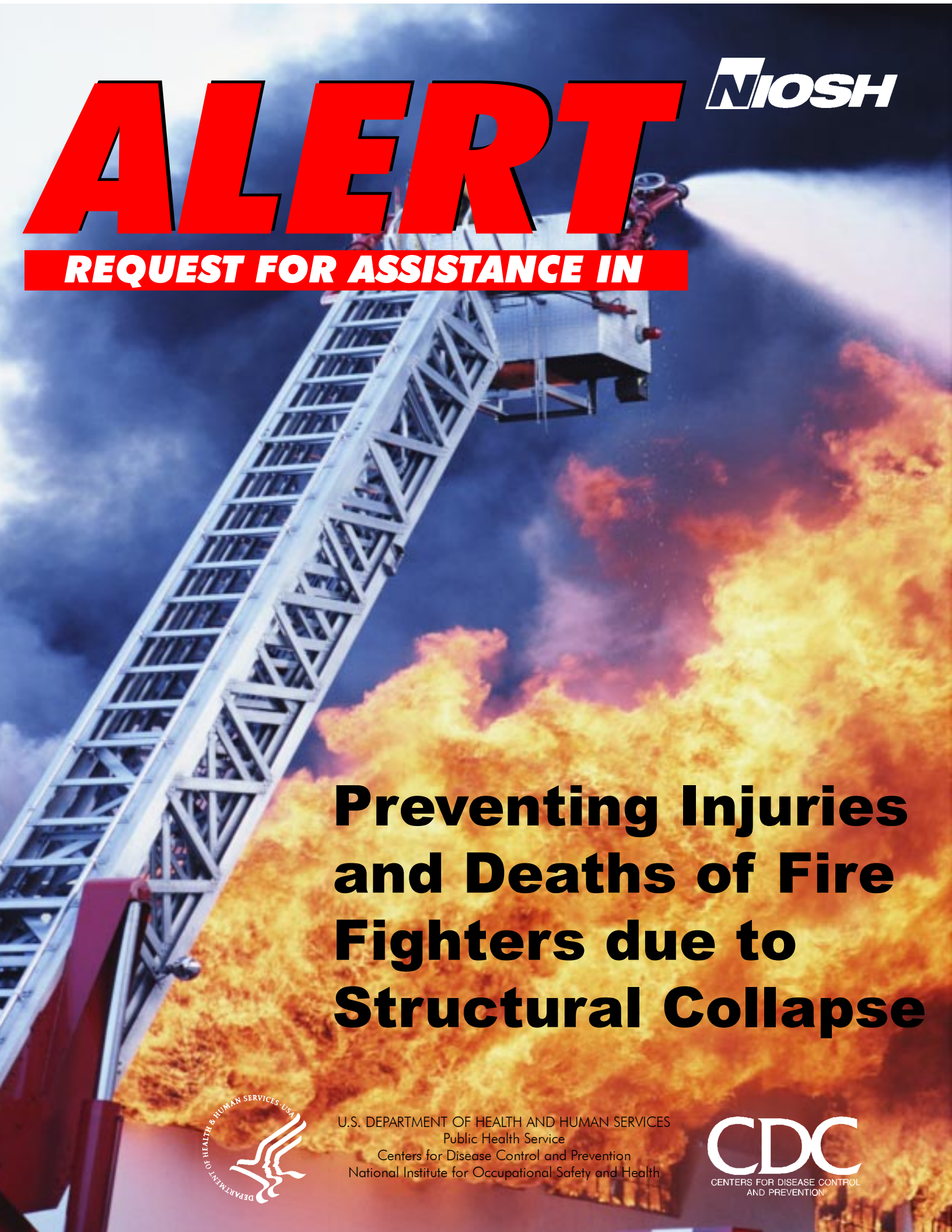

ALERT

NIOSH

REQUEST FOR ASSISTANCE IN

Preventing Injuries and Deaths of Fire Fighters due to Structural Collapse

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
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Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

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DHHS (NIOSH) Publication No. 99–146
August 1999

NIOSH **ALERT**

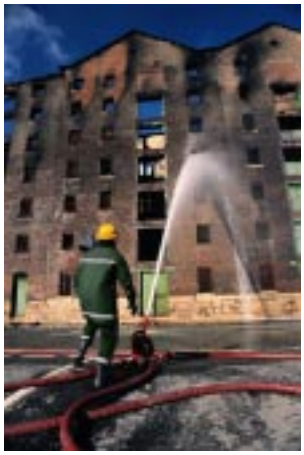
Preventing Injuries and Deaths of Fire Fighters due to Structural Collapse

WARNING!

