FIRE FIGHTER SURVIVAL

Approved and Adopted by the
Office of the State Fire Marshal

Recommended for adoption by the
Statewide Training and Education Advisory
Committee and the
State Board of Fire Services

INSTRUCTOR and STUDENT GUIDE

June 2010

FIRE FIGHTER SURVIVAL

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Mission Statement

The mission of State Fire Training is to enable the California fire service to safely protect life and property through education, training, and certification.

Fire Service Training and Education Program

The Fire Service Training and Education Program (FSTEP) was established to provide specific training needs of local fire agencies in California. State Fire Training coordinates the delivery of this training through the use of approved curricula and registered instructors.

The FSTEP series is designed to provide both the volunteer and career fire fighter with hands-on training in specialized areas such as fire fighting, extrication, rescue, and pump operations. All courses are delivered through registered instructors and can be tailored by the instructor to meet your department's specific need. Upon successful completion of an approved FSTEP course, participants will receive an Office of State Fire Marshal course completion certificate.

Acknowledgments

State Fire Training coordinated the development of the material contained in this guide. Before its publication, the Statewide Training and Education Advisory Committee (STEAC) and the State Board of Fire Services (SBFS) recommended this guide for adoption by the State Fire Marshal (SFM). This guide is appropriate for fire service personnel and for personnel in related occupations.

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Tonya Hoover Acting State Fire Marshal	**Vacant** Assistant State Fire Marshal
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"We gratefully acknowledge the hard work and accomplishments of those before us who built the solid foundation on which this program continues to grow."

Course Outline

Course Objectives: To provide the student with…

a) Fire fighter survival terminology.

b) Knowledge of the federal government involvement to reduce fire fighter injuries and fatalities and the guidelines and laws put in place from tragic fire loss events.

c) Fire fighter fatality case study recommendations to enhance fire fighter training to handle their own emergencies on the fireground.

d) Techniques for developing fire fighter survival attitude and identify personal equipment that fire fighters should carry in their possession for self-preparedness measures.

e) Situational awareness to prevent the fire fighter emergency and recognize critical structural fireground factors.

f) Knowledge and the application of "When to call a fire fighter emergency" and emergency communications when fire fighters become lost, trapped, or disoriented inside a burning structure.

g) SCBA knowledge and techniques for air awareness and SCBA air emergencies, and applying them during hands-on evolutions.

Course Content.....**16:00**

1. Orientation And Administration..... 1:00
2. Developing A Survival Attitude..... 0:45
3. Preventing The Fire Fighter Emergency..... 0:45
4. The Fire Fighter Emergency..... 0:45
5. SCBA Emergencies 0:45
6. Fire Fighter Survival Skills..... 8:00
   - #1: SCBA Emergency Procedure Check
   - #2: Calling "Mayday"
   - #3: Reading Couplings
   - #4: Window Hang
   - #5: Hose Slide
   - #6: Emergency Ladder Escape – Hook-two/Slide-to-four Method
   - #7: Entanglement Emergencies – Swim or Sweep Method
   - #8: Entanglement Emergencies – SCBA Removal Method
   - #9: Wall Breach
   - #10: Changing Your SCBA Profile – Nonremoval Method
   - #11: Changing Your SCBA Profile – Low or Reduced Profile (Partial-removal Method)
   - #12: Changing Your SCBA Profile – Zero or No Profile (Full-removal Method)
7. Fire Fighter Survival Evolutions..... 4:00
   - #1: SCBA Confidence Course
   - #2: SCBA Awareness

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  http://www.cdc.gov/niosh/fire/reports/face200113.html
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- ❒ NIOSH #20032896: Volunteer Fire Fighter Dies After Falling Through Floor Supported By Engineered Wooden-I Beams At Residential Structure Fire – Tennessee
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- ❒ NIOSH #20035012: Nine Career Fire Fighters Die In Rapid Fire Progression At Commercial Furniture Showroom – South Carolina
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- ❒ NIOSH Publication No. 2007-133: Preventing Fire Fighter Fatalities Due To Heart Attacks And Other Sudden Cardiovascular Events, June 2007
- ❒ NIOSH Publication No. 2007-154: The NIOSH Fire Fighter Fatality Investigation And Prevention Program, August 2007
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- ❒ NIOSH Publication No. 2009-114: Preventing Deaths And Injuries Of Fire Fighters Working Above Fire-Damaged Floors, February 2009
- ❒ OSHA-Occupational Safety & Health Administration
- ❒ The Art of Reading Smoke, David W. Dodson (DVD), 2007
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Topic 1: Orientation and Administration

Scope: This topic serves as an introduction to the course, providing students with general information and expectations of the course.
Terminal Learning Objective (TLO): At the end of this topic, the student will be aware of the course goals, and the requirements for successfully completing the course.
Enabling Learning Objectives (ELO):
1. Describe the course objectives
2. Define the intent of the Fire Fighter Survival course.
3. Describe student's safety recommendations and personal protective equipment.
4. Describe the student evaluation process.

"Live for something rather than die for nothing."
George Patton

The Fire Fighter Survival course was developed in the continuing effort to reduce the number of fire fighter injuries and fatalities that occur on an annual basis. This course will supply you with a greater understanding of the need for situational awareness, fire fighter survival skills, and the technical survival skills to help you avoid committing fatal errors on the fireground. Avoiding situations that could cause you to become lost, trapped, or injured is the best way to prevent tragedies at a fire scene. The Fire Fighter Survival course will aid in preventing fire fighter emergencies by teaching personnel to be resourceful when facing dangerous entrapment situations.

Course Objectives

The Fire Fighter Survival course is intended to reduce the number of fire fighters killed or injured while performing their duties on an annual basis. It is a 16-hour class delivered in a two-day format. You must effectively complete the class in its entirety to receive a course completion certificate and is a prerequisite for the Rapid Intervention Crew Operations course.

During this class, you will gain a greater understanding of fire fighter survival terminology, developing a survival attitude, increasing situational awareness, and being trained in problem-solving techniques so you can become more self reliant in an emergency. Case studies will be reviewed to outline factors common in many line-of-duty deaths (LODDs) across the nation.

Student Evaluations

You must successfully perform all 12 fire fighter survival skills and both evolutions in order to pass the class.

- ❒ Skill #1: SCBA Emergency Procedure Check
- ❒ Skill #2: Calling "Mayday"

- ❒ Skill #3: Reading Couplings
- ❒ Skill #4: Window Hang
- ❒ Skill #5: Hose Slide
- ❒ Skill #6: Emergency Ladder Escape : Hook-two/Slide-to-four Method
- ❒ Skill #7: Entanglement Emergencies – Swim or Sweep Method
- ❒ Skill #8: Entanglement Emergencies – SCBA Removal Method
- ❒ Skill #9: Wall Breach
- ❒ Skill #10: Changing Your SCBA Profile – Nonremoval Method
- ❒ Skill #11: Changing Your SCBA Profile – Low or Reduced Profile (Partial-removal Method)
- ❒ Skill #12: Changing Your SCBA Profile – Zero or No Profile (Full-removal Method)
- ❒ Evolution #1: SCBA Confidence Course
- ❒ Evolution #2: SCBA Awareness

Safety/Injury Reporting

Safety is of paramount importance in any training evolution. Fire fighter emergency escape methods will be practiced in accordance with the NFPA 101: Life Safety Code, 2009 Edition. Notify your instructor if you have any condition or limitation that may affect your participation in a training evolution. In addition, notify your instructor immediately if you sustain an injury during the class.

Sample Calendar of Events

DAY	TOPIC	TITLE	TIME	ACTIVITY
Day 1	1	Orientation And Administration	4:00	
	2	Developing A Survival Attitude		
	3	Preventing The Fire Fighter Emergency		
	4	The Fire Fighter Emergency		
	5	SCBA Emergencies		
	6	Fire Fighter Survival Skills	4:00	
		SCBA Emergency Procedure Check		Skill #1
		Calling "Mayday"		Skill #2
		Reading Couplings		Skill #3
		Window Hang		Skill #4
		Hose Slide		Skill #5
		Emergency Ladder Escape : Hook-two/Slide-to-four Method		Skill #6
		Day 1 Total	**8:00**	
Day 2		Entanglement Emergencies – Swim or Sweep Method	4:00	Skill #7
		Entanglement Emergencies – SCBA Removal Method		Skill #8
		Wall Breach		Skill #9

DAY	TOPIC	TITLE	TIME	ACTIVITY
		Changing Your SCBA Profile – Nonremoval Method		Skill #10
		Changing Your SCBA Profile – Low or Reduced Profile (Partial Removal Method)		Skill #11
		Changing Your SCBA Profile – Zero or No Profile (Full Removal Method)		Skill #12
	7	Fire Fighter Survival Evolutions	4:00	
		SCBA Confidence Course		Evolution #1
		SCBA Awareness		Evolution #2
		Day 2 Total	**8:00**	
		Course Total	**16:00**	

***Minimum course hours = 16:00**.*
If additional skills or evolutions are to be conducted, adequate time and materials must be added.

Topic 2: Developing a Survival Attitude

Scope: This topic serves to enhance fire fighter survival training by developing a survival attitude from gathered recommendations for multiple entities.
Terminal Learning Objective (TLO): At the end of this topic, the student will be able to describe recommendations for developing a fire fighter survival attitude.
Enabling Learning Objectives (ELO):
1. Describe the need to develop a fire fighter survival attitude.
2. Identify changes needed to reduce the potential for serious injury and death to fire fighters.
3. Describe studies performed to increase fire fighters' situational awareness and to enhance fire ground knowledge.
4. Describe recommendations used to empower and enhance fire fighter training to handle their own emergencies.

"They wrote in the old days that it is sweet and fitting to die for one's country. But in modern war, there is nothing sweet nor fitting in your dying." Ernest Hemmingway

Safety and Survival, Creating the Culture

Every year statistics are published regarding fire fighter fatalities. A number of causes are listed ranging from cardiovascular emergencies, motor vehicle accidents, to traumatic injuries. A review of the traumatic injury and LODD reports reveals that year after year, the causes of fireground fatalities remain the same. Fire fighters must maintain situational awareness at all times to avoid becoming one of the 100 or more fire fighters who perish annually in the line of duty. A cultural shift must occur in our profession if we hope to reduce these numbers. It is no longer acceptable to die in the line of duty. The cavalier attitude of some fire fighters must be replaced with one of overall risk management. Risk versus benefit analysis at every incident gives fire fighters a greater chance of leaving the fire scene and ultimately, their career, healthy.

"Insanity is doing the same thing over and over again and expecting different results." John Dryden

The National Institute for Occupational Safety and Health (NIOSH) reports do not specifically account for attitudes regarding safety and survival when publishing reports on fireground fatalities. Hauntingly, NIOSH LODD reports echo the same findings year in and year out -- the names, number of the dead, and location of the tragedies are all that change. The fact that fire fighters continue to die in the same situations points to a lack of knowledge and a cultural apathy regarding safety and survival. Unsafe practices and attitudes are an

unfortunate reality in our profession. We must strive to change the attitude in the fire service that it is noble to die while performing your job. A LODD will destroy families, cripple the psyche of fire organizations, and damage communities for many years after it occurs.

Year after year, the fire service lays to rest over a 100 fire fighters. There was once an "unspoken" competition with the members of the mining service: Which was the most dangerous job? We were neck and neck until the early 1960s, when the unions for the mining industry said "This is nuts!" And today, mining deaths are down—way down! Now the mining industry is averaging fewer than 60 deaths annually. Yet the fire service is still averaging over one hundred line of duty deaths.

Author unknown.

NIOSH Recommendations:

Ensure that interior search crews are protected by a staffed hoseline.

Ensure that fire fighters understand the influence of positive pressure ventilation on fire behavior and can effectively apply ventilation tactics.

Develop and implement standard operating procedures (SOPs) regarding the use of backup hoselines to protect the primary attack crew from the hazards of deteriorating fire conditions.

Develop and implement SOPs to ensure that incident command is properly established, transferred, and maintained.

Ensure that a Rapid Intervention Crew is established to respond to fire fighters in emergency situations.

Implement joint training on response protocols with mutual aid departments.

Consider developing more comprehensive training requirements for fire behavior to be required in NFPA 1001: Standard for Fire Fighter Professional Qualifications and NFPA 1021: Standard for Fire Officer Professional Qualifications and states, municipalities, and authorities having jurisdiction should ensure that fire fighters within their district are trained to these requirements.

Ensure that fire and emergency alarm notification is enhanced to prevent delays in the alarm and response of emergency units.

Ensure that adequate numbers of staff are available to immediately respond to emergency incidents.

Instruct and train fire fighters on initiating emergency traffic (Mayday-Mayday) and on the importance of activating their personal alert safety system (PASS) device when

they become lost, disoriented, or trapped ensure that fire fighters are trained in the tactics of defensive search.

Ensure that fire fighters performing fire-fighting operations under or above trusses are evacuated as soon as it is determined that the trusses are exposed to fire.

Ensure consistent use of PASS devices at all incidents and consider providing fire fighters with a PASS device integrated into their self-contained breathing apparatus, which provides for automatic operation.

Ensure that personnel equipped with a radio, position the radio to receive and respond to radio transmissions.

Ensure that fire fighters wear protective clothing whenever they are exposed or potentially exposed to hazards.

"Thoughts are things; they have tremendous power. Thoughts of doubt and fear are pathways to failure. When you conquer negative attitudes of doubt and fear, you conquer failure. Thoughts crystallize into habit and habit solidifies into circumstances." Bryan Adams

Attitude

Attitude is a mindset that affects behavior. Attitude can be a very powerful influence within an organization regardless of size, location, or structure. Positive attitudes towards the work environment can motivate, encourage team cohesion, and contribute to fire fighter fulfillment, all the while promoting the organization's vision, mission, and values. Positive attitudes can also lead to participation, problem solving, mentoring, longevity, and a commitment to excellence by those influencing and being influenced.

Safety, service delivery, pride in the organization, morale, and employee retention are just a few human resource-related areas in the fire service that can be strongly influenced by the attitudes of leadership and in turn, its members. Fire fighters must make a conscious decision to follow accepted safety practices. Most attitudes are the result of either direct experience or observational learning from the environment.

Developing the Right Attitude

This total commitment needs to be constantly displayed and promoted from the top of the organization down to the bottom. It also has to be absolute with no shortcuts taken in order to retain integrity in the program. When these things occur, safety then, becomes an attitude. The concept of safety should become an integral thread of an organization's culture.

Attitude is one of the critical components of the accident prevention formula:

ATTITUDE

TRAINING

SKILLS

KNOWLEDGE

EXPERIENCE

SUPERVISION

A deficiency in one of these critical components is often a direct contributing factor to the cause of an accident, injury, and/or death.

Learning and Attitude

The cognitive domain (knowledge) is reinforced in the classroom, the psychomotor domain (muscle memory) is displayed on the training ground, and the affective domain (attitude) is related to our values. Teaching students how to have heart, be motivated, and show passion for their role in the fire service is difficult. Proper direction and mentoring are keys to developing safe and successful fire fighters.

U.S. Government Involvement to Reduce Fire Fighters Injuries and Fatalities

The USFA is part of the Department of Homeland Security's Federal Emergency Management Agency (FEMA). The mission of the USFA is to foster a solid foundation in prevention, preparedness, and response by providing national leadership to local fire and emergency service agencies.

America's fire losses today represent a dramatic improvement from years ago. In 1971, this Nation lost more than 12,000 citizens and 250 fire fighters to fire. Acting to halt these tragic losses, Congress enacted the Federal Fire Prevention and Control Act, in 1974; it established the USFA and its National Fire Academy (NFA). Through data collection, public education, research and training efforts, USFA has helped reduce fire deaths by at least half making our communities and our citizens safer.

In 2002, the USFA released fire fighter death statistics for the years 1990-2000. While some of these statistics reflect situations that are not preventable, most are. The report was intended to help identify approaches that could reduce the number of fire fighter deaths in future years. The underlying theme or cause of most statistics is lack of a "Safety First" attitude. The mindset of the fire service must change if we are to alter future rates of injuries and fatalities. The leading cause of death for fire fighters is heart attack—from stress and overexertion—according to the USFA.

The second on the USFA list was trauma. Often aggressive interior fire-fighting operations are being conducted when the building is no longer capable of supporting human occupancy, especially ours. Perhaps the most unfortunate and easily preventable cause of fire fighter deaths—especially in the volunteer sector—is the high incidence of driver/operator deaths. We must demand the attitude of safe driver/operator programs that require regular training, certification, and testing.

2008 Firefighter Fatalities in the United States (USFA/FEMA)

In September 2009, the USFA released the 2008 Firefighter Fatalities report. One-hundred and eighteen (118) fire fighters died while on duty in 2008, the same number of fire fighter fatalities as the previous year. This total includes fire fighters who died under circumstances that are included in this report as a result of inclusion criteria changes resulting from the Hometown Heroes Act of 2003.

The lowest number of on-duty fire fighter fatalities recorded within the past three decades was 1992 with 77 fatalities, followed by 1993 with 81 fatalities. Unfortunately, we are still averaging over 115 on-duty fire fighter deaths in the last five year period from 2003 to 2007.

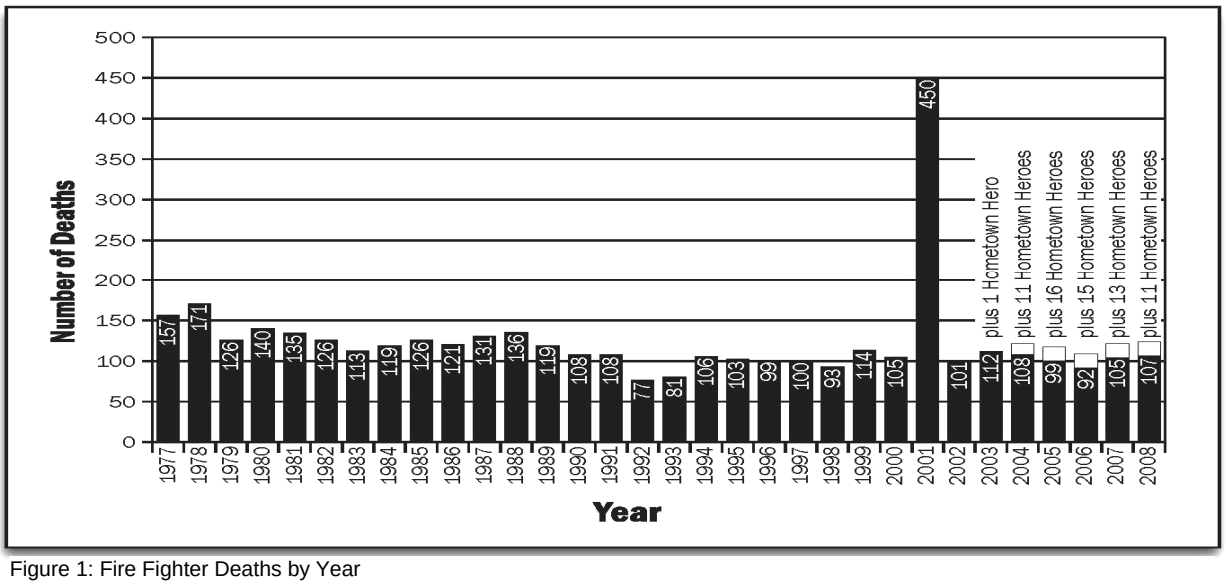


Figure 1: Fire Fighter Deaths by Year

Our industry is guilty of missing some of the factors that should dictate how we operate on fire scenes and how fire behaves in buildings. We need to continue to be well versed in fire behavior concepts and ever-changing construction methods. With today's lower incident of structure fires, our high-risk/low-frequency operations should stress the underlying attitude that safety comes foremost in all issues. Why do we establish safety policies that we do not universally enforce in all areas?

Programs that support fitness and an overall mindset of safety must continue to be created and maintained in the interest of saving our own. The mindset of the fire service must change if we are to alter future rates of injuries and fatalities.

Fatalities by Cause of Fatal Injury (USFA/FEMA)

Stress or overexertion is still the most frequent cause of death for 2008, with 52 fire fighter deaths.

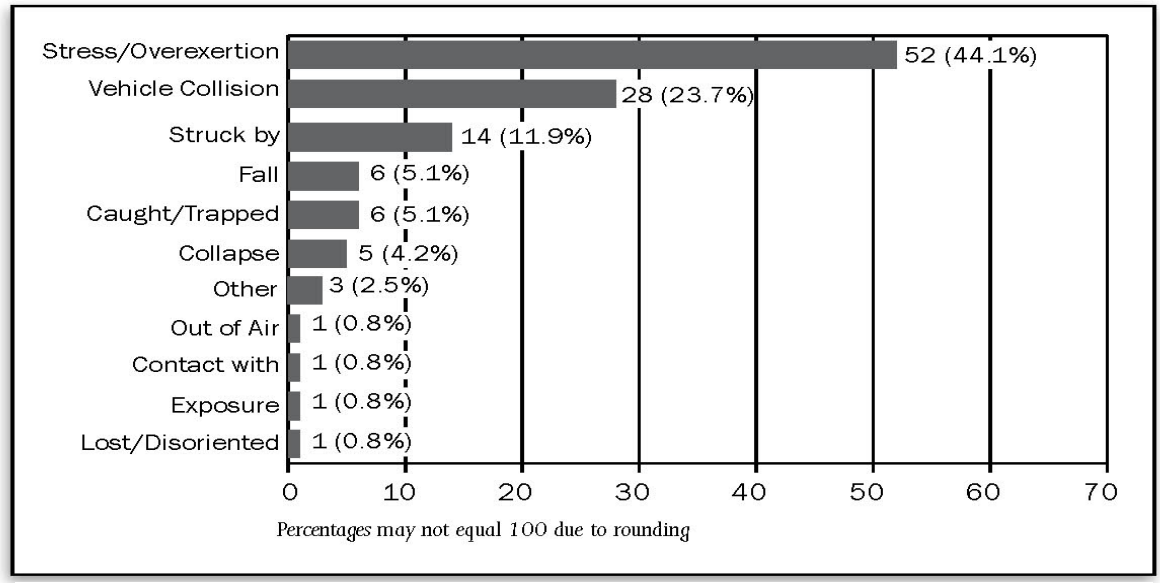


Figure 2: Cause of Fatal Injury

Lost or Disoriented

One fire fighter died in 2008 when he became lost or disoriented inside a residential structure fire. The fire fighter was on the first engine to arrive on the scene. He and another fire fighter advanced a hoseline to the front door of the residence. One of the fire fighters was sent back to the fire truck for a tool. When he returned, his partner was gone and the nozzle remained by the doorway. At the same time, the fire inside the structure intensified.

