Fireground Strategies & Tactics

Understanding the capabilities and limitations of the fire department

By Frank Baker

ACCORDING TO "A Needs Assessment of the U.S. Fire Service," a joint report published by National Fire Protection Association (NFPA) and Federal Emergency Management Agency (FEMA) in 2002, it was estimated that:

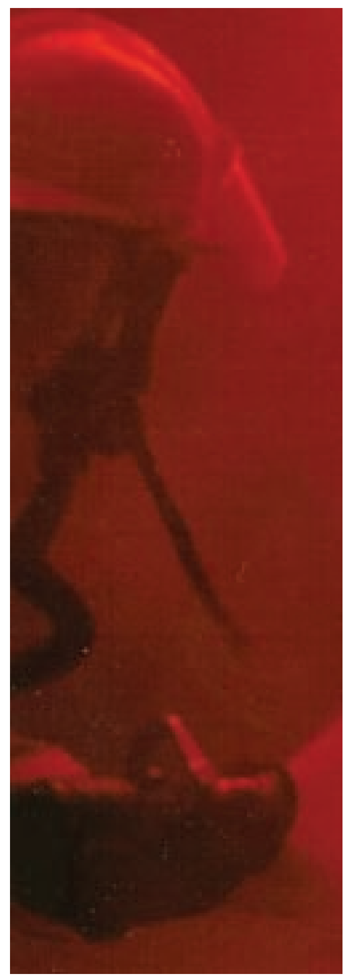
- 60% to 75% of all fire departments did not have enough fire stations to meet Insurance Services Organization (ISO) guidelines for response times and distances.
- 50% of all fire engines were more than 15 years old.
- 38% of firefighters in communities of 50,000 population and larger were responding on crews with fewer than the NFPA-recommended four persons assigned to an engine company.
- Only 25% of all departments owned thermal imaging cameras, which are vital in performing efficient searches for victims in smoke filled buildings.

A follow-up survey conducted in 2006 shows only marginal—if any—improvement in many areas (NFPA & FEMA, 2006). The percentage of fire departments that do not have enough fire stations remained unchanged. The survey found a 1% decrease in the percentage of fire engines more than 15 years in age. Significant progress was made in the percentage of departments owning thermal imaging cameras—it increased to 55%, while most of the remaining departments reported plans to obtain one or more units.

However, major ground was lost in crew sizes for firefighters serving communities with populations greater than 50,000. In 2006, more than 44% (up from 38%) reported having fewer than the NFPA-recommended four persons assigned to each engine company. This manpower shortage is magnified in many smaller communities, which for the most part still lack key equipment, prevention programs and training.

These findings highlight issues that may reduce a fire department's ability to effectively handle a large fire emergency. As a result, the steps a facility takes prior to such an event assume a higher level of importance. Understanding the resources that might be available, their limitations as well as some of the basic strategies and tactics employed by fire departments may help a company in its pre-fire emergency planning process. Understanding what actions fire department personnel will likely be able to perform upon arrival and during their ongoing efforts to control the situation should help those involved develop realistic expectations about the fire department's capabilities. Without this information, a facility may unknowingly create situations that will hamper the ability to ensure the safety of all persons involved and to effectively extinguish the fire.

Given improvements in fire safety efforts, hostile fire events still occur and are often catastrophic in nature,



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resulting in injuries, deaths and disruption of business operations. The number of structure fires, civilian deaths and firefighter fatalities (from structure fires) has been steadily declining since 1977, although the total number of firefighter fatalities is not decreasing at the same rate (NFPA, 2005a, 2005b).

While improvements in fire safety, technology, training and equipment have been credited for these reductions, fire departments as a whole still suffer from a serious lack of funding, equipment, manpower and training across the U.S. (NFPA & FEMA, 2002). Since the capabilities of the responding department can vary greatly, the SH&E professional should meet with the responding agency to assess its capabilities and resources, then compare this information to "worst-case scenario" needs.

Fire Service/Public Protection Rating System

ISO Public Protection Classification

Municipal fire departments are rated by the ISO using a complex matrix known as the Fire Suppression Rating Schedule. This schedule is based on three major categories of data: fire alarms, engine companies and water supplies. Within each of these broad categories, many individual criteria are evaluated to arrive at the final rating. Each department is assigned a numerical rating that defines its Public Protection Classification (PPC), with 1 being the best protection and 10 representing no recognized protection or protection that does not meet minimum ISO standards (ISO, 2005).

Ten percent of the overall grading is based on how reliably the fire department receives fire alarms and dispatches its firefighting resources. This includes an evaluation of the communications center, number of emergency operators at the center, the phone service, number of phone lines coming into the center and the listing of emergency numbers in the phone book. Dispatch circuits and the method by which the firefighters are notified are also evaluated.

Fifty percent of the overall grading is based on the engine companies and the amount of water a community needs to fight a fire. This category encompasses the number of engine companies; distribution of fire stations throughout the area; whether the fire department tests its pumps regularly; and inventories of each engine company's nozzles, hoses, breathing apparatus and other equipment. Fire department recordkeeping is also reviewed to determine the type and extent of training provided to fire company personnel, the number of people trained, firefighter response to emergencies, and maintenance and testing of the department's equipment.

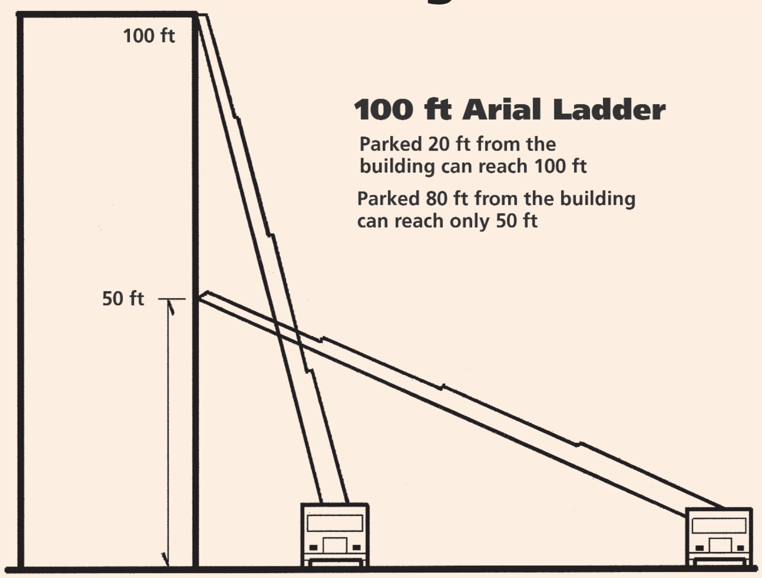
The remaining 40% of the grading is based on the

