Discussion Paper
Designing for Habitability

INTRODUCTION

Habitability can be defined as “the acceptability of a structure (as determined by its noise, vibration, motion, or other characteristics) according to prevailing standards for human comfort or efficiency” (ABS, 2013; ABS, 2013). "Other characteristics" include the quality of temperature and lighting conditions, and the physical design that affects the livability of a space. Noise and vibration levels, thermal comfort (heating, air conditioning, ventilation, and humidity), and lighting levels are ambient environmental factors that can impinge on working and living spaces. The physical design includes personnel living and working spaces, berthing areas, recreational facilities, mess areas, and workstations.

Terms/Definitions

Accommodations: Interior vessel and offshore installation areas in which the primary purpose is to work, rest, or recreate. Accommodations spaces include cabins, statesrooms, medical facilities or sick bays, offices, bridge and engineering stations, and public and recreation rooms.

Ambient Environment: The environmental conditions the crew is exposed to during periods of work, rest, and leisure.

Anthropometry: Data relating to physical body dimensions. It includes body characteristics such as size and breadth; distances between anatomical landmarks such as elbow to finger-tip; and height measured from the bottom of the feet to the top of the head.

Crew Member: A person on board a ship or offshore installation who is neither passenger nor observer.

Crew Spaces: Areas on a vessel intended for personnel only such as crew accommodations spaces and crew work spaces.

Ergonomics: 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, 2009).

Habitability: The acceptability of the conditions of a vessel in terms of vibration, noise, indoor climate variables, and lighting as well as physical and spatial characteristics according to prevailing research and standards for human efficiency and comfort.

Vessel: Ship, boat, or offshore installation where personnel work, live, and are subjected to the marine environment.

DISCUSSION

Level of Concern

The major objective of designing for habitability is to provide a design that will enhance and help maintain human performance, mental alertness, and comfort with the goal of promoting the general well-being of maritime personnel. Appropriate levels of habitability can improve work performance, productivity, quality of life, morale, safety and comfort. They can also reduce human fatigue.

Inappropriate habitability design can cause danger to physical and psychological health at a potentially high cost to the individual, owner, and industry.

Recent reports by the International Maritime Organization (IMO) indicate crew member fatigue is increasingly recognized as a significant factor in maritime accidents (MCS/Circ.565). Crew member fatigue can jeopardize ship and crew safety if it leads to human error. Evidence of the role human error plays in maritime accidents has been provided by recent submissions to the IMO (MSC 71/INF.8; MSC 69/INF.16; MSC 68/INF.15; MSC 69/INF.15).

It is accepted that maritime personnel work in a physically demanding environment that requires a high degree of alertness and concentration. Fatigued personnel are more vulnerable to error as well as to the many hazards onboard ships and offshore structures. These hazards frequently result in slips, trips, falls, strikes by falling objects, burns, body strains, and other injuries. Injury and accident statistics from Protection and Indemnity Clubs (P&I Clubs) reveal these mishaps are costly to owners and to the industry and contribute to crew member lost-time, reduced work quality, loss of productivity, and vessel delays.

What Elements of Habitability Can Be Influenced by the Design Process?

The objective of incorporating habitability during design is to comply with criteria that will produce suitable overall living and working conditions within design and budget constraints. When absolute adherence to habitability criteria is not possible, design alternatives are employed to improve environmental conditions. Examples of alternatives are dampening noise transmission with acoustic insulation and applying resilience techniques to alleviate vibration.

One major aspect of designing for habitability refers to the ergonomics of the workplace, meaning the design, placement, and arrangement of the various components and spaces onboard where crew members live and work. Unfavorable living and working space design can be improved if addressed early in the planning stages. For example, the decision to locate crew berthing away (or suitably protected) from spaces containing equipment that contributes high levels of noise or vibration is more easily taken before construction has begun.

Habitability design characteristics should be considered concurrently with user expectations (see topic *Cultural Calibration of Vessel and Offshore Installation Designs*), the sizes and dimensions of the expected users, the ship trade, and the areas traded. Expected ship motions, exposures to extremes of heat and cold, and related regional environmental conditions should also be considered (ABS, 2014; ABS, 2013; ABS, 2013).

Listed below are various ambient environmental conditions that impact habitability. The design objective of each variable is discussed with background and design information.

- Noise levels
- Vibration
- Thermal comfort (temperature, humidity, and ventilation)
- Illumination

Noise

The objective of noise design is to establish a satisfactory environment relative to human response to noise. This is to prevent hearing loss as well as to minimize disruption of speech communications and noise-induced annoyance/stress factors. Excessive noise degrades performance during vigilance tasks, complex mental tasks, tasks involving complex motor skills, and communications. Excessive noise can also interfere with speech and other communication tasks (Kryter, 1994). Unexpected intermittent noises are more disruptive than continuous ones, and sudden or impact noises can induce physiological reactions and emotional changes that return to normal after continued exposure. Additional human responses to high levels of noise include the masking of speech, impeded crew member reaction/response times, and increase the possibility of human error. Research also shows that high levels of noise disrupt sleep patterns by delaying the onset of sleep, awakening one from sleep, and interfering with rest due to the reduction in the amount of deep sleep (Salvendy, 1997).

