Introduction to Fireground Strategies and Tactics for the Non-firefighter Safety Professional – Understanding the Capabilities and Limitations of the Fire Department

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Introduction

According to "A Needs Assessment of the U. S. Fire Service" published jointly by the National Fire Protection Association and the Federal Emergency Management Agency in 2002, it is estimated that:

- 60 to 75% of all fire departments do not have enough fire stations to meet ISO guidelines for response times and distances.
- 50% of all fire engines are over 15 years old.
- 38% of firefighters in communities of 50,000 population and larger are responding on crews with less than the NFPA recommended 4 persons on the first due apparatus.
- Only 25% of all departments own thermal imaging cameras vital in performing efficient searches for victims in smoke filled buildings. (NFPA – A Needs Assessment)

These statistics identify some issues that may reduce the ability of a fire department to handle your emergency. As a result, the steps you take prior to that event take on 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 you in the pre-fire emergency planning process. Understanding what actions the fire department will likely be able to perform upon arrival and during their ongoing efforts to control the situation should help you develop realistic expectations about that department's capabilities. Without this information, you may be unknowingly creating situations that will hamper their ability to ensure the safety of all persons involved and effectively extinguishing the fire.

Given improvements in fire safety efforts, hostile fire events still occur and are often catastrophic in nature; resulting in personal injuries, the loss of human lives 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 c.2005) 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 United States. (NFPA – A Needs Assessment) The capabilities of the responding department can vary greatly so the Safety

Professional should meet with the responding agency to assess their capability and resources; then compare this information to your "worst case" scenario needs.

Fire Service / Public Protection Rating System

ISO Public Protection Classification

Municipal Fire Departments are rated by the Insurance Services Organization (ISO) using a complex matrix known as the Fire Suppression Rating Schedule that is based on 3 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 their Public Protection Classification (PPC); 1 being the best protection to 10 representing no recognized protection or protection that does not meet minimum ISO standards (ISO c.2005)

Ten percent (10%) of the overall grading is based on how reliably the fire department receives fire alarms and dispatches its fire-fighting resources. This includes an evaluation of the communications center, number of emergency operators at the center, the telephone service, number of telephone lines coming into the center and the listing of emergency numbers in the telephone book. Dispatch circuits and the method by which the firefighters are notified are also evaluated.

Fifty percent (50%) of the overall grading is based on the Engine Companies and the amount of water a community needs to fight a fire. Included in this category are: the number of engine companies, distribution of fire stations throughout the area, if the fire department tests of its pumps regularly, inventories each engine company's nozzles, hoses, breathing apparatus, and other equipment. Fire department recordkeeping is reviewed to determine the type and extent of training provided to fire-company personnel, number of people who participate in training, firefighter response to emergencies and maintenance and testing of the fire department's equipment.

Forty percent (40%) of the grading is based on the 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 includes various components of the water supply system, including 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 c.2005) What cannot be contemplated are unusual conditions such as droughts that may reduce the overall volume of water in the system to the extent that pressures cannot be maintained; or frozen hydrants and mains during the winter that can interfere with the ability to extract what water 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 manifesting itself in broken water mains that can disrupt the supply.

Interpreting the PPC Rating

As a general rule the lower the numerical PPC rating number the better the protection afforded to the community, and consequently lower fire insurance rates for those property owners. ISO research clearly shows the impact of better public fire protection on both commercial and homeowner's insurance fire losses. A PPC rating of 1 indicates exemplary fire protection. There are maximum travel distances and response times that cannot be exceeded with penalty on the scoring. Presently there are only 45 (0.1%) departments holding the rating of Class 1 out of an estimated 44,000 fire response jurisdictions ISO has evaluated. DuBois Volunteer Fire Department, in Pennsylvania, is one such example; showing not only that achieving Class 1 status is possible, but by volunteer department. Only 419 (< 1%) of the 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 of the needs for the community, but some split classifications such as 5/9 are given. You may find through research that your local fire department has a rating of Class 5, but your building carries a Class 9 for fire insurance rating purposes. This would usually be the result of your 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 over 5 miles from the nearest fire station and in excess of 1000 feet to the nearest hydrant will be assigned a Class 10 rating. (ISO c.2005)

The PPC is merely an indication of the response capabilities for typical fire suppression emergencies. It may not be truly reflective of their ability to address your particular hazards during a fire event caused by storage or use of products that are not compatible with water, those requiring high volumes of special fire fighting foams or involve hazardous materials for which their protective gear would provide little or no protection. If you are located in a jurisdiction with a high PPC the greater the likelihood you will need to rely on your 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 your area, and a crew that should include at least 4 persons to perform effectively and safely. Their 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 or engine companies available, how much water they can pump and carry, their proximity and manpower available. To qualify, a fire engine / pumper is required to have an on board pump, a water supply tank, large diameter supply hose and a compliment of ground ladders. ISO's 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. (ISO c.2005) Many years ago, a 500 gpm (gallons per minute) pump with a 300 gallon tank and 3 inch diameter supply hose was the state of the art. Heavier fire loads have created a demand for higher water flows. Fortunately, technology has given the fire service the ability to improve the amount and efficiency by which water can be delivered to the fire scene. New fire apparatus is being commonly fitted with 1500 gpm pumps, 1000 gallon and larger on-board water tanks and 5 inch diameter supply hose. Manufacturers are now offering pumps in the 2000 gpm range and 1500 gallon capacity water tanks on a standard fire engine / pumper. Much 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, is made up of a vehicle equipped with an aerial device (elevating ladder or man platform) and should have a crew of at least 4 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 requires the truck company to be within 2.5 miles with a response time of 4.9 minutes or less. (ISO c.2005) The truck company can have many assignments on the fire scene, but usually involve forcible entry, search and rescue; and ventilation at the beginning of the incident. After the fire is under control their 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 1000 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 about 75 degrees from the horizontal plane; the same as a ground ladder, since it must often be safely climbed by personnel. *NFPA 1901: Standard for Automotive Fire Apparatus* requires the device to reach a height of at least 50 feet, but more commonly the full size aerial ladder will be 85 to 105 feet high. They must be capable of delivering at least 1000 gpm at a minimum of 100 psi from the nozzle located at the tip of the ladder or boom. Apparatus designed as a water tower only are designed to deliver the water, but do not have the benefit of an integral ladder for access to the tip or to perform work from the middle. These may be of telescoping or articulating design 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 is usually directly tied to the length of the ladder.

