Session No. 541

"COPE" & the "Rules of Engagement"—How Construction, Occupancy, Protection, Exposures and Firefighting Tactics Affect the Outcome of a Fire Emergency

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Introduction

The risk assessment factors commonly abbreviated in the insurance industry as COPE: include building construction, occupancy, protection systems and exposures. These factors are reviewed and described in detail in the Loss Control or Engineering Survey reports used by insurance Underwriters. Underwriters rely on these internal confidential reports to accurately describe what is there, what it not and what needs to be improved. The same terminology may also be found in many fire and building codes defining prescriptive standards as to how a property should be constructed, how it is used, fire and life safety protection features and allowable exposures.

A less commonly recognized factor that can also affect the outcome of fire events are the "Rules of Engagement" for the fire service. As building construction changes and fire loading increases, these Rules of Engagement are evolving as well in an ongoing effort to improve firefighter safety. The impact is a calculated reduction in the risks they are willing to take to save property from the peril of fire and reduce unnecessary exposure to serious injury or death.

Although we can transfer risk through the mechanism of insurance in many cases, knowledge of the methods by which our business property is evaluated in the process of determining insurability can be crucial to making it as desirable as possible to prospective underwriting entity. Also, a reasonable expectation of the outcome of a fire loss event based on these factors can have a great impact on preparation for continuity of your business operations.

This article will review a few insurance related implications related to property protection, and discuss the specifics of how the four factors of COPE are impacted by the ever changing firefighting Rules of Engagement.

Insurance Underwriting

Insurance is one of the most commonly used methods of protecting a property owner from the risk of loss due to the peril of fire. This is accomplished by a contract to transfer the uncertainty of loss to another party (insurer) in exchange for consideration (premium paid). The amount of premium charged is based upon several factors including: the hazards present, the chance of loss, the risk, the degree of risk, and perils being covered by the insurer. This is part of the basic underwriting process. (Mehr, p. 37) Although a basic understanding of the concepts of insurance as a risk transfer method is important, the critical terms for the purposes of this discussion include the following:

Probable Maximum Loss – the portion of the subject property subject to loss in the event of a single fire event where early detection and suppression take place and all protective systems operate properly.

Possible Maximum Loss – the portion of the subject property subject to loss as a worst case scenario or without any intervention on the part of fire control or suppression.

These two terms apply to one of the elements for determining a sufficient premium and deal with degree of risk the insurer is expecting to accept. Depending on the insurer, these two terms can be used interchangeably, and in that case carry the definition of the greatest possible loss exposure. Factors that will result in a difference between probable and possible maximum loss will include: separation of buildings on a given property, properly designed and constructed fire walls, protection systems that are being properly maintained, 24 hour supervision of the property, etc.

Ultimately, even if a structure is capable of withstanding the effects of fire long enough to safely evacuate the occupants or provide ample working time to extinguish the fire without collapse, it may still end up a total insurance loss. Structures that are severely damaged, but still standing may be so unstable as to require them to be completely demolished either during salvage and overhaul by the fire department or to dismantle down to a point where they are structurally sound.

Firefighting Rules of Engagement

The Fire Officer in the course of conducting the initial on scene 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?”, etc. 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)

Many fire departments have used this basic tenant to develop more detailed guidelines or internal practices known as Standard Operating Procedures or Guidelines (SOP or SOG) to assist in the decision making process of how a fire event will be managed. Use of these basic guidelines has allowed departments like the Phoenix, AZ Fire Department to develop strategies that provide for best firefighter safety when using a risk based decision making process. Some of these specific areas include ensuring firefighters are effectively managing their SCBA air supply, limiting the distance to which they will stretch hose lines inside a large structure or ultimately deciding certain property is not worth risking their own lives.

Factors related to this philosophy will be discussed in each section that follows. However, some knowledge of basic firefighting operations including strategies and tactics will be assumed in the following discussion. A introduction to this subject is contained in "Introduction to Fireground Strategies and Tactics for the Nonfirefighter Safety Professional – Understanding the Capabilities and Limitations of the Fire Department" by this author published in the February (part 1) and March (part 2) 2008 *Professional Safety – the Journal of the American Society of Safety Engineers*, although several applicable subjects excerpted from that article also appear in this review for purposes of clarity.

Construction of the Building

Construction of the building relates to the types of materials used and how there are assembled or held together to keep the structure from falling down by forces of gravity or wind pressure. Two major building classification systems exist. One was developed by ISO (Insurance Services Organization) and the other by NFPA (National Fire Protection Association). While these two systems describe the same buildings, they are polar opposites in how the buildings are identified by numerical classification.

Common Name / Construction Details	ISO Classification	NFPA Classification
Wood Frame – combustible wood framing members for roof and sidewalls, combustible floor and roof decking, with or without non-bearing masonry veneers – includes wood pole structures	**Class 1**	**Type V**
Ordinary (Joisted Masonry) – bearing masonry walls, usually of brick or block, supporting floor and roof structural members of combustible wood construction	**Class 2** incl. Heavy Timber or Mill	**Type IV** incl. Heavy Timber or Mill **Type III** Ordinary
Light Non-combustible – unprotected steel frame structure, with metal or non-combustible exterior cladding	**Class 3**	N/A
Masonry Non-combustible – fully or partially bearing masonry walls combined with unprotected structural steel and unprotected non-combustible floor and roof decking	**Class 4**	**Type II**
Modified Fire Resistive – structural steel with at least 1 hr rated fire protection coatings or encased in concrete with reinforced concrete floors and roof decking at least 4" thick	**Class 5**	**Type II**
Fire Resistive – reinforced concrete structural members, floor of at least 2 hour rated material, roof at least 1 hour fire rated material (often misnamed "Fireproof")	**Class 6**	**Type I**

(ISO c.2008), (Hall p 65)

The ISO building classification system uses six categories and is based more on the use of specific types of materials with commonly known fire resistance ratings or durability. The NFPA system and each of the model building codes classify building construction in different terms, but are essentially dividing them into five classifications, and are generally based on prescriptive requirements of fire resistance of the construction elements and less so on the particular materials used. (Hall p 65)

Because of the conflicts and overlaps of these systems the remainder of this article will deal with those classifications commonly assigned for purposes of insurance classification. Each individual type of construction has what would be considered its own strengths and weaknesses depending on how the building is intended to be used as well as from the standpoint of limiting the damage from a hostile fire.

Wood Frame Construction – ISO Class 1

Wood frame construction is characterized by the use of lightweight wood or steel framing members in the common sizes of dimensional lumber. This includes 2" x 4", 2" x 6", 2" x 8", 2" x 10" and 2" x 12" members referred to a "dimensional lumber". The floors that are not supported directly by the ground (poured concrete slab) are usually wood decking on either a large dimensional lumber system or engineered lightweight truss. Roof supporting structures are either conventional rafters using a ridge beam to connect each side or a lightweight engineered truss connected with metal fastener plates or gussets. Some newer construction will use the metal studs for interior and exterior wall framing. Although the use of the lightweight metal studs within the walls offers a reduced fire load, there is no appreciable gain in the structures ability to withstand fire conditions as these members are only stable as long as the entire wall system remains intact. Large open areas within this type of structure can also be created by use of laminated wood beams (engineered lumber or laminated veneer lumber) or the use of steel I beams. This type of structure may also have a non-load bearing masonry veneer, but is still considered wood frame by classification. There is often limited fire resistance provided to the structural members. Any fire separations are either of limited resistance rating or must be constructed of non-wood frame materials such as masonry to effectively divide the structure into two or more free standing compartments. Most wood frame structures are far smaller in size than those of other construction types that will be discussed later. A large wood frame structure would be 10,000 square feet per floor or less and usually not greater than 3 floors in height. Pole frame construction also falls into this classification, while originally limited to farm buildings, they are now found in a wide variety of uses including commercial, recreational and storage facilities. (ISO Prop. Res. online)

Advantages of the wood frame system include the ability to erect it quickly when building smaller structures. The cost is usually much less than those involving masonry bearing walls, or the self supporting steel building frame. It is often used in residential, apartment buildings, offices, light commercial occupancies and in single story long term care facilities.

