

COLD STORAGE WAREHOUSE

Madison, WI

May 3, 1991

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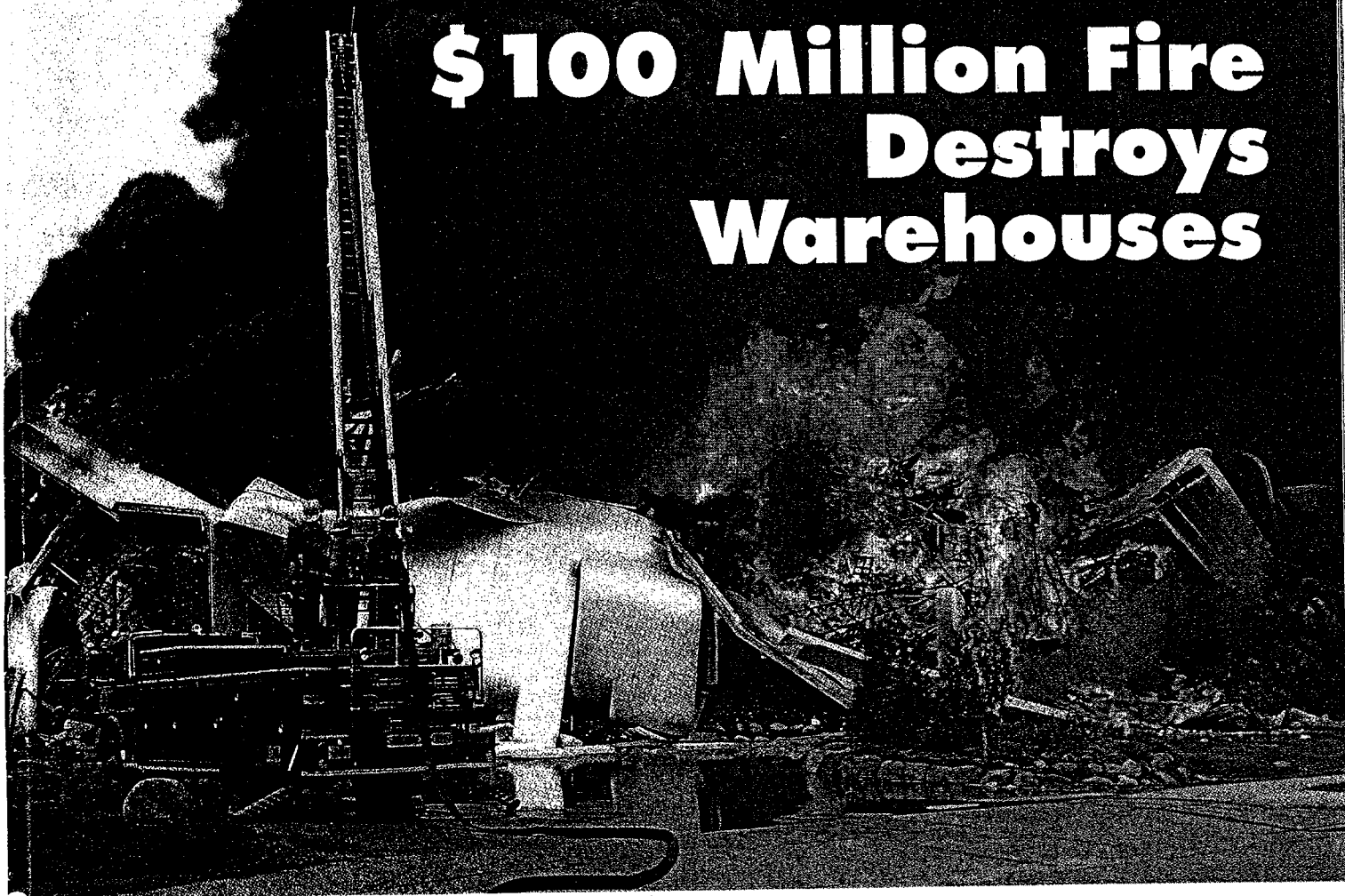


FIRE INVESTIGATIONS

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\$100 Million Fire Destroys Warehouses



FIRE SERVICE

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Michael S. Isner

An inadequately designed sprinkler system appears to have played a critical role in the fire which, fueled by a large amount of combustible materials, burned for days.