Fire fighters are frequently injured or killed when burning structures collapse without warning.

Fire departments should take the following steps to minimize the risk of injury and death to fire fighters during structural fire fighting:

- **Implement and review occupational safety programs and standard operating procedures.**
- **Ensure that the incident commander conducts an initial size-up and risk assessment of the incident scene before beginning interior fire fighting.**
- **Ensure that the incident commander always maintains accountability for all personnel at a fire scene—both by location and function.**
- **Establish rapid intervention crews (RICs)—often called rapid intervention teams—and make sure they are positioned to respond immediately to emergencies.**
- **Ensure that at least four fire fighters are on the scene before beginning interior fire fighting at a structural fire (two fire fighters inside the structure and two outside).**
- **Equip fire fighters who enter hazardous areas (such as burning or suspected unsafe structures) to maintain two-way communications with the incident commander.**
- **Ensure that standard operating procedures and equipment are adequate and sufficient to support radio traffic at multiple-responder fire scenes.**
- **Provide all fire fighters with personal alert safety system (PASS) devices and make sure that they wear and activate them when they are involved in fire fighting, rescue, or other hazardous duties.**
- **Conduct prefire planning and inspections that cover all building materials and components of a structure.**
- **Transmit an audible tone or alert immediately when conditions become unsafe for fire fighters.**
- **Establish a collapse zone around buildings with parapet walls.**



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NIOSH

NIOSH **ALERT**

Preventing Injuries and Deaths of Fire Fighters due to Structural Collapse

WARNING!

Fire fighters are frequently injured or killed when burning structures collapse without warning.

The National Institute for Occupational Safety and Health (NIOSH) requests assistance in preventing injuries and deaths of U.S. fire fighters due to structural collapse during fire-fighting operations. Structural collapse of a building during fire fighting is a leading cause of death among fire fighters. Such collapse is very difficult to predict during fire fighting, and it usually occurs without warning.

Fire departments should implement and review occupational safety programs and standard operating procedures to prevent serious injuries and deaths of fire fighters. NIOSH recommends that fire departments take 10 essential steps to minimize the risk of injury and death to fire fighters during structural fire fighting:

1. Ensure that the incident commander conducts an initial size-up and risk assessment of the incident scene before beginning interior fire fighting.

2. Ensure that the incident commander always maintains accountability for all personnel at a fire scene—both by location and function.

3. Establish rapid intervention crews (RICs)—often called rapid intervention teams—and make sure they are positioned to respond immediately to emergencies.

4. Ensure that at least four fire fighters are on the scene before beginning interior fire fighting at a structural fire (two fire fighters inside the structure and two outside).

5. Equip fire fighters who enter hazardous areas (such as burning or suspected unsafe structures) to maintain two-way communications with the incident commander.

6. Ensure that standard operating procedures and equipment are adequate and sufficient to support radio traffic at multiple-responder fire scenes.

7. Provide all fire fighters with personal alert safety system (PASS) devices and make sure that they wear and activate them when they are involved in fire fighting, rescue, or other hazardous duties.

8. Conduct prefire planning and inspections that cover all building materials and components of a structure.

9. Transmit an audible tone or alert immediately when conditions become unsafe for fire fighters.

10. Establish a collapse zone around buildings with parapet walls.

NIOSH requests that the information in this Alert be brought to the attention of all U.S. fire fighters—including those in the largest metropolitan and the smallest rural departments— by the following: fire chiefs and fire commissioners and administrators, editors of trade journals and other publications, safety and health officials, State fire marshals, unions and labor organizations, fire-fighting agencies, and insurance companies.

BACKGROUND

The National Fire Protection Association (NFPA) reports that 968 fire fighters died between 1989 and 1998 [NFPA 1999]. Nearly half of these deaths (443) occurred on the fireground. Furthermore, structural collapse caused 56 (18%) of the 316 fire fighter deaths at structure fires. A structural collapse often results in multiple fire fighter fatalities. For example, during this time period, 43 fire fighters were fatally injured by collapsing materials at 11 fires.

