Selected Published Incidents Involving Cold Storage Facilities

One-Stop Data Shop
Fire Analysis and Research Division
National Fire Protection Association

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National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471
www.nfpa.org

The following are selected published incidents involving cold storage facilities. Included are short articles from the "Firewatch" or "Bi-monthly" columns in *NFPA Journal* or it predecessor *Fire Journal* and incidents from either the large-loss fires report or catastrophic fires report. If available, investigation reports or NFPA Alert Bulletins are included and provide detailed information about the fires.

It is important to remember that this is anecdotal information. Anecdotes show what can happen; they are not a source to learn about what typically occurs.

NFPA's Fire Incident Data Organization (FIDO) identifies significant fires through a clipping service, the Internet and other sources. Additional information is obtained from the fire service and federal and state agencies. FIDO is the source for articles published in the "Firewatch" column of the *NFPA Journal* and many of the articles in this report.

For more information about the National Fire Protection Association, visit www.nfpa.org or call 617-770-3000. To learn more about the One-Stop Data Shop go to www.nfpa.org/osds or call 617-984-7443.

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National Fire Protection Association
One-Stop Data Shop
1 Batterymarch Park
Quincy, MA 02169-7471
www.nfpa.org
e-mail: osds@nfpa.org
phone: 617-984-7443

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Fire Destroys Cold Storage, Fruit Packing Buildings, Washington
A large cold storage warehouse was destroyed when a fire spread through the two middle floors, eventually causing the building to collapse. One exterior wall fell into a nearby fruit packing plant.

The four-story building was constructed of heavy timber with a steel frame and exterior brick walls, and covered approximately 111,550 square feet (10,363 square meters). The building, which also had a basement, had an exterior elevator on one side. The basement and first floor were in use; there was limited activity on the second floor; and the third and fourth floors were unoccupied. The structure had no fire detection or suppression equipment.

As the building was closing for the night, an employee detected the fire and called 911 at 6:04 p.m. Firefighters arriving eight minutes later saw smoke coming from the exterior elevator on the third floor and from the fourth-floor roof overhang. An employee told firefighters that the blaze was on the second floor and that the ammonia refrigeration system had been secured and the power shut off.

The fire department's pre-incident plan called for the application of nearly 6,000 gallons (22,712 liters) of water per minute if the building were 50 percent involved. Knowing that the hydrant system could supply only 1,000 gallons (3,785 liters) per minute, the incident commander ordered additional alarms and resources for a drafting and water-shuttle operation.

Within an hour, the fire had spread to the third floor and vented through the roof in one corner. About 50 minutes later, an exterior wall collapsed onto an attached building in which fruit was packed. At that point, firefighters abandoned their efforts to save the warehouses. Another wall then collapsed onto a hose, shearing it off at the hydrant. Thirteen apparatus and 55 firefighters fought the blaze until 11:30 a.m. the next day, finally using a crane to complete extinguishment.

The buildings, valued at $1.97 million, and their contents, valued at $1.3 million, were a total loss. There were no injuries. The cause is undetermined.

Kenneth J. Tremblay, 2005, "Firewatch", *NFPA Journal*, September/October, 22.

Six Firefighters Die in Vacant Cold Storage Facility Fire, Massachusetts
At 6:13 p.m. on a December evening, a fire was reported in a vacant, five-story, cold storage warehouse of heavy timber construction. The fire started when a homeless couple knocked over a candle. Two firefighters became lost searching for the two occupants, and four others died searching for their colleagues. This vacant building was a known hangout for homeless people. The interior of the building was maze-like, and fire conditions changed rapidly. Six firefighters died in this fire.

Adapted from Robert S. McCarthy’s 2000, “1999 Catastrophic Fires” NFPA Journal, September/October 59.

Indiana
Date: December
Time: 3:45 p.m.
Dollar Loss: $85,000,000

Property Characteristics and Operating Status:
This plastic products warehouse was of unprotected, noncombustible construction. It was operating at the time of the fire.

Fire Protection Systems:
The warehouse had no automatic detection system. It did have a complete-coverage, wet-pipe sprinkler system that activated but was unable to control the rapidly spreading fire.

Fire Development:
An unknown heat source ignited polystyrene material in stacks of wooden pallets. The fire grew rapidly and spread vertically then horizontally to engulf the structure.

Contributing Factors:
None reported.

Stephen G. Badger and Thomas Johnson, 1999, "1998 Large-Loss Fires and Explosions," *NFPA Journal*, November/December, 91.

Indiana
Date: February
Time: 10:45 p.m.
Dollar Loss: $17,000,000

Property Characteristics and Operating Status:
This one-story cold storage and frozen food distribution warehouse was of unprotected, noncombustible construction and had a ground-floor area of 90,000 square feet (8,361.3 square meters). It was operating at the time of the fire.

Fire Protection Systems:
The warehouse had no automatic detection or suppression equipment. Workers tried to put the fire out with 10-pound (4.5-kilogram) dry-powder extinguishers, but the fire was too large.

Fire Development:
A fire of unknown cause started in wood pallets and cardboard on a rail loading dock outside the building. The fire spread from there to a wall, then up to the roof. One firefighter was injured.

Contributing Factors:
High winds outside and operating fans inside helped spread the fire.

Stephen G. Badger and Thomas Johnson, 1999, "1998 Large-Loss Fires and Explosions," *NFPA Journal*, November/December, 92.

State: Texas
Dollar Loss: $5,000,000
Time: 4:00 am
Month: July

Property Characteristics and Operating Status:
This frozen food storage building had a ground-floor area of 97,000 square feet (9,011.6 square meters). Its height and construction weren't reported. The plant was operating at the time of this explosion.

Detection and Suppression Systems:
No information was reported on detection equipment. The building had a sprinkler system, but the type and coverage weren't reported. The system was disabled by the explosion.

Fire Development:
Instrumentation detected an ammonia leak in the building. Shortly after workers were evacuated, there was an explosion in the plant's freezer. Other details are still under investigation. No injuries were reported.

Contributing Factors and Other Details:
None reported.

Stephen G. Badger, 1999, "Large-Loss Fires and Explosions," *NFPA Journal*, November/December, 93-94.

State: California
Dollar Loss: $6,200,000
Time: 1:24 p.m.
Month: September

Property Characteristics and Operating Status:
This 16-foot-tall structure was used for cold storage of grapes in wood boxes and Styrofoam cases. It was of unprotected ordinary construction and covered a ground-floor area of 40,000 square feet. The warehouse was in full operation at the time of the fire.

Detection and Suppression Systems:
There were no automatic detection or suppression systems.

The Fire**:**
The fire started when a forklift being operated by an employee inside the building collided with an LPG-powered steam cleaner used for building maintenance. The collision broke off the valve to the cleaner's LGP tank, and the cleaner's pilot light ignited escaping gas. The fire spread rapidly to the storage cases and wall coverings of foam insulation, then throughout the building through horizontal ductwork with no dampers. Two employees tried to fight the blaze, and the fire department mounted an aggressive interior attack. When it failed, firefighters switched to an exterior attack. Two firefighters and one civilian were injured.

Contributing Factors and Other Details:
Stored goods were stacked 15 feet high in some areas of the 16-foot-high structure. The water supply was inadequate for fire suppression activities. The water supply was from a 6-inch dead end main,

and a 25,000-gallon water tank on the property was depleted early in the fire. Exposed insulation on the walls contributed to fire spread.

Stephen G. Badger, 1997, "Large-Loss Fires and Explosions," *NFPA Journal*, November/December, 57.

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Stephen G. Badger, 1997, "Large-Loss Fires and Explosions," *NFPA Journal*, November/December, 57.

Sprinklers Limit Damage in $3 Million Blaze in Retail Warehouse, Washington
A retail discount warehouse that sold general merchandise in bulk suffered a $3 million loss when a forklift struck a rack containing a pallet of flammable aerosol lubricant. The pallet fell, damaging the canisters and causing an explosion and fire. The property's fire protection features, including draft curtains, automatic smoke vents, and a sprinkler system, worked well to limit fire spread.

The single-story, 117,204-square-foot structure had 30-foot ceilings and was built on a concrete slab. Unprotected steel columns supported steel bar joists that were covered with metal. The walls and ceilings were insulated with fiberglass, and plywood covered the lower 8 feet of the interior walls. Rack storage units, which held rows of storage and sales merchandise, were located in the sales/storage area. The property also contained automotive tire sales and service area, a bakery, and an outside canopied sales area.

The building was fully protected by three wet-pipe sprinkler systems, which were monitored by a central station monitoring company. One of the risers also supplied an auxiliary dry-pipe system that protected the outside canopied area. A 1,000-gpm automatic fire pump designed to maintain 150 psi supported the sprinkler systems. The sprinklers, which had a 17/32-inch nominal orifice and a temperature rating of 286°F, were spaced so that each covered an 80-square-foot area. The building had 138 skylights, 38 of which served as automatic smoke vents. Draft curtains divided the building into seven areas, each measuring approximately 17,000 square feet. The building had no smoke detectors.

At the time of the blaze, the store was operating, and 25 employees were restocking inventory. A forklift operator was removing a pallet of pressure washers from rack storage when the guard protecting the truck's forks struck a cross member for the rack above, knocking over a pallet of aerosol cans containing a flammable solvent/lubricant. The operator saw the pallet falling and got off the truck. As it fell, he saw several canisters release their product and explode. Other witnesses in the area also saw the explosions and flames coming from canisters, as well as broken valves flying through the air like fireworks. All employees were ordered to evacuate as smoke quickly filled the building.

The central station alarm company received a fire pump and water flow alarm activation and notified the fire department at 6:48 a.m. Warehouse employees also called to report the blaze.

Two engines and seven command officers responded to the first alarm. As part of the department's prefire plan, a large number of officers are sent to all structure fires to get the incident command system in place before additional alarms are called and more units arrive. Arriving firefighters saw dark smoke venting from two skylights. They verified that all employees had safely evacuated and determined the involved area.

Five minutes after the first firefighters arrived, command struck another alarm, bringing two additional engine companies to the scene. Firefighters supported the sprinkler system, set up a telesquirt, and began advancing handlines into the building.

Although the roof vents were open and positive pressure ventilation was in use, smoke inside the building obscured visibility. However, crews reported cold smoke, which indicated that sprinklers were controlling the blaze.

Firefighters were hampered by pallets blocking the aisles and oil residue on the floor. Using two 1 1/2-inch handlines, crews located the seat of the blaze and quickly extinguished a few remaining spot fires.

The fire occurred in the northwest corner of the building near an automobile tire display. The most severe fire damage was in the rack storage area near the forklift. Investigators determined that one of the forklift's electrical components ignited the flammable aerosol lubricant. The fire spread vertically to the ceiling, then horizontally until it reached the draft curtain. Thirty-seven sprinklers in two zones activated.

Overall, investigators stated that the systems in place worked very well. In fact, one investigator later said that "the building was saved because of the sprinkler system. With the vapor explosion and the amount of initial fire, along with lightweight trusses, our fire department feels that the fire would have become a defensive fire before our arrival and would have been fought as such."

Damage to the building, valued at $4 million, and its contents, valued at $7 million, was estimated at $500,000 and $2.5 million, respectively. Most of the damage to the contents was attributed to smoke.

One firefighter sustained a chemical burn to his forehead and several sets of firefighting gear had to be decontaminated or destroyed because of oil in the water runoff.

Kenneth J. Tremblay, 1996, "Firewatch," *NFPA Journal*, July/August, 23.

Texas
Date: July
Time: 3:00 a.m.
Dollar Loss: $5,500,000

Property Characteristics and Operating Status:
This cold storage building was used to store peanuts. It was on-story high and had a ground-floor area of 43,000 square feet. It was predominately of ordinary construction, although the entire structure contained various types of construction. The building was closed for the night.

Fire Protection Systems:
The building had no automatic fire detection equipment. At the time of the fire, the sprinkler system was being removed without fire department notification or approval.

Fire Development:
The fire began in the attic, where a cutting torch used to remove sprinkler piping in the cold storage room ignited combustible ceiling material. Workers hadn't checked the area after cutting operations ended for the day.

A passing police officer reported the fire, which spread through the attic and into storage rooms.

Contributing Factors:
A 12-hour delay transpired between ignition and detection.

Stephen G. Badger and Rita F. Fahy, 1995,"Billion-Dollar Drop in Large-Loss Property Fires," *NFPA Journal*, November/December, 108.

Illinois
Date: August
Time: 7:37 p.m.
Dollar Loss: $28,000,000

Property Characteristics and Operating Status:
This facility was used as a cold storage warehouse for perishable foods. The single-story warehouse was of unprotected noncombustible construction with a ground-floor area of 89,000 square feet. The facility was operating at the time of the fire.

Fire Protection Systems:
The warehouse was fully equipped with sprinklers. Coverage consisted of one wet-pipe system for the office and mezzanine areas and two dry-pipe preaction systems with heat actuating devices. The systems' water supply was supplemented by a 1,000-gpm electric fire pump.

Fire Development:
The running lights of a tractor trailer truck that had been backed into a loading dock were accidentally left on, and the heat they generated eventually ignited the polyurethane truck bumpers on the dock. The fire was discovered when the driver pulled the vehicle from the dock. Workers tried to extinguish the fire before notifying the fire department, but the fire spread through an open docking bay into the polystyrene insulation surrounding the cold storage areas. The fire department arrived within 5 minutes but was unable to contain the fire due to its rapid extension and the collapse of the mezzanine. The warehouse and its contents were a total loss.

Contributing Factors:
Although the wet-pipe sprinkler system operated as designed, both dry-pipe valves for the two preaction systems failed to operate. The reason for this failure was not reported. The failure of the preaction system resulted in rapid fire extension throughout the warehouse.

There was a 10 -to-15-minute delay in notifying the fire department as employees tried to put out the fire with portable extinguishers.

The loading dock door was left open during the early stages of the fire, allowing the blaze to spread to the interior building insulation.

Michael J. Sullivan, 1994, "Property Loss Rises in Large-Loss Fires," *NFPA Journal,* November/December, 96.

Faulty Aluminum Wiring Connection Causes $1.5 Million Fire at Cold Storage Warehouse, Oregon
Fire severely damaged a cold storage fruit warehouse when the building's fixed aluminum wiring short-circuited.

The single-story warehouse, constructed of metal-over-wood framing, was divided into numerous sections, including a packing house, cold storage room, a sorting room, and other small service/utility rooms. The building contained fire extinguishers, but it did not have any sprinklers or fire detection equipment.

The fire, which began in an unoccupied section of the warehouse during working hours, was discovered by someone at an adjacent business, who called the fire department at 11:14 a.m. Approaching units saw a column of thick, black smoke hundreds of feet high. By the time firefighters arrived, the fire was spreading to a second-story room and to the roof.

Later investigations showed that flame spread was accelerated by burning urethane foam wall covering used as insulation in cold storage. Exposure of 1,000 gallons of liquid ammonia refrigerant posed an additional firefighting challenge. Eighty-three firefighters from 15 engine companies and 3 truck companies were finally able to control the blaze, but with so many exposures to protect, they were unable to prevent significant damage to other parts of the building.

Investigators determined that the fire began at an interior wall approximately 8 feet above the floor in electrical conduit that supplied an air conditioning unit on the roof. The conduit contained three conductors of aluminum wiring that met in a junction box, where they were fastened with brass-on-copper splicing devices. When the aluminum wires broke loose from the connector and started arcing in the box, two of the fuses that protected the wires blew. Heat from the arcing conductors ignited the wire insulation, which led to a chain of events that blew out conduit at several points up to 50 or 60 feet away. The fire, which burned for 30 minutes before it was detected, eventually involved a compressor room, offices, and the cold storage rooms.

Damage to the building and its contents was estimated at $1.5 million.

Kenneth J. Tremblay, 1994, “Firewatch”, *NFPA Journal*, November/December, 27

Washington
Date: September
Time: 8:18 a.m.
Dollar Loss: $62,000,000

Property Characteristics and Operating Status:
Cold storage facility. This one-story building of protected ordinary construction had a ground-floor area of 186,000 square feet. The facility was closed for the night.

Fire Protection Systems:
Six separate sprinkler systems were present in the facility-five pre-action and one dry-pipe system. The systems included in-rack sprinklers. There was a heat detection system associated with the sprinkler system.

Fire Development:
A patrolling police officer discovered flames coming from the roof of the warehouse and notified the fire department. Firefighters arrived within 6 minutes to find a fire in the ceiling level of the -10~F cold storage area. Flames entered a 2-foot deep void filled with a thick layer of insulation that extended over the entire warehouse. Ninety percent of the roof eventually collapsed as the fire consumed the insulation in the roof and walls. The structure and 22 million pounds of frozen foods were destroyed. Investigators were unable to determine the cause of the fire.

Contributing Factors:
The automatic sprinkler systems were not in service at the time of the fire, and there was no manual means of activating the sprinkler system. Firefighters were not notified of the sprinkler system impairment until considerably after they had arrived at the fire. Sprinklers were then activated, but they failed a short time later due to the collapse of the warehouse roof.

Michael J. Sullivan, 1993, "Large-Loss Fires Rise Slightly While Property Loss Drops," *NFPA Journal*, November/December, 85.

Indiana
Dollar Loss: $17,000,000
Date: February
Time: 10:45 p.m.

Property Characteristics and Operating Status**:**
This one-story cold storage and frozen food distribution warehouse was of unprotected, noncombustible construction and had a ground-floor area of 90,000 square feet (8,361.3 square meters). It was operating at the time of the fire.

Fire Protection Systems:
The warehouse had no automatic detection or suppression equipment. Workers tried to put the fire out with 10-pound (4.5-kilogram) dry-powder extinguishers, but the fire was too large.

Fire Development:
A fire of unknown cause started in wood pallets and cardboard on a rail loading dock outside the building. The fire spread from there to a wall, then up to the roof. One firefighter was injured.

Contributing Factors:
High winds outside and operating fans inside helped spread the fire.

Stephen G. Badger and Thomas Johnson, 1999, 1998 Large-Loss Fires and Explosions, *NFPA Journal*, November/December, 92

Wisconsin
Date: May 1991
Time: 3:31 p.m.
Dollar Loss: $77,500,000

Property Characteristics and Operating Status:
Cold storage warehouse complex.