When a fire of undetermined origin destroyed two cold-storage warehouses in Madison, Wisconsin, on May 3, 1991, the estimated loss was placed at more than \$100 million. The warehouses were part of a five-building complex where food—including 13 million pounds of butter and 15½ million pounds of cheese—was stored. All of the buildings were large metal structures, and several were equipped with automatic sprinkler systems.

As part of an ongoing program to investigate technically significant fires, the NFPA documented this incident to establish facts, to analyze factors contributing to the property loss, and to report on lessons learned. The NFPA investigation of this incident was made possible through the cooperation of the Madison Fire Department.

The warehouses

The warehouse complex consisted of five cold-storage buildings in close proximity to one another (see Figure 1). All of the buildings were of light, noncombustible, Type-2 (000) construction.¹ The exterior walls of the buildings' freezer areas were nonload-bearing, with foam insulation between metal sheathing. A layer of foam

insulation over the roof's metal deck was covered with tar and gravel. A single ammonia refrigeration system serviced the facility's coolers and freezers.

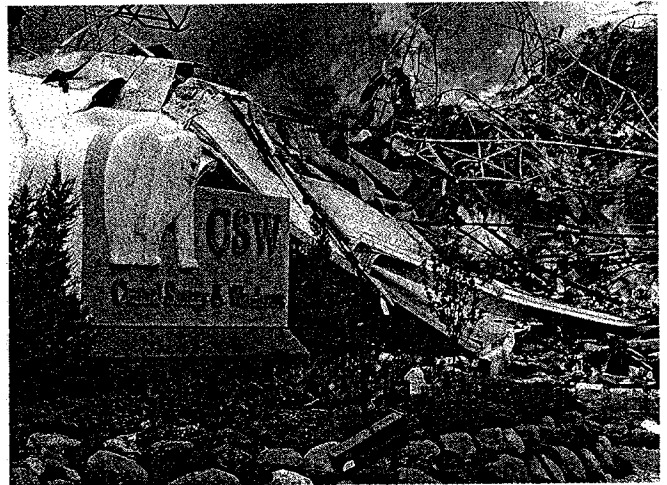
The building of fire origin measured about 170 feet wide by 365 feet long by 55 feet high. It was divided into two areas: the freezer/cooler and the dock/mezzanine (see Figure 1). The freezer/cooler area, which was called Freezer 8, was 260 feet long and the full height and width of the building. Metal-clad, foam-insulated interior walls divided Freezer 8 into three separate storage areas. The temperature in the largest storage area was a constant -10°F. In the second storage area, the temperature ranged from -10°F to +34°F, and in the third and smallest storage area it was a constant +34°F.

The dock/mezzanine area was two stories high. The dock, which was on the first story, was a large, enclosed space used for the temporary storage of materials being loaded onto or unloaded from trucks. The second-story mezzanine also was an open area; it was used for the storage of packaging materials and food products that did not require refrigeration during storage.

The commodities stored in Freezer 8, which were packaged and loaded on pal-



The foam insulation contained in Freezer 8's walls, partitions, and roof generated heavy black smoke as it burned. This photograph was taken from the northeast corner of Freezer 8.



Five days after the fire had started, deep-seated fires still burned in the rubble. They were extinguished as heavy equipment uncovered them.

lets, included butter, meat, poultry, gift packs (butter, meat, and cheese products), cranberries, corn, other vegetables, juice concentrate, and packaging materials. The majority of the pallet loads were banded with stretch wrapping around the sides. The rest of the loads had no wrapping at all.²

Commodities in Freezer 8 were stored on metal racks that were two pallets deep. The racks, which were the full height of the storage area (55 feet) and connected to the roof assembly, supported both the roof assembly and the

stored commodities.

