NISTIR 6242

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Book of Abstracts

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Kellie Ann Beall, Editor

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Species Formation using Liquid *n*-hexane Fires in a Scaled ISO Compartment

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Fires occurring in occupancies such as hospitals, dormitories, and nursing homes pose a serious treat to occupants. Poisoning due to carbon monoxide inhalation affects not only the occupants in the room of origin but also those located at remote locations from the fire.[1] The objectives of the present study is the development of correlations for CO formation and transport in compartment-hallway assemblies. The first step, present here, addresses the compartment.

Initial studies[2,3,4] of CO formation were conducted in the open under a collection hood. Data from these studies indicated that the CO yields could be correlated to the equivalence ratio, however the studies also indicated that the CO levels were dependent on the upper layer gas temperatures. Studies to determine if similar correlations between the CO levels and the global equivalence ratio (GER) could be made within a compartment were conducted by Tewarson[5] and Gottuk[6]. Tewarson assumed that the mass flow rate of air into the compartment through the widow openings was ventilation limit. Gottuk performed his studies with an experimental apparatus which allowed the direct measurement and calculation of the mass flow rates of air and fuel and therefore the direct calculation of the GER. Gottuk showed that the CO levels within the experimental apparatus could be well correlated to the GER.

More recently, studies have been conducted within scaled ISO compartments. Bryner et al.[7] conducted tests using natural gas, supplied from a burner placed in the center of the compartment. Bryner et al. stipulated that the concentrations within the compartment could not be correlated to a single GER, instead local GER's would be required, since the measured species concentrations were non-uniform between the front and the rear of the compartment. Bryner et al. attributed the non-uniformity of the concentrations within the compartment to the presence of a door, which was not present in the previous studies of Tewarson and Gottuk. Also, the compartment clearly presented a different reactor geometry than in the hood experiments.

Tests were conducted in a ½-scaled ISO compartment using *n*-hexane pool fires placed at the center of the compartment, Figure 1. Fully and partially opened door fire scenarios were simulated by varying the door width between 0.165m and 0.33m. A gas sampling probe was located 0.10m down from the compartment ceiling and 0.10m back from the front of the compartment. The concentrations of produced species, CO, CO_2, and UHC, measured as equivalent ethylene (C_2H_4), were measured along with the concentration of O_2.

The mass flow rates through the door were calculated using the temperature profile method discussed by Janssen and Tran.[8] The temperature profiles were determined by using two aspirated type K thermocouple rakes, each containing 8 thermocouples evenly spaced 0.10m apart. The rakes were located in the doorway and front left corner of the compartment as shown in Figure 1.

The experimental parameters examined in this investigation were the fire size and door width, while the analyzed parameters were the species concentrations, species yields and the GER. The GER for the compartment was varied by using different size hexane pools and by changing the door width. In addition to having an effect on the GER, the narrow door increases the residence time of the gases within the compartment.

The following results represent a total of 24 tests of which 11 were performed with the baseline door width (0.33m) and 13 were performed with the narrow door width (0.165m). The GER varied between 0.2 and 3.7. The concentrations and species yields shown represent an average over the quasi-steady-state periods of the developed fire. The criterion for quasi-steady burning was a constant GER.

The GER is a function of the mass flow rates into and out of the compartment. Since there is no direct method for measuring the flow rates with the compartment, it is necessary to determine if the calculated GER's were accurate. In previous studies[2,6,7] it was shown that at a GER of 1.0 the oxygen concentration was approximately zero. The oxygen concentration shown in Figure 2 does in fact decrease to approximately zero at an equivalence ratio of 1.0. This indicates that the calculated GER is valid, therefore the method of Janssen and Tran[8] for determining the mass flow rates into and out of the compartment is also valid for this configuration.