To qualify as an Aerial / Ladder it is not required that it have its own pump or booster tank to carry water to the fire scene, although most will at least have an on board 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 there is 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 piece of apparatus known as a "Quint" (short for quintuplet: meaning 5 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 on board 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 "Tele-squirt" with ladders from 50 to 75 feet high. (NFPA 1901)

Pre-Incident Interaction with the Fire Department

Pre-Incident Survey

Pre-Incident Surveys are 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 done 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 first hand. (Goodson p 231) This information is then documented on a generic report, often called a Quick Access Pre-fire Plan. In addition to the basic information above, initial resource requirements, water availability, required Fire Flow (water demand) calculations are also made and potential fire behavior predictions and problems are identified. This document can then be made accessible to the 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 assisting with size up of 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 that can affect strategic decision making even before arriving on the scene. (PICO pp. SM 2-7, 2-8)

Code Enforcement Inspections

The authority for a Fire Department 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 your location, the Local Authority Having Jurisdiction may be enforcing one or more codes as adopted by the local or state government. These may include National Electric Code NFPA – 70, Uniform Fire Code or NFPA 1, Life Safety Code – NFPA 101, etc. The purpose of this inspection visit is to reasonably regulate activities of the public to control the risk of fire hazards. While information may be gathered during the visit that is used for pre-planning, the primary objective is the control of unreasonably dangerous activities. (Goodson pp189-190)

Managing the Fire Scene

Primary Incident Objectives

The basic rule of thumb used for decision making by an Incident Commander (IC) is: "Will my intervention positively affect the outcome of this event". It is a well known fact that all events will eventually terminate themselves without any intervention, but that degree of loss is usually unacceptable. To that end, a short list of primary objectives have been established and prioritized to assist the IC with decision making on the scene.

The primary objectives on the fireground are: first and foremost is Life Safety, second is Incident Stabilization and third is Property Conservation. They 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. Lastly, Property Conservation by saving what can be saved, but never at the expense of human lives. (Goodson p 285)

Lloyd Layman, noted fire service author, developed a list used to assist the Fire Officer in identifying priorities in emergency situations that has become an industry standard. Layman's priority list is represented by the acronym RECEO-VS (ree'-cee-oh, vee, ĕs). This list is not only used to identify priorities, but also provide a recommended sequence of operations. The first five letters represent operations that occur on almost every fire scene and usually in that specific order. The last two letters representing Ventilation and Salvage are not always necessary, nor are they always done at the same point in the operation, thus they are separated out on the list. The initials in the acronym represent the following:

- Rescue
- Exposures
- Confinement
- Extinguishment
- Overhaul
- Ventilation
- Salvage (Goodson p 277)

Incident Command

Command for an incident 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 that will be used for the duration of the event. Command of the incident may later be transferred to a ranking officer depending on department policy or based on the success of the current Incident Commander (IC) in accomplishing the objectives that will mitigate the event. A modular Incident Command system is necessary to provide the necessary flexibility to address the unique exposures for any given situation. This modular 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.

Incident Command Systems over the years have used varying terminology with one of the more popular systems being the FIRESCOPE system. However since 2004, many departments as part of a Federal mandate are standardizing their Incident Command systems to bring them in line with the National Incident Management System (NIMS). The reason for this standardization is so all responding agencies at any given event follow the same Incident Command System to reduce the risk of miscommunication, as well as fulfilling the requirement to have inter-agency communication capability.

The Incident Commander is ultimately in charge of everything that occurs on scene, but will often delegate authority to complete certain objectives, usually that of Safety Officer and direction of an Operations Group. The Operations Group is responsible for carrying out 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 cover an extended time period more functional areas are taken out of the proverbial "tool box" and placed into use. This modular system permits adding resources to the system as needed depending on the needs of the incident If the IC does not assign a specific authority to a group leader, he/she retains full control of that function for the duration of the incident. A small incident may result in only the Safety Officer designated to a separate individual and all other responsibility remains 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, Inter-agency Liaison Officer; Logistics, Planning and Finance groups. Further delegation to maintain the ideal span of control takes place within each group by creating division, task forces, strike teams, etc. (NIMS pp. 12-24)

In order to keep management of the 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 involved in the Incident Action Plan are: size-up, selection of strategies & tactics, followed by implementation of the plan. (MCTO-D 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." (MCTO-D p SM 1-12) It is the stepping off point for what happens during the remainder of the incident.

Pre-incident information is critical to successful outcomes. Sources of information include the Fire Department Pre-plans, 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 other 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. (MCTO-D pp SM 2-11 to 2-13)

The first arriving Fire Officer on the scene is responsible for providing all remaining en route units a Size-Up Report that will contain specific information about the incident that can be visually observed. Early recognition of the need for resources beyond the initial response can save both lives and property. In cases where department resources may be limited, additional resources may be in the form of mutual aid responses from other area departments; that in rural areas may be significantly delayed due to long travel distances.

The Fire Officer in the course of conducting the Size-Up should attempt to identify the scope of the fire problem, predict its behavior and make initial decisions on how to apply the available or needed resources to the problem. Questions that need to be answered include: "Where is the fire now? Where is the fire going? Who or what is in its way?" to determine if confinement and extinguishment are possible. (STICO p SM 3-11) If it is determined that there is reasonable likelihood of success with the resources that can be mustered, then a Risk / Benefit Evaluation must be conducted. Questions asked during this process will include: "Are the risks being taken worth the benefits being gained?" and "If it is worth the risk; for how long?" (MCTO-D p SM 2-17)

Fire Chief Alan Brunacini of the Phoenix, Arizona Fire Department is credited with development of a risk based decision policy that has been integrated into their 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."
- The will "NOT risk their lives at all to save lives and property that have already been lost." " (Goodson p 285)

The Operational Mode

The 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 that mode might change. Goodson & Sneed in *Fire Department Company Officer,* list the three modes as: Rescue, Offensive and Defensive. However, the FEMA / National Fire Academy *Managing Company Tactical Operations – Decision Making: Student Manual,* lists these 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, the rescue operations are done in conjunction with a coordinated fire attack. However, in extreme cases like multiple occupants, the need to move extremely fast through the structure or lack of sufficient manpower on scene to perform both, all available personnel are assigned to this task in what is commonly called an "all-hands rescue". (Goodson 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 usually limited to that necessary to protect the rescuers and those being rescued. Some consider rescue operations to always be part of the Offensive Mode and not a separate mode of its own.

The Offensive Mode of operation may also involve rescue operations, but is primarily focused on containment and extinguishment of the fire with 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 through the structure. It is also the mode in which the fire service prefers to operate. (Goodson p 283)

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

The mode of operation can change at any given time during an incident based on the conditions observed. During this change, the operations are in what is termed the Transitional Mode and involve the strategic realignment of resources (MCTO-D p SM 2-19).

Strategies & Tactics – Capabilities & Limitations

The primary fireground objectives of ensuring Life Safety, Incident Stabilization and Property Conservation are 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 (also called tasks). For example:

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. (PICO p SM 1-49)

Search & Rescue

Rescue of any building occupants and the safety of firefighters take precedence over any other incident objective. During the initial size up on the scene, contact with a knowledgeable building representative is critical to quick and effective assignment of resources. This should be someone with both knowledge of the facility, but able to account for the building occupants. If no information is available or it is suspected there are still occupants in the building, the search and rescue function will supercede all other operations. While other tactics like ventilation or extending protection lines may be observed, they are intended to facilitate the search and rescue effort, not necessarily extinguishment.

