NATIONAL FALLEN FIREFIGHTERS FOUNDATION®

Incident Analysis


MEGA-WAREHOUSE FIRE

9590 Allpoints Parkway | Plainfield, Indiana

MARCH 15, 2022

This report was conducted by a team of experts that was assembled and coordinated by the National Fallen Firefighters Foundation at the request of several organizations that were seeking understanding of the incident that is analyzed in this report. The magnitude of the incident and the resulting property loss and economic impacts make it important to understand how this fire resulted in the total destruction of a facility that was built according to current fire protection standards and provided with an array of engineered fire protection systems. The fact that the incident came very close to costing the lives of at least three firefighters makes it even more important to understand what happened.

The objective of the report is to provide information and understanding of this unusual occurrence, with the hope that it will contribute to preventing similar occurrences in the future.

MESSAGE FROM INDIANA STATE FIRE MARSHAL

To my fellow State Fire Marshals and firefighters,

I am writing to share critical insights from a recent fire incident that occurred at a mega-warehouse in Plainfield, Indiana. This fire, which resulted in a total loss exceeding $500 million and nearly lost firefighters, underscores the unique challenges and risks associated with mega-warehouses, which are increasingly prevalent nationwide.

I want to extend my deepest appreciation to the Plainfield Fire Territory and the Town of Plainfield for their willingness to share their experience and insights from this incident. Their transparency has provided invaluable lessons that can help us all better understand the dynamics of mega-warehouse fires and, most importantly, enhance the safety of our firefighters.

The analysis of this incident highlights several critical factors:

- The fire spread rapidly due to the high combustible load and the structural configuration of the warehouse, which included a multi-level Pick Module. This complexity underscores the need for specialized training and preparedness for such environments.
- While the warehouse was equipped with advanced fire protection systems, the incident revealed potential limitations in their effectiveness under certain conditions. This calls for reevaluating current fire protection strategies and systems in mega-warehouses.
- The incident also highlighted challenges in communication within large steel structures, which can impede coordination efforts during emergencies.
- The rapid escalation of the fire situation emphasizes the critical need for operational strategies prioritizing firefighter safety, including the potential need for defensive tactics when interior conditions become untenable.

As we continue to see the proliferation of mega-warehouses, it is imperative that we share knowledge and experiences to improve our collective ability to manage these complex incidents. The insights from the Plainfield incident should serve as a catalyst for developing enhanced training programs, reviewing fire protection standards, and fostering collaboration across jurisdictions.

Thank you to the Plainfield Fire Territory and the Town of Plainfield for their invaluable contribution to our understanding of mega-warehouse fire dynamics. Let us use this knowledge to ensure the safety of our firefighters and communities.

Sincerely,

Stephen Jones | Indiana State Fire Marshal

COVER PHOTOS: COURTESY OF WRTV.COM

PLAINFIELD FIRE ANALYSIS PROJECT

Plainfield Fire Territory
Brent Anderson
Jeffery Dixon
Greg Williams
Keith Rinehart
Wade Stevens

National Fallen Firefighters Foundation
Ron Siarnicki
Victor Stagnaro
John Tippett
Gary Krichbaum
Kelly Lynch
Larry Curl
Susan Proels

Indiana State Fire Marshal
Stephen Jones

National Fire Protection Association
Lorraine Carli
Bob Duval
Meredith Hawes
Raymond Bizal
Robin Zevotek

National Fire Sprinkler Association
Shane Ray

UL Fire Safety Research Institutes
Steve Kerber

FM
Michael J. Spaziani

Bureau of Alcohol, Tobacco and Firearms (ATF)
Walter W. Shaw

Fire Service
Adam Thiel
Richard McKee
J. Curtis Varone

Investigation and Analysis Team
J. Gordon Routley
Kevin Roche
John M. Buckman III
Taylor Bagnall

Table of Contents

Executive Summary

This report provides a detailed analysis of a massive fire that occurred in a mega-warehouse facility in Indiana in 2022. The incident is remarkable because of the magnitude of the property loss, the sudden change in fire conditions that occurred, and the resulting very close call to several firefighters who were inside the warehouse at that time.

The model building codes allow for storage buildings to be constructed without height or area restrictions, as long as the construction classification is non-combustible, the building is protected by automatic sprinklers and it is surrounded by open space. These code provisions have allowed for huge warehouses, often exceeding one million square feet, to be built in many areas. Many of them are located in suburban and semi-rural areas with limited public fire protection capabilities.

The particular fire protection challenges that exist in each facility are extremely variable, depending on the goods that are present and how they are stored and handled, so the fire protection systems must be adapted to each situation. The specific characteristics of this facility where this incident occurred are significant, because they created unusual fire protection challenges; however, the fire protection systems were designed to meet those challenges.

In the incident that is addressed in this report, firefighters responded to a fire in a 1.2 million square foot mega-warehouse. When they arrived, the sprinkler system had already controlled the fire and confined it to a small area of storage shelving, deep inside the building. The residual flames were fully extinguished within a few minutes by firefighters operating a single hose line. For all intents and purposes, this could be described as a routine incident up to that point.

The fire originated on the second level of a four-level racking system that was loaded with combustible consumer goods. Automatic sprinklers protected each level of this storage area. The sprinklers on the second level had performed as expected and all that remained was a mass of burned debris that was saturated with water. The areas around and above the fire were checked for possible extension and no indications were found. A large portion of the building was filled with cold smoke that obscured visibility, but everything indicated that the fire had been successfully and thoroughly extinguished.

At that point, the order was given to begin shutting off the sprinklers and opening loading dock doors to provide ventilation. Neither of these tasks could be accomplished quickly, because the building was protected by 30 separate sprinkler systems at the roof level and eight additional systems that provided additional coverage within the immense multi-level racking system. Each of the rack sprinkler systems was divided into three zones to cover the individual levels. Locating the appropriate valve or valves to close to stop the flow to the operating sprinklers was the first challenge.

At the same time, the crews assigned to accomplish ventilation found 53-foot trailers backed up to every one of the 100 loading dock doors that lined two sides of the building. No ventilation could be accomplished until some of those tailers could be moved away from the building. Vertical ventilation was infeasible, because the cold smoke would not rise, even if openings were made in the vast roof that covered the building. The crew that had been assigned to the roof to check for indications of smoke or fire had observed nothing more than a few traces of smoke around some of the rooftop ventilation units.

The situation became even more complicated, when a company supervisor reported that they were unable to account for 55 of the 565 employees who had been working in the facility on the day of the fire. There should have been ample time for an orderly evacuation when the fire alarm sounded, about 10 minutes before the first firefighters arrived, but the report that 55 employees could still be inside the huge smoke-filled building required a search to be initiated.

Firefighters began to search the complex array of aisles and levels within the rack storage area, looking for any employees who might have become lost or overcome in the smoke. It was later determined that all of the employees had safely evacuated and the reports were erroneous.

Approximately 15 minutes after the confirmation that the fire had been fully extinguished, the fixed fire pump that supplied water to the sprinkler systems was shut down. During those 15 minutes the sprinklers had continued to discharge a full flow of water onto the fire area, while firefighters remained in the immediate area completing overhaul of the debris.

Up to that point everything indicated that the sprinkler systems had performed as expected, the fire was out, and firefighters were dealing with the typical problems that can be anticipated when a fire occurs in a sprinklered building. Aside from the reports of potentially missing employees, there was nothing unusual, alarming, or ominous about the situation.

The situation changed very suddenly and radically approximately 10 minutes after the fire pump was shut down. The firefighters who were on the roof, gathering their equipment to return to ground level, reported that smoke and flames suddenly erupted through the roof near the middle of the building. This was the first indication that anything unusual was happening. Within the next 60 to 90 seconds conditions inside the building changed radically as a large fire developed and began to spread quickly in the upper part of the building. Heavy dark smoke descended to the floor level, more than 40 feet below.

Most of the firefighters were able to exit quickly, but three were still close to the original fire area, within the racking structure, and totally enveloped by the dark smoke. A MAYDAY was declared and they were extremely fortunate to survive by finding the single hose line that had been extended far into the building and following it to the door where they had entered.

Within minutes it was evident that the fire inside the building was uncontrollable. The fixed fire pumps were restarted, but they could not deliver enough water to control a fire of this magnitude. The incident commander called for massive reinforcements and established defensive operations, but the efforts of firefighters had no impact on the fire that rapidly involved the entire building. A four-hour fire wall that divided the building into two sections was ineffective in stopping its progress and the inevitable result was a total loss of the entire facility and its contents, valued at hundreds of millions of dollars. Fortunately, there was no loss of life and only a few minor injuries to firefighters during their rapid evacuation.

In the aftermath, there are obvious questions related to what went wrong. The origin and cause of the fire could not be determined due to the extent of the destruction, although the location was identified by several witnesses who had observed the fire in its very early stages.

The contents of the building were known to be readily combustible and the rack storage system created the potential for an extremely challenging fire; however, the building and the rack storage systems were protected by engineered fire protection systems that were specifically designed to meet those challenges. Moreover, the sequence of events provided several indications that the fire had been successfully controlled, confined to a small area, and effectively extinguished. There was no evident explanation for the sudden eruption of the massive and uncontrollable fire that consumed the entire building and almost claimed the lives of three firefighters.

The extensive analysis that is documented in this report reaches the conclusion that the fire, which originated on the 2nd level of the racking system, probably found a path to extend vertically and ignite goods that were stored on one of the upper levels. This probably occurred during the very early stages of the incident, possibly before the sprinklers on the 2nd level had activated. The timing suggests that that secondary fire could have smoldered for 30 to 40 minutes without being detected or observed, while the sprinklers controlled the original fire. The secondary fire only began to develop around the time that the fire pump was shut down, rendering the sprinklers in the upper levels of the rack system and at the roof level ineffective.

Within less than 10 minutes, the upper-level fire grew to a point that it was able to penetrate the roof deck and spread rapidly in the upper levels of the building. By the time it was observed, it was already uncontrollable and the loss of the entire facility was inevitable.

This hypothesis of the fire spread cannot be proven; however, there is no other logical explanation for the sequence of events that occurred. The construction details of the rack system provided openings that could have allowed the fire to spread vertically, most likely before the sprinklers on the 2nd level activated or at least before they gained control of the fire on that level. The explanation that the secondary fire must have smouldered undetected for an extended period of time, without activating any sprinklers on the higher levels, also cannot be proven. The fact that the fire pump was shut down at almost exactly the same time that the secondary fire began to develop and activate sprinklers at the roof level, appears to be coincidental and extremely unpredictable.

The possibility that a completely separate fire was ignited somewhere in the upper levels of the rack storage area, after the original fire was under control, cannot be eliminated as a potential alternative explanation. Nevertheless, there is no evidence to support this alternative hypothesis.

The detailed analysis of this incident is intended to provide information that will be useful to many components of the fire protection community, particularly to those that are involved in the design of fire protection systems for mega-warehouse facilities, and for fire departments that provide the public fire protection component for these facilities. Several lessons and recommendations are provided to reduce the risk of similar occurrences in the future.

From the fire service perspective, it is extremely important to recognize the magnitude of the fire risk that is present in many of these facilities. The potential for uncontrollable fires and huge losses is evident, if the fixed fire protection systems fail to control a fire in its very early stages. The fire conditions that can be anticipated greatly exceed the capabilities of any fire department using conventional firefighting methods. As a general rule, if the sprinklers do not succeed during the very early stages of a fire, nothing else is going to stop the fire from consuming the entire facility.

It is equally important for firefighters to recognize the risk factors associated with this type of facility. The environment inside a mega-warehouse is vastly different from the types of buildings where most conventional fire suppression operations are conducted, and the risk factors are much greater. A very cautious and conservative approach is recommended for this type of incident.

It is essential for fire departments to become very familiar with any mega-warehouse facilities that exist or are planned in their response areas, including the contents, storage arrangements, and materials handling systems. It is also essential for fire departments to understand all of the fire protection systems that are incorporated into each facility; a basic familiarity with sprinkler systems is far from sufficient preparation for response to a fire in one of these facilities.

Introduction

On March 15, 2022, a fire of unknown origin completely destroyed a mega-warehouse and order fulfillment center in Plainfield, Indiana. The magnitude of the fire and the resulting property loss, which is estimated to be in excess of $500 million, makes this an exceptional incident. If the total economic and social impacts are considered, the resulting loss is considerably greater. The fire also had observable environmental impacts within the surrounding area.

This incident occurred in a relatively new building that was protected by state-of-the-art fixed fire protection systems, including automatic sprinklers, dedicated fire pumps and water storage, as well as sophisticated smoke detection and alarm systems and a 4-hour rated fire wall. Despite this major investment in engineered fire protection that was designed to protect the building and its contents, as well as the occupants, the outcome was a total loss.

A wide range of interests are involved in the design, construction, operation and protection of large storage occupancies. An incident of this magnitude prompts each of these interests to question what could have gone wrong to cause the total loss of a facility that was thought to meet or exceed all of the currently applicable fire protection standards.

This incident is especially concerning to the fire service, because unanticipated rapidly changing fire conditions placed several firefighters in imminent danger, resulting in a MAYDAY event. Fortunately, all of the firefighters as well as an estimated 565 employees, were able to evacuate the building without injury.

In addition, it has been questioned whether the actions of firefighters at the scene of the incident were appropriate and whether operational errors, misjudgements, or a lack of training could have contributed to the loss.

This incident analysis is intended to identify the critical factors that contributed to the unanticipated and undesirable outcome. The objective is to identify lessons and provide important information that should be broadly shared among all of the organizations, interests, and individuals that are involved with this type of risk. It is not intended to establish blame or responsibility, but simply to develop an understanding of what actually occurred and to make that information available for educational purposes.

This report does not address the origin and cause of the fire. This subject was addressed through a very extensive and detailed investigation by the appropriate authorities. The time and location of the fire origin were obtained from the investigative report; however, the cause of the fire was not determined.

Mega-warehouses

The generic classification of mega-warehouse includes a variety of large storage and distribution buildings, generally exceeding 200,000 ft^2 in area. These buildings are typically stand-alone single-story structures, surrounded by open spaces that are used for parking and truck access. The most common distinguishing characteristics are non-combustible construction and very large open areas with high overhead clearance. These buildings are almost always protected by automatic sprinkler systems that are designed to protect whatever contents are expected to be stored and handled within that large space.

Large warehouses and storage facilities are not a new phenomenon; however, the number and size of mega-warehouses and similar structures have both increased significantly in concert with the evolution of supply and distribution chains and especially e-commerce. It is estimated that thousands of buildings meeting the generic description of a mega-warehouse have been constructed in the past 20 years and many more are planned.

Many of these facilities have been constructed in suburban and rural areas, as well as small communities, where it is geographically advantageous to meet the demands of different business and distribution models. In many cases the public fire protection resources in these areas are very limited and the local fire services are faced with new and unanticipated challenges.

Building codes generally permit storage buildings to be constructed with unlimited floor areas, if the construction is classified as non-combustible or fire resistive, they are protected by automatic sprinklers and surrounded by open spaces. There is a presumption that the engineered fixed fire protection systems will be capable of controlling any foreseeable fire that could occur in these buildings.

The level of fire risk in a mega-warehouse is primarily associated with the contents. Many of these facilities contain massive quantities of highly combustible goods that create the potential for extremely large and rapidly developing fires. This level of fire risk would be unacceptable if the buildings were not provided with sprinkler systems that are specifically designed to react quickly and control fires before they become uncontrollable.

If the fixed fire protection systems fail to control a fire, it is recognized that it would quickly exceed the capabilities of any public fire department. Although these facilities do not depend on fire departments to have the ability to control a fire, the local fire department will almost always be called upon to respond and take action if a fire does occur. Even if the fixed fire protection systems have succeeded in controlling a fire, the firefighters will often be needed to complete the extinguishment of the fire. In addition, they will have to address overhaul, ventilation, debris removal, and loss mitigation. If the fixed systems have not controlled the fire, responding firefighters are likely to be faced with a situation that far exceeds their capabilities.

The interior of a mega-warehouse is very different from the environments where most fire departments are used to operating. These facilities are likely to involve a wide variety of challenges and risks that are much more complex and larger in scale than the typical buildings in most communities. A solid foundation of training, standard operating procedures, and years of experience fighting fires in residential and small commercial buildings will not prepare firefighters for the operational challenges that are likely to be encountered in these buildings. Unfortunately, most fire departments have had very little training to prepare for operations in mega-warehouses.

In many cases, firefighters have very limited awareness or information with respect to the contents of these buildings, the activities that are conducted inside, and the details of the fire protection systems. When a fire occurs, the fire department becomes responsible for the operations that need to be conducted and for the health and safety of everyone involved, including employees and visitors, firefighters and other emergency responders, as well as the general public. If things do not go well, lives may be lost, millions of dollars worth of property may be destroyed, and the overall impact on the community, the environment and the economy may be immense.

Several of the fire risk and fire protection factors that apply to mega-warehouses are shared with big-box retail outlets, such as retail building supply and hardware outlets. These buildings also tend to be very large in area with high overhead clearance and contain very large quantities of combustibles. The major difference with big-box retail occupancies is that they are open to the public, so the potential life safety risk is typically much greater. They also tend to be located in more densely developed areas.

Applicable Codes

The Indiana Fire Prevention and Building Safety Commission is responsible for adopting and enforcing a statewide system of fire safety and building laws. The applicable codes are adopted at the state level and cannot be amended locally. Code enforcement at the local level is conducted under delegated authority. The codes applicable to this facility are the 2012 editions of the International Building Code (IBC) and the International Fire Code (IFC).

The Indiana State Fire Marshal is appointed by the Governor and serves as the director of the Division of Fire and Building Safety within the Indiana Department of Homeland Security. The Fire Marshal is responsible for overseeing fire prevention and protection services throughout the state. The State Fire Marshal also has oversight of the Indiana Fire and Public Safety Academy, fire and explosion investigations and the radiation and hazardous materials sections.

Plainfield Fire Territory

The Town of Plainfield has a population of over 35,000 and is located just west of Indianapolis International Airport. This is a rapidly developing area, which has become a regional center for logistics, distribution, and e-commerce with over 70 large warehouses and distribution facilities and several more in the planning and construction phases.

The Plainfield Fire Territory (PFT), which includes the Town of Plainfield and adjacent areas of Guilford, Liberty, and Washington Townships, operates three fire stations. It is the busiest fire department in Hendricks County; in 2022, PFT responded to more than 8,500 incidents. Almost 70% of those calls were emergency medical responses.

The services provided by PFT include fire prevention, fire suppression, emergency medical services, hazardous materials response, and technical rescue.

The PFT organization structure includes:

- Fire Chief
- Deputy Chief of Operations
- Deputy Chief of Administration
- Division Chief of Fire Prevention/Fire Marshal
- Division Chief of Emergency Medical Services
- Division Chief of Support Services

At the time of the incident, PFT was staffed by 88 career personnel and operated three engine companies, one ladder company, three transporting medic units and one squad, under the direction of an on-duty battalion Chief. Emergency response personnel worked on rotating shifts of twenty-four hours on-duty and forty-eight hours off-duty. All engine and ladder companies had four crew members assigned on each shift, but often operated with only three personnel on duty. The squad was staffed with two personnel who normally attached themselves to the ladder company at a fire incident.

The fire departments in and around Indianapolis participate in a regional automatic response and mutual aid system. This ensures that the closest units are assigned to emergency incidents, without regard to jurisdictional boundary lines. The regional system provides coordinated communications and utilizes standardized operating procedures.

The Plainfield Fire Territory also participates in the Hendricks County Rescue Task Force through the Hendricks County Fire Chiefs Association.

The Fire Prevention staff includes the Division Chief and two full-time Fire Prevention Officers who are also qualified as fire investigators. They are supplemented by qualified fire suppression personnel who are assigned as needed.

The Fire Prevention Division conducts annual code enforcement and educational inspections of all existing non-residential occupancies. Fire prevention education programs are conducted at a variety of locations including schools, day cares, hospitals, and nursing facilities. NFPA 1730 is used as a reference for determining inspection policy, procedure, and frequency.

The Fire Prevention Division, is also responsible for plans review, construction site inspections, and sprinkler and fire alarm testing for new installations. All new buildings receive a certificate of occupancy from the Fire Prevention Division as well as the Plainfield Building Department. These functions are coordinated through an online permit management system.

The PFT Fire Prevention staff members were familiar with the facility where the incident occurred. They had conducted regular code enforcement inspections since the facility was constructed, working closely with the occupant's loss prevention personnel. There were no known code enforcement issues at the time of the incident.

Operations units conduct familiarization and pre-fire planning visits in the larger facilities in the territory. This is a challenge with more than 50 million square feet of non-residential buildings under roof, while also responding to more than 6,000 emergency calls each year.

Most of the responding on-duty personnel were somewhat familiar with the facility where the incident occurred. PFT units had responded to several calls at the facility over the preceding years; however, there had been only one reported fire in the building. The previous event involved a trash compactor and occurred only a few weeks prior to the fire that destroyed the facility.

The PFT training program included exercises and simulations at some of the larger facilities within the response area. An exercise of this type, involving mutual aid units, was concluded at a nearby facility shortly before the incident occurred. A large-scale simulation had been scheduled to take place a few days after the incident in another facility.

Description of the Facility

The building where this incident occurred was constructed in 2014 as a shell building that could accommodate a wide variety of occupants. A twin building was constructed on the same property and subsequently leased to the same occupant.

The exterior dimensions of the building were 1,760′ in length (north-south) and 650′ in width (east-west), providing a total of 1,144,000 square feet (ft^2) of floor area. A four-hour rated fire wall was positioned slightly north of the mid-point, dividing the interior into two large sections.

Figure 1: Aerial view from the west side of the building.

2a

Figures 2a, b, and c: Aerial view of the building looking toward the north-east. The pump house and fire protection water tanks are visible near the south-west corner.

