# Natural Gas-Fueled Building Explosion and Resulting Fire
New York City, New York
March 12, 2014


**Accident Report**

NTSB/PAR-15/01
PB2015-104889

**National Transportation Safety Board**

NTSB/PAR-15/01
PB2015-104889
Notation 8696
Adopted June 9, 2015

# Pipeline Accident Report

## Natural Gas-Fueled Building Explosion and Resulting Fire

National
Transportation
Safety Board

490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

**National Transportation Safety Board. 2015.** ***Natural Gas-Fueled Building Explosion and Resulting Fire*****. Pipeline Accident Report NTSB/PAR-15/01. Washington, DC.**

**Abstract:**

On March 12, 2014, about 9:30 a.m. eastern daylight time, two adjacent multiuse five-story buildings were destroyed by a natural gas-fueled explosion and resulting fire. The buildings were situated on the west side of Park Avenue between East 116th Street and East 117th Street in the East Harlem district of the Borough of Manhattan in New York City. The violent explosion damaged buildings on the east and west sides of Park Avenue and along East 116th and East 117th Streets. Eight people died, more than 50 people were injured, and more than 100 families were displaced from their homes as a result of this accident. The accident investigation focused on the following safety issues: the adequacy of Consolidated Edison's (Con Edison) quality assurance and quality control procedures for joining plastic pipes, the effectiveness of Con Edison's public awareness program, the adequacy of Con Edison's gas odor report response, the effectiveness of the New York City Department of Environmental Protection sewer integrity program, and the effectiveness of federal and state oversight. Safety recommendations are made to the New York State Public Service Commission, the City of New York, and Con Edison.

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# Acronyms and Abbreviations

| | |
|---|---|
| API | American Petroleum Institute |
| ASTM | ASTM International |
| Buildings 1642, 1644, 1646 | 1642, 1644, and 1646 Park Avenue |
| Call Center | Con Edison Customer Service Call Center |
| CFR | *Code of Federal Regulations* |
| Con Edison | Consolidated Edison Company of New York, Inc. |
| CSR | customer service representative |
| DOT | US Department of Transportation |
| FDNY | New York City Fire Department |
| FDS | Manhattan Fire Dispatch System |
| GERC | Gas Emergency Response Center |
| HDPE | high-density polyethylene |
| mechanic | gas distribution service mechanic |
| Metro-North | Metro-North Railroad |
| NGA | Northeast Gas Association |
| NTSB | National Transportation Safety Board |
| NYCDEP | New York City Department of Environmental Protection |
| NYCDOT | New York City Department of Transportation |
| NYCRR | *New York Codes, Rules and Regulations* |
| NYPD | New York City Police Department |
| NYPSC | New York Public Service Commission |
| NYSDPS | New York State Department of Public Service |
| OPS | Office of Pipeline Safety |
| PHMSA | Pipeline and Hazardous Materials Safety Administration |
| psig | pounds per square inch, gauge |

# Executive Summary

On March 12, 2014, about 9:30 a.m. eastern daylight time, two adjacent multiuse five-story buildings were destroyed by a natural gas-fueled explosion and resulting fire. The buildings were situated on the west side of Park Avenue between East 116th Street and East 117th Street in the East Harlem district of the Borough of Manhattan in New York City. The violent explosion damaged buildings on the east and west sides of Park Avenue and along East 116th and East 117th Streets. The Metro-North Railroad suspended rail service for about 7 1/2 hours on the elevated railway along Park Avenue because of debris from the explosion on the track. Eight people died, more than 50 people were injured, and more than 100 families were displaced from their homes as a result of this accident. The cost to Consolidated Edison Company of New York, Inc. (Con Edison), of equipment damages, emergency response activities, remediation, and replacement exceeded $1.9 million.

The National Transportation Safety Board determines that the probable cause of the accident was (1) the failure of the defective fusion joint at the service tee, installed by Consolidated Edison Company of New York, Inc., in 2011, that allowed natural gas to leak from the gas main and migrate into the building where it ignited and (2) a breach in the sewer line that went unrepaired by the New York City Department of Environmental Protection since at least 2006 that allowed groundwater and soil to flow into the sewer, resulting in a loss of support for the gas main, which caused the line to sag and overstressed the defective fusion joint.

The accident investigation focused on the following safety issues:

- **Adequacy of Con Edison's quality assurance and quality control procedures for joining plastic pipes.** A Con Edison contractor installed the service tee in 2011 using a Con Edison heat fusion procedure for plastic pipe. Postaccident examination of the separated service tee joint showed fracture features indicating that the surfaces were contaminated, resulting in a weak joint. Review of the Con Edison plastic pipe fusion procedure revealed that some industry-standard steps, such as cleaning the surface with alcohol, were omitted. In addition, inspection of the fusion joint revealed inconsistent bead sizes.
- **Effectiveness of Con Edison's public awareness program.** Con Edison had an extensive public awareness program that included informing the public and gas customers to call Con Edison in the event of a suspected gas leak. This information was included in customer billings, in newspaper advertisements, and in flyers posted in apartment buildings. However, the investigation found that people who said they smelled gas the day before the accident did not call Con Edison, the fire department, or 911.
- **Adequacy of Con Edison's gas odor report response.** About 25 minutes before the accident, Con Edison received a call from a resident of an adjacent building who reported a gas odor inside and outside of his residence. He said the gas was coming from one of the accident buildings. During the call, the Con Edison customer service

representative's computer stopped responding, which delayed the notifications. Although a gas service mechanic was dispatched, the fire department was not notified as required by Con Edison's response procedure.

- **Effectiveness of the New York City Department of Environmental Protection sewer integrity program.** Investigators discovered a large breach in the sewer main near the destroyed buildings that had gone unrepaired for more than 8 years. They also learned of recurring major street repair work in the vicinity of the sewer breach over several years. This work included a repair that was made a few days before the accident to correct significant ground settling below the pavement in the vicinity of the gas main and building service lines.
- **Effectiveness of federal and state oversight.** The state pipeline safety program certifications in Title 49 United States Code section 60105(a) allow states to inspect and enforce intrastate pipeline safety. The state must adopt the minimum federal regulations for pipeline safety. Examination of the New York state pipeline safety regulations revealed that they are less stringent than the federal regulations in two areas: definition of service line and pipeline pressure testing. These deficiencies were not identified by the Pipeline and Hazardous Materials Safety Administration during state program recertifications.

As a result of this investigation, the National Transportation Safety Board makes safety recommendations to the New York State Public Service Commission, the City of New York, and Consolidated Edison Company of New York, Inc.

# 1 Factual Information

## 1.1 Accident Synopsis

On March 12, 2014, about 9:30 a.m. eastern daylight time, two adjacent multiuse five-story buildings were destroyed by a natural gas-fueled explosion and resulting fire. The buildings were situated on the west side of Park Avenue between East 116th Street and East 117th Street in the East Harlem district of the Borough of Manhattan in New York City. (See figure 1.)

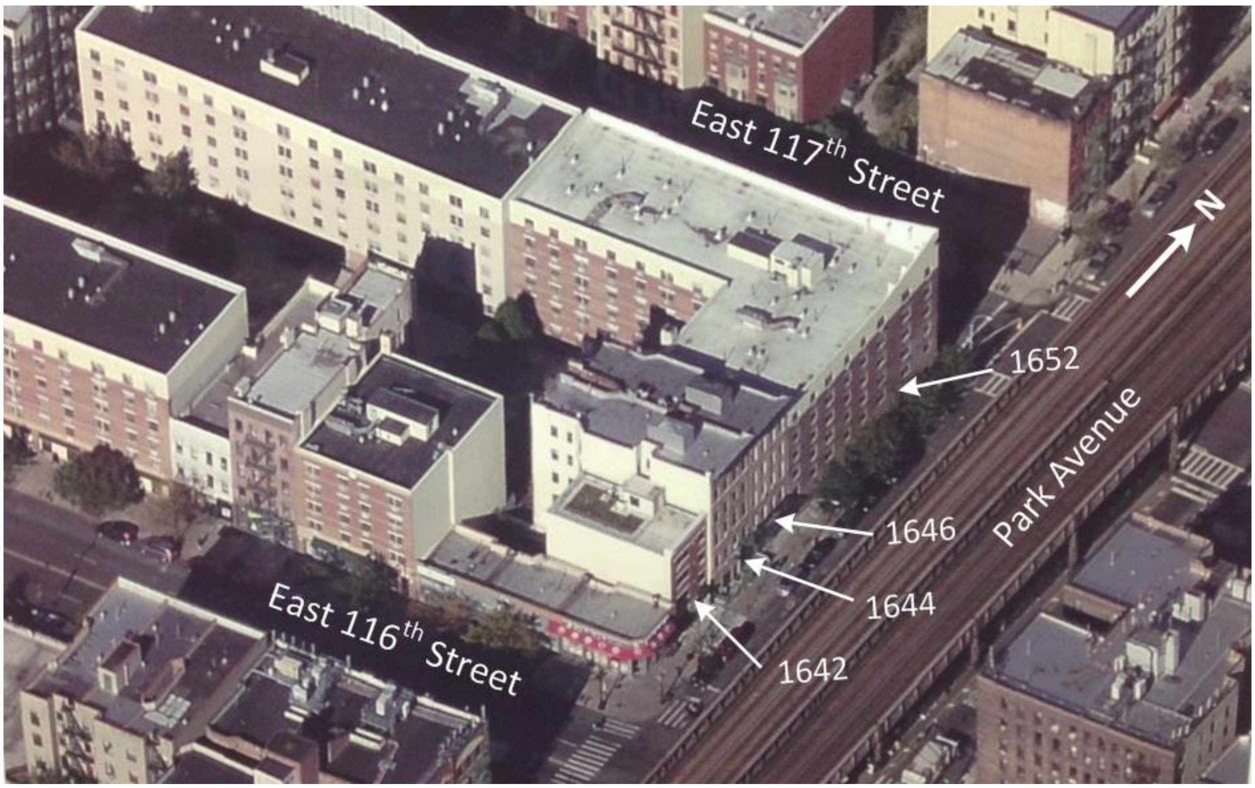


**Figure 1.** Buildings on west side of Park Avenue between East 116th and East 117th Streets before March 12, 2014, accident.

The violent explosion damaged buildings on the east and west sides of Park Avenue and along East 116th and East 117th Streets. The Metro-North Railroad (Metro-North) suspended rail service on March 12 for about 7 1/2 hours on the elevated railway along Park Avenue because of debris from the explosion on the track.

Eight people died, more than 50 people were injured, and more than 100 families were displaced from their homes as a result of this accident. Although the amount of natural gas released from the distribution system could not be accurately estimated, Consolidated Edison Company of New York, Inc. (Con Edison) stated that in the worst-case scenario, at the operating pressure of 8 inches of water column (about 1/3 pound per square inch, gauge [psig]), up to

158 cubic feet of natural gas could be released per minute through the 1 7/8-inch-diameter hole that was tapped into the 8-inch-diameter high-density polyethylene (HDPE) gas main in front of Building 1642. The cost of equipment damages, emergency response activities, remediation, and replacement to Con Edison exceeded $1.9 million.

## 1.2 Accident Site

The building at 1644 Park Avenue (Building 1644) was a five-story walk-up built about 1898. It contained the Spanish Christian Church, which occupied the basement and the first two floors, and three residential floors with two apartments on each floor.[1] This building had an oil-fired heating system, with natural gas used for cooking. Five fatalities occurred in this building. The building at 1646 Park Avenue (Building 1646) also was a five-story walk-up built about 1898. This building contained a piano store that occupied the basement and the first floor and four residential floors with two apartments on each floor; one of the eight apartments was vacant. Three fatalities occurred in this building. The building at 1642 Park Avenue (Building 1642) had four stories and four apartments and was built in 2011. It was significantly damaged in the explosion.

## 1.3 Gas Odor Calls to Con Edison

About 9:06 a.m. on March 12, a resident of Building 1652 called the Con Edison Customer Service Call Center (Call Center) to report a natural gas odor.[2] The caller's building was north of and next to Building 1646. (See figure 1.) The caller reported smelling gas both inside and outside and said that the odor was coming from "another building … right next to [this one]." The caller further described the odor as coming from a building with a piano store. During the call, the Call Center computer system stopped responding to the customer service representative's [CSR] entries), and the CSR put the call on hold several times. The call took about 6 minutes to complete. The CSR told the caller to evacuate immediately, and added, "we'll be there within 45 minutes."

At 9:12 a.m., the CSR called the Con Edison Gas Emergency Response Center (GERC) and spoke with a dispatcher about the gas odor report. Con Edison's *Gas Operations Emergency Response Plan* describes GERC in section 3.2. a. (4) (Con Edison 2014):

> The GERC is responsible for the safe and reliable operation of the company's gas distribution system. Activities include dispatching and directing gas crews in response to gas odor reports and other gas system problems, and monitoring excavation activities in the vicinity of gas transmission mains and identifying/initiating contingency plans. The GERC coordinates emergency response efforts associated with incidents on the gas distribution system and

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[1] The New York City Fire Department (FDNY) determined that the explosion and fire originated inside of 1644 Park Avenue, in the Spanish Christian Church on the first and second floors, when a mixture of natural gas and air was ignited by an unidentified ignition source (FDNY 2014).

[2] See appendix B for a timeline of the activities of Con Edison and first responders beginning with the call to Con Edison.

> implements the incident command system. GERC is responsible for notifying and receiving information from appropriate federal, state, or local agencies, including first responders, regarding gas distribution system status. The GERC maintains the Emergency Contact and Notification list for Gas Operations and first responders. …

The Con Edison computer system was designed so that data from the call taken by the CSR—time, location, content—was transmitted to the GERC computer system. In addition, the Con Edison procedure required the CSR to call GERC to confirm that the key information from the report was received and correctly understood as it had been entered into the computer. On March 12, when the CSR called GERC after receiving the gas odor call from Building 1652, she told the dispatcher that her computer was down, but then she noted that it was back up and said that she was entering a ticket for an indoor gas leak.[3] The dispatcher asked the CSR to call back.

About 9:13 a.m., the CSR made a second call to GERC to confirm receipt by the dispatcher of the indoor gas leak ticket that she had just entered and to confirm the key information provided by the caller. During this call, the CSR gave the address and details of the ticket to the dispatcher. The CSR indicated that the caller had stated that there was a smell of gas both inside and outside. The dispatcher told the CSR that another ticket, for a report of gas odor outside, should be entered into the computer.

About 9:15 a.m. the dispatcher called a gas distribution service mechanic (mechanic) who was about 4 miles away from the location of the gas odor report. The dispatcher told the mechanic that he would receive two tickets for gas odor, one for inside the building and one for outside.

About 9:16 a.m. the CSR made a third call to the GERC dispatcher to follow up the outside gas leak ticket. The CSR told the dispatcher that the computer system was “freezing” and asked if the ticket for Building 1652 had been received. The dispatcher said that it had not.

About 9:19 a.m. the dispatcher called the New York City Fire Department (FDNY) to report the gas odor at Building 1652. During the call, the dispatcher said, “Hold up, no, sorry, hold on one second, hold on, hold on, I’ll call you right back.” After this call, GERC made no calls to the FDNY before the buildings exploded at 9:30 a.m.

About 9:39 a.m. the GERC operations manager called the Manhattan Fire Dispatch System (FDS), which is part of the FDNY, to ask whether the FDNY had received any reports of fire at the Park Avenue location of the gas odor report. The FDNY operator said that there was a report of a “building that exploded” at Park Avenue and 114th Street, it had “collapsed, and it’s on fire.” About 9:46 a.m. the operations manager called all Manhattan gas operations personnel to request that all available personnel respond to the explosion location.

[3] A *ticket* is a work order for a mechanic to investigate a gas odor report.

The GERC operations manager called a gas construction planner about 9:55 a.m. to discuss where to dig fire banks to stop the flow of natural gas to the two destroyed buildings.[4] The operations manager told the planner that he would call back once he determined the distance from the curb line to the gas mains. About 10:08 a.m. he called the New York State Department of Public Service (NYSDPS) to report where the fire banks would be located. Fire bank excavation began in three locations about 10:45 a.m.

By 1:44 p.m. Con Edison had completed the emergency excavations and the necessary pipe work, mechanics had placed stoppers at three locations, and gas flow to the accident scene had stopped.

