National Transportation Safety Board

Pipeline Accident Brief

Birmingham Public Housing Gas Explosion

Accident No.:	DCA14MP001
Type of System:	Natural gas main pipeline
Accident Type:	Rupture and fire
Location:	Birmingham, Alabama
Date:	December 17, 2013
Time:	2:29 a.m. central standard time
Owner/Operator:	Alabama Gas Corporation
Fatalities:	1
Injuries:	3
Damage/Clean-up Cost:	$505,300
Material Released:	Natural gas
Quantity Released:	147,000 cubic feet
Pipeline Pressure:	19 pounds per square inch, gauge
Maximum Allowable Operating Pressure:	25 pounds per square inch, gauge
Component Affected:	2-inch cast iron distribution pipeline

The Accident

At 2:29 a.m. on December 17, 2013, one side (unit 80) of a two-story duplex at a public housing project in Birmingham, Alabama, exploded when natural gas in the apartment ignited.[1] (See figure 1.) The explosion and fire destroyed unit 80 and heavily damaged the adjoining apartment (unit 79). The explosion also damaged several adjacent homes at the Charles P. Marks Village, operated by the Housing Authority of the Birmingham District.

A Birmingham Fire and Rescue Service (BFRS) official said the six residents of unit 79 escaped. At least three unit 80 residents were sleeping in upstairs bedrooms and were blown out of the apartment; two received non-life-threatening injuries. Two adults sleeping in a downstairs bedroom were crushed when the second floor collapsed. One died at the scene, and the other was critically injured.

The BFRS arrived at the scene at 2:34 a.m. and extinguished the structure fire by 3:16 a.m. Meanwhile, a separate, torch-like fire continued to burn from the broken natural gas service pipeline riser adjacent to the building. (See figure 2.) Alabama Gas Corporation (Alagasco) crews assisted with the recovery and rescue efforts and searched for a debris-free path to uncover the natural gas service line to the affected apartment. At 6:14 a.m., an Alagasco crew isolated the gas flow at the riser valve stopping the fire.

[1] All times in this brief are central standard time.

Figure 1. Aerial view of the Charles P. Marks Village before the explosion.

Figure 2. The riser fire shoots up from the ground amid the rubble at Charles P. Marks Village.

The occupants of several neighboring apartments were evacuated; many took shelter at a nearby recreation center. One unit 80 resident was killed, and three were injured. Alagasco estimated the property damage was $505,300.

The explosion destroyed unit 80. Unit 79, the other half of the duplex, sustained less severe damage, mostly from the post-explosion fire. The common wall between units 79 and 80 pushed away from unit 80; debris from the top of the wall landed into the living areas of the first floor of unit 79. (See figure 3.)

The force of the explosion blew large fragments of concrete and brick into the yard, the alley between 64th and 65th Courtway South, and onto Joppa Avenue. The flying debris damaged buildings near unit 80. Based on the location and extent of explosion-related damage, investigators determined the origin of explosion was inside unit 80.

Figure 3. Units 79 and 80 after the explosion.

During interviews by NTSB investigators, occupants of unit 79 and 80 and the surrounding apartments stated they had smelled gas outside—some as far back as two weeks before the explosion. Most said they smelled gas just outside the entrance to their homes. One resident said he had smelled a faint gas odor inside the home; however, no one notified Alagasco or the fire department the day of the explosion.

During the 3 years before the incident, Alagasco had received several complaints of gas odors from Marks Village residents, but none involved units 79 or 80. Unit 79 and 80 residents said they had reported gas odors to the office at Marks Village, but housing authority officials were unable to locate records documenting complaints for those units.

