9 Volunteer Fire Fighters and 1 Off-Duty Career Fire Captain Killed by an Ammonium Nitrate Explosion at a Fertilizer Plant Fire – Texas

Revised on January 20, 2015 to address comments from the Institute of Makers of Explosives to remove potentially confusing references to "incipient" fires and to add reference to IME's ammonium nitrate best practice guidelines.

Executive Summary

On April 17, 2013, ten emergency first responders (ranging in age from 26 to 52 and all male) were killed when a burning fertilizer plant containing an estimated 40 to 60 tons of ammonium nitrate exploded just outside the city limits. The explosion occurred less than 20 minutes after the emergency responders arrived on-scene. The victims included 5 volunteer fire fighters with the city's volunteer fire department, and 4 volunteer fire fighters from 3 neighboring volunteer fire departments who were attending an emergency medical services (EMS) class in the city. One off-duty career fire captain and two civilians who responded to offer assistance to the volunteer fire department were also killed by the explosion. The victims were among a number of first responders engaged in fire suppression and support activities and were in close proximity to the burning structure when the explosion occurred. Five other volunteer fire fighters with the city's fire department were injured. The two civilians were providing non-suppression support to the fire department when they were killed by the blast. Three civilians living nearby also died as the result of the blast.

Burning fertilizer plant prior to the explosion, as seen from the South looking North.
(Cell phone photo courtesy of ATF)

Contributing Factors

- *Non-recognition of the hazards associated with ammonium nitrate*
- *Limited pre-incident planning of commercial facility*
- *Fire quickly spread to an un-controllable size*
- *Approximately 40-60 tons of solid ammonium nitrate unexpectedly detonated*
- *Responders working within blast radius at time of explosion*
- *Large non-sprinklered, wood construction, commercial structure.*

Key Recommendations

- *Fire departments should conduct pre-incident planning inspections of buildings within their jurisdiction to facilitate development of safe fireground strategies and tactics, especially for high hazard / high risk structures and occupancies*

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- *Fire departments should have a written risk management plan, use risk management principles at all structure fires and especially at incidents involving high risk hazards*
- *Fire departments should develop, implement and enforce a written Incident Management System to be followed at all emergency incident operations*
- *Fire departments should ensure that fire fighters wear a full array of turnout clothing and personal protective equipment appropriate for the assigned tasks*
- *Fire departments should ensure that fire fighters are trained to standards that meet or exceed NFPA 1001 Standard for Fire Fighter Professional Qualifications.*

Additionally, governing agencies (federal, state, regional, and local municipalities) should:

- *Consider requiring automatic sprinkler systems, performing regular fire inspections, and other types of active fire prevention methods in industrial facilities, especially those with high risk / high hazard inventory*
- *Consider following the most current safe handling procedures for ammonium nitrate fertilizer storage and handling.*

Engine 2 post explosion. Note that it is believed the force of the explosion moved the engine from its original location and orientation at the time of the blast.
(NIOSH Photo)

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For further information, visit the program website at www.cdc.gov/niosh/fire or call toll free 1-800-CDC-INFO (1-800-232-4636).

Introduction

On April 17, 2013, ten emergency first responders (ranging in age from 26 to 52) were killed when a burning fertilizer plant that contained an estimated 40 to 60 tons of ammonium nitrate exploded. The victims included 5 volunteer fire fighters with the city's volunteer fire department, and 4 volunteer fire fighters from 3 neighboring volunteer fire departments who were attending an EMS class in the city. One off-duty career fire captain who responded to offer assistance to the city's volunteer fire department was also killed by the explosion. The 10 victims were among a number of first responders engaged in fire suppression and support activities and were in close proximity to the burning structure when the explosion occurred. Five other volunteer fire fighters with the city's fire department were injured. Two civilians who were providing non-suppression support to the fire department in their fire suppression efforts were also killed by the blast. Three civilians who lived nearby also died as a result of the explosion. The explosion occurred less than 20 minutes after the emergency responders arrived on-scene.

The National Institute for Occupational Safety and Health (NIOSH) became aware of the incident the same day through numerous media outlets. The U.S. Fire Administration reported the deaths of the five city volunteer fire fighters on April 22, 2013 and continued to update the number of line-of-duty deaths as additional information became available.

On April 22, 2013, a safety engineer and an occupational safety and health specialist with the NIOSH Fire Fighter Fatality Investigation and Prevention Program traveled to Texas to investigate this incident. The NIOSH investigators met with representatives of the Texas State Fire Marshal's Office (FMO) and the U.S. Department of Justice, Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) and were integrated into the incident management system as part of the line-of-duty death investigation (LODD) team. The NIOSH investigators visited the site of the fire and explosion and worked with Texas FMO investigators to evaluate, catalog and photograph over 185 pieces of personal protective clothing and personal protective equipment collected on-scene that was used by the deceased fire fighters. The NIOSH investigators and FMO investigators also examined, photographed, and cataloged as evidence four fire apparatus damaged by the blast. NIOSH investigators and Texas FMO investigators met with representatives of the Texas Department of Public Safety, Texas Highway Patrol in an attempt to download and recover vehicle event data recorder information from three fire apparatus and an ambulance. This effort was unsuccessful, since due to their ages, the four vehicles did not contain data logging equipment. As part of this investigation, the NIOSH investigators met with representatives of the Texas FMO; ATF; Federal Emergency Management Agency (FEMA); the U.S. Chemical Safety Board (CSB); the U.S. Attorney's Office, Western District of Texas; the city fire department; the city policy department and the county precinct court justice.

On May 13, 2013, the NIOSH investigators returned to Texas and conducted interviews with fire fighters and fire department officials with the city fire department, the city emergency medical services

(EMS) personnel, and also the fire department that was dispatched to the initial fire for mutual aid. *Note: Two members of this mutual aid fire department were attending an EMS class at the time the fire was reported and responded to the incident scene and became victims. A total of four victims killed by the explosion were participating in the EMS class. Three of the victims responded to the scene in personally-owned vehicles that were damaged by the explosion. The fourth class participant rode to the scene in an ambulance with two city EMS personnel.* The NIOSH investigators reviewed the mutual aid fire department's standard operating procedures, training records, incident reports, 911 dispatch recordings, photographs and cell-phone videos of the incident.

Fire Department

The city where this incident occurred is served by an all-volunteer fire department that had served the community since 1894. The fire department operates from one station located near the center of town. At the time of the incident, the fire department had 30 active members. The fire department serves a population of approximately 2,690 in an area of approximately 54 square miles with 1500 residents living within the city limits. Potential members must be 21 years old in order to join the fire department. Potential members must submit an application which is voted on by the existing fire department membership. If the application is accepted by majority vote, the police department conducts a background check. No prior fire service training or experience is required to join the department. There were also no physical fitness or ability requirements.

The fire department holds two meetings per month. The first meeting of the month is a business meeting while the second meeting is devoted to some type of training. Meeting attendance is mandatory unless excused by the chief. New members must be voted in by the existing membership and successfully pass a background check before participating in fire department training. At the time of the investigation, the fire department did not have any minimum training requirements but members missing more than two training sessions per year were required to present a valid excuse. The fire department did not have any standard operating procedures and guidelines. The fire department did not have a formal pre-incident planning program.

During 2011, the fire department responded to a total of 118 emergency calls including 55 fire calls. The 55 fire calls involved 3 structure fire calls, 2 vehicle fire calls and 50 "other fire" calls including brush fires, grass fires, miscellaneous fires and false alarms. During 2012, the fire department responded to a total of 104 emergency calls including 73 fire calls. The 73 fire calls involved 18 structure fires, 12 vehicle fires and 43 "other fire" calls involving grass fires, miscellaneous fires and false alarms. During the first 3 months of 2013, the fire department responded to 2 structure fires, 1 auto fire, and 5 miscellaneous fire calls.

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The fire department had recently received an upgraded rating from the Insurance Services Organization (ISO), moving from a rating of 7 to a rating of 5. In the ISO rating system, Class 1 represents exemplary fire protection, and Class 10 indicates that the area's fire-suppression program does not meet ISO's minimum criteria.[a]

Additional information about the fire department can be found on the department's website at http://www.cityofwest.com/city-services/west-fire-dept.

Training and Experience

Victim Numbers and Experience

Note: Throughout this report, the 10 victims are identified by the order in which they were located at the scene, removed from the scene and transported. The following table provides information on each victim.

Table One

Victim (Order located)	Rank	Age	Years experience
1	Fire Fighter	48	15 years with city VFD
2	Career Fire Captain Off duty	52	31 years with career FD
3	Fire Fighter	26	2 years at mutual aid VFD
4	Fire Fighter	37	3 years at mutual aid VFD
5	Volunteer Captain	29	10 years at mutual aid VFD
6	EMT/ FF	33	1 year at mutual aid VFD
7	Fire Fighter	41	2 years with city VFD
8	Fire Fighter	50	13 years with city VFD
9	Volunteer Captain	50	18 years with city VFD
10	Fire Fighter	29	3 years with city VFD

[a] ISO is an independent commercial enterprise which helps customers identify and mitigate risk. ISO can provide communities with information on fire protection, water systems, other critical infrastructure, building codes, and natural and man-made catastrophes. ISO's Public Protection Criteria program evaluates communities according to a uniform set of criteria known as the Fire Suppression Rating Schedule (FSRS). More information about ISO and their Fire Suppression Rating Schedule can be found at the website http://www.isogov.com/about/ .

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Victim 1 had been a fire fighter with the city's volunteer fire department for 15 years. Training records included training certificates for: landing zone safety, propane emergency response, fire & ems emergency response, Introduction to Incident Command, Hazardous materials awareness, ladder practices, hose handling, live burns, basic SCBA, ICS-100, ICS-200, IS-700, IS-800.b.

Victim 2 was an off-duty career fire captain who had responded via personally-owned vehicle to offer advice and assistance to the city fire department. He had over 31 years of experience as a career fire fighter.

Victim 3 had been a volunteer fire fighter for 2 years with the fire department dispatched for mutual aid to the fertilizer plant fire. He was attending an EMT class in the city at the time the fire was dispatched. Training records included certificates for ICS-100, ICS-200, ICS-300, ICS-400, IS-700.a, IS-701.a, IS-702.a, and IS-703.a.

Victim 4 had been a volunteer fire fighter at two nearby volunteer fire departments. He was attending the EMT class in the city at the time the fire was dispatched and responded to the scene in his POV. Training records included certificates for emergency vehicle operations, compressed air foam operations, basic auto extrication, basic fire fighter, ICS-100, ICS-200, IS-700.a, and IS-800.b.

Victim 5 had been a volunteer with the fire department dispatched for mutual aid to the fertilizer plant fire for over 10 years and held the rank of captain. He was attending the EMT class in the city at the time the fire was dispatched and responded to the scene in his POV.

Victim 6 was a volunteer fire fighter at a nearby volunteer fire department. He was attending the EMT class in the city at the time the fire was dispatched and rode in a city ambulance to the scene with two city EMTs.

Victim 7 had been a fire fighter with the city's volunteer fire department for 2 years. Training records included training certificates for: basic auto extrication, emergency driving, landing zone safety, ICS-100, ICS-700.a. He responded to the fire station and rode to the incident scene on Engine 1 (F-8)

Victim 8 had been a fire fighter with the city's volunteer fire department for 13 years. Training records included training certificates for: propane emergency response, landing zone safety, ground cover (basic and intermediate), fire and ems emergency vehicle response, vehicle extrication, hazardous materials awareness, introduction to incident command, fire emergency vehicle response, ladder practices, hose handling, live burns, rescue operations, basic SCBA, ICS-100, ICS-200, IS-700, IS-700.a, IS-800.b. He responded to the fire station and drove brush truck (F-6) to the incident scene.

Victim 9 had been a fire fighter with the city's volunteer fire department for 18 years. Training records included training certificates for: basic fire fighter, fire emergency vehicle response, propane emergency response, ICS-100, IS-700.a. He responded to the incident scene in his POV.