The initial search of a building is called the Primary Search. This is a very rapid search conducted to determine if there are actually persons in the building. The primary search will start at the area involved in fire and expand towards uninvolved areas until the likely areas of refuge and normal escape routes of building occupants have been searched. Unfortunately it is often done under conditions of extremely high heat and poor visibility. A charged hose line should be taken into the building by a one or more fire crews to provide protection for those involved in conducting the primary 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 1-3/4" diameter that might not always have sufficient water flow to overcome the heat being produced by the fire or might be necessary to extinguish it. Other supporting tactics might include early implementation of ventilation to release excessive heat and smoke from the building to provide the 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 all areas will be searched. If a crew is assigned the prime task of search and rescue, they can conduct a more thorough search in less time than if they are advancing a hose line through the building. The goal is make sure all areas where occupants may have taken refuge from the heat and smoke have been searched to locate those persons with reasonable chance of survival. (Hall p 176-177)

The Thermal Imaging Camera or TIC has become an invaluable tool in effective search and rescue operations as well as quickly locating the seat of hidden fires while minimizing property damage. This device uses infrared heat sensing technology in a handheld sized unit to enable fire crews to 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 vitally important. Where fires are hidden behind walls or in large spaces filled with heavy smoke that would obscure their vision and hamper finding the actual seat of the fire, these can greatly speed this process of locating exactly where to apply the water stream to be the most effective. In situations where a 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 providing direction as to where to head to apply water without wasting time searching for the seat of the fire. Ever improving technology has also brought about the availability of miniaturized helmet mounted camera units that free up the firefighters hands. However, since 75% of departments do not have access to even first generation technology that is hand carried, helmet mounted versions would be out of the financial reach for all but the most well funded departments. (NFPA – A Needs Assessment)

A secondary search is conducted once the fire is under control or completely out to search for further victims who might not have been found on the primary or initial search patterns. (Hall p 178) Rather than being a rescue, this is usually a victim recovery 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 an exposure today. The decision as to what to attempt to save first, or at all, is going to be made during the initial size up.

Radiant heat is the number one enemy of exposure protection. The amount of radiant heat and how much of a building is contacts will determine the original fire's ability to damage it by setting on fire as well. Generally a building less than 40 feet from the fire building is most likely an exposure. If it is located 40 to 100 feet away it will probably be an exposure depending on the radiant heat being produced by the initial fire. A building over 100 feet would not generally considered an exposure, unless severe environmental conditions exist that can spread the fire like flying brands spread by high winds or ground brush in dry conditions. (PICO p SM 5-5)

Exterior exposures would usually be protected by use of water applied to the exterior to remove heat from the surfaces. Water curtains sprayed into the air between an exposure and a fire are ineffective at stopping the transfer of the 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. (STICO p SM 3-8)

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

Preventing fire spread from one floor to another in a high-rise building is sometimes difficult due to the nature in which they naturally auto ventilate or are 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 the building.

Interior exposures due to 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 intended to merely hold the fire in check and prevent its forward progress. If and when additional resources become available, including back up 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 fire fighting operations."(Hall p 345)

The ultimate goal is to localize the fire by preventing its horizontal spread through the building. As heat builds up inside the structure from the fire, it collects at the highest points first, then banks downward with the other products of combustion and will eventually reach 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 up until it either causes the fire area to ignite simultaneously in a flashover or result in an explosive like event, commonly called a backdraft. When used properly ventilation is also an effective exposure protection strategy by controlling how a fire is allowed to travel through a structure.

Timing of the ventilation during a fire will be dictated by the primary objectives. The existence of a life hazard in the building will require ventilation to be performed before the extinguishing crews are in place in order to help improve the visibility and atmosphere within the building to increase the chances of survival of trapped occupants and speed the primary search process. In this case, a crew will usually be assigned the task of holding the fire in check or ensuring it does not compromise the egress paths for those performing searches. If ventilation is primarily to facilitate location and extinguishment of 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 will cause the fire to grow in intensity. When the fire suppression crew uses a large enough diameter hose line, they can overcome the heat being generated and quickly gain control of and extinguish the fire. If inadequate water is applied to the fire, they might only accomplish holding it in check, or worse end up pushing it into another area of the building. Properly timed and executed ventilation techniques can also be very effective at reducing the risk of phenomena known as flashover and backdraft from occurring. (STICO 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 pyrolosis and give off flammable gases at extremely high rates. These flammable gases combined with other unburned products of combustion undergo almost simultaneous ignition causing the entire space to become rapidly engulfed in flame. This occurs almost instantaneously from top to bottom and causes fire to push out of the space from any available opening. This can occur in a space where free burning of the contents is taking place and 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 they make entry into the fire area for the initial attack. (STICO p SM 4-9)

A backdraft is the ignition of superheated products of combustion that have been generated by pyrolosis and have been trapped in an oxygen deficient space. This lack of oxygen in the space prevents a free burning state from occurring and thus is the main difference between a backdraft and a flashover. The products of combustion are already above their autoignition temperature and only need a source of fresh air to provide oxygen for them 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 even weakened walls from a structure. If such a space is ventilated horizontally by opening a door or window without first releasing the superheated gases vertically it will cause fresh air to be drawn into the oxygen starved space. Ignition of the superheated products of combustion will occur almost instantaneously. Telltale signs that a backdraft is imminent include the production of thick brown smoke and the appearance of the structure to be "breathing" or puffing smoke from openings like attic vents, window and door frames, etc. Timing for ventilation to avoid an impending backdraft is before crews attempt to open doors or windows at lower levels of the building or confined fire area for entry. Ventilation must then be as high and directly over the suspected seat of the fire as possible to reduce lateral spread and rapidly exhaust the products of combustion. (STICO p SM 4-9)

Various methods of ventilation can be employed to remove the contaminants from the building. The most common method observed by the public is ventilation by convection. Most often this is achieved vertically, but can be accomplished through horizontal openings like 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. Larger vent holes are often 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 permits easier location of the base of the fire by improving the visibility factor and providing a much safer environment to work in. Depending on the location of the vent hole in relation to the main fire, it can be used to either help confine it or 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 both fire suppression and for salvage or overhaul operations. Both methods have advantages and disadvantages. Use of either of these is usually reserved for situations where convection methods would not provide effective removal of smoke and heat, would be impractical due to the building design, or where the building would be considered unsafe for rooftop operations.