2b

2c

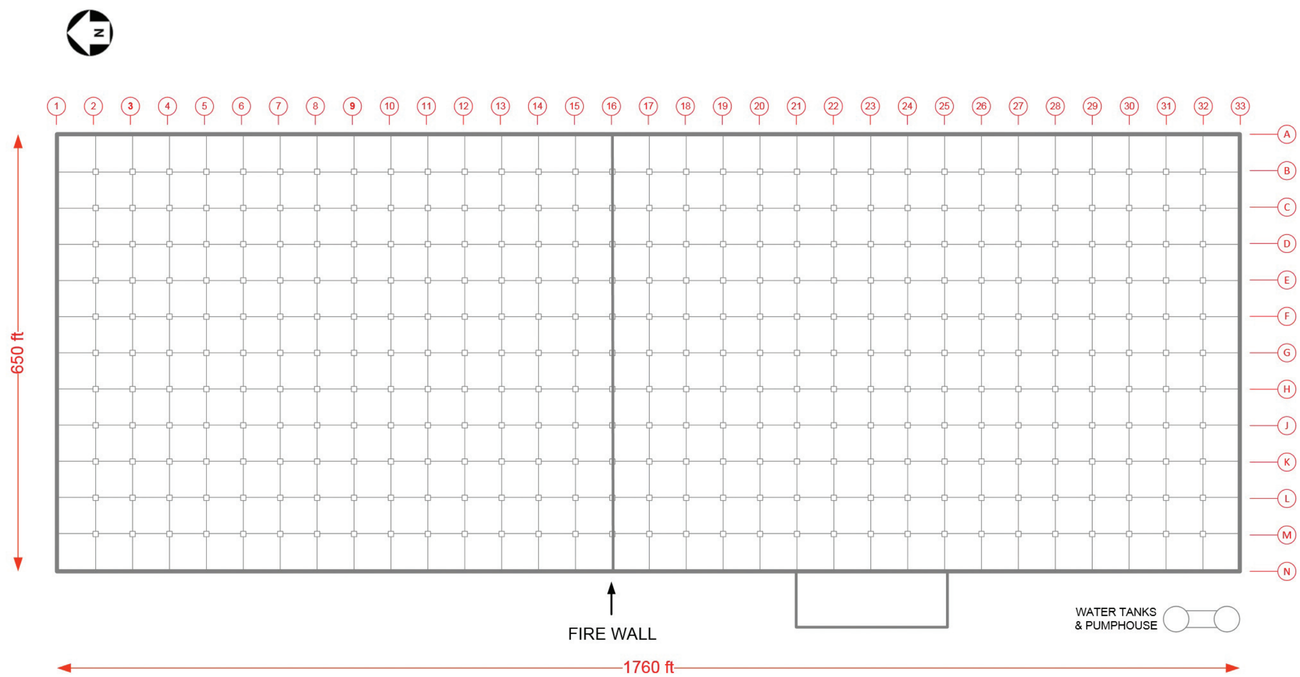

Figure 3: The roof was supported by unprotected steel trusses and columns that were arranged in a grid. Each grid square represents 2,862 ft^2, measuring 54' in the east/west direction X 53' in the north/south direction.

The construction was classified as Type II, non-combustible. The floor was concrete and the exterior walls were precast tilt-up concrete panels insulated with foam plastic cores. The roof was 20-gauge steel deck, supported by unprotected steel trusses and columns.

The roof deck was approximately 45' above the concrete floor, while the open space under the trusses was approximately 40' in height. The roof was covered with four inches of foam plastic insulation (polyisocyanurate) and an elastomeric membrane (thermoplastic polyolefin).

The building was surrounded by paved yards and parking areas. There were 100 truck loading docks for receiving and shipping, as well as large parking areas for trucks and employees.

The Building Code allowed for the building to be constructed with unlimited area, based on non-combustible construction with automatic sprinklers and surrounded by open spaces. An ESFR (early-suppression fast-response) sprinkler system and water supply were installed when the building was constructed to meet the code requirements and to accommodate the type of fire load that could be anticipated in this type of storage building.

The shell building was leased to a large retail corporation as a very large unoccupied space. All of the interior office and support spaces, as well as storage systems and conveyors, were added as tenant improvements to meet the needs of the operation. Additional sprinkler and fire protection systems were installed to protect these installations.

The facility was operated as an order fulfillment center, where individual customer orders were assembled and shipped. It was designed to process orders that are placed through the company's website. The company operates several similar facilities that are distributed across North America and in other countries to support rapid delivery objectives. Several other companies operate similar facilities using similar order fulfillment processes.

The company's website offers a huge variety of items for sale and tens of thousands of different products were in storage, on shelves and in movement within the building. There was a constant flow of merchandise arriving from suppliers and outbound shipments to customers. This facility handled small and lightweight items that could be manually selected and packaged. The twin building to the west handled larger and heavier items.

The operation was highly automated; however, as many as 1,000 employees worked at the facility during the peak seasons. The specific items that were needed to fulfill an order were manually selected from shelves in storage racks. The order processing system directed an employee to go to a particular shelf at a particular location to select an item and place it in a plastic bin. Multiple items ordered by the same customer could be placed in the same bin or an order could involve items that were picked from different areas of the warehouse and placed in different bins.

The bins were then placed on conveyors which transported them to the packing and shipping area. After packaging and labelling, each shipment was placed on a different conveyor system that delivered it to the appropriate outbound truck at a designated loading dock. These systems had the capacity to process thousands of shipments per hour.

The area where individual items were selected to assemble an order was known as the Pick Module. This was a massive multi-level steel rack structure that was constructed within the shell building. The Pick Module occupied a ground floor area of 801′ 6″ X 347′-10″ or a total of 278,761 ft^2.

The Pick Module occupied most of the section of the building that was south of the fire wall. The packaging and shipping areas were on the north side of the fire wall, as well as bulk storage of products that would be used to restock the Pick Module. The inbound shipments generally arrived as pallet loads that were stored in a separate racking system.

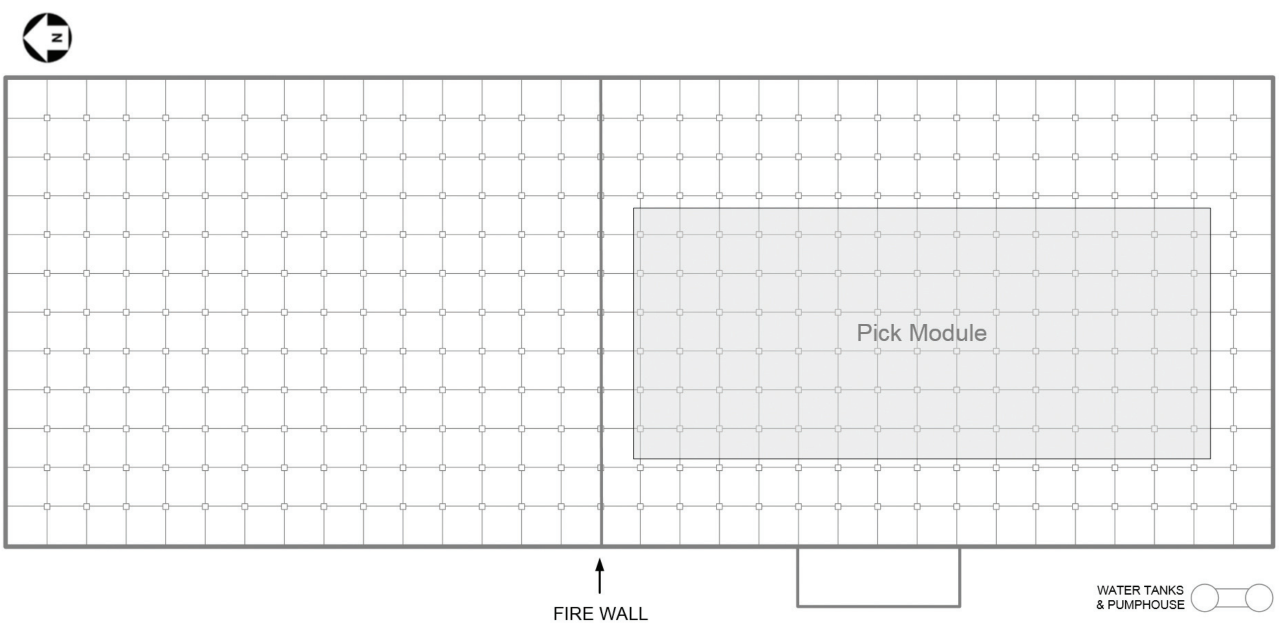

Figure 4a: The Pick Module occupied most of the section of the building south of the fire wall.

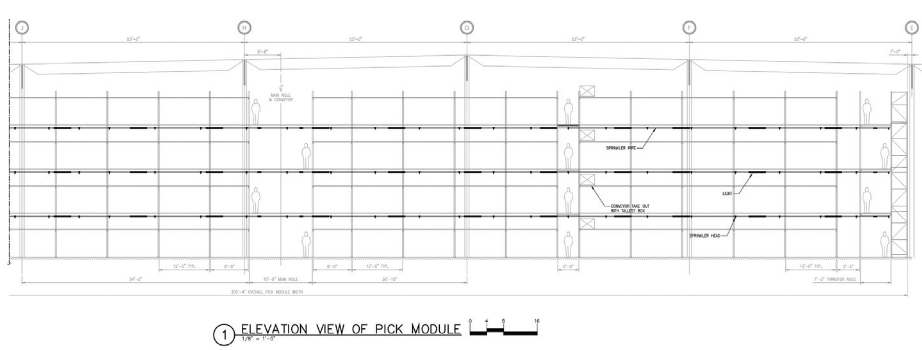

Figure 4b: Pick Module cross-section

Figure 5: The Pick Module included 1.1 million square feet of floor area on 4 levels.

The Pick Module structure was 39′- 4-1/2″ in height and incorporated three full mezzanines that were vertically separated by 10′-6″. This created the equivalent of a very large four-story warehouse within the shell building; however, it was constructed of racking materials and did not have its own exterior walls or a roof. The four storage levels within the Pick Module added up to approximately 1.1 million square feet of floor area.

The three mezzanines were constructed of prefabricated steel decking, which is often described as "Q-decking". An engineered wood-composite material (Resindek) was attached to the steel decking in the aisles and other walking areas, allowing merchandise carts to be rolled easily. Aside from these areas, the steel decking was exposed on both sides.

The Pick Module structure was erected in two phases that were separated by a gap of ten feet running from north to south. Bridge sections linked the expansion area to the original structure at nine locations on each level.

On each level of the Pick Module there was a system of aisles that were lined on both sides with shelving that contained the tens of thousands of different items that could be ordered from the facility. The same basic floor plan was repeated on each level, with 87 east-west aisles in the original structure and four north-south aisles in the expansion area. The aisles were 5′-2″ wide in the original sections and 4′-6″ wide in the expansion area. The total length of all the aisles in the Pick Module was more than 20 miles.

On each level there was a wide central north-south aisle and two smaller parallel aisles. The central aisle incorporated two conveyors; one to transport the filled plastic bins to the packing and shipping area and the other to return the empty bins. Each of the smaller aisles incorporated a conveyor that was used to remove empty cardboard cartons. These conveyors emptied into large compactors that were located on the ground at the southern end of the structure.

There were wider north-south aisles on the east and west sides of the Pick Module that were used to distribute arriving merchandise and place it on shelves in the picking aisles. Lift platforms, which were used to move stock from the ground floor up to the level where it would be stored, were located on the perimeters of the Pick Module.

Most of the items that were stored on the shelves of the Pick Module were stored in cardboard cartons that opened toward the aisles to allow for individual items or packages to be easily picked and placed in the plastic bins.

The shelving sections between the aisles were 48″ deep to allow for two 24″ deep cardboard cartons to occupy each space, with one side of each carton open to an aisle. Some smaller items were stocked in individual packaging and placed on the shelves. There were no vertical spaces or separations within the shelving sections. The shelves themselves were metal grilles to allow for water from the sprinkler systems to pass through to reach the lower shelves.

The shelves were set at the same levels throughout the Pick Module. The specific dimensions were established to accommodate different sizes of cartons. The bottom shelves were positioned approximately four inches above the steel mezzanine deck and the higher shelves were separated by 20″, 24″, 12″ and 18″. The top shelves were open to the underside of the deck above with a vertical clearance of approximately 48″.

Figures 6 & 7: Employees selected items from the shelves that lined both sides of the picking aisles.

Figures 8 & 9: Larger aisles were provided to distribute arriving merchandise to stock the shelves.

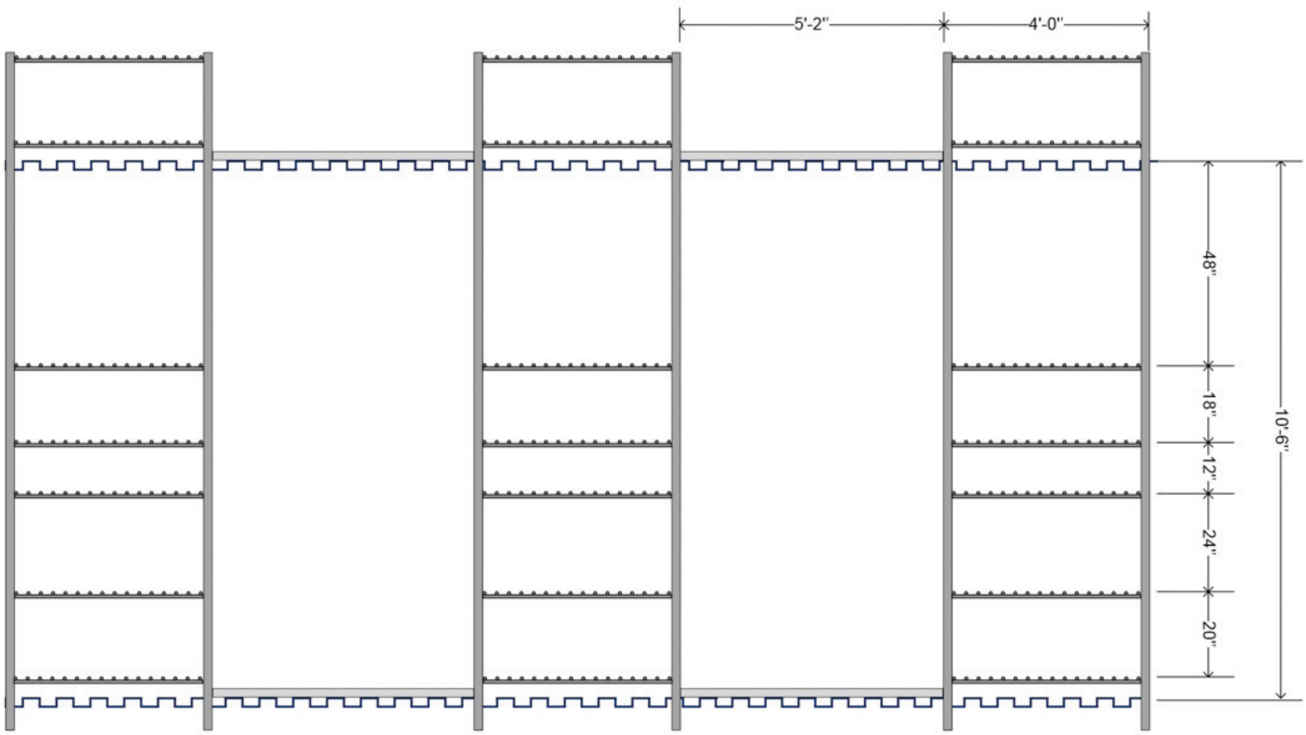

Figure 10: Cross-section of typical Pick Module configuration.

The inventory control system kept track of the items that were placed on each shelf, and when it was time to replenish the stock. The human order pickers were directed to the appropriate locations to obtain the items that were required and place them in the plastic bins.

The same system kept track of the availability of shelf space, so items arriving at the Pick Module were directed to locations where there was space of the required dimensions available.

In order to maximize the efficient use of space, there were very few designated locations for the storage of specific items. In general, any item that was available for sale could be found on any shelf, in any location, at any time. The exceptions were particularly high value items, which were limited to areas with higher security, and highly flammable items, such as aerosols and motor oil, which were stored in designated areas with special fire protection systems.

The combination of packaging materials and the stored goods themselves represented a very significant fire load throughout the Pick Module. The materials on the shelves were generally tightly packed with exposed surfaces that were easily ignitable.

Chapter 32 of the International Fire Code establishes fire protection requirements for High Piled Combustible Storage which would be applicable to the Pick Module. This requires a detailed engineering analysis of the racking system and the commodities that will be stored within it to determine the specific requirements. This section of the Fire Code refers to NFPA Standard 13 for the detailed requirements for in-rack sprinklers.

The metal decking of the mezzanines did not provide any rated fire resistance that would prevent vertical fire spread from one level to the next. There were many small openings in the steel decking, particularly adjacent to the vertical supports and the columns that supported the roof. The mezzanine decks were also penetrated by several stairways.

Sprinklers were installed at each level, under the mezzanine decking, to protect the contents and the structure. The combination of sprinklers and steel decking created the appearance of an assembly that should prevent a fire on one level from extending vertically to the higher levels; however, this concept has not been tested as fire-rated assembly. The assumptions that were incorporated into the conceptual design could not be determined.

Fixed Fire Protection Systems

The primary fire protection for the facility was provided by automatic sprinkler systems. The applicable standard at the time of construction was NFPA 13 – 2010 edition.

The overall structure was protected by the ESFR (early suppression fast response) sprinklers that were installed at the time of construction of the shell building. Additional CMDA (control mode density/area) sprinklers were installed as part of the tenant improvements. The added sprinklers were installed within the Pick Module and in special hazard areas, as well as offices, conference rooms, and ancillary spaces. Sprinklers were also installed under conveyors and walkways that were more than 4 ft. in width. In the northern section of the building there were additional storage areas that were protected with in-rack sprinklers.

> *ESFR and CMDA refer to the two types of sprinkler systems that are commonly installed in storage occupancies. Conventional sprinklers are intended to control a fire and prevent it from spreading, with the assumption that firefighters will respond and use hose lines to complete the extinguishment of the fire. While in many cases the sprinklers do completely extinguish the fire, the design objective is control.*
>
> *Conventional sprinkler systems in storage areas are classified as CMDA – control mode density area – because they are designed to discharge a particular density of water application (gallons per minute per square foot or gpm/ft^2) over a defined area. The density and area requirements are based on the fire load and characteristics of the protected area. The required density of water application increases in proportion to the anticipated rate of heat release from a fire. In order to control a fire, the water discharge must have the capability to absorb heat at the rate it is being released by the fire.*

Prior to the development of ESFR sprinklers, conventional systems with large orifice sprinklers were commonly used in large warehouses to provide high density water discharge over a specified design area. Higher temperature sprinklers were installed at the ceiling level to slow the reaction time in order to limit the number of heads that would open in a fire. If too many heads opened, the available water would be distributed over a larger area and the density of application could fall below the level that was needed to control the fire. The higher temperature heads provided more time for the closer heads to control the fire before more distant heads opened.

As warehouses became larger and higher and contents became more readily combustible, conventional sprinklers were found to be incapable of controlling rapid growth fires. These high-challenge fires would overwhelm the capabilities of the initial discharge, leading to more heads opening, which decreased the water discharge density below the level that was needed to control the fire. This led to the development of ESFR sprinklers, specifically for large storage occupancies.

The designation ESFR – early suppression fast response – refers to sprinkler systems that react quickly and discharge a very high flow of water within a limited area to overcome high challenge fires. In simple terms, they are intended to hit a fire hard and fast, before it becomes too large to control. The ultimate objective is not simply to control the fire, but to actively suppress it, by absorbing thermal energy (i.e. heat) at a higher rate than it is being released by the fire.

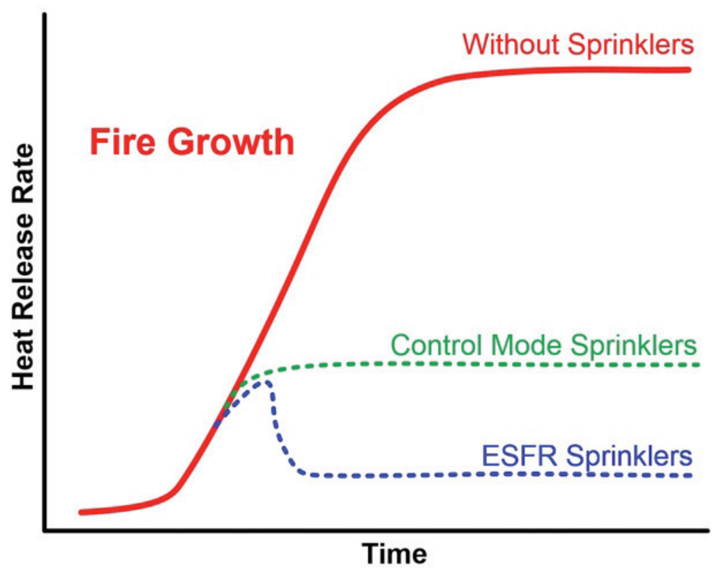

Figure 11: Comparison of anticipated fire growth without automatic sprinklers, compared to the same fire with Control Mode and ESFR sprinklers.

The expectation of fire department response to complete extinguishment of the fire with hose lines applies to both ESFR and CMDA sprinkler systems. It is anticipated that some residual combustion will remain within the fire area, despite the water application from the sprinklers, and that overhaul will be required to ensure that the fire has been fully extinguished.

The following diagram illustrates conceptually the anticipated impact of Control Mode versus ESFR sprinklers.

ESFR Sprinklers

Due to the size of the building, there were 30 ESFR systems, each covering approximately 38,000 ft^2 of gross floor area. Each of these systems was supplied with water from a separate riser. Risers 1 through 15 were located along the east wall of the building and risers 16 through 30 were located along the west wall. Most of the risers were grouped in pairs, fed by a common underground connection. Wall indicator valves allowed the water supply for each riser to be controlled from the exterior of the building.

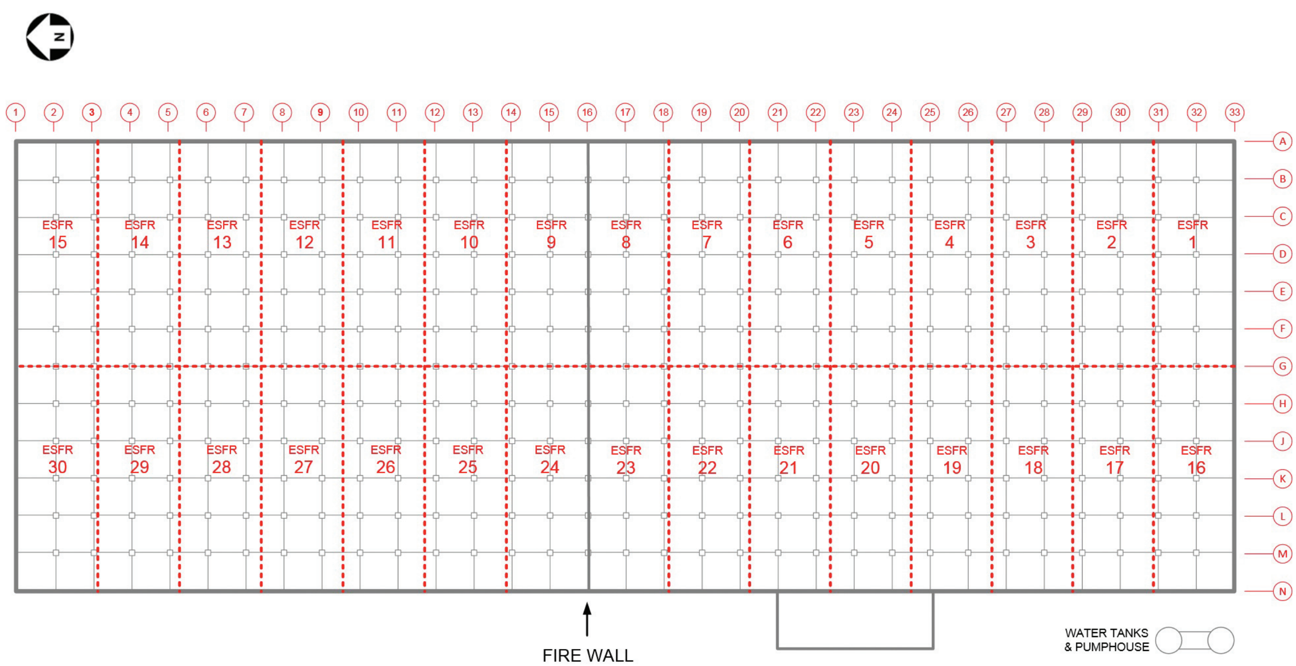

Figure 12: ESFR risers 1 to 15 were located on the east side of the building, while risers 16 to 30 were on the west side.