Caught or Trapped

Six fire fighters were killed in five incidents when they were caught or trapped in 2008. This classification covers fire fighters trapped in wildland and structural fires who were unable to escape due to rapid fire progression and the byproducts of smoke, heat, toxic gases, and flame. This classification also includes fire fighters who drowned, and those who were trapped and crushed.

- ❒ One fire fighter was trapped while conducting a search of a duplex residence when the water supply to the fire scene was interrupted due to frozen hydrants.
- ❒ One fire fighter on the nozzle of a line that was advanced into the basement of a residence was trapped and overcome by heat conditions when trying to escape and encountered a blocked door.

- ❒ Two fire fighters of a four-person crew were caught and trapped as fire conditions rapidly changed due to the collapse of an interior wall of a large 79,000 square foot manufacturing occupancy structure.
- ❒ One fire fighter was caught by rapid fire progress after he and another fire fighter, both on the first truck to arrive on scene, advanced a charged 1¾" preconnected handline into a residential structure, but then had difficulty locating the fire as smoke and heat conditions intensified. The two fire fighters became separated and rapid fire progress occurred.

Collapse

Five fire fighters in four incidents died in 2008 as the result of structural collapses.

- ❒ Two fire fighters in the basement of a residential structure were buried under collapsed structural components when a large portion of the first floor collapsed.
- ❒ One fire fighter was operating a nozzle at a doorway of a commercial occupancy structure when a two-story brick façade collapsed outward, pinning him as he was running away.
- ❒ One fire fighter was crushed by debris while putting out hotspots in the attic of an abandoned residential structure when the roof collapsed.
- ❒ One fire fighter's helmet and facepiece were dislodged by a collapse while working in the attic of a residential structure fire.

Fall

Six fire fighters died in 2008 as the result of falls.

- ❒ One fire fighter fell into the fire-involved basement of a residential structure and died from positional asphyxiation when he was crushed by debris, principally a couch, and was unable to breathe.

Out of Air

- ❒ One fire fighter died of smoke inhalation and thermal burns on the 14th floor of a high-rise residential occupancy. The fire fighter ran out of air less than 20 minutes after donning his facepiece and was unable to exit the apartment before being overcome.

Focusing our Attitudes towards Fire Fighter Survival

Adjust our attitudes; learn from "close calls." To get the job done, fire fighters need to be safe and aggressive. Sometimes fire fighters push a little farther or try to "squeeze" another few minutes out of an air bottle. Sometimes fire fighters act on limited information, which leads to less than ideal assessments, decision making, and errors. These "close calls" are unintentional. However, real change could result if a department or station environment encouraged fire fighters to share their "close-call" experiences with other members. This attitude adjustment would also require fellow fire fighters to listen to descriptions of "close calls" with an open mind, without ridicule and judgmental comments that disrupt an opportunity to learn.

Stay up-to-date with trends in the fire service by visiting www.firefighterclosecalls.com

Dedication toward Health and Wellness

Fire departments and fire fighters need to practice health and wellness concepts. Fire fighters need to practice a healthful lifestyle with proper diet, exercise, and preventative health measures. Implementing health and wellness programs in fire departments are often hampered by budgets and logistics. However, the important thing is for fire departments and fire fighters to move in the right direction. Like an athlete, being fit and ready for action has dual benefits. It not only enhances your capability to perform your job, it could save your family from needless suffering.

Focused on Training and Gaining Knowledge

Fire departments and fire fighters are required to train on so many mandatory topics that there is little time to train or practice in areas for self-improvement. Fire departments and fire fighters need to dedicate some time to train on topics with which members are uncomfortable or that are infrequently discussed. The topics could be specific to a company or an individual. If a fire fighter determines that he is not comfortable with building construction, reading fire conditions, or safety, that member should have an opportunity to receive that training. The opportunity is created by making time and basic resources available. A solid knowledge of basic fire-fighting skills in engine or truck work, rescue, building construction, fire behavior, size-up, and communications is essential if you are going reduce fire fighter deaths. Do not learn in a bad situation, learn from other situations that went bad. By addressing these gaps in knowledge, skills, and abilities, the company will become stronger and safer.

The fire service needs to amend its "can-do, will-do" attitude by tempering it with an attitude that supports the concept of "accidents and injuries are not a part of the profession and are preventable." We need to create a team atmosphere where each of us helps the other to be aware of the little things we do that may lead us down the path to the major accident.

"If I always appear prepared, it is because before entering an undertaking, I have meditated long and have foreseen what might occur. It is not genius where reveals to me suddenly and secretly what I should do in circumstances unexpected by others; it is thought and preparation." Napoleon Bonaparte

Summary

The single most important and far-reaching action the fire service can take to reduce fire fighter injuries and deaths is to change its attitude. We must change our attitude to positively impact these statistics. If the USFA's goal of cutting fire fighter deaths by 25% is to be a reality, then it is clearly the responsibility of all of us—the fire service, each fire department, every fire officer, and every fire fighter—to define our attitude and actions as genuinely "***safety first***."

Topic 3: Preventing the Fire Fighter Emergency

Scope: This topic serves as an introduction to preventing the fire fighter emergency.
Terminal Learning Objective (TLO): At the end of this topic, the student will be able to recognize and evaluate a potentially hazardous situation.
Enabling Learning Objectives (ELO):
1. Describe the key elements of conducting a thorough size-up.
2. Describe the importance of a concise size-up.
3. Describe the proper procedures for preincident planning.

NIOSH Case Study: Arizona (F2001-13)

Supermarket Fire Claims the Life of One Career Fire Fighter and Critically Injures another Career Fire Fighter

NIOSH – Fire Fighter Fatality Investigation and Prevention Program July 25, 2002

On March 14, 2001, a 40-year-old male career fire fighter/paramedic died from carbon monoxide poisoning and thermal burns after running out of air and becoming disoriented while fighting a supermarket fire. Four other fire fighters were injured, one critically, while fighting the fire or performing search and rescue for the victim. The fire started near a dumpster on the exterior of the structure and extended through openings in the loading dock area, into the storage area, and then into the main shopping area of the supermarket. The fire progressed to five alarms and involved more than 100 personnel. Fire fighters removed the victim from the structure and transported him to a local hospital where he was pronounced dead.

Photo 1: Southwest Aerial View of the Supermarket

NIOSH recommends:

Ensure that a proper size-up, using common terminology, is conducted by all fire fighters responsible for reporting interior/exterior conditions to the Incident Commander (IC).

Ensure that pre-incident plans are established and updated on mercantile occupancies in their district.

Ensure that fire fighters manage their air supplies as warranted by the size of the structure involved.

Instruct and train fire fighters on initiating emergency traffic (Mayday-Mayday) and on the importance of activating their personal alert safety system (PASS) device when they become lost, disoriented, or trapped.

Ensure that multiple Rapid Intervention Crews (RIC) are in place when an interior attack is being performed in a large structure with multiple points of entry.

Building owners should consider upgrading or modifying structures to incorporate new codes and standards to improve occupancy and fire fighter safety.

Fire departments should consider as a part of their pre-incident planning, educating the public they serve on the importance of building owners, building personnel, or civilians immediately reporting any fire conditions to the first-arriving fire company on the scene.

Manufacturers and research organizations should conduct research into refining existing and developing new technology to track the movement of fire fighters inside structures.

Size-up

Size-up is the mental process of evaluating all of the influencing factors at a fire scene before committing personnel and equipment to a course of action. Size-up is the most important factor regarding fire fighter survival. Many fireground tragedies are a direct result of improper or incomplete size-up. Conducting a thorough and ongoing size-up is a critical component of situational awareness. True situational awareness cannot exist if adequate and continuing size-up is not performed as an incident evolves. An all-inclusive size-up sets the incident up for overall success.

To maintain good situational awareness, it is important that you identify the three main areas that require continuous size-up.

➢ YOUR SITUATION ➢

➢ EXTERIOR SIZE-UP ➢

➢ INTERIOR SIZE-UP ➢

Your Situation

Size-up begins before dispatch, with a candid evaluation of your own knowledge, skills, and abilities (KSAs), as well as those of the entire crew. Keeping your KSAs in mind is part of your overall risk-versus-benefit analysis.

Fire fighting is an inherently dangerous occupation. By learning to examine your own situation, you can avoid placing yourself and your crew in jeopardy. Just like structural size-up, your personal size-up begins well before you are dispatched to an incident. Key elements that you must be aware of when sizing up your personal situation are:

- YOUR KSAs
- YOUR CREW'S KSAs
- AGE AND PHYSICAL ABILITY OF YOU AND YOUR CREW
- FIRE CONDITIONS
- RATE OF AIR CONSUMPTION

In a structure fire, you must continually watch these elements and give them the maximum priority. Without monitoring these factors, situational awareness cannot be maintained.

In the fire environment, the importance of monitoring air consumption, fatigue and its affects, progress, location, and accountability, cannot be overemphasized. These factors can be the difference between success and disaster. Fire fighters who remain vigilant of these factors will reduce the likelihood of becoming lost, trapped, or injured during the course of an incident. All fire fighters must know their limitations based upon their KSAs and must function within those parameters.

Air Consumption

One of the main factors that limit your ability to operate effectively at an incident is how quickly you consume the air contained in your SCBA. You must have a precise understanding of how long you can work under fire conditions while on-air. Crews should monitor their air supply closely while in an immediately dangerous to life and health (IDLH) environment, and appreciate that air consumption rates increase with fatigue. Fatigue can lead to loss of situational awareness and errors in judgment. You must have enough air in reserve to safely exit the hazard area prior to low-air activation.

Communication

A key aspect of safe operations is clear communication. Strategy and tactics must be clearly communicated and understood by all present at a fire scene. Crews should be efficient and adept at communication on all levels. Officers must relay pertinent information to command such as personnel accountability report (PAR), entry point, and air prior to entering the

hazard zone. Once inside, crews must continually update Command with timely PAR, conditions-actions-needs (CAN), location, and air reports. The discipline of transmitting timely and accurate updates helps to maintain accountability, crew integrity, and reduces the occurrence of freelancing.

Exterior Size-up

It is important to remember that as with any size-up, structural assessment begins well before the dispatch of a structure fire. The first phase of the size-up process begins by preincident planning buildings and hazards in your response area. Risk-versus-benefit measurement occurs when target hazards, unique construction features, and building history are identified ahead of time. Other components to ponder are response times in the area, staffing, and resources available to combat a fire in the building that is being evaluated.

During the preincident plan phase of size-up, fire personnel should consider a number of aspects when evaluating structures. Construction type, size, height, and roof type are important when assessing structures prior to an emergency. Access and egress points should be identified, as well as potential breach points should personnel become cut off from primary exit routes. It is also important to note the location of utilities, standpipe locations, sprinkler connections, hazardous materials on the premises, heavy loading on the roof, and any obstructions that could impede the ability of fire fighters to gain access to the building.

Proper preincident planning allows fire crews to begin size-up while en route to the scene. By performing hazard assessment prior to an emergency, personnel are one step ahead of the incident. Within a few seconds of arrival, you can start to identify the fire intensity and possible location within the structure by reading smoke and visible flame. Through preincident planning, building size, number of stories, and configuration have already been identified. Taking time to evaluate the structure and its disposition allows company officers and fire fighters to determine the complexity of an incident, make appropriate suppression decisions and prepare for additional resource requests.

Before making a fire attack, it is essential that an exterior lap encompassing all six sides of the structure be taken to identify potential hazards, building features, points of access and egress, fire location and activity, or any other dangers or obstacles presented by the structure.

Interior Size-up

After completing an exterior size-up of the structure, it is now necessary to make an interior size-up of the building. The interior size-up can begin well before the onset of the emergency with preincident planning and area orientation. On the fireground, the interior size-up can be started during the exterior size-up by using windows and doors to gain a vantage point. Once you enter a burning structure, you must continuously size-up the interior to locate potential hazards, maintain orientation, locate points of egress, identify structural integrity, and be aware of the fire activity.

Potential Hazards

- ❒ Energized utilities.
- ❒ Items causing entanglement.
  - Wires.
  - Cords.
  - Cables.
  - Drop ceilings.
  - Heating ducts.
- ❒ Items causing entrapment.
  - Falling materials.
  - Wall collapse.
  - Structural collapse.
  - High-piled storage.
  - Hazardous materials.

Orientation

- ❒ Building layout and configuration.
  - Open space/warehouse.
  - Compartmentalized.
  - Center hallway.
- ❒ Established an exterior anchor point.
- ❒ Identified egress points.
- ❒ Interior construction.
  - Wood frame.
  - Metal.
  - Masonry.

Egress

- ❒ Doors.
  - Type.
  - Locking mechanisms.
  - Locations.
- ❒ Windows.
  - Size.
  - Height.
  - Barred.
  - Location.
  - Possible breach points.

- ❒ Building material to be breached.
  - Areas to enlarge openings.
  - Cripple walls.

Structural Integrity

- ❒ Damaged or compromised floors.
  - Sagging.
  - Soft.
  - Bowed.
- ❒ Damaged or compromised ceilings.
  - Sagging.
  - Falling debris.
- ❒ Damaged or compromised walls.
  - Bowed.
  - Shifted.
- ❒ Compromised door jams.
  - Fire damage.

Fire Location and Activity

- ❒ Determine the involved area of the structure.
- ❒ Identify the material being burned if possible.
- ❒ Determine the direction of fire spread.
- ❒ Be aware of fire activity and intensity.
  - Rollover.
  - Thermal balance.
  - Indications of flashover.
  - Fire above in void spaces.
  - Fire below.
  - Smoke volume, velocity, density, and color.

Smoke

Smoke is a product of incomplete combustion composed of solids, aerosols, and fire gasses that are toxic, flammable, and very volatile. Smoke is a fuel source at any structure fire waiting for the right mixture and temperature to ignite. Some of the events that injure and kill fire fighters every year are flashover, backdraft, smoke explosions, and rapid fire spread. Being able to read the characteristics of smoke and understand fire dynamics may reduce catching you off-guard to these events.

Reading Smoke

Reading smoke is by no means an absolute, yet a source of information to gather along with other factors on the fireground to establish a safe operation. The characteristics of smoke: volume, velocity, density, and color are used to determine what may be burning, what stage the fire is at, the location of the fire and if the structure itself is safe to enter to perform search and interior attack operations.

Volume

Volume may indicate the amount of fuel that is off-gassing in a given space. A high volume of smoke can occur with hot, fast, moving fire in an under-ventilated building, dampened material, and/or low mass contents. The volume of smoke may be used to determine proper hand line for an attack operation.

Velocity

The velocity of smoke is defined by the speed at which it leaves the building and is an indicator of the pressure within the structure. Turbulent smoke may be a sign that the smoke is ready to ignite and a flashover is likely to occur. Laminar smoke on the other hand is a smooth smoke flow indicating the heat of the smoke is being absorbed. Velocity may also assist in locating the fire.

Density

Density refers to the thickness of the smoke. Density is an indicator of how much fuel is laden in the smoke. Thick smoke spreads a fire event further than less dense smoke. Keep in mind that thick, black smoke in a compartment reduces the chance of survivability. Density is the most important characteristic of smoke as dense smoke accompanied with high heat banked to the floor level indicates flashover may be imminent!

Color

Color of smoke indicates the stage of heating and points to the location of the fire in the structure. The blacker the smoke, the more heat output. You must be aware of black dense smoke as this is a warning to eminent flashover. Grey to white smoke with high velocity may indicate a hot fire that has traveled some distance within the structure. Brown smoke exiting from the structure indicates unfinished wood is burning. This may indicate the fire has transitioned from the contents to the structure itself.

On July 21, 2007, a 34-year-old career captain and a 37-year-old engineer died while conducting a primary search for two trapped civilians at a residential structure fire. The two fire fighters where found by crews in a back bedroom where they had been overcome by a rapid fire event. NIOSH Report F2007-28

Building Construction

Although many things can happen unexpectedly and without warning while operating in the fire environment, there are proactive measures that you can take to better equip you when the alarm comes in. Knowing the building construction in your response area and how different building components react when exposed to high temperatures and direct fire impingement will better protect you from being caught off-guard by building collapse events.

Preincident Planning

With building construction constantly changing and buildings regularly being modified with new business owners, preincident planning is a proactive approach for you to be aware of the environment in which you will be operating. When conducting the preincident plan, the following items should be addressed and all personnel should be aware of the overall hazards associated with each.

Conventional Construction vs. Lightweight Construction

Conventional construction is becoming outdated with the more common use of lightweight construction. Conventional construction, which used true dimensional solid lumber held together by nails, has been replaced with smaller lightweight material held together by fasteners or glue, such as glue laminated beams or Gluelam. Lightweight construction, such as a truss, is cheaper and faster to erect and many times sent to the jobsite prebuilt. Under normal circumstances, lightweight construction does not pose a problem to fire fighters. Once introduced to the fire environment of today with higher temperatures and faster burn rates, these lightweight structural members are failing at alarming rates.

Lightweight Wood Truss Construction

According to the Wood Truss Council of American (WTCA), lightweight wood trusses are used in more than 60% of all buildings in the United States. Many fire fighters have been injured or killed when operating above or below lightweight construction that has collapsed. These structural elements use lightweight wood members (2"x4", 2"x6", or 2"x8") that are held together by fasteners that penetrate the wood at approximately ½-inch. If it is determined that these structural members are exposed to fire, all fire fighters must be evacuated from the area. More information can be found in the NIOSH Alert: Preventing Injuries and Deaths of Fire Fighters due to Truss System Failures, April 2005.

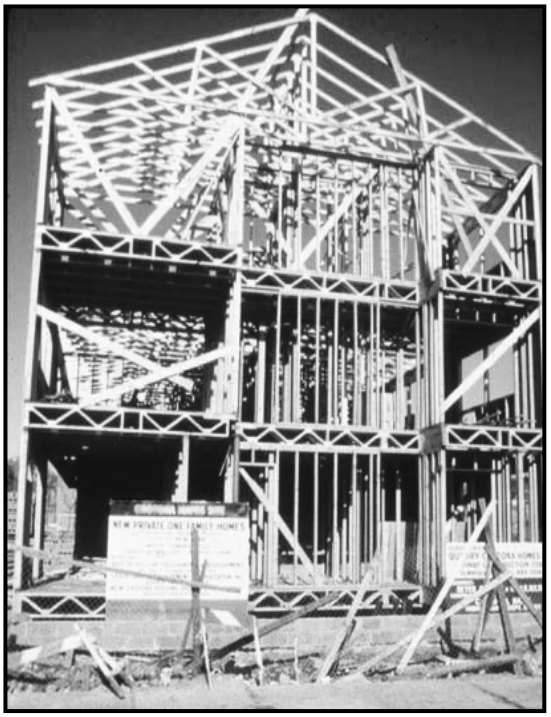


Photo 2: Lightweight Wood Truss Construction

Lightweight Steel Construction

Photo 3: Lightweight Steel Construction

Engineered lightweight steel construction is becoming more common replacing solid wood roof and floor systems mostly due to its cost effectiveness. Steel has no fire resistive properties and unprotected steel, when exposed to temperatures ranging from eight hundred to twelve hundred degrees Fahrenheit, may not be able to support its load. The use of lightweight steel joist has also created spans up to eight feet, vs. wood joist which were spaced sixteen inches. These spans create larger collapse areas when one of the joists fails. Additionally, if one joist fails more weight will be distributed to the other joist on the floor or roof. This new load may exceed the designed load of the joist causing a larger collapse.

Engineered I-joists

Photo 4: Engineered I-joists

Wood I-joists are composed of two horizontal components called flanges and a vertical component called a web. Wood I-joists are used as a framing material primarily in floors, but may also be used as roof rafters where long length and high load capacity are required (American Forest and Paper Association).

These beams have been known to fail in less time than lightweight wood trusses. In one case, a floor supported by an I-joist failed after being exposed to fire at four minutes and forty seconds sending a fire fighter into a basement (NIOSH Report F2007-07). Oftentimes, these manufactured beams are penetrated by utilities, reducing strength and fire resistance. More information on I-joist can be found through American Forest and Paper Association.

Large Area Floor Design

Performing search operations in large, open-floor buildings such as those in home improvement stores, warehouses, and supermarkets may be difficult due to the lack of interior partition walls. The use of rope for search lines may be needed to ensure a means to safely enter and exit the building. Additionally, search lines, when used properly, will ensure the area being searched has been adequately covered. Regardless of what tools will be used to assist search operations in large area buildings, you must be aware of these buildings and their layout if they are located in your response area.