Freezers 3 and 4 were in an adjacent building, and an enclosed passageway provided access to Freezer 8 (see Figure 1). Freezers 3 and 4 also used storage racks, but commodities there were stored on pallets both in bulk containers and in smaller boxes. For example, cranberries were stored in 4-foot-square wood crates, while 1-pound bricks of butter were on pallets in cardboard boxes banded with stretch wrap.

Some of the buildings in the complex were equipped with both dry- and wet-

pipe sprinkler systems. Freezer 8 was equipped with a dry-pipe system, and ceiling-level sprinklers provided 0.15 gpm/sq. ft. A wet-pipe system protected the dock/mezzanine area. The building in which Freezer 7 was located had both dry- and wet-pipe systems, similar to the building of fire origin. All sprinkler systems were connected to a central station monitoring service. The building housing Freezers 3, 4, and 5 was not sprinklered.

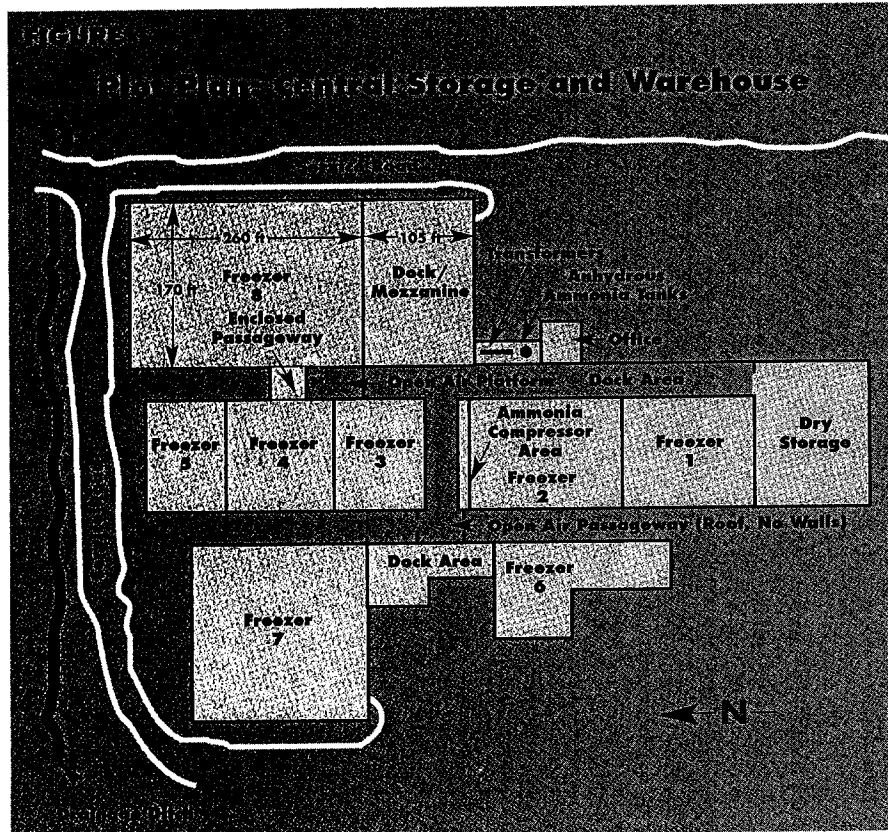
Fire suppression operations

The crew of Engine 5 had been testing a 4-inch supply line in the fire station's rear parking lot and were reloading it when a fire fighter noticed flames above the roof of the Central Storage and Warehouse building, situated about one block from the station.