## 1.4 Emergency Response

Fire department personnel in the fire station at 5th Avenue and West 113th Street, 5 blocks away, heard and felt the explosion and saw a plume of smoke in the direction of Park Avenue and East 114th Street. The two FDNY companies at the station dispatched trucks, and the first unit arrived at the scene about 9:34 a.m. Fire suppression and rescue operations began immediately.

The initial 911 call about the explosion was received at 9:31 a.m. from a witness near the accident site. The details of the call were forwarded immediately to the FDNY and the New York City Police Department (NYPD).

Beginning about 10:00 a.m. about 100 patrol officers were at the accident scene to provide evacuation support, site security, and traffic control. As needed, additional NYPD resources were dispatched to investigate arson and conduct interviews of victims and witnesses to the event.

Also about 10:00 a.m., the deputy commissioner for operations in the New York City Department of Emergency Management arrived at the accident scene and started several activities. These included removal of debris from the railroad track with the help of Metro-North and the NYPD and providing heavy equipment and assisting the FDNY in debris search and removal. Body identification and recovery operations with the office of the chief medical examiner began later, after the gas flow was stopped.

Sometime between 1:30 p.m. and 2:00 p.m., during fire suppression and recovery activities, a hole about 18 inches wide opened up on Park Avenue in front of Building 1642 and began to increase in size. Inside the hole, a high-velocity water stream was spraying against the overhanging pavement until the water main was shut off at 5:20 p.m. Between 3:00 p.m. and 3:30 p.m., firefighters observed a small explosion in the hole that was most likely fueled by natural gas. Late that evening, the hole and the area around it were excavated, filled with gravel,

[4] *Fire banks* are trenches or excavations dug to expose gas mains so gas main stoppers can be installed in the pipes to stop the gas flow.

and covered with steel plates so the FDNY could resume rescue and recovery operations using heavy excavation equipment.

Fire suppression and recovery activities continued for 6 more days and were concluded on March 18 about 5:40 p.m.

## 1.5 Injuries

Eight occupants of the two buildings died in the accident. Several vehicle occupants were injured when debris from the two buildings fell onto the sidewalk and into the street. In addition, several people who were near the two buildings were injured by falling debris. In total, 46 people were transported to local hospitals for treatment for serious or minor injuries.

Two firefighters and 12 police officers were injured during the emergency response. A New York City contractor who was removing debris after the explosion also sustained a minor injury. Table 1 summarizes the injuries.

**Table 1.** Injuries.

| Injury Type | Civilians | Emergency Responders | Total |
|---|---|---|---|
| Fatal | 8 | 0 | 8 |
| Serious | 2 | 0 | 2 |
| Minor | 44 | 15 | 59 |
| Total | 54 | 15 | 69 |

[a] Title 49 CFR 830.2 defines fatal injury as any injury that results in death within 30 days of the accident and serious injury as an injury that (1) requires hospitalization for more than 48 hours, commencing within 7 days of the date the injury was received; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages or nerve or tendon damage; (4) involves any internal organ; or (5) involves second- or third-degree burns, or any burn affecting more than 5 percent of the body surface.

## 1.6 Damages

As a result of the explosion, the buildings at 1644 and 1646 Park Avenue collapsed, and fire erupted in the debris. (See figure 2.) Most of the rear masonry wall of Building 1646 remained standing, with substantial damage. Rescue and recovery operations were hindered by the risk that the wall might collapse.


**Figure 2.** Buildings 1644 and 1646 Park Avenue in New York City after March 12, 2014, explosion.

Building 1642 sustained structural damage from the explosion. The New York City Department of Buildings determined that it was unsafe for occupancy. The explosion also broke windows in many nearby buildings.

Explosion debris fell on the railroad tracks of the Metro-North viaduct. As a result, Metro-North suspended service on the tracks for about 7 1/2 hours to clear the tracks and to inspect the tracks for damage. Upon service resumption, trains were operated at reduced speeds through the accident site area as a precaution to protect personnel and reduce vibrations as rescue and recovery work continued.

## 1.7 Natural Gas and Other Utilities

Natural gas to the buildings on the west side of Park Avenue between East 116th and East 117th Streets, including Buildings 1642, 1644, and 1646, was supplied through a buried 8-inch natural gas pipeline (gas main) owned and operated by Con Edison. The low-pressure (about 8 inches of water column or about 1/3 psig) gas main consisted of 8-inch cast iron pipe, installed about 1887, and 8-inch high-density polyethylene (HDPE) pipe, installed in 2011. Other public utilities buried underneath the pavement in the accident block included a water main, a sewer main, and an electrical conduit. (See figure 3.)

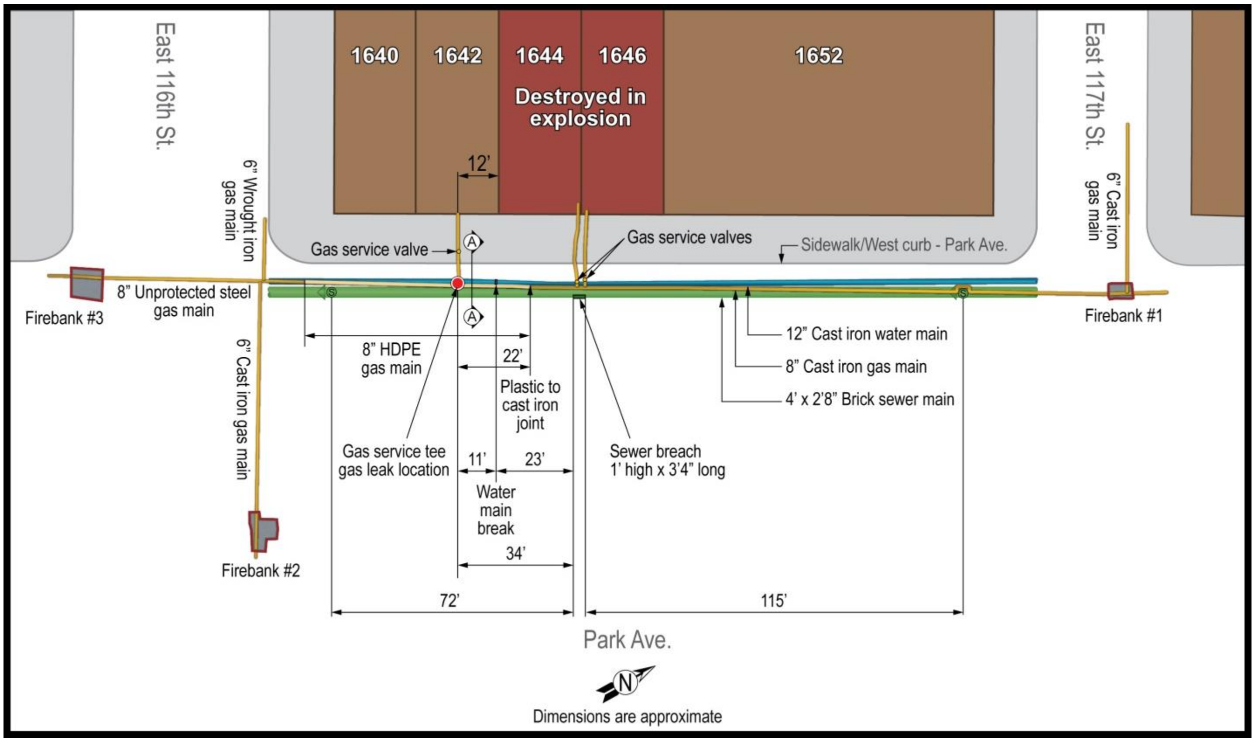


**Figure 3.** Overhead view of accident block.

The 12-inch cast iron water main, installed about 1887, supplied domestic water, typically between 45 and 55 psig, to customers on the west side of Park Avenue in the accident block. The water main was buried about 4 1/2 feet deep. The water main was situated close and about parallel to the 8-inch natural gas main. The New York City Department of Environmental Protection (NYCDEP) was responsible for the water main.

The oval-shaped brick-lined sewer main, constructed about 1873, served customers in the accident block. The sewer main was 32 inches wide by 48 inches high and was situated about 15 feet below the street at the north end, near 117th Street, and about 26 feet below the street at the south end, near 116th Street. The NYCDEP was responsible for the sewer and for collecting and treating wastewater.

In 2011, major work was performed in front of 1642 Park Avenue to connect a sewer lateral and water and gas service lines to the new building.[5] The sewer connection involved digging a trench about 8 feet wide and up to 19 feet deep and connecting an 8-inch sewer lateral to the existing sewer main. The water service line was installed about 4 feet deep and connected to the existing 12-inch cast iron water main. According to the contractor, the excavated area was backfilled and compacted after each installation using material from an approved Department of Transportation yard, and the street was repaved.

[5] A sewer *lateral* is a service line that connects a building to a main sewer line.

The gas service line for Building 1642 was installed about 3 feet deep and about 18 inches horizontally from the water service line. When a cast iron gas main is exposed in connection with utility work, such as the sewer and water installations in 2011, Con Edison policy is to replace the cast iron gas main with HDPE pipe. In the case of Building 1642, in 2011 Con Edison replaced about 72 feet of 8-inch-diameter cast iron pipe with 8-inch HDPE pipe in the vicinity of the construction area. A 2-inch-diameter HDPE gas service line and a fusion-welded plastic service tee were connected to the new 8-inch HDPE low-pressure gas main to supply natural gas to the new building. The vertical separation between the bottom of the HDPE gas main and the top of the cast iron water main was less than 2 inches in the vicinity of the new service tee installation. (See figure 4.)

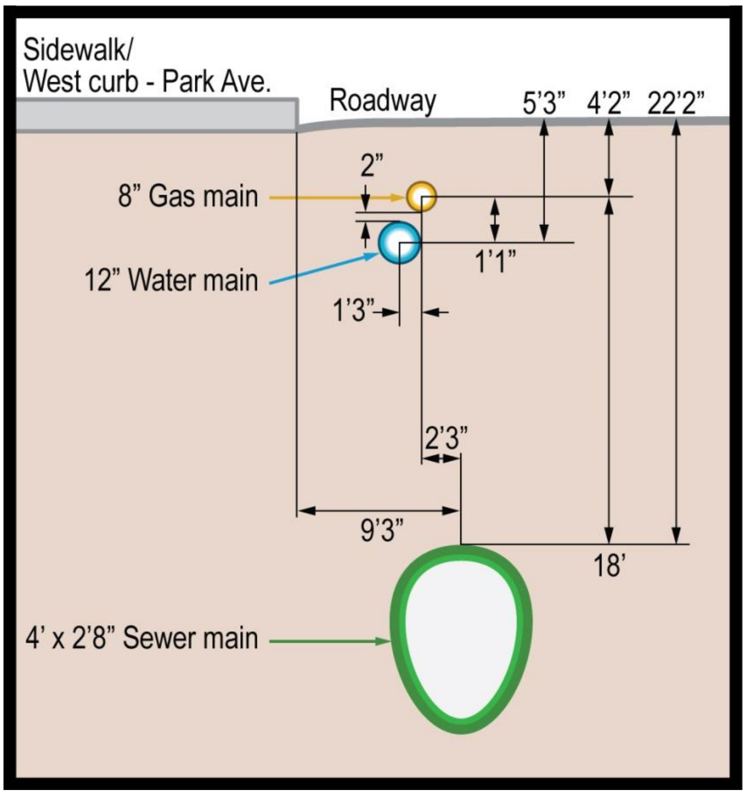


**Figure 4.** Gas main, water main, and sewer main positions below road at gas service tee location.

## 1.8 Preaccident Activities

### 1.8.1 Gas Odor Reports

During postaccident interviews conducted by the FDNY, several people residing in Buildings 1642, 1644, and 1646 said that they smelled gas the evening of March 11, 2014 (the night before the accident). For example, a person living in an apartment in Building 1646 said he smelled gas about 11:00 p.m., when he went out the front exterior door to throw out garbage. A bookkeeper for the Spanish Christian Church in Building 1644, who left the church about

9:50 p.m. on March 11, said that she smelled gas outside the church and told the person at the counter in the deli next door. A woman living in an apartment in Building 1642 said she smelled gas in her apartment the evening of March 11. She said she smelled gas again in the lobby of the building about 8:35 a.m. the next day, March 12 (the day of the accident), as she was leaving the building. However none of these people who said they smelled gas before the accident called the Con Edison Call Center to report the gas odor.

In addition to the emergency reporting provided through traditional 911 services, New York City operates a 311 line to provide the public with easy access to New York City government information and nonemergency services. The 311 system offers users the ability to access and enter information online, through text messaging, by phone, over Skype, or using a smartphone application.[6]

The 311 electronic reporting system does not offer a selection specifically for reporting natural gas releases or odors, but reports called into the 311 operator are logged into the system. At the time of the accident, 311 operators directed people with gas odor reports to call the gas company.

In an interview conducted by the FDNY on April 1, 2014, a resident of Building 1644 said she had called 311 to report "… the gas smell …" the day before the accident. An online search of the 311 database for Park Avenue addresses between East 116th and East 117th Streets returned 226 entries; none was a gas odor report. Furthermore, no reports of gas odor were made to 311 around the time of the accident.

Gas odor reports also may be reported through the NYSDPS. The NYSDPS is the staff arm of the New York Public Service Commission (NYPSC), which is the state agency responsible for inspecting natural gas pipelines for the Pipeline and Hazardous Materials Administration's (PHMSA) Office of Pipeline Safety (OPS). To better direct gas leak and odor calls received by the NYSDPS, the department has developed a procedure for reporting incidents. If a caller is reporting a leak inside a building, the caller is instructed to leave the building and call the gas company or 911 from a safe location. The caller may follow up with NYSDPS if further assistance is necessary. If a caller is reporting a gas odor outside, the department records the call and contacts the gas company while the caller remains on the line. A copy of the gas odor report is sent to the New York state Office of Gas Safety, which determines whether followup is required.

[6] The 311 system supports payments such as those for parking tickets, dog licenses, and water and sewer bills; accepts complaints such as those about noise, public hazards, and parking; and provides neighborhood information, such as the police precinct number and trash and recycling pickup. Online reporting is available for more than 50 languages; the 311 number supports more than 170 languages.

### 1.8.2 Gas Leak Surveys

In residential districts, Con Edison conducted walking leak surveys using infrared gas detectors.[7] Con Edison conducted these surveys over gas service lines every 3 years and over gas distribution mains every year. The most recent service line survey before the explosion was conducted on August 3, 2011. In addition, Con Edison annually conducted mobile 5-mph leak surveys of distribution mains in nonbusiness areas. The most recent mobile survey of the accident block was in July 2013. Con Edison also conducted weather-related mobile 15-mph leak surveys on 4-inch, 6-inch, and 8-inch cast iron pipelines as needed.[8] In the month before the explosion, on February 10 and 28, 2014, Con Edison conducted two of these surveys in the accident block. No natural gas leaks were detected in the distribution main in the accident block in any of these three surveys.

### 1.8.3 Water Leak Surveys

To detect leaks in water distribution lines, the NYCDEP used acoustic equipment to survey pipes for the noise made by leaking water. The NYCDEP surveyed the water main and service lines in the accident block six times between January 2012 and March 5, 2014, and no leaks were detected.

National Transportation Safety Board (NTSB) investigators reviewed the record of calls to the New York City 311 line between March 20, 2004, and March 20, 2014. No calls reporting water leaks on the street or into any property basements were made from the accident block during the 10 years before the accident.

### 1.8.4 Sewer Inspections

The NYCDEP conducted internal inspections of the sewer main in the accident block using a video camera. The most recent inspections were conducted on October 16, 2006, and August 24, 2011. (See figure 5.) Both video inspections show damage to the sewer line in the same location and to the same extent. The sewer breach was about 12 inches high by about 40 inches wide. The observed damage, shown in figure 5, identified in the October 2006 inspection, is in front of Buildings 1644 and 1646. When the NYCDEP becomes aware of a sewer breach, it makes a determination either to repair the breach or to monitor it.

[7] An *infrared gas detector* is a device that passes infrared light through an atmospheric gas sampling chamber and a reference gas chamber to determine the gas concentration in the sample chamber.

