Among the most challenging occupancies from a property loss control viewpoint are warehouses, distribution centers and large retail businesses referred to as “big box” establishments.

“Warehouses represent a unique fire challenge to both fixed fire suppression systems and the manual firefighting forces that are called upon to deal with a fire. Modern warehouses and storage occupancies are especially subject to rapidly developing fires of great intensity, because complex configuration of storage and building layout are usually conducive to fire spread, presenting numerous obstacles to manual fire suppression efforts. The only proven method of controlling a warehouse fire is with properly designed and maintained automatic sprinkler systems. If sprinkler protection is not provided, the likelihood of controlling a fire in a warehouse is minimal, at best.”

In this white paper, we will examine critical elements you must consider when developing a comprehensive risk mitigation strategy to protect your facilities. These elements include:

- Commodity classification
- Common storage configurations
- Various protection schemes
- Hazards associated with some of the common types of warehouses
- Loss prevention guidelines for minimizing the frequency and severity of a loss

Merriam-Webster defines a warehouse as “a structure or room for the storage of merchandise or commodities.” Warehouses can thus range from several hundred to more than a million square feet and can include among other occupancies storage garages, refrigerated storage facilities, isolated storage buildings, underground storage locations, and air-supported structures.

Big box retail facilities typically have large footprints, many of which approach or exceed 100,000 square feet in area. A variety of commodities is displayed and stored within these facilities, including soft goods, clothes, furnishings of all types, bedding materials, paints, home repair and building materials, chemicals, and plastics. Moreover, big box retail spaces often have ceiling or roof heights in excess of 16 feet and, in many cases, as high as 35 to 40 feet. Using rack storage configurations, these types of retail stores will typically display products at lower elevations and use the higher elevations for product storage.

Commodity Classification

So how do we determine what we are protecting? Commodities are classified taking into account three factors:
1. The specific item or product
   - Its heat of combustion
   - Its rate of heat release
   - Its rate of flame spread

2. The packaging of the specific item or product
   - Interior and exterior packaging components (e.g., type of carton or container as well as the material inside the carton or container).

3. The individual storage units
   - The commodity classification shall be determined based on the makeup of individual storage units (e.g., a unit load or a pallet load).*
   - As a general guideline, Table 1 outlines the Commodity Classes and Classification of Plastics, Elastomers and Rubber.

   It is critically important to properly identify the correct commodity class as this will serve as the foundation for determining the appropriate fire suppression protection scheme.

<table>
<thead>
<tr>
<th>Table 1: Commodity Classes and Classification of Plastics, Elastomers and Rubber</th>
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<tbody>
<tr>
<td><strong>Class I</strong></td>
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* In accordance with National Fire Protection Association (NFPA) 13, Standard for the Installation of Sprinkler System
* Section 3.9.1.8 of NFPA 13 states - Encapsulation. A method of packaging consisting of a plastic sheet completely enclosing the sides and top of a pallet load containing a combustible commodity or a combustible package or a group of commodities or combustible packages. Combustible commodities individually wrapped in plastic sheeting and stored exposed in a pallet load.
Storage Configuration

Generally speaking, storage arrangements include bulk storage, solid piling, palletized pile storage and rack storage. The differences among the four arrangements that affect the behavior of fire and the difficulty of fire control are in the flues; i.e., horizontal and vertical air spaces created by the storage configurations.3

- **Bulk storage** consists of piles of unpackaged material in loose, free-flowing condition, such as powder, granules, pellets or flakes – such materials as can be found in silos, bins, tanks, or in large piles on the floors of storage buildings.

- **Solid piling** consists of cartons, boxes, bales, bags, etc., in direct contact with each other.

- **Palletized storage** consists of unit loads mounted on pallets.

- **Rack storage** consists of structural framework into which unit loads (usually on pallets) are placed. Rack storage can be further classified into single-row, double-row, multi-row, carousel, and flow-through racks.