The ESFR sprinklers were installed approximately one foot below the underside of the steel deck roof. The sprinklers were arranged on a grid of approximately 10' X 10', so each head covered approximately 100 ft^2 of floor area.

The hydraulic calculations were based on ten ESFR sprinklers operating at a minimum discharge pressure of 50 pounds per square inch (psi). The sprinklers had an operating temperature of 214° F and a K-factor of 25.2, so at the minimum discharge pressure of 50 psi a single head would flow 180.3 gallons per minute (gpm). This translates to a minimum density of 1.8 gallons per minute per square foot (gpm/ft^2) over an area of 1,000 ft^2.

The calculated demand for the most remote ESFR system was 2,075 gpm, plus an additional allowance of 250 gpm for hose streams. A discharge pressure of 122 psi was required at the pump house to meet this demand. The water supply information indicates that each fire pump could meet this demand at over 150 psi, providing a considerable buffer above the minimum requirements. The first ESFR sprinklers to operate probably would have flowed between 200 and 250 gpm, delivering more than 2.0 gpm/ft^2 in the area directly below.

Pick Module Sprinklers

The Pick Module sprinklers were installed when the multi-level shelving system was constructed inside the shell building. Because of the mezzanines, the ESFR system could only protect the top (4th) level, so additional sprinklers were installed under each mezzanine deck.

Eight CMDA sprinkler systems were added to protect the three lower levels of the Pick Module. Each of these systems was supplied an additional riser, four on the east side of the building and four on the west side. These risers were identified with the number of the adjacent ESFR riser and the letter A.

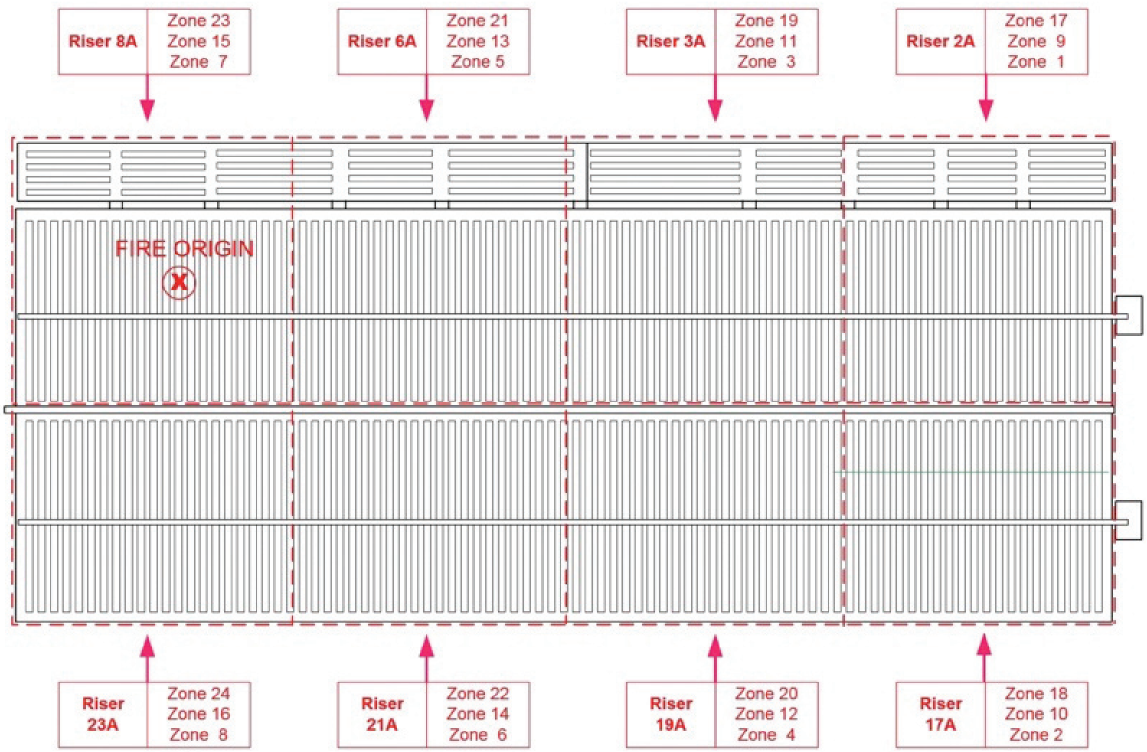

Figure 13: The Pick Module was protected by eight CMDA sprinkler systems. Each system was divided into three zones to cover the three lower levels of the structure.

Each of the eight risers supplied water to three separate sprinkler zones, one for each level (1st, 2nd and 3rd). Separate control valves and water flow switches were provided for each of these zones. The 24 zone control valves and flow switches were located within the Pick Module structure.

The area of fire origin was on the 2nd level of the Pick Module, within the coverage area of Zone 15. The area directly above on the 3rd level was in Zone 23, and the ground level area immediately below was in Zone 8. Riser 8A, on the east side of the building, provided the water supply for these three zones. The area directly above on the 4th level was covered by ESFR System 7.

The sprinkler systems also supplied water to 2-1/2" fire hose outlet valves on each level of the Pick Module. These outlets could be used by firefighters to connect their hose lines inside the building. There were no hose storage cabinets at these locations.

The hose valves regulated the discharge pressure at 100 pounds per square inch. The hose valves on the 1st, 2nd, and 4th levels were connected to the 3rd level sprinkler zones, while the hose valves on the 3rd level were connected to the 2nd level sprinkler zones. This arrangement was intended to allow for the sprinklers on each level to be shut-off without interrupting the water supply to the hose connections on that level.

The sprinklers within the Pick Module had an operating temperature of 155° F and a K-factor of 11.2. The system was designed to provide a flow of at least 0.3 gpm/ft^2 over an area of 2,500 ft^2. This is a relatively high application density for conventional sprinklers and was based on the anticipated fire load.

Each sprinkler head within the northeast section of the Pick Module covered an area of approximately 9′6″ X 10′, so the design calculations were based on 29 sprinklers operating within a coverage area of 2,535 ft^2.

The calculated demand for Pick Module sprinklers anticipated a total flow of 955.5 gpm, plus an allowance of 500 gpm for hose streams. The pressure required to meet this demand was 83 psi at the pump house. Each of the two fire pumps had the capacity to deliver 2,500 gpm at 150 psi or more than 3,500 gpm at 83 psi; this greatly exceeded the calculated demand for the Pick Module sprinklers.

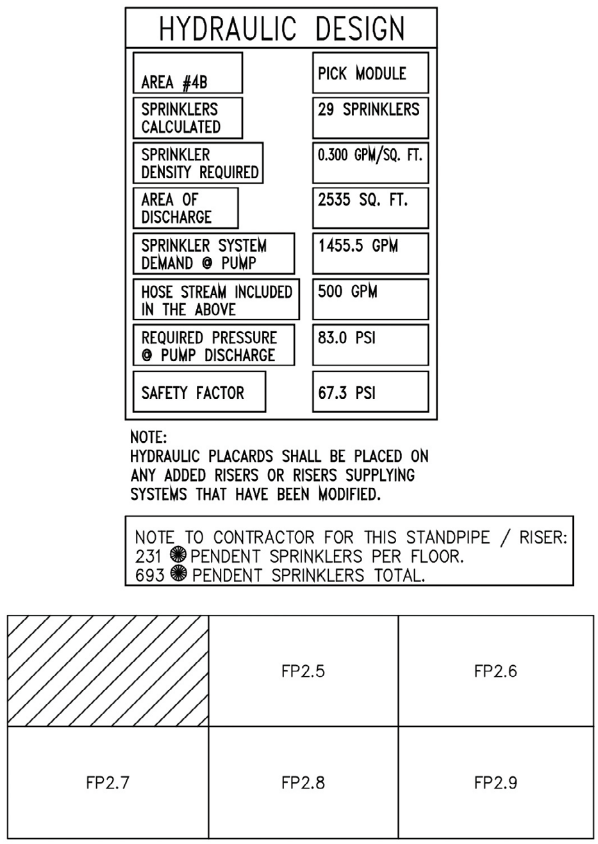

Figure 14: The three lower levels of the Pick Module were protected by CMDA (control mode) sprinklers. The top level was covered by the ESFR sprinklers that were installed when the building was constructed.

The minimum flow that was required from each sprinkler head to meet the design density requirement would have been approximately 26 gpm; however, with the additional pressure provided by the fire pumps the flow would have been considerably higher. The first heads to operate probably would have discharged approximately 135 gpm. With 29 heads in operation, the total flow would have been close to 1,300 gpm.

The calculations that were submitted with the sprinkler plans assumed that all of the 29 operating sprinklers would be on the same level of the Pick Module. The calculations did not contemplate that sprinklers on multiple levels of the Pick Module or a combination of Pick Module and ESFR sprinklers, would be operating simultaneously. This suggests that it was assumed that a fire would be confined to a single level of the Pick Module.

The sprinklers were positioned in the aisles, between the sections of shelving, and below the steel decking. This allowed the discharge pattern to cover the faces of the shelves, as well as the top of the storage in each shelving section.

The discharge pattern from the pendant sprinklers was directed downward onto the stored merchandise. They did not direct any discharge upward against the underside of the steel mezzanine decking or to cover any of the openings in the decking.

The shelves were constructed of open steel grating to allow water from the sprinklers to flow down to reach the goods that were stored on the lower shelves; however, the tight packing of goods on the shelves would tend to limit the amount of water that could reach the lower levels.

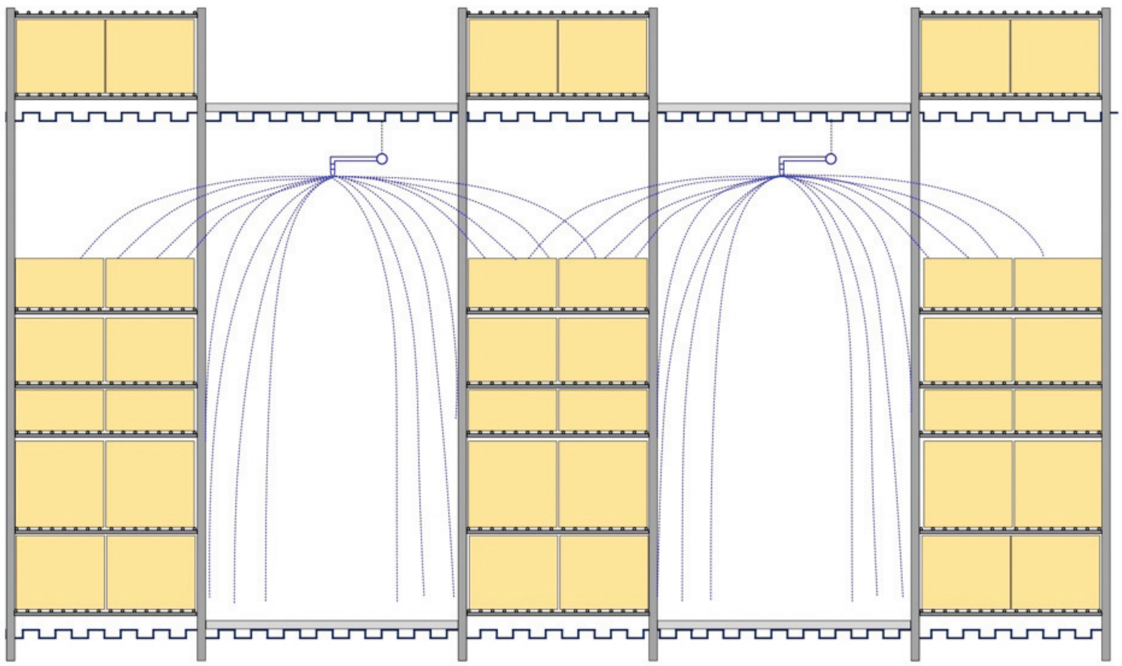

Figure 15: The Pick Module sprinklers were positioned to discharge water onto the top level of the stored goods and to cover the vertical faces on each side of the aisles.

The sprinkler plans indicate that the deflectors of the pendant heads were positioned 32″ above the top shelves. The maximum height limit of 12″ for boxes stored on the top shelves provided for a minimum clearance of 20″ to avoid obstruction of the sprinkler discharge pattern. In storage areas it is always important to ensure that there are no tall items encroaching on the required space and blocking the sprinkler distribution pattern.

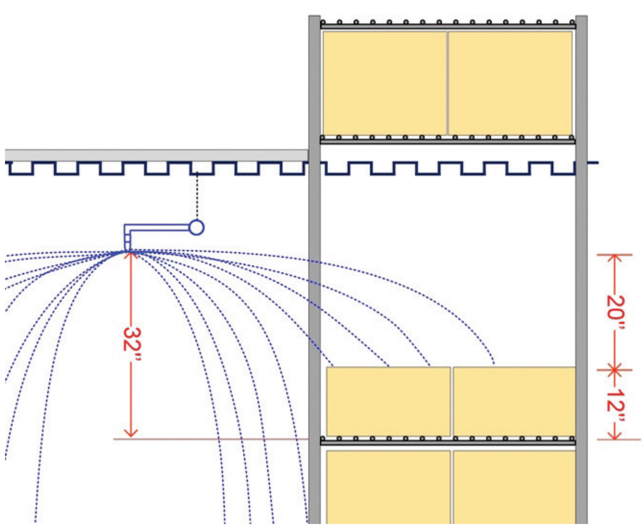

Figure 16: The 12″ height limitation for goods placed on the top shelves was required to provide 20″ of unobstructed space for the sprinkler discharge pattern.

Additional Sprinklers

Additional sprinklers were installed in offices and ancillary spaces, under the many conveyors and walkways in different parts of the building. Riser 23B controlled an extra-hazard system that covered a segregated area on the west side of the building where aerosol products were stored. Another extra-hazard system protected a small area that was reserved for motor oil storage.

Overall, the sprinkler systems protecting the property incorporated 39 individual risers and at least 24 zone control valves.

Water Supply

The fire protection water supply for the property was established when the shell building was constructed to meet the demand of the ESFR sprinkler systems. The same pumps and storage tanks also provided the water supply for the sprinklers in the neighboring building that was essentially a twin of the building where the fire occurred. The additional sprinkler systems that were installed as tenant improvements were connected to the same water supply.

There was no direct connection between the municipal water system and the fire protection systems in the building. Two large water storage tanks, each with a nominal capacity of 300,000 gallons, were located near the southwest corner of the building.

This configuration was based on the expectation that the municipal water system could not deliver the flow that was required to support the ESFR sprinklers. A 10-inch underground connection to the municipal system was configured to fill the two storage tanks. If the water in the tanks was being used, this line had the ability to deliver between 1,000 and 1,500 gallons per minute to refill the tanks.

The construction plans indicate that the 10-inch supply line was divided into two 6-inch fill lines, one for each tank. Float valves were installed on these lines to regulate the flow into the tanks.

At some time after the original construction, a 3-inch pressure regulated fill line was added for each tank. These lines were controlled by valves that opened or closed, based on the static pressure exerted by the water in the tanks. The new valves were connected in parallel to the original fill lines. It appears that the 6-inch fill lines were closed and the float valves were removed when the new fill lines were added.

The pump house was located between the two storage tanks and divided into two sections by a fire wall. The primary electric pump and its associated equipment were located on the north side of the fire wall, while the back-up diesel pump and its associated equipment were on the south side. A common intake manifold allowed water from both storage tanks to flow to either fire pump, so the combined storage capacity of 600,000 gallons was available to both pumps.

The primary and back-up fire pumps were each rated to supply 2,500 gpm at 150 psi, so either pump could supply the full calculated demand for the building's fire protection systems. The controls were arranged so that the electric pump would start automatically if there was a pressure drop in the system, indicating that water was flowing. If the electric pump failed or was off-line, the diesel back-up pump would start automatically.

There were also two jockey pumps, a primary and a back-up, to maintain pressure on the fire protection systems. The system pressure was maintained at approximately 150 psi.

The combination of two fire pumps and two storage tanks provided a fully redundant on-site water supply. The 600,000 gallons of stored water could provide a flow of 2,500 gallons per minute for more than four hours. The connection to the municipal system was configured to continually refill the tanks as water was being used, extending the duration well beyond four hours.

The two fire pumps were connected in parallel to a 12-inch underground fire main that looped around the building. The loop main provided water for the 39 sprinkler risers, as well as 20 private yard hydrants on the property. There were 16 separate 12-inch underground connections from the loop main to the building; most of the underground connections provided water to two or three grouped sprinkler risers, as well as fire hose valves that were positioned near many exit doors.

A fire department connection was located on the street frontage near the southwest corner of the building. This line was connected to the fire pump discharge header so that an additional pumped water supply could be provided from a hydrant on the municipal system to the private fire main.

The pump capacity curve indicates that the water supply with one fire pump in operation would have been capable of supporting the design requirement of ten ESFR sprinklers, with the allowance of 250 gpm for hose streams. Each pump also had sufficient capacity to support a total of at least 30 CMDA sprinklers within the Pick Module, whether they were located on one level or on multiple levels, with an allowance of 500 gpm for hose streams.

The figures indicate that if the full calculated flow for the Pick Module sprinklers was being used, only a limited number of ESFR sprinklers could be supplied. If the full ESFR demand was being used, only a limited number of Pick Module sprinklers could be supported. These conclusions were reached by interpretation and interpolation of the data that was provided when the plans were submitted.

Smoke Detection System

An air-aspirating smoke detection system (VESDA = Very early smoke detection and alarm) was installed within the Pick Module to provide early detection of an incipient fire. A series of small aspiration tubes captured ambient air in many different locations and transported it to detection units. Each detection unit used laser to monitor the air flow for traces of smoke. The sensitivity of each unit could be adjusted independently. If a VESDA unit detected smoke it would immediately activate the building's alarm system and identify the area where smoke was detected.

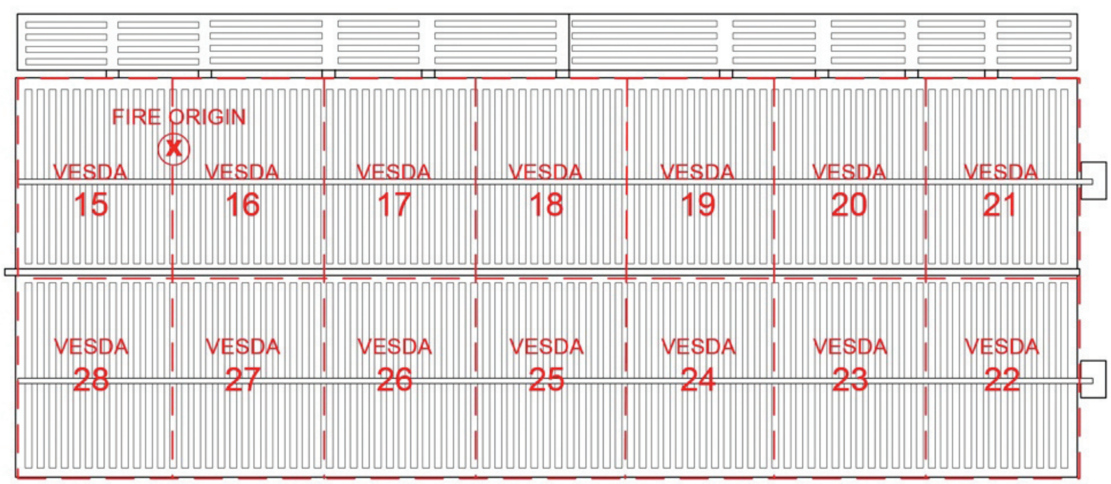

Figure 17: VESDA systems 15 through 28 covered the 2nd level of the Pick Module

Alarm System

The fire alarm system monitored all of the fire protection systems in the building. The primary control panel was located at the security office inside the building and a secondary panel was located in the guard house at the entry to the yard. The entire system was also monitored remotely at a corporate central alarm center in a different state.

A fire alarm activation would initiate audible and visual alarm signals to alert occupants to evacuate the building. It would also shut down conveyors and ventilation systems and cause fire doors to close.

Fire Extinguishers

Portable fire extinguishers were distributed throughout the facility. Most of the extinguishers, if not all, contained A-B-C dry chemical.

Fire Wall

A four-hour fire wall was incorporated into the structure of the building, slightly north of the midpoint. This wall was intended to subdivide the large area into two smaller areas. The area on either side of the fire wall represented the maximum foreseeable loss in the event of a catastrophic fire that had not been successfully controlled by all of the other fire protection systems. A four-hour fire wall is generally considered to be capable of preventing any anticipated fire on one side from spreading to the opposite side.

There were several openings in the fire wall and several conveyors passed through it. All of the openings were protected by automatic closing fire doors that met existing standards. The actions triggered by a fire alarm were sequenced to allow for packages to clear the openings, and then for sections of the conveyors to drop away from the openings before the fire doors closed.

Smoke Control and Exhaust System

The facility was not provided with a mechanical smoke control system or any type of smoke exhaust system. These systems were not required by the applicable codes; however, they would have been permitted to be installed as part of an overall fire protection plan.

Maintenance and Inspections

The facility was well maintained and all of the fixed fire protection systems were regularly inspected and tested. The operator of the facility had an active loss prevention program at the corporate level and engaged qualified contractors to maintain all of the fire protection systems. The Plainfield Fire Territory Fire Prevention staff had a well-established relationship with the on-site personnel who were responsible for loss control and maintenance.

On the day of the fire, the regular testing of sprinkler system flow switches was conducted. This process began at approximately 8:30 am and was completed at around 10:18 am. During this period, the alarm system was placed in test mode at 8:24 am, so that the alarm system would not be activated and the fire pumps would not start-up automatically as the flow switches were tested.

The alarm system was restored to normal status at 10:34:35 am and a full system clear indication was recorded at 11:51:56 am, indicating that all outstanding supervisory events had been resolved after the prior system clear. This was only 24 seconds before the first smoke detection alarm was activated, indicating that there was smoke on the second level of the Pick Module.

Incident Description

Fire Origin

The fire occurred on the morning of March 16, 2022, while the facility was open and operating. The weather was sunny with scattered clouds and an outside temperature of 66° F. The wind was from the southwest at 12 mph.

An exhaustive multi-agency effort was conducted to investigate the cause and origin of the fire. The investigation was led by the National Response Team of the Bureau of Alcohol, Tobacco and Firearms (ATF). The State Fire Marshal's Office, Indiana Arson Task Force, Plainfield Fire Territory, and Plainfield Police Department were also directly involved in this investigation. The specific cause and origin of the fire remain undetermined.

Many of the details included in this report were obtained, with permission, from the ATF investigation report.

The fire was first observed by employees in Section 200 on the 2nd level of the Pick Module. Various witnesses placed the fire in the vicinity of aisles 70 to 75. This would be close to Column 19-F, which was approximately 275' in from the east wall and 165' south of the fire wall.

Several employees noted an odor of smoke shortly before the fire alarm system activated. The first reported observation of the fire was at approximately the same time as the initial alarm activation. Multiple witnesses stated that flames were evident on the face of the shelving on one side of an aisle and reached the underside of the mezzanine decking above. Smoke was accumulating in the surrounding area.

The first smoke detection alarm was registered from VESDA Zone 16 at 11:52:20 am. This was followed by smoke detection alarms from VESDA Zones 15 and 30 within the next 52 seconds. Zones 15 and 16 were on the 2nd level of the Pick Module and Zone 30 was on the 3rd level, directly above.