Abstract: *This article, which will be presented in two parts over two issues, provides a general introduction to fire department operations. Understanding these operations, as well as the resources available through the local fire department and its limitations, can help a company complete an effective prefire emergency planning process.*

LARGE PHOTO BY FRANK BAKER; INSET PHOTO BY ROBERT BRAHANY

Figure 1

Aerial 30- & 75-Degree Elevation



This figure shows how positioning required by the limited accessibility and collapse zone awareness of the operator can significantly affect the reach of an aerial ladder.

water supply available in the community. Does the community have sufficient water supply for fire suppression beyond the daily estimated maximum consumption? The ISO surveys also assess various components of the water supply system, such as pumps, storage and filtration. Fire flow tests are also observed in representative parts of the community to determine the rate of flow the water mains provide, as well as the distribution of fire hydrants (ISO, 2005).

What cannot be predicted are unusual conditions such as droughts, which may reduce the volume of water in the system to the extent that pressures cannot be maintained; or frozen hydrants and mains that can interfere with the ability to extract water which should be available under ideal circumstances. In cases where water flow demand is severe or involves an extended duration, it is not uncommon to deplete the municipal water reserves or cause physical damage to the distribution system, which manifests itself as broken water mains that can disrupt the supply.

Interpreting the PPC Rating

As a general rule, a lower PPC rating means better protection is afforded to the community and, consequently, lower fire insurance rates for property owners. ISO research clearly shows the impact of better public fire protection on both commercial and homeowner insurance fire losses. A PPC rating of 1 indicates exemplary fire protection. Presently, only 45 (0.1%) departments—of the estimated 44,000 fire response jurisdictions that ISO has evaluated—hold a Class 1 rating.

Only 419 (less than 1%) departments have achieved Class 2 status. ISO data show just under half (21,848) would be Class 6 PPC or better. This indicates respectable protection to address most community needs, but some split classifications, such as 5/9, are given.

For example, suppose the local fire department has a Class 5 rating, but the company's building carries a Class 9 for fire insurance rating purposes. This would usually be the result of the building's proximity to the nearest fire station and access to public water. The farther the travel distance and proximity to a public hydrant or reliable water supply, the higher the protection class rating at a given location, regardless of the department rating. Anything that is more than 5 miles from the nearest fire station and more than 1,000 ft away from the nearest hydrant will be assigned a Class 10 rating (ISO, 2005).

The PPC is merely an indication of the response capabilities for typical fire suppression emergencies. It may not be truly reflective of the department's ability to address hazards caused by storage or use of products that are not compatible with water; those that require high volumes of special firefighting foams; or those that involve hazardous materials for which a firefighter's protective gear would provide little or no protection. If a site is located in a jurisdiction with a high PPC, it will likely need to rely on its own resources to effectively control a fire or to supplement the resources of the responding department.

Fire Suppression Apparatus

The engine company consists of what is commonly called a fire engine or pumper (depending on the area), and a crew of at least four persons to perform effectively and safely. The crew's primary responsibility on the fire scene is to confine and extinguish the fire by applying water in large quantities. ISO rates fire departments based on the number of engine companies available, how much water they can pump and carry, their proximity and manpower available. To qualify, a fire engine/pumper must have an onboard pump, a water supply tank, large-diameter supply hose and a complement of ground ladders. ISO's (2005) requirement for crediting an engine company is a travel distance of 1.5 road miles or less and a response time of 3.2 minutes.

Many years ago, a 500 gallons per minute (gpm) pump with a 300-gallon tank and 3-in. diameter supply hose was the state of the art. Heavier fire loads have created a demand for higher water flows. Technology has given the fire service the ability to improve the amount and efficiency by which water can be delivered to the fire scene. A new fire apparatus is commonly fitted with 1,500 gpm pumps, 1,000 gallon and larger onboard water tanks and a 5-in. diameter supply hose. Manufacturers now offer pumps in the 2,000 gpm range and 1,500-gallon capacity water tanks on a standard fire engine/pumper. Larger tanks can be installed on fire engines/pumpers that may also serve as tanker-tenders. These mobile water supplies are used where the public water supply system does not extend into outlying areas.

The aerial/ladder company, most commonly called a truck company, consists of a vehicle equipped with an aerial device (elevating ladder or man platform) and should have a crew of at least four persons. Aerials are generally not located in every fire station, but are usually more centrally located to cover more than one primary response district. ISO (2005) requires the truck company to be within 2.5 miles with a response time of 4.9 minutes or less.

The truck company can have many assignments on the fire scene, but it usually is involved in forcible entry, search and rescue, and ventilation at the beginning of the incident. Once the fire is under control, these duties often shift to salvage and overhaul. In cases where the only option is to prevent the fire from spreading to other structures, an aerial ladder equipped with a waterway may be used to flow water at 1,000 gpm or more from a high angle above the fire by means of a master stream nozzle.

The working height of the aerial device (ladder or tower) is measured with the ladder at its maximum elevation and extension from the last rung to the ground. The maximum working angle is usually 75 degrees (Figure 1) from the horizontal plane (the same as a ground ladder since it must often be climbed by personnel). NFPA 1901, Standard for Automotive Fire Apparatus, requires the device to reach a height of at least 50 ft, but more commonly the full-size aerial ladder will be 85 to 105 ft high (NFPA, 1999).

The device must be able to deliver at least 1,000 gpm at a minimum of 100 psi from the nozzle located at the tip of the ladder or boom. An apparatus designed as a water tower only is designed to deliver the water; it does not have the benefit of an integral ladder for access to the tip or to perform work from the middle. The apparatus may be a telescoping or articulating device and will include a bucket, master stream nozzle or both at the terminal end. Whether the apparatus has a single or tandem axle configuration will depend on the gross vehicle weight and wheelbase selected, but usually depends on the length of the ladder.

