



Eight Fire Fighters from a Combination Department Injured in a Natural Gas Explosion at a Strip Mall – Maryland

SUMMARY

On May 7, 2009, two captains, a lieutenant, and five fire fighters were injured during a natural gas explosion at a strip mall in Maryland. At 1254 hours, dispatch reported a natural gas leak inside a business at a strip mall. Five minutes later, the initial responding crew and the incident commander (IC) arrived on scene to find a gas company employee looking for an underground gas leak. Approximately 6 minutes later, a natural gas leak was found near the exterior rear corner of the structure. After 23 minutes on scene, approximately 45 civilians were evacuated from 7 occupied businesses.

A captain exited the rear door of the business that had called in the natural gas leak and noticed fire along the roof line. Crews in the front and rear of the structure had begun to pull hoselines as another captain was looking out the rear doorway of a middle unoccupied business and noticed the electric meter located on the exterior wall on fire. Anticipating an explosion, he tried to leap out the rear doorway. At the same time, a fire fighter had entered the front door of the unoccupied business, noticed the heavy smell of natural gas, and felt air rush by as the structure exploded. Debris and fire blew out the front, rear, and roof of the structure. The captain who tried to leap out the rear doorway was blown into the rear parking lot and the fire fighter who had entered the front of the structure was blown out the front door and covered with debris. Numerous other fire fighters, primarily near the front of the structure were blown off their feet and hit with debris.

An uninjured captain issued a Mayday, followed by the IC ordering evacuation tones and a personnel accountability report. Crews began to look for the captain who was blown out the rear doorway. He had walked around the side to the front of the structure, and radioed his location to command. Fire fighters began moving injured personnel to ambulances staged in the front parking lot. Eight fire fighters and a gas company employee were transported to local hospitals. The injuries ranged from third degree burns to an ankle sprain.

The National Institute for Occupational Safety and Health (NIOSH), an institute within the Centers for Disease Control and Prevention (CDC), is the federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. In fiscal year 1998, the Congress appropriated funds to NIOSH to conduct a fire fighter initiative. NIOSH initiated the Fire Fighter Fatality Investigation and Prevention Program to examine deaths of fire fighters in the line of duty so that fire departments, fire fighters, fire service organizations, safety experts and researchers could learn from these incidents. The primary goal of these investigations is for NIOSH to make recommendations to prevent similar occurrences. These NIOSH investigations are intended to reduce or prevent future fire fighter deaths and are completely separate from the rulemaking, enforcement and inspection activities of any other federal or state agency. Under its program, NIOSH investigators interview persons with knowledge of the incident and review available records to develop a description of the conditions and circumstances leading to the deaths in order to provide a context for the agency's recommendations. The NIOSH summary of these conditions and circumstances in its reports is not intended as a legal statement of facts. This summary, as well as the conclusions and recommendations made by NIOSH, should not be used for the purpose of litigation or the adjudication of any claim. 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).



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Key contributing factors identified in this investigation included: insufficient execution of the fire department's updated standard operating guidelines (SOGs) on incidents involving flammable gas, e.g., apparatus and fire fighters operating in a flammable area (hot zone); the accumulation of natural gas in the structure's void spaces; unmitigated ignition source; insufficient combustible gas monitoring equipment usage and training; and, ineffective ventilation techniques.

NIOSH investigators concluded that, to minimize the risk of similar occurrences, fire departments should

- *ensure that standard operating guidelines for natural gas leaks are understood and followed*
- *contact utility companies (natural gas and electric) immediately to cut external supply/power to structures when gas leaks are suspected*
- *ensure gas monitoring equipment is adequately maintained and fire fighters are routinely trained on proper use*
- *ensure ventilation techniques are conducted after ignition sources are mitigated*
- *ensure that rapid intervention teams are staged at the onset of an incident*
- *ensure that collapse/explosion control zones are established when dealing with a potential explosion hazard*

Although there is no evidence that the following recommendations would have prevented these injuries, they are being provided as a reminder of good safety practices.

- *provide manual personal alert safety system (PASS) or tracking devices to locate potentially missing fire fighters when SCBA are not utilized*
- *ensure standard operating guidelines for communications are understood by dispatch*
- *ensure adequate staffing for emergency medical services and rapid intervention teams (RITs)*
- *ensure training is evaluated for rank and skill levels across the combination department personnel*