Victim 10 had been a fire fighter with the city's volunteer fire department for 3 years. Training records included training certificates for: firefighting phase 1, emergency driving, basic auto extrication, landing zone safety, SCBA and smokehouse training, ICS-100, ICS-200.b, ICS-300, ICS-400, IS-700.a, IS-701.a, IS-702.a, IS-703.a, IS-704, IS-706, IS-800.b. He responded to the fire station and drove Engine 1 (F-8) to the incident scene.

Equipment and Personnel

The fire department responded with four fire department apparatus. Engine 1 (also referred to as F-8) was a 1997 model engine that carried a 750 gallon water tank and responded with two fire fighters on board (Victim 10 driving with Victim 7 onboard).

Engine 2 (also referred to as F-9) was a 2004 model engine with a 1000 gallon water tank. Engine 2 responded with a captain driving and one fire fighter (injured) onboard.

A brush truck (referred to as F-6) was a 1991 model equipped with a 750 gallon water tank and a powered hose reel with 100 feet of 1-inch booster hose. F-6 was driven by Victim 8.

F-7 was a 1997 model water tender equipped with a 2000 gallon water tank. F-7 was driven to the scene by the Fire Chief (injured).

Two fire department members who responded in their personally-owned vehicles (POV) were killed (Victim 1 and Victim 9). A total of five fire department members were injured in the explosion.

An aerial ladder truck was dispatched from a nearby mutual aid volunteer fire department. The ladder truck was approaching the incident scene from the north at the time of the explosion and was slightly damaged by the blast.

Victim 2, Victim 3, Victim 4, and Victim 5 also arrived on-scene in their personally owned vehicles (POV). Victim 6 rode in a city ambulance from the EMT class to the incident scene with two city EMS personnel.

Timeline

An approximate timeline summarizing the sentinel events in the April 17, 2013 explosion at a fertilizer processing plant in Texas, up to the time of the explosion, is listed below. The times are approximate and were obtained by studying the available dispatch channel records, witness statements, run sheets, fire department records and NIOSH interview information. The timeline is not intended, nor should it be used, as a formal record of events. Only those dispatch channel communications directly related to the fatal incident are included. This timeline is approximate and is not intended to represent all the different events that occurred during this time period.

- **19:29:19 Hours**
  Cell phone call to 911 Dispatch Center reporting smoke at fertilizer plant

- **19:34:13 Hours**
  Fire Department dispatched for fire at fertilizer plant

- **19:35:33 Hours**
  Police officer on scene asks dispatch for contact information for fertilizer plant owners

- **19:37:03 Hours**
  Fire Department enroute – Engine 1 with two fire fighters; Engine 2 with Captain and fire fighter

- **19:39:00 Hours (approximate)**
  Engine 1 on scene and confirms fire
  Brush Truck (one fire fighter onboard) and Tanker enroute (driven by Fire Chief)

- **19:51:25 Hours**
  Cell phone call to 911 Dispatch Center reporting explosion

- **20:20:51 Hours**
  Radio traffic about triage and patient staging area

Personal Protective Equipment

As part of this investigation, the NIOSH investigators worked with representatives of the Texas State Fire Marshal's Office to inspect and catalog a number of pieces of fire fighter personal protective equipment and clothing collected at the scene. The majority of the personal protective equipment was destroyed by the force of the explosion. A number of component pieces were too small to be positively identified and could not be associated with a particular victim. Autopsy records were used to document the type of clothing worn by each victim at the time of examination. In some cases, the autopsy records were compared to the evidence records for the PPE fragments collected at the scene. In many cases, it was not possible to determine whether the victims were wearing a self-contained breathing apparatus or a fire helmet at the time of the explosion (see Table Two).

Components from three self-contained breathing apparatus (SCBA) collected by representatives of the Texas State Fire Marshal's Officer were sent to the NIOSH National Personal Protective Technology Laboratory (NPPTL) for evaluation. The SCBA components appeared to be consistent with SCBA certified by NIOSH to the requirements of *Title 42, Code of Federal Regulations (CFR) Part 84,* *Subpart H*[1] and to the National Fire Protection Association (NFPA) requirements of NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for the Fire Service*, 2002 Edition.[2] Due to the condition of each SCBA resulting from the explosion, no testing was conducted by NIOSH. It was not possible to associate any of the SCBA collected at the scene with a particular victim and it could not be confirmed if any of the SCBA were actually in use. A summary of the SCBA evaluation is included as Appendix One. The complete evaluation report is available upon request.

Table Two

Victim	Clothing worn at time of explosion
1	Turnout coat, street shorts, work gloves
2	Street clothing
3	Turnout coat and pants, boots
4	Turnout coat and pants, boots, gloves
5	Turnout coat and pants
6	Undetermined
7	Undetermined
8	Turnout coat and pants, boots
9	Street clothing
10	Turnout coat and pants, boots

Weather Conditions

The weather conditions at the time of the incident included a temperature of approximately 80 degrees Fahrenheit, relative humidity of 58 percent, and winds from the southeast at approximately 20 miles per hour with gusts to 27 miles per hour. Scattered clouds were in the area and visibility was reported at 10 miles. There was no precipitation on the day of the incident.[3] The high winds may have contributed to the rapid fire growth.

Structure and Facility

This incident occurred at a commercial facility that sold seed, custom-blended fertilizer (mixed in-house) and related agriculture products to farmers in the community and surrounding areas. This incident occurred during the spring planting season when the facility routinely handled thousands of tons of ammonium nitrate, anhydrous ammonia and other fertilizer products. The facility was a complex of wood frame buildings, metal grain storage bins, metal storage tanks for liquefied ammonia and other products, silos and related equipment. The facility was located just outside the city limits and was bordered on the east by agricultural crop fields and to the west by a north-south running railroad track. Access to the complex was by a two-lane north-south county road that separated the complex from the agricultural fields to the east. The complex was originally constructed in the early 1960s. At that time, the location was in a rural area outside of the city limits. Over the years, the surrounding areas to the south and west had been developed, extending to the railroad tracks to the west and across the railroad tracks to the south and east. Recent development in close proximity to the fertilizer plant included a city high school located south and a middle school located south-west of the facility. The area immediately to the west of the railroad track included a city park, an apartment complex, an assisted-living facility and single-family residential homes. See Photo 1 and Photo 2 for overhead views of the fertilizer plant complex before and after the explosion.

This fire is believed to have originated in a wood-frame structure known as the bulk processing plant, in the area known as the seed room. This structure was mostly one-story in height and enclosed an estimated 12,000 square feet of floor space. The west side of the structure enclosed wooden storage bins that contained bulk granular materials including ammonium nitrate, potash, ammonium sulfate, diammonium sulfate and KMAG, a mixture of potassium, magnesium, and sulfur. These bulk products were blended in-house and transferred to customers through loading docks and a conveyor system located on the east side of the structure. The north-east end of the structure was a separate room known as the seed room where several hundred bags of seed and fertilizer were stored on wooden pallets. Liquid anhydrous ammonia was stored in a number of large metal tanks located at the south end of the structure (see Photo 1 and Photo 2). The cause of the fire was officially ruled as "undetermined" by the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) and other investigating agencies in a press release dated May 16, 2013. An "undetermined" cause finding is typically given when the cause cannot be proven to an acceptable level of certainty, which could be due to insufficient information or if multiple causes could not be eliminated.[b] Additional research into possible causes of the fire and resulting explosion continues by the ATF.

The structure was built of wood-frame construction on a concrete slab with several additions and modifications. The structure was mostly one-story in height with the exception of vertical storage bins fed by an overhead conveyor system. This area was estimated to be approximately 75 feet in height. One of these vertical storage bins was designated for ammonium nitrate but was empty at the time of the fire. The roof was a mixture of asphalt rolled roofing materials, asphalt shingle and corrugated metal. The structure did not contain a sprinkler system or other means of automatic fire suppression.

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[b] See the ATF press release dated May 16, 2013 for more information about the cause of the fire: https://www.atf.gov/press/releases/2013/05/051613-hou-atf-and-the-state-fire-marshals-office-conclude-scene-investigation-at-the-west-fertilizer-plant.html.

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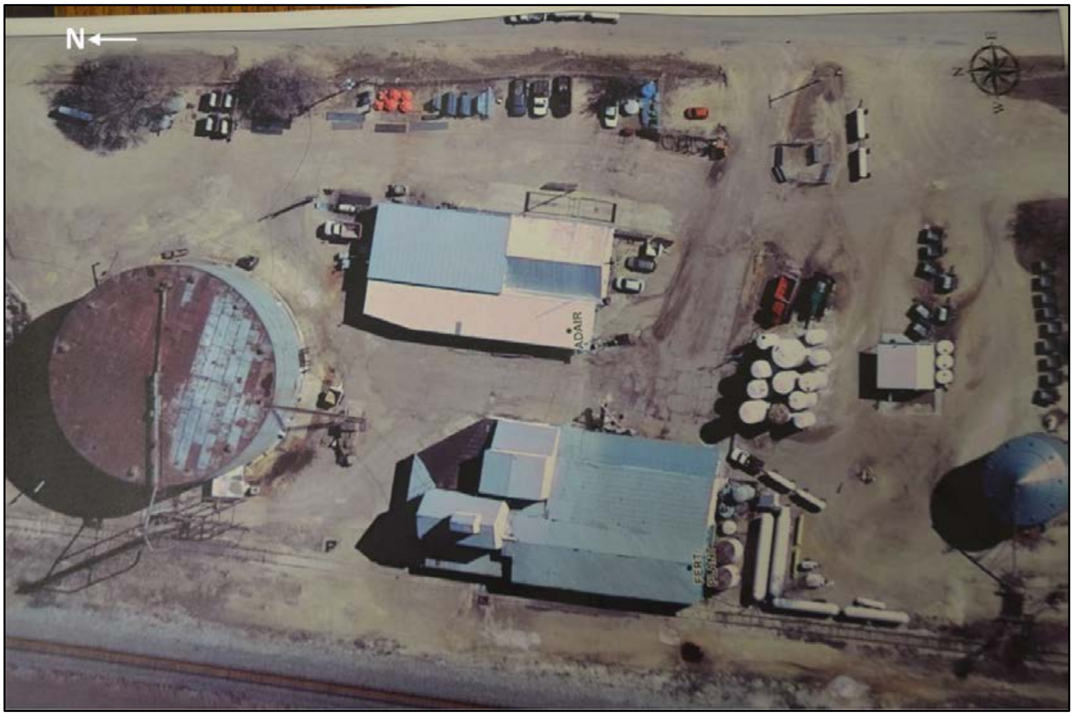

Photo 1 and Photo 2. Overhead views pre-blast (top) and post-blast (bottom).
(Source - ATF)