Fire Loads

Today's homes contain different fuels than in the past; solid and foamed plastics have replaced natural products such as cotton, wood, wool, etc. These synthetic fuels combined

with the insulating properties of newer homes have created faster burning fires with more intense heat output. This is one reason why fire fighters are seeing faster flashover rates than backdraft rates as in those of fires in the past. When performing preincident planning, take note of the type of fuels, as well as the amount of fuel, contained in the structure. This knowledge can dictate not only proper attack methods such as choosing a 2½" hoseline over a 1¾" attack line, but may also determine the need for additional personnel and equipment.

High-target Structures

Fires in structures, such as abandoned homes and commercial facilities, will pose safety hazards to responding fire fighters. These buildings create a problem mainly due to the lack of maintenance and being exposed to the elements. Wood may begin to rot from water leaking in from holes in roofs and cracks in the walls. This deterioration will, in turn, weaken overall strength and increase burn rates to roofs, walls, and floors. Older masonry buildings that contain sand and lime mortar, such as many unreinforced masonry buildings, may have weakened load-bearing walls caused by unattended leaks allowing water to deteriorate the mortar. Additionally, abandoned structures may present an egress problem to interior crews as doors and windows are commonly boarded up to keep out transients.

Photo 5: High-target Structure

Training

One of the best ways for you to prevent the fire fighter emergency is to train and be prepared. Performing company drills or simply getting out of the firehouse to throw ladders or preplan a new building in the area is a proactive approach to prevent a fire fighter emergency. All aspects of fireground skills such as SCBA proficiency drills, search evolutions for civilian and missing fire fighters, building construction, interior attack evolutions, hose management, etc., should be performed on a regular basis, not only for professionalism but also to ensure you are performing your job safely.

Physical Fitness

Physical fitness is widely overlooked when discussing training. It is a fact that the number one killer of fire fighters is heart attacks. (*See NIOSH: Preventing Fire Fighter Fatalities Due to Heart Attacks and Other Sudden Cardiovascular Events DHHS (NIOSH) Publication No. 2007-133).* This is mainly due to lack of physical fitness and/or an unhealthy diet. Fire fighters that do not stay physically fit or have an unhealthy diet will most likely find themselves depleting more air in the IDLH environment and having to exit the structure faster due to fatigue.

Summary

As we all know, this is the most dangerous time to be a fire fighter. We are running fewer fires today than in the past, yet fire fighter injuries and fatalities continue at an alarming rate. Constantly sizing up the situation of you and your crew in the fire environment and on the fireground, understanding fire dynamics and certain characteristics of smoke, keeping up with the always changing engineered building construction, preincident planning buildings in your areas, being aware of which structures present special hazards, and most importantly training is now more than ever not just a part of the job -- ***your life depends on it!***

Topic 4: The Fire Fighter Emergency

Scope: This topic serves as an introduction to the fire fighter emergency.
Terminal Learning Objective (TLO): At the end of this topic, the student will be aware of preventing the fire fighter emergency, recognizing a fire fighter emergency, and proper procedures for calling and dealing with the fire fighter emergency.
Enabling Learning Objectives (ELO):
1. Describe the ways to prevent a fire fighter emergency incident.
2. Define situations which create or may create a fire fighter emergency.
3. Describe the proper procedures for calling the fire fighter emergency.

Sacramento Fire Department Green Sheet: Burn Injuries (SFD #55285)

On October 7, 2008, at approximately 0929 hours, the Sacramento Fire Department responded to a structure fire located at 17 Stilt Court. A first alarm structure response was dispatched and Engine 15 was first to arrive at 0935 hours reporting "heavy dark smoke coming from the second floor." Engine 15 initiated an offensive attack and an attack line was moved into position onto the second floor.

Engine 18 arrived, assumed Command, and sent one additional fire fighter to assist Engine 15. As the other companies began to arrive, smoke conditions began to change drastically forcing crewmembers out of the building, which separated the crewmembers of Engine 15. As the three fire fighters exited the Alpha side of the building, a Mayday was called for the Captain from Engine 15.

The Captain from Engine 15 was able to exit the building and was located on the Charlie side of the building. The Captain and all three fire fighters were transported to the University of California Davis Medical Center for treatment.

Conditions

- ❒ Weather conditions observed from the Regional Dispatch Center 10-7-08 at 0923.
  - Temperature: 63.9ºF
  - Humidity: 75%
  - Wind speed: 4 mph
  - Wind direction: North
  - Visibility: Clear
- ❒ Structure
  - Two-story single family residence.
  - Wood frame with a tile roof.
  - 2448 square feet.

Sequence of Events

On October 7, 2008, Sacramento Regional Fire Emergency Communications Center (SRFECC) received multiple calls for a building fire located at 17 Stilt Court with smoke coming from the second floor.

At 0929, SRFECC dispatched a residential structure assignment for Sacramento Fire Department (SFD) consisting of three engine companies, two truck companies, two Battalion Chiefs, and one ALS medic. SFD staffs four-person companies. Engine 15, Engine 18, Engine 30, Truck 2, Truck 5, Battalion Chief 3, Battalion Chief 4, and Medic 30 were assigned to the initial dispatch reported as "structure fire with visible smoke."

Engine 15 arrived first on-scene (6 minutes and 7 seconds) after initial dispatch and reported heavy dark smoke from the second floor. They took fire attack and requested the second due engine to take command, water supply, and pull a backup line. Engine 15 crew, consisting of the Captain, nozzle fire fighter, and a backup fire fighter stretched a 1¾" hoseline to the second floor.

E18 arrived 35 seconds after E15 with only three (3) crewmembers: the acting Captain, nozzle fire fighter, and Engineer. Engine 18's acting Captain established Stilt Command and directed the nozzle fire fighter to pull a backup line.

Command was able to get a 360 of the building, opened up a sliding glass door on the Bravo side and noticed two windows opened on the Bravo side on the second floor. Command went back to the Alpha side of the building and noticed the Engine 18 nozzle fire fighter assisting in stretching the initial attack line from the front door. Command ordered Engine 18 nozzle fire fighter to assist Engine 15 with stretching the hoseline upstairs. Command then advised the third arriving engine to staff the backup line. The water supply was established with Engine 18 on the hydrant feeding water to Engine 15.

Engine 15 Captain advised Command that they were not able to locate the fire on the second floor and that they needed positive pressure ventilation. Command advised the Engine 15 Captain that there were no truck companies on-scene and a door was opened on the outside of the building. Engine 15 Captain opened three windows on the second floor, one window at the top of the stairs and two windows in the master bedroom.

Engine 30 and Medic 30 arrived on-scene (3 minutes and 42 seconds) after Engine 15. Engine 30 nozzle and backup fire fighters began masking up on the front lawn, preparing to staff the backup line. Engine 30 Engineer threw a 24-foot extension ladder to the Bravo/Alpha corner of the building and Medic 30 fire fighter threw a 14-foot roof ladder to the Alpha side of the building. The smoke conditions in the interior began to deteriorate. The Medic 30 fire fighter went to the Delta side of the building and noticed fire coming out of a window on the Delta side. The Medic 30 fire fighter used a 2"x4" to clear the window glass and remove smoke from the building. Before breaking the window glass, the Medic 30 fire fighter noticed the window was cracked. The Medic 30 fire fighter then broke out the sliding glass door and removed the screen on the Charlie side. After the Medic 30 fire fighter evaluated the Bravo side of the building, the Medic 30 fire fighter went back to the Alpha side and advised the Engine 30 Captain that the fire was on the first floor in the Charlie/Delta corner. The Engine

30 Engineer had opened up the side door on the Delta side and the garage door on the Alpha side. When the Engine 30 Engineer opened the interior door to the kitchen and discovered heavy fire conditions, Engine 30 Engineer closed the door. The Engine 30 Engineer immediately advised the Engine 30 Captain that the first floor was fully involved.

Conditions quickly deteriorated followed by the hoseline going flat. It became immediately apparent, by all crewmembers, that they needed to exit the building. Engine 18 nozzle fire fighter and Engine 15 backup fire fighter escaped down the stairway exiting through the Alpha side via the front door. Engine 15 nozzle fire fighter exited a window located at the top of the stairs and onto the roof of the garage. Engine 15 Captain retreated to the master bedroom searching for windows he had opened earlier. Unable to locate the windows, the Engine 15 Captain decided to follow the hoseline down the staircase.

As fire fighters began to exit the building, Stilt Command discovered that the Engine 15 Captain was unaccounted for and initiated a Mayday. Shortly after the Mayday, the Engine 15 Captain was located in the backyard on the Charlie side of the building. By his own account, the Engine 15 Captain came down the stairs, dove over the railing, and ran out a sliding glass door on the Bravo side.

Truck 2 with five fire fighters and Truck 5 arrived simultaneously (approximately 4 minutes and 23 seconds) after Engine 15. Truck 2 began exterior operations with setting up the aerial and ground ladders on the Alpha side at which time, Truck 5 prepared to enter the building for a search of the interior.

Battalion Chief 4 arrived on-scene (9 minutes and 18 seconds) after Engine 15 arrived requesting a transfer of command and was advised of conditions and the initial Mayday. Battalion Chief 4 took over Command and acknowledged the priority traffic. Command ordered all personnel out of the building and to get an account of all members from Engine 15. Command began to move Medic units into position and conduct a PAR. An "emergency traffic" was broadcast by the Truck 2 Captain, advising Command that a Medic unit was also needed at the Charlie side of the building.

Battalion Chief 3 moved to the Charlie side of the building and established the Safety position. Safety assisted Command with a PAR of crews operating on-scene.

All members from Engine 15 and Engine 18 were located and moved into Medical units. Medic 30 transported the Captain from Engine 15 with the most severe burns to University of California Davis (UCD). The three fire fighters were moved into Medic 17 and transported to UCD.

Injuries/Damages

- ❒ Engine 15 Captain suffered serious 2nd degree burns on the hands, neck, and left ear.
- ❒ Engine 15 nozzle fire fighter and Engine 15 backup fire fighter suffered moderate 2nd degree burns to the ears and hands.
- ❒ Engine 18 nozzle fire fighter suffered 2nd degree burns to the ears, neck, hands, and leg.

Safety Issues for Review

- ❒ Need for secondary hoselines for protection of stairwell and/or floors in multiple story buildings.
- ❒ Appropriate staffing levels on incoming companies to perform fire operations.
  - Prioritize needs for fire scene.
- ❒ Ventilation techniques performed in coordination with fire attack.
- ❒ Proper use of radios to advise crews of specific actions or conditions, i.e. location of fire, ventilation activities performed.
- ❒ Proper personal protective equipment (PPE) worn on fire scene.
  - This includes all members operating on the fire scene.
- ❒ Ensure that all members are compliant of SFD fire fighter accountability tracking system.

The Term "Mayday"

The term "Mayday" comes from the Maritime industry and has been the universal distress call for nearly a century. Mayday literally means 'Help me' when translated from its French derivative. Mayday in the fire service arena should mean that a fire fighter is in a life threatening situation and requires immediate and aggressive intervention.

Per ICS 910: Firefighter Incident Safety and Accountability Guidelines, FIRESCOPE, July 2008

When fire fighters or response personnel are faced with life-threatening emergencies, they may call for help using a variety of terms that may include the use of "Mayday," "Help," or "Responder down." The acronym "Mayday" is used by some fire agencies as a distress signal (hailing call) indicating a fire fighter is in trouble.

In compliance with NFPA 1500 and 1561 standards, Incident Commanders shall acknowledge the person in trouble declaring "Emergency Traffic" to clear radio traffic. Clear text shall be used to identify the situation of emergency.

The rescue of fire fighters who are lost, trapped, injured or running out of air is extremely time sensitive. The sooner a fire fighter can process information and realize that they are in a life threatening situation and call for help the sooner the mechanism for rescuing the fire fighter can be activated. If a fire fighter waits until their last breath to call for help because of loss of situational awareness, pride, or denial, they have all but guaranteed a grim outcome. All fire fighters must be thoroughly trained in recognizing when they are in a dangerous situation that

they cannot extricate themselves from and be able to communicate important information to aid the Rapid Intervention Crew (RIC) or other crews in finding them. The military model of recognition prime decision-making (RPD) simulator training is often used to train fire fighters to act in an appropriate manner when faced with a fireground emergency.

Across the nation, fire fighters are faced with perilous situations that many are able to escape from, but others tragically do not. Most investigations of LODDs identify factors that are common to all fire fighter fatalities. The NIOSH report after nine fire fighters died in the line of duty while battling a furniture warehouse blaze in Charleston, South Carolina on June 18, 2007 contained the following recommendations regarding fire fighter emergency situations:

NIOSH recommends:

Ensure that Mayday transmissions are received and prioritized by the Incident Commander.

Train fire fighters on actions to take if they become trapped or disoriented inside a burning structure.

Ensure that fire fighters are trained in air management techniques to ensure they receive the maximum benefit from their SCBA.

Preventing the Fire Fighter Emergency

Prior to initiating suppression efforts, all fire fighters should conduct a risk versus benefit analysis as part of their initial size-up. Fire fighters must maintain situational awareness at all times while operating at an incident to be aware of critical factors which could contribute to personnel becoming lost, trapped, or injured. Risk versus benefit analysis and thoughtful implementation of tactics and strategy are vital to maintaining fire fighter safety as an incident evolves. Company officers must consider the KSAs of their crew as well as age and physical abilities when assigning tasks. Fire fighters must be skilled in recognizing the "triggers" that set the chain of events in motion leading to fire-fighting personnel emergencies. Sound, fundamental fire-fighting and search techniques should be employed at all times to guard against getting lost or trapped during an incident. Fire fighters should remain vigilant as to what is occurring both inside and outside of the structure as a result of fire conditions. Interior crews must maintain an awareness of their own location within the structure. Communication and coordination between interior crews, exterior crews, and command is essential to maintaining safety. All members must be aware of the strategy and tactics to be sure that the two are not conflicting. Crews should remain together at all times, monitor their air consumption, stay in contact with anchor points (hose, wall, search line), and give frequent PARs, CAN, location, and air reports to command.

Recognizing the Fire Fighter Emergency

"We are given one life and the decision is ours whether to wait for circumstances to make up our mind or whether to act, and in acting, to live." General Omar Nelson Bradley

There are many different situations that a fire fighter can encounter that warrant calling a fire fighter emergency. Some situations can be simply mitigated by the fire fighter with assistance from a partner or nearby crew. If the fire fighter is able to self rescue, the fire fighter emergency should be canceled. Some situations are complex and may require additional resources, personnel, and equipment. These situations require swift and deliberate action by the endangered fire fighter. The fire fighter must call the emergency immediately upon determination that a fire fighter emergency is encountered and self rescue is impossible. This allows for timely dispatch of the RIC to aid the fire fighter in distress. It is important to emphasize the need for clearly defined procedures for identifying fire fighter emergency situations. Further, training on these procedures must be conducted regularly to ensure fire fighters maintain their skills in this area.

The following is a list of situations that have lead to the deaths of fire fighters around the United States. These six situations are only a partial list of fire fighter emergency situations.

If any of the following occur, fire fighters should not delay in calling for help.

1. Failure of floor joist causing a large area floor collapse sending fire fighters to the floor or basement below. Tennessee, NIOSH Report F2007-07
2. Failure of lightweight or conventional roof members causing overhead loads to collapse on interior crews or block a means of egress. California, NIOSH Report 98F-7
3. Having PPE become entangled in cables or wires. Fire fighter dies after becoming entangled in cable television wire. Tennessee, April 11, 1994.
4. Being separated from the hoseline, interior wall, search rope, or crew causing disorientation in a structure. Arizona, NIOSH Report F2001-13
5. Not properly monitoring SCBA air supply while operating in an IDLH environment. Michigan, NIOSH Report F2005-05
6. A fire fighter being injured while performing interior operations.

Why Fire Fighters Delay the Fire Fighter Emergency Call

"Never fight fire from ego." Author unknown

There are many reasons why fire fighters delay or do not call a fire fighter emergency. Despite training and practice, fire fighters may not perform as required when a fire fighter emergency presents itself. The reasons range from loss of situational awareness, fear of retribution, pride, ego, and denial among others. Because the reasons why fire fighters delay

in calling for help varies, the need for training on specific fire fighter emergency procedures is abundantly clear. Through sound procedure and training fire fighters are required to call for assistance when presented with a fire fighter emergency. By implementing a policy stating when a fire fighter is supposed to call a fire fighter emergency, the problems with fear of retribution, pride, ego, and denial can be reduced.

The Fire Fighter Emergency

"To lead untrained people into battle is to throw them away."
Confucius

The fire fighter that is caught in a life threatening situation in a burning structure has brutal and relentless factors working against them. Events are both rapid and unpredictable. The amount of air remaining in the fire fighters SCBA cylinder, the rate of fire spread, and the degree to which the fire fighter is trapped or injured all limit the ability to communicate and the amount of time that is presented for rescue. Fire fighters experienced in SCBA air management, fire fighter survival, and fire fighter emergency procedures increase their probability of a positive outcome if they fall victim to the many hazards which are present at fire scenes. When a fire fighter calls a fire fighter emergency, clear, concise and comprehensible radio communications are of paramount importance when the RIC is trying to find a downed fire fighter. The National Fire Academy acronym LUNAR can be used to report important information.

LUNAR

- ***L*** Location (where are you?)
- ***U*** Unit (apparatus?)
- ***N*** Name (who are you?)
- ***A*** Assignment (what were you doing?)
- ***R*** Resources (what do you need?)

Research has proven that response in an emergency situation can be improved dramatically through repetition and training. This is why the military and civilian aviation and maritime industries stress rapid prime decision-making (RPD) simulator training to elicit the correct response when participants are faced with emergencies.

Sample LUNAR Fire Fighter Emergency Transmission

Fire fighter: "Mayday, Mayday, Mayday!"

IC: "Fire fighter calling the emergency, give me your LUNAR report"

Fire fighter: "IC, I'm in the basement, Bravo side. Engine 3, Fire Fighter Jones. I was performing a left-hand search on the first floor and have experienced a floor collapse. I am pinned and cannot move. I have a

half cylinder of air and am turning on my PASS device. I need immediate assistance from the RIC."

Through recurrent training and practice, fire fighters are taught 'learned resourcefulness' rather than 'learned helplessness'. The fire fighter that has initiated the fire fighter emergency must carry out learned fire fighter survival skills and try to remain calm while awaiting rescue. They must attempt to conserve air, move slowly, and continue to communicate.

NUCAN

Another recognized acronym to use when calling a fire fighter emergency is NUCAN.

- **N** Name
- **U** Unit / Assignment / Location
- **C** Conditions
- **A** Actions
- **N** Needs

Fire Fighter Emergency Procedures

If self rescue is not possible, there are fire fighter emergency procedures that you should take after an emergency has been transmitted. These steps, when used properly, can assist in a successful recovery of the fire fighter in distress:

- ❒ Activate the PASS device.
  - Turn PASS device off when talking on the radio.
- ❒ Communicate your surroundings.
- ❒ Monitor and control your air.
- ❒ Turn on your flashlight (facing up if possible).
- ❒ Make tapping noises against the floor or wall.
- ❒ Look for exits (windows, doors, light from the outside).
- ❒ Stay calm.
- ❒ Stay low.

Summary

You must be thoroughly trained on fire fighter emergency procedures prior to experiencing a potentially deadly situation on the fireground. These emergency procedures should be embedded into your consciousness from the recruit academy until the day you retire from the profession. You might have only one chance to transmit a fire fighter emergency message and therefore must get it right. The skill of recognizing critical danger factors and communicating in a manner that can be understood is something that you must practice time and again throughout your career to ensure that the most appropriate response is selected during these critical, perhaps life-and-death situations.

Topic 5: SCBA Emergencies

Scope: The focus of this topic is to give fire fighter a basic understanding of the importance of the SCBA, its operation, and emergency procedures for fire fighter survival.
Terminal Learning Objective (TLO): At the end of this topic, the student should be able to overcome a variety of obstacles and SCBA emergencies faced during a fire fighter survival emergency.
Enabling Learning Objectives (ELO):
1. How to determine your air consumption rates.
2. How to perform emergency check procedures.
3. Demonstrate techniques utilized by fire fighters when running out of air.
4. Demonstrate various techniques utilized for escaping from restrictive areas.

The self-contained breathing apparatus (SCBA) is the most important and widely used tool in the fire service today. Its advancements over the years have greatly expanded the capabilities of the fire fighter when performing aggressive interior searches and fire attack. You must be thoroughly familiar with the specific piece of breathing apparatus that you will use.

This topic focuses on emergency procedures and techniques that will help you troubleshoot your SCBA in a crisis. You will be instructed in various emergency check procedures when faced with equipment malfunction as well as how to deal with a low air event. You will also explore the various techniques and methods you may use to escape from restrictive areas.

SCBA Training

SCBA training should begin at the most basic level and rapidly work towards the more difficult, refined level. Repetitions of skills need to be emphasized, as skills must be performed numerous times before proficiency is to be expected. You must be intimately familiar with the operation of the SCBA used by your department. You must instinctively know where every component of your SCBA is located so that under extreme conditions your actions are automatic. When training, the only boundaries that exist are safety on the training ground and the physical abilities of the participants.

Air Consumption for Survival

Basic physiology tells us that different fire fighters will consume the air in their SCBA at different rates. The working air supply will depend on the fire fighter's training, physical condition, activity, and mental state as experienced under the stressful conditions encountered during fire fighting.

