dampers, compensators and balancers; and

  4 Structural reinforcement to increase rigidity and reduce structural response, or conversely, where structural rigidity is reduced specifically to reduce structural responses.

- Due to the variety of effective measures that can be taken and the complex nature of vibration phenomena, it is not possible to apply simple prescriptive formulae for scantling calculation.

- Structural measures are mainly prescribed in the following sections, but other measures as stated in 1-4 above may be considered as effective alternatives.

B) Vibration reduction design

- Vibration level in the spaces normally occupied during operation should be estimated by an appropriate method, such as estimation based on empirical statistics and/or

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application of analytical tools. When a vibration level exceeding the acceptable ergonomic standards is envisaged, suitable countermeasures should be taken.

- In general, natural frequencies should be calculated using theoretical formulae in way of local panels and stiffeners in the spaces close to the main exciting sources, i.e. propeller and main engine. These local scantlings should be decided so that the estimated natural frequencies are apart from the exciting frequencies adequately to avoid resonance.

- For heavy equipment or machinery in the spaces close to the main exciting sources, suitable measures should be taken at the deck structure underneath the equipment or machinery to reduce vibration.

C) Anti-vibration design in structural arrangements

- Vibration should be controlled at the source as far as possible.

- To prevent hull girder vibration, the following measures are recommended for consideration;

  - selection of hull forms, girders and other ship structures with consideration to vibration control;
  - selection of main machinery with inertia force and moment balanced;
  - adjusting natural frequency (the natural frequency of hull girder increases as the number of bulkheads increases).

- To prevent vibration of the local structure, the following measures are recommended for consideration;

  - line (mainly the ship tail shape) and propeller design modification;
  - adjustment of general arrangements, such as cabin arrangement, weight distribution, location of main machinery;
  - adjustment and modification of local structures, such as superstructure, aft structures, bottom frame structure in engine room;
  - other damping measures, such as vibration isolators, nozzle propeller.

D) Anti-vibration design of engine room, engine, propeller and thrusters

- Consideration should be paid to the vibration response of main machinery base and shafting.

- Consideration of control of vibration from the engine room should include installing bracings at the top and front of diesel engines and increasing the stiffness and natural frequency of the machine base to reduce the vibration of the base.

- Bow thruster induced vibration should be minimized by following good acoustic design practices relative to the design of the propeller and the location and placement of the thruster itself. Supply of resilient supported tunnels (tunnel within a tunnel), bubbly air injectors, and tunnels coated with a decoupling material can be considered.

- Propeller induced vibration should be minimized by following good acoustic design practices relative to the design of the propeller and the location and placement in relation to the hull.

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Stern shape should be optimized and considered through theoretical calculation and model testing so as to improve the wake. The gap between the shell and the propeller should be appropriate to reduce the exciting force. Damping treatments can be applied to shell plates with severe vibration.

E) Anti-vibration design of superstructure

- Preventing vibration along the longitudinal area of the superstructure should be considered by increasing the shear and strut stiffness of the superstructure. To achieve this, the following measures are recommended;

  - Superstructure side wall can be vertically aligned,
  - The internal longitudinal bulkhead can be set up with more than four (4) tiers of superstructure,
  - Strong girders or other strong elements can be provided under the main deck,
  - The transverse bulkhead and the front bulkhead of superstructure can be vertically aligned as much as possible, otherwise large connection brackets should be provided,
  - The superstructure aft bulkhead of each superstructure deck can be aligned vertically with the main hull transverse bulkheads as far as possible, otherwise strong beams under the main deck should be provided.
  - To control vibration of outfitting, dimensions and the means of fixing and strengthening at the point of mounting can be considered.
  - To prevent vibration of high web girder, the following should be considered;

    - Increase dimension of longitudinals and face plate,
    - Increase the stiffness of face plate stiffeners,
    - Add horizontal stiffener.

F) Anti-vibration installation design

- Sources of vibration (engines, fans, rotating equipment), to the extent possible, should be isolated from work and living spaces (use of isolation mounts or other means can be considered).

- Hull borne vibration in living and work areas can be attenuated by the provision of vibration absorbing deck coverings or by other means.

4.5 Noise Design

4.5.1 Aims

- Following a review of IMO Res. MSC.337(91) Code on Noise Levels On Board Ships, the structural arrangements to minimize noise in spaces normally occupied or manned by shipboard personnel should be considered.

- A space may be considered as being ‘normally occupied’ or ‘manned’ when it is routinely occupied for a period of 20 minutes or more.

4.5.2 Application

- The recommendations presented in this section are applicable to vessels covered by SOLAS Regulation II-1/3-10.

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4.5.3 Locations

- Locations in which noise should be minimized include the following;

- Living quarters (accommodation, recreation, offices, dining)
- Work Areas (such as control rooms, bridge, machinery spaces, living quarters and offices)

4.5.4 Structural Arrangements

Allowance should be made for the following ergonomic recommendations during structural design and construction as appropriate.

A) General

- Sources of noise (engines, fans, rotating equipment), to the extent possible, should be isolated and located away from work and living spaces (through use of isolation mounts or other means).

- If necessary hull borne noise transmitted through the steel structure may be attenuated by the provision of noise absorbing deck coverings.

- Noise for typical underway conditions should be specified for the following areas:

  - In living quarters
  - In open engineering and mechanical spaces
  - In offices, the bridge, engineering offices

- Noise on the hull from the propeller tips, athwart thrusters, or azipods should be designed to minimize structure borne noise to accommodations and work areas.

- Specific noise levels are to be obtained from the revised IMO Code on Noise Aboard ships (Resolution MSC.337(91)).

- To reduce noise transmitted to accommodation cabins, the crew accommodations areas are usually arranged in the middle or rear of the superstructure or on the poop deck and above.

B) Noise sources and propagation

- Ship noise can be divided into airborne noise and structure borne noise according to the nature of the sound source. It consists of main machinery noise, auxiliary machinery noise, propeller noise, hull vibration noise and ventilation system noise.

- There are three main routes of transmission of ship noise;

  - airborne noise radiated directly to the air by main or auxiliary machinery system;
  - structure borne noise spread along the hull structure through mechanical vibration and radiated outward;
  - fan noise and air-flow noise transmitted through the pipeline of the ventilation system.

