



GUIDANCE NOTES ON

ERGONOMIC DESIGN OF NAVIGATION BRIDGES

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Foreword

The focus of ergonomics is the study of the role of humans in the safe and efficient operation of complex industrial systems and the application of ergonomic principles and data to the design of equipment and systems. The importance of the “human element” and ergonomics in maritime safety is increasingly recognized and embraced by the maritime community (O’Neil, 2001). These *Guidance Notes for the Ergonomic Design of Navigation Bridges* inform vessel designers of the ergonomic principles and data appropriate to the design of navigation bridges; and in doing so serve to supplement and support the *ABS Guide for Bridge Design and Navigational Equipment/Systems*.

These Guidance Notes are consistent with the principal international statutory and discretionary guidance addressing the design of bridge systems, including: International Association of Classification Societies *Standard for Bridge Design, Equipment, and Arrangement*; International Safety of Life at Sea Convention (SOLAS), as amended, and; the International Maritime Organization’s *Guidelines on Ergonomic Criteria for Bridge Equipment and Layout*. The guidance contained in this document is deemed generally appropriate to seagoing vessels of various types and categories, such as container vessels, oil carriers, bulk carriers, workboats, ferries, surface type utility vessels passenger vessels and so on. This being the case, this document provides:

- i) *General ergonomic design guidance* (design principles) for navigation bridges (Section 2),
- ii) *Specific bridge design guidance* gleaned from international sources, such as the International Maritime Organization (IMO) and the International Association of Classification Societies (IACS) (see Sections 3 through 11),
- iii) *A process* to identify individual vessel bridge requirements to guide application of ergonomic design principles (see Appendix 1).

These Guidance Notes do not provide more generally applicable detailed ergonomic design guidance or data, such as control dimensions, environmental limits or human anthropometry. Those data can be found in the *ABS Guidance Notes on the Application of Ergonomics to Marine Systems*. Detailed environmental control guidance is available in the *ABS Guide for Crew Habitability on Ships* and the *ABS Guide for Crew Habitability on Offshore Installations*.

These Guidance Notes do not restate all of the bridge-related requirements of international agreements and statutes. Designers must use those source documents to create and define a base bridge requirements matrix for any particular bridge design effort. This document can be used to support the identification or refinement of requirements based on: ergonomic analysis techniques; the application of guiding principles of ergonomic design as related to bridges; and the application of detailed guidance contained in these Guidance Notes.

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SECTION 1 Introduction

1 Background

The *ABS Guide for Bridge Design and Navigational Equipment/Systems* presents requirements that “are applicable to vessels possessing SOLAS certificates and having the bridge so designed and equipped as to enhance the safety and efficiency of navigation.”

That Guide also recommends that the design of bridges is to be based on sound ergonomic principles. To support the bridge design and engineering community in promulgating these principles, these *ABS Guidance Notes for the Ergonomic Design of Navigation Bridges* have been developed.

A definition of 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.

International Ergonomics Association, 2000

2 Application

These *Guidance Notes for the Ergonomic Design of Navigation Bridges* provide vessel designers with the ergonomic principles and data appropriate to the design of navigation bridges; and in doing so serve to supplement and support the *ABS Guide for Bridge Design and Navigational Equipment/Systems*. Ergonomic design guidance herein applies only to navigation bridges and associated equipment.

These Guidance Notes do not provide more generally applicable detailed ergonomic design guidance or data, such as control dimensions, environmental limits or human anthropometry. Those data can be found in the *ABS Guidance Notes on the Application of Ergonomics to Marine Systems*.

Extensive reference is also made to the *ABS Guide for Crew Habitability on Ships* and the *ABS Guide for Crew Habitability on Offshore Installations*. These documents present guidance related to the design of the accommodations and the ambient environment of a vessel's bridge such as human whole body vibration, noise, indoor climate and lighting.

3 Scope

Guidance in this document is consistent with the principal international statutory and discretionary guidance addressing the design of bridge systems (such as: IACS Standard for Bridge Design, Equipment and Arrangement; SOLAS V; and IMO Guidelines on Ergonomic Criteria for Bridge Equipment and Layout). The guidance contained in this document is deemed generally appropriate to seagoing vessels of various types and categories, such as cargo vessels, passenger vessels and certain offshore structures and vessels, (e.g., surface-type drilling units, offshore supply vessels and mobile offshore drilling units). This being the case, this document provides:

- i) *General ergonomic design guidance* (design principles) for navigation bridges (Section 2, “General Guidance”),
- ii) *A process* to identify individual vessel bridge requirements to guide application of ergonomic design principles (see Appendix 1, “Ergonomic Design and Evaluation Process”), and
- iii) *Specific bridge design guidance* gleaned from international sources, such as the International Maritime Organization (IMO) and the International Association of Classification Societies (IACS) (see Sections 2 through 11).

These Guidance Notes do not restate all the bridge-related requirements of international agreements and statutes or any particular flag state requirements imposed on the design of navigation bridges. Designers must use those source documents to create and define a database of bridge requirements for any particular bridge design effort. This document can be used to support the identification or refinement of requirements based on: ergonomic analysis techniques; the application of guiding principles of ergonomic design as related to bridges; and the application of detailed guidance contained in these Guidance Notes.

SECTION 2 General Guidance (Principles of Ergonomic Design)

1 Background

This Section presents an overview of the principles of human interface design appropriate to the design and use of navigation bridges. These principles are applicable to the design of displays, controls and the bridge workspace for persons on watch duty who must conduct and monitor operations and respond to ambient and operational conditions. Applying these principles to bridge design will lead to interfaces and work environments that simplify bridge operations, reduce human error, are maintainable and limit the physical demands imposed on persons on watch duty and other bridge personnel.