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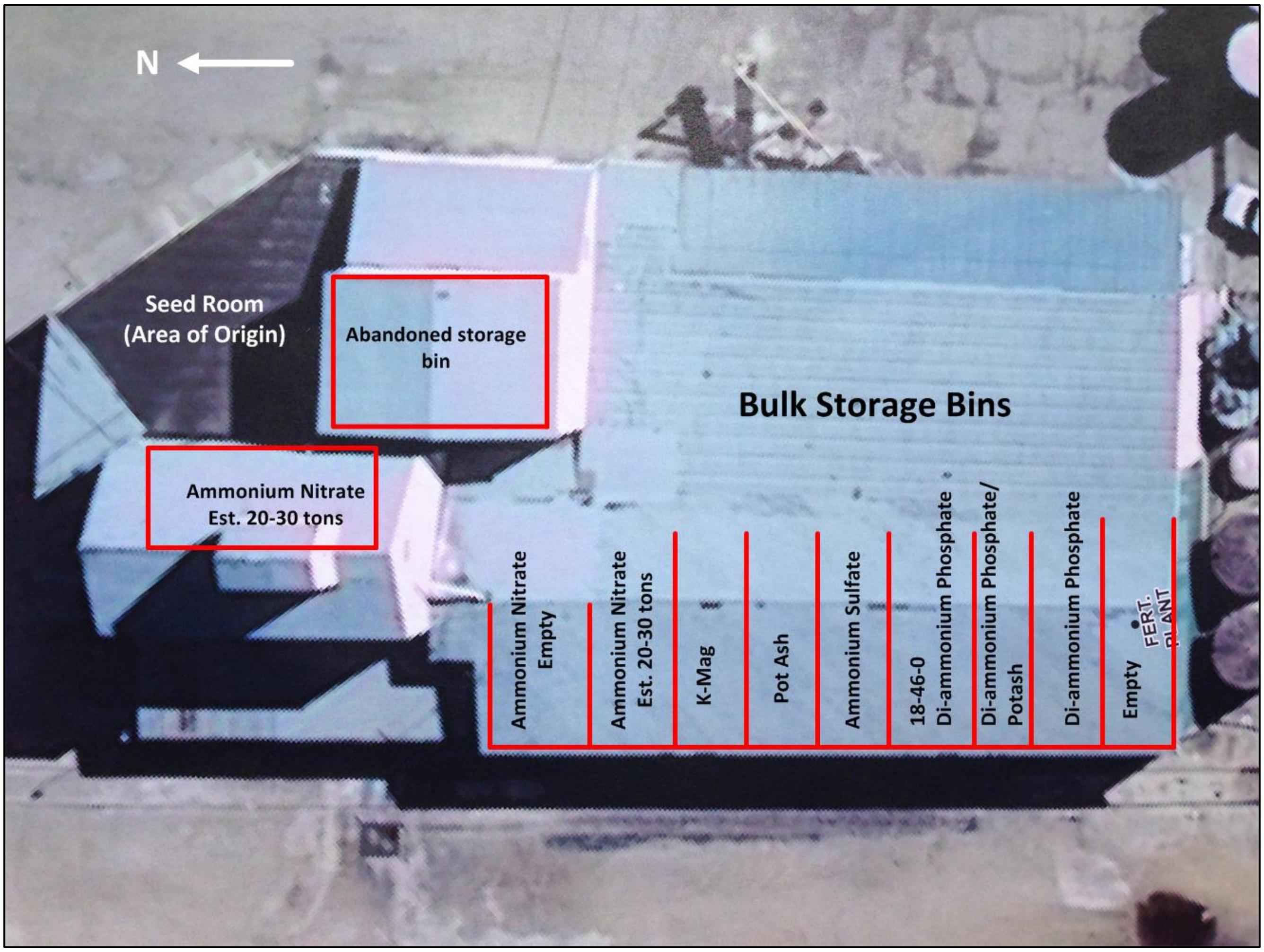

Photo 3. Overhead view of fire building showing the approximate locations of the storage bins that contained the bulk dry fertilizer materials. The seed room is believed to be the room of origin.
(Adapted from ATF Diagram)

Fire department members reported that they were aware of the chemicals routinely stored at the fertilizer plant but formal training to prepare for a fire or chemical emergency at the plant was never conducted. One of the members of the volunteer fire department who died in the explosion was a manager at the fertilizer plant.

An estimated 40 to 60 tons of ammonium nitrate were inside the bulk storage plant at the time of the fire. A rail car containing an estimated 100 tons of ammonium nitrate was located on a rail spur approximately 100 yards north of the structure waiting to be unloaded at the time of the fire. The rail car was knocked off the rails and upset by the blast but the contents of the rail car did not detonate and did not contribute to the force of the explosion.

Investigation

On April 17, 2013, at approximately 1929 hours, the county 911 dispatch center began receiving calls reporting a fire at a fertilizer processing facility located just outside the city limits. A city police officer was in the area on patrol and noticed the smell of smoke and burning wood. The police officer drove around the property from west to east and stopped at the north entrance. He reported to dispatch that thick smoke was visible at the north end of the fertilizer plant. Moments later, the police officer radioed dispatch that flames were visible at the north end of the fertilizer plant. The local volunteer fire department was dispatched at approximately 1934 hours and the first fire apparatus was on-scene at approximately 1939 hours.

Three volunteer fire fighters were at a local gas station and convenience store when they received the page for the fire. One of these volunteer fire fighters worked at the fertilizer plant as a manager and was familiar with the plant layout and contents. He immediately responded directly to the fertilizer plant in his personally-owned vehicle (POV). The other two fire fighters immediately responded the short distance to the fire station to collect their turnout gear and make fire apparatus ready for response.

The first fire apparatus to respond was Engine 1(E-1). E-1 was driven by a fire fighter (Victim 10) with another fire fighter on board (Victim 7). E-1 left the fire station just as the two fire fighters who had been at the gas station arrived at the station.

The second fire apparatus en-route was Engine 2 (E-2). E-2 was driven by a volunteer Fire Captain (one of the two fire fighters who responded from the convenience store) with one fire fighter on-board. A brush truck (F-6) was driven to the scene by Victim 8 (the other fire fighter who responded from the convenience store). A few minutes later, the Fire Chief drove a 2000-gallon tanker and parked on the county road directly east of the burning structure (see Figure 1). Other fire fighters drove their POV to the scene. See Table Two for details describing the type of personal protective clothing and equipment worn by each victim. Access to the site was via a north-south county road located on the east side of the complex. The complex was bordered by a north-south railroad track to the west. The closest fire hydrant was located approximately 1600 feet to the south on the west side of the north-south county road. All city fire apparatus arrived from the south. All POVs were parked in approximately in the same location to the east of the burning fertilizer plant (see Figure 1). The fire department followed a procedure where the first arriving captain was to assume incident command. The Fire Chief and assistant chief provided support and advisory functions but did not actively engage in managing fireground operations.

Engine 1 arrived on scene and staged east of the burning fertilizer plant. The brush truck staged east and north of the structure (north of Engine 1). Two 1 ½ - inch pre-connected hand lines were pulled

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from E-1 (bumper line and crosslay) and put into service using tank water. At least one 1 ½-inch hand line was deployed from brush truck F-6. Victim 1, 7, 8 and 10 worked the hand lines from outside the structure, directing water through the sliding doors that accessed the seed room. Victim 9, the volunteer fire fighter who worked at the fertilizer plant and who responded directly from the convenience store, was already on scene and assisted. All five fire fighters were members of the city volunteer fire department.

Figure 1. Apparatus position of first three fire department apparatus on scene. Positions and orientation are approximate estimates.
(Figure adapted from Google Earth satellite image. Imagery date 10/2012.)

Additional fire fighters continued to respond in their POVs, including the assistant fire chief. Once on scene, the assistant fire chief met with the Fire Chief and the city police officer. The Fire Chief and the assistant chief walked the short distance to where fire fighters were preparing to fight the fire but neither assumed incident command. They talked to the volunteer fire fighter who worked as a manager at the fertilizer plant (Victim 9). They discussed the possibility of an explosion and Victim 9 reportedly stated that the burning fertilizer would not explode. They also discussed whether to continue to fight the fire or to back up to a more defensive position. The fire was rapidly growing in size and intensity, burning from north to south.

An off-duty career fire captain (Victim 2) arrived on-scene via his POV and walked to where E-1 was located. He asked the assistant chief if he could offer assistance and advised that the fire was too big to extinguish with the resources on hand. He advised the fire fighters to concentrate on cooling the liquid ammonia tanks located just south of the burning structure.

Engine 2 drove north toward the fertilizer plant and immediately saw smoke after leaving the station. E-2 stopped at the hydrant located south of the complex. The captain and fire fighter pulled a 4-inch supply line from the rear of E-2 to the hydrant. Engine 2 then drove toward the fertilizer plant, laying out the 4-inch supply line until all the supply line was unloaded on the ground. The end of the supply line was still hundreds of feet from where Engine 1 was located (see Figure 2, Photo 3, Photo 4, and Photo 5). The fire fighter stayed at the end of the supply line while the captain continued north toward the fertilizer plant, driving E-2 to where E-1 was located on the east side of the fertilizer plant. The captain observed that two 1 ½ - inch hand lines were pulled from E-1 and two fire fighters were on each hand line. The captain recalled that two fire fighters were on each hand line but their backs were toward the captain so he could not positively identify any of the fire fighters. The two hand lines pulled from E-1 were the 1 ½-inch bumper line pulled from the front bumper, and a 1 ½-inch pre-connected cross-lay. The captain observed fire coming out an open sliding door at the north end of the east side of the plant. The two hand lines were in operation and tank water was being directed toward the open door. The fire was rapidly growing in size. The captain yelled to the four fire fighters working the hose lines that they were too close to the structure and needed to back up. As they backed away from the burning structure, the captain told them that they needed to break down their hose lines because he wanted to switch the two engines. The captain intended to lay out the supply line on Engine 1 back to the end of the supply line previously dropped from Engine 2, then position Engine 1 at the hydrant to boost pressure in the supply line back to Engine 2.

In order to establish a water supply, the fire fighters needed to add supply hose from E-1 to the supply line that the captain had dropped from E-2. The captain felt that E-1 had a better pump and wanted to put it at the hydrant and use E-1 to pump water to E-2 located near the burning structure. The captain quickly disconnected the bumper line while the fire fighters drained the cross-lay and threw it on top of E-1. The captain drove E-1, along with another fire fighter who had arrived in his POV, south to the hydrant but forgot to reverse lay the needed amount of supply line. They were at the hydrant when the explosion occurred.

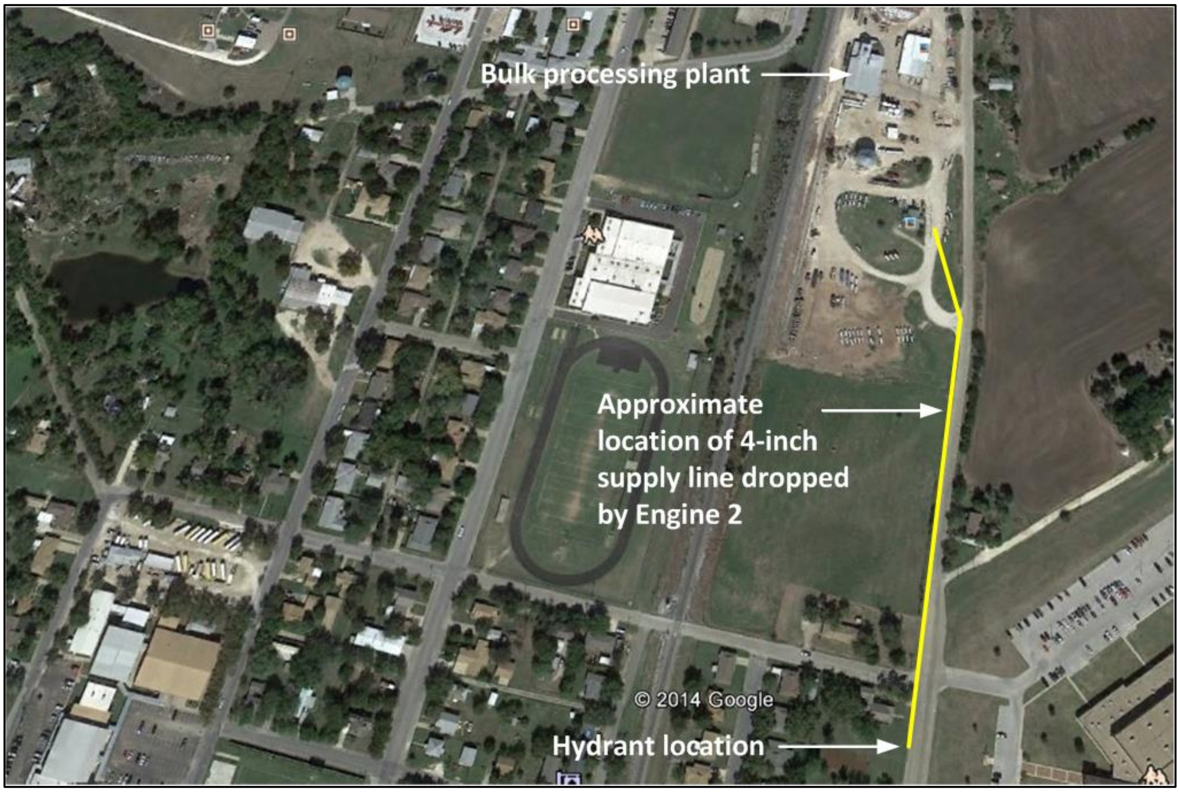

Figure 2. Approximate location of 4-inch supply line dropped by Engine 2.
(Figure adapted from Google Earth satellite image. Imagery date 10/2012.)