A fire fighter was trying to contact the Madison Fire Department's dispatch center when the alarm was transmitted at 3:33 p.m. A division chief, two engine companies (including Engine 5), one truck, one squad, and one rescue company were dispatched for the initial response. Engine 5's officer made an initial size-up while still on the fire station apron, and he immediately requested a second alarm. Two engines, one truck, and a rescue vehicle were dispatched at 3:35 p.m.

When the crew members of Engine 5 arrived at the incident scene at 3:35 p.m., they drove to the south side of the building of origin. As the driver went to connect to a hydrant, the officer entered the dock/mezzanine area, and an employee directed him to the fire area inside Freezer 8.

As he entered the freezer, the officer found an apparent pile of rubble engulfed in yellow flames and the freezer's sprinklers operating. The officer directed the crew to stretch a 2½-inch attack line into Freezer 8, but he would not allow fire fighters to enter the freezer because he





Most of the 13 million pounds of butter—stored in cardboard boxes with stretch wrap—melted, fueling the fire and hampering suppression efforts.



The light metal frames of the fire building's storage racks supported both the stored commodities and the warehouse roof assembly.

could hear the sound of warping and twisting metal.

From the freezer's doorway, the officer noted the door's plastic drapes being drawn into the freezer and realized that the fire was drawing large quantities of air into the room. Because exterior flames had been observed during the initial response, the officer thought the fire had vented through the roof. However, he was unable to see the ceiling to confirm this because of heavy black smoke.

Engine 5's crew was able to control the rubble fire with the assistance of personnel from Engine 3, who also had a 2½-inch attack line. The officer on Engine 5 believed the attack was beginning to suppress the interior fire at this time.

The division chief, who had been dispatched on the first alarm, arrived at 3:42 p.m. and assumed the role of incident commander. He established a command post at the northeast corner of the fire building and directed the first-alarm fire companies to the dock/mezzanine area to support operations begun by personnel from Engine 5.

The incident commander, like the officer on Engine 5, was concerned about structural stability in the fire area. For that reason, he had fire crews attack the fire from the doors between the dock and Freezer 8, without entering the fire area.

When crew members from Engine 5 exhausted their air supply, personnel from Engine 8 relieved them. Once outside the building, the officer from Engine 5 realized the fire was still intense in the top part of the building. The exterior roof fire, which appeared to be 10 to 15 feet in diameter when the officer first entered the building, had spread horizontally and now involved a large section of the roof. As soon as he and the crew replaced their air cylinders, they returned to the door of Freezer 8.

From his position there, the officer still was unable to see a fire at ceiling level because of the heavy black smoke. Nor did he see any floor-level flames extending to the ceiling, despite his knowledge that the fire on the roof was spreading.

When the officer left the building again to confirm exterior conditions, he saw Truck 1 setting up a ladder-pipe operation on the building's southeast corner. As he was walking near the truck at about 4:22 p.m., the east wall of Freezer 8 collapsed and the roof dropped down.

Arriving second-alarm companies were assigned to the exposed buildings, and

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Fire crews attacked the fire from the doors between the dock and Freezer 8 because of concerns about structural stability in the fire area.

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sector commander assignments were made. When a third alarm was initiated, crews were assigned to the exterior attack against the growing fire in the collapsed Freezer 8. A fourth and last alarm for additional personnel was struck at 5:11 p.m.

At approximately 4:52 p.m., the contents of Freezer 4 ignited, and despite fire fighters' efforts, the fire began spreading through the freezer. By 8:40 p.m., it had extended into Freezer 3, and by 9:00 p.m., both freezers were completely involved. Fire fighters were able to confine the fire to Freezers 3, 4, and 8.

The fire continued to burn intensely until about 6:00 p.m. on Saturday, May 4. As it gradually subsided, personnel extinguished surface fires they were able to

reach with hoses and ladder pipes positioned around the building's perimeter.

On May 8, five days after the fire had started, deep-seated interior fires still burned. They were extinguished as heavy equipment, used to remove debris, uncovered them. On Saturday, May 11, the fire department declared the fire extinguished.