Natural Gas System Examination

A 2-inch, cast iron natural gas main operating at 19.5 pounds per square inch gauge (psig) ran along the north side of units 79 and 80 parallel to 65th Courtway South. One and one-half-inch service lines supplied gas to units 79 and 80. (See figure 4.) The natural gas lines from the meter outlets into the duplex consisted of threaded, black-iron pipe. The unit 80 line entered the apartment through the wall about 3 feet above the concrete slab at the northeast corner of the unit. From this point, the line followed the north wall and turned south into the kitchen. The gas service line continued vertically into the structure along the wall, turned horizontally directly below the second level concrete slab, and traveled the length of the kitchen toward the back of the building. The pipe dropped vertically on the wall behind the sink to provide gas to the range. The pipe continued downward where it supplied the water heater; it then passed through an adjacent wall to supply gas to the living room heater where flues for the heater and water heater joined and routed to a central chase in the closet with the water heater.[2]

Alagasco and housing authority officials said they had no records showing the residents of units 79 or 80 reported gas odors either inside or outside their apartments in the 24 hours before the accident. Investigators found no evidence of a malfunctioning appliance or leaking gas lines in units 79 and 80.

The investigation showed the explosion occurred inside the unit 80 ground floor and was directed outward. Evidence of this includes the entry door deformation that was indicative of an outward blast; the pattern of the debris field indicating debris was blown outward and away from the residence; and the position of the second floor slab, which collapsed when the first floor walls supporting the slab were blown outward. The NTSB investigators ruled out a gas leak inside the unit.

A teenage resident of unit 80 told NTSB investigators he smelled a faint gas odor after arriving home late the night of the accident. “I smelled it [gas] when I came in the door, but it wasn’t that strong, you know, so I just didn’t pay it no mind,” he said.

After the accident, investigators found no evidence of pre-explosion damage to the gas supply piping inside the duplex. Although there was extensive damage to the appliances, investigators found no evidence of a malfunction—determining instead that the tenants would likely have detected a malfunction of the appliances that they used for heat, hot water, and cooking.

The Pipeline and Hazardous Materials Safety Administration (PHMSA) requires operators to odorize natural gas in distribution lines as necessary so that the gas is readily detectable by a person with a normal sense of smell when the gas concentration in the air is one-fifth of the lower explosive limit.[3] Alagasco uses tertiary butyl mercaptan to odorize its

[2] “Chase” refers to the space in a building, typically behind walls where utilities are routed.

[3] Pipeline Safety Regulation 49 *Code of Federal Regulations* (*CFR*) 192.625; Odorization of Gas.

natural gas. When odorized natural gas passes through the ground from a leaking supply pipe, the soil can absorb and deplete the odorant from the gas.[4]

Before the fire was extinguished, two Alagasco technicians and a supervisor arrived at 3:28 a.m. and began conducting bar hole tests around the building along the buried gas pipe to determine the source of the gas leak.[5] Technicians located multiple areas close to the scene that indicated the presence of leaking natural gas, including an area on the west side of Joppa Court adjacent to unit 80 and along 65th Courtway South north of units 79 and 80.

The Alagasco employees noticed bubbles in standing water that had accumulated near the curb on the northeast side of the apartment, which is an indication of a subsurface gas leak. At 7:14 a.m., they excavated down to the gas main and found a tree root tightly wrapped around the cast iron gas main. A rock was wedged between the tree root and the cast iron pipe. Investigators observed a crack in the main at that location. (See figure 4.) They confirmed the gas main leak using a soap solution while the line was at operating pressure. According to the Alagasco technician, the gas was escaping through a crack at the 5 o'clock position and was approximately one-quarter to one-half inch long. At 9:30 a.m., they removed the tree root, cleaned the pipe surface, and installed a mechanical clamp to stop the leak. On December 18, 2013, Alagasco technicians cut an 8-foot segment with the newly-installed clamp out of gas main and replaced it with a plastic pipe. The pipe segment, rock, and tree root that had been wrapped around the pipe were sent to the NTSB laboratory in Washington, DC, for examination.

Figure 4. Aerial view showing route of underground utilities near unit 80.

[4] Tenkrat, Daniel; Hlincik, Tomas; and Prokes, Ondrej (2010). *Natural Gas Odorization*, Natural Gas, ISBN: 978-953-307-112-1, InTech, DOI: 10.5772/9825. Available from: http://www.intechopen.com/books/natural-gas/natural-gas-odorization.