C) Mechanical vibration induced noise control

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- Mechanical vibrations are the largest source of noise. Methods relating to anti-vibration design in the structural arrangements are also useful for vibration induced noise control, including the following;

- Reducing the noise level of the various noise sources;
- Using vibration isolator for main and auxiliary machinery to reduce the noise;
- Improving the machine's static and dynamic balance;
- Installing soundproof cover with sound-absorbing lining for machines.

D) Noise control of ventilation system

- Fans with relative low pressure may be used to reduce noise when the flow resistance of ventilation ducts is low. Low flow resistance can be achieved by rational division of the ventilation system, reasonable determination of ability of ventilation and the ducts layout, adoption of reasonable duct type and provision of suitable materials.

- Fans and central air conditioners may be installed in a separate acoustic room or the damper elastomeric gasket or silencer box.

- Ventilation ducts can be encased in damping material if necessary. Penetration of compartments with a low-noise requirement by main air tubes may be avoided.

- Ventilation inlet, outlet, and diffuser elements can be provided that are designed for noise abatement to reduce ventilation terminal noise.

- If needed, an appropriate muffler can be used based on the estimated frequency range of the noise.

E) Noise Prevention/Mitigation

- The statements that follow should be considered in the context of the prevention and mitigation of human whole body vibration, which also have a noise reducing effect.

- Different treatments may be needed to reduce airborne sources, structureborne sources, airborne paths, structureborne paths, HVAC induced noise, etc. Each treatment type depends on an understanding of the prevailing airborne or structureborne noise components (e.g., low frequency or high frequency). A thorough understanding of the source, amount of noise, the noise’s components, and the noise’s path(s) is essential for cost effective noise abatement/treatment. Listed below, are summarized some of the more common noise control treatment methods,

    - Selection of equipment that by its design or quality are lower noise and/or vibration.
    - Reduction of vibration by mechanically isolating machinery from supporting structure.
    - Use of two layers of vibration isolation mounts under machinery with seismic based mounts between the machinery and the ship’s structure.
    - Reduce vibration energy in structures. Pumpable material used as ballast can also be used as damping in voids and tanks.
    - An air bubble curtain can be considered to shield the vessel’s hull from water borne noise.
    - A decoupling material can be applied to the exterior (wet side) plating in order to reduce the radiation efficiency of the structure.

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- The airborne source level and airborne path are the most critical factors affecting noise within a machinery space itself and in the compartments directly adjacent to the machinery space. Structureborne sources and the structureborne path carry acoustical energy everywhere else on the vessel.

- Depending on the level of treatment, secondary structureborne noise (a combination of the airborne source level and the response of the structure inside the machinery space itself) may also be important in spaces remote from the machinery itself.

F) Noise modelling

- A technique becoming more common among designers is noise or acoustical modelling. In these models, it is essential that the factors related to the source-path receiver be very well understood.

- Noise/acoustical models should include the following components:

  - Source, acoustic path, and receiver space description
  - Sources - machinery source descriptions (e.g., noise and vibration levels, size and mass, location, and foundation parameters)
  - Sources - propulsor source description (e.g., number of propellers (impellers), number of blades, RPM, clearance between hull and tips of propeller, vessel design speed)
  - Sources – HVAC source description (e.g., fan parameters (flow rate, power, and pressure), duct parameter, louver geometry, and receiver room sound absorption quality)
  - Path - Essential parameters for sound path description include hull structure sizes and materials, (damping) loss factors, insulation and joiner panel parameters.
  - Receiver - Receiver space modelling is characterized by the hull structure forming the compartment of interest, insulation/coatings, and joiner panels.

4.6 Access & Egress Design

4.6.1 Aims

- Following a review of IMO Resolution MSC.296(87), the design of stairs, vertical ladders, ramps, walkways and work platforms used for permanent means of access and/or for inspection and maintenance operations should be considered.

- Following a review of IMO Resolution MSC.296(87), the structural arrangements to facilitate emergency egress of inspection personnel or ships' crew from tanks, holds, voids etc. is to be considered.

4.6.2 Application

- The recommendations presented in this section are applicable to vessels covered in SOLAS Regulation II-1/3-10.

4.6.3 Locations

- Locations for provision of access aids in manned spaces should be provided permanently and include the following;

- Living quarters (accommodation, recreation, offices, dining)

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- Work Areas (control rooms, bridge, machinery spaces, offices, spaces and voids entered)
- Access to deck areas, muster stations, work platforms associated to periodic inspection, operation, or maintenance
- Locations for access in infrequently manned spaces may be temporary and include the following;
  - Tanks, small holds, infrequently occupied closed spaces

4.6.4 Structural Arrangements

A) Stairs

General Principles

The following are general recommendations to consider for stairs design:

- Stairs are appropriate means for changing from one walking surface to another when the change in vertical elevation is greater than 600 mm (23.5 in.).
- Stairs should be provided in lieu of ladders or ramps in accommodations spaces, office spaces, or to the navigation bridge.
- The angle of inclination should be sufficient to provide the riser height and tread depth that follows, a minimum angle of 38 degrees and maximum angle of 45 degrees is recommended.
- Stairs exposed to the elements should have additional slip resistance due to potential exposure to water and ice.
- Stairs should be used in living quarters instead of inclined ladders.
- No impediments or tripping hazards should intrude into the climbing spaces of stairs (for example, electrical boxes, valves, actuators, or piping).
- No impediments or tripping hazards should impede access to stair landings (for example, piping runs over the landing or coamings/retention barriers).
- Stairs running fore and aft in a ship are preferable but athwartship stairs are allowed.

Stair Landings

The following are recommendations to consider during the design of stair landings:

- A clear landing at least as wide as the tread width and a minimum of 915 mm (36 in.) long should be provided at the top and bottom of each stairway.
- An intermediate landing should be provided at each deck level serviced by a stair, or a maximum of every 3500 mm (140 in.) of vertical travel for stairs with a vertical rise of 6100 mm (240 in.).
- Any change of direction in a stairway should be accomplished by means of an intermediate landing at least as wide as the tread width and a minimum of 915 mm (36 in.) long.
- Stairways should have a maximum angle of inclination from the horizontal of 45 degrees.
- Where stairs change directions, intermediate landings along paths for evacuating personnel on stretchers should be 1525 mm (60 in.) or greater in length to accommodate rotating the stretcher.