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INTRODUCTION

On May 7, 2009, eight fire fighters were injured when a natural gas explosion occurred at a strip mall in Maryland. On May 8, 2009, the International Association of Fire Fighters (IAFF) requested that the National Institute for Occupational Safety and Health (NIOSH) conduct an investigation of the incident. On May 11 and 12, 2009, a general engineer and a safety engineer from the NIOSH Fire Fighter Fatality Investigation and Prevention Program conducted an opening meeting with the fire chief, the fire marshal, an IAFF representative and key staff officers. The NIOSH investigators also visited the incident scene. On May 14 and 15, 2009, a general engineer, a safety engineer, and a safety and occupational health specialist from NIOSH returned to visit the incident scene, met with the strip mall's property manager and with the state public service commission's representative on issues related to the site, and conducted interviews with officers and fire fighters who were at the incident scene. On June 3 through 5, 2009, the general engineer returned to complete interviews of injured fire fighters. The NIOSH investigators reviewed the department's standard operating guidelines (SOGs), the officers' and fire fighters' training records, photographs and a video of the incident scene captured by the fire apparatus video surveillance system, written witness statements, dispatch transcripts, and medical records of the injured fire fighters. NIOSH reviewed the Maryland Public Service Commission's report on the incident (see the Additional Information section).

FIRE DEPARTMENT

The combination department involved in this incident had seven battalions consisting of 45 stations with approximately 800 career and 1,100 volunteer fire fighters serving a population of more than 820,800 residents in a geographic area of approximately 485 square miles. The department responded to a 6-year average of 126,362 calls per year, including 3,220 structure fires and 1,873 gas leaks. *Note: Due to budget constraints, a station is typically manned with only a crew of 4 personnel. Frequent EMS calls result in only 2 personnel to respond on a fire apparatus.* The department had 498 pieces of apparatus, including 92 engines, 86 ambulances, 24 trucks, 9 brush trucks, 6 rescue, 5 mini-pumpers, 4 tankers, and 1 quint. The department had 51 career personnel assigned to hazardous materials, 35 assigned to technical rescue, and 13 assigned to the marine division.

Two months prior to the incident, the fire department's SOGs were updated. This included the SOG for incidents involving flammable gases. The revised SOG provided more detailed guidance on staging and duties of arriving apparatus, minimizing personnel within the hot zone, and the systematic elimination of ignition sources. Many officers and fire fighters were not aware of the latest revision.

TRAINING/EXPERIENCE

The combination department's training system offers numerous opportunities for training, both at the fire department's academy and at the State's training institute. The training is offered free of charge



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and is open to any member of the fire department, both career and volunteer. Classes are often integrated with both career and volunteer members. *Note: Several interviewees mentioned that the training budget had been impacted by the recent economic downturn providing less training opportunities at this time to department personnel.*

The following table lists the primary officers and fire fighters involved in the incident and their training and experience.

Fire Fighter	Injured (yes/no)	Fire Fighter Status	Training Courses	Years experience
FF#1	yes	career	Basic, Intermediate, and Paramedic Emergency Medical Technician (EMT) I; Introductory and 200-level Incident Command System (ICS); Introduction to National Incident Management System (NIMS); Basic Wildland; and various administrative and technical courses.	6
FF#2	yes	volunteer	Basic EMT, HazMat Operations, Fire Fighter 1 Practical–Live Fire Training, Introduction to ICS and NIMS, and various other administrative and technical courses.	3
FF#3	yes	career	Fire Fighter 1 and 2, Basic and Intermediate EMT, HazMat Technician, Basic and Intermediate Wildland, Introduction to NIMS, and various other administrative and technical courses.	2.5
FF#4	yes	career	Basic EMT, HazMat Operations, Fire Fighter 1, and various other administrative and technical courses.	18
FF#5	yes	career	Fire Fighter I and II, HazMat Technician, Basic Wildland, EMT Paramedic, Introduction to NIMS, and various other administrative and technical courses.	3



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Lieutenant	yes	career	Fire Fighter 1 and 2, Basic and Intermediate EMT, HazMat Operations, Incident Safety Officer, Leadership I, Introductory and Level 200 ICS, Introduction to NIMS, several Weapons of Mass Destruction courses, and various other administrative and technical courses.	28
Captain #1 (C#1)	yes	career	Fire Fighter 1 and 2, Basic and Intermediate EMT, HazMat Operations, Incident Safety Officer, Leadership I, Introductory and Level 200 ICS, Introduction to NIMS, several Weapons of Mass Destruction courses, and various other administrative and technical courses.	20
Captain #2 (C#2)	yes	career	Fire Fighter 1 and 2, Basic EMT, HazMat Operations, Incident Safety Officer, Leadership I, Introductory and Level 200 ICS, Introduction to NIMS, Leadership Challenge 2006 & 2007, and various other administrative and technical courses.	21
Battalion Chief (Incident Commander)	no	career	Fire Fighter 1, Fire Officer I – III, Introductory and Level 100 and 200 ICS, Introduction to National Incident Management System (NIMS), HazMat I and II, Building Construction: Non-combustible, Large Structure Considerations, and various other administrative and technical courses.	19

Note: Fire Fighter 1 and 2 training are equivalent to National Fire Protection Association (NFPA) 1 and 2.