The decision to ventilate the building using a vertical or horizontal pathway is often dictated by the building construction features. A fire located on the top floor of a building is often easily ventilated through the roof allowing for natural convection to assist the process. This is where use of the existing features such as roof mounted vent caps, skylights, etc., become ready made ventilation sites. However, these are often insufficient in square footage to release the volume of heated gases necessary and the crews must resort to manually opening up large holes in the roof. If the fire is not on the top floor of a building, horizontal ventilation of the products of combustion becomes the only option. Windows and doorways then become the next available source for ready-made vents. In high rise structures with large glass curtain walls, removing windows can provide good ventilation but might also 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 his initial size up as to where ventilation is necessary due to a life safety hazard, to stabilize the incident, to effect property conservation or other tactical objectives. The next decision will be where, when and how (tactic) the ventilation should be implemented to fulfill the strategic goal. Poor decision making, such as not getting far enough ahead of the fire, can significantly affect the outcome. (STICO p SM 4-10)

Water Supply & Fire Flow

Water is the going to be the most commonly available extinguishing agent. Water can absorb about 140 Btu's per pound when its temperature is raised from 72 degrees F. to its boiling point of 212 degrees F. The same pound then absorbs another 900 Btu's when its physical state is converted to from a liquid to steam. This steam displaces about 1700 times its original liquid volume making it useful for displacing oxygen needed by the fire. (Hall p 488)

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

Obviously a municipal water system is the most desirable, but can still have significant limitations in the event of a major fire. Municipalities with large diameter (12" and larger) looped main systems can expect water flows of 1200 to 1500 gallons per minute from a single hydrant. In older communities, the water mains may be as small as 4 inches 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 might well be less than what can be delivered by an effective rural fire department adept at tanker shuttle operations. Other municipal water system problems 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. 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. (STICO p SM 5-3)

Large diameter supply hose, generally considered 5 inch diameter and larger, has replaced 2-1/2 and 3 inch diameter dual supply lines in many communities for connecting the fire apparatus to hydrants. Using 600 feet 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 inch, large diameter supply hose can flow 1250 gpm. Compare this to a 2-1/2 inch supply hose connected to the same hydrant will only flow 210 gpm. Six of these 2-1/2 inch supply lines would be necessary to flow 1260 gpm. Doubling the diameter provides nearly six times the flow capacity. (STICO 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 due to friction loss in the supply hose. In 2-1/2 inch dual supply lines a relay engine / pumper is necessary every 700 feet as compared to every 1200 feet for 5 inch diameter hose.

One of the main challenges to firefighting in the rural setting is how to deliver the necessary volumes of water on a sustainable basis. Static sources such as lakes and ponds can be suitable sources of water, provided they are easily accessible at all times during the year. Fire apparatus is not designed for off road use due to its weight and will quickly sink in soft soil or may roll over if parked on too steep an incline. Therefore it has become popular to install dry hydrants so drafting of water from these naturally occurring supplies can be performed 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 them to draft water out of the source regardless of the weather conditions. If a dry hydrant connected to a natural water reservoir, or a municipal hydrant is not located in close proximity to the fire building, tanker/tender operations may be needed to shuttle water to the fire scene. A series of portable dump tanks that are like above ground 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. (STICO p SM 5-6)

The amount of water, expressed in gallons per minute (gpm), necessary to fight a fire is easily determined and should have already been incorporated into the Quick Access Pre-Fire Plan. The National Fire Academy uses a formula based on the size of the building to estimate the necessary fire flow or amount of water that will be necessary 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. This calculation provides a baseline flow for 100 percent involvement of a single floor. If there are exposures, 25 percent of the basic fire flow is then added for each side of the building where they exist in order to account for protecting them as well. The total fire flow is then scaled back based upon the extent of fire involvement at the time of arrival and anticipated fire spread before resources can be properly placed and put into action. For example, a 10,000 square foot single story building with one adjacent exposure would have a basic fire flow for 50% involvement as follows:

Math Step 1: 10,000 square feet / 3 = 3,334 gpm
Math Step 2: 3,334 gpm + (25% exposure charge for 1 side) = 4,168 gpm
Math Step 3: 4,168 gpm x (50% building involvement) = 2,084 gpm. (PICO p SM 5-4)

Application Methods & Hose Streams

Getting the 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 done by various configurations of hand extinguishment hose lines. Several options are available in the between nozzle types and hose diameters. The nozzle is the fitted to the end of the hose to shape the water stream. The hose, often called a hand line is the flexible conduit used to carry the water from the engine / pumper to the fire. This hand line can be pre-connected 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 hand lines fall into two basic categories, adjustable fog and smooth bore straight stream. An adjustable fog nozzle may be designed for use with a pre-established flow rate and pressure to operate at maximal efficiency; or it may be an "automatic" variety capable of compensating for operation within a wider variety of pressures and flow rates. Adjustable nozzles give the operator the ability to change the stream from a narrow pattern to wide spray as needed. The design drawback is that this type has a reduced ability for the stream to penetrate deeply into a super heated space before the stream is vaporized. The rapid vaporization of the 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, others 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 do not have any adjustability in the pattern other than to control the total flow of water. They are designed to keep the water stream in tact 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. The ability to reach deeply into an area heavily involved in fire with a straight stream can be advantageous to achieve a quick knock down of the fire at the area of most intense heat. If quicker vaporization of the stream is necessary, the water can be bounced off of obstructions or walls to break it up and create a spray pattern more like the fog nozzle.

Selection of hose size for hand lines will depend on how much fire and fire load there is. Commercial fires will often dictate the use of a 2-1/2 inch hand line to get the necessary water flow to overcome the heat being produced and quickly knock the fire down. Unfortunately this larger diameter hose, easily capable of flowing 275 gpm is difficult for two firefighters to maneuver and will often require three or four persons to advance it into a building where obstructions are a problem. (Hall p 526)

Some departments use 1-1/2 inch hose line for pre-connected attack line, while others use 1-3/4 inch diameter lines. While the increase in diameter of only ¼ inch 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 still be inadequate, but in many cases the extra 50 gpm makes a significant impact on fire control. (Hall p 526)

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 feet. Most pre-connected attack lines in a Minuteman configuration are limited to 150 feet without having to add more hose, however they can be as long as 250 feet. (Hall pp 420-422) In cases where the distance from the apparatus to the building and the estimated seat of the fire is greater than 100 feet, a yard lay or larger diameter supply line is used to bridge the gap. This large diameter hose can supply multiple hand lines once the water flow is diverted through a gated wye connection. The larger the supply line, the more lines or larger diameter hand lines it can support.

A back-up water supply should always be taken into the building as soon as possible. This is a hose line from another engine / pumper in case of a mechanical pump problem or hose rupture that would disable one of the water supplies. This can mean the difference between becoming trapped by a rapidly advancing fire and being able to escape if one hose line becomes damaged or inoperable.

Master stream devices are used when there is a need to flow from 350 to 2000 gpm into a specific area of the fire or building. Master stream devices can be portable for set up away from the apparatus, mounted on top of the apparatus or at the tip of an aerial ladder/platform. They most commonly used when large quantities of water are necessary to cool exposures or to flow water into a structure that is considered lost to prevent further spread of the fire to surrounding exposures. Before any 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 have the capability to absorb great quantities of water and create an unsafe environment due to the potential for building collapse from floor overloading. This water weight accumulates rapidly since water weight 8.34 pounds per gallon. A 2-1/2 inch hose line can introduce over 2200 pounds of weight into the structure per minute if not being applied to the fire and converted to steam. Hence a master stream flowing 1000 gpm can add over 8300 pounds of weight to the building per minute to what is already a potentially fire compromised structure. (Hall p 596)

Confinement & Extinguishment

The ability to merely confine the fire or to extinguish it will be determined largely by the available resources, but will also include issues related to fire behavior prediction. Questions include: “Where is the fire now? Where is it going to go? Who or what is in its way?” (STICO 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 their own. They must wait for additional manpower and equipment to arrive before any serious control and extinguishment efforts can be undertaken. They 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 due to the changes that may occur in the stratification of the products of combustion due to the cooling effect of water or displacement by steam. It is this stratification due to a thermal balance condition that keeps the superheated products of combustion above the floor level. Disrupting this thermal balance can make the environment untenable for the firefighters and the building occupants awaiting rescue. In this case crews will merely attempt to keep the fire from spreading while the rescue efforts are underway. A lack of sufficient manpower to perform all the necessary operations associated with an aggressive attack such as ventilation, back-up hose lines, Rapid Intervention Team (RIT) or water supply may also cause the efforts to be limited to confinement versus extinguishment. Temporary fire confinement is simply a method to buy time to accomplish other strategic goals.

