# **Missouri Public Service Commission**



# Gas Incident Report

Laclede Gas Company Case No. GS-2011-0245

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3810 Council Grove Avenue Pine Lawn, Missouri January 8, 2011

Energy Unit ... Regulatory Review Division December 2011 Jefferson City, Missouri

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#### **1.0 SYNOPSIS**

At approximately noon Central Standard Time (CST) on January 8, 2011, a natural gas explosion and flash fire occurred at 3810 Council Grove Avenue in Pine Lawn, Missouri. The single-family residence sustained substantial damage and the occupants reported minor injuries.

Laclede Gas Company (Laclede or Company) provides natural gas service in Pine Lawn, Missouri. The residences from 3802 to 3914 Council Grove Avenue were supplied natural gas through a 2-inch diameter coated steel main, located along the east side of Council Grove Avenue. The natural gas main was operating at approximately18 pounds per square inch gauge (psig) at the time of the incident.

The Missouri Public Service Commission's Energy Unit-Safety/Engineering Section Staff (Staff) has determined the probable cause of the incident was the release of natural gas from a circumferential fracture in the 2-inch diameter coated steel main in front of 3810 Council Grove Avenue. The released natural gas migrated through backfill material and sanitary sewer lines. The migrating natural gas then accumulated within the structure located at 3810 Council Grove and was ignited by an undetermined source.

The bottom of the natural gas main was dented in two locations and the pipe had been bent upward, probably during a previous excavation to install the sanitary sewer lateral to 3810 Council Grove Avenue in 2000 or 2001. The backfill of the sanitary sewer lateral excavation continued settling in the subsequent years, exerting a downward force on the natural gas main and creating increasing bending stresses over time. The resulting stress at one of the dents caused a brittle fracture to initiate and propagate around 85% of the pipe circumference.

There is no record that Laclede nor Missouri One Call were called when the steel gas main was damaged. This incident illustrates the importance of excavators reporting any damage to natural gas facilities that occurs during an excavation, even if that damage does not cause a natural gas release at the time of the excavation.

Staff is making one recommendation to Laclede as a result of this investigation.

#### 2.0 CONCLUSIONS

- 1. At approximately noon CST on Saturday, January 8, 2011, an explosion and flash fire occurred in a residence at 3810 Council Grove Avenue in Pine Lawn, Missouri.
- 2. The explosion caused substantial structural damage to the residence, which was deemed a total loss by the fire department. The occupants reported minor injuries.
- 3. The probable cause of the incident was the ignition of natural gas released from a circumferential fracture in the 2-inch diameter coated steel gas main located between the sidewalk and curb in front of 3810 Council Grove Avenue. The released natural gas migrated through the backfill for the natural gas main, the adjacent water main, and various nearby service lines, and through the nearby sanitary sewer lines. The natural gas migrated to and into 3810 Council Grove Avenue through one or more entry locations, accumulated, and was ignited. The probable source of ignition was not determined.
- 4. The probable cause of the fracture was a combination of previous excavation damage that dented the bottom of the steel main and bent it upward during installation of a sanitary sewer lateral in 2000 or 2001 followed by ten years of backfill settlement below and above the natural gas main. At the fracture location, the excavation damage to the main created a weak point in the steel pipe and the backfill settlement induced bending stresses in the pipe which initiated a brittle fracture that continued circumferentially around the pipe.
- 5. The natural gas that was migrating through the soil and sanitary sewer system also entered 3808 and 3908 Council Grove Avenue. Emergency response actions to ventilate the soil near the fracture, ventilate the sanitary sewer system at nearby manholes, evacuate residents, and turn off electric power to the vicinity were successful in preventing natural gas ignitions in these two residences.
- 6. Laclede used "air-jacking" to ventilate the soil during the emergency response to this incident, but did not have emergency response procedures for this action. Laclede started "air-jacking" at what Staff believes was an improper location on the west side of Council Grove Avenue. "Air-jacking" at this location could have caused additional migration of natural gas from the main fracture on the east side of Council Grove Avenue to the sanitary sewer lines located under the street and later, "air-jacking" was moved to a proper location near the fracture. "Air-jacking" was temporarily suspended for a period of time resulting in an increased level of natural gas in the sanitary sewer manhole at the intersection of Council Grove Avenue and Vetter Place.

- 7. The cathodic protection (CP) of the 2-inch diameter coated steel gas main serving 3802 to 3914 Council Grove Avenue was inadequate at the time of the incident and for some time period prior to the incident. This resulted in past corrosion leaks along the main and corrosion leaks in the days following the incident. However, no corrosion leaks were observed at the location of the gas main fracture. The CP issues found during this investigation are not directly related to the incident at 3810 Council Grove Avenue. Staff plans to provide further information on these CP issues and recommendations to the Commission in the near future, and in a subsequent case.
- 8. Notifications should have been made to Missouri One Call and Laclede when the natural gas main was damaged at 3810 Council Grove Avenue. If the damage to the natural gas main had been reported, Laclede could have repaired or replaced the damaged main segment. Because a locate request was not specifically made for the address of 3810 Council Grove Avenue and there was no report of the damage, Staff was not able to positively identify the excavator that damaged the natural gas main.

# 3.0 RECOMMENDATION

Staff recommends that Laclede develop procedures for using soil ventilation ("air-jacking") during an emergency response and provide training to personnel who would use them during an emergency.

# 4.0 FACTS

NOTE: Except for the information gathered during the on-site investigation and/or interviews, the information used to compile this portion of the report was obtained in record and/or statement form.

# 4.1 The Incident

At approximately noon CST on Saturday, January 8, 2011, an explosion and flash fire occurred in a single-family residence at 3810 Council Grove Avenue in Pine Lawn, Missouri.

#### 4.2 Personal Injuries

The occupants were on the first floor and reported minor injuries that did not involve hospitalization.

# 4.3 Property Damage

The residential structure at 3810 Council Grove Avenue was a one-story house with a basement. The explosion caused substantial structural damage and the flash fire in the basement caused charring and minor burning of the floor joists. The gas meter located outside near the southwest corner was pulled upwards during the explosion and the outlet connection was severed. The damaged structure was deemed by the fire department to be a total loss with an estimated value of \$90,000.

# 4.4 Site Description

The 3800 block of Council Grove Avenue is located in Pine Lawn, Missouri, a suburb of St. Louis bounded by I-70 on the north and the City of St. Louis on the east (See Appendix A-1, Figure 1). The structure at 3810 Council Grove Avenue is located in a primarily residential area on the east side of Council Grove Avenue, with the front of the structure facing west (See Appendix A-2, Figure 2). For this Report, Council Grove Avenue is considered to traverse along a north-to-south direction.

The residence at 3810 Council Grove Avenue was a single-story wood-frame structure with steel siding. The structure was built in 2000 and 2001 over a full basement consisting of poured concrete. An attached single-car garage was located on the north side of the structure (See Appendix B-1, Photograph 1).