As these statistics show, structural collapse of any part of a building (floors, walls, ceilings, roofs, or structural members) during fire fighting is a leading cause of death among fire fighters. The potential for structural collapse is one of the most difficult factors to predict during initial size-up and ongoing fire fighting. Structural collapse usually occurs without warning. For example, the floor of a burning structure may suddenly collapse, spilling fire fighters into a burning inferno. Or a sudden roof collapse may trap fire fighters inside the structure. After arrival at a fire scene, the incident commander must consider numerous variables to determine the structural integrity of a burning building [Dunn 1988]:

- Fire size and location
- Length of time the fire has been burning
- Conditions on arrival
- Size of the building (single or multistory, floor area, and height)
- Age of the building (deterioration of structural members, evidence of weathering, use of lightweight materials in new construction)
- Presence of combustible materials
- Occupancy
- Renovations or modifications to the building
- Previous fires
- Supported loads (such as roof-top heating and cooling systems) that might affect the integrity of the structure
- Exposures that might pose fire and smoke hazards to nearby people or buildings
- Resources at the scene for extinguishing the fire (number of apparatus, fire-fighting personnel, water supply, and auxiliary appliances)
- Other factors such as the time of day (day or night) and weather conditions (extreme heat or cold)

CURRENT STANDARDS

OSHA

State and local government employees (such as fire fighters) are exempt from Federal Occupational Safety and Health Administration (OSHA) standards. However, in the 25 States currently authorized by OSHA to run an occupational safety and health program, all OSHA regulations apply to both public and private employees.

Current OSHA regulations that apply to fire fighters include 29 CFR* 1910.134 (*Respiratory protection*) and 29 CFR 1910.156 (*Fire brigades*). In 29 CFR 1910.134, employers are required to provide respirators suitable for the purpose intended and to establish and maintain a respirator protection program. The standard also states that if fire fighters must enter an area that is immediately dangerous to life and health (IDLH), at least two must enter the area together and remain in visual or voice contact with one another at all times. They must also conduct interior fire fighting using self-contained breathing apparatus (SCBA). In addition, at least two properly equipped and trained fire fighters must be

— positioned outside the IDLH atmosphere,

— account for the interior team(s), and

— remain capable of rapid rescue of the interior team(s).

In 29 CFR 1910.156, OSHA lists the requirements for organizing, training, and equipping fire brigades established by the employer.

*Code of Federal Regulations. See CFR in references.

NFPA

The National Fire Protection Association (NFPA) recommends in NFPA 1500 that all fire departments establish a policy of providing and operating at "the highest possible levels of safety and health for all members" [NFPA 1997a]. Several NFPA standards apply to structural fire fighting operations:

- NFPA 220, *Standard on Types of Building Construction*, specifies methods of classifying types of construction and fire resistance ratings [NFPA 1995a].

- NFPA 1404, *Standard for a Fire Department Self-Contained Breathing Apparatus Program*, specifies the minimum requirements for a respiratory protection training program in a fire department [NFPA 1996].

- NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, specifies (1) the minimum requirements for a fire department's occupational safety and health program; (2) the safety procedures for members involved in rescue, fire suppression, and related activities; and (3) the integration of risk management into regular functions of the incident commander [NFPA 1997a].

- NFPA 1561, *Standard on Fire Department Incident Management System*, defines the essential elements of an incident management system [NFPA 1995b].

- Other relevant NFPA Standards include the following:

  NFPA 1971, *Standard on Protective Ensemble for Structural Fire Fighting*, which includes protective coat, pants, helmet, gloves, hood, and footware [NFPA 1997b]

  NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for the Fire Service* [NFPA 1997c]

  NFPA 1982, *Standard on Personal Alert Safety Systems (PASS) for Fire Fighters.* [NFPA 1998].

CASE REPORTS

The following case reports describe incidents involving fire fighter injuries and deaths due to structural collapse. They were investigated by the NIOSH Fire Fighter Investigation Team using the Fatality Assessment and Control Evaluation (FACE) protocol.

CASE 1—Commercial Structure Fire in California

On March 8, 1998, one male fire fighter (a captain) died at a fire scene while trying to exit from a commercial structure. The first unit on the scene reported light smoke showing from a one-story commercial building. A ventilation team proceeded to the roof of the building and began ventilating. Another team began forcible entry into the front of the building through two metal security doors (which took 7½ to 9 minutes to force open). While fire companies waited for the front door to be opened, fire conditions changed dramatically on the roof. Fire was coming from the ventilation holes opened by the ventilation crew.

