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An Experimental Study on Compartment Crib Fires with Open Ventilation

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Abstract

The paper describes an experimental study on the behavior of crib fire with open ventilation conditions. An experimental setup is designed and fabricated in the fire research laboratory, IIT Roorkee to investigate and analyze the crib fire behavior in a compartment. Experiments are carried out in a compartment of the dimension of 4×4×4 and having a door of 2×1(All in meters). The parameters, including the gas temperature, mass loss rate, heat flux, flame temperature, and compartment pressure, were measured during the experiments. Based on experimental results and recognized fire theories, the effect of ventilation conditions on the burning properties of wood cribs was studied.

Keywords: Fire hazard, wood crib, compartment fire, heat flux, gas temperature, flame temperature

1. Introduction

Physical experiments are necessary to understand fire dynamics and their applications. For the last few decades' efforts have been made consistently to investigate the basic phenomena involved in fire and the possible variables to develop an engineering approach accordingly to predict the course of fire and response of fire safety measures to fire. Over the past decades, several experiments have been performed to analyze the fire dynamics of compartment fire. The fire source commonly used is wood crib due to their easy availability and low cost. Ingberg (1928) and Kawagoe (1958) performed many fire experiments in reduced and complete scale enclosures for wood crib fire, especially fuel load and fire severity. Theoretical relationships between burning rate and ventilation have also been found. He also discovered that the burning rate relies not just on the ventilation but also on a component of ventilation height. Because of various exploratory information, the absolute first theoretical model was created by Kawagoe and Sekine (1963) for post-flashover fires, which allowed the assurance of compartment gas layer temperature from the fire load and ventilation factor and thermal qualities of the compartment limits.

Wood cribs are simple structures. Their burning behavior close to the real compartment fire scenarios is often used for the heat release rate experiment for room fire tests and other experiments like to check the extinguishers' performance. (Zhang et al. , 2015) Therefore, it is mandatory to study their behavior in the compartment fires.

Internal characteristics include wood species, crib size, and layer arrangement of wood sticks, amongst many others. Gross (1962) and Block (1971) discovered that the steady burning mass-loss rates of wood cribs could be divided into two categories: porosity regulated and the surface area controlled.

Based on the results of cone calorimeter testing, Xu et al. (2008) discovered that the porosity governed the heat release rate of small-scale wood cribs.

Through a series of bench-scale studies, Hu et al. (2006) discovered that a linear growth model could characterize the development of cubic wood cribs burning.

Apart from its inherent qualities, the surrounding environment dramatically influences how wood cribs burn. Li et al. (2009) , for example, investigated the influence of height on the burning process of wood cribs and discovered that at high altitudes, the burning rate, radiation heat flow, and flame temperatures were lower than at low altitudes. Furthermore, investigations involving the wind's influence by Rios et al. (1967) on the burning properties of a wood crib in a tunnel revealed that as the wind velocity rose, the flame propagation rate, total burning rate, and depth of the burning zone increased, but the burning rate per unit area reduced.

According to the author's knowledge, a less comprehensive investigation of plyboard crib fire in a compartment with open ventilation has been done. Because cribs are the most usually encountered fuel source for fires in modern structures, ship cabins, and certain other places, the current research focuses on their burning behavior in a compartment. During the tests, various parameters such as mass loss rate, gas temperature, heat flux, wall temperature, and compartment pressure were monitored over time.

2. Experimental Layout:

The experimental compartment at the Indian Institute of Technology, Roorkee, has been built up to analyze data from large-scale fire testing. The compartment's internal dimensions are 4 × 4 × 4 (All in meters), with walls built of regular bricks with 3 cm plaster of cement and sand mortar on both sides and a roof constructed of RCC concrete 0.15 m thick. A 1 m wide and 2 m high door aperture is located in the front wall center.

Before doing the experiment, we have to fix the locations of thermocouples and heat sensors means how they are installed and at what positions they are installed because according to this, we

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can understand the condition of the compartment. In the current experiments performed, the wood crib has been used as a fire source with open ventilation conditions. The wood crib is made up of wood sticks of length 50 cm and a square cross-section of size 5 cm. 7 sticks were used in a layer in a total of 7 layers in the compartment for the testing.