# 4.5 Meteorological Data and Conditions

The temperature steadily dropped from 36 °F at noon on January 7 to 14 °F at 6 a.m. on January 8,  $2011^1$ . The temperature remained at 14 °F until 9 a.m. and gradually rose to 19 °F at the time of the incident, with wind out of the northwest during this time period. Light snowfall was observed from 6 a.m. on January 7 to 4 a.m. on January 8, 2011, measuring 0.4 inches with no accumulation.

# 4.6 Natural Gas System

Natural gas service in the St. Louis, Missouri area is provided by Laclede Gas Company. The distribution main supplying the 3800 block of Council Grove Avenue is a 2-inch diameter coated steel gas main located parallel to and east of the east curb line of Council Grove Avenue (See Appendix A-3, Figure 3). The main was installed in 1953 and the depth of cover at the incident location was approximately 4½ feet. The main was operating at a pressure of approximately 18 psig at the time of the incident and the maximum allowable operating pressure<sup>2</sup> (MAOP) established by Laclede was 60 psig. The Company does not have records for the main regarding the pipe manufacturer or pipe specification. The Company also does not have records regarding the coating on the main, but the coating on the main at the incident location was observed to be factory-applied spiral-wrapped coating made with some type of coal-tar material.

The natural gas service line for 3810 Council Grove Avenue was a 1-inch diameter polyethylene pipe installed by Laclede on January 9, 2001, at the time the house was built. The service line extended from the main to the natural gas meter located on the south side of the house.

# 4.7 Previous Company Actions

# 4.7.1 Leak Surveys

Prior to the incident, a leak survey was conducted along the involved gas main on September 3, 2009<sup>3</sup>. The service lines in the 3800 block of Council Grove Avenue were leak surveyed on May 28, 2008. No leaks were found during these leak surveys.

<sup>&</sup>lt;sup>1</sup> Meteorological data is from the weather reporting station located at Lambert St. Louis International Airport.

<sup>&</sup>lt;sup>2</sup> MoPSC regulation 4 CSR 240-40.030(1)(B)19., defines the "maximum allowable operating pressure (MAOP)" as the maximum pressure at which a pipeline or segment of a pipeline may be operated.

 $<sup>^{3}</sup>$  For distribution systems located outside of business districts, 4 CSR 240-40.030(13)(M)2.B. requires leak surveys to be conducted at intervals not exceeding 39 months, but at least once each third calendar year.

#### 4.7.2 Cathodic Protection

All steel gas mains in the incident area were considered to have cathodic protection (CP) and Laclede was using operation and maintenance procedures for cathodically protected steel mains. The Company's map (See Appendix A-3, Figure 3) showed the steel main serving 3802 - 3914 Council Grove Avenue was electrically continuous (no insulating fitting shown) with a steel main extending east from Council Grove Avenue, which indicated both mains were connected to CP test station<sup>4</sup> 4410 located at 3800 Council Grove Avenue (vacant lot). This CP test station had been checked on an annual basis<sup>5</sup> and had been meeting the CP criterion that requires a negative polarized voltage of at least 0.85 volt (V), with reference to a saturated copper-copper sulfate half cell. After the incident, it was determined that an insulating union (not shown on the Company map) was located in the steel main just north of CP test station 4410 and there had been no CP test station connected to the electrically-isolated steel main serving 3802 - 3914 Council Grove Avenue. CP test station 4410 was only connected to an electrically-isolated steel main located along an alley between Council Grove Avenue and Margaretta Avenue to the east.

The electrically-isolated steel main to the north of 3914 Council Grove Avenue had a CP test station that was annually monitored prior to the incident. Connected to this main, the electrically-isolated steel main on Charlotte Avenue had a CP test station that was annually monitored prior to the incident. To the west of Council Grove Avenue, the electrically-isolated steel main on Margaret Avenue had a CP test station that was annually monitored prior to the incident, but the electrically-isolated steel main on Vetter Place did not have a CP test station.

# 4.7.3 Active Leaks, Trouble Calls, or Leak Calls in the Vicinity

There were no known active leaks in the 3800 block of Council Grove Avenue at the time of the incident. During the month prior to the incident, there were no trouble, leak or odor calls in the 3800 block of Council Grove Avenue.

#### 4.7.4 Past Leaks

There were twelve leaks on the steel main and service lines serving 3802 - 3914 Council Grove Avenue from 1969 until the incident – see list below. Eight of these leaks were caused

<sup>&</sup>lt;sup>4</sup> A CP test station is a location where a wire connected to the underground steel gas pipe can be accessed from the surface for testing the pipe-to-soil potential.

 $<sup>^{5}</sup>$  4 CSR 240-40.030(9)(I)1. requires each pipeline that is under cathodic protection to be tested at least once each calendar year, but with intervals not exceeding 15 months, to determine whether the CP meets one or more of the applicable criteria.

by corrosion, five of which were at 3902 Council Grove Avenue. The Company does not have leak records prior to 1969, so it is not known if there were any additional leaks on this main between installation in 1953 and 1969.

1) 3814 Council Grove	04-13-71	Coupling thread leak	Clamp
2) 3902 Council Grove	03-07-73	Service tee leak	Tighten
3) 3832 Council Grove	10-31-84	Curb valve leak	Tighten
4) 3902 Council Grove	12-22-89	Corrosion leak	Clamp
5) 3902 Council Grove	12-21-93	Corrosion leaks	Two clamps
6) 3902 Council Grove	03-10-95	Corrosion leak	Clamp, anode
7) 3802 Council Grove	06-26-95	Corrosion leak @ fitting	Replace fitting cap
8) 3902 Council Grove	03-31-00	Corrosion leak (service line)	Replace 3' of service
9) 3808 Council Grove	03-30-01	Thread fracture – corrosion	Replace joint, anode
10) 3810 Council Grove	04-23-01	Excavation damage leak	Replace 2' of service
11) 3902 Council Grove	03-05-02	Corrosion leak	Clamp, anode
12) 3820 Council Grove	07-21-06	Corrosion leak	Clamp, anode

#### 4.7.5 Previous Excavations Nearby

Through its review of Missouri One Call locate requests, Laclede determined that there had been two proposed excavation projects in the vicinity of the incident. The first project involved a locate request for 3812 Council Grove Avenue received on February 17, 2000, with sewer/water line indicated as the type of work to be performed. Laclede's records indicate the main and service line(s) were located on February 22, 2000. There is no 3812 address on Council Grove Avenue and in February 2000, it is not likely there were structures in place. This locate request was approximately 6½ months prior to the time the excavations for the basement foundations were made as noted below. The second project involved locate requests for basement excavation work at 3814 Council Grove Avenue to begin on September 6, 2000, and at 3808 and 3810 Council Grove Avenue to begin on September 7, 2000. The locate requests for the second project were for 3 of the 7 homes constructed during this time. In addition, Laclede made an excavation over the natural gas service line to 3810 Council Grove Avenue on April 23, 2001 to repair the service line due to third-party damage.