[8] A *weather-related survey* is conducted when the weather conditions meet certain parameters that match those that have resulted in an increased number of cast iron pipe leaks. Examples are temperatures below 32°F and significant variations in temperature that fluctuate above and below 32°F.


**Figure 5.** Sewer damage on south-facing video frame from October 2006 inspection.

### 1.8.5 Street Cave-ins and Repairs

The New York City Department of Transportation (NYCDOT) had performed road repair work in the accident block on several occasions in the years before the accident. On June 2 and June 8, 2004, both the NYCDOT and the NYCDEP received similar reports about a cave-in on Park Avenue between East 116th and East 117th Streets. The NYCDEP wrote in its report that it had not found the reported cave-in. The NYCDOT repaired the street on December 17, 2004. Additional reports of a cave-in or depressed pavement on Park Avenue between East 116th and East 117th Streets were made to the NYCDEP in 2004 and 2007; in 2004, the NYCDOT reported "a sewer undermining condition," and in 2007, the NYCDEP received a report of depressed pavement. On October 13, 2009, an anonymous caller reported an area of the street at 1646 Park Avenue that had sunk several inches. The NYCDOT inspector noted that the area was about 7 feet by 20 feet, had sunk 2 to 3 inches, and had been patched previously. On June 3, 2010, a 5-inch-deep depression in front of Building 1644, measuring about 20 feet by 30 feet, was reported to the NYCDOT. The depressed area included a 10- by 20-foot road patch from a previous repair. On September 6, 2013, a 9- by 15-foot area of the road that was about 1 inch deep was repaired with an asphalt patch. On March 9, 2014, an area in front of Building 1646 measuring about 14 feet by 18 feet and about 1 1/2 inches deep was repaired using hot asphalt. According to the repair foreman, the repaired area was an asphalt patch from a previous repair.

## 1.9 Con Edison Operations

### 1.9.1 Heat Fusion Procedure

In 2011, to supply natural gas to the new building at 1642 Park Avenue, a 2-inch-diameter HDPE gas service line and a fusion-welded plastic service tee were connected to the new 8-inch HDPE low-pressure gas main.[9] Con Edison used a saddle fusion joint to connect the service tee to the gas main. A saddle fusion joint is the welded portion between a service tee and a pipe. The term also refers to a joint that results when sections of pipe and fittings are fusion joined and those segments are oriented perpendicular to each other. (See figure 6.) The Con Edison heat fusion procedure for making a plastic pipe saddle fusion joint is "Heat Fusion Joining of Polyethylene Plastic Pipe/Tubing Fittings for Gas Mains and Services," specification G-8123-12. It is supplemented by "Operation of Butt Fusion and Sidewall Fusion Equipment," which provides detailed instructions for operating the saddle fusion machine (shown in figure 7) and specific fusion parameters for making the saddle fusion joint.[10]

[9] *Fusion welding* is a welding process in which materials of similar compositions and melting points are melted together, or fused, to create a strong bond.

[10] A *saddle fusion machine* is an apparatus used to hold and align the fitting to the pipe and the contoured heater blocks during fusion welding. A *butt-fusion joint* is the welded portion between two pipe segments that are aligned end to end.


**Figure 6.** Exemplar gas main with service tee welded to it.

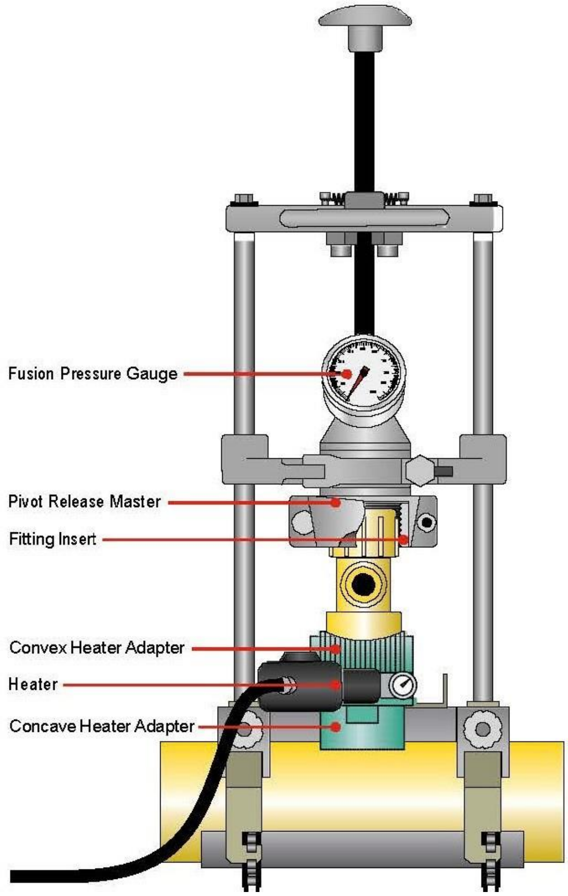


**Figure 7.** Saddle fusion machine.

The Con Edison fusion procedure required that the surfaces to be joined be roughened with emery cloth. The emery cloth leaves behind dirt fragments, but the procedure did not require the technician to clean the surfaces after using the emery cloth. The procedure also did not require the technician to use a cleaning solution on the surfaces before fusing the joint. Oil or other contaminants on the surfaces can result in a weak joint. The industry standard ASTM F2620, *Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings*, specifies the use of alcohol to clean the surfaces before they are fusion joined.[11]

## 1.9.2 Emergency Call Response

In his interview with NTSB investigators, the Con Edison GERC dispatcher received a call from the CSR at 9:12 a.m. informing the dispatcher that she was entering information from a gas odor call. The second call from the CSR to the dispatcher occurred a minute later. The

[11] ASTM (ASTM International, formerly known as the American Society for Testing and Materials).

dispatcher said he thought the message from the CSR (about a gas odor report on Park Avenue) was abnormal because it was about a gas odor both inside and outside the apartment. He said further that GERC has certain conditions that require the CSR to notify the fire department. A report of a gas odor both inside and outside is one such condition.

The dispatcher said that he considered the situation hazardous, and that is why his fellow dispatcher called the fire department at 9:19 a.m. However, the dispatcher did not complete the call about the odor report but promised to call the fire department back, which he never did.

The GERC operations manager told investigators that it was his understanding that the dispatcher who called the FDNY believed he had provided all the pertinent information, and that the dispatcher meant to say “good-bye” and not “I will call you back.” The operations manager further stated that if the call to the fire department had been completed properly, it was his understanding that the fire department would have dispatched personnel to the reported leak site. The Con Edison mechanic arrived in the general area of` the accident less than 25 minutes after he was dispatched, about 9:39 a.m., which was a few minutes after the explosion.

The explosion prompted numerous 911 calls to the fire department. The first FDNY responders, from a nearby fire station, arrived at the scene less than 3 minutes after the first 911 call.

### 1.9.3 Pipeline Integrity Management

Con Edison implemented its gas distribution integrity management program in August 2011. Federal regulations require review of the program every 5 years. Con Edison did so more frequently, conducting complete plan updates in 2011 and 2012 and an annual update in 2013. Con Edison used a risk scoring process to evaluate and rank the gas distribution system. Some of the threat types evaluated include corrosion, natural forces, and excavation damages.

The Con Edison policy requires installation of an isolation valve at each street intersection when a new or replacement pipe is installed. This is intended to improve Con Edison’s ability to quickly isolate a leaking pipeline and reduce the number of customers who are disrupted by a gas supply interruption. The isolation valve installation program does not consider currently installed pipelines, nor does it take into account the length of the pipe or the population density. The 2011 replacement of cast iron pipe with HDPE pipe on Park Avenue did not include the installation of an isolation valve, contrary to Con Edison policy.

### 1.9.4 Emergency Preparedness and Response

Con Edison has developed and maintains various preparedness plans that include training activities and exercises. The company has conducted at least 38 formal training activities and drills specific to gas pipeline operations with various New York City emergency services agencies. In addition, Con Edison has conducted at least one internal unannounced communications drill involving GERC and Con Edison employees in all regions who respond to emergencies.

## 1.10 Tests and Research

### 1.10.1 Materials Laboratory Examination of Accident Pipe and Joint

The NTSB examined segments of the 8-inch-diameter HDPE gas main, the HDPE service tee, and the 2-inch-diameter HDPE service line to Building 1642. A special type of service tee incorporates an internal circular steel cutter. (See figure 8.) This type of service tee can be installed onto a pressurized main without shutting off the natural gas supply and without interrupting service to other customers. Figure 9 shows the segments of the accident pipes and the service tee used to tap into the gas main.


**Figure 8**. Exemplar service tee showing cutter and seal cap.

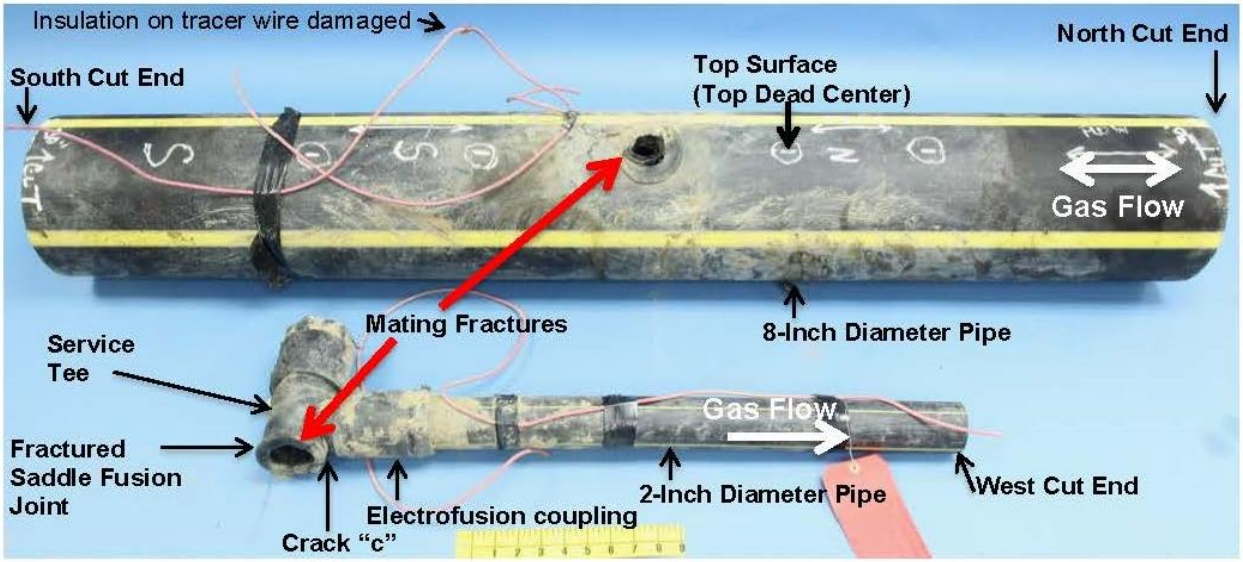


**Figure 9.** Accident 8-inch-diameter HDPE service main (top) and HDPE service tee at left of 2-inch-diameter HDPE service pipe (bottom).

Figure 10 shows the positions of the accident HDPE service main, service tee, and HDPE service line relative to each other as they were installed. The service tee was attached to the top of the 8-inch-diameter main by a saddle fusion joint. Preliminary visual examination of the separated joint between the service tee and the gas main revealed a fracture in the saddle fusion joint. The service tee also contained a crack at the lower corner outlet portion that leads to the service line. (See Crack "c" in figure 9.)

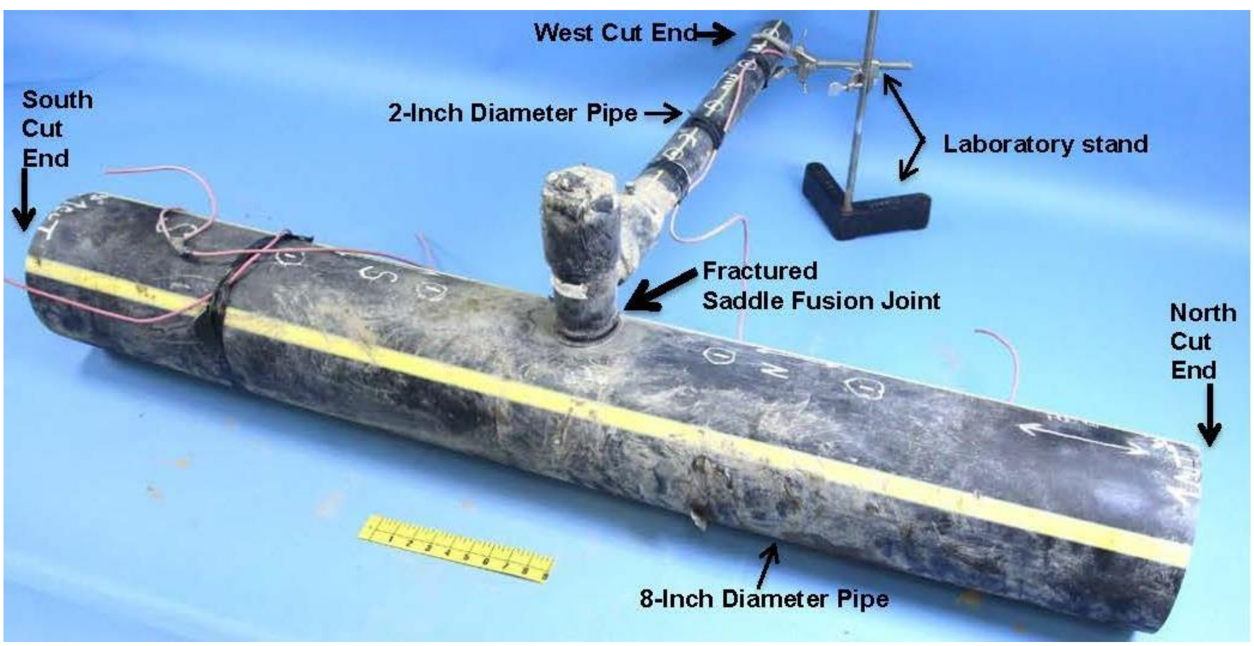


**Figure 10.** Installed configuration of accident 2-inch-diameter service pipe and 8-inch-diameter main.

### 1.10.2 Saddle Fusion Joints

Making a saddle fusion joint includes the following three essential steps: the two surfaces to be joined are roughened with emery cloth, both surfaces are heated simultaneously using a hot plate preheated to between 475°F and 525ºF under pressure, and then the two surfaces are joined under pressure. The heat fusion process for making a saddle fusion joint produces three distinct fusion beads: tee bead, pipe bead, and heating iron bead. (See figure 11.)

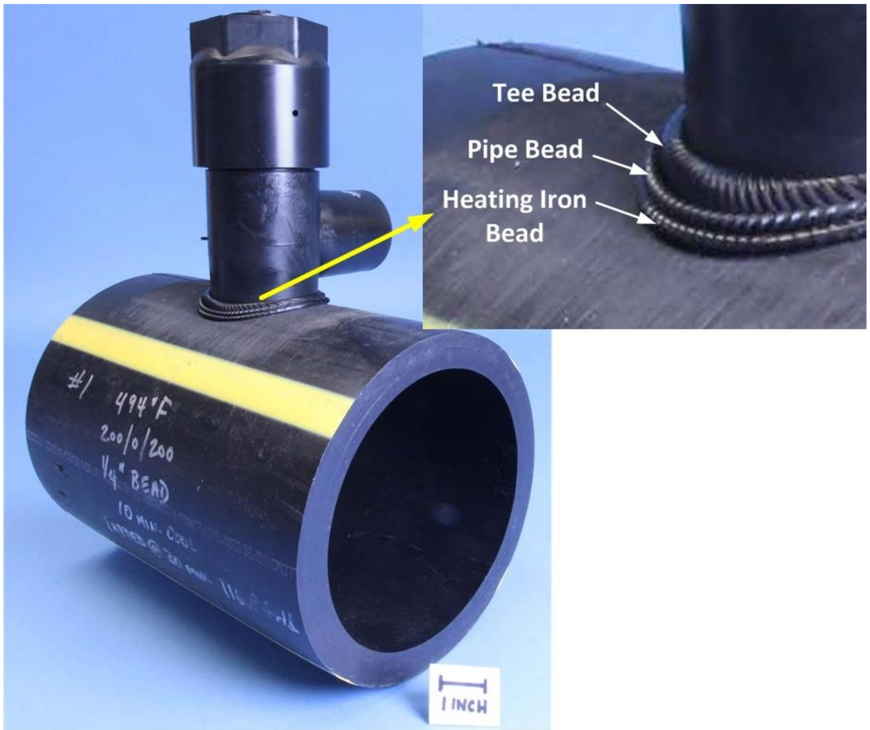


**Figure 11.** Exemplar saddle fusion joint service tee assembly with a round base portion and showing three distinct fusion beads.

