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ORIGINAL ARTICLE

# Parametric analysis of a cabin fire using a zone fire model

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## KEYWORDS

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**Abstract** Fire onboard has always been considered as one of the most relevant hazards to ships. As an effect of ship fires, toxic smoke might develop and start spreading from the compartment of fire origin to other connected compartments. Such smoke can cause injuries and deaths and can impair the passengers and crew's abilities to muster and evacuate the ship on time. Fire simulation models have been developed and are continuously being refined and validated to estimate the consequences of compartment fires. The available fire models generally include the capability to evaluate fire development and smoke movement as well as the time to reach critical untenable conditions inside such compartments. The work presented in this paper shows the results of a parametric study using the latest version of one of the available fire models of the zone model type, called BRANZFIRE, in order to assess the effect of changing the size of the compartments on the time available for occupants to escape safely.

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## 1. Introduction

The majority of fatal and non-fatal casualties from fires result from exposure to toxic smoke, but there can be considerable differences between different types of fires in terms of the smoke composition and the ways in which it affects people. Passenger ship's occupants may be many hours or days from shore, so that any fire that develops rapidly and makes a

way into the accommodation spaces is likely to be lethal due to asphyxiation of occupants.

Fortunately, such occurrences are rare. But if it happened, it may result in contamination of the atmosphere of the compartment with low-concentration of toxic gases that may have to be tolerated for a number of hours. In such situations the major concerns must be initially the psychological and physiological effects on passengers and crew of exposure to an irritant and optically obscure smoke, and then the asphyxiation hazards presented by lung inflammation and gradual intoxication by asphyxiant gases such as carbon monoxide, both of which may result in long-term respiratory tract and neural damage in survivors [1].

When evaluating the consequences of heat and fire effluents to human life, the crucial criterion for life safety in fires is that, the available safe egress time to be greater than the required safe egress time. The available safe egress time is the interval between the time of ignition and the time after

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### Nomenclature

|                              |                                                    |                 |                                                         |
|------------------------------|----------------------------------------------------|-----------------|---------------------------------------------------------|
| $C_{soot}$                   | mass concentration of soot in the upper layer (kg) | ppmCO           | concentration of carbon monoxide as part per million    |
| %COHb                        | percentage concentration of carboxy-haemoglobin    | $\dot{q}_{rad}$ | incident radiation ( $W/m^2$ )                          |
| %CO <sub>2</sub>             | percentage concentration of carbon dioxide         | RMV             | volume (in litres) of air breathed per minute           |
| %O <sub>2</sub>              | percentage concentration of oxygen                 | $t$             | time step (min)                                         |
| FED                          | fractional effective dose                          | $T_u$           | upper layer temperature (K)                             |
| FED <sub>CO</sub>            | fractional effective dose for carbon monoxide      | $V$             | visibility (m)                                          |
| FED <sub>O<sub>2</sub></sub> | fractional effective dose for oxygen hypoxia       | $Y_{soot}$      | soot yield                                              |
| FED <sub>rad</sub>           | fractional effective dose for thermal radiation    | $\varepsilon_u$ | upper layer emissivity                                  |
| FED <sub>tot</sub>           | total fraction effective dose                      | $\phi$          | configuration factor between layer interface and target |
| $k_{avg}$                    | average extinction coefficient ( $m^{-1}$ )        | $\sigma$        | Stefan–Boltzmann constant ( $W/m^2 K^4$ )               |
| $k_m$                        | specific extinction coefficient ( $m^2/kg$ soot)   | $\rho_u$        | upper layer density ( $kg/m^3$ )                        |

which conditions become untenable such that occupants can no longer take effective action to accomplish their own escape.

The required safe egress time is the time required for occupants to travel from their location at the time of ignition to a place of safe refuge. As occupants are exposed to heat and fire effluents, their escape behaviour, movement speed, and choice of escape route are also affected, reducing the efficiency of their actions and delaying escape. All of these factors affect the time required for escape.

The available safe egress time depends on many characteristics of the fire, the compartment, and the occupants themselves. The nature of both the fire (e.g., HRR, quantity and types of combustibles, fuel chemistry) and the compartment (e.g., dimensions, ventilation) determines the toxic gas concentrations, the gas and surface temperatures, and the density of smoke throughout the compartment as a function of time. The characteristics of the occupants (e.g., age, state of health, location relative to the fire, activity at the time of exposure) also affect the impact of their exposure to the heat and smoke. Moreover, estimation of exposure is determined in part by assumptions regarding the position of the occupants' heads (noses) relative to the hot smoke layer that forms near ceilings and descends as the fire grows. As a result of all these factors, each occupant will likely have a different estimated available safe egress time [2].

There are different methods (e.g., computer fire modelling programs, hand calculation models), which enable estimation of the status of exposed occupants at specified time intervals throughout the development of a fire scenario, up to the time at which such exposure may prevent occupants from taking effective action to accomplish their own escape. Comparison of this time with the time required for occupants to escape safely to a place of safe refuge serves to evaluate the effectiveness of a structure's fire safety design. If such comparison reveals insufficient available safe egress time, a variety of protection strategies will then need to be considered by the designer of that structure.

There are two types of computer fire models available to the community of fire protection engineers and to the research arena, namely, zone models and field models. Among the 56 zone fire models, declared in Salem [3], there are only two models, which are commonly in use in many practical applications. This is due to their abilities to deal with multi-connected

compartments, their availability to everyone and their continuous update. These zone models are CFAST and BRANZFIRE.

A series of comprehensive comparisons between three existing zone fire models, namely CFAST, BRANZFIRE and Räume, and a benchmark field model called FDS, involving typical ship layouts, have been carried out in Salem [4]. The most important findings of these comparisons are that there is no zone fire model which is useful for all applications, and also that some of the available zone models have some deficiencies in their sub-models that make them incapable of predicting some of the important parameters identified.

The objective of the current work is to study the process of using a computer fire simulation program to evaluate the effects of changing the main dimensions of the compartments of certain design fire scenario, which is probable to take place onboard ro-ro/passenger ships, on the output parameters related to the potential fire hazard (i.e., the available safe egress time). The author selected BRANZFIRE 2012.1 [5–8], which is the latest version, to carry out this analysis. The reason for selecting BRANZFIRE is that the model has been tested by the author with another zone model against available experimental results [9]. The outcome of this test was that BRANZFIRE has showed reasonable agreement with the experimental results and it is found suitable for conducting the current study.

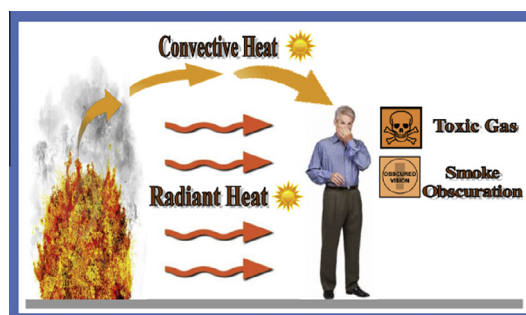


Figure 1 Different hazards of smoke and heat to occupants.

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