The single-story building measured 260 feet by 168 feet and had a ceiling height of 55 feet. Construction was of unprotected metal and concrete materials. Floors were concrete slab, and the walls and roof framing were unprotected steel with a metal covering. Walls had insulation-consisting of insulation, membrane, and ballast decking-between the metal sheeting and the roof covering. The complex consisted of five warehouses with nine individual storage areas that were used as freezers, coolers, and a combination freezer/cooler. The complex and storage buildings were in close proximity. The facility was operating at the time of the fire.

Fire Protection Systems:
Automatic suppression and detection equipment was present in buildings 1, 3, 4, and in the corridor between buildings 2 and 5. The detection equipment-waterflow alarms with central station supervision-operated. No information was reported on the type of smoke or heat detectors present.

Automatic sprinklers were present in the freezer area and in the corridor. The sprinklers--designed to deliver 0.15 gpm per square foot were located at the ceiling level only; there were no in-rack sprinklers. Overwhelmed by the fire, the sprinklers were rendered inoperable by the building's collapse. No other information concerning the coverage or performance of sprinklers was reported.

Fire Development:
The fire was caused by an electrical malfunction in an electric forklift truck in the warehouse. An employee heard a noise and saw the fire in and around the forklift. The employee reported the fire to the building manager, and they attempted to extinguish it using portable fire extinguishers. Another employee notified the fire department by calling 911 on an emergency telephone.

At the time the fire department received the emergency telephone call, fire personnel stationed across the street from the warehouse had noticed smoke and fire and were responding. The fire department also received an automatic fire alarm signal.

First-arriving firefighters reported that the automatic sprinkler system was operating. However, the fire intensified during suppression operations, and the collapse of the building hampered firefighting efforts. The fire was extinguished after the building collapsed. Nine firefighters were injured.

Contributing Factors:
An inadequately designed sprinkler system. A large quantity of combustible materials

John R. Hall, Kenneth T. Taylor, and Michael J. Sullivan, 1992, Large-Loss Fires Top $2.6 Billion in Damage in 1991, *NFPA Journal*, November/December 75.

California
Dollar Loss: $10,000,000
Date: July
Time: 3:05 p.m.

Property Characteristics and Operating Status**:**
Agricultural packing and cold storage facility: ordinary unprotected construction; 60,000 square feet; 1 story; 25-foot ceiling. Packing plant operating; cold storage under construction.

Fire Protection Systems:
No Detection or Suppression system.

Fire Development:
The exact cause of the fire is undetermined, but investigators believe that an on-site contractor may have caused a short circuit in the fixed wiring. This ignited foam insulation in the ground-level electrical and mechanical room.

Contributing Factors:
Fire walls were in place, but the fire spread through open doors. No deaths, no injuries.

Kenneth T. Taylor and Kenneth J. Tremblay, 1990, Large-Loss Fires in the United States During 1989, *Fire Journal*, November/December, 60.

Maryland
Dollar Loss: $30,000,000
Date: October
Time: 1:10 a.m.

Property Characteristics and Operating Status**:**
Cold storage warehouse; ordinary construction; 160 square feet; 3 stories. No one on premises.

Fire Protection Systems:
No Detection or Suppression system.

Fire Development:
A fire of undetermined cause started in a ground-floor storage locker. It progressed from the center of the building to individual freezers that contained six million pounds of butter.

Contributing Factors:
Melting butter allowed the fire to spread and intensify. Ammonia leaking from the freezers made conditions hazardous for firefighters. There was a delay in alarm due to the construction of the building and the fire's location. No deaths; 1 civilian injury; 1 firefighter injury.

Kenneth T. Taylor and Kenneth J. Tremblay, 1990, "Large-Loss Fires in the United States During 1989", *Fire Journal*, November/December, 61.

Washington
Dollar Loss: $9,000,000
Date: November
Time: 8:33 p.m.

Property Characteristics and Operating Status**:**
Cold storage facility; ordinary construction; 4 stories, 60,000 square feet. Normal operation

Fire Protection Systems:
None.

Fire Development:
A worker discovered a 220-volt electrical utility panel arcing in an electrical service room. He immediately notified the fire department. Arriving firefighters were delayed 15 to 20 minutes due to high-voltage discharge, until the utility disconnected the building's power. This delay allowed the fire to gain considerable headway. High dollar loss was attributed mostly to the loss of 15 million pounds of frozen food.
Contributing Factors:
None noted. No deaths; 6 firefighter injuries.

Kenneth T. Taylor and Kenneth J. Tremblay, 1990, "Large-Loss Fires in the United States", *Fire Journal*, November/December, 69.

Hot Slag Ignites Insulation, Illinois
Workers at this three-story building that had brick walls, wood floors, and a built-up roof on wood deck shut off the sprinklers to cut an 18-inch section out of the main sprinkler. At 2:45 pm, a piece of hot slag from the cutting operation ignited insulation in an ammonia coil room in the basement. When workers opened the trap door to the fire area, a backdraft explosion occurred that either ruptured ammonia coils or melted soldered joints.

A worker reported an ammonia explosion to the fire department. Firefighters found the building full of ammonia upon their arrival had begun a search-and-rescue operation, during which they discovered the fire-at least 30 minutes after it had started.

The fire spread through stored cardboard on the second floor and across oil-soaked flooring, involving two large vegetable oil cookers and 6,000 gallons of vegetable oil.

The lack of firestops on the cooling and machinery floor (five feet below the floor of origin) contributed to the fire spread. Also, although two hydrants were available for firefighting, the fire department was not aware of their existence.

Fire Analysis and Research, 1980, "Bimonthly Fire Record", *Fire Journal*, September, 20.

Ammonia Explosion, Mississippi
Leaking ammonia ignited by a gas-fired unit heater exploded at this milk-processing, ice-cream manufacturing plant.

The explosion occurred in a one-story packaging warehouse. The building was constructed of concrete blocks with a roof system of cement fiberboard on steel joists and steel columns. There was no automatic sprinkler protection.

At approximately 7:05 am, the plant superintendent noticed that the high-pressure compressor to the freezers was not operating. At 7:10 am, he returned to the compressor room with a maintenance man. They observed that the pressure gauge on the intermediate cooling system was reading in excess of 150 psi. They could also hear gas escaping in the adjoining warehouse area. The two men immediately began to shut down electrical equipment and notified plant employees to evacuate the building. At approximately 7:15 am, the escaping ammonia exploded. Because the explosion damaged telephone lines, a maintenance man was sent across the street to phone the fire department.

Firefighters ventilated the roof and extinguished the fire using four large handlines. There were no reported injuries to plant personnel or firefighters.

Investigation revealed that a pressure switch failed in the intermediate cooling system. This caused a relief valve on a coil-jacketed tank to open, leaking gas into the warehouse area. This valve was not vented to the outdoors or back into t lower-pressure section of the system. The ceiling-hung gas unit heaters provided ignition.

Loss to the structure and building contents was estimated at $200,000.

Fire Analysis and Research, 1979, “Bimonthly Fire Record”, *Fire Journal*, September, 13.

Exposed Polyurethane Insulation, Washington
This 200,000-square-foot apple packing and storage complex consisted of three separate buildings. The building of origin was subdivided into about seven controlled-atmosphere cold storage rooms. This building had corrugated-steel walls and roof on a steel frame. The room of origin was insulated with two layers of foam plastic material. The first layer was polystyrene block and the exterior layer consisted of 2 1/1 to 3 inches of sprayed-on polyurethane. There was no thermal barrier protecting the foam insulation. The buildings were not protected by an automatic sprinkler system, nor did they have an automatic fire detection system. The facility’s fire-extinguishing equipment was limited to several portable fire extinguishers in each section and two yard fire hydrants supplied by the district irrigation system.

At approximately 11:10 am, tow workmen were cutting a hole in a steel truss near the ceiling of the cold storage room with a cutting torch. The polyurethane insulation became ignited, and the workmen attempted to extinguish the fire using a small carbon dioxide extinguisher. The extinguisher was quickly emptied, and had no apparent effect on the fire. The men left to get an additional 40-lb. dry chemical extinguisher, but by the time they returned, the fire had spread across the ceiling of the room and had heavy black smoke forced them to abandon their efforts.

The fire knocked the telephones out of service, which further delayed transmission of the alarm to the fire department. The fire department received the first alarm at 11:24 am and promptly responded.

Arriving firefighters found two sections of the complex almost totally involved. Firefighters wore self-contained breathing apparatus as they attacked the fire. It was extinguished in about two hours.

The rapid flame spread over the unprotected polyurethane insulation and the lack of fire protection and extinguishment equipment were key factors contributing to this estimated $2,500,000 loss.

Fire Analysis and Research, 1977, “Bimonthly Fire Record”, *Fire Journal*, September, 45.

FIRES INVOLVING REFRIGERATION SYSTEMS, PARTICULARLY WHEN ANHYDROUS AMMONIA WAS USED AS A REFRIGERANT

Prepared by: Marty Ahrens
Fire Analysis and Research Division
National Fire Protection Association
1 Batterymarch Park, PO Box 9101
Quincy, MA 02269-9101

November, 2000

Fires Involving Refrigeration Systems, Particularly When Anhydrous Ammonia Was Used As A Refrigerant

Wisconsin 1993

At about 2:00 a.m., the fire department received a 911 call about a fire at this meat processing and packing plant. The structure involved had a concrete floor and brick walls. Four sprinklers were above a storage area for combustibles at one end of the building.

The engine room of the structure contained six compressors. A thermo-siphon, including an ammonia tank, valving and piping that carries lubricating oil through heat exchangers, was on the roof. (Three ammonia compressors were in a separate building.) Three air compressors were in another room, and a transformer was in a third area.

A security officer reported hearing a loud rumbling noise for a few minutes, and then the power went out. He was notified that a waterflow alarm had been received from the fire building, and was sent to investigate. He encountered smoke throughout the building and flames near the floor. Water flowing out the doors indicated that sprinklers were working.

When the power went out, the fire pump ceased to operate. Witnesses reported hearing at least two small explosions during the incident. These were believed to be ammonia ignitions.

During the year, one ammonia compressor had been making a vibration noise. The noise had been evaluated, was attributed to the fan housing and was not considered dangerous. The same compressor had been making new noises in recent weeks. A service call had been requested, but the noise had not been evaluated by the day of the fire. Two compressors, including the one previously mentioned, were severely damage by heat and covered with large amounts of soot. Neither contained any oil after the fire. About 36,000 pounds of ammonia had been released during the incident. Studs and bolts were found loose on the compressor that had reportedly been making vibration noises. Other ammonia compressors in the building were also damaged by fire, as were the roof wiring, transformer and air compressors. Some meat also spoiled.

The cause of this fire was not determined. Direct property damage was estimated at $1,850,000.

California 1990
At about 2:20 a.m., the fire department was notified of a problem at this ice storage facility. Arriving firefighters noted a southerly wind and a cloud of anhydrous ammonia above the building. Fire was coming from a corner of the wood and block structure. The facility also contained a mechanical equipment room. The police department began evacuating people near the area.

An electrical arc was believed to have ignited ammonia vapors. The resulting fire caused $1,250,000 in direct property damage to the structure. Loss to the contents was estimated at $550,000. The exteriors of three nearby vehicles were also damage by heat from the fire.

Oregon 1990
At 4:01 a.m., a passer-by called 911 to report a problem at this 50-year-old, single-story frozen food warehouse. The walls in this 300' by 200' structure were made of concrete, as was the floor framing. The roof framing and roof deck were both made of wood, and the roof covering was built-up. No automatic fire detection system was present. A sprinkler system was present in the warehouse, but not in the compressor room. The business was closed for the night.

Anhydrous ammonia vapors had filled the compressor room when a small coiled ammonia line broke. After the fire department arrived on the scene, the relay opened or closed, and the resulting spark ignited the vapors. Flame damage was confined to the compressor room; smoke damage extended beyond the warehouse. Direct property damage to the $2,500,000 structure was estimated at $10,000. No loss was reported to the contents, valued at $2,500,000. One firefighter's finger was burned by a road flare during the incident. The original break in the ammonia line was blamed on the age of the equipment.

Wisconsin 1989
A fire in an electric room electrical panel spread to the roof area of this cattle slaughtering and beef processing plant. The electrical transformer, located on the roof, also ignited. During the fire, anhydrous ammonia was discharged into the air.

The structure was a combination of wood and concrete block, with concrete walls, wood floor and roof framing, a wood roof deck, and asphalt covering on the roof. No automatic fire detection or suppression systems were present. The building was equipped with fire extinguishers, but these would not have helped. The concrete block walls helped delay the fire's spread to other areas.

Damage to the structure was estimated at $500,000. The loss to contents was estimated at $250,000. The fire was considered unintentional, but the exact ignition sequence was unreported or unknown. Details were limited due to pending litigation.

Massachusetts 1989

At 11:41 a.m., a worker called to report an explosion at this single-story ice cream manufacturing plant. The 150' by 66' structure had concrete and cinder block walls, poured concrete floor framing, steel roof framing, a metal roof deck and a built-up roof. No automatic fire detection or suppression systems were present.

When firefighters arrived, one injured man was in the snow, and snow was being applied to burns on his face and head. A strong smell of ammonia was coming from an overhead plant door. Company employees reported that a colleague was injured and remained in the explosion area. Firefighters found the victim, and discovered he had already succumbed to his injuries. With that discovery, the priority switched to ventilation and locating and stopping the leakage of anhydrous ammonia.

A leak in the oil trap (accumulator) drain valve of a 1950 ice cream freezer had resulted in leakage of anhydrous ammonia into the plant. This machine held about five cubic feet of ammonia. It was last used a week prior to the explosion. At the time of the explosion, the plant manager (the deceased) was attempting to repair the valve by either attaching a new valve to the leaky one or replacing the one that was leaking. He had begun draining the anhydrous ammonia into a pail of water to purge the ammonia from the container. A rubber hose steam line was under the machine and steam was flowing into the air.

The valve that let liquid ammonia into the freezer, the suction valve on the gaseous ammonia return line and the oil trap drain valve were all closed to separate the machine from the plant's refrigeration system and to prevent any additional anhydrous ammonia from getting into the equipment.

As the temperature in the machine rose to room temperature or higher from the steam hose underneath it, the anhydrous ammonia in the vessel changed from a liquid into a gas. The rising temperature also raised the vessel's pressure, causing it to rupture. The machine did not have a pressure relief valve, and it appeared that the pressure gauge was not working.

When the vessel ruptured, a small amount of oil from the system was released with the anhydrous ammonia, resulting in a flash fire and a simultaneous combustion explosion. The mechanical damage from the overpressure rupture caused an electric arc that triggered these ignitions. Equipment was destroyed in the blast area, and ceiling tiles were dislodged in the plant offices. People outside of the building heard the ground shake and saw the plant's doors fly open. No after-fire resulted from the explosion, and the incident was self-extinguished. Direct property damage to the $552,100 structure was estimated at $25,000. Damage to the $212,800 worth of contents was estimated at $175,000. Two firefighters were treated for exposure to ammonia. Civilian casualties from the explosion included the plant manager, who suffered massive trauma from the blast and was found dead at the scene, and two injured employees, one with burns to the head and face and the other with a laceration on the hand.

Kansas 1988
An explosion in an ammonia oil separator at this single-story concrete meat packing plant claimed the life of one worker. A second worker suffered an ammonia burn as he attempted to rescue his colleague. Because the explosion put the phones out of service, the fire department was not notified until 35 minutes after the explosion. Consequently, the fire department delayed search and rescue operations until the scene was secured and no additional ammonia was being released.

Only maintenance personnel were working at the time of the incident. Human error had led to excessive pressure on equipment that lacked a relief pressure valve. This resulted in the failure of the tanks and equipment.

A dry pipe sprinkler system was present but was not activated because the explosion did not result in an after-fire. Damage to the structure and contents was estimated at a total of $100,000.

California 1985
At 11:28 a.m., a worker at this single-story, wood frame and stucco fruit and vegetable cold storage plant called the fire department to report arcing wires. When firefighters arrived on the scene, they found an arcing electrical subpanel in the plant's refrigeration engine room. About 500

gallons of liquid ammonia was in the room's ammonia receiver at the time. Electrical wiring was first ignited, and fire spread quickly through the wood truss, built-up roof. When the receiver vented, ammonia was released. The subpanel was still arcing. The small fire in the subpanel resulted in the release of ionized gas. Electricity was conducted through the gas and made it possible for wires to arc without pulling enough amperage to cause fuses to blow or to trip the circuit breakers. The transformer and main panel were at the other end of the 30' by 50' structure; they also began to arc. The panel box was blown partially off the wall.

The arcing went on for about ten minutes. A utility worker pulled the fuses for the poles that provided the building with electricity. Firefighters used one hose line to neutralize the leaking ammonia and to keep the refrigeration condensors cool; a second was used for fire attack; and a third was used for backup.

Three rooms of the building contained ammonia receivers, and three multi-ton ammonia condensors were located on the roof. All told, the system held 10,000 pounds of ammonia refrigerant. The fire was controlled just when the building was beginning to collapse. Ammonia was still leaking in the equipment room after the fire was put out. The contents of one receiver were lost, but slowly. The leaking ammonia was neutralized with 15,000-20,000 gallons of water, and left in a drainage ditch until the pH level dropped from 12.5 at the time of the incident to eight. This took several weeks. Damage to the $500,000 structure was estimated at $20,000; damage to the $1,000,000 in contents was estimated at $500,000. Two firefighters were treated for ammonia inhalation.

No automatic fire detection or suppression systems were present.