After the saddle fusion joint cools to ambient temperature and the service pipe is installed downstream of the service tee to a closed valve, the internal steel cutter of the service tee is screwed into the gas main using a wrench. This cuts a hole in the plastic gas main. The cutter is then backed out of the new hole and into the top of the service tee, allowing gas to flow through the service tee into the downstream pipe. The wrench is removed from the cutter and the service tee cap is installed.

As a part of the investigation, several experiments and exemplar saddle fusion joints were made at Georg Fischer Central Plastics facility in Shawnee, Oklahoma, using a service tee of the same model and material as the accident tee.[12] The fusion machine, heater plate, and heater

[12] Georg Fischer Central Plastics is the manufacturer of the service tee that was involved in the accident.

adapter plates with serrated surfaces were the same model as those that were used to make the saddle fusion joint involved in the accident.

In one experiment, the surfaces of the pipe and the service tee to be joined were heated with heater adapters with serrated surfaces, but the pipe and the service tee surfaces were not joined, and the parts were allowed to cool to room temperature. Figure 12 shows the serrated impression pattern on the service tee inlet consistent with the serrated pattern of the heater adapters.

**Figure 12.** Inlet face of exemplar service tee that was pressed against heater adapter plate (heating iron) preheated to about 500°F but not fusion joined to a pipe.

In another experiment, the surfaces of an exemplar pipe and exemplar service tee were heated using heater adapters with serrated surfaces and joined using the fusion joining procedure. Another set of an exemplar pipe and service tee had a soybean oil mold release agent sprayed on the surfaces to be joined and the heater adapters to simulate contamination in the fusion joint. Both sets of exemplar pipes and tees were then heated and joined using the fusion joining procedure. The service tee fusion joint correctly made and the joint that was contaminated before joining were subjected to drop weight tests.[13] In the drop weight test, which is designed to cause a fracture in a fusion joint, including correctly made joints, a 40-pound weight is dropped from a height of 4 feet. Both service tee fusion joints fractured through the fusion interface (that is, between the tee bead and the pipe bead) as intended. The mating fracture faces of the correctly made joint were smooth, indicating complete fusion. In contrast, the joint that had contaminated surfaces exhibited a radial band pattern consistent with incomplete fusion. (See figure 13.) Incomplete fusion results in a weak bond.

[13] The drop weight test is one of a series of tests used by industry for qualification of polyethylene saddle-fused joints. "Standard Practice for Qualification of Polyethylene Saddle-Fused Joints," ASTM F905.

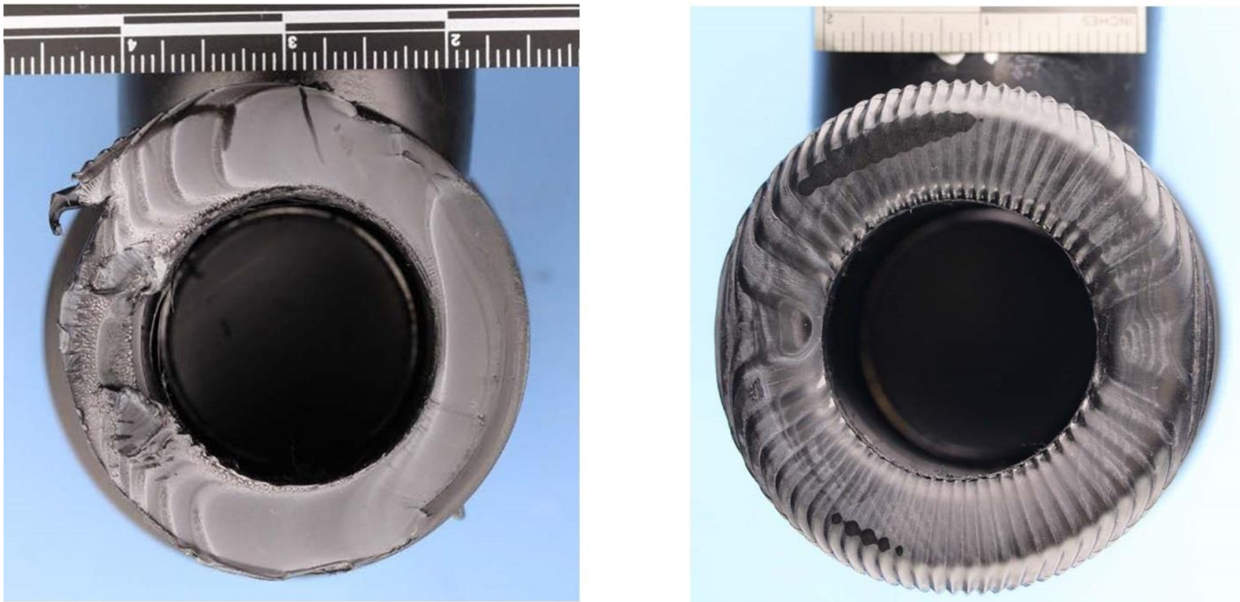

**Figure 13.** Fracture faces after drop weight tests on exemplar service tee inlet fusion joint from the sound fusion joint (left) and the oil-contaminated fusion joint (right).

### 1.10.3 Accident Service Tee

Postaccident examination of the service tee revealed that the service tee-to-pipe fusion joint was completely separated. The service tee also contained a crack in the lower corner of the tee outlet. (see “Crack c” in figures 9 and 14.) The two faces of the joint fracture are shown in figures 14 and 15.

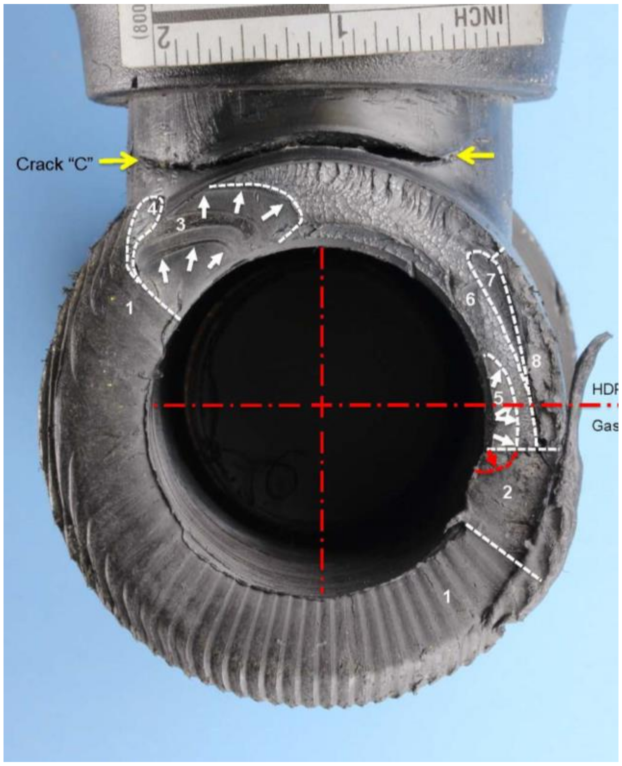


**Figure 14.** Upper fracture face (saddle end) recovered from accident saddle fusion joint.

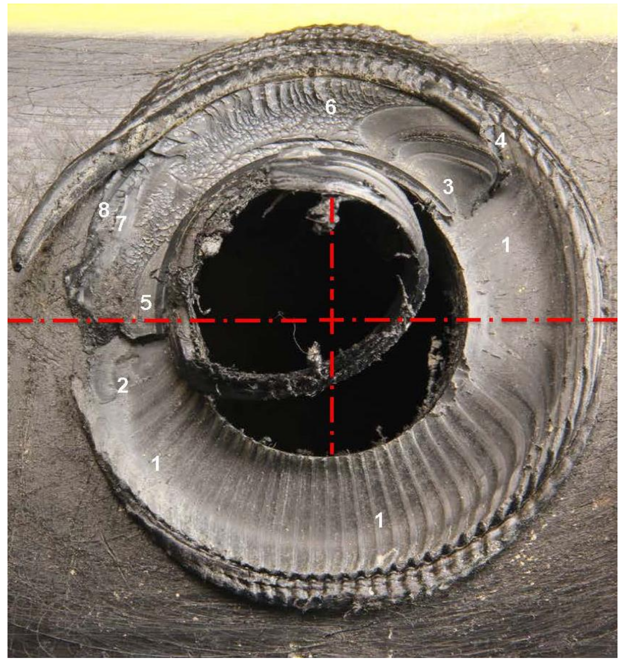

**Figure 15.** Fusion joint on 8-inch gas main recovered from accident site.

The upper face of the fracture showed fracture features in eight regions (labeled 1 through 8). The fracture intersected the fusion interface between the tee bead and the pipe bead through about 60 percent of the circumference of the service tee fracture face. This arc length around the separated saddle fusion joint exhibited a radial band pattern consistent with incomplete fusion, which is a weld defect. The radial band pattern extended into regions 1 and 2. On the upper fracture face the radial band pattern in region 2 was obliterated by mechanical damage. The dashed line in region 2 in the lower right quadrant indicates a portion of the fracture face (in region 5) that extended underneath region 2. The curved rib markings in regions 3 and 5 show the general direction of crack propagation (indicated by arrows), consistent with a crack that propagated away from the radial band portion of the fracture in regions 1 and 2. Region 4 is located at the fractured tee bead portion and contains elongated fibrils.[14] Region 6 contains features consistent with void coalescence. Regions 4 and 6 are both consistent with final overstress fracture. The fracture portion in region 7 contained Wallner lines and rib marks consistent with a fracture that generally propagated radially outward.[15] Region 8 contains coarse

[14] A *fibril* is polymer drawn out and oriented into an elongated filament.

[15] *Wallner lines* are regular, periodic lines on a fracture surface caused by the interaction of reflected stress waves with the front of a propagating crack. The curvature of the lines often indicates the general direction of fracture propagation. *Rib marks* are prominent randomly spaced lines on a fracture face that typically are indicative of crack arrest or changes in crack velocity. The curvature of rib marks often indicates the general direction of fracture propagation.

white dimple features and the longest fibril typical of ductile deformation, consistent with its being the last portion of the fusion joint to fracture.

The coiled plastic portion in the center, at the bore, in figure 15 is a remnant of the gas main from the tapping process. The radial band pattern is visible on this side of the fracture face, and extends into regions 1 and 2. The Con Edison fusion procedure requires that the surfaces to be joined are roughened with emery cloth. The surface of the pipe in the area of the fusion joint exhibited a rough texture consistent with a surface that had been roughened with emery cloth. The surface texture of the fusion beads shows a serrated pattern consistent with the use of a serrated heater adapter to heat the surfaces to be joined.

The accident service tee also contained a crack at the corner junction between the main body and the service line fitting. (See "Crack c" in figures 9 and 14.) The crack extended through the thickness of the tee wall. The circumferential crack on the outer surface was about 3 inches long on the outer surface and 2.3 inches long on the inner surface. The widest portion of the crack measured about 0.08 inch and was located at the bottom of the tee outlet.

The fracture features indicated that the crack emanated from the outer surface at the lower corner fillet (relief radius) between the vertical tube portion of the tee and the horizontal outlet portion of the tee that leads to the service line. The fracture extended up and through the wall thickness of the horizontal outlet portion of the tee, then propagated laterally to both sides of the tee. Examination of the fracture features showed that some locations had evidence of parallel (step-like) lines that were oriented perpendicular to the direction of fracture propagation, consistent with Wallner lines. The fracture face exhibited features consistent with an overstress fracture. The fracture face of the crack at the bottom corner of the outlet exhibited round or volcano-like crater fracture features that were similar to those found in portions of the fracture face of an exemplar saddle fusion joint that was subjected to drop weight testing.

### 1.10.4 Accident Saddle Joint Fusion Bead Size

According to the Con Edison joint fusion specifications for the 8-inch-diameter main and service tee combination, the proper size of the tee bead that extends entirely around the service tee should be between 3/16 inch (0.1875 inch) and 1/4 inch (0.25 inch). This size requirement applies only to a molten tee bead as it is squeezing out between the joint tee and the heater adapter during the fusion process and is also referred to as the "melt bead size." This size requirement does not apply to any of the beads after they have cooled. (See figure 16.)

**Figure 16.** Exemplar saddle fusion joint service tee assembly with a round base portion showing three distinct fusion beads.

On the accident main and the service tee, the sizes of the three solidified fusion beads were measured at 12 locations about evenly spaced around the circumference of the separated saddle fusion joint. The sizes of the solidified beads around the joint were not uniform. The size of the tee bead measured between 0.133 and 0.180 inch, the size of the pipe bead measured between 0.041 inch and 0.165 inch, the size of the iron bead measured between 0.048 inch and 0.182 inch. Industry standards, such as ASTM D2657, *Standard Practice for Heat Fusion of Polyolefin Pipe and Fittings*, indicate that the beads should be uniformly shaped and sized all around the joint.

### 1.10.5 Gas Pipe Size and Dimensional Conformity

NTSB investigators measured the dimensions of the 8-inch main and the 2-inch service line in accordance with ASTM D2513, *Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing and Fittings,* and ASTM D2122, *Standard Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings*. For each pipe they measured the average outer diameter and the thickness. They also calculated the variation in pipe wall thickness around the circumference of each pipe. All of these, for both the 2-inch pipe and the 8-inch pipe, were within the ranges specified in the ASTM standards.

### 1.10.6 Mechanical and Physical Properties

NTSB investigators removed plastic material samples from the gas main and the service tee for testing. They tested the samples to determine the tensile strength at yield and elongation at break. They analyzed the samples to determine melt flow indexes, carbon black contents, densities, melting temperatures, and molecular weight distributions and to obtain Fourier transform infrared spectra.[16] The results indicated that the material properties were consistent with HDPE.

[16] *Fourier transform infrared spectroscopy* is used to identify the composition of polymeric and organic materials.

### 1.10.7 Finite Element Modeling

Finite element modeling[17] was used to study possible loading scenarios applied to the plastic pipe assembly. A three-dimensional finite element model of the main pipe, service tee, and service line was constructed using specification drawings and measurements of the accident parts. The lengths of the main pipe and service line varied for different load cases examined. The stress-strain behavior of the HDPE material in the assembly was extracted from tensile tests of samples taken from the accident parts. A failure strain was calculated from the tensile test and validated using a finite element model of a test on an exemplar main pipe/service tee assembly that was loaded in combined bending and tension.

Two zones of cracking in the pipe assembly were of interest. The first zone of cracking was in the saddle fusion joint between the main pipe and the service tee. The second zone of cracking was at the lower corner outlet portion leading to the service line. All of the loads were applied quasi-statically.

Five of the nine loading cases examined simulated sagging during normal service as a result of loss of support from the surrounding soil coupled with deadweight loads from the soil and pavement above the gas main. The finite element modeling showed that the loads from sagging in normal service were unlikely to cause the crack in the service tee body.

Four of the nine cases applied higher loads or displacements that could have been introduced during postaccident excavation. The loads simulating the postaccident excavation were large enough to cause the service tee body crack.

For either of the assumed initial separations at the saddle fusion joint, it was possible for the remaining ligament (regions 3 through 6, or regions 4 through 6 in figure 14) to carry sufficient load to allow the crack to initiate in the service tee body. In addition, the modeling showed that sagging of the gas main in normal service would open a portion of the assumed initial separation by about 0.05 inch to 0.10 inch.

### 1.10.8 Metallurgical Examination of Cast Iron Water Pipe

The NTSB examined the 12-inch-diameter cast iron water main, which contained a circumferential crack. About 2 inches of the circumference at the bottom of the pipe remained intact when the pipe was excavated. Metallographic examination of a polished and etched specimen taken from an arbitrary location of the water main showed evidence of graphite flakes consistent with the microstructure of cast iron. Chemical analysis of the sample taken from the pipe was consistent with the composition of gray cast iron, which is typical for pipe used in natural gas service.