[5] A bar hole survey is performed by boring a hole in soil or pavement in the area of a suspected gas leak to test the subsurface environment with a combustible gas indicator. The results are read in percentage of combustible gas with respect to the lower explosive limit (LEL) as a percentage of gas in air; a 100 percent reading indicates the gas concentration in the bar hole is at or above the LEL. The natural gas LEL is 5 percent gas concentration in air.

The sewer and gas mains ran parallel along 65th Courtway South. Units 79 and 80 receive gas through service lines that branch from the main gas line in a southward direction. The sewer connection for the units—made of 4-inch terra cotta—runs north from the units and ties into an 8-inch sewer main. After the explosion, investigators excavated the 4-inch sewer lateral from unit 80 and discovered a 23-inch-long broken (collapsed) section. (See figure 5.) The break was located approximately 20 feet from the north edge of the foundation of unit 80 and about 25 feet south of the gas main leak.

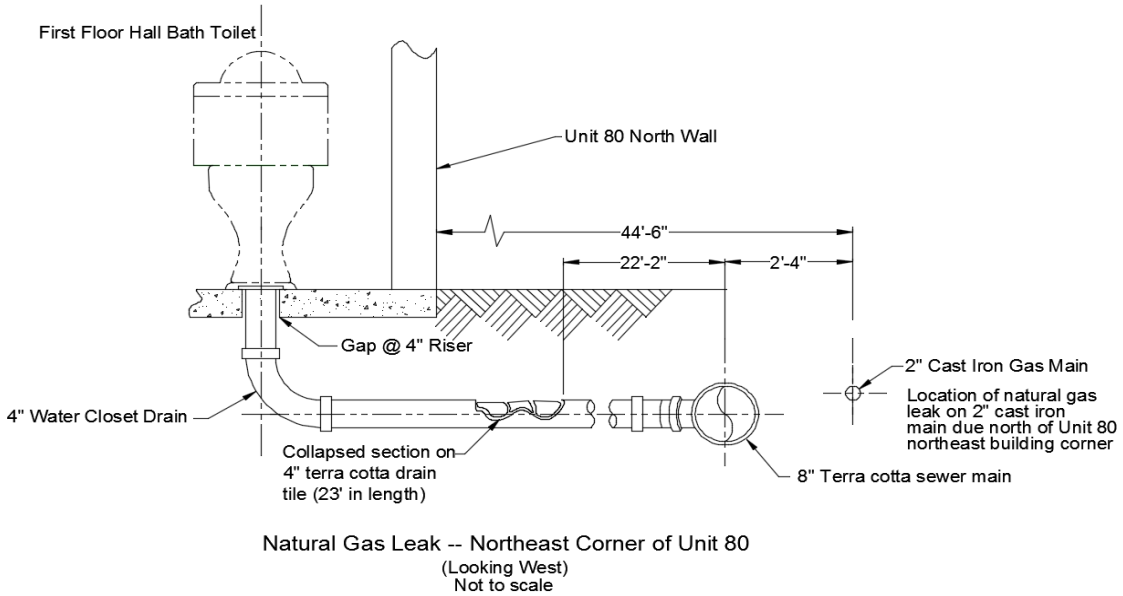

Figure 5. Cross section of underground piping to the northeast corner of the half-bath in unit 80.

Emergency Response

The BFRS received the first 911 call at 2:29 a.m., and firefighters arrived at the scene within 5 minutes. By 3:16 a.m., firefighters had extinguished the structure fire, but not the riser fire. The first Alagasco service technician arrived at 3:23 a.m. followed by a supervisor at 3:28 a.m. and additional crew members at 4:00 a.m. The first service technician began checking nearby sewer lines using a gas measurement instrument but detected no natural gas. However, the continuing riser fire prevented the technician from checking the sewer lines between the sewer main and unit 80.

Two separate fires burned during the accident, the structure fire and a riser fire at the natural gas service line riser adjacent to the northeast wall of unit 80. Early in the emergency operation and continuing until approximately 6:30 a.m., the BFRS presumed there were no trapped victims inside the burning building. This presumption was based on their search efforts and limited information from the other building tenants who were transported to the hospital. The riser fire prevented firefighters from gaining access to the collapsed unit, which delayed a comprehensive search for possible survivors.