Stair Risers and Treads

The following are recommendations to consider during the design of stair risers and treads:

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- A riser height should be no more than 230 mm (9 in.) and a tread depth of 280 mm (11 in.), including a 25 mm (1 in.) tread nosing (step overhang).
- For stairs the depth of the tread and the height of riser should be consistent
- Minimum tread width on one-way (where there is expected to be only one person transiting, ascending *or* descending stairway) stairs should be at least 700 mm (27.5 in.)
- Minimum tread width on two-way (where there may be two persons, ascending *and* descending, or passing in opposite directions) stairs should be at least 900 mm (35.5 in.)
- Once a minimum tread width has been established at any deck in that stair run, it should not decrease in the direction of egress
- Nosings should have a non-slip/skid surface that should have a coefficient of friction (COF) of 0.6 or greater measured when wet.

Headroom

- Clear headroom (free height) maintained in all stairs is recommended to be at least 2130 mm (84 in.).

Design Load

- It is recommended that stairways should be built to carry five times the normal anticipated live load, but less than a 544-kg (1000-lb) moving concentrated load.

Stair Handrails

The following are recommendations to consider during the design of stair risers and treads:

- Stairs with three or more steps should be provided with handrails.
- A single-tier handrail to maintain balance while going up or down the stairs should be installed on the bulkhead side(s) of stairs.
- A two-tier handrail to maintain balance and prevent falls from stairs should be installed on non-enclosed sides of stairs.
- Handrails should be constructed with a circular cross section with a diameter of 40 mm (1.5 in.) to 50 mm (2.0 in.).
- Square or rectangular handrails should not be fitted to stairs.
- The height of single tier handrails should be 915 mm (36 in.) to 1000 mm (39 in.) from the top of the top rail to the surface of the tread.
- Two-tier handrails should be two equally-spaced courses of rail with the vertical height of the top of the top rail 915 mm (36 in.) to 1000 mm (39 in.) above the tread at its nosing.
- A minimum clearance of 75 mm (3 in.) should be provided between the handrail and bulkhead or other obstruction.

B) Walkways and Ramps

General Principles

The following are general recommendations to consider for walkways and ramps:

- Guard rails should be provided at the exposed side of any walking or standing surface that is 600 mm (23.5 in.) or higher above the adjacent surface and where a person could fall from the upper to the lower surface.
- Ramps should be used with changes in vertical elevations of less than 600 mm (23.5 in.).

- Ramps should be provided with a non-skid surface that should have a coefficient of friction (COF) of 0.6 or greater measured when wet.
- Headroom in all walkways should be ≥ 2130 mm (84 in.).
- Toeboards should be provided on elevated walkways, platforms, and ramps. No impediments or tripping hazards should intrude into the transit space (for example, electrical boxes, valves, actuators, or piping).
- No impediments or tripping hazards should impede use of a walkway or ramp (for example, piping runs, hatch covers, deck impediments (e.g., through bolts) or combings/retention barriers).
- The maximum opening in a walkway grating under which the presence of persons is expected should be less than 22 mm (0.9 in.).
- The maximum opening in a walkway grating under which the presence of persons is not expected should be less than 35 mm (1.7 in.).
- Toeboards should have a height of 100 mm (4.0 in.) and have no more than a 6 mm (0.25 in.) clearance between the bottom edge of the toeboard and the walking surface.

C) Vertical Ladders

General Principles

The following are general recommendations to consider for the design of vertical ladders:

- Vertical ladders should be provided whenever operators or maintainers must change elevation abruptly by more than 300 mm (12.0 in.).
- Vertical ladders should not be located within 1.83 m (6 ft.) of other nearby potential fall points (including the deck edge, cargo holds and lower decks) without additional fall protection, such as guardrails.
- Vertical ladders should be provided with skid/slip resistant on the rungs that should have a coefficient of friction (COF) of 0.6 or greater measured when wet.
- The angle of inclination for vertical ladders should be 80 to 90 degrees.
- Permanent vertical ladders should be attached to a permanent structure.
- The maximum distance from the ladder’s centreline to any object that must be reached by personnel from the ladder should not exceed 965 mm (38.0 in.).
- Vertical ladders should be located so as not to interfere with the opening and closing of hatches, doors, gratings, or other types of access.
- No impediments should intrude into the climbing space (for examples, electrical boxes, valves, actuators, or piping).
- Overhead clearance above vertical ladder platforms should be a minimum of 2130 mm (84.0 in.)
- There should be at least 750 mm (29.5 in.) clearance in front of the ladder (climbing space).
- There should be between 175 mm (7.0 in.) to 200 mm (8.0 in.) clearance behind the ladder (toe space).
- A means of access to a cellular cargo space should be provided using staggered lengths of ladder. No single length is to exceed 6.0 m (91.5 ft) in length.

Rung Design

- Rungs should be equally spaced along the entire height of the ladder.
- If square bar is used for the rung, it should be fitted to form a horizontal step with the edges pointing upward.
- Rungs should also be carried through the side stringers and attached by double continuous welding.
- Ladder rungs should be arranged so a rung is aligned with any platform or deck that an operator or maintainer will be stepping to or from.

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- Ladder rungs should be slip resistant or of grid/mesh construction.

Provision of Platforms

- When the height of a vertical ladder exceeds 6.0 m (19.5 ft), an intermediate or linking platform should be used.
- If a work task requires the use of two hands, working from a vertical ladder is not appropriate. The work area should be provided with a work platform that provides a flat, stable standing surface.

Vertical ladders as Means of Access

- Where vertical ladders lead to manholes or passageways, horizontal or vertical handles or grab bars should be provided. Handrails or grab bars should extend at least 1070 mm (42.0 in.) above the landing platform or access/egress level served by the ladder.

Safety Cages

- Safety cages should be used on vertical ladders over 4.5 m (15.0 ft) in height.
- Climber safety rails or cables should be used on vertical ladders in excess of 6.1 m (20.0 ft).

D) Work Platforms

General Principles

- Work platforms should be provided at locations where personnel must perform tasks that cannot be easily accomplished by reaching from an existing standing surface.
- Work platforms exposed to the elements should have additional slip resistance due to potential exposure to water and ice.
- Work platforms more than 600 mm (23.5 in.) above the surrounding surface should be provided with guard rails and hand rails.
  - Work platforms should be of sufficient size to accommodate the task and allow for placement of any required tools, spare parts or equipment.