As discussed further in Section 4.10.1, a previous excavation patch in the street at 3810 Council Grove Avenue corresponded to the location of the sanitary sewer lateral to 3810 Council Grove (See Appendix B-1, Photograph 2). Similar additional street patches from previous excavations between the east curb and the sanitary sewer main were also located in front of 3808, 3814, 3816, 3820, 3824, and 3828 Council Grove Avenue (See Appendix A-2, Figure 2). These street patches apparently correspond to the location of the sanitary sewer laterals installed to these addresses, which were built during the same time period as 3810 Council Grove.

Since it was over six months before the basement foundation excavations, the purpose of the February 2000 locate request is not clear. It also is not clear whether the locate request resulted in excavation work actually being performed, or if this one locate request was in any way related to the installation of the sewer laterals on Council Grove Avenue noted above. Laclede's review of Missouri One Call locate requests indicate this is the only locate request that may be related to the sewer lateral installation work. The Company's review of damage notifications to Missouri One Call, as well as Company records for damage notifications directly to Laclede, indicated no damage notifications had been made for any of these locations.

Additionally, the Metropolitan Sewer District notified Laclede that it had no record of any permits obtained in the 3800 or 3900 blocks of Council Grove Avenue for sewer lateral taps. If the sanitary sewer lateral for 3810 Council Grove used the existing sewer tap, a new sewer tap permit would not have been required.

# 4.7.6 Odorization

During the three months prior to the incident, Laclede conducted weekly odorant concentration tests of its natural gas systems. The odorant concentration varied from 0.33% to 0.50% gas-in-air<sup>6</sup> for the test point at Bellrive and Natural Bridge, which is in the vicinity of the incident.

# 4.8 Laclede Notification and Actions

# 4.8.1 Initial Response and Actions

Laclede dispatch received a call of a possible explosion at 3810 Council Grove Avenue, Pine Lawn, Missouri, on January 8, 2011 at 12:07 p.m. A Laclede service technician was dispatched at 12:10 p.m. and arrived on the scene at 12:23 p.m. The service technician observed that the structure at 3810 Council Grove Avenue had been lifted off its foundation and he smelled the odor of natural gas in the air. The service technician also observed bubbles coming up through cracks in the street in front of 3810 Council Grove Avenue. The

 $<sup>^{6}</sup>$  4 CSR 240-40.030(12)(P)1. requires that the odorant in natural gas be readily detectable by a person with a normal sense of smell at a concentration less than 0.90% gas-in-air, based on a lower explosive limit of 4.5% gas-in-air.

service technician notified emergency responders on the scene of his presence and was able to obtain information from the occupants at 3810 Council Grove Avenue. A Service and Installation Department (SAID) supervisor arrived on the scene at 12:25 p.m. The service technician and SAID supervisor coordinated with emergency responders to perform evacuations and turn off the gas to addresses from 3802 Council Grove Avenue to 3832 Council Grove Avenue (See Appendix A-3, Figure 3). The service technician then began his leak investigation at 3810 Council Grove Avenue. For safety reasons, no attempt was made to gain access into the structure. The service technician obtained a 30% gas-in-air reading in the sanitary sewer lateral vent in the front yard of 3810 Council Grove Avenue, 15% gas-inair in a bar-hole<sup>7</sup> at the outside wall and bar-hole readings of 80% to 100% along the curb and over the gas main in front of 3810 Council Grove Avenue. The service technician checked for natural gas inside of 3808 and 3814 Council Grove Avenue and found 5% gas-in-air at the inside wall of 3808 Council Grove Avenue. No readings were found inside of 3814 Council Grove Avenue. A second service technician arrived at the scene at 12:30 p.m. and began assisting the first service technician with checking for migrating natural gas. Also, during this time period at around 12:45 p.m. to 1:00 p.m., Ameren Missouri shut off electric service to the 3800 block of Council Grove Avenue. A Construction and Maintenance (C&M) leak crew and another service technician arrived at 12:50 p.m. and 1:00 p.m. respectively and began assisting with leak investigations. A Laclede Claims Supervisor arrived at 12:55 p.m. Shortly after 12:55 p.m., Laclede, along with the Northeast Fire Department, made a decision to create a "safety zone"<sup>8</sup> encompassing the 3800 block of Council Grove Avenue and to make preparations to stop the flow of natural gas in the 2-inch diameter steel gas main feeding the incident site. The C&M crew then began making excavations at three locations in the area to facilitate making a bypass and to stop the flow of natural gas in the leaking 2-inch diameter steel gas main while maintaining natural gas flow to other customers in the area. Two members of Laclede's Incident Response Team arrived at 1:57 p.m. and 1:59 p.m.

To help mitigate natural gas migration toward 3808, 3810 and 3814 Council Grove Avenue, the C&M Leak crew began "air-jacking"<sup>9</sup> at 12:50 p.m. The "air-jack" was initially set at the

<sup>&</sup>lt;sup>7</sup> Bar-holes are small diameter holes made in the ground by a steel rod to facilitate sampling of the subsurface atmosphere for natural gas with a combustible gas indicator (CGI).

<sup>&</sup>lt;sup>8</sup> "Safety Zone" is a term used to describe a perimeter, in conjunction with evacuations, established at a distance from a structure that may contain accumulated natural gas allowing Company and emergency personnel to safely perform emergency activity. All customers and the public are kept out of the affected area.

<sup>&</sup>lt;sup>9</sup> "Air-jacking" is a Company term used to describe the procedure of forced ventilation of the subsurface atmosphere. The purpose of the "air-jack" is to eject a volume of air out of an area which is to be ventilated. To draw natural gas from a subsurface area, a pipe connected to an air compressor is inserted into a bar-hole, excavation, man-hole, etc., and the air is forced across a venturi in the pipe creating a vacuum in the space to be ventilated. This accelerates the removal of natural gas from the space to be ventilated.

southwest corner of Council Grove Avenue and Margaret Avenue at the intersection of both curb lines in the pavement. To avoid the possibility of pulling migrating natural gas into the sanitary sewer in the center of Council Grove Avenue, the "air-jack" was moved to the east side of Council Grove Avenue, east of the curb and over the natural gas main at the service line tee for 3810 Council Grove Avenue. "Air-jacking" was suspended for a period of time when that particular crew moved to a position in front of 3828 Council Grove Avenue to help with exposing the 2-inch diameter natural gas main to facilitate shutting off the gas main.

At 2:35 p.m., Laclede conducted an odorant intensity test at 6104 Margaret Avenue and the natural gas was found to be readily detectable at 0.33% gas-in-air.

# 4.8.2 Evacuations

Laclede and the Northeast Fire Department completed house evacuations in three phases. The initial evacuation, which created a "safety zone" and involved nine houses from 3802 to 3832 Council Grove Avenue, began at 1:00 p.m. The evacuations were expanded at approximately1:45 p.m. and involved 35 houses from 6104 to 6115 Margaret Avenue, 6102 to 6115 Vetter Place, 6028 to 6043 Margaretta Avenue, and the odd-numbered houses from 3803 to 3831 Philbrook Street. Due to the extent of natural gas in the sanitary sewer (natural gas reading obtained at the inside sink drain in 3908 Council Grove Avenue), a third evacuation began at 2:20 p.m. and involved 21 houses from 3902 to 3924 Council Grove Avenue and the even-numbered houses from 3806 to 3832 Philbrook Street.