You are responsible for determining your individual point of no return (end of air supply) when entering a hazardous atmosphere. Fire fighters often mistakenly rely on their "low-air alarm" as their signal to exit a building. Most activate when 20%-25% of cylinder pressure remains in the SCBA bottle. Depending on the size of the structure and potential hazards you may face

during exit, the amount of air remaining when the low-air alarm activates may not be sufficient.

NFPA 1404 Standard for Fire Service Respiratory Protection Training (2006)

Beginning January 1, 2007, new requirements were established under NFPA 1404 by requiring departments to establish and enforce a written SOP for training in the use of a SCBA. The SOP should include an individual air management program that will develop the ability of the individual to manage his or her air consumption as part of a team during a work period. The individual air management program should include the following directives:

- ❒ Exit from the IDLH atmosphere should be before consumption of the reserve air begins.
- ❒ Low-air alarm is notification the individual is consuming their reserve air.
- ❒ Activation of the reserve-air alarm is an immediate action item for the individual and the team.

The NFPA 1404 standard outlines that the fire department must train their members to operate in accordance with the rule of air management, which states, "Know how much air is in your SCBA, and manage that air so that you leave the IDLH environment BEFORE your low air warning alarm activates."

*A question that every fire fighter should be able to answer without hesitation is, **"How long can I work while wearing a SCBA?"** The fireground is not the place to figure out that answer.*

Consumption Rate Testing

Consumption rate testing should be conducted annually by the department so that fire fighters have a better understanding of their point of no return. The testing is conducted on a set course determined by the department to simulate the work of fire fighting. A fire fighter begins the course with a full SCBA bottle that is gauged and starting pressure recorded. The test is continued until the fire fighter completely runs out of air and time is stopped. That time is recorded as well as at the time the low-air alarm activated. Simple division gives the rate of consumption. Knowing the rate of consumption and understanding how much time you have until your low-air alarm activates, you learn your limitations while using a SCBA.

Types of Tests

- ❒ SCBA consumption course.
- ❒ Treadmill.
- ❒ Stair climber.

Once you have a better understanding of how much air you will consume while performing a task, you begin to increase your situational awareness and are less likely to get yourself past your point of no return. Knowing this information can help keep you calm and possibly enable self-survival in an emergency.

Reducing Your Air Consumption

Certain situation may warrant the need to reduce you rate of air consumption. Whether it is to search for an exit or hose line during a disorientation emergency or becoming trapped, fire fighters must be able to employ techniques to increase their window of survival. There are various methods of breathing that may help in reducing a fire fighter's consumption rate. It will take some experimentation on the fire fighter's part to find out which one works best. When using any method, it is important to take normal breaths and exhale slowly to keep the CO_2 in the lungs in proper balance.

What can fire fighters do to reduce their consumption rate during an emergency?

- ❒ Controlled breathing methods.
  - ■ Inhale through the mouth.
  - ■ Exhale through the nose.
    - ● Can be reversed.
    - ● Slow, deliberate exhalation is key.
- ❒ Skip-breathing.
  - ■ Inhale fully and hold this breath for the duration that a normal exhalation would take.
  - ■ Take an addition breath and begin to slowly exhale.
    - ● This cycle is then repeated.

SCBA Emergencies

It is imperative that you become thoroughly familiar with your breathing apparatus and possess a basic knowledge about preventative maintenance for the particular unit you are using. Minor failures, such as free flow of air or improper connections, are very common on the fireground. These are often the result of operator error or improper preventative maintenance. Upon reporting for duty, you should make a point to thoroughly test and inspect the functions of your assigned SCBA. This should also be repeated every time the unit is put into use or service.

Common SCBA Emergencies

Throughout your career, you will face a variety of equipment failures that may jeopardize your safety if not quickly corrected. No such failure is equal to that of a SCBA emergency during a fire-fighting operation. Today's fire fighters must maintain a high degree of confidence and personal proficiency in handling SCBA emergencies. The following, although not comprehensive, is a list of the most common SCBA emergencies encountered by fire fighters and some suggested solutions for each.

The four most critical actions in each of these situations are:

1. **Remain calm.**
2. **Transmit the Mayday.**
3. **Initiate Mayday procedures.**
4. **Search for an exit.**

Early Low-pressure Alarm Activation/Decreased Air Flow

- ❒ Check to ensure the cylinder valve is turned on completely.
  - If not, fully open the valve.
- ❒ Open purge/bypass valve.
- ❒ Transmit a fire fighter emergency and initiate fire fighter emergency procedures.
- ❒ Search for an exit.

Cracked, Broken, or Damaged Lens

- ❒ Get as low as possible.
- ❒ Cover the damaged area with a gloved hand to filter out the particulate matter.
- ❒ Transmit a fire fighter emergency and initiate fire fighter emergency procedures.
- ❒ Search for an exit.

Audible Leak from Hose Connection at the Cylinder Connection

- ❒ Immediately drop to one knee to avoid unnecessary exposure to superheated gases.
- ❒ Turn the cylinder valve off.
- ❒ Tighten the high-pressure connection.
- ❒ Turn the cylinder valve back on.
- ❒ If the leak persists, transmit a fire fighter emergency and initiate fire fighter emergency procedures.
- ❒ Search for an exit.

Air from Regulator Discharging Uncontrollably

- ❒ Immediately attempt to control the leakage with a gloved hand.
- ❒ Transmit a fire fighter emergency and initiate fire fighter emergency procedures.
- ❒ Search for an exit.
- ❒ Conserve your air supply by turning the cylinder off.
  - Hold your breath.
  - Turn the cylinder valve ¼ turn to allow yourself to inhale.
  - Turn it back off.
  - Hold your breath.
  - Continue this process.

Ripped or Severed Hose

- ❒ Immediately cover or hold together the affected hose with a gloved hand.
- ❒ Transmit a fire fighter emergency and initiate fire fighter emergency procedures.
- ❒ Search for an exit.

Air Supply Interruption

- ❒ Get as low as possible.
- ❒ Begin an emergency assessment.
  - First attempt a ¼ turn of your purge/bypass valve.
  - Check your cylinder valve.
- ❒ If no air, transmit a fire fighter emergency and initiate fire fighter emergency procedures.
- ❒ Search for an exit.

Out of Air

- ❒ Get as low as possible.
  - To avoid breathing superheated gases found in the upper levels of the thermal column.
- ❒ Transmit a fire fighter emergency and initiate fire fighter emergency procedures.
- ❒ Search for an exit.
  - If unable to locate an exit immediately.
    - Disconnect your regulator (low-pressure hose if waist mounted regulator).
    - Place a gloved hand over the face piece opening or low-pressure hose

Face Piece Removal

Do NOT attempt to remove your face piece if possible, even though human nature is to immediately attempt to remove the face piece. Proper training and strict discipline must be enforced to prevent such action. Removing your face piece may expose you to super-heated air and toxic gases causing immediate death.

Remember, your face piece is your lifeline to your SCBA; without it, your chance of survival is drastically reduced.

Alternative Means of Obtaining Additional Air

With a complete failure of a SCBA, it is imperative that fire fighters work in pairs allowing the second fire fighter and his or her SCBA to become the primary source of air using buddy-breathing techniques. Modern SCBAs have the ability to supply air to a second user through the EBS connection. These connections should only be used in an emergency allowing the fire fighters to buddy breathe while quickly exiting the hazardous atmosphere. Making these connections is a skill that every fire fighter should practice under low and zero visibility conditions in a drill setting.

Most rapid intervention teams or companies utilize some form of a rescue air pack that is taken to a down fire fighter or fire fighter running low on air during an emergency deployment. These packs generally consist of a 45-minute or 1-hour bottle and allow the user to deliver air to the fire fighter in a number of ways.

RIC Pack Familiarization

You should be able to go through the five options to get air to the down fire fighter. Do them in a light environment and then try it in the dark or limited visibility.

Option 1: Universal Air Connection

- ❒ This is the easy one.
- ❒ You should be able to feel the difference between the high- and low- pressure hoses with a gloved hand in the dark.
- ❒ Where do find the connection in the RIC bag?

Option 2: Low-pressure Hose to EBS

- ❒ This is your buddy-breather connection.

Option 3: Low-pressure Hose to Fire Fighter's Mask Mounted Regulator

- ❒ Used when you may not be able to access the rear of the pack.
  - Example: Fire fighter fell through a hole or is buried under debris.

Option 4: Regulator Exchange

- ❒ Used when there is a malfunction of the fire fighter's regulator.

Option 5: Full Mask Exchange

- A toxic bottle exchange is an advanced skill that should be practiced.
- It involves changing an empty cylinder for a full one while using the SCBA.
- It requires the fire fighter to doff the SCBA and be able to hold their breath while they disconnect the old and connect the new cylinder.

Options 4 and 5 should also be attempted as a two-person exercise.

Restrictive Area Techniques

Before going through obstacles, it is paramount that you make certain that conditions on the other side are safe. It is also highly recommended that you train on the following techniques wearing full PPE so you become confident in working with the different components of your SCBA in less than ideal conditions.

Nonremoval Method

If you are caught in a collapse or cutoff from your means of egress, you may have to fit through a tight spot to get yourself to safety while wearing a SCBA.

Low or Reduced Profile (Partial Removal)

A conventional way for you to get through an obstacle is to simply shift your SCBA to the left side, allowing protection of the regulator. It will also allow you more freedom of movement, because air lines are located on the left side and running to the face piece on most units.

- ❒ Fully loosen the right shoulder strap and remove it.
- ❒ Loosen the waist strap to allow the harness assembly to be rotated around to your left hip.
- ❒ Grasp the neck of the cylinder with your left hand.
- ❒ Rotate the harness assembly to the left to allow you to pass through the obstacle.
- ❒ Proceed through the obstacle.
- ❒ Don the SCBA.
  - Tighten both shoulder and waist straps.

Zero or No Profile (Full Removal)

In an extreme circumstance, you may have to resort to removing your SCBA to facilitate clearing an obstacle. Be very cautious when removing your SCBA since this will further complicate the nature of the situation you are presented. To remove your SCBA in a constricted area or if heat conditions dictate, follow these steps:

- ❒ Be as low as possible.
- ❒ Fully loosen the waist strap.
  - Disconnecting the buckle and both shoulder straps.
- ❒ Remove the right shoulder strap.
- ❒ Remove the left shoulder strap.
- ❒ Maintain a firm grip on the left shoulder strap.
- ❒ Reduce your profile.
  - Rotating to the left with your right shoulder facing the obstacle.
- ❒ Proceed through the obstacle.
  - Pulling your SCBA assembly through with your left hand.
- ❒ Don the SCBA.
  - Tightening both shoulder and waist straps.

An alternate method is to pass the SCBA in front of you while keeping it close to the body.

Alternate Restrictive Area Techniques

There are other techniques used to pass through restrictive areas such as the simple left side shift, backwards swim, or forward dive (Superman).

Left Side Shift Technique

- ❒ Check the floor on the opposite side of the opening.
- ❒ Loosen right shoulder strap.
- ❒ Loosen waist strap.

- ❒ Shift SCBA to left side.
  - Removing right shoulder strap if necessary.
- ❒ Place left hand over the cylinder neck.
- ❒ Lead with left side, bottle and shoulder through the opening.
- ❒ Bring the rest of your body through the opening.
- ❒ Tighten both shoulder and waist straps.

Backwards "Swim" Maneuver

- ❒ Check the floor on the opposite side of the opening.
- ❒ Sit with your back against the opening.
  - SCBA cylinder through the opening.
  - Feet positioned in front of you.
  - Buttocks off the ground.
- ❒ Shift cylinder bottle to the right side of the opening.
- ❒ Rotate your left arm over and through the opening.
- ❒ Lean back as your arm passes through.
- ❒ Rotate your hips and body to the left.

Forward Dive Technique (Superman)

- ❒ Check the floor on the opposite side of the opening.
- ❒ Stand centered and facing the opening.
- ❒ Place both arms through the opening.
- ❒ Exhale and pull arms inward toward the center of your body.
  - Allowing them to fall forward through the opening.
- ❒ If the opening is too narrow, shift the SCBA cylinder to left (low profile).
  - Performing the maneuver with your right side to the floor (sideways Superman).
- ❒ Once SCBA cylinder clears the obstacle, use your arms to pull you the rest of the way through.

SCBA Confidence Course

One of the best ways to train fire fighters the skills needed for self-survival is to frequently engage them in a SCBA confidence course. The course is designed to test the fire fighter's skills by requiring the deployment of different survival techniques such as low or zero profiles to maneuvers in tight or restricted areas. They can be designed with various components and degrees of difficulty forcing the fire fighter to negotiate hazards they may face such as wire entanglements and wall breaches. A confidence course can be constructed to test a fire fighter's ability to avoid disorientation, test their resilience to claustrophobia, and reinforce the need for controlled breathing techniques.

The construction of a SCBA confidence course can be simple to complex. Depending on the site, the prop can be permanent and fixed as part of a training facility or tower, or the components can be built separately and portable for use at a fire station. The length of the course is up to the instructor, but should have the following recommended components:

- ❒ Joist crawl, testing balance, and the ability to identify spacing.
- ❒ Changes in elevation, testing proper sounding of path ahead.
- ❒ Reduced profile areas causing fire fighters to demonstrate both low profile and zero profile maneuvers.
- ❒ Wall stud pass through, techniques to move between studs.
- ❒ Wire entanglement, avoidance, and disentanglement techniques.
- ❒ Wall breach.

Other components can be added such as stairs, sloping and collapsing floors, holes in floors, floor surface identification, exit identification, drop ceiling props, and hoseline/ coupling identification. Face pieces should be blacked out or smoke machines used to add realism. Heat and noise are other methods that can be used to heighten the level of anxiety.

The course must be supervised with safety measures in place to ensure fire fighters are not injured and can be assisted if they encounter a real emergency or need to discontinue the exercise. Live fire or smoke conditions should never be used in a SCBA confidence course. The goal of any SCBA confidence course should be to increase fire fighters' level of confidence while using their SCBAs. To be able to calmly and methodically mitigate any obstacle or emergency they may face in a self-survival situation.

Summary

The fireground is a very dynamic and dangerous environment. Every fire fighter, from the most seasoned veteran to the greenest rookie, can experience a problem with a SCBA. Emergency procedures involving SCBAs should be second nature to all fire fighters. As with all aspects of fire fighting, practice and training prior to an emergency will increase a fire fighter's chance for survival.

Fire fighters should be trained in and familiar with techniques used to prolong air supply duration, their own personal air consumption rate, emergency procedures check for SCBA equipment, techniques used to share air between two fire fighters, and what to do if the SCBA runs out of air.

In addition to these skills, fire fighters should also be trained in techniques used to escape from restrictive areas and overcome obstacles. As noted, self-preparedness is the key to fire fighter survival. During an emergency is not the time to develop self-survival skills.

Topic 6: Fire Fighter Survival Skills

Scope: The focus of this topic is to give the student techniques for survival an emergency and apply them during hands-on evolutions.
Terminal Learning Objective (TLO): At the end of this topic, the student should be able to overcome a variety of obstacles and SCBA emergencies faced during a fire fighter survival emergency.
Enabling Learning Objectives (ELO):

1. Demonstrate reading couplings techniques.
2. Demonstrate escaping an entanglement emergency using the swim/sweep and SCBA removal methods.
3. Demonstrate escaping an emergency using the hose slide.
4. Demonstrate escaping an emergency using the emergency ladder escape hook-two/slide-to-four method.
5. Demonstrate calling "Mayday."
6. Demonstrate changing your SCBA profile using the Nonremoval, low or reduced profile (partial-removal), and zero or no profile (full-removal) methods
7. Demonstrate escaping an emergency using the window hang.
8. Demonstrate escaping an emergency using the wall breach.
9. Demonstrate performing a SCBA emergency procedure check.

Student's Eligibility to Participate

Students attending a Fire Fighter Survival class may be asked to provide the Primary Instructor verification of the following prior to participating in any skill or evolution.

- ❒ Authorization to attend the training, including a statement of insurance for the student.
  - If the class will be coordinated through a community college, the college may provide additional insurance for participants and instructional staff.
- ❒ Access to approved personal protective equipment including competency in donning and using the personal protective equipment.
- ❒ Current fit test documentation.

Safety Briefing

- ❒ Maintain hydration.
- ❒ Break often or as needed.
- ❒ Remove PPE when not participating, especially on warm days.

Medical Briefing

- ❒ Students will notify the instructor if you have any condition or limitation that may affect their participation in a training evolution.
- ❒ Students will notify the instructor immediately if they sustain an injury during the class.
- ❒ Instructors will advise students of the location of available medical equipment.

Personal Protective Equipment, Tools, and Equipment

- ❒ Students will wear full personal protective equipment for all skills.
- ❒ All student PPE will conform to NFPA 1971: Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting, 2007 Edition.
- ❒ Recommended tools and equipment to be carried by each fire fighter.
  - Spring-loaded wire cutters
  - Extra flashlight
  - Door wedge
  - Webbing

SCBA Component

- ❒ All SCBAs will conform to NFPA 1981: Standard on Open-Circuit Self-Contained Breathing Apparatus (SCBA) for Emergency Services, 2007 Edition and NFPA 1982: Standard on Personal Alert Safety Systems (PASS), 2007 Edition.
- ❒ Students will be familiar with all components of their SCBA.
- ❒ Students must show competency in the use of their SCBA.

SCBA Daily Check

Here is an example of a daily check for a Scott 4500 psi (pounds per square inch) SCBA with an integrated PASS device, heads-up display (HUD), and emergency breathing system (EBS).

- ❒ Visual inspection.
  - Ensure all parts and components are intact and free of damage.
  - Check all straps for fraying or other damage.
    - Ensure the straps are fully extended.
  - Ensure all buckles are in good condition.
  - Check cylinder hydro date and psi.
    - Must be 4000 psi or higher to be considered in-service.
  - Check face piece for cracked lens or frayed straps.
    - Ensure the nose cup is present.
  - Ensure second stage regulator docking device is in good condition.
    - Clear tabs and latch channel.
- ❒ Ensure bypass is closed and air saver switch is reset.
- ❒ Open cylinder valve.
  - Listen for the audible alarm indicating PASS device has been armed.
- ❒ Compare cylinder psi to remote gauge.
  - Both must be within approximately 100 psi of each other.
- ❒ Keep SCBA still for 20 seconds.
  - PASS device should begin to pre-alarm.
  - Shake SCBA to reset PASS device.

- ❒ Keep SCBA still for 30 seconds.
  - At 20 seconds, PASS device should pre-alarm.
  - At 30 seconds, PASS device should go into full alarm.
  - Shake SCBA and verify that PASS device full alarm does not reset with movement.
  - Reset PASS device using the (yellow) reset button on the remote gauge assembly.
- ❒ Manually activate PASS device using (orange) button on the remote gauge assembly.
  - Reset PASS device using the (yellow) reset button.
- ❒ Don face piece and check seal.
  - Clearly announce, "Good seal."
- ❒ Connect second stage to mask.
  - Verify that it locks in.
- ❒ Take a breath in.
  - Verify "First Breath On" function works.
- ❒ Open bypass to verify it works
  - Close bypass.
- ❒ Compare HUD display with remote pressure gauge to verify they are in sync with each other.
- ❒ Hold breath.
  - Disconnect the second stage pigtail.
  - Connect the second stage pigtail to the EBS hose.
  - Verify EBS and all connections are working.
  - Breathe.
- ❒ Hold breath.
  - Disconnect the EBS.
  - Reconnect the second stage pigtail to its hose.
- ❒ Close cylinder valve.
  - SLOWLY breathe remaining pressure out of the system while comparing the HUD and remote pressure gauge drop together.
  - Ensure low-air audible alarm activates between 25%-20% (1125-900 psi) of cylinder pressure.
- ❒ Bleed all pressure out of the system.
- ❒ Reset air saver switch.
- ❒ Reset PASS device.
- ❒ Stow EBS hose and make SCBA and face piece ready for immediate use.

When failure occurs in a hostile environment and if you are familiar with your SCBA unit, you will be able to remain calm and provide a remedy to the situation while exiting the area. The most important rule to remember in the case of a malfunction or depletion of air is to never remove the SCBA face piece. The face piece itself will afford you some protection to the face, eyes, and respiratory area while leaving the hazard area.

To find and remedy a failure, a standardized emergency procedure check to find, locate, and remedy a malfunction in a SCBA is stressed. This ensures you will find the problem and execute the proper procedure that will enable you to leave the hostile environment.

Emergency Procedures Check

- ❒ Determine if there is a need. Is there a problem?
- ❒ Place your hand on your face piece and check for problems.
- ❒ Check the bypass or purge valve.
  - Simultaneous check the main cylinder valve and ensure it is fully open.
- ❒ Check the air pressure.
- ❒ Check the low-pressure line from the mask to the second stage regulator/pressure reducer for escaping air.
- ❒ Check that the high-pressure line is securely connected to cylinder.
- ❒ Correct any problems when you find them during the emergency procedures check.
  - If you cannot correct a problem, leave the area at once with assistance.
    - Consider buddy breathing with your partner.

Site Preparation

- ❒ The training site will be free of all hazards, i.e., glass, nails, etc.
- ❒ Instructor will perform a final safety check prior to training on each skill.

What's in your Pockets?