E) Egress

- Doors, hatches, or scuttles used as a means of escape should be capable of being operated by one person, from either side, in both light and dark conditions. Doors should be designed to prevent opening and closing due to vessel motion and should be operable with one hand.
- Doors (other than emergency exit) used solely by crew members should have a clear opening width of at least 710 mm (28 in.) The distance from the deck to the top of the door should be at least 1980 mm (78 in.).
- The method of opening a means of escape should not require the use of keys or tools. Doors in accommodation spaces (with the exception of staterooms), stairways, stair towers, passageways, or control spaces, should open in the direction of escape or exit.
- The means of escape should be marked from both the inside and outside.
- Deck scuttles that serve as a means of escape should be fitted with a release mechanism that does not require use of a key or a tool, and should have a holdback device to hold the scuttle in an open position.

  Deck scuttles that serve as a means of escape should have the following dimensions:

  i) Round – 670 mm (26.5 in.) or greater in diameter

  ii) Rectangular – 670 mm (26.5 in.) by 330 mm (13 in.) or greater

Annex A - Recommended Measurement Values

1.1 General

The recommendations in the following section outline measurement values for lighting, ventilation, vibration and access from a best practice ergonomics perspective. The information provided can assist designers when applying structural arrangement guidance.

See the IMO Code on Noise Aboard ships (IMO Resolution MSC.337(91)) for recommended shipboard noise levels guidance.

1.2 Lighting

The following tables give details of recommended illuminance levels in Lux which support task performance, safety and visual comfort for the operator. Emergency lighting is covered in SOLAS and IMO Resolutions and has not been considered in the below table. Lighting measurements should be made with the probe approximately 800 mm (32 inches).

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Table 1 - Lighting for Crew Accommodations Spaces

Space	*Illuminance Level in Lux*	*Space*	*Illuminance Level in Lux*
Entrances and Passageways			
Interior Walkways, Passageways, Stairways and Access Ways	100	Exterior Walkways, Passageways, Stairways and Access Ways (night)	100
Corridors in Living quarters and work areas	100	Stairs, escalators	150
		Muster Area	200
Cabins, Staterooms, Berthing and Sanitary Spaces*			
General Lighting	150	Bath/Showers (General Lighting)	200
Reading and Writing (Desk or Bunk Light)	500	All other Areas within Sanitary Space (e.g., Toilets)	200
Mirrors (Personal Grooming)	500	Light during sleep periods	<30
Dining Spaces			
Mess Room and Cafeteria	300	Snack or Coffee Area	150
Recreation Spaces			
Lounges	200	Gymnasiums	300
Library	500	Bulletin Boards/Display Areas	150
Multimedia Resource Centre	300	All other Recreation Spaces (e.g., Game Rooms)	200
TV Room	150	Training/Transit Room Office/Meeting rooms	500
Medical, Dental and First Aid Centre			
Dispensary Hospital/ward	500	Wards - General Lighting - Critical Examination - Reading Hospital/ward	 150 500 300 500
Medical and Dental Treatment/ Examination Room Hospital/ward	500		
Medical Waiting Areas	200		
Laboratories	500	Other Medical & Dental Spaces	300
*Note: If there is any opportunity for light to enter cabins or staterooms at the times of day or night when people sleep (e.g., portlights, transoms, etc.), the maximum lighting levels should be 30 Lux.			

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Table 2 - Lighting for Navigation and Control Spaces

Space	*Illuminance Level in Lux*	*Space*	*Illuminance Level in Lux*
Wheelhouse, Pilothouse, Bridge	300	Offices - General Lighting - Computer Work - Service Counters	 300 300 300
Chart Room - General Lighting - On Chart Table	 150 500		
Other Control Rooms (e.g., Cargo Transfer etc.) - General Lighting - Computer Work Central Control Room	 300 300 500	Control Stations - General Lighting - Control Consoles and Boards, Panels, Instruments - Switchboards - Log Desk Local Instrument room	 300 300 500 500 400
Radar Room	200		
Radio Room	300	Gyro Room	200

Table 3 - Lighting for Service Spaces

Space	*Illuminance Level in Lux*	*Space*	*Illuminance Level in Lux*
Food Preparation - General Lighting - Galley - Pantry - Butcher Shop - Thaw Room - Working Surfaces, Food Preparation Counter and Range Tops - Food Serving Lines - Scullery (Dishwashing) - Extract Hood Store rooms Package handling/cutting	 500 500 300 500 300 750 300 300 500 100 300	Laundries - General Lighting - Machine, Pressing, Finishing and Sorting	 300 300
		Chemical Storage	300
		Storerooms - Large Parts - Small Parts - Issue Counters	 200 300 300
		Elevators	150
		Food Storage - Non-refrigerated - Refrigerated	 200 100
Mail Sorting	500		

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Table 4 - Lighting for Operating and Maintenance Spaces/Areas

Space	*Illuminance Level in Lux*	*Space*	*Illuminance Level in Lux*
Machinery Spaces (General) Unmanned Machinery spaces	200 200	Cargo Holds (Portable Lighting) - General Lighting - During Cargo Handling - Passageways and Trunks	 30 300 80
Engine Room	300		
Generator and Switchboard Room Switchboard, transformer room Main generator room/switch gear	300 500 200		
Fan Room HVAC room	200 200	Inspection and Repair Tasks - Rough - Medium - Fine - Extra Fine	 300 500 750 1000
Motor Room	300		
Motor-Generator Room (Cargo Handling)	150		
Pump Room, Fire pump room Steering Gear Room Windlass Rooms Battery Room Emergency Generator Room Boiler Rooms	200 200 200 200 200 100	Workshops Paint Shop Workshop office Mechanical workshop Inst/Electrical Workshop	300 750 500 500 500
Bilge/Void Spaces	75		
Muster/Embarkation Area	200	Unmanned Machinery Room	200
		Shaft Alley	100
Cargo Handling (Weather Decks) Lay Down Area General Process and Utility area Loading ramps/bays	200 200 200 200	Escape Trunks	50
		Crane Cabin	400
Cargo Storage and Manoeuvring areas	350	Hand signalling areas between crane shack and ship deck	300

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Table 5 - Lighting for Red or Low-level White Illuminance

Area	*Illuminance Level in Lux*
Where seeing is essential for charts and instruments	1 to 20
Interiors or Spaces	5 to 20
Bridge Areas (including chart tables, obstacles and adjacent corridors and spaces)	0 to 20 (Continuously Variable)
Stairways	5 to 20
Corridors	5 to 20
Repair Work (with smaller to larger size detail)	5 to 55

Brightness (Adopted from DOT/FAA/CT-96/1 - Human Factors Design Guide).