Noise abatement and control techniques include:

- *Source control:* These methods include balancing rotating parts, using rubber mountings and surface dampening, tightening loose connectors that could cause component rattle, and avoiding resonances.
- *Path control:* Methods of controlling noise traveling down passageways, through ventilation ducting, etc. include increasing distance between source and crew members by design layout, enclosing the source, or placing intervening structures in the noise path.

- *Noise attenuation/active noise control:* These methods include employing baffles, mufflers, absorptive materials on bulkheads and decks, and other acoustical treatments. Noise attenuation can also be achieved with noise-cancellation speakers.
- *Receiver control:* These methods include implementing noise-isolating devices and active noise control at the receiver end (ear). Personal hearing/ear protection such as inserts, muffs, or both conserve hearing but can interfere with voice communications and sound signals (audible alarms) (Sanders and McCormick, 1993). Active noise control at the receiver end (the human) includes noise-canceling ear buds or headphones. These interfere less with voice communications than noise isolating devices and feature up to 85% noise attenuation, but they can be uncomfortable.

Vibration

Vibration control establishes a safe and satisfactory working and living environment with respect to human response to excessive vibration, motion sickness, vibration-induced injury/illness, reduced performance, and comfort factors (Griffin, 1990).

The human body is exposed to whole-body vibration and to vibrations applied to specific body parts such as head or limbs (Salvendy, 1997). Designers should be primarily concerned with vibration transmitted to the body through supporting surfaces such as the buttocks or feet (Sanders and McCormick, 1993). Research shows that mechanical vibration interferes with work quality, productivity, safety, health, and comfort, and can induce motion sickness. Vibration can modify crew member perceptions (e.g., reading text and instruments, the perception of depth and distance), influence body control movements (e.g., tactile sense, head/hand movements, manual tracking, reaching), and impair speech. These factors can result in impeded crew member reaction/response times and can increase the likelihood of human error (Griffin, 1990; BS 6841, 1987).

Vibration control techniques are similar to those employed in noise control. These techniques include source control, path control, and receiver control (Sanders and McCormick, 1993; Griffin, 1990).

Thermal Environment

The objective of designing with the thermal environment in mind is to provide conditions that crew members find satisfactory and to support human performance. To achieve this, temperatures are controlled within a tight range and conditions should be such that personnel are unaware of changes (Salvendy, 1997; Sanders and McCormick, 1993).

The human body thermo regulates itself in different environments by producing or losing extra heat to maintain its core comfort level. Yet studies indicate unfavorable thermal environments impact the body's physiology and can cause extreme reactions such as heat stroke, exhaustion, and hypothermia. Less extreme physiological responses adversely impact human performance as well. Performance degradation causes increased energy expenditure, decreased work capacities, reduced work intervals, decreased quality and productivity, reduced hand/arm control manipulation capabilities, stiffness, and decreased cognitive functioning (Salvendy, 1997; ASTM F1166, 2007, 1995; ANSI/ASHRAE 55a, 2009; BS ISO 11399, 1995).

In addition to temperature-related concerns, the thermal environment also includes humidity levels and air exchanges rates. Design concerns include the intended areas of operations for the vessel or offshore installation, location of the spaces within the design, tasks performed in these spaces, and personnel exposure to these conditions in these areas (BS ISO 11399, 1995).

Illumination

For most activities, vision is the main sensory channel for receiving information. Suitable illumination for effective visual task performance is therefore a critical element in designing for habitability. (Salvendy, 1997; Sanders and McCormick, 1993; IESNA RP-12, 1997; BS 5266, 1999). The objective of controlled illumination is to enhance crew safety and emergency and escape activities, and to maintain satisfactory lighting levels in all workspaces. Lighting installations are designed for performance of visual tasks but also for visual comfort. Visual discomfort-causing conditions such as flicker, glare, shadows, and veiling reflections can lead to degraded visual performance in the form of visual task difficulty, under- or overestimation of distances, distraction, and perceptual confusion leading to, for example, the misreading of a display. Ineffective lighting systems contribute to eye fatigue, increased human error and rates, and increases in reaction/response times. (Salvendy, 1997; Sanders and McCormick, 1993).

Ergonomic workplace lighting design involves factors such as the source of illumination, the technology of lighting fixture design, reflection from surfaces, flicker, glare, and shadow reduction, control of cast light direction, distribution, diffusion, and the intensity of illumination required for specific tasks. Early design considerations in the selection and placement of suitable lighting fixtures are essential to attain satisfactory lighting levels (Salvendy, 1997; IESNA RP-12, 1997; BS 5266, 1999; NORSOK, 1996; NORSOK, 1997).

SUMMARY

Due to the identification of fatigue and human error as major factors in maritime accidents, recent publications address the design, placement, and arrangement of the various spaces onboard where crew members must live and work. Although these are not as well defined as ambient environmental criteria, they provide the designer with general and specific design requirements. The objective is to provide the seafarer with satisfactory accommodations in which to live and work which will not contribute to decreases in safety or increases in fatigue (NORSOK, 1996; NORSOK, 1997; ILO, 1998).

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