[17] *Finite element modeling* is a simulation of a structure under applied loads using a computer model of its geometry and material properties. A finite element model consists of a virtual assembly of many simplified structural elements used to approximate a complex structure. The behavior of the complex structure is then calculated by combining the actions of the interconnected simpler elements.

Small sections of the pipe were cut for further evaluation. The wall of the 12-inch cast iron pipe measured between 0.62 inch and 0.71 inch thick. Tubercles as thick as 1 inch were observed on the inside surface of the pipe.[18] Two ring segments about 6 inches long that included each side of the separation were cut from the pipe. (See figure 17.) After the segments and fracture faces were extensively cleaned, small black-brown oxide-like features were observed on the bottom half of the fracture face in isolated areas. (See figure 18.)

Detailed examination of the north face of the separated joint revealed areas adjacent to the inner and outer pipe surfaces that exhibited black regions consistent with graphitic corrosion.[19] Graphitic corrosion extended through the pipe wall at about the 4 o'clock, 10 o'clock, and 12 o'clock positions. In general, graphitic corrosion on the inner surface of the pipe was greater than that on the outer surface. In several areas of the pipe, graphitic corrosion on the inner surface extended to as much as 50 percent of the wall cross section.


**Figure 17.** Mating fracture faces of 12-inch cast iron water main.

[18] *Tubercles* are knoblike mounds resulting from localized corrosion. They can grow into tubes or plates, which can, in time, occlude the entire pipe interior.

[19] *Graphitic corrosion* is selective leaching of iron from gray cast iron or conversion of iron to corrosion products, where iron matrix are removed and a network of graphite flakes remain intact.

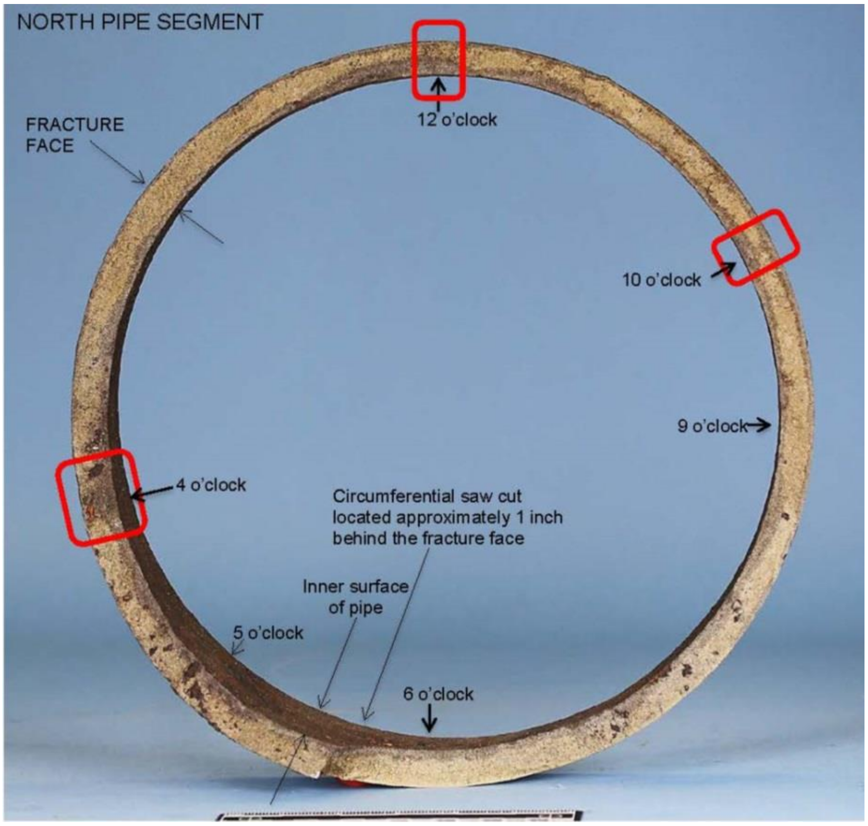


**Figure 18.** North water main pipe segment fracture face showing regions of graphitic corrosion that appear as dark features adjacent to outer and inner surfaces.

## 1.11 Public Awareness

### 1.11.1 Regulatory Requirements

Title 49 *Code of Federal Regulations* (CFR) 192.616 requires local gas distribution companies to have a written continuing public education program. Part of the objective of a public education program is to increase the awareness of the affected public and stakeholders of the presence of gas pipelines and to help the public understand what actions can be taken to respond to pipeline emergencies. The programs are required to follow the general recommendations in the American Petroleum Institute (API) recommended practice, *Public Awareness Programs for Pipeline Operators*, API RP 1162, 2003. Part 192 requires the public awareness programs to educate both the public and appropriate government organizations about the hazards associated with unintended releases from gas pipelines, the physical indications that a release may have occurred, the steps that should be taken for public safety in the event of a gas pipeline release, and the procedures for reporting natural gas releases.

API RP 1162 covers public awareness for both intrastate and interstate natural gas and hazardous liquid pipelines and for local distribution and gathering systems. It is divided into eight sections that cover program development, intended audiences, message content and delivery methods, supplemental enhancements to the program, program documentation and record keeping, and evaluation of program effectiveness. A public awareness program should be evaluated to determine whether the program is effective in meeting the objectives documented in the program so that pipeline operators can measure the success of the program and implement needed improvements. The recommended practice identifies four areas for measuring the effectiveness of a public awareness program:

- Is the information reaching its intended audience?
- Is the audience understanding the message from the operator?
- Is the audience acting in accordance with the information supplied to them?
- Is the program resulting in fewer accidents such as in the case of excavation damage?

These "evaluations of effectiveness of program implementation," should be conducted not more than 4 years apart.

### 1.11.2 Con Edison Public Awareness Program

The Con Edison public awareness program was developed from a template developed by the Northeast Gas Association (NGA). The template, *Regional Public Awareness and Education Program for Gas Distribution and Transmission Pipelines*, follows the requirements in 49 CFR 192.616 and incorporates all of the elements covered by API RP 1162. Con Edison tailored the NGA template specifically for its operations with the addition of appendices. The Con Edison public awareness program was first released in June 2006; the most recent version (revision B2), which was in effect at the time of the accident, is dated July 2012.[20] The document covers stakeholder audiences, message type and content, frequency and method of message delivery, supplemental program materials, and evaluation of the program. The appendices are updated continuously as new content is delivered to stakeholders or new program evaluations are added.

The Con Edison program states that its overall goal is to enhance public, environmental, and property protection through increased public awareness and knowledge. Two key elements of the public awareness program include educating stakeholders on how to notify the pipeline operator in the event of an emergency or with general questions or concerns; and educating stakeholders on how to respond safely to a pipeline emergency. The stakeholder audiences identified are the affected public, emergency officials, local public officials, and excavators. The definition of each audience follows those in API RP 1162.

[20] The program was revised in January 2009 (Rev. A), April 2011 (Rev B), November 2011 (Rev. B1) and July 2012 (Rev. B2).

### 1.11.3 Con Edison Public Awareness Program Leak Recognition and Response

The Con Edison public awareness program includes the following regarding pipeline leak recognition and response:[21]

"What should you do if you suspect a leak?"

- Move to a safe environment,
- Call 1-800-75-CONED (1-800-752-6633),
- Do not strike match, use telephones, switch on/off appliances, lights, or even a flashlight in the area where you smell gas. These items can produce sparks that might ignite the gas and cause an explosion.

Before March 2014, the Con Edison public awareness communications did not include the information that the public could report suspected natural gas leaks to the fire department, the police department, or to the 911 emergency telephone number. The materials stressed the importance of contacting the company in the event of a gas leak. The public awareness materials directed only to excavators stated that blowing gas should be reported as an emergency to 911.

After the March 12, 2014, accident, Con Edison added to its public awareness materials and communications the information that the public could report suspected natural gas leaks to the fire department through the 911 emergency number. The company also launched a new public awareness campaign in March 2014: "Smell Gas Act Fast." This new message notes that members of the public may report suspected gas leaks to 911 or 1-800-75-CONED. To reach its customers in master-metered buildings, Con Edison mailed bilingual (English and Spanish) "Smell Gas. Act Fast." peel-and-sniff postcards to about 1 million households.[22] Materials for the new campaign are provided in English, Spanish, Chinese, Korean, Russian, and Haitian Creole.

### 1.11.4 Con Edison Public Awareness Program Effectiveness

#### Northeast Gas Association Evaluations

Con Edison contracts with the NGA to evaluate the effectiveness of its public awareness program every 4 years. The evaluations measure four areas of the program: outreach, understandability of the message, behaviors by the intended audience, and measurable results. The NGA evaluated the Con Edison program in 2006, 2010, and 2014.

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[21] "Regional Public Awareness and Education Program for Gas Distribution and Transmission Pipelines," revision B2, July 17, 2012; page 13.

[22] A *master-metered* building is one where multiple users share a common meter and pay for their utilities based on some measure other than their specific use, These can be apartment buildings, condos, shopping malls, and office buildings.

In 2013, GreatBlue Research conducted the Pipeline Media Ad Campaign Evaluation Study that evaluated the effectiveness of five areas of public awareness for all NGA member companies. The study surveyed a sample of 538 people; the Con Edison territory represented 65 respondents (up from 58 respondents in 2012). Particularly relevant to this accident are the answers of Con Edison respondents to the question, "If you did detect a natural gas leak, what would you do?" Forty-nine percent said they would call 911, whereas 40 percent said they would call the natural gas company or the pipeline operator. These percentages represent an increase over the previous year. In 2012, 32.8 percent said they would call 911, and 31 percent said they would call the gas company.

#### New York State Department of Public Service Assessment

After the accident, NYSDPS investigators interviewed tenants living along Park Avenue between East 116th and East 117th Streets, as well as people associated with the church and the businesses that operate within the buildings. Interviewees were asked whether they recalled the public awareness information sent to them from Con Edison and the numbers they would call to report natural gas odor. Seven of the 11 people interviewed said that to report gas odors they would call the fire department. Some of the interviewees expressed confusion over whether odor alone was an emergency. One tenant said he did not call 911 when he smelled gas because he did not realize it was a dangerous condition. Another tenant told investigators that he would call Con Edison to report odors because "that is the information provided." One tenant said the smell of gas would not have prompted him to call 911 because he associates 911 with a fire emergency.

Several interviewees were aware that Con Edison has a specific phone number (1-800-75-CONED) to report gas safety issues, and they noted that the number is not easy to remember. Most interviewees were aware of the safety information included in Con Edison utility bills, but they did not read the information. One of the tenants interviewed was a roommate of the primary leaseholder and never saw the gas bill or the safety inserts. Many could not recall seeing any information about gas safety in newspapers, billboards, television, or radio, although Con Edison also uses those methods to inform the public. None of the people interviewed mentioned seeing information about gas safety posted on the bulletin boards inside the main doors of their buildings.

## 1.12 Regulatory Oversight

### 1.12.1 Federal Oversight

The Pipeline and Hazardous Material Safety Administration (PHMSA) in the US Department of Transportation (DOT) oversees the national regulatory program for the safe transportation of natural gas through the OPS. After the passage of the Natural Gas Pipeline Safety Act of 1968, the OPS established minimum safety standards for natural gas transmission and distribution pipeline operators under 49 CFR Part 192. Federal pipeline safety regulations include a provision for states to assume regulatory, inspection, and enforcement responsibilities for intrastate pipeline systems under an annual certification program administered by PHMSA.

### 1.12.2 New York State Oversight

The state pipeline safety program certifications in Title 49 United States Code section 60105(a) allow states, which perform annual certification through the US Secretary of Transportation, to inspect and enforce intrastate pipeline safety. When qualifying for certification, a state must adopt the minimum federal regulations for pipeline safety. However, states may mandate more stringent safety regulations as long as they are not in conflict with the established federal minimum standard.

The New York state natural gas pipeline safety regulations are contained in the *New York Codes, Rules and Regulations* (NYCRR), which comprises all state agency rules and regulations adopted under the State Administrative Procedure Act. The state laws governing natural gas transmission and distribution are contained under Title 16 NYCRR Chapter III, Subchapter C, Part 255, "Transmission and Distribution of Gas."

Natural gas distribution safety and oversight under Part 255 of the NYCRR is the responsibility of the NYPSC. The NYPSC is certified by the US Secretary of Transportation as the state agent responsible for inspecting both interstate and intrastate natural gas and hazardous liquid pipelines for the OPS.[23] The NYPSC oversees about 49,000 miles of distribution pipeline and about 3,400 miles of transmission pipeline. The NYSDPS is the staff arm of the NYPSC and is responsible for developing an inspection program and conducting intrastate inspections of regulated state operators. The NYSDPS has a written annual plan and a 5-year plan for conducting these inspections, which inspect operations and maintenance functions primarily. In the 5-year plan, inspections are based on risk categories, that is, high, moderate, and low risk. Requirements considered high risk are inspected every year, those considered moderate risk are inspected every 3 years, and low-risk conditions are inspected every 5 years. In addition, all issues identified from a previous audit are addressed to determine compliance.

In the 5-year plan, each section of the state code is assessed by a records audit or a field inspection. Records audits are performed at the pipeline operator's office and may include areas such as operations procedures and leak survey records. NYSDPS inspectors conduct field inspections at an operator's job site. Inspectors conduct unannounced visits to a construction site or operations activity and observe the work being performed and review the work against the operator's written procedures and state regulations. In addition, inspectors check the qualifications of workers for performing covered tasks.[24] Further, the NYPSC (through the NYSDPS) conducts field inspections to evaluate compliance with the operator (staff) qualification program. However, the 5-year plan did not specifically address audits of operator qualifications.

Field inspections are a means of observing covered tasks and whether the tasks are being performed as required under the procedure and by qualified individuals.[25] When visiting a

[23] New York is one of eight states that act as the PHMSA agent for the inspection of interstate pipelines. The OPS enforces the federal regulations.

[24] *Covered task* is defined in 49 CFR Part 192 Subpart N and 16 NYCRR 255.3(40).

[25] *Qualified* is defined in 49 CFR Part 192 Subpart N and 16 NYCRR 255.604.

construction site, NYSDPS inspectors ask to see operator qualification cards. Previous NYSDPS inspections have cited Con Edison for operator-qualification lapses, but none of the citations were for plastic fusion work. Also, the NYPSC reported no violations in this area in the 5 years before this accident.

### 1.12.3 Comparison of Federal and State Regulations

In the course of the investigation, NTSB investigators reviewed NYCRR Title 16, Part 255 and compared it with the federal minimum standards of 49 CFR Part 192, which are incorporated by reference under NYCRR Title 16, Part 10.2. Investigators identified at least two subsections of the state regulations that were less stringent than the federal regulations. These included the definition of "service line" and pressure test requirements for short sections of newly installed pipe.

#### Service Line Scope Inside a Building

Under 49 CFR Subpart A, 192.3, PHMSA defines service line endpoint as "the outlet of the customer meter or … the connection to a customer's piping, whichever is further downstream, …." Contrary to the PHMSA definition, under NYCRR Title 16 part 255.3, when the meter is inside the building, the service line ends at the first indoor valve: "Service line means the piping … that transports gas below grade from a main or transmission line to the first accessible fitting inside a wall of the customer's building where a meter is located within the building …."

In the federal definition of a service line, the operator remains responsible for the maintenance and leak survey of the service line up to the outlet of the gas meter. Under the New York state regulation, the operator's responsibility to maintain a service line ends at the first fitting inside the building wall, so the operator is not responsible for leak survey or maintenance of the service line between the first fitting inside the building and the outlet of the gas meter. (See figure 19.) Although this discrepancy in the state regulations is not related to this accident investigation, the NTSB is concerned because the discrepancy means that significant lengths of natural gas service pipe and associated pipe fittings inside buildings may not be adequately maintained or inspected. Therefore unsafe conditions such as leaks or improper pipe installations inside affected buildings could go undetected.