The following table recommends the brightness ratio between the lightest and darkest areas or between a task area and its surroundings.

Table 6 - Recommended Maximum Brightness Ratios

	Environmental Classification		
Comparison	A	B	C
Between lighter surfaces and darker surfaces within the task	5 to 1	5 to 1	5 to 1
Between tasks and adjacent darker surroundings	3 to 1	3 to 1	5 to 1
Between tasks and adjacent lighter surroundings	1 to 3	1 to 3	1 to 5
Between tasks and more remote darker surfaces	10 to 1	20 to 1	b
Between tasks and more remote lighter surfaces	1 to 10	1 to 20	b
Between luminaries and adjacent surfaces	20 to 1	b	b
Between the immediate work area and the rest of the environment	40 to 1	b	b

Environmental Classification Notes:

A Interior areas where reflectances of entire space can be controlled for optimum visual conditions.

B Areas where reflectances of nearby work can be controlled, but there is only limited control over remote surroundings.

C Areas (indoor and outdoor) where it is completely impractical to control reflectances and difficult to alter environmental conditions.

b Brightness ratio control is not practical.

1.3 Ventilation

- Thermal comfort varies among individuals as it is determined by individual differences. Individually, perception of thermal comfort is largely determined by the interaction of thermal environmental factors such as air temperature, air velocity, relative humidity, and factors related to activity and clothing.

- The Heating, Ventilation and Air-Conditioning (HVAC) systems onboard a vessel should be designed to effectively control the indoor thermal environmental factors to facilitate the comfort of the crew.

- The following are a set of ergonomic recommendations that aim to achieve operator satisfaction from a thermal comfort perspective.

A) Recommended Air temperature

- A Heating, Ventilation, and Air Conditioning (HVAC) system should be adjustable, and temperatures should be maintained by a temperature controller. The preferred means would be for each manned space to have its own individual thermostat for temperature regulation and dehumidification purpose.

- International Standards recommend different bands for a HVAC system, but there is little difference in the minimum and maximum values they stipulate. A band width between 18°C (64°F) and 27°C (80°F) accommodates the optimum temperature range for indoor thermal comfort.

B) Recommended Relative humidity

- A HVAC system should be capable of providing and maintaining a relative humidity within a range from 30% minimum to 70% maximum with 40 to 45% preferred.

C) Enclosed space vertical gradient recommendation

- The difference in temperature at 100 mm (4 in.) above the deck and 1700 mm (67 in.) above the deck should be maintained with 3°C (6°F).

D) Recommended Air velocity

- Air velocities should not exceed 30 metres-per-minute or 100 feet-per-minute (0.5 m/s or 1.7 ft/s) at the measurement position in the space.

E) Berthing Horizontal Temperature Gradient

- In berthing areas, the difference between the inside bulkhead surface temperature adjacent to the berthing and the average air temperature within the space should be less than 10°C (18°F).

F) Air exchange rate

- The rate of air exchange for enclosed spaces should be at least six (6) complete changes-per-hour.

Summary of Indoor Climate Recommendations

Item	*Recommendation or Criterion*
Air Temperature	18 to 27°C (68 to 77°F)
Relative Humidity	The HVAC system should be capable of providing and maintaining a relative humidity within a range from 30% minimum to 70% maximum
Vertical Gradient	The acceptable range is 0 – 3°C (0 – 6°F)
Air Velocity	Not exceed 30 meters-per-minute or 100 feet-per-minute
Horizontal Gradient (Berthing areas)	The horizontal temperature gradient in berthing areas should be <10°C (18°F)
Air Exchange Rate	The rate of air change for enclosed spaces should be at least six (6) complete changes-per-hour

1.4 Vibration

- Vibration comfort varies among individuals as it is determined by individual differences. Individually, perception of vibration comfort is determined by the magnitudes and frequencies of those vibrations.

- The following are recommendations aiming to control levels of whole body vibration exposure that are generally not considered to be uncomfortable, and these are based on the recommendations of ISO 6954 (2000).

- The following levels of whole body vibrations should not be exceeded when measured in three axes (x, y, and z) using the w weighting scale (whole body, as discussed in ISO 6954:2000) with a band limitation in all axes limited from 1 to 80 hz.

Maximum RMS vibration levels	
Accommodations Areas	Workspaces
180 mm/second^2 (5 mm/s)	215 mm/second^2 (6 mm/s)

1.5 Access

- The following provide further ergonomic guidance on access arrangements to support the recommendations given in Section 4.6 Access & Egress Design, with a view to covering wider scope than those covered by the mandatory requirements such as SOLAS Regulation II-1/3-6 and IACS UI SC191.

- The measurements hereunder are based on one of recognised practices for ergonomic design with a view to providing general guidance to cover not only means of access for inspections but also means of access for operation. Therefore, they are not necessarily identical to those specified in the mandatory requirements.

No. 132 (cont)

Stair Handrail

In addition to the recommendations for Stair Handrails presented in Section 4.6 Access & Egress Design, the following recommended dimensions relating to the design of Stair Handrails are presented in the following table. Stairs with three or more steps should be provided with handrails.

Stair Handrail Arrangements

Arrangement	*Handrail Recommendation*
1120 mm (44 in.) or wider stair with bulkhead on both sides	Single tier handrail on both sides
Less than 1120 mm (44 in.) stair width with bulkhead on both sides	Single tier handrail on one side, preferably on the right side descending
1120 mm (44 in.) or wider stair, one side exposed, one with bulkhead	Two tier handrail on exposed side, single tier on bulkhead side
Less than 1120 mm (44 in.) stair width, one side exposed, one with bulkhead	Two tier handrail on exposed side
All widths, both sides of stairs exposed	Two tier handrail on both sides