Photo 4. 4-inch supply line dropped by Engine 2 as seen looking south toward location of the hydrant. Note that hose has been moved out of the roadway and some hose removed.
(Photo taken by NIOSH investigators.)

Photo 5 and Photo 6. Close-up views of 4-inch supply line (on left) and coupler (on right).
(Photos taken by NIOSH investigators.)

Additional resources including volunteer fire fighters and civilians continued to arrive on-scene. The city emergency medical services (EMS) department was holding an EMT class at the EMS department at the time of the fire. A number of class participants were volunteer fire fighters with nearby departments, including two members of the mutual aid fire department that was requested to respond with their ladder truck. These two members of the mutual aid fire department responded to the fire in their POVs (Victim 3 and Victim 5). Another class participant would become Victim 4. The EMS department was dispatched to the fire and an ambulance responded with two EMTs on-board and also a volunteer fire fighter (Victim 6) who had been participating in the class. The ambulance arrived on-scene and staged to the east and south of the burning structure near the complex's scale house. The location was also south of where a number of responders had parked their POVs. When the ambulance was staged, Victim 6 left the ambulance to offer assistance to the fire department. Victim 3 and Victim 5 arrived on-scene, ran past the ambulance and continued toward the fire.

The E-2 fire fighter who had originally stayed at the end of the E-2 supply line walked north to where the ambulance was positioned to talk to the ambulance crew. He was near the ambulance and behind the scale house building when the explosion occurred.

The burning fertilizer plant contained an estimated 40 to 60 tons of ammonium nitrate at the time of the fire. The explosion at approximately 1951 hours produced a crater 93 feet in diameter and approximately 10 feet deep. The surrounding complex was totally destroyed (see Photo 1 and Photo 2 for overhead views before and after the explosion). Debris from the complex was scattered for a distance of approximately 2.5 miles. The U.S. Geological Survey recorded the force of the explosion as a small-scale earthquake. In addition to the 10 fire fighters who were killed and 5 who were seriously injured, two civilians who were supporting the fire department in non-suppression activities were killed. One of the civilians worked for a local company who built fire apparatus and routinely responded to fires to provide support and advice to the apparatus operators. The 5 injured fire fighters suffered a variety of explosion-related trauma injuries including bruises, broken bones, lacerations and other injuries. Figure 3 indicates the approximate area where the victims were recovered.

Figure 3. Approximate area where the deceased fire fighters were recovered.
(Figure adapted from Google Earth satellite image. Imagery date 10/2012.)

Two civilians who lived in an apartment complex west of the railroad tracks were killed by the explosion. A third civilian who lived west of the railroad tracks was injured by the blast and later died.

Ammonium Nitrate

Ammonium nitrate is a solid compound containing nitrogen, hydrogen and oxygen (NH_4NO_3). It is commercially produced by mixing nitric acid with ammonia and evaporating the ammonium nitrate solution to a concentrated solid form. Ammonium nitrate has a molecular mass of 80.1, a density of 1.7 gm/cm3, a melting point of approximately 170 degrees Celsius and decomposes at about 210 degrees C.

International Chemical Safety Cards (ICSC) are data sheets intended to provide essential safety and health information on chemicals in a clear and concise way. The primary aim of the cards is to promote the safe use of chemicals in the workplace. The main target users are workers and those responsible for occupational safety and health. The ICSC project is a common undertaking between the World Health Organization (WHO) and the International Labor Organization, with the cooperation of the European Commission. The European Commission (CEC) and the International Programme on Chemical Safety (IPCS) has developed a series of chemical safety cards for over 1700 common chemicals [Reference http://www.ilo.org/safework/info/publications/WCMS_113134/lang--en/index.htm].[4]

In the United States, the National Institute for Occupational Safety and Health (NIOSH) has modified these chemical safety cards to include the following information:

- Occupational Safety and Health Administration Permissible Exposure Limits (OSHA PELs).
- National Institute for Occupational Safety and Health Recommended Exposure Limits (NIOSH RELs).
- Immediately Dangerous to Life and Health values (IDLHs)
- Links to related information such as the NIOSH Pocket Guide to Chemical Hazards http://www.cdc.gov/niosh/ipcs/icstart.html.

The International Chemical Safety Card, ICSC 0216, states that ammonium nitrate is not combustible but enhances combustion of other substances, is explosive, and gives off irritating or toxic fumes (or gases) in a fire. The ICSC 0216 further states there is a risk of fire and explosion under confinement and high temperatures. ICSC 0216 states that the danger area should be evacuated and fire should be combated from a sheltered position. The size and scope of the danger area is not identified in ICSC 0216 (see Appendix Two).[5]

The National Fire Protection Association (NFPA) 400, *Hazardous Materials Code*, Chapter 11, contains recommendations for safe storage, handling and use of ammonium nitrate but does not contain specific recommendations on how to fight fires when ammonium nitrate is present (Annex E does provide some general fire fighting suggestions).[6] NFPA 400, Chapter 11 is based on NFPA 490 which was originally developed by the Technical Committee on Storage, Handling and Transportation of Hazardous Chemicals. NFPA 400, Chapter 11 covers subjects such as bulk storage (indoor and outdoor), fire protection, and special operations precautions. Annex E of NFPA 400 covers suggested fire-fighting procedures. Section E.2.1 states that “should a fire break out in an area where ammonium nitrate is stored, it is important that the mass be kept cool and the burning be promptly extinguished. Apply large volumes of water as quickly as possible. If fires reach massive and uncontrollable proportions, fire-fighting personnel should evacuate the area and withdraw to a safe location.”

NFPA 400, Annex E, Section E.2.2 states “provide as much ventilation as possible to the fire area.” Rapid dissipation of both the products of decomposition and the heat of reaction is very important.

Section E.2.3 states "Approach the fire from upwind as the vapors from burning ammonium nitrate are very toxic. Self-contained breathing apparatus …. should be used to protect personnel against gases."

Emergency Planning and Community Right to Know Act

The Emergency Planning and Community Right to Know Act (EPCRA) is a federal law enacted by Congress on October 17, 1986 following the 1984 chemical gas leak in Bhopal, India that killed 4,000 people who lived near a chemical processing facility[7]. The EPCRA requires companies in the United States to report hazardous chemicals stored on their properties to state and local authorities including local emergency responders. EPCRA is Title III of the Superfund Amendments and Reauthorization Act (SARA) of 1986. This legislation is sometimes referred to as SARA Title III, but more commonly as EPCRA. The principal reason for the existence of EPCRA is to provide citizens with information on the manufacture, use, and environmental release of potentially toxic chemicals in their communities.

Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA) created the Toxics Release Inventory (TRI) Program. Under the requirements of EPCRA, all U.S. facilities that meet TRI reporting criteria must submit TRI data to EPA and the states in which they are located by July 1 of each year. See the website http://www2.epa.gov/toxics-release-inventory-tri-program/tri-compliance-and-enforcement for more information.

Through EPCRA, Congress mandated that the TRI data be made public. EPA considers the Toxics Release Inventory a public "report card" for industrial facilities. After the paperwork is filed, it is up to the companies and local fire departments, paramedics, police and local emergency management agencies to plan for and train for potential chemical-related disasters.

What Fire Fighters Need to Know About Fires and Emergency Responses Involving Ammonium Nitrate

See Appendix Three for emergency response information taken from the *Chemical Advisory: Safe Storage, Handling, and Management of Ammonium Nitrate* (EPA 550-S-13-001) released August 2013 as a joint announcement by the U.S. Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA) and the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF).[8]

The Institute of Makers of Explosives (IME) has provided additional guidance on fighting ammonium nitrate fires entitled *Safety and Security Guidelines for Ammonium Nitrate*.[9] IME recommends that whenever ammonium nitrate, or any oxidizer fire is involved, responding fire fighters should avoid efforts to extinguish the fire. Instead, fire fighters should concentrate on evacuating the area, including all civilians, and withdraw to a safe location.

See Photo 7 through Photo 9 for images of the destructive forces created by the explosion.

9 Volunteer Fire Fighters and 1 Off-Duty Career Captain Killed by an Ammonium Nitrate Explosion at a Fertilizer Plant Fire – Texas

Photo 7. Damage to Tanker F-7. Tanker is shown in the same location on county road east of fertilizer plant as it was at the time of the explosion several hundred feet from the center of the explosion.
(Photo NIOSH.)

9 Volunteer Fire Fighters and 1 Off-Duty Career Captain Killed by an Ammonium Nitrate Explosion at a Fertilizer Plant Fire – Texas

Photo 8. Side view of Brush Truck F-6. Truck has been moved from its location at the time of the explosion.
(NIOSH Photo.)

9 Volunteer Fire Fighters and 1 Off-Duty Career Captain Killed by an Ammonium Nitrate Explosion at a Fertilizer Plant Fire – Texas

Photo 9. Photo shows fire apparatus locations post-explosion. Orientation is looking east. ***(Photo source – ATF.)***

Contributing Factors

Occupational injuries and fatalities are often the result of one or more contributing factors or key events in a larger sequence of events that ultimately result in the injury or fatality. NIOSH investigators identified the following items as key contributing factors in this incident that ultimately led to the fatalities:

- Non-recognition of the hazards associated with ammonium nitrate
- Limited pre-incident planning of commercial facility
- Fire quickly spread to an un-controllable size
- Approximately 40-60 tons of solid ammonium nitrate unexpectedly detonated
- Responders working within blast radius at time of explosion
- Large non-sprinklered, wood construction, commercial structure.

Cause of Death

Autopsy reports for the 10 emergency responders listed blunt force trauma or blast injuries as the cause of death for each of the victims. The documents listed multiple injuries and many were severe. Toxicology test results identified blood alcohol in four of the victims' systems. The test reports identified that two of the volunteer fire fighters had blood alcohol levels above the state legal limit of 0.08 while a third victim had a blood alcohol level just below the legal limit. The toxicology report for a fifth responder stated that marihuana/cannabinoid was detected in his system.

Recommendations

Recommendation #1: Fire departments should conduct pre-incident planning inspections of buildings within their jurisdictions to facilitate development of safe fireground strategies and tactics, especially for high hazard / high risk structures and occupancies.

Discussion: National Fire Protection Association (NFPA) 1620 *Standard for Pre-Incident Planning, 2010 Edition, Annex A, A.4.9* states "the pre-incident plan should be a foundation for the decision making process during an emergency situation and provides important data that will assist the Incident Commander in developing appropriate strategies and tactics for managing the incident."[10] Section A.1.2 states that pre-incident planning involves evaluating the protection systems, building construction, contents, and operating procedures that can impact emergency operations."[10] This standard also states that "the primary purpose of a pre-incident plan is to help responding personnel effectively manage emergencies with available resources. A pre-incident plan identifies deviations from normal operations and can be complex and formal, or simply a notation about a particular problem such as the presence of flammable liquids, explosive hazards, modifications to structural building components, or structural damage from a previous fire.[10-12]

NFPA 1620 outlines the steps involved in developing, maintaining, and using a pre-incident plan by breaking the incident down into pre-, during- and post-incident phases. In the pre-incident phase, for example, it covers factors such as physical elements and site considerations, occupant considerations, protection systems and water supplies, hydrant locations, and special hazard considerations. Building characteristics including type of construction, materials used, occupancy, fuel load, roof and floor design, and unusual or distinguishing characteristics should be recorded, shared with other departments who provide mutual aid, and if possible, entered into the dispatcher's computer so that the information is readily available if an incident is reported at the noted address. Since many fire departments have tens and hundreds of thousands of structures within their jurisdiction, making it impossible to pre-plan them all, priority should be given to those having elevated or unusual fire hazards and life safety considerations.