The first waterflow indication was registered 61 seconds after the first smoke detection, at 11:53:21 am. The alarm system registered north (electric) pump start-up and waterflow indications from Riser 8A and Zone 15 in rapid succession. Riser 8A is the source of water for the sprinklers in northeast quadrant of the Pick Module and Zone 15 covers the 2nd level within that area. The fire pump would have started automatically as soon as a pressure drop was indicated in the fire protection system.

This rapid succession of alarms indicates that the fire was developing very rapidly. Several additional VESDA units and air handlers detected smoke within the following minutes, which is consistent with smoke accumulating and spreading within the Pick Module.

Attempts were made by employees to attack the fire with portable fire extinguishers; however, these efforts were unsuccessful.

This type of rapid fire growth could be anticipated if a fire originated within the stored materials in the Pick Module. Most of the contents were packaged in cardboard cartons that were open toward the aisles. In many cases the inner packaging was plastic bags or other forms of plastics. A fire could be expected to spread upward very rapidly through the open shelving and on the open sides facing the aisles. The quick response sprinklers were intended to interrupt this type of fire growth before it could spread beyond a limited area.

In the aftermath of the fire, there was much speculation relating to the possible involvement of lithium-ion batteries as either the cause of the fire or a major contributor to its rapid growth. No conclusions were reached that either support or refute this possibility. There were lithium-ion batteries in many of the items stored on the shelves, as well as in materials handling equipment that was used in the building. All of these batteries eventually became involved in the fire and were consumed; however, their involvement in the fire's origin and initial rapid growth is unknown.

Initial Alarm

The building's fire alarm system was automatically activated by the first smoke detection indication. The audible alarm system notified all of the employees to evacuate and triggered a sequence of functions that included stopping all of the conveyor systems and automatically closing the fire doors that protected openings in the fire wall.

The alarm system initially operated for 17 seconds before it was manually silenced at the control panel. It was automatically reactivated as additional alarm indications were registered and was manually silenced a second time. After a third activation the audible alarms continued to sound.

Most of the employees self-evacuated to designated areas outside the building, while a few remained to investigate and attempt to control the fire with portable extinguishers.

Notification

The first call to the Hendricks County Emergency Communications Center was made by the corporate central station monitoring center at 11:54:19 am, which was within two minutes after the first smoke detection indication. This call was made to a number that was designated for central station monitoring facilities to report alarm system activations.

A 9-1-1 call from the facility itself was received at 11:56:52 am. The caller reported a confirmed fire on the second level of the building. A full first alarm structure fire assignment, consisting of four engine companies, two ladder companies, a battalion chief and a medic unit, was dispatched at 11:57:58 am.

While the units were en route, the Communications Center transmitted a text message to respond to door 45 on the east side of the building.

Time Sequence[1]:

Black = Radio/telephone recordings

Blue = Event logs/computer systems

11:52:20	Smoke detection VESDA 16 – 2nd level
11:52:37	Alarms silenced
11:53:10	Smoke detection VESDA 30 – 3rd level
11:53:12	Smoke detection VESDA 15 – 2nd level
11:53:21	Fire pump start – electric pump
11:53:25	Waterflow Riser 8A
11:53:39	Waterflow Zone 15 - Pick Module Level 2. (Supplied by Riser 8A)
11:53:53	Smoke detection VESDA 2 – 1st level
11:54:19	Corporate central station calls Hendricks County Communications Center
11:55:55	Alarms silenced
11:56:34	Duct detector activation RTU 30 Rooftop
11:56:52	Call to Hendricks County 9-1-1 from Building Security
11:57:45	Call entered at Hendricks County 9-1-1
11:57:58	First Alarm Dispatch: E123 E121 E143 E122 L121 L84 M122 BC120
11:59:30	Urgent Message to responding units «Enter the yard through E45»
12:00:20	E141 is close by – added to assignment
12:02:33	Duct detector activation RTU 26 Rooftop
12:02:37	Corporate central station comment – CONFIRMED FIRE

[1] The time notations in blue were obtained from the building fire alarm system and corporate central station records. The times noted in black are from the computer aided dispatch system and/or recorded radio traffic.

Fire Department Operations

Several of the units that were dispatched on the first alarm had just completed a training activity at a nearby facility. This resulted in most of the assigned units arriving quickly and in rapid succession.

The first units arrived on scene at 12:03 pm. The first arriving ladder company (L121) proceeded to door 45 and reported that there were no indications of fire or smoke from the exterior. They were redirected by employees to door 38. The first arriving engine company (E121) stopped at the pump house and confirmed that the fire pump was operating, before proceeding to the same location. The second arriving engine company (E123) also proceeded to door 38, while the third arriving engine company (E141) stood by at the fire department connection. The fourth arriving engine company (E122) laid a 5-inch supply line from an off-site hydrant to E123. All of these units arrived within a span of one minute and their actions were based on established standard operating procedures.

The initial entry team, consisting of L121 and E123, entered the building through door 38, which was just south of the fire wall. They encountered moderate smoke inside the warehouse. Ladder 121 reported the smoke condition and declared a working incident at 12:05 pm.

The firefighters were met by employees who directed and accompanied them to the second level of the Pick Module and to within approximately 100 feet from the fire area. At that point, they encountered heavy smoke and began using their self-contained breathing apparatus.

Battalion Chief 120 arrived three minutes later and assumed command of the incident. The command post was positioned in the open area outside door 38.

Within the first few minutes, a company supervisor came to the command post and advised that the evacuation was in progress, but at that time they were unable to account for 55 employees who were presumed to still be inside the building. Smoke conditions inside the building at that time would not have prevented employees from self-evacuating without assistance.

The first hose line to enter the building was a 3-inch "yard line" that was extended from E123 into door 38, This line had to be extended with additional lengths of 2-1/2 inch hose to reach the fire area.

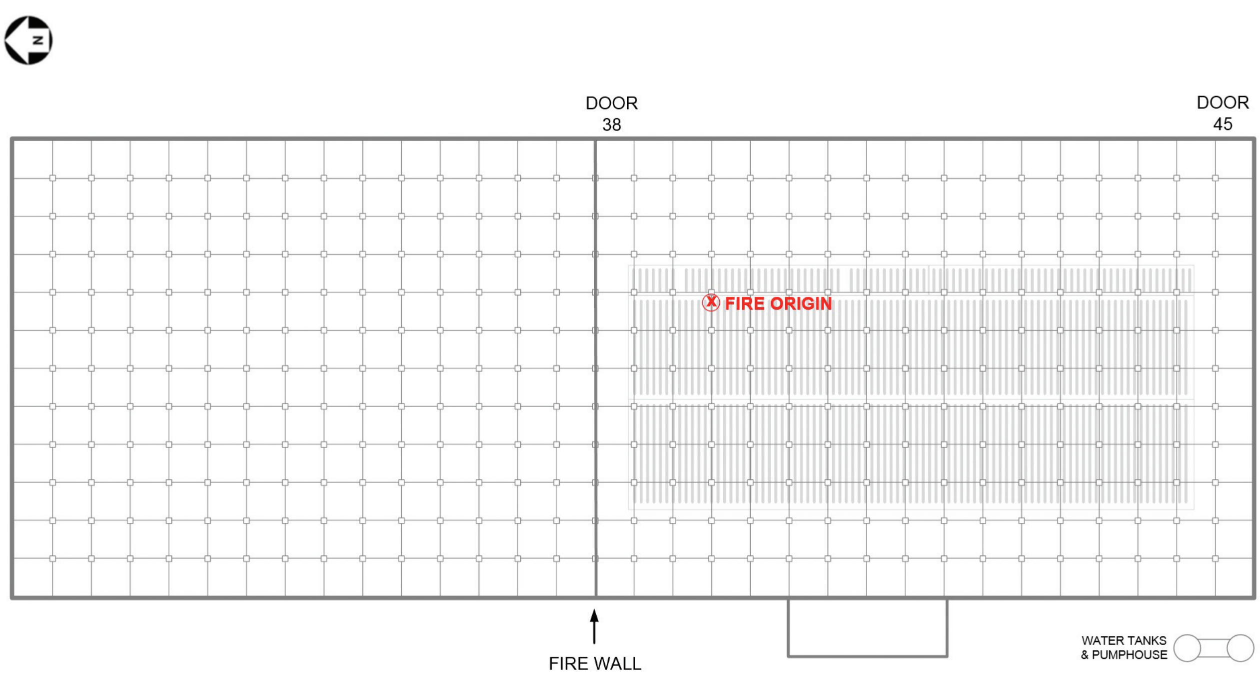

Figure 17: Responding units were originally directed to door 45 and were redirected by employees to enter through door 38. This door was approximately 350 feet from the fire area on the 2nd level of the Pick Module; however, the direct path was obstructed by stored goods and a complex system of conveyors.

While the yard line was being stretched, the firefighters located a fire hose outlet valve on the 2nd level of the Pick Module near the northeast stairway. They connected a 2-1/2 inch hose line to this outlet and advanced it into the smoke-filled area to the south. This line had to be extended with 100 feet of 1-3/4 inch hose to reach the fire area.

The first firefighters reached the fire area at approximately 12:10 pm. They noted that that the sprinklers were operating and had successfully confined the fire to a section of shelving between two parallel aisles. They observed that two or three sprinklers were operating in each aisle.

The fire had involved the goods on all five shelves over a length of 20 to 30 feet. While the fire had been effectively contained by the sprinklers, there were still residual flames within the debris. This is consistent with the expected performance of a control mode sprinkler system. Most of the debris consisted of wet and smoldering cardboard cartons; however, the firefighters could not determine what had been in the cartons.

Visibility in the immediate area of the fire was very limited by the smoke and the discharge of water from the sprinklers; however, there was no sensation of heat. It was impossible to evaluate the fire with a thermal image camera because of the heavy discharge of cold water from the sprinklers.

Between approximately 12:10 pm and 12:23 pm, firefighters operated the 1-3/4" hose line that was connected to the hose outlet valve to complete the extinguishment and overhaul of the fire. This line probably flowed between 150 and 200 gallons per minute during the time it was operated. They were also able to move some of the cardboard boxes that were still burning on the shelves and hold them directly under the sprinkler discharge.

The second hose line, which was supplied by E123, was advanced to the fire area and charged, but it was not needed to complete the extinguishment of the fire. This line consisted of 300' of 3-inch hose, extended with several lengths of 2-1/2 inch hose.

> *The hose valve on the 2nd level of the Pick Module was connected to sprinkler Zone 23 on the 3rd level. A waterflow signal was recorded from Zone 23 at 12:10 pm, so it is likely that this indication was triggered by the opening of the hose valve.*
>
> *The waterflow switch for Zone 23 also would have operated if any sprinklers activated on the 3rd level, above the fire. The fact that there was no flow indication before 12:10 pm establishes that no sprinklers were activated on the 3rd level before that time. There would have been no additional waterflow indication if any sprinklers on the 3rd level activated after that time.*
>
> *An additional waterflow signal was recorded from Zone 7 at 12:13 pm. This zone is on the ground floor, directly below the fire area. It is not known what caused this waterflow indication; however, it is possible that the heat of the fire caused an additional sprinkler head to activate on this level.*

The Incident Commander assigned L84 to check the roof for indications of smoke or fire at 12:14 pm.

While the fire attack was being conducted on the 2nd level, the officer of Engine 121 went to the 3rd level to check for fire extension. He examined the area directly above the fire, both visually and with a thermal image camera, and noted no indications of fire extension. He also noted that no sprinklers were operating on the 3rd level at that time, which would have been between approximately 12:15 and 12:20 pm.

The Deputy Chief of Operations, who had arrived and assumed the role of Incident Safety Officer, also checked the 3rd level from the northeast stairway at approximately 12:20 pm. He also observed no indications of fire or operating sprinklers on that level.

Time Sequence:

12:03:58	L121 on scene – nothing showing – evacuation in progress - investigating
12:04:08	E121 on scene – 1st engine – checking fire pump
12:04:35	E123 on scene – 2nd engine – assisting ladder 121

12:04:42	E141 on scene – 3rd engine – standing by FDC at S/E corner
12:04:59	E122 on scene – 4th engine – establishing water supply
12:05	E121 reports zero visibility inside – Fire on 2nd floor - Entering door E38
	BC80 (Wayne Township) added to assignment
	E121 is at pump room – pump is running
12:06	"We will be about 300 feet inside door E38"
	E123 will be bringing yard line in door E38
12:06:29	Duct detector activation RTU 21 Rooftop
	L121 Declares working incident - will have command for the moment
	Duct detector activation RTU 23 Rooftop
	Working Fire Dispatch: L82 S192 M141 C1220 C1203
12:06:55	Duct detector activation RTU 24 Rooftop
12:08	E121 has secondary water supply at entrance
	L121 to E123 we have a hose drop in here (fire hose connection)
	M122 on scene – 1st medic
	M121 added to assignment – self dispatch replacing M141
	E143 on scene – 5th engine – will take RIC
	BC120 on scene – assuming command
12:09	L84 on scene – second truck
	E123A to B - do you need more yard lay or good to charge it?
	Hold off on yard lay – we are going to hit standpipe
12:10	E122 to E123 - Do not charge the line - we are extending the stretch now
	M121 on scene
12:10:58	Fire alarm activation - Waterflow Zone 23 Pick Mod level 3 (Supplied by Riser 8A)
12:11	M121 on scene second medic
	E121B - I am on the second floor, come on up
12:11:43	Waterflow System 23
12:11:58	Trouble VESDA 48 and Low Water North Tank & South Tank
12:13	BC80 on scene
	E122 - Charge the line
	C1203 on scene – assuming Safety Officer
12:13:20	Waterflow Zone 7 Pick Mod level 1 (Supplied by Riser 8A)
12:14	L84 assigned to roof
12:15	Charge the yard line
12:16	SQ121 added to assignment – Self-dispatched
	Building representative reports 55 people unaccounted for
12:18	L82 on scene

Low water level indications

At 12:11 pm, the alarm system recorded low water level indications from both storage tanks. The full level was approximately 45 ft. and the low water level indicators were set to activate at the 44 ft. level, so this would be an indication of "not full" as opposed to "almost empty". It is logical that both low water alarms would activate at approximately the same time, because the two tanks were connected to a common intake manifold for the fire pumps and the water levels would be equal.

At that time, the sprinklers had been operating for approximately 18 minutes and the hose line had just begun to flow water. If six sprinklers were operating, the estimated flow rate at that point would have been approximately 600 gpm. The sprinklers could have discharged approximately 10,800 gallons of water from the storage tanks up to that time. This is a very small fraction of the 600,000 gallon combined capacity of the two tanks.

With the hose line in operation the flow rate probably increased to approximately 800 gpm. The 10-inch connection to the municipal water supply had the capacity to refill the tanks at a rate of between 1,000 and 1,500 gallons per minute, so it had the ability to replace all of the water that was being discharged at that time. The actual refill rate depended on the settings of the pressure regulated valves.

The meter that measured flow through the connection to the municipal water system indicated that water had flowed into the storage tanks before 10:00 am, presumably to replace water that was used during the waterflow testing. The meter did not indicate any additional flow after 10:00 am. It has not been determined why there was no refill flow registered when the sprinklers began to operate.

Communication Problems

The steel roof structure and the steel structure of the Pick Module created serious communication problems with the 800 MHz trunked radio system. The firefighters who were inside the building had difficulty communicating with each other and with the Incident Commander who was outside. Many of the recorded radio communications were garbled and it appears that several attempts to communicate by radio were not registered.

The firefighters indicated that they attempted to communicate with each other on a talk-around channel (direct simplex), but this was also unsuccessful.

The Deputy Chief, who was inside the Pick Module, determined that the radio reception was better, but still sporadic, when he crossed over to the newer section of the Pick Module and stood on a platform that overlooked the open area to the east. He was able to use his cellular telephone to communicate with the Command Post.

The communication limitations created difficulties, but they did not cause any critical problems during the initial operations period; however, this is a very significant cause for concern. Firefighters rely on having radio communications for tactical coordination and particularly for firefighter safety.

This type of problem is often encountered inside large buildings, particularly when the structure contains a lot of steel. The steel structure of the Pick Module probably created even more shielding. The actual shielding characteristics often vary significantly from one building to another and even in different areas of the same building.

Most trunked radio systems are designed to provide exterior coverage; however, coverage inside buildings, particularly this type of structure, is often not included as a system performance requirement.

The limitations of a radio system should be recognized before an incident occurs and steps should be taken to ensure that reliable communications will always be available for firefighters inside buildings, as well as outside. There are several technological enhancements that can be used to provide reliable *interior coverage, including the use of simplex channels and mobile or portable repeaters for on-scene communications. Fixed amplified antenna systems can be installed in large buildings that are known to shield radio communications. In many jurisdictions codes have been adopted to require the owner to install this type of equipment inside new buildings, where shielding of radio communications can be anticipated.*

It is impossible to determine why direct "portable to portable" communications on the simplex talk-around channel were unsuccessful. This deserves further analysis in a similar environment.

Fire Under Control

At 12:23 pm the Deputy Fire Chief (functioning as Incident Safety Officer) reported that the fire was under control and called for the loading dock doors to be opened to ventilate the smoke that was trapped in the building. One minute later he called for the sprinklers to be shut off, but to leave the fire pump running to prevent interruption of the water supply to the hose line that was connected to the outlet valve.

Teams were assigned to locate and close the appropriate sprinkler riser valve and to accomplish horizontal ventilation; however, neither task was accomplished before the situation changed radically. The details of those efforts are described later.

At 12:29 pm and again at 12:32 pm L84 reported that there were no indications of smoke or fire on the roof of the building.

At approximately 12:34 pm, the Deputy Chief, who had by then assumed the role of Operations Officer, advised the Incident Commander that the fire pump could be shut down. He indicated that he was confident that the fire on the 2nd level of the Pick Module was completely under control and there was no risk of rekindle. The hose line from the outlet valve was in the process of being disconnected; however, the line from Engine 123 was still charged and available, close to the fire area.

Fire Prevention Officer C1221 had arrived at the pump house at approximately 12:31 pm. He noted that the electric fire pump was operating and making very loud cavitation noises, which suggests that there could have been a problem with the water supply. When the order was transmitted to shut down the fire pump, he switched off the electric pump at the control panel. This action was recorded at 12:35 pm.

Shutting down the electric pump caused the diesel back-up pump to start automatically. Over the next two to three minutes the electric pump restarted automatically two or three times until the manual power disconnect switch was opened. The diesel pump was then shut down manually at 12:38 pm. Fire Prevention Officer C1221 then left the pump house and returned to the Command Post.

The observation that the electric pump was cavitating when Fire Prevention Officer C1221 initially arrived at the pump house suggests that there could have been a water supply problem at that time. This condition cannot be confirmed or explained.

Cavitation occurs when the supply of water entering a pump is unable to meet the demand created by the pump. This causes vacuum bubbles to be created within the pump, accompanied by a loud and distinctive noise.

The report of cavitation suggests that there could have been a problem on the upstream side of the fire pump, which restricted the supply of water from the storage tanks to the pump. This condition could be caused by a partially closed valve or some other obstruction in the piping between the storage tanks and the pump or if the depth of water in the tanks was insufficient to maintain a positive residual pressure at the pump intake.

Cavitation could also occur if the demand on the discharge side of the pump greatly exceeded the capacity of the pump. The demand created by the sprinklers on the 2nd level of the Pick Module was *estimated at 600 gpm, which is well within the capacity of the 2,500 gpm pumps. It is not known if any additional sprinklers on the 3rd level had activated by that time.*

The first ESFR activation occurred just before the electric pumps was shut down and this would have created an immediate demand for additional flow, which could have caused the cavitation. A major rupture of an underground line on the discharge side of the fire pumps also could have created this type of demand, causing the fire pump to cavitate; however there are no indications that this occurred.

After confirming that the fire on the 2nd level had been extinguished, the crews began a primary search in the aisles surrounding the fire area. An update was requested on the number of employees that were earlier reported to be unaccounted for; however, there was no additional information. It was later determined that all of the employees had safely evacuated the building.

The search began in the aisles close to the fire area where visibility was heavily obscured by smoke. At 12:42 pm, Operations requested three additional teams to search the higher levels of the Pick Module. The Incident Commander assigned E141 and L82 to begin this task.

At 12:43 pm, the crew of Ladder 84 was reassigned from the roof to assist with the search. They had previously reported that there were no indications of smoke or fire at the roof level.

Time Sequence[2]:

12:20	Safety reports - water on the fire Smoke throughout the building – need truck to get doors opened-up
12:22	Safety Reports - Need fire prevention to identify risers and get sprinklers shut off or pump off - Can't shut-off pump because we are using the standpipe
12:23	Safety reports - Fire is under control Need to get doors opened-up to start ventilation Need pumps to stay on and need ventilation
12:29	L84 reports no indications of smoke at roof level
12:31	C1221 at pump room asking which risers to close
12:32	L84 can see whole roof – no indications of smoke – nothing coming from exhausts
12:33	E122 reports risers for Pick Module are inside on west wall – we can go over there
12:34	Operations reports we can shut the pumps down now – then we can evaluate
12:34:25	Waterflow Riser 7 – ESFR system
12:35	C1221 - Do you want me to shut pump down?– Command responds affirmative E122 requests silence alarms
12:35:42 12:35:44	Diesel fire pump automatic start Electric fire pump manual shut down
12:37	Operations (C1203) requests bay doors to be opened for ventilation
12:38:39	Diesel fire pump manual shut down
12:39 12:39:29	E123, M2 and S121 assigned to open doors Riser 23A Tamper – Valve closure – Pick Mod Sprinklers west side
12:40	Operations reports fire is still under control – Crews are conducting primary search in fire area and smoke-filled aisles.

12:41	Operations asks for update on number of missing employees – no new information E122 has one of the risers shut down – going to shut another valve
12:42	Operations requests 3 more companies to work on primary search E141 and L82 assigned L84 come down from the roof – we going to use you for search
12:43	E122 reports aerosol room is all clear – no smoke – primary search completed
12:43:09	Riser 21A Tamper – Valve closure – Pick Mod Sprinklers west side

[2] Notations in black are from the incident record and radio recordings. Notations in blue come from the building alarm system records.

Fire Extension and Rapid Growth

At 12:34 pm, at approximately the same time that the fire pumps were being shut down, the fire alarm system registered a waterflow signal from ESFR Riser 7. This indicates that at least one ESFR sprinkler was operating above the 4th level of the Pick Module. ESFR Riser 7 covers a large area, including directly above the fire on the 2nd level of the Pick Module.

The firefighters were not aware of this waterflow indication when the fire pumps were shut down. No one was monitoring the alarm panels in the security office or at the guard station outside the building. If someone had been assigned to monitor the alarm systems, it is questionable if the significance of an additional flow indication at that time would have been recognized, since numerous alarm and supervisory signals had already been activated.