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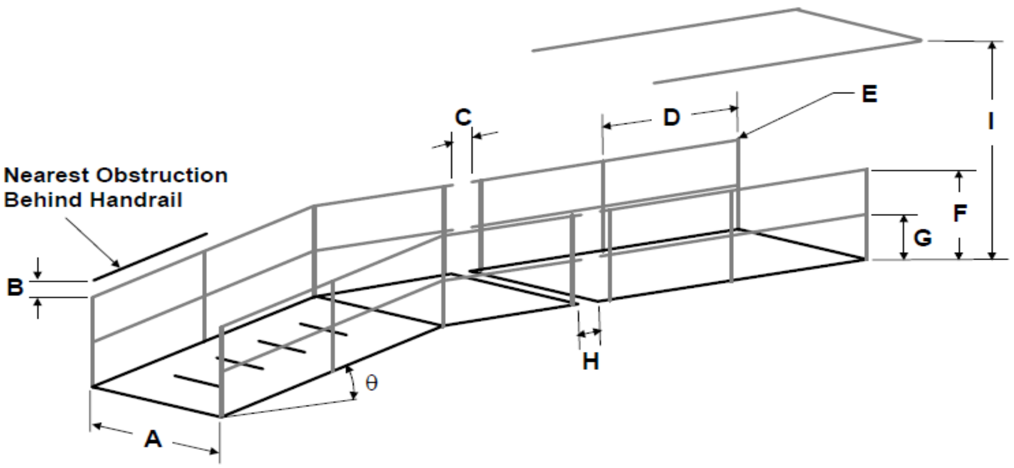
Walkway and Ramp Design

In addition to the recommendations for Walkway Design presented in Section 4.6 Access & Egress Design, the following recommended dimensions relating to the design of walkways and ramps are presented in Figure 1 'Walkway and Ramp Design'.

Figure 1 Walkway and Ramp Design

Dimension		*Recommendations*
A	Walkway width – one person[2]	≥ 710 mm (28 in.)
	Walkway width – two-way passage, or means of access or egress to an entrance	≥ 915 mm (36 in.)
	Walkway width – emergency egress, unobstructed width	≥ 1120 mm (44 in.)
B	Distance behind handrail and any obstruction	≥ 75 mm (3.0 in.)
C	Gaps between two handrail sections or other structural members	≤ 50 mm (2.0 in.)
D	Span between two handrail stanchions	≤ 2.4 m (8 ft)
E	Outside diameter of handrail	≥ 40 mm (1.5 in.) ≤ 50 mm (2.0 in.)
F	Height of handrail	1070 mm (42.0 in.)
G	Height of intermediate rail	500 mm (19.5 in.)
H	Maximum distance between the adjacent stanchions across handrail gaps	≤ 350 mm (14.0 in.)
I	Distance below any covered overhead structure or obstruction	≥ 2130 mm (84 in.)
Θ	Ramp angle of inclination – unaided materials handling	≤ 5 degrees
	Ramp angle of inclination – personnel walkway	≤ 15 degrees

Notes:
1. Toeboard omitted for clarity
2. The walkway width may be diminished to ≥ 500 mm around a walkway structure web frames



No. 132 (cont)

Vertical Ladder Design and Dimensions

In addition to the recommendations for Vertical Ladders presented in Section 4.6 Access & Egress Design, the following recommended dimensions relating to the design of Ladders are presented in Figure 2 to Figure 5.

- Figure 2 – Vertical Ladders (General Criteria)
- Figure 3 – Staggered Vertical Ladders
- Figure 4 – Vertical Ladders to Landings (Side Mount)
- Figure 5 – Vertical Ladders to Landings (Ladder through Platform)

Figure 2 Vertical Ladders (General Criteria)

Dimension		*Recommendation*
A	Overhead Clearance	2130 mm (84.0 in.)
B	Ladder distance (gap accommodating toe space) from surface (at 90 degrees)	≥ 175 mm (7.0 in.) ≤ 200 mm (8.0 in.)
C	Horizontal Clearance (from ladder face and obstacles)	≥ 750 mm (29.5 in.) or ≥ 600 mm (23.5 in.) (in way of openings)
D	Distance between ladder attachments / securing devices	≤ 2.5 m (8.0 ft)
E	Ladder angle of inclination from the horizontal	80 to 90 degrees
F	Rung Design – (Can be round or square bar; where square bar is fitted, orientation should be edge up)	Square bar 25 mm (1.0 in.) x 25 mm (1.0 in.) Round bar 25 mm (1.0 in.) diameter
G	Distance between ladder rungs (rungs evenly spaced throughout the full run of the ladder)	≥ 275 mm (11.0 in.) ≤ 300 mm (12.0 in.)
H	Skew angle	≤ 2 degrees
I	Stringer separation	400 to 450 mm (16.0 to 18.0 in.)
J	Ladder height: Ladders over 6 m (19.7 ft) require intermediate/linking platforms)	≤ 6.0 m (19.5 ft)

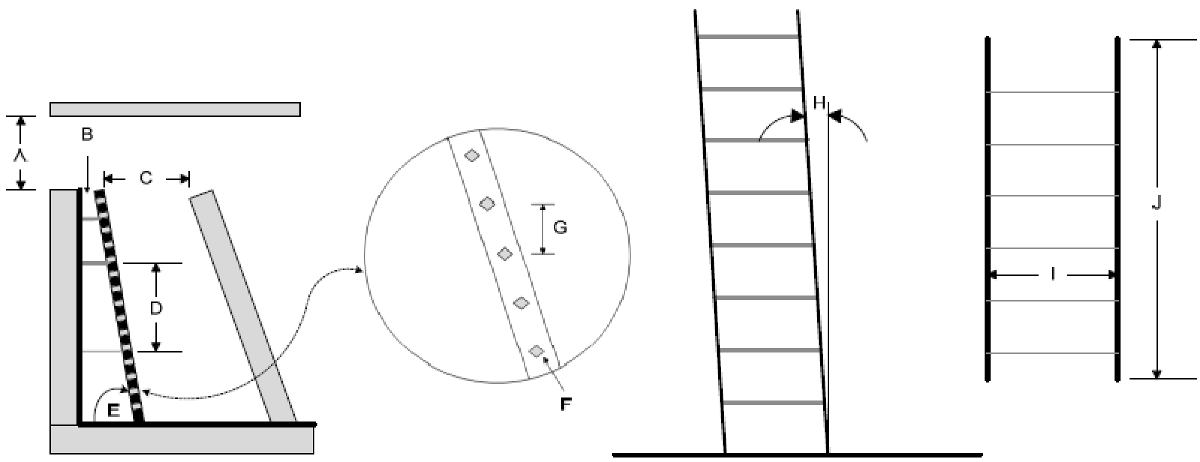


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Figure 3 Staggered Vertical Ladders