Damage

Damage in Freezer 8, the area of origin, was extensive. The roof over the freezer collapsed, and the exterior metal sheathing fell away from the east wall. Large sections of metal sheathing also fell away from the north and west walls. All of the metal racks in Freezer 8 collapsed, and the fire destroyed or consumed the commodities in the freezer.

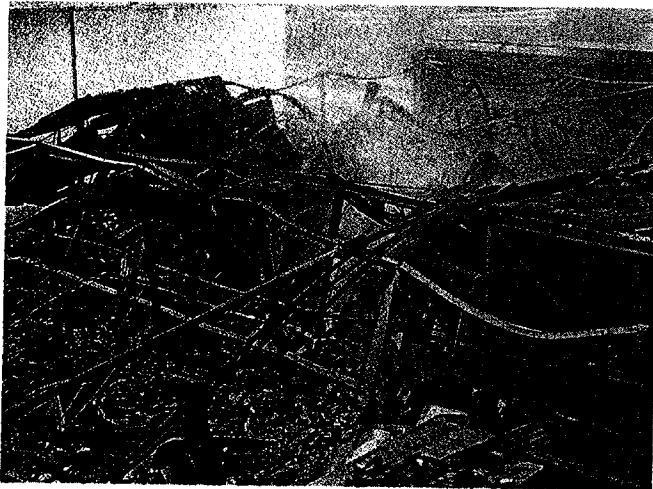
There was no fire damage in the dock/mezzanine area adjacent to Freezer 8. However, both the dock and mezzanine levels sustained smoke damage, and water, melted butter, and other debris from Freezer 8 flooded the dock area.

The roof over Freezers 3 and 4 collapsed, and fire heavily damaged or consumed the commodities stored in those freezers.

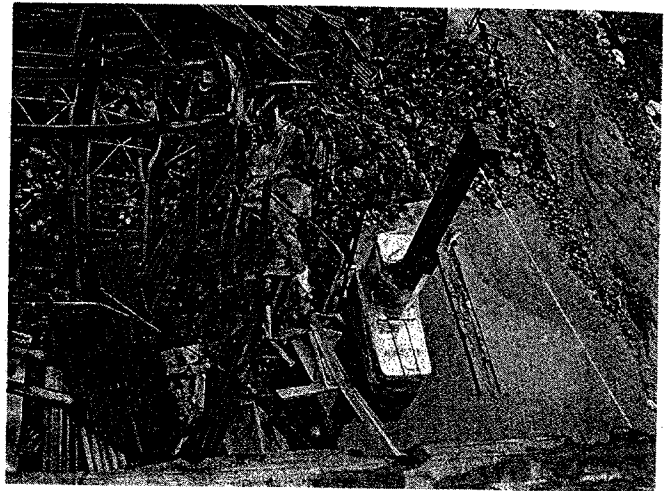
Analysis

The cause and origin of the fire remained under investigation at the time this report was prepared. Preliminary findings of local investigators indicate that the fire probably started in Freezer 8's cooler area (see Figure 2).

It appears that the fire grew and spread rapidly. However, fire department investigators have been unable to establish specific details, such as how long the fire burned before the sprinkler system activated. Though details regarding the interior fire were unavailable, it appears that flames were visible above the roof at the time the central station monitoring service notified the fire department's dis-



In addition to butter, the warehouse contained large quantities of meat, corn, cranberries (shown here), and other commodities.



Investigators suspect that this forklift truck was near the point of fire origin, and they are studying it to determine whether it was involved in the fire's ignition.

patch center of the waterflow alarm at 3:33 p.m.³

The officer on Engine 5 indicated that an apparent pile of rubble was engulfed in yellow flames when he entered Freezer 8 and that the fire did not appear to be extending to the ceiling. Fire department investigators determined that the burning rubble probably included a large electrical forklift. Other investigators are studying the forklift to determine whether it was involved in the fire's ignition.