The following eight principles are presented:

- Principle 1 - Define the roles and responsibilities of bridge personnel
- Principle 2 - Design for human limitations, capabilities and expectations
- Principle 3 - Arrange bridge devices, controls and displays to maximize access
- Principle 4 - Design displays consistent with task requirements
- Principle 5 - Design simple, direct and easy to use inputs and controls
- Principle 6 - Design for productive performance and to reduce human error
- Principle 7 - Provide job aids and training
- Principle 8 - Perform testing.

2 Terminology

Achromatic: Designating color perceived to have zero saturation and therefore no hue, such as neutral grays, white or black.

Alarm: A visual and/or audible signal indicating an abnormal situation.

Annunciation: An audible signal indicating a condition or system state (usually of an emergency or off-normal nature) via audible signals.

Expectation: A belief about or mental picture of the future. In ergonomic contexts, an expectation is a belief concerning the effect of an action, especially a control action.

Function: The appropriate action of any special components or part of a system to meet some defined purpose or objective; specific occupation or role; an assigned duty or activity.

Habituation: The reduction of a task performance likelihood following repeated false exposures to the stimulus (e.g., an oft repeated false alarm will reduce its ability to command a timely response).

Human Task: A piece of work performed as part of one's duties; a function performed; an objective.

Perception: The process of becoming aware of the immediate environment through any of the senses.

Situation Awareness: The degree of accuracy by which one's perception of the current environment mirrors reality.

Warning: A cautionary or deterrent indication of an impending abnormal situation.

3 General Guidance

3.1 Principle 1: Define the Roles and Responsibilities of Bridge Personnel

For any given bridge design activity, the relative roles and responsibilities of humans and hardware/software need to be defined. Roles and responsibilities will vary depending on vessel trade, owner/operator objectives and processes, level of vessel automation and other factors. Whatever the specific contexts, the roles and responsibilities of the bridge personnel should be clearly identified.

The design process presented in Appendix 1, “Ergonomic Design and Evaluation Process” provides a method to identify bridge design requirements based on human-machine functional allocation. The following provides general guidance on defining roles and responsibilities for bridge personnel.

3.1.1 Identify Bridge Functions and Conduct Requirements Analysis

Identify specific functions that bridge systems (including personnel) need to perform. These should include not only those functions performed by equipment (e.g., depth sounding), but also those that are essentially human (e.g., visual lookout, route planning). The objective of this is to completely characterize what has to be accomplished from the bridge, in terms of:

- i) Functions (e.g., sea surveillance),
- ii) Means to perform or support the function (e.g., radar sets, binoculars),
- iii) Requirements of functions (e.g., detect target presence, determine range and bearing, determine course and speed, compute closest point of approach, etc.).

For each function, requirements are further analyzed to identify (or define by allocation) the specific roles of bridge personnel. Each human role/function will have associated human tasks that need to be identified and listed.

3.1.2 Generate Task-Based Requirements

Identify bridge personnel tasks and the objectives of those tasks. Examine each task to determine information requirements, control requirements, as well as the skill and knowledge required to the perform tasks.

3.1.3 Identify Task Overlap

Identify, based on contextual and environmental factors, which tasks may overlap in time or bridge location. Examine the relationship between tasks and the subsequent prioritization of tasks.

3.1.4 Specify System Failure Procedures

Consider what information and control provisions must be available from the bridge in case of a loss of automated functions. As far as possible, bridge systems should “fail-safe” (meaning that they do not fail leaving the systems in a hazardous or risky condition).

3.1.5 Solicit Bridge Personnel Inputs to Requirements

Solicit experienced bridge personnel to identify and verify human tasks, as well as associated information, displays and controls required to perform those tasks.

3.1.6 Design for Efficiency and Control of Workload

Select and arrange bridge equipment and design jobs and tasks so that bridge personnel:

- i) Can reliably perform their functions
- ii) Are productive
- iii) Are not overloaded with work.

3.2 Principle 2: Design for Human Capabilities, Limitations and Expectations

Humans and machines have, of course, very different capabilities. Humans are creative, can make decisions in the face of uncertainty, are highly mobile, learn rapidly, can generalize knowledge to novel situations, are communicative and have massive sensing and sensory processing capability. Machines can exert great force for sustained periods, can do repetitive work flawlessly for long periods, can withstand a wide range of physical environments and do not get bored, complacent, forgetful, tired or angry.

The objective in bridge design is to take full advantage of the relative capabilities and limitations of humans and machines. In the broadest sense, humans should be involved in vessel management and planning activities and should communicate those plans and activities to the machines that perform the work (without a sense of tedium). Humans also monitor machinery and intervene when plans are not followed and perform replanning as needed when the environment or material condition of the equipment changes. In other words, humans plan and decide and machines implement the outcomes of those decisions at the bidding of the human. Guidance related to design of navigation bridges consistent with human capability is presented below.

3.2.1 Limit Human Data Processing

The design of interfaces should be compatible with human capabilities and limitations as information processors. Where possible, machines should perform data manipulation and present the result to the human for decision-making. A common example is the Automatic Radar Plotting Aid (ARPA) radar that computes Closest Points of Approach (CPA) to other vessels. The human uses that result in the context of knowledge-based decision making (e.g., applying the Rules-of-the-Road, negotiating passing plans and replanning ship's course and speed). Machines should be used for such tasks as storing masses of information or performing complex calculations. Humans should be used as sensors, planners and deciders and monitors of machine performance.

3.2.2 Organize Interfaces in Harmony with Physical Layouts

Where appropriate, control and display layouts representing equipment arrangement (e.g., thruster orientations, ballast tank arrangements, navigation light control panels) should mimic the spatial and functional relationships of the equipment monitored and controlled. Where possible, mimic lines should be used to show the physical relationships (e.g., lines connecting pumps and valves) of the components.