> *The activation of one or more ESFR sprinklers at 12:35 pm suggests that there was active fire on the 4th level of the Pick Module at that time. The ESFR activation could only occur if there was a fire large enough to create a vertical flow path that reached the roof level. Because the ESFR sprinklers react quickly, the fire on the 4th level could not have been burning for more than a few minutes.*
>
> *It cannot be determined if there was active fire on the 3rd level at that time.*
>
> *The fire on the 2nd level had been extinguished several minutes earlier and was under close observation when the first ESFR sprinkler activation occurred. The sprinklers on the 2nd level were still flowing at that time. The fire on the 2nd level did not flare-up or rekindle, so it could not have caused the ESFR sprinklers to activate.*

An additional waterflow signal was recorded from ESFR Riser 6 at 12:43 pm, eight minutes after the waterflow signal from Riser 7. This indicates that the upper-level fire was growing and additional ESFR sprinklers were opening to the south of the original fire area. This was followed by waterflow signals from Risers 22 and 8 at 12:44 pm and from Risers 21 and 23 at 12:45 pm.

> *This type of rapid fire growth is consistent with expectations, if the ESFR sprinklers were not functioning properly. ESFR sprinklers were developed to suppress this type of fire; however, they cannot function effectively without an adequate water supply, which required at least one of the fire pumps to be operating.*

At 12:45 pm, Ladder 84 reported that fire had penetrated the roof near the middle of the building. It is not clear whether the fire had created a rupture in the steel deck or ignited the foam plastic insulation and polymeric membrane on top of the deck.

The report from L84 was the first indication to firefighters inside or outside the building that anything unusual was occurring. From that moment, conditions inside the building changed very quickly and radically. The officer of E141 observed fire spreading rapidly from west to east on the 3rd level of the Pick Module. Other firefighters observed fire spreading rapidly below the roof deck and in the upper levels of the Pick Module. Within one to two minutes a layer of dense smoke dropped from the roof to the floor level, filling the entire space.

From the exterior Command Post a column of heavy smoke and flames became visible, coming from the roof near the middle of the building. All firefighters inside the building were ordered to evacuate and the 2nd and 3rd alarms were transmitted in rapid succession.

Three firefighters, who were on the 2nd level of the Pick Module, became disoriented in the dense smoke. There were several tense moments before they were able to find the hose line and follow it toward an exit. A MAYDAY was declared when it was recognized that firefighters were still inside the building and teams were preparing to re-enter to search for them when the missing firefighters reached the exit. The MAYDAY was quickly cleared and a PAR check was initiated to confirm that all firefighters were out of the building.

The following section describes the situation inside the building as conditions changed in the words of the Deputy Chief, who was supervising operations on the 2nd level of the Pick Module.

> We fully believed the fire was under control and we were experiencing cold smoke. I was still unable to contact Command by radio, but I was able to call out on my cell phone. I requested additional companies to focus on the search for the 55 missing employees. The smoke condition was light to moderate - I was off air the majority of time without issue.
>
> E141 came up and I had them double check the fire area for any extension. They reported back they found no extension.
>
> E121 and L121 had started working on the search for missing employees. L121 went towards the A side, which was south of the fire, to search those rows, while E121 searched between the stairs and the fire area. E141 started to check the D side of the Pick Mod in the area I was able to transmit from. I asked Command about the status of opening the overhead doors to try and improve visibility and whether there was any update on the number of missing employees.
>
> E141 completed their assignment, so I told them to head to the third level and start to search for occupants there. L82 was coming up about the same time and I told them to go with E141 to the third level.
>
> A moment later I heard a loud crashing sound and E141 returned to tell me we had fire above us. At the same time, L84 reported fire through the roof and Command ordered evacuation of the building.
>
> I returned to the stairway and observed a large volume of fire running out toward the D side. I went to try and retrieve the 2 ½ without any luck moving it. I returned to the stairs and noticed a much larger body of fire above us that was quickly moving down and from north to south. I told the crews to exit the building. This all occurred within 60 to 120 seconds.
>
> The loud noise of things collapsing, or high voltage arcing, increased in volume and frequency - it was deafening and terrifying. I knew there were still crews working on completing the search on the second level and time was no longer our friend. The area was so large that only the immediate fire area had been searched.
>
> Conditions had changed from winning to losing in record speed. Just 60 seconds before the fire event I was sure we had the fire under control if not completely out. In a matter of seconds, I was fearful I had made my last mistake and the three of us would perish in the Pick Mod. The conditions went from tolerable and no heat to complete disaster in seconds.

I returned to the south side of the fire area to look for L121, but I couldn't find them. The noise of crashing metal was increasing in loudness and frequency and I was worried the next one would be the last one. I found the E121 Lieutenant and he told me he was missing one of his firefighters. We attempted to call a MAYDAY, but we could not get out on the radio. I told him to check the area they had been searching again to try to locate him.

Just shy of complete panic was setting in - the building was collapsing and a ladder company and an engine firefighter were missing. I made another try to find L121 but was unable to locate them. I surmised they must have exited. The lieutenant had found the firefighter and we started to make our way out. Fire conditions had worsened, and visibility had decreased to a foot or less, although I never noticed any heat.

We followed the line out of the building. About halfway we heard a MAYDAY being declared on the radio. I exited the building and asked who the MAYDAY was for and they told me it was for us. I was completely relived in that moment that we had all made it out of the building. I told the Incident Commander that he could clear the MAYDAY. Everyone was ordered to report to their trucks and a PAR was taken.

Re-starting Fire Pumps

The officer of E122, and his crew members, were on the west side of the building, attempting to close the valves that controlled the Pick Module sprinklers, when the report from L84 was transmitted. He proceeded directly to the pump house to restart the pumps. When he arrived, he noted that the diesel pump was already operating and cavitating.

At 12:49 pm, he restarted the electric fire pump and noted that it also began to cavitate as soon as it was started. He reported that both pumps were operating at 12:51 pm and at 12:54 pm and both pumps were cavitating. The pump controller recorded an initial discharge pressure of 65 psi, which quickly dropped to 35 psi.

It is evident that the fire had overwhelmed the capabilities of the ESFR sprinklers. This point was probably reached before the fire penetrated the roof and was observed by the crew of L84. At that point, waterflow indications had been recorded from five of the ESFR systems. When the pumps were restarted the demand greatly exceeded their capacity.

Time Sequence:

Black = Radio/telephone recordings

Blue = Event logs/computer systems

12:43:41	Waterflow Riser 6 – ESFR system
12:44:11	Waterflow Riser 22 – ESFR system
12:44:20	Waterflow Riser 8 – ESFR system
12:45:01	Alarm system trouble Module 02
12:45:05	Waterflow Riser 21 – ESFR system
12:45:32	Waterflow Riser 23 – ESFR system
12:45:34	L84 reports fire coming through the roof
12:46	Command orders Second Alarm Operations from Command – Let's get everyone out E122 recommends getting fire pump back in operation
12:48	Command orders Third alarm
12:49	**Mayday** – 2 firefighters missing inside C1201 reports Mayday cleared Command to 1220 – are you able to get pump operating?

12:49:45	Electric fire pump reset
12:49:51	Electric fire pump running
12:50	E122 reports both fire pumps are running PAR checks initiated
12:54	E 122 for info - Fire pumps are cavitating
12:58	L84 reports fire is running entire south end of building – elevated streams not reaching

Uncontrollable Fire Conditions

From the time the fire penetrated the roof and conditions inside the building began to change rapidly, there was nothing that could be done to stop the fire from spreading throughout the portion of the building that was south of the fire wall. The capabilities of the sprinkler systems had been surpassed and the fire was beyond the capabilities of any fire department. At that point it was inevitable that the south section of the building would be lost.

The only option at that point was to employ defensive strategy to attempt to confine the fire to the portion of the building that was south of the fire wall. Several elevated master streams were set-up on the east and west sides of the building; however, due to the 650' width there was a large area in the center that was beyond their reach. A portable master stream device was positioned inside the building on the north side of the wall as an additional defensive measure.

At approximately 1:28 pm, the fire extended to the section of the building that was north of the fire wall. This occurred very suddenly and with such force that the firefighters who were operating the portable master stream device were knocked off their feet.

Once the fire extended beyond the fire wall, it spread rapidly throughout the northern section of the building. Within 30 minutes, the entire building, both north and south of the fire wall, was fully involved.

The fire ultimately destroyed the building and all of the combustible contents, as well as most of the trailers that were positioned at the loading docks. Fire department operations continued for several days and during this time, units from approximately 50 fire departments responded in rotation to provide mutual aid. Most of those efforts involved the application of water to extinguish residual fire in the ruins, after most of the fuel had been consumed.

The smoke that was produced by the fire created significant environmental concerns in the immediate area. Fortunately, the atmospheric conditions allowed most of the smoke plume to rise and disperse over a large area.

Runoff from the fire was also a concern in the surrounding area due to the tremendous variety of contents that were involved in the fire and the application of large volumes of water over several days. The runoff was closely monitored by environmental protection agencies to ensure that there was no danger to the surrounding area or population.

PHOTOS: COURTESY OF WRTV.COM

Analysis

Overview

The information that is available indicates that the building and the fixed fire protection systems were designed according to accepted standards and practices and that those systems were properly installed and maintained. Nevertheless, the fire on March 16, 2022, resulted in a total loss of the building and contents, as well as a very close call for the firefighters who were working inside the building when conditions changed very suddenly.

The objective of this analysis is to understand what happened to produce the unanticipated and highly undesirable outcome. The intent is to use this event as a learning experience and to share valuable information that will help to avoid similar occurrences in the future.

The following analysis begins with an examination of the fire risk and fire protection characteristics of the building and how those systems performed when a fire occurred. This is followed by an analysis of the fire department response and actions on the scene of the incident. The third section examines the interactions between those two major components.

Building Characteristics and Systems Performance

Initial Stages

The specific source of ignition of the fire on the 2nd level of the Pick Module is unknown. Once it was ignited, the initial rate of fire growth was very rapid, which was anticipated due to the fuel load and arrangement on the shelves. The initial fire would have been very challenging with a high rate of heat release.

Smoke and flames were observed by employees who were in the vicinity, approximately one minute before the fire alarm sounded. The first alarm was initiated by the VESDA smoke detection system at 11:52:20 am. During the next minute, two additional VESDA zones detected smoke, one on the 2nd level and one on the 3rd level. The first waterflow indications were recorded 61 seconds after the first detection of smoke. Several additional smoke detection zones activated in the following minutes as smoke spread within the building.

The rapid succession of alarms indicates that the fire was developing very rapidly, but the fire protection systems were also reacting very quickly. Water was flowing from the sprinklers within approximately two minutes after the first observation of a fire. The sprinkler systems were designed to control that type of rapidly developing fire.

By the time the first firefighters reached the 2nd level of the Pick Module, approximately 18 minutes after the fire was first observed, the fire had been controlled, but not fully extinguished, by the sprinkler system. The firefighters used a single hose line to complete the extinguishment of the fire within the next 10 minutes.

Up to that point everything functioned as expected. The sprinklers controlled the fire and the firefighters completed the extinguishment. When they were confident that the fire had been extinguished, the firefighters called for the sprinklers to be shut off and for the loading dock doors to be opened to exhaust the smoke. The overall situation was consistent with normal expectations for a fire in this type of building. There were no indications that the fire had extended to the higher levels of the Pick Module or that anything unusual or unanticipated was occurring.

Sudden Change in Conditions

The situation began to change radically approximately 20 minutes later when there was a sudden penetration of fire through the roof of the building. At almost the same time, firefighters observed active fire on the 3rd level of the Pick Module. At that point, the fire had already surpassed the capabilities of the sprinkler systems and was essentially uncontrollable. The resulting inferno completely destroyed the building and its contents and came very close to taking the lives of at least three firefighters. This sudden and unanticipated occurrence is the primary focus of the incident analysis.

The initial assumptions were that control of the fire was lost because the sprinklers had been shut off prematurely, before the fire was completely extinguished. There have been many instances where a fire flared-up or rekindled after the sprinklers had been shut off and ultimately destroyed a building. It was also suspected that premature or inappropriate ventilation could have contributed to the extremely rapid fire growth.

These assumptions are not supported by the detailed analysis of the incident. The reality of this incident is much more complex. The fire on the 2nd level of the Pick Module had been extinguished and it did not flare-up or rekindle. The sprinklers in the original fire area were still flowing and no ventilation had occurred when a sequence of unanticipated events began, somewhere above the 2nd level of the Pick Module.

It is evident that a secondary fire developed on either the 3rd or 4th level of the Pick Module, but this fire did not become active until several minutes after the fire on the 2nd level had been extinguished. The secondary fire became uncontrollable after the fire pumps were shut down.

There is a presumption that the secondary fire probably resulted from vertical extension of the fire on the 2nd level; however, there is no conclusive evidence indicating how or when this would have occurred. The possibility that the secondary fire was unrelated to the fire on the 2nd level, cannot be eliminated. While this seems to be improbable and there is no evidence indicating that a second fire was ignited on one of the upper levels, it is impossible to eliminate as a possibility.

The timing and the sequence of events leave several questions unanswered. The fire on the 2nd level was under control at least 35 minutes before the fire penetrated through the roof deck.

No eyewitnesses inside or outside the building observed any indication of active fire during that period. The 3rd level had been checked after the initial fire was under control and there were no indications of vertical fire extension at that time, but active fire was observed on the 3rd level at essentially the same time the fire penetrated the roof deck. If the secondary upper-level fire was the result of vertical extension of the fire on the 2nd level, the path of extension and the sequence of events remain as subjects of speculation.

The key question is how the fire could have extended from the 2nd level of the Pick Module to the 3rd and 4th levels and then through the roof, in spite of the fire protection systems that were in place and without being observed by any of the firefighters who were inside the building. The degree of destruction left no traces of how this could have occurred. This analysis is intended to examine the situation objectively and to determine what is most likely to have occurred by a process of elimination.

Potential for Vertical Fire Extension

The Pick Module was a giant structure, equivalent to a large four-story warehouse, that had been erected within the shell building. It was essentially a system of 40′ tall metal storage racks, which were subdivided by the mezzanines into four storage levels. The configuration of each level was a maze of corridors and shelving, loaded with highly combustible merchandise, creating a very large, complex and challenging fire protection problem.

The mezzanine decks were not rated as fire resistive assemblies. There were several large openings, including stairways and the 10-foot-wide gap between the original and expansion sections of the Pick Module. There were also many smaller openings adjacent to the vertical assemblies that supported the Pick Module and the large columns that supported the roof of the building. Any of these openings could have provided a flow path for vertical fire extension, similar to the void spaces in a balloon-frame building.

> One of the employees, who worked in the Pick Module and observed the fire before the alarm system activated, told the ATF investigators that there were gaps in the mezzanine decking that would allow items to drop through to a lower level.

The steel decking itself was particularly vulnerable to heat conduction. There was no insulating material other than the flooring panels in the aisles, which were made of combustible material. Direct flame impingement on the underside of the steel deck could have resulted in the ignition of combustible materials that were in contact with the upper side. The steel support structure and the columns that supported the roof could also conduct heat and possibly ignite materials that were in contact with them. Without sprinklers, it would be almost inevitable that a fire would extend rapidly from one level to the next within the Pick Module.

The Pick Module was protected by automatic sprinkler systems that were designed to meet the challenge of a fast-developing fire within the storage shelves. The three lower levels were covered by control mode (CMDA) sprinklers, while the 4th level was covered by the building's ESFR sprinklers. The performance criteria for the CMDA sprinklers were based on the fire risk classification that would be applicable to the storage conditions on each level of the Pick Module.

It is assumed that there was an expectation that the CMDA sprinklers would control a fire on the level of the Pick Module where it originated and also prevent vertical extension to the higher levels. If a fire did extend to a higher level, it would have to be anticipated that it would develop rapidly in the same manner as the original fire. The design calculations were based on a fire on a single level, with no allowance for the CMDA sprinklers to be operating on two levels at the same time, or for CMDA and ESFR sprinklers to be operating simultaneously.

It is evident that the fire originated on the 2nd level, but the critical sequence of events began when the fire became active on the 4th level.

There are three alternative theories for how the fire might have reached the 4th level:

1. The fire on the 2nd level extended to the 3rd level and then the fire on the 3rd level extended to the 4th level.
2. The fire extended directly from the 2nd level to the 4th level, bypassing the 3rd level.
3. The fire on the 4th level resulted from a second independent ignition and was unrelated to the fire on the 2nd level.

The most predictable path of fire extension would have been from the 2nd level to the 3rd level and then from the 3rd level to the 4th level. The fire could have extended from one level to the next through any of the openings in the mezzanine decks or by conduction through the steel structures.

The alternative theory, that the fire extended directly from the 2nd level to the 4th level, appears to be possible, but considerably less likely. That could have occurred if there was a flow path available through to the 4th level.

As noted previously, it is impossible to eliminate the possibility that the fire did not extend from the 2nd level to the 4th level and that the fire on the upper levels resulted from a separate and unrelated ignition.

Sequence of Events

The greatest risk of fire extension would have occurred before the sprinklers on the 2nd level of the Pick Module activated at 11:53 am. Witnesses reported observing fire reaching as high as the 4th level of the Pick Module before the sprinklers activated.

> Another employee told the ATF investigators that he smelled smoke, which he thought was from a cigarette, and began to look around for the source. He stated that he was on his way to the 4th floor when the fire alarm began to sound. He stated that the alarm sounded and then stopped. He also stated that while he was investigating, the smell turned from a cigarette smell to a wood burning smell.
>
> The same witness stated that once on the 4th floor, he went south on the B side of the conveyor, turned east, crossed the "drawbridge," and observed fire. He stated the flames were coming up from the 3rd floor at the end of the Pick module (near the 300 Section). He stated the flames were in the

area of Aisles 70 to 73. He stated there was no smoke, only fire, and the sprinklers were not going off when he was up on the 4th floor.

A third employee arrived in the fire area after the sprinklers had activated. He described the fire as free burning like a Christmas tree and extending to the level above. He checked for employees on the 3rd level and did not observe any indications of fire at that time. He went to the 4th level and opened a roof hatch for ventilation near the west side of the building. He noted that there were no indications of heat or smoke in that area at that time.

During those first few minutes, before the sprinklers on the 2nd level activated and gained control of the fire, it could have ignited combustible contents on either the 3rd or 4th level. The risk would have decreased significantly when the sprinklers activated and continued to decrease until the fire on the 2nd level was under control.

Several witnesses confirmed that the fire on the 2nd level of the Pick Module had been effectively controlled by the sprinklers before firefighters arrived at 12:10 pm, so it is very unlikely that vertical extension would have occurred after that time. The firefighters completed the extinguishment of that fire before 12:22 pm.

The expectation would be that any fire extension to either level would ignite a fast-developing fire, similar to the initial fire on the 2nd level of the Pick Module. Nevertheless, it is possible that the ignition began with a cardboard carton on one of the lower shelves or sitting on the floor near one of the openings. That fire could have smoldered for a considerable length of time before transitioning to flaming combustion.

Firefighters checked the 3rd level at around 12:20 pm and found no indications of fire or operating sprinklers at that time. The fire on the 2nd level was fully under control by that time and the sprinklers were still operating, so it is extremely unlikely that the fire could not have extended from the 2nd level to the 3rd level, after the 3rd level had been checked.

This suggests that there could have been a smoldering fire on the 3rd level that was not detected. That fire could have subsequently transitioned to flaming combustion and then extended to the 4th level.

The transition from smoldering combustion to flaming and extension to the 4th level would have had to occur within a narrow time window. The ESFR sprinkler activation, at 12:34 pm, indicates that there was fire on the 4th level of the Pick Module at that time. Because the ESFR sprinklers are designed to activate quickly, this also indicates that there was no active fire on the 4th level before approximately 12:30 pm. This means that a smoldering fire on the 3rd level would have transitioned to flaming combustion after 12:20 pm, but before 12:30 pm. Sprinklers on the 3rd level should have activated within approximately two minutes after the fire became active.

This hypothesis is possible, but the full sequence of events would have to be described as improbable and unpredictable.

The second hypothesis assumes that the fire extended from the 2nd level directly to the 4th level, without igniting anything on the 3rd level. This also could have occurred during the first few minutes, when flames were observed as high as the 4th level; however, this condition probably lasted only a few minutes. The window of opportunity for the fire to reach the 4th level was probably between 11:52 am and 12:00 pm.

This suggests that there could have been a smoldering ignition on the 4th level before 12:00 pm that only transitioned to flaming combustion at around 12:30 pm. This is also possible, but it would have to be described as even more improbable and unpredictable.

Rapid Fire Development Phase

The first definitive indication of fire above the 2nd level was the ESFR sprinkler activation that occurred at 12:34 pm. The waterflow indication from ESFR Riser 7 was registered by the alarm system, but no one at the scene was aware of this occurrence. At that moment firefighters had already been directed to shut off the operating sprinklers in the Pick Module and shut down the fire pump. The fire pumps would not have been shut down if anyone had known or suspected that a fire was developing on the 4th level.

The decision to shut down the fire pump(s) appears to be the primary factor that contributed to the rapid fire growth that occurred in the following minutes. It can only be assumed that the ESFR sprinklers would have been able to control the fire on the 4th level, if the water supply had not been interrupted.

The electric fire pump was initially shut down at 12:35 pm, but the diesel fire pump started automatically and operated until it was shut down at 12:38 pm. At that point, the ESFR sprinklers would have become ineffective. The fire was totally out of control within 5 to 7 minutes after the pumps were shut down.

There is a possibility that the water supply might have already reached its limits, before the pumps were shut down. It cannot be determined if there was also active fire on the 3rd level at that time and whether the sprinklers on that level were operating. This could have resulted in a deficient flow to the ESFR sprinklers during the first three minutes. This possibility is addressed in a subsequent section.

Timing Sequence

The timing of the sequence of events has been examined in detail.

11:51 am	First observation of fire	Fire on 2nd level
11:52 am	Initial smoke detection	
11:53 am	Initial water flow	Fire pump start
12:03 pm	Fire department arrival	
12:10 pm	Firefighters reach fire area	Sprinklers have controlled fire on 2nd level
12:15 - 20 pm	Firefighters check 3rd level	No indications of fire or sprinklers operating on 3rd level
12:22 pm	Safety Officer report	Fire on 2nd level extinguished
12:23 pm	Request to shut off sprinklers	
12:31 pm	Request to shut down fire pump	
12:34 pm	Electric fire pump off – diesel on	
12:35 pm	ESFR Riser 7 waterflow	Active fire on 4th level
12:38 pm	Diesel fire pump shut down	
12:45 pm	L84 observation	Fire penetrates roof
12:46 pm	E141 observation	Active fire on 3rd level
12:49 pm	Fire pumps restarted	Fire out of control

Sprinkler System Performance

The automatic sprinkler systems that were installed in the facility were the most essential component of the overall fire protection strategy. If the sprinklers failed to perform as intended, there was nothing else that could prevent a total loss. There was nothing that firefighters could do to compensate for inadequate performance of the sprinklers.

The CMDA sprinklers that were installed within the Pick Module appear to have functioned normally. The fire on the 2nd level was under control, and had been, and was confined to a relatively small area by the time firefighters arrived. This is consistent with the expected performance of CMDA sprinklers.

It is assumed that the sprinklers on the 3rd level must have activated at some point, after that level had been checked for fire extension. It is impossible to determine when the sprinklers on the 3rd level activated, how many activated, or how they performed.

It is known that the first ESFR activation occurred at 12:34 pm, indicating that there was active fire on the 4th level at that time. The process of shutting down the pumps began one minute later, but at least one fire pump was in operation until 12:38 pm. It cannot be determined how many ESFR sprinklers operated during those three minutes or what effect they had on the fire.