2.1 Thermocouples:

64 thermocouples are installed on ceiling. 18 above flame. 20 left corner wall and 9 in doorway.

2.2 Heat sensors:

There are 4 sensors on floor, 5 on ceiling, 4 on east wall and 2 each on west, south and north wall.

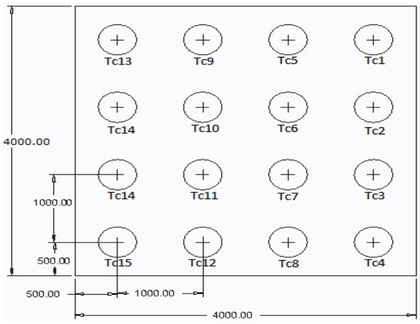

Figure 2.1 Ceiling thermocouples

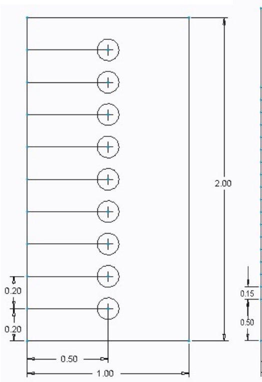

Figure 2.2 Doorway thermocouple

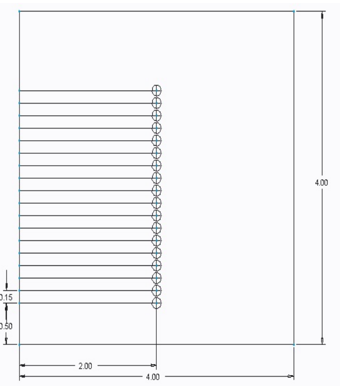

Figure 2.3 Flame thermocouples

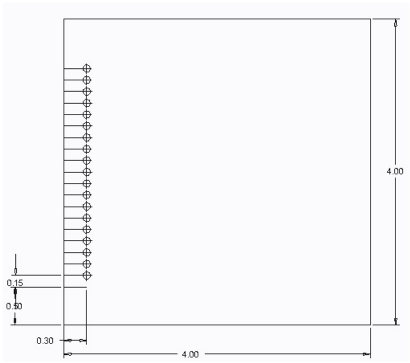

Figure 2.4 Wall corner thermocouples

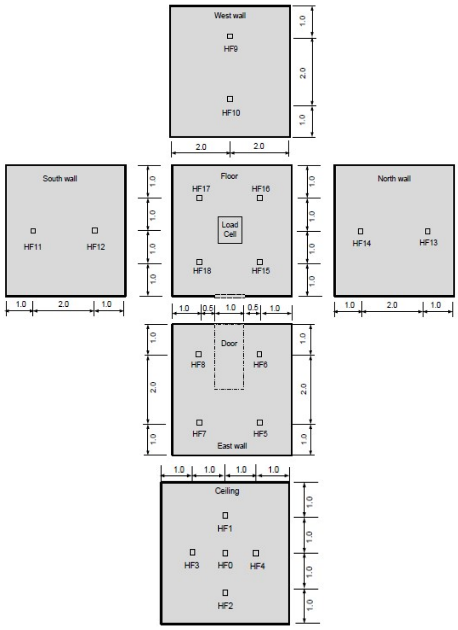

Figure 2.5 Heat flux sensors locations

2.3 Velocity probes:

There are 7 velocity probes are used just above the flame front and 6 velocity probes are used in doorway to find pressure difference of air between inside and outside of compartment.