3.2.3 Accommodate Human Expectations

Experience influences how humans interpret a display or operate a control. Equipment design should be consistent with those expectations. Design of control actions and display response (directions of movement) should be consistent across workstations. Be concerned where different vendors are used to select/assemble bridge hardware and software (vendors may have designed to different expectations) or where different teams generate designs for different interfaces.

3.2.4 Standardize Display Characteristics

Display characteristics should be consistent among locations (or computer display pages):

- i) Colors should have the same meaning across all displays.
- ii) Schematics should have similar formats (e.g., process flow is normally from left to right) to maintain, when possible, an exact spatial mapping of one display onto another.
- iii) Computer display and panel display information layouts should be spatially compatible with one another.

3.2.5 Facilitate Human Attention

Matching the task to the attention strengths and capabilities of the human can mitigate possible errors due to distraction, complacency, habituation and high workload:

- i) Avoid distractions or requirements to perform meaningless tasks (at least during a watch).
- ii) Place frequently used and important displays (e.g., navigation, helm control, radar) in a central viewing area.
- iii) Ensure alarms are not so frequent that they cease to have an attention-getting effect.
- iv) Use meaningful information groupings so that bridge personnel will be able to easily deal with a large amount of information.
- v) Avoid tasks that compete for attention (e.g., paperwork that is not related to standing watch and keeping a proper lookout).
- vi) Define clear task priorities.

3.2.6 Design within Physical and Perceptual Limits

These guidelines address the compatibility of equipment design within the limits of humans to exert force, reach and manipulate objects and sense the physical environment:

- i) Controls should be placed within easy reach and adjacent to related displays.
- ii) Displays that are viewed from a nominal position should be:
 - Easy to read (e.g., character size compatible with viewing distance),
 - Within an immediate field of view (directly in front of the viewer) and not obscured,
 - Provided sufficient color, brightness and contrast,
 - Large enough to be seen from expected viewing distances and under expected ambient environments (day/night and weather conditions).
- iii) Control the physical environment so that ambient conditions do not interfere with visual or audible signals.
- iv) Guard against inadvertent control operation.
- v) Arrange the bridge so that objects can be easily and readily reached and manipulated.

3.2.7 Limit Memory Requirements

Human memory is limited in capacity, is often unreliable (i.e., error prone) and can be affected significantly by factors such as fatigue, stress and physical health.

- i) Provide efficient methods of calling up display of important or changing information.
- ii) Avoid having to page through several displays to access frequently used or critical information – It should be possible to display time critical information immediately.
- iii) Avoid the need to cross-reference between information displays.
- iv) Clearly identify all controls and displays.
- v) Use simple and memorable codes that are easily distinguishable.
- vi) Include rapid information updating so that bridge personnel do not have to wait.
- vii) Provide obvious, ongoing display of automated system status (e.g., to indicate when automatic processes have been manually overridden, disabled or failed).

3.2.8 Use Color Coding to Simplify Information Search and Interpretation

Where carefully applied, color can be very effective in: reducing visual search, simplifying interpretation of displayed information, reducing ambiguity in decision making and reducing requirements to recall information from memory. Inappropriate use of color can lead to confusion and error. When designing color codes, consider the following:

- i) Add color only after the effectiveness of an interface has been maximized in an achromatic format.
- ii) Do not use color as the sole coding mechanism to convey information. Color coding should be redundant to some other coding mechanism (such as symbols or text).
- iii) The use of color should not reduce readability of displays, labels, maps, etc.
- iv) Color should be applied to avoid or minimize difficulties for personnel having impaired color vision.
- v) Where color coding is employed to denote discrete conditions (e.g., auto-pilot on/off, pump is running, in standby or off, etc.), no more than seven different colors and associated meaning should be used. If similar hues are used, they should be used only with logically related information.

3.3 Principle 3: Arrange Bridge Devices, Controls and Displays to Maximize Access**3.3.1 Component Grouping to Minimize Bridge Traffic**

Group components, consoles and devices according to frequency, importance and sequence of use. Arrange bridge components to minimize the need for the persons on watch duty to move to alternative positions on the bridge. For example, locate vessel-to-vessel communications devices adjacent to radar displays and maneuvering stations. Arrange components on the bridge to facilitate unobstructed external visibility, especially forward-looking. Ensure that any task (or several tasks that need to be performed simultaneously) can be performed from a single standing or seated position.

3.3.2 Arrange Displays by Task Association

When possible, group all of the information relating to a particular task together in one place.

- i) Locate related information together.
- ii) Locate related items such that they are easy to associate.
- iii) Locate displays close to (or on) other displays and controls with which they are associated.

3.3.3 Centralize Important Information

Centralize important information to allow actions to be prioritized.

3.3.4 Optimize Arrangements

Optimize arrangements to support time and safety critical tasks. Layouts should emphasize ease and reliability of performance of safety critical tasks, such as collision avoidance, tug interface, piloting and berthing.

3.3.5 Group Information to Support Operations

Bridge personnel should not have to page through computer displays to collect information required for a particular operation.

3.4 Principle 4: Design Displays Consistent with Task Requirements

3.4.1 Provide External and Internal Consistency

Coding should be consistent among software displays, hardware displays, written documentation and job aids. For example, when designing symbols used to represent equipment (e.g., pumps, thrusters, sea chests, impellers) use the same symbols that bridge personnel are familiar with from drawings, labels, procedures, national and industry standards or training materials.

3.4.2 Provide Situation Awareness Displays

Provide situation awareness displays to keep a summary check on the whole of the system and environment for which bridge personnel have responsibility. Ensure sufficient time to refresh situation awareness at the following times:

- i)* Watch turnovers
- ii)* When additional staffing must be used (e.g., in emergencies, port approaches and departures)
- iii)* Following changes in the use of automation (e.g., changing from auto to manual steering or transitioning to bridge monitoring of engineering functions during times when engine rooms are unattended)
- iv)* As changes in requirements for surveillance, navigation and piloting occur (e.g., due to increased sea-lane occupancy, weather changes or system failures).

