

WORKPLACE SOLUTIONS

From the National Institute for Occupational Safety and Health

Preventing Deaths and Injuries of Fire Fighters Working at Basement and Other Below-Grade Fires

Summary

Fire fighters are at significant risk of injury or death when fighting fires in basements or floors below-grade level. The increased risk is due to limited entry and egress; working above the fire; weakened floor structures; being caught in the fire's flow path; unknown fire load; ventilation issues; utility panels, hanging wires, meters, and connections; and appliances. These risks can lead to fire fighter entrapment from floor collapse, burns, and asphyxiation. Fire departments should conduct a complete 360-degree size-up to locate the fire, attack the fire externally, and reassess fire conditions prior to conducting interior operations.

Description of Risk

Fire in a building level that is either partially or completely below the ground presents problems for the fire fighter. Whether classified as a basement or other below-grade area (such as a cellar or a multi-level structure built on sloping ground with a single visible point of entry at street level), access to a fire below-grade may require a descent.

In many cases, access to a basement or other below-grade area is limited to a single interior stairway. A fire below-grade will create a chimney effect when the door to the stairway is opened, resulting in a rapidly expanding rush of fire from below. Fire fighters attempting to descend the stairway will be caught in the fire's flow path and confronted with rising heat, fire, and smoke. Conditions may immediately become untenable, and access to the basement will be lost, potentially trapping and/or injuring fire fighters below-grade, on the stairway, or at the top of the stairs. An interior stairway may also spread fire through the structure, endangering fire fighters.

Fire fighters should not attempt to reach a basement fire by an interior stairway. Instead, they should work to extinguish it through an exterior doorway, window, or other penetration points, and then reassess interior conditions.

Indicators of a Basement Fire

Initial indicators can often be observed from the exterior of the structure during a 360-degree size-up that locates and assesses the fire. During recent

basement fire experiments conducted by NIST and UL, smoke was observed coming out of the eaves in buildings that were not balloon-frame construction. Researchers suspect this was due to the presence of unprotected vertical penetrations, pipe chases, and holes for cable, phone, internet, and vent pipes. These openings will allow smoke and heat to move vertically in a structure. Internal indicators of a below-grade fire include the presence of modest heat and dense smoke at the ground or first floor level, and the absence of visible fire. Smoke rising from baseboards and floor vents on the lower floors and banking down on the top floor may also indicate a below-grade fire.

A thermal imager should be used during the initial size-up, but fire fighters must be properly trained on its use and limitations. Test fires have determined that thermal imagers may not detect a basement fire when scanning the ground level floor. This is because the wood flooring, along with carpet and laminate floor covering, tend to insulate and prevent heat transfer. Since the ignition time of a fire is unknown to the responding fire fighters, the extent of structural fire damage is often unknown,



Centers for Disease Control
and Prevention
National Institute for Occupational
Safety and Health

and thermal imagers cannot provide a reliable indicator of a structural hazard [NIST 2011].

Fire fighters should always remember to check a structure for a basement or other below-grade area even if the fire appears to be on the ground or higher level.

Firefighting strategy and tactics for basement and other below-grade fires

Basement fires are one of the most challenging situations fire fighters encounter. As with all fires, a risk assessment and an occupant survivability profile should be conducted to evaluate what is at risk—lives or property. Current research strongly suggests that before entering the structure, fire attack should be started as soon as possible from exterior positions, applying water directly on the fire through an exterior doorway or window, or by penetrations through the basement wall using a penetrating nozzle.

If exterior approaches are not possible, fire suppression should be attempted by making penetrations in the floor above the basement using a distributor nozzle to knock down the fire. The choice to operate above the fire places fire fighters at a higher risk of injury or death from structural collapse, and therefore, should be considered a last choice in the selection of tactics. Fire fighters should initially insert these devices from a safe position (i.e. just inside the entry door). Additional penetrations can be made in the floor to move further into the structure if warranted. However, structural stability must be assessed before fire fighters proceed out over a floor above a fire. Caution should be taken at all times to not place the fire fighter in that position. The structure should be evacuated immediately if structural compromise is suspected.

These approaches have demonstrated a faster drop in temperatures within the fire compartment compared with advancing a hoseline inside the basement to the seat of a fire. These approaches also help slow structural compromise in the fire compartment, creating safer conditions for fire fighters, [UL 2013].

This rapid lowering of temperatures in the below-grade fire compartment is critical from a life safety perspective where controlling and knocking down a fire is of utmost importance. Fire fighters must be aware that an active and growing fire in a below-grade compartment is not likely to allow for occupant survival, particularly where the only exit is up a stairway. However, survival might be possible with the application of water into the below grade compartment from the exterior because of the rapid cooling, making search and rescue activities feasible.