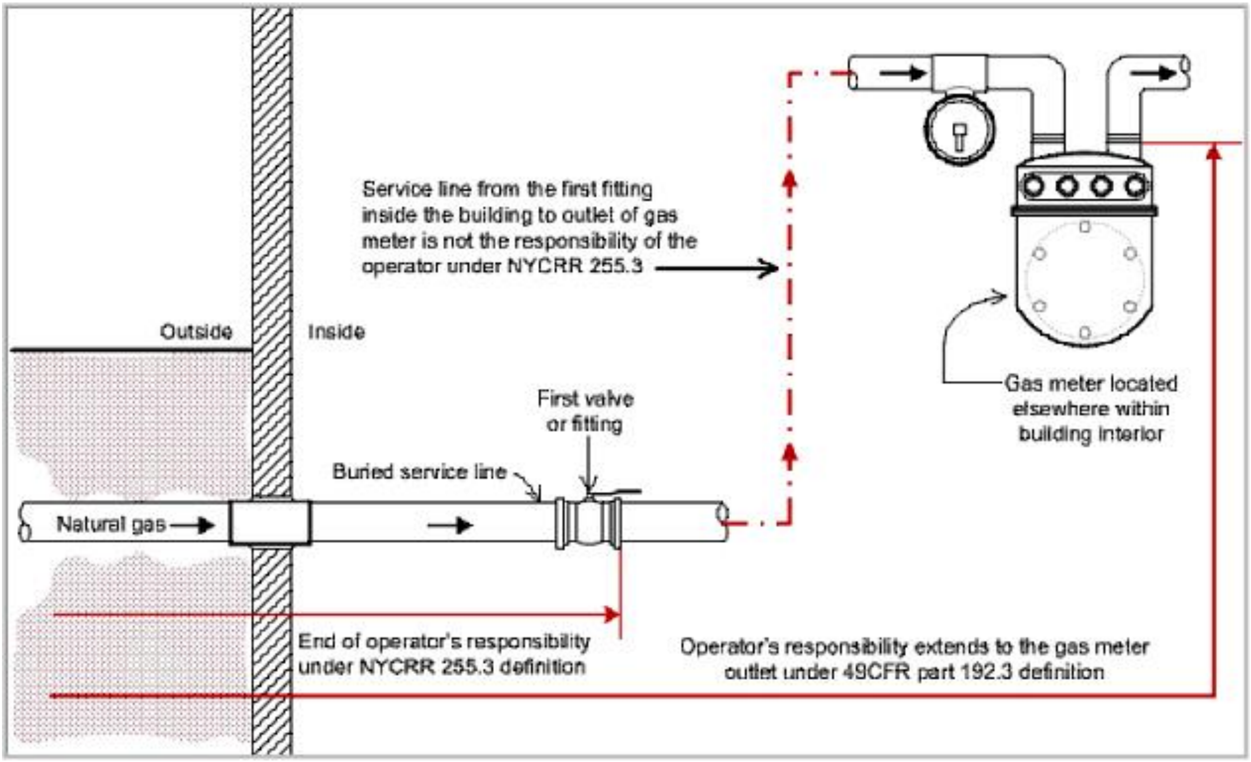


**Figure 19.** Schematic comparing federal and New York regulatory definitions of service line leading to a gas meter inside a building.

## Plastic Pipe Pressure Test Requirements

For testing plastic pipe, 49 CFR 192.513(c) requires that "the test pressure must be at least 150 percent of the maximum operating pressure or 50 psig, whichever is greater. …" and does not provide any exceptions for the length of the pipe.

For testing plastic pipe, 16 NYCRR Part 255.507(f), *Test requirements for pipelines to operate at less than 125 psig*, states, "On short sections (100 feet (30.5 meters) or less) of pipe, and tie-in sections, where all joints, uncoated portions of longitudinal seams, and/or fittings are exposed, a soap test is acceptable at line pressure…." A soap test for pipeline leaks involves application of liquid soap to the outside of the pipe at the fusion joints and threaded fitting connections. If there is a leak, a soap bubble will form.

Con Edison performed a leak test on the new 8-inch HDPE gas main in front of 1642 Park Avenue when the cast iron main was replaced in 2011. The test was performed before the service tee was installed and was conducted at the operating pressure of about 1/3 psig using soap solution. Federal regulations required a pressure test at 50 psig minimum.

## 1.13 Postaccident Activities

### 1.13.1 FDNY Fire Investigation

The FDNY investigated the accident and determined that the explosion originated inside Building 1644, in the Spanish Christian Church on the first and second floors. The FDNY report stated that the explosion was caused by a mixture of natural gas and air that was ignited by an unidentified ignition source (FDNY 2014).

### 1.13.2 Con Edison Heat Fusion Procedure Upgrade

After the accident, Con Edison revised its plastic pipe fusing procedure. The new edition of *Heat Fusion Joining of Polyethylene Plastic Pipe/Tubing Fittings for Gas Mains and Services* is dated 2014. The new procedure requires that after the surface of the pipe to be joined is roughened with emery cloth, any residues from the roughened surface shall be removed using a dry, clean cloth. However, the revised procedure still does not include a requirement to use alcohol wipes or another solvent to clean and degrease the surfaces to be joined. The industry standard ASTM F2620, *Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings,* specifies the use of alcohol to clean the surfaces before they are fusion joined.

### 1.13.3 Sewer Inspection and Excavation

At the request of the NTSB, the NYCDEP conducted a video inspection of the sewer main on March 28, 2014, to determine whether the sewer damage observed in previous inspections, including one that was performed immediately after the accident on March 19, was providing a path for groundwater to enter the sewer. Using large hoses, water containing fluorescent tracing dye was poured from a tanker into the trench in the area of the defective gas service tee, gas main, and water main in front of Building 1642.[26] A robotic camera was inserted in the sewer main from the upstream manhole near East 117th Street and was pushed south toward the downstream manhole. The inspection showed that water containing the dye was flowing freely through the breach in the sewer main. (See figure 20.) The inspection also showed dyed water dripping from the top and seeping from the side of the sewer at various locations. The video inspections conducted in 2006 and 2011 show sewer main damage in the same location. (See figure 5.)

[26] At the time of this work, the water main, gas main, and service tee had been exposed by excavation and removed.


**Figure 20.** Water containing fluorescent dye flowing into sewer main through damaged area in east side of sewer main as shown in a video frame from March 28, 2014, inspection.

### 1.13.4 Gas Pressure Tests

Con Edison conducted postaccident pressure tests of the gas service main along the accident block, upstream and downstream from the Building 1642 damaged service tee connection. The tests of two segments at the operating pressure of 8 inches of water column or 1/3 psig, identified very small, insignificant leaks in the service main. The underground portions of the gas service lines from the main to Buildings 1644 and 1646 also were pressure tested. These tests showed no leaks.

### 1.13.5 Examination of Area Below the Pavement

A portion of the west side of Park Avenue in front of the destroyed buildings was excavated to expose underground utilities. A circumferential crack in the 12-inch water main was observed in front of Building 1642. (See figure 21.) The crack was wide on the top of the pipe (12 o'clock position) and narrowed toward the bottom of the pipe. The crack extended about 340° around the circumference, with the pipe intact at the bottom. In addition, a large rock was underneath the water pipe at the crack location.

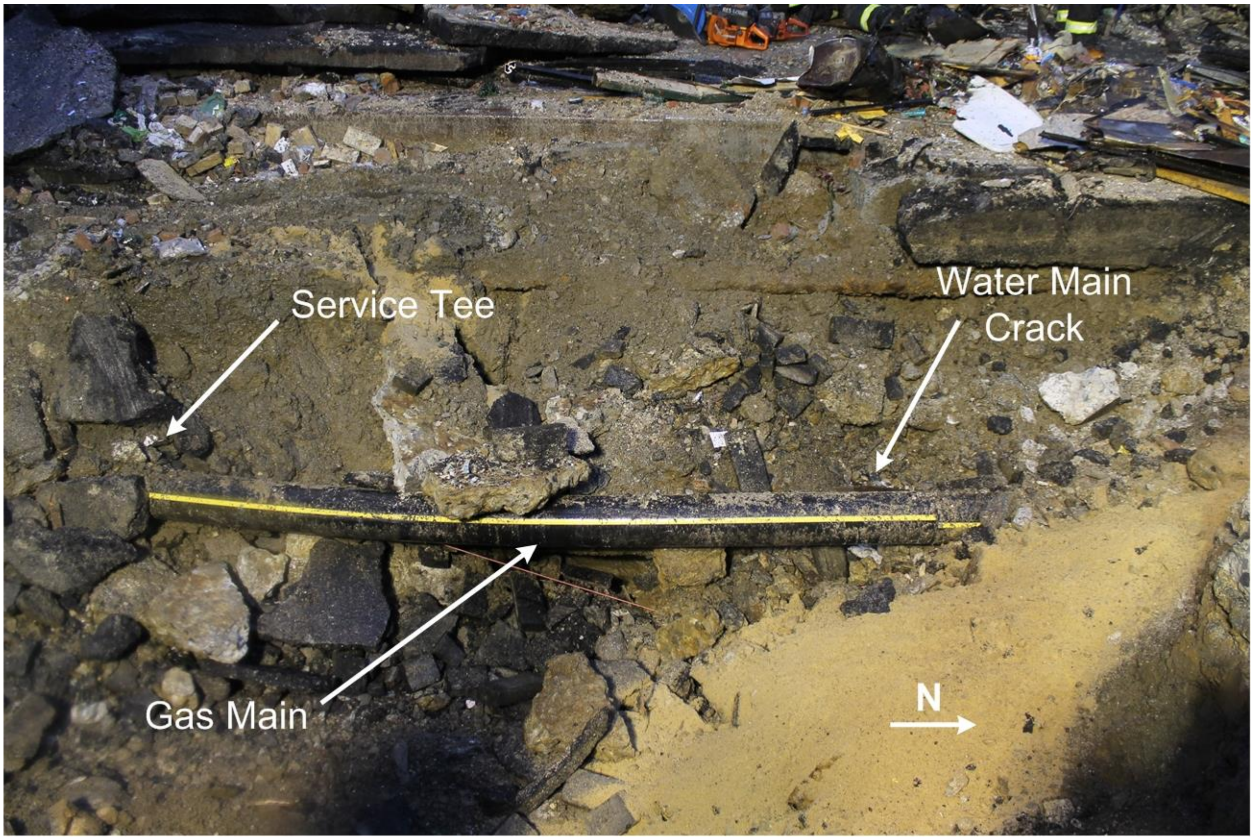


**Figure 21.** Circumferential crack in exposed 12-inch cast iron water main near 8-inch HDPE gas main.

The 2-inch gas service tee that was detached from the 8-inch gas main was about 12 feet south of the water main crack and about 35 feet south of the breach in the sewer line. (See figure 22.)

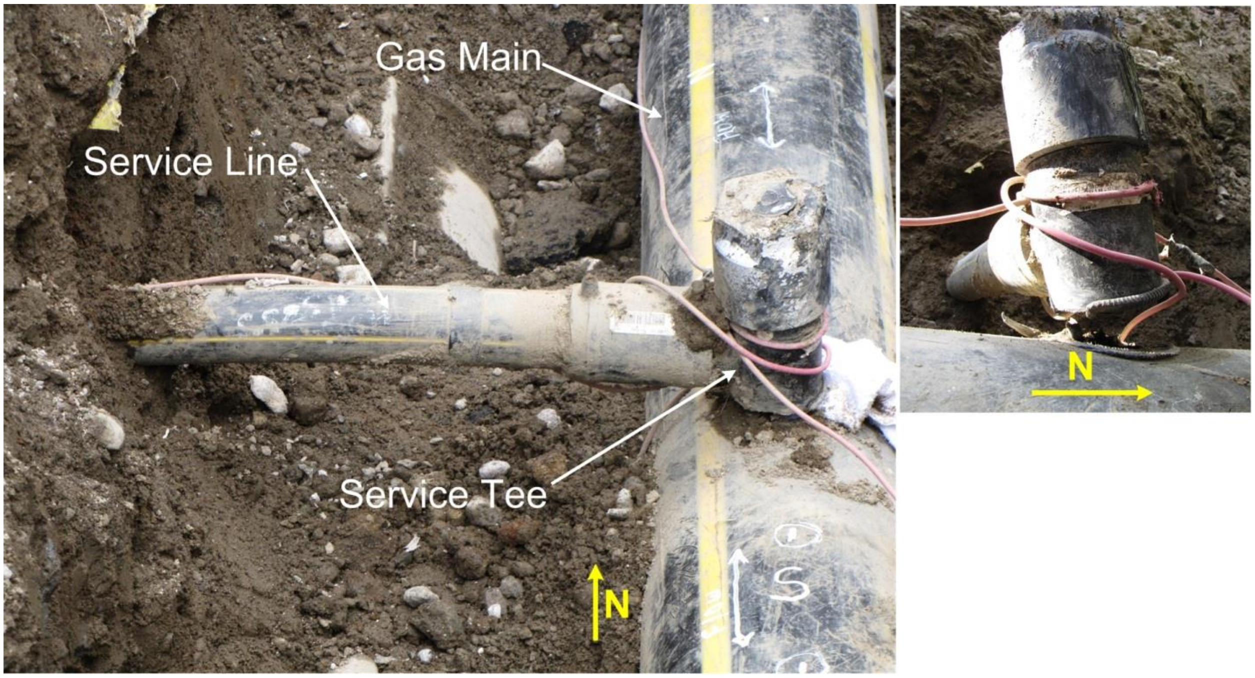


**Figure 22.** Eight-inch HDPE gas main, detached service tee, and service line in front of Building 1642 with closeup of detached service tee.

Layers of concrete and asphalt were more than 12 inches thick in some locations in the street in front of Buildings 1644 and 1646. The excavated trench showed many areas of significant underground voids. The sidewalk was removed, which exposed voids and gaps at least 4 inches high and up to several feet long in front of Buildings 1642 and 1644. Figure 23 shows a large void under the sidewalk next to Building 1642 and a folding ruler inserted into a void under the sidewalk in front of Building 1644. The insert photo shows the opening directly above the Building 1644 basement brick foundation that extends more than 85 inches under the sidewalk.

**Figure 23.** Voids and gaps in ground beneath sidewalk in front of Buildings 1642 and 1644. Inset photo shows void above brick basement foundation at Building 1644.

### 1.13.6 New York City Underground Infrastructure Working Group

After the accident, New York City convened a working group to address the under-street infrastructure. The working group was made up of members from the Departments of Transportation, Environmental Protection, Design and Construction, and Buildings; the Fire Department; the Economic Development Corporation; and the Mayor's Office of Long-Term Planning and Sustainability. The working group was convened to address "emergency response to defective under-street conditions; under-street infrastructure prioritization and street opening procedures and the pace and schedule for upgrading and replacing the most vulnerable portions of New York City's aging utility infrastructure." The group's report, *New York City Underground Infrastructure Working Group*, was released in June 2014. According to the report, the working group met with Con Edison in the course of developing recommendations. The recommendations of the working group include the following:

> Improving emergency response to defective under-street conditions by incorporating private utility notification into street defect response procedures, instructing FDNY to respond to gas calls, and sending a clear and coordinated message that people who smell gas should call 911.

The working group initiative included a public awareness campaign that encourages the public to call 911 if they smell natural gas. Based on the current level of gas calls to utilities, 311, and 911, the FDNY concluded that it will be able to handle all gas odor calls, even if such calls increase considerably because of high-profile public messaging. The report stated that the FDNY will respond to all gas odor calls reported to 911, and 311 notifications will be immediately routed to 911. The report further stated that response to gas odor reports will follow the standard operating procedures but will include notifying the pipeline operators, disconnecting leaky appliances, venting the space, and evacuating buildings. According to the report, the average FDNY response time to suspected gas leak calls was less than 8 minutes; the Con Edison average response time was 20 to 25 minutes.

On June 23, 2014, the NYPSC asked Con Edison to explain how 911 gas odor and leak reports that the FDNY responds to will be coordinated with Con Edison.[27] The company stated that New York City "has urged Con Edison to inform the public that gas odors can be reported to 911 for the prompt response of the FDNY." Con Edison began a public awareness campaign during the week of March 17, 2014, to encourage the public to notify 911 or Con Edison in the event of a suspected gas odor.