3.4.3 Base Display Design on Information Requirements

Design displays based on the requirements of the task. Avoid prior (hardware or software) display formats as a sole basis for the design of computer displays or back-up hardwired displays.

- i)* Involve bridge personnel in the identification of interface requirements (be advised that their understanding of requirements may be based on prior designs and practices that may have been clumsy).
- ii)* Involve bridge personnel in the usability evaluation of interfaces under development.

3.4.4 Provide Sufficiently Accurate and Precise Information

Provide information to the level necessary for accuracy and precision required by the task. For example, if a task requires information display only in whole units, do not present decimal values in displays (e.g., “Depth under keel 12 feet,” versus “Depth under keel 12.214 feet”). Information accuracy and precision includes how current (up to date) information is (as it changes with the passage of time).

3.4.5 Limit Display Complexity

The contents of a display should provide all of the information required to perform tasks in a simple, directly usable form (e.g., without having to transform or extrapolate the information).

3.4.6 Display Actual Equipment Status

Display equipment status (e.g., valve status or rudder position) directly from the actual equipment and not from the demanded control setting (e.g., actual rudder angle as opposed to ordered angle).

3.4.7 Group Information to Support Task Performance

Group information to make it easy to make data comparisons, discern cause and effect relationships, identify time lags and assess rates of change in processes such as changing vessel course against other targets' movements.

3.4.8 Prioritize Alarms and Audible Indicators

An alarm is a visual and/or audible signal typically indicating an abnormal situation demanding human attention and response (e.g., a depth under keel alarm). An audible indication is usually a display of status or vessel condition (e.g., tones that indicate a telephone or radio call is incoming or that an equipment function has failed).

Priorities of alarms and audible indicators should be clearly coded. Prioritize alarms to allow quick assessment of the importance of simultaneous alarms. Prioritization schemes include:

- i) Sequencing alarms in a way that enables the development of abnormal events to be better understood.
- ii) Separating critical alarm information from information or status indications.
- iii) Using dedicated computerized alarm displays.
- iv) Provision of distinct audible indicators (being separate from alarms) that indicate automatic or semi-automatic actions of the system (e.g., transitioning from autopilot to manual steering). If a failure by the persons on watch duty to notice the occurrence of an audible indicator can lead to unsafe conditions (e.g., failure to notice that the vessel's gyro has failed or low lube oil pressure in the steering gear) then that condition should be considered an *alarm condition* and should not be designed as a simple *audible indication*.

3.4.9 Avoid Nuisance Alarms

Alarms are used to signify urgent events and conditions. When alarms are presented, only to be discovered as false or of no real importance, subsequent alarms can tend to be regarded as unimportant, to the point of being dismissed (not investigated) entirely. It is important that audible and visual alarms consistently signify events or conditions that require immediate action. This can be accomplished by the following:

- i) Use audible alarms for abnormal or emergency conditions only.
- ii) Do not use alarms to indicate equipment status or normal conditions (e.g., watertight doors closed, running lights on, control valve position, etc.).
- iii) It should be possible for every bridge alarm to gain immediate attention (even if personnel are not able to deal with the condition immediately).

3.4.10 Acknowledging Alarms

It should not be possible to dismiss critical alarms until the initiating condition is resolved. Locate acknowledgement devices such that audible components of alarms can be acknowledged while allowing alarm information to be read. It should be possible to silence an audible alarm only when that does not cause a loss of alarm information (e.g., visual display of the alarmed parameters).

3.4.11 Avoid Alarm Ambiguity

- i) Alarms should have a unique code (audible signal) if a unique type of response is required.
- ii) Color should not be the only means of distinguishing between alarm and non-alarm conditions.
- iii) Labeling and other information should obviously associate the alarm indicator with the equipment or condition about which the alarm was triggered.

3.5 Principle 5: Design Simple, Direct and Easy to Use Inputs and Controls

3.5.1 Provide Direct Human Control

Design the system interaction such that bridge personnel pace the tempo of operations. Ensure that the human controls the pace of control entries by explicit actions and that such entries occur through explicit human actions. This includes the actions of automated systems by allocating to the human the function of determining and inputting plans and activities for automated system performance (such as voyage plans) and by providing the human with the ability to intervene in automatic system performance and functioning.

3.5.2 Clearly Identify Control Modes

Automated, aided or manual control modes (e.g., auto-pilot steering vs. manual control of the steering wheel) should be clearly indicated by a display associated in close proximity to the controlled component.

3.5.3 Operating Mode Changes are Indicated and Annunciated

When transitioning between control modes (e.g., from manual to auto-pilot steering or transitioning control of the propulsion system from engineering spaces to the bridge), ensure that:

- i)* Positive action on the part of bridge personnel is required (e.g., by positioning a control or issuing a computer command)
- ii)* At the time of transfer, associated displays need to indicate the current, actual control mode and then announce the transfer, with an audible signal that sounds at each affected workstation
- iii)* In the case of the steering wheel, if transfer of helm control to the steering wheel (or joystick or thruster control) is accomplished solely by motion of the device (e.g., a helmsman assumes manual control by directly manipulating the wheel) a positive indication of the mode of control should be provided by conspicuous visual and audible displays.

3.5.4 Provide Guidance for Human Intervention in Automated Systems

Guidance (in the form of written procedures or placards) for when human intervention is needed should be explicit for the following conditions:

- i)* When to take over from automatic functions or control
- ii)* When and how to hand over control from a local control space to another location
- iii)* When to shut down equipment or systems.

3.5.5 Provide Direct and Immediate Feedback for Control Actions

When possible, locate controls and displays (related by action and effect/feedback) together.