	Dimension	*Recommendation*
A	Stringer separation	400 to 450 mm (16.0 to 18.0 in.)
B	Horizontal separation between two vertical ladders, stringer to stringer	≥ 225 mm (9 in.) ≤ 450 mm (18 in.)
C	Distance between ladder rungs (rungs evenly spaced throughout the full run of the ladder)	≥ 275 mm (11.0 in.) ≤ 300 mm (12.0 in.)
D	Stringer height above landing or intermediate platform	≥ 1350 mm (53.0 in.)
E	Rung design – (Can be round or square bar; where square bar is fitted, orientation should be edge up)	Square bar 22 mm (0.9 in.) x 22 mm (0.9 in.) Round bar 25 mm (1.0 in.) diameter
F	Horizontal separation between ladder and platform	≥ 150 mm (6.0 in.) ≤ 300 mm (12.0 in.)
G	Landing or intermediate platform width	≥ 925 mm (36.5 in.)
H	Platform ladder to Platform ledge	≥ 75 mm (3.0 in.) ≤ 150 mm (6.0 in.)

*Note: Left side guardrail of platform omitted for clarity.

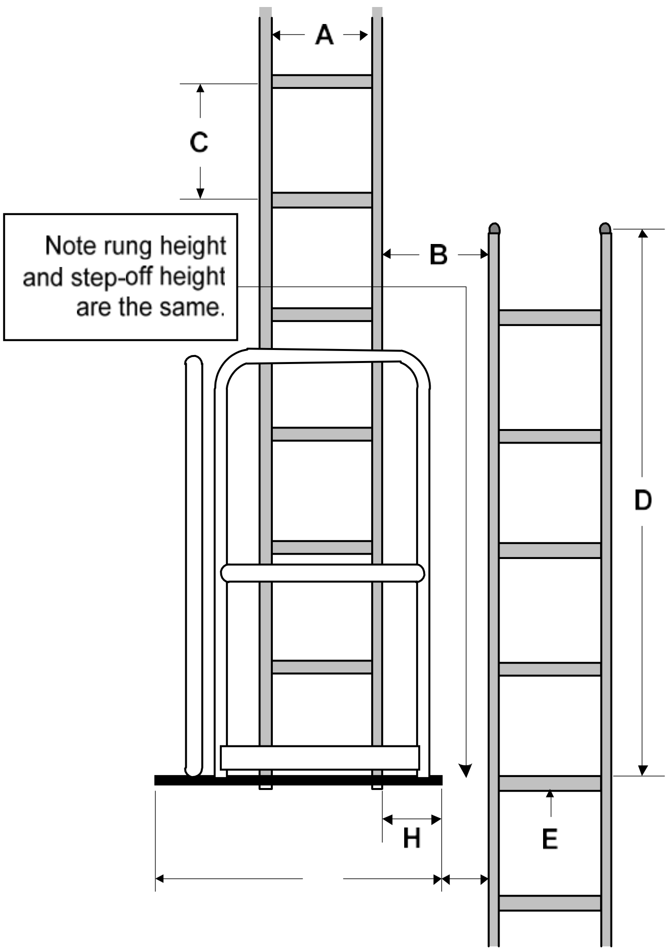

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Figure 4   Vertical Ladders to Landings (Side Mount)*

Dimension		Recommendation
A	Platform depth	≥ 750 mm (29.5 in.)
B	Platform width	≥ 925 mm (36.5 in.)
C	Ladder distance from surface	≥ 175 mm (7.0 in.)
D	Horizontal separation between ladder and platform	≥ 150 mm (6.0 in.) and ≤ 300 mm (12.0 in.)

* Notes: Top view. Guardrails/Handrails not shown.

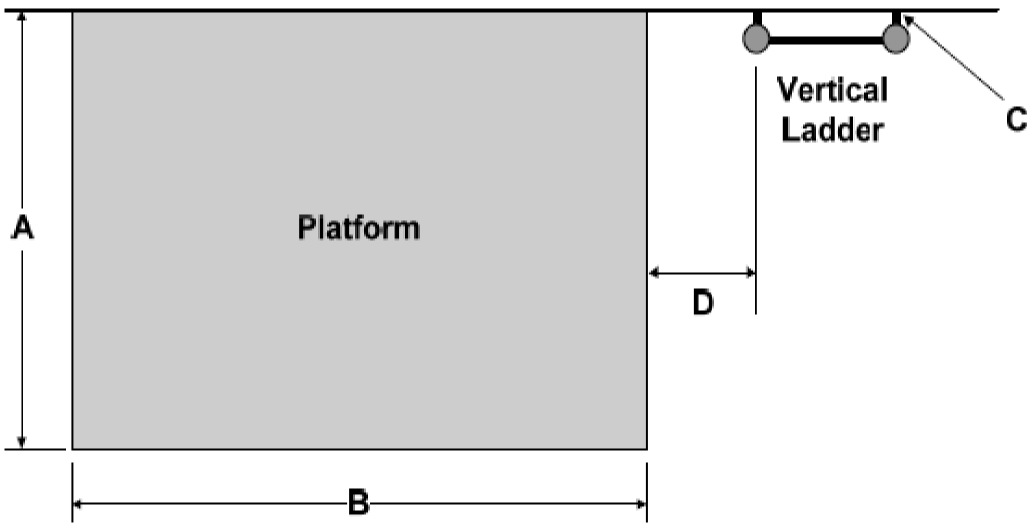

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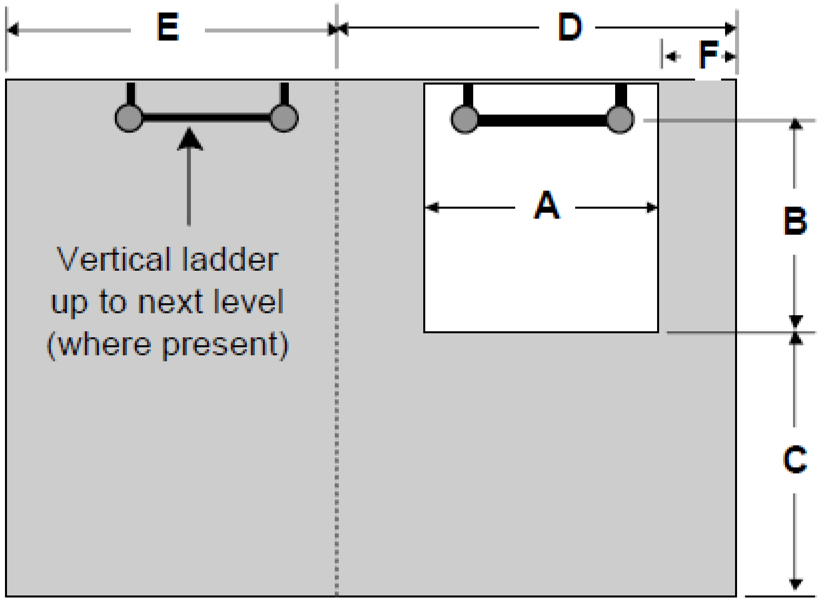
Figure 5 Vertical Ladders to Landings (Ladder through Platform)*