If a decision is made that it is necessary to enter the basement or below-grade area for fire attack or search/rescue, an

interior fire attack strategy with properly coordinated ventilation is necessary to ensure fire fighter safety. In many cases, the preferred method of attacking this type of fire is from the same level. An example would be using an exterior access point such as a walk-out doorway or window. While this fire attack method provides quick access, fire fighters should always use caution. Any active fire will have damaged the structural integrity of the floor system above them, creating a collapse risk.

Basements are known for very limited ventilation possibilities. In the absence of built-in basement vents, such as exterior doors or windows, heat and smoke from basement fires can quickly spread upward throughout the building. This is especially true in balloon-frame construction and structures without vertical fire stops between floors. Modern construction also contains many vertical penetrations. Exposed and unprotected construction features below and through floors (such as laundry chutes, stud channels, and duct work) may contribute to rapid fire, heat, and smoke spread, increasing collapse potential.

If a ventilation opening is made in an area away from where the fire fighters entered, smoke and heat may be pulled away from the attack crew towards the ventilation opening. This will allow the crew to better attack the fire. However, a back-up hose line should be in place to protect the attack crew [IFSTA 2013].

Case Study

On June 2, 2011, a 48-year-old male career lieutenant and a 53-year-old male fire fighter/paramedic died in a multi-level residential structure fire while searching for the seat of the fire. The structure was built on a steeply sloped hillside. The fire floor was one floor below street level.

The lieutenant and a fire fighter/paramedic on the first-arriving crew, Engine 26 (E-26), noticed light smoke as they advanced a hose line through the street-level front door on Side A. Minutes later, the incident commander (IC) tried contacting them over the radio but received no response. A battalion chief (BC) assigned to the fire attack group followed the hose line through the door and spoke to the E-26 crew near the stairway to the below-grade main living areas. The lieutenant told the BC that the fire must be a floor below them. The BC stated the fire would be attacked from the structure's Side B and exited the front door. The E-26 crew did not follow.

A few minutes later, the IC again tried to contact the E-26 crew via radio with no response. The BC went to the Side B door (located on the outside, one floor below street level) and forced the door with another hose line crew, Engine 11 (E-11). The E-11 crew immediately felt a blast of heat from

the fully involved basement area and proceeded to knock down the fire (Figures 1 and 2).

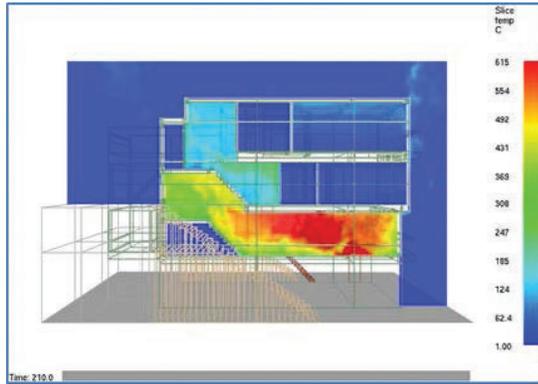


Figure 1. Image from computerized fire model showing flow path and conditions in interior stairwell of the structure. Photo by NIST.



Figure 2. Fire is visible at the rear balcony (Side C). Stairs seen on the right side of the structure were used by fire fighters to enter the structure at Side B. Photo by the fire department.

At about this time, a crew from Engine 24 (E-24) followed the E-26 crew's hose line through the street-level front door. In zero visibility conditions, the E-24 crew found the two downed members of E-26 in the basement. Both members were removed from the structure, and medical attention was initiated before they were transported to a local hospital.

The lieutenant was pronounced dead and the fire fighter/paramedic died two days later. Contributing factors that led

to the fatalities included the below-grade fire within a house on a steep hillside, uncoordinated ventilation, ineffective size-up, ineffective fire ground communications, and situational reporting [NIOSH 2011].

Additional basement fire hazards, such as fire fighters falling through fire-weakened floors, wind driven fires, and chimney effect of internal stairways are highlighted by the following NIOSH investigation reports: (1) F2008-08: Volunteer Fire Lieutenant Killed While Fighting a Basement Fire—Pennsylvania; (2) F2008-09: A Career Captain and a Part-time Fire Fighter Die in a Residential Floor Collapse—Ohio; (3) F2014-09: Lieutenant and Fire Fighter Die and 13 Fire Fighters Injured in a Wind-Driven Fire in a Brownstone—Massachusetts; and (4) F2014-25: Career Female Fire Fighter Dies after Becoming Lost and Running out of Air in a Residential Structure Fire—Pennsylvania.

