International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 32, No. 1, March 2022, pp. 107–113; https://doi.org/10.17736/ijope.2022.jc836

http://www.isope.org/publications

A Mathematical Model of Lifeboat Microclimates in Polar Regions

Caitlin E. Piercey and Jonathan T. Power
Ocean, Coastal and River Engineering Research Centre, National Research Council Canada
St. John's, Newfoundland and Labrador, Canada

With marine traffic increasing in remote polar regions, more people may be at risk of abandoning ship into lifeboats. In this paper, we present a model that uses iterative calculations based on the principles of heat transfer to analyze the interior microclimate of lifeboats, including temperature and air quality. The model considers a number of factors in these scenarios, such as environmental conditions, occupant anthropometrics, lifeboat size, and the clothing worn. The results indicate that many difficult-to-predict factors that can occur during a marine accident could significantly affect the habitability of the interior environment of a lifeboat.

INTRODUCTION

In the event of a maritime accident, the order may be given to abandon the vessel and seek temporary safe refuge until rescue resources can arrive. Although it is possible to abandon ship directly into the water, the preferred method is to evacuate the vessel into a life raft or a lifeboat. Generally speaking, inflatable life rafts and rigid lifeboats are temporary shelters used during the evacuation of vessels to provide safe refuge to evacuees until help arrives. Both of these lifesaving appliances (LSA) can provide temporary safe refuge for people until rescue and are therefore incredibly important "links" in the survival chain.

Ships travelling in remote polar regions must rely on these LSA more heavily than other ships operating in areas closer to more traditional shipping lanes, as rescue assets will oftentimes take significantly longer to arrive. As a response to growing marine traffic in the polar regions, the International Maritime Organization (IMO) created the International Code for Ships Operating in Polar Waters (the Polar Code) to enhance safety for ships travelling in polar waters. The Polar Code specifies that survival crafts must offer a "habitable" environment for the survivors (IMO, 2021). Thus, in an emergency situation, one of the most important goals is to ensure an interior environment that allows occupants to remain as close to their natural homeostatic state as possible. The closer, and longer, a person can remain to a homeostatic state, the greater that person's chance of survival. An environment that shifts humans away from their homeostatic state would therefore be a threat to their survival. In a maritime survival situation, there exist issues with both air quality and temperature values inside of lifeboats and life rafts that can significantly impact survival (Solberg et al., 2016, 2017; Taber et al., 2011).

Although life rafts can be considered "weather resistant" in that they reduce the amount of water entering the craft when their hatches are closed, totally enclosed lifeboats are watertight and can prevent any ingress even when completely submerged. A consequence of this water tightness in lifeboats is that they require a way to exchange air with the external environment to ensure that carbon dioxide (CO_2) and carbon monoxide (CO) gasses remain at acceptable levels inside the craft. CO_2 is a natural by-product of human metabolism, whereas CO is a result of the incomplete combustion of hydrocarbons, which are commonly used as fuel for lifeboats. At sea level, CO_2 composes about 0.04% (400 ppm) of the air that we breathe. Given that CO_2 is 20 times more soluble in tissue fluids compared with oxygen (O_2), it has a rapid effect on both respiration and the central nervous system. Inhaling increased CO_2 concentrations can increase ventilation rate, blood pressure, heart rate, and cerebral blood flow (Scott et al., 2009). At very high concentrations, CO_2 can cause restlessness, muscle twitches, unconsciousness, and even death (Scott et al., 2009; Harper, 2011). All these conditions would be extremely detrimental to the survivability of people inside of a lifeboat while they await rescue. Therefore, it is extremely important to reduce CO_2 levels to a point where they do not interfere with normal metabolic processes, allowing the humans to remain in the much desired homeostasis.

Along with a decrease in air quality, cold temperatures can be another threat to humans who had to abandon ship into a LSA. If an individual begins to cool to the point where he or she could develop hypothermia, then the chances for survival can decrease significantly (Tikuisis, 1995). For a resting human, a deep body temperature of ~37°C is associated with being in a homeostatic state (Stocks et al., 2004). Therefore, from a survival perspective, it is imperative that whatever environment a survivor is in that he or she is allowed to remain in a state of homeostasis to increase his or her survival chances until rescue arrives. Although humans are capable of defending against mild changes in the environment to remain in homeostasis, the larger the degree of change, and the longer it is in effect, the more physiologically taxing it will be. A person may be able to endure cold temperatures (e.g., an air temperature of 5°C) inside a lifeboat for a few hours until help arrives, but longer periods of time and colder temperatures may not be defensible. Performing physical activity to increase metabolic heat production to compensate for the cold temperatures is likely not an option because of the confined nature of lifeboats. Ships operating in polar regions face the additional challenge that rescuers may take five days or more (Kennedy et al., 2013) and are therefore required to ensure that people can survive in a lifeboat for up to the same time period (IMO, 2021).

The dynamic nature of a marine accident will make it highly improbable to be able to take into account all the factors that could influence survival in polar regions. For example, although it may be possible to estimate ambient temperature conditions through a weather forecast, it can be difficult to determine whether that will be the same temperature experienced by lifeboat occupants inside the craft. If the exterior temperature is approximately −10°C, then

Received May 21, 2021; revised manuscript received by the editors August 30, 2021. The original version was submitted directly to the Journal.
KEY WORDS: Lifeboat, thermal, carbon dioxide, survival, Arctic.