# 4.8.3 On-going Leak Survey and Monitoring

Numerous Laclede personnel conducted concurrent leak surveys of the incident area from 12:23 p.m. on January 8, 2011 until 1:24 a.m. on January 9, 2011. Generally, bar-holes were made every five feet and gas-in-air readings taken every hour. The readings in the bar-holes remained generally consistent throughout the periods technicians were completing their leak surveys until the leaking gas main was shut off at approximately 8:21 p.m. on January 8, 2011. The gas-in-air readings provided below are considered to be the highest sustained readings obtained during the leak survey period.

Bar-holes were made and sampled over the 2-inch diameter natural gas main along Council Grove Avenue from the south end of Council Grove Avenue to 3828 Council Grove Avenue. Bar-hole readings ranged from 70% gas-in-air to 100% gas-in-air between 3804 and 3814 Council Grove Avenue with the highest readings of 80% to 100% in front of 3810 Council Grove Avenue. Bar-hole readings over the main between 3814 and 3828 Council Grove Avenue were all 0%. Bar-holes were made and sampled along the west side of Council Grove Avenue directly across from 3808 Council Grove Avenue and readings of 25% to 45% gas-in-

air were found. Bar-holes were also made and sampled along the west side of Council Grove Avenue directly across from 3814 Council Grove Avenue, and along the north and south side of Margaret Avenue to approximately 6105 Margaret Avenue. No natural gas was found in any of these bar-holes.

In addition, bar-holes were made and sampled at the west outside walls of 3802, 3804, 3808 and 3810 Council Grove Avenue and the west and south outside walls of 3814, 3816, 3820, 3824 and 3828 Council Grove Avenue. Sampling of these bar-holes indicated 15% gas-in-air at the outside wall of 3810 Council Grove Avenue and 16% gas-in-air at the outside wall of 3808 Council Grove Avenue. No natural gas was found in any of the other bar-holes at the other addresses noted above.

Gas-in-air readings were taken inside the structures at 3808 and 3814 to 3828 Council Grove Avenue, beginning during the Company's initial leak surveys at 12:30 p.m. and continuing every hour thereafter until natural gas was shut off in the leaking main at 8:21 p.m. Readings were generally consistent throughout the time technicians were completing their surveys. Access could not be made into 3802 and 3804 Council Grove Avenue. At 1:30 p.m. the North East Fire Department found 5% gas-in-air at the inside wall of 3808 Council Grove Avenue at the point where the water service line came into the basement. The Fire Department checked inside at the water service point of entry every hour until the gas was shut off in the leaking main and reported these readings to a Laclede SAID Supervisor. At 9:30 p.m., a Laclede service technician found 7% gas-in-air at the water service entry point and 4% to 5% gas-in-air was found at the outside wall over the water service point of entry. Due to these gas-in-air readings, the "air-jack" was set over the gas main near the curb at the crossing of the water service and was operated until the gas-in-air readings dissipated. All further readings at 3808 Council Grove in the open air or in the sanitary sewer drain were 0% gas-in-air. The North East Fire Department also checked the air inside of 3810 Council Grove Avenue at one hour intervals until the leaking gas main was shut off. These readings were reported to a Laclede SAID Supervisor as approximately 1% gas-in-air. The inside air of 3810 Council Grove Avenue was found to be clear (0% gas-in-air) by Laclede personnel at 8:45 p.m. Due to a customer odor complaint, at approximately 2:15 p.m., Laclede personnel checked for the presence of natural gas inside of 3908 Council Grove Avenue and found 20% gas-in-air in a sink drain. Laclede and the Fire Department extended the "safety zone" due to the gas-in-air readings inside of 3908 Council Grove Avenue. Laclede personnel continued to check for the presence of natural gas inside of 3908 Council Grove Avenue at 15 minute intervals until 4:00 p.m. These readings fluctuated between 20% and 27% gas-in-air. Another Laclede service technician checked the sink drain at 15 minute intervals and found 23% gas-in-air from 4:30 p.m. through the time gas was shut off to the leaking main at

approximately 8:21p.m. Subsequent checks in the sink drain up to 5:00 a.m. on January 9, 2011, indicated no presence of natural gas.

Gas-in-air readings were taken in the sanitary sewer manholes located at 3800 (front and back), 3832, 3900, 3920 and 3924 Council Grove Avenue, 6105 Margaret Avenue, 6105 Vetter Place and on Charlotte Avenue west of Council Grove Avenue (See Appendix A-1, Figure 3). Sanitary sewer manholes were sampled at one hour intervals from approximately 12:25 p.m. on January 8 to 4:00 a.m. on January 9, 2011, unless otherwise noted. Only the sanitary sewer manhole located at the intersection of Council Grove Avenue and Vetter Place and the sanitary sewer manhole located at the intersection of Council Grove Avenue and Charlotte Avenue had indications of natural gas. No natural gas was found in any of the other sewer manholes. Gas-in-air readings in the sanitary sewer manhole located at 3832 Council Grove Avenue ranged as high as 35% during the time period between 12:25 p.m. and 6:00 p.m. A second Laclede service technician checked this same manhole at 15 minute intervals between 1:00 p.m. and 4:00 p.m. and obtained readings of approximately 28%. A third Laclede technician checked this manhole at 15 minute intervals between 4:30 p.m. on January 8, 2011 and 4:00 a.m. on January 9, 2011 and obtained gas-in-air readings as high as 26% until the time that natural gas was shut off to the leaking main at approximately 8:21 p.m. on January 8, 2011. After that, gas-in-air readings progressively decreased to 0% through 5:00 a.m. on January 9, 2011. The manhole located at 3832 Council Grove Avenue had a slotted lid, which was removed by Laclede personnel at approximately 1:45 p.m. for venting purposes. Laclede personnel checked gas-in-air readings in the sanitary sewer manhole located at 3920 Council Grove Avenue at 15 minute intervals during the time period between 1:00 p.m., January 8, 2011 and 4:00 a.m. on January 9, 2011 and the readings ranged as high as 20% until the time that natural gas was shut off to the leaking main around 8:21 p.m., January 8, 2011. After that, gas-in-air readings progressively decreased to 0% through 4:00 a.m. on January 9, 2011. For venting purposes, Laclede personnel removed the manhole lid at 1:30 p.m. on January 8, 2011.