Disadvantages of this construction from an engineering standpoint vary based largely on the age of the building, but also because of the ease with which later modifications can be made.

Concealed spaces exist throughout any wood frame structure that can result in fire spreading unchecked from one side of the building to the opposite, one end to the other, and even one floor to another. These include vertical chases between the wall framing members and for utility chases between floors. Horizontal chases exist between every floor supporting member across the building, but also in attics above the occupied areas and potentially under floors in crawl spaces or unfinished basements. These may or may not have any fire stopping measures installed depending on local building codes.

Older wood frame construction is generally considered to be more inherently stable than the newer configurations that include a large degree of engineered components and sub-systems to provide the structural integrity. The older systems relied on the mass of individual members and the method of construction used to provide resistance to movement, flex and direct flame impingement. The framing of an older structure using only dimensional lumber held together with common nails to will usually have a greater ability to resist the damaging effects of direct flame impingement than one of lightweight engineered members. The primary reason for this is the mass of the members. Direct impingement on these members by fire creates an insulating char on the surface, thus slowing the rate at which the member is consumed and providing longer structural integrity. The common nails of 8d, 10d and 16d that are commonly used in framing applications penetrate to their entire length providing a solid grip on the lumber even after development of char on the surface.

Lightweight engineered “I” joists that are now used for floor and roof systems do not have enough mass, especially through the center web of the truss which may only be ½ inch or less in total thickness, to resist the effects of fire. It is important to understand when these have become directly exposed to fire as their resistance to degradation is very limited.

Other styles of engineered lightweight trusses employ an open web design using a top and bottom chord and the vertical compression members are held together with stamped metal plates often called a “gang nail”. These plates generally only penetrate the truss chords by about 1/2 inch, thus not giving any support once the surface has begun to char to any degree. This is the same type of fastener used in roof truss construction that is pressed into place at the connection points of the members. Many fire codes enforced for one and two family dwellings will require periodic draftstopping to limit the size of each concealed space in an effort to control the unchecked spread of fire. Studies have shown that lightweight construction using engineered wood products can fail in as little as five minutes after fire impingement on the assembly. (PICO p SM 1-10)

The age of the structure can be a good indicator, even without close investigation of the framing members, of relatively how much safe working time the fire department may have to perform necessary search and rescue or interior firefighting activities. Critical factors affecting the durability of a structure when involved in a fire include the actual construction method and materials used, whether the structural members are protected from direct flame impingement (based on where the fire originated) and fire stopping within the concealed spaces. While an older conventionally framed structure may have more working time than a newer one, but this is not an absolute rule by any means.

Flame spread as a result of the unchecked concealed spaces can permit the fire to run through the structure at a rapid pace. This often occurs in case of fires in concealed attic spaces without any firestopping. Fires in the concealed space of an attic or the space between original and later roof structures can move so fast that the fire department has extreme difficulty in getting ahead of the flame spread. Controlling the advance of the fire can only be done by opening up a large enough ventilation hole ahead of the flame front that the fire will be drawn upward and stop its horizontal advance. This is a radical procedure called a “trench cut” creating an opening that traverses the entire width of the building so the fire will vent vertically and not progress past the opening horizontally.

A NIOSH Alert issued in 2005 warns of increasing hazards due to the presence of truss construction and unpredictability with collapse. It recommends that work above a truss supported structure or under any truss roof be suspended and the area evacuated immediately when it becomes apparent the structural members have become exposed to fire. (NIOSH Alert 2005) This may become apparent by visual observation of direct flame impingement or a change in smoke color from white, grey or black to a brown color. Due to the nature of engineered systems, they are only stable when all the structural elements are intact. Unfortunately, once that integrity is compromised the collapse will be imminent and often total in nature.

Ordinary Masonry Construction – ISO Class 2

This category is characterized by load bearing masonry walls and combustible roof and floor structures spanning between them. The masonry materials used for the walls can include solid brick laid in multiple courses interlocked together, hollow concrete block or a combination are most common. However, precast or poured in place reinforced concrete can also be found as wall materials. The roof and floor assemblies are going to be primarily of wood and can utilize either dimensional lumber framing or engineered lumber products. This type of construction is well suited for single and low rise structures, although it can and has been used for much taller buildings. The wall material is a non-combustible material with great compressive strength for withstanding the vertical down force created by the weight of the roof, upper floors and the walls themselves. This is a more labor and material intensive construction method than wood frame. It is usually afforded cheaper insurance rates than wood frame because of the limited combustibility of the wall material even though the effects of fire on the most common wall materials will vary greatly. (ISO Prop. Res. online)

A sub-classification of this type is known as Heavy Timber or Mill construction. This group is categorized by very large dimensional wooden support members referred to as “timbers” due to the size. Minimum sizes include 8” x 8” wooden columns and 6” x 6” horizontal beams. It is commonly found in older industrial buildings with solid brick walls using straight timbers of even larger dimensions. In modern buildings, the members are usually comprised of laminated beams like those found in churches to create large open areas. The large mass of these timbers allow them to char to a limited depth while most of the cross sectional area remains unaffected by the initial fire exposure.

Advantages of this construction method include its ability to withstand relatively high wind, even if the roof is compromised as long as all the exterior walls remain intact. In cases where solid brick has been used, the thickness of the walls will increase as the height of the structure increases, to a point where they may reach several feet thick for a multiple story structure. The enormous mass of a solid brick wall of a foot or more in thickness using interlocked courses of brick enables it to absorb great quantities of heat from a fire without sustaining significant damage. In fact a unique construction detail called a “fire cut” where the floor beams or joists enter pockets in the exterior walls are designed to permit a beam to pull away when it collapses, without pulling down the walls. Due to labor intensive nature of constructing a solid brick wall, this method of building is usually only found in older buildings. What may appear to be solid brick on the exterior may be a brick face with a hollow concrete block back up.

The greatest disadvantage of this type of construction is found in those structures built with hollow concrete block as the supporting wall material. This lightweight material has great compressive strength to resist the vertical down force created by the weight of the structure above, but has little mass to absorb thermal energy unless it has been “slushed” or filled with concrete during construction. This inability to absorb thermal energy is compounded by the thin webs that connect the inner and outer faces that do not allow the energy to transfer efficiently from one face to another. When one side is heated by fire exposure and the other is cooled by water, the block often cracks at the web making the structure prone to sudden collapse. Because of the cracking due to thermal imbalance and separation that can be induced by wind forces, water streams or pulling toward the interior by collapsing roof and floor members, the wall can separate and fall both inward and outward.