About the same time, three engine crews advanced hand lines through the front door to determine the origin of the fire. Approximately 15 feet inside the front door, the fire fighters encountered heavy smoke and near-zero visibility. The engine crews advanced their lines 30 to 40 feet inside the building, but could not locate the fire. Conditions continued to deteriorate rapidly, so the officers on the engine crews ordered their fire fighters to exit from the building. During this time, the victim became separated from his crew and remained in the building. About 1 minute later, a partial roof collapse blocked the front door. The rapid intervention team subsequently located the victim. Cardiopulmonary resuscitation was performed immediately and en route to the hospital, where the victim was pronounced dead. The medical examiner listed smoke inhalation and burns as the cause of death [NIOSH 1998a].

Applicable Recommendations: 1, 2, 4, 5, 6, and 9 in the Recommendations section.

CASE 2—Floor Collapse in a Single-Family Dwelling in Kentucky

On February 17, 1997, one male fire fighter died and another was injured in a fire in a single-family dwelling. When the fire company arrived at the fire scene, the district major reported that heavy smoke was coming from the roof area of the dwelling. Two male fire fighters pulled two 1¾-inch charged lines from their assigned engine and proceeded toward the dwelling. After knocking down a ceiling fire, they entered the dwelling, apparently without the district major's knowledge. On entering the front door, both fell through the floor into the basement. The fire fighters landed at the fire's origin in extremely hot water and heavy black smoke. Neither was equipped with a radio, so an emergency transmission to the incident commander was impossible. The fire fighters manually triggered their PASS devices, but the pumps and engines operating on the street made it impossible to hear the alarm. About 8 minutes into the operation, the district major discovered that two fire fighters were missing. A lieutenant noticed the hose lines leading into the front door. He crawled along the ground, following them to the front door, where he saw a light shining up from the basement. A ladder was lowered. One fire fighter grabbed the ladder and was pulled from the basement. He stated that another fire fighter was still in the basement. After numerous search efforts, the second fire fighter was found (about 53 minutes into the operation). Eight to ten minutes after the two fire fighters had entered the structure, their SCBAs had run out of air and they had tried to breathe entrained air from the water spray in their lines. The first fire fighter was injured but survived. The second fire fighter died from asphyxiation due to smoke inhalation [NIOSH 1997].

Applicable recommendations: 2, 3, and 5 in the Recommendations section.

CASE 3—Sudden Roof Collapse of a Burning Auto Parts Store in Virginia

On March 18, 1996, two male fire fighters died while fighting a fire in an auto parts store. At 1129 hours, a 911 call to the fire dispatch reported sparking in the fuse box at a local auto parts store. At 1135 hours, fire fighters arrived, not knowing that a power company service truck had accidentally broken the neutral line to the auto parts store. The store did not have adequate electrical grounds; thus all electrical circuits in the store superheated and started a series of fires above the dropped ceiling. A lieutenant and a fire fighter from Engine 3 went into the auto parts store with a charged 1¾-inch line to locate the origin of the fire (only light smoke was showing inside). All employees had left the store and all lights were out. At 1149 hours, the lieutenant inside the store radioed that they were in trouble and could not get out. However, because of heavy radio traffic, the battalion chief did not understand the transmission. At 1150 hours, the fire rapidly accelerated without warning and the entire roof (containing 50-foot wood trusses supporting heavy heating and cooling units) collapsed into the store. Both fire fighters died from burns and smoke inhalation [NIOSH 1996].

Applicable recommendations: 2, 3, 6, and 8 in the Recommendations section.

CASE 4—Parapet Wall Collapse during a Warehouse Fire in Vermont

On September 5, 1998, one fire fighter died when a parapet wall collapsed on him during a warehouse fire. Four fire departments were dispatched to fight a fire in a warehouse that stored recycled paper. The warehouse was built in the late 1800s of brick masonry frame with heavy wood truss construction. The first arriving chief of an engine company saw smoke issuing from below the

Photo courtesy of Bradley Whitcomb, St. Johnsbury Fire Department, St. Johnsbury, Vermont

eaves at the rear of the structure. He decided not to enter the building but to "surround and drown" it. When the Engine 3 crew arrived, they were ordered to place their engine at the north end of the structure and attack from the exterior. One of the fire fighters from Engine 3 approached the structure to open the large, barn-like doors and enable the fire fighters to attack from the exterior. The fire fighter then returned to the hose line and discovered that the doors had closed behind him (they were self closing). He was returning to prop them open when, without warning, the parapet wall above the doors suddenly collapsed on him. He died as a result of multiple crushing injuries [NIOSH 1998b].