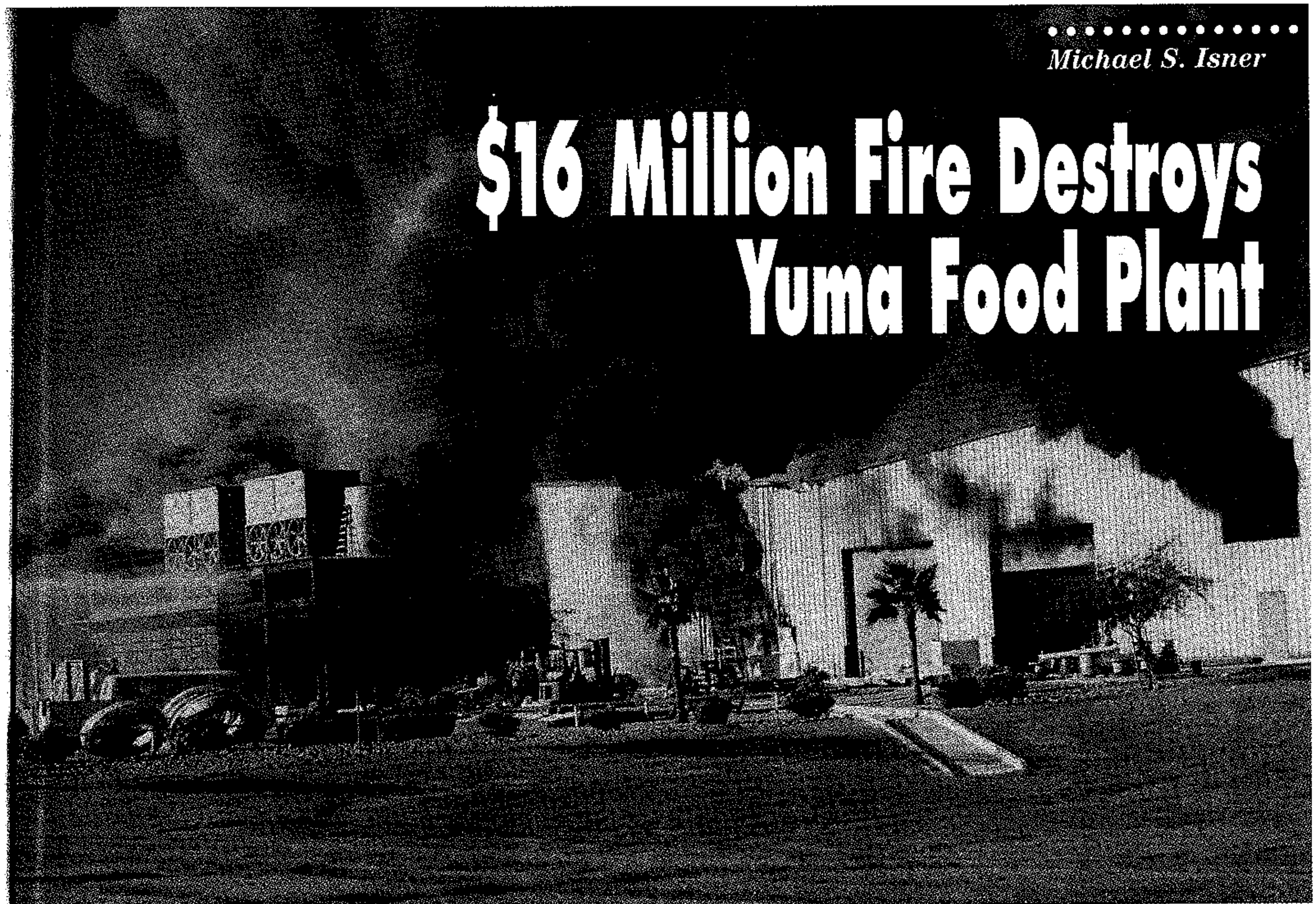
Oklahoma 1981

At 9:26 a.m., an employee of this ice manufacturing and frozen food storage facility called the fire department to report a fire. The two-story structure had brick walls, concrete floor framing, wood roof framing, a metal roof deck, and roof covering made of metal and wood. No automatic fire detection or suppression systems were present.

The fire started in the engine room after an ammonia compressor malfunctioned. Pressurized ammonia gas escaped and exploded when the fumes reached an open flame heater. The explosion ignited other combustible material in the room, and also involved insulation for the refrigerated rooms. Three firefighters were treated at the emergency room for inhalation of ammonia fumes. Direct property damage to the $165,000 structure was estimated at $50,000; damage to $1,200,000 worth of contents was estimated at $400,000.

Michael S. Isner

$16 Million Fire Destroys Yuma Food Plant



This accidental fire, which spread through concealed spaces, underscores the importance of the proper design and placement of sprinkler systems.

INVESTIGATION REPORT

An accidental fire at the Dole Fresh Vegetables plant in Yuma, Arizona, destroyed most of the facility on November 12, 1992, and resulted in an estimated loss of $16 million.

On the day of the fire, the construction of an addition to the facility was nearing completion. It appears that welders installing processing equipment may have accidentally ignited combustible materials, including sprayed-on foam insulation inside a wall assembly.

The fire then spread in a combustible concealed space between wood-frame interior walls and metal exterior walls. Sprinklers had not been installed in the combustible concealed space, and although some sprinklers in the facility operated, they could not control the fire spreading within the walls.

The fire also appears to have spread from the interior of the walls to the occupiable areas of an addition, which was under construction. Sprinklers in this area were not operational. As a result, the fire grew rapidly and spread into the area known as the salad plant, where operational sprinklers were overwhelmed.

The NFPA investigated the Dole Fresh Vegetables plant fire to document and analyze significant factors that resulted in loss of property. The association funded the study as part of an on-going program to investigate technically significant fires.

The International Conference of Building Officials (ICBO) assisted the NFPA with data collection and analysis under an agreement between the NFPA and the three model building code organizations to investigate significant structural fires and other emergencies throughout the United States. The model building code groups assist the NFPA by providing technical staff support for on-site field work and building code analysis.

A 3-day, on-site study and subsequent analysis of the event were the basis for this report. The cooperation of the Yuma Fire Department and the Dole Fresh Vegetables Company made entry to the fire scene and data collection activities possible. Information and details regarding fire safety conditions are based on the best available data and observations that were made during the on-site data collection phase, as well as on additional information provided during the report development process.

The NFPA does not intend that this report pass judgment on or fix liability for the loss of property resulting from the Dole plant fire. Rather, the association

DAVE LEWIS

intends that this report present the findings of its data collection and analysis efforts and that it highlight factors that contributed to the loss of property.

Current codes and standards were used as criteria for this analysis so that conditions at the facility on the day of the fire can be compared with current fire protection practices. It is recognized that these codes and standards may not have been in effect during the construction or operation of the Dole Fresh Vegetables facility. The NFPA has not analyzed the facility regarding its compliance with the codes and standards that were in existence when the facility was built or during its operation.

The facility

The Dole Fresh Vegetables plant in Yuma was a seasonally operated facility where locally grown lettuce was cleaned, chopped, and packaged. The lettuce then was sold to restaurants as a salad base and to retail food stores for direct sale to consumers.

In 1988, Yuma adopted some 21 NFPA codes, including the 1985 edition of NFPA 13, *Installation of Sprinkler Systems*. In the same year, Yuma also adopted the 1985 editions of the Uniform Building Code™ and the Uniform Fire Code™, which the city applied during the construction of the first two sections of the Dole facility. The final section was constructed using the 1985 Uniform Building, Mechanical, and Plumbing Codes and the 1990 edition of NFPA 70, the *National Electrical Code®*.

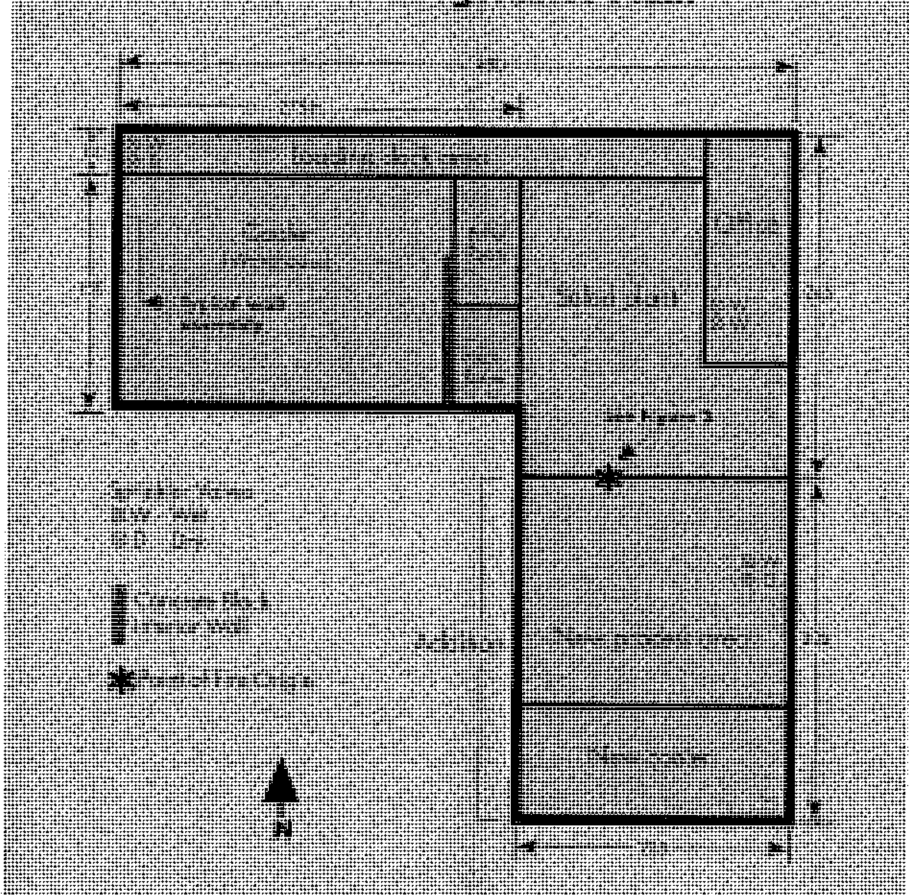
The plant building was an L-shaped structure divided into three areas (see Figure 1). The west one-third of the building, a warehouse area referred to as the "cooler," measured about 215 feet by 275 feet. A small, sectioned-off area in the cooler was used as a mechanical space.

The center one-third of the building—referred to as the "salad plant"—was the facility's original structure. Constructed in 1990, this section measured about 205 feet wide by 265 feet long.

The newest part of the building, called the "addition," was still under construction at the time of the fire. It was scheduled to be completed about 1 week after the fire occurred. This section was approximately 205 feet wide by 220 feet long, and included a new salad processing area and a new cooler.

FIGURE 1

Dole Fresh Vegetables Plant



All three of the building's sections were of a light-gauge noncombustible construction. Because a cool environment had to be maintained, some 4 inches of sprayed-on polyurethane foam insulation covered the interior faces of all exterior walls. Similarly, approximately 5 inches of sprayed-on polyurethane foam insulation covered the undersides of the metal roof assemblies. Wood-frame walls throughout the building, which were installed in front of the foam insulation, permitted the washing of interior surfaces. Automatic sprinklers protected the facility's occupiable spaces.

The insulation in the cooler had a flame spread index of 25 and a smoke development value of 200; the insulation in the addition had a flame spread index of 20 and a smoke development value of 205.5. No information is available regarding the characteristics of the insulation in the salad plant.

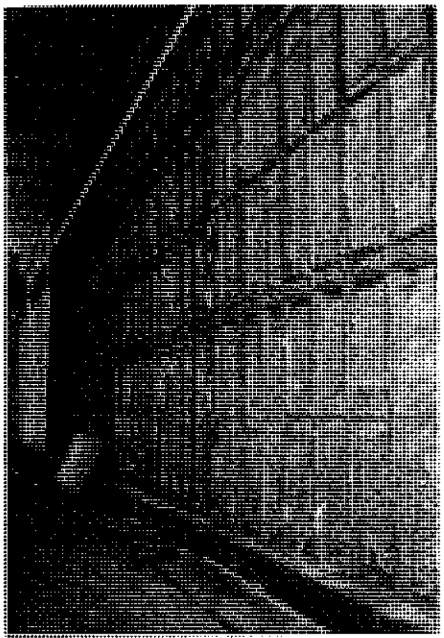
Wood-frame interior walls in the salad plant and the addition protected the surface of the sprayed-on foam insulation. Constructed with 2-by-4-inch wood studs, the walls were covered with nominal ½-inch plywood. Three coats of fiberglass—applied at the site to provide a durable and washable interior finish—covered the plywood surface facing the occupied area.

Because of the placement of the interior wood-frame walls, there was a concealed space between the plywood sheathing and the foam. This combustible concealed space, which was about 8 to 12 inches wide in most areas, extended the length and width of the building and was the full height of the building's exterior walls.

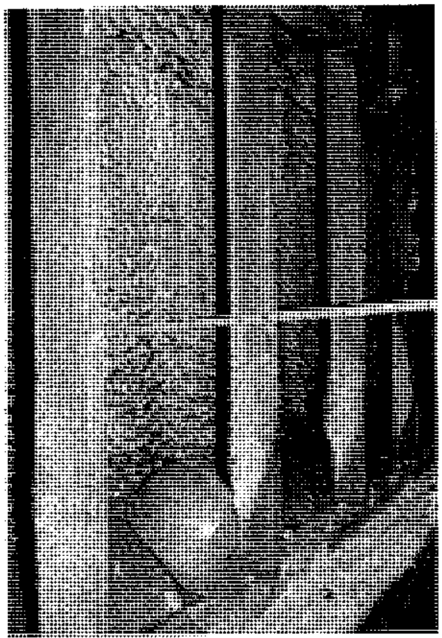
The cross-sectional detail for walls varied at different locations in the building. For example, the wall between the salad plant and the addition reportedly had horizontal barriers to prevent vertical fire spread installed at each girt level (see Figure 2).[1,2] The barriers were constructed by extending gypsum wallboard between horizontal 2-by-4-inch wall-framing members and the metal wall girts. None of the facility's walls had vertical barriers to prevent horizontal fire spread in the walls.

The interior wall assembly that separated the salad plant from the addition had penetrations in many areas to facilitate the installation of processing equipment, pipes, and wires for systems common to both areas. For example, two 1½-inch pipes for hydraulic fluid and several conduits for equipment controls penetrated the wall between the salad plant and the addition. In addition, there were three 5-by-5-foot openings in the wall for conveyor equipment within 20

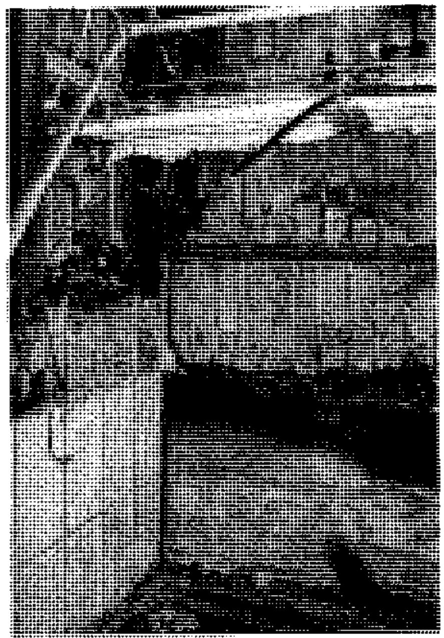
Reg. TM, The National Fire Protection Assoc., Inc.



Typical wall construction: Exterior metal sheathing with sprayed-on plastic foam and wood-frame-supported, fiberglass-covered plywood walls.



A view of combustible concealed space between the wood-framed interior surface and the plastic foam insulation.



Walls in the corner of the cooler, near the mechanical room. Wallboard and plywood covered the wall at left.

feet of the area of fire origin. The openings were finished with wood framing and plywood covered with fiberglass.

The ceiling assemblies in the salad plant and in the addition were similar to the wall assemblies: plywood covered by three layers of fiberglass. The ceiling assemblies had noncombustible channels and runners, and were suspended several feet below the building's pitched roof assemblies. As a result, there was a large cockloft area between the pitched roof and the ceiling assemblies above the salad plant and the addition.

The construction of the cooler's interior walls was similar to the wall construction in the salad plant and the addition. As in most of the other walls, the wood framing of the cooler walls was several inches from the foam insulation and was covered with plywood which was covered with fiberglass. However, the plywood and fiberglass in the cooler covered only the bottom half of the walls; moisture-resistant gypsum wallboard covered the top half of most of the walls. The horizontal barriers in these walls were installed at alternating girt levels (see Figure 2).

The wall separating the cooler and the mechanical room had another construction difference when compared to the walls in the salad plant and the addition. The bottom half of that wall consisted of concrete block, and the 2-by-4-inch wood-frame interior wall that faced the cooler was placed directly against the block. Foam insulation filled the cavities between the wood-frame members and the plywood, which was fastened to the wood framing as it was in other areas of the building. However, the top half of the wall was constructed like all the other exterior walls: Foam insulation covered metal siding, and there was a wood-frame interior wall and a void space between the two assemblies.

The roof/ceiling assembly in the cooler also was different. As in other areas of the facility, the roof had a metal frame and decking, and was covered with sprayed-on foam insulation. However, the ceiling in the area was a standard suspended assembly with metal runners and 2-by-4-foot noncombustible tiles. The assembly was installed about 4 inches below the surface of the foam insulation.

PHOTOS: MICHAEL S. ISNER

Fire protection systems

Six automatic sprinkler systems were the primary provision for fire protection in all three sections of the building. Both the cooler and the new addition were partially protected by a wet sprinkler system, with a dry sprinkler system protecting the remainder of each section.

A wet and a dry sprinkler system originally protected the salad plant. However, when the dry sprinkler system was converted to a wet system, the result was two wet systems to protect this area. Sprinklers also were installed in the large cockloft above the salad plant.

All sprinkler systems were hydraulically calculated. As a basis for the sprin-

Welders working on these elbows accidentally ignited combustible materials inside the wall at this location.

kler system design, it was expected that the commodity in the cooler would be palletized and would not exceed 12 feet in height, and that the entire building would be classified an Ordinary Hazard Group II, according to the criteria of NFPA 13, *Installation of Sprinkler Systems*.

The design for the cooler's two sprinkler systems called for 0.19 gpm over 1,950 square feet; the sprinkler system design in the salad plant called for 0.19 gpm over 1,400 square feet. The two sprinkler systems in the addition were not operational because this section was still under construction. All the sprinkler systems were supervised by a central station facility that was staffed around the clock.