Of the two main types of wall construction within this classification, the solid brick is more likely to have a structure left to rebuild from. Hollow concrete block without reinforcing steel and concrete filling the voids is likely to be a total insurance loss down to the foundation. HCB construction, while cheaper to build than the solid brick often leaves very little of the supporting walls to rebuild from.

From a fire fighting standpoint, it is recognized widely recognized that the solid brick tends to endure the heat exposure for longer periods, it is not immune from its detrimental effects. In older buildings it is common to see reinforcing steel rods that connect the outer walls characterized by decorative “stars” or plates with large threaded nuts on the exterior. Also, thickened wall segments known as “pilasters” are also used to help stabilize the wall. Given enough exposure to intense heat and lateral forces caused by collapse of interior floors from fire damage and absorbed water weight into the contents, this structure will still fail. The key is that if a fire cannot be controlled with offensive strategies, even this type of structure can be damaged beyond repair.

One particularly infamous type of construction that falls within this category is the ordinary masonry building with a “bow string” wooden truss roof. This is easily recognizable by the arched roof that extends from one end of the building to the other. As with any truss assembly, its strength lies in the system as a whole, not in the strength of the individual component members. Once any single part fails, the entire assembly will ultimately fail.

The size of these structures is usually smaller than those of non-combustible materials as the natural wood materials have structural limitations that require more interior supporting interior walls, columns and beams as a result of the limited open spans that can achieved unless modern trusses are used. Although the use of modern engineered trusses can span distances of 90 feet or more, this is not as common as spans of 40 to 60 feet between bearing members. An older building of this variety will generally have more compartmentalization created by bearing interior walls than a newer one because of modern building technology and ability to eliminate this extra support with use of engineered beams and columns to carry the weight. However, these walls are often not considered true fire walls due to deficiencies in design related to thickness, parapet extension and opening protection.

Vertical ventilation of this type of building during a fire is usually easy to accomplish with the proper tools and sufficient manpower. However, if there are multiple roof surfaces, as are common with older structures the original roof under the outermost surface cannot be breached and thus effective vertical ventilation cannot be accomplished.

Light Non-Combustible – ISO Class 3

This type of building is characterized by materials that are classified as non-combustible or slow burning supported by an engineered steel framework. The roof and sidewalls are usually of metal siding attached to metal girts and purlins that are attached to the unprotected structural steel frame. This type of building will usually not have any supporting columns except at the exterior walls. Often used as commercial and industrial occupancies, this is a structure that can be erected quickly at a relatively low cost. It can be finished on the exterior with a wide variety of materials including brick or stone veneers to enhance its appearance. (ISO Prop. Res. online)

The trade off for the low cost and speed of erecting the framework is that it is highly susceptible to fire damage as the structural steel frame is commonly not protected with any sort of fire rated protection. Steel will fail to support even its own weight when heated to temperatures of 1000 degrees F or higher, and thus result in collapse of the structure. However, there are several factors that can affect this process including: size of the member, the load placed on it, type of steel and geometry of the member. Large dimensional structural I beams will tend to withstand this heat somewhat longer than a lightweight open web steel bar joist which does not have nearly the same mass. (Hall p 70)

Unless used for partitioned office space, this type of structure will consist on one large open area with no features to restrict the spread of heat and fire throughout the building. The activities normally conducted during ventilating the structure during fire suppression operations can be more hazardous with this type of construction due to the limited strength of the lightweight roof materials.

Masonry Non-combustible – ISO Class 4

Masonry non-combustible construction is characterized by the combination of masonry and steel materials that make up the supporting structure. Roof is of non-combustible or slow burning material, usually a metal decking supported by various configurations of steel joists and beams. This roof structure is supported by bearing masonry walls and unprotected steel vertical columns. Commonly this is a single story industrial building, but can reach several stories in height. (ISO Prop. Res. online)

The most common roof supporting structure in this classification is what is termed the "open web steel bar joist" system which employs the use of a lightweight parallel chord truss design. This can have many different materials making up the assembly, but the basic design is the same. The open web steel bar joist is effectively a truss comprised of a top and bottom chord, held together by vertical and / or angled members. The lightweight feature of these bar joists / trusses is also detrimental to their ability to withstand exposure to fire. The smaller dimensions of the members in a metal truss cannot absorb nearly as much heat as large dimension steel I beam. When exposed to fire open web steel bar joists have been known to collapse in as little as 9 minutes. (PICO p SM 1-10) The infamous Sofa Super Store fire that occurred in Charleston, SC in June 2006 where 9 firefighters were tragically killed in a sudden and catastrophic building collapse involved a building of ISO Class 4 construction.

This type of construction can have a single building divided into several fire divisions by strategically located free standing masonry walls that extend through the roof. The fact that these walls do not support the roof on either side allows one side to collapse without compromising the wall and exposing the unburned side to fire.

In a multistory structure of this type, the upper floors are often constructed of a lightweight concrete poured on top of metal decking similar to that used for the roof and also supported by the same arrangements of joists, trusses and columns. In these cases local fire codes often will require some level of protection of the steel with a spray on fire retardant material or encasement of columns in drywall to provide a limited amount of protection from heat.

The roof deck in this type of building will have a waterproof covering, but will not have concrete poured over the decking as with Class 5 or 6. This metal decking can be easily breached with metal cutting saws for purposes of vertical ventilation during a fire. However, crews working on the roof need to be cognizant of the fire location, size and rate of spread to limit their exposure risks as once the heat levels become sufficient to weaken the steel, all roof operations need to cease and the crews must vacate the roof.

Modified Fire Resistive – ISO Class 5

This classification of construction is characterized by the lack of unprotected steel that is used to support the building. A minimum of 1 hour fire resistance rating is required on any exposed steel either by spray on insulation, metal lathe and plaster or being encased in concrete. Floor and roof decking are of a masonry product, usually precast panels. Any exterior walls are also of masonry of concrete panel construction, but are not load bearing as the framework actually supports the building. (ISO Prop. Res. online)

Although this type of construction generally lasts longer when exposed to fire due to the fire resistance of the protective coverings on the steel, any compromise of this protective system will leave weak points that can cause a premature failure because of weakening at that point. It is not uncommon to see where contractors have compromised these protective systems to install cable clamps or in the course of fishing wire through concealed ceiling spaces and along supporting columns.

Fire Resistive – ISO Class 6

This classification is characterized by the use of cast in place, steel reinforced concrete beams and columns to support the building. The floors and roof are either reinforced precast panels or poured in place reinforced concrete. Floors must have a 2 hour fire resistance rating and the roof structure at least a one hour rating. Exterior building skin materials can be of almost any type as they have no load bearing capability. Obviously the most expensive type of building to construct, but offers the greatest resistance to fire exposure. This type of construction was once identified as "fireproof", but this identifier has long since been dropped as it is now realized there is no such type of building. Every building will fail in time with sufficient fire exposure – fire resistive construction only provides the most exposure time before that failure would occur. (ISO Prop. Res. online)

Unique features of this classifications ability to resist the affects for fire due to the thermal mass created by the use of heavy masonry and concrete materials for the structure and floors also provide it extra strength. This allows a structure to withstand more collateral loading caused by the extra weight of water soaked contents. Although not unlimited, this does provide for a longer safe working period inside during extended firefighting operations.