To qualify as an aerial/ladder, the apparatus need not have its own pump or booster tank to carry water to the fire scene, although most will at least have an onboard pump. In the case of no booster tank, a connection to a hydrant or other portable water supply would be necessary to supply the pump. If the device has no onboard pump, the water pressure would be provided by an accompanying engine/pumper.

It is becoming increasingly popular for fire departments to purchase a multipurpose apparatus known as a *quint* (short for quintuplet because it has five major components) to improve their ratings for outlying stations in large districts. These can serve in a dual capacity as an engine or an aerial ladder, as they have an onboard water pump, booster tank, supply hose, ground ladders and an aerial device. These can be built in the full aerial ladder configuration or a smaller version commonly called a *telequirt* with ladders from 50 to 75 ft high (NFPA, 1999).

Preincident Interaction with the Fire Department

Preincident Survey

A preincident survey is conducted at a business to gather information on hazards associated with the building construction, occupancy, protection systems and exposures. This survey may be conducted by a fire prevention officer or the nearest responding engine company. When conducted by the nearest responding engine company it serves a dual purpose in that it also allows those personnel to become familiar with the layout and conditions firsthand (Goodson & Sneed, 1998, p. 231). This information is then documented on a generic report, often called a quick access prefire plan.

PHOTO BY FRANK BAKER

A typical fire truck carries the crew, pump, water tank, supply hose, ground ladders, handlines and other specialized equipment.

In addition to this basic information, initial resource requirements and water availability are assessed, required fire flow (water demand) calculations are performed, and potential fire behavior predictions and problems are identified. This document can then be made accessible to responders—either through printed copies carried on the fire apparatus or through CAD systems that can be accessed by mobile computers. This document is invaluable in assessing a situation by identifying critical issues such as required fire flow that clearly exceeds the public water supply or resource being dispatched, or special hazards which can affect strategic decision making even before arriving on the scene (FEMA, USFA & NFA, 2005, pp. SM 2-7, 2-8).

Code Enforcement Inspections

A fire department's authority to conduct a code enforcement inspection is generally provided by local ordinance or state statute to the local fire chief or fire marshal as his designee. Depending on the location, the local authority having jurisdiction may be enforcing one or more codes as adopted by the local or state government. These may include the National Electrical Code (NFPA 70), Uniform Fire Code (NFPA 1) and Life Safety Code (NFPA 101), among others. The purpose of this inspection is to reasonably regulate activities of the public to control the risk of fire hazards. While information to be used for preplanning may be gathered during the visit, the primary objective is the control of unreasonably dangerous activities (Goodson & Sneed, 1998, pp. 189-190).

Managing the Fire Scene

Primary Incident Objectives

The basic decision-making rule of thumb used by an incident commander (IC) is "Will my intervention positively affect the outcome of this event?" All events will eventually terminate themselves without any intervention, but the degree of loss that would be involved is usually unacceptable. To that end, a short list of primary objectives has been established and prioritized to help the IC make decisions on the scene.

The primary objectives on the fireground are life safety, incident stabilization and property conservation. These objectives are considered in that specific order, almost without exception. The life safety priority supersedes all others and is based on the life hazard to both building occupants and firefighters. Incident stabilization refers to containment—not letting the situation involve more people or property than it already has. Finally, property conservation involves saving what can be saved, but never at the expense of human lives (Goodson & Sneed, 1998, p. 285).

Preincident information provides details that cannot be quickly obtained upon arrival at the incident scene.

Layman (1953) developed a list that the fire officer can use to identify priorities in emergency situations. This priority list, which has become an industry standard, is represented by the acronym RECEO-VS (ree'-cee-oh, vee, es): rescue, exposures, confinement, extinguishment, overhaul, ventilation, salvage (Goodson & Sneed, 1998, p. 277).

This list is used not only to identify priorities, but also to provide a recommended sequence of operations. The first five operations occur on almost every fire scene and usually in that specific order. The last two activities, ventilation and salvage, are not always necessary, nor are they always performed at the same point in the operation, so they are separated on the list.

Incident Command

Incident command is established upon arrival of the first fire officer, who may or may not be accompanied by a crew. This is the initiation of the incident command system (ICS) that will be used throughout the event. Command may later be transferred to a ranking officer depending on department policy or based on the success of the current IC in accomplishing the objectives that will mitigate the event. A modular ICS provides the flexibility needed to address the unique exposures for any given situation. This structure permits a reasonable span of control to be maintained by each officer with responsibilities over crews, physical divisions or functional areas within the incident.

Over the years, ICSs have used varying terminology. Since 2004, however, as part of a federal mandate, many departments are standardizing their ICSs to bring them in line with the National Incident Management System (NIMS). Such standardization helps to ensure that all responding agencies at any given event follow the same ICS, which reduces the risk of miscommunication and fulfills the requirement of having interagency communication capability.

The IC is ultimately in charge of everything that occurs on scene, but s/he often delegates authority to, for example, an operations group supervisor and a safety officer to complete certain objectives. The operations group is responsible for conducting the rescue, fire control and extinguishment, and overhaul strategies. Divisions can be created within the operations group, such as designating the individual floors or sides of a building. On large incidents or those that occur over an extended time, more functional areas are taken out of the proverbial toolbox and placed into use. This modular system permits adding resources to the system as needed.

If the IC does not assign a specific authority to a group leader, s/he retains full control of that function for the duration of the incident. A small incident may result in only safety being designated to a separate individual, while all other responsibilities remain with the IC. In a large or extended duration incident, it will likely become necessary to include the following positions to distribute the workload and maintain the span of control: public information officer, interagency liaison officer, logistics, planning and finance groups. Further delegation to maintain the ideal span of control takes place within each group by creating divisions, task forces, strike teams, etc. (FEMA, 2004, pp. 12-24).

To keep management of incident priorities on track, a basic command sequence is usually followed. This is a three-step decision-making model that is intended to lead the officer through the development and implementation of the incident action plan. The three steps are: size-up, selection of strategies and tactics, and plan implementation (FEMA, et al., 1991a, p. SM 1-12).

Size-Up

"Size-up is an ongoing process of gathering and analyzing information critical to incident factors that lead to problem identification" (FEMA, et al., 1991a, p. SM 1-12). It is the stepping-off point for what happens during the rest of the incident.