Sprinkler Design Concept

Both ESFR and control mode (CMDA) sprinklers were installed to protect the building and contents. The ESFR sprinklers were installed when the building was constructed and the CMDA sprinklers were added when the Pick Module was assembled. The CMDA sprinklers were connected to the water supply system that had been installed for the ESFR sprinklers.

Control mode sprinklers were installed under each mezzanine deck, because the mezzanines made it impossible for water from the ESFR sprinklers to reach a fire in the three lower levels. The CMDA sprinklers covered the three lower levels, while the ESFR sprinklers provided coverage for the top level. The CMDA sprinklers were designed according to accepted standards (NFPA 13 and/or FM) based on the anticipated contents and storage configuration on each level. There is no indication that any special provisions were made to protect the openings in the mezzanine decks.

The design calculations for the CMDA sprinkler systems suggest that the Pick Module was considered to be four independent fire areas, with the assumption that a fire would not extend vertically within the structure. The calculations were based on delivering the required flows to sprinklers on one level, with no indication that sprinklers could be operating simultaneously on more than one level or that the ESFR and CMDA sprinklers would be operating simultaneously.

Neither the sprinklers nor the mezzanine decks alone could be expected to prevent vertical fire extension. It is inferred from the design that the two components together were expected to accomplish this objective; however, it cannot be confirmed that this was established as a performance objective when the sprinkler systems were designed. There is no documentation available to address this key question.

Experience with fires in sprinklered buildings indicates that if a fire does extend vertically, it is usually controlled by a few sprinklers on the next higher floor level. It would be unusual for a significant fire to develop on the higher floor.

In tall rack systems, without horizontal barriers, it would not be unusual for a fire to extend vertically via flue spaces to the top of the racks, even with in-rack sprinklers opening on intermediate levels. The design for that type of configuration would anticipate that the roof level sprinklers and a certain number of in-rack sprinklers would operate together to control a fire.

In this case, the combination of three mezzanine decks, with a full sprinkler system under each mezzanine, created the appearance of barriers that should be able to confine a fire to one level. It would not be anticipated that a fire would be able to extend progressively from the 2nd level to the 3rd and 4th levels.

The fire analysis indicates that the fire probably did spread vertically within the Pick Module, in spite of the sprinklers and mezzanine decks. This appears to be a failure with regard to the overall risk assessment and design concept for the Pick Module, more than a failure of the sprinkler systems to perform as expected.

The vertical extension could have occurred before the sprinklers operated or before they controlled the fire on the 2nd level. It is also possible that the sprinkler discharge pattern on the 2nd level was partially obstructed, which provided an opportunity for fire to extend vertically through an opening to the 3rd level. If that occurred, the expectation would be that the sprinklers on the 3rd level would activate and that they would be able to control the fire on that level and prevent extension to the 4th level.

It cannot be determined what happened on the 3rd level; however, it is evident that the fire reached the 4th level. It is possible that a fire began to develop on the 3rd level, after it had been checked, and that fire extended to the 4th level in the same manner that it had extended from the 2nd level to the 3rd level.

Water Supply

The water supply for the Pick Mode sprinklers shared the storage tanks, fire pumps, and underground distribution system that had been installed for the ESFR sprinklers. This system was designed to meet the demand for the ESFR system, which was considerably greater than the demand for the CMDA sprinklers in the Pick Module.

The design calculations for the CMDA sprinklers were based on 29 sprinklers operating on a single level. The calculated demand was 955.5 gpm at 83 psi, with a 500 gpm reserve for hose streams. The data indicates that the fire pumps would have provided ample capacity to meet that demand. The water supply would have been able to supply at least the minimum requirement of 29 sprinklers within the Pick Module, whether they were all on one level or distributed among the three levels. It is estimated that only six sprinklers operated on the 2nd level, so there should have been sufficient capacity for several additional sprinklers to operate on the 3rd level.

The calculated demand for the ESFR sprinklers was based on 10 sprinklers operating. The required flow was 2,075 gpm at 122 psi, with a 250 gpm reserve for hose streams. The water supply was designed to meet this demand, but it did not have the capacity that would have been required to meet the full demand of both the CMDA and ESFR systems operating simultaneously.

When the ESFR sprinklers began to operate at 12:34 pm, they created a simultaneous demand for water to supply both the ESFR and CMDA systems; however, it is unknown how many sprinklers were operating in either system at that point or how quickly additional heads were opening. If both systems were operating at their design capacities, the combined demand would have been approximately 3,200 gpm[3] at more than 122 psi.

A pump test that was conducted after the fire indicates that this combined demand would have exceeded the capacity of a single fire pump. This suggests that the capacity of the water supply system could have been exceeded or it could have been very close to that point before the fire pumps were shut down. This also provides a possible explanation for the observation that the electric fire pump was cavitating before it was shut down.

The engine company that was in position to pump into the fire department connection to provide additional water for the sprinklers did not initially charge the lines, because the fire was reported to be under control by the time their lines were in place. When the situation changed, the lines were charged, but it was already too late to make a difference.

[3] This figure does not include any allowance for hose streams. No hose streams were being used at the time the maximum flow would have occurred.

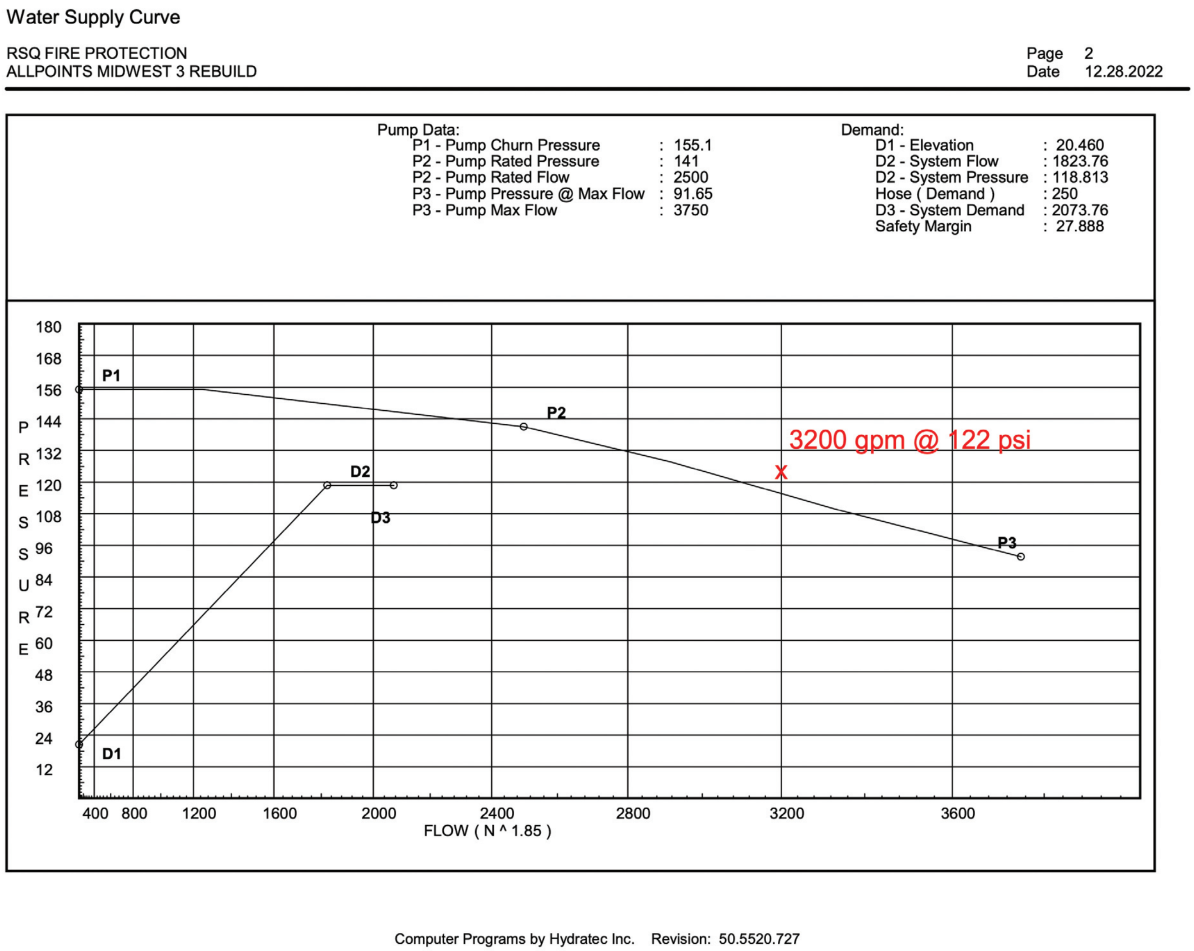

Figure 17. The water supply curve that was derived from a pump test after the fire indicates that the combined design flows from the ESFR and Pick Module sprinklers probably would have exceeded the available supply with one fire pump in operation.

Analysis of Fire Department Actions

One of the major questions in this incident is whether the actions of the fire department caused or contributed to the eventual loss that occurred. The fire department assumes the legal responsibility for operations that are conducted at the scene of a fire from the time of arrival until the incident is terminated and the property is returned to the owner or occupant. This includes the responsibility for determining when to shut off sprinklers and shut down fire pumps and when to initiate ventilation. It also includes the responsibility for the safety of employees, firefighters, and anyone else who is present while operations are being conducted.

The reference sources that were consulted during this component of the analysis were NFPA 13E – *Recommended Practice for Fire Department Operations in Properties Protected by sprinkler and Standpipe Systems – 2020 edition*; published by the National Fire Protection Association and the Fire Service Training Programs that have been developed by FM.

All of the significant decisions that were made and actions that were taken by firefighters at this incident have been carefully and objectively examined. The fire department responded promptly and initiated a standard set of actions for a fire in a sprinklered building, applying standard operating procedures. The operational analysis indicates that the initial actions, up to and including the extinguishment of the initial fire, were based on appropriate standard operating procedures and guidelines and were performed in relatively routine manner.

The three primary actions that require more detailed analysis are:

1. Shutting off the Pick Module sprinklers.
2. Opening loading dock doors to provide ventilation.
3. Shutting down the fire pumps.

These three actions were initiated after the fire on the 2nd level of the Pick Module was under control and had been effectively extinguished. The sprinklers had already controlled the fire on the 2nd level of the Pick Module before the first firefighters arrived in the fire area, at approximately 12:10 pm. The firefighters were able to complete the extinguishment of that fire within approximately 10 minutes, using a single hose line.

There were no indications that the fire had extended beyond the area that was involved on the 2nd level of the Pick Module. The area directly above the fire, on the 3rd level, was checked and there were no indications of vertical fire extension or operating sprinklers.

At 12:23 pm, the initial request was made to shut down the Pick Module sprinklers and to begin opening loading dock doors to ventilate the smoke that had accumulated inside the building. At that point, the firefighters were confident that the fire had been extinguished. There were no indications that the fire had extended vertically within the Pick Module. Firefighters remained in the fire area and a charged hose line was available for immediate use, in case the fire rekindled. These decisions were consistent with all established guidelines and recommended practices.

Sprinkler Shut Off

At 12:33 pm, E122 was assigned to locate the appropriate riser valve to shut down the sprinklers in the Pick Module. The officer in charge of this unit had worked in fire prevention and was familiar with the building and its fire protection systems. He knew that there were dedicated risers on the west side of the building that controlled sprinklers in the Pick Module. He did not know or recall that there were additional risers on the east side of the building that controlled the sprinklers in the eastern portion of the Pick Module.

The PFT Fire Marshal, who was also familiar with the property, joined the crew of E122 on the west side of the building.

At 12:37 pm, E122 reported that they were on the west side of the building looking for the appropriate riser to shut down. The control valves for Risers 23A and 21A were closed at 12:39 and 12:43 pm respectively. Closing these two valves had no impact, because they only controlled sprinklers on the west side of the Pick Module. The fire was on the east side of the Pick Module in an area that was controlled by Riser 8A, which was located on the east side of the building.

The crew was preparing to close a third valve on the west side of the building when they heard the reports that the fire had penetrated through the roof.

> *Whenever possible, sprinklers should be shut off by closing the first valve upstream of the sprinklers that are operating. This minimizes the area in which the sprinklers are shut off and maintains the water supply to other areas.*
>
> *In this instance, Riser 8A provided water for the sprinklers in the northeast section of the Pick Module where the fire originated. Individual zone valves controlled the sprinklers on each level. The most appropriate valve to close would have been the control valve for Zone 15, which was located on the 2nd level of the Pick Module near the northeast stairway. Closing that valve would have stopped the flow to the sprinklers in the immediate area of the fire, without interrupting the water supply to the hose outlet or the sprinklers on the 1st and 3rd levels.*
>
> *Due to the size of the Pick Module, the sprinklers within it were controlled by eight risers and 24 individual zone valves. Detailed plans and/or intimate knowledge of the system arrangement would*

have been needed to identify which system and which zone covered each area and where each valve was located. That information was not available at the time of the fire.

The two recognized reference sources, NFPA 13E and the FM Training Program *Fighting Fire in Sprinklered Buildings* both warn against shutting down sprinklers prematurely and indicate that the sprinklers should continue to operate until the fire has been extinguished. The actual determination of when the fire has been extinguished and it is appropriate to shut off the sprinklers is left to the judgement of the Incident Commander. Both sources also call for a firefighter with a portable radio to remain at the valve until overhaul has been completed, in case it needs to be reopened.

The decision to shut off the sprinklers that were operating on the 2nd level of the Pick Module was reasonable, based on an assessment of the situation at that time. The fire on that level had been effectively extinguished and the fire area was under close surveillance, with a charged hose line standing by in case of a flare-up or rekindle. The area directly above the fire had been checked and there were no indications of fire extension at that time. There was nothing to indicate that it was not appropriate to shut off the sprinklers at that point.

The decision to shut off the Pick Module sprinklers had no impact on the subsequent events, because the valves that controlled the sprinklers in the original fire area were not closed. The sprinklers in the original fire area were still operating when the situation on the higher levels of the Pick Module began to change. There was no flare-up or rekindle of the original fire.

Ventilation

The request to open the loading dock doors to ventilate the smoke that had accumulated in the building was also made after the firefighters were confident that the fire had been extinguished. This decision was also consistent with recommended practices and guidelines.

This request had no impact on the subsequent events, because no ventilation was accomplished. The crews that were assigned to open the doors found that every doorway was blocked by a 53-foot trailer.

The only ventilation actions that were actually accomplished were taken by employees, before the first fire department units arrived. One employee opened a small hatch that provided access to the roof. The size of the opening and the distance from the fire probably made this opening insignificant. The firefighters who were assigned to the roof did not observe any smoke emitting from it or indications that fresh air was entering through it, before the fire penetrated the roof.

It was reported that members of the Environmental Safety and Health (ESH) group had opened some of the personnel doors that were located between the loading dock doors to ventilate the smoke, also before the first fire department units arrived. It is unknown how many of these doors were opened; however, these openings were very small in proportion to the dimensions of the building.

Firefighters did not observe smoke emitting from any of the open doors and there was no indication of a significant inward air flow.

In a sprinklered storage building, ventilation should not be initiated while the sprinkler system is operating and there is still active fire. Premature ventilation is likely to interfere with the sprinkler discharge and may cause additional sprinklers to open. Ventilation may also allow fresh air to flow into the building, which could cause a fire to rekindle after it had been controlled by the sprinklers.

Recommended practices and guidelines suggest that ventilation should only be initiated after the fire has been extinguished. Ventilation should be carefully planned and coordinated, while continuing to monitor for the possibility of a flare-up or rekindle.

Ventilation of a sprinklered building is often difficult, because cold smoke mixed with water vapor creates a heavy fog that does not rise or flow like heated smoke. This mixture is not buoyant or subject *to convective forces, making it very resistant to movement. This problem is particularly difficult in mega-warehouses because of the very large volumes of cold smoke that may be present.*

At the time ventilation was requested, the area south of the fire wall contained more than 25 million cubic feet of this mixture. Ventilation of this space probably would have required several high-capacity fans and strategic openings to allow the smoke to flow out of the building and fresh air to enter.

Shutting Down Fire Pumps

The decision to shut down the fire pumps was made at 12:31 pm. This decision was critical, because it interrupted the water supply to all of the sprinkler systems, including the ESFR sprinklers. This appears to have resulted in the failure to control the secondary fire that produced the disastrous outcome, although it can only be assumed that the ESFR sprinklers probably would have controlled the secondary fire, if the pumps had not been shut down.

When the first request was made to shut off the sprinklers, at 12:23 pm, it was specified to keep the fire pump in operation, because the hose line that had been used to complete the extinguishment of the fire was being supplied by a hose outlet that was fed by the fire pump. By 12:31 pm this line had been disconnected and the second charged hose line, supplied by a pumper outside the building, was available if it was needed.

All of the available information at that point indicated that the fire pump was no longer needed. The fire on the 2nd level of the Pick Module had been extinguished at least 10 minutes earlier and the potential for rekindle was remote. Everything in the fire area had been thoroughly soaked by the sprinklers, which were still operating at that point. The areas around and directly above the fire had been checked and there were no indications of fire extension. Based on that information, the order was given to shut down the fire pump, because there was no known reason to keep it in operation.

There are no established guidelines for when it is appropriate to shut down a fire pump in this type of facility or how long it should be left running after a fire has been extinguished. Both NFPA 13E and the FM training program are silent on this point. Both reference sources indicate that a firefighter should be assigned to confirm that the fire pump is operating properly at the beginning of an incident. The FM program also indicates that a firefighter or a qualified operator should remain at the pump to monitor its operation during the incident. Neither source provides specific guidance or recommendations for when it is appropriate to shut a fire pump down.

The determination of when to shut down a fire pump is left to the judgement of the Incident Commander, just as the Incident Commander is responsible for determining when it is appropriate to shut off the sprinkler system. The fire pump can be shut down when the Incident Commander determines that it is no longer needed.

Many firefighters believe that fire pumps should not be left running for longer than they are needed, based on the belief that there is a risk of overheating and causing serious damage to the pump if no water is flowing. This information is not found in any textbooks or training manuals; however, it appears to be a common belief. It is most likely based on the training that is provided for fire department pump operators relating to fire apparatus pumps.

Several experts and reference sources have confirmed that a fixed fire pump can be left running, even if it is not delivering any water, because the pump casing incorporates a system that allows a continuous flow of cooling water to be discharged to a drain. The protocol for testing fire pumps calls for them to be run with no flow (a churn condition) for periods of up to 30 minutes.

The consensus among fire protection engineers appears to be that fire pumps should be left running after sprinklers and standpipe systems have been shut off, as long as there is a possibility that those systems might have to be reopened. Nevertheless, at some point it is appropriate to shut down a fire pump and that determination is left to the judgement of the Incident Commander.

This is a subject that requires further analysis and discussion. Fire departments should be provided with guidelines for shutting down fire pumps. There is clearly a lack of good information to guide firefighters in making appropriate decisions.

In this case, the decision to shut down the fire pump was reasonable at the time it was made, based on the information that was available. That situation changed when the waterflow signal from the first ESFR system was registered, which was at almost the exact same moment that the electric fire pump was being shut down. The fire pump(s) would not have been shut down, if this new waterflow indication had been observed by someone monitoring the alarm system.

This highlights a recommendation that can be found in the FM firefighter training program for fires in storage occupancies. This program recommends assigning a firefighter to monitor the fire alarm panel during an incident to watch for changes and new alarm indications. In this case, there was no one from the fire department or the facility assigned to monitor the alarm system at the security office inside the building or at the guard station outside. The alarm systems were monitored remotely at the proprietary central alarm facility; however, the additional waterflow information was not transmitted back to the scene of the fire.

The records indicate that the waterflow from ESFR Riser 7 was registered at 12:34 pm and the electric fire pump was shut down at 12:35 pm. As described in a previous section, the diesel back-up pump started automatically and operated until 12:38 pm. It was only at that point that the water supply to the sprinkler systems was interrupted.

Shutting down the fire pumps appears to be the critical action that allowed the fire to rage out of control. Within seven minutes after the water supply was interrupted, the fire had penetrated the roof and the situation had become uncontrollable. It cannot be determined how many ESFR heads had opened before the water supply was interrupted and whether they were controlling the fire on the 4th level of the Pick Module.

Although the pumps were restarted within four minutes after firefighters became aware of the fire above them, it was too late for the sprinklers to regain control of the fire. The fact that both fire pumps were operating and cavitating by 12:50 pm confirms, that the demand for water far exceeded the capabilities of both pumps operating together.

Checking for Fire Extension

It is reasonable to expect that firefighters would check for the possibility of vertical fire extension above a fire before calling for the sprinklers to be shut off and the fire pump to be shut down. In this incident the 3rd level was checked, directly above the fire area on the 2nd level, and no indications of fire extension were found. There were no sprinklers operating on the 3rd level at that time.

The analysis suggests that there may have been a smoldering fire above the 2nd level that was not detected when the 3rd level was checked. One scenario assumes that the smoldering fire was on the 3rd level and that it developed into a rapid growth fire after the area had been checked and extended to the 4th level. The alternative scenario assumes that there was no fire extension to the 3rd level, but there was a smoldering fire on the 4th level that subsequently transitioned to flaming combustion.

This could be a valuable lesson for fires in similar occupancies. Firefighters routinely check for indications of vertical extension above a fire in a building. In many cases, particularly with combustible construction, there is an expectation that a fire easily could have extended vertically, so the areas above are checked very thoroughly. In a fire resistive or fully sprinklered building, most firefighters would anticipate that a fire should not extend vertically, but the area above would still be checked to confirm that expectation.

The Pick Module presented an unusual combination of factors. It had many of the characteristics of a fully sprinklered building, but it was essentially an assembly of racking components with no inherent fire resistance. The combination of sprinklers and a mezzanine deck appeared to provide a barrier that should prevent or at least reduce the risk of fire extension. There were numerous openings in the decking that could potentially provide flow paths for fire extension; however, many of them were concealed within the racking structure and by the densely packed storage on the shelves. The environment was crowded, confusing and, at that time, filled with smoke.

If the fire had extended vertically, most firefighters would expect to find either active fire on the 3rd level or additional operating sprinklers that had already controlled the fire on that level. In either of those circumstances, the evidence of fire extension would be obvious.

The firefighters probably would not have expected to encounter a smoldering fire that was hidden somewhere within the shelves. As noted previously, under normal circumstances it can be very difficult to find a small smoldering fire in a smoke-filled building. It would be much more difficult if the smoldering fire was occurring somewhere within the crowded and confusing environment of the Pick Module. Even with the assistance of a thermal imaging camera, which was used, a smoldering fire could easily be missed in those conditions.

In retrospect, it is understandable that the vertical extension could have been missed when the 3rd level was checked. This is predicated on the presumption that the fire actually had extended vertically and was smoldering when the 3rd level was checked.

The valuable lesson is that the potential for vertical fire extension in this type of structure is probably much greater than expected. It also appears that a fire can smolder for a considerable time in this environment, before it becomes evident.

Smoke Conditions

Smoke conditions often provide valuable indications of fire behavior inside a building. In this instance the smoke conditions provided no advance warning that a critical situation was developing.

When the first firefighters arrived at the building, there were no indications of smoke or fire from the exterior. Upon entering the warehouse, they encountered hazy smoke, but there was still good visibility at the floor level and employees were able to lead them to the area of the fire. The firefighters were able to connect their hose line to an outlet on the 2nd level of the Pick Module and advance to within 50 to 75 feet of the fire area before connecting the regulators to their SCBA facepieces.