	Dimension	*Recommendation*
A	Vertical ladder opening	≥ 750 mm (29.5 in.)
B	Distance from front of vertical ladder to back of platform opening	≥ 750 mm (29.5 in.)
C	Minimum clear standing area in front of ladder opening – Depth	≥ 750 mm (29.5 in.)
D	Minimum clear standing area in front of ladder opening – Width	≥ 925 mm (36.5 in.)
E	Additional platform width for intermediate landing (where present)	≥ 925 mm (36.5 in.)
F	Horizontal separation between ladder and platform	≥ 150 mm (6.0 in.) and ≤ 300 mm (12.0 in.)

*Notes: Top view. Guardrails/Handrails not shown.



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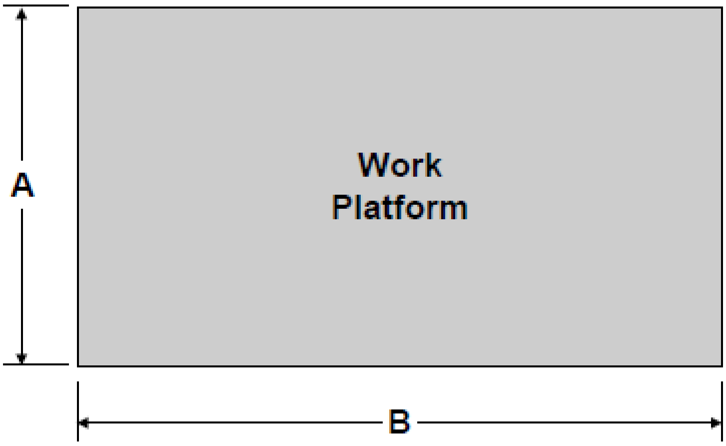
Work Platform

In addition to the recommendations for Work Platforms presented in Section 4.6 Access & Egress Design, the following recommended dimensions relating to the design of Work Platforms are presented in Figure 6 'Work Platform Dimensions'.

Figure 6 Work Platform Dimensions

Dimension		*Recommendation*
A	Work platform width	≥ 750 mm (29.5 in.)
	Work platform width (if used for standing only)	≥ 380 mm (15.0 in.)
B	Work platform length	≥ 925 mm (37.0 in.)
	Work platform length (if used for standing only)	≥ 450 mm (18.0 in.)



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Annex B - Relevant Standards, Guidelines and Practices

This Annex presents a list of standards and guidance documents used by industry in relation to lighting, ventilation, vibration, noise and access in the context of their effects on human working onboard ships.

2.1 Lighting

- ASTM F1166 2007 Standard Practice for Human Engineering Design for Marine Systems, Equipment and Facilities
- IESNA RP-12-97, Recommended Practice for Marine Lighting
- ISO 8995:2000 (CIES 008/E), Lighting of indoor work places
- ILO Maritime Labour Convention
- JIS F 8041: Recommended Levels of illumination and Methods of illumination Measurement for Marine Use

2.2 Ventilation

- ANSI/ASHRAE (15) (2010). Practices for Measuring, Testing, Adjusting, and Balancing Shipboard HVAC&R Systems
- ANSI/ASHRAE 55a, (2010). Thermal environmental conditions for human occupancy
- ANSI/ASHRAE 62.1 (2010) Ventilation for Acceptable Indoor Air Quality
- ISO 7547:2008 Ships and marine technology – Air-conditioning and ventilation of accommodation spaces – Design conditions and basis of calculations
- ISO 7726 (E), (1998), Ergonomics of the thermal environment – Instruments for measuring physical quantities

2.3 Vibration

- ISO 2631-1:1997, Mechanical Vibration and Shock – Evaluation of Human Exposure to Whole Body Vibration – Part 1: General Requirements
- ISO 2631-2:2003, Mechanical Vibration and Shock – Evaluation of Human Exposure to Whole Body Vibration – Part 2: Vibration in Buildings.
- ISO 6954:2000, Mechanical Vibration and Shock – Guidelines for the Measurement, Reporting and Evaluation of Vibration with Regard to Habitability on Passenger and Merchant Ships.
- ISO 8041:2005, Human response to vibration – Measuring instrumentation.

2.4 Noise

- IMO Resolution MSC.337(91), Code on Noise Levels on Board Ships
- IMO Resolution A.468(XII), Code on Noise Levels on Board Ships

2.5 Access

- American Society for Testing and Materials (ASTM) F1166 2007 Standard Practice for Human Engineering Design for Marine Systems, Equipment and Facilities
- IACS (2002). Recommendation No. 78 – Safe Use of Portable Ladders for Close-up Surveys
- IACS (2005). Recommendation No. 90 – Ship Structure Access Manual
- IACS (1992). Recommendation No. 91 – Guidance for Approval/Acceptance of Alternative Means of Access
- IACS, Unified Interpretations (UI) SC191 for the application of amended SOLAS regulation II-1/3-6 (IMO Resolution MSC.151 (78)) and revised Technical provisions for means of access for inspections (IMO Resolution MSC.158 (78))
- IMO Maritime Safety Committee Resolution MSC.133 (76) Adoption of Amendments to the Technical Provisions for Means of Access for Inspections
- IMO Maritime Safety Committee Resolution MSC.134 (76) Adoption of Amendments to the International Convention for the Safety of Life At Sea
- IMO Maritime Safety Committee Resolution MSC.158 (78) (adopted 20 May 2004), Amendments to the Technical Provisions for Means of Access for Inspections

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