The CO yields are shown in Figure 3 compared to those of Beyler and Gottuk. A larger degree of scatter is seen in the current data for equivalence ratios between 1.0 and 2.0, however the data tends to plateau to a level

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slightly less than that of Gottuk, for GER's greater than 1.5. The yields of other species, CO_2, O_2, and UHC also compare well with previous data and can be correlated to the GER (not shown here).

The data combines results for both door geometries, no measurable impact on the species levels was seen between the results. The difference between the two geometries is in the rate of air entrainment resulting in different global residence times within the compartment. The residence time within the compartment for the baseline door was calculated to be on average 9.3 seconds, while for the narrow door the residence time of the gases was on average 19.5 seconds. For both instances the compartment fires are oxygen limited at equivalence ratios greater than 1.0. With the narrow door no further impact on the species levels is observed because there is no additional oxygen present in the system to react with either the unburned hydrocarbons or the carbon monoxide, hence the longer residence time has no additional effect.

The objective of this study was to determine if the species levels within a compartment with a doorway could be correlated to the global equivalence ratio. The current findings have shown that the combustion products and reactants correlated well over a wide range of equivalence ratios, 0.21 to 3.7. The data included two door scenarios, fully and partially open, simulated by varying the door width. The correlations applied equally for both cases, implying that in both the reactions progress is limited by the available oxygen and not the residence time. The species yields reported here are those exiting the compartment. The development of correlations for the evolution of these fire product gases in adjacent spaces, e.g. a hallway, is the subject of the continuation of the study reported herein.

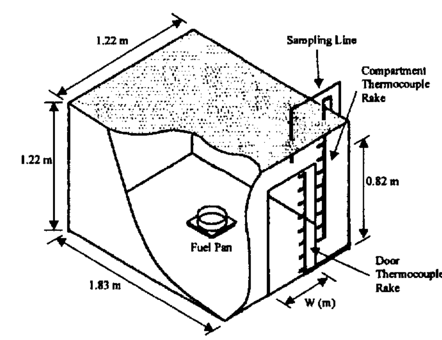

Figure 1: ½-scaled ISO 9705 compartment with instrumentation.

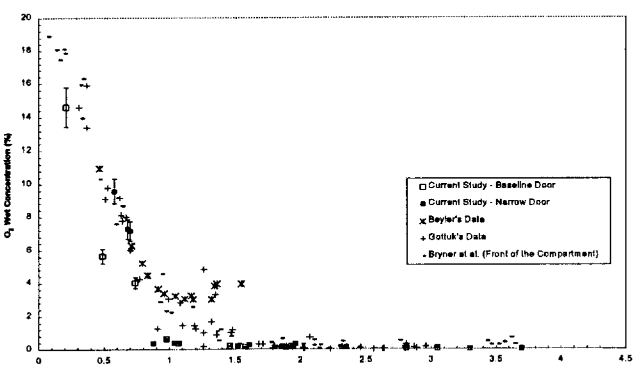

Figure 2: Wet concentration of O_2 within the compartment exhaust plume compared with Beyler, Gottuk and Bryner.

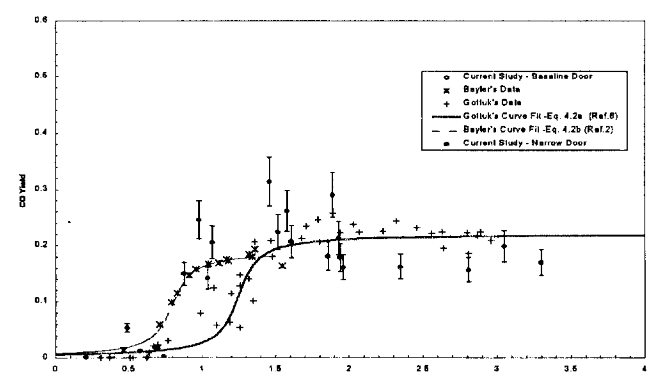

Figure 3: Yields of CO as a function of the global equivalence ratio compared with data from Beyler and Gottuk and the curve fits to the data.

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