CONDITIONS PERMITTING THE TRANSPORT OF HIGH CONCENTRATIONS OF CARBON MONOXIDE IN BUILDING FIRES

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INTRODUCTION

The percentage of deaths due to smoke inhalation (mainly from carbon monoxide poisoning) has risen 1% ever year since 1980, and was responsible for 76% of the deaths in 1990.[1] Two-thirds of the smoke inhalation victims in building fires are found at locations distant from the burning room.[2] The research over the past year at VPI & SU has focused on determining the phenomena responsible for the transport of high levels of CO in building fires, specifically, investigating the transport of these toxic gases away from a room on the side of a hallway.

EXPERIMENTAL METHODS

Experiments were performed with a 1.52 m wide, 1.22 m deep, 1.22 m high compartment connected to the side end of a 1.22 m wide, 1.67 m high, 5.18 m long hallway, forming a L-shape.[3] Air is naturally drawn into the compartment through a plenum below the burn room, while combustion gases exit the compartment through a variable size opening. The experiments reported utilized opening sizes of 0.12 m^2 (0.50 m wide, 0.24 m high) and 0.04 m^2 (0.25 m wide, 0.16 m high). A 0.20 m inlet soffit was present above the opening. The soffit at the open end of the hallway, termed an exit soffit, (5.18 m downstream of the compartment) where the fume hood collects combustion gases was varied in height from 0.0 to 0.80 m in 0.10 m increments. The exit soffit height governed the depth of the upper-layer in the hallway; except for cases where the exit soffit height was less than 0.20 m where the upper-layer height was determined to be approximately 0.20 m from temperature profiles.

RESULTS AND DISCUSSION

In building fires, a deep upper-layer of combustion gases forms in the space adjacent to the burning room during the pre-flashover period of the fire. At the onset of flashover, high levels of CO and other incomplete combustion products begin issuing into the adjacent space from the room. The depth of the oxygen deficient combustion gas layer within the hallway plays an integral role on the degree to which the products of incomplete combustion get oxidized. The effect of varying the depth of the oxygen deficient upper-layer in the hallway on the downstream species yields was investigated. The evolution of species concentrations in the hallway with a deep upper-layer, 0.60 m, was also studied.

The species yields, which were calculated from measurements performed downstream of the hallway, were plotted against a nondimensional upper-layer depth ($\gamma=\delta/z$), defined as the hallway upper-layer depth, δ, divided by the distance between the bottom of the opening and the ceiling, z (0.44 m with a 0.12 m^2 opening and 0.36 m with a 0.04 m^2 opening). The nondimensional upper-layer depth physically represents the degree to which the plume of compartment fire gases entering the hallway is surrounded by oxygen deficient combustion gases.

In experiments with a 0.12 m^2 opening, the increase in the upper-layer depth resulted in a gradual increase in the CO and UHC downstream yields and a decrease in the CO_2 yields, see Fig. 1. With an upper-layer depth of $1.4 < \gamma < 1.7$, the CO yields downstream were measured to be 0.27, on average, which is 23% higher than levels measured inside the compartment (0.22) by Gottuk.[4] The increase in CO is attributed to the oxidation of UHC to levels 27% lower than in-compartment yields (0.33). The limited radical pool generated in the oxygen deficient environment surrounding the jet of hot compartment fire gases entering the hallway was utilized to oxidize the UHC. Before the UHC were reduced to levels where the CO oxidation reactions were competitive, the gas temperature fell below 850 K and inhibited the occurrence of measurable CO oxidation . At a $\gamma \geq 1.7$, the oxygen deficient upper-layer had increased to a depth where the ignition of the gases was not possible, and thus prevented external burning.

The presence of 0.04 m^2 opening increased the entrainment into the plume of gases entering the hallway by approximately 25%. The increase in entrainment prevented the CO and UHC yields from rising until approximately a $\gamma > 1.4$, see Fig. 2. The higher entrainment caused CO yields to remain less than in-compartment yields with $\gamma < 1.7$. Again with a $\gamma \geq 1.7$, the oxygen deficient upper-layer in the hallway inhibited the occurrence of external burning in the hallway.

A series of 25 experiments was also conducted to map the temporal and spatial variation in species concentrations and temperatures in the upper-layer of the hallway and compartment 0.05 m below the ceiling. Experiments utilized a 0.12 m^2 opening and a 0.60 m exit soffit ($\gamma = 1.4$); a situation where downstream yields were measured to be higher than in-compartment yields. With the burning room on the side of the hallway, toxic levels of CO (>2.1%-wet) were measured to be transported non-uniformly within the hallway. Gases containing high levels of CO were measured crossing the hallway and then traveling down the hallway on the side opposite the compartment. External burning in the hallway increased the CO levels to 2.6%-wet with a corresponding decrease in UHC to 1.0%-wet.

CONCLUSIONS

The depth of the oxygen deficient upper-layer in the hallway determines the degree to which CO and other incomplete combustion products are oxidized within the hallway. Results also show that external burning in the hallway can lead to CO yields greater than yields measured inside the compartment. Finally, a non-uniform transport of these toxic gases was measured to be present when the burning compartment was located on the side of the hallway.

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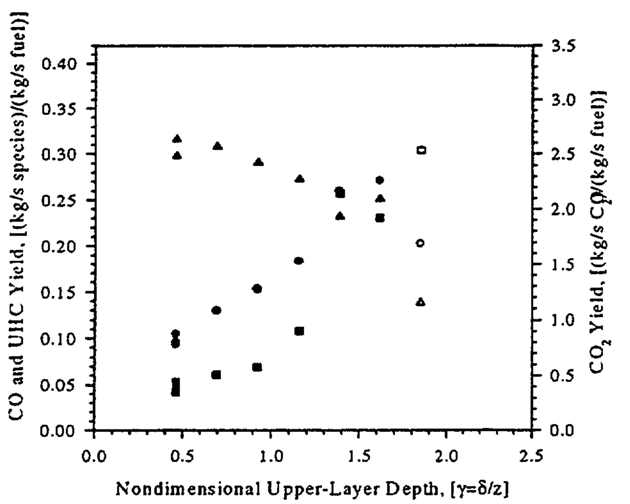

Fig. 1 Experiments with a 0.12 m^2 opening. ●-CO, ■-UHC, and ▲-CO_2. Filled symbols were experiments with external burning.

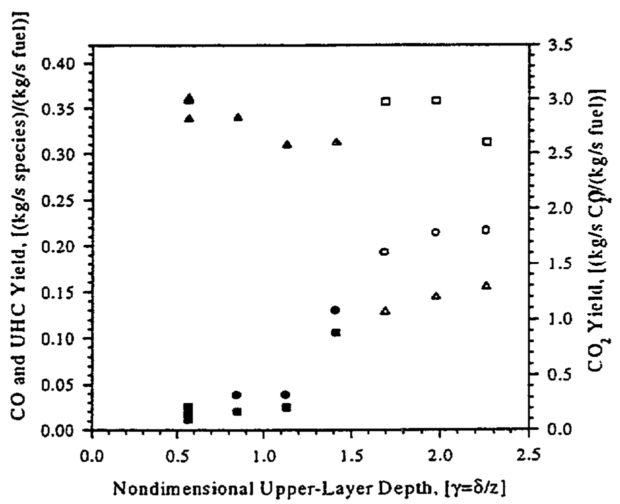

Fig. 2 Experiments with a 0.04 m^2 opening. ●-CO, ■-UHC, and ▲-CO_2. Filled symbols were experiments with external burning.