Applicable recommendations: 8 and 10 in the Recommendations section.

CONCLUSIONS

Many complex factors are present when fighting a structural fire, and conditions can deteriorate rapidly at the fire scene—sometimes with little or no warning. Fire departments need to be constantly aware of the potential for a structural collapse and take appropriate steps to ensure the safety of fire fighters.

RECOMMENDATIONS AND DISCUSSION

To minimize the risk of injury and death to fire fighters during structural fire fighting, NIOSH recommends that fire departments (1) implement and review occupational safety programs and standard operating procedures and (2) take the following steps:

1. Ensure that the incident commander conducts an initial size-up and risk assessment at the incident scene before beginning interior fire fighting.

This size-up and risk assessment should continue throughout the incident and should include evaluation of the situation, fire-fighting strategy, tactical planning, plan evaluation and revision, and operational command and control. A primary concern is whether the scene involves an imminent life-threatening situation that may require rescue.

An initial size-up and assessment of a fire should include an evaluation of the following factors [Dunn 1988]:

- Fire size and location
- Length of time the fire has been burning
- Conditions on arrival
- Size of the building (single or multistory, floor area, and height)
- Age of the building (deterioration of structural members, evidence of weathering, use of lightweight materials in new construction)
- Presence of combustible materials
- Occupancy
- Renovations or modifications to the building
- Previous fires

  Supported loads (such as roof-top heating and cooling systems) that might affect the integrity of the structure
- Exposures that might pose fire and smoke hazards to nearby people or buildings
- Resources at the scene for extinguishing the fire (number of apparatus, fire-fighting personnel, water supply, and auxiliary appliances)
- Other factors such as the time of day (day or night) and weather conditions (extreme heat or cold)

2. Ensure that the incident commander always maintains close accountability for all personnel at the fire scene—both by location and function.

Accountability for all fire fighters at a fire scene is essential and constitutes one of the incident commander's most important duties. Personnel accountability systems should be integrated into the incident command policy and used to track locations and assignments of companies operating at a fire scene. Personnel accountability systems include accountability checks that require the incident commander to communicate with officers at each level within the incident command system.

3. Ensure that at least four fire fighters are on the scene before entering a structure and beginning interior fire fighting at a structural fire (two fire fighters inside the structure and two outside).

The NFPA and the OSHA state that at a minimum four persons (each with full protective clothing and respiratory protection) are needed to assure the safety of those working inside a burning structure. Two fire fighters may be inside the structure, but two must remain outside. The team members should be in visual, audible, or electronic communication with each other to coordinate all activities and determine whether emergency rescue is needed.

Photo courtesy of National Institute of Standards and Technology

4. Establish rapid intervention crews (RICs) and make sure they are positioned to respond immediately to emergencies.

The primary purpose for an RIC is to provide a dedicated and specialized team of fire fighters ready to rescue fire fighters who become trapped in a burning structure. An RIC is vitally important at a structure fire, as it provides the incident commander with a designated emergency team and thereby eliminates the need for reassigning other fire fighters to this duty during a critical period. The RIC's primary duty is to respond to emergencies in which fire fighters are trapped, lost, or disoriented in a burning structure. Under optimum conditions, an RIC should respond with the first alarm to eliminate later response time. The RIC should be equipped with full turnout gear, SCBAs, portable radios and lights, axes, forcible entry tools, hooks, and other equipment needed for the rescue effort. The RIC should report directly to the incident commander and be nearby to await rescue commands. An RIC should consist of at least two fire fighters, but the size and complexity of the incident dictates the size of the RIC.

5. Equip fire fighters who enter hazardous areas (such as burning or suspected unsafe structures) to maintain two-way communications with the incident commander.

Lack of effective communications on the fireground can result in tragic loss of life. Fire fighters who enter burning structures must be able to communicate with the incident commander about interior conditions, the need for additional support, and emergencies that require rescue or response teams. Effective communications are of primary importance to the incident commander in decision making, overall operations, and safety on the fireground.

6. Ensure that standard operating procedures and equipment are adequate and sufficient to support radio traffic at multiple-responder fire scenes.

