Missouri Public Service Commission

Gas Incident Report

Laclede Gas Company
Case No. GS-2004-0264

#6 Hagers Mill Court
Manchester, Missouri
December 11, 2003

Gas Safety/Engineering Section … Energy Department ... Utility Operations Division
April 2004… Jefferson City, Missouri

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SYNOPSIS

At approximately 06:22, Central Standard Time (CST, all times in this report are Central Standard Time and indicated as military time) on Thursday, December 11, 2003, a natural gas explosion and fire occurred at #6 Hagers Mill Court, Manchester, Missouri. The explosion and subsequent fire destroyed the single-family residence and damaged adjacent residential structures. The adjacent structure damage included broken windows and melted/burned vinyl siding. Four people were in the residence at the time of the explosion and sustained various injuries. There were no other injuries reported.

Laclede Gas Company (Laclede) provides natural gas service in Manchester, Missouri. Hagers Mill Court is supplied natural gas through a 1¼-inch diameter polyethylene distribution main. The residence at #6 Hagers Mill Court was supplied natural gas through a ? -inch outside diameter (O.D.) polyethylene service line. Laclede's records indicated the natural gas main and service line were operating at approximately 37 pounds per square inch gauge (psig) at the time of the incident.

The Missouri Public Service Commission's Energy Department - Safety/Engineering Staff (Staff) has determined that the probable cause of the incident was the escape of natural gas from the service tee connection for the service line serving #6 Hagers Mill Court.

The escape of natural gas was due to a pullout of the service line from the compression coupling at the natural gas service tee. Subsequent investigation revealed that the joint between the service tee and service line had not been assembled properly during initial installation in 1974. In the time interval since installation, tree roots had placed longitudinal force on the service line and the pullout resulted.

Based upon information collected during its investigation, the Staff has determined that evidence exists to conclude that Laclede violated a Missouri Public Service Commission (Commission) regulation regarding proper assembly of plastic pipe mechanical joints. The Staff believes that the probable violation of the Commission pipeline safety regulation contributed to this incident by reducing the force necessary to cause failure of the compression coupling.

The Staff is making 4 recommendations as a result of this investigation.

FACTS

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

The Incident

At approximately 06:22, CST on Thursday, December 11, 2003, an explosion and subsequent fire occurred within the residence located at #6 Hagers Mill Court, in Manchester, Missouri.

Personal Injuries

One adult and one child with minor injuries were treated and released at a local hospital. One child with moderate injuries and one child with severe injuries were admitted to a local hospital for in-patient treatment. There were no other injuries reported.

Property Damage

The residence at #6 Hagers Mill Court and its contents were destroyed as a result of the explosion and fire. Fire department loss estimates were $128,000 for the structure and $65,000 for the contents. Two adjacent residences (#5 and #7 Hagers Mill Court) received significant exterior damage. The damage included broken windows and melted/burned vinyl siding. (See Appendix B-1, Photograph 1)

Site Description

#6 Hagers Mill Court is located in the southern portion of Manchester, Missouri, near the intersection of Highway 141 and Big Bend Road (See Appendix A-1, Figures 1 and 2). Hagers Mill Court is a one-block residential street ending in a cul-de-sac, which contained a grass island in the center (See Appendix A-2, Figure 3). Hagers Mill Court originates at an intersection with Hazel Falls Drive. Hagers Mill Court runs approximately east-west, with the cul-de-sac on the west end. There are thirteen single-family residences on Hagers Mill Court, numbered consecutively from #2 at the northwest corner of the Hagers Mill Court-Hazel Falls Drive intersection to #14 at the southwest corner of the same intersection. #6 Hagers Mill Court was located on the north-northeast corner of the cul-de-sac, facing south-southwest.

The residence at #6 Hagers Mill Court was a single story, wood frame structure with a partial brick facade on the front exterior wall and a walkout basement. (Photograph 2, Appendix B-1, shows a similar house at #9 Hagers Mill Court.) The foundation consisted of poured concrete walls on the front and sides, with wood frame construction on the rear. The basement was approximately 70% finished. A natural gas water heater and furnace were located in the basement of the structure. A programmable thermostat, which shifted to a higher setpoint at approximately 06:15, controlled the furnace. The cooking stove on the main floor and the clothes dryer in the basement were electric. A double car, attached garage (on a concrete slab) was located on the east end of the house (See Appendix A-3 and A-4, Figures 4 and 5). The lot at #6 Hagers Mill Court sloped downward from front to rear.

Meteorological Data

The National Weather Station at St. Louis, Missouri, reported the following meteorological conditions for 05:51, December 11, 2003: skies were clear to partly cloudy; temperature was 19.9 degrees Fahrenheit (°F); and wind was out of the west-northwest at 10.4 miles per hour. Precipitation for December 11 was 0.0 inches. Precipitation for December 10 was 0.37 inches, with 0.1 inches of snow. Precipitation total for December 1 to 11, 2003 was 0.95 inches. Precipitation total for the month of November was 5.34 inches. The ambient temperature had been below the freezing point (32° F) since approximately 19:51 on December 10, 2003. The average wind speed on December 10 was 18 miles per hour with maximum wind gusts to 38 miles per hour. Similar wind speeds and gusts were experienced in the previous month (November 12, 17, 23, 24 and 28).

Natural Gas System

Natural gas service in Manchester, Missouri is provided by Laclede. The distribution main supplying Hagers Mill Court is a 1¼-inch diameter polyethylene distribution main located along the south edge of the pavement of Hagers Mill Court. The main loops around the south, west and north sides of the cul-de-sac and ended at a location that is approximately the lot line separating #5 and #6 Hagers Mill Court. The main was installed by Laclede between May 13, 1974 and May 17, 1974. The main was at a depth of approximately 36-38 inches at the location of the service line tap for #6 Hagers Mill Court. The main was operating at a pressure of approximately 37 psig at the time of the incident. The maximum allowable operating pressure (MAOP) for the main is 60 psig.

The natural gas service line was a ? -inch O.D. polyethylene (plastic) pipe that extended from the natural gas main to the natural gas meter located at the west side of the residence at #6 Hagers Mill Court. The service line was installed by Laclede on November 4, 1974, and was connected to the main with a Continental® bolt-on service tee and compression coupling. See Appendix A-5, Figures 6 and 7, for service tee schematics recently created and provided by Laclede, at Staff's request. Review of Laclede's records for this installation revealed that the plastic service line was satisfactorily tested to 90 psig.

Previous Company Actions

Laclede conducted a mobile flame ionization (FI) leak survey over the natural gas main along Hagers Mill Court on October 25, 2001. A mobile FI instrument is used to measure the amount of combustible gas in an air sample (measured in parts per million). On March 6, 2003, Laclede performed a service line leak survey using a portable FI instrument over all of the service lines on Hagers Mill Court. No underground leaks were discovered during either of these surveys. 4 CSR 240-40.030(13)(M)2.B. requires leakage surveys to be conducted outside of the principal business district using a leak detection instrument at three year intervals (not exceeding thirty-nine months) for plastic pipelines.

Laclede's weekly odorant concentration records for the nine months prior to the incident, recorded at a location near the incident site, indicated the natural gas to be adequately odorized at an average concentration of 0.40% gas-in-air. 4 CSR 240-40.030(12)(P)1. requires that odorant in natural gas be readily detectable by a person with a normal sense of smell at a concentration of less than 0.90% gas-in-air.

A leak call for "odor at meter" from #5 Hagers Mill Court was received at 13:13, on September 30, 2003. In response to this call, Laclede personnel arrived at 13:40. A small leak was identified and corrected on the service line riser. Barhole test results of the subsurface atmosphere at the riser, following leak repair, were 0% gas-in-air. Barhole tests involve penetrating the soil and/or material covering the soil with a rod and then utilizing a combustible gas indicator (CGI) to sample the subsurface atmosphere.

There were no other odor/leak calls from any residents along Hagers Mill Court during the six months preceding the incident.

Company Notification and Actions

St. Louis County North Central Fire Alarm notified Laclede at 06:32. This call reported a two-alarm fire, explosion, and house collapse at #5 Hagers Mill Court (the location was subsequently corrected to #6). Laclede Service and Installation Department (S.A.I.D.) personnel and Construction and Maintenance (C&M) personnel were notified and immediately dispatched. Testing for natural gas commenced shortly after the arrival of S.A.I.D. personnel at approximately 07:10. Visual indication of a natural gas leak was noted by the presence of bubbles in water in the front yard of #6 Hagers Mill Court. There was also a natural gas odor noted. CGI samples of sanitary sewer manholes also revealed the presence of natural gas. Manhole #2 contained 30% gas-in-air and manhole #3 contained 26% gas-in-air (See Appendix A-2, Figure 3).

The buildings immediately adjacent to #6 Hagers Mill Court were checked for the presence of natural gas. No detectable readings were found in #5 Hagers Mill Court or underground at the service entrance to the house. Because of the proximity to the fire, Laclede personnel shut off natural gas service to #5 by closing the shut-off valve located on the meter set piping. Gas service had been shut off to #7 and #8 Hagers Mill Court by closing the shut-off valve located on the meter set piping (Fire Department personnel shut off gas service to these structures prior to Laclede's arrival). #7 Hagers Mill Court contained 4% gas-in-air in the open air of the basement and detectable natural gas readings on the second floor. These readings were taken after Fire Department personnel had initiated ventilation of the building by opening windows. #8 Hagers Mill Court had a slight natural gas odor and Laclede personnel obtained 0.25% gas-in-air readings in the open air of the basement and in a basement sanitary sewer. Natural gas was detected (10% gas-in-air) in the storm sewer curb inlets located in front of #5 and #11 Hagers Mill Court (See Appendix A-2, Figure 3). The explosive range for a mixture of gas and air is 4.5% to 14.5% gas-in-air by volume.

Based on the findings noted above, a safety zone was established just west of #2 Hagers Mill Court at approximately 07:35. Fire Department and Law Enforcement personnel evacuated the residences at #2 through #14 Hagers Mill Court. Residences on Hobbs Mill Drive and Dover Falls Drive that were adjacent to #6 Hagers Mill Court were also evacuated (See Appendix A-1, Figure 2). Following the evacuation, natural gas was detected (3% gas-in-air) in the sanitary sewer manhole #1 in front of #2 Hagers Mill Court (See Appendix A-2, Figure 3). Fire Department personnel requested AmerenUE assistance to terminate electrical service to the incident site area. Laclede personnel excavated the distribution main near #14 Hagers Mill Court and shut off the main at approximately 08:37 utilizing two

squeeze-off devices. (See Appendix A-2, Figure 3 and Appendix B-2, Photograph 3) Squeeze-off is a process where a vise-like device is installed on a gas main and the device is used to squeeze the plastic pipe together so that the flow of natural gas can be restricted or stopped.

An odorant concentration test was conducted at 10:00 at 915 Hazel Falls Drive (See Appendix A-2, Figure 3 for relationship to incident site). The test revealed adequate odorization, detectable at 0.38% gas-in-air. Natural gas readings were no longer obtained in open air within any structures at approximately 10:00. Natural gas service was restored to the Hagers Mill Court distribution main at approximately 14:45 on December 11, 2003. Most residences had gas service restored by 20:10 on December 11, however two residences were restored on December 12 (due to availability of residents). Residents were allowed to return to their homes (except for #6 and #7 Hagers Mill Court) at approximately 14:00 on December 11.

Pressure tests were conducted at normal operating pressure on sections of the distribution main adjacent to #6 Hagers Mill Court and the service line to #6 Hagers Mill Court. All tests of the distribution main were satisfactory except for the test associated with the service tee connection. A subsequent pressure test of the service line from approximately 6 feet downstream of the service tee to the service line riser shut-off valve indicated a small amount of leakage on an aboveground fitting of the service line riser. This fitting had been exposed to intense heat from the structure fire. The service line riser piping was disconnected from the service line and another service line pressure test was conducted. No leakage was detected during this final test.

Missouri Public Service Commission Reporting Requirements

The Missouri Public Service Commission incident reporting requirements were completed as follows:

1. The initial telephone notification of a possible natural gas incident was made to a Staff member at 07:59 on December 11, 2003.

2. Laclede notified the United States Department of Transportation-Office of Pipeline Safety (DOT-OPS) of a natural gas incident at 08:15 on December 11, 2003.

3. DOT-OPS form RSPA F 7100.1, was completed by Laclede and transmitted to Staff on January 9, 2004. The Staff forwarded the report to DOT-OPS on January 16, 2004.

Missouri Public Service Commission Staff Investigation

Incident Site Investigation

Two members of the Staff arrived at the incident site at approximately 11:00 on December 11, 2003. A third member of the Staff arrived at approximately 12:00 on December 11, 2003. The Staff observed numerous emergency response personnel at the site including St. Louis County Police Department and various police/fire departments from county and municipal agencies. Staff met with Laclede personnel regarding Laclede's actions prior to Staff's arrival. Laclede personnel had detected natural gas in sanitary sewer manholes in the front yards of #5 and #8 Hagers Mill Court. Readings of approximately 4% gas-in-air had been obtained in the basement of #7 Hagers Mill Court. The neighborhood surrounding #6 Hagers Mill Court had been evacuated after these readings were obtained. Emergency response personnel and Laclede personnel reported observing bubbles in water at the front yard of #6 Hagers Mill Court. The bubbles were in the vicinity of the service line. The main supplying Hagers Mill Court had been squeezed off (with two clamps) to stop the flow of gas to the incident site at approximately 08:37. The squeeze-off location was approximately 61 feet west of the west curb of Hazel Falls Drive (See Appendix A-2, Figure 3). This squeeze-off stopped the flow of natural gas to all residences on Hagers Mill Court.

Staff's initial observations at the incident site revealed the following information. Most of the house structure and contents had burned and/or fallen into the basement area. (See Appendix B-2, Photograph 4) A small amount of unburned debris was in the front and side areas of the yard. A significant amount of unburned debris was located in the backyard and the adjoining backyard of the neighboring house to the rear. (See Appendix B-3, Photograph 5) A portion of this debris was comprised of a wooden deck that had been attached to the rear of the house. A section of a wooden panel fence at the rear of the lot was knocked down by the explosion and/or debris. (See Appendix B-3, Photograph 6) The aluminum gas meter case and pressure regulator had melted. (See Appendix B-4, Photograph 7) Various underground entrance points for natural gas to migrate into #6 Hagers Mill Court existed. A potable water line penetrated the front basement wall. There were floor drains in the basement of the structure. The front (south) foundation walls contained a horizontal crack, approximately halfway up the wall, which extended the entire

length of the wall. The west wall also contained a similar crack. Most of the burning material had been extinguished, however some smoldering debris remained in the basement structure. External damage was noted on the two adjacent residences (#5 and #7 Hagers Mill Court), consisting primarily of broken windows and melted/burned vinyl siding. Laclede personnel were beginning to excavate in the vicinity of the service line tap for #6 Hagers Mill Court.

The natural gas service tee was approximately 22 feet horizontally from the sanitary sewer main (See Appendix A-2, Figure 3). The horizontal distance to the sanitary sewer lateral serving #6 Hagers Mill Court was not determined. Sanitary sewer manhole #2 depth was measured. Its depth was approximately 10 feet, sloping down towards #7 and #8 Hagers Mill Court. Witnesses stated that sanitary sewer laterals came out from the front of the homes in this area to this sanitary sewer main.

During discussions with the Fire Marshall from West County EMS and Fire, it was determined that there were four occupants in #6 Hagers Mill Court at the time of the incident, an adult male (father) and three children. The four were taken to an area hospital for treatment of burns and other injuries. According to the information from the Fire Marshall, the occupants were at the following locations at the time of the incident: the adult male was in the garage; one child was in the basement; one child was in a bathroom located in the center of the main floor; and one child was located in a bedroom located in the front center portion of the main floor. Approximate locations of the occupants are shown on Figures 4 and 5 (See Appendix A-3 and A-4). Based on the information available to the Fire Marshall, the occupants of the home had not reported any smell of natural gas immediately prior to the incident. Post-incident interviews (conducted by emergency services personnel) of the residents of the house determined that family members were awakening and preparing for work and school at the time of the incident.

Neighbors provided a consistent sequence of events, saying that they heard an explosion and when they looked in the direction of the residence at #6 Hagers Mill Court, they saw the house burning. Some reported a secondary flash on the west side of the house (in the general vicinity of the gas meter and service entrance). None of the neighbors reported smelling natural gas earlier on the day of December 11 or the previous day. One neighbor (occupant of #8 Hagers Mill Court) recalled smelling gas at various times earlier in the year, typically after a rain and at locations in the front of the house located at #8 Hagers Mill Court. No gas odors were reported to Laclede at #8 Hagers Mill Court.

During the afternoon of December 11, Laclede personnel were air jacking to remove natural gas from the front yard area of #7 Hagers Mill Court. Air jacking is a process that uses compressed air passing through a venturi connected to a pipe. This pipe is perforated and is inserted in the ground. The device creates a vacuum to remove residual natural gas from the subsurface atmosphere and disperses it into the above ground atmosphere. (Note: The air jacking continued through December 15. Checks on December 16 confirmed that the natural gas had been removed from the subsurface atmosphere at the incident site.)

Just prior to 11:00 on December 11, 2003, Laclede personnel began excavation of the distribution main and service line at #6 Hagers Mill Court. The distribution main (running roughly parallel to the street curb) was uncovered on the east side of a tree. (See Appendix B-4, Photograph 8) The tree was located in the grassy area between the street and sidewalk. (See Appendix B-5, Photograph 9) The distribution main was also uncovered on the west side of the tree. Neither of these excavations revealed the service tee connection to the distribution main or the service line. An additional excavation on the north side of the tree uncovered the service line. Expansion of this excavation and the other two excavations determined that the service tee was located under the tree root ball. As measured at a height of 18 inches above ground, the tree circumference was approximately 65 inches (~20 inches diameter). (Approximately 29 growth rings were counted on the tree after its removal.) It was noted during the excavation activities that a volume of soil directly under the tree and along the service line was dried out. (See Appendix B-5, Photograph 10) In other areas around the tree and distribution main, the soil was moist or wet.

The service line was observed originating under the root ball of the tree and then proceeding upwards and northerly alongside and above a major tree root. (See Appendix B-6, Photograph 11) The service line was observed to initially contact the root on the west side and then transitioned to the top of the root proceeding toward the house. It appeared that the root had grown under and east of the service line. The tree root growth had displaced the service line and placed it in tension. This tree root was approximately 5 to 6 inches in diameter adjacent to the tree root ball.

Laclede and other on-scene personnel determined that the tree would need to be removed to facilitate removal and inspection of the service tee. Prior to removal of the tree, the distribution main was cut upstream of the service tee for #6 Hagers Mill Court. A pressure test was performed on the distribution main and service line. A leak was evident but could not be specifically located due to the tree covering the service line connection. As detailed

in **Company Notification and Actions**, additional pressure tests of service line and main segments were conducted by Laclede and witnessed by Staff.

City of Manchester Department of Public Works personnel removed the tree down to approximately 43 inches from ground level. Concurrent with the tree removal activity, a demolition contractor had arrived on site. The demolition contractor's hydraulic excavator (equipped with a contractor's grapple) was utilized to remove major appliances from the basement of the house and clear the floor of the basement to allow access by investigators and emergency services personnel.

It was determined that the hydraulic excavator could be used to remove the tree stump and root ball in one piece. In preparation for the removal, all major roots were cut and the service line was secured to the one major tree root with tape. This tree root was initially cut near the tree root ball and then approximately 64 inches away from the initial cut. This preparation activity required removal of a portion of sidewalk north of the tree. When the tree stump was lifted, the tracer wire that was installed with the distribution main and service line was embedded in the soil adhering to the root ball. The tracer wire was also wrapped around the distribution main. The tracer wire and distribution main were lifted approximately 18 inches and then pulled free from the soil and fell back into the excavation. (See Appendix B-6, Photograph 12) The service tee was exposed by this action. A section of distribution main, including the service tee and service line, was removed from the ground. (See Appendix B-7, Photograph 13) It was noted that a plastic bag, which appeared to be the packing material for the new service tee (prior to installation), covered the service tee. A protective sleeve (1? -inch polyethylene piping) was installed over the service line at the service tee connection. A protective sleeve is a short section of pipe installed over system piping where there is a transition from relatively rigid piping (distribution main) to relatively flexible piping (service line) to protect the transition region from excessive bending or shear stresses. The protective sleeve is not designed to provide any protection from longitudinal stresses. The protective sleeve had been partially split for installation and secured in place with duct tape. The duct tape also secured the plastic bag in place. This intact assembly (with tree root attached) was transported to Laclede's Shrewsbury laboratory for safekeeping and further analysis. The Staff members left the incident site at approximately 18:00, December 11, 2003.

Laboratory Investigation

Two members of the Staff met with Laclede personnel at Laclede's Shrewsbury laboratory at approximately 08:00 on December 12, 2003. The distribution main/service line assembly had been brought to the laboratory. (See Appendix B-7, Photograph 14) The overall dimensions of the items comprising this assembly were: approximately 62-inch section of distribution main; approximately 74-inch section of service line (with protective sleeve, approximately 24 inches long); approximately 64-inch long section of tree root; and service tee (covered by plastic bag). Laclede personnel had made a decision to not disassemble the distribution main, service tee and service line assembly or remove anything from the assembly until representatives of all interested parties could be present. The primary work to be performed at the laboratory was photography, measurements and pressure tests of the assembly. Using material in the laboratory and photographs taken at the incident scene, the assembly was placed in a configuration similar to the as-found condition. Print line information was obtained from the service line: PERFEX 5/8" O.D. X .090 WALL PE 2306 3/28/74 TR418 ASTM D2513M. Print line information was obtained from the protective sleeve: CONIND MARK II-PE 2306-D2513 A4 1 1/8 OD X .099 LA-11-28-73 TR418 MI. No print line information could be seen on the distribution main. The plastic bag covering the service tee could not be examined completely due to its installation configuration. Visible text on the bag included: "Operating Instructions", "The Eliminator", and "Rev. Inst. 8/11/1___".

It was noted that the section of distribution main had a noticeable downward bow in the section of pipe. When placed on the laboratory floor, the center of the main (at the location of the service tee) was approximately ½ inch off the floor. This was due to the thickness of the service tee lower clamp. The ends of the section of main (approximately 62 inches in length with the service tee centered on the section) were approximately 1¼ inch off the floor. (See Appendix B-8, Photograph 15) Based on this observation, it appeared that the root ball of the tree had been deflecting the service tee/distribution main downward. This deflection was opposite to the upward deflection of the service line by the tree root.

After the assembly was measured and photographed, preparations were made to conduct a pressure test of the assembly. Test fittings were installed on the three open piping ends, two on the distribution main and one on the service line. A pressure test was conducted at various pressures (up to approximately 35 psig). These pressure tests confirmed the pressure test results at the incident site, indicating significant leakage at the service tee location. Due to the plastic bag and protective sleeve over the service tee and service line,

neither Laclede personnel nor Staff could observe the service line at the location where it entered the service tee. The exact location of the leakage could not be determined.

Following the pressure test, a decision was made to cut the service line at approximately the location where it first contacted the tree root and outside of the protective sleeve. This decision was made to facilitate handling of the assembly and minimize stresses on the fittings (due to the large tree root that was attached to the service line). The section of distribution main with the shortened section of service line was then moved to a different location in the laboratory to remove the pressure test fittings from the distribution main. During the removal of the test fittings, the section of distribution main was rotated to a position that resulted in the service line being in a near vertical alignment, pointing downward. At this time, the service line fell from the assembly to the floor. Due to the protective sleeve and plastic bag, the service tee still could not be examined thoroughly. (See Appendix B-8, Photograph 16)

Laclede personnel had made arrangements to perform radiographic testing (non-destructive testing) on the service tee on December 15, 2003. No other examinations or disassembly were performed on December 12, 2003.

Incident Site Follow-up Investigation

Two members of the Staff returned to the incident site at approximately 11:30 on December 12, 2003. The tree root ball was measured. (See Appendix B-9, Photograph 17) The imprint of the distribution main and service tee was readily apparent on the bottom of the tree root ball. (See Appendix B-9, Photograph 18) Laclede personnel at the site counted the growth rings on the tree stump and reported approximately 29 rings were present. The depth of the distribution main was measured at both ends of the excavation, approximately 36-38 inches. The street curb to sidewalk distance was measured at both ends of the excavation--81 inches at east end, 77 inches at west end. It was also noted that there was a gravel bed exposed under the street curb. The gravel bed layer was approximately 6 inches thick. Air jacking was still in progress in the front yard of #7 Hagers Mill Court due to detectable levels of natural gas at a crack in the basement at this location.

The service tee was installed in 1974. The 29 growth rings on the tree existed after the 2003 growing season. There were 29 growing seasons from the installation of the service tee to the date of the incident. Assuming the tree was at least 2 years old when planted, it is believed that the tree was planted after the service tee installation.

Additional Information

On December 15, 2003, radiographic examination of the service tee was performed. This testing included radiographic examination of a similar service tee that was known to be properly assembled for comparison purposes. Laclede notified the Staff that review of the radiographic examinations indicated that the tubular stiffener and the grip ring did not appear to be present in the service tee removed from the incident site. Additional visual examinations and disassembly were to be scheduled at a later date.

Laclede performed testing to determine pullout strength for various service tee configurations. A service tee identical to the one installed at #6 Hagers Mill Court was not available, however, fittings with a mechanical compression outlet of similar design were used for the testing. The fittings did not contain an integral tubular stiffener. The two essential variables for this testing were the presence/absence of a tubular stiffener and a grip ring. Test results are provided in the table below.

Configuration	Test Results
Internal tubular stiffener and grip ring	310 pounds, plastic tubing failed, no pullout occurred
Internal tubular stiffener and no grip ring	190 pounds, pullout occurred
Grip ring and no internal tubular stiffener	200 pounds, pullout occurred
No internal tubular stiffener and no grip ring	145 pounds, pullout occurred

During the week of January 19, 2004, Laclede conducted an inspection of nine plastic service tees, which were installed under the direction of the same crew foreman who directed the service tee installation at #6 Hagers Mill Court on November 4, 1974. These service tees were selected because they were the same make and type as the one installed at #6 Hagers Mill Court. They were installed during the weeks immediately before and after installation of the service line at #6 Hagers Mill Court. Each of the nine service tees were non-destructively inspected utilizing radiography. All service tees inspected had internal tubular stiffeners installed. No grip rings were installed in any of the nine tees. It is Laclede's understanding that the grip ring was part of the manufacturer's design, integrated into the fitting delivered to the Company (See Appendix A-5, Figure 6).

On March 10, 2004, Staff observed disassembly of the service tee from the incident site. This disassembly occurred at Laclede's Shrewsbury laboratory. Representatives of various

interested parties were present. The results of the post-disassembly inspection confirmed the radiographic examination results; no tubular stiffener or grip ring was installed in the service tee. Based on residual markings on the service line and physical measurements of the service line and service tee, it appeared that the service line was inserted into the service tee to the appropriate depth (approximately 1¼ inches) during installation.

Joining of Plastic Pipe Regulations and Procedures

Regulations For Joining Plastic Pipe

March 12, 1971 to July 1, 1980

In 1970, U.S. Department of Transportation-Office of Pipeline Safety (DOT-OPS) promulgated 49 CFR part 192 and prescribed in §192.13(a) that the regulations regarding installation applied to pipeline segments "readied for service after March 12, 1971". The Commission adopted 49 CFR part 192 after it was issued by DOT-OPS. Subpart F, titled *Joining of Materials Other Than by Welding*, contained §§192.271 through 192.281. In §192.273 titled *General*, paragraph (a) stated:

> (a) The pipeline must be designed and installed so that each joint will sustain the longitudinal pullout or thrust forces caused by contraction or expansion of the piping or by anticipated external or internal loading.

In §192.281 titled *Plastic Pipe*, paragraph (e) stated:

> (e) *Mechanical Joints.* Each compression type mechanical joint on plastic pipe must comply with the following:
>
> (1) The gasket material must be compatible with the plastic.
>
> (2) A rigid internal tubular stiffener, other than a split tubular stiffener, must be used in conjunction with the coupling.

Notes:

1) Subpart F did not specify any additional requirements regarding tensile forces beyond the requirements of §192.273(a) as shown above.
2) §192.281(e) specifically required an internal tubular stiffener, however a grip ring was not specifically required by regulations.

July 1, 1980 to December 15, 1989

DOT-OPS issued Amendment 192-34, which resulted in the addition of §§192.283, 192.285 and 192.287 in Subpart F with an effective date of July 1, 1980. §§192.273(a) and 192.281(e) were not amended and continued as shown above. In §192.283 titled *Plastic Pipe; qualifying joining procedures*, paragraph (b) stated the following for mechanical joints less than 4-inch diameter:

> (b) *Mechanical Joints.* Before any written procedure established under §192.273(b) is used for making mechanical plastic pipe joints that are designed to withstand tensile forces, the procedure must be qualified by subjecting 5 specimen joints made according to the procedure to the following tensile test:
>
> …
>
> (4) Pipe specimens less than 102 mm (4 inches) in diameter are qualified if the pipe yields to an elongation of no less than 25 percent or failure initiates outside the joint area.

Note: For new installations after July, 1, 1980, a grip ring would be necessary to meet the pullout requirements of the above regulation for the style of service tee installed at #6 Hagers Mill Court.

December 15, 1989 to Present

The Commission promulgated new pipeline safety regulations effective December 15, 1989, and the requirements of §§192.273(a), 192.281(e), and 192.283(b)(4) were codified for the state regulations and are now found at 4 CSR 240-40.030(6)(B)1., (6)(F)5., and (6)(G)2.D., respectively.

Laclede's Procedures for Joining Plastic Pipe

Laclede had established a written procedure for installation of polyethylene plastic pipe. Laclede Gas Company Standard No. 13451B, dated 1-14-74, included the following section:

> VIII. Compression Joints When compression type mechanical joints are used in joining polyethylene tubing or fittings, an internal tubular rigid stiffener must be used.

Additionally, Laclede had established a written procedure for ? " OD plastic service installation. Laclede Gas Company Standard 16152B, dated 5-19-72, detailed

configurations for installation on steel mains. Laclede personnel indicated this standard was also used for plastic mains. In fact, this standard was updated on 7-9-76 to include plastic and cast iron mains. In either case, the detailed configurations showed a steel insert in the plastic tubing at the compression fitting. Laclede's procedures did not reference grip rings.

Additional Information Regarding the Service Tee

The grip ring is a design component of the compression outlet that may be included, but was not required, in the type of service tee used at the incident location. The manufacturer would install the grip ring in the rubber seal ring. The rubber seal ring/grip ring assembly would be an integral part of the compression nut supplied by the manufacturer. A grip ring is not used as a design component when the tubular stiffener is an integral part of the service tee.

Normal assembly of the service tee/service line connection for a tee similar to the one that was used at #6 Hagers Mill Court when supplied with a grip ring consists of the following general steps: (1) A tubular stiffener is inserted into the end of the service line; (2) The end of the service line is inserted to the proper depth through the compression nut/rubber seal ring/grip ring assembly into the service tee; and (3) the compression nut is tightened, compressing the rubber seal ring/grip ring and retaining the service line within the service tee assembly. (Photograph 19, Appendix B-10, shows component parts of a similar service tee.) The tubular stiffener inserted into the service line reinforces the joint by providing support to the plastic line to allow greater compressive forces when making the connection and preventing long-term radial relaxation of the plastic pipe. Any long-term relaxation of the plastic would result in a reduction of the outside diameter of the plastic pipe and a corresponding reduction in the gripping forces of the compression fitting on the exterior of the plastic service line.

The service tee used at the incident location was a type that could be used for connecting copper service lines or plastic service lines. When used with copper service lines, no tubular stiffener was required, due to the radial rigidity of the copper line. Because of the dual application of this model service tee, the tubular stiffener was a separate component (purchased separately from the service tee). Present-day service tees to be used with plastic pipe contain an integral tubular stiffener that cannot be removed. The grip ring is not required on present-day service tees because of the integral tubular stiffener.

Police and Fire Department Reports

Formal reports from the responding agencies provided the following information. The first West County Fire & EMS alarm was received at 06:24:08 on December 11, 2003. The first responding unit arrived on the scene at 06:29:34. The last unit cleared the scene at 14:04:46. Upon arrival at the scene, fire department personnel noted that the structure at #6 Hagers Mill Court was burning on the ground and the two adjacent structures (#5 and #7 Hagers Mill Court) were smoking. The occupants of #6 Hagers Mill Court were located and identified at the corner of Hagers Mill Court and Hazel Falls Drive. A strong odor of natural gas was noted at the fire scene. Following arrival of Laclede employees and sampling for natural gas, firefighters and residents were evacuated until the distribution main to Hagers Mill Court could be shut off. Laclede personnel had informed firefighters that gas had been detected in the sewer system and two nearby homes. Immediately following the initial explosion, the father and two children were in the front yard of the residence. The third child was in the basement at that time. He then called out to his father and came out of the house and joined the family in the front yard. Neighbors were assisting the family and the father moved his automobile from the driveway. After he relocated his automobile, he returned to the children. At this time, they observed a "huge fireball" engulfing the collapsed building. The father had lived at the residence for fourteen years and had not reported any natural gas problems during that time.

ANALYSIS

Structural Damage

The residential structure at #6 Hagers Mill Court was totally destroyed by the explosion and subsequent fire. Small amounts of unburned debris were present in the front and side yards. Significant amounts of unburned debris were present in the backyard and the backyard of the adjoining property to the rear. A portion of this debris was comprised of a wooden deck that had been attached to the rear of the house. A section of wooden panel fence separating the backyards had been knocked down by the explosion and/or flying debris.

The explosion occurred when a mixture of gas and air in the explosive range (4.5% to 14.5% gas-in-air by volume) was ignited. The natural gas water heater and furnace could provide ignition sources. Additionally, electrical switches could have been operated at various locations in the structure. The specific source of ignition was not determined.

Based on the debris pattern and the ratio of burned-to-unburned debris, it appears that a low order explosion occurred followed by significant burning. Witness accounts of the incident indicated that the initial explosion was followed by a large fireball that engulfed the residence. The design of the structure (walk-out basement to the rear) would tend to direct the explosive forces to the rear if the explosion occurred in the basement area.

The large amount of burned debris is indicative of a gas-in-air mixture that was at the upper limit of the explosive range. An explosion at this concentration may cause secondary fires and continued burning due to the gaseous products formed by the explosion. These gaseous products and residual natural gas can be re-ignited by the temperatures generated by the initial explosion. Following the explosion, a broken natural gas fuel line in the structure could have provided additional natural gas to fuel the fire. A broken fuel line would have fed the fire until the gas meter or pressure regulator was destroyed outside the structure or the gas main was squeezed off, stopping the flow of gas to the area. It is estimated that greater than 90% of the structural materials and house contents were burned and remained in the structure's basement and garage areas.

Service Line/Service Tee Separation

The weight of the tree plus the displacement of soil by the tree roots would push the gas main and service tee downward. Additionally, the tree root ball was restraining the service tee and distribution main in the horizontal plane. The service line was lifted upward by the tree root growing under it. These two deflections (in opposite directions) would act to place the service line connection in tension. The forces and movements applied by the tree and roots to the pipeline components were gradual and assumed to take place over a number of years. The tree roots would naturally follow the service line since the soil disturbed by the excavation during installation would be less compacted and more aerated than the surrounding soil and it would become a path of least resistance to water flow. The soils surrounding pipelines are frequently wet because of the low resistance to water flow. Trees growing near pipelines seek the disturbed soil, particularly in dry seasons.

Typically, service tees (for this size piping) were designed to be stronger than the piping material; even though pipeline safety regulations, at the time the service line was installed, did not require it. That is, if a service line/service tee connection is placed in tension to the point of failure, the failure should not be a pullout of the service line, but a destructive failure of the service line pipe. In the case of this incident, the service line was pulled approximately 1¼ inch and eventually it was pulled out of the service tee fitting.

Based on the radiographic examination on December 15, 2003, and subsequent disassembly on March 10, 2004, no tubular stiffener or grip ring had been utilized when the service tee from the incident site was assembled. Figures 6 and 7 (Appendix A-5) show the assembly of the service tee as believed to be installed and the as-found assembly of the service tee at #6 Hagers Mill Court. The absence of the tubular stiffener and grip ring allowed the service line to pull out of the compression coupling with significantly less force than would be required to cause a failure of this connection with tubular stiffener and grip ring (145 pounds for pullout versus 310 pounds for tubing failure) based on tests of similar couplings by Laclede. The same testing indicated that a pullout force of 190 pounds was required for a fitting with the tubular stiffener, but without a grip ring. The table in the **Additional Information** portion of the **FACTS** section of this report provides data for representative test results. While the forces imparted by the tree and roots may have been sufficient to result in a failure of a properly installed fitting at some point in time, the absence of a tubular stiffener significantly increased the likelihood of occurrence. 49 CFR 192.281(e), as adopted by the Commission, required that each compression type mechanical joint on plastic pipe must comply with the following: a rigid internal tubular stiffener, other than a split

tubular stiffener, must be used in conjunction with the coupling. This requirement has been in effect since 1970. Laclede installation standards that were in effect at the time of construction specifically required use of the tubular stiffener for plastic pipe service connections.

In 1970, the Commission adopted 49 CFR 192.273, which required that each compression-type service line to main connection must be designed and installed to effectively sustain the longitudinal pullout or thrust forces caused by contraction or expansion of the piping, or by anticipated external or internal loading. Tests conducted by Laclede after the incident at #6 Hagers Mill Court indicated that the service line to distribution main connection would have sustained the anticipated longitudinal pullout forces (due to expansion/contraction only) even though the joint was not properly configured.

Natural Gas Migration

The natural gas escaping from the service tee at a pressure of approximately 37 psig would have migrated rapidly through the soil. There was a volume of soil in the vicinity of the service tee that was dried out. Passage of natural gas through soil has a drying effect and can remove most of the moisture from the soil. Natural gas is lighter than air. It would normally tend to migrate upward or follow the path of least resistance. However, the recent precipitation and freezing temperatures would tend to restrict the upward migration and seal the soil surface, preventing escape to the atmosphere. Additionally, the areas immediately north and south of the service tee connection were concrete sidewalk and street, further restricting the upward migration of natural gas. The presence of natural gas in the sanitary sewer system and two additional residences (#7 and #8 Hagers Mill Court) indicated that the natural gas had migrated to various locations in the vicinity of the leak.

The natural gas could have entered the structure through one or more entry points and accumulated until it ignited. Various underground entrance points to #6 Hagers Mill Court were observed (cracks, utility entrances), as well as, floor drains.

CONCLUSIONS

1. At approximately 06:22 CST, Thursday, December 11, 2003, a natural gas explosion and subsequent fire occurred at a residence at #6 Hagers Mill Court, in Manchester, Missouri.

2. The residence was totally destroyed. One adult and one child with minor injuries were treated and released at a local hospital. One child with moderate injuries and one child with severe injuries were admitted to a local hospital for in-patient treatment. There were no other injuries reported.

3. The probable cause of the incident was the ignition of natural gas that had escaped from the service tee connection to the service line for #6 Hagers Mill Court. The service line had pulled out of the compression coupling at the service tee. The natural gas migrated into the structures at #6, #7 and #8 Hagers Mill Court, the sanitary sewer system, and the storm sewer system. The specific source of ignition in #6 Hagers Mill Court was not determined.

4. The pullout of the service line from the compression coupling was caused by longitudinal forces on the connection imposed by a tree and associated tree roots growing in the location of the distribution main, service tee and service line. These longitudinal forces eventually exceeded the pullout strength of the compression coupling. This condition was exacerbated by the absence of an internal tubular stiffener in the service line and grip ring inside the compression nut. The service tee was an original installation from November 4, 1974.

5. Design of the service tee installed at #6 Hagers Mill Court satisfied regulatory requirements that existed at the time of installation. This is based on the supposition that the service tee is properly assembled with all components installed. The mechanical compression outlet, on any service tees similar to the tee installed at the incident site, must meet current regulatory requirements following any maintenance activities involving disassembly of the service line/service tee connection.

6. Design of the service tee utilized by Laclede now contains a tubular stiffener, integral to the tee; therefore a Staff recommendation is not necessary regarding installation of new service tees.

7. Based on inspections of work performed by the same crew in the weeks immediately preceding and succeeding the incident site installation, no additional service tees were identified with a missing tubular stiffener.

8. Laclede's investigations to identify the extent of migration of any escaping natural gas and actions to stop the flow of escaping natural gas were conducted in a timely manner. A safety zone was established and the Company's emergency procedures were effectively implemented.

9. Laclede's installation standards that were in effect at the time of construction specifically required use of a tubular stiffener for plastic pipe service connections. Laclede did not comply with these standards during the installation of the service tee at #6 Hagers Mill Court.

10. The Staff believes that Laclede violated 49 CFR 192.281(e), as adopted by the Commission, which states: "Each compression type mechanical joint on plastic pipe must comply with the following: A rigid internal tubular stiffener, other than a split tubular stiffener, must be used in conjunction with the coupling." This regulation was in effect at the date of installation for this facility.

11. The Staff's investigation revealed a probable violation of 49 CFR 192.281(e), as adopted by the Commission, and has requested that the Office of General Counsel file a complaint against Laclede accordingly.

RECOMMENDATIONS

1. Based on Laclede's review of factors related to this incident, the following actions have been initiated.

   A. Laclede will modify its current procedures to inspect for the presence of a tubular stiffener in each plastic service tee manufactured for use with a non-integral tubular stiffener when exposed for routine work by Laclede crews. Any tee inspected and found not to contain a tubular stiffener will be upgraded to meet current regulatory requirements if the tee is to remain in service. The performance of these inspections will be documented on Laclede's Service Order F-610 for a period of one year beginning on June 1, 2004, with an anticipated sample size of approximately 100. The results of this sampling will be reviewed with Staff to determine if any further actions are required.

   B. Laclede will instruct all field crews to inspect any Continental® service tee whenever such service tees are exposed and taken out of service for any reason (i.e., leak repairs, service replacements, and service relocations). Any tee not meeting current regulatory requirements for new installations must be upgraded to meet today's standards if the tee is to remain in service.

   C. As a result of a search of its electronic database of Leak Repair and Pipe Condition Reports, Laclede has identified six occurrences where a service line was pulled from the tee connection and the service tee was likely to have been the same type as was installed at #6 Hagers Mill Court. One of the service tees was replaced with a new tee meeting current standards. Laclede will perform an inspection of the remaining service tees at these locations and report the results to Staff. Any of these inspected tees not meeting current regulatory requirements for new installations will be upgraded to meet today's standards if the tee is to remain in service.

   D. Laclede is in the process of revising its leak repair and pipe condition reporting to allow additional documentation and database tracking of specific issues related to fitting pullouts. Laclede forms are undergoing a revision to facilitate this tracking and are expected to be in use by May 14, 2004.

Laclede has developed procedures to continually review its leak repair and pipe condition database for issues related to fitting pullout and commits to provide Staff with annual updates of statistics related to plastic fitting pullouts.

The Staff was considering recommendations in this Incident Report that would require information and changes to current procedures similar to the actions proposed by Laclede. The Staff has carefully considered the actions proposed by Laclede in response to this incident and if these actions are fully implemented, they would address the concerns that Staff has related to this Incident Report.

2. The Staff recommends that Laclede file for review by the Commission a commitment to its actions initiated in response to this incident and any additional comments or actions, in Case No. GS-2004-0264, within 30 days of the filing of this Incident Report.

3. The Staff recommends that this Case remain open until Laclede's filing has been received and reviewed by the Commission.

4. The Staff recommends that the Office of General Counsel cause a complaint to be filed with the Commission regarding the violation noted in this Incident Report.

APPENDIX A
(Figures)

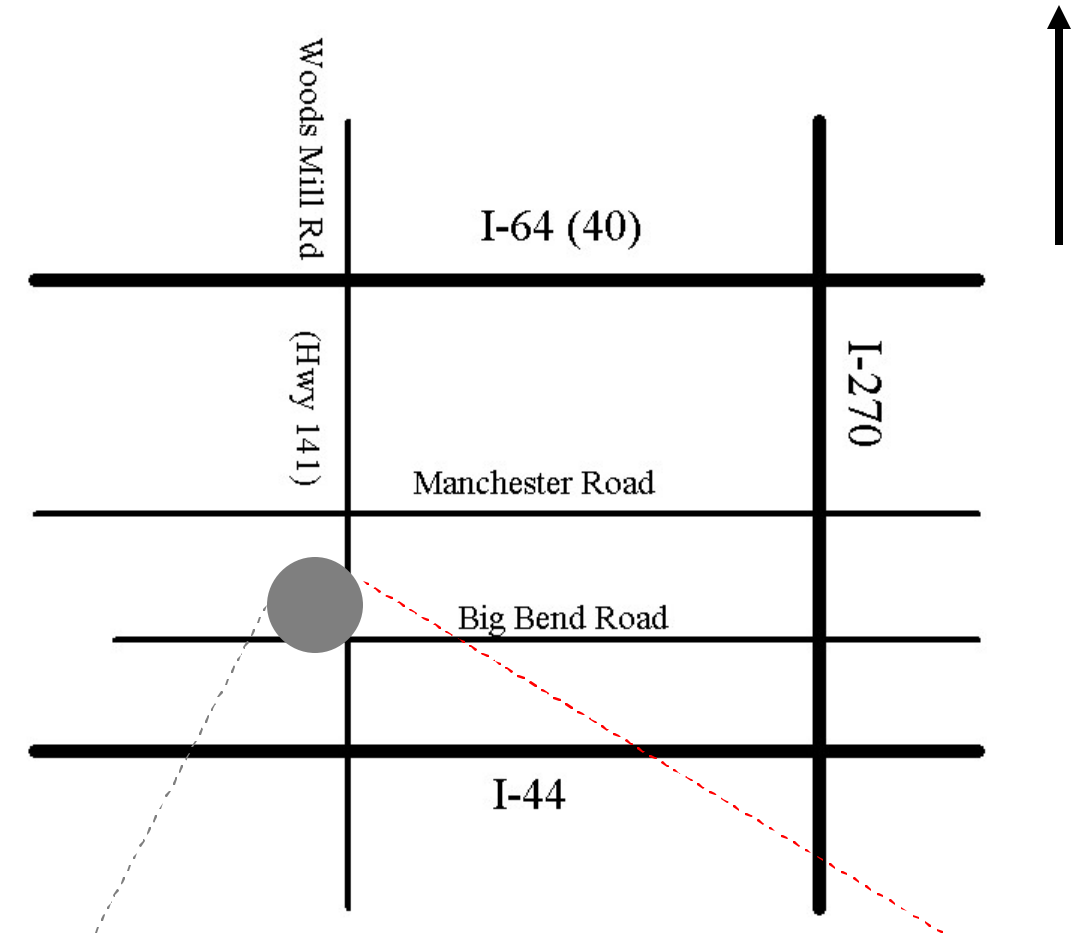


Figure 1

Drawings not to scale

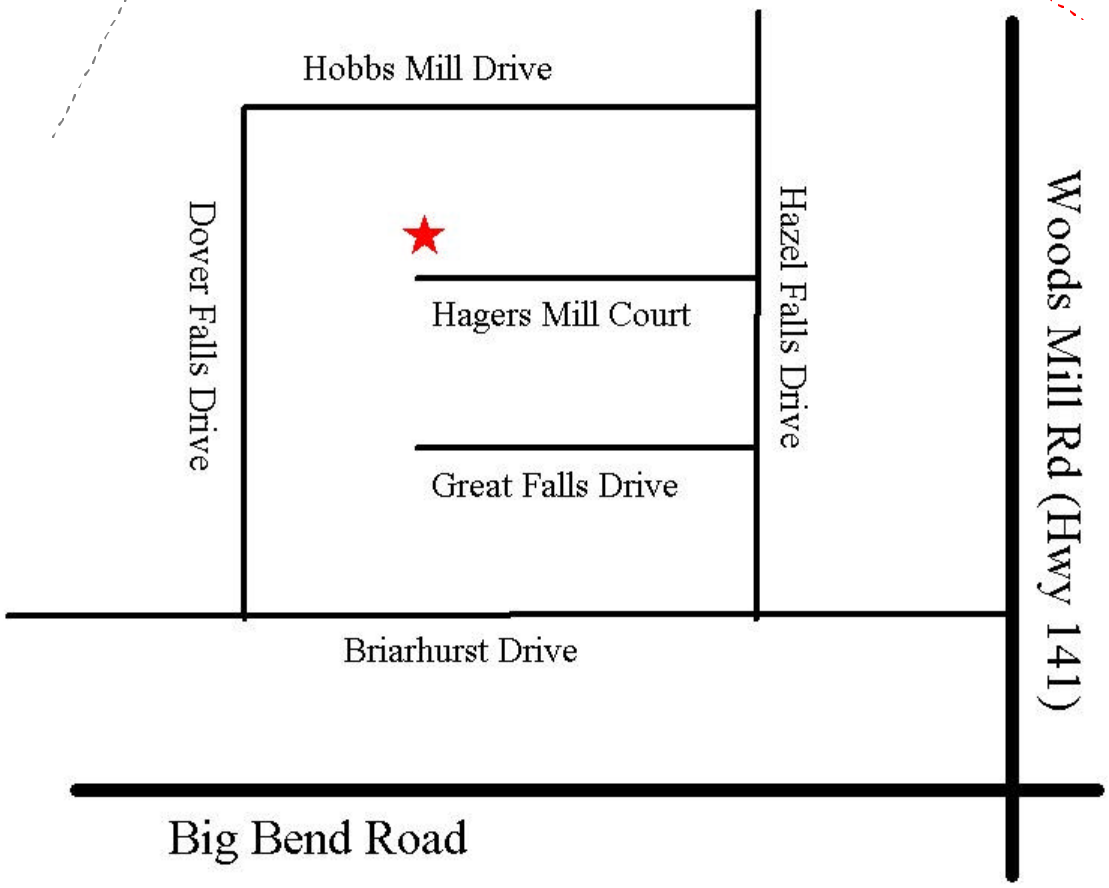
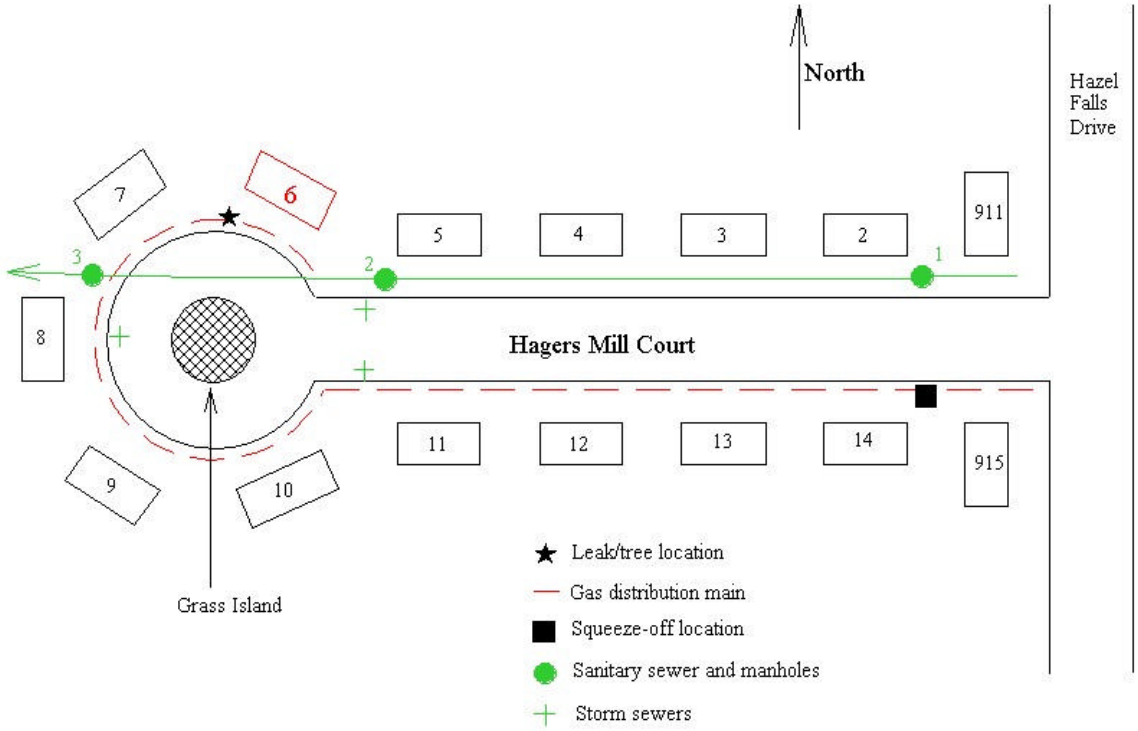


Figure 2

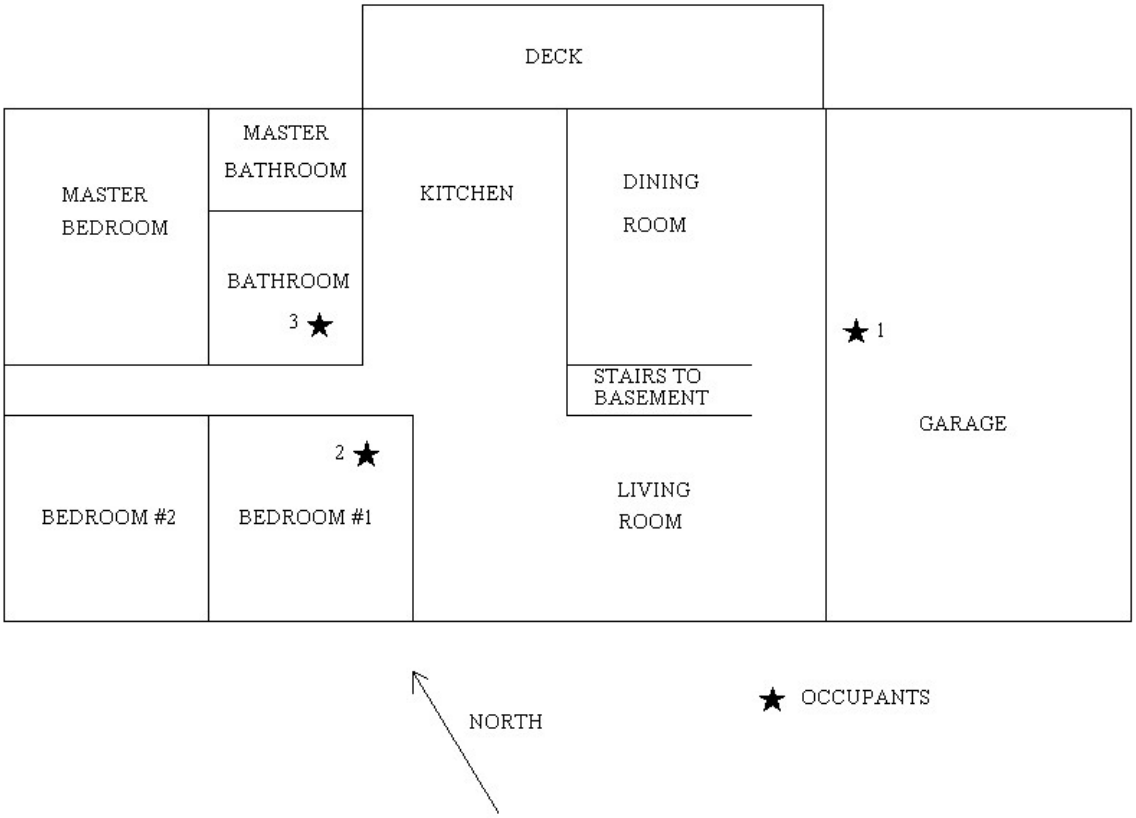
Incident Site



Drawing not to scale

Hagers Mill Court

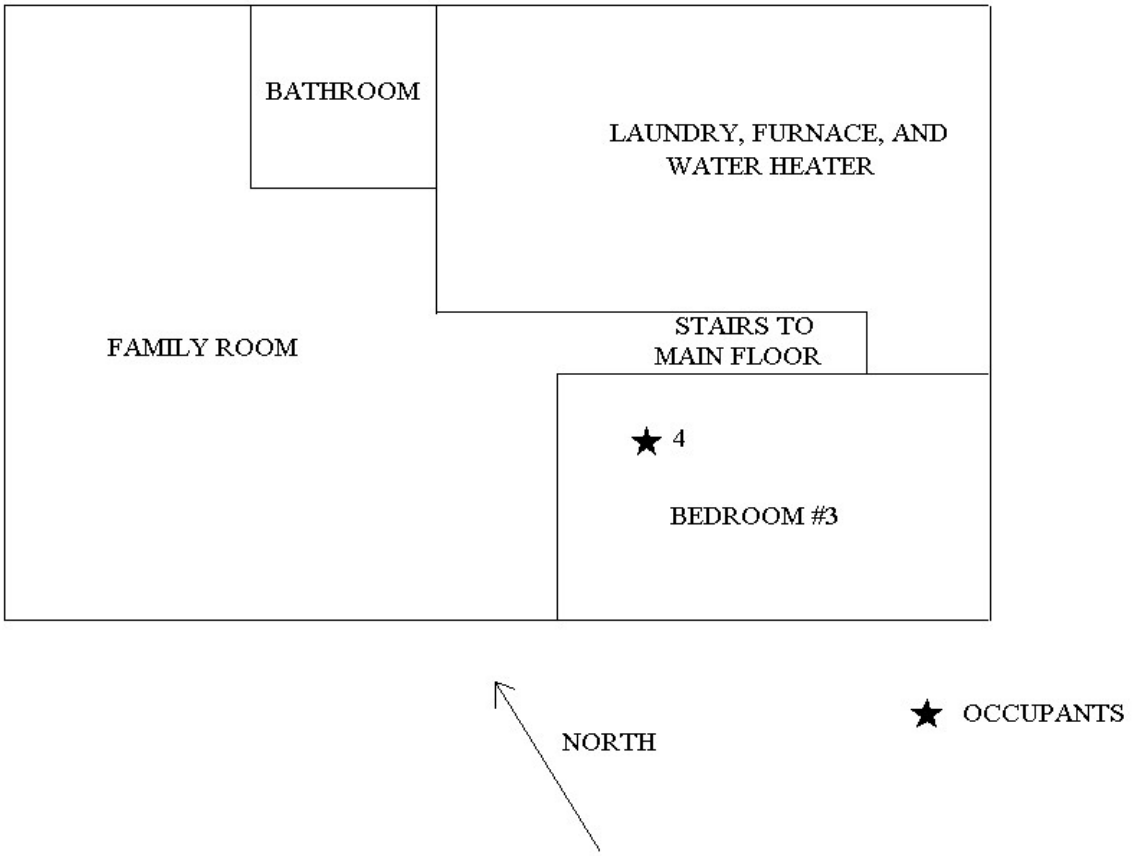
Figure 3



Drawing not to scale

#6 Hagers Mill Court
First Floor Plan

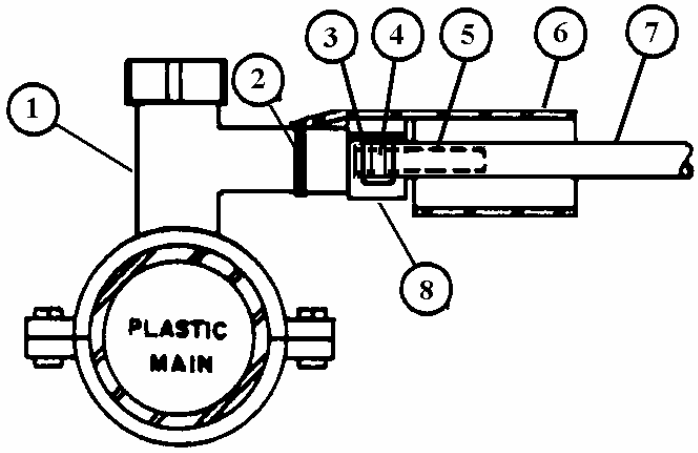
Figure 4



Drawing not to scale

#6 Hagers Mill Court
Basement Floor Plan

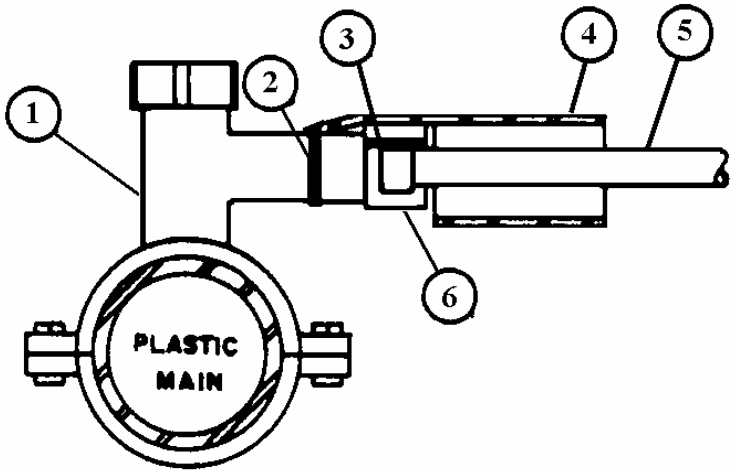
Figure 5



1. Service Tee
2. Stainless Steel Band Clamp, Gray Cotton Tape or other appropriate method
3. Rubber Seal Ring (Gasket)
4. Steel Grip Ring
5. Steel Insert
6. PE Support Sleeve
7. PE Service
8. Compression Nut

Installation as believed to be installed

Figure 6



1. Service Tee
2. Gray Cotton Tape
3. Rubber Seal Ring (Gasket)
4. PE Support Sleeve
5. PE Service
6. Compression Nut

Installation as found at 6 Hagers Mill Ct.

Figure 7

Note: Position of Service Line within tee at time of incident is unknown.

Drawings provided by Laclede Gas Company

Appendix B
Photographs

Note: Date/time stamp on photographs is not correct.

Photograph 1
West end of #5 Hagers Mill Court, showing heat damage to exterior of building.

Photograph 2 Front of #9 Hagers Mill Court, a residence similar to the structure destroyed at #6 Hagers Mill Court.

Photograph 3 Squeeze-off of distribution main near #14 Hagers Mill Court.

Photograph 4 Basement of #6 Hagers Mill Court, looking towards the front and east walls from the rear of the foundation.

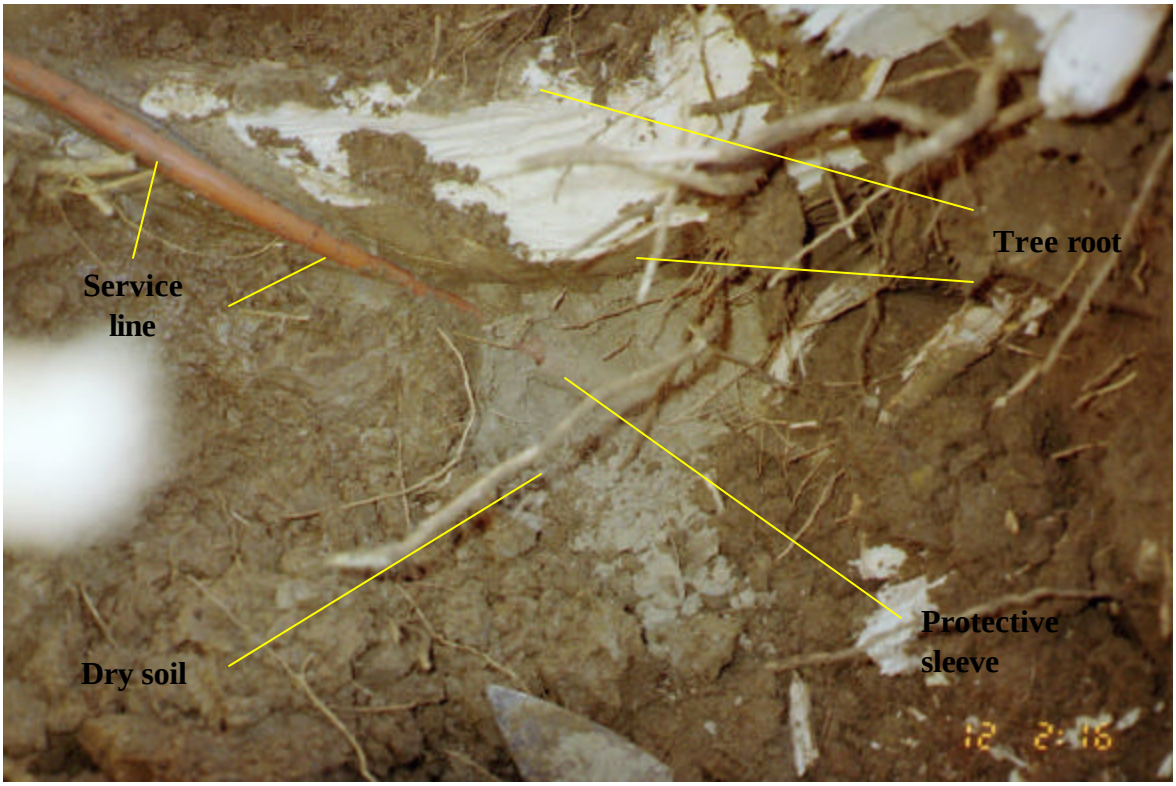
Photograph 5 Backyard of #6 Hagers Mill