The riser fire continued to burn while Alagasco looked for a safe, debris-free path to excavate to the service line leading to unit 80 and stop the gas feeding the riser fire. The BFRS agreed with the decision to allow the riser to continue burning to avoid the formation of a natural gas cloud that could possibly re-ignite.

About 6:00 a.m. when technicians were still unable to locate the buried service line to stop the riser fire, Alagasco decided to shut off the gas using the riser isolation valve directly below the venting, burning gas. At 6:14 a.m., the technician closed the service isolation valve, which stopped the gas flow.

Firefighters then resumed their search and found a critically injured, conscious man pinned beneath the second floor slab on the southeast end of the first floor of unit 80; the body of a woman was nearby. The rescue team used airbags and hydraulic spreaders to raise the collapsed second floor slab enough to rescue the man and recover the woman's body.

Postaccident Investigation

Natural Gas Leak Path into Unit 80

In addition to the gas pipe configuration, the investigation included the examination of other pipes in the home, including the wastewater pipes. The 4-inch waste sewer connections from unit 80 traveled vertically through two penetrations about 29 feet apart in the first floor concrete slab. The laterals then ran horizontally at approximately 32 inches below grade where they were connected to the 8-inch terra cotta bell-and-spigot style sewer main.

The NTSB determined that one credible path for the natural gas to enter unit 80 was by migrating through the soil from the cracked cast iron gas main to the buried sewer main about 3feet away. It then traveled along the exterior of the buried sewer main to the building about 45 feet away. (See figure 5.) It accumulated under the first floor slab and entered the unit where the sewer pipe passed through the concrete slab at:

- The annulus around the 4-inch cast iron sewer pipe below a toilet located in the northeast corner of unit 80 on the first floor. Close examination of the floor penetration around the pipe revealed gaps in the annulus.

- The 4-inch waste piping penetration through the slab near the kitchen sink, the area at the annulus of the 4-inch penetration also had gaps.

The second credible path involved the gas leaking inside of the 4-inch sewer at the collapsed section described earlier. In this scenario, gas flowed through the soil from the cracked gas main and into the collapsed, 4-inch sewer lateral about 22 feet away. Gas could travel inside the sewer pipe and pass through the water traps in the toilet and under the bathroom sink and into the ground floor. Based on the nearly 20 psig gas pressure, the expected gas flow volume out of the cracked gas main, and the breach in the 4-inch sewer, natural gas likely bubbled through the water seals in the toilet and the sink drains. From either route, the appliances provided the ignition source for the gas inside the apartment; the range had three open, active pilots, and the room heater had one pilot and might have had the main burner operating. (See figure 6.)

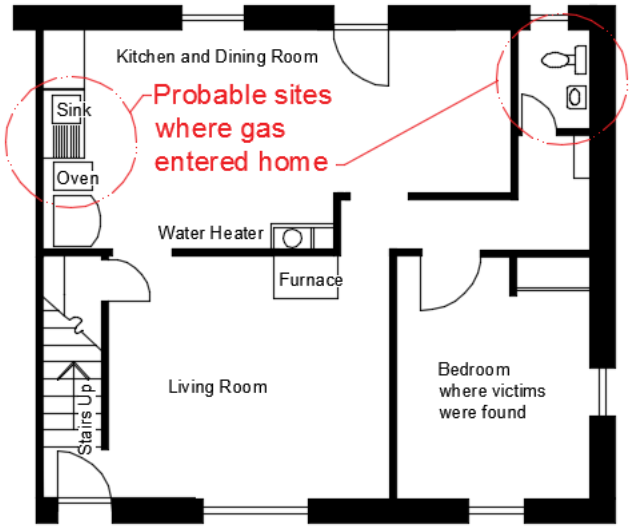

Figure 6. First level of unit 80 showing areas gas entered the apartment.