A 16- and a 12-inch water main supplied city water to the land on which the Dole plant was constructed. A loop main, consisting of 10- and 8-inch pipe, provided city water to the facility and all of its sprinkler systems. Under normal operating conditions, gravity tanks throughout the city provided pressure in the city water distribution system. However, system pressure could be increased by high head pumps in the water distribution system. In 1989, the gravity-fed main was tested, and the water flow under gravity pressure exceeded the simultaneous water demands of all of the building's sprinklers.

Activities of the occupants

On the morning of the fire, the Dole Fresh Vegetables plant was being prepared to begin operations for the season. About 90 Dole employees were working the normal plant shift, which began at 5:00 a.m. Most were performing various duties in the salad plant; a few were working in the cooler, where some 2,200 tons of boxed lettuce were stored on pallets. There was no product in the salad plant. Also present in building were processing equipment installers and other contractors, such as the welders, who were assisting in the installation of processing equipment.

Some 110 other construction workers on the site were finishing final construction details and performing other tasks to prepare the addition for service. The construction workers began their work at 7:00 a.m.

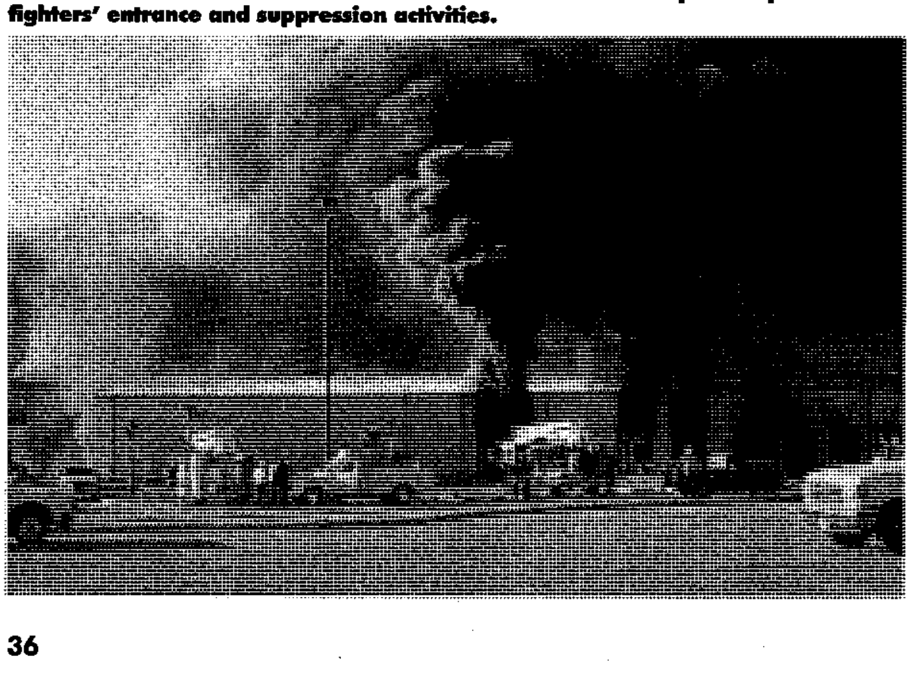
Fire discovery and occupant response

As one of its first tasks, a welding crew was going to attach elbows to two hydraulic-fluid pipes that passed through an insulated wall between the existing salad processing plant and the addition.[3,4] During this operation, the welders reportedly noticed a glow inside the holes through which the pipes ran.

The actions of the two welders following their discovery could not be verified. In their statements to investigators, they indicated that one of them remained near the wall while the other went to get a fire extinguisher. However, other construction workers said no one was in the area of fire origin when they first observed the glow inside the wall. In response to the fire, these construction workers got a fire extinguisher and discharged it into the hole through which the pipes ran, but they could not extinguish the fire.

Two carpenters in the cockloft above the salad plant were working on an access door to the cockloft area above the new addition. One of them noticed smoke in their work area. The men knew that their way out of the area was through the office in the salad plant, and they immediately tried to leave.

Dense smoke that billows from doors at the front of the Dole plant impeded fire fighters' entrance and suppression activities.



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One of the carpenters reported that the smoke became much thicker as he left the area and that he could see flames near the floor as he approached the door to the office area. When the two reached the outside of the building through an exit in the office area, fire fighters from the Marine Corps Air Station (MCAS), which was about 1 mile from the plant, had arrived and were initiating operations.

Fire department response

At about 8:09 a.m., an assistant chief at the MCAS noticed a column of black smoke and left the station to investigate. At about the same time, the Yuma Fire Department dispatch center received a 911 call reporting the fire.

While the MCAS assistant chief was enroute to find the source of the smoke, he heard on his radio scanner the Yuma Fire Department dispatch 3 engines, 1 rescue vehicle, 1 truck, and a battalion chief to the plant. Aware that his personnel could reach the facility sooner, the MCAS assistant chief had an engine, a telesqurt, and a rescue crew respond to the scene. He notified the Yuma Fire Department of his actions by radio.

The MCAS fire crews arrived at 8:13 a.m. and found dense smoke and fire showing above the east side of the building toward the middle of the structure. The assistant chief established a command post near the northeast corner of the building. He instructed the engine crew to pump in to the fire department connection for the sprinkler system,[5] the rescue crew to provide care to injured civilians, and the telesqurt crew to make an initial interior fire attack.

The MCAS telesqurt crew entered the building through the doors on the north side toward the east end of the building. After passing through the loading dock area, the fire fighters in the operations area of the salad plant encountered thick smoke, which obscured their vision. As a result, they were unable to find their way through the maze of conveyors and processing equipment. The crew abandoned its attempt to enter that area and went to the east side of the building. They tried to enter the building through several doors there, but encountered thick smoke and other conditions that prevented them from entering the process areas.

An injured civilian, who was brought to the command post by his coworkers, told fire fighters that another worker might be missing. The MCAS assistant chief ordered fire fighters from the engine company to begin searching the area of the building where the missing person had been last seen. When the crew attempted to enter the addition through doors at the northeast corner of that area, they encountered dense black smoke down to the floor. The engine crew also was unable to enter the processing areas because of poor visibility and the complex arrangement of the floor-mounted equipment.

When the first Yuma Fire Department units arrived at about 8:18 a.m., the Yuma battalion chief assumed the role of incident commander, and the MCAS assistant chief assumed command of operations on the east side of the building. Other sectors, such as the south side and the interior, were established as fire ground operations expanded and became more complex. Yuma fire officers were assigned to command the various sectors.

The missing worker was found outside the building at about 8:24 a.m. Because he was injured, the man was brought to the fire department command post. Emergency medical service personnel then took him to a medical triage area.

A large explosion occurred in the salad plant; a couple of smaller explosions followed. These apparently occurred in the addition. Investigators do not know the causes or the effects of the explosions. However, soon after the explosions, small sections of the roof collapsed, allowing the fire to vent freely.

Fire fighters from an MCAS engine company, who were maintaining a position just inside an open overhead door at the northeast corner of the addition, saw a sudden increase in the fire. Flames filled the ceiling in the salad plant, some passing over their heads as the fire vented through the overhead door to the outside. Using 1¾-inch hose lines, the fire fighters were able suppress the flames in their immediate area. At about 8:40 a.m., the incident commander ensured that crews were out of the building and initiated defensive operations.

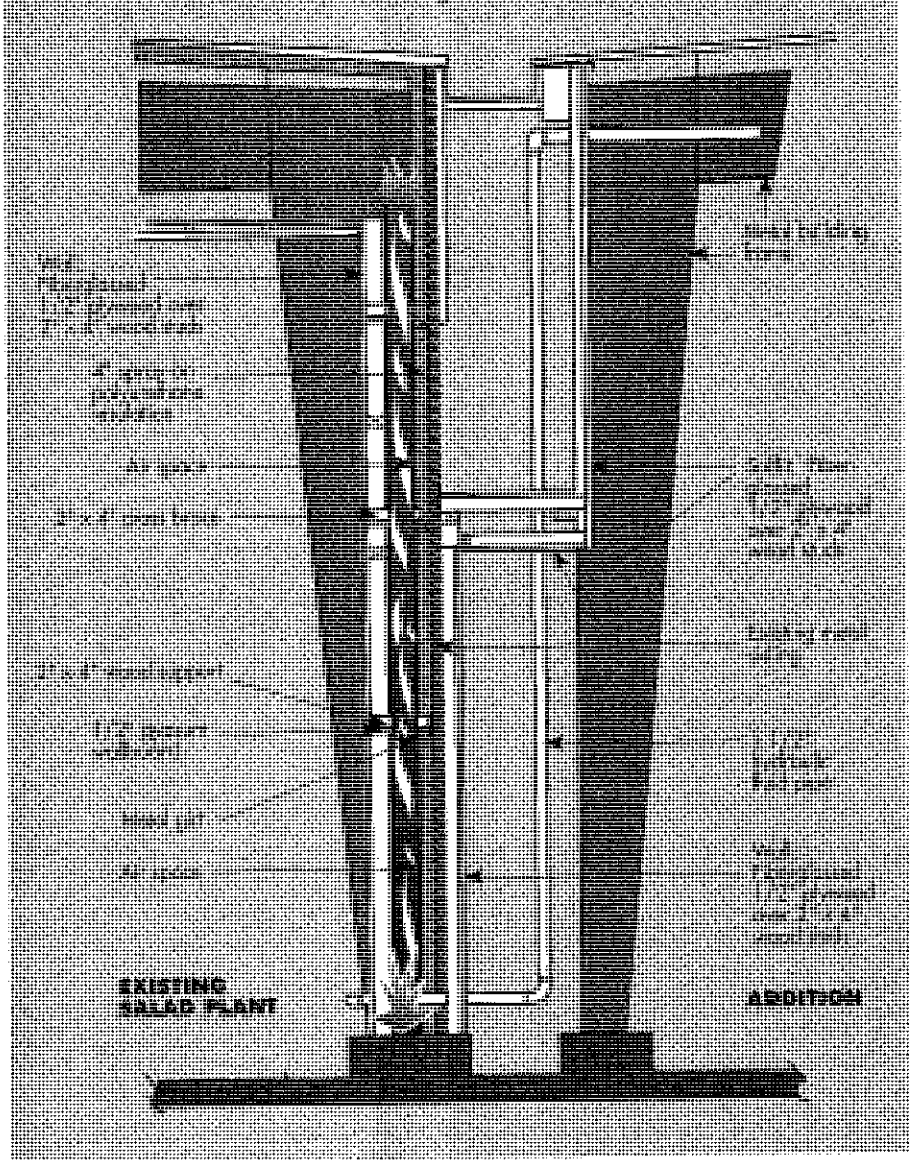
During the next hour, the Yuma Fire Department struck two additional alarms, recalling all off-duty fire fighters. The MCAS department also recalled all off-duty fire fighters. As a result, 126 fire fighters responded with some 20 fire apparatus, including structural, crash/fire/rescue, and other emergency vehicles.

Several fire fighting teams were assigned to protect specific hazards, such as the refrigeration system's 1,000-gallon ammonia storage tank. Others were assigned to protect uninvolved areas of the building. Despite their efforts, the fire continued to grow and spread, and at about 9:25 a.m., the incident commander called for a precautionary evacuation of populated areas within 1 mile downwind of the facility. Fire fighters, police, and other emergency personnel carried out the evacuation.

In an effort to protect the cooler from the approaching fire, several master streams were positioned in the cooler; others were placed in the mechanical area. At about 11:40 a.m., fire fighters began making the first of two trench cuts at the east end of the cooler roof. The combined effect of the master streams and the venting halted the fire spread. The fire was considered under control at about 12:45 p.m. Although final extinguishment was not declared, the last fire company was released from the scene at 6:30 a.m. on November 13, almost 24 hours after the fire began.

FIGURE 2

Wall of Fire Origin, Sectional View



Casualties and damage

Three construction workers were injured before fire fighters arrived. A laborer installing pipe insulation on ceiling-level pipes in the addition received second- and third-degree burns on his hands. The two carpenters working in the addition's cockloft area were treated for smoke inhalation.

In the addition, all structural members collapsed onto the construction and processing equipment. Structural damage in the salad plant was not as extensive as in the addition, although some sections of the salad plant's roof collapsed and most of its structural members were badly damaged. In addition, it appeared that all of the processing equipment in the area was destroyed. The cooler sustained the least damage. The wall between the cooler's storage area and the mechanical room was badly damaged. There was extensive damage to the eastern portion of the roof assembly as far as the trench cuts, but the remainder of the cooler sustained little or no fire damage.

The estimated loss of $16 million includes damage to the structure and equipment, etc.

Fire cause and origin

Local investigators believe it is most likely that the welders accidentally caused the fire when they tried to fasten fittings on two hydraulic-fluid pipes passing through the insulated wall between the salad plant and the addition (see Figure 3).

Officials believe that hot materials may have entered the wall during welding operations by means of the large holes through which the pipes passed. The materials then may have ignited the insulation or combustible debris in the wall.

Fire growth and spread

The fire initially grew within the walls, fueled primarily by the polyurethane foam insulation and wood. The wall assembly's design placed the insulation and wood framing materials in close proximity. Because of the small distance between the combustible materials, it is likely that radiative feedback between the two surfaces enhanced fire growth in the concealed spaces. Growing within the walls, the fire was able to spread horizontally without restriction because there were no vertical fire barriers in the walls to prevent such spread.

The carpenter's report of visible fire in the cockloft above the addition and the MCAS fire fighters' reports of visible flames above the building when they arrived indicate that the fire probably was spreading vertically during its early stages. However, it appears that initial vertical fire spread in the walls would have been affected temporarily by the horizontal fire barriers installed at all of this wall's girt levels. The length of time that these barriers would have stopped the vertical fire spread could not be estimated.

Investigators believe that early vertical fire spread may have been the result of fire escaping out of the wall and involving the wall assembly's exterior surfaces. Because the wall assemblies had many small openings and penetrations—including the three 5-by-5-foot openings for conveyors—investigators theorize that the fire below the first girt level may have escaped initially from the interior of the wall through numerous small, unprotected openings. In addition, the fire could have spread into occupiable areas of the building through the conveyor openings after the fire in the wall damaged the combustible materials enclosing the openings.

Fire spreading from the interior of the walls would have ignited the combustible fiberglass finish on the walls of the salad plant and the addition. Operational sprinklers initially may have controlled fire entering the salad plant. However, fire entering the addition would have continued to grow because sprinklers in that area were not operational. Fire in the addition would have impinged quickly on a large, wood-frame soffit that was close to the conveyor openings, and the soffit's ignition would have increased vertical fire spread and growth.

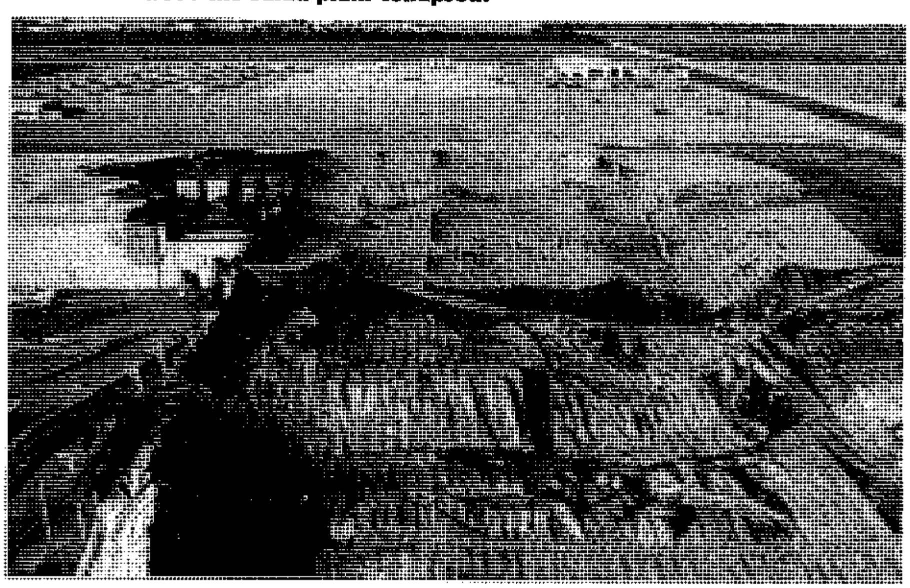
After the fire, physical evidence confirmed that the fire grew and spread inside the wall assemblies and in the building's occupiable areas. Throughout the facility, wall assemblies that were badly damaged—but not completely destroyed—were burned extensively on both their interior and exterior surfaces. Moreover, the fire damage inside some wall sections was more severe than the damage on surfaces that faced occupiable areas. This confirmed that a significant amount of fire burned and spread inside the walls, although the fire burned fiercely in the occupiable areas of the building.

The fire damage to the wall between the cooler and the mechanical room differed from the fire damage in other areas of the building. In wall sections where gypsum wallboard was in contact with the insulation, fire damage was minimal: some insulation was only superficially discolored. This damage was significantly less severe compared to the damage in adjacent areas where there were void spaces in the wall and the fire almost completely consumed the foam insulation. There was no discernable fire damage in wall sections where plywood was in direct contact with insulation. Since the reduction in fire damage occurred only in areas where gypsum wallboard or

Aerial view of the Dole plant. Exposure to severe fire conditions caused portions of the roof to collapse, allowing fire and smoke to vent freely.

JOHN JUDGE/YUMA DAILY SUN

Aerial view after the fire was extinguished. The roof above the addition and most of the roof above the salad plant collapsed.



MICHAEL S. ISNER

plywood was in contact with insulation, it appears that when materials cover and are in contact with the surface of the insulation, the materials' potential to contribute to a fire can be reduced.

Code analysis

To compare conditions and other details of this incident with current national consensus codes, the NFPA used the 1991 edition of NFPA 101, the *Life Safety Code®*, and the 1991 edition of the Uniform Fire Code as the basis of the comparison. However, it is recognized that these codes were not part of the legal requirements governing life safety at the Dole plant. The following discussion concerns requirements that have particular relevance to this fire; it is not intended to be a complete description of all parts of the codes that could be applied to this facility.

National estimates of fires in the United States between 1986 and 1990 indicate that an average of 58 storage facility fires occurred when cutting and welding equipment ignited insulation materials.[6] The total loss from these incidents is estimated at $923,000. National estimates also indicate that 3 of these 58 fires involved the ignition of polyurethane insulation and resulted in losses of about $157,000, or about 17 percent of the total dollar loss.