Preincident information is critical to successful outcomes. Sources of information include fire department preplans; recognized hazards commonly associated with a certain type of occupancy; available water supplies; environmental conditions; time of day; knowledge of the area; departmental resources; and outside assistance that may be needed. This provides additional information vital to the decision-making process of the command sequence that usually cannot be quickly obtained upon arrival at the incident scene (FEMA, et al., 1991a, pp. SM 2-11-2-13).

The first fire officer on the scene is responsible for providing all en route units a size-up report that will contain specific information which can be visually observed at the scene. Early recognition of the need for resources beyond the initial response can save both lives and property. In cases where department resources are limited, additional resources may take the form of mutual aid responses from other area departments, which in rural areas may be delayed because of long travel distances.

When conducting the size-up, the fire officer should attempt to identify the scope of the fire problem, predict its behavior, and make initial decisions about how to apply the available or needed resources to the problem. Questions should include: Where is the fire now? Where is it going? Who or what is in its way? (FEMA, et al., 2004, p. SM 3-11).

If it is determined that there is a reasonable likelihood of success with the resources that can be mustered, then a risk/benefit evaluation must be conducted. Questions to ask include: Are the risks being taken worth the benefits being gained? If it is worth the risk, for how long? (FEMA, et al., 1991a, p. SM 2-17).

Fire Chief Alan Brunacini of the Phoenix, AZ, Fire

Department developed a risk-based decision policy that has been integrated into that department's standard operating procedures. It defines the extent of risk that is acceptable in a given situation as follows:

- Each emergency response is begun with the assumption that "they can protect lives and property."
- They will "risk their lives a lot to save savable lives."
- They will "risk their lives a little, and in a calculated manner, to save savable property."
- They will "NOT risk their lives at all to save lives and property that have already been lost" (Goodson & Sneed, 1998, p. 285).

The Operational Mode

Fireground operations are usually categorized into three primary modes. The situational circumstances will dictate which mode of operation is employed initially and at what stage of the response this mode might change. Goodson & Sneed (1998) identify the three modes as rescue, offensive and defensive. However, FEMA, et al. (1991a) list the modes as offensive, defensive and transitional. In either case, the definitions for offensive and defensive are the same.

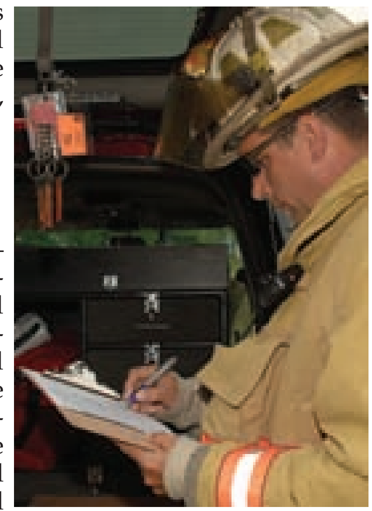
When there is a report of entrapped or unaccounted for building occupants, the fire department will engage in rescue-related operations. This is termed rescue mode. In most cases, rescue operations are performed in conjunction with a coordinated fire attack. However, in extreme cases such as those involving multiple occupants, those that require moving extremely fast through the structure or those in which there is not enough manpower on scene to perform both functions, all available personnel are assigned to what is commonly called an "all-hands rescue" (Goodson & Sneed, 1998, pp. 284-286).

The volume of response resources directed toward this effort will depend on the number of persons presumed at risk, the size and scope of the potential search operation, and the likelihood of being able to reach persons who may still be alive. A limited amount of fire attack may be conducted, but it is usually limited to what is necessary to protect the rescuers and those being rescued. Some consider rescue operations to be part of the offensive mode, not a separate mode.

The offensive mode of operation may also involve rescue operations, but it is primarily focused on containing and extinguishing the fire via aggressive strategies and tactics. This is generally associated with interior structural firefighting where the fire is attacked from the unburned side to confine the fire and prevent its spread. It is also the mode in which the fire service prefers to operate (Goodson & Sneed, 1998, p. 283).

The defensive mode of operation is intended to hold the incident in check or prevent it from getting worse. This mode is usually the result of determining that there are insufficient resources to overcome the fire or that the building is a total loss and not worth risking the lives of firefighters. The telltale signs of defensive mode operations include aerial devices flowing water downward onto the fire; and personnel set up outside the building's collapse zone applying water through existing openings with no attempt to advance toward the fire (Goodson & Sneed, 1998, p. 284).

Based on conditions observed, the mode of operation can change at any given time. During this change, operations are in what is termed the transitional mode and involve the strategic realignment of resources (FEMA, et al., 1991a, p. SM 2-19).



PHOTOS BY ROBERT BRAHANY

Incident commanders can use mobile PCs (top) or preprinted worksheets (bottom) to track operational objectives, strategies and tactics being implemented on a fire scene, as well as to maintain accountability systems for personnel safety.

Strategies & Tactics: Capabilities & Limitations

The primary fireground objectives—life safety, incident stabilization and property conservation—are best accomplished through the use of what are termed strategies and tactics. Specific strategies and tactics can support the completion of one or more of the primary incident objectives. Strategies are general plans that are comprised of individual tactics. Tactical steps are further broken into individual tasks. Often, the tactical or task-level functions support one or more objectives or strategies at the same time. For example:

- **Primary objective #1:** Life safety.

Strategy #1: Rescue trapped building occupants.

Tactic #1: Truck company crew to conduct a primary search of the fire building.

Tactic #2: Engine company crew to provide a protection line for the truck company conducting the primary search.

Tactic #3: Ventilate the structure directly over the fire to remove heat and products of combustion from the area where the victims may be trapped.

Strategy #2: Rapid intervention team (RIT).

Tactic #1: Engine company or rescue squad company to report with full RIT gear to the location where primary entry to the structure is being made.

- **Primary objective #2:** Incident stabilization.

Strategy #1: Extinguish the fire.

Tactic #1: Engine company crew to establish a reliable water supply.

Tactic #2: Truck company crew to ventilate the structure directly over the fire to remove heat and products of combustion from the structure.

Tactic #3: Engine company crew to begin direct fire attack with adequately sized hose stream(s).

Strategy #2: Protect exposures.

Tactic #1: Engine company crew to establish protective hose streams to combat radiant heat and flying brands from igniting adjacent structures.

Tactic #2: Truck company crew to ventilate the structure directly over the fire to remove heat and products of combustion from the structure.