Fire department investigators have not established the specific relationship between the initial flames above the roof and the burning rubble on the floor of Freezer 8.

The officer on Engine 5 also observed

that the sprinkler system in Freezer 8 was operating when he first entered the freezer. Local fire officials found no evidence and received no reports suggesting that the system had operational or maintenance problems.

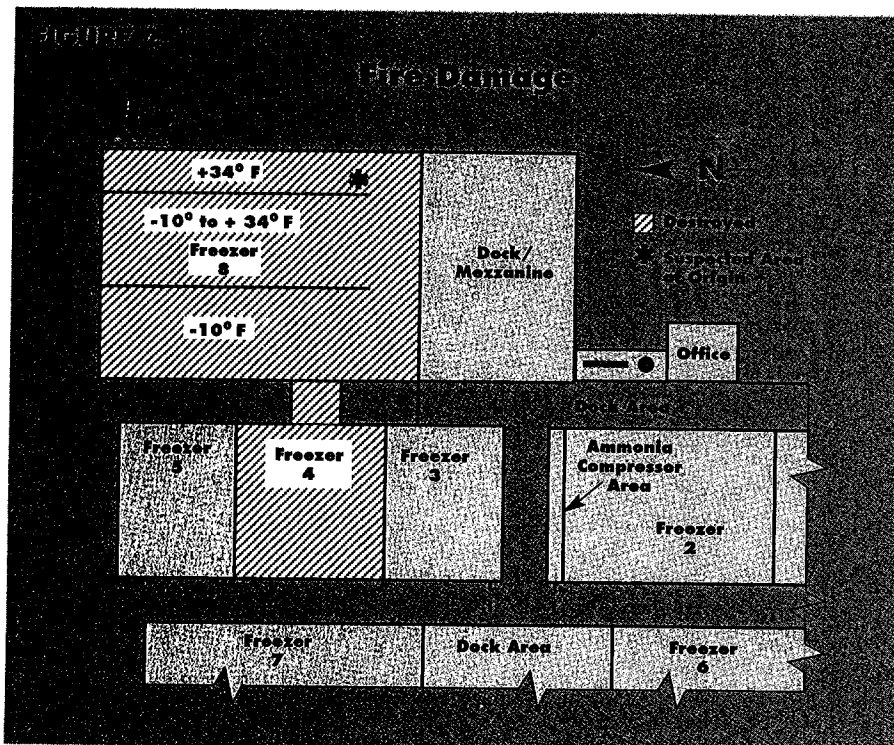
The sprinkler system's design appears the most likely reason for its failure to control the fire. A critical deficit was the system's lack of longitudinal and "face" sprinklers. Within racks, there are sizable areas that cannot be protected adequately by sprinklers alone. In-rack sprinklers were conceived to provide a degree of wetting of those shielded areas to interrupt the otherwise free horizontal and vertical spread of fire.⁴ The taller a rack is, the more essential in-rack sprin-

klers become. Similarly, the need for face sprinklers increases as rack height increases. The discharge of ceiling sprinklers can effectively wet only the upper 15 feet or so of exposed storage at the aisles. Thus, for rack storage more than 25 feet tall, the lower faces of the racks must be protected by face sprinklers.

Paragraph 7-10.2 of NFPA 231C, *Rack Storage of Materials*, requires the installation of in-rack sprinklers in double-row racks that are taller than 25 feet. Because the sprinklers in Freezer 8 were rated at 286°F, Table 7-10.1 of NFPA 231C requires ceiling sprinkler densities of at least 0.40 gpm/sq. ft. and possibly as high as 0.45 gpm/sq. ft., depending on the in-rack sprinkler arrangement.⁶ Therefore, an installed sprinkler system with only ceiling-level sprinklers providing a sprinkler density of 0.15 gpm/sq. ft. would not meet basic ceiling protection requirements specified by NFPA 231C. The inadequately designed sprinkler system in this cold-storage warehouse could not be expected to control the fire.