Recognizing the potential for accidental fires during cutting and welding operations, the NFPA promulgates two documents that establish procedures to reduce the potential hazards associated with these operations. The 1992 edition of NFPA 1, the *Fire Prevention Code*, is a general document that prescribes minimum requirements necessary to attain a reasonable level of fire safety and property protection from hazards created by fire and explosion.[7]

Several of the requirements of NFPA 1 focus directly on reducing the risks associated with welding and cutting operations. For the most part, these requirements have been based on the requirements contained in the 1989 edition of NFPA 51B, *Fire Prevention in Use of Cutting and Welding Processes.* NFPA 51B provides operational guidance for cutters and welders, fire watchers, supervisors, and property managers responsible for properties where cutting and welding operations are to be performed. Moreover, NFPA 51B contains specific and detailed requirements for the fire-safe use of electric arc and oxy-fuel welding and cutting equipment.

Two factors that influenced the effectiveness of the sprinkler systems were observed and documented. The extent of sprinkler coverage was the most important factor that had an impact on sprinkler effectiveness. Section 4-4.4.1 of the

JOHN JUDGE/YUMA DAILY SUN

Aerial stream applies water to smoking roof of the Dole plant in suppression activities that lasted almost 24 hours.

1991 edition of NFPA 13, *Installation of Sprinkler Systems*, requires the installation of sprinklers in concealed combustible spaces that are enclosed wholly or partly by exposed combustible construction. NFPA 13 would consider the concealed space between the building's interior wood-frame and exterior metal walls such a space.[8] As a result, the wall cavities would have been required to be sprinklered; however, sprinklers were not installed in these areas. The absence of sprinklers in the wall cavities allowed the fire to be shielded from the sprinklers protecting the occupiable areas of the building. The fire was able to spread freely in the wall cavities enveloping the addition and the salad plant.

The second factor that had an impact on the effectiveness of the various sprinkler systems was the operational condition of the sprinkler systems in the addition. Although sprinklers had been installed in the addition at the time of the fire, the sprinkler systems had not been connected to a water supply because the construction of these systems was still in progress. As a result, the uncontrolled fire spread through this part of the building as though it were nonsprinklered, and spread into the salad plant, reducing the effectiveness of the operational sprinklers there.

Significant factors

Based on the NFPA's investigation and analysis, the following significant factors contributed to the property loss:

- The presence of concealed combustible spaces in which the fire could readily spread;
- The ignition of combustible materials in a concealed space;
- The lack of sprinkler protection in the concealed combustible spaces; and
- Sprinkler systems that were not operational because of ongoing construction in the facility.

Michael S. Isner is a fire protection engineer in the NFPA fire investigations department.

1. Information regarding the wall of fire origin was provided from drawings prepared after the incident. The damage to the wall in which the fire originated was so extensive that exact details regarding the wall's design could not be established.

2. Girts are the horizontal structural members to which the building's exterior metal siding was fastened. The girts, which ran horizontally, were mounted to the exterior of rigid frames supporting the structure. The first level of girts was installed 7 feet above the foundation; the other girts were installed at 5-foot vertical intervals.

3. The wall through which the pipe ran was an exterior wall for the salad plant before the addition was built. As a result, this was an insulated wall similar to exterior walls in its construction.

4. There was no information available regarding the welding safety training that equipment installers may have had. Similarly, there was no information regarding the safety precautions that the equipment installers may have been using during their operations.

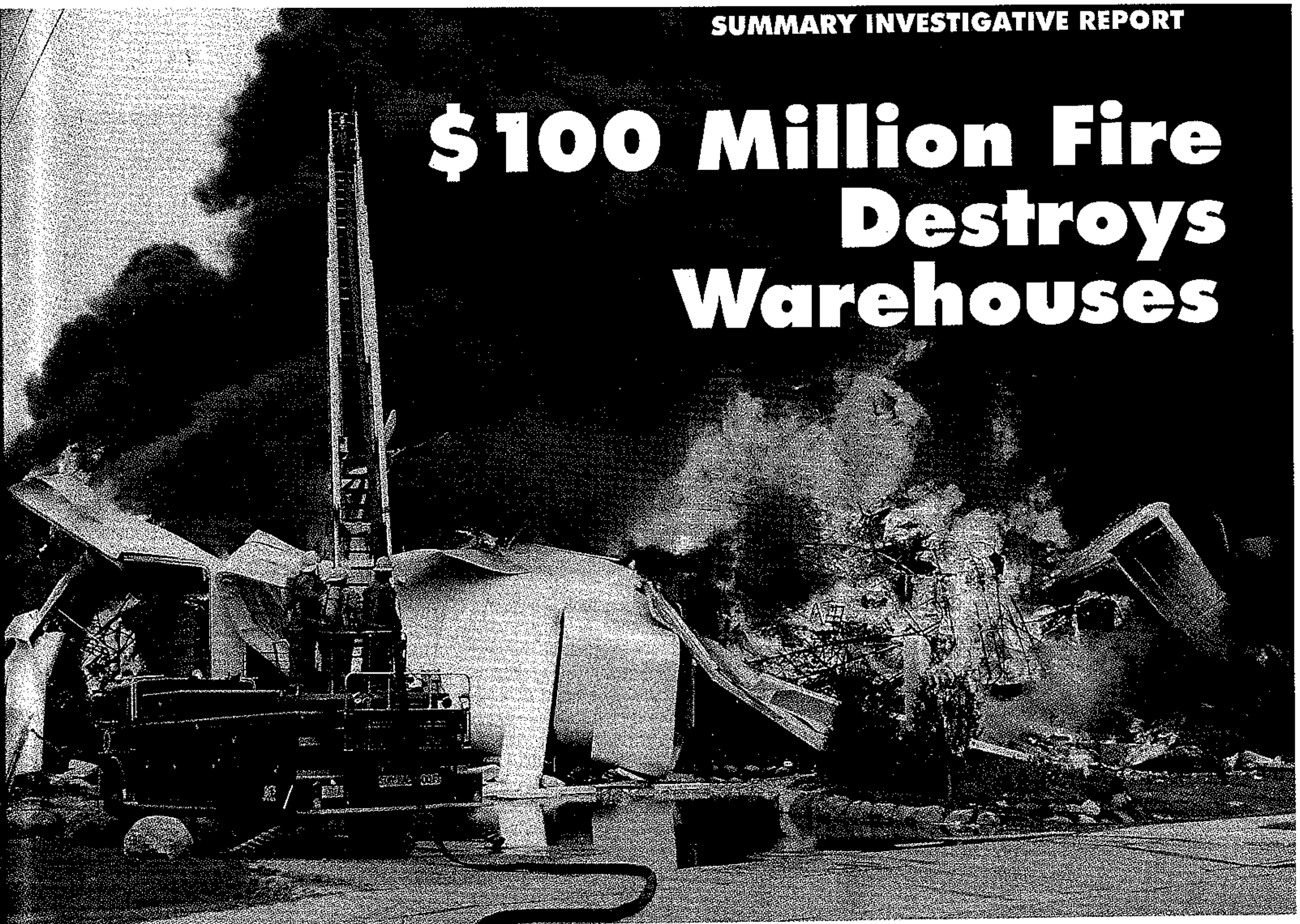
5. Though assigned to connect to the fire department connection for the sprinkler system, this assignment was not completed because the MCAS fire fighters could not find the connection.

6. The estimates are based on data from the NFPA's annual stratified random sample survey and the U.S. Fire Administration's (USFA's) National Fire Incident Reporting System. They are combined using statistical methods developed by analysts at the NFPA, the USFA, and the U.S. Consumer Product Safety Commission.

7. Codes such as the 1992 edition of NFPA 1, the *Fire Prevention Code*, and the 1988 edition of the Uniform Fire Code will be used in this report as the basis for comparison of existing conditions in the facility with selected requirements of these codes. It is recognized, however, that the codes were not in effect during the construction or use of this facility.

8. The cockloft area above the salad plant and the new addition also would be considered combustible concealed spaces. However, these areas were protected by automatic sprinklers.

$100 Million Fire Destroys Warehouses



FIRE SERVICE

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.

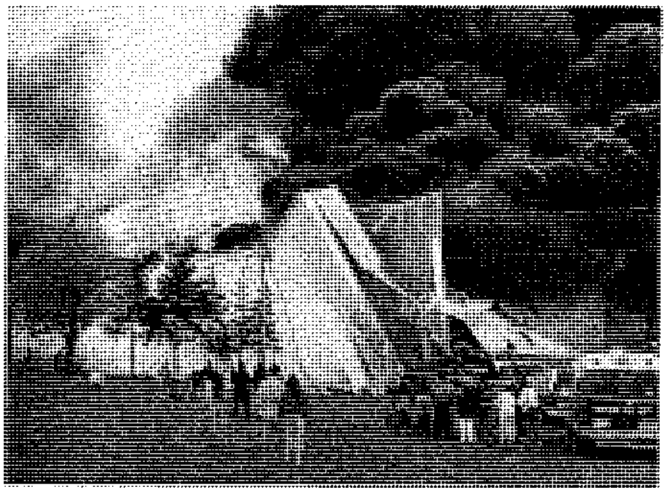
The warehouses

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.

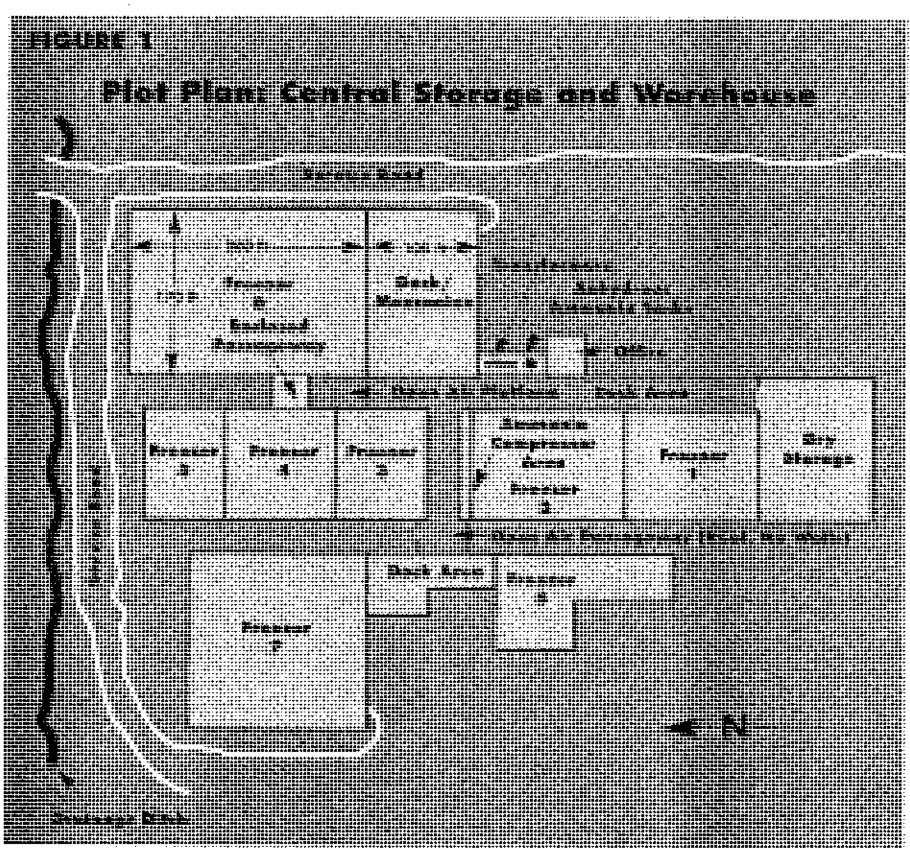
PHOTOS: MICHAEL S. ISNER

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 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.

• • • • •

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

• • • • •

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.

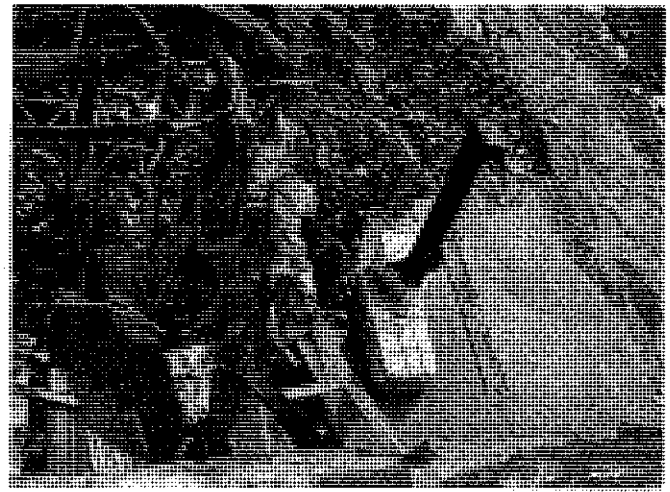
The roof over Freezers 3 and 4 collapsed, and fire heavily damaged or consumed the commodities stored in those freezers.

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.

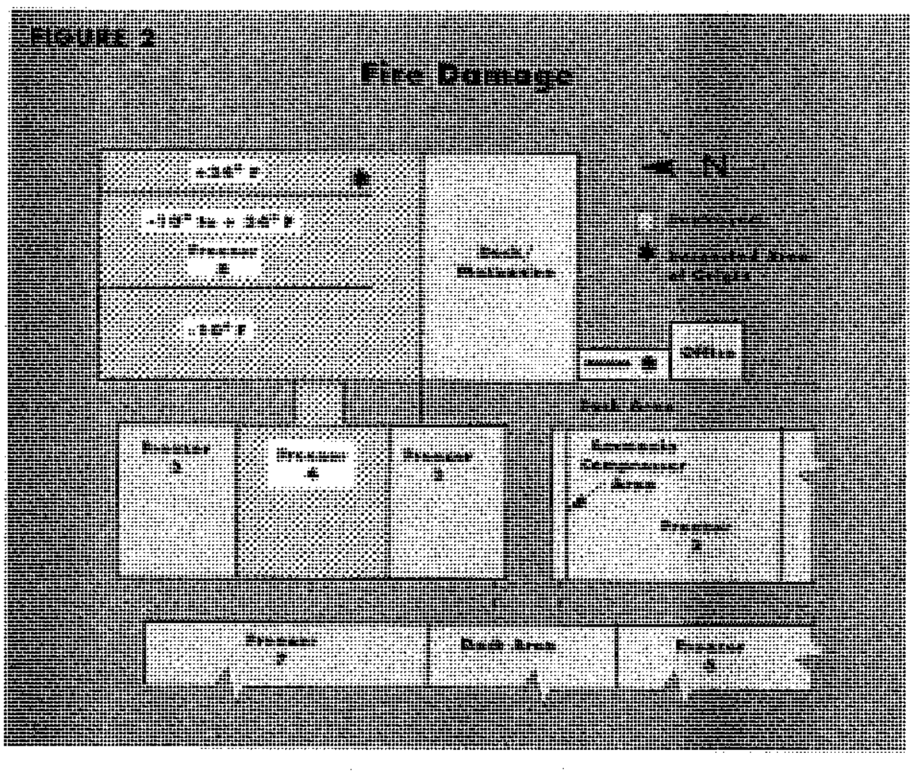
The officer on Engine 5 also observed that the sprinkler system in Freezer 8 was operating when he first entered the freezer. Local fire officials found no evidence and received no reports suggesting that the system had operational or maintenance problems.

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 sprinklers 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.[5]

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 sonth 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, noncombustible high-rack/roof support system. The system collapsed within 1 hour of the fire department receiving notification 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.

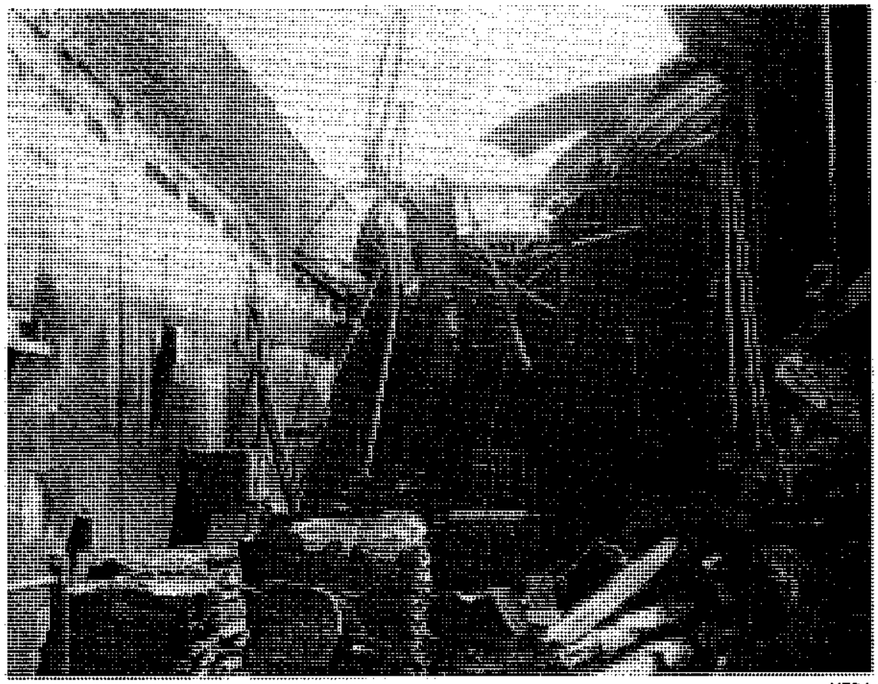
4. Chapter 11, "General Indoor Storage Practices," *Fire Protection Handbook*, 16th edition, Quincy, Mass.: NFPA, 1986.

5. *Ibid.*

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

Michael S. Isner is a fire protection engineer in the NFPA's Engineering Division.

INVESTIGATION REPORT



NFPA

Explosion in Cold Storage Kills Fire Fighter

THOMAS J. KLEM

On September 17, 1984, two members of the Shreveport, Louisiana, Fire Department's Hazardous Material Unit were caught in an explosion at the Dixie Cold Storage Company as they attempted to isolate an anhydrous ammonia leak in the company's cold storage warehouse. Warehouse employees had already tried to repair the leak themselves, but had been unsuccessful due to the effects of the ammonia.