PERSONAL PROTECTIVE EQUIPMENT

At the time of the incident, each injured fire fighter was wearing personal protective equipment consisting of a turnout coat and pants, a helmet, and boots. Each fire fighter carried a hood, gloves,



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and self-contained breathing apparatus (SCBA) with an integrated personal alert safety system (PASS) device. Only the officers and 3 of the 5 injured fire fighters had portable radios (one was personally owned).

SPECIALIZED EQUIPMENT

Specific calls require the use of specialized equipment, such as, SCUBA gear for water rescues, extrication tools for motor vehicle incidents, and monitoring devices for hazardous material incidents. This specific incident, a natural gas leak, required the use of atmospheric monitoring equipment. The fire department had an atmospheric monitoring program that addressed the distribution, training, and maintenance of the monitoring equipment. The fire department had purchased a total of 76 monitors in 2003 that included a 5-year warranty covering repair and maintenance. Following the expiration of the warranty in mid-2008, the responsibility for repair and maintenance transferred to the fire department. The fire department's standard operating guidelines required monthly calibrations. To minimize out of service time for repair and maintenance of monitors, reserve monitors were to be issued. Due to budget constraints, the calibration schedules had not been kept up and reserve monitors were dismantled to provide parts to repair monitors. The fire department had only 45 of its' initial 76 monitors in operation at the time of the incident.

APPARATUS, PERSONNEL, and ON-SCENE ARRIVAL TIMES

1259 hours

Engine #23 (E23)—Captain #1 (C #1) (*injured*), driver, and three fire fighters, including FF #5 (*injured*)

Ambulance #23 (A23) – FF #3 (*injured*)

Battalion Vehicle #03-Battalion Chief (Incident Commander)

1305 hours

Engine #17 (E17)—Captain, fire fighter technician and two fire fighters

1306 hours

Squad #27 (SQ27)—Captain and two fire fighters

Engine #26 (E26)—Lieutenant (Lt) (*injured*) and four fire fighters, including FF #2 (*injured*)

1316 hours

Truck #5 (T5)-Captain #2 (C #2) (*injured*) and three fire fighters, including FF #1 (*injured*) and FF #4 (*injured*)

1320 hours

Engine #38 (E38)—Acting Captain and two fire fighters

Notes: 1) See Diagram for placement of apparatus. 2) An engine had been dispatched as a RIT, but was delayed because of insufficient staffing and arrived after the incident.



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BUILDING INFORMATION

The south side of the structure was comprised of 10 business spaces (three of which were vacant) in a strip mall designed and constructed as a Type II, noncombustible classification in the 1970s. The section of the commercial structure involved in the incident was comprised of a main 2 story building, which included 2 vacant businesses and a mall office, with an adjoining wing on the right consisting of 6 businesses (1 unoccupied) in a single story with high dropped ceilings, large attic void spaces, and a sprinkler system. In the wing along the C-side were utility rooms housing the electrical circuit panels, sprinkler system controls, and security panels. It was constructed of brick/block and mortar with large plate glass windows on the A-side, block and mortar exterior C and D-side walls, and a block and mortar interior B-side wall adjoining the rest of the structure. The roof was a commercial flat roof consisting of open web, steel bar flat roof trusses covered with corrugated metal “q-deck” with multi-layered plies of bitumen laminated roof felts and topped with a granule-surfaced cap sheet. The open web steel bar roof trusses were connected to a steel beam and column structural assembly system.

The interior walls separating the businesses were primarily light weight galvanized metal studs covered with a ½ inch gypsum wall board providing tenant separation and compartmentation. The ceiling was a suspended acoustic tile ceiling system which provided a common void space over the business occupied areas of the adjoining right wing. The businesses contained office furniture, partitions, restaurant equipment and supplies, and health and beauty equipment and products.

