EXECUTIVE SUMMARY

Under the United States Department of Homeland Security (DHS) Assistance to Firefighter Grant Program, Underwriters Laboratories examined fire service ventilation practices as well as the impact of changes in modern house geometries. There has been a steady change in the residential fire environment over the past several decades. These changes include larger homes, more open floor plans and volumes and increased synthetic fuel loads. This series of experiments examine this change in fire behavior and the impact on firefighter ventilation tactics. This fire research project developed the empirical data that is needed to quantify the fire behavior associated with these scenarios and result in immediately developing the necessary firefighting ventilation practices to reduce firefighter death and injury.

Two houses were constructed in the large fire facility of Underwriters Laboratories in Northbrook, IL. The first of two houses constructed was a one-story, 1200 ft^2, 3 bedroom, 1 bathroom house with 8 total rooms. The second house was a two-story 3200 ft^2, 4 bedroom, 2.5 bathroom house with 12 total rooms. The second house featured a modern open floor plan, two-story great room and open foyer. Fifteen experiments were conducted varying the ventilation locations and the number of ventilation openings. Ventilation scenarios included ventilating the front door only, opening the front door and a window near and remote from the seat of the fire, opening a window only and ventilating a higher opening in the two-story house. One scenario in each house was conducted in triplicate to examine repeatability.

The results of these experiments provide knowledge for the fire service for them to examine their thought processes, standard operating procedures and training content. Several tactical considerations were developed utilizing the data from the experiments to provide specific examples of changes that can be adopted based on a departments current strategies and tactics.

The tactical considerations addressed include:

- **Stages of fire development**: The stages of fire development change when a fire becomes ventilation limited. It is common with today's fire environment to have a decay period prior to flashover which emphasizes the importance of ventilation.

- **Forcing the front door is ventilation**: Forcing entry has to be thought of as ventilation as well. While forcing entry is necessary to fight the fire it must also trigger the thought that air is being fed to the fire and the clock is ticking before either the fire gets extinguished or it grows until an untenable condition exists jeopardizing the safety of everyone in the structure.

- **No smoke showing:** A common event during the experiments was that once the fire became ventilation limited the smoke being forced out of the gaps of the houses greatly diminished or stopped all together. No some showing during size-up should increase awareness of the potential conditions inside.

- **Coordination:** If you add air to the fire and don't apply water in the appropriate time frame the fire gets larger and safety decreases. Examining the times to untenability gives the best case scenario of how coordinated the attack needs to be. Taking the average time for every experiment from the time of ventilation to the time of the onset of firefighter untenability

conditions yields 100 seconds for the one-story house and 200 seconds for the two-story house. In many of the experiments from the onset of firefighter untenability until flashover was less than 10 seconds. These times should be treated as being very conservative. If a vent location already exists because the homeowner left a window or door open then the fire is going to respond faster to additional ventilation opening because the temperatures in the house are going to be higher. Coordination of fire attack crew is essential for a positive outcome in today's fire environment.

- **Smoke tunneling and rapid air movement through the front door:** Once the front door is opened attention should be given to the flow through the front door. A rapid in rush of air or a tunneling effect could indicate a ventilation limited fire.

- **Vent Enter Search (VES):** During a VES operation, primary importance should be given to closing the door to the room. This eliminates the impact of the open vent and increases tenability for potential occupants and firefighters while the smoke ventilates from the now isolated room.

- **Flow paths:** Every new ventilation opening provides a new flow path to the fire and vice versa. This could create very dangerous conditions when there is a ventilation limited fire.

- **Can you vent enough?:** In the experiments where multiple ventilation locations were made it was not possible to create fuel limited fires. The fire responded to all the additional air provided. That means that even with a ventilation location open the fire is still ventilation limited and will respond just as fast or faster to any additional air. It is more likely that the fire will respond faster because the already open ventilation location is allowing the fire to maintain a higher temperature than if everything was closed. In these cases rapid fire progression if highly probable and coordination of fire attack with ventilation is paramount.

- **Impact of shut door on occupant tenability and firefighter tenability:** Conditions in every experiment for the closed bedroom remained tenable for temperature and oxygen concentration thresholds. This means that the act of closing a door between the occupant and the fire or a firefighter and the fire can increase the chance of survivability. During firefighter operations if a firefighter is searching ahead of a hoseline or becomes separated from his crew and conditions deteriorate then a good choice of actions would be to get in a room with a closed door until the fire is knocked down or escape out of the room's window with more time provided by the closed door.

- **Potential impact of open vent already on flashover time:** All of these experiments were designed to examine the first ventilation actions by an arriving crew when there are no ventilation openings. It is possible that the fire will fail a window prior to fire department arrival or that a door or window was left open by the occupant while exiting. It is important to understand that an already open ventilation location is providing air to the fire, allowing it to sustain or grow.

- **Pushing fire:** There were no temperature spikes in any of the rooms, especially the rooms adjacent to the fire room when water was applied from the outside. It appears that in most cases the fire was slowed down by the water application and that external water application

had no negative impacts to occupant survivability. While the fog stream "pushed" steam along the flow path there was no fire "pushed".

- **No damage to surrounding rooms:** Just as the fire triangle depicts, fire needs oxygen to burn. A condition that existed in every experiment was that the fire (living room or family room) grew until oxygen was reduced below levels to sustain it. This means that it decreased the oxygen in the entire house by lowering the oxygen in surrounding rooms and the more remote bedrooms until combustion was not possible. In most cases surrounding rooms such as the dining room and kitchen had no fire in them even when the fire room was fully involved in flames and was ventilating out of the structure.