Pipeline History

Natural gas delivered to the Marks Village community is supplied through cast iron distribution mains. Most of the branches are 2-inch diameter cast iron with some mains as large as 6 inches. The cast iron main that served units 79 and 80 was about 45 feet north of the apartment.

Service line installation records for units 79 and 80 show the 1-1/2-inch steel service line with pipe enamel coating was installed in October 1951. Gas company records did not accurately show the underground routing of the service lines to the two units. Existing records did not identify the pipe wall thickness used at the time of installation. Other historical information, including manufacturing and purchase records for cast iron piping in the community, was no longer available. A grandfathered rule established the maximum allowable operating pressure of the pipeline at 25 psig.[6] The Alagasco records reflect that pressure testing was not performed because codes at the time of installation did not require the testing.

[6] Pipeline Safety Regulation 49 *CFR* 192.619 (a)(3) by using the highest actual operating pressure to which the pipe segment was subjected to during the 5-year period preceding July 1, 1970.

Alagasco maintains the integrity of its gas mains and service lines by walking surveys performed on a 3-year basis through a subcontract with a qualified leak detection contractor.[7] The contractor last surveyed the gas mains for leaks in May 2011 and surveyed the service lines in November 2011. All identified leaks were repaired, although the main and service lines in the vicinity of units 79 and 80 did not require any repair work.

Leak Surveys

At the request of the NTSB, Alagasco leak-surveyed the community for indications of a natural gas leak near the damaged unit 80 as well as other addresses within the property in the days following the accident. In areas where technicians suspected a leak, they excavated the region to approximately 3 feet below grade to expose the suspected leak location. In total, excavations would involve the removal of six gas-piping segments, labeled A through F. (See figure 7.) All the segments were shipped to the NTSB laboratory in Washington, DC, for examination. Alagasco technicians detected gas leaks at the locations marked with the white rectangles. The clamp on segment A (sleeve 1 in figure 7) was installed the morning after the explosion to stop the leak and stabilize the pipe for removal.

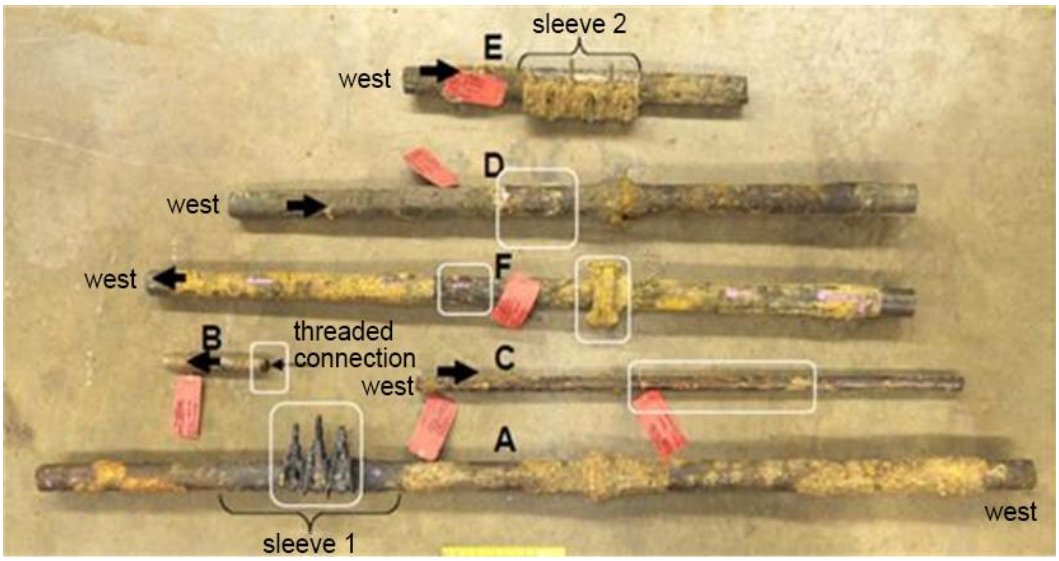

Figure 7. Pipe segments recovered from the accident; rectangles indicate the leak locations.