#### 4.8.4 Main Shutdown and Temporary Bypass

To facilitate shutting off the gas in the leaking 2-inch diameter natural gas main while maintaining natural gas service to other customers in the area, Laclede constructed a bypass to route natural gas around the failed segment of gas main to other gas mains in the area. Excavations were concurrently made to expose the natural gas main at the southwest corner of Council Grove and Margaret Avenue, in front of 3828 Council Grove Avenue, and in front of the vacant lot at 3800 Council Grove Avenue (See Appendix A-1, Figure 3). For the bypass, Laclede installed a 1-inch diameter plastic gas line aboveground between the exposed natural gas main in the excavations at the southwest corner of Council Grove Avenue and in front of

3800 Council Grove Avenue. Once the bypass was established, control fittings in each of these excavations were closed shutting off the flow of natural gas from the north and from the west into the leaking segment of natural gas main. The exposed 2-inch diameter natural gas main in the excavation in front of 3828 Council Grove Avenue was then squeezed-off<sup>10</sup> and capped, stopping the flow of natural gas into the leaking segment of natural gas main at 8:21 p.m. This action also stopped the flow of gas to the service lines from 3802 to 3828 Council Grove Avenue. The working bypass allowed natural gas to continue flowing into the main east of 3800 Council Grove Avenue, maintaining service to 105 customers in the incident area.

#### 4.8.5 Removal of Fractured Segment of Natural Gas Main

After gas was shut off, the leaking segment of 2-inch diameter steel natural gas main in front of 3810 Council Grove Avenue was excavated and exposed. Examination revealed a fracture around 85% of the pipe circumference. Laclede removed an approximate seven-foot section of main containing the fracture and service tapping saddle for 3810 Council Grove Avenue and transported it to Laclede Claim's evidence locker for safekeeping. The section of pipe was later transported to a metallurgical testing laboratory for failure analysis. The service line to 3810 Council Grove Avenue was abandoned in-place. Laclede then installed a segment of 2-inch diameter plastic pipe, replacing the removed segment of 2-inch diameter steel pipe containing the fracture. At 2:30 a.m. on January 9, 2011, natural gas was re-introduced into the 2-inch diameter steel gas main between 3802 and 3832 Council Grove Avenue. Laclede then turned natural gas on to these individual customers and lit their natural gas appliances. A bond wire was connected to the steel main on each side of the new plastic pipe segment to restore electrical continuity along the steel main for CP purposes.

# 4.8.6 Post-Incident Leak Repairs, CP Checks, and Main Replacement

In the days following the incident, Laclede investigated and repaired leaks on the 2-inch diameter gas main along Council Grove Avenue. These leaks were caused by corrosion and involved repairs in front of 3828 and 3824 Council Grove Avenue on January 14 and January 15, respectively. The corrosion leak in front of 3828 Council Grove Avenue appeared to be caused by a copper water service line in direct contact with the 2-inch diameter gas main (See Appendix B-2, Photograph 3). The main segments containing these corrosion repairs were later replaced during a main replacement project in the incident area.

<sup>&</sup>lt;sup>10</sup> A vise-like device operated hydraulically that is used to clamp the walls of the steel main together to stop the flow of natural gas.

CP readings were taken in the incident area by Laclede on January 13 and 14, 2011. The steel mains at 3810 and 3828 Council Grove Avenue were discovered to be less negative than the -0.85 V criterion. An unmapped insulating union was found in the steel main just north of CP test station 4410 at 3800 Council Grove. As a result, CP test station 4410 was not electrically continuous with the steel mains at 3810 and 3828 Council Grove. Further investigation of the steel gas main serving 3802 to 3914 Council Grove found two probable metallic contacts/shorts with other buried piping in addition to the contact with a copper water service line at 3828 Council Grove. A shorted steel gas main was found at 3908 Council Grove. In front of 3814 Council Grove, the steel gas main was found to be in contact with the iron water main installed below it.

Further CP testing in the incident area of the five steel gas mains that were connected to the steel main serving 3802 to 3914 Council Grove Avenue found they had adequate cathodic protection, but discovered the steel main on Vetter Place (to the west of Council Grove Avenue) did not have a CP test station and was not being monitored.

Considering the possibility of additional third-party excavation damage to the steel main at nearby homes built during the same time period as 3810 Council Grove and the corrosion leaks found on the 2-inch diameter steel gas main along Council Grove Avenue, Laclede wrote a work order to replace the steel gas mains in the incident area. The 2-inch diameter steel mains were replaced with 1<sup>1</sup>/<sub>4</sub>-inch plastic mains along Council Grove Avenue between 3800 and 3914 Council Grove, along Margaret Avenue between Council Grove Avenue and Jennings Station Road, and along Vetter Place between Council Grove Avenue and Jennings Station Road. These main replacements were completed on March 17, 2011.

# 4.9 Laclede Reporting to MoPSC

The Missouri Public Service Commission (MoPSC) incident reporting requirements<sup>11</sup> were completed as follows:

- 1. The Company called the MoPSC answering service on January 8, 2011 at 1:42 p.m. to provide notification of the incident.
- 2. The Company made an initial telephonic notification to the Pipeline and Hazardous Materials Safety Administration (PHMSA) on January 8, 2011 at 2:32 p.m.
- 3. The Company filed an incident report with PHMSA on February 7, 2011.

<sup>&</sup>lt;sup>11</sup> 4 CSR 240-40.020(4)(A) requires initial telephonic notice to designated commission personnel within 2 hours of Federal Incidents and 4 CSR 240-40.020(4)(C) requires completion of an incident report form within 30 days of the incident.

#### 4.10 MoPSC Staff Investigation

#### 4.10.1 On-site Investigation, January 8, 2011

At the direction of the Utility Regulatory Engineering Supervisor, three Staff members traveled to the incident site on Saturday, January 8, 2011, arriving at approximately 5:05 p.m. When Staff arrived, Council Grove Avenue was closed to traffic south of Charlotte Avenue and numerous Laclede and emergency response personnel were observed. Staff then met with a member of the Company's Claims Department who presented a verbal synopsis and chronological description of the events that had taken place. Natural gas was still leaking in front of 3810 Council Grove Avenue and Laclede had established a "safety zone" in coordination with emergency response officials. Natural gas was being vented from the soil in front of 3810 Council Grove Avenue by "air-jacking" to draw gas out of the soil and vent it to the atmosphere. Even with these venting measures, natural gas was entering the sanitary sewer system and was being vented from opened manholes in Council Grove Avenue at intersections with Vetter Place and Charlotte Avenue. Company personnel were periodically monitoring the gas-in-air readings in the sanitary sewer system and in various bar-holes in the incident area. Other Company personnel were working to install a temporary bypass from Margaret Avenue to 3800 Council Grove Avenue so the leaking section of gas main could be shut off. Staff observed the Company's action to complete this bypass, shutdown the gas main, and monitor pressures in the downstream system.

The Company truck with the air compressor that was used for the "air-jacking" at 3810 Council Grove Avenue was parked on Margaret Avenue near the intersection with Council Grove Avenue. The gas-in-air readings in the sanitary sewer manhole at Council Grove Avenue and Vetter Place were holding at approximately 26% gas-in-air. During work to squeeze-off and cap the gas main at 3828 Council Grove, this Company truck was moved to assist at that location and the "air-jacking" at 3810 Council Grove, the gas-in-air readings in the sanitary sewer manhole at Council Grove Avenue and Vetter Place increased (by approximately 5% gas-in-air). After finishing work at 3828 Council Grove, the Company truck was moved back to Margaret Avenue and the "air-jacking" at 3810 Council Grove was resumed. Staff later requested a copy of the Company procedures for "air-jacking" during an emergency response and the Company did not have written procedures for this process.