Single-row racks have no longitudinal flue space (the open spaces between rows of storage perpendicular to the direction of loading), are up to six feet deep and have aisles at least four feet wide. Double-row racks are two single-row racks placed back to back separated by a longitudinal flue space, with aisles at least four feet wide. Multiple-row racks are racks greater than 12 feet wide, or single-row or double-row racks separated by aisles less than four feet wide having an overall width, including flues, greater than 12 feet. Multiple-row racks can be drive-in, drive-through, flow-through, push-back or double-deep standard racks. **The rack depth is the determinant.**

Furthermore, Data Sheet 8-9 classifies flue spaces as the open spaces between rows of storage. In addition to longitudinal flue spaces previously mentioned, transverse flue spaces are parallel to the direction of loading. Flue spaces within storage racks should be six inches wide. However, they must have at least a three-inch-wide net clear space in order to be considered a flue. A net clear space is the actual width of the flue space minus the width of any obstructions (such as rack uprights). In solid-piled and palletized storage, flue spaces may run in either direction.

Fire Protection Design Challenges

When designing the fire protection system(s) for warehouse type occupancy, in addition to commodity classification and storage configuration, there are many other variables to consider such as storage height versus building height, aisle width, and specific design features of automatic sprinkler systems (including temperature rating, orifice size, response time and in-rack sprinklers).

**Storage Height vs. Building Height**

“Other than the fire properties of the commodities themselves, probably no other condition has a more profound influence on the progress of fire in a storage occupancy and on the difficulty of fire control than storage height.”4 Rack storage to heights of 40 feet or higher in buildings with ceiling or roof height of 45 feet or above is common. One can also find automated storage and retrieval systems which use computer-controlled robots for material handling operations to be as tall as 100-feet with very narrow aisles!
Aisle Width
Aisle width is determined by the horizontal distance between the faces of the storage in the racks. Aisles are usually four to eight feet wide, and the aisles allow for water from the ceiling sprinklers to reach a fire, help keep a fire from jumping from rack to rack and provide egress for manual firefighting efforts.

Sprinkler Systems
Hundreds of different models and styles of automatic sprinklers are available. It is critical that the type of sprinkler head you select is approved, listed and installed for the correct application.

Sprinklers are divided into two categories based on the mechanisms by which they are designed to attack a fire. **Control mode** sprinklers rely on cooling and pre-wetting, allowing the fire to continue to burn in the area of ignition while controlling roof and ceiling temperatures and preventing fire spread until firefighters arrive or the fuel is consumed and the fire goes out. These types of sprinklers are characterized by a relatively large area of operation (e.g., 15-50 sprinklers). **Suppression mode** or Early Suppression Fast Response (ESFR) sprinklers rely on penetration to stop fire growth quickly and drastically reduce heat release. Usually six or fewer of this type of sprinkler is required.\(^5\)

Section 3.6.1 in NFPA 13 outlines the characteristics of a sprinkler that define its ability to control or extinguish a fire.

a) **Thermal sensitivity** – A measure of the rapidity with which the thermal element operates as installed in a specific sprinkler or sprinkler assembly. One measure of thermal sensitivity is the response time index (RTI) as measured under standardized test conditions.

b) **Temperature rating** – Usually ranges from 135°F to 650°F.

c) **Orifice size** – The opening through which the water flows depending on the amount of water (density) needed to protect the occupancy. They can range from one-half-inch to as much as one inch in diameter.

d) **Installation orientation** – Sidewall, pendent, upright, etc.

e) **Water distribution characteristics** – Application rate, wall wetting.

f) **Special service conditions** – Dry sprinklers, corrosion resistant, rack storage sprinklers.

As defined in FM Data Sheet 8-9, rack storage sprinklers (also called in-rack sprinklers or intermediate level sprinklers) are typically control mode sprinklers equipped with an attached water shield over the top of the operating element. In addition, they are classified as either longitudinal or face in-rack sprinklers. Face in-rack sprinklers are located within 18-inches of the edge (face) of the rack; longitudinal in-rack sprinklers are positioned throughout the inner areas of the rack no more than three inches from their designated transverse flue space.

The factors determining whether or not in-rack sprinklers are needed are usually the storage height and/or the solid shelving in the rack structure. Solid shelving is fixed-in-place solid, slatted (fixed or non-fixed), grated (less than 70% open) or other types of shelves that restrict the amount of water that can reach the entire length of the rack.