If there are sufficient resources, mainly water, manpower and quick access to the fire area without unnecessarily endangering personnel then a conscious decision to extinguish the fire can be made. Large amounts of water may be necessary, especially if the fire has not been successfully confined with previous efforts. Multiple crews may need to maneuver large diameter hand lines into the building to provide the necessary water flow onto the fire. Advancing these lines places great hardship on the crews and takes precious time off of their ability to stay and fight the fire due to limitations of their air supply limitation of the 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 just advancing the hose line. When this is the case they will not have much time in the fire area to either extinguish the fire or retreat. This is a common problem in very large buildings like 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 are going to be made to halt its progress before the resources can be set up and put into action. (STICO SM 3-4)

Building Construction

The type of building construction will determine how long is can endure exposure to fire. Fire resistive (NFPA Type I) offers the best resistance to fire exposure, while wood frame (NFPA Type V) offers the least. In between are non-combustible (NFPA Type II), ordinary masonry (NFPA Type III) and heavy timber (NFPA Type IV) construction. Each has advantages and disadvantages due to their unique construction features. Knowledge of building construction features, limitations and hazards associated with each will assist the Incident Commander in determining how long the fire crews can safely work within the structure before collapse becomes likely. (PICO p SM 4-3)

Compartmentalization or open spaces can significantly affect fire spread. While compartmentalization can make access to the fire area difficult for maneuvering hose lines, it can work to the advantage of the fire crews in being able to hold the fire in place by using the existing physical barriers to its spread. Open spaces on the other hand make it easier to advance hose lines, but do not provide any barriers to its lateral spread throughout the structure.

Compromise of the building construction features like removal of draft curtains in large open areas, failure to maintain and test fire doors for proper operation and breaches in fire walls and partitions are some the primary reasons for extensive fire spread. Improper storage of things like flammables and aerosol cans can cause fires to move so rapidly through a structure that they get ahead of the main body of heat that would otherwise activate fusible links. Contractors working in the building can unwittingly remove the fire protective materials on metal components such as open web bar joists or I beams. Penetrations in firewalls for ventilation ducts without fire dampers or holes cut for piping or conduit without proper sealing around them can permit fire to spread from one side of a firewall or partition to the other.

Building Protective Systems

If there are building protective systems in place such as automatic sprinklers or standpipes and hose stations (for fire department use), their support and use can be critical in effective control and extinguishment of the fire. In the case of automatic fire sprinklers their intent is to only control, not totally extinguish the fire; although they often do provide complete extinguishment. If the fire load is much higher than the sprinkler system was originally designed for, it may be overwhelmed and not even hold the fire in check with only the municipal water pressure.

Year of data indicate that about 96% of all fires are controlled or extinguished by an automatic sprinkler system if the building is properly equipped. The remaining 4% are usually the result of water being shut off before the fire or prematurely, only partial sprinkler protection, inadequate water supplies, faulty building construction, obstructed piping, disrupted flow from heads, hazards of the occupancy, outdated equipment and/or inadequate maintenance. (STICO p SM 2-28) Automatic sprinkler systems should be fitted with a Fire Department Connection on the exterior of the building or in a free standing configuration away from the structure. This inlet can either be a 3 inch Siamese or a 5 inch Storz connection depending on what the local authority having jurisdiction or local fire codes mandate. The valve that controls water to the sprinkler system from the public water supply also controls whether the fire department can provide additional water volume and pressure to the system. These should be locked in the open position and supervised to monitor for tampering. Removable covers should be in place to prevent debris from being placed into the piping system that can obstruct the flow of water. Once established that water can be provided to the system, supply lines are attached from one of the first responding engines / pumpers to provide additional water volume and boost the system pressure to 150 psi. When this is done, the normal water main pressure is exceeded and the engine / pumper will become the sole water supply for the sprinkler system. A check valve will keep the water from flowing back into the municipal main. This additional pressure and volume cause the system to flow significantly more water into the fire area where heads have activated. By increasing the pressure by two for four times the municipal pressure, it may help to overcome deficiencies caused by excess fire loading beyond the original design criteria. On site fire pumps designed into the system need to be noted as to whether they activate automatically or need to be manually started. (STICO p SM 5-9)

Standpipes and hose stations will also need supplemental pressure and volume to flow the required 500 gpm for those rated as NFPA Class I or III. Standpipes are pre-plumbed vertical water mains, usually located in a stair tower. They provide a readily accessible location for connecting hose packs carried into the building. A hose station is a remote point on an internal water main that either has hose pre-connected to it, or has fittings for the fire department to connect their hose packs. Using these significantly cuts the time that would otherwise be required to bring supply hose to that particular location. High rises and large buildings can benefit from use of these systems as it will limit the amount of hose each firefighter has to carry into the structure for at least the primary attack line, conserving valuable energy and time. However, back-up hose lines will also be taken into the building from a secondary source such as the next nearest engine / pumper that is not supplying the building standpipe system. Central control valves for these systems also need to be locked in the open position and supervised to monitor them for tampering. (STICO p SM 5-8)

Apparatus & Manpower

The total quantity of apparatus and manpower that an individual department can muster may often be limited strictly due to the size of the department. This forces them to rely heavily on mutual aid from nearby departments. The National Incident Management System now requires departments to have mutual aid agreements in place. In some cases these are on a “call only” basis, in other areas they may be automatically dispatched together on the same call when the location is near the district borders.

While ISO does evaluate mutual aid in their rating system, it is prudent to know what capabilities your responding department has and what must come from mutual aid. Going back to the basic fire flow formula of square footage divided by 3 to arrive at the 100% single floor demand, we can determine how much water will need to be supplied. If the basic fire flow formula indicates a need for 4,168 gpm at 100% involvement, does the department have enough pump capacity to flow that much water? Pump capacity of a given engine/pumper may vary from 750 gpm to 2000 gpm depending on its age, design and maintenance history. If they do not have the capacity to do this, mutual aid the only alternative. If the mutual aid agreement does not provide for automatic response, valuable time may be lost waiting to decide upon arrival that the incident is too big to handle with the resources at hand.