The compartmentalization provided by the fire resistive nature of the floors helps to slow fire spread from one floor to another, unless it finds penetrations such as improperly protected vertical shafts or leap frogs through the exterior openings from one floor to the next. On the flip side is that vertical fire control ventilation operations on this type of structure are nearly impossible, and thus limited to horizontal methods

Special Construction Considerations

Fire walls and parapets are a critical construction feature for limiting the fire spread from one area of a large structure to another. A fire wall or separation by definition is: a wall of sufficient fire resistance, durability, and stability to withstand the effects of an uncontrolled fire exposure, which may result in the collapse of the structural framework on one side or the other. I must have a specific fire resistance rating based on the materials used for its construction and how they are arranged. Variations in the material and wall thickness affect the ratings that can be from ½ hour to 4 hours. A rated fire wall must include protection of the openings with rated assemblies of doors and windows that provide a complimentary degree of resistance to fire as set forth in NFPA 221 – Standard for Fire Walls and Fire Barrier Walls. (NFPA FPH, p 7-18)

Parapets are features of a true free standing firewall that help to prevent the fire from traveling across the fire wall along the roof surface. They consist of vertical and horizontal extensions of the main wall that rise above or extend past the edges of the building roof by at least 30 inches if constructed to NFPA 220 and Factory Mutual Research Corporation standards, but many local codes allow them to be a low as 18 inches above the roof surface. (NFPA FPH p 7-20)

The Big Box is a fairly recent term in firefighting practice. It is not uncommon to find single fire division buildings exceeding 100,000 square feet with high ceilings equaling two stories in height. Usually this is of the ISO Masonry Non-combustible Class 4 construction due to current construction technology. This is now commonly known as the Big Box when it comes to retailing operations, but manufacturing facilities can be five or ten times larger. This amounts to a building that is too large to reach much of the interior under the new Rules of Engagement.

These new rules on how fires will be fought have resulted in limitations on the amount of hose that can or will be stretched into a building from the nearest doorway. Many departments have adopted the rule that no hose lines longer than 150 feet in total length will be extended past the outermost door opening, so this will greatly limit the effective reach of suppression activities. For this reason placement of additional exit / egress doors need to be strategically located to provide access with less interior travel distance to reach the seat of the fire or to access critical systems such as the sprinkler controls, electrical and natural gas disconnects.

Another driving factor in restricting the entry distances for firefighters involves management of their SCBA air supply. Due to the number of firefighters dying as a result of running out of air when they become disoriented or trapped while waiting on the Rapid Intervention Team to rescue them, the concept of shortening work cycles within the structure has come of age. Although most departments are moving toward the higher capacity (high pressure and/or high volume) cylinders for the SCBA, the actual working times inside the building are shortening due to better practices of managing their air. Instead of waiting for the low air alarm to sound on the SCBA before beginning to retreat, the use of the Heads Up Display (HUD) located in the face piece has now made it easier to monitor the air supply so exiting can begin with a substantial reserve air supply in case of emergency. NFPA 1404 – *Standard for Fire Service Respiratory Protection* now requires implementation of an Air Management policy with the intent that the reserve air is not used for entry, interior work or exiting the structure – but only to preserve the firefighters life while they are being rescued. Current guidelines are to use not more than 75% of the air for entering, working and exiting, leaving a 25% reserve air component. The impact is that actual interior work cycles could be reduced to as little as 12 minutes or less if the firefighter is not in top aerobic condition.

Curtain boards or draft curtains are interior features of the building construction designed to help trap heat from the fire from a predetermined area that rises to the ceiling level. Preventing the unchecked lateral spread of heat and smoke can potentially help to control water damage in sprinkler protected occupancies by reducing the number of sprinkler heads exposed to sufficient heat to cause them to fuse and operate. They also may be required supplemental equipment to an automatic roof venting system or as part of an Early Suppression Fast Response (ESFR) sprinkler system. (NFPA 13, Ch 5-4.6.4)

Automatic Roof Venting is used in both sprinkler and non-sprinkler protected structures. These systems are designed to allow the products of combustion to ventilate through the roof of the structure and slow the horizontal spread of heat along the ceiling. Although some jurisdictions may mandate their installation, some fire protection schemes prohibit them as they are detrimental to the effective operation of the systems – such as is the case of ESFR sprinkler systems. These roof vents can be either a thermoplastic drop out design or a fusible link activated hinge opening model. Local codes can require elimination of the automatic feature in lieu of manual operation from remote cables placing the fire department in control of when and where to apply the ventilation. Although there is controversy about whether this automatic venting is beneficial in sprinkler protected buildings, it does provide some relief for the interior firefighting crews from the build up of heat and smoke and may reduce the need for roof crews to perform this task from the dangerous areas above the fire.

Combustible Concealed Spaces are commonly found in those buildings of ISO Class 1 – Wood Frame construction. If these spaces are not properly “draft stopped”, fire can spread unchecked throughout this space consuming the structural members without ever breaking through the surface materials such as floors or ceilings. Controlling fires that are located in these concealed spaces is often difficult as they are difficult to find without the aid of a thermal imaging camera. Once located, they require a great amount of manpower to open up the space and suppress the fire at the same time. Therefore the “draft stopping” is required when these concealed spaces reach specific square footages depending on the occupancy of the building and local codes. When the floor support system is made up of dimensional lumber and the concealed space runs only in one direction, draft stopping may not be required unless unusually large spans occur. However, when an open web truss of wood construction is used to support the building, fire can spread in any or all directions without the draft stopping. Although the draft stopping in a wood frame structure is not usually a fire rated material, it does help to significantly slow the progress of the fire through the confined space.

Multiple Roofs are common on older buildings where the structure was originally built with a flat roof, and through age or neglect has fallen into a state of disrepair, and has been replaced with a second structure above it that is often sloped or pitched. This modification creates a significant problem for trying to ventilate directly above a fire inside. The outermost roof can be breached effectively, but the one below cannot be reached to open it up and allow the products of combustion to rise upward. This modification can include any combination of wooden and metal structures to form the first and second roofs. In any scenario, the interior cannot usually be effectively breached as it cannot be reached with power ventilation saws from the upper deck. Without vertical ventilation the fire will spread laterally throughout the structure until stopped by firewalls. Not only is effective vertical ventilation nearly impossible in this situation, but it also creates a confined space, that depending on the materials can enable the fire to run unchecked from one length of the building inside the space.

Compromised fire protective materials and fire stopping occur during renovations, remodeling, building additions and updating of utility or wiring services in a building. This leaves critical structural members exposed to the effects of fire. In some cases this damage to the fire resistive materials, commonly spray on fire retardants, plaster and metal lathe or concrete cannot be avoided to do the work necessary. However, it is crucial that the protective features be restored immediately upon completion of the work. Some occupancies such as JCAHO accredited healthcare facilities are required to conduct regular inspections of all fire rated partitions and walls within the facility for integrity of the firestopping materials at all penetrations.