In its response to the NYPSC, Con Edison further stated the following:

> While the June, 2014 report of the New York City Underground Infrastructure Working Group apparently suggests that the public call only 911 to report gas odors, it is not Con Edison's intention to discourage reporting to 1-800-75-CONED. The Working Group that promulgated the report consisted solely of representatives of the City, and although Con Edison has been working with the City regarding implementation of report recommendations, we did not contribute to nor review the report before it was released.

At the request of the NYSDPS, Con Edison has continued to develop coordinated training with the FDNY to improve the response procedures used by the utilities and the FDNY.

### 1.13.7 Use of 911 for Gas Odor Calls

After the March 12, 2014, accident, calls to Con Edison reporting gas odors increased significantly. On May 20, 2014, the NYPSC asked Con Edison whether the company was capable of responding effectively to the gas odor calls. In its June 10, 2014, response, Con Edison stated that it was taking measures that included "working more closely with the City of New York in several areas, including with local emergency services to use the 911 emergency calling system for the public to report gas odors in order to reduce response time."[28] In addition, Con Edison discussed assigning additional resources to assist in investigating odor reports and developing enhanced public education materials that highlight the importance of reporting gas leaks.

[27] June 23, 2014, letter from NYPSC Chair Audrey Zibelman to Con Edison Senior Vice President of Gas Operations Edward Foppiano.

[28] June 10, 2014, letter from Con Edison President Craig S. Ivey to NYPSC Chair Audrey Zibelman.

### 1.13.8 Plastic Fusion Welder Qualifications

In a May 21, 2014, letter to Con Edison, the NYPSC stated that the annual plastic fusion qualification of the installer of the service tee at Building 1642 was expired at the time of installation. His qualification for plastic fusion welding was valid until November 25, 2011. The accident tee was installed in late December 2011. The NYPSC asked Con Edison for a list of all plastic fusion joints completed after November 25, 2011, by the installer who installed the Building 1642 service tee. It also requested a list of all the work performed by all plastic fusion welders whose annual requalifications were found to be expired.

Con Edison employees and contractors who failed to requalify were prohibited from performing fusion welds until they had successfully passed the qualifying test. Con Edison's qualification procedure followed the New York state natural gas safety regulations for qualification and required making a plastic fusion joint observed by a skilled fusion weld instructor in a classroom environment. The qualification process included visual inspection of the joint and a destructive test to confirm that the fusion joint was a good weld.

In its response to the NYPSC, Con Edison stated that the tee installer, who worked for a contractor, had been involved in 136 jobs from November 2011 to November 2013. Of these jobs, 120 involved low-pressure and 16 involved high-pressure pipe joints. In addition, Con Edison noted that 13 of that contractor's employees were plastic pipe installers, and 12 of them, including the accident tee installer, had performed plastic pipe installations during periods after their qualifications had expired. In addition, Con Edison estimated that the contractor that employed the tee installer had made about 700 plastic fusion welds from May 1, 2011, to April 30, 2014, and it noted that 186 Con Edison employees and 115 contractor employees had lapses in their operator qualifications at different intervals.

On June 27, 2014, the NYPSC issued the Plastic Fusion Order to investigate Con Edison and its practices of qualifying employees to perform plastic fusions on natural gas facilities. The Plastic Fusion Order notes that "staff has found no evidence that Con Edison placed into service any pipe that had not been fused according to acceptable procedures and specifications." However, the Plastic Fusion Order requires Con Edison to provide records of compliance and noncompliance with the state regulations.

The Plastic Fusion Order stated that Con Edison had failed to comply with natural gas safety regulations for plastic fusion qualification that required, on an annual basis, that employees and contractors submit a plastic fusion joint in a classroom environment for both a visual inspection and a destructive test. The order further stated that Con Edison was not destructively testing the sample fusion joints prepared during annual qualification. In addition, Con Edison had failed to requalify its employees and contractors on an annual basis as required under its procedures. The order contained 12 items that require Con Edison to take corrective action or provide details within 5 to 15 days of the order, including the following:

- Identify how the company will ensure (through inspection or other means) that the plastic fusion work performed by unqualified contractors or employees, between 2011 and 2013, is not defective or result in "adverse consequences."

- Provide documentation showing how the company will continue to ensure that employees and contractors are qualified or re-qualified to perform plastic fusions in the future.

- Commence continuous leakage detection surveys (as defined under 16 *New York Codes, Rules and Regulations* [NYCRR] 255.3) over all plastic fusion facilities joined by the plastic fusion process until the NYPSC directs otherwise.

- A list of people tested since May 29, 2014, (the date when Con Edison began to requalify contractors and employees) and a list of persons that failed to requalify.

In its July 2, 2014, response to the NYPSC Plastic Fusion Order, Con Edison offered its existing programs for material selection, training, visual inspection, pressure testing, and leak tracking. The response identified two additional initiatives involving enhanced leakage surveys and on-site fusion joint inspection that would improve the existing programs. Con Edison also proposed to use high-speed mobile gas leak survey equipment under a pilot program. These mobile surveys would be capable of surveying about 300 miles of gas distribution mains per week. Also proposed was gradually increasing the frequency of distribution main surveys from once per year to 13 times per year. In addition, Con Edison noted that it was developing a program to provide on-site inspection of existing plastic fusion joints that are exposed during work.

Con Edison further reasserted the measures currently in place to ensure that plastic fusion joints are made correctly. Con Edison stated that "the use of visual quality inspection is the current industry standard method for evaluating the quality of field fusion joints; it also satisfies the field fusion inspection code requirements." Con Edison described a visually acceptable saddle fusion joint as one that has three complete fusion beads around the entire joint. It also stated that pressure testing pipelines to 90 psig on low-pressure lines and leak testing (soap test) where pressure testing is not possible "provides assurance they are leak free." In addition, the company points to the leak-tracking database it maintains, noting that between January 2011 and July 2014, in 222 miles of installed plastic mains and 46,000 service lines and associated fittings, only four fusion-related leaks had been reported, and only one was related to workmanship.

In a July 7, 2014, followup to the NYPSC, Con Edison stated that 288 Con Edison employees and 155 contractor employees took requalification tests for plastic pipe fusion. The tests included butt fusion joints, electrofusion fittings, and saddle fusion. Of those tested, 25 Con Edison employees (9 percent) and 37 contractors (24 percent) failed; 34 of those tested (8 percent) failed the saddle fusion qualification test.[29] The accident tee installer passed the requalification tests.

[29] July 7, 2014, letter from Con Edison to Kathleen H. Burgess, NYPSC. NYPSC Case No. 14-G-0212, Con Edison correspondence to the NYPSC, July 7, 2014; appendices A and B.

### 1.13.9 New York Public Service Commission Notice of Proposed Rulemaking

On September 11, 2014, the NYPSC issued a Notice of Proposed Rulemaking to revise 16 NYCRR Part 255, Subchapter C, to “make [the regulations] at least as stringent as the federal rules - 49 CFR Part 192 - Transportation of Natural and other Gas by Pipeline: Minimum Federal Safety Standards.”[30] If adopted, these changes will bring the New York State pipeline safety regulations in line with the federal minimum safety standards. In this notice of proposed rulemaking the NYPSC proposed, in part, the following:

- The adoption of the federal definition of Service Line as stated under 49 CFR 192.3
- Changes to the 16 NYCRR 255.723 regarding leakage surveys which, with the adoption of the federal definition of service line, require local gas distribution companies to perform leakage surveys of piping interior to a building, upstream of the meter.
- Elimination of soap testing (leak testing) under 16 NYCRR 255.507 for short sections of piping before it is placed in service.

The NYPSC adopted the proposed revisions to 16 NYCRR Part 255; the changes were issued and effective on April 2, 2015.

[30] NYPSC Case No. 14-G-0357, “In the Matter of Revising 16 NYCRR Gas Safety Regulations for Consistent Application of More Stringent Federal Gas Safety Standards in 49 CFR,” issued September 11, 2014.

# 2 Analysis

## 2.1 Water Main Damage

The hole that opened up on Park Avenue in front of Building 1642 after the accident and the discovery of the water main break both raised the possibility that leaking water may have caused the natural gas leak. For that to be the case, the water main would have had to leak a significant amount of water for a long time to wash out the soil supporting the gas main, which would then sag, overstressing the service tee joint. A leak in the 12-inch-diameter water main, operating at 55 psig, large enough to cause the soil washout and service tee damage, would have had to occur before the gas odor was detected by residents more than 12 hours before the explosion.

Emergency responders observed high-velocity water spraying from the water main crack below the hole in the street and striking the underside of the pavement. Many hours would have been required for such a water leak to undermine the gas main and break the service tee, then for gas to accumulate to a level sufficient for residents to smell it. Water flowing at high velocity and volume sufficient to cause the damage would most likely have manifested itself in the street or nearby buildings a day or more before the explosion. However, the water leak did not appear in the street until more than 4 hours after the explosion. In addition, the NYCDEP did not detect a water main leak during a routine leak survey it conducted along Park Avenue on March 5, 7 days before the explosion. Furthermore, the NTSB review of the 311 call records from before the accident revealed no calls from the accident block reporting water leaks on the street or into basements in the days preceding the explosion.

When the water main was excavated, a large rock was discovered directly beneath the cracked cast iron pipe, which could have created significant bending stress on the cast iron pipe from the heavy traffic on the street directly above the water pipe during firefighting activities. The NTSB therefore concludes that the water main break was not a factor in the accident and the water main most likely failed some time after the explosion when the pipe, weakened by graphitic corrosion, was shaken by the natural gas explosion shock wave or from the increased loading from the incident response equipment on the street directly above the water main.

## 2.2 Sewer Damage

The NYCDEP identified the large hole in the sewer main during inspections in 2006 and 2011 but took no action to repair it. The postaccident fluorescent tracer dye inspection showed water flowing directly into the sewer through the breach. Resident observations and the NYDOT street repair records dating back more than 8 years confirm significant and continuing pavement damage caused by ground settlement in front of Buildings 1642, 1644, and 1646. The water flow dye testing conducted after the accident confirmed that the sewer breach provided an unrestricted and direct flow path for groundwater and soil into the sewer main.

The NTSB concludes that the supporting soil under the gas and water mains was washed into the sewer through the large hole in the sewer wall over many months or years when groundwater accumulated in the area. The NTSB further concludes that as the soil washed away after the plastic gas main and service tee were installed in 2011, the gas main was no longer supported in the vicinity of the service tee for Building 1642, which caused the line to sag and overstressed the defective fusion joint at the service tee.

The accident service tee was installed about 27 months before the accident. The disruption of the soil and the underground voids beneath the service tee likely affected the gas main and service tee, moving the joined pipes and highly stressing the saddle fusion joint. In addition, the soil disruption caused gaps beneath the street and the sidewalk, providing an unobstructed path for natural gas leaking from an underground pipeline to enter the building. The NTSB concludes that had the NYCDEP repaired the breach in the sewer main after it was discovered in 2006, damage to the street in the vicinity of Buildings 1642, 1644, and 1646 would have been prevented by minimizing local soil movement and settlement caused by the localized groundwater movement. The NTSB recommends that the NYCDEP implement a written program or procedure to ensure the integrity of its sewer lines, repair breaches in a timely manner, and coordinate with other agencies to identify and address potential soil disruption and voids.

## 2.3 Gas Main and Service Tee

The water main break was identified sometime after the explosion when a section of the street pavement caved in and water was spraying at high velocity against the underside of the pavement. The plastic gas main became visible in the hole after the water main was shut off and water in the hole receded. The flowing water from the water main break washed out the dirt supporting the gas main. On the day of the accident, a large backhoe was brought in to remove the loose dirt, large chunks of concrete and asphalt pavement, and debris from the hole. The hole was then backfilled with gravel and partially covered with a steel plate to allow the firefighting equipment and recovery equipment to access the destroyed buildings. After the firefighting and recovery operations were completed, the backhoe was used to reexcavate the area to expose the broken water main and the gas main in front of Buildings 1642 and 1644.

When the 8-inch plastic gas main was exposed, it showed evidence of significant sagging, likely because of the large asphalt chunks and dirt on top of the pipe. The service tee connecting Building 1642 was found to be completely separated from the gas main and the cap was gouged and scratched. After the service line was cut and the service tee removed, investigators discovered a large through-wall crack at the bottom of the service tee outlet.

### 2.3.1 Service Tee Failure Examination

The NTSB conducted finite element modeling of the service tee to examine various loading conditions and resulting stresses and deflections in the two damaged areas, the crack in the service tee outlet and the incomplete fusion in the service tee-to-gas main joint. Multiple load and deflection cases were selected to mimic the various loads imposed during operation or postaccident excavation work. Based on the results, the NTSB concludes that normal loads during operation, and the abnormal loads that resulted from the soil displacement around and below the gas main, were not sufficient to cause either the crack in the service tee outlet or the complete separation of the gas main-to-service tee fusion joint. The NTSB further concludes that the complete separation of the fusion joint and the crack in the service tee resulted from damage sustained during the postaccident excavation work.

## Service Tee Branch Crack

The crack at the lower corner outlet portion of the service tee most likely was the result of a rapid overloading event, such as sudden soil movement resulting from the gas explosion, local soil disturbance caused by the backhoe bucket during the recovery effort after the accident or direct impact from the backhoe bucket. A comparison of the fracture surface features between the service tee branch crack and an exemplar crack created under impact conditions confirmed the crack was formed by a rapid overloading event. The finite element modeling showed that the loads from sagging in normal service were unlikely to cause the crack in the service tee body, but that loads intended to simulate postaccident excavation were large enough to cause the crack in the service tee body. The finite element modeling also showed that even with an assumed initial separation as large as regions 1 and 3 in figure 14, the fusion joint was still strong enough to allow high loads to be applied to the service tee to initiate the crack at the lower corner outlet portion.

## Service Tee-to-Gas Main Fusion Joint

Based on the testing conducted at the service tee manufacturer's facility, NTSB materials engineers examined the possible causes of the fusion joint failure. The exemplar saddle fusion joint made with intentionally oil-contaminated joint surfaces was subjected to the drop weight test, which is used to evaluate the quality of the fusion joint. Then the exemplar joint fracture faces were compared to those from the accident service tee fusion joint. The fracture features on the accident joint and the exemplar joint were similar. A large portion of the saddle fusion joint fracture face of the accident tee exhibited a radial band pattern consistent with incomplete fusion, indicating that the joined surfaces were inadvertently contaminated before the fusion bond was made. The fusion joint was significantly weaker than one made following the correct procedure.

The Con Edison heat fusion procedure that was in effect at the time the accident service tee was installed required that the surfaces to be joined only be roughened with emery cloth. The procedure did not require any cleaning method. Contamination such as oil, dirt, water, and other materials are known to reduce the strength of a fusion bond in plastic pipe materials. Industry standards, such as ASTM F2620, *Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings*, provide guidance on cleaning pipe surfaces, including the use of alcohol to clean surfaces to ensure that they are not contaminated before the fusion joint is made. Lacking such precautions, defective joints caused by incomplete fusion cannot be detected by visual inspection.

Incomplete fusion causes weak bond strength in fusion joints. A joint with poor bond strength may pass an on-site pressure test but can fracture or develop a crack under normal loading conditions, such as soil loads and operating stress, after the pipeline is placed in service. Construction records indicate that the saddle fusion joint involved in the accident was pressure tested at 90 psi prior to placing the pipe into service and no leaks were reported. Detection of fusion joints with poor bond strength continues to be a challenge for the HDPE pipeline industry. The NTSB therefore concludes that the surfaces of the service tee and the gas main were not adequately prepared before the tee was fusion welded to the gas main in 2011, resulting in a defective joint that contained an area of incomplete fusion. Since the accident, Con Edison has revised its heat fusion procedure to require cleaning to remove dry contaminants, but has not incorporated a solvent cleaning procedure. The NTSB recommends that Con Edison revise its plastic pipe fusion welding procedure to require cleaning of the surfaces to be welded with suitable solvents to remove all dirt, water, oil, paint, and other contaminants as recommended in ASTM F2620, *Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings*.

The heat fusion process for saddle fusion produces a solidified joint that contains three distinct fusion beads. After the beads solidify, Con Edison requires that operators perform a visual inspection and verify that the completed joint has three fusion beads and that they extend all around the joint. Industry standards such as ASTM F2620 also require that the solidified beads be uniformly shaped and sized all around the joint. However, the failed service tee did not contain uniform bead sizes around the circumference. The NTSB therefore concludes that visual inspection of the fusion joint to confirm only the required number of beads are present does not provide sufficient evidence of a properly welded joint. The NTSB recommends that to ensure consistent and acceptable heat fusion joints, Con Edison revise its plastic pipe fusion welding procedure to specify that the solidified beads should be visually examined after completing a joint to ensure the beads are uniformly shaped and sized around the joint as recommended in ASTM F2620, *Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings*.