Tactic #3: Engine company crew to begin direct fire attack with adequately sized hose stream(s) (FEMA, et al., 2005, p. SM 1-49)

This is not intended to be an all-inclusive list of actions that could or would be taken in any given set of circumstances; rather, it is intended to indicate how resources must be assigned and coordinated to achieve the primary, strategic and tactical objectives. The most critical issue is that no one element—strategic, tactical or task level—can outperform the others. They are interconnected and dependent on each other to achieve the incident objectives.

Search & Rescue

Rescue of any building occupants and the safety of firefighters takes precedence over any other incident objective. During the initial scene size-up, contact with a knowledgeable building representative is critical to the quick, effective assignment of resources. This representative should be someone who knows the facility and can account for its occupants.

If no information is available or it is suspected that occupants remain in the building, the search-and-rescue function will supersede all other operations. While other tactics such as ventilation or extending protection lines may be performed, they are intended to facilitate the search-and-rescue effort, not necessarily to achieve extinguishment.

The initial search of a building is called the primary search. This is a rapid search conducted to determine whether anyone is actually in the building. The primary search will start at the area involved in fire and expand toward uninvolved areas until the likely areas of refuge and normal escape routes have been searched.

In many cases, this search is performed under extreme conditions involving high heat and poor visibility. A charged hose line should be taken into the building by one or more fire crews to provide protection for those involved in conducting the search. The purpose is to hold the fire in check long enough that the means of escape for search crews is not cut off by the advancing fire, not to attempt to extinguish the fire.

A protection line is usually a highly mobile hose line (such as 1¾-in. diameter) that might not have sufficient water flow to overcome the heat being produced by the fire or to extinguish it. Other supporting tactics may include early implementation of ventilation to release excessive heat and smoke from the building in order to give occupants a better chance of survival.

The actual search methods used include various search patterns such as right-hand or left-hand routes, marking doors, etc., to ensure that all areas are searched. If a crew is assigned the primary task of search and rescue, it can conduct a more thorough search in less time than if it is advancing a hose line through the building. The goal is to make sure all areas where occupants may have taken refuge have been searched to locate those with a reasonable chance of survival (Hall & Adams, 1998, pp. 176-177).

The thermal imaging camera (TIC) has become a valuable tool in search-and-rescue operations, as well as in locating the seat of hidden fires while minimizing property damage. This handheld device uses infrared heat-sensing technology to help fire crews see through dense smoke and quickly identify shapes based on their heat signature. In situations where heavy, dense smoke would limit the ability to search to what can be felt by touch, the TIC allows rapid scanning of an area to identify humans from many feet away. In a situation where seconds count, this is critical.

Where fires are hidden behind walls or in large spaces filled with heavy smoke that would obscure firefighters' vision, a TIC can greatly speed the process of identifying where to apply the water stream. In situations where the seat of a basement fire would be impossible to locate from the first floor of the building, the TIC can be used to identify the hottest part of a floor; this provides direction as to where to apply water without wasting time searching for the seat of the fire.

However, as noted in the 2002 NFPA/FEMA survey, only 25% of U.S. fire departments had one or more TICs. Although this increased to about 45% by 2006, that still leaves more than half of all departments in the U.S. without access to even first-generation handheld technology. Another beneficial technology is a miniaturized helmet-mounted camera unit, which frees the firefighters' hands. Currently, these cameras are out of reach for all but the most well-funded departments.

A secondary search is conducted once the fire is under control or completely out. This search looks for victims who might not have been found on the primary or initial search patterns (Hall & Adams, 1998, p. 178). In most cases, this is a recovery rather than rescue effort.

Exposure Protection

An exposure is any other property not involved in fire at the time of arrival by the first fire officer and crew. Depending on the conditions encountered at any given time, what might not have been considered an exposure yesterday might very well be one today. The decision of what to save first, or at all, is made during the initial size-up.

Radiant heat is the primary concern. The amount of radiant heat and how much of a building it contacts will determine the original fire's ability to cause damage by setting that building on fire as well.

Generally, a building that is less than 40 ft from the fire building is most likely an exposure. If it is located 40 to 100 ft away, the building will probably be an exposure depending on the radiant heat being produced by the initial fire. A building more than 100 ft away would not generally be considered an exposure, unless severe environmental conditions (such as flying brands spread by high winds or ground brush in dry conditions) can spread the fire (FEMA, et al., 2005, p. SM 5-5).

Exterior exposures would usually be protected by applying water to remove heat from the surfaces.

Water curtains sprayed into the air between an exposure and a fire do little to stop the transfer of radiant heat since the energy can only be blocked by placing a solid object between the source and an exposure. If sufficient volumes of water are applied, no damage will result because the heat will be removed from the surface by the cooling effects of evaporating water (FEMA, et al., 2004, p. SM 3-8).

Interior exposures are those areas adjacent to the fire area where fire could easily spread. This spread can occur through radiant energy, convection or conduction in vertical and horizontal directions. When operating in the defensive mode, the focus is on protecting primarily exterior exposures as the fire building is already considered a total loss or because there are insufficient resources to make progress in extinguishing the fire.

Preventing fire spread from one floor to another in a high-rise building can be difficult due to the nature in which such a building naturally autoventilates or is manually ventilated. Impingement of fire on the glass of the next upper floor can readily break it, permitting the fire to ignite the contents of the next floor as the fire laps up the side of the building.

Interior exposures caused by horizontal spread of the fire also need to be protected if possible. Often, the resources for mounting a full attack on the fire will not be immediately available so protective lines are used to hold the fire in check. If additional resources become available, including backup lines from a secondary water source, an offensive attack might be mounted to attempt to extinguish the fire.

Ventilation

"Ventilation is the systematic removal and replacement of heated air, smoke and gases from a structure with cooler air. The cooler air facilitates entry by firefighters and improves life safety for rescue and other firefighting operations" (Hall & Adams, 1998, p. 345).

The ultimate goal is to localize the fire by preventing its horizontal spread through the building. As heat builds inside the structure from the fire, it collects at the highest points first, then banks downward with the other products of combustion, and eventually reaches the floor. This process of stratification keeps the super-heated air above the cooler air at the lowest level. If not properly released from the structure, it will continue to build until it causes either the fire area to ignite simultaneously in a flashover or an explosive-like event commonly called a backdraft. Proper ventilation is also an effective exposure protection strategy by controlling how a fire is allowed to travel through a structure.