[7] A "walking survey" consists of a technician walking through a neighborhood sampling the areas (pipe runs and meters) with electronic gas detection equipment. Leak grades and categories of interest are: Grade 1, which includes (among other things) any reading of 20 percent LEL or greater at the outside of a building or where gas would likely migrate to an outside wall of a building; Grade 2, which includes(among other things) any reading of 40 percent LEL or greater under a sidewalk in a wall-to-wall paved area that does not qualify as a Grade 1 leak; and Grade 3 which includes (among other things) any reading less than 100 percent LEL under a street without wall-to-wall paving where it is unlikely that gas could migrate into a building.

In accordance with 49 *CFR* 192.723 (b)(2) Distribution leakage surveys; cathodically unprotected pipe requires 3-year maximum interval.

Materials Laboratory Testing

Prior to destructive testing, several pipe segments were pressure tested with compressed air at the NTSB Materials Laboratory to verify the leak locations; determine pressure decay with time; and estimate the leak rate. In summary, the leak tests showed that pipe segments C, D, and F contained leaks in the same respective areas as those identified during the on-scene accident investigation and revealed evidence of a leak at the ends of the sleeve 2 that was not detected previously. Pipe segment B was not pressure tested since Alagasco reported the leak to be at the threaded connection on the segment and the fitting had been disconnected in the field.

Alagasco technicians identified segment E to be of interest and submitted it for testing because it contained an existing sleeve. Testing revealed evidence of leaks at both ends of the sleeve that were not detected during the on-scene pressure testing. Visual examination of segment F (a 2-inch nominal diameter cast iron pipe) revealed a 4-inch long linear indication at the 12 o'clock position. Leak testing confirmed the field test results and identified two additional leaks at the 10 o'clock and 1 o'clock positions. The length of the 10 o'clock and 1 o'clock cracks measured approximately 3.6 inches and 2 inches, respectively, along the pipe axis.

NTSB investigators disassembled and removed the new clamp on pipe segment A. They discovered a fracture that extended circumferentially around the pipe. (See figure 8.) The fracture surface revealed a radiating pattern that originated from the outer surface at the bottom of the pipe. The fracture extended from each side of the fracture origin and propagated circumferentially up toward the top of the pipe.

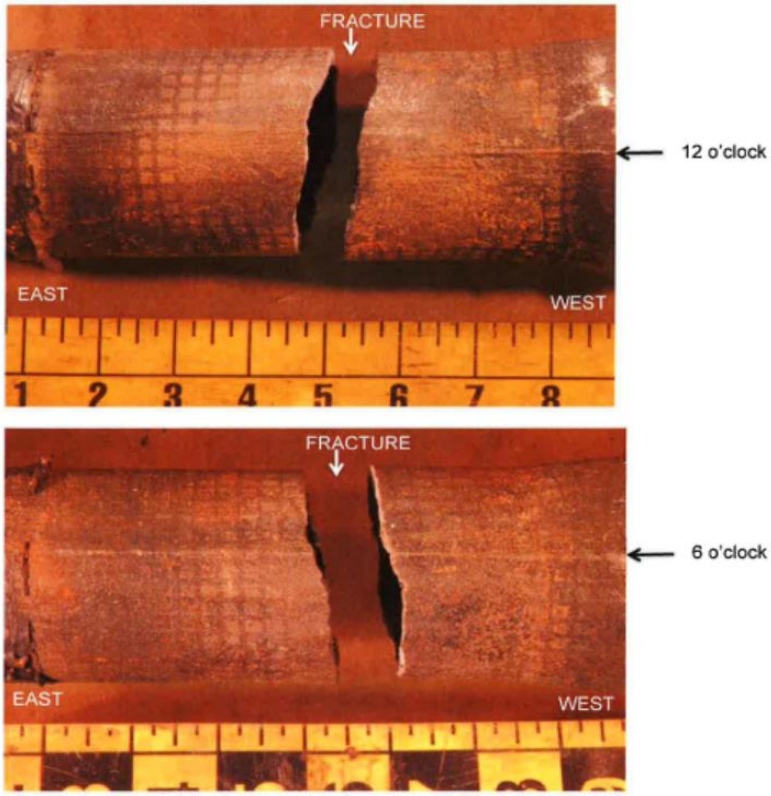

Figure 8. Pipe segment A after the new clamp was removed to expose the crack.