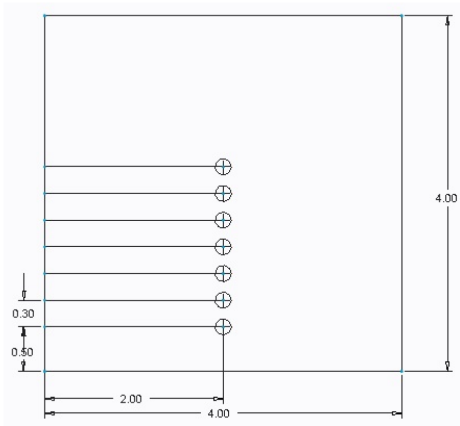

Figure 2.6 Flame velocity probe

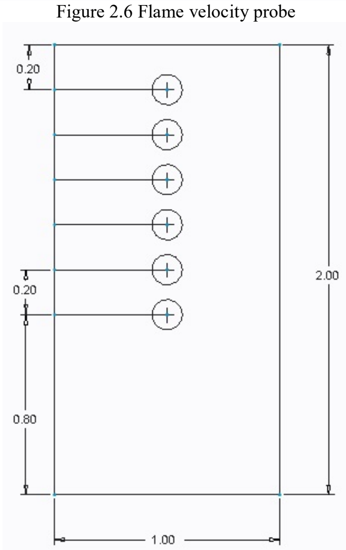

Figure 2.7 Doorway velocity probe

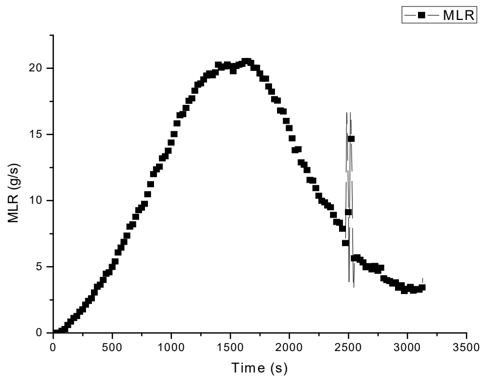

Figure 3.1 Mass loss rate in test

3. Results and discussion

3.1 Mass loss rate:

Mass loss rate is the rate at which mass of wood crib is decreasing or we can say mass of crib burning in the process of sustaining the fire. From the figure we can also see that at around 1500 seconds, the maximum MLR is observed. It is also considered in further experiments to include the mass loss rate with different ventilation condition.

3.2 Gas concentration:

From the figure 5, the variation in concentration of O_2, CO_2, and CO is observed. From figure we can see when the door is fully open the concentration of O_2 decreases very rapidly and early goes to minimum point and then increases. On the other hand concentration of CO_2 also increases then goes to maximum and then falls downwards.

3.3 Heat release rate:

As it can be seen from the figure 3.3, the heat release rate is decreasing as the ventilation area is becoming small this is due to shortage of oxygen in the compartment environment.

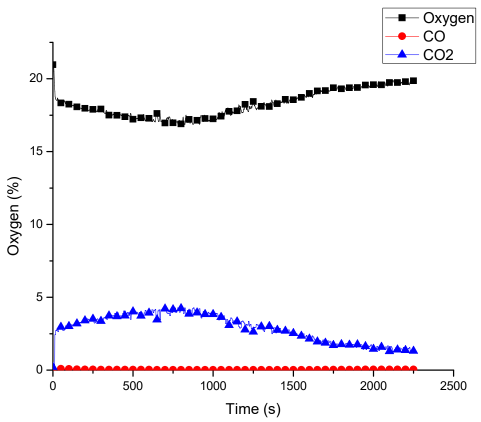

Figure 3.2 Concentration of O_2, CO_2, CO in upper layer of compartment

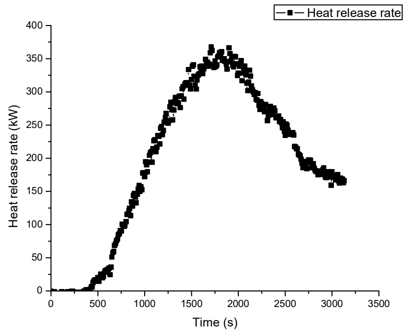

Figure 3.3 Heat release rate with time

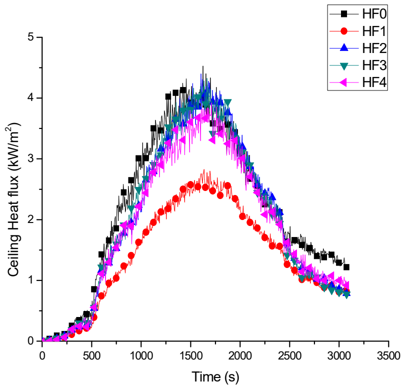

Figure 3.4 Ceiling heat flux

3.4 Heat flux:

3.4.1 Ceiling heat flux

From the figure it can be seen that the maximum ceiling heat flux goes up to the value of 4.5 kW/m^2 for HF2.