Once the fire overwhelmed the sprinkler system, the wood pallets, packaging materials, and commodities created a sizable fuel load, as did the foam insulation in the roof assembly, exterior walls, and interior walls. These large quantities of combustible materials supported the fire for days.

The building's structural design affected fire suppression tactics and strategies. The vertical structural members in the storage racks provided support for the roof above Freezer 8. Apparently, the fire—in combination with the loads from the roof assembly and stored commodities—began affecting the structure's integrity early in the incident. Because both the incident commander and Engine 5's officer felt there was a serious threat of collapse during the fire's early stages, they did not allow crews to enter Freezer




8. By opting to keep fire fighters out of the freezer, the officers reduced the ability of suppression crews to reach the seat of the fire and attack it. However, the two chose to reduce the risk to their crews posed by the possibility of a structural collapse. That possibility became a reality when a collapse occurred at about 4:22 p.m., 45 minutes after the first fire fighters arrived at the scene.

The sizes and locations of the buildings also affected fire suppression tactics, especially the use of aerial equipment. Fire fighters were unable to place ladder trucks and other aerial equipment on the building's west side because of the proximity of the building housing Freezers 3, 4, and 5. Similarly, aerial equipment could not be positioned on the building's east side because the wall had collapsed, covering the service road adjacent to the building. Aerial equipment on the building's south and north sides had to be parked away from the perimeter of Freezer 8 because of the two-story dock/mezzanine area and a large drainage ditch, respectively.

Several factors apparently contributed to the fire spread from Freezer 8 to Freezers 3 and 4, which were separated by about 25 feet. A primary factor was the collapse of Freezer 8's exterior walls, which affected the fire spread to Freezer 4. In addition, the nonfire-rated doors between the freezers allowed fire to spread from Freezer 8 through the covered passageway connecting it to Freezer 4. Prevailing winds during operations blew the fire plume from the building of origin into and over the building that housed Freezers 3 and 4, and fire fighters were unable to position aerial equipment to protect these areas.

However, masonry walls and the actions of fire fighters stopped the fire spread in several locations. A concrete-block wall that separated Freezer 8 from the dock/mezzanine area helped fire fighters stop the fire in Freezer 8 from spreading into the dock/mezzanine area. In addition, fire fighters placed several hose lines in the corridor between Freezer 3 and the ammonia compressor area, and they were the primary factor in stopping the fire spread from Freezer 3. Finally, a concrete-block wall separating Freezers 4 and 5 was the primary factor stopping the fire spread from Freezer 4 to Freezer 5.

In conclusion, the fire, fueled by packaging materials, combustible pallets, and combustible commodities, overwhelmed the building's inadequately designed sprinkler system. Because the sprinkler system failed to control it, the fire grew and weakened the building's light, non-combustible high-rack/roof support system. The system collapsed within 1 hour of the fire department receiving notifica-

tion of the blaze. The building's size prevented fire fighters from reaching interior areas with hoses, master streams, and ladder pipes, allowing the fire to burn freely in these areas for days. 

1. A Type-2 (000) structure will have a 0-hour fire rating for the exterior bearing walls (first digit); a 0-hour fire rating for structural frame or columns and girders supporting loads for more than one floor (second digit); and a 0-hour fire rating for the floor assembly (third digit). NFPA 220, *Standard Types of Building Construction*, 1985 edition.

2. A pallet load is not considered encapsulated when stretch wrapping covers only the sides of the load.

NFPA 231C, *Rack Storage of Materials*, 1991 edition.

3. A 3:31 p.m. telephone call from an employee in the warehouse was the first notification received by the Madison Fire Department dispatch center regarding this fire.

4. Chapter 11, "General Indoor Storage Practices," *Fire Protection Handbook*, 16th edition, Quincy, Mass.: NFPA, 1986.

5. *Ibid.*

6. NFPA 231C, *Rack Storage of Materials*, 1991 edition.

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