Controls

To minimize the risks of working basement and other below-grade fires, NIOSH recommends that fire departments take the following precautions.

Pre-Incident:

- Develop and enforce standard operating procedures (SOPs) for safely attacking fires in basements and other below-grade structures.
- Ensure that an incident management system is used at all incidents including a personnel accountability system. Also, ensure that all members involved in firefighting operations wear full personal protective equipment, including an SCBA with integrated PASS device, and are provided a portable radio.
- Provide fire fighters with practical hands-on training for identifying indicators of basement and other below-grade fires, heat and smoke movement through ventilation, fire location, and a safe exterior and interior firefighting operations.
- Conduct pre-planning of first due response areas to identify construction types, building access, and below-grade areas and structures.

Incident:

- Ensure a thorough initial 360-degree size-up is conducted, and a crew is assigned to Side C.
- Use a thermal imager as part of a 360-degree size-up to assist in determining the fire location.
- Ensure the first arriving officer and/or incident commander completes an initial survivability profile and risk assessment with continuous monitoring of risk versus gain.

- Ensure the strategy and incident action plan is communicated to all on-scene and responding personnel before a decision is made to enter a building.
- Ensure the incident commander assigns a safety officer who is trained to recognize hazards associated with basement and other below-grade fires.
- At any point when risk outweighs gain, especially for property only, the incident commander should initiate a defensive strategy.

If the risk assessment determines interior operations are necessary and feasible, take the following steps:

- Prior to conducting interior fire attack operations, ensure at least one rapid intervention crew is on site with necessary equipment to respond to missing or trapped fire fighters.
- Do not attempt to attack the basement fire from an interior stairway.
- Before entry, ensure a thorough 360-degree size-up has been conducted that determines fire location, primary and alternate ingress and egress points, strategy and incident action plan (tactics), and communicate this information to all personnel responding or on scene.
- Use a thermal imager to aid in locating fires burning below or between floor systems but understand its use and limitations when trying to determine structural integrity. Scan over baseboards and vents. If possible and safe, a floor should be inspected from below prior to operating on it [Kerber et al. 2012].
- Secure an uninterrupted water supply that will provide an adequate and necessary water flow needed for complete fire extinguishment.
- Perform an exterior offensive attack by flowing water onto the fire from an exterior basement door, window, or by breaching exterior basement walls and then reassess conditions before advancing a hose line and/or looking for interior extension.
- Stretch a back-up line to protect the primary hose line crew's egress route and additional hose lines to protect secondary entry and egress points such as basement windows or doors.
- Be aware of how ventilation affects fire behavior and coordinate ventilation with firefighting operations so that the flow path is appropriately identified and controlled.
- Fire fighters should keep the wind at their back and stay upwind of the fire.
- Fire departments should use all available options to prevent fire fighters from working on unrated floor assemblies above a fire [Madrzykowski 2013].
- If necessary, make penetrations in the floor above the basement using a distributor nozzle to knock down the fire. Fire fighters should initially insert these devices from a safe position (i.e. just inside the entry door). Additional

penetrations can be made in the floor to move further into the structure if warranted, but only if the floor is stable.

- Immediately evacuate a structure if a floor above a fire has been weakened. If possible, use an alternate exit route to avoid crossing over a weakened area.
- Use defensive overhaul procedures after fire extinguishment in structures containing fire damaged floor systems and stairways.

Post Incident:

Every fire department should conduct a post incident analysis for significant incidents, especially basement or below-grade fires.

Every fire department should periodically update their community risk assessment program and pre-incident planning process based on recommendations from post incident analysis reports.

In addition, the best protections for fire fighters and occupants, as well as for structures, are preventive measures such as (1) smoke alarms; (2) equipping basements with automatic sprinkler systems; (3) covering the underside of floor systems with a fire-resistant membrane; (4) not using a basement or other below-grade structure in a manner that conflicts with the code it was designed to, and; (5) including egress points such as windows or walk-out doorways that are accessible.

Acknowledgments

The principal contributors to this publication were Timothy Merinar, Stacy Wertman and Murrey Loflin, National Institute for Occupational Safety and Health, Fire Fighter Fatality Investigation and Prevention Program; and Fire Chief Gary Morris, International Association of Fire Chiefs; Safety, Health, and Survival Section.