Vertical and horizontal opening protection is important to stop the unchecked spread of fire and the products of combustion throughout the building. Whether these are planned openings such as those needed for doorways and ventilation ducts, or unplanned openings like those for plumbing and wiring that are not placed in dedicated utility chases, both require proper protection. Doorways, stairwells and elevator lobbies, etc. require rated fire protection of a specific rating and includes self closing mechanisms to ensure the protection is in place when needed. For the other situations where the openings are created out of need, but the exact location is not specified in construction plans require "as built" fire stopping to be put into place. This usually takes the form of a fire rated caulking or foam product that is used to fill the voids surrounding conduit or piping that has penetrated the fire wall or partition. Both NFPA and local fire and building codes will dictate where the firestopping is to be used and what fire rating is required. In typical wood frame construction, firestopping can be as simple as 2 inch thick (nominal) lumber. In other applications it should be of noncombustible materials with a sufficiently high melting point to remain in place during a fire. (NFPA FPH p 7-89)

Collateral Loading of building structures is very common. One of the most common situations involving collateral loading is that of the roof structure by equipment such as HVAC units, dust collection systems, etc. If installed when the building was originally constructed, the building design should have accounted for this additional loading. However, if later modifications are made their impact on the roof design and safety factors of loading may not have been contemplated.

Another area is that caused by weather situations. In northern climates, extreme snowfall may increase the roof loads beyond the design parameters. If a fire erupts inside the structure and causes heating under the roof, this can rapidly melt the snow, causing water to mix with it and form slush which is much heavier and cannot escape through the normal roof drainage system.

Occupancy

The occupancy of the building as used by NFPA can mean two different things. One is related to the occupancy fire load and is based upon normal expectations of fire loading as "low, moderate and high hazard" that would be encountered with a particular type of operation. (NFPA FPH p 1-28) The other is how the building is occupied as related to its use. This classification system breaks down the building use into categories such as Business, Residential, Educational, Mercantile, Industrial, Place of Assembly, Healthcare, etc. when used in reference to Life Safety issues. However, in the insurance industry it is defined as how the building is being used and specifically describes the operations within it – including the type of business and its relative hazards.

What a particular business does as part of its regular operations or what it may do on an infrequent basis is taken into account from an underwriting standpoint. Every business has hazards associated with its daily operations. The degree to which those hazards impact the risk of loss is of primary concern to the Underwriting entity. These factors are evaluated by the insurance Loss Control or Prevention Representative by comparison to both carrier Underwriting Standards and Fire Codes to provide an assessment of risk. These are not intended to be compliance inspections, but are done for the purpose of making an educated decision about the acceptability of a risk during the Underwriting process. Three of the most commonly occurring occupancies are discussed below.

Offices: The typical office building has a known set of hazards that would commonly be present. This would include the used of electronic machines for communications and data, paper file storage and potentially combustible office furniture. The fire services would grade this to be a relatively low hazard, although the fire loading of this hazard group has increased significantly in the last 20 to 25 years. In the early 1980's it was not uncommon to find primarily metal desks, a telephone and typewriter at most workstations spread throughout a large relatively open office setting. As time has passed, that has evolved into cubicle partitions covered in fabric and multiple electrical devices including computers, monitors, printers, copiers, fax machines, adding machines, telephones, clocks, radios, compact disc players, personal fans, heaters and PDA's and cell phone chargers. Combined with the fact that most businesses have yet to completely paperless, there is still the preponderance of papers and files scattered throughout the office areas that previously existed.

This increased fire load of synthetic materials and plastic cased devices (made primarily of petroleum) in the last 20 to 25 years has significantly increased the fire loading to the point where the Btu output of a fire in the same space has grown exponentially. As the noted fire service safety advocate Deputy Chief Billy Goldfeder has espoused many times when speaking on the subject – "this is not your father's fire" and that strategies and tactics for all fire need to change with the times. This increased thermal output has resulted in better personal protective equipment for the firefighters and mandated use of SCBA's on all fires due to the respiratory hazards from the toxins off gassed in the products of combustion. With the presence of more vertical partitions to form cubicles, the firefighters can easily become disoriented and lost in a maze consisting of rows and rows spreading out on large floors of a building, but also making it difficult to advance hose lines through this labyrinth. Therefore a greater emphasis has been placed on municipal mandates for fire sprinkler protection.

Manufacturing: Producing a finished good or a component part of that finished good is considered to be manufacturing. Whether that product is liquid, solid or gaseous, made from naturally occurring raw materials or from synthetic products made from raw materials does not matter. All manufacturing operations have inherent hazards associated with their processes. The major difference from an occupancy standpoint is how severe the hazards caused by the operation are and how well they can be controlled.

The raw or component materials that go into a product can have varying degrees of hazard associated with them. Some are inherently dangerous in their natural state. Others can be reasonably safe as received, but as they are processed become more susceptible to ignition from outside sources, reaction with other incompatible chemicals, or even spontaneous heating. In some cases, how the component materials are used increases the risk of fire, explosion or toxicity and therefore must be handled differently depending on the stage of the operation. Inadequate control of these hazards can result in vapor explosions, flash fires, dust explosions, toxic chemical releases, etc. The final product if properly controlled and packaged for consumer use can be innocuous as an individual unit, but collectively in an entire shipment may create an unreasonable hazard if not controlled.

Common hazards associated with manufacturing processes include fabrication of metal parts using various welding processes; machining of parts that depending on the alloy may create combustible shavings; surface finishing with aerosolized powders or solvent based wet paints; and plastics molding using thermoplastic resins or catalyst reaction hardening. Each aspect of an operation must be evaluated to ensure that the applicable safety codes are being followed to eliminate the risks or reduce them to a safe level.

From a firefighting standpoint, it is important for the local Fire Department to be aware of what hazards are present at all phases of the operation, as well as specific actions to take or not take that may worsen an emergency. Such instances would include: the presence of water reactive products since their primary extinguishing agent is water, or large open top pits that crews could fall into, chemical operations that if not shut down properly will cause runaway reactions, etc. At least annually the local department should be invited into the facility to either initially develop or update their Quick Action Pre-Fire Plan.

Warehousing: All operations will have some degree of storage, whether raw materials, materials in process or finished goods. Common methods include use of solid piles of stackable items or use of tiered storage racks, both with aisles between them to facilitate handling of the goods with forklifts.

Solid piling of goods requires a natural shape or container that inherently stable. Where high ceilings are not available to accommodate racking systems and the packaging can withstand its own weight as well as that of several layers of goods above it, this type of storage method can provide the best use of the area available. Goods and containers that can withstand the detrimental effects of fire or water saturation and remain stable for piling to heights of 20 feet or more are rare unless constructed of metal or reinforced plastics. Wood and corrugated cardboard containers that are stacked directly atop one another can be damaged in a very short period of time when involved directly in the fire and collapse in any direction. The rapid degradation of the containers is often not a consideration for the building owner, and thus may be unwittingly changing the firefighting tactics that may be employed out of concern for the safety of the firefighters. If the solid pile remains stable and does not collapse, it can actually slow the progression of fire by acting as a single large mass, rather than many smaller individual items. Some products stored by this method of solid stacking can be made more stable by simple measures that also decrease their susceptibility to feeding the fire. One such example is large rolls of paper used by paper converting operations. When stacked on end, but not banded with steel strapping, they begin to unfurl when the outer wrapping burns away and can contribute greatly to the intensity of the fire. If they are stacked on the side, they cannot react in a detrimental way when exposed to fire.