Several NFPA standards including NFPA 1500 *Standard on Fire Department Occupational Safety and Health Program*, NFPA 1001 *Standard for Fire Fighter Professional Qualifications* (at the Fire Fighter II level) and NFPA 1021 *Standard for Fire Officer Professional Qualifications NFPA 1031 Standard for Professional Qualifications for Fire Inspector and Plan Examiner*, and *NFPA 1037*

Standard for Professional Qualifications for Fire Marshal identify the need to conduct building inspections and pre-incident surveys, including the pre-requisite knowledge and training necessary to conduct such inspections. NFPA 1500, Section 4.1.4 states “Fire Departments shall develop pre-incident plans as determined by the authority having jurisdiction.”

The fire department involved in this incident did not have a detailed pre-planning program. The fire department had responded to a number of reported ammonia leaks at the facility over the years without incident. In addition, one of the members of the fire department worked as a manager at the fertilizer plant and, during the fire, reportedly stated that the ammonium nitrate would not explode. Without a complete understanding of the overall risks posed by industrial fires, the lack of a pre-planning program can leave emergency responders unprepared for high-hazard events and, in the event of an explosion or chemical leak, can also endanger civilians living nearby. A detailed pre-plan that included a thorough assessment of the characteristics of the material stored at the facility may have identified the potential for an ammonium nitrate fire and the risks associated with fighting it, including the risk of explosion.

Recommendation #2: Fire departments should have a written risk management plan, use risk management principles at all structure fires and especially at incidents involving high risk hazards.

Discussion: While it is recognized that fire fighting is an inherently hazardous occupation, established fire service risk management principles are based on the philosophy that greater risks will be assumed when there are lives to be saved and the level of acceptable risk to fire fighters is much lower when only property is at stake. Interior (inside a structure) offensive fire-fighting operations can increase the risk of traumatic injury and death to fire fighters from structural collapse, burns, and asphyxiation. Established risk management principles suggest that more caution should be exercised in abandoned, vacant, and unoccupied structures and in situations where there is no clear evidence indicating that people are trapped inside a structure and can be saved.[13]

The incident commander (IC), with input from the assigned Incident Safety Officer and/or Division/Group Supervisors, is responsible for evaluating conditions at a structure fire and determining safe tactics for fighting the fire. To accomplish this, the IC should use a standardized strategic decision-making model. First, the IC should size up the critical fireground factors.[12] The incident commander must make a determination that offensive (interior) operations may be conducted without exceeding a reasonable degree of risk to fire fighters before ordering an offensive attack and must be prepared to discontinue the offensive attack if the risk evaluation changes during the fire fighting operation. A full range of factors must be considered in making the risk evaluation, including (but not limited to):

- Presence of occupants in the building
- A realistic evaluation of occupant survivability and rescue potential
- Size, construction, and use of the building
- Age and condition of the building
- Nature and location of building contents

- Location and extent of the fire within the building
- Adjacent exposures (structures)
- Fire involvement or compromise of the building's structural components
- Considerations of fire loading and fire behavior
- A realistic evaluation of the ability to execute a successful offensive fire attack with the resources that are available.[13]

These fireground factors must be weighed against the risk management plan. There is absolute recognition of the fact that fire fighters are routinely exposed to certain known and predictable risks while conducting operations that are directed toward saving property. The Incident Commander is responsible for recognizing and evaluating those risks and determining whether the level of risk is acceptable or unacceptable. However, risks taken to save property should always be lesser than those to save lives.[12] Risks to fire fighters versus gains in saving lives and property must always be considered when deciding whether to use an offensive or defensive attack. The Incident Commander should routinely evaluate and reevaluate conditions and radio progress reports in reaching objectives to dispatch and on-scene fire fighters. This process allows the Incident Commander to determine whether to continue or revise the strategy and attack plans. Failure to revise an inappropriate or outdated attack strategy is likely to result in an elevated risk of death or injury to fire fighters.[13, 14]

Retired New York City Deputy Fire Chief Vincent Dunn states the following: "When no other person's life is in danger, the life of the firefighter has a higher priority than fire containment."[15] Chief Dunn also states "The protection of life is the highest goal of the fire service…When a life is clearly threatened, there is no risk too great. At most fires, however, lives are not clearly endangered. At most fires, then, the priority of firefighting is the protection of the fire fighters' lives." In general terms, the risk management plan must consider the following: (1) risk nothing for what is already lost—choose defensive operations; (2) extend limited risk in a calculated way to protect savable property—consider offensive operations; (3) and extend very calculated risk to protect savable lives—consider offensive operations.[13,16] NFPA 1500 *Standard on Fire Department Occupational Safety and Health Program*, Chapter 8.3 addresses the use of risk management principles at emergency operations. Chapter 8.3.4 states that risk management principles shall be routinely employed by supervisory personnel at all levels of the incident management system to define the limits of acceptable and unacceptable positions and functions for all members at the incident scene. Chapter 8.3.5 states that at significant incidents and special operations incidents, the Incident Commander shall assign an incident safety officer who has the expertise to evaluate hazards and provide direction with respect to the overall safety of personnel. The annex to Chapter 8.3.5 contains additional information.[14] Modern incident demands on the fireground are unlike those of the recent past, requiring incident commanders and commanding officers to have increased technical knowledge of building construction with a heightened sensitivity to fire behavior, a focus on operational structural stability and considerations related to occupancy risk versus the occupancy type. Strategies and tactics must be based on occupancy risk, not occupancy type, and must have the combined adequacy of sufficient staffing, fire flow and tactical patience orchestrated in a manner that identifies with the fire profiling, predictability of the occupancy profile and accounts for presumptive fire behavior.[17] NFPA 1500, Section 8.3.2 states that in situations where the risk to fire department members are excessive, activities shall be limited to defensive operations.[14]

This incident occurred in a commercial structure that contained high risk hazards. The structure was constructed almost entirely of wood to accommodate very large volumes of ammonium nitrate and other compounds used to custom mix different blends of solid fertilizer for the surrounding agricultural community. The fire quickly grew to an uncontrollable size while the fire department attempted to establish water supply from a hydrant located over 1600 feet away. Fire fighters debated whether the fire would cause the ammonium nitrate to explode. The explosion occurred before the water supply was established and before other fire fighting resources were on-scene.

Recommendation #3: Fire departments should develop, implement and enforce a written Incident Management System to be followed at all emergency incident operations.

Discussion: National Fire Protection Association (NFPA) 1500 *Standard on Fire Department Occupational Safety and Health Program*, 2013 Edition,[14] and NFPA 1561 *Standard on Emergency Services Incident Management System*, 2014 Edition,[18] both state that an Incident Management System (IMS) shall be utilized at all emergency incidents (including but not limited to training exercises). The U.S. Department of Labor, Occupational Safety and Health Administration has issued a guidance document intended to be used by agencies to prepare emergency response plans. The intent of the National Response Team (NRT) guidance is to provide a mechanism for consolidating multiple agencies' plans into one functional emergency response plan or integrated contingency plan (ICP).[19]

NFPA 1561, Chapter 3.3.30 defines the Incident Management System, also known as the Incident Command System (or ICS) as "A system that defines the roles and responsibilities to be assumed by responders and the standard operating procedures to be used in the management and direction of emergency incidents and other functions.[18] Chapter 4.1 states "The incident management system shall provide structure and coordination to the management of emergency incident operations to provide for the safety and health of emergency services organization (ESO) responders and other persons involved in those activities." Chapter 4.2 states "The incident management system shall integrate risk management into the regular functions of incident command." Each fire department or emergency services organization (ESO) should adopt an incident management system to manage all emergency incidents. The IMS should be defined and in writing and include standard operating procedure (SOPs) covering the implementation of the IMS. The IMS should include written plans that address the requirements of different types of incidents that can be anticipated in each fire department's or ESO's jurisdiction. The IMS should address both routine and unusual incidents of differing types, sizes and complexities. The IMS covers more than just fireground operations. The IMS must cover incident command, accountability, risk management, communications, rapid intervention crews (RIC), roles and responsibilities of the Incident Safety Officer (ISO), and interoperability with multiple agencies (police, emergency medical services, state and federal government, etc.) and surrounding jurisdictions (mutual aid responders).

The Incident Command System is intended to provide a standard approach to the management of emergency incidents. The many different and complex situations encountered by fire fighters require a considerable amount of judgment in the application of the Incident Command System. The primary objective is always to manage the incident, not to fully implement and utilize the Incident Command System. The Incident Commander should be able to apply the Incident Command System in a manner that supports effective and efficient management of the incident. The use of the Incident Command System should not create additional challenges for the Incident Commander, but rather provide a systems approach to ensuring for a successful outcome of the incident.[18]

Most incidents are considered routine and involve a small commitment of resources, while few incidents involve large commitments of resources, complex situations, and are low frequency/high risk events. It is imperative that the Incident Command System be able to accommodate all types and sizes of incidents and to provide for a regular process of escalation from the arrival of the first responding resources at a routine incident to the appropriate response for the largest and most complex incidents. The Incident Command System should be applied, even to routine incidents, to allow fire fighters and other first responders to be familiar with the system, prepared for escalation, and aware of the risks that exist at all incidents.[18]

The incident management system covers more than just fireground operations. The incident management system must ensure for command and fire fighter safety which includes situational evaluation, strategy and the incident action plan, personnel accountability, risk assessment and continuous evaluation, communications, rapid intervention crews (RIC), roles and responsibilities of the Incident Safety Officer (ISO), and interoperability with multiple agencies (law enforcement, emergency medical services, state and federal government agencies and officials, etc.) and surrounding jurisdictions (automatic aid or mutual aid responders).

One of the most critical components of this system is the development and implementation of an Incident Action Plan (IAP). For the fire service, the majority of times the Incident Action Plan is communicated verbally. The IAP is based on the resources immediately available and those responding. The goal is determined in accordance with the incident priority from which a strategy must emerge; tactical objectives, aimed at meeting the strategy, are determined and specific assignments made. A personnel accountability system should be established as assignments are made. The important point is that the Incident Commander communicates the IAP to tactical and task level supervisors.

In this incident, fire department members had received some training on the use of an incident management system (NIMS ICS 100, 200, 300, 700, etc.) but the fire department did not have detailed standard operating procedures in place for incident management, incident command, or other fire fighting procedures to direct standard fireground operations such as size-up, developing an incident action plan, personnel accountability, fireground communication, rapid intervention team (RIT) deployment, and other recognized best practices. The fire department's normal procedure was for one of the captains to assume incident command. An incident command structure was not implemented and no incident action plan was developed and communicated.

Recommendation #4: Fire departments should develop and coordinate pre-incident planning protocols with mutual aid departments.

Discussion: NFPA 1620 *Standard for Pre-Incident Planning* provides guidance to assist departments in establishing pre-incident plans. Pre-incident planning that includes agreements formed by a coalition of all involved parties including mutual aid fire departments, emergency medical services companies, and police, will present a coordinated response to emergency situations, and may save valuable time by a more rapid implementation of pre-determined protocols.[10] Examples of such pre-incident planning for this type of incident include better coordination with the police department concerning traffic control and better utilization of the resources available from mutual aid departments, extra air cylinders for self-contained breathing apparatus, joint tactical operations to allow for combining resources for tactical operations such as water supply, rapid intervention team (RIT) deployment, personnel accountability, a dedicated safety officer and related functions.

During this incident, all available resources were focused on extinguishing the fire. Personnel accountability, a rapid intervention team, and a dedicated safety officer were among the fireground functions that were never established.