After the leaking gas main was shutdown and the natural gas dissipated, Staff made observations of the incident site. The house at 3810 Council Grove Avenue had sustained considerable damage due to the explosion. Several windows were blown out and the walls had been shifted off of the basement foundation and were bowed out. At the outside gas

meter set, the outlet piping had been pulled upward and was severed (See Appendix B-2, Photograph 4). Looking through the basement windows, scorching was observed on the floor joists. Due to darkness, more extensive observations were not made until the following Monday, January 10, 2011.

Staff then observed Laclede crews excavating to expose the 2-inch diameter steel gas main at the leak site in front of 3810 Council Grove Avenue. Once the gas main was exposed, Staff observed a circumferential fracture of the pipe and the pipe appeared to have been dented at the fracture site (See Appendix B-3, Photograph 5). The fracture appeared to have initiated on the bottom of the pipe and had propagated approximately 85% around the circumference of the pipe. The fracture also was in line with a previous excavation patch observed in the street from the east curb to a few feet east of the street centerline (See Appendix B-1, Photograph 2). Staff made additional observations in the sanitary sewer lateral vent (located in the front yard) and determined that the sanitary sewer lateral for 3810 Council Grove ran at an angle through the front yard towards the street patch and beneath the fracture in the gas main. Since the street patch did not extend all the way to the sewer main located below the street centerline, it appeared that the old sewer main tap had been used and the newer sewer lateral was connected to the old sewer lateral a few feet east of the sewer main.

Staff left the scene at approximately 12:30 a.m. on January 9, 2011. At the time of departure, Laclede was working to install a new gas main segment in place of the removed gas main segment in order to restore gas service to the mains and service lines that had been turned off.

#### 4.10.2 On-site Investigation, January 10, 2011

Two Staff members returned to the scene on Monday morning, January 10, 2011. Additional daylight observations were made of the incident site and area. As noted above, the structure located at 3810 Council Grove Avenue sustained extensive damage as a result of the explosion and flash fire. The structure had lifted off the basement foundation and had shifted slightly. Some walls had buckled outward and some windows were pushed outward. There was displaced and thrown debris on the ground around the structure (See Appendix B-3, Photograph 6 and Appendix B-4, Photographs 7 and 8). Staff noted a natural gas odor in the street in front of 3828 Council Grove Avenue and requested a leak investigation by the Company. Staff later observed a Laclede employee conducting a leak survey along Council Grove Avenue and pointed out the odor location. Staff later learned that the Company investigation resulted in a Class 3 leak based on a 16% gas-in-air reading at the street curb in front of 3828 Council Grove Avenue. Additional information on the repair of this leak is provided in Section 4.8.6.

#### 4.10.3 Observations at Laclede Lab, January 10, 2011

As mentioned previously in this Report, an approximate seven-foot segment of the 2-inch diameter steel gas main containing the fracture was removed, transported to Laclede Claim's evidence locker, and later transported to Laclede's lab for observation and cleaning. The fracture was observed, measured and photographed (See Appendix B-5, Photographs 9 and 10). The fracture initiated in a dent created during previous excavation damage. Corrosion pitting was also observed at some locations along the pipe.

#### 4.10.4 Pipe Testing and Analysis

The MoPSC Staff arranged for a failure analysis of the removed steel pipe segment (length of 80.5 inches) by a third-party laboratory. Staff and Company personnel observed the laboratory testing on April 13, 2011, which resulted in the following information. Laboratory measurements of the 2-inch steel pipe confirmed a nominal outside diameter of 2.375" and a nominal wall thickness of 0.154". Two dents were observed on the pipe, located approximately 25.5" apart. The fracture occurred at one of these dent locations - the pipe was dented 5/32" inward (See Appendix B-6, Photograph 11). There also was an approximate 20degree bend in the pipe that started at the second dent location. The bend and two dents were indicative of mechanical loading caused by excavation equipment. The pipe fracture was circumferential, and the crack was 85% around the pipe's circumference. The pipe fracture was primarily brittle even though steel pipe is normally ductile (tensile testing was conducted on the pipe at a location away from the fracture and the steel sample deformed in a ductile manner). The fracture origin corresponds with the dented area from mechanical loading. The pipe's average hardness was measured using the Rockwell "B" scale (HRB) near the fracture (HRB = 81.6) and at a location away from the fracture (HRB = 75.3). The higher hardness at the fracture was likely the result of the local cold-work from the dent. The longitudinal pipe seam weld was located on the opposite side of the pipe from the fracture origin and did not appear to have played any role in the failure. There were no manufacturing defects in the pipe that led to the failure. There was external corrosion and pitting in numerous locations on the outside surface of the pipe, and some of the pitting was severe. There was some pitting at one location in the vicinity of the fracture, but not in the dented area with the fracture origin (See Appendix B-6, Photograph 11).

#### 4.10.5 Cathodic Protection Issues

Several cathodic protection issues were investigated due to the corrosion leaks on the steel gas main along Council Grove Avenue that were repaired before and after the incident. The cathodic protection on the steel main serving 3802 to 3914 Council Grove had not been

annually monitored prior to the incident and cathodic protection levels were found to be inadequate following the incident. Direct metallic contacts between the gas main and other underground piping were found after the incident and Staff made another visit to the site to observe excavations of these metallic contacts. There was no corrosion leak or corrosion leak repair at the location of the steel gas main fracture. As a result of the cathodic protection issues found during this investigation, Laclede has been taking actions and is continuing to take actions to address those issues. Since the cathodic protection issues were not directly related to the incident at 3810 Council Grove Avenue, Staff is monitoring these actions and plans to provide further information and recommendations to the Commission in a subsequent case in the near future.

#### 5.0 ANALYSIS

#### 5.1 Structural Damage

Once an explosive mixture of natural gas in air reached an ignition source inside 3810 Council Grove Avenue and ignited, a low order explosion occurred. Natural gas explosions are often characterized by the level of gas and air mixture prior to the explosion: mixtures near the lower explosive limit (LEL, approximately 4.5% gas-in-air), the optimum limit (approximately 9%-10% gas-in-air), or upper explosive limit (UEL, approximately 14.5%). When a natural gas explosion occurs near the LEL, walls are heaved or pushed out. Explosions that occur in mixtures near the LEL produce low order damage.<sup>12</sup> Fire damage is minimal at the LEL because most of the gaseous fuel has been consumed by the ignition and venting.

The west exterior wall was dislodged and pushed out and the south exterior wall was dislodged from the top of the foundation, both of which provide evidence of a heaving or pushing effect from inside. The relatively short distance of the thrown debris surrounding the structure, and displacement of some windows and a sliding glass patio door also resemble the occurrence of an explosion producing low order damage.