The primary objectives dictate the timing of ventilation during a fire. The existence of a life hazard in the building will require that ventilation be performed before extinguishing crews are in place. This will help to improve the visibility and atmosphere within the building, which increases the chances that trapped occupants will survive; it also speeds the primary search process. In such cases, a crew will be assigned to hold the fire in check or to ensure that it does not compromise the egress paths for those performing searches. If ventilation is done primarily to help the firefighters locate and extinguish the fire, it must not be done until charged hose lines are in place inside the building.

As the heated products of combustion are vented out of the structure, they must be replaced with fresh air from lower openings in the structure. The fire suppression crew must be ready to extinguish fire in a coordinated effort with ventilation crews as this large influx of fresh air will cause the fire to grow in intensity.

When the fire suppression crew uses a hose line with a large enough diameter, crew members can overcome the heat being generated and quickly gain control of and extinguish the fire. However, if inadequate water is applied to the fire, the crew may only hold the fire in check—or worse, push it into another area of the building.

(Top): Typical setup for preconnected handlines used for rapid deployment when fires are located within close proximity to the fire apparatus.

(Bottom): This engine is equipped with a second large diameter inlet on the front bumpter (commonly called a "steamer connection") as well as a rapid deployment handline.

PHOTOS BY FRANK BAKER

Properly timed and executed ventilation techniques can also reduce the risk of flashover and backdraft (FEMA, et al., 2004, p. SM 4-9). A flashover occurs when the contents of a fire area are heated by radiation and convection to a point where they begin to undergo pyrolysis and give off flammable gases at extremely high rates. Combined with other unburned products of combustion, these gases undergo almost simultaneous ignition, causing the entire space to become rapidly engulfed in flame.

This occurs almost instantaneously from top to bottom and causes a fire to push out of the space from any available opening. This can occur in a space where the contents are free burning and where there is sufficient oxygen to support the combustion process. Flashover can be prevented if the superheated products of combustion can be released rapidly enough from the space. The proper time to ventilate to avoid flashover on the fire suppression crew is during or shortly after the crew enters the fire area for the initial attack (FEMA, et al., 2004, p. SM 4-9).

A backdraft is the ignition of superheated products of combustion that have been generated by pyrolysis and have been trapped in an oxygen-deficient space. This lack of oxygen prevents a free-burning state from occurring, which is the main difference between a backdraft and a flashover. The products of combustion are already above their

Table 1

Waterflow Comparison Based on Diameter & Pressure

Diameter (in.)	Application	Cross-sectional area (in.)	Approximate flow rate, 150 psi pump pressure	Approximate flow rate, 65 psi hydrant pressure
1.5	Handline	1.767	125 gpm	
1.75	Handline	2.405	175 gpm	
2.5	Handline	4.908	275 gpm	
2.5	Supply	4.908		210 gpm
5	Supply	19.635		1,250 gpm

Note. *Hose appliances such as nozzles and friction loss due to turbulence of the water flowing inside the hose can significantly affect delivery volumes.*

autoignition temperature and only need a source of oxygen to ignite.

The backdraft creates a large fireball as these unburned products of combustion ignite, accompanied by a strong pressure wave capable of removing doors, windows and weakened walls from a structure. If such a space is ventilated horizontally by opening a door or window without first releasing the super-heated gases vertically, the fresh air will be drawn into the oxygen-starved space, and the super-heated products of combustion will ignite almost instantaneously.

Telltale signs that a backdraft is imminent include the production of thick brown smoke and the appearance that the structure is "breathing" or puffing smoke from openings such as attic vents, windows and door frames. To avoid an impending backdraft, ventilation should be performed before crews attempt to open doors or windows at lower levels of the building or confined fire areas for entry. Ventilation must then be as high and as directly over the suspected seat of the fire as possible to reduce lateral spread and rapidly exhaust the products of combustion (FEMA, et al., 2004, p. SM 4-9).

Various methods of ventilation can be employed to remove contaminants from the building. The most common method observed by the public is ventilation by convection. This is typically achieved vertically, but it can be accomplished through horizontal openings such as windows and doors if the building design does not permit a vertical approach. Vertical ventilation uses the natural propensity for hot gases to rise, allowing them to escape by opening existing penetrations or creating additional vent holes in the upper part of the structure.

Common existing penetrations include skylights, scuttle hatches, elevator shaft penthouses, HVAC ducting and attic vents. Often, larger vent holes are necessary to exhaust the heated gases quickly enough to outpace their production by the fire. Venting allows the thermally stratified layers of smoke to lift as they are exhausted uniformly from above, which permits easier location of the base of the fire by improving the visibility factor and providing a safer work environment. Depending on the location of the vent hole in relation to the main fire, it can be used either to confine it or to draw it in a specific direction.

Mechanical ventilation by positive- or negative-pressure fans placed into openings can also be used to force the gases out of the space. Positive-pressure ventilation forces fresh air into the fire building to cause smoke and heat to be exhausted through the natural or improvised vent openings. Positive-pressure fans can be set up in multiple locations to control the fire. Negative-pressure ventilation attempts to draw the smoke and heat directly from a specific area from usually a single point. It can be used for fire suppression and salvage or overhaul operations. Both methods have advantages and disadvantages. Use of either is usually reserved for situations in which convection methods will not provide effective removal of smoke and heat; are impractical because of building design; or in which the building is considered unsafe for rooftop operations.

The decision to ventilate the building using a vertical or horizontal pathway is often dictated by building construction features. A fire located on the top floor of a building is easily ventilated through the roof, allowing for natural convection to assist the process. This is where existing features such as roof-mounted vent caps or skylights become ready-made ventilation sites. However, these features are often insufficient in square footage to release the volume of heated gases necessary, so crews must open large holes in the roof.

If the fire is not on the top floor of a building, horizontal ventilation of the products of combustion is the only option. Windows and doorways become the next-available source for ready-made vents. In high-rise structures with large glass curtain walls, removing windows can provide good ventilation, yet may result in a fire lapping up the sides of the building and spreading to another floor, creating an exposure hazard that will need to be protected.