INVESTIGATION

On May 7, 2009, two captains, a lieutenant, and five fire fighters were injured during a natural gas explosion at a strip mall in Maryland. At 1254 hours, dispatch reported a natural gas leak inside a business at a strip mall. At 1259 hours, Engine #23 (E23), Ambulance #23 (A23), and a Battalion Chief (the incident commander (IC)) arrived on scene to find a gas company employee, who had been on scene for approximately 15 minutes, looking for an underground gas leak. The IC staged in the A-side parking lot in line-of-sight of business #3426 that had reported the gas leak (see Diagram). E23 staged at the A-side curb to the left of the front entrance to business #3426 while A23 staged on the curb in the neighboring parking lot on the D-side of the strip mall. The crews from E23 and A23 consisting of C#1, FF#3, FF#5, and 2 other fire fighters began investigating the source of the natural gas odor. At 1305 hours, a natural gas leak was found near the exterior C/D corner of the structure with the assistance of a gas company employee. Engine #17 (E17) arrived and was assigned to the rear (C-side). At 1306 hours, Squad #27 (SQ27) and Engine #26 (E26) arrived on scene (see Diagram). Atmospheric monitoring with a combustible gas lower explosive limit (LEL) monitor was initialized by E17 and SQ27 crews but the monitors did not alarm. E17's monitor read 25% LEL and SQ27's monitor read 4% LEL. *Note: Several interviewed fire fighters stated that they were unsure if the monitors initialized properly and after the initial readings the monitors were left unmanned.* C#1 was in business #3426 but could not smell gas in the front of the building. An employee indicated the odor was coming from the rear. C#1 walked to the rear and smelled natural gas; he then exited the building



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to see natural gas bubbling up out of three ¾ inch holes in the asphalt which had been found minutes earlier. The gas company employee indicated it was an underground leak but didn't know the source.

The IC assigned the crews to evacuate the businesses on the south section of the strip mall (#3410 - #3436). C#1 and FF#3 preceded to evacuate business #3426 then went to the second floor office area (#3420) in the strip mall to evacuate civilians. The captain from SQ27 shut off the main circuit breakers to businesses #3436, 3434, 3432, and 3430 at the circuit panel in the rear of #3432. At 1316 hours, Truck #5 (T5) arrived on scene and staged at the A-side curb in front of the vacant business #3430. T5 was assigned to assist E26 in evacuating business #3434 and start ventilation using T5's positive pressure fan. The fan was started several times but would not stay running.

By 1322 hours, approximately 45 civilians had been evacuated from the businesses on the southside of the strip mall. C#1 and FF#3 were exiting the office area when they heard what they thought was a door slamming shut. *Note: During interviews, several other fire fighters reported hearing the same sound while evacuating the other businesses. It is now thought to have been a small explosion possibly igniting the fire along the roof line and electric meter.* At 1323 hours, the captain from Squad #27 exited the rear door of business #3426 and noticed a fire along the C-side roof line underneath the gutter and an electric meter on fire near the C/D corner. The gas company employee retrieved a fire extinguisher from his vehicle and tried unsuccessfully to extinguish the fire at the electric meter. He then ran to move his vehicle back from the building. At 1324 hours, the IC requested a rapid intervention team (RIT) and a second alarm for the working fire. Hearing the report of fire in the rear, E17 and E38 crews in the rear and E23's crew in the front of the structure began to pull hoselines and T5's driver started putting down the outriggers on the truck. C#1 was sizing up the interior/exterior conditions of business #3430 before committing his crew to fire operations. He looked out the C-side doorway of the vacant business #3430 and noticed the electric meter on fire on the exterior wall of the structure. Anticipating an explosion, he tried to leap out the rear doorway. At the same time, FF#1 with a pike pole in hand had entered the A-side door of the vacant business #3430 and noticed the heavy smell of natural gas and felt air rush by as the structure exploded (see Photos 1, 2, 3 and 4). At approximately 1326 hours, debris and fire blew out the A-side, C-side, and roof of the south section of the structure. C#1 was blown into the rear parking lot and FF#1 was blown out the A-side door and covered with debris. On the A-side of the structure, C#2, the Lieutenant from E26, FF#2, FF#3, FF#4, FF#5, and several other fire fighters were blown off their feet and hit with debris (see Diagram).

On the C-side, a fire fighter from E17 was blown several feet across the rear paved service drive and the captain from E17 assisted him to the grassy bank bordering the service drive. The E17 captain then promptly issued a Mayday. The IC ordered evacuation tones and a personnel accountability report. E26 and E23 drivers sounded air horns to evacuate.

Fire fighters rushed to assist downed fire fighters and move them to the grassy islands in the A-side parking lot for evaluation. Fire fighters from E26, T5 and E23 began to look for C#1 in the debris and rubble of the common interior wall between business #3430 and #3432. C#1's helmet was seen on the floor in the rear of #3430 by several of the fire fighters looking for him. C#1 had walked around the



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D-side and went to the rear of A23 which was unmanned so he continued to the A-side of the structure. After hearing radio traffic about the search for him, C#1 radioed command of his location. Fire fighters began moving injured personnel to ambulances staged in the A-side parking lot. At 1332 hours, the IC requested that the electric company be dispatched to the scene. Ambulance #27 arrived on scene just a minute after the explosion and transported the most seriously injured fire fighters (C#1 and FF#1) to the hospital at 1340 hours. *Note: At the time of the 2nd alarm dispatch for a working fire, several ambulances were enroute and were approximately 20 minutes out. All district fire fighters, from several stations, were either injured in the blast or involved in fire suppression leaving the ambulances unmanned in their stations and requiring ambulances to come from the other side of the county.* In all, eight fire fighters and a gas company employee were transported to local hospitals.