The fracture face exhibited five regions adjacent to the outside surface consistent with oxidized cast iron. The largest oxidized region was located at the bottom of the pipe and extended through the pipe wall. The circumferential length of the oxidized region measured approximately 1.6 inches along the outer surface. The oxidized region at the inner surface measured approximately 0.7 inch circumferentially.

The dark gray area on the fracture face in the area adjacent to the outer surface indicates significant graphitic corrosion in the cast iron gas main. (See figure 9.) Graphitic corrosion reduced the strength of pipe segment A and made it more brittle.

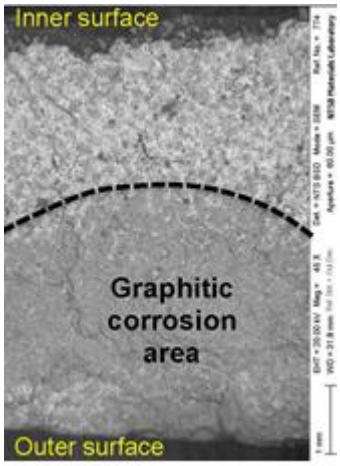

Figure 9. SEM electron backscatter image of the pipe segment A fracture face.

In addition, NTSB investigators examined the large tree root and rock that had been recovered with the pipe segment. They concluded that the tree root around the pipe increased the force exerted by the rock against the corroded cast iron pipe wall. The compressive, pinpoint forces exerted by the rock and downward forces from ground settlement likely caused the corroded pipe to crack.

Distribution Integrity Management

PHMSA amended the Federal Pipeline Safety Regulations on December 4, 2009, and February 1-2, 2010, to require operators of gas distribution pipelines to develop and implement an integrity management program that includes a written integrity management plan. The regulations took effect in 2011. Although there are required program elements, PHMSA does not mandate specific methods of implementation. Alagasco performs an evaluation of its Distribution Integrity Management Program (DIMP) on an annual basis; plus the program is periodically audited by the Alabama Public Service Commission, most recently in March 2014.

The Alagasco cast iron management program has evolved over the last three decades. Since 1997, Alagasco has replaced approximately 405 miles of cast iron piping. The pipe replacement program operates as a separate, but related, program from DIMP. The focus of the pipe replacement program is to prioritize areas for replacement. Management bases the replacement on evaluation of leak repair data and input from field operations personnel to create the pipe replacement priority list.

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Alagasco analyzes 10 years of pipeline data and evaluates its list of scheduled pipeline replacements on an annual basis. On the June 2013 priority list, it ranked Marks Village near the bottom of the priority list. Following the explosion at Marks Village, Alagasco re-ranked the priority list and completed the replacement of all cast iron gas pipes at Marks Village in March 2014.

After the accident, Alagasco reviewed the condition of cast iron piping at 13 other Birmingham public housing communities. The assessment revealed two installations of cast iron piping that dated back to 1917. Again, following a review of these properties, Alagasco re-ranked and scheduled the cast iron replacement work well ahead of the previously planned replacement dates. Alagasco has replaced cast iron at one of the two 1917 era communities.

Alabama Public Service Commission Audits

The Alabama Public Service Commission (ALPSC) is an intrastate regulator that oversees all operator distribution mains and service pipelines within the state of Alabama. The regulator's inspection of Alagasco encompasses the auditing of records, physical plants, corrosion control programs, operator qualification, and field inspection. The ALPSC also conducts "protocol 9" inspections.[8] These inspections cover all areas of the operation through all territories of the gas company.