Recommendation #5: Fire departments should ensure that fire fighters wear a full array of turnout clothing and personal protective equipment appropriate for the assigned task while participating in fire suppression and overhaul activities.

Discussion: NFPA 1500 Standard on Fire Department Occupational Safety and Health Program, Chapter 7 contains the general recommendations for fire fighter protective clothing and protective equipment.[14] Chapter 7.1.1 specifies that "the fire department shall provide each member with protective ensembles, ensemble elements and protective equipment that is designed to provide protection from the hazards to which the member is likely to be exposed and is suitable for the tasks that the member is expected to perform." Chapter 7.1.2 states "protective ensembles, ensemble elements and other protective equipment shall be used whenever the member is exposed or potentially exposed to the hazards for which it is provided." Chapter 7.1.3 states "structural fire-fighting and proximity fire fighting protective ensembles and ensemble elements shall be cleaned at least every 6 months as specified in NFPA 1851 *Standard on Selection, Care, and Maintenance of Structural Fire Fighting Protective Ensembles*."[20] Chapter 7.2.1 states "members who engage in or are exposed to the hazards of structural fire fighting shall be provided with and shall use a protective ensemble that shall meet the applicable requirements of NFPA 1971 *Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting*."[21] Chapter 7.10.7 states "when engaged in any operation where they could encounter atmospheres that are immediately-dangerous-to-life-or-health (IDLH) or potentially IDLH, or where the atmosphere is unknown, the fire department shall provide and require all members to use SCBA that has been certified as being compliant with NFPA 1981 *Standard on*

Open-Circuit Self-Contained Breathing Apparatus for Fire and Emergency Services."[2] Additionally, the OSHA Respirator Standard requires that all employees engaged in interior structural fire fighting use SCBAs.[22]

During this incident, there were multiple instances where fire fighters were observed working in close proximity to the burning structure with incomplete personal protective ensembles. Table Two details the type of personal protective clothing worn by each of the victims. Some of the victims were dressed in street clothes while others wore incomplete personal protective ensembles.

It is important to note that the 2013 revision to NFPA 1982 *Standard on Personal Alert Safety Systems (PASS)* included new heat and flame resistance requirements resulting from documented reports where PASS devices were not heard during fatal fireground incidents.[23] Laboratory testing conducted by NIST determined that exposure to high temperature environments caused the loudness of the tested PASS alarm signal to be reduced (PASS devices tested to the 2002 standard). This reduction in loudness can cause the alarm signal to become indistinguishable from background noise at an emergency scene. Initial laboratory testing by NIST highlighted that this sound reduction may begin to occur at temperatures as low as 300°F. While the use of PASS devices did not have any impact on the outcome of this event, the use of PASS devices meeting the requirements of NFPA 1982, 2013 Edition, or the most current edition, by all fire service members is highly recommended.

Recommendation #6: Fire departments should ensure that fire fighters are trained in situational awareness, personal safety, and accountability.

Discussion: The instructional book *Essentials of Fire Fighting and Fire Department Operations*[23] defines situational awareness as an awareness of the immediate surroundings. On the fire ground, every fire fighter should be trained to be constantly alert for changing and unsafe conditions. Even though a safety officer may have been designated for the incident, all personnel are obligated to remain alert to their immediate surroundings. They must maintain their situational awareness and be alert for unsafe conditions. This applies not only to the conditions found within a burning structure, but to the exterior fire ground as well.[24]

All fire fighters operating at an incident should maintain situational awareness and conduct a continuous risk assessment throughout the incident, reporting unsafe or changing conditions to the Incident Commander. Fire fighters need to understand the importance of situational awareness and personal safety on the fire ground. The fire ground dangers and hazards can and do change as the incident becomes larger and the event duration increases. The structural conditions of the fire building(s) can change significantly and endanger areas of the fire ground that were not present earlier in the event.

The opposite of situational awareness is tunnel vision where the fire fighters become so focused on fire-fighting or other operational assignments that they fail to sense changes in their environment. Fire fighters can maintain their situational awareness by looking up, down, and around themselves as well as listening for new or unusual sounds and feeling vibrations or movement. Fire fighters and officers should communicate any changes in their environment to other members as well as to the Incident Commander.

The International Association of Fire Chiefs, Safety, Health and Survival section developed the "Rules of Engagement for Structural Fire Fighting." The rules of engagement have been developed to assist both the fire fighter and the Incident Commander (as well as command team officers) in risk assessment and "Go or No-Go" decisions. The fire ground creates a significant risk to fire fighters and it is the responsibility of the Incident Commander and command organization officers to minimize fire fighter exposure to unsafe conditions and stop unsafe practices.[16]

The rules of engagement can assist the Incident Commander, company officers, and fire fighters (who are at the highest level of risk) in assessing their situational awareness. One principle applied in the rules of engagement is that fire fighters and the company officers are the members most at risk for injury or death and will be the first to identify unsafe conditions and practices. The rules integrate the fire-fighter into the risk assessment decision making process. These members should be the ultimate decision makers as to whether it's safe to proceed with assigned objectives. Where it is not safe to proceed, the rules allow a process for that decision to be made while still maintaining command unity and discipline.

In this incident, fire fighters may not have been fully aware of the hazards presented by the ammonium nitrate in the burning structure. The Fire Chief and assistant chief expressed concerns about the contents of the fertilizer plant and wanted fire fighters to back away from the structure. One of the victims who worked at the fertilizer plant reportedly stated that the ammonium nitrate would not explode. Another victim, who was an off-duty career fire captain, advised the fire fighters to concentrate on cooling the liquid ammonia tanks located just south of the burning structure. Given the size of the structure (over 12,000 square feet), the combustible construction materials and building contents, and high winds in the area, it is unlikely that sufficient resources were readily available to establish a water supply sufficient to extinguish the rapidly growing fire.

Recommendation #7: Fire departments and authorities having jurisdiction should implement national fire fighter and fire officer training standards and requirements.

Discussion: In 2008, the National Volunteer Fire Council (NVFC) adopted a policy position that all volunteer fire departments should establish a goal to train all personnel to a level consistent with the mission of the fire department,[25] based on the job performance requirements outlined in *NFPA 1001: Standard for Fire Fighter Professional Qualifications*.[26] The NVFC is committed to ensuring that volunteer firefighters have an appropriate level of training to safely and effectively carry out the functions of the department(s) that they belong to.[25]

"The roles and responsibilities of the fire service have evolved over the years. As the breadth and scope of what it means to be a firefighter has expanded, to varying degrees depending on the jurisdiction, the necessity for training within the fire service has grown. Unfortunately, a large number of volunteer fire departments are still operating with personnel who are not trained to a level consistent with national consensus standards for basic firefighter preparedness. This can lead to ineffective and unsafe responses that put lives and property at risk."[25] This issue actually encompasses the entire fire service and not just the volunteer ranks.

"As the need for proper training has become more urgent, many volunteer fire departments are finding it increasingly difficult to attract new members. The average age of volunteer firefighters has risen steadily over the past two decades, as many young people move out of rural areas and the ones who stay find themselves with less free time to devote to training." [25] Standard setting organizations, states and authorities having jurisdiction should move to develop national standards so that fire fighters across the United States are trained to the same minimum levels.

The State of Texas does not have any minimum training requirements for volunteer fire departments. It is up to each fire chief at each department to set their own training requirements. The fire department involved in this incident did not have specific training requirements for fire fighter, fire officer or incident commander duties. The fire department's normal procedure was for one of the captains to assume incident command.

Many fire fighters may be called upon to fill company officer and incident commander roles when they may not have received adequate training to prepare them for the additional responsibilities that are required of fireground officers. At a minimum, fire fighters who serve as company officers and who may be expected to serve as the initial incident commander should receive training equivalent to Fire Fighter II, as defined by NFPA 1001.[26] Fire department members that are assigned to or assume supervisory positions at an incident scene must have an additional level of competencies that are necessary to ensure for the safety of themselves and the members they supervise while mitigating the hazard encountered. A company officer must have the correct combination of practical experience, training and skill sets that correspond with their job requirements and expected functions in order to execute the expected duties in a safe, effective, efficient and competent manner. The company officer fulfills a mission critical role within the fire service that directly affects department personnel, public safety and community accord. The title carries with it the opportunity to ride the "front seat" and be in charge of directing a company to address incident operations and demands dictated by the company's function, responsibility, and task assignment. NFPA 1021, *Standard on Fire Officer Professional Qualifications* provides clear and concise job performance requirements (JPR) that can be used to determine if an individual, when measured to the standard, possess the skills and knowledge to perform as a fire officer.[27] Fire departments should ensure that all fire fighters who are expected to perform the duties of a company officer or greater responsibility have the necessary knowledge, experience and receive adequate training equivalent to Fire Fighter II, as defined by NFPA 1001 and Fire Officer as defined by NFPA 1021. In general, FF I reflects minimum training standards for a fire fighter who is always working under supervision. FF II addresses the assumption of command and transfer of command but does not contain specific job performance requirements (JPRs) to illustrate the required skills.

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Recommendation #8: Fire departments should enforce standard operating procedures on a "zero-tolerance policy" for alcohol use while engaged in any fire department activity.

Discussion: Fire departments and authorities having jurisdiction should strictly prohibit any member of the fire department from responding to a call or engaging in any fire department activity if they have been drinking or are otherwise not fit for duty (e.g. prescription or recreational drug use). The International Association of Fire Chiefs (IAFC) has developed guidance on implementing a "zero-tolerance" alcohol policy.[28] NFPA 1500 *Standard on Fire Department Occupational Safety and Health Program, Chapter 10* states in 10.1.5 "Members who are under the influence of alcohol or drugs shall not participate in any fire department operations or other duties." Chapter 11, Behavior Health and Wellness Programs, states in 11.1.3 "The fire department shall adopt and follow clear, written policies regarding alcoholism, substance abuse, and other behavior conditions that can adversely affect performance or fitness for duty or both.

The International Association of Fire Chiefs (IAFC) has adopted a Policy Statement (IAFC Policy Number 03/04) intended as a "**zero tolerance**" standard concerning the use of alcohol by members of any fire or emergency services agency or organization at any time when they may be called upon to act or respond as a member of those departments.[28] According to the IAFC policy statement, "if someone has consumed alcohol within the previous eight (8) hours, or is still noticeably impaired by alcohol consumed previous to the eight (8) hours, they must voluntarily remove themselves from the activities and function of the fire or emergency services agency/organization, including all emergency operations and training."

The IAFC policy further states that "No member of a fire & emergency services agency/organization shall participate in any aspect of the organization and operation of the fire or emergency agency/organization under the influence of alcohol, including but not limited to any fire and emergency operations, fire-police, training, etc."

The full policy statement can be found on the International Association of Fire Chiefs website at http://www.iafc.org/associations/4685/files/downloads/ABOUT/POLICY_STATES/IAFCpol_Alcohol_inFireEmergServ.pdf .

The autopsy records identified the presence of drugs and alcohol in some of the victims. Although there is no clear evidence indicating that this was a contributing factor to any of the fatalities or injuries, good safety practice dictates that a zero-tolerance policy should be adopted by all fire departments. An online search of the key words "alcohol" and "firefighter safety" will produce a vast amount of information that can used to address the problem of alcohol in the fire service.

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Recommendation #9: Fire Fighters should use available resources such as the US Department of Transportation's Emergency Response Guidebook to identify hazardous chemicals and the appropriate emergency response actions such as initial evacuation considerations and fire fighting precautions.