The force of the blast raised the roof/ceiling assembly in the immediate area of the leak about a foot and severely damaged the building's interior wall assemblies. The initial explosion also caused a severe fire in areas adjacent to the room in which the explosion occurred.

Thomas J. Klem is the Director of NFPA's Fire Investigations and Applied Research Division.

This investigation was conducted by the NFPA under an agreement with the Federal Emergency Management Agency/United States Fire Administration (FEMA/USFA) and the National Bureau of Standards/Center for Fire Research (NBS/CFR). It was jointly funded by these agencies and the NFPA.

INVESTIGATION REPORT: EXPLOSION

The two fire fighters trapped in the room where the explosion occurred were badly burned when their protective clothing ignited. One died within 36 hours of the accident; the other was admitted to a hospital in critical condition.

Based on his research, NFPA's fire investigator considers the major factors contributing to the loss of life in this fire to be the warehouse workers' failure to take proper precautions to reduce the possibility of a hazardous accumulation of anhydrous ammonia, the fire fighters' lack of awareness that a hazardous accumulation of gas had collected in the room, and the ignition of the hazardous accumulation of gas during the emergency repair operation.

The Building

The Dixie Cold Storage Company is located in an industrial area of Caddo Parish, Louisiana, just outside the Shreveport city limits. The company's building contains an office and a refrigeration warehouse in which frozen meat products are processed and stored before they are shipped to distribution centers. The original one-story structure, built in 1972, covered approximately 40,000 square feet. An addition of about 30,000 square feet had recently been constructed.

The older portion of the building, in which the explosion and fire occurred, most closely resembled unprotected noncombustible construction, or Type II (000) construction as defined in NFPA 220-1979, *Standard Types of Building Construction*. The 52-by-52-foot room of origin was typical of the building's several storage areas. Its main support members consisted of exposed structural steel beams and columns, while the roof/ceiling assembly was made of built-up roof on metal deck supported by steel bar joist. Because of the nature of the occupancy, three inches of foam plastic material were provided as a thermal barrier in the roof/ceiling assembly.

Three sides of the room were enclosed in prefabricated, self-supporting wall panels 20 feet high and 4 feet wide. The panels consisted of six inches of foam plastic material sandwiched between two thin layers of aluminum, and formed the interior surface of the room's walls. They were placed on concrete curbing six inches high that ran around the entire perimeter of the room. The remaining wall was of similar construction, but ½ inch of cement had been applied to the surface of the wall facing into the room.

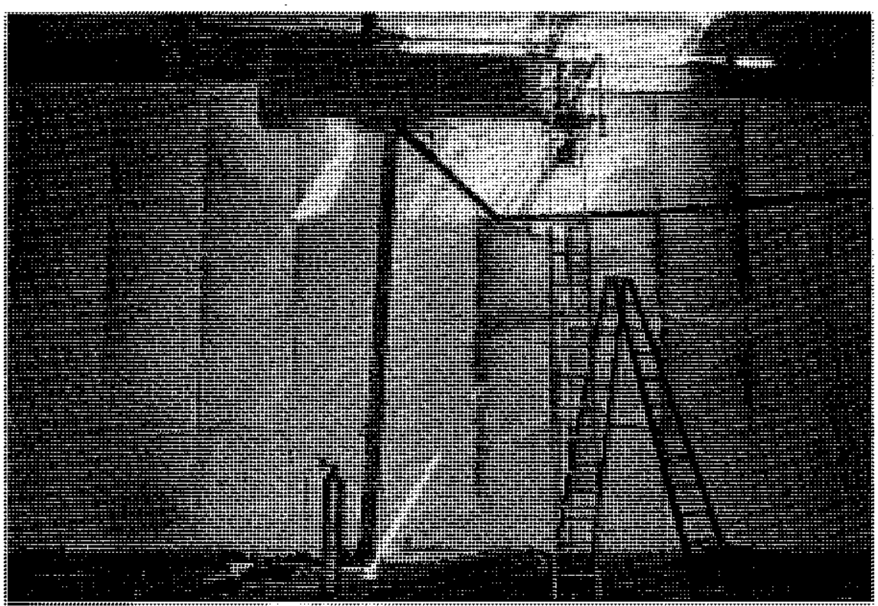
One entered the room through a pair of pneumatically operated, sliding metal doors. Strips of plastic material had been hung in front of these doors inside the room to keep the conditioned air from escaping. The temperature within all the storage rooms was normally kept at approximately −12°F.

The building's conditioned air was supplied by a mechanical refrigeration system through a ceiling-mounted evaporator unit located in the room in which the explosion and fire occurred. Insulated piping was used to provide the evaporator unit with its refrigerant, anhydrous ammonia. A compressor, located in a remote portion of the building, was also part of the system.

The older portion of the building had no automatic sprinkler system. An automatic dry-pipe sprinkler system had been installed in the addition, but it was not a factor in the incident.

The Explosion and Fire

Several days before the fire, warehouse employees detected the odor of ammonia. Maintenance personnel pinpointed the source of the odor as a leak in the refrigeration system and determined that a valve at the evaporator unit in the room of origin



NFPA

Workers were trying to replace a leaking valve to this evaporator unit when the concentration of ammonia drove them from the room. Below the unit is the carbon dioxide tank workers used to try to reduce the amount of the gas in the area before they were forced out.

had to be repaired. They removed merchandise from the room, and scheduled the repairs for Monday, September 17. Reportedly, they also shut the evaporator unit down, allowing temperatures in the room to rise to an estimated 50°F by the time of the repair.

Work on the evaporator unit began at approximately 10:00 am on Monday. The weather that day was reported to be hot and humid, with a temperature of 85°F. Winds were from the north at 9 miles per hour.

As the workmen replaced the refrigeration system valves, they noticed that the concentration of ammonia in the room was building to an extremely uncomfortable level. They were protected from the gas only by industrial-type filter masks, or chemical respirators; there was no other protective equipment iu the area.

The exact cause of this increase in anhydrous ammonia is unknown, but it could have been the result of a pressure increase in the system caused by the rise in the ambient temperature after the system was shut down. It could also have resulted if that portion of the system on which the maintenance crew was working had not been completely isolated. The crew apparently shut the system's isolation valve, but it is not known if they isolated that portion of the system entirely or if they drained or purged the liquid downstream of this valve. The exact procedures the maintenance workers used to repair the leak were not available to the NFPA.

The maintenance crew tried to reduce the ammonia in the room by "absorbing" it with a 50-pound cylinder of carbon dioxide. When ammonia and carbon dioxide come in contact with each other, they react to form ammonium carbonate or ammonium bicarbonate. Evidently, this technique can be effective in dispersing small quantities of isolated ammonia gas. However, it is not a recognized industry practice for handling ammonia leaks. (See *Safety Requirements for Storage and Handling of Anhydrous Ammonia*, ANSI/CGA G-2.1-1972, and ANSI/ASHRAE 15–78, *Safety Code for Mechanical Refrigeration*.)

As the carbon dioxide came into contact with the moist air in the room, it condensed. The ammonia also condensed, and the combination greatly reduced visibility in the area.

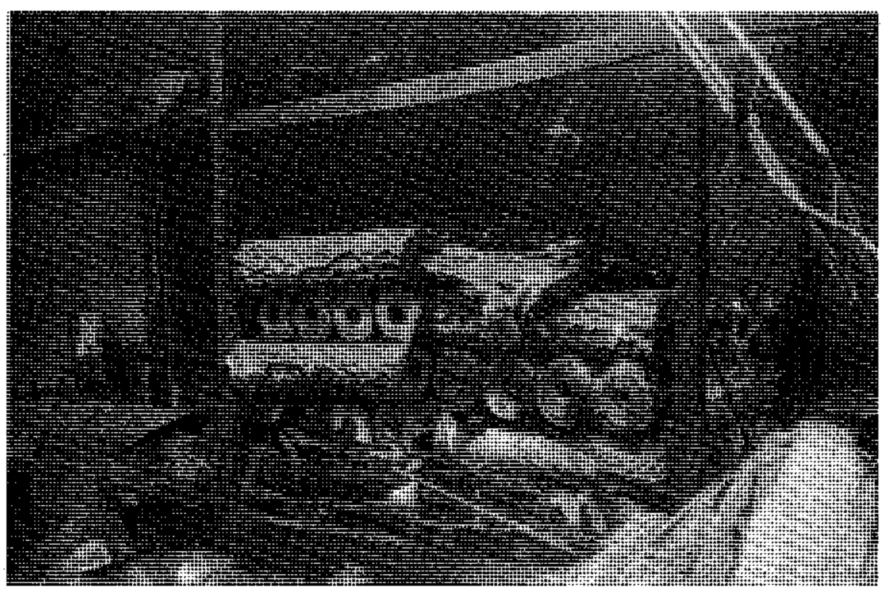
As more anhydrous ammonia was released into the room, conditions began to deteriorate. The room was becoming untenable for anyone not wearing full protective equipment, and the workers had nône.

The gas forced the crew to stop work and leave the room. They called a neighboring fire department to ask if they could borrow some self-contained breathing apparatus (SCBA). Sometime after the neighboring fire department received the employees' call, the Shreveport Fire Department became aware of the incident and dispatched an engine company to the scene at 2:40 pm.

First-arriving fire fighters were told that the leak had been isolated and that only residual gas remained in the room. When they had assessed the problem themselves, they decided to send for the department's Hazardous Material Unit. While waiting for the unit to arrive, some of the fire fighters began spraying the area with water fog from fire hoses to absorb the residual gas, hoping to thus disperse it.

The Hazardous Material Unit of the Shreveport Fire Department is operated by the department's Training Division. Three of its officers, a captain, an assistant chief, and the chief training officer, were dispatched to the scene at 3:12 pm. While they were studying the problem, fire fighters placed exhaust fans at the door of the room to help get rid of the ammonia. Other fire fighters flushed the protective equipment that the men trying to disperse the ammonia wore with a portable waterspray device in an effort to remove the residual gas from the equipment and to reduce the gas's irritating effects.

The Hazardous Material Unit decided that fire fighters could correct



NFPA

Combustibles stored in an area adjacent to the room of origin ignited soon after the explosion.

the problem by replacing the leaking valve while wearing chemical encapsulated suits and SCBA to protect themselves from the ammonia's toxic and irritating effects. At this time, fire fighters believed that they were dealing with stabilized conditions and that they were taking the actions necessary to control the situation. This belief was based in part on their understanding that the company's maintenance workers had isolated the affected part of the system and that the gas had not been leaking for very long. It was also based on their use of the Department of Transportation's *Hazardous Material Emergency Response Guidebook* and the Bureau of Explosives' *Emergency Handling of Hazardous Materials in Surface Transportation,* which classify anhydrous ammonia as a nonflammable gas, although they do indicate that the gas can ignite and burn under some conditions.

The fire fighters decided to use an electric forklift truck to replace the valve. One fire fighter would operate the truck, raising another fire fighter into position to work on the valve, which was located near the ceiling about 17 feet above the floor.

By this time, visibility in the room was near zero and the floor was very slippery. As the fire fighters were positioning the forklift truck with the help of workers, it slid into one of the interior walls of the room and the concrete curb at the base of the wall assembly. The result was an explosion. It was 4:00 pm.

The fire fighter who had been on the ground directing the vehicle reported that the explosion occurred immediately after the forklift struck the wall and that the fire fighter driving the forklift was engulfed in flames instantly. The fire fighter on the ground was knocked down by the force of the explosion and his encapsulated suit ignited. After he had managed to get most of the burning suit off, he saw a light shining through an opening the explosion had ripped in a wall and began to move toward it. He squeezed through the 12-inch opening, releasing himself from his SCBA equipment when it became lodged in the wall, and eventually escaped from the building.

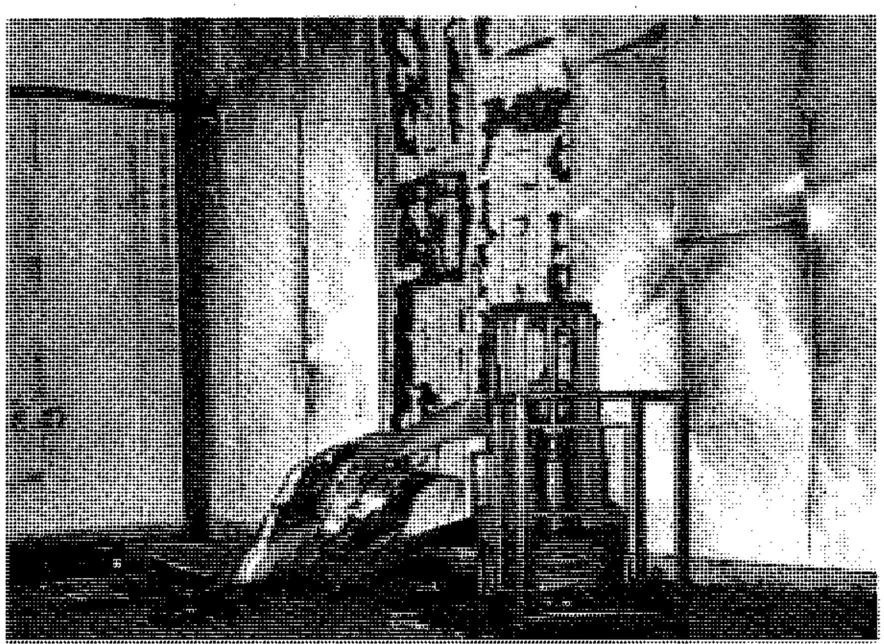
The fire fighter driving the forklift apparently left the vehicle and tried to remove his burning encapsulated suit. He had only partially succeeded when he collapsed. He was eventually found and removed from the building.

Since most of the combustible materials normally present in the room had been removed before the repair work began, there was little fire extension in the area of origin beyond burning insulatiou. Thermal insulation dislodged from the roof/ceiling assembly by the force of the explosion fell burning to the floor, while other insulation burned at the ceiling. However, combustible materials in adjoining areas ignited, and a severe fire ensued. The fire fighters on the scene summoned additional help, and they soon had the fire under control.

The Damage and Injuries

Damage to the building was extensive. The force of the blast lifted the roof of the room an undetermined amount and moved the evaporator unit approximately 12 inches from its original position. It also buckled the interior walls of the room. The ensuing fire damaged ordinary combustible materials stored outside the cold storage areas, and caused the roof/ceiling assembly to collapse partially.

Both of the fire fighters who had been in the room when the explosion occurred were severely burned. The driver of the forklift, age 32, died within 36 hours of the incident from burns over 97 percent of his body. The other fire fighter, age 31, had third-degree burns over 50 percent of his body and second-degree burns over another 20 percent. He was originally listed in critical condition, but has improved steadily. He was awaiting release from the hospital when this report was written.


NFPA

The electric forklift truck fire fighters were using to replace the valve slid into one of the walls, and an explosion resulted.

(Continued on page 79)

 (continued from page 46)

Analysis of the Explosion and Fire

Investigators from the Shreveport Fire Department, the Caddo Parish Sheriff's Department, and the Louisiana State Police determined that the cause of the explosion was the ignition of a hazardous accumulation of ammonia gas. They further determined that the ignition source was either an electrical arc from the forklift truck or a spark produced when the steel frame of the truck hit the concrete curbing at the base of the wall assembly.

Investigators from the NFPA consider that the factors contributing to the loss of life during this fire were:

1) The ignition of a flammable mixture of anhydrous ammonia gas during the emergency repair operation;

2) The failure of the company's maintenance workers to take the precautions that would have reduced the possibility of a hazardous accumulation of the gas; and

3) The fire fighters' lack of awareness that conditions existed that could lead to a hazardous accumulation of flammable anhydrous ammonia gas.

ABOUT THE INVESTIGATION

The NFPA investigated the explosion and fire at the Dixie Cold Storage Company in Shreveport, Louisiana, to document and analyze the significant factors that resulted in the fire fighter's death. The study was condncted under a Major Fires Investigation Agreement among the Federal Emergency Management Agency/United States Fire Administration, the National Bureau of Standards/Center for Fire Research, and the NFPA. The agreement, funded by all three organizations, allows the NFPA Fire Investigations and Applied Research Division to investigate technically significant fires in order to record and analyze details of the incidents and to report lessons learned for loss prevention purposes.

The NFPA became aware of the fire on September 19, 1984. Shortly thereafter, Thomas J. Klem, Director of the NFPA Fire Investigations and Applied Research Division, traveled to Shreveport to document the facts about the fire during a three-day on-site study. His entry to the scene and data collection activities were made possible by the Shreveport Fire Department.

This report, which represents his on-site findings and the subsequent analysis of the event, is another of the NFPA's studies of fires that are of important educational or technical interest. The information presented here is based on the best available data, and the report is not intended to pass judgment on, or fix liability for, the loss of life or property.

We wish to thank Dallas W. Green, Jr., Chief of the Shreveport Fire Department; Chief Harry Strealy, Assistant Director of the Bureau of Fire Prevention; Captain Robert Mayence of the Bureau of Fire Prevention; Don Cotton, Chief Training Officer; Don Majune of the Sheriff's Department, Caddo Parish; William E. (Ed) Bobbit of the Louisiana State Police; and Jim Alexander, Deputy State Fire Marshal, for their help and cooperation.

When released from containment, anhydrous ammonia presents a combustion explosion and fire hazard, as well as a toxic hazard. If it is released outdoors, it may have difficulty reaching the lower flammability limit (16 percent) concentration except in small zones in the immediate vicinity of the leak. In unusually tight buildings such as refrigerated process or storage areas, however, the release of liquid anhydrous ammonia or large quantities of ammonia gas can result in the accumulation of a flammable mixture that may cause a combustion explosion.[1]

Since the gas has a vapor density of 0.6 and is lighter than air, it will tend to accumulate at the ceiling and build down. Vapor density is usually calculated at standard temperature and pressure. In this particular incident, the low temperature of the leaking gas would have caused it to first accumulate near the floor. As the gas was warmed by the environment, it would have begun to collect at the ceiling. During this process, hazardous amounts of the gas could also have accumulated at various levels within the room.