**Water supply** – Finally, as with any sprinkler system, it is imperative that an adequate and reliable water supply is in place to ensure that design requirements are met for ceiling sprinklers, in-rack sprinklers, hydrants, standpipes and hose systems. In the case of suppression mode sprinklers, it is not uncommon for water supply requirements to exceed 1,500-gallons per minute. A booster fire pump as well as a redundant or supplemental water supply is often required.
Building Construction

Buildings used for both manufacturing and warehousing/distribution should have a good barrier wall (preferably a bona fide fire wall) between these components. The goal is to limit the spread of smoke and fire to other areas within a structure, a concept called compartmentation. It is crucial that any penetrations within these walls are fire stopped at all times to limit the spread of smoke and fire. Furthermore, steel columns within storage racks over 15 feet high in which there are no in-rack enclosed sprinklers need to be fireproofed, protected by one or two sidewall sprinklers or under high-density ceiling sprinklers.6

Hazards

Assuming that all fixed protection is designed, installed and maintained in proper fashion, as with any occupancy, there are several additional hazards unique to warehouses, distribution centers and big box retail establishments.

Industrial Lift Trucks

In most cases, material handling systems such as industrial lift trucks are used extensively throughout the facility. LP-Gas powered forklifts are common, making precautions regarding the use and storage of LP-Gas tanks necessary. LP-Gas vapors are heavier than air and tend to collect in low floor areas. Special precautions might be needed if they are used or stored in a concentrated area (such as explosion-proof electrical equipment or used in an area where other heat/ignition sources are present).

When battery-powered lift trucks are in use, special attention must be given to the battery charging area. Due to the fumes that may be released from gassing batteries during charging, this area may need ventilation, gas detection, as well as explosion-proof electrical equipment.

High Intensity Discharge (HID) Lighting Systems

Lighting systems utilizing HID lamps have existed for several years and are widely used in warehouse occupancies. Although commonly recognized as a safe means of providing high quality lighting, one type of HID lighting is suspected of being the source of ignition for several major fires. The three main types of HID lamps are metal halide lamps, mercury vapor lamps and high-pressure sodium lamps. These systems are typically found in newer facilities or as part of a refurbishment program at older facilities. Such systems appear to be most appropriate for the more open settings found in occupancies with high ceilings, but may certainly be found in other applications.

Metal halide lights consist of an assembly of conical outer fixture housing, a replaceable bulb (lamp) within the fixture and, in most designs, a fixture lens cover or light diffuser. Some fixtures are approved for use with a specifically designed lamp that may not require the lens/diffuser. Otherwise, the lens cover/diffuser is constructed of materials such as tempered glass or high temperature, high impact plastic that will contain the fragments of a ruptured arc tube (filament) within the bulb which would be part of the lamp. The normal pressure within a metal halide lamp can reach 70 psi and interior temperatures can be over 1,000° C (1,832° F). Sudden internal failure can cause lamp rupturing and result in the forceful spraying of hot fragments into the general area below the fixture. These hot fragments are capable of igniting any combustibles within the area. The hot fragments can fall within the storage and generate a fire some time later. If possible, install HID lights over aisle spaces and not over storage areas.

Pallet Storage

Proper protection regarding the use and storage of wood and plastic pallets is essential. Based on fire tests, pallets are divided into two groups for determining the level of protection needed for their storage.

Group I
1. Wood pallets with slatted and/or solid top and/or bottom.

2. Pallets made of combinations of solid sheets of corrugated paperboard, separated by either polystyrene blocks of short rolls of corrugated paperboard edge.
3. Non-expanded, high-density polyethylene pallets with solid deck.

**Group II**
All other plastic pallets. Since pallets in Group I are a lesser fire hazard than those in Group II, their storage is permitted in the following areas:

1. A cut-off room located anywhere in the building.
2. Any storage area with no cut-offs between pallet storage and other storage’s (storage in such areas should be limited to a maximum height of 20-ft. (6.0 m)).

**Group II Pallets**
The locations, in order of preference, for idle plastic pallet storage are:

1. Outdoors, a safe distance from important buildings
2. A detached low value building at least 20 ft. (6.0 m) from important buildings
3. A cut-off room located along the exterior wall and outside of the building
4. A cut-off room located along the exterior wall and inside of the building
5. A non-cut-off area (4 ft. (1.2 m) maximum storage height)

For indoor pallet storage, specific sprinkler design and storage requirements are needed in order to provide adequate protection.