The US Department of Transportation's Emergency Response Guidebook[29] is a guidebook for first responders during the initial phase of a dangerous goods/hazardous materials transportation incident. Although the guide is for initial phase involving transportation incidents, it is a valuable resource at structure fires and other incidents when no other information is available. The Emergency Response Guidebook was developed jointly by the US Department of Transportation, Transport Canada, and the Secretariat of Communications and Transportation of Mexico (SCT) for use by firefighters, police, and other emergency services personnel who may be the first to arrive at the scene of a transportation incident involving a hazardous material. It is primarily a guide to aid first responders in (1) quickly identifying the specific or generic classification of the material(s) involved in the incident, and (2) protecting themselves and the general public during this initial response phase of the incident. The ERG is updated every three to four years to accommodate new products and technology. Emergency Response Guidebooks (2012 version) were found in the glove boxes of some of the fire department's responding apparatus (see Photo 9). A quick look in the guidebook under ammonium nitrate fertilizer would have shown "May explode from heat or contamination" and a recommendation for large fires that says "for massive fires, use unmanned hose holders or monitor nozzles; if this is impossible, withdraw from area and let fire burn." Under the evacuation section the initial evacuation distance recommended for rail or tank trucks is "½ mile in all directions."

This fire involving ammonium nitrate was considerably larger than one tank or rail car, and the recommendation from the *Emergency Response Guidebook* to withdraw from the area would have been a well suited strategy considering the amount of fire, the known presence of ammonium nitrate at the facility, the amount of available resources and the lack of available water supply.

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Photo 10. Emergency Response Guidebook found in cab of tanker F-7.
(Photo NIOSH.)

Recommendation #10: Fire departments should develop, implement, and enforce written standard operating procedures (SOPs) for fireground operations and all emergency response operations.

Discussion: Written SOPs enable individual fire department members an opportunity to read and maintain a level of assumed understanding of operational procedures. The *NIOSH Alert, Preventing Injuries and Deaths of Fire Fighters* identifies the need to establish and follow fire fighting policies and procedures.[30] To be effective, guidelines and procedures should be developed, fully implemented, and enforced. The following NFPA standards also identify the need for written documentation to guide fire fighting operations:

> NFPA 1500 *Fire Department Occupational Safety and Health Program* states that "fire departments shall prepare and maintain written policies and standard operating procedures that document the organizational structure, membership, roles and responsibilities, expected functions, and training requirements, including the following: The procedures that will be employed to initiate and manage operations at the scene of an emergency incident."[14]

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> NFPA 1561 *Standard on Emergency Services Incident Management System* states that standard operating procedures (SOPs) shall include the requirements for implementation of the incident management system and shall describe the options that are available for application according to the needs of each particular situation.[18]
>
> NFPA 1720 *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Volunteer Fire Departments* states that the authority having jurisdiction shall promulgate the fire department's organizational, operational, and deployment procedures by issuing written administrative regulations, standard operating procedures, and departmental orders.[31]

It is important to understand the difference between a policy and a procedure, also known as a guideline. A department policy is a guide to decision making that originates with or is approved by top management in a fire department. Policies define the boundaries within which the administration expects department personnel to act in specified situations. A procedure is a written communication closely related to a policy. A procedure describes in writing the steps to be followed in carrying out organizational policies. SOPs are standard methods or rules in which an organization or a fire department operates to carry out a routine function. Usually these procedures are written in a policies and procedures handbook and all fire fighters should be well versed as to their content.[24] Operational procedures that are standardized, clearly written, and mandated to each department member establish accountability and increase command and control effectiveness.[24] The benefits of having clear concise, and practiced SOPs are numerous. For example, SOPs can become an outline for training curriculum and a tool to guide fire department members. Above all, successfully integrated SOPs improve departmental safety. [32]

In this incident, the city's volunteer fire department did not have any written standard operating procedures or guidelines covering fireground operations or other types of emergency responses.

Recommendation #11: Fire departments should ensure that specialized training is acquired for high risk sites with unique hazards, such as ammonium nitrate and other explosive materials that exist within their response areas.

Discussion: Fire departments often respond to complex or unique hazards which require specialized/advanced knowledge and/or training in dealing with these hazards. This incident highlights the unique and potentially dangerous hazards that ammonium nitrate presents to fire fighters and emergency responders. Fire departments need to ensure that all members are properly trained and equipped to deal with the hazards presented by high risk locations within their areas of response. According to IFSTA's Essentials of Fire Fighting and Fire Department Operations, explosions can cause four different types of hazards (three mechanical and one thermal):

- Blast pressure wave (shock wave)
- Shrapnel fragmentation

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- Seismic effect
- Incendiary thermal effect.[24]

Each of these four hazards presents different risks that fire fighters and emergency responders must be prepared for. The proper selection and use of personal protective equipment is essential. According to IFSTA, the blast pressure wave is the primary reason for injuries and damage following an explosion.[24] Shrapnel may be thrown over a wide area and great distances causing personal injury and property damage. Shrapnel is produced by the fragmentation of the container holding the explosive and by debris propelled by the blast pressure wave. Shrapnel can result in bruises, punctures, or even avulsions (part of the body being torn away) when the flying objects strike a person. When an explosion occurs at or near ground level, the air blast creates shock waves that produce seismic disturbances. The shock waves can produce a crater and damage nearby structures. Thermal energy released during an explosion can ignite flammable vapors and combustible gases, producing a short-lived fireball present for a limited time after the explosive event.[24]

The fire department and fire fighters involved in this incident had limited training. Fire departments should ensure that all members are properly trained and equipped to respond to high risk hazards within their response areas.

Recommendation #12: Municipalities, building fire code officials, and authorities having jurisdiction should consider requiring automatic sprinkler systems, performing regular fire inspections, and other types of active fire prevention methods in industrial facilities, especially those with high risk / high hazard inventory.

Discussion: There are many structures across the country, both industrial/commercial and residential that were built prior to the implementation of modern building codes. These building codes were developed and put in place to specifically protect life and property.

Fire development beyond the incipient stage is one of the greatest hazards that fire fighters are exposed to. This exposure and risk to fire fighters can be dramatically reduced when fires are extinguished or fire growth controlled by the activation of automatic sprinkler systems. NFPA statistics show that most fires in sprinklered buildings are controlled prior to fire department arrival by the activation of one or two sprinkler heads. The presence of automatic fire sprinklers reduces the exposure risk to fire fighters since fire growth is limited and in many cases the fire extinguished before the fire fighters arrive on scene. The potential risks associated with civilian rescue situations are also reduces since sprinkler activation also helps facilitate the safe egress of building occupants before the fire department arrives on scene. Finally, by controlling fire development, the exposure to hazards such as building collapse and overhaul operations are greatly reduced, if not eliminated.

In this incident, the fertilizer plant did not contain a sprinkler system or other means of active fire prevention. The facility was located outside of the local city limits. The city and county did not have any existing fire codes. The ammonium nitrate explosion that devastated the fertilizer plant and killed 10 emergency responders occurred after the fire grew to an uncontrollable size. The presence of a sprinkler system could have reduced the possibility of an explosion by limiting fire growth and possibly extinguishing the fire before emergency responders arrived.

Recommendation #13: Authorities having jurisdiction at all levels (federal, state, regional, and local) should consider following the most current safe handling procedures for ammonium nitrate fertilizer storage and handling facilities.

Discussion: Following this incident that occurred on April 17, 2013, a number of federal and state governmental agencies began evaluating safe handling procedures for ammonium nitrate fertilizer storage and handling. In August 2013, The U.S. Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) issued the joint safety advisory (EPA 550-S-13-001) *Chemical Advisory: Safe Storage, Handling, and Management of Ammonium Nitrate*.[8] This safety advisory identifies a number of steps that facility owners or operators can take to reduce the hazards of ammonium nitrate during storage and handling. The advisory identifies storage and process conditions to avoid, building design considerations, and fire protection recommendations including automatic sprinkler systems.

Two key recommendations in the safety advisory include:

- Ammonium nitrate should be stored in purpose-built facilities of non-combustible construction.
- Fire service personnel and other emergency responders should visit facilities that report the presence of ammonium nitrate, noting the conditions of storage and handling, and also note the specific location(s), amounts, and packaging of stored ammonium nitrate. This information should be used in the development of an emergency plan in case of fire or explosion.

The OSHA Standard for Explosives and Blasting Agents at 29 CFR 1910.109(i) contain requirements for ammonium nitrate storage and safe handling procedures. Additionally, ammonium nitrate should be handled in accordance with the safe practices found in NFPA 400 Hazardous Materials Code, Chapter 11.[6]

Trade-based organizations, manufacturers and processors can help facilitate this process by expanding their facility operator training and awareness programs to include outreach activities to local fire departments. This would be especially beneficial to fire departments in rural areas where volunteer fire departments are prevalent. Following this incident, a number of trade organizations whose members are involved in the manufacture and distribution of ammonium nitrate developed safety guidelines for ammonium nitrate. In July 2013, the Institute of Makers of Explosives released *Safety and Security Guidelines for Ammonium Nitrate*, with some minor clarifications made in December of 2013.[9] The IME guidelines have been endorsed by the International Association of Fire Chiefs, the National Sand, Stone, and Gravel Association, and the International Society of Explosives Engineers. In February 2014, the Fertilizer Institute and the Agricultural Retailer's Association released a joint ammonium nitrate safe handling guide titled *Safety and Security Guidelines for the Storage and Transportation of Fertilizer Grade Ammonium Nitrate at Fertilizer Retail Facilities*.[33]

Lessons learned from this incident, as reflected by the recommendations of the above mentioned guidelines, suggest that whenever ammonium nitrate or any oxidizer fire is involved, responding fire fighters should avoid efforts to extinguish the fire. Instead, fire fighters should concentrate on evacuating the area, including all civilians, and withdraw to a safe location.

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Investigator Information

This incident was investigated by Tim Merinar, Project Officer and Safety Engineer, and Steven Miles, Occupational Safety and Health Specialist, with the Fire Fighter Fatality Investigation and Prevention Program, Surveillance and Field Investigations Branch, Division of Safety Research, NIOSH located in Morgantown, WV. An expert technical review was provided by Mr. David Dodson, Response Solutions, LLC. A technical review was also provided by the National Fire Protection Association, Public Fire Protection Division. Final reviews were also provided by representatives of the Texas State Fire Marshal's Office; the U.S. Department of Justice, U.S. Attorney's Office, Western District of Texas; and the U.S. Department of Justice, Bureau of Alcohol, Tobacco, Firearms and Explosives.

Additional Information

Texas State Fire Marshal's Office / Texas Department of Insurance

The Texas State Fire Marshal's Office conducted a separate investigation of this incident. The Texas State FMO investigation report is available at http://www.tdi.texas.gov/reports/fire/documents/fmloddwest.pdf. Additional investigation reports conducted by the Texas State FMO involving recent fire fighter line-of-duty deaths can be found at http://www.tdi.texas.gov/fire/fmloddindividuals.html.

Chemical Advisory: Safe Storage, Handling and Management of Ammonium Nitrate
In August 2013, the U.S. Environmental Protection Agency (EPA), the U.S. Occupational Safety and Health Administration (OSHA), and the U.S. Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) issued a joint safety advisory as part of the ongoing federal effort to improve chemical risk management and to advance safety and protect human health and the environment.
http://www.epa.gov/emergencies/docs/chem/AN_advisory.pdf

The Fertilizer Institute (TFI) and the Agricultural Retailer's Association (ARA) released a joint ammonium nitrate safe handling guide as a result of this incident. The document *Safety and Security Guidelines for the Storage and Transportation of Fertilizer Grade Ammonium Nitrate at Fertilizer Retail Facilities* can be accessed at: http://www.tfi.org/ammonium_nitrate_guidelines.

The Institute of Makers of Explosives (IME) with endorsements from the National Stone, Sand and Gravel Association, the International Society of Explosives Engineers, and The International Association of Fire Chiefs (IAFC) released a joint best practices guideline for the safety and security of technical grade ammonium nitrate (TGAN) in the manufacturing, storage and transportation from risks of fire, shock and misappropriation. The document Safety and Security Guidelines for Ammonium Nitrate can be accessed at: http://www.ime.org/userfiles/files/AN%20Guidelines_IAFC-IME-NSSGA-ISEE(FINAL)(3).pdf.