References

- IFSTA [2013]. Essentials of fire fighting, 6th ed. Oklahoma State University. Stillwater, OK: Fire Protection Publications. International Fire Service Training Association.
- NIOSH [2011]. A career lieutenant and fire fighter/paramedic die in a hillside residential house fire—California. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, FACE Report 2011-13, www.cdc.gov/niosh/fire/reports/face201113.html
- NIST [2011]. Examination of the thermal conditions of a wood floor assembly above a compartment fire. <https://www.nist.gov/el/fire-research-division-73300/firegov-fire-service/examination-thermal-conditions-wood-floor>
- Kerber S, Madrzykowski D, Dalton J, Backstrom R [2012]. Improving fire safety by understanding the fire performance of engineered floor systems and providing the fire service with information for tactical decision making. Northwood, IL: Underwriters Laboratories.

Madrzykowski D [2013]. Fire dynamics: the science of fire fighting. *International Fire Service Journal of Leadership and Management*, Volume 7. Fire Protection Publications/IFSTA.

UL [2013]. Innovating fire attack tactics. Underwriters Laboratories. https://www.ul.com/global/documents/new-science/article/firesafety/NS_FS_Article_Fire_Attack_Tactics.pdf

Training Materials and Additional Sources of Information

Underwriters Laboratories (UL) maintains a website dedicated to fire fighter safety. <https://ulfirefightersafety.org/>

UL also maintains a website dedicated to the risks of modern fire behavior. <http://modernfirebehavior.com/>

The National Institute of Standards and Technology (NIST) Building and Fire Research Laboratory maintains a website with links to publications on a number of fire safety topics and research. <https://www.nist.gov/el/fire-research-division-73300>

Jerrard J [2012]. UL Basement fire study. *Fire Rescue* 7(8). <http://www.firerescuemagazine.com/articles/print/volume-7/issue-8/firefighter-safety/ul-basement-fire-study.html>

Kirby M [2013]. Basement fire tactics. *Fire rescue* 8(8). <http://www.firerescuemagazine.com/articles/print/volume-8/issue-8/strategy-and-tactics/basement-fire-tactics.html>

NIOSH [2009a]. Volunteer fire lieutenant killed while fighting a basement fire—Pennsylvania. <https://www.cdc.gov/niosh/fire/pdfs/face200808.pdf>

NIOSH [2009b]. A career captain and a part-time fire fighter die in a residential floor collapse—Ohio. <https://www.cdc.gov/niosh/fire/pdfs/face200809.pdf>

NIOSH [2016]. Lieutenant and fire fighter die and 13 fire fighters injured in a wind-driven fire in a brownstone—Massachusetts. <https://www.cdc.gov/niosh/fire/pdfs/face201409.pdf>

NIOSH [2017]. Career female fire fighter dies after becoming lost and running out of air in a residential structure fire—Pennsylvania. <https://www.cdc.gov/niosh/fire/pdfs/face201425.pdf>

For More Information

More information about the NIOSH Fire Fighter Fatality Investigation and Prevention Program can be found at <https://www.cdc.gov/niosh/fire/>.

A complete list of NIOSH fire fatality reports can be found at https://www.cdc.gov/NIOSH-fire-fighter-face/Default.cshtml?state=ALL&Incident_Year=ALL&Submit=Submit.

To receive documents or other information about occupational safety and health topics, contact NIOSH at

Phone: 1-800-CDC-INFO (1-800-232-4636)
TTY: 1-888-232-6348 ■ E-mail: cdcinfo@cdc.gov

or visit the NIOSH website at www.cdc.gov/niosh.

For a monthly update on news at NIOSH, subscribe to *NIOSH eNews* by visiting www.cdc.gov/niosh/eNews.

Mention of any company or product does not constitute endorsement by NIOSH. In addition, citations to websites external to NIOSH do not constitute NIOSH endorsement of the sponsoring organizations or their programs or products. Furthermore, NIOSH is not responsible for the content of these websites.

This document is in the public domain and may be freely copied or reprinted. NIOSH encourages all readers of the *Workplace Solutions* to make them available to all interested employers and workers.

As part of the Centers for Disease Control and Prevention, NIOSH is the Federal agency responsible for conducting research and making recommendations to prevent work-related illnesses and injuries. All *Workplace Solutions* are based on research studies that show how worker exposures to hazardous agents or activities can be significantly reduced.

Preventing Deaths and Injuries of Fire Fighters Working at Basement and Other Below-Grade Fires

DOI: <https://doi.org/10.26616/NIOSH PUB2018154>

DHHS (NIOSH) Publication No. 2018-154