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 injuries of eight fire fighters:

- Insufficient execution of the fire department's updated standard operating guideline on incidents involving flammable gas, e.g., apparatus and fire fighters operating in a flammable area (hot zone).
- The accumulation of natural gas in the structure's void spaces.
- An unmitigated ignition source.
- Insufficient combustible gas monitoring equipment usage and training
- Ineffective ventilation techniques.

CAUSE OF INJURIES

According to medical records, all of the fire fighters' injuries were due to the natural gas explosion resulting in concussive, debris impact and thermal-related injuries. Of the fire personnel in the structure at the time of the incident, C #1 sustained second and third degree burns to the face, left hand and right ear; FF #1 had second degree burns to the right hand, head, and forehead. Of the fire fighters on the exterior A-side of the structure, C #2 had a laceration to the back of the head and back pain, FF #2 had left rib pain and lacerations to the left hand and elbow, FF #3 had burns to the eyes, FF #4 had a sprained ankle, FF #5 had back pain, and the LT had a laceration to the right hand. The gas company employee sustained injuries to his back.



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RECOMMENDATIONS

Recommendation #1: Fire departments should ensure that standard operating guidelines for natural gas leaks are understood and followed.

Discussion: Written standard operating guidelines (SOGs) enable individual fire department members an opportunity to read and maintain a level of assumed understanding of operational procedures. Conversely, fire departments can suffer when there is an absence of well developed SOGs. The NIOSH Alert, *Preventing Injuries and Deaths of Fire Fighters* identifies the need to establish and follow fire fighting policies and procedures.¹ Guidelines and procedures should be developed, fully implemented, trained on and enforced to be effective. 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 policies and standard operating procedures that document the organizational structure, membership, roles and responsibilities, expected functions, and training requirements, including the following....(4) The procedures that will be employed to initiate and manage operations at the scene of an emergency incident.²

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 available for application according to the needs of each particular situation.³

In this incident, several interviewed fire fighters were unaware of their fire department's standard operating guideline for incidents involving flammable gases. In addition, officers were aware of the SOG, but had not been made aware of the latest revision that had been released 2 months prior to the incident. The revised SOG provided more detailed guidance on staging and duties of arriving apparatus, minimizing personnel within the hot zone, and the systematic elimination of ignition sources. The additional personnel in the hot zone had the potential for additional injuries.

Recommendation #2: Fire departments should contact utility companies (natural gas and electric) immediately to cut external supply/power to structures when gas leaks are suspected.

Discussion: Fire fighters are often the first on the scene in an emergency involving natural gas, and understanding the related dangers is a must. Natural gas leaks have a great potential for an explosion and a fire to occur. The greatest risk is an explosion which can be ignited by a spark or open flame. Sparks can come from unexpected sources, such as turning on electrical equipment. If possible, radios, pagers, cell phones, etc., should be turned off before approaching the area. Fire fighters should avoid using doorbells, light switches, matches, and lighters, and prevent their use by others. Fire fighters should be alert for evacuees and bystanders who may try to turn off lights or make phone calls.⁴ In order to eliminate potential electrical equipment hazards, the electric company should be notified



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immediately to cut power at an external source when fire fighters are dispatched to a natural gas leak, especially at a commercial structure. This would be in addition to notifying the gas company to shut off the gas service and assist in investigating the source of the leak.

In this incident, the gas company was notified and arrived on scene approximately 15 minutes prior to the fire department. The fire department safely evacuated 45 civilians prior to the explosion. The fire department personnel found an electrical panel and began to turn individual breakers off, instead of the main disconnect to the building. This was done without incident, however, any breaker could have the potential to spark, causing an explosion if the requisite concentration of gas was present. The electric company was not notified until after the explosion. (*Note: The power to business #3432 went off at noon and the fire department was not informed of this. It is uncertain why the power went off, but the electric meter that was seen to be on fire was believed to be that of business #3432.*) Per the Public Service Commission Report (see Additional Information section), the source of ignition was undeterminable but fire fighters on scene recall seeing an electric meter on fire.⁵ If notified at the time of dispatch, the electric company may have been able to mitigate any possible electrical ignition sources.

Recommendation #3: Fire departments should ensure gas monitoring equipment is adequately maintained and fire fighters are routinely trained on proper use.