National Volunteer Fire Council
In 2008, the National Volunteer Fire Council adopted a policy statement that all volunteer fire departments should establish a goal to train all personnel to a level consistent with the mission of the fire department, based on the job performance requirements outlined in NFPA1001: Standard for Fire Fighter Professional Qualifications. The NVFC white paper containing more information can be found at http://www.nvfc.org/files/documents/Volunteer_Training_White_Paper.pdf .

Ammonium Nitrate chemical safety information
International Chemical Safety Card, ICSC 0216: Ammonium Nitrate.
http://www.cdc.gov/niosh/ipcsneng/neng0216.html

International Chemical Safety Card, ICSC 1590: UREA Ammonium Nitrate.
http://www.cdc.gov/niosh/ipcsneng/neng1590.html

NIOSH Pocket Guide to Chemical Hazards: Ammonium chloride fume.
http://www.cdc.gov/niosh/npg/npgd0029.html

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Appendix One

Personal Protective Equipment Evaluation

Summary and Conclusions

Three SCBA units were submitted to NIOSH by the NIOSH Division of Safety Research for evaluation. The SCBA units were delivered to NIOSH on May 3, 2013 and initially inspected on June 5, 2013. The units were identified as a Sperian Respiratory Protection models Survivair, 4500 psi, 30-minute, SCBA (NIOSH approval numbers TC-13F-284). The complete inspections of the SCBA units were conducted on June 5, 2013. The units suffered extensive damage, exhibited other signs of wear and tear and the units were covered generally with dirt, grime, and some foreign material. The cylinder valves as received on Unit #1 and Unit #2 were in the closed position. The cylinder gauge on Unit #1 indicated that 0 psig was in the cylinder. The cylinder gauge on Unit #2 indicated that 1000 psig was remaining in the cylinder. The cylinder valve hand-wheels could be turned. The facepiece that was assigned to Unit #1 had a relatively clean regulator mating and sealing area There was minimal debris on the inside of the facepiece. Unit #1 facepiece had some slight lens damaged due to heat. Visibility through the facepiece lens was fair as the lens had dirt and scratches present. The facepiece head harness webbing on Unit #1 was in fair condition with some dirt present and only some evidence of wear or damage. Unit #1 was missing the second stage regulator. Units #2 and #3 did not have a facepiece included or assigned. The second stage regulators for Units #2 and #3 were extensively damaged. Unit #3 second stage regulator was very dirty. None of the SCBAs had PASS units. The NFPA approval labels on Units #1 and #3 were partially present and mostly readable. Unit #2 did not have a NFPA label visible.

The air cylinder on the Unit #1 had a manufactured date of 02/06. The air cylinder on Unit #2 had a manufactured dated of 12/06. Under the applicable DOT-E-10945-4500 exemption, the air cylinders are required to be hydro tested every 5 years. For the air cylinder on Unit #1, a retest date before the last day of 02/11 is required. For the air cylinder on Unit #2, a retest date before the last day of 12/11 is required. The retest labels on both cylinders indicated that the cylinders were hydro-test on 11/11. Both cylinders appeared to be within the hydro certification when last used. Both cylinders were in fair condition with only minor scratches and damage present. Air was remaining in Unit #2 cylinder. A sample was taken for analysis to NFPA Grade D air level. None of the SCBAs were in a condition to be tested therefore no testing was performed. In light of the information obtained during this investigation, NIOSH has proposed no further action on its part at this time. Following the inspection, the SCBAs were returned to storage pending return to the Fire Department.

The complete evaluation report is available from NIOSH upon request.

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Appendix Two

International Chemical Safety Card O216: Ammonium Nitrate

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Home

AMMONIUM NITRATE **ICSC:** 0216

Peer-Review Status: 04.10.2013 Validated

Nitric acid, ammonium salt

CAS #: 6484-52-2 RTECS #: BR9050000
UN #: see Notes
EINECS #: 229-347-8

Formula: NH_4NO_3
Molecular mass: 80.0

TYPES OF HAZARD / EXPOSURE	ACUTE HAZARDS / SYMPTOMS	PREVENTION	FIRST AID / FIRE-FIGHTING
FIRE	Not combustible but enhances combustion of other substances. Gives off irritating or toxic fumes (or gases) in a fire.	NO contact with combustible substances or reducing agents.	Use water in large amounts. NO other agents. In case of fire in the surroundings, use appropriate extinguishing media.
EXPLOSION	Risk of fire and explosion on confinement and exposure to high temperatures or when contaminated with other materials.	See Notes.	In case of fire: keep drums, etc., cool by spraying with water. Combat fire from a sheltered position.
EXPOSURE		**PREVENT DISPERSION OF DUST!**	
Inhalation	Cough.	Use local exhaust or breathing protection.	Fresh air, rest. Seek medical attention if you feel unwell.
Skin	Redness.	Protective gloves.	Rinse skin with plenty of water or shower. Remove contaminated clothes.
Eyes	Redness. Pain.	Wear safety goggles.	First rinse with plenty of water for several minutes (remove contact lenses if easily possible), then refer for medical attention.
Ingestion	Vomiting. Diarrhoea. Blue lips, fingernails and skin. Weakness.	Do not eat, drink, or smoke during work.	Rinse mouth. Refer for medical attention .

SPILLAGE DISPOSAL	PACKAGING & LABELLING
Personal protection: particulate filter respirator adapted to the airborne concentration of the substance. Sweep spilled substance into covered non-combustible containers. Store and dispose of according to local regulations. Wash away remainder with plenty of water.	**EC Classification** **UN Classification** UN Hazard Class: 5.1; UN Pack Group: III

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ICSC 0216 - AMMONIUM NITRATE Page 2 of 3

GHS Classification
Signal: Warning
May intensify fire; oxidizer
May be harmful if swallowed
Causes skin irritation
Causes serious eye irritation
May cause damage to blood

EMERGENCY RESPONSE	SAFE STORAGE
NFPA Code: H0; F0; R3; OX.	Separated from combustible substances and reducing agents. Dry. Well closed.

IMPORTANT DATA

Physical State; Appearance
COLOURLESS-TO-WHITE HYGROSCOPIC SOLID IN VARIOUS FORMS.

Physical dangers

Chemical dangers
Heating may cause violent combustion or explosion. Decomposes on heating. This produces toxic fumes. The substance is a strong oxidant. It reacts with acids and combustible and reducing materials.

Occupational exposure limits
TLV (NOT-ESTABLISHED):.

Routes of exposure
The substance can be absorbed into the body by inhalation and by ingestion.

Inhalation risk
Evaporation at 20°C is negligible; a harmful concentration of airborne particles can, however, be reached quickly when dispersed, especially if powdered.

Effects of short-term exposure
The substance is irritating to the eyes, skin and respiratory tract. The substance may cause effects on the blood. This may result in formation of methaemoglobin. The effects may be delayed.

Effects of long-term or repeated exposure

PHYSICAL PROPERTIES	ENVIRONMENTAL DATA
Decomposes at > 210°C Melting point: 170°C Density: 1.7 g/cm³ Solubility in water, g/100ml at 20°C: 200	Avoid release to the environment in circumstances different to normal use.

NOTES

UN number 1942 refers to pure ammonium nitrate with not more than 0.2% combustible material.
Ammonium nitrate can refer to a range of ammonium nitrate-based fertilizers (with UN number 2067).
The physico-chemical properties may vary according to the chemical composition.
This ICSC covers pure ammomium nitrate - the properties of fertilizers will be different.
Becomes shock-sensitive when mixed with organic materials.
Rinse contaminated clothing with plenty of water because of fire hazard.
Depending on the degree of exposure, periodic medical examination is suggested.
The storage of pure ammonium nitrate is often regulated - check for local regulations.

http://www.inchem.org/documents/icsc/icsc/eics0216.htm 9/24/2014

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In the event of a fire, large piles of ammonium nitrate present an explosion hazard. Large piles might need to be dismantled.

ADDITIONAL INFORMATION

See Also:
Toxicological Abbreviations

http://www.inchem.org/documents/icsc/icsc/eics0216.htm 9/24/2014

Appendix Three

*(**Note:** In December 2014, the Institute of Makers of Explosives (IME) provided comments to NIOSH regarding ammonium nitrate fires. IME recommends that whenever ammonium nitrate or any oxidizer fire is involved, responding fire fighters should avoid efforts to extinguish the fire. Instead, fire fighters should concentrate on evacuating the area, including all civilians, and withdraw to a safe location.)*

What Fire Fighters Need to Know About Fires and Emergency Responses Involving Ammonium Nitrate

The following information comes from the *Chemical Advisory: Safe Storage, Handling, and Management of Ammonium Nitrate* (EPA 550-S-13-001) released August 2013 as a joint announcement by the U.S. Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA) and the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF).[8]

Emergency Response
Owner / operators of storage facilities containing ammonium nitrate should develop a site emergency response plan which includes:

- Coordination with local first responders
- Joint training with first responders if possible
- Employee training
- Community outreach
- Analysis of what may be at risk in a serious accident and appropriate planning
- Signs that clearly mark high hazard areas, safe areas, emergency contact numbers, fire fighting equipment, and other essential areas during an emergency response
- A site and area evacuation plan.

Before responding to a fire involving ammonium nitrate, fire fighters should ensure that the community emergency response plan includes:

- Ammonium nitrate hazard information and emergency response guidelines
- Quantity, storage types, and locations of ammonium nitrate at facilities in their communities
- Specific response procedures; including a decision process to determine under which conditions a fire should be fought or whether the fire should be allowed to burn
- Evacuation procedures for the community
- Training requirements for all response personnel
- A schedule for exercising the response plan related to ammonium nitrate accidents.

When responding to a fire where ammonium nitrate is stored, fire fighters should:

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- First consider if they can safely fight the fire or whether they should just let it burn, move to a safe location, and focus on evacuating nearby residents and preventing further safety issues for the surrounding community.

To determine whether or not it makes sense to fight a fire involving ammonium nitrate or to just let it burn, fire fighters and emergency responders should consider the following information:

- Fire fighters should not fight an ammonium nitrate fire and everyone, including fire fighters, should be evacuated to a safe distance if they observe any of the following:
  - A fire involving ammonium nitrate is judged to be out of control;
  - The fire is engulfing the ammonium nitrate; or
  - Brown/orange smoke is detected, indicating the presence of nitrogen dioxide (which is toxic); or
  - A rapid increase in the amount/intensity of smoke or fire in the area of ammonium nitrate storage.
- If fire fighters consider it safe and appropriate to respond to a fire involving ammonium nitrate, then the following information should be considered:
  - An ammonium nitrate fire should be fought from protected locations or maximum possible distance. Approach a fire involving or close to ammonium nitrate from upwind to avoid hazardous vapors and toxic decomposition products. Self-contained breathing apparatus of types approved by the National Institute for Occupational Safety and Health (NIOSH) should be used to protect personnel from gases.
  - Use flooding quantities of water from a distance as promptly as possible. It is important that the mass of ammonium nitrate be kept cool and the burning be quickly extinguished. Keep adjacent fertilizers cool by spraying with large amounts of water. When possible and appropriate, only use unmanned hose holders or monitor nozzles.
  - DO NOT use steam, CO_2 dry powder or foam extinguishers, sand or other smothering agents.[c]
  - Ensure maximum ventilation of the ammonium nitrate storage container as quickly as practical to prevent heat and pressure buildup. This is different than ensuring maximum ventilation of the entire building or structure where the ammonium nitrate is stored. Ventilation of the structure should be conducted only in a manner to limit fire spread and growth and should be minimized until a suppression water supply is established.

[c] Keep in mind that ammonium nitrate is an oxidizer – that is – it provides its own oxygen and once combustion begins, it cannot be smothered. Moreover, the combination of heat and confinement will accelerate combustion, perhaps to the point of detonation.

- If practical and safe to do so, attempt to prevent ammonium nitrate from entering the drains where explosive confinement could occur. Remember ammonium nitrate may be washed into drains by fire water, but it can also melt and flow without impetus from water.
- Prevent or minimize contamination of water bodies or streams to reduce the potential for environmental effects.