**Multi-Tenanted Facilities**
Off-site and third-party warehousing are commonly used to accommodate spillover storage and for distribution purposes. Although these facilities offer operational flexibility, this is often at the cost of accepting lower fire prevention and control standards. Furthermore, products may be stored adjacent to other clients’ higher hazard or non-compatible products significantly increasing exposure to a serious fire which is often not evaluated.

All third-party warehousing contracts should specify standards of both fire prevention and control that are in place and utilized. You should undertake regular audits to ensure standards are maintained.

**Special Hazards**
Items such as rubber tires, rolled paper, carpet, baled fibers, hazardous materials and other commodities require particular attention. Because of their unique burning characteristics and storage arrangements, protecting these items is especially challenging. For example, on more than one occasion, fires have occurred resulting in total destruction of the warehouse due to the presence of aerosols. This has led to special protection requirements including the storage of these items in a segregated and fenced-in area within a structure.

**Cold Storage Warehouses**
Cold storage warehouses are used primarily for long-term storage of food products at temperatures that reduce the chances of spoilage. Other products such as medicine and chemicals may also require refrigeration. Depending on the products, temperatures may range from -35° F to 65° F.

Polyurethane and polystyrene foam are two common insulation materials used to aid in maintaining cold temperatures. When used in walls or ceilings, these materials should be protected by an approved thermal barrier or by a half-inch coat of cement plaster on metal lath attached to the building framing. For polystyrene, the barrier also may be either half-inch Type X gypsum wallboard or three-quarter-inch fire-retardant plywood supported by studs or furring attached to the framing. A cold storage warehouse should be protected by an automatic sprinkler system. The system should be designed so it can be easily inspected and disassembled for the removal of ice plugs (e.g., the use of tees and caps or other easily removable arrangements) on both sides of the freezer wall starting on the warm side of the wall and continuing to a point beyond where the sprinkler pipe is insulated.
Metal Building Systems

A Metal Building System (also known as a Pre-engineered Building) is defined by the Metal Building Manufacturers Association as “a complete integrated set of mutually dependent components and assemblies that form a building. It includes the primary and secondary framing, covering, and accessories, all of which are manufactured to permit inspection on site prior to assembly or erection.” These buildings can be totally comprised of steel, or their appearance can be enhanced, completely or partially, by the use of other cladding materials such as masonry, EIFS\(^8\), pre-cast, cast-in-place, or tilt-up concrete wall systems.

Many of these buildings utilize standing/lap seam roof coverings. The standing/lap seam roof cover generally consists of 22-, 24- or 26-gage exterior metal sheets or panels, field seamed to adjacent sheets by a special roll-forming machine to create an upstanding seam (rib) of folded metal along the sheet sidelaps. This folded sidelap is secured by a panel clip which contains metal tabs roll-formed into the panel seam. The heavy gage clip is secured to the building’s structural framework.\(^9\) This lightweight roof cover is highly susceptible to wind damage if not properly secured and to collapse due to excessive weight from heavy snowfall or roof mounted equipment.

Conclusion

Years of live fire testing and volumes of standards and guidelines have clearly proven the challenges involved with adequately protecting warehouses, distribution centers and big box establishments. With ongoing research, as well as continued changes in commodity classification, the importance of developing adequate protection schemes cannot be emphasized enough. Extensive consultation and plan review is needed before any work commences, whether it appears to be a simple change in storage configuration, a complete renovation or new construction. Willis looks forward to working with you to help ensure these projects are properly designed.

References

8. EIFS (Exterior Insulation Finish System) is a system which uses sheets of expanded polystyrene or polyisocyanurate attached to the exterior of the buildings. The expanded plastic is covered by a material that looks and feels like concrete. EIFS can be installed over concrete blocks or panels, or on wood, gypsum board or metal panels. The insulation can be mechanically fastened, clipped or adhered with adhesive to the wall system. A reinforcing mesh (mostly polypropylene) is troweled into a base coat applied to the insulation board to add additional strength and to minimize damage to the assembly. A finish coat of either a thin portland cement or acrylic is applied over the base coat. The finish coat can be textured to look like concrete or stucco.