Manpower is another critical area where there is often a shortage. On average the number of personnel needed to carry out fire ground operations is one firefighter for each 25 to 50 gpm of required fire flow. This takes into account the other operations such as search and rescue, ventilation, RIT, relief crews, etc. Hence in our case of 4,168 gpm required fire flow, we will need a minimum of 21 and as many as 42 firefighters if the building is only 25% involved in order to adequately staff all the required functions to make a successful attack and extinguish the fire. Extra Alarms on fires are often struck or called to bring additional manpower to the scene, not necessarily the equipment they arrive on. (MCTO-P p IG 5-39)

Depending on the departments manpower resources a piece of apparatus may arrive on the scene with anywhere from one to six personnel. The ISO PPC rating does take this into account as far as regular staffing and the availability of personnel where they are on a "call" basis. In this case they would use data from prior fire reports to see how many personnel respond to arrive at an average, as it impossible to tell just how many people might respond to any given call. OSHA does not require a specific number of personnel on an individual apparatus (for those states where municipal employees are covered), but does require a minimum number on scene before interior fire attack can be initiated per 29 CFR 1910.134 (g) (4), the OSHA Respiratory Protection Program Standard (Two in / Two out Rule). However, NFPA 1710 addresses staffing for career fire departments and recommends a minimum of 4 persons on each apparatus. NFPA 1720, the counterpart standard to 1710 for volunteer departments recommends 4 persons on the scene before interior fire attack can begin, much like the wording in the OSHA Respiratory Protection standard.

In order to operate effectively and safely a structure needs to have paved access around all sides to permit positioning fire apparatus as needed to reduce the distance of hose stretches to the building for interior fire attack and for placement of aerial ladders for roof or upper floor access. Since fire apparatus cannot be taken off of a hard surface, this access must be paved or at least compacted gravel that is not subject to seasonal softening due to subsurface frost. Fire apparatus or personnel should not be positioned closer than 1-1/2 times the height of the building as there is always the risk of collapse as fire continues to weaken the structure. Also, there is the potential for exposure to radiant heat on the fire apparatus just as with adjacent buildings. Once fire apparatus are placed, pumps are engaged and hose is on the ground, it is difficult to move them without great effort and time. Accessibility for fire apparatus to all sides of the building from a level paved surface extending at least 3 to 4 times the height of the structure would be recommended. This would provide enough space to position multiple pieces of apparatus in close proximity to each other if needed, but far enough away to be outside the potential collapse zone. If the paved surface and the building are separated by too much grass area or due to physical barriers it can limit the reach of aerial ladders to upper floors or the rooftop. This might result in a 100 foot aerial only being able to reach to the second or third floor instead of the eighth floor.

Salvage, Overhaul and Investigation

This operation may also be tied to final fire extinguishment in searching for any fire extension in hidden areas inside of wall spaces and above ceilings. Overhaul is the search for hidden fire to ensure it is completely extinguished. The primary goals are to ensure the fire is completely out and reduce the amount of collateral damage to a structure and contents by opening up concealed spaces in the fire area. Salvage is the work done to preserve property and protect it from further damage by evacuating smoke and water to the extent possible. In some jurisdictions, there are special crews who perform these tasks, in other areas it may be done by the Truck Company personnel or with any available personnel on the scene. (Hall p 587 & 596)

Although salvage and overhaul operations are most commonly done after the fire has been determined to be under control or completely out. The most effective method of reducing damage to the structure and contents is to extinguish the fire as quickly as possible. Equipment used in salvage and overhaul includes: ventilation fans, salvage covers or tarps and various hand tools like brooms, squeegees, pike poles to remove drywall and shovels. While this activity is intended to assist the property owner in immediate property conservation efforts, it does not reduce or eliminate the need to have qualified property restoration services called in immediately to pick up where the fire department leaves off to secure the area from further damage due to exposure to the elements.

If the salvage and overhaul operations are not conducted properly, critical evidence can be destroyed or displaced before it is properly evaluated and documented. This can be of critical importance where a third party may be responsible for fire through action, failure to act or product liability. There is a fine line that crews must negotiate in performing this operation to ensure fire extinguishment, but not destroy evidence in the process and hamper the fire investigation to the point of making it impossible to determine the point of origin or cause. The property owner will not be permitted into an area that has been involved in fire until it has been determined to be safe and fire investigation is complete to enable them to maintain a chain of custody for any evidence that may need to be secured. Depending on the size of the fire, damage to the structure and difficulty in determining the cause; it may take several hours to days or weeks before you will be permitted inside.

Firefighter Safety

The Protective Ensemble

The protective gear (turnout gear) worn by today's firefighter has changed drastically from that common just 30 or 40 years ago when a helmet with no internal shock absorbing system, rubber coat, hip boots and rubber coated gloves was considered to adequate PPE. Most fire departments have since adopted use of protective gear that is compliant with the current or one of the previous editions of *NFPA 1971: Standard on Protective Ensemble For Structural Fire Fighting*. Protective gear that meets this standard will be comprised of a pant and coat that fully covers the body and extremities. It must be capable of protecting the firefighter from exposure to limited flame contact by the outer shell, extreme heat through insulation and steam burns by a modern vapor barrier lining. A fire resistant Nomex or other aramid fiber hood is also required to protect skin areas not covered by the helmet liner, SCBA facepiece and coat collar. The latest versions of firefighter turnout gear now have built in features such as drag harnesses to facilitate rescue of a downed firefighter. Supplemental protective equipment the compliments the ensemble is specified in NFPA 1972 for helmets, NFPA 1973 for gloves and NFPA 1974 for footwear.

The Self-contained breathing apparatus (SCBA) provides a supply of fresh breathing air from a tank of compressed air through a pressure regulator and facemask. The intent is to prevent inhalation of the toxic products of combustion and other air contaminants during the fire attack and salvage /

overhaul operations after extinguishment. The rated service period of these will range from 30 to 60 minutes in duration depending on the working pressure and cubic foot capacity of the bottle. The mobility provided by using a tank is offset by the limitation on the capacity thus reducing the amount of time a firefighter can spend in a hazardous environment. New NFPA requirements stipulate added safety features like an integrated Personal Alert Safety System (PASS device) that activates automatically when the SCBA regulator is pressurized; an emergency pressure equalization fitting to permit transfer of air from one unit to another, and a lighted "Heads Up Display" inside the mask to keep the firefighter apprised of his air supply status in poor visibility situations. (NFPA 1981)

Incident Safety Officer

NFPA 1521: *Standard for Fire Department Safety Officers* specifies that an Incident Safety Officer be appointed at all incidents where there is an identified need due to the size of the event or activities being conducted. (Foley p 112) In the National Incident Management System, the Safety Officer is designated as a Command Staff position that reports directly to the Incident Commander. (NIMS p 13) The person staffing this position on the fire scene acts as a Risk Manager and is directly responsible for oversight of firefighter safety. The person filling this position is granted the authority to alter, suspend or terminate activities that present an imminent danger situation before notifying the Incident Commander. Therefore they must be knowledgeable in building construction, fire behavior and fire ground operations. They are looking for unsafe acts of firefighters, unsafe conditions caused by fire damage to the structure and assist the Incident Commander by acting as another set of eyes on the constantly changing situation. Typical hazards might include: freelancing, improper tool use, unsafe positioning of personnel and lack of proper PPE. This position will also have responsibility for ensuring a Personnel Accountability System for firefighters is in place and that precautions are being taken to prevent injury or illness due to heat stress, overexertion and fatigue (a.k.a. Rehabilitation). In cases where the hazard does not pose an imminent threat to the safety of personnel, the Safety Officer will take action through Incident Commander. (Foley pp 114-115)

Fire Travel Predictions – Forecasting Tools

The ability of the Incident Commander, Operations Officer and Safety Officer to predict the speed and direction of fire travel has a direct impact on their ability to stay ahead of a fast moving fire and properly direct the resources to extinguish it. Depending on the size of the incident, the IC and the Operations Officer may be one in the same person or may involve several persons in much larger events. These individuals must work in concert with each other to ensure the safety of trapped building occupants and firefighters.