The first arriving fire officer must make a decision during the initial size-up as to where ventilation is necessary because of a life safety hazard, to stabilize the incident, to conserve property or to achieve other tactical objectives. The next decision is where, when and how (tactic) the ventilation should be implemented to fulfill the strategic goal. A poor decision, such as not getting far enough ahead of the fire, can significantly affect the outcome (FEMA, et al., 2004, p. SM 4-10)

Water Supply & Fire Flow

Water is the most commonly available extinguishing agent. It can absorb about 140 Btu per pound when its temperature is raised from 72 ºF to its boiling point of 212 ºF. The same pound then absorbs another 900 Btu when its physical state is converted from a liquid to steam. This steam displaces about 1,700 times its original liquid volume, making it useful for displacing oxygen needed by the fire (Hall & Adams, 1998, p. 488).

Water can be available to the fire department from several sources, including municipal systems, static sources, and portable or mobile sources. In most cases, a response within a city or town will involve use of the municipal water delivery system. If the fire building is located in a rural area with no municipal system, the water available will be limited to what can be delivered from static sources (e.g., lakes, ponds) in the area and on portable delivery systems (tanker/tenders).

A municipal water system is the most desirable, although it can have significant limitations in the event of a major fire. Municipalities with large diameter (12 in. and larger) looped main systems can expect water flows of 1,200 to 1,500 gpm from a single hydrant. In older communities, the water mains may be as small as 4 in. in diameter and arranged in a dead-end layout. If the fire is in a building located at the end of a long dead-end water main of small diameter, the amount of water may well be less than what can be delivered by an effective rural fire department adept at tanker shuttle operations.

Other municipal water system concerns include depleting the reserves in the water storage system or causing unusually low pressure in the city mains. The size and condition of these mains is a significant factor in the sustainable water flow as well. If a main is ruptured due to surges or pressure drops, water supply may be completely cut off, causing the fire building to become a total loss and endangering nearby exposures (FEMA, et al., 2004, p. SM 5-3).

Large-diameter supply hoses—generally considered 5-in. diameter and larger—have replaced 2.5- and 3-in.-diameter dual-supply lines in many communities for connecting the fire apparatus to hydrants. Using 600 ft of hose between a hydrant with 65 psi and a residual pressure at the fire engine of 10 psi due to friction loss, a 5-in.-diameter supply hose can flow 1,250 gpm. A 2.5-in. supply hose connected to the same hydrant will only flow 210 gpm. Six of these 2.5-in. supply lines would be necessary to flow 1,260 gpm. Doubling the diameter provides nearly six times the flow capacity (FEMA, et al., p. SM 5-5). When long stretches of hose are necessary to reach the fire scene, relay pumping may be necessary to keep the water moving because of friction loss in the supply hose. In 2.5-in. dual-supply lines, a relay engine/pumper is necessary every 700 ft as compared to every 1,200 ft for 5-in. diameter hose (Table 1).

One challenge of firefighting in a rural setting is how to deliver the necessary volume of water on a sustainable basis. Static sources such as lakes and ponds can be suitable sources, provided they are easily accessible at all times during the year. A fire apparatus is not designed for off-road use and will quickly sink in soft soil or may roll over if parked on a steep incline. Therefore, it has become popular to install dry hydrants so water can be drafted from these naturally occurring supplies without placing the fire apparatus at risk. The dry hydrant is a large diameter piping system leading into the lake or pond with a compatible fire apparatus connection at the roadside, driveway or parking lot. This enables the firefighters to draft water from the source regardless of weather conditions.

If a dry hydrant connected to a natural water reservoir or a municipal hydrant is not located nearby the fire building, tanker/tender operations may be needed to shuttle water to the fire scene. A series of portable dump tanks (similar to aboveground swimming pools) are used as temporary reservoirs to serve as a buffer supply to pump from between deliveries. The rate of water delivery on the fire will be limited to what can be brought to the fire scene with the equipment available. Round-trip travel time is usually a larger impediment to maintaining high flows than the time it takes to fill or discharge the water from the tankers (FEMA, et al., 2004, p. SM 5-6).

The amount of water (in gpm) necessary to fight a fire is easily determined and should be incorporated into the quick access prefire plan. National Fire Academy uses a formula based on the size of the building to estimate the necessary fire flow or amount of water required to bring a fire under control. Calculating the necessary fire flow starts with the square footage of the building divided by 3.

This is a much simpler formula for estimating demand than used by ISO. The calculation provides a baseline flow for 100% involvement of a single floor. If there are exposures, 25% of the basic fire flow is then added for each side of the building in order to account for protecting them as well. The total fire flow is then scaled back based on the extent of fire involvement at the time of arrival and anticipated fire spread before resources can be properly placed and activated.

For example, a 10,000 sq ft single-story building with one adjacent exposure would have a basic fire flow for 50% involvement as follows (FEMA, et al., 2005, p. SM 5-4):

Step 1: 10,000 sq ft/3 = 3,334 gpm

Step 2: 3,334 gpm + 25% (exposure charge for 1 side) = 4,168 gpm

Step 3: 4,168 gpm x 50% (estimated amount of building involvement) = 2,084 gpm

Application Methods & Hose Streams

Getting water from the fire engine/pumper onto the seat of the fire quickly and in sufficient volumes to overcome the heat being produced is the next challenge in effective extinguishment. This is achieved by various configurations of hand extinguishment hose lines.

Water can be available to the fire department from several sources, including municipal systems, static sources, and portable or mobile sources.

Hose carried on an engine includes large-diameter supply lines for connecting to hydrants and smaller-diameter supply line for "yard lays" to extend the reach of the handlines or supply portable master stream appliances.

PHOTO BY FRANK BAKER

Several options are available in nozzle types and hose diameters. The nozzle is fitted to the end of the hose to shape the water stream. Often called a handline, the hose is the flexible conduit that is used to carry the water from the engine to the fire. This line can be preconnected to the fire engine/pumper, attached to a larger-diameter supply line or carried into the fire building in a hose pack for attachment to a standpipe water supply. Each configuration has distinct advantages and drawbacks depending on how it is to be used.

Nozzles for handlines fall into two basic categories: adjustable fog and smooth bore straight stream. An adjustable fog nozzle may be designed for use with a preestablished flow rate and pressure to operate at maximal efficiency; or it may be an automatic variety that can compensate for operation within a wider variety of pressures and flow rates.