Rack storage is a more expensive method of arranging goods in a warehouse, first by the cost of the engineered racking systems themselves, and secondly by the limitations of height by ceilings or by the vertical reach of the forklift. From a fire propagation standpoint, the rack systems cause problems with fire suppression as each pallet load of product is a separate unit with flue (horizontal and vertical air flow) spaces created between it and the adjacent unit to each side as well as above and below. This helps to provide air to any fire within the racking system as well as radiation feedback between the goods to accelerate the fire growth. Although there is less danger of immediate collapse since each pallet of commodity is individually supported, it is still present should the fire burn with enough intensity to weaken the racking system. The use of in-rack automatic fire sprinklers can be very beneficial in controlling fires that may develop within the system.

Forklifts used can be electric running on rechargeable lead acid batteries, but are more often powered with liquefied petroleum (LP) gas. As no one ever wants to have a situation where you run out, extra cylinders are always on hand. Ideally, these should be stored outside the building in a secure location that is well marked and protected. However, OSHA standards permit storage of up to 300 pounds of LP which equates to eight of the 33.5 lb. or six of the 43.5 lb. typical cylinders. LP cylinders when directly exposed to flame impingement can undergo a phenomenon known as a boiling liquid expanding vapor explosion (BLEVE) with catastrophic results. The effects of larger quantities will be discussed later under the topic of Exposures.

Pallets, particularly those considered "idle pallets" are great concern since fire can grow involving a stack of pallets with alarming speed and intensity. A stack of idle pallets presents basically a perfect fire set up since the individual members of the pallet are combustible, have a relatively low in comparison to the surface area and also possess the previously mentioned horizontal and vertical flue spaces that permit rapid flame propagation. Although they present a significant fire hazard in any building, there are strict requirements outlined in NFPA 13 – Standard for Installation of Automatic Sprinkler Systems in an attempt to keep from overwhelming the suppression capabilities of the sprinkler system. These guidelines generally require that not more than four stacks of pallets of not more than 6 feet in height be assembled into a single pile, and piles be separated by at least 8 feet of clear space or 25 feet of other commodity. If delivery densities of the sprinkler system are greater than that required by Ordinary Hazard, Group 1, additional storage heights can be achieved as specified in the standard. (NFPA 13 Ch. 7-5.2.2)

Private (Fire) Protection

Protection under the terms being discussed is primarily focused on how the peril of fire can be avoided or controlled. The scope of this discussion will be limited to common fire control methods of portable fire extinguishers, hose stations, standpipes and automatic fire sprinkler systems. Specialized systems such as for commercial cooking or clean agent systems used for high value assets will not be addressed.

Portable Fire Extinguishers

Portable fire extinguishers are considered to be the front line defense when dealing with incipient stage fires. These are commonly not intended for use on larger fires, but larger units are available, up to a size that requires them to be equipped with wheels to facilitate moving when needed. Guidelines for selection, installation and maintenance of these are found in NFPA 10 – *Standard for Portable Fire Extinguishers*.

Selection of the proper portable fire extinguisher is critical to how effective it will be in controlling an incipient stage fire. Classifications are based on the ability of the agent used on particular types of fires. There are five basic classifications in use today to identify the proper type for a given situation and can range in size from 1 pound in agent lasting only about 10 seconds to those carrying over 300 pounds capable of discharging agent for over 100 seconds.

The size needed will vary based on the fire hazard, type of unit, area to be protected and capabilities of the personnel who will use them.

Classification	Primary Hazard	Examples
Class A	Ordinary Combustibles	Natural fibers, paper, wood, cloth, plastics, etc.
Class B	Flammable & Combustible Liquids	Oils, grease, alcohols, ethers, gasoline, solvents, etc.
Class C	Energized Electrical Equipment (incl. Class A)	Any electrically powered equipment requiring a non-conductive extinguishing agent to reduce shock hazard potential
Class D	Combustible Metals	Aluminum, magnesium, sodium, potassium, lithium, etc.
Class K	Commercial Cooking Exposures	Commercial kitchen exposures protected by foam agents systems

In no instance is the maximum travel distance ever greater than 75 feet to the nearest portable fire extinguisher, and in some cases as little as 30 feet depending on the hazard involved. Ensuring that the maximum square footage per unit and total travel distances are not exceeded when locating these throughout your facility can take some creativity and mapping skills. In addition to the strategic locations to meet the minimum requirements, it is also recommended by many to locate them near exits and fire alarm pull stations for convenience in locating them during an emergency. In all cases, proper signage or marking of the locations is necessary to ensure they can be located when needed. Whatever method is chosen to indicate the location, it should be visible from all directions taking into account adequate height to clear any visual obstructions caused by stock, storage or partition walls that may otherwise obstruct signage at the 7 to 8 foot level.

Hose Stations & Standpipes

Hose stations and standpipes are fixed location fire suppression equipment that requires manual operation to suppress a fire. OSHA standards only address use of those hose stations and standpipes rated as Class I and Class III having fittings to accommodate 2 ½ " diameter hose lines and have a flow capacity of at least 500 gpm. Class II standpipes and hose stations are limited to 1 ½" diameter outlets. Hose stations are actually part of a standpipe system, but not all standpipe systems include hose stations. Automatic fire sprinkler systems may often include provisions for use of the hose station. Although additional water supply is calculated into the demand for automatic sprinkler systems, this is usually intended for use by the fire service. Specifications for these can be found in NFPA 14 – *Standard for Installation of Standpipe and Hose Systems*.

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. For occupant use, the hose lines that are attached are only 1 ½" in diameter, nozzle pressure is restricted to about 50 psi and hose length is limited to 100 feet or less as it is felt that untrained personnel cannot easily handle anything greater. (NFPA FPH p 6-256)

Standpipes are pre-plumbed vertical water mains, usually located in a stair tower, but can be located anywhere based on need. They provide a readily accessible location for connecting hose packs carried into the building. A standpipe or hose station significantly cuts the amount of time and effort that is required to bring supply hose to a remote 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 remotely supervised to monitor them for tampering. (STICO p SM 5-8)

The presence of occupant use hose stations has been declining in many occupancies for several reasons: lack of knowledge about the advantages in incipient stage firefighting; inability or lack of funding to properly train occupants in their use; and Local Authorities permitting, or in some cases mandating their removal. Maintenance of these devices can be quite involved due to the need for testing and inspection on a regular basis. This includes reracking annually with a different fold pattern and pressure testing of the hose as specified in NFPA 1962 – *Standard for the Care, Use and Service Testing of Fire Hose* every three years (after the first testing within 5 years).

Automatic Fire Sprinkler Systems

Automatic fire sprinkler systems are designed to be essentially a self operating fire control method. These systems use a system of piping and automatic operating sprinkler heads to deliver water to the immediate area of a fire. They are designed to control, not necessarily completely extinguish the fire, although this often occurs. There are several different types of systems to meet various occupancy needs. The variations include to meet these specific needs can be accomplished by use of different types of heads, operating controls and layout of the piping systems. The two most common types of systems are wet and dry pipe variations. Different hazards can be controlled by what sprinkler heads are used, how frequently they occur on the piping system, the size of the piping members and the available water supply. Extremely high hazard situations can be addressed with combinations of special Early Suppression Fast Response (ESFR) heads, piping arrangements and fire pumps to provide the needed pressure and volume of water.