> *The first officer to enter the building transmitted a radio report of "zero visibility inside." He later described the conditions as thick smoke in the area of the Pick Module, but only hazy smoke between the entry point and the stairs leading to the 2nd level.*

Visibility in the immediate area of the fire was very limited because of the smoke and the heavy discharge of water from the sprinklers. There was no sensation of heat, because the water was cooling the smoke and creating a dense foggy condition. This mixture continued to accumulate as the firefighters worked to complete the extinguishment of the fire.

The smoke did not dissipate after the fire had been extinguished. It continued to accumulate in the aisles on the 2nd level of the Pick Module.

> *This type of cold smoke condition is often encountered in very large buildings where sprinklers are operating. It is extremely difficult to ventilate cold smoke, because it is heavy and does not rise or flow due to buoyancy and convective forces. The fire does not create thermal columns or natural flow paths. The sprinklers cool the atmosphere and produce high humidity, so the resulting mixture of smoke and fog tends to sit or hang in the atmosphere. Powerful fans or large openings and a strong wind are often needed to accomplish ventilation.*
>
> *This condition should be recognized as potentially dangerous. It is easy for firefighters to become disoriented in a large warehouse that is filled with this type of smoke. It is also possible that conditions are changing somewhere within the building, but the visual indicators are shrouded by the mass of cold smoke.*

The firefighters who were assigned to the roof did not see any indications of smoke, other than occasional wisps from some of the air handling units. They were preparing to return to ground level when the fire suddenly erupted through the roof.

The crews that were assigned to open loading dock doors, after the fire on the 2nd level of the Pick Module had been extinguished, were able to enter and walk toward the south, along the west wall of the building, without using their breathing apparatus. They reported that there was still only hazy smoke near the floor level and somewhat thicker smoke overhead. They could see thicker smoke in the vicinity of the Pick Module structure, but they did not observe any smoke conditions that appeared to be ominous before L84 reported that the fire had penetrated the roof.

When they heard the report from L84 and looked back toward the north, they observed heavy dark smoke at the roof level and flames spreading rapidly from north to south in the upper part of the Pick Module. Within the following 60 to 90 seconds, the dense smoke descended to the floor level and all visibility was lost. This is an additional indication of how quickly conditions changed inside the building.

Fire Wall

The fire wall that was incorporated into the construction of the building was intended to divide it into two potential fire areas. Each side of the fire wall was described as an area of "maximum foreseeable loss" in a worst-case scenario. A 4-hour rated fire wall is usually considered to be virtually impenetrable to a typical building fire.

In this case, the fire passed the fire wall and spread from the south section to the north section of the building within approximately 30 minutes after the south section became fully involved in the fire. This calls into question many of the performance assumptions for fire walls in this type of building.

The fire wall was still standing and relatively undamaged after the fire. The fire did not destroy the wall and it did not pass through it or outflank it at either end. There were several openings in the wall, but all of them were protected by automatic closing fire doors. One of the fire doors did not descend fully; however, it was part of an assembly that included fire doors on both sides of the wall and the door on the opposite side did close fully.

Witnesses who were observing the fire wall area offered differing descriptions of what happened, although all agreed that it was sudden, unstoppable, and downward. Firefighters on the north side felt a strong downdraft and had to evacuate immediately. The roof on the north side began to collapse within minutes.

It appears that the magnitude of the fire produced a massive thermal column that radiated heat downward. This appeared to cause the roof membrane and insulation on the opposite side of the wall to ignite. The roof fire quickly penetrated downward into the building. It is also possible that the radiant heat compromised parts of the steel structure that supported the roof north of the fire wall, causing it to fail very rapidly.

It is evident that the fire created a much greater challenge than the 4-hour fire wall could resist. This can be attributed to the combustibility of the contents and the size of the fire that was produced when the south side of the building became fully involved.

Conclusions

The detailed analysis of this incident provides a significant quantity of information that should be valuable to several different interests. It also leaves a number of important questions unanswered.

The predominant factor appears to be the complex arrangement of the Pick Module and the extremely challenging fire problem that it created. It appears that the fire protection systems that were designed to protect it functioned properly, but the fire was still able to extend vertically from the 2nd level to the 4th level, without being observed. It is impossible to determine exactly what happened; however, the analysis provides two possible explanations of how that could have occurred. The third hypothesis, that a completely separate fire was ignited on one of the upper levels, remains as a possibility.

These issues must be addressed in the context of facility design and a fire protection engineering problem. It is evident that the complex configuration of the Pick Module and the highly combustible contents that were stored in it created an exceptionally challenging fire problem. That risk had been addressed by the installation of fire protection systems that were expected to quickly detect and control a fire within the Pick Module. All of those systems appeared to be well designed, installed according to the plans and properly maintained, but the outcome was catastrophic.

The specific lessons that can be derived from the detailed analysis of the fire extension within the Pick Module are probably only applicable to other facilities that have similar installations.

There is no indication that the firefighters committed any serious errors that caused or allowed the fire to become uncontrollable. When firefighters arrived, they found a fire that had been successfully controlled and confined within a limited area on the 2nd level of the Pick Module. This was expected, if a fire occurred within that structure.

The firefighters completed the extinguishment of the fire on the 2nd level. They checked the 3rd level and found no indications of fire extension. Firefighters on the roof saw nothing that indicated the fire was still burning. The firefighters inside the building did not see any indications that the fire had extended. The situation appeared to be fully under control and all of the fire protection systems appeared to have performed as expected. At that point, their operations transitioned to property conservation and a secondary search for any employees who could still be in the smoke-filled Pick Module.

There was nothing that would indicate that it was not appropriate, at that time, to shut off the sprinklers, begin ventilation to remove the smoke, and then shut down the fire pump. Each of these actions was reasonable, based on their observations, training, and experience. The actions were also consistent with the operational recommendations available from NFPA 13E and the training programs developed by FM.

There are several unknowns relating to what happened during the period of 10 to 15 minutes, between the time the fire was effectively extinguished on the 2nd level and the ESFR sprinklers activated above the 4th level. It is known that the fire became active on the 4th level, at almost the exact same time that the fire pumps were being shut down. The pumps would not have been shut down, if anyone had known that there was active fire at the top of the Pick Module and the ESFR sprinklers were operating. This set of circumstances was extremely unpredictable and directly related to the complex nature of the Pick Module.

While it appears that shutting down the fire pumps was the critical action that allowed the fire to become uncontrollable, it is possible that the water supply for the sprinkler systems had already been surpassed, before the fire pumps were shut down. It cannot be determined if there was active fire on the 3rd level, before the fire became active on the 4th level, and if any additional CMDA sprinklers had activated on that level. The sprinklers on the 2nd level were still operating, so together the CMDA sprinklers could have been using a substantial portion of the available water supply ESFR sprinklers began to operate.

The overall incident analysis provides several important lessons relating to the types of fires that can occur in a mega-warehouse and the unusual situations that can be encountered. It is very significant that the situation appeared to be under control and everything appeared to be occurring as expected, until suddenly the situation was out of control and nothing could be done to change the outcome.

This provides several lessons that are generally applicable to mega-warehouses and to fire departments that respond to very large storage occupancies. These subjects are discussed in the following section.

Discussion Points & Recommendations

Overview

This incident, along with several similar very large loss incidents, has created a heightened awareness of the level of fire risk that is associated with mega-warehouses. The magnitude of the property loss alone makes this incident very significant, while the overall economic impact is much greater than the value of the building and contents. When the potential risks to firefighters and occupants and the impacts on the community and the environment are considered, the significance is even greater.

There are very significant economic factors that justify the construction of mega-warehouses for a wide range of purposes. Many similar buildings, in terms of size and construction, have been built in the United States and around the world and many more are planned or under construction. Each of these buildings represents a very large property value and potential loss in the event of a fire. These buildings also present extreme challenges for fire departments and risks to firefighter health and safety that have not been widely recognized.

Almost all mega-warehouses rely on automatic sprinkler systems to prevent a catastrophic loss if a fire occurs. The magnitude of the fire risk can only be managed by automatic sprinklers and other fixed fire protection systems, because conventional fire suppression methods are incapable of controlling the type of fire that can occur in these buildings. It is very unlikely that firefighters, using conventional equipment, strategy and tactics, would be able to change the outcome of a fire, if the fixed systems fail to control it. Nevertheless, the fire department is expected to respond and assume responsibility for managing the incident when a fire does occur.

Public fire departments, even in the largest cities, cannot provide the fire suppression capacity that would be required to control a mega-warehouse fire. Many of these facilities have been built in suburban and rural areas that have very limited public fire protection resources and capabilities. The training and experience of firefighters in these areas are often oriented toward fighting fires in residential and small commercial properties. They may assume that a new mega-warehouse is adequately protected by its own fixed fire protection systems and that it should not create a great concern for local firefighters. This could be a grave error that is not recognized until a significant incident occurs.

In many cases, the fire risk characteristics of these facilities allow for very little margin for error in the fire suppression capabilities that are installed to protect them. The fire suppression systems in these buildings are designed to control fires within a closely defined set of parameters. The level risk is considered to be acceptable, at least from a property insurance perspective, as long as the risks have been properly evaluated, the fire protection systems have been appropriately designed and maintained, and everything functions as intended. Any deviation from those expectations could result in a catastrophic loss. If the sprinklers and associated fixed systems fail to control a fire, a total loss is virtually inevitable.

In most cases, the fixed fire protection systems do function properly and succeed in controlling fires, usually before firefighters arrive. The responding fire department is often faced with the tasks of confirming that the fire is under control and extinguishing any residual fire, followed by overhaul and property conservation measures. The exceptional cases are infrequent, but the consequences can be overwhelming. The information that can be obtained from the detailed analysis of those incidents is essential to understand and manage the risk factors and to be prepared for similar incidents in the future.

Training

There is a serious need for more training and information to prepare fire departments for the low frequency, high risk incidents that can occur in very large storage occupancies. Training programs should be developed to specifically address fire department operations in these types of facilities.

The training and reference guides that are available today tend to focus on the basic characteristics of sprinkler systems and conducting operations in typical sprinklered buildings. They do not prepare firefighters and officers for the complex and very large scale challenges that may be encountered in a mega-warehouse, especially if the fixed fire protection systems are not successfully controlling a fire. An incident commander, who could have limited experience and no specific training for dealing with a fire in a mega-warehouse, could suddenly become responsible for making critical decisions. Firefighters may be needlessly exposed to risks while trying to fight a fire in this type of building and an operational error could compromise the effectiveness of the fixed fire protection systems and contribute to a mega-loss.

Fire departments need to develop standard operating procedures for conducting operations in mega-warehouses and other types of very large buildings, even if they appear to be fully protected by automatic sprinklers and other fire protection systems. Firefighters need to be prepared for the types of situations they are likely to encounter, including fire dynamics in large spaces, strategy and tactics, and familiarity with complex sprinkler systems, fire pumps, water supplies, and alarm systems. It may not be feasible for every firefighter to become an expert in the details of complex fire protection systems, but there should at least be qualified personnel on duty or available to respond promptly to assume this role.

Pre-fire Planning

The importance of pre-fire planning and familiarity with each facility is evident. This requires equal commitments from the property owner/operator and the fire department to share information and provide opportunities for firefighters to visit and become familiar with the facility and its fire protection systems. All of the essential information relating to each facility should be documented in a standard format and immediately available when an incident occurs.

It is important to provide fire departments with information that includes the basis of design and performance expectations for the fire protection systems in a mega-warehouse. The assumption that the sprinklers should be able to control any fire that occurs is far from sufficient.

The on-site managers, who are responsible for day-to-day operations, may have very little understanding of fire risk factors or the details of the fire protection systems in their buildings. In many cases, they rely on external contractors to maintain and inspect those systems and assume that the local fire department has the expertise and resources to handle any fire situation that could occur.

In some cases, there is considerable technical expertise available at a corporate level, often from consultants or insurers, but this does not extend to the level of individual facilities. Fire departments should reach out to obtain detailed information relating to all of the fire protection systems in facilities within their jurisdiction and ensure that the information is verified and updated at least annually. This requires a significant commitment to pre-fire planning.

Complexity and Variety

The exterior appearance of a mega-warehouse generally provides little or no indication of the contents or activities that are being conducted inside. While many mega-warehouses look very similar from the exterior, there are countless variables with respect to the contents, storage arrangements, and materials handling systems, based on the particular operations that are being conducted within the walls.

The fire that is analyzed in this report occurred in a mega-warehouse that contained a huge pick module. That installation created an extremely challenging fire risk and required its own custom-designed fire protection systems. Similar installations exist in many other facilities; however, it is only one of many types of storage configurations and materials handling systems that can be found inside a mega-warehouse. In many cases, the fixed fire protection systems must be custom designed by fire protection engineers based on the particularities of each situation.

It is increasingly common for these facilities to incorporate automated storage and retrieval systems (ASRS) that are designed to maximize the utilization of space and optimize the efficiency of materials handling. These installations often include robots moving materials around the building and very large and complex rack systems that provide no space for human access. In some cases, it may be infeasible for firefighters to even reach the fire area to confirm that a fire has been extinguished by the sprinklers and conduct any type of overhaul. It is essential for firefighters to become familiar with these facilities and the special challenges they present, before a fire occurs.

Strategy and Tactics

For many years, the recommended actions for fire departments responding to fires in sprinklered buildings have emphasized the need to confirm that the sprinklers are operating and support their operation. This includes verifying that the appropriate valves are open and fixed fire pumps are operating, as well as connecting a pumper to the fire department connection to supplement the water supply to the sprinklers.

In cases where the fire is not already under control, the recommended actions have included advancing hose streams into the building and as close as possible to the area where sprinklers are operating. These recommendations were based on the presumption that sprinkler systems are expected to control fires and keep them from spreading, but not necessarily extinguish them. The hose streams were primarily intended to complete the extinguishment and overhaul of the fire; however, if necessary, they could also provide added suppression power to overcome a stubborn fire that was not being controlled by the sprinklers. There have been numerous cases where this approach has been successful in gaining control of a fire. In some of those incidents portable master streams were brought into a sprinklered building to assist in controlling and extinguishing the flames.

A much more conservative approach is now being advocated for fires in very large storage occupancies, primarily by the National Fire Sprinkler Association and FM. This recommendation is for firefighters to conduct the initial verifications to ensure that the sprinkler systems are functioning properly and the water supply is adequate, then to stand by and let the sprinklers flow for as long as necessary to completely extinguish the fire. This approach is primarily intended to eliminate the risk of sending firefighters into very large buildings that are filled with smoke and present a wide variety of risks.

This recommendation is based on the assumption that properly designed sprinklers should be able to control any fire that occurs in a large storage building. This strategy also recognizes that the actions of firefighters are unlikely to have a significant impact on the fire if the sprinklers are not effective, so there is no reason to expose them to the avoidable risks. The premise is that once the sprinklers have controlled the fire and eliminated the possibility of fire extension, allowing them to continue to flow will eventually result in complete extinguishment. If the water does not extinguish the fire, it should extinguish itself when all of the fuel within the fire area has been consumed.

At the present time, this recommendation is relatively new to the fire service and has not been widely disseminated. It represents a radical departure from traditional thinking; however, it appears to be very logical and deserves further analysis and discussion. The information should be incorporated into training programs and widely disseminated to reach all fire departments that respond to fires in large storage occupancies.

Sprinkler Shut Off Criteria

The analysis of this incident highlights the lack of specific criteria or guidelines for when it is appropriate to shut off sprinkler systems and fire pumps in mega-warehouses and similar large storage buildings. The recommendation to stand back and let sprinklers flow for as long as necessary to extinguish the fire does not eliminate the problem of determining when that point has been reached and it is appropriate to shut them off. Sooner or later that decision will have to be made.

At the present time, there are several reference sources that caution against shutting sprinklers off prematurely or shutting them off to permit a visual evaluation of whether the fire is under control, but there are no specific documented criteria for when it is appropriate to shut off a sprinkler system or shut down a fire pump.

Firefighter training has emphasized that control mode sprinklers are only expected to confine a fire and prevent it from spreading or growing; it has long been anticipated that the fire department will be needed to complete the extinguishment. Suppression mode sprinklers are expected to control and suppress the fire; however, until recently, it has been anticipated that firefighters would still be needed to complete the final extinguishment. It has always been left to the experience and judgement of the fire officer in command of the incident to determine when it is appropriate to shut off the sprinklers. Presumably, they would not be shut off until the fire was fully under control and firefighters were in position with hose lines to complete the extinguishment.

The revised recommendation is to let the sprinklers operate longer so that they can fully extinguish the fire. This approach delays the decision point, but the incident commander will still have to determine when it appears that the fire has been extinguished and the sprinklers can be shut off.

In most cases, the incident commander has to rely on the observations of firefighters or officers who can visually evaluate the situation in the fire area, because the command post is positioned outside the building. This requires a determination of when it is safe enough to send a team inside to assess the situation. In many cases, it is difficult to fully assess the situation while the sprinklers are operating, especially with the heavy discharge that is produced by ESFR sprinklers.

There have been cases with fires in very tall racking, where the fire area was inaccessible and sprinklers were left operating for hours after there was any indication of active fire, but the fire flared-up as soon as the sprinklers were shut off. In one such case, the sprinklers were shut down three times and then quickly reopened each time because the fire was still active. On the third attempt the fire overwhelmed the sprinkler system and the building was lost.[4]

Automatic storage and retrieval systems (ASRS) often provide little or no access for firefighters to approach close enough to fully evaluate the situation. In these circumstances the sprinklers can be left to flow for extended periods, but eventually they will have to be shut off. Some type of guidelines for "how long is long enough" would be valuable.

The water supply could be a limiting factor in many cases. Sprinkler system designs always include a minimum duration that the water supply should be capable of delivering the required flow, which could provide a starting point for determining how long to wait before shutting off the sprinklers if it is not possible to determine that the fire has been extinguished. The storage tanks at this incident contained enough water to support the full anticipated flow for four hours. (600,000 gal/2500 gpm = 240 minutes)

If the sprinkler systems depend on a local water distribution system, there is probably a maximum flow rate and a maximum duration that it can be provided without draining the storage reservoirs.

There are situations where allowing the sprinklers to continue to flow after the fire is under control could create additional risks to firefighters. If the water is being absorbed by the contents, they could overload racks or destabilize stacks of materials, causing them to collapse. Firefighters should always approach an area where sprinklers are flowing, or have been flowing, with extreme caution, watching for indications of instability.

Automatic sprinklers have a very high success rate for quickly controlling fires, even in mega-warehouses and large storage occupancies. In most cases, the sprinklers will have already controlled the fire before firefighters arrive. The situations where the fire has not been controlled are exceptional, but they are also the most dangerous and have the greatest potential for sudden changes in conditions inside a large building.

[4] Tupperware Warehouse, Williamsburg County, SC, December 2007

The new recommendation, to let sprinklers flow until the fire has been extinguished, is a significant departure from traditional thinking. Nevertheless, someone is still going to have to assess the situation and make the determination of when to shut the sprinklers off. Because the margin for error is often very narrow, the incident commander will have to be very confident that the fire has been effectively extinguished before calling for the sprinklers to be shut off.

Even then, hose lines should be in position in anticipation of potential flare-ups or rekindle. In most cases, there will still be a need for overhaul to confirm that the fire is fully extinguished.

Several factors often combine to create unusual difficulty in evaluating fire conditions inside a mega-warehouse:

- The interior of the building is likely to be filled with a mixture of cold smoke and steam resulting in very limited visibility.
- The sprinkler discharge contributes to an atmospheric inversion, causing the smoke to drop toward the floor and stratify, hindering natural ventilation.
- The water discharge from the sprinkler system, particularly from an ESFR system, further obscures visibility and makes it very difficult for firefighters to approach the seat of the fire.
- The quantity of water in the atmosphere makes it difficult or impossible to make effective use of thermal imaging cameras to evaluate fire conditions.
- The quantity of stored material, the storage height and arrangement may make it both difficult and dangerous to access the fire area.
- The weight of water that is absorbed by the contents may overload storage systems and compromise containers, creating serious risks to firefighters.

When the decision is made to shut down a sprinkler system, the closest control valve upstream of the discharging heads should be closed. This requires familiarity with the arrangement of the sprinkler and standpipe systems. All valves should be properly labelled and clearly indicated on pre-fire plans. Visual flow indicators, such as an LED connected to the flow switch, can be extremely valuable in determining which valve needs to be closed.

- If the system is divided into zones, the zone valve should be closed.
- In the absence of zones, the riser valve should be closed.
- If closing a zone or riser valve would also interrupt the water supply to hose lines that are connected to standpipe outlets, alternative hose lines should be in place before the valve is closed.

Shutting down fixed pumps should not be a priority. In a properly designed system, the fire pump can be left running after the sprinklers have been shut off, until the Incident Commander is confident that it is no longer needed. In many cases, it would be appropriate to leave the pump running until a qualified operator, a technician, or contractor arrives.

Property Conservation

Fire departments generally prioritize property conservation measures after a fire has been controlled or fully extinguished. The value of the contents of a mega-warehouse is often estimated in tens or hundreds of millions of dollars, so the concern for property conservation is significant. Traditional thinking has been that sprinklers should be shut off promptly, but not prematurely, to reduce water damage and that ventilation should be conducted as soon as possible to reduce smoke damage.

Experience with fires in large storage buildings indicates that letting the sprinklers run longer outweighs the risk of shutting them down prematurely. The concern for additional fire damage that would result from losing control of a fire is usually greater than the concern for additional water damage. This factor is a major concern in mega-warehouses, because the potential for losing control of a fire is greater and the results can be catastrophic.

It is also recognized that premature ventilation may compromise the performance of a sprinkler system. This factor is particularly critical in a mega-warehouse because of the very large spaces and the air flow volumes that could be involved. Ventilation should be delayed until there is confirmation that the fire has been extinguished.

The concerns for smoke and water damage depend on the nature of the contents that are stored in a warehouse. In some cases, the exposure to smoke and water may have little or no impact, while in other cases the contents may be highly susceptible to either or both. When the contents are already wet and the building is already filled with smoke, it is probably too late to prevent the damage from occurring. If the contents of a warehouse are consumer goods, food or drugs, the insurers will probably declare them to be a total loss if there has been any exposure to smoke or water.

Effective ventilation of a large warehouse that is filled with cold smoke usually requires powerful fans and adequate openings to let fresh air enter and the smoke vent to the exterior. In some situations, it may be a reasonable option to simply let nature take its course. The particulate components of the smoke will gradually settle and the gaseous components will be eliminated by natural ventilation.

Several reference sources suggest that all of the burned debris should be removed from a building during the overhaul process to be absolutely sure that there can be no possibility of a rekindle inside. This may be difficult or impossible in some cases, particularly if the fire area is inaccessible. In some mega-warehouses it may be impossible to access the fire area and remove the debris without special equipment and without exposing firefighters to unnecessary risks. This introduces a series of concerns relating to the availability of qualified operators, the use of protective clothing and self-contained breathing apparatus, and the suitability of the equipment to function in proximity to a fire or operating sprinklers. In many cases, it could be appropriate to leave the problem of debris removal to the property owner or a private contractor, after the building has been fully ventilated.