Discussion: Fire departments often respond to natural gas leaks, and lower explosive limit monitors are an essential tool for helping establish whether it is safe to enter a structure when a natural gas odor has been detected. The minimum concentration of gas that will support combustion is called the lower explosive limit (LEL). LEL monitors read 0-100% of LEL. The gas monitoring equipment manufacturer states, if the monitor reads 100, that means the atmosphere is flammable. If it reads 50, it means that the atmosphere is 50 % of the way to being flammable. The use of a properly calibrated and functioning LEL monitor can help increase the safety of responding fire fighters and the building occupants when natural gas is smelled.⁶

LEL monitors require maintenance (including frequent calibration) and proper training in their use to be accurate and effective in the field. Manufacturer guidelines should be followed in maintaining and calibrating these technical devices. Understanding the proper use and readings requires routine training by qualified personnel. Inadequate training and maintenance will put fire fighters at risk.

The fire department had purchased 76 LEL monitors, but due to funding constraints, had been unable to adequately maintain and train on the proper use of the equipment. At the time of the incident, only 45 units were in operation. At least two of the fire department's atmospheric monitoring equipment (E17 and SQ27) were in use at the incident. At no time did either go into alarm. At one point at the scene, E17's monitor read 25% LEL and SQ27's monitor read 4% LEL. The monitors were later checked by the fire department's technician and were found to be functioning properly and within calibration. The failure for the meters to initialize, self calibrate, and/or have abnormally low readings



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upon activation can be attributed to a dirty filter, an attached calibration adapter, or turning devices on in highly concentrated gas environments.⁷ It cannot be determined if the latter occurred in this incident.

Recommendation #4: Fire departments should ensure ventilation is conducted after ignition sources are mitigated.

Discussion: Normally, ventilation is performed to remove the products of combustion, allowing fire fighters to advance on a fire. But, when dealing with natural gas in the absence of fire, venting can increase the danger of an explosion. Natural gas has an explosive or flammable concentration range between 4 percent to 16 percent gas to air.⁴ At concentrations below or above this range, natural gas will not burn, but it should always be treated as highly flammable.

Fire fighters should never ventilate structures containing natural gas while personnel are inside. Fire fighters should not open windows until they are certain the gas supply has been shut off and ignition sources have been eliminated because gas can ignite as it passes through the explosive range. If gas is still leaking into the structure, concentrations can hover within the explosive range, causing prolonged danger. Migrating gas can accumulate in storm drains, construction trenches, structures, void spaces (e.g., attics, dropped ceilings, etc.) and other utility conduits/lines, particularly as it moves laterally and seeks a path upward. As it migrates, localized concentrations will change. When it is determined to be safe to ventilate, structures should be ventilated from the top to bottom because natural gas is lighter than air.⁸

In this incident, a positive pressure ventilation (PPV) fan was set in front of one of the store front doors, but it did not operate properly. The fact that it didn't work may have prevented an explosion from occurring earlier in the evacuation. At that point in the incident, ventilation may have put the concentration of natural gas in the explosive range. In addition, the PPV could have provided the ignition source.

Recommendation #5: Fire departments should ensure that rapid intervention teams are staged at the onset of an incident.

Discussion: Fire departments should have a designated rapid intervention team (RIT) as a part of the first alarm assignment standing by on scene during any structure fire or potential explosion in a structure to rescue a trapped, injured, or missing fire fighter. NFPA 1500, section 8.8.7 states that: "At least one dedicated RIT shall be standing by with equipment to provide for the rescue of members that are performing special operations or for members that are in positions that present an immediate danger of injury in the event of equipment failure or collapse."² A qualified RIT team should always be a part of the initial first alarm. When the team is assigned as the RIT, they must be at the ready to initiate rescue when called upon. When standing by, the RIT team should monitor designated radio traffic and size up the incident, but not assist in regular fire fighter activities.



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Training is an important aspect of all fire fighter tactics. RIT tactics are unique and properly conducted RIT operations require conducting RIT specific training. Continual RIT training is necessary to have successful rapid intervention team members.⁹

In this incident, Engine #37 should have been the RIT, however, staffing resources caused it to delay leaving the station until later in the incident. A RIT team had not been established at the time of the incident. Consequentially, fire fighters from E26, T5, and E23 initiated rescue efforts, potentially endangering themselves, not being fully equipped, and causing accountability issues for command.

Recommendation #6: Fire departments should ensure that collapse/explosion control zones are established when dealing with a potential explosion hazard.

Discussion: During operations dealing with a gas leak and the possibility of an explosion, apparatus should be positioned outside the hazard area (330 feet/100 meters per the fire department's SOG and the Department of Transportation).¹⁰ Positioning should combine a barrier, if possible, and water supply considerations.

Although there is no evidence that the following recommendations would have prevented these injuries, they are being provided as a reminder of good safety practice.

Recommendation #7: Fire departments should provide manual personal alert safety system (PASS) or tracking devices to locate potentially missing fire fighters when SCBA are not utilized.

