



On the management and prevention of heat stress for crews onboard ships



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ABSTRACT

From the thermo-hygrometric perspective, some ship compartments are undoubtedly considered severe hot environments due to high temperature values, such as the engine room and, depending on external conditions, cargo holds and storage areas. Such peculiarity further increases already high stress levels related to awkward work postures, lack of space and appropriate lifting tools, noise, vibrations, and a poor air quality. Despite the extensive efforts made by National Governments and International Organizations to improve the quality and the safety of the work on board, over the last several years the thermo-hygrometric characterization of working conditions on board ship seems to have not been investigated enough. Particularly, little monitoring data are available and the use of obsolete or insufficiently validated heat stress indices is a common practice. Addressed to both trained and untrained specialists, this paper discusses how the ergonomic approach of the strategy SOBANE – successfully used for 15 years for risk management and prevention in industrial application – can be implemented on-board. Finally, based on the limited microclimatic data available in the literature, it will be shown which and how heat strain indices should be used for the analysis of heat stress on board.

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1. Introduction

1.1. Safety and working conditions onboard

The European Directive 89/391/EEC (Council of the European Community, 1989) devoted to the introduction of measures to encourage improvements in the safety and health of workers at work obliged UE Members to restructure the legislation concerning the organization of health, safety and wellbeing at work. From this perspective, the Italian Law 271/99 (Italian Parliament, 1999) extended to on board ship working environments the general rules valid for any working context in order to provide the maritime industry with efficient legislation covering all the main aspects of work at sea relating to duties and responsibilities (Table 1).

Despite a significant reduction of mortality rates in fatal disasters (Oldenburg et al., 2010), the incidence of accidents in on board work environments is one order of magnitude higher than in land based workplaces (Lu and Tsai, 2008; Oldenburg et al., 2010). Usually,

aboard ships there are two different working sites. The first includes all areas generally frequented by the passengers or subjects not involved in technical tasks (or services: cabins, lunchrooms, service zones, etc.). The second are the technical rooms (engine room, auxiliary and machinery areas, rudder and shafts tunnels and so on) where life and working conditions are much harsher with risks higher than other ships areas. This is mainly due to:

1. Work postures: lack of space, and the presence of spare parts and other equipment on steep ladders and slippery surfaces increasing the risk of slip, trips and falls (Jensen et al., 2005). Furthermore, in engine rooms there are many fixed or moving machines and instruments even more dangerous during navigation (e.g. due to vibrations, sudden movements of the ship, etc.).
2. Noise: as described by Kaerlev et al. (2008), hearing problems are common among personnel working in the engine room.
3. Indoor Air Quality (IAQ): although several studies seem to confirm that high ventilation rates effectively reduced the risk of high concentrations of harmful substances (Forsell et al., 2007; Lundh et al., 2011), when tasks were being performed in places with less ventilation, the concentration of oil mist, hydrocarbons and dust exceeded maximum safe limits. This is remarkably often associated with the cleaning of engine parts (Forsell et al., 2007).

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Symbols			
BR	boiler room	M	metabolic rate, $W m^{-2}$ or met
DLE	maximum allowable exposure time, min	p_a	water vapor partial pressure, Pa
$D_{lim,tre}$	maximum allowable exposure time for heat storage, min	PHS	predicted heat strain
$D_{lim,loss,50}$	maximum allowable exposure time for water loss, mean subject, min	PMV	predicted mean vote
$D_{lim,loss,95}$	maximum allowable exposure time for water loss, 95% of the working population, min	PR	pump room
ER	engine room	R.H.	relative humidity, %
I_{cl}	basic clothing insulation, $m^2 K W^{-1}$ or clo	SW_{TOT}	water loss, g
$IREQ_{min}$	minimal required clothing insulation, $m^2 K W^{-1}$ or clo	t_a	air temperature, $^{\circ}C$
$IREQ_{neu}$	neutral required clothing insulation, $m^2 K W^{-1}$ or clo	t_r	mean radiant temperature, $^{\circ}C$
		t_{re}	rectal temperature, $^{\circ}C$
		v_a	absolute air velocity, $m s^{-1}$
		WBGT	wet bulb globe temperature, $^{\circ}C$
		$WBGT_{lim}$	limit wet bulb globe temperature value for the working situation, $^{\circ}C$

Table 1
Main duties and related responsible according to Italian Law 271/99.

Ship owner	Ship owner and captain	Captain
Safety plan editing	Limiting the number of workers onboard exposed to toxic and noxious agents and the duration of the exposure period	Immediate substitution of decaying or deteriorating equipment that could compromise the hygiene and safety of the working environment
Shipping safety plan for the competent maritime Authority	Supplying the Personal Protective Equipment (PPE) to workers and maintaining them in efficient conditions	Conservation and management of the sanitary material onboard
Integration and updating of the safety plan	Providing training and instruction of the Personnel with the help of easy-to-use operative manuals	Preparing instruction for safety procedures for the crew in a clear and comprehensible language
Appointing the Person in charge of the Service of Prevention and Protection	Granting the efficiency of the work environment and the regular maintenance of plants	Warning to the ship owner in case of inadequacies and anomalies observed onboard
Updating the risk assessment	Taking technical and organizational measures in order to contain the risks due to the use of working tools	Appointing, within the crew members, the personnel in charge of prevention measures in case of an emergency
Supply and maintenance of the health care onboard	Supplying adequate instruction of the Safety Delegate	In case of accidents or unpredictable events, he should inform the Ship Owner and the security delegate and take measures to identify and eliminate the causes of the event
Supply of adequate training of the maritime workers	Applying the procedures in the art. 33 – comma 3 in case of changes concerning the work environment conditions	
Compulsory supply of training in case of: (1) Boarding; (2) transfer or change of task; (3) new instrumentations or technologies	Appointing the Personnel in charge of the Prevention and Protection Services Appointing the Doctor	
Recurring refresher courses of training	Organizing the work onboard with the aim of reducing the stress factors to the minimum	
Holding regular meetings on prevention and protection onboard	Informing workers about risks they run while performing their tasks and training them in the use of instrumentation Informing workers on the emergency Getting the workers to respect the hygiene and safety rules Having the workers verify the application of the measures of safety and access to the related information Supplying rules, technical documentation, manuals (see art. 17, guides) (see art. 24 – comma 4) and procedures useful to development of activities in safe conditions to the crew Supplying information to the Service Prevention and Protection on: (1) risk nature; (2) work organization; (3) description of the equipment onboard; (4) data from the “Register of Accidents” Giving adequate information to the workers about: (1) risks for safety and health connected with the navigation; (2) protection measures adopted; (3) specific risks they are exposed to; (4) dangers connected with materials and preparations present onboard; (5) specialist doctor and Responsible of the Prevention Service	
	Limiting the number of workers onboard to be exposed to toxic and noxious agents and the duration of the exposure time Granting the efficiency of the work environment and the regular maintenance of equipment Making technical and organizational measures adequate to contain risk connected with the use of the work equipment Adequate training of the Representative of the Safety Editing an “Register of Accidents”	

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