The age, occupancy hazards, construction of the building, its unique features and changes made after construction will largely determine where and how fast a fire will spread through the building. The amount of fire present on arrival will also determine if enough resources can be brought to bear on the situation to change the eventual outcome. How the fire moves and the rate of spread can also be controlled to some extent by certain tactics. A fire can be pushed or drawn by use of ventilation to move the fire direction contrary to what would be its natural path. It is much easier to spread the fire by improper use of ventilation practices and therefore any ventilation tactics used other than in the immediate proximity to, or directly over the fire, must be implemented with great care to lessen the risk of an unintended outcome.

Reading the smoke produced by a fire is both an art and science. The ability to tell what stage the fire is in and whether the building about to undergo what is called a "hostile fire event" are critical to effective risk management on the fire scene. Reading smoke is based on knowledge relevant to fire behavior, but relies on observation of four critical factors including: volume, velocity (pressure), density and color to determine the approximate location of a fire in a building and imminent signs of a hostile fire event such as collapse, rapid fire spread, backdraft or flashover. (Dodson 2005) Smoke as a product of combustion is volatile since it is comprised of unburned and incompletely burned solid fuels that have been converted to particulates, aerosols and gases and can cause conditions within the building to change rapidly, but usually with some warning. It is the ability to pick up on these warning signs and quickly change strategies or tactics in response is how the lives of firefighters are saved. Not only is this knowledge necessary for the Incident Safety Officer or Incident Commander, but every firefighter needs to understand what has happened inside the building and be able, with a reasonable degree of certainty, predict what is going to happen, with or without intervention.

Safety & Rules of Engagement

As previously discussed, Brunacini's SOP's to ensure firefighter safety offer guidelines as to when the life hazard justifies specific action; many other departments have also developed very similar "Rules of Engagement" for this very purpose.

Incident Command guidelines taught in fire ground tactics classes advise that tactics are to be re-evaluated every 10 minutes. Another common practice is called the 20 Minute Rule. This rule states: If the fire is not under control after 20 minutes, consideration should be given to withdrawing firefighters and beginning defensive mode operations. Some consider this rule to be outdated due to the preponderance of lightweight construction types that cannot withstand the direct exposure to fire as well as some older building methods. The time frame must either be shortened or lengthened based on the construction type, condition of the building and other factors addressed in the size up. For example: a fire resistive construction building could stand longer, while one of lightweight metal construction may only be safe for 10 minutes before collapse becomes imminent. (NIOSH FFIR 99F-04)

Roof operations conducted for the purpose of ventilating the structure are extremely dangerous due the fact crews are working as close to being directly over the fire as possible. This will obviously be the first area of the structure likely to fail due to fire impingement on the structural members or weakening caused by indirect exposure to heat. Studies have shown that lightweight construction using engineered wood products can fail in as little as five minutes after fire impingement on the assembly. Steel bar joists have been known to collapse in as little as 9 minutes (PICO p SM 1-10). Steel expands about 1inch per ten feet of length when heated to about 1000 degrees F. This can cause it to push against masonry walls that have very limited shear strength in this plane contributing the risk of collapse. It can also be anticipated that steel heated to temperatures above 1000 degrees F. is subject to potential failure. (Hall p 70) Protection of any steel members with a fire resistant or insulating material is critical to extending the life expectancy of the structure. Due to the nature of roof operations or working above the ground floor, a secondary means of egress for these persons is essential to ensure their ability to escape a dangerous situation. At least two ladders should be available for emergency egress. If possible, ventilation activities should be done directly from the aerial ladder or roof ladder to provide more support for the firefighter's weight to eliminate concentrated loads on a compromised roof. Once ventilation is complete, the roof should be evacuated immediately. (Hall p 356)

Rapid Intervention Teams & OSHA 2 In /2 Out Rule

The assignment of a dedicated team of at least two firefighters that is immediately available to enter the structure and rescue a downed firefighter during fire extinguishment operations has been part of NFPA 1500: *Standard on Fire Department Occupational Health & Safety Programs* since 1992. This dedicated team is called a Rapid Intervention Crew or Rapid Intervention Team. In most cases, an entire company of four or more firefighters will be assigned this responsibility if there is sufficient manpower available on scene. The RIC / RIT should be equipped with a thermal imaging camera and a universally adaptable air supply to provide the downed firefighter(s) with additional breathing air for the trip out of the building. (Foley p 75)

In those 24 states and 2 U.S. Possessions where there are state administered OSHA programs covering the municipal sector, the Respiratory Protection Standard 29 CFR 1910.134 (g) (4) requires a similar rescue capability be in place. This is more commonly known as the OSHA 2 In / 2 Out Rule. It stipulates a minimum of two firefighters, ready to make entry, be standing by before interior fire attack can begin. It does not require an arithmetic progression where one person is required outside for each person inside. The OSHA rule also does not preclude entry into the building for purposes of conducting the primary search for potential victims before the RIC / RIT is ready. As previously discussed, this search is usually done with a protective hose line to ensure the safety of the firefighters and potential victims and prevent fire spread that would compromise the path of egress for these persons. Enforcement of the OSHA rule began in April 1998 after issuance of a new final rule that amended the Respiratory Protection Standard. (Fed. Reg. 63:1245-1247)

Personnel Accountability – PAR – Mayday

The ability to account for the whereabouts and activity of all personnel on the fire scene is critical for their safety as well as efficient allocation of available resources. NFPA 1500 requires use of an Accountability System at all incidents. This system, like the NIMS, should incorporate a modular ability to expand with the complexity of the incident. As the incident grows in size and scope, the need for an Accountability Officer may become necessary to ensure the safety of and ability to monitor the whereabouts of all personnel. The personnel are tracked by both their location on the fire scene and function with regard to tactical operations or assigned tasks. (Foley p 72)

PAR is an acronym for Personnel Accountability Report. This is a verbal report to the Incident Commander or Accountability Officer by each crew or Company Officer that all personnel in their charge are safe and accounted for. If it is determined that there is a firefighter has gone missing and is unaccounted for, all other operations are suspended and an immediate search will begin to rescue the downed individual or crew. The IC or Accountability Officer should be asking for PAR on a regular basis during the incident so that an extended time period does not pass before discovery of a potentially downed firefighter.