Finite element modeling showed that the pipe's sagging could open the area of the incomplete fusion wide enough to allow a gas flow rate sufficient over a period of hours to cause the explosion of Building 1644. The leaking gas flowed through the voids under the street and sidewalk and entered the basement of Building 1644 through voids in the basement wall. Natural gas accumulated in the basement and in the church on the ground and second floors. An unknown ignition source ignited the natural gas, which exploded because it was confined in the building.[31] The NTSB concludes that stresses created by the vertical displacement of the sagging gas main opened a crack in the defective service tee fusion joint, allowing natural gas to escape into the subterranean area and migrate into Building 1644. The NTSB further concludes that the defective service tee fusion joint was the only credible source of natural gas that could have provided a large enough flow rate to have fueled the building explosion.

### 2.3.2 Fusion Joint Operator Qualification

The plastic fusion qualification of the installer of the service tee at Building 1642 was expired at the time of installation. Con Edison determined that the tee installer, who worked for a contractor, had been involved in 136 jobs from November 2011 to November 2013. In addition, Con Edison found that 12 installers, including the accident tee installer, had performed plastic pipe installations during periods after their qualifications had expired, and it noted that 186 Con Edison employees and 115 contractor employees had lapses in their operator

[31] Natural gas, like all flammable gases, will explosively ignite only if it is contained inside a closed volume.

qualifications at different intervals. These qualification deficiencies went undetected by both Con Edison and its contractors.

The NYSDPS audits utility companies using a 5-year plan. Each section of the state code is assessed by a records audit or a field inspection. Records audits are performed at the pipeline operator's office and may include areas such as operations procedures and leak survey records. Inspectors conduct unannounced visits to a construction site or operations activity and review the work against the operator's written procedures and state regulations. However, the 5-year plan did not specifically address audits of operator qualifications. The expired qualifications of Con Edison and contractor employees were undetected by the NYSDPS auditors. The NTSB concludes that the NYSDPS audit program for pipeline operators does not effectively address all aspects of the state regulations. Therefore, the NTSB recommends that the NYSPSC revise the NYSDPS gas utility operator program to ensure all elements of the regulations are included in the 5-year audit plan.

## 2.4 Con Edison Emergency Call Response

Some residents who lived in or near the buildings that were destroyed in the explosion told investigators that they smelled gas the night before the accident. However, the Con Edison incoming call logs contained no records of any gas odor calls for the accident block the day before the accident. The NTSB concludes that had Con Edison received a report of the gas odor on the evening of March 11, it likely would have found the gas leak and taken appropriate corrective actions to prevent the accident; this accident highlights the critical importance for members of the public to notify 911 or the gas company when the odor of natural gas is first detected. On the morning of March 12 at 9:06 a.m., about 25 minutes before the explosion, the Call Center received a call reporting gas odor inside and outside the building. The Con Edison computer system, which CSRs use to transfer the information to GERC, stopped responding. GERC is responsible for dispatching gas mechanics and other response actions, including notifying the FDNY when necessary. Based on a phone conversation with the CSR, GERC was aware that the gas odor was reported inside and outside the building, thus requiring GERC to notify the FDNY. GERC dispatched the mechanic at 9:15 a.m., and at 9:19 a.m. called the FDNY to inform them of the gas odor. However, GERC ended the call without informing the fire department of the leak. After the building exploded, the FDNY arrived at the scene within 4 minutes. The NTSB concludes that had Con Edison notified the FDNY at 9:14 a.m., when the call from the CSR ended, FDNY responders likely could have arrived at the gas leak location up to 15 minutes before the explosion; it is unclear, however, whether the emergency responders could have safely evacuated two 5-story buildings that were not equipped with elevators or fire alarm systems. The NTSB recommends that Con Edison provide clear written guidance to the GERC staff on the conditions for promptly notifying the FDNY and provide additional staff training.

Con Edison was unable to turn off the gas to the leaking pipeline until 1:44 p.m., more than 4 hours after the accident, when the street was excavated in three locations and stoppers were put on the gas main. The NTSB concludes that had Con Edison installed appropriately located isolation valves on the gas distribution main, the leaking gas main could have been isolated sooner after the explosion, minimizing both the danger to the first responders and the delay in recovery operations. The NTSB recommends that Con Edison extend its gas main isolation valve installation program to include strategic locations where long distribution mains currently cannot be isolated, giving priority to pipelines in more densely populated areas.

## 2.5 Con Edison Public Awareness Program

The Con Edison public awareness program was based on the NGA template for public awareness and education programs. It included material on how to notify Con Edison in the event of an emergency. Specifically, all of the Con Edison public awareness materials stress the importance of contacting the company in the event of a gas leak. However, the results of the recent evaluations of the effectiveness of the public awareness program show that the most effective method for reporting suspected gas leaks is not well understood by the general public. Despite the inclusion of this information on bulletin boards in apartment buildings, in gas bills mailed to customers, and in newspaper advertisements, people who smelled gas on the accident block the night before the explosion did not call Con Edison or the fire department to report the odor. During assessments of the Con Edison public awareness and education programs, 49 percent of respondents said they would call 911 if they detected a natural gas leak. The NTSB therefore concludes that the Con Edison public awareness and education programs did not effectively inform customers and the public about both the importance of reporting a gas odor and the number to call to report a gas odor.

After the March 12, 2014, accident, New York City and Con Edison began providing new training guides to inform the public how important it is to report gas odors, either to Con Edison or to the fire department through the 911 emergency number. The company also launched a new public awareness campaign in March 2014: “Smell Gas Act Fast.” This new message notes that suspected gas leaks may be reported to either Con Edison at 1-800-75-CONED or the FDNY using 911 or the telephone number of the local fire station. Materials for the new campaign are provided in English, Spanish, Chinese, Korean, Russian, and Haitian Creole.

## 2.6 Alignment of State and Federal Gas Pipeline Regulations

Under 49 CFR 192.3, the operator is responsible for a service line from the distribution main to the outlet of the gas meter, whereas under NYCRR 255.3, the operator is responsible for the service line up to the first fitting entering the building. The distinction between the two definitions is limited to cases where the gas meter is located inside a building, as is common in New York City. Under the federal definition of service line, the gas operator remains responsible for the maintenance and leak survey of the service line up to the outlet of the gas meter. Under the New York state regulation, the operator’s responsibility to maintain a service line ends at the first fitting inside the building wall, and the operator is not responsible for leak surveys or maintenance of the service line between the first fitting inside the building and the outlet of the gas meter, which could be tens of feet away from the first valve. The NTSB found that the New York state regulation addressing the scope of the definition of natural gas service line did not comply with the PHMSA regulation. However, effective April 2, 2015, the NYPSC corrected the deficiency.

After comparing the federal and the New York state regulations relating to pressure testing of pipelines, NTSB investigators found that the federal regulations are more stringent than those of New York. The federal regulation does not distinguish between gas pipelines of differing lengths. In contrast, the New York state regulation allows sections of pipe shorter than 100 feet long to be tested using a less stringent pressure test requirement than that required by federal regulations. The NTSB found that the New York state regulation at 16 NYCRR 255.507(f) addressing natural gas pipeline pressure testing did not comply with the PHMSA regulation at Title 49 CFR 192.513(c). However, effective April 2, 2015, the NYPSC also corrected this deficiency.

# 3 Conclusions

## 3.1 Findings

1. The water main break was not a factor in the accident and the water main most likely failed some time after the explosion when the pipe, weakened by graphitic corrosion, was shaken by the natural gas explosion shock wave or from the increased loading from the incident response equipment on the street directly above the water main

2. The supporting soil under the gas and water mains was washed into the sewer through the large hole in the sewer wall over many months or years when groundwater accumulated in the area.

3. As the soil washed away after the plastic gas main and service tee were installed in 2011, the gas main was no longer supported in the vicinity of the service tee for 1642 Park Avenue, which caused the line to sag and overstressed the defective fusion joint at the service tee.

4. Had the New York City Department of Environmental Protection repaired the breach in the sewer main after it was discovered in 2006, damage to the street in the vicinity of 1642, 1644, and 1646 Park Avenue would have been prevented by minimizing local soil movement and settlement caused by the localized groundwater movement.

5. Normal loads during operation, and the abnormal loads that resulted from the soil displacement around and below the gas main, were not sufficient to cause either the crack in the service tee outlet or the complete separation of the gas main-to-service tee fusion joint.

6. The complete separation of the fusion joint and the crack in the service tee resulted from damage sustained during the postaccident excavation work.

7. The surfaces of the service tee and the gas main were not adequately prepared before the tee was fusion welded to the gas main in 2011, resulting in a defective joint that contained an area of incomplete fusion.

8. Visual inspection of the fusion joint to confirm only the required number of beads are present does not provide sufficient evidence of a properly welded joint.

9. Stresses created by the vertical displacement of the sagging gas main opened a crack in the defective service tee fusion joint, allowing natural gas to escape into the subterranean area and migrate into 1644 Park Avenue.

10. The defective service tee fusion joint was the only credible source of natural gas that could have provided a large enough flow rate to have fueled the building explosion.

11. The New York State Department of Public Service audit program for pipeline operators does not effectively address all aspects of the state regulations.

12. Had Consolidated Edison Company of New York, Inc., received a report of the gas odor on the evening of March 11, it likely would have found the gas leak and taken appropriate corrective actions to prevent the accident; this accident highlights the critical importance for members of the public to notify 911 or the gas company when the odor of natural gas is first detected.

13. Had Consolidated Edison Company of New York, Inc., notified the New York City Fire Department at 9:14 a.m., when the call from the customer service representative ended, New York City Fire Department responders likely could have arrived at the gas leak location up to 15 minutes before the explosion; it is unclear, however, whether the emergency responders could have safely evacuated two 5-story buildings that were not equipped with elevators or fire alarm systems.

14. Had Consolidated Edison Company of New York, Inc., installed appropriately located isolation valves on the gas distribution main, the leaking gas main could have been isolated sooner after the explosion, minimizing both the danger to the first responders and the delay in recovery operations.

15. The Consolidated Edison Company of New York, Inc., public awareness and education programs did not effectively inform customers and the public about both the importance of reporting a gas odor and the number to call to report a gas odor.

## 3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was (1) the failure of the defective fusion joint at the service tee, installed by Consolidated Edison Company of New York, Inc., in 2011, that allowed natural gas to leak from the gas main and migrate into the building where it ignited and (2) a breach in the sewer line that went unrepaired by the New York City Department of Environmental Protection since at least 2006 that allowed groundwater and soil to flow into the sewer, resulting in a loss of support for the gas main, which caused the line to sag and overstressed the defective fusion joint.

# 4 Recommendations

As a result of this investigation, the National Transportation Safety Board makes the following new safety recommendations:

**To the City of New York:**

> Implement a written program or procedure to ensure the integrity of your sewer lines, repair breaches in a timely manner, and coordinate with other agencies to identify and address potential soil disruption and voids. (P-15-33)

**To Consolidated Edison Company of New York, Inc.:**

> Revise your plastic pipe fusion welding procedure to require cleaning of the surfaces to be welded with suitable solvents to remove all dirt, water, oil, paint, and other contaminants as recommended in ASTM F2620, Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings. (P-15-34)
>
> Revise your plastic pipe fusion welding procedure to specify that the solidified beads should be visually examined after completing a joint to ensure the beads are uniformly shaped and sized around the joint as recommended in ASTM F2620, Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings. (P-15-35)
>
> Provide clear written guidance to the Gas Emergency Response Center staff on the conditions for promptly notifying the New York City Fire Department and provide additional staff training. (P-15-36)
>
> Extend your gas main isolation valve installation program to include strategic locations where long distribution mains currently cannot be isolated, giving priority to pipelines in more densely populated areas. (P-15-37)

**To the New York State Public Service Commission:**

> Revise the New York State Department of Public Service gas utility operator program to ensure all elements of the regulations are included in the 5-year audit plan. (P-15-38)

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**Adopted: June 9, 2015**

# Appendix A. Investigation

The National Transportation Safety Board (NTSB) received notification of the building explosion from the National Response Center about 11:11 a.m. on March 12, 2014, and launched a team of investigators. Investigative groups were formed for pipeline operations, public awareness, regulatory oversight, survival factors, and pipeline materials. Member Robert Sumwalt accompanied the team and was the on-scene spokesperson. Sean Dalton, special assistant to Member Sumwalt, also was on scene.

The City of New York, the New York Public Service Commission, the Pipeline and Hazardous Materials Safety Administration, Consolidated Edison Company of New York, and Georg Fischer Central Plastic were parties to the investigation.

The NTSB held no public hearing in connection with this accident.

# Appendix B. Timeline

| Date | Time | Event |
|---|---|---|
| **March 12, 2014** | 9:06 a.m. | Resident of 1652 Park Avenue called Con Edison to report smelling gas that morning and the night before. |
| | 9:12 a.m. | The customer service representative (CSR) who took the call and entered the information into the computer placed a routine followup call to the Gas Emergency Response Center (GERC) dispatcher. |
| | 9:13 a.m. | The CSR called the GERC dispatcher again to confirm receipt of the indoor gas leak ticket the CSR had just entered in the computer system and submitted. |
| | 9:15 a.m. | The dispatcher sent a gas service mechanic (mechanic) to the 1652 Park Avenue address. |
| | 9:19 a.m. | The dispatcher called to ask the FDNY to respond to the inside and outside gas leak reports from 1652 Park Avenue. Then the dispatcher told the FDNY, “Hold on, … I’ll call you right back.”<br><br>No additional calls were made from GERC to the FDNY before the explosion. |
| | 9:30 a.m. | An explosion destroyed Buildings 1644 and 1646 Park Avenue, resulting in loss of eight lives and multiple injuries.<br><br>The Con Edison mechanic was en route to the accident block.<br><br>A Metro-North operations manager 8 blocks away heard and felt the explosion. He broadcast an emergency radio message, and all train movements in the area were suspended immediately thereafter.<br><br>FDNY firefighters at the station at 1367 5th Ave. and West 113th St. heard a loud explosion and saw a plume of smoke in the direction of East 114th Street and Park Avenue. Firefighters at the station called the Manhattan Fire Dispatch System (FDS), and two companies dispatched trucks to the accident scene. The FDS received the first calls reporting the explosion and fire. |
| | 9:31 a.m. | A witness called New York City 911 to report the explosion.<br><br>The NYPD dispatched patrol officers to the accident scene. |

| Date | Time | Event |
|---|---|---|
| **March 12, 2014** | 9:34 a.m. | The first FDNY truck arrived at the accident scene. |
| | 9:35 a.m. | Fire suppression and rescue and recovery operations began.<br>Additional FDNY resources were dispatched as the situation was elevated through several alarms. |
| | 9:39 a.m. | The Con Edison mechanic arrived within a few blocks of the accident scene.<br>The GERC operations manager called FDS. |
| | 9:46 a.m. | The GERC operations manager requested that all available personnel respond to the accident location.<br>Con Edison began to locate and excavate to isolate and stop the gas supply to the accident scene. |
| | 1:44 p.m. | Con Edison put stoppers at three locations on the gas main, isolating the gas supply to the accident scene. |
| | 2:00 p.m. | A void opened in the street in front of 1642 Park Avenue. The hole grew in size and water was seen in the hole.<br>The hold was temporarily filled with gravel debris so that heavy equipment could continue excavation. |
| | 3:00–3:30 p.m. | A gas explosion occurred at the hole. |
| **March 13–17, 2014** | | Recovery operations continued. |
| **March 18, 2014** | 5:41 p.m. | The FDNY declared on-scene operations concluded. |

# References

FDNY (New York City Fire Department). 2014. Fire Incident Report. Bureau of Fire Investigation, New York City Fire Department. 10257 2014.

Con Edison (Consolidated Edison Company of New York, Inc.). 2014. *Gas Operations Emergency Response Plan*. EMP-200. New York City: Con Edison.