COLD STORAGE WAREHOUSE

Shreveport, Louisiana
September 17, 1984

FIRE INVESTIGATIONS

NATIONAL FIRE PROTECTION ASSOCIATION

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

Prepared by

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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 $85^{o}F$; 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 $50^{o}F$ 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.

[1]U.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,

[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:

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(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.