Many fire departments have adopted the use of the “Mayday!” as a distress signal that is to be communicated in the event a firefighter or crew find themselves in trouble on the fire scene. The call: “Mayday! – Mayday! – Mayday!” is used to alert command of their situation. This term was adopted from the ship and aircraft navigation terminology. Activation of a Mayday also results in all other operations being temporarily suspended until such time as the firefighter or crew in trouble can be rescued.

Conclusion – Improving the Outcome

How can the private sector assist the Fire Service to improve the outcome of a fire incident? First, you must be proactive and address priorities in the same order as the Fire Service: life safety, followed by incident stabilization, then property conservation. While all of the outlined action items take place before the incident, some must either be designed into the facility at the conceptual phase of the project or done in conjunction with retrofitting, remodeling or renovations.

Life Safety

- Have an effective Emergency Action Plan that addresses training for employees in what to do based on their responsibilities outlined in that plan. If they are responsible for fighting incipient stage fires, hands on training with the equipment is necessary according to OSHA standards.
- An Accountability System that is up to date and can be used for an accurate head count at each muster point. This may include use of preprinted rosters, radio communication capability, an Incident Commander / Management Representative and multiple "marshals or attendants" to ensure everyone is safely out of the building.
- Proper maintenance of early detection and alert systems to provide the maximum time to evacuate.
- Adequate emergency means of egress from all areas of the operation, protected as necessary to ensure their integrity during fire exposure.
- Remote monitoring of alarm systems and capability for quick contact of the local fire department by telephone to provide additional information that can be critical for their "size-up".

Incident Stabilization

- Actively participate in the Pre-Incident Survey process and comply with any required Fire Safety Inspection orders conducted by the Local Authority Having Jurisdiction.
- Ensure adequate access to the interior of the building through doors strategically placed to lessen travel distances to high hazard areas.
- Locate utility services and protective system controls near exterior doors where they can be readily accessed by the Fire Department and shut down if necessary.
- Provide paved access to as many sides of the building as possible – extending from the foundation outward to at least 3 to 4 times the building height to provide flexibility for apparatus placement and not limiting aerial ladder reach.
- Where possible, do not construct facilities that exceed the capabilities of the Fire Department reach with aerial ladders or access for their placement.
- If a reliable public water supply is a problem, install dry hydrants or above ground storage tanks to provide at least 90 minutes of the minimum required fire flow.
- Replace explosive, flammable and combustible products used in operations with less hazardous alternatives where possible.
- Use a Knox Box or other secure means (lock box) on premises to store detailed hazard information for the responding Fire Officer(s).
- Do not compromise building construction features such as fire doors, fire walls or draft curtains that can increase the rate of horizontal and vertical fire spread or lessen the effectiveness of protective systems.
- Manage fire loading to lessen the risk of overwhelming property protection features such as automatic fire sprinklers and fixed fire suppression systems.
- Maintain and supervise fire protection and detection systems to ensure reliable operation.
- Have protective systems set for automatic operation and instruct security personnel not to shut down any protective system without direct orders from the Fire Department.
- Incident Commander / Management Representative should meet the incoming Fire Officer outside the building at a pre-arranged location, to provide supplemental information about the situation and direction for the easiest access to the fire area.

Property Conservation – Business Restoration

- NFPA 1600: *Standard on Disaster / Emergency Management and Business Continuity Programs* compliant business recovery plan.
- Back up critical data and records at a remote location.
- Develop plans for to secure and occupy alternative facilities, temporary access or rapid replacement of critical equipment after the event.
- Advance planning for post fire clean up for removal of water and clean up of smoke contamination to restore operational capabilities and resume normal business operations.
- Pre-qualify potential contractors for damage repairs that may be necessary to secure the building or stabilize the structure.

Bibliography

Dodson, D. "The Art of Reading Smoke." Fire Department Instructors Conference. Indianapolis, IN, April 2005. http://www.firefighternearmiss.com Response Solutions, LLC PowerPoint presentation retrieved 2/5/2006..

Federal Emergency Management Agency & National Fire Protection Association, *A Needs Assessment of the U. S. Fire Service*, publication #FA-240. Quincy, MA: FEMA / NFPA, 2002.

Federal Emergency Management Agency, United States Fire Administration & National Fire Academy. *Incident Safety Officer, ISO Student Manual*. Emmitsburg, MD: FEMA, USFA, NFA, 1999.

Federal Emergency Management Agency, United States Fire Administration & National Fire Academy. *Managing Company Tactical Operations: Decisionmaking, MCTO-D Student Manual.* Emmitsburg, MD: FEMA, USFA, NFA 1991.

Federal Emergency Management Agency, United States Fire Administration & National Fire Academy. *Managing Company Tactical Operations: Preparation, MCTO-P Instructors Guide.* Emmitsburg, MD: FEMA, USFA, NFA, 1991.

Federal Emergency Management Agency, United States Fire Administration & National Fire Academy. *Preparation for Initial Company Operations, PICO Student Manual.* Emmitsburg, MD: FEMA, USFA, NFA, 2005.

Federal Emergency Management Agency, United States Fire Administration & National Fire Academy. *Strategy & Tactics for Initial Company Operations, STICO Student Manual.* Emmitsburg, MD: FEMA, USFA, NFA, 2004.

"Firefighter Activities, Injuries and Deaths." National Fire Protection Association Research & Reports / Fire Statistics / Fire Service / NFPA's Fire Incident Data Organization. http://www.nfpa.org July 2005, retrieved 11/13/2005.

Foley, Stephen N., ed. *Fire Department Occupational Health & Safety Standards Handbook*, First Edition. Quincy, MA: National Fire Protection Association, 1998.

Goodson, C. & Sneed, M. ed. *Fire Department Company Officer*, Third Edition. Stillwater, OK: Fire Protection Publications, Oklahoma State University, 1998.

Hall, R. & Adams, B. ed. *Essentials of Firefighting*, Fourth Edition. Stillwater, OK: Fire Protection Publications, Oklahoma State University, 1998.

"ISO's Public Protection Classification (PPC™) Program." Insurance Services Organization – ISO Mitigation Online. http://www.isomitigation.com 2005: retrieved 11/21/2005.

National Archives & Records Division of the Government Printing Office. Federal Register Volume 63: Thursday January 8, 1998, pp. 1245-1247.

National Fire Protection Association. *NFPA 1600: Standard on Disaster / Emergency Management and Business Continuity Programs*. Quincy, MA: NFPA 2004 Edition

National Fire Protection Association. *NFPA 1710: Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments.* Quincy, MA: NFPA 2004 Edition.

National Fire Protection Association. *NFPA 1720: Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Volunteer Fire Departments*. Quincy, MA: NFPA 2004 Edition

National Fire Protection Association. *NFPA 1901: Standard for Automotive Fire Apparatus.* Quincy, MA: NFPA 1999 Edition.

National Fire Protection Association. *NFPA 1971: Standard on Protective Ensemble for Structural Firefighting.* Quincy, MA: NFPA 2000 Edition.

"Structure Fires The U.S. Fire Problem." National Fire Protection Association Research & Reports / Fire Statistics / Trends / NFPA's Fire Incident Data Organization. http://www.nfpa.org July 2005, retrieved 11/13/2005.