10. Summary of Findings:

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. UL conducted a series of 15 full-scale residential structure fires to examine this change in fire behavior and the impact of 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.

The increased use of synthetic materials in the home has created faster flashover times. The two experiments demonstrated flashover times of less than 4 minutes with modern furnishings as compared to more than 29 minutes with legacy furnishings. This difference has a substantial impact on occupant and firefighter safety.

Tenability in these two homes was limited for occupants but the possibility of savable lives, especially behind closed doors should be considered by the fire service in their risk analysis. Also, emphasis should be placed on closing doors when the fire service is educating the public. Tenability for firefighters can also be quantified for these experiments. Firefighters had 100 seconds in the one-story house and 200 seconds in the two-story house after ventilation before water would have to be applied to remove the hazard or the firefighter would have to exit the house. These numbers should be considered conservative as the fire were allowed to become ventilation limited and decrease to a low temperature without becoming extinguished.

A significant portion of the 100 second and 200 second time to firefighter untenability is fresh air being entrained into the ventilation limited fire. In many of the experiments the time from the beginning of temperature escalation until untenability was less than 10 seconds. This provides little warning that the fire is going to flashover and highlights the need to understand that ventilation opening are not only allowing hot gases to escape but fresh air to enter.

Several ventilation comparisons could be made from the experimental series. First, the more ventilation openings that were made the faster the fire room transitioned to flashover. This shows that even in these modestly furnished homes fuel is not the limiting factor and that more air will create more burning and less tenability. Ventilating near the seat of the fire localized the combustion and temperatures within the house. Ventilating remote from the seat of the fire created a flow path which expanded the area available to burn and further decreased tenability within the homes. Allowing air into a ventilation limited fire low and letting the hot gases out high can create prime conditions for a flashover, even in a large volume like the two-story family room. More efficient ventilation can mean more efficient air entrainment which can lead to faster flashover times if water is not applied in the shorter tenability window.

Several tactical considerations were able to be developed with the assistance of the technical panel of fire service leaders. In summary, 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 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. 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 smoke showing during size-up should increase awareness of the potential conditions inside. 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.

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. 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. 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.

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. 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.

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.

This research study developed empirical fire experiment data to demonstrate fire behavior resulting from varied ignition locations and ventilation opening locations in legacy residential structures compared to modern residential structures. The data will be used to provide education and guidance to the fire service in proper use of ventilation as a firefighting tactic that will result in mitigation of the firefighter injury and death risk associated with improper use of ventilation.