Communications become ineffective at the fire scene when radio traffic becomes so heavy that messages cannot be understood. The ambient noise on the fireground further hampers effective communication. Specified channels should be

used for the tactical channel and dispatch to prevent competition for air time. Radio traffic can be reduced if users

— avoid unnecessary transmissions,

— are brief but accurate,

— speak clearly,

— wait for the air channel to clear, and

— allow priority for emergencies and rescues.

The standard operating procedures, personnel, and communications equipment should be of sufficient quality and quantity to support the volume of communications encountered at various types of fire scenes. Fire department communication policies should include a standard operating procedure for the delivery and acknowledgment of "emergency traffic" at the incident scene. Common terminology must be readily identifiable by all personnel at the incident scene and by the dispatcher or telecommunicator in all communications centers.

7. Provide all fire fighters with PASS devices and make sure that they wear and activate them when they are involved in fire fighting, rescue, or other hazardous duties.

PASS devices are designed to set off an audible alarm when a fire fighter becomes motionless for 30 seconds. However, a primary complaint about PASS devices is that the alarm often sounds while fire fighters are on standby or in a rest period. The alarm is manufactured so that any movement by the fire fighter should reset the alarm. Also, the fire fighter can manually activate the PASS device alarm whenever assistance is required.

The PASS device should be worn by fire fighters and activated whenever they operate in a hazardous area. The devices are not designed to be heard outside a building, but they are intended to alert nearby fire fighters or officers that someone is missing, lost, or trapped. An activated PASS alarm will also help an RIC find lost or trapped fire fighters.

8. Conduct prefire planning and inspections that cover all building materials and components of a structure.

Prefire inspections are an excellent opportunity for fire departments to determine the following:

- Age of the structure
- Structural integrity
- Exposed interior insulation materials
- Type of roof structure and supports (truss, bow, etc.)
- Type of interior support structures
- Type of materials used in the structure (such as wood, steel, plastics, foam, or materials that produce toxic gases when subjected to heat)
- Storage of flammable or toxic materials
- Amount of load (for example, heavy heating and cooling units) on roof structures that could weaken the supports
- Water supply
- Automatic sprinkler systems

Truss roofs should be evaluated for a minimum fire resistance rating of 1 hour. Each structure in a multistructure (such as a strip mall) should receive a prefire inspection to determine the interior design and types of materials used in construction.

9. Transmit an audible tone or alert immediately when conditions become unsafe for fire fighters.

An emergency evacuation is ordered when an extremely serious emergency has occurred or is about to happen. Examples of such emergencies are missing fire fighters, explosion, and structural collapse. Unlike a withdrawal, an emergency evacuation requires that fire fighters leave behind tools and hoses and that the incident commander

conduct a roll call or a head count. An emergency evacuation is a rare event in fire fighting, and thus confusion and delay usually occur when it is ordered. For this reason, a prearranged audible signal should be sounded to alert fire fighters of an emergency evacuation. Fire departments should train their members to evacuate the building at the sound of the signal.

10. Establish a collapse zone around buildings with parapet walls.

A parapet wall is the continuation of an exterior wall above the roof level. A parapet wall has reduced stability because it has fewer connections to the rest of the structure and is subject to collapse if it suffers any movement, shock, or vibration during fire-fighting operations. A collapse zone is the distance from the fire building equal to the height of the wall. However, since the falling wall may break apart and allow flying debris to cover a greater distance than the height of the wall, a safety margin should be considered when establishing a collapse zone. Fire fighters should not be allowed to operate inside a collapse zone. For example, they should not advance attack lines or conduct staging or fire fighter rehabilitation within this zone. In addition, hose streams, deck guns or pipes, portable deluge nozzles, and aerial ladders with fire fighters operating at the tip or inside buckets should operate outside the collapse zone.

ACKNOWLEDGMENTS

The principal contributors to this Alert were Ted Pettit, Division of Safety Research, NIOSH; Vincent Dunn, Deputy Chief (retired), New York City Fire Department; and Greg Main, District Chief, Evansville Indiana Fire Department. Rita Fahy, NFPA, provided the NFPA data. Ted Pettit, Richard Braddee, and Frank Washenitz, Fire Fighter Investigation Team, Division of Safety Research, NIOSH, investigated the cases used. Kim Clough, Health Effects Laboratory Division, NIOSH, created the document design and layout. Jason Britton, Health Effects Laboratory Division, NIOSH, created the Web document.

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Linda Rosenstock, M.D., M.P.H.
Director, National Institute for
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