- i)* All the effects of an action or command on the process should be simultaneously observable on associated displays. If equipment or system response time is slow, feedback should be provided indicating the action has been initiated and is progressing (e.g., rudder position and rate of turn indicators).
- ii)* If more than one person controls the action of a bridge (or related) system, all relevant information should be simultaneously available to the person responsible for coordinating the task.
- iii)* When possible, supply all the necessary information simultaneously (e.g., in parallel rather than sequentially) that is needed for a diagnosis or a control decision.

3.5.6 Provide Simple Computerized Display Navigation

Navigation through computer displays should not require that bridge personnel remember paths to information. Rather, they should be led to the information through recognition techniques (e.g., by use of pop-up menus, navigational maps or navigation palettes).

- i) Help bridge personnel not to get lost when navigating among windows. Limit the depth of window and menu hierarchies to no more than three levels.
- ii) Provide maps or other cues to provide awareness of “where they are” in the interface.

3.5.7 Response Latency and Visibility of System Status

Where system responses to control actions are slow or delayed, provide intermediate indications of system response. For example, an indication of a ship’s speed of course change can be provided by a Rate of Turn indicator for a ship with a wide turn radius and slow vessel response. This allows the helmsman and deck officer to more immediately verify system response to the control order.

3.6 Principle 6: Design for Productive Performance and to Reduce Human Error**3.6.1 Provide Error Prevention and Tolerance**

To the extent possible, equipment should safeguard against human error. In other words, actions that could directly lead to damage to the vessel, people or the environment should be provided guarded controls or in the case of software, potentially dangerous actions should require a confirmatory action (e.g., “Click CONTINUE to confirm that all watertight doors are to be opened or Click CANCEL to exit.”). Further, and where possible, software should be able to monitor and advise on the safety of human actions. An example of this is a radar system that computes a closest-point-of-approach to a navigational hazard or other vessels navigating in the near vicinity after a change in helm order and alerts the persons on watch duty if there is a danger of collision.

3.6.2 Consider Task Communication Needs

Communication systems should be designed to:

- i) Avoid requiring personnel to frequently move to different locations on the bridge to access communications equipment.
- ii) Consider using portable or wearable, as well as fixed, communication equipment, where item i), above, is considered difficult to comply with.

3.6.3 Avoid Control Conflict

Avoid simultaneous control of systems or equipment from different workstations. Avoid two or more people being able to simultaneously influence the same part of a process from different control and display locations (e.g., controlling engine speed from an engineering station and from the bridge). In other words, do not require ship personnel to compete for control of a system.

3.6.4 Compatibility of Bridge Staffing with Operational Requirements

The following principles should be applied to ensure compatibility among: the bridge staffing complement; the tasks to be performed; the environment (time of day, weather conditions, congestion of waterways, etc.); and the bridge design and its automation.

- i) Determine staffing for all modes of operation, based on high workload operations.
- ii) Consider whether staffing levels, skills and experience will be sufficient for all known operational and failure conditions.

- iii)* Consider staffing implications for worst-case scenarios.
- iv)* Consider staffing for normal conditions.
- v)* Allocate tasks according to skills and experience.

3.7 Principle 7: Provide Job Aids and Training

3.7.1 Identify Required Knowledge, Skills and Abilities

Know what bridge personnel have to do and provide the training to perform the required tasks. Performing a task analysis (see Appendix 1) is sufficient to identify bridge personnel task requirements.

3.7.2 Identify Training Needs and Requirements

- i)* Define training needs specific to a given bridge design and specific automated functions.
- ii)* Identify automated functions and what interventions may be necessary by bridge personnel. Identify the conditions dictating automated or human task performance.
- iii)* Provide training involving vessel control when automated control functions or information is unavailable.
- iv)* Provide training for conditions where important tasks compete for attention.
- v)* Provide hands-on training in transitioning between automatic and manual control functions.

3.7.3 Provide Procedures

- i)* Provide available written or on-line procedures to guide and document infrequent, complex or safety critical operations.
- ii)* Through procedures, indicate appropriate human actions in case of particular alarm conditions (scenarios), rather than cluttering displays with instructions.
- iii)* Provide procedures to address infrequent or postulated conditions.
- iv)* Provide on-line help.

3.7.4 Provide Adequate Labels and Warnings

Provide standardized, durable, readable, usable labels for all equipment and components. Labels and marking should be consistent in terms of:

- i)* Coding and colors used
- ii)* Mounting location
- iii)* Language and nomenclature
- iv)* Stylistic design.

3.8 Principle 8: Perform Testing

3.8.1 Verify Functionality

Verify that the identified functional requirements of the bridge are correctly implemented.

3.8.2 Perform Usability Testing

Observe bridge personnel using hardware and software. Simulate infrequent, uncommon, hazardous and unpredictable tasks. During testing note:

- i) Any observed confusing or error-inducing design aspects
- ii) Bridge personnel observations (Masters, Mates, lookouts, etc.)
- iii) Unnecessary work or task activities
- iv) Observed or reported errors in task performance
- v) Bridge persons on watch duty comments on the usability of components, tasks or arrangement of components.
- vi) Usability testing should occur throughout the design cycle of the bridge and at every instance of bridge equipment modification or upgrade.

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SECTION 3 Bridge Functionality

1 Background

Work required of bridge personnel extends well beyond that imposed by primary operational and system requirements. Often, analysis of functions and identification of requirements examine only those tasks directly associated with piloting and navigation, interfaces with engineering and means to address a limited number of off-normal events. Additional duties, however, are required of bridge personnel to meet additional technical, administrative and statutory requirements and so on. These requirements should be examined as well during the design of navigation bridges.

Design of navigation bridges should consider the entirety of the watchstander job – whether or not specific responsibilities involve some specific hardware interface. Decisions as to how to apply automation to influence bridge personnel workload, for example, must consider task demands that have no attendant hardware and software or that require general purpose hardware and software (e.g., electronic mail).