Even though ammonia's low heat of combustion produces pressures lower than those of most flammable gases, they are enough to do major structural damage. Anhydrous ammonia also irritates the eyes, skin, and mucous membranes, and may severely injure the respiratory membranes with fatal results.

Industry recommends that workers repairing leaks in refrigeration systems that contain anhydrous ammonia be familiar with its characteristics and adhere to safe handling practices. These include isolating the leak and stopping the flow of ammonia by shutting valves, staying upwind of any leak that occurs outside a building, using large quantities of

[1] "Ammonia Explosion Destroys Ice Cream Plant," *Fire Command*, Vol. 51, No. 4 (April 1984), p. 36.

water fog to disperse the ammonia, and wearing protective equipment, including self-contained breathing apparatus. If a leak is severe or if isolating it is difficult, further measures, such as purging the system, may be necessary. Recommended operating procedures indicate that self-contained breathing apparatus and protective clothing should be available to workers in case an emergency develops during the repair process.[2]

Workers followed some of these precautions during the initial repair procedure at the warehouse, but they apparently were unable to isolate the portion of the system they were working on. As a result, ammonia accumulated in the room throughout the day, unable to escape because the tight wall and ceiling arrangement permitted no ventilation. The concentration most likely increased as the rise in ambient temperature caused the liquid ammonia to boil.

The workers were not able to isolate the leak completely until Friday, September 21, four days after the fire. However, they evidently told first-arriving fire fighters that they had managed to isolate it and that the ammonia had only been leaking for a short time. Using this information, as well as their own assessment of conditions in the room and information they gathered from the Department of Transportation's *Hazardous Material Emergency Response Guidebook,* fire fighters sent two men with encapsulated suits and SCBA equipment in to replace the leaking valve.

The *Hazardous Material Emergency Response Guidebook* was designed primarily for use at hazardous material accidents occurring on highways and railroads, and mentions that its recommendations are not necessarily adequate for, or applicable to, all cases. With certain limitations, though, it is of use in handling incidents in other modes and at facilities such as terminals and warehouses.

Both NFPA 325M, *Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solids,* and NFPA 49, *Hazardous Chemicals Data,* indicate the flammable nature of anhydrous ammonia and classify it accordingly. NFPA 325M lists the gas as a "1" using NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials,* but notes that it receives this designation instead of a "4" because it is normally "hard to burn." In this instance, however, the conditions that confronted fire fighters were ideal for allowing the gas to reach its flammable range and it did. △

[2] See *Safety Requirements for Storage and Handling of Anhydrous Ammonia,* ANSI/CGA G-2.1-1972 and ANSI/ASHRAE 15–78, *Safety Code for Mechanical Refrigeration.*

Summary Investigation Report
Cold Storage Building Fire
Shreveport, Louisiana
September 17, 1984
1 Fire Fighter Fatality

Prepared by

Thomas J. Klem
Director, Fire Investigations
and Applied Research Division
National Fire Protection Association

In Cooperation with

Federal Emergency Management Agency
United States Fire Administration

and

National Bureau of Standards/
Center for Fire Research

This investigation was conducted by the National Fire Protection Association (NFPA) under an agreement with the Federal Emergency Management Agency/United States Fire Administration (FEMA/USFA) and the National Bureau of Standards/Center for Fire Research (NBS/CFR). It was jointly funded by these agencies and the NFPA.

ABSTRACT

On Monday, September 17, 1984, at approximately 4:00 p.m., an explosion occurred in a cold storage warehouse building near Shreveport, Louisiana. The explosion occurred while two members of the Shreveport Fire Department's Hazardous Material Unit were attempting to isolate an anhydrous ammonia leak in a section of the building's refrigeration system. Employees had earlier detected the leak and workers had begun repairs earlier in the day, but were unable to complete the repair due to the effects of the ammonia.

The force of the explosion raised the building's roof/ceiling assembly in the immediate area of the leak approximately one foot and severely damaged interior wall assemblies. The initial explosion also resulted in a severe fire from the ignition of ordinary combustibles in the adjacent areas of the building. The two fire fighters within the room of origin were severely burned when their protective clothing became ignited. One fire fighter died within 36 hours of the explosion; the other fire fighter was admitted to a hospital in critical condition.

Based on the investigative study, the following are considered to be major contributing factors to the loss of life in this incident:

(1) The ignition of a flammable mixture of anhydrous ammonia gas during the emergency scene operation.

(2) The lack of proper precautions by workers to reduce the possibility of a hazardous accumulation of anhydrous ammonia gas, and

(3) The lack of awareness by fire fighters that the conditions for a hazardous accumulation of flammable anhydrous ammonia gas were present.

I. INTRODUCTION

The National Fire Protection Association (NFPA) investigated the Dixie Cold Storage Company, Shreveport, Louisiana explosion and fire in order to document and analyze significant factors that resulted in the fire fighter fatality.

This study was conducted under a Major Fires Investigation Agreement among the Federal Emergency Management Agency/United States Fire Administration (FEMA/USFA), the National Bureau of Standards/Center for Fire Research (NBS/CFR), and the NFPA. The agreement, funded by FEMA/USFA, NBS/CFR and NFPA, provides for the investigation of technically significant fires by the NFPA Fire Investigations and Applied Research Division to document and analyze incident details and report lessons learned for loss prevention purposes.

The NFPA became aware of the incident on September 19, 1984. Thomas J. Klem, Director of the NFPA Fire Investigations and Applied Research Division, traveled to Shreveport, Louisiana, to document the facts related to this incident. A three-day on-site study and subsequent analysis of the event were the basis for this report. Entry to the fire scene and data collection activities were made possible through the cooperation of the Shreveport Fire Department. This report represents the findings of the data collection and analysis efforts.

This report is another of NFPA's studies of fires having particularly important educational or technical interest. The information presented is based on the best data available immediately after the fire incident and that obtained during subsequent follow-up. It is not NFPA's intention that this report pass judgment on, or fix liability for, the loss of life and property.

This report describes fire safety conditions at the Dixie Cold Storage Building and presents findings on contributing factors to the loss of life based on NFPA analysis of collected data and observations during the investigation.

The cooperation and assistance of Chief of the Shreveport Fire Department, Dallas W. Greene, Jr., Chief Harry Strealy, Assistant Director Bureau of Fire Prevention; Captain Robert Mayence, Bureau of Fire Prevention; Don Cotton, Chief Training Officer; Don Majune, Sheriff's Department, Caddo Parish; William E. (Ed) Bobbitt of the Louisiana State Police and Jim Alexander, Deputy State Fire Marshal is greatly appreciated.

II. BACKGROUND

The Dixie Cold Storage Company's warehouse and office building is located in an industrial area of Caddo Parish, Louisiana just outside the city limits of Shreveport. Dixie Cold Storage is a refrigeration warehouse which processes and then stores frozen products before shipping to distribution centers. The products, including meats and poultry, are stored in refrigerated rooms throughout the building. The original (approximately 40,000 sq. ft.) one-story structure was constructed in 1972; an approximate 30,000 sq. ft. addition had recently been added to the building. The older portion of the building in which the fire occurred most closely resembled unprotected noncombustible construction (Type II [000] constructed per NFPA 220-1979, Standard Types of Building Construction).

Construction of the 52-foot by 52-foot room of origin was typical of the several storage areas provided in the building. Exposed structural steel beams and columns were the main support members for the room. The roof/ceiling assembly consisted of built-up roof on metal deck supported steel by bar joist. Because of the nature of the occupancy, three inches of foam plastic material was provided as a thermal barrier in the roof/ceiling assembly. Twenty-foot high by four-foot wide, prefabricated, self-supporting, wall panels were provided to enclose three sides of the room . The panels consisted of six inches of foam plastic material which was enclosed between two thin layers of aluminum, which was the interior surface of the walls. The wall panels were placed on 6-inch high concrete curbing which was provided around the entire parameter of the room. The remaining wall was of similar construction; however, 1/2 inch of cement was applied on the interior side of the room. Access to the room was through a pair of pneumatically operated, sliding metal doors. Strips of a plastic material were placed in front of the doors on the inside portion of the room to retain conditioned air. Temperatures within these rooms were normally kept at approximately $-12^{o}F$.

A ceiling-mounted evaporator unit was located in the room. The unit was part of the building's refrigeration system which also supplied other cold storage rooms. The building's mechanical refrigeration system utilized a refrigerant, anhydrous ammonia, which was supplied to the room's evaporator unit through insulated piping. A compressor, located in a remote portion of the building, was also part of the system.

There was no automatic sprinkler system provided in the older portion of the building in which the explosion and subsequent fire occurred. There was an automatic dry-pipe sprinkler system in the new addition of the building, which was not a factor in the incident.

Weather conditions the day of the incident were reported to be hot and humid with a temperature of $85^{0}F$; winds were from the north at 9 mph.

The Fire Incident

Several days before the incident, an ammonia odor was detected by employees. Maintenance personnel located a leak in the refrigeration system in one of the cold storage rooms and determined that a valve at the evaporator unit needed repair. Merchandise in the room was removed and maintenance scheduled for Monday, September 17, 1984. The evaporator unit was shut down and temperatures in the room were allowed to rise to an estimated 50^{0}F at the time of the repair.

Repair work began at approximately 10:00 a.m. on Monday. The exact procedures being used by the workers to repair the leak were not available to NFPA; however, the crew apparently shut an isolation valve in the system. It is not known if the liquid downstream of this valve was drained or purged. The workers were equipped with industrial-type filter masks (chemical respirators) to help protect them during the repair. No other protective equipment was being utilized by the workers, nor was there any available in the area for their use.

At some time during the repair a 50-pound cylinder of CO_2 was utilized by the workmen "to absorb the ammonia" as it was released to the atmosphere.* After one valve had been replaced, the workmen realized that additional equipment was needed in order to repair another valve. Apparently well before the fire department was notified of the incident, the concentration of ammonia

When CO_2 contacts ammonia, a chemical reaction between the gases occurs and a white powder (ammonium carbonate or ammonium bicarbonate) is formed. Apparently this technique can be effective for dispersing small quantities of isolated ammonia gas; however, it is not recognized by industry as a practice for handling ammonia leaks. See "Safety Requirements For Storage and Handling of Anhydrous Ammonia," ANSI/CGA G-2.1-1972, and ANSI/ASHRAE 15,-78 "Safety Code For Mechanical Refrigeration" gas increased to the point that it began to cause extreme discomfort and irritation to the men.

Further, visibility in the room was reduced as a result of condensation caused as the ammonia and CO_2 contacted the moist air. The conditions within the room just before the explosion were described as, visibility near zero, untenable for a person without full protective equipment; and the floor was becoming extremely slippery.

After employees initially called a neighboring fire department, the Shreveport Fire Department was notified of the incident and dispatched an engine company to the scene. (2:40 p.m.) Apparently, the nature of the call was a request by the workers to borrow self-contained breathing apparatus (SCBA). First arriving fire fighters assessed the problem and determined that the department's hazardous material unit was needed. Fire fighters were told that the leak had been isolated and only residual gas remained in the room. Attempts were made to disperse the ammonia by utilizing fire hoses to distribute water fog to absorb the residual gas.

The Training Division of the Shreveport Fire Department operates the Hazardous Material Unit. Three officers (a Captain, Assistant Chief, and the Chief Training Officer) were dispatched to the scene (3:12 p.m.). After an initial assessment by two men from the hazardous material unit, it was decided that they would correct the situation by replacing the leaking valve, wearing encapsulated suits and SCBA. Other fire fighters utilized a portable water spray device to flush the protective equipment worn by fire fighters who were assisting in the assessment and dispersement

*Since the refrigeration system was partially shut down, the increasing concentration of ammonia could have been caused by increasing pressure in the system due to the rising ambient temperature. The boiling point of anhydrous ammonia is -28^{o}F. Another possibility is that the isolation of that portion of the system was incomplete.

efforts. In addition, fire fighters were placing exhaust fans at the cold storage room door to help disperse the ammonia.

Fire fighters believed that they had an isolated leak (i.e., stabilized conditions) and that they were taking the necessary actions (i.e., water spray and exhaust fans, replace valve, etc.) to control the situation. This overall assessment was in part based on the understanding that workers had isolated the affected part of the system and that the leak had not been occurring for an extended length of time. Hazardous materials reference guides utilized by the fire fighters classified anhydrous ammonia as a nonflammable gas, but also indicated that under some conditions the gas could ignite and burn.[1] Based on this assessment and understanding, the fire fighters planned to utilize SCBA and chemical encapsulating suits to protect them from the toxic and irritating effects of the ammonia.

Using an electric forklift truck, it was decided that one fire fighter would operate the truck while the other was raised into position to replace the valve, which was located near the ceiling level approximately 17 feet above the floor. Workers assisted the fire fighters in positioning the forklift truck in the storage room. At this time visibility in the room was near zero.

The fire fighters were positioning the forklift truck when, apparently because of the slippery floor conditions and poor visibility, the forklift truck slid into and struck one of the interior walls of the room and the concrete curb at the base of the wall assemblyresulting in an explosion (4:00 p.m.). The fire fighter (fire fighter #1) who was on the ground directing the operator of the vehicle (fire fighter #2) reported that the explosion occurred immediately after the vehicle struck the wall area, and that fire fighter #2 was immediately engulfed in flames.

1U.S. Department of Transportation's "Hazardous Materials Emergency Response Guidebook" and the Bureau of Explosives "Emergency Handling of Hazardous Materials in Surface Transportation."

Fire fighter #1 was knocked down by the force of the explosion and his encapsulated suit was ignited. He struggled to remove the suit as he moved about the room. After removing most of the suit, he saw a light and began to move toward it. (Eventually it was learned that the light was coming from an adjoining room and shining through a wall opening caused by the force of the explosion.) The fire fighter squeezed through an approximately 12-inch opening and eventually exited the building. In his struggle to escape, his SCBA equipment became lodged in the wall and he had to release himself from the equipment.

Fire fighter #2 apparently left the forklift truck and attempted to remove the burning encapsulated suit. He was partially successful at this effort but collapsed during the process. He was eventually found and removed from the building.

Since most combustible materials had been removed from the room, there was little fire extension in the area of origin. Thermal insulation became dislodged in the roof/ceiling assembly by the force of the explosion and burned at the floor level other insulation burned at the ceiling level. Combustible materials in adjoining areas were ignited following the explosion and a severe fire ensued. Fire fighters summoned additional assistance and began to suppress the fire and search for the missing fire fighter. The fire was soon controlled by fire fighters.

The force of the explosion was sufficient to lift the roof of the room an undetermined amount and lift the evaporator unit approximately 12 inches from its original position. Interior walls of the room were buckled. The ensuing fire damaged combustible material stored outside of the cold storage area and caused partial collapse of roof/ceiling assembly.

The two fire fighters in the room of origin were severly burned when their encapsulated protective suits become ignited due to the explosion. Fire fighter #2, age 32, died within 36 hours of the incident from burns over 97 percent of his body. Fire fighter #1, age 31, was in critical condition with third-degree burns over 50 percent and second-degree burns over another 20 percent of his body.* Both fire fighters had 10 years experience with the department.

*At the time of this report fire fighter #2's condition has improved steadily. He has been removed from the critical list and is awaiting release from the hospital.

ANALYSIS

Investigators from the Shreveport Fire Department, the Caddo Parish Sheriff's Department and the Louisiana State Police determined that the cause of the explosion was the ignition of a hazardous accumulation of ammonia gas. The ignition source was determined to be either an electrical arc from the forklift truck or a spark caused by the steel frame of the truck contacting the concrete curbing at the base of the wall assembly.

Anhydrous ammonia presents a combustion explosion and fire hazard (as well as a toxic hazard) when released from containment. If anhydrous ammonia is released outdoors, it is difficult for it to reach the lower flammability limit (16%) concentration except for small zones in the immediate vicinity of the leak. In unusually tight buildings, such as refrigerated process or storage areas, however, the release of liquid or large quantities of gas can result in the accumulation of a flammable mixture and result in a combustion explosion.[1] Since the gas is lighter than air (vapor density 0.6*) it will tend to accumulate at the ceiling area and build down. Even though the low heat of combustion of ammonia produces lower pressures than most flammable gases, the pressure is enough to do major structural damage.

Since anhydrous ammonia also causes varying degrees of irritation to the eyes, skin or mucous membranes, it may also cause severe injury to the respiratory membranes with fatal results. Emergency instructions concerning the handling of an incident involving this material include stopping the flow,

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[1] "Ammonia Explosion Destroys Ice Cream Plant", Fire Command, April, 1984.

*Vapor density is usually calculated at standard temperature and pressure (STP). In this incident because of the temperature of the leaking gas, it would have at first accumulated near the floor area. As the gas was warmed by the environment, it would then tend to accumulate at the ceiling level. As this dynamic process occurred, hazardous accumulation of the gas could be reached at various levels within the room of origin.

utilizing full protective equipment, isolating the area, staying upwind (if outside) and using large quantities of water fog to disperse (absorb) the ammonia.

Industry recommends that workers repairing leaks to refrigeration systems containing anhydrous ammonia should be knowledgeable about the characteristics of ammonia and adhere to safe practices such as isolating leaks in an ammonia refrigeration system by shutting valves, and wearing protective breathing apparatus. If a leak is severe or if isolation is difficult, further measures may be necessary, such as purging the system. Recommended operating procedures indicate that self-contained breathing apparatus and protective clothing should be available in case an emergency develops during the repair process.[2]

The initial repair procedure at the warehouse involved some of these techniques; however, the portion of the system being worked on was apparently not isolated. As a result, the ammonia continued to accumulate in the room throughout the day. The concentration most likely increased as the liquid began to boil due to the rise in ambient temperature. The tight wall and ceiling arrangement of the cold storage room resulted in the lack of ventilation which was a factor contributing to the high concentration of ammonia. As the ammonia accumulated, workmen experienced severe irritation and reduced visibility. The use of CO_2 by the workmen to absorb the leaking ammonia may also have been contributing to the reduced visibility. Workers were not equipped to handle an ammonia leak of this magnitude and summoned the fire department to the scene to assist them.

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[2]See "Safety Requirements For Storage and Handling of Anhydrous Ammonia," ANSI/CGA G-2.1-1972 and ANSI/ASHRAE 15-78, "Safety Code for Mechanical Refrigeration".