Discussion: Often fire fighters can and do carry out their duties at a hazard scene without donning or activating their SCBAs. In this scenario, SCBA with the integrated PASS device would not be activated since the SCBA were not turned on. If an unexpected explosion or collapse occurs, there may not be an indication that a fire fighter is down because the PASS would not be activated. The use of a manually activated device in this situation may be helpful to pinpoint the fire fighter's location.

In this incident, the captain was missing and firefighters were looking for him in the rubble. Fortunately, he had walked out the rear of the structure and around to the front. If however, he had been trapped, there would have been no system to locate him.

Recommendation #8: Fire departments should ensure standard operating guidelines for communications are understood by dispatch.

Discussion: An effective radio communication system is a key factor in fire department operations. The communication system, or central dispatch center, is used for receiving notification of emergencies, alerting personnel and fire apparatus, coordinating the activities of the units engaged in emergency incidents, and providing non-emergency communications for the coordinating fire departments. The dispatch system must be able to identify the type and number of units due to respond to the type of incident in advance, based on risk criteria and unit capabilities.⁹ The central dispatch



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center should also monitor fireground activity and inform command of time intervals or of possible missed transmissions such as Maydays. Having a pre-determined response for apparatus arranged by district, address or by type of incident, makes the job of the Incident Commander and the dispatcher much easier. The pre-determined assignment lists the apparatus slated to respond to the incident and should take into account apparatus that are out of service by filling in for such units with similar units.

In this incident, the municipal fire department maintained its own dispatch center in cooperation with the city police department. Numerous dispatch personnel were unfamiliar with fire fighter standard operating procedures and terminology.

Recommendation #9: Fire departments should ensure adequate staffing of emergency medical services and rapid intervention teams (RITs).

Discussion: Many fire fighters are also emergency medical technicians (EMTs), and depending on the call, their primary duty is either as a fire fighter or EMT. However, many fire stations are understaffed for the number of apparatus they have in the station. Often if out on a medical call, and a call comes in for a fire, there are not enough personnel to staff the engine or truck and vice versa.

In this incident, the initial EMS personnel, also being fire fighters, joined up with their company and were involved with evacuating the incident scene. When the fire fighter/EMS personnel became injured, ambulances from outside the district were called in because all the fire fighters/EMS personnel in the area were on scene as fire fighters. Additionally, the assigned RIT arrived after the incident because of staffing issues.

Recommendation #10: Fire departments should ensure training is evaluated for rank and skill levels across combination department personnel.

Discussion: Fire departments should assess whether the differences in training levels between career and volunteer personnel has an impact on safety. If so, these differences should be identified and resolved before an emergency occurs where lives may be at stake. Training protocols must be developed for rank and skill levels regardless of career or volunteer status.

Volunteers are an essential part of any combination fire department. Volunteers often are not afforded the time to receive advanced training due to primary job requirements and duties.



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ADDITIONAL INFORMATION

The Maryland Public Service Commission Office conducted a separate investigation of this incident. Their investigation report is available by requesting a copy from: Ms. Terry Romine, Executive Secretary, Public Service Commission of Maryland, William Donald Schaefer Tower, 6 Saint Paul St.,

Baltimore, MD 21202. The cause and source of the gas leak was determined to be the result of the main underground electric line failing, which resulted in the main gas line melting. This allowed natural gas to escape and migrate into the structure (see Photo 5). The replacement of a section of pavement in the area of the electrical short and bubbling of natural gas up through the pavement was never explained (see Photo 6). Per the Maryland Public Service Commission Report, the electric company's records indicate that the line was buried in March of 1977 and the gas main was installed in October of 1998.

The potential catastrophic consequences of gas leaks and insights into response safety can be gleaned from a 1983 incident in Buffalo, New York that resulted in the deaths of five fire fighters and two civilians, and injuries to nine fire fighters and 60-70 civilians,

<http://commandsafety.com/2009/12/buffalo-box-191-north-division-december-27-1983/>

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INVESTIGATOR INFORMATION

This incident was investigated by Matt Bowyer, General Engineer, Tim Merinar, Safety Engineer, and Stephen Miles, Safety and Occupational Health Specialist, with the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Division of Safety Research. The report was authored by Matt Bowyer. An expert technical review was conducted by Christopher J. Naum, Society of Fire Protection Engineers; Chief of Training, Command Institute, Washington, DC.; Board of Directors, International Association of Fire Chiefs Safety, Health & Survival Section.