Fire records show that nearly 70% of all fires in sprinkler protected buildings are extinguished with five or fewer heads operating. A common misconception about sprinkler systems is that they operate like what is seen in motion pictures. Very few systems, known as deluge systems, are designed to function where water will automatically flow from every head in the system when activated. (NFPA FPH p 6-138, 139) Systems using conventional sprinkler heads operate each head on a individual basis as they are exposed to sufficient heat. Most commonly, the heat melts a fusible metal solder holding two parts of a plug together, or heats a liquid filled capsule to the point of bursting. Each design has a pre-determined activating temperature, response time and ability to flow water through its discharge opening. Heads have other design characteristics specific to their use such as the type of deflector to control the water spray and how they must be positioned on the piping or next to adjacent structures.

Wet pipe sprinkler systems are probably the most common type found in the United States. This type of system uses one or more vertical risers (water mains) to supply water to piping that located high in the building near the roof or ceiling. The wet pipe system can flow water onto the fire immediately upon fusing of the sprinkler head since the piping system is already charged with water. Piping systems previously were limited to “black iron, schedule 30 and 40 pipe” with threaded connections. However, new technology has brought with it different couplings for connecting the pipe as well as the limited use of plastic piping in some situations. These systems must be protected from freezing temperatures to prevent the pipes from bursting and disabling the entire system as well as causing unnecessary water damage.

Dry pipe sprinkler systems use a piping system similar to that of the wet pipe systems except the overhead piping is charged with air pressure instead of water. This air pressure is used to hold back water behind a control valve. Once a head fuses, the air pressure in the piping is released and the valve opens under the pressure of the water held back at the base of the riser. The system then floods with water moving in the direction of the open head. The systems are designed to keep the delay of the water travel through the piping within limits specified in NFPA 13 – *Standard for Installation of Sprinkler Systems* of less than 3 minutes to the most remote head, even in a very large system. Piping in this type of system also needs to have sufficient pitch to permit it to drain back to specified low points after it has been charged.

System design is based on what the occupancy of the building is going to be and the expected fire loading. Older systems still in use today will likely have been designed using the "Pipe Schedule method. Pipe schedule design relies on known values of friction loss for specific sizes of pipe to determine how many heads can be placed on a single branch line. This relied on classification of only three hazard groups – light, ordinary and extra hazard. These systems can be identified in large open areas by visually observing the piping arrangements.

Pipe Schedule System: Maximum Number of Heads Supplied by "X" Diameter of Pipe					
Branch Dia.	**1"**	**1.25"**	**1.5"**	**2"**	**2.5"**
	Maximum Number of Heads per Branch Line				
Light Hazard	**2**	**3**	**5**	**10**	**30**
Ordinary Hazard	**2**	**3**	**5**	**10**	**20**
Extra Hazard	**1**	**2**	**5**	**8**	**Max. Limit**

(NFPA 13)

The pipe schedule method of designing systems has been replaced by modern engineering referred to as "hydraulically calculated" to provide a more precise method of ensuring adequate water flow to control a fire. This method uses "Area-density Curves" that specify how many gallons per minute must be delivered to the fire area based upon a maximum area of operation. These systems are much easier to identify as they should have a data plate attached to the control riser indicating information such as the delivery density, maximum operating area, number of heads designed to operate and standard pressures used to conduct the calculations. The system is designed based on how much water is expected to be available, then friction loss for each size of pipe is taken into account to determine the piping layout to achieve the desired flow at the most remote sprinkler head. Typical design parameters for a hydraulically calculated system would correspond to a single point on a graph curve as found in NFPA 13. Multiplying the gallon per minute (gpm) requirement by the square footage give the total water flow capability for the system.

Hydraulically Calculated Systems – Area / Density Curve Values		
<u>**Hazard Classification**</u>	**Lower GPM / Sq. Ft. Delivery Volume**	**Upper GPM / Sq. Ft. Delivery Volume**
Light Hazard (Offices, Schools, Residential, Public Assembly)	**.10 gpm / 1500 sq. ft 150 gpm**	**.07 gpm / 3000 sq. ft. 210 gpm**
Ordinary Haz. – Group 1 (Canneries, Electronic Plants, Restaurant Service Areas)	**.15 gpm / 1500 sq. ft. 225 gpm**	**.10 gpm / 4000 sq. ft. 400 gpm**
Ordinary Haz. – Group 2 (Dry Cleaners, Libraries, Repair Garages, Wood Product Assembly)	**.20 gpm / 1500 sq. ft. 300 gpm**	**.15 gpm / 4000 sq. ft. 600 gpm**
Extra Hazard – Group 1 (Combustible Fluid Use Areas, Printing w/ flammable inks, Upholstering with plastic foams)	**.30 gpm / 2500 sq. ft. 750 gpm**	**.20 gpm / 5000 sq. ft. 1000 gpm**
Extra Hazard – Group 2 (Flammable Liquid Spraying, Mfrd. Home Assembly, Plastics Processing)	**.40 gpm / 2500 sq. ft. 1000 gpm**	**.30 gpm / 5000 sq. ft. 1500 gpm**

(NFPA FPH pp 6-141,142, 156)

Matching the sprinkler system design to the actual hazard classification is critical to proper operation and control of a fire. If the system is not capable of delivering adequate water to the fire, it cannot be expected to control, let alone overcome the heat being produced.

Maintaining the system is critical to reliable operation. Specifics about testing and maintenance are outlined in NFPA 25 – *Standard for Maintenance and Inspection of Sprinkler Systems*. Years 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 during the fire, 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)

All systems with over 20 sprinkler heads must have at least a local water flow alarm. should be supervised for water flow. All control valves should either be supervised through electronic monitoring or be locked in the open position to deter tampering that can disable the system.

Fire Department Support of the automatic sprinkler system can boost the performance of the system by providing more water through any heads that have already opened, allowing them to work more efficiently at discharging water directly onto the fire. All systems should be fitted with a Fire Department Connection to provide a method for direct connection to the system. It is to be located 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. Even if the main control valve is closed preventing water from flowing into the system from the public main, the proper location of this connection should still permit the fire department to supply water to the sprinkler system. Removable covers should be in place to prevent debris from being placed into the piping system that can obstruct the flow of water. Supply lines are attached from one of the first responding engines / pumpers to provide additional water volume and boost the system pressure to about 150 psi. A check valve will keep the water from flowing back into the municipal main. 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 set so they activate automatically. These pumps should only be shut down under direction of the fire department once a fire has been detected. (STICO p SM 5-9)

Public (Fire) Protection

<u>The Fire Department</u>
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)

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 homeowners 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. Less than 1% of the US fire departments carry a PPC of 1 or 2. 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 more on your own resources to effectively control a fire or to supplement the resources of the responding department.

Water Supplies

Water supply for the fire protection systems is a vital element in protecting property. Water can be available from several sources. These include municipal systems, static sources and portable or mobile sources. In most cases, a fire response within a city or town will involve use of the local municipal water delivery system, whether for the sprinkler system or for firefighting. The prevalence of sprinkler protected properties in rural areas is small due to the challenges with reliable water supply. 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).