Adjustable nozzles allow the operator to change the stream from a narrow pattern to wide spray as needed. The drawback is that these nozzles are less able to deliver a stream that can penetrate deeply into a super-heated space before the stream is vaporized. The rapid vaporization of stream is caused by the stream being broken up by the nozzle tip into individual droplets that have a large surface-area-to-mass ratio. In some cases, this is desirable, but at other times, it may not be the most effective method of water application. In cases where rapid absorption of heat and production of steam to displace oxygen are needed, a fog nozzle may be the preferred application method.

Smooth bore straight stream nozzles have no adjustability in water pattern other than to control the total flow of water. They are designed to keep the water stream intact as nearly a solid column and permit it to carry deep into the fire area. This permits delivery of much more water to the seat of the fire. This can help quickly knock down the fire at the area of most intense heat. If quicker vaporization of the stream is necessary, the water can be bounced off obstructions or walls to break it up and create a spray pattern more like the fog nozzle.

Selection of hose size for handlines depends on the amount of fire and fire load. Commercial fires will often dictate the use of a 2.5-in. handline to get the necessary water flow to overcome the heat being produced and quickly knock the fire down. However, this larger diameter hose, which can easily flow 275 gpm, is difficult for two firefighters to maneuver and often requires that three or four firefighters advance it into a building where obstructions are a problem (Hall & Adams, 1998, p. 526).

Some departments use 1.5-in. hose lines for preconnected attack lines, while others use 1.75-in.-diameter lines. While the increase in diameter of only 0.25 in. may seem insignificant, it can increase the flow rate by as much as 50 gpm at the same 150 psi pump pressure, thus increasing the flow to around 175 gpm.

The reduction in mobility for the larger hose is almost imperceptible. The only drawback is that for heavy fire loads, the 175 gpm flow rate may be inadequate; in many cases, however, the extra 50 gpm significantly affects fire control (Hall & Adams, 1998, p. 526) (Table 1, p. 28).

The length of hose needed for a fire crew to attack a fire follows a rule of thumb suggesting the distance to the fire plus 50 ft. Most preconnected attack lines in a minuteman configuration are limited to 150 ft without having to add more hose, although they can be as long as 250 ft (Hall & Adams, 1998, pp. 420-422).

In cases where the distance from the apparatus to the building and the estimated seat of the fire exceeds 100 ft, a yard lay or larger-diameter supply line is used to bridge the gap. This line can supply multiple handlines once the water flow is diverted through a gated wye connection. The larger the supply line, the more lines or larger diameter handlines it can support.

A backup water supply should be taken into the building as soon as possible. This is a hose line from another engine/pumper and it is positioned in case a mechanical pump fails or a hose ruptures, which would disable water supply. If a hose line is damaged or inoperable, this can mean the difference between becoming trapped by a rapidly advancing fire and being able to escape.

Master stream devices are used when there is a need to flow 350 to 2,000 gpm into a specific area of the fire or building. These devices can be portable for setup away from the apparatus, or mounted on top of the apparatus or at the top of an aerial ladder/platform. They are commonly used when large quantities of water are needed to cool exposures or to flow water into a structure that is considered lost to prevent spread of the fire to surrounding exposures. Before a master stream device can be discharged onto a fire from above by an aerial ladder, all firefighting personnel must be evacuated from the building for safety reasons.

The excess water introduced into the structure that is not evaporated or converted to steam adds weight, especially if applied to upper floors. Contents may be able to absorb great quantities of water and create an unsafe environment because of the potential that the building will collapse due to floor overloading.

Water weight accumulates rapidly—water weighs 8.34 lb per gallon. A 2.5-in. hose line can introduce more than 2,200 lb of weight into the structure per minute if not being applied to the fire and converted to steam. Hence a master stream flowing 1,000 gpm can add more than 8,300 lb per minute to what is already a potentially compromised structure (Hall & Adams, 1998, p. 596).

Confinement & Extinguishment

The ability to merely confine or extinguish a fire is largely determined by the available resources. Another consideration is fire behavior prediction—that is, where is the fire now, where is it going to go and who or what is in its way (FEMA, et al., 2004, p. SM 3-4).

As is often the case with a fire that has grown to any significant size before arrival of the fire department, the first due company will not have sufficient resources to mount a full frontal attack and extinguish the fire on its own. This company must wait for additional manpower and equipment before undertaking serious control and extinguishment efforts.

The company will be initially concerned with the assessment of life hazard inside the structure and protection of any surrounding exposures to prevent spread of the fire. It may not be advisable to attempt extinguishment because of changes that may occur in the stratification of the products of combustion due to the cooling effect of water or displacement by steam.

This stratification due to a thermal balance condition keeps the super-heated products of combustion above the floor level. Disrupting this thermal balance can make the environment untenable for firefighters and building occupants awaiting rescue. In such cases, the crew merely attempts to keep the fire from spreading while rescue efforts are underway. Insufficient manpower to perform all the necessary operations associated with an aggressive attack (such as ventilation, backup hose lines, RIT or water supply) may limit the efforts to confinement. Temporary fire confinement is simply a method to buy time to accomplish other strategic goals.

If resources—water, manpower and quick access to the fire area—are sufficient without unnecessarily endangering personnel, then a conscious decision can be made to extinguish the fire. Large amounts of water may be necessary, especially if the fire has not been successfully confined through previous efforts. Multiple crews may need to maneuver large diameter handlines into the building to provide the necessary water flow onto the fire.

Advancing these lines places great stress on the crews and takes precious time away from their ability to stay and fight the fire because of limited air supply in self-contained breathing apparatus. If the fire is deep inside the structure and access cannot be gained close to the fire area, a significant amount of breathing air will be expended simply advancing the hose line. When this is the case, the crew members will not have much time in the fire area to either extinguish the fire or retreat. This is a common problem in large buildings such as warehouses, large retail stores and factories.

The concept of "lead time" is critical to being able to prevent the advance of a fire. A decision must be made as to how much of the building must be considered lost already in order to properly place the resources for confinement and extinguishment. If the fire is advancing rapidly, it may pass a particular point where attempts will be made to halt its progress before the resources can be set up and activated (FEMA, et al., 2004, p. SM 3-4).

Looking Ahead to Part 2

Part 2 of this article will appear in the March 2008 issue of *Professional Safety.* It will cover building protective systems and construction, salvage, overhaul and investigation, firefighter safety, and ways to improve the outcome at fire events. ■

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