Several windows and the large patio door were pushed out or dislodged during the explosion and would have provided venting avenues for any remaining pockets of natural gas. Evidence, such as the broken fuel line at the gas meter, suggests the house was lifted off and settled back on the foundation walls when the explosion occurred. Fire resulting from the ignition was minimal inside 3810 Council Grove Avenue and was concentrated in the basement area.

# 5.2 Fracture of the 2-inch Diameter Steel Natural Gas Main

#### 5.2.1 Soil Settlement

The residence at 3810 Council Grove Avenue was built in 2000 and 2001, and the sanitary sewer lateral installed for this residence crossed beneath the gas main in the vicinity of the fracture, based on observations of the street pavement patch and in the sanitary sewer lateral vent in the front yard. Installation of this sanitary sewer lateral in 2000 or 2001 would have involved a ditch excavated from the surface down to the depth required to install the sewer

<sup>&</sup>lt;sup>12</sup> National Fire Protection Association (NFPA) 921 describes low order explosion as "a slow rate of pressure rise of low force explosion characterized by a pushing or dislodging effect upon the confining structure or container and short debris distances."

pipe where it crossed below the gas main. The excavation to expose the steel gas main fracture following the incident extended several inches below the gas main and did not expose the sanitary sewer lateral, which was at an even greater depth. For deep excavations like the one used to install this sanitary sewer lateral, it is difficult to achieve adequate backfill compaction unless numerous thin layers and proper compaction methods are used.

The movement of earth and/or backfill material underneath a buried pipeline can be a significant factor in causing a failure. A pipeline buried in the ground is in a static position relative to the soil surrounding it. A substantial movement of that soil could cause the pipe to move in a vertical or horizontal direction, or both, inducing stresses in the pipeline.

A typical event that can cause soil movement around a pipeline is subsidence.<sup>13</sup> This causes settlement of the soil and can exert forces on the pipeline due to loss of uniform support under the pipeline combined with the weight of the backfill and soil over the pipeline. As subsidence occurs, stresses in the pipe can lead to failure of the pipeline, such as at a location where the pipe has been damaged.

In the intervening 10-11 years following installation of the sanitary sewer lateral under the gas main in front of 3810 Council Grove Avenue, the backfill material under and above the gas main had time to compact and settle under environmental and outside forces, such as moisture, drought, and freeze/thaw cycles. The origin of the fracture on the bottom of the pipe was likely a result of subsidence due to poor or incomplete compaction of the backfill material in conjunction with the installation of the sewer lateral. The weight of the backfill material and soil above the pipe placed downward forces on the gas main. The downward forces would create bending stresses in the pipe and tensile stresses along the bottom of the pipe at the location of the previous third-party excavation. These tensile stresses at the damage on the gas main caused a brittle fracture to initiate in the damaged location. The fracture continued circumferentially around the pipe.

# 5.2.2 Mechanical Damage to the Pipe

Mechanical damage to a pipe wall can produce a scratch, gouge, and/or dent. Mechanical damage can occur due to third-party damage during nearby excavation activities while the line is in service. Mechanical damage during operation can be produced by backhoes, trenching machines, etc. Whether the damage leads to a leak or a failure when the damage occurs, or at a later time, depends upon a number of factors, including primarily the severity of the

<sup>&</sup>lt;sup>13</sup> Subsidence is a term used to describe downward movement of the soil due to poor or incomplete compaction or general movement of the soil.

damage. With severe damage, a leak or break can occur at the time of the damage; however, failure can also occur sometime later. This is the hazard involved with this type of damage.

The damage to the pipe observed by Staff in the area of the fracture could have occurred any time prior to the incident. However, the most likely time that the damage occurred was at the time of the sewer lateral construction for 3810 Council Grove Avenue in 2000 or 2001 near the gas main. The two dents were 25.5 inches apart, which would correspond to a 2-foot backhoe bucket. The pipe was bent upward in this same area, which would correspond to the pipe being lifted upward by a backhoe bucket during mechanical damage. It is likely that a backhoe was used to install the sanitary sewer lateral and struck the steel gas main with enough impact and upward lifting force to cause the two pipe dents and the upward pipe bend observed in the pipe.

The dent in the pipe at the fracture would have produced local stress concentrators and hardening of the metal in this area of the pipe. The localized hardening of the metal combined with the subsequent loading due to soil settlement resulted in a brittle-type fracture. Brittle fractures occur abruptly and generally propagate perpendicular to the direction of the greatest applied force. Since the crack on the gas main propagated circumferentially rather than longitudinally, this indicates that external loading forces rather than internal pressure caused the fracture of the gas main.<sup>14</sup>

# 5.2.3 Corrosion of the Pipe

The corrosion along the coated steel gas main serving 3802 to 3914 Council Grove Avenue was also evaluated. None of the corrosion leaks that had occurred prior to the incident were near the fracture at 3810 Council Grove, but there was some corrosion pitting in the area of the fracture. As noted below, the fracture origin was most likely in the dent caused by the third-party damage and the observed corrosion pitting was located outside of the dent. This indicates that the corrosion pitting on the pipe was not involved in the initiation of the fracture at the point of the mechanical damage.

# 5.2.4 The Fracture

The fracture initiated in the area of the pipe that had been weakened from the mechanical damage (dent) and where downward forces were applied to the pipe by soil settlement. The bending stresses due to the backfill settlement acting at the stress concentrators created by the mechanical damage in the pipe finally caused a fracture to initiate in the pipe at the location

<sup>&</sup>lt;sup>14</sup> Hertzberg, R.W. (1996). *Deformation and Fracture Mechanics of Engineering Materials*, Fourth Edition. John Wiley & Sons, Inc. pp. 45-48.

that had sustained mechanical damage. The downward force caused the fracture to propagate around the circumference of the pipe.

# 5.3 Natural Gas Migration and Entrance

The natural gas escaping from the circumferential fracture in the steel gas main would have exited under a pressure of approximately 18 psig at the time of the fracture. The space in the separated pipe ends in the fracture area was approximately <sup>1</sup>/<sub>8</sub>-inch wide, with this open space releasing gas at a rapid rate. The loose compaction of the backfill material along the gas main, and the loose and porous compaction of the rock backfill around the sewer lateral work, which was below the fracture, would have provided a path of low resistance to migration of natural gas escaping from the fracture. Since natural gas is lighter than air<sup>15</sup>, it will migrate along paths of least resistance through the soil and upward into the atmosphere. However, the top surface layer of soil, frozen by the subfreezing temperatures, would have restricted the upward migration of the natural gas into the atmosphere.

With the upward migration of the natural gas restricted, the natural gas would migrate laterally through the soil. Excavations made to install utilities and to place foundation walls are normally less compacted when backfilled as compared to undisturbed soil. Natural gas emanating from the fractured gas main apparently migrated toward 3810 Council Grove Avenue as evidenced by 15% gas-in-air readings at the outside wall and 80% to 100% gas-in-air readings along the curb and over the main in front of 3810 Council Grove Avenue.