Due to the amount of condensation, the amount of irritation experienced by the workers, from the large build-up of the gas mixture within the room, and the lack of adequate protective equipment, the workers were not able to isolate the leak. It was not until Friday, September 21st, after the incident, that workers completely isolated the ammonia leak.

First arriving fire fighters apparently were told that the leak had been "isolated" and believed that the duration of the leak had been only a short interval of time. Fire fighters used water fog lines to absorb the ammonia gas and exhaust fans to disperse the gas. Basing their assessment on the conditions and information provided to them at the scene, and the information contained in reference material* available to them, the fire fighters believed that they had stabilized the conditions and committed two men with encapsulated suits and SCBA equipment to replace the leaking valve.

Both NFPA 325M, "Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solids," and NFPA 49, "Hazardous Chemicals Data", indicate the flammable nature of anhydrous ammonia and classify it accordingly. NFPA 325M classifies the gas as a "1"**, but notes that it receives this designation instead of a "4" "because it is hard to burn." In this incident, the conditions confronted by fire fighters were ideal for the gas to reach its flammable range.

Based on the investigative study, the following are considered to be major contributing factors to the loss of life in this incident:

(1) The ignition of a flammable mixture of anhydrous ammonia gas during emergency scene operation.

(2) The lack of proper precautions by workers to reduce the possibility of a hazardous accumulation of anhydrous ammonia gas, and

3) The lack of awareness by fire fighters that the conditions for a hazardous accumulation of flammable anhydrous ammonia gas were present.

*The DOT "Hazardous Material Emergency Response Guidebook" mentions that the recommendations are not necessarily adequate or applicable in all cases. The document was primarily designed for use at a hazardous material incident occurring on a highway or a railroad. It will, with certain limitations, be of use in handling incidents in other modes and "at facilities such as terminals and warehouses."

**Using NFPA 704, Standard System for the Identification of the Fire Hazards of Materials.

Ammonia Explosion

(Houston Fire Department Photo)

Destroys Ice Cream Plant

First arriving fire fighters responding to an anhydrous ammonia leak at Borden's Ice Cream Company near downtown Houston barely escaped death or serious injury when the building blew apart in a violent explosion. The incident shattered a misconception about ammonia that had evolved in the minds of both fire fighters and refrigeration people.

On Sunday morning, December 11, 1983, when the plant engineer arrived to check the building, production had been shut down since Thursday and only three of the 16 ammonia compressors in the basement were operating to maintain product storage. After finding everything normal, the engineer continued to the opposite end of the basement, when he heard a loud noise, looked back and saw a huge ammonia cloud developing. He escaped up the back stairs, shut the king valve on the liquid line as he left the building and ran to a hotel on the next block, where he called the fire department.

He returned to the plant in time to meet arriving fire companies. The engineer, at the request of the district chief, agreed to point out a valve in the basement that might stop the leak. This proved a salvation because the delay in outfitting the engineer in bunker gear and showing him how to use self-contained breathing apparatus prevented an earlier entry into the building. Just as fire fighters and the engineer started toward the building, an explosion tore through the two-story building and set fire to a one-story annex in the rear.

Reinforced concrete support columns in the basement parted as the explosion raised the floors and roof. Part of a brick wall collapsed in the street near the fire fighters and engineer. Every window had blown out, and windows across the street to the east were shattered.

A second alarm was sounded as first alarm companies set up heavy streams to disperse the vapor cloud and cool the large ammonia tanks on the roof of the burning annex.

The Hazardous Materials Response Team (HMRT), which responded on the box alarm, was assigned to stop the leaking ammonia. Attempts to descend the debris-clogged stairways proved impossible, and the team finally had to reach the basement via an elevator shaft. The trip proved worthless. The

MAX H. McRAE

District Chief
Hazardous Materials Response Team
Houston Fire Department, Texas

partially collapsed floor had shattered the overhead ammonia piping, and water from broken sprinkler pipes was submerging the compressors. The decision was made to totally flood the basement and allow the water to absorb the remaining ammonia.

Apparently, a break occurred in a discharge pipe from one of the operating, high-stage compressors, which had been installed some 50 years ago. No check valve was in the discharge line and all the ammonia in the main 6-inch discharge pipe, the master oil separator, three large evaporative condensers and the liquid receiver eventually escaped into the basement compressor room.

The amount of liquid ammonia in this high side of the system, which initially registered 140 psi, was between 4000 and 5000 pounds. It is estimated that only 460 to 725 pounds of ammonia would put the confined, unventilated basement area within the explosive range of ammonia (16 percent to 25 percent by volume).

The ignition point was narrowed down to a white hot filament of one of the 300-watt incandescent light bulbs in the basement. A burning light bulb would shatter when cold vapors of the escaping ammonia reached the bulb.

The building engineer briefs the Hazardous Materials Response Team on the plant layout before the team enters the basement to stop the leaking ammonia. (Houston Fire Department Photo)

During the fire, several fire fighters expressed astonishment that ammonia would burn and others speculated that the explosion had to be from natural gas rather than ammonia. After all, ammonia carries a green, nonflammable gas label and rates a flammability of but 1 in the NFPA 704 classification system — because "it is hard to burn."

Houston fire fighters and the HMRT handle numerous ammonia leaks each year, ranging from small cylinders in the confines of office buildings to giant refrigeration systems in cold storage warehouses. Several years ago, an ammonia tank truck split open after a fall from a freeway overpass and released its 8000-gallon load in one swoop. Never has the problem been more than a health hazard.

Even the investigating consultant, who had 45 years experience in refrigeration, registered surprise. He had always worked on ammonia systems with cutting torches and arc welders.

"It is hard to find any of the old experienced ammonia refrigeration men who believe it is possible for ammonia to explode," he said. The consultant admitted to being a member of that group until he inspected the ruins.

Experience, fortunately, reveals that components for an ammonia explosion rarely come together. But they did at Borden's. The incident proves that ammonia can burn — and burn violently — and validates the warning by Isman and Carlson on anhydrous ammonia in the book *Hazardous Materials*: "Emergency response personnel must not be lulled into a false sense of security by the nonflammable label."

The Department

The Houston Fire Department is manned by 3500 fire fighters who last year responded to 38,536 emergencies, 2418 of which involved hazardous materials; 85,067 emergency medical calls were answered.

Houston has a population of 1.8 million and covers an area of 564 square miles.

FOR MORE INFORMATION

- Contact the author at: Houston Fire Department, 410 Bagby St., Houston, TX 77002, (713) 222-7791.
- *Fire Protection Guide on Hazardous Materials*, Seventh edition. Available from NFPA.

What the Handbook says

[illegible]

URETHANE INSULATION FIRE
One Dead, Several Injured

Cuba, New York

JAMES K. LATHROP, *NFPA Fire Analysis Specialist*

A mid-morning fire in a refrigerated cheese warehouse in Cuba, New York, on October 21, 1974, resulted in the death of one construction worker and injury to several fire fighters and employees. The fire started when a cutting torch ignited sprayed-on urethane insulation. The death and injuries all resulted from smoke inhalation.

BACKGROUND

The 60-foot-by-75-foot warehouse was one-story high. The roof was 16 feet high on the sides and 19 feet in the center. The floor was of poured concrete and the walls were constructed of steel. The roof was pitched from the center and was made of steel sheets on steel beams on steel columns. There were no ceilings or dividing walls. The inside surfaces of the walls and roof were covered with approximately two inches of sprayed-on urethane foam. The urethane was coated with one layer of sprayed-on intumescent paint. The temperature in the warehouse, which was used to store cheddar cheese and whey, was kept at approximately 40°F. The doors leading out of the warehouse swung in both directions and were loose fitting so that warehouse vehicles could push through them.

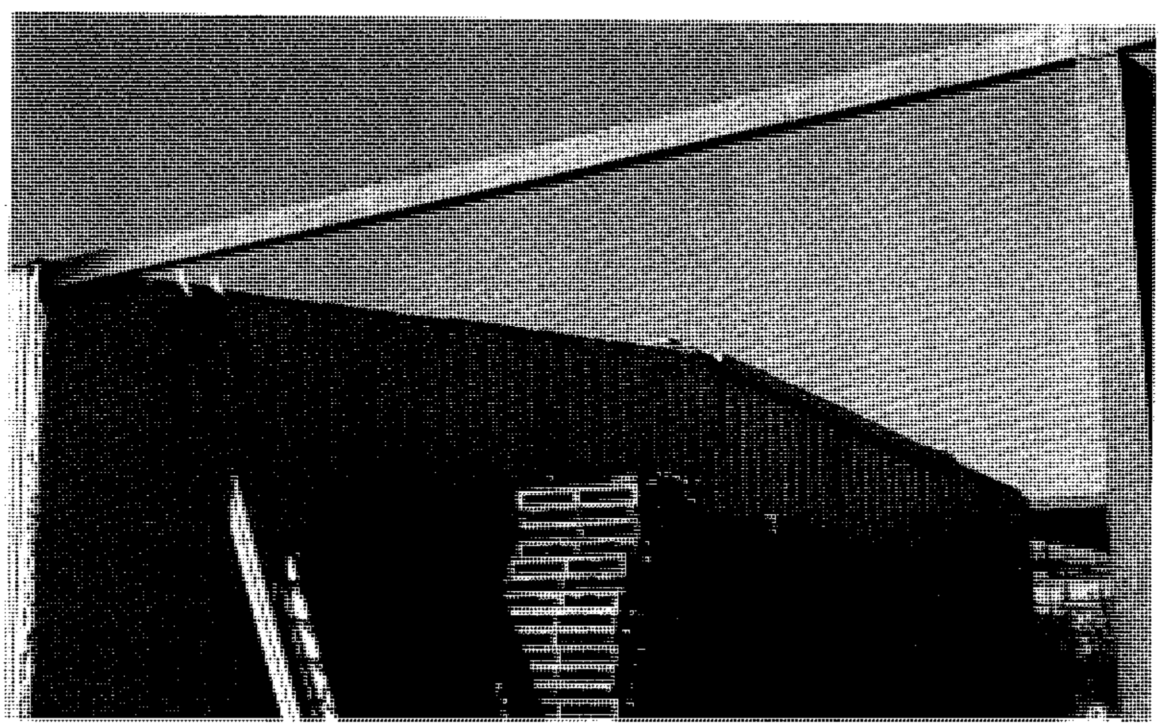
A large addition had been started adjacent to the existing structure. It was to be of similar construction.

THE FIRE

On the day of the fire, construction workers were cutting through the walls of the warehouse to attach beams for the new addition. The holes were being cut with a torch from the outside on the south wall at the roof line. Two holes had been cut and the scaffolding was then moved so that a third hole could be cut. About

This investigation was a cooperative effort by the NFPA Fire Analysis Department and the National Bureau of Standards. The cooperation of the Cuba Fire Department, Deputy County Coordinator Larry Dyer, and the Cuba Memorial Hospital is acknowledged.

The south end of the warehouse. Fire started when a cutting torch was used on the upper right-hand corner above scaffolding.
NFPA



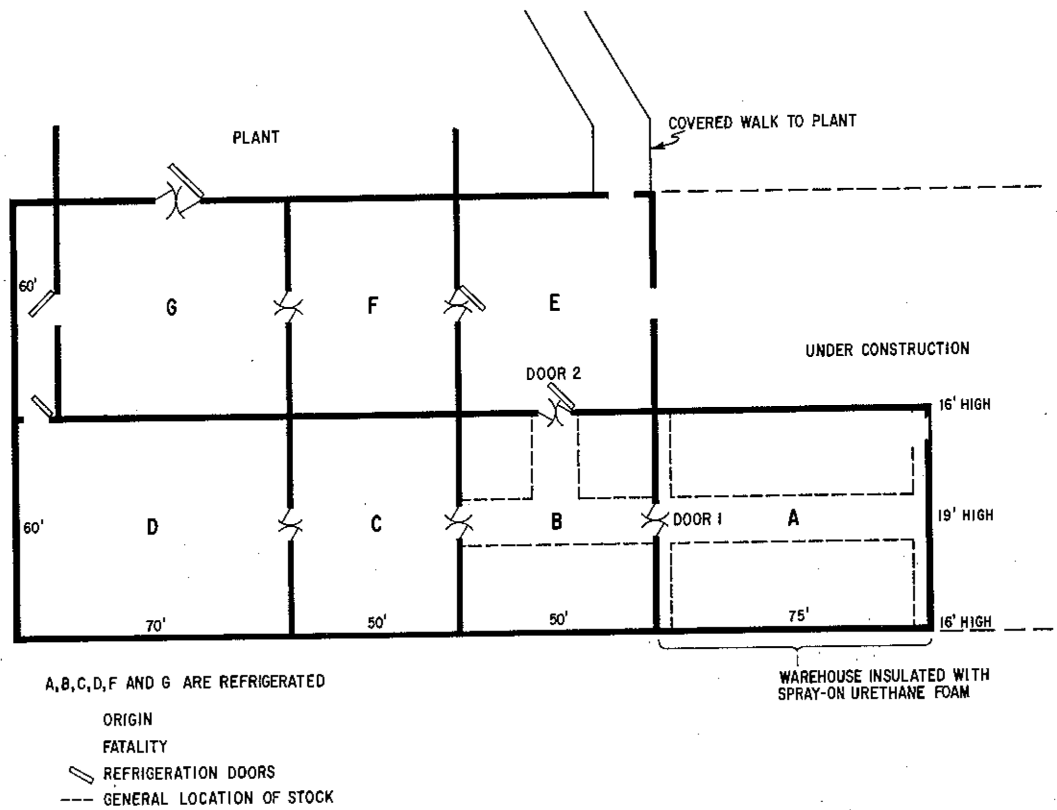


Figure 1.

10:00 am, the third hole was started. A few minutes later, the worker who was cutting the hole could see that a fire had started inside the warehouse. The construction workers ran into the warehouse and saw the urethane insulation burning near the area where the hole was being cut. One man was sent to call the Fire Department, which received the telephone alarm at 10:10 am. When the man who notified the Fire Department returned to the scene, attempts were being made to use extinguishers on the fire; however, the men doing so realized that the roof-level fire was too high to reach from the ground. Suddenly the room became filled with smoke, and the men crawled out. They all went out through Door No. 1, and then through Door No. 2. (See Figure 1.)

Reportedly, the worker who died had accompanied one of the survivors all the way to Door No. 2; however, the survivor was starting to close a tight-fitting refrigerator door at this location when it was discovered that the victim had disappeared.

All three engines of the Cuba Volunteer Fire Department arrived on the scene between 10:13 and 10:15 am. The fire fighters immediately donned self-contained breathing apparatus and entered the building. They found the victim inside near Door No. 1 and carried him outside. The victim was taken to the hospital, where he was pronounced dead from smoke inhalation. No autopsy was performed.

Fire fighters reported that they found little, if any, fire when they arrived; there was only very dense smoke. They laid a supply line and four hand lines; however, they used only about 200 gallons of water and felt that this was perhaps more than was needed. Extensive ventilation of the building was performed.

DAMAGE

The fire caused little structural damage to the building. The urethane insulation near the area of origin was destroyed, and the intumescent paint throughout the upper area of the warehouse was charred and blistered.

ANALYSIS

The urethane insulation was ignited from the unprotected side by the cutting torch. The intumescent paint retarded the spread of the fire; however, sufficient toxic products were given off to fill Warehouses A and B (see Figure 1), and to kill the construction worker (who,

(*Continued on page 95*)

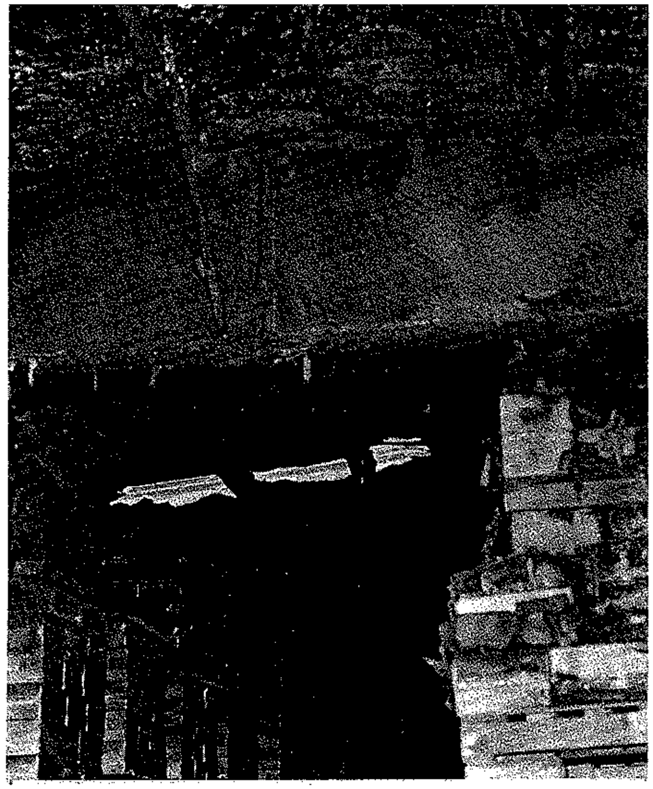
Urethane Insulation Fire (*continued from page 45*)

incidentally, was the man operating the cutting torch). Also, Sections C, D, E, and F contained smoke.

Several fire fighters and workers complained of nausea, headaches, difficulty in breathing, and a burning sensation in their lungs for many days after the fire, even though no one was allowed inside the warehouse without self-contained breathing apparatus.

One interesting observation made by the men was that at no time did they feel any heat; however, as they

This photo was taken from inside the warehouse close to the south wall and shows the ceiling condition after the fire. NFPA



View of the south wall looking north. Note condition of the insulation on the roof near side of the heam. White area is where the Fire Department ventilated. NFPA

left the building, the pressure in the warehouse had built up to such an intensity that Doors No. 1 and 2 were being held open by the strong wind that it had created.

This fire again demonstrated the extreme fire hazards of sprayed-on rigid urethane foam insulation. Spraying intumescent paint on the exposed surfaces of the urethane may have retarded the spread of fire. Nevertheless, production of the thick, toxic smoke was still extremely rapid. △