2 Terminology

Alarm: A visual and/or audible signal indicating an abnormal situation.

Annunciation: An audible signal indicating a condition or system state (usually of an emergency or off-normal nature).

Function: The appropriate action of any special components or part of a system to meet some defined purpose or objective; specific occupation or role; an assigned duty or activity.

Human Task: A piece of work assigned or done as part of one's duties; a function to be performed; an objective.

Situation Awareness: The degree of accuracy by which one's perception of the current environment mirrors reality.

Warning: A cautionary or deterrent indication of an impending abnormal situation.

3 General Guidance

3.1 Bridge Functions

Bridge personnel task requirements should consider the types of functions listed in Table 1, "Sample Bridge Functions and Responsibilities," when performing bridge design tasks such as:

- i) Designing overall layouts and component arrangements
- ii) Selecting devices to meet requirements
- iii) Estimating and allocating workload
- iv) Designing procedures and job aids

- v) Determining communications requirements
- vi) Determining internal and external visibility requirements.

Note in Table 1 that not all functions are primarily bridge related. These functions are addressed in the table since bridge persons on watch duty must at least maintain cognizance of those functions.

3.2 Growth of Bridge Functionality

Allow for update of bridge functions, in terms of both expanded functional requirements (e.g., Voyage Data Recorders) and system upgrades since bridge requirements and components will change over the life cycle of use and new technology may be employed, replacing older equipment. Provisions for such growth of the functionality of a bridge and its technology updates, should be anticipated and accommodated during initial design. For example, it is likely that new or additional alarms will be required and initial design of alarm systems should anticipate that growth.

3.3 Ancillary Bridge Functions

Task and functional responsibilities of bridge personnel will change over time. Changing bridge requirements (due to international agreements, port/coastal state requirements, customer demands, changes in owner operating philosophies and practices and so on) will alter the job and duties of bridge personnel. One example of such a change would be when a vessel moves from a manned to an unattended engine space. In this case, transitioning to operations associated with unattended engineering spaces introduces bridge requirements such as the following:

- i) Extensive monitoring of propulsion systems (operation, start-up, emergency shutdown, fuel system, lubrication systems, cooling system, alarm conditions, ballast and trim, etc.)
- ii) Monitoring electrical generators
- iii) Control of other fire suppression systems
- iv) Bilge monitoring and management.

In addition, numerous other control or alarm conditions related to engineering and auxiliary systems may be required to be monitored/controlled from the bridge, including:

- i) Steering gear alarms (e.g., power failure, failure to override autopilot)
- ii) Fire detection and fire fighting (fire main displays and alarms, fire detection panels)
- iii) Release of towing hook or lines (for towing vessels)
- iv) Gas monitoring and detecting (hydrocarbon and explosion concentrations limits)
- v) Loss of ventilation/refrigeration to cargo tanks/containers
- vi) Liquid levels in oil cargo tanks (high and high high alarms)
- vii) Steering gear status (failures, location of control, off-normal conditions, etc.)
- viii) Bilge alarms.

TABLE 1
Sample Bridge Functions and Responsibilities

Interfacing with Deck Operations - Anchoring - Bunkering, Storing - Cargo (load plan, lightering, etc.) - Cargo management - Direct Shore Gangs - Docking/undocking - Line Handling - Line/wire Maintenance - Pilot embarkation/debarkation - Small boat deployment and recovery - Tug and Towing Operations Navigation, Piloting, Vessel Control - Berthing/Unberthing - Area Surveillance – visual - Area Surveillance – auditory - Surveillance – sea (state, tides, currents, bottom conditions, hazards to navigation, temperature, etc.) - Communications - Internal - Communications – External - Collision Avoidance/Traffic surveillance - Tug interface - Helm control/Conning - Hull Performance/Station Keeping - Bridge Maintenance - Maneuvering in congested waters - Maintain trim and ballast - Signals and lights - Lookout - Position Fixing - Record/chart Keeping - Voyage Track Keeping - Voyage Planning - Weather Monitoring Awareness of Maintenance Activities - Vital Systems - Propulsion - Hull - Schedules/Equipment availability - Calibrations (LORAN, GPS, etc.)	Miscellaneous/Special Operations - Extreme Weather and Seas - Fire - Large and Small - Flooding/Ballast control - Collision/Grounding/Stranding - Internal Security - Loss of Propulsion/Steering - Search and Rescue/Man Overboard - Vessel Security - Fuel Spills/Environment Hazards - Bridge - Housekeeping - Medical - Structural Maintenance Performing functions related to unattended engine rooms: - Monitoring/control of propulsion systems (operation, start-up, emergency shutdown, fuel system, lube systems, cooling system, alarm conditions) - Steering Gear - Monitoring Electrical System - Fire main control - Fire suppression activation - Bilge monitoring and management - Pollution monitoring and control Administration - Port entry (Pilots, Dock/Harbor Masters, etc.) - Log keeping - NOAA/Weather service/reporting - Oceanographic reporting - Health Care - Ship's Meetings - Finance/Payroll - Planning (watch schedules, hours of rest) - Crew assessment - fitness - In-port inspections (P&I, auditors, Customs, Immigration, maintenance personnel, suppliers, vetting inspectors, Port State Control, Port Logs/Records, etc.) - Stores logistics and loading - Personnel issues (STCW, etc.)
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The point of this discussion is that task requirements of bridge personnel extend beyond those directly related to piloting and seamanship and task requirements will likely change over the life-cycle of a vessel.

To the extent possible, design of the navigation bridge should anticipate and accommodate planned or unexpected change and growth in bridge functionality in terms of:

- i)* Alarming and annunciating systems
- ii)* General space allocated to functional areas
- iii)* Potential changes in bridge manpower
- iv)* Design of communications systems
- v)* Design of computing systems
- vi)* Persons on watch duty workload and bridge staffing.