Natural gas emanating from the fracture also entered the sanitary sewer system, as evidenced by the gas-in-air readings obtained in the sanitary sewer lateral vent in the front yard of 3810 Council Grove Avenue, in the sanitary sewer manholes located in the intersection of Council Grove Avenue and Vetter Place and the intersection of Council Grove Avenue and Charlotte Avenue, and the inside sink drain in 3908 Council Grove Avenue. The exact point of entry into the sanitary sewer system was not determined, but the natural gas could have entered the sewer system at a point where sewer lateral work was conducted sometime during 2000 or 2001 to connect the new sewer lateral for 3810 Council Grove Avenue to the existing sanitary sewer lateral near the sewer main tap. The natural gas also may have entered the sewer system through joints, cracks or holes in the sewer main piping. Once the natural gas entered into the sanitary sewer main, there would have been little or no resistance to migration of the natural gas.

<sup>&</sup>lt;sup>15</sup> Natural gas has specific gravity of approximately 0.6 while air has a specific gravity of 1.0.

Natural gas readings in the sanitary sewer lateral vent in front of 3810 Council Grove Avenue and the two sanitary sewer manholes indicate natural gas from the fracture was freely entering the sewer system and conversely dissipated quickly after Construction and Maintenance crews stopped the flow of natural gas from the fractured gas main.

How natural gas entered into 3810 Council Grove Avenue was not determined, but there could have been one or more entrance points. Possible migration paths to 3810 Council Grove Avenue would include the sewer system, and through the soil used to backfill the excavations made to install the natural gas service line, the water service line, and the sewer lateral to the foundation. Natural gas migrating through the soil to the foundation could then migrate under the foundation and under the basement floor. Natural gas migrating along the basement foundation and under the basement floor could have entered the basement of 3810 Council Grove Avenue through cracks in the concrete foundation walls and floor, or through the juncture of the basement floor with the basement walls. Natural gas present in the sanitary sewer system could have entered the structure at 3810 Council Grove Avenue through the sewer lateral serving the dwelling. Once in the sewer lateral to the structure, the natural gas could have entered the structure through a dry sewer drain trap in the basement floor.

Because natural gas is lighter than air, the natural gas entering the basement would have accumulated near the ceiling in the basement first. The accumulated natural gas was probably ignited in the basement as evidenced by the burning and scorching of the basement ceiling joists and the pushing out and bulging of the bottom of the west and south walls of the structure. The source of ignition was not identified. However, several sources were available in the structure, including natural gas pilot lights and electrical appliances.

**APPENDIX A** 

FIGURES



Overall location of 3810 Council Grove Avenue with respect to the City of St. Louis and surrounding highways (Map provided by Google Maps).

Appendix A-1



**Figure 2** – Surrounding Neighborhood View of 3810 Council Grove Avenue. Note the similar construction of houses 3808 to 3828, which were built during the same time period. Red arrows show street patches from previous sanitary sewer lateral excavations in front of 3808, 3810, 3816, 3820 and 3828 Council Grove Avenue. The purple arrows show the approximate location of street patches from previous sanitary sewer lateral excavations in front of 3814 and 3824 Council Grove Avenue (the patches in the street are covered over by parked vehicles). The involved residence (3810 Council Grove Avenue) is shaded. (Map provided by Google Maps)

Figure 2 Surrounding Neighborhood View of 3810 Council Grove Avenue

Appendix A-2



Figure 3 - Overall Plan View of Incident Area y) Appendix A-3

**APPENDIX B** 

PHOTOGRAPHS



**Photograph 1** View of the incident site at 3810 Council Grove Avenue (photograph courtesy of Laclede Gas Company).



Note: The yellow line represents the approximate location of the natural gas main and the green line represents the approximate location of the sewer lateral. The gas main fracture was found at the location where the yellow and green lines intersect.

**Photograph 2** View of the patch in the street in front of 3810 Council Grove Avenue. (photograph courtesy of Laclede Gas Company).



**Photograph 3** View of the corrosion pit and hole in the 2-inch diameter steel natural gas main removed from the front of 3828 Council Grove Avenue (photograph courtesy of Laclede Gas Company).



**Photograph 4** View of the displaced and severed natural gas piping at the southwest corner of the structure at 3810 Council Grove Avenue.



**Photograph 5** View of the fracture and dent in the 2-inch diameter steel natural gas main in front of 3810 Council Grove Avenue. Note that the bottom of the pipe is reflected a mirror.



**Photograph 6** View of the west side of 3810 Council Grove Avenue. Note the vertical crack and displaced siding between the windows



**Photograph 7** Close-up view of the west side of 3810 Council Grove Avenue. Note that the wall is displaced outward from the top of the foundation.



**Photograph 8** View of the east side of 3810 Council Grove Avenue. Note the displaced window and sliding glass door to the deck. Note also the structure has shifted to the right and the lack of burning inside of the structure (photograph courtesy of Laclede Gas Company).



**Photograph 9** View of the removed segment of 2-inch diameter steel natural gas main. Note the bend in the piping.



**Photograph 10** View of the fracture and dent in the 2-inch diameter steel natural gas main removed from the excavation in front of 3810 Council Grove Avenue.



**Photograph 11** View of the fracture and dent in the 2-inch diameter steel natural gas main. Note the corrosion pitting at the top of the pipe around the fracture. The dent is identified in the yellow oval.

#### BEFORE THE PUBLIC SERVICE COMMISSION OF THE STATE OF MISSOURI

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In the Matter of Laclede Gas Company concerning a Natural Gas Incident at 3810 Council Grove Avenue in Pine Lawn, Missouri.

GS-2011-0245

#### **AFFIDAVIT OF RICHARD A. FENNEL**

STATE OF MISSOURI ) ) ss COUNTY OF COLE )

Richard A. Fennel, employee of the Staff of the Missouri Public Service Commission, being of lawful age and after being duly sworn, states that he has participated in the preparation of the accompanying Gas Incident Report, and that the facts therein are true and correct to the best of his knowledge and belief.

RICHARD A. FENNEL

Subscribed and affirmed before me this  $21^{5F}$  day of December 2011.

SUSAN L. SUNDERMEYER Notary Public - Notary Seal State of Missouri Commissioned for Callaway County My Commission Expires: October 03, 2014 Commission Number: 10942086

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#### BEFORE THE PUBLIC SERVICE COMMISSION OF THE STATE OF MISSOURI

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In the Matter of Laclede Gas Company concerning a Natural Gas Incident at 3810 Council Grove Avenue in Pine Lawn, Missouri.

GS-2011-0245

#### **AFFIDAVIT OF JOHN D. KOTTWITZ**

STATE OF MISSOURI ) ) ss COUNTY OF COLE )

John Kottwitz, employee of the Staff of the Missouri Public Service Commission, being of lawful age and after being duly sworn, states that he has participated in the preparation of the accompanying Gas Incident Report, and that the facts therein are true and correct to the best of his knowledge and belief.

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JOHN D. KOTTWITZ

Subscribed and affirmed before me this  $21^{5^{t}}$  day of December 2011.



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