Ask any fire fighter what is in the pockets of their gear and each one will have a different explanation for the choice of equipment they decide to carry. Think carefully when selecting the items you will carry in the pockets and consider the following:

- ❒ Portable radio
- ❒ Extra flashlight
- ❒ Wire cutters
- ❒ Webbing sling (approximately 20 feet)
- ❒ Door stops/chocks
- ❒ Vise grips

Once you make the decision on what you will carry, ask yourself where you will carry these items and why. If these items are carried in pockets that are difficult to access, they are of little use to you when you really need them. Take the time when deciding where you will carry these items. Put on your bunker gear, don your SCBA, put on your gloves, and experiment with accessing these tools. Can you easily get to your radio's emergency activation button? Can you access your wire cutters for an entanglement? Can you grab a door chock to complete a primary search? A little preplanning on what tools you will carry and where you will carry them will pay big dividends when you need to access them in the heat of battle.

Fall Protection

Any evolution that has a potential fall hazard above 6 feet or could lead to injury of a student requires fall protection. Instructors will ensure that students are connected to an approved fall protection system when performing training evolutions off ladders or out upper floor windows. Personnel/students assigned to fall protection positions will be competent in the system's operation.	
Materials Needed:	All equipment used should comply with NFPA 1983: Standard on Life Safety Rope and Equipment for Emergency Services, 2006 Edition. • Anchor point in compliance with Title 8, Section 1670 • Class 3 harness • Various webbing • ½" static kernmantle rope • Pulley • Two prusiks • Three carabiners • Edge protection (as needed)

Fall Protection

1. Start with an anchor point assembled with double prusiks on the safety line to arrest any student's possible fall.

2. Use a Class 3 harness that properly fits each student.

3. Establish a change of direction above and inline with the descent of the student. This is an example with webbing and a pulley to form a change of direction over the prop.

Fall Protection

4. Secure the student to the safety line and harness before attempting any skill.

5. Monitor the student closely during the entire descent.

Skill #1: SCBA Emergency Procedure Check

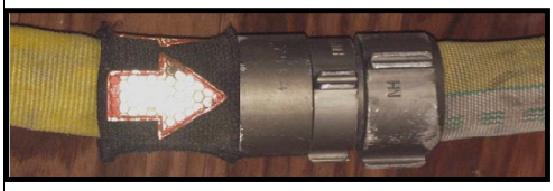
Skill #1: SCBA Emergency Procedure Check	
At the time of the emergency, you must be completely familiar with the components and operation of your breathing apparatus in order to easily diagnose and correct problems.	
Time Frame:	0:20
Students (Minimum):	One company
Materials Needed:	• Full personal protective equipment
Site Preparation:	This skill can be performed in any setting. It can also be combined with an evolution.
Instructor Directions:	1. Review Topic 5: SCBA Emergencies. 2. Review the operation of the evolution and the desired outcome with the students.
Student Directions:	
	1. Determine if there is a need; is there a problem? 2. Check for problems. 3. Check the bypass or purge valve. 4. Simultaneous check the main cylinder valve and ensure it is fully open. 5. Check the air pressure. 6. Check the low-pressure line from the mask to the second stage regulator/pressure reducer for escaping air. 7. Check that the high-pressure line is securely connected to cylinder. 8. Correct any problems when you find them during the emergency procedures check. 9. If you cannot correct a problem, leave the area at once with assistance. ▪ Consider buddy breathing with your partner.

Skill #2: Calling "Mayday"

Skill #2: Calling "Mayday"	
When a fire fighter is confronted with an emergency situation, such as becoming lost/trapped or encounters a SCBA emergency, he or she must be able to call for help and initiate proper fire fighter emergency procedures. This scenario is something that needs to be practiced and maintained because it is not a common occurrence.	
Time Frame:	0:30
Students (Minimum):	One company
Materials Needed:	• Full personal protective equipment • Portable radio
Site Preparation:	This skill can be performed in any setting. It can also be combined with an evolution.
Instructor Directions:	1. Review the skill. 2. Ensure all students are wearing full personal protective equipment.
Student Directions:	
	1. Locate the portable radio. 2. Press "Push To Talk." 3. Call "Mayday." ▪ The instructor will acknowledge the transmission. 4. Transmit your LUNAR. 5. State your personal procedures to assist in a successful recovery. ▪ Activating the PASS device. ▪ Monitoring and controlling your air. ▪ Turning on your flashlight. ▪ Making some noise. ▪ Looking for exits (windows, doors, light from the outside). ▪ Staying calm. ▪ Staying low.

Skill #3: Reading Couplings

Skill #3: Reading Couplings	
If fire fighters get disoriented, the hoseline can be a valuable solution in giving direction to exit the structure. There are many different expressions used in the fire service to remind fire fighters how to read the coupling so that it will lead them out of the building. Examples include "Bump to the Pump" and "Long Lugs Lead Out." In this skill, the students will demonstrate a last resort method of escaping the heat, smoke, and fire gasses from an advancing fire.	
Time Frame:	0:15
Students (Minimum):	One company
Materials Needed:	• Appropriate training structure • 1¾" charged hoseline (minimum size) • Full personal protective equipment
Site Preparation:	Ensure the site is free of all hazards. This skill can be combined with an evolution.
Instructor Directions:	1. Review the skill. 2. Assign personnel to appropriate positions. 3. Ensure each student is wearing full personal protective equipment. 4. Perform a final safety check prior to performing the skill.
Student Directions:	



1. Locate the hoseline.
2. Using your hands, search the hoseline until a coupling is located.
3. Find the male coupling.
   - Lugs on the male coupling are larger.
   - Lugs on the male coupling run the entire length.
4. Follow the hoseline attached to the male coupling until you safely exit the structure.

Skill #4: Window Hang

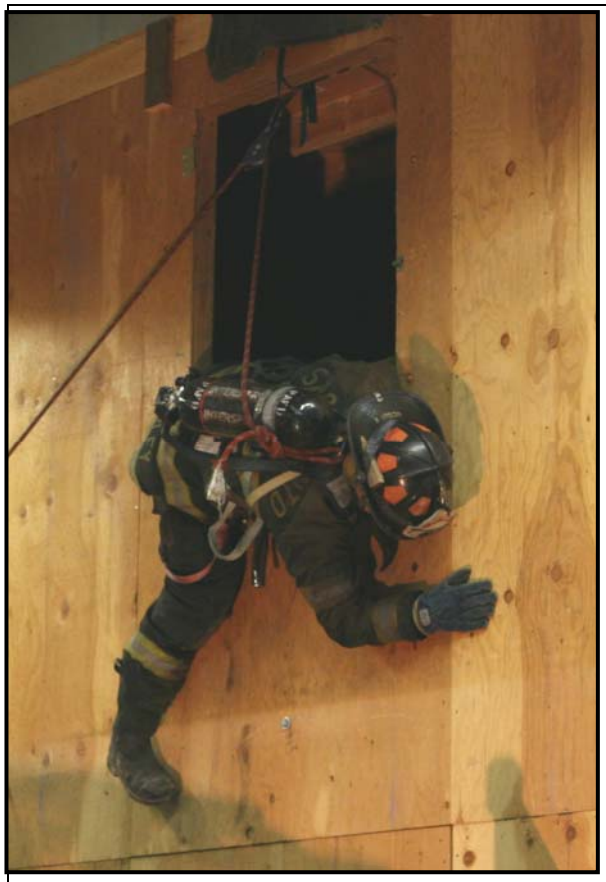
Skill #4: Window Hang	
The window hang represents the last option of seeking refuge. If operating above the first floor and you find your primary means of egress cutoff, with no other options such as ladder escape, wall breaching, or hose slide, the window hang may provide a safe location until help arrives. In this skill, the students will demonstrate a last resort method of escaping the heat, smoke, and fire gasses from an advancing fire.	
Time Frame:	0:30 If combined with other aboveground skills; time frame must be adjusted.
Students (Minimum):	One company
Materials Needed:	• Appropriate training structure with 1st- or 2nd- story window (recommended minimum 24"x24") • Fall protection system • Full personal protective equipment
Site Preparation:	• Ensure that site is free of all hazards. • Confirm that appropriate anchor can be constructed in accordance with fall protection system.
Instructor Directions:	1. Review the skill. 2. Review fall protection system requirements. 3. Assign personnel/students to appropriate fall protection positions. 4. Review the fall protection system with all personnel/students. 5. Ensure all students are wearing full personal protective equipment. 6. Ensure all students are wearing a full-body harness attached to a safety line in accordance to the fall protection system requirements. 7. Perform a final safety check prior to performing the skill.

Student Directions:

1. Locate the window.
   - Closing the door to the room to buy additional time if possible.
2. Travel to the window.
   - Staying low due to heat and smoke.
3. Clear the window frame of glass and screen if needed.
   - Starting at the top to ensure maximum removal of fire gasses and heat.
   - Removing any glass on landing on the sill to avoid any injury.

4. While on hands and knees, position yourself with one shoulder against the wall below the window.

5. Rise only enough to exit window.
   - Leading with your arm.
   - Then your head.
   - Then your leg.
   - Rolling over the sill.
   - Leaving other arm and leg inside on the sill for support.



6. Remain in this position until the fire is extinguished, a ladder is raised, or other rescue efforts can reach you.

Skill #5: Hose Slide

Skill #5: Hose Slide	
If operating above the first floor and performing fire attack, you may find your means of egress cut off due to rapidly advancing fire. Using your attack line as a means of escape is similar to sliding the pole at the fire house. But as with any of these last resort skills, proper training and practice is always necessary. This is a last resort method of escaping the heat, smoke, and fire gases from an advancing fire.	
Time Frame:	0:30 (if combined with other aboveground skills; time frame must be adjusted.
Students (Minimum):	One company
Materials Needed:	• Appropriate training structure with 1st- or 2nd-story window (recommended minimum 24"x24") • 1¾" charged hoseline (minimum size) • Fall protection system • Full personal protective equipment
Site Preparation:	• Ensure that site is free of all hazards. • Confirm that appropriate anchor can be constructed in accordance with fall protection system.
Instructor Directions:	1. Review the skill. 2. Review fall protection system requirements. 3. Assign personnel/students to appropriate fall protection positions. 4. Review the fall protection system with all personnel/students. 5. Ensure all students are wearing full personal protective equipment. 6. Ensure all students are wearing a full-body harness attached to a safety line in accordance to the fall protection system requirements. 7. Perform a final safety check prior to performing the skill.
Student Directions:	
1. Locate the window. ▪ Closing the door to the room to buy additional time, if possible. 2. Travel to the window. ▪ Staying low due to heat and smoke.	

Skill #5: Hose Slide

3. Clear the window frame of glass and screen if needed.
   - Starting at the top to ensure maximum removal of fire gasses and heat.
   - Removing any glass landing on the sill to avoid injury.
4. Push the nozzle and hoseline out the window.
   - Removing all slack.

5. Once the hoseline is out the window, proceed onto the window sill.
   - Staying low.
   - Placing right arm and leg out the window.
   - Rotating body to the left so both arms are in the room and both legs are outside the window.
   - Balancing on your abdominal area.

6. Position yourself on the hoseline.
   - Grabbing hoseline above the sill with one hand and below the sill with the other hand.
   - Wrapping legs around the hoseline.
   - Securing the hoseline between your knees and feet.
7. Slide hoseline to a safe location.
   - Always maintaining four points of contact.
   - Feet, knees, both hands.

Skill #6: Ladder Escape – Hook-two/Slide-to-four Method

Skill #6: Ladder Escape – Hook-two/Slide-to-four Method	
If operating above the first floor and you find your primary means of egress cut off, using a ladder may be your only option. The ability to exit out a window onto a ladder in an emergency is a skill that must be practiced and has already potentially saved fire fighters' lives. This is a last resort method of escaping the heat, smoke, and fire gases from an advancing fire.	
Time Frame:	0:30 (if combined with other aboveground skills; time frame must be adjusted.
Students (Minimum):	One company
Materials Needed:	• Appropriate training structure with 2nd- story window (recommended minimum 24"x24") • Fall protection system • Full personal protective equipment
Site Preparation:	• Ensure that site is free of all hazards. • Confirm that appropriate anchor can be constructed in accordance with fall protection system. • Consider adding and securing a parallel ladder for an instructor.
Instructor Directions:	1. Review the skill. 2. Review fall protection system requirements. 3. Assign personnel/students to appropriate fall protection positions. 4. Review the fall protection system with all personnel/students. 5. Ensure all students are wearing full personal protective equipment. 6. Ensure all students are wearing a full-body harness attached to a safety line in accordance to the fall protection system requirements. 7. Perform a final safety check prior to performing the skill.
Student Directions:	
1. Locate the window. ▪ Closing the door to the room to buy additional time, if possible. 2. Travel to the window. ▪ Staying low due to heat and smoke.	

Skill #6: Ladder Escape – Hook-two/Slide-to-four Method

3. Clear the window frame of glass and screen if needed.
   - Starting at the top to ensure maximum removal of fire gasses and heat.
   - Removing any glass landing on the sill to avoid injury.

4. Locate the ladder.
   - Leaning over the window sill.
   - Staying as low as possible.
   - Feeling for the ladder.
5. Place both hands on the beams.

6. Slide one hand along the ladder beam to the fourth rung, while hooking the other hand under the second rung.

Skill #6: Ladder Escape – Hook-two/Slide-to-four Method

7. Grasp the fourth rung.
8. Prepare to transition your weight from the second rung down to the fourth rung.

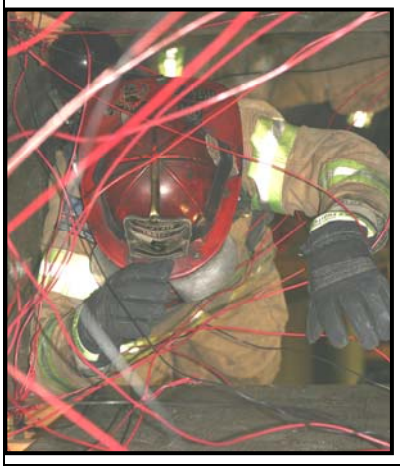
9. Secure the second rung with the inside left elbow as a pivot point.
10. Rotate the body clockwise.

Skill #6: Ladder Escape – Hook-two/Slide-to-four Method

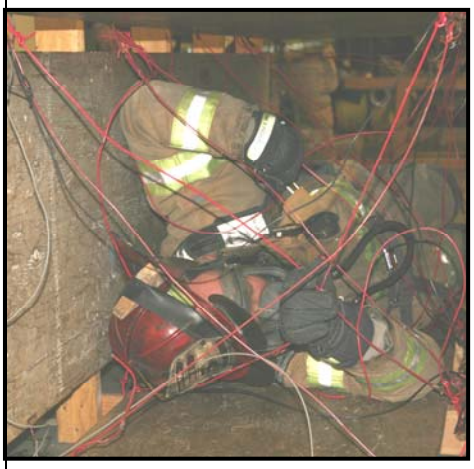
11. Slide your right thigh down the right beam of the ladder while rotating on your left arm.
    - Keeping your head down and knees bent.

12. When rotation is complete, slide your lower legs to the outer beams.
13. Slide down the ladder to the ground.
14. When you reach the bottom of the ladder, get out of the way to allow additional fire fighters to escape.

Skill #7: Entanglement Emergencies – Swim or Sweep Method

Skill #7: Entanglement Emergencies – Swim or Sweep Method	
Due to the flex duct work in residential occupancies and the number of wires and cables in drop ceilings in commercial buildings, fire fighters are becoming exposed to more possible wire entanglements these days. The skills needed to maneuver through these wires or the necessary tools to carry to cut these wires will be discussed in this skill set. In this skill, the students will demonstrate a last resort method of escaping the heat, smoke, and fire gasses from an advancing fire.	
Time Frame:	0:45
Students (Minimum):	One company
Materials Needed:	• Appropriate training structure • Entanglement prop (See Appendix B) • Full personal protective equipment
Site Preparation:	• Ensure that site is free of all hazards.
Instructor Directions:	1. Review the skill. 2. Assign personnel to appropriate positions. 3. Ensure each student is wearing full personal protective equipment. 4. Perform a final safety check prior to performing the skill.
Student Directions:	
1. Identify the entanglement. 2. Identify your desired route. ▪ Sweeping with outstretched arms to identify the largest possible opening that can be created.	
	3. Swim or sweep through the opening. ▪ Arms and head first. ▪ Maintaining the opening the entire way through. ▪ Avoiding the temptation to raise onto your elbows. ▪ This will raise the profile.

Skill #7: Entanglement Emergencies – Swim or Sweep Method



4. Rotate your shoulders, SCBA, and waist through the largest portion of the opening.

5. Free yourself if a snag occurs.
   - Recognizing the resistance.
   - Stopping forward progress to release the tension.
   - Reaching for the entanglement.
   - Adjusting to work the snag free from your equipment.
   - Continuing through the entanglement.

Skill #8: Entanglement Emergencies – SCBA Removal Method

Skill #8: Entanglement Emergencies – SCBA Removal Method	
Due to the flex duct work in residential occupancies and the number of wires and cables in drop ceilings in commercial buildings, fire fighters are becoming exposed to more possible wire entanglements these days. The skills needed to maneuver through these wires or the necessary tools to carry to cut these wires will be discussed in this skill set. In this skill, the students will demonstrate a last resort method of escaping the heat, smoke, and fire gasses from an advancing fire.	
Time Frame:	0:45
Students (Minimum):	One company
Materials Needed:	• Appropriate training structure • Entanglement prop (See Appendix B) • Full personal protective equipment
Site Preparation:	• Ensure that site is free of all hazards.
Instructor Directions:	1. Review both methods of the skill. 2. Assign personnel to appropriate positions. 3. Ensure each student is wearing full personal protective equipment. 4. Perform a final safety check prior to performing the skill.
Student Directions:	

1. Identify the entanglement.
2. Loosen harness straps.
3. Fully extend all straps.
4. Detach waist strap.
5. Remove the shoulder strap opposite of the air supply hose.
6. Remove the shoulder strap that contains the air supply hose.
   - Maintaining control of the air supply.
   - Without dislodging the SCBA mask.

Skill #8: Entanglement Emergencies – SCBA Removal Method
7. Turn into the air pack and identify entanglement ▪ Turning into the air pack as opposed to moving the air pack around to the user reduces further entanglement 8. Feel or sweep over the air pack. 9. Remove any entanglements away from the harness, cylinder, or valves. ▪ Moving the hazard to a location that will not present further entanglement when the pack is redonned. 10. Redon the air pack. 11. Adjust and gather equipment. 12. Continue forward. 13. If movement through the environment must be made with the SCBA removed (least preferred method), the SCBA and the individual wearing it must take the same path through the entanglement to avoid the face-piece becoming dislodged.

Skill #9: Wall Breach

Skill #9: Wall Breach	
The ability to escape or maneuver through a wall requires a knowledge of building construction materials and your equipment. This practice situation allows you to identify the obstacles that may be encountered as well as offer the techniques that may be used to remedy the situation. In this skill, the students will demonstrate a last resort method of escaping the heat, smoke, and fire gasses from an advancing fire.	
Time Frame:	0:30 If combined with other aboveground skills; time frame must be adjusted.
Students (Minimum):	One company
Materials Needed:	• Appropriate training structure • Breaching tool • Full personal protective equipment
Site Preparation:	• Ensure that site is free of all hazards.
Instructor Directions:	1. Review the skill. 2. Assign personnel to appropriate positions. 3. Ensure all students are wearing full personal protective equipment. 4. Perform a final safety check prior to performing the skill.
Student Directions:	
	1. Locate the area to breach. ▪ Closing the door to the room to buy additional time, if possible. 2. Identify the material to be breached. 3. Send a tool through the material first. ▪ Ensuring there are no obstacles. ▪ Checking the area to be entered is safe.

Skill #9: Wall Breach

4. Make the breach.
   - Ensuring the opening is large enough to exit through quickly.
5. Exit the area.
   - Using a reduced profile if necessary.

Skill #10: Changing Your SCBA Profile (Nonremoval Method)

Skill #10: Changing Your SCBA Profile (Nonremoval Method)	
Building collapse due to lightweight construction, earthquakes, gas explosions, terrorist attacks, lack of training, or just lack of experience due to the amount fires and the amount of new fire fighters are just a few possible reasons why you may find your means of egress cut off. Finding your way through a small opening may be your only way to safe refuge or the outside. Maneuvering your SCBA into a low- or zero-profile is a skill you may need to use. This skill is something we hope you will never need, but should be practiced by all. In this skill, the students will demonstrate a last resort method of escaping the heat, smoke, and fire gasses from an advancing fire.	
Time Frame:	0:45
Students (Minimum):	One company
Materials Needed:	• Appropriate training structure • Profile prop (See Appendix B) • Full personal protective equipment
Site Preparation:	• Ensure that site is free of all hazards.
Instructor Directions:	1. Review all three methods of the skill. 2. Assign personnel to appropriate positions. 3. Ensure all students are wearing full personal protective equipment. 4. Perform a final safety check prior to performing the skill.
Student Directions:	
	1. Identify the opening to be used for escape. ▪ Determining the size and shape. ▪ Noting the largest portion of the opening as the most desirable for the SCBA. 2. Lie prone. ▪ Stomach flat on the ground. ▪ Head toward the opening.

Skill #10: Changing Your SCBA Profile (Nonremoval Method)

3. Stretch your arms toward your head.
   - Loosening your shoulder straps if necessary, ***but not removing.***
   - Attempting to touch your ears with your upper arms.

4. Manipulate yourself into and through the opening.
   - Arms and head into and through the opening first.
   - Rotating your shoulders, SCBA, and waist as necessary.
   - Avoiding the temptation to raise onto your elbows.
   - This will raise the profile.

5. When you are through the opening, get out of the way.
   - Allowing additional fire fighters to escape.
6. Adjust and gather your equipment.
7. Move on.