All of these factors require a different approach to property conservation in a mega-warehouse. The priorities relating to salvage and the protection of unburned property must be considered in the context of the overall situation.

Occupant Life Safety

The issues relating to occupant life safety are usually much less concerning in storage occupancies than other types of buildings, primarily because there are expected to be relatively few occupants and they should be able to evacuate without assistance, probably before the fire department arrives.

The facility where this incident occurred was probably exceptional, because there were reported to be 565 employees at work on the day of the fire and close to 1,000 could be present during the peak activity season. Shortly after firefighters arrived at the scene, a company representative reported that they were unable to account for 55 employees who were believed to have been in the building.

The report of that many employees potentially missing within such a large building was a serious cause for concern; however, it was not judged to be critical at that moment. The firefighters inside the building were reporting conditions that would still permit employees to self-evacuate without assistance. There was hazy smoke throughout the warehouse, but the thick smoke was limited to a small area in proximity to the fire. The first entry team had been met by employees who guided them to the fire without the use of SCBA.

After the fire had been extinguished, teams were assigned to conduct a search for occupants in the sections of the Pick Module that were filled with smoke. After confirming that there was no additional information with respect to the missing employees, additional teams were requested to conduct a search of the upper levels. These teams had just arrived when the fire conditions changed dramatically.

It was later determined that all employees were out of the building and the report of missing persons was a result of inadequacies in the personnel accounting system. Apparently, many of the employees wandered around outside or went to their cars in the parking lot, instead of reporting to designated assembly areas.

From a practical perspective, attempting to search for 55 employees in such a huge building would have been an overwhelming challenge, especially if the interior had been filled with smoke and the fire was not under control. In that case search and rescue would have become the first priority. The Incident Commander would have had to weigh the risks of sending firefighters into a huge and extremely dangerous environment to look for the missing employees.

Building Codes anticipate that the sprinkler system in a large warehouse should control a fire before conditions become immediately dangerous to life and health. It is presumed that there should be ample opportunity for employees to self-evacuate before firefighters arrive.

The Indiana Building Code allowed for a maximum exit travel distance of 400 feet in this type of building and a variance had been obtained to increase the travel distance to 450 feet in this facility. The variance was based on the presence of both sprinklers and a smoke detection system to provide early warning and allow adequate time for evacuation.

The concern for occupants is much greater in large warehouses and retail "big box" occupancies that are open to the public. Experience has shown that customers in these types of occupancies may not react quickly when an alarm sounds and probably do not know where exits are located. There are many videos that show customers in retail stores continuing to shop, in spite of obvious flames and smoke banking down from the ceiling. The shoppers appear to be oblivious to the fact that they could be in imminent danger within seconds.

Fire Department Operations in Mega-warehouses

Fire departments that respond to mega-warehouses and other very large facilities should be prepared to conduct operations inside large and complex buildings. Communications and personnel accountability are two essential concerns; however, this extends to the challenges of air management, crew rotation and rehabilitation, and supporting an operation that could be taking place hundreds of feet from the nearest entry and exit points.

Radio Communications

Reliable communications are essential for firefighter safety and operational coordination. Firefighters who are working inside a building must always have effective two-way communications with the Command Post. If the existing radio system cannot ensure that this link is maintained, an equivalent means of communication must be provided.

Many radio systems, particularly trunked radio networks, are not designed to provide reliable coverage inside large buildings. Steel roof structures and concrete exterior walls can create barriers that effectively block signals and the installation of steel racking in many buildings can interfere with transmission and reception.

Many fire departments conduct fireground communications on simplex channels, as opposed to trunked networks, because they do not depend on maintaining a connection to a network tower site that could be miles from the fire scene. Short range transmissions from portable to portable inside a building or from inside a building to a command post directly outside are less likely to be blocked by the shielding effect.

Because the characteristics of different buildings are extremely variable, the only way to know what coverage is available is to conduct tests with both trunked and simplex channels. The results may be significantly different in different buildings or different areas within the same building.

Several options are available to enhance coverage in different situations. Indiana has adopted requirements for new large buildings to install amplified antenna systems or network extension equipment to provide full interior coverage; however, this requirement will not be applicable retroactively to existing buildings. Fire departments may be able to achieve similar results with mobile repeaters in vehicles or portable repeaters that can be taken inside. Typically, these systems allow for portable-to-portable simplex communications with a direct link to the trunked network outside the building. Several different configurations are feasible to meet different requirements and circumstances. The solution that is chosen must ensure that there is a reliable and continuous communications link with every firefighter who is operating in a hazardous area.

Operational Coordination and Logistics

Fire departments that respond to all types of very large buildings must be prepared for the operational and logistical challenges of operating deep inside a large interior space. It can become very difficult to move firefighters in and out, to rotate crews and to provide logistical support when the operations are being conducted hundreds of feet from the closest access point. In many cases, this begins with simply determining where the fire is located, where to enter, and how to identify a path to that area, as well as an exit path.

The problems become much more severe if the interior is filled with smoke and SCBA must be used to enter and exit, but even if the atmosphere is relatively clear going in initially, the possibility that conditions could change must be considered. Paths in and out should be marked and breathing air must be managed so that firefighters do not run out of air before they can reach a safe atmosphere. Crews may have to be sent inside and staged in proximity to the work area in anticipation that the working crews will have to be replaced at a predicted time. It could also be necessary to position a rapid intervention team inside the building, because of the distance to the area where they could be needed.

Strict accountability must be maintained for all personnel entering and exiting and crews must stay together. It is easy to become lost and disoriented inside a large warehouse, but much more so if it becomes filled with smoke while crews are operating. It is recommended to stretch at least one hose line from outside the building into the fire area, even if interior hose outlet valves are being used, to provide a line that can be followed to an exit.

Each of these considerations involves additional time, planning and coordination, as well as sufficient resources to conduct operations and provide logistical support at the same time. Training exercises should simulate conducting operations deep inside a building to develop an appreciation of the complexity that can be involved, even if the situation is limited to conducting overhaul of a fire that has been effectively extinguished by the sprinkler system.

As noted previously, in most cases if the sprinklers have not effectively controlled a fire inside a mega-warehouse before firefighters arrive, it is unlikely that their actions will be able to change the outcome. The recommendation to let the sprinklers flow until the fire has been extinguished is intended to limit the needless exposure of firefighters to the risks that could be involved in trying to fight a fire in an environment that is beyond their capabilities.

Dispatch Protocols

There was a notable delay in dispatching the initial assignment to this incident. While the delay does not appear to have made any difference with respect to the operations that were conducted or the outcome of the incident, the procedures for processing alarm system calls should be re-evaluated.

The first call to the Hendricks County Emergency Communications Center came from the corporate alarm monitoring facility at 11:54:19 am. This call was made within two minutes after the first smoke detection alarm was registered and was received on a line that was reserved for reporting alarm system activations. The caller provided the location and name of the facility and the nature of the incident within the first 20 seconds; however, the call continued for a duration of 4 minutes and 11 seconds.

The caller indicated that several different smoke detection and waterflow alarms had been activated and was asked to provide information on all of the individual alarm indications. The call-taker entered all of this information into the computer-aided dispatch (CAD) system, but did not dispatch any units while the information was being obtained.

A second call was received via 9-1-1 at 11:56:52 am and answered by a different call-taker. This call came directly from the facility and reported a confirmed fire in the building. This information was entered into the CAD system by the second call-taker at 11:57:45 am and the first alarm units were dispatched at 11:57:58 am. The first call-taker was still talking to the monitoring facility when the call was dispatched.

This incident suggests that the established procedures for processing alarm system calls should be reviewed. Many communication centers treat fire alarm system activations as low priority incidents and focus on capturing all of the detailed information before dispatching units. It should be possible to dispatch an initial assignment, while the call-taker remains on the line to record any additional details. If necessary, the assignment can be modified or upgraded while the initial assignment is en route.

Many fire departments, including PFT, send a limited response to an alarm activation call, based on the low probability that they will encounter a serious fire. If additional information is received, the call can be immediately upgraded a full building fire assignment.

Call-takers should also be trained to interpret the information that is received. While most alarm system calls are routine, a call from a monitoring service indicating multiple smoke detection and waterflow indications coming from a large facility should be quickly recognized as more significant than an ordinary alarm system activation. In that situation it would probably be appropriate to dispatch a full building fire assignment without waiting for someone on the scene to confirm that there is a fire.

Guidelines for Fire Department Actions in Mega-warehouses

Overview

The initial actions of firefighters arriving at a fire in a sprinklered storage building begin with initial size-up and confirmation that the sprinklers and other fire protection systems are operating. It may not be immediately evident if they are effectively controlling a fire inside the building or even where the fire is located.

The water supply should be verified by checking to ensure that all valves controlling the flow to the sprinklers are fully open. If there is a fire pump, a knowledgeable firefighter needs to ensure that it is operating properly. A firefighter or a qualified operator should remain at pump house to monitor its operation.

At least one pumper from the initial assignment should prepare to supply water to the fire department connection (FDC). The lines to the FDC should be charged if there are any indications that the fire is not already under control.

The Incident Commander should, as soon as possible, establish a liaison with a responsible person, who is intimately familiar with the building and its fire protection systems.

If there are multiple sprinkler systems, it is essential to know which ones are indicating water flow. This information can usually be determined from an alarm control station or annunciator panel or an audible waterflow alarm on a sprinkler riser. If possible, a firefighter or knowledgeable person should be assigned to monitor the alarm system to be aware of any changes in alarm conditions, such as additional water flow signals.

NOTE: It has been suggested that most firefighters do not have the training that would be required to monitor a fire pump or a complex alarm system and interpret a situation in real time. This training should be provided in the future; however, these functions could also be delegated to qualified responsible individuals from the facility, with a means of communication to advise the command post of any significant changes.

If there are indications of active fire inside a mega-warehouse, the conservative approach is recommended. Firefighters should stand-by outside and allow the sprinklers to operate until the fire has been fully extinguished.

Criteria for Shutting Off Sprinklers and Fire Pumps

There is a need for scientific research and discussion among experts to develop more definitive guidelines to determine if and when sprinklers have successfully extinguished a fire in a mega-warehouse. It may be very difficult to determine when this point has been reached if the fire is deep inside a very large smoke-filled warehouse. At the present time the, only established guidelines depend on the judgement and experience of the fire department incident commander.

The consensus of expert opinion on this question is to keep the sprinklers in operation for as long as it takes to confirm that the fire has been effectively extinguished.

While it is expected that the sprinkler systems should be able to control a fire, it must also be recognized that if the sprinklers do not successfully control a fire in this type of occupancy, it is very unlikely that the fire department will be able to do anything to change the outcome. The fire risk is simply too great in relation to conventional firefighting capabilities.

When shutting off sprinklers, the closest valve(s) upstream from the operating sprinklers should be closed. This determination often requires detailed knowledge of the sprinkler system arrangement and the locations of all control valves. This information should be documented in the pre-fire plan, which should be immediately accessible and formatted to make the information easy to find.

It would be desirable if each riser and each zone had an indicator light that indicated when water is flowing. This would help to quickly locate the area of a building where a fire is located. It would also be helpful in determining which valve to close when a decision is made to shut off the flow. (*This should be submitted as a proposed amendment to NFPA 13*.)

At least one charged hose line should be in place in proximity to the fire area before sprinklers are shut off. Before shutting off a riser or zone valve, it is important to confirm that shutting that valve will not interrupt the water supply to any hose valves that are being used.

A firefighter with a portable radio should be assigned to standby at the valve in case it is necessary to restore the flow. This assignment should be maintained until it is confirmed that there is no possibility that the fire could rekindle.

If a fire pump is running, it should be left running until a qualified person is available to ensure that the appropriate shut down procedure is followed. It is generally not necessary to shut down a fire pump when the sprinklers are shut off.

Most fixed fire pumps are programmed to start automatically if there is a demand for water. If the pump has been shut off and reset for automatic start-up, it should restart if the sprinkler valve is reopened. This requires a person with knowledge of the pump controls to be involved in shutting down the pump.

Overhaul and Debris Removal

At some stage, it usually becomes appropriate for firefighters to conduct overhaul operations to ensure that there are no hidden pockets of fire or glowing embers within the debris, even if the fire area has been thoroughly soaked for an extended period of time. There are cases where is it not safe to approach close enough to conduct a standard overhaul. It might not be feasible to reach the fire area because the area is inaccessible, such as a tall rack that is beyond the reach of firefighters. This could be a significant problem in a warehouse that uses automated access and retrieval systems. The only reasonable option could be to establish a fire watch from a safe distance and reactivate the sprinklers, if necessary.

The equipment that is used to move stock in a warehouse is generally not designed to operate in a fire area or to safely transport firefighters. It is recommended to avoid using this type of equipment to reach a fire in order to conduct overhaul.

The same applies to the use of equipment that requires skilled operators to move stock or remove debris. In most cases, the qualified operators are not trained to operate with the protective clothing and SCBA that would be required in the fire area, and firefighters are not qualified to operate the equipment.

While it is often recommended to remove debris to the exterior after overhaul has been conducted, the option of leaving it in place with a fire watch should be considered. The responsible party, or the insurer, can arrange for contractors with the necessary equipment to do the work.

<u>Firefighter safety considerations:</u>

- The interior of a mega-warehouse should be classified as a high-risk environment for firefighters, because unusual hazards may be encountered and conditions can change very rapidly. An incident that appears to be easily manageable can suddenly become extremely dangerous.
- In many cases, the contents of a mega-warehouse are unknown or highly varied. Without good information, firefighters could encounter hazardous materials or highly flammable contents deep inside a building.
- Several firefighter fatalities and near-miss incidents have occurred simply as a result of becoming disoriented and running out of air inside a large smoke-filled warehouse, in some cases after the fire was under control.

- If a decision is made to enter, the approach should be careful and deliberate to avoid the exposure of firefighters to avoidable risks. Entry should not be made if the interior is filled with smoke or there are indications of a fire that is not being controlled by the sprinklers.
- At least one hose line should be extended from a pumper outside the building to the fire area. This can serve as a guide to the exit if conditions change and visibility is lost.
- Firefighters need to be aware of the weight of water that may be absorbed by the stored materials and packaging, especially in tall racks and high-piled storage. The added weight could create instability that places firefighters in danger. Firefighters have been killed by collapsing stacks of waterlogged goods while conducting overhaul. Numerous instances of heavy loads falling from tall racks and progressive collapse of rack structures have been reported. Operations in proximity to the fire area should be conducted with extreme caution, watching for indications of unstable racks or stored materials.
- Reliable communications and strict accountability are mandatory for personnel entering a mega-warehouse. Rapid intervention teams should be positioned in safe locations as close as possible to the area where operations are being conducted. Entry and exit paths should be identified by illuminated devices.

CHECKLIST

- [ ] Detailed pre-fire plans in standardized format immediately available.
- [ ] Advanced control stations that provide a comprehensive graphic overview of conditions inside the building and the status of each system.
- [ ] Rapid access to inventory management systems that can indicate exactly what goods are located in each area in real time.
- [ ] Location indicators that can be used to orient firefighters inside a building and direct them to a specific location.
- [ ] Communications infrastructure to ensure that firefighters can communicate inside each facility.
- [ ] Engineered ventilation systems that can be used for smoke control and removal.
- [ ] Understanding of fire dynamics in very large spaces.
- [ ] Risk management guidelines, potentially based on a conservative approach.
- [ ] Guidelines for fire department resource requirements to conduct operations in mega-warehouses.
- [ ] Guidelines for when it is appropriate to shut-off sprinklers and shut-down fire pumps.
- [ ] Recommendations for conducting overhaul and removing debris.
- [ ] Specific guidelines for fire department operations with different types of ASRS installations.

Tactical Considerations for Mega-warehouse Fires

1. If sprinklers are operating, the first priority should be to ensure that they have an adequate water supply. The sprinklers are probably applying water to the area where it is needed and where can be most effective. Ensure that valves are fully open and fixed fire pumps are operating. Connect pumped lines to the fire department connection to reinforce the water supply.

2. There is no urgent need to send firefighters into a smoke-filled warehouse to search for a fire and evaluate conditions. It is recommended to remain outside and let the sprinklers continue to flow, while cautiously evaluating conditions inside.

3. Risk versus gain should be carefully considered in determining if and when it is appropriate to enter to evaluate fire conditions. If there are indications that sprinklers have successfully confined and controlled the fire, consider a cautious approach to enter, observe, and evaluate conditions from a safe distance. If entry cannot be made safely, remain outside and let the sprinklers continue to operate.

4. Firefighter safety must be a priority. The risks that can be anticipated inside a mega-warehouse are complex and conditions can change very rapidly. Residential tactics are not appropriate for fires in mega-warehouses.

5. There is serious risk of firefighters becoming lost inside a mega-warehouse due to distances, confusing layouts, and smoke obscuration. Entry should not be considered without reliable interior radio coverage. Air supplies must be closely managed and firefighters should remain in contact with hose lines or search ropes. Strict accountability must be maintained for all personnel.

6. Do not shut off sprinklers unless there are reliable indications that the fire is fully under control. Beware that a brief interruption in sprinkler flow can allow the fire to quickly grow and surpass the capabilities of the sprinklers, even if the flow is restored promptly.

7. In some situations, it could be feasible to operate hose streams or portable master streams from safe positions inside a mega-warehouse to reinforce the sprinklers. This should only be considered after careful analysis of the risk factors.
    a. The minimum size handline for interior fire attack should be 2-1/2", staffed by at least 3 firefighters for mobility.
    b. A portable monitor nozzle capable of flowing 500 gpm could also be advanced into the interior.
    c. 1-3/4" handlines should only be used for overhaul.

8. Firefighters should train on hand stretching large hose lines 200 ft. or more into a building.

9. Beware of the risk of racks collapsing or materials falling from tall racks. Firefighters should not operate in the aisle spaces between racks that have been involved in a fire.

10. The water discharged by flowing sprinklers may interfere with the ability of a TIC to measure heat conditions.

11. Firefighters should become familiar with the arrangement and operation of the sprinkler systems and other fire protection features in a mega-warehouse. Plans of the layout and valve locations should be available at the site or in pre-fire plans. The flow capacity and duration of water supplies should be known.

12. A firefighter, or a qualified operator, should be assigned to the pump house to verify that pumps are operating properly and monitor flows and pressures. If there is a static water tank, the water level should also be monitored.

13. The alarm system should be monitored by a firefighter, or qualified operator, to maintain an awareness of signals indicative of changing conditions.

14. Interior operations may require more resources (personnel, equipment, apparatus, water supplies) than are on the scene or available in a reasonable period of time.

15. Occupant accountability may be a problem in this type of structure. It is essential to know how many occupants were in the building at the time of the alarm and if they were safely evacuated to the exterior meeting place and remained on site. Conducting a thorough interior search in a timely manner could be infeasible.

16. The combustibility of the contents and packaging in a mega-warehouse can be extremely high. Fire and smoke conditions can change very rapidly.

17. Overhaul and debris removal after a fire has been extinguished may involve complex problems. The best strategy could be to maintain a fire watch until the appropriate equipment can be obtained to accomplish these tasks safely and effectively.

Appendix

Roles and Responsibilities

The planning, installation, and ongoing management of fire protection for a mega-warehouse involves a series of complex relationships and responsibilities. While the details may vary significantly from one case to another, an overview of the situation relating to this building serves as an example.

The building itself was constructed by a developer as a shell building that could accommodate a variety of occupants. The building code requires automatic sprinklers in a building of this size; however, the design of the sprinkler system has to be based on a risk classification for the anticipated use of the building. The decision to install an ESFR sprinkler system, which is typical for this type of building, was intended to provide the capability to accommodate a wide variety of occupants, commodities, and storage arrangements.

The initial installation included the 30 individual ESFR systems that were supplied by the underground fire main that looped around the entire building. The same main supplied water to the private fire hydrants that were installed around the building.

The fire pumps, primary and back-up, were required to provide sufficient volume and pressure to meet the water demand for the ESFR sprinklers. The water storage tanks were needed because the municipal water supply could not provide the flow rate that was required for the sprinklers.

The ESFR sprinkler systems and the water supply were included in the basic construction of the building, as specified by the architects and engineers. A fire protection engineer may have been involved in the design of the sprinkler systems or in determining the applicable standards and performance criteria for the systems. The fire protection systems were installed by a qualified contractor to comply with NFPA and/or FM standards and the Indiana Building and Fire Codes.

The detailed plans for the building and the sprinkler and fire alarm systems were submitted to the authority having jurisdiction, the Indiana Department of Homeland Security, for review and construction design release. The local building and fire protection authorities would have also reviewed the plans and inspected the work in progress.

The shell building was subsequently leased to a major international corporation that determined the operational requirements and engaged another team of architects and engineers to design the tenant improvements. The fire risks were analyzed by fire protection engineers who may have been employed by the corporation itself or by a consulting firm that was engaged by the corporation. Their role was to work closely with the teams that designed the storage and materials handling systems to determine the detailed requirements for additional fire protection systems. The corporate insurers would have also been directly involved in determining the fire protection requirements for each area.

The Pick Module introduced a very challenging fire protection problem that required its own sprinkler systems, as well as the sophisticated smoke detection system. The Pick Module sprinkler systems were designed to react quickly and produce a high-density discharge pattern to accommodate the wide variety of contents that could be stored on the shelves. The sprinkler system design also created constraints, such as limiting the storage of goods on the shelves to certain commodity classifications and excluding higher risk goods. Certain items, such as motor oil and aerosol containers could only be stored in specific areas where enhanced sprinkler systems were provided. The sprinkler design also required limitations on the height of items that could be stored on the top shelves to prevent obstructions to the sprinkler discharge pattern.

The installation of the additional fire protection systems, as well as the smoke detection and alarm systems, was also performed by qualified contractors and the plans were submitted to the authority having jurisdiction to obtain the necessary approvals and permits. Most authorities having jurisdiction do not have the expertise or the capacity to perform a detailed analysis of the design and flow calculations for engineered sprinkler systems. In most cases the review is limited to ensuring that the appropriate design standards and classification criteria have been used, while the engineering responsibility remains with the design professionals.

Once a building has been built and occupied and all of the fire protection systems have been installed and approved, the building tenant/operator becomes responsible for ensuring that all of the required maintenance and tests are performed. The tenant is also responsible for ensuring that the design constraints are respected and that the factors that provided the basis for the design of those systems are still valid. If there are changes in the commodities that are stored, or the storage configuration, or the conveyor systems or any other details, the impact on the fire protection systems must be checked. In a facility that is used for e-commerce order fulfillment, the changes and adjustments may be frequent. These responsibilities require continuing attention from the tenants/operators of the facility in coordination with their fire protection specialists, their insurers, and the local fire department. Any major modifications to the fixed systems require plans to be submitted and approved.

PHOTOS: COURTESY OF WRTV.COM

This report was made possible through the support and ongoing commitment of the Plainfield Fire Territory, Plainfield, Indiana.

NATIONAL FALLEN FIREFIGHTERS FOUNDATION®

WWW.FIREHERO.ORG

EMMITSBURG
PO DRAWER 498
EMMITSBURG, MD 21727
301-447-1365
301-447-1645 (FAX)

CROFTON
2130 PRIEST BRIDGE DRIVE
SUITE 6 CROFTON, MD 21114
410-721-6212
410-721-6213 (FAX)

NATIONAL FALLEN FIREFIGHTERS FOUNDATION