SECTION 4 Bridge Arrangement and Layout

1 Background

This Section specifies the basic function and design requirements for bridge arrangement and layout. It has been developed to help ensure that designs of ships' bridges adequately provide for the requirements for safe navigation by preventing confusion arising from bridge layout, designing for ease of device access and use and reducing workload and human fatigue.

2 Terminology

Accessibility: The ability for personnel to easily access equipment that requires maintenance, inspection, removal or replacement while wearing the appropriate clothing, including personal protective equipment and using all necessary tools and test equipment.

Anthropometrics: Data relating to physical body dimensions. It includes body characteristics such as size, breadth and the distances between anatomical landmarks, such as elbow to fingertip

Anthropometric Percentile: Given the range of variability of [human] bodily dimensions, anthropometric data are typically expressed as percentile statistics, such as 5th or 95th percentile. A percentile statistic defines the anthropometric point at which a percentage of a population falls above or below that value. For example, the seated eye height of a 95th percentile North American male is 850 mm (33.5 in), so by definition, 5 percent of North American males will have a seated eye height of greater than this figure and 95 percent will have a lesser seated eye height.

Bridge: Area from which the navigation and control of the vessel is exercised, including wheelhouse, chartroom area and bridge wings.

Bridge Wing: Parts of the bridge on both sides of the vessel's wheelhouse that extend to the vessel's sides.

Catwalk: Extension to a deck that is wide enough to allow the passage of a person.

Chartroom Area: Part of the wheelhouse situated and equipped for adequate performance of voyage planning/plotting activities.

Commanding View: View without obstructions that would interfere with the ability of a navigator to perform all immediate tasks.

Communications Workstation: Workstation for operation and control of the equipment for distress/safety communications and public correspondence communications.

Conning Position: Place on the bridge with a commanding view that is used by navigators when commanding, maneuvering and controlling a vessel's movements.

Field of View: Angular dimension of a scene that can be observed from a position on the vessel's bridge.

Helmsman: Person who steers a vessel while underway.

Monitoring: Act of constantly checking equipment and surroundings in order to detect changes.

Monitoring Workstation: Workstation where formal vessel monitoring activities are performed.

Navigation and Maneuvering Workstation: Workstation where vessel's speed and course are considered and controlled.

Navigator: Person navigating, operating bridge equipment and maneuvering the vessel.

Wheelhouse: Enclosed area of the bridge.

Workstation: Position at which one or several tasks constituting a particular activity are carried out. This position includes a combination of job-related items necessary to fulfill job tasks, such as the console, with all devices, equipment and furniture.

3 Internal Visibility

3.1 Height of Lower Edge of Front Windows

The height of the lower edge of the front windows should allow a forward view over the bow, from which a person seated at the workstations can monitor, navigate and maneuver. The height of the lower edge of front windows above the deck should be kept as low as possible. It should not, as far as practicable, be more than 1000 mm (39 inches) above the deck.

3.2 Height of Upper Edge of Front Windows

The height of the upper edge of the front windows should allow a forward view of the horizon for a person in a standing position with a standing eye height of 1800 mm (71 inches) at the navigating and maneuvering workstation.

- i) If 1800 mm (71 inches) eye height is unreasonable and impractical, the eye height may be reduced, but should not be less than 1600 mm (63 inches).
- ii) The height of the upper edge of the front windows above the deck should be as high as practicable and at least allow a forward view of the horizon when the bow is 10° below its even keel position.
- iii) The minimum height of the upper edge of the front windows above the deck surface should be 2000 mm (79 inches). (See Figure 1, "Example of Height of Upper Edge of Front Window in Relation to Eye Height.") The dimensions in Figure 1 are based upon an eye height of 1800 mm (71 inches), for a person of 1900 mm (75 inches) stature, at a distance of 750 mm (30 inches) from the bridge front bulkhead. As a point of reference, the standing eye height of a 95th percentile Northern European or North American male is approximately 1750 mm (69 inches) and stature of that same 95th percentile male is approximately 1860 mm (73 inches).
- iv) For arrangements where the navigator would normally stand further back from the bridge-front bulkhead, the same eye height should be used to determine the height of the upper edge of the front windows.

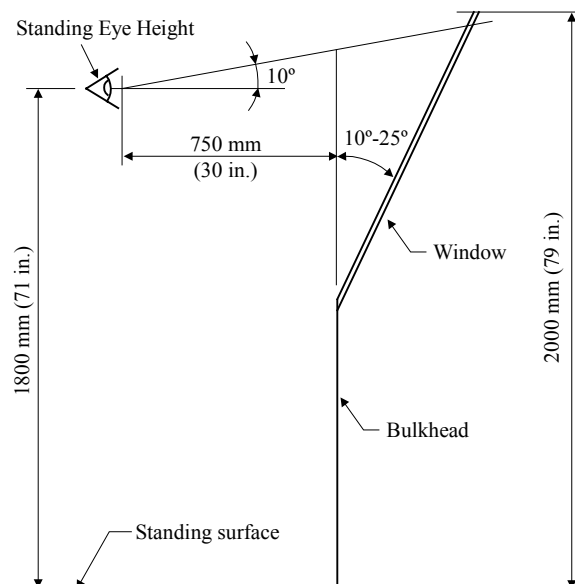
3.3 Window Framing

Divisions/frames between windows should be kept to a minimum. No frames, including the centerline, should be installed immediately forward of any workstation. The frames between front windows should not exceed 150 mm (6 inches). If stiffeners between windows are to be covered, this should not cause further obstructions of the field of view from any position inside the wheelhouse. If stiffeners are used, frames should not exceed 100 mm (4 inches) in width and 120 mm (4.7 inches) in depth. In no case should horizontally sliding windows be used.