3.4.2 Floor heat flux

It is observed that maximum heat flux value in the floor is 4.1 kW/m^2 for HF18.

3.4.3 Upper hot layer heat flux:

From the figure 3.6, it is found out that HF9 has the maximum heat flux value with 24.4 kW/m^2.

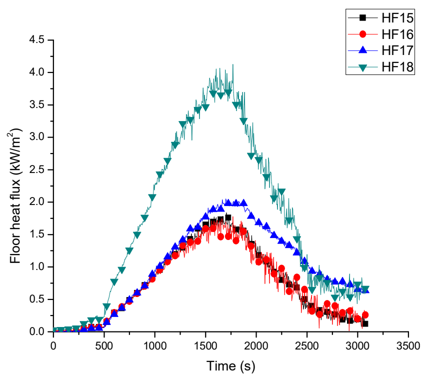

Figure 3.5 Floor heat flux variation

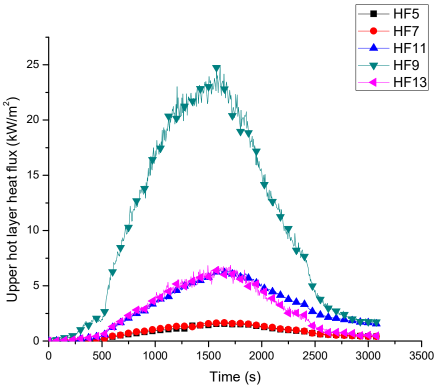

Figure 3.6 Upper hot heat flux variation

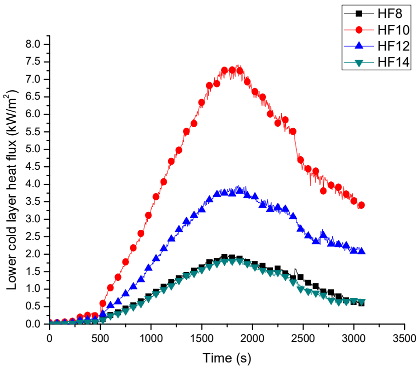

Figure 3.7 Lower hot heat flux variation

3.4.4 Lower cold layer heat flux

This can be seen in the figure that the maximum value for the lower cold heat flux is 7.45 kW/m^2 for HF10.

3.5 Flame temperature:

At time 2360 seconds the maximum flame temperature is noticed.

3.6 Ceiling temperature:

Ceiling temperature has been characterized in 4 groups according to the distance of thermocouples from ceiling as layer 1, layer 2, layer 3 and layer 4.

3.6.1 Ceiling temperature 1

Layer 1 thermocouples are installed on false ceiling which is 0.075 cm below the ceiling.

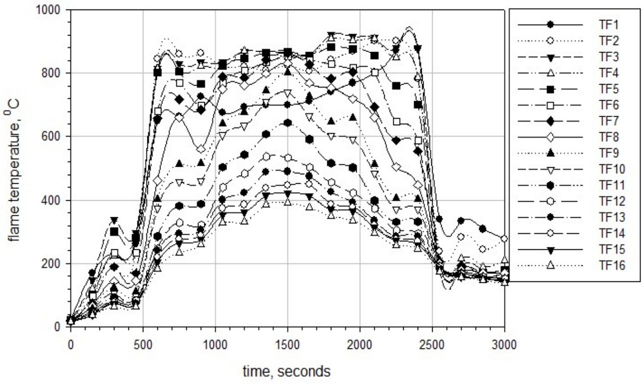

Figure 3.8 Flame temperature variation

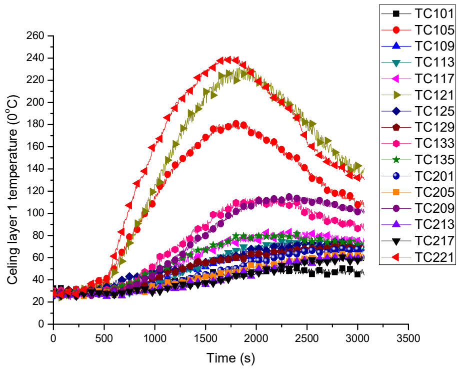

Figure 3.9 variation in layer 1 ceiling temperature (0.075 m from ceiling)

