Performance-Based Fire Safety Design of Cold Storages

Atli Rutur Thorsteinsson & Bödvar Tomasson
EFLA consulting engineers
Hofdabakki 9, IS-110 Reykjavik Iceland.

ABSTRACT

Introduction

Cold storages can accommodate large quantities of valuable goods and high fuel loads due to densely arranged solid-pile and high-rack storage configurations. Although the probability of fire may be low in this type of occupancy, cold-storage fires may result in significant property losses. Frozen storage products in high volume spaces with limited openings to the outside result in complicated fire dynamics that is a challenging topic for the fire safety engineer in pursuing the most economic design without jeopardizing safety.

Fire load in cold storages

The fire load in cold storages can be very significant when considering the entire quantity of combustible materials within the compartment. However, studies on fires in cold storages have suggested that where frozen products are kept, a proportion of the fire load is protected and will not be involved in fire or contribute well to fire spread. [1]

The most extreme examples of this are densely arranged piles of palettes with block frozen fish, where no air gap exists between the frozen product and the packaging. In this case fire spread occurs only on the exposed surface, but does not penetrate the storage pile. The ratio of protected fire load needs to be assessed individually, depending on storage configuration, type of goods stored and so forth.

Fire dynamics in cold storages

Cold storages generally have large volumes, relatively high fuel loads and limited openings to the outside. The magnitude of a fire may therefore be limited by the lack of oxygen supply, but this can also cause unburned combustion products to accumulate in the building. This can cause increased risk, e.g. for the fire brigade when doors are opened and more oxygen is suddenly supplied to the fire.

Fire spread and fire growth are significantly dependent upon the density, heat capacity and thermal conductivity of solid fuels, as well as the ambient temperature. In cold storages, the ambient temperatures can be as low as -30 °C. Stored products such as block frozen fish, where no air gap exists between the frozen product and the packaging, a lot of energy is consumed while heating the surface of the packaging. This delays the onset of pyrolysis that finally leads to flaming combustion of the fuel. Based on this, fire growth in cold storages can be considered to be relatively slow and these special conditions can be taken into consideration in performance-based fire design.

Numerical modelling of cold storage fires

Computational Fluid Dynamics (CFD) fire models are commonly used in performance-based fire safety design of buildings. Most commonly a prescribed design fire is used, so the model is only used to determine smoke spread and temperature, but not to predict fire spread. Modelling the reaction of burning materials has two main issues, namely, lack of computing power and the accuracy and quality of the input parameters.

Figure 1 shows a model comprising of one continuous pair of palettes with frozen products, fire spread is simulated using a material reaction model, capturing the effect of highly dense frozen food products on fire spread across outer packaging. Fire simulations are carried out by implementing the CFD code Fire Dynamics Simulator

(FDS) by the National Institute of Standards and Technology (NIST). [2] The model takes into account the relevant thermal properties of the materials and other principles of fire dynamics incorporated in the combustion and fluid flow models of FDS.

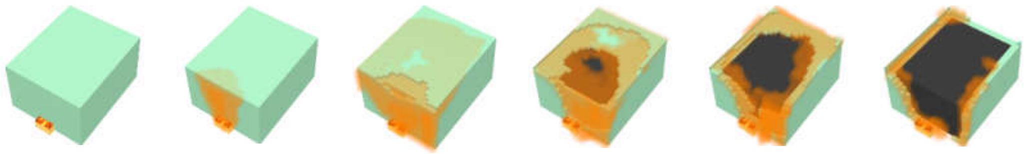

Figure 1: Simulated fire spread over a surface in a 3D fire model including a material reaction model.

Figure 2 shows a larger model of a whole storage rack unit where the information from the smaller model is incorporated as a prescribed design fire curve for each of the palettes in the storage rack. Analytical models are used to determine the critical heat flux and ignition delay times based on the material properties of the stored product, to predict fire spread between palettes. The results from the fire model are then used to determine the need for smoke ventilation, structural fire protection, fire separating requirements and other fire safety measures in the cold storage.

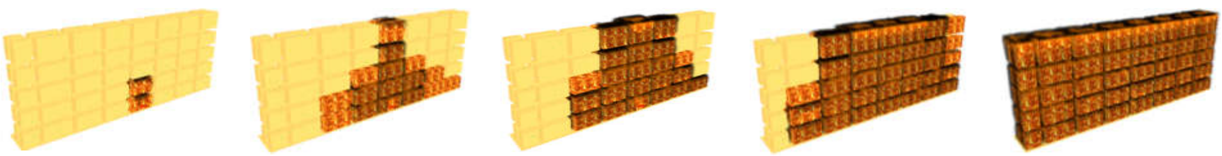

Figure 2: Simulated fire spread in one storage rack unit in a cold storage.

Design implementation

The regulatory environment in many countries now allows performance-based fire safety design of buildings. In contrast with a fire safety design based on prescriptive requirements. In this way, the designer is enabled to optimize the fire safety design for each project based on fire loads, size and type of building and other relevant parameters. Simulations and calculations can be carried out to illustrate that the design satisfies clearly defined performance requirements. If carried out according to best practice, performance-based design should give a much clearer image of the available level of safety, compared to prescriptive design.

By taking into account the special conditions in cold storage facilities described earlier, calculations can be carried out to obtain the most economic design while retaining an acceptable level of safety. This includes determining the need for structural fire protection, smoke ventilation, escape routes, fire compartments and so forth. The calculations can also be used to determine the fire resistance requirements and reaction to fire requirements for insulating sandwich panels, commonly used in cold storages. Furthermore, fire simulations can be used to decide whether to use natural smoke vents or mechanical smoke extract fans, and to determine the necessary size and capacity of the smoke ventilation. It is very important that the selection of equipment takes into account the special conditions in a cold storage environment. The performance of equipment needs to be ensured in case of fire, for example by using heated door frame elements and opening equipment for smoke vents suitable for cold storage environments.

Concluding remarks

The suggested paper will present a methodology for performance-based fire safety design of cold storages based on numerical fire models. The paper will demonstrate how fire simulations with material reaction models can be used to determine fire spread and fire growth parameters in cold storages and how fire models with prescribed design fire curves can be used to determine the need for fire safety measures.

The aim of the suggested paper is to highlight the main issues in cold storage fire safety design and to provide data, solutions and design methods that can be directly applied in the fire safety design of cold storages. This includes determining fire loads and fire growth parameters for different storage heights, storage configurations and different type of stored product. The paper will also discuss practical implementation of fire safety measures in the design of cold storages. Including the design of smoke ventilation, selection of equipment and building materials, structural fire resistance requirements, fire separating requirements and other relevant issues involved with cold storage fire safety design.

References

[1] J. H. Hunt, "Behaviour of frozen meat products in fire situations," *Int. J. Refrig.*, vol. 6, no. 1, pp. 39–42, Jan. 1983.

[2] *Fire Dynamics Simulator (FDS) Version 6. A computational fluid dynamics (CFD) model of fire-driven fluid flow*. National Institute of Standards and Technology.