3.4 Window Inclination

To help avoid reflections, the bridge front windows should be inclined from the vertical plane, top forward, at an angle of not less than 10° and not more than 25° (see Figure 1). The rear and side windows should be inclined from the vertical plane top outboard, at an angle of not less than 10° and not more than 25° . Exceptions can be made for windows in bridge wing doors.

FIGURE 1
Example of Height of Upper Edge of Front Window
in Relation to Eye Height



3.5 Clear View

A clear view through at least two of the bridge windows and depending on the bridge configuration, an additional number of windows should be provided at all times. A clear view should be provided at all times, regardless of the weather conditions.

3.5.1 Bright Sunshine

To ensure a clear view in bright sunshine, sunscreens with minimum color distortion should be provided at all windows in front of workstations. Such screens should be readily removable and not permanently installed.

3.5.2 Inclement Weather

Heavy-duty wipers should be provided for the majority of the front windows. These wipers should do the following:

- i) Include an interval function and fresh water wash
- ii) Be in accordance with ISO 3904 if clear view screens are installed
- iii) Be capable of operating independently of each other
- iv) Have efficient cleaning, de-icing and de-misting systems installed to ensure a clear view in all operating conditions
- v) Have heated glass panels, where installed, be in accordance with ISO 3434
- vi) Include a fixed catwalk with guardrails, fitted under the bridge windows, to allow cleaning of the windows in the event of a failure of other cleaning systems.

3.5.3 Glass Characteristics

Neither polarized nor tinted glass should be used.

3.6 Visibility from Bridge Window

It should be possible to watch the area in front of the bridge superstructure from the wheelhouse.

3.6.1 Position Close to Forward Center Window for Adequate Conning

A position close to the forward center window should be provided with a clear view. If the view in the centerline is obstructed by large masts, cranes, etc., two additional positions giving a clear view ahead should be provided, one on the port side and one on the starboard side of the centerline, no more than 5 meters (16.5 feet) apart.

3.6.2 Access to Front Window

A second close approach access, besides the forward center window position described above, should be possible, or the width of the position described above should be sufficient to accommodate two people.

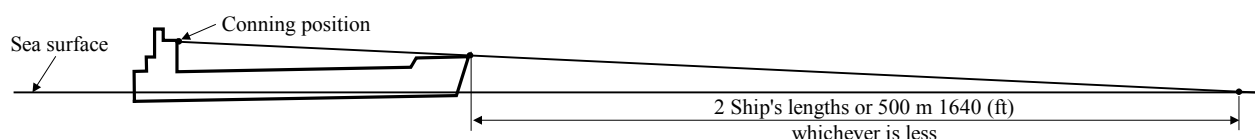
4 External Visibility

Guidance in this Subsection generally applies to ships. For floating units which do not move frequently and that normally can not meet blind view requirements, visibility procedures should be set up as prescribed in the Convention on the International Regulations for Preventing Collisions at Sea, as amended (1972, rules 6, 7 and 8) with respect to safe speed, posting of lookouts and watches and use of sound signals and collision avoidance using Radar and plotting devices.

4.1 View of Sea Surface

The view of the sea surface from the conning position should not be obscured by more than two vessel lengths or 500 meters (1640 feet), whichever is less, forward of the bow to 10° on either side irrespective of the vessel's draft, trim and deck cargo (e.g., containers). See Figure 2, "View of Sea Surface."

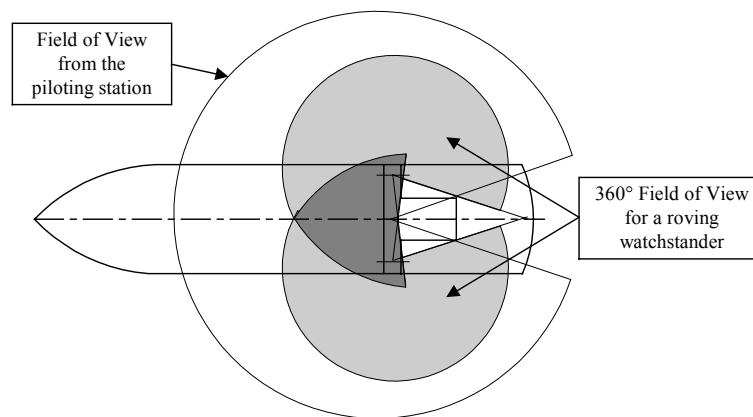
FIGURE 2
View of Sea Surface



4.2 Field of View Around Vessel

It should be possible to observe all objects necessary for navigation, such as ships and lighthouses, in any direction from inside the wheelhouse. There should be a field of view around the vessel of 360° for an observer moving within the wheelhouse. See Figure 3, "Field of View Around Vessel."

FIGURE 3
Field of View Around Vessel



4.3 Navigating and Maneuvering Workstation Field of View

At the navigating and maneuvering workstation and at the conning position, the navigator's field of view should be sufficient to allow compliance with the International Regulations for Preventing Collisions at Sea Guidelines. See Figure 4, "Navigating, Maneuvering and Monitoring Workstations and Conning Position Field of View."

- i) The forward horizontal field of view from the navigating and maneuvering workstation and from the conning position, should extend over an arc from 22.5° abaft the beam on one side of the vessel, forward through the bow centerline to 22.5° abaft the beam on the other side of the vessel at a minimum.
- ii) From a monitoring workstation, the field of view should extend over an arc from 90° on one bow, through forward, to 22.5° abaft the beam on the other bow at a minimum.
- iii) The field of view from a workstation on the bridge wing should extend over an arc from at least 45° on the opposite bow through dead ahead and then aft to 180° from dead ahead.

FIGURE 4
Navigating, Maneuvering and Monitoring Workstations and Conning Position Field of View