Skill #11: Changing To a Low or Reduced SCBA Profile (Partial Removal Method)

Skill #11: Changing To A Low or Reduced SCBA Profile (Partial Removal Method)	
Building collapse due to lightweight construction, earthquakes, gas explosions, terrorist attacks, lack of training, or just lack of experience due to the amount fires and the amount of new fire fighters are just a few possible reasons why you may find your means of egress cut off. Finding your way through a small opening may be your only way to safe refuge or the outside. Maneuvering your SCBA into a low- or zero-profile is a skill you may need to use. This skill is something we hope you will never need, but should be practiced by all. In this skill, the students will demonstrate a last resort method of escaping the heat, smoke, and fire gasses from an advancing fire.	
Time Frame:	0:45
Students (Minimum):	One company
Materials Needed:	• Appropriate training structure • Profile prop (See Appendix B) • Full personal protective equipment
Site Preparation:	• Ensure that site is free of all hazards.
Instructor Directions:	1. Review all three methods of the skill. 2. Assign personnel to appropriate positions. 3. Perform a final safety check prior to performing the skill. 4. Ensure all students are wearing full personal protective equipment.
Student Directions:	
	1. Identify the opening to be used for escape. ▪ Determining the size and shape. ▪ Noting the largest portion of the opening as the most desirable for the SCBA.

Skill #11: Changing To A Low or Reduced SCBA Profile (Partial Removal Method)

2. Loosen your waist strap, ***but do not remove.***

3. Loosen both shoulder straps.

Skill #11: Changing To A Low or Reduced SCBA Profile (Partial Removal Method)

4. Remove the shoulder strap opposite the air supply hose.
   - Maintaining control of the shoulder strap.
   - Without dislodging the SCBA face piece.

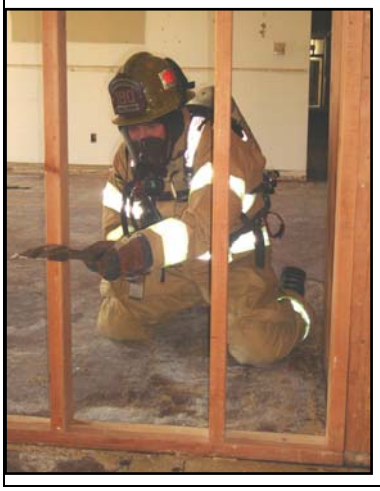
5. Sling the SCBA under your arm.
   - Sliding it into a position under the arm that the air supply hose travels over.
   - Positioning the top of the SCBA in your armpit.
   - Allowing the SCBA to rest along the side of your body.
   - Reaching down with a hand to hold the SCBA at the bottom or stem.

Skill #11: Changing To A Low or Reduced SCBA Profile (Partial Removal Method)

6. Outstretch your arm.
7. Lie flat on your side.
   - Attempting to touch your upper arm to your ear.
   - Avoiding temptation to rest on your elbow, as this will raise the profile.
8. Manipulate into and through the opening.
   - Outstretched arm, head, and upper body first.
   - Rotating your shoulders through the largest opening.
   - Keeping your hand on the SCBA bottom or stem.

9. When you are through the opening, get out of the way, allowing additional fire fighters to escape.
10. Redon the air pack.
11. Adjust and gather your equipment.
12. Move on.

Skill #12: Changing To a Zero or No SCBA Profile (Full Removal Method)

Skill #12: Changing To a Zero or No SCBA Profile (Full Removal Method)	
Building collapse due to lightweight construction, earthquakes, gas explosions, terrorist attacks, lack of training, or just lack of experience due to the amount fires and the amount of new fire fighters are just a few possible reasons why you may find your means of egress cut off. Finding your way through a small opening may be your only way to safe refuge or the outside. Maneuvering your SCBA into a low- or zero-profile is a skill you may need to use. This skill is something we hope you will never need, but should be practiced by all. In this skill, the students will demonstrate a last resort method of escaping the heat, smoke, and fire gasses from an advancing fire.	
Time Frame:	0:45
Students (Minimum):	One company
Materials Needed:	• Appropriate training structure • Profile prop (See Appendix B) • Full personal protective equipment
Site Preparation:	• Ensure that site is free of all hazards.
Instructor Directions:	1. Review all three methods of the skill. 2. Assign personnel to appropriate positions. 3. Ensure all students are wearing full personal protective equipment. 4. Perform a final safety check prior to performing the skill.
Student Directions:	
	1. Identify the opening to be used for escape. ▪ Determining the size and shape. ▪ Noting the largest portion of the opening as the most desirable for the SCBA.

Skill #12: Changing To a Zero or No SCBA Profile (Full Removal Method)	
	2. Loosen and remove the waist strap.
	3. Loosen both shoulder straps. 4. Remove both shoulder straps. ▪ Strap opposite the air supply hose first. ▪ Maintaining control of the shoulder straps. ▪ Without dislodging your face piece.
	5. Remove SCBA. ▪ Maintaining constant contact with the pack. ▪ Allowing the SCBA to be just ahead of your body. ▪ Without dislodging your face piece.

Skill #12: Changing To a Zero or No SCBA Profile (Full Removal Method)

6. Move into and through the opening.
   - Lying flat.
   - Starting with outstretched arm, head, and upper body.
   - Manipulating the shoulders through the opening.
   - Maintaining constant contact with the SCBA.

7. When you are through the opening, get out of the way, allowing additional fire fighters to escape.
8. Redon the SCBA.
   - Staying low in a hot environment.
9. Adjust and gather your equipment.
10. Move on.

Topic 7: Fire Fighter Survival Evolutions

Evolution #1: SCBA Confidence Course
Evolution #2: SCBA Awareness

Evolution #1: SCBA Confidence Course

Evolution #1: SCBA Confidence Course	
The student must successfully navigate the entire SCBA confidence course using survival skills when needed.	
Time Frame:	Determine by course structure.
Students (Minimum):	One student at a time in the course.
Materials Needed:	• Appropriate training structure • SCBA confidence course (see Appendix B) • Full personal protective equipment
Site Preparation:	Ensure that site is free of all hazards.
Instructor Directions:	1. Review Topic 2: Developing a Survival Attitude. 2. Review the operation of the evolution and the desired outcome with the students. 3. Review the safety considerations with the students. 4. Show the students the starting and ending points of the course. 5. Ensure all students are wearing full personal protective equipment. 6. Perform a final safety check prior to performing the evolution.
Student Directions:	
1. Go on-air. 2. Enter the course at the designated starting point. 3. Navigate each obstacle encountered using any required survival skills. ▪ Redonning the SCBA after performing any reduced profile maneuvers. 4. Move calmly and deliberately through the course. Using breathing techniques to reduce your air consumption.	

Evolution #2: SCBA Awareness

Evolution #2: SCBA Awareness	
The student will size-up, enter, search, locate, and don a SCBA while maintaining room/building orientation. The student then activates the fire fighter emergency, perform personal procedures, and exit the building while maintaining room/building orientation using a hoseline and/or a left/right search pattern.	
Time Frame:	0:15
Students (Minimum):	One company
Materials Needed:	• Appropriate training structure • Flashlight • SCBA with PASS device • 1¾" charged hoseline (minimum size) with sufficient length to extend throughout the entire structure • Personal protective equipment
Site Preparation:	• Training structure or prop should simulate an actual interior working environment. • Ensure that site is free of all hazards.
Instructor Directions:	1. Review Topic 4: The Fire Fighter Emergency. 2. Review the operation of the evolution and the desired outcome with the students. 3. Review the safety considerations with the students. 4. Perform a final safety check prior to performing the skill. 5. The student will enter the course in personal protective equipment, but without a SCBA.
Student Directions:	
	1. Size-up the structure. 2. Determine point of entry. 3. Enter the structure. ▪ Using a hoseline or walls of the structure to maintain room/building orientation. ▪ Staying low.

Evolution #2: SCBA Awareness

4. Locate SCBA.
   - Listening for PASS device or by touch.
5. Ensure SCBA is on-air.
6. Don regulator.
7. Activate the PASS device.
8. Transmit the fire fighter emergency.
   - Using LUNAR.

9. Don SCBA.
   - Securing all straps, buckles, and clips.
10. State your personal procedures.
    - Monitoring and controlling your air.
    - Turning on your flashlight.
    - Making some noise.
    - Looking for exits (windows, doors, light from the outside).

11. Exit the structure.
    - Using hoseline and/or walls.
    - Maintaining room/building orientation.
    - Staying low.
    - Staying calm.

Appendix A: Glossary

2-in/2-out rule ..... Provision in OSHA 1910.134 that outlines deployment of first arriving fire personnel and provision of personnel available for their rescue if needed.

90-degree angle collapse ..... Wall collapse where a large portion or even the entire wall falls outward at a 90-degree angle.

A-frame collapse ..... Collapse that result when a floor separates from the exterior wall creating a void space toward the center of the structure.

Backdraft ..... When oxygen is introduced into an area holding superheated products of incomplete combustion resulting in an immediate ignition of the products.

Balloon frame construction ..... Wood-stud framing system that runs continuously from the ground-level to the attic that provides channels that allow for rapid fire spread.

CAN ..... Conditions-actions-needs

Convected heat currents ..... Heat transfer by the movement of air currents.

Conventional construction ..... Framing with conventional joists, rafters, and wall studs. This construction has solid structural elements that will result in a longer burn time before failing.

Curtin wall collapse ..... Wall collapse where a wall crumbles or collapses upon itself straight downward.

Dead load ..... The weight of a building an any permanent feature, including structural members and building materials such as floors, walls, HVAC systems, etc.

Disorientation ..... Mental state that a fire fighter may experience if he or she becomes lost or confused while working in a hazardous atmosphere.

EBS ..... Emergency breathing system.

Engineered I-joist ..... Structural member which uses a center portion composed of wood chips held together with glue. I-beams are used to span large areas and can fail very quickly if unprotected and exposed to high heat.

Emergency breathing system (EBS) ..... A feature on some SCBAs that allows one user to share their air supply with another.

Emergency radio traffic ..... Used to signify that a priority message is to follow on the radio.

Flashover..... Gases trapped at the ceiling that reaches their ignition temperature spontaneously involving the entire interior space.

IDLH ..... Immediately dangerous to life and health.

Immediately dangerous to life and health (IDLH)..... An atmosphere that when entered could result in immediate fire fighter or civilian injury or death.

Lean-to collapse ..... Collapse caused when the supports for the roof or floor of a building fall to one side.

Lightweight truss construction..... Type of construction that obtains its strength from compression and tension of materials used in its construction as opposed to mass. Pieces of truss are held together with metal gusset plates, nails, or glue that fail under high heat conditions resulting in failure of the truss.

Lightweight construction..... Type of construction in which the structural members that provide framework and support are fabricated out of composite materials made up of wood chips and glue. These materials will degrade very quickly when exposed to heat.

LUNAR..... Acronym used by a lost or trapped fire fighter during a fire fighter emergency to relay the following pertinent information, L - last know location, U - Unit, N - Name, A - Assignment, and R - Resources Needed.

Mayday ..... Term used only to signify that a person is in a life threatening situation and needs immediate assistance. A fire fighter emergency can be declared by anyone having knowledge of someone in distress.

Metal frame construction..... Type of construction in which the structural members that provide framework and support are fabricated out of metal components. These materials will degrade very quickly when exposed to heat.

Mule kicking..... A technique performed by a distress fire fighter for penetrating a wall for emergency egress from one area to another when the use of a tool is not available.

NFPA..... National Fire Protection Association

NIOSH ..... National Institute for Occupational Safety and Health

OSHA ..... Occupational Safety and Health Administration

OSHA 29 CFR 1910.134 ..... OSHA standard that covers the parameters required for a respiratory protection program. It contains the 2-in/2-out rule.

Oriented search ..... A systematic search technique that provides good coverage of a small or medium sized open area in place of a complete right or left-hand search.

PAC-CAN ..... Systematic process used by RIC personnel when they find a downed fire fighter. Pass - silence alarm, Assess - fire fighter to determine whom it is and what their air level is, Communicate - critical information to RIC leader who then communicates the critical information to the RIC Group Supervisor. Followed by Conditions of fire, Actions - what is RIC going to do, Needs - what needs to be done to be successful.

Pancake collapse ..... Collapse that results fro the failure of a structures bearing wall causing the roof and floors to collapse upon each other.

PAR ..... Personnel accountability report.

PASS ..... Personal accountability safety system.

PASS Device ..... Personal alarm safety system worn by each fire fighter that will go into an audible alarm if the fire fighter fails to move. This alarm should alert other fire fighters of a possible emergency.

Penciling ..... Technique used during fire attack to determine heat levels within the room. Short bursts of water are directed at the ceiling to determine heat conditions. If water droplets fail to fall back down, flashover may be imminent. Effective penciling can help prevent flashovers from occurring.

Personnel accountability report (PAR) ..... Roll call of companies operating at an emergency incident. Commonly performed when mode of operation changes (i.e., offensive to defensive), or a significant event such as a fire fighter emergency or collapse.

PIA ..... Post-incident analysis.

Point of no return ..... Refers to a fire fighter's individual management of air supply. It is determined by the amount of air consumed going into a structure versus the amount of residual air needed to exit the structure.

Positive pressure ventilation.... Utilization of fans to force air into an enclosure or void by creating pressure differentials. This method of ventilation can affect fire behavior inside a structure; therefore, it must be coordinated closely with interior crews.

Post-incident Analysis ..... A recap and in-depth review of an incident or training session to seek out information to address areas that went well as well as areas that need improvement.

PPPN..... Acronym used to determine a crew's Personnel accountability, Position on the incident, Progress made, and Needs to be successful.

Preincident planning ..... A building walk-through, inspection, or survey prior to an emergency taking place that provides knowledge about the building, potential fire behavior, pre-established strategic and tactics scenarios.

Radio-assisted feedback..... A procedure using two portable radios that are placed closely together and keyed to the talk position, creating a high-pitched feedback sound. This feedback sound can be heard over a downed fire fighter's radio and be used to assist a RIC team in finding the downed fire fighter's location.

Rapid intervention crew (RIC)..... Team of specially trained fire fighters who are solely responsible for the safety, search, and rescue of trapped or lost fire fighters at an emergency incident. Ideally, the RIC should be made up of four fire fighters.

RIC ..... Rapid intervention crew.

Risk management process ..... A method used to recognize and then reduce the risks to fire fighters. The process includes situational awareness, hazard assessment, hazard control, decision point, and evaluation.

Roof decking..... Materials that make up the construction of a roof before covering materials such as asphalt are applied.

RPD..... Rapid prime decision-making.

Sheathing ..... Material applied to wood-frame structure over structural framing to which exterior material finish is applied.

Skip breathing..... Technique used by a fire fighter when lost or trapped that maximizes their SCBA air supply.

Size-up the building ..... The process of providing multiple visible structure type indicators, such as, shape and size, construction type, egress points on a structure; which may include, doors, security gates, rollup doors, barred windows, etc., fire conditions outside and inside the structure. Your own mental blue-print of the building.

Support lean-to collapse..... Collapse that results from the failure of one side of a roof or floor that falls until it rests and is supported by substantial objects inside the structure.

Thermal imaging camera (TIC) ..... Device that used infrared energy technology that allows fire fighters the ability to ascertain objects by shape in conditions that do not allow normal vision. Some models also monitor heat conditions.

TIC..... Thermal imaging camera.

Unsupported lean-to collapse .. Collapse where one side that has failed is without any support. This failed side floats freely and is very unstable and could result in a secondary collapse.

Void search ..... A physical search that is conducted in a collapse environment by rescuers moving over and around debris, locating spaces created by the collapse of building materials.

V-shaped collapse ..... Collapse that is caused by the failure of an interior support, resulting in void spaces on both sides of the collapse toward the bearing walls.

Walk-out basement..... Architectural feature in the construction of a building with an elevation difference between the grade at the front the building and the back of the building.

Wall breach ..... The penetration of a wall through various methods for the purposes of emergency egress by a lost or trapped fire fighter or entry by RIC personnel for rescue purposes.

Wood frame construction ..... Type of construction in which the structural members that provide framework and support are fabricated out of wood. Most common type of construction.

Appendix B: Props and Systems

Entanglement Prop

Materials Needed:

- 2 sheets of plywood - ½" 4'x8'
- 10 boards - 2"x3"x6'
- 160 - 2½" wood screws
- Wire and or rope of all dimensions. The more the better. As this will need to be replaced over time.

1. Cut both sheets of plywood in half, resulting in two 2'x8' sheets.
2. Cut the ten 2"x4"x6' boards in half, resulting in twenty 2"x4'x3' boards.
3. Screw four 2"x4"x3' boards into a square using at least 4 screws per corner.
4. Repeat this until you have 5 squares.
5. Drill a 1" hole from where the 2"x4"x3' boards cross. This where the wire is attached.
6. Attach a sheet of plywood to the squares at each end and 2-feet on center using at least 4 screws per connection.
7. Center the sheets from side to side, so the squares are like ribs around the plywood sheets.
8. Repeat this with all four sheets, forming a tunnel.
9. Attach the wire from one corner to the diagonal corner.
10. Repeat from the opposite corner.
11. There is no specific pattern; just make some tighter and some loose.
12. Looking down the tunnel, it should look like an "X."
13. After each person has completed the prop, turn it one rotation and this "shuffles the cards."

Eight feet later, you will be a better fire fighter!

Confidence Course

Profile Prop

Appendix C: NIOSH Alert – Truss System Failures

NIOSH ALERT

Preventing Injuries and Deaths of Fire Fighters due to Truss System Failures

WARNING!

Fire fighters may be injured and killed when fire-damaged roof and floor truss systems collapse, sometimes without warning.

The National Institute for Occupational Safety and Health (NIOSH) requests assistance in preventing injuries and deaths of fire fighters due to roof and floor truss collapse during fire-fighting operations. Roof and floor truss system collapses in buildings that are on fire cannot be predicted and may occur without warning. NIOSH recommends that fire departments review their occupational safety programs and standard operating procedures to ensure they include safe work practices in and around structures that contain trusses. Building owners should follow proper building codes and consider posting building construction information outside a building to advise fire fighters of the conditions they may encounter.

NIOSH requests that the information in this Alert be brought to the attention of all U.S. fire departments and fire fighters. To bring the recommendations in this Alert to the attention of the fire service community, NIOSH requests help from the following individuals and organizations: fire commissioners, fire chiefs, State and local fire district administrators, State fire marshals, safety and health officials, trainers, fire investigators, unions, labor organizations, insurance companies, and editors of trade journals and other publications.

BACKGROUND

According to the Wood Truss Council of America (WTCA), wooden trusses are used in roof systems in more than 60% of all buildings in the United States [SBCMAG 2004]. Truss and related engineered wooden floor systems are also becoming more common. Today, more engineered structures use lighter weight materials, producing larger spans and clear openings. Trusses can be designed to carry expected loads, be produced economically, be safely handled, and reduce construction costs (see Figure 1).

Engineered building components may provide adequate strength under normal loading; but under fire conditions, these truss systems can become weakened and fail, leading to the collapse of roofs, floors, and possibly the entire structure. Truss systems are usually hidden, and fires within truss systems may go unnoticed for long periods

1

Figure 1. Typical lightweight truss construction. (*Photo courtesy of Vincent Dunn.*)

of time, resulting in loss of integrity. Structural design codes often do not factor in this decreased system integrity, as fire degrades the structural members. Fire fighters typically rely on warning signs to indicate imminent truss failure such as roofs and floors that feel spongy or are visibly sagging. Quite often, these warning signs are not good predictors of truss system failures.

The United States Fire Administration (USFA) reports that during 1990–2000, structural fires and explosions accounted for 46.1% of all reported fire fighter fatalities (500 of 1,085) [USFA 2002]. Statistics compiled by the WTCA suggest that 4.7% of the total fatalities (108 of 2,286) during 1980–2001 were due to structural collapse [Grundahl 2003b]. Fifteen separate incidents investigated by NIOSH identified at least 20 fatalities and 12 injuries that have occurred from 1998–2003 during fire-fighting operations in buildings containing truss systems (see Appendix A).

What is a Truss?

A truss can be defined as structural members (such as boards, timbers, beams, or steel bars) joined together in a rigid framework. They are most often in the shape of a triangle or series of triangles. Some trusses are rectangular. Trusses can be built of wood, steel, wood and steel, or aluminum. Concrete trusses are not common but do exist, usually in very large structures (see Appendices B and C for descriptions of different truss types). The truss framework is usually arranged in a single plane so that loads applied at points of intersecting members will cause only direct stress (compression or tension). Three-dimensional trusses (space frames) are very light in weight. The design of a truss, which separates compressive and tensile stresses, allows for a minimum of materials to be used, resulting in economic benefit.

The top and bottom members of a truss are called chords. The top chord of a truss is in compression, and the bottom chord is in tension. The inner members are called webs and give stability to the truss system. The unique characteristic of a truss is the inherent stability of the triangle. Web and chord members arranged in a triangle are much more stable than the same members arranged in a square. The square configuration requires diagonal bracing, which then produces multiple triangles.

Truss Types

Although many types of trusses exist, three typical truss construction methods are most commonly used:

- Heavy timber roof and floor truss systems
- Lightweight wooden roof and floor truss systems
- Steel roof and floor truss systems

Each of these construction methods is described in detail in Appendices C and D, along with causes of failure for each under fire conditions.