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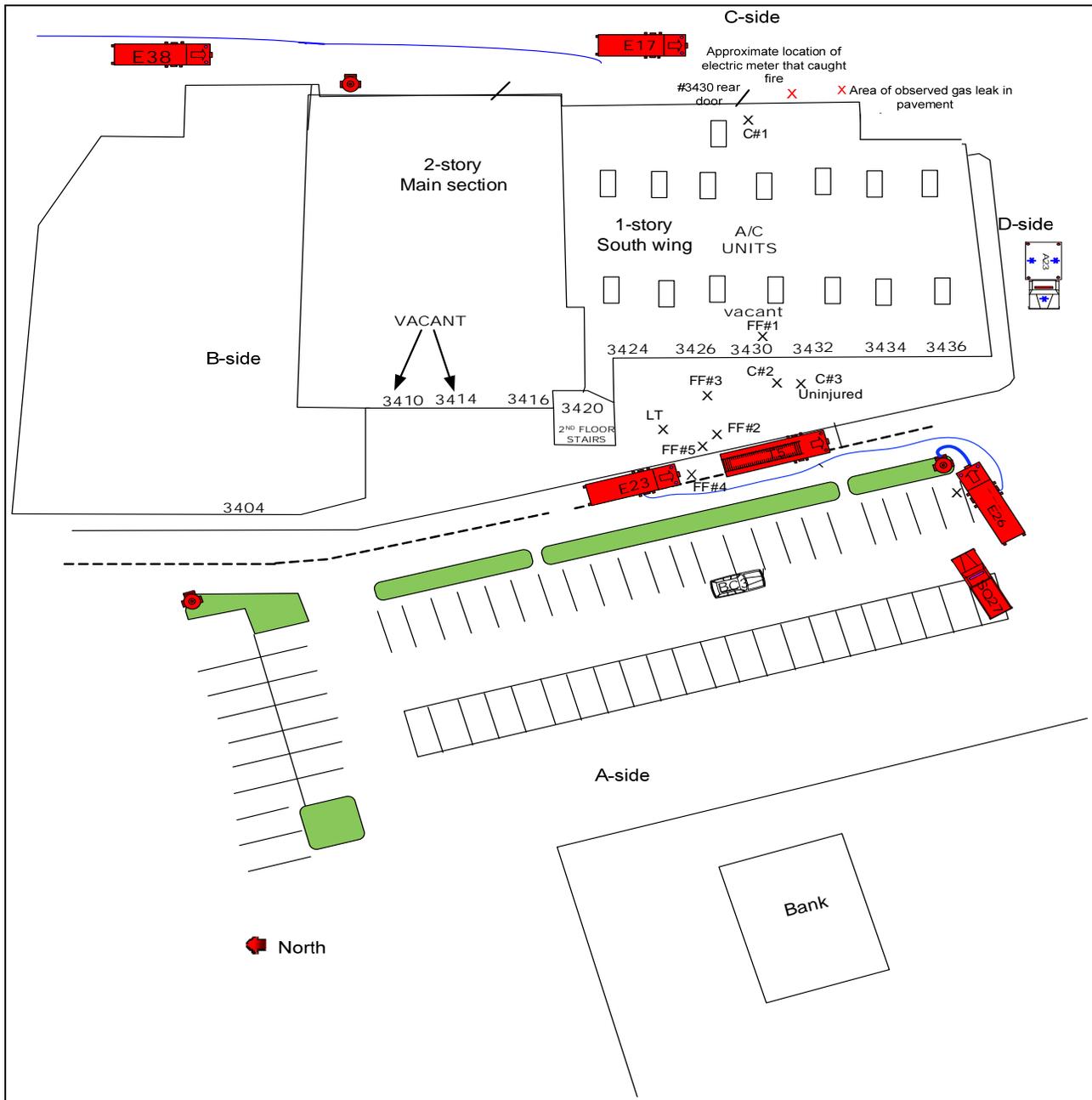


Diagram. Approximate locations of key apparatus and personnel at the time of the explosion.
(Courtesy of Fire Department)



**Photo 1. Vacant business #3430 after the explosion; C#1 was at the C-side door and FF#1 had just entered the A-side door.
(NIOSH photo.)**



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Photo 2. C-side of business #3430 after the explosion. The green exterior door in the lower part of the picture was the location of C#1 at time of explosion. (NIOSH photo.)



**Photo 3. Shows damage to roof's exterior which was directly above FF#1 at the time of explosion.
(NIOSH photo.)**



**Photo 4. Shows hole through ceiling and roof which was directly above FF#1 at time of explosion.
(NIOSH photo.)**



**Photo 5. Shows overheating of electrical wires 6 to 8 inches above 2 ½ inch plastic natural gas main which was softened from the heat.
(NIOSH photo.)**



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**Photo 6. Area underneath the steel plate is where gas was bubbling up through pavement. The cause of this gas leak is unknown. Also, shows section of replaced asphalt suggesting work had been done in this area.
(NIOSH photo.)**