In 2012, the ALPSC sent letters to all operators of natural gas pipelines in Alabama in response to an NTSB safety recommendation from an incident in Allentown, Pennsylvania. In its August 23, 2012, letter to Alagasco, the ALPSC noted that cast iron pipe has been considered a serious threat to natural gas distribution systems. The ALPSC noted that the Alabama ranks among the top 10 states with the most cast iron piping remaining in its distribution systems. Recognizing the economic difficulty of large-scale replacements, the regulators called on Alagasco to look at cast iron replacement as a top priority. The ALPSC noted the efforts that Alagasco had already taken with respect to cast iron replacement and encouraged the company to accelerate and address replacements, particularly in business areas, as soon as practical.

Alagasco reported that during the past five years it replaced an average of 41 miles of cast iron pipe per year. In its 2011 Gas Distribution System annual report, Alagasco reported it has 928 miles of cast iron pipe remaining in its system. Alagasco anticipated replacing an additional 35 miles in 2012 and 51 miles in 2013. As a result, Alagasco estimated it would have all of its cast iron pipelines replaced in approximately 20 years.

[8] Pipeline and Hazardous Materials Safety Administration, Form 15; through Amendment 195-95 -- Inspection report format requiring covered task performance, qualification status, abnormal operating condition recognition and reaction, verification of qualification, and program inspection deficiencies.

Postaccident Actions

Following the accident, Alagasco reviewed its actions and response to identify potential areas of improvement. The postaccident actions included:

- Replaced the cast iron pipe in Marks Village in early 2014. The cast iron mains were replaced with polyethylene pipe ranging from ¾-inch to 4-inch diameter. The majority of the service lines were replaced with polyethylene pipe from the main lines to the meter locations. In addition, Alagasco added main isolation valves with the capability of stopping the flow of gas into this community if such an action is required in the future.

- Alagasco completed the scanning of all available service cards (service line location information), trained its field personnel in the use of the new service information, and made the information electronically accessible in the service trucks.

- Initiated annual leak surveys for cast iron and unprotected steel mains serving multi-family residences. These surveys were previously conducted on a 3-year cycle in accordance with DOT 192 requirements. Alagasco now conducts these surveys annually. The first cycle for such surveys was completed in 2014.

- Met with the BFRS and created an "Emergency Response Lessons Learned" document. On August 25, 2014, Alagasco met with members of the BFRS involved in the emergency response for this incident. The purpose of the meeting was to discuss Alagasco's actions/response to the Marks Village incident and to allow the BFRS to provide its observations concerning the response efforts.

- Revised Alagasco's evaluation process for future cast iron pipe replacement locations. Alagasco's evaluation process now includes analysis of leak history for both mains and services.

- Prepared a special mail-out of procedures for reporting gas leaks to customers in multi-family units. This was mailed in August 2014 to customers in multi-family units who are served by a cast iron or bare steel gas main. It instructs customers to call Alagasco or 911 first (rather than the landlord or maintenance department) if a gas leak is suspected.

- Changed safety information processes for electronic bill customers. Alagasco now ensures that customers who receive and pay their bills electronically receive the same safety information (by US Mail) as those who receive their bills in paper format.

- Revised the Alagasco Customer Natural Gas Safety brochure (also known as the Alagasco 16-75 brochure) to include language specifically targeting customers living in rental properties (including multi-family units). The first semi-annual mailing of the revised brochure occurred in April 2015.

- Ensured customers have continuous access to safety information through the website, http://www.alagasco.com/safety---education/if-you-smell-natural-gas-58.html.

- Expanded the practice of distributing the 16-75 safety brochures to customers at service calls. For the Birmingham customer base, 16-75 safety brochures were given to all customers during service calls where the mechanic interacted with the customer. Alagasco has expanded that practice into all of its service areas.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the release of natural gas through a large crack in the 62-year-old, cast iron gas main that resulted when tree growth cracked the corroded pipe. Once the accumulating gas reached the explosive limit inside the apartment, an active pilot light on an appliance ignited the gas. Contributing to the accident was the absence of the odorant, which was absorbed by the soil and prevented residents from smelling the gas.

For more details about this accident, visit www.ntsb.gov/investigations/dms.html and search for NTSB accident ID DCA14MP001.

Issued: March 30, 2016