CURRENT STANDARDS

National Fire Protection Association (NFPA)

The NFPA develops voluntary standards aimed at protecting fire fighters and civilians from fire-related injuries and deaths. The following NFPA standards address fire fighter safety related to roof and floor trusses:

- NFPA 1620, *Recommended Practice for Pre-Incident Planning*, presents a guide to help fire department officials develop a pre-incident plan to help responding personnel effectively manage emergencies with available resources. The pre-incident plan should not be confused with fire inspections, which monitor code compliance. Pre-incident planning involves evaluating occupancies before an incident to identify information critical for fire-fighting operations in case an incident occurs. Chapter 3 recommends that these pre-incident plans address the structural integrity of walls, roofs, and floors [NFPA 2003a].
- NFPA 1521, *Standard for Fire Department Safety Officer*, stresses pre-incident planning and requires that data regarding roof construction be recorded, including roof support components (e.g., wooden joist, wooden truss, steel joist, steel truss, and beam and girder), length of the support spans, roof deck material (e.g., wood, metal, concrete), and other features [NFPA 2002a].
- NFPA 1001, *Standard for Fire Fighter Professional Qualifications*, requires Fire Fighter II candidates to be familiar with building construction and hazards such as indicators of imminent building collapse [NFPA 2002b].
- NFPA 921, *Guide for Fire and Explosion Investigations*, is intended to help the fire investigator understand the reaction of buildings and building assemblies to fire. Chapter 5 addresses manufactured lightweight wooden truss failures [NFPA 2001].

Other relevant NFPA Standards include the following:

- NFPA 5000, *Building Construction and Safety Code*, addresses the construction, protection, and occupancy features necessary to minimize danger to life and property by providing minimum design regulations for construction, quality of materials, use and occupancy, location, and maintenance. All framing methods are addressed, including the use of roof and floor trusses [NFPA 2003b].
- NFPA 13, *Standard for the Installation of Sprinkler Systems*, provides the minimum requirements for the design and installation of automatic fire sprinkler systems and exposure protection sprinkler systems. This standard addresses different sprinkler systems for protecting various roof systems [NFPA 2002c].
- NFPA 501, *Standard on Manufactured Housing*, covers the equipment and installations used in the design, construction, transportation, fire safety, plumbing, heating, and electrical systems of manufactured homes designed to be used as dwelling units. Chapter 5 addresses load requirements for roof trusses [NFPA 2003c].

Building and Construction Codes and Standards

Roof and floor trusses are designed and manufactured to comply with American National Standards Institute (ANSI) and industry consensus standards. NFPA and the International Code Council (ICC) policy require that industry-accepted design standards be developed following ANSI consensus guidelines. However, these and other standards do not take into consideration exposure to real fire conditions and the impact of fire on structural performance [Brannigan 1988; Cutter 1990].

The fire endurance testing done to determine 1- and 2-hour rated assemblies does not accurately replicate structural fires, and as such does not take into consideration fire fighter safety [Grundahl 1992]. ASTM International (formerly known as the American Society for Testing and Materials) developed standardized test methods for building and construction materials (including roof and floor trusses). ASTM E119–00a, *Standard Test Methods for Fire Tests of Building Construction and Materials*, is the primary standard used to test roof and floor trusses and related assemblies. It is recognized and accepted by most building codes. However, test methods described in ASTM E119 may not be truly representative of real fire conditions. For example, ASTM E119 assumes fire spread will be upward, while many fires burn downward into floor truss voids and then spread horizontally [Brannigan 1999].

Building codes vary by jurisdiction. Since the early 1900s, various organizations have developed model building codes used throughout the United States. In 1994, the Building Officials and Code Administrators International (BOCA), International Conference of Building Officials (ICBO), and the Southern Building Code Congress International (SBCCI) combined to form the International Code Council (ICC). This resulted in the development of a consistent set of requirements for architects, engineers, building designers, and contractors to follow throughout the country. The ICC codes address both fire protection and fire fighter safety. However, the focus of building codes is not to protect fire fighters once a fire has started in a building. Building code provisions are developed so that occupants can evacuate safely and the fire service has adequate access (clear path for trucks, etc.) to the building to suppress the fire. The International Building Code (IBC) developed by ICC contains many of the same requirements found in the NFPA 5000 Building Construction and Safety Code.

CASE REPORTS

At least three scenarios can occur in which fire fighters suffer fatalities and injuries while operating at fires involving truss roof and floor systems [Dunn 1992]:

1. While fire fighters are ***operating above a burning roof or floor truss***, they may fall into a fire as the sheathing or the truss system collapses below them.

2. While fire fighters are ***operating below the roof or floor inside a building with burning truss floor or roof structures***, the trusses may collapse onto them.

3. While fire fighters are ***operating outside a building with burning trusses***, the floor or roof trusses may collapse and cause a secondary wall collapse.

The following case reports describe incidents involving fire fighter injuries and deaths due to fires involving truss system failures. The incidents were investigated through the NIOSH Fire Fighter Fatality Investigation and Prevention Program.

Case 1

On March 8, 1998, one male career fire fighter, a captain (victim), died when the wooden-bowstring trussed roof of a building collapsed and blocked his exit route. The first company on the scene reported light smoke showing from a one-story commercial building. While fire companies waited for the security doors to be opened, fire conditions changed dramatically on the roof. Heavy fire was coming from the ventilation holes opened by the ventilation crew. When the doors were opened, the fire fighters encountered heavy smoke with near-zero visibility approximately 15 feet inside the door. The engine crews advanced until deteriorating conditions forced them to withdraw. During this time, the victim became separated from his crew and did not exit from the building. Approximately 20 minutes after the engine crews entered the building, the roof partially collapsed, blocking the front entry and hampering rescue operations. The victim was later located by the Rapid Intervention Team, and cardiopulmonary resuscitation was performed immediately and enroute to the hospital, where the victim was pronounced dead [NIOSH 1998a].

Case 2

On September 5, 1998, a 54-year-old male career fire fighter (the victim) died when an exterior brick parapet wall collapsed on him. The warehouse was constructed of brick masonry walls with heavy timber trusses supporting the roof. The front and rear masonry walls extended above the peak of the roof, forming parapet walls. The first responding officer ordered an exterior-only attack using deck guns and hose lines. The incident commander called dispatch to request mutual aid from three additional fire departments. A career department (including the victim) arrived on the scene approximately 15 minutes later and was positioned at the north end of the building and prepared for an exterior attack. The victim approached the building to open a set of large doors (each 15 feet high by 6 feet wide) so that hose lines could be directed through the doors. The doors closed as the victim returned to the hose lines. The victim was approaching the building a second time to prop the doors open when the brick parapet wall suddenly collapsed outward, killing him instantly. Fire fighters at the east side of the warehouse reported a partial roof collapse at approximately the same time the parapet wall on the north side collapsed [NIOSH 1998b].

Case 3

On December 28, 2000, four career fire fighters were injured when a section of a church roof collapsed, trapping them inside. The roof system was formed using lightweight wooden trusses with gusset plate connectors. Two different truss systems were used in the different construction phases. The exterior peaked roof was covered with standard asphalt shingles. The interior ceiling consisted of ½-inch drywall attached to the bottom of the trusses. Three 1¾-inch hose lines were advanced into the building by three crews. The incident commander ordered the first crew to enter the structure for an aggressive fire attack, cautioning them not to enter the structure very far. Two subsequent crews were sent into the building through a different set of doors. Approximately 7 minutes after the first crew

entered, the second and third crews met in a classroom. They noticed intense fire in the ceiling/truss void area where a small piece of ceiling in the classroom had fallen. Soon afterward, the roof collapsed in the classroom area, trapping and injuring four fire fighters. Three were able to escape by breaking through an exterior window. The fourth fire fighter located the classroom door, and the incident commander led him into the hallway and out of the structure. The lightweight truss roof collapsed less than 10 minutes after the fire fighters entered the building [NIOSH 2001].

Case 4

On March 7, 2002, a 28-year-old male volunteer fire fighter (Victim 1) and a 41-year-old male career fire fighter (Victim 2) died after becoming trapped in the basement by a floor collapse in a residential fire. The victims were attempting to advance a hose line on the first floor of the structure. The roof and floor systems both consisted of lightweight, pre-engineered wooden trusses covered with plywood sheeting. The incident commander directed a crew of two fire fighters to take a hose line through the garage down the stairs toward the fire. They were unable to reach the basement because of heavy fire coming from the stairway. They were attempting to check the interior of the house through a second door leading from the garage when the nozzleman's low-air alarm sounded. They exited from the garage to exchange their air cylinders. Victim 1 and Victim 2 entered the house through the door inside the garage to relieve the initial attack crew on the hose line. The captain from the mutual aid department followed the hose line through the garage to the doorway to assist his crew. Soon after the two victims entered the house, the floor collapsed, dropping them into the basement. The captain encountered intense heat at the doorway but could not see any flames. He was unaware the floor had collapsed but heard Victim 2 yelling for help. As the captain attempted to lift Victim 2 out of the basement, the victim grabbed and ripped the captain's self-contained breathing apparatus (SCBA) mask from his face. The captain was forced to exit from the garage and was later transported to a local hospital. Two other fire fighters attempted to remove Victim 2, but they were overcome by intense flames shooting from the basement, which eliminated further rescue attempts. The area of entrapment was inaccessible because of the floor collapse. Rescue crews finally breached the masonry foundation wall and recovered both victims. The area of the floor collapse was directly above the origin of the fire [NIOSH 2002].

Case 5

On June 15, 2003, a 39-year-old male career lieutenant (Victim 1) died, and another 39-year-old career fire fighter (Victim 2) was fatally injured while trying to exit from a commercial structure following a partial collapse of the building's flat metal roof, which was supported by lightweight metal trusses (bar joists). Victim 1, the lieutenant of the first responding engine company, reported light smoke on arrival at a discount store. The flat roof consisted of metal decking covered by wooden fiber insulation and asphalt. A suspended ceiling in the main store area approximately 12 feet high covered the metal roof trusses and obstructed their view from below. Victim 1 led his crew into the store to search for the fire. After proceeding approximately halfway to the rear of the store, he directed two fire fighters to go outside and bring in a preconnected hand line. Victim 1 and a lieutenant from the second

engine company proceeded to the rear of the store. This lieutenant found the fire behind the closed office door and exited to pull a second hand line. Soon afterward, Victim 1 requested a truck company to enter the store and pull ceiling tiles to search for fire extension; a third lieutenant and a fire fighter immediately responded. The truck company searching for fire extension observed fire in the truss void above the suspended ceiling. The accumulation of smoke and hot gases within the truss void mixed with fresh air as the ceiling was opened and violently ignited. The fire rapidly spread from the rear office area to the main store room through the hidden truss void. Victim 1 radioed that it was getting too hot and everyone needed to back out. At this point, the roof system at the rear of the store room began to fail, sending debris downward, with several bar joists coming to rest on metal merchandise shelving. Several fire fighters were able to escape by following the hose lines toward the front of the store. Victim 1 and Victim 2 (the nozzleman from the first responding engine company) became separated from the rest of the fire fighters and were unable to escape. As conditions worsened, the building was evacuated, and a rescue attempt for the two missing fire fighters was initiated. Fire fighters working at the rear of the building heard a personal alert safety system (PASS) device and quickly entered to investigate. Victim 2 was located in the rear storage room close to the office. A second PASS device was also heard further into the building. Soon after Victim 2 was brought outside, the rear of the building collapsed, preventing further rescue efforts until the fire was brought under control. Victim 1 was located approximately 1½ hours later. Victim 2 was hospitalized and died the next day [NIOSH 2004].

CONCLUSIONS

More than 60% of the roof systems in the United States are built using a truss system. By design, wooden truss systems contain a significant fuel load and are often hidden from sight. Fires in truss systems can burn for long periods before detection and can spread quickly across or through the trusses. Steel trusses are also prone to failure under fire conditions and may fail in less time than a wooden truss under the same conditions.

The number of fire fighter fatalities related to structural collapse could be significantly reduced through proper education and information concerning truss construction. Fire fighters should be discouraged from risking their lives solely for property protection activities.

Unfortunately, fires are not predictable: conditions often deteriorate quickly, and fire-damaged building components, including trusses, can collapse with little warning. Engineering calculations provide data for an approximate time of failure under specified fire conditions; however, under uncontrolled fire conditions, the time to truss failure is unpredictable.

Early detection of fires involving truss systems is important for safe fireground operations. Pre-incident planning is an important tool for identifying the type of building, the building contents, the load-bearing and interior wall locations, and the presence of trusses. This information will aid incident commanders in managing the multiple hazards in a fire. Today's construction methods incorporate lightweight building components, and this trend is expected to grow. Learning about trusses and their performance under

fire attack can greatly enhance fire fighter safety. Lives will continue to be lost unless fire departments make appropriate fundamental changes in fire-fighting tactics involving trusses. These fundamental changes include the following:

- Venting the roof using proper safety precautions
- Opening concealed spaces quickly to determine fire location
- Being constantly aware of the time the fire has been burning
- Providing continuous feedback on changing conditions to the incident commander
- Watching for signs of structural deterioration
- Employing a defensive strategy once burning of truss members is identified
- Broadly disseminating new tactical safety concepts learned at each fire

RECOMMENDATIONS AND DISCUSSION

NIOSH recommends that fire departments, fire fighters, building owners, and managers take steps to minimize the risk of injury and death to fire fighters during fire fighting operations involving structures with truss roof and floor systems:

Fire Departments

- ***Ensure that fire fighters are trained to identify different types of roof and floor truss systems and the hazards associated with each.***
- ***Conduct pre-incident planning and inspections to identify structures that contain truss construction.***
  - — Inspect buildings within your jurisdiction and note the type of construction, materials used, presence of trusses in the roof and floor, occupancy, fuel load, exit routes, and other distinguishing characteristics [Brannigan 1999, Klaene and Sanders 2000].
  - — Check the structural integrity of walls, roofs, and floors.
  - — Record data regarding roof and floor construction (e.g., wooden joist, wood truss, steel joist, steel truss, beam and girder, etc.) [NFPA 2003a].
  - — Share this information with other departments who provide mutual aid response in the same area.
  - — Whenever possible, inspect buildings during the construction phase to help assess the different types of construction, materials, etc.
  - — Enter preplan information into the dispatcher's computer so that when a fire is reported at preplanned locations, the dispatcher can notify by radio all first responders with critical information [Dunn 2001].
- ***Develop and implement standard operating procedures (SOPs) to combat fires safely in buildings with truss construction.***
  - — Modify existing work practices when necessary to ensure safety during operations around truss construction.
  - — Provide SOPs to all fire fighters for combating fires in buildings with all types of construction, including the different truss types. Also offer training on identifying buildings constructed with trusses.

— Use defensive strategies whenever trusses have been exposed to fire or structural integrity cannot be verified. Unless life-saving operations are under way, evacuate fire fighters and use an exterior attack [Brannigan 1999; Dunn 2001].

- ***Ensure that the incident commander conducts an initial size-up and risk assessment of the incident scene before beginning interior fire-fighting operations.***
  - — Consider using a thermal imaging camera as part of the size-up operation to aid in locating fires in concealed spaces.
  - — Account for the type of building construction (i.e., presence of truss construction) when determining (1) the number of fire fighters available, (2) the amount of apparatus and equipment needed to control the blaze, (3) the most effective point of fire extinguishment attack, (4) the most effective method of venting heat and smoke, and (5) whether the attack should be offensive or defensive.
  - — Continually conduct size-up from the time the alarm is received until the fire is under control [Brunacini 1985]. Analyze risk versus gain continuously during incident operations [Dunn 1998].
  - — Evaluate the type of structure (residential, commercial, etc), time of day, occupancy, contents of the structure, hazards, exposures, etc.
  - — Try to find out the type of construction, age of the building, and whether modifications or additions have been completed to help assess structural stability [Dunn 1996].
  - — Pay close attention to the conditions outside the structure, monitor the roof, and also check on interior conditions [Dunn 1996; NIOSH 1999].
  - — Plan for search and rescue operations before an emergency occurs in case a fire fighter becomes trapped.
  - — Immediately notify the Rapid Intervention Team when truss construction is identified.
- ***Ensure that fire fighters performing fire-fighting operations under or above trusses are evacuated as soon as it is determined that the trusses are exposed to fire (not according to a time limit).***
- ***Establish a collapse zone when operating outside a burning building, since truss roof collapses can push out on the walls, causing a secondary collapse of the exterior walls.***
  - — The collapse zone should be equal to the height of the building plus allowance for scattering debris [Brannigan 1999; Klaene and Sanders 2000; NIOSH 1999], usually at least 1½ times the height of the building.
- ***Use defensive overhauling procedures after fire extinguishment in a building containing truss construction. Use outside master streams to soak the smoldering truss building and prevent rekindling [Brannigan 1999; Klaene and Sanders 2000].***
- ***Consider becoming involved in the building code development and enforcement process.***
- ***For more information about preventing fire fighter injuries and deaths from structural collapse, see NIOSH***

[1999] and relevant research on new structural collapse prediction technologies: www.usfa.fema.gov/inside-usfa/research/safety/nist1.shtm [USFA 2004a].

Fire Fighters

- ***Use extreme caution when operating on or under truss systems.***
  - — Notify the incident commander whenever truss construction is discovered.
  - — Communicate interior conditions to the incident commander as soon as possible and provide regular updates.
  - — Use a defensive fire-fighting strategy once burning of truss members is identified (unless someone is trapped).
  - — Expect imminent collapse once lightweight truss roofs or floors are involved in a fire [Klaene and Sanders 2000].
  - — If possible, avoid cutting the truss chords when cutting holes for roof ventilation. Cuts can weaken the roof.
  - — Avoid roof areas loaded by air conditioning units, air handlers, and other heavy objects.
  - — Be aware of alternative exit routes at all times when working above or below a truss.
  - — Consider using roof ladders or working from aerial ladders or platforms instead of walking or standing directly on the roof [Brannigan 1999; Dunn 1998].
- ***Immediately open ceilings and other concealed spaces whenever a fire is suspected in a truss system.***
  - — Be aware that fires can be in the truss void or other concealed areas (see Figure 2). Once the fire enters a concealed space, it can travel to remote locations rapidly, since the wooden web members surrounded by open air space provide an excellent fuel source [Brannigan 1999].
  - — When a truss is suspected to be above a ceiling, use a pike pole or other tools to open up the ceiling and check for truss construction [Brannigan 1999]. If there is a fire barrier in the void, use the same procedure on the opposite side.
  - — Be aware of the possibility of flashover or back draft when opening concealed spaces and take the appropriate safety precautions.
  - — When opening ceilings or other concealed spaces, have charged hose line(s) ready.
  - — Be aware of the nearest exit and of other fire fighters in the area. The incident commander must consider and provide for alternative exit routes from all locations where fire fighters are operating [Klaene and Sanders 2000].
- ***Understand that fire ratings may not be truly representative of real-time fire conditions.***

Building Owners and Managers

- ***Consider placing building construction information outside the building. Include information about roof and floor type (presence of trusses***

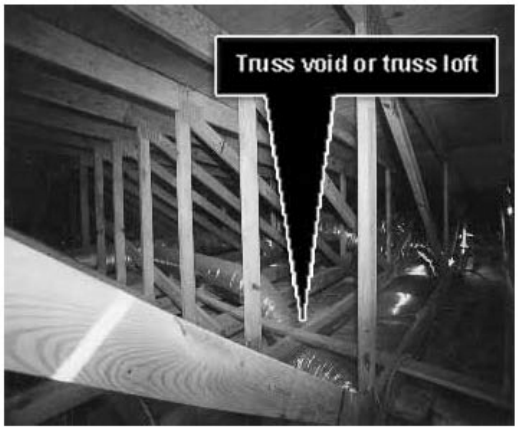


Figure 2. Truss loft with space for ventilation ductwork, wiring, etc. (*Photo courtesy of National Fire Protection Association.*)

[Figure 3], materials used), roof loads (heating, ventilation, and air conditioning [HVAC] units, displays), sprinkler systems, utilities, chemicals on site, and contact numbers.

- ***Use and follow proper building codes.***

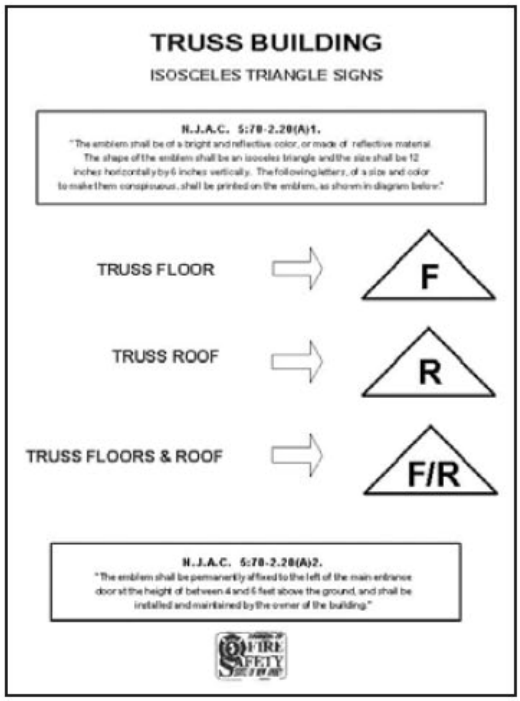


Figure 3. Truss Placard—State of New Jersey; NJAC 5:70–2.20(a) 1 and 2 [NJAC 1992].

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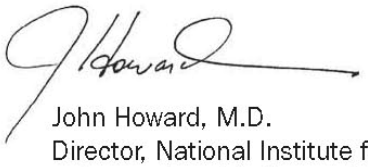
We greatly appreciate your assistance in protecting the safety and health of fire fighters.



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and Prevention

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APPENDIX A

Incidents Involving Structures Containing Truss Construction

The NIOSH Fire Fighter Fatality Investigation and Prevention Program has investigated the following incidents that involved structures containing truss construction. The complete NIOSH investigation report for each incident can be obtained at www.cdc.gov/niosh/facerpts.html.