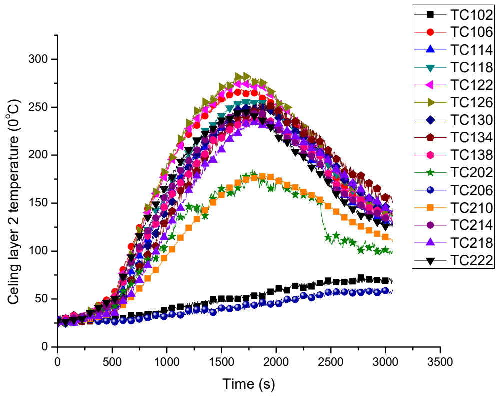

Figure 3.10 Temperature variation in layer 2 of ceiling

3.6.2 Ceiling temperature 2

Layer 2 thermocouples are installed on false ceiling which is 15 cm below the ceiling.

3.6.3 Ceiling temperature 3

Layer 3 thermocouples are installed 0.5 m below false ceiling means 0.65 m from ceiling.

3.6.4 Ceiling temperature 4

Layer 4 thermocouples are installed 1 m below the false ceiling and 1.15 m from ceiling.

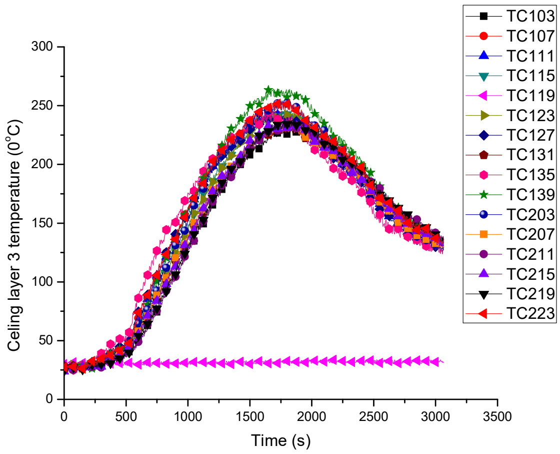

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Figure 3.11 Temperature variation in layer 3 of ceiling

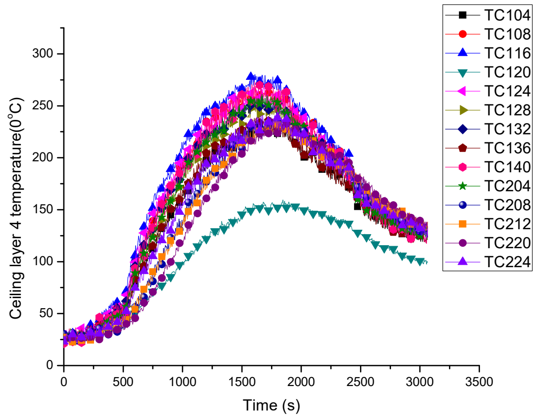

Figure 3.12 Temperature variation in layer 4 of ceiling

4. Conclusions

The wood crib experiments are done for the open ventilation condition in the compartment to study the influence on mass loss rate, gas concentration, and flame temperature. The results from the study can be summarized as follows:

1. Mass loss rate has been dramatically affected due to the open ventilation by the door. The maximum value of mass loss rate is less affected, but the rise duration has been significantly affected.
2. The ventilation affects the combustion of the crib, and the temperature of the hot gas layer decreases, which results in the formation of two zones.
3. Ventilation also has an impact on the heat flux intensity and distribution. As the ventilation decreases, the heat flux of the ceiling, floor, and upper zone of the wall have invariably decreased, but the heat flux in the lower zone increases.
4. The thermal layer height plays an essential role in the distribution of heat flux in a compartment being ventilated variably.

This research helps to better understand compartment fire behavior under various ventilation circumstances. Meanwhile, the findings may be valuable for fire prevention engineering, such as automatic fire monitoring and extinguishing systems in buildings with various ventilations.

Disclosures

Free Access to this article is sponsored by SARL ALPHA CRISTO INDUSTRIAL.

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