Water is known as the universal solvent, but is also the most readily available fire suppression agent. It will 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)

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)

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 fire departments water requirement to fight the fire, expressed in gallons per minute (gpm), is easily determined. 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 no adjacent exposures would have a basic fire flow for 100% involvement as follows:

Math Step 1: 10,000 square feet / 3 = 3,334 gpm for 100% involvement of the building
Math Step 2: 3,334 gpm × 100% maximum involvement = 3,334 gpm required fire flow

If the building has rated fire walls to create fire divisions, fire flow can be reduced to represent the smaller footprint exposed. For instance a 4 hour rated fire wall and not unprotected openings separating the structure into two halves may allow for reduction in the basic fire flow. In that case each half could be calculated separately and reduce the demand by 50%

Math Step 3: 3,334 gpm × 50% maximum involvement = 1,667 gpm required fire flow
(PICO p SM 5-4)

Required Fire Flows (water demands) that exceed 1000 gpm may create problems depending on the fire department apparatus availability, water main sizes, configurations and municipal storage available. On average at least one fire department engine / pumper will be needed for each 750 to 2000 gpm of Required Fire Flow depending on the number of engine / pumpers available and their condition. If old or not well maintained, the rated capacity may be significantly different than the actual capacity. The local municipal water utility should be contacted for exact information about water main layout, sizes and hydrant flows. Multiple hydrants will be needed that are supplied by looped (fed from more than one direction) larger diameter mains for larger demand situations.

Staffing/Manpower

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. Average responses will require a minimum of 20 to as many as 40 firefighters for each 1000 gallons of required fire flow 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)

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 NFPA 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.

Exposures

Although building fire exposures from a protection standpoint can be either internal or external, most do arise from outside the structure involved in the fire event. Fire exposures include anything that could either permit fire to communicate to the subject building or that could be endangered by a fire extending from the subject building. Depending on which structure is involved in the fire event, the other is considered its' exposure. Examples of exposures include adjacent buildings, chemical and fuel tanks that normally accompany manufacturing operations, material yards containing combustible goods, even open fields subject to wildfire if not maintained.

The fire department, as part of their strategic plan to stabilize the incident, is responsible for protecting exposures that may be damaged by the fire as well as extinguishing the fire itself. Protecting exposures can demand valuable resources be diverted from normal fire suppression activities. This can result in situations where insufficient manpower or water remains to effectively control the situation at hand.

Radiant heat and flying brands are the two most common methods of fire communicating from one structure to another. 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. To combat radiant heat exposure, water must be applied to the surface of an adjacent structure in order to absorb the radiant heat energy that was transmitted through the air from the fire. Water curtains are ineffective at preventing transmission of radiant heat. Flying brands can create significant problems when high winds are present causing them to travel great distances setting fire to building hundreds of feet away. (PICO p SM 5-5)

Exposures that must be protected affect the Required Fire Flow needed by the fire department and never in a positive way. Each side of the structure with an adjacent exposure, regardless of size requires a surcharge to the Required Fire Flow of at least 25%, before any reductions for percentage of fire involvement are made. Based on the scenario above, the calculation would be as follows:

Math Step 1: 10,000 square feet / 3 = 3,334 gpm for 100% involvement of the building
Math Step 2: 3,334 gpm + 25% (exposure charge for 1 side) = 4,168 gpm
Math Step 3: 4,168 gpm × 50% maximum involvement = 2,084 gpm required fire flow

Therefore the more potential exposures there are to a fire building, the greater the anticipated water demand will be to protect them as well as the additional fire crews to man those hose lines.

Access Limitations

In order for the fire department to operate effectively and safely at a fire, a structure needs to have paved access around all sides. This is 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.

Improving the Outcome of the Fire Emergency

The issues of how building construction, occupancy, protection and exposures impact the firefighting Rules of Engagement as related to how any fire emergency is handled are not absolute by any means, but can have a great impact on the situation. It is important to remember to seek the advice of your insurance Loss Prevention / Control experts and the local fire service to determine exactly what you risk factors are and how they can best be controlled in your particular situation. Also, implementation of an *NFPA 1600 – Standard on Disaster / Emergency Management and Business Continuity Programs* compliant or similar business recovery plan can be beneficial for managing those issues outside the strict scope of what is addressed here. While there are many different business continuity and recovery models, the most recent 2007 edition is available free from the National Fire Protection Association at http://www.nfpa.org.

Construction

It is important to remember that any type of construction will have its own set of issues when it comes to how well it can withstand the damaging effects of fire. Regardless of the specific type of construction, there are protective measures that can improve the survival of the structure and reduce the overall loss.

- Design for fire safety when considering new construction or renovations.
- Fire Walls & Partitions – Where possible use these to separate high hazard areas from lower hazard areas, or to separate large areas into smaller exposure units when constructing new buildings.
- Fire Stopping – Inspect fire walls and partitions for penetrations that may allow fire to communicate from one side to another. This includes draft stopping in large concealed spaces to slow fire spread.

- Opening Protection – Properly rated opening protection in place in fire walls and partitions to limit the spread of fire through the wall.
- Protective Coverings – ensure any missing or damaged protective materials are repaired such as spray on coatings over exposed steel, or plaster, drywall or concrete coatings over structural columns and beams.
- Provide additional exterior doors that can serve not only as emergency exits, but provide improved access by the fire department to locate the seat of the fire and conduct extinguishing operations or manage utility services due to the limited interior travel distances for firefighters caused by air management policies and limited hose lengths.
- Avoid multiple roof scenarios that create concealed spaces where if not properly draft stopped can permit fire to spread the entire length of the facility as well as make vertical ventilation of the fire area nearly impossible.

<u>Occupancy</u>
The primary factors related to occupancy involve the materials and processes that are part of the normal day to day operations.

- Reduce operational hazards by conformance with local and state safety codes as well as OSHA and NFPA standards.
- Replace highly hazardous operations with those known to be less hazardous alternatives.
- Occupancy hazards should not exceed the protection capabilities of either the private or public fire protection.
- Ensure that all personnel can evacuate safely and be accounted for quickly.
- Provide wide, clear aisles through the facility that will not be compromised by storage collapse.
- Pre-qualify contractors who will perform work in your facility to ensure they follow proper safety guidelines and pose a manageable risk.

<u>Protection</u>
Since the protection component consists of both private and public elements, some are within the control of the building owner, and others are not. However, for those situations where circumstances are out of the control of the owner, knowledge is power for advance planning.

Private Protection

- Install automatic fire sprinklers (new construction or retrofit) as a first line of defense to prevent small fires from becoming large fires.
- Fire detection systems should be installed to provide early warning for employees and response by the fire department.
- 24/7 supervision of all fire detection and control systems.
- Maintain all fire protection equipment and systems according to NFPA standards to ensure reliability. This includes not only the fire extinguishers and sprinkler systems, but also fire doors, smoke and heat venting and early detection capabilities.
- Employees should be trained in handling incipient stage fire control, even if response is optional for most.
- If the local fire department(s) will not be able to handle your anticipated fire emergency, serious consideration should be give to establishing an Industrial Fire Brigade.

- If municipal water supplies will be inadequate, serious consideration should be given to alternative water sources such as elevated tanks, ponds, or underground cisterns that will be accessible during a fire emergency.

Public Protection

- Work with the local responding fire department(s) in establishing their Quick Access Pre-fire Plan. Understand their capabilities and limitations such as equipment available, staffing and the ISO Public Protection Classification.
- Evaluate public and private water supplies for adequacy.

<u>Exposures</u>

- Use sound principles of layout for buildings on your own property to limit how they expose one another
- Control outdoor storage of fuels, combustible materials and natural exposures that can cause fire to be communicated to the buildings
- Provide large paved driveways capable of supporting fire apparatus weights as far around the structure as possible, taking into account the potential collapse zone and additional traffic for extended fire operations.

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