Table A-1. Reports of incidents involving structures containing truss construction

Report ID	State	Truss type	Number of injuries and fatalities	Event leading to death or injury
98F005	Illinois	Heavy timber	2 F,* 3 I	Backdraft
98F007	California	Heavy timber	1 F	Roof collapse
98F020	Vermont	Heavy timber	1 F	Roof/wall collapse
98F021	Mississippi	Lightweight wood	2 F	Roof collapse
99F002	Indiana	Lightweight wood	1 F	Roof collapse
F2000–13	Texas	Lightweight wood	2 F	Roof collapse
F2000–26	Alabama	Lightweight wood	1 F	Floor collapse
F2000–43	Delaware	Lightweight wood	3 I	Fire spread through truss voids
F2001–03	Arkansas	Lightweight wood	4 I	Roof collapse
F2001–09	Wisconsin	Heavy timber	1 F, 1 I	Roof/wall collapse
F2001–16	Ohio	Lightweight wood	1 F	Floor collapse
F2001–27	South Carolina	Lightweight wood	1 F	Roof collapse
F2002–06	New York	Lightweight wood	2 F, 1 I	Floor collapse
F2002–50	Oregon	Heavy timber	3 F	Roof collapse
F2003–18	Tennesse	Lightweight metal	2 F	Roof collapse

*F = Fatality, I = Injury

APPENDIX B

Triangular trusses are the most common trusses used in single-family dwellings. Triangular trusses provide a peaked roof.

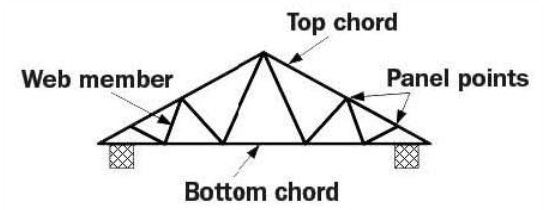

Figure B-1. Triangular truss

Scissor trusses are common in construction with cathedral ceilings. They are often found in churches.

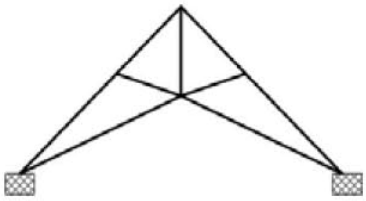

Figure B-2. Scissor truss

Parallel chord trusses provide a flat roof or floor. The top and bottom chords are parallel. They are commonly used in single-family dwellings, row houses, apartment buildings, and smaller office buildings.

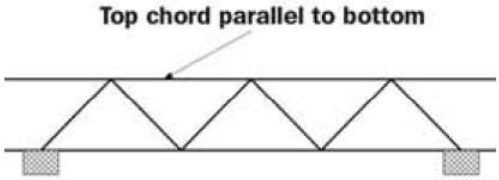

Figure B-3. Parallel chord truss

Bowstring trusses get their name from the curved shape of the top chord. Parapet walls may hide the curved roofline on large commercial buildings.

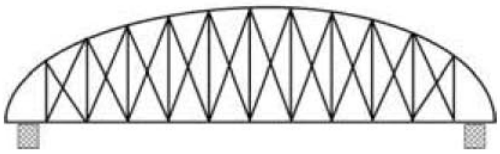

Figure B-4. Bowstring truss

Inverted king/queen post trusses are used in place of support columns to provide open floor space under the truss.

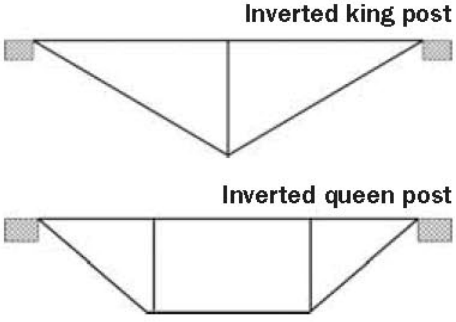

Figure B-5. Inverted king/queen trusses

APPENDIX C

Truss Systems

Heavy Timber Roof and Floor Truss Systems

Heavy timber trusses are often engineered to provide large open areas—such as under a cathedral ceiling. The timbers in a heavy timber truss are usually joined together by bolts that pass through the center of metal or steel plates. The most common connector is the split-ring metal connector that is embedded in prepared depressions on the face of the timber. The embedded plates are used to transfer shear stresses and increase the load-carrying capacity of the bolted connection. Until the 1960s, the bowstring timber truss was one of the most common designs used in commercial construction and can be recognized by its curved top chord (see Figure B–4 in Appendix B). A classic example of a fire in a bowstring truss roof is the Hackensack, New Jersey, automobile dealership fire in 1988. Bowstring truss roofs are sometimes incorrectly described as arches or arched roofs [Brannigan 1999].

Lightweight Wooden Truss Roof and Floor Systems

Engineered lightweight construction trends result in buildings designed and constructed using trusses manufactured from lumber (2 × 4, 2 × 6, or 2 × 8 inches)—where such trusses meet the engineering specifications and applicable building codes. Engineering and construction economics cause the design process to use the minimum-sized structural members necessary to support or carry the anticipated load. Engineered lightweight truss systems are the most commonly used truss systems in residential and single-family structures, and they are also used in many commercial buildings. This type of truss became popular in the early 1950s after the invention of the metal connector plate, also known as the gusset plate, gang-nail, nailer plate, or truss plate. This plate is used to rigidly connect the different wooden web members into various truss shapes.

The fastener is designed to connect the truss members by small teeth punched out of 20-, 18-, or 16-gauge galvanized steel sheets (see Figures C–1 and C–2). The teeth are hydraulically or roller pressed into the lumber so that the metal plate forms a bridge across the joint between the wooden web and chord members. These teeth may vary in size and length, but they typically do not penetrate more than ½ inch into the wood.

Concealed spaces are created when both the top and bottom of lightweight wooden truss systems are covered with wooden sheathing, gypsum wallboard, or other materials enclosing the area from roof to ceiling. These concealed spaces are also known as truss voids or truss lofts. Joist and rafter roof systems also have these concealed spaces.

Figure C-1. Gusset plates used to connect wooden truss members. (*Photo courtesy of Kirk Grundahl.*)

Figure C–2. Gusset plates. Note length of teeth/ penetration depth. (*Photo courtesy of Vincent Dunn.*)

This truss void space is often used for HVAC ductwork, plumbing, and wiring. Truss voids are also found between floors of buildings constructed with floor trusses. The open area from the top chord of the truss to the bottom chord can create a path for rapid horizontal fire spread. Even if fireblocking is placed in the voids, openings for ductwork, appliance piping, electrical wires, conduit, or additional utility installations can still create a path for fire to spread throughout roof and floor systems (Figure C–3). The truss void provides a reservoir for hot gases that may flash over when the void is opened as a result of ceiling collapse or fire-fighting tactics (such as pulling ceiling or searching for the seat of the fire). Horizontal flame spread is also possible through open space created between roof rafters.

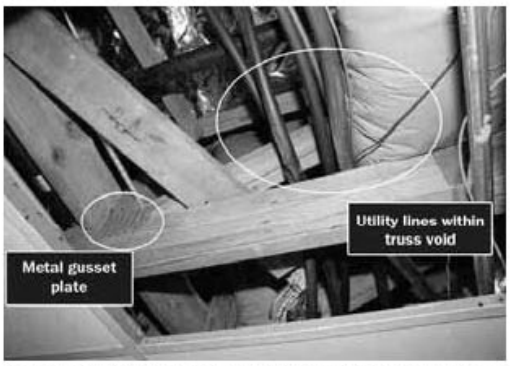

Figure C–3. Utility lines routed through truss voids. (*Source: NIOSH [2000].*)

Steel Truss Roof and Floor Systems

Steel trusses are available in different types and shapes. The current trend is toward engineered, lightweight steel construction. Engineered structural steel building materials have been developed that are more cost effective than solid wood or masonry construction. For example, modern lightweight building practices have led to long-span steel trusses designed with a steel cable as the bottom chord [Brannigan 1999]. The steel bar joist (a parallel-chord truss) is commonly used for both roofs and floors in commercial buildings (see Figure C–4). To give steel trusses increased fire rating, they must be encased or covered with a spray-applied material to provide for the proper hourly fire resistance rating. This material insulates the steel from heat exposure and increases the time for the metal to reach the critical temperature (in the range of 800° to 1,200° F) at which the steel has lost too much strength and can no longer support its load. The insulation increases the time to failure but may not totally prevent it.

Steel trusses may fail in less time than a wooden truss under the same conditions.

Figure C–4. Lightweight steel trusses. (*Photo courtesy of Francis Brannigan.*)

Some of the worst incidents involving fire fighter fatalities have involved metal trusses. These include the Brockton, Massachusetts, Strand Theater disaster in 1941 (in which 13 fire fighters were killed) and the Wichita, Kansas, automobile dealership fire in 1968 (in which 4 fire fighters were killed) [Brannigan 1999]. The twin towers of the World Trade Center contained 60-foot steel bar joists in their floor construction.

For more information about truss construction and educational or training materials being developed for the fire service, visit www.usfa.fema.gov/inside-usfa/research/construction.shtm [USFA 2004b].

Appendix D

Truss Failure Modes Under Fire Conditions

All parts and connections of a truss are vital to the stability of the truss system. The bottom chord of a truss is under tension. A tension member acts like a rope. If the bottom chord of the truss breaks, the truss system may fail by pulling apart. Conversely, the top chord of a truss is under compression. The top chord acts like a column. Failure of a compression member reduces the overall load-bearing capacity of the truss. The failure of any one element can lead to failure of the entire truss. The failure of a single truss transfers additional load to the surrounding trusses, which results in multiple truss failures. The failure of one truss can cause serious problems to other parts of the structure, even parts separate from the initial failure point. However, when a truss member is cut or fails, the load may be redistributed to adjacent structural elements to mitigate the domino effect. The overall collapse potential depends on the supported load and how many adjacent trusses are also weakened. Fire fighters need to be aware of this phenomenon and use extreme caution when working around cut or damaged trusses.

An often overlooked hazard is found where interior trusses or wooden beams extend beyond the exterior wall to provide a balcony or a stairway landing. Fire burning inside the building can degrade the truss or beam, resulting in collapse of the cantilevered balcony or stairway landing. Fire fighters standing on or under the collapsing exterior landing may be injured or killed. Different types of trusses can fail in different ways, as described in the following subsections.

Heavy Timber Truss Systems

Heavy timber truss systems may be constructed of wood or wood and steel. Heavy timber members are defined in building codes and are at least 6 inches wide and deep. The wooden web members connecting the top and bottom chords may be smaller dimensionally; however, they are critical to the overall strength of the truss section during a fire. In general, heavy timber trusses are long span and are placed at wide on-center spacings because they have such high load-carrying capacity. When impinged by flames and weakened to the point of collapse, large areas generally collapse. However, heavy timber trusses have the longest time to failure of any truss type because as the outer wood burns and turns to char, the char acts as an insulator and slows the rate of degradation to the inner wood [Grundahl 1992]. Hazards include the following:

- Although the heavy timber trusses may resist substantially more fire exposure than lightweight wooden trusses, another problem develops when the thinner roof

boards (much thinner than the heavy timbers) are consumed. Fire fighters may fall through these weakened roof boards.

- Heavy timber trusses are spaced several feet apart—much further apart than lightweight trusses, which may be spaced on 16- or 24-inch centers. Roof ventilation on a heavy timber truss roof may leave the fire fighter standing on several feet of unsupported roof board.
- The metal connectors or pins holding the heavy truss system together can fail before the wooden timber fails.
- The metal connectors may also transfer heat to the wood and weaken the wooden timber through pyrolysis (a chemical change brought about by the action of heat), leading to early failure of the connection.
- A collapsing heavy wooden timber truss roof system can cause the subsequent collapse of the building's front, rear, or side masonry enclosure walls.
- Heavy timber trusses are often located so far apart that usable storage or office space can be constructed between them, or post-construction equipment such as air-conditioning units may be placed on the roof. Timbers weakened by fire could then fail much earlier than expected.

Lightweight Wooden Truss Systems

Findings reported from the *National Engineered Lightweight Construction Fire Research Project* indicate that unprotected wooden assemblies fail within 6 to 13 minutes of exposure to fire [Grundahl 1992]. This 1992 report provides time to failure under laboratory conditions for a number of structural members and may not be truly representative of fireground conditions. Fire fighters should never rely solely on time-to-failure data to initiate fireground procedures. Continual evaluation of the fireground conditions, with emphasis on size-up and structural integrity, is necessary to ensure that fire suppression is carried out safely.

Lightweight chords are often continuous, and connecting web members often transfer substantial loads to other parts of the truss. This means that cutting a member may not automatically result in truss failure. There is much debate over whether fire immediately weakens or loosens the connecting gusset plates. Some researchers [Dunn 2001; Brannigan 1999] contend that these metal gusset plates can contribute to the degradation of wooden truss members through pyrolysis. Heat transferred through the metal fastener's teeth may destroy the wooden fibers held in tension by the gripping action of the metal teeth. This process loosens the plate and leads to a weakened truss and possible catastrophic failure if the gusset plate falls away and allows the weakened truss to pull apart. Other researchers [Grundahl 2003a; Meeks 2001; Cutter 1990] suggest that the metal plates protect the underlying wood during the initial stages of a fire. They suggest that the wooden members between truss joints may bum before the areas underneath the metal plates. The unprotected areas become charred to a depth that reduces the strength of the wooden member. Eventually, as the fire progresses, wood charring takes place underneath the metal connector plate. This causes the load-carrying capacity of the metal-plate-connected joint to be reduced. This reduction in the joint capacity eventually causes the metal connector plate to pull out and the joint to fail.

Lightweight wooden trusses are prefabricated at a factory and shipped to the construction site. If these trusses are improperly transported or stored at the site (exposed to the elements), or if they are dropped or handled improperly, the gusset plate or the entire truss can be significantly damaged. This can cause the plate to pull away from the wood surface or become weakened or loosened. In such cases, where the truss has not been properly repaired, the truss is weakened before installation and could fail under fire conditions much sooner than normally expected. Unexpected failure caused by mishandling is not unique to trusses and is difficult or impossible to predict during initial size-up.

The following are common causes of lightweight wooden truss failure that may be encountered in a fire:

- **Loose gusset plates.** The loss of a gusset plate on the bottom chord can lead to tensile forces pulling the truss apart. The loss of a gusset plate on the top chord will cause any web members attached to the top chord to pull away. Both situations will significantly reduce the load-carrying capacity of the installed truss and may even lead to a truss collapse.
- **Increasing the span width below the truss.** Trusses provide wide-open rooms below long, clear spans. For example, consider two adjoining rooms under a trussed roof, each 10 feet wide. The dividing wall serves as additional support in the center of the 20-foot span. In residential construction, catastrophic failure may be averted or minimized by the individual room walls supporting different sections of the failing truss. In a commercial building, the same truss (with clear-span space below and fewer partition walls to provide support as it deflects) could fail with less warning.
- **Alterations to individual trusses or to the building.** Although it is an unsafe practice, trusses are often cut or altered to accommodate plumbing, wiring, ventilation ducts, and other fixtures. This practice can significantly reduce the load-carrying capacity of the truss. These alterations are often hidden in the finished construction and go unnoticed until a failure occurs.
- **Excessive loads.** A truss is designed to support the roof above and to provide the desired clear span below. Adding weight that was not taken into consideration in the design stage can seriously compromise the load-carrying capacity of the truss and is a violation of building codes. Truss systems may be overstressed by heavy suspended ceilings, light fixtures, or other objects suspended below the truss; air conditioning units; ventilation systems; material storage; or other loads within or above the roof system that the truss was not designed to bear. Consider fireground conditions (including snow or ice and water from fire suppression operations), as well as the weight of fire fighters in full turnout gear. In a fire, all of these loads in combination can significantly reduce time to failure. Heavy loads of any type in any building should be of concern to the fire service.

Steel Truss Systems

All-steel trusses present their own hazards when exposed to fire. The mass and surface area of steel truss components are factors that determine time to failure. A heavy, thick section of steel has greater resistance to fire than a lightweight section of the same

length because of the increased mass. A large, solid steel truss can absorb heat and take longer to reach its failure temperature, whereas a lightweight steel truss such as an open-web bar joist will be heated to its failure temperature much faster. Once the failure temperature is reached, heavy steel trusses and lightweight metal trusses will react to the fire and fail in a similar manner. A steel member fails at the internal temperature of the steel and not at the ambient air temperature. This temperature is often referred to as the critical temperature of the steel member.

Findings reported by the *National Engineered Lightweight Construction Fire Research Project* indicate that unprotected lightweight steel C-joists fail within 4 to 6 minutes of exposure to fire [Grundahl 1992]. Testing conducted by the U.S. Bureau of Standards (now known as the National Institute of Standards and Technology, or NIST) showed that unprotected steel open-web bar joists reached 1,200° F in 6 to 8 minutes [Brannigan 1999]. Table D–1 illustrates that steel retains only 25% of its original strength at 1,200° F and retains only half its original strength at approximately 900 °F. Building design calculations are based on original strength at normal temperatures. At elevated temperatures, steel may retain no excess strength.

Steel is noncombustible and does not contribute fuel to a fire. This property may cause a false sense of security and overshadow the fact that steel loses strength when exposed to temperatures commonly found in structural fires. Steel has a high thermal conductivity, which means it can transfer heat away from a localized source and act as a heat sink. As long as the flame impingement is localized, the steel can transfer heat to other regions of the member—and thus the time to reach the critical temperature is delayed. If an intense fire is evenly distributed along the steel member, the critical temperature may be reached very quickly. Steel also has a high coefficient of expansion that results in the expansion of steel members as they are heated. As an example, a 50-foot-long steel beam heated uniformly over its length from 72° to 972° F will expand in length by 3.9 inches. The same beam uniformly heated to 800° F would expand by 3.2 inches; if heated to 1,200° F, the beam would expand by 4.9 inches [Grundahl 1991; Cotes 1997].

Table D-1. Loss of strength by low-carbon steel as it is heated

Internal temperature of the steel (°F)	% of original strength retained by the steel	% yield strength lost by the steel
70	100	0
400	87.5	12.5
600	72.5	27.5
800	57.5	42.5
1,000	42.5	57.5
1,200	25	75

Source: Tapley [1990].

Examples of steel truss failure modes that fire fighters may encounter in fires include the following:

- Cold-drawn steel cables can totally fail at 800° F [Brannigan 1999].
- At temperatures above 1,000° F, the expanding steel in bar joist trusses can exert lateral thrust forces on surrounding

masonry walls sufficient to cause their collapse. Higher temperatures can lead to failure of the steel itself [Brannigan 1999; Cotes 1997].

- Expansion within metal trusses may also cause the bottom chord to buckle and fail, resulting in downward thrust and collapse of the roof or floor.

APPENDIX E

This unique truss contains web members made of steel cables.

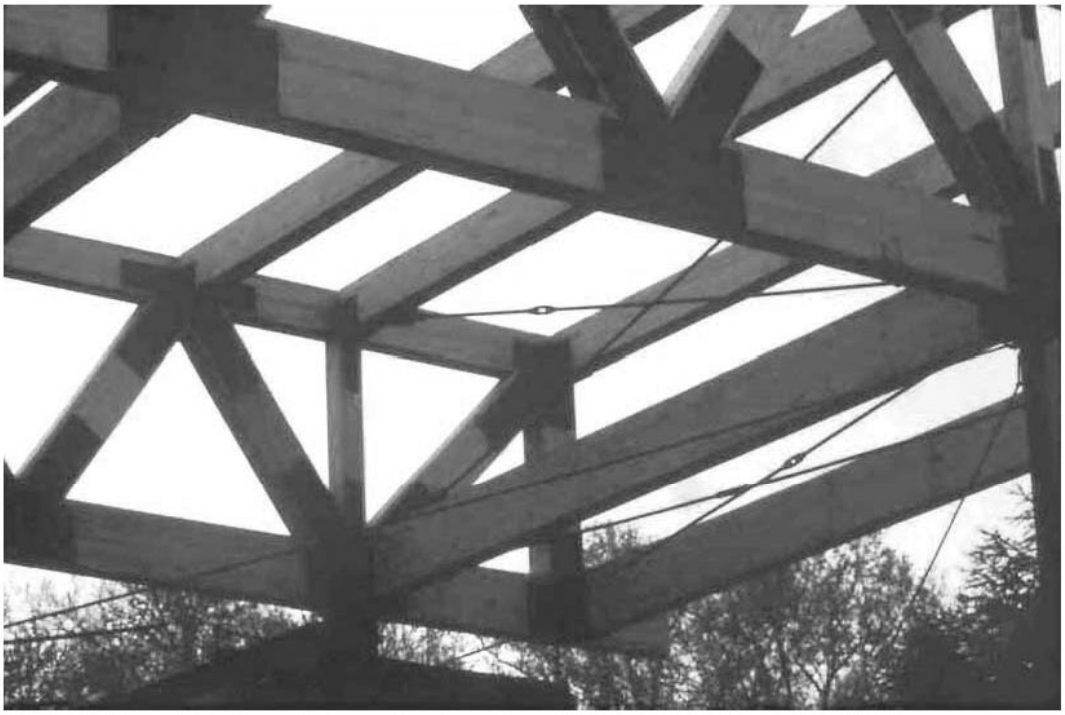

Figure E–1. Heavy timber truss with steel cable web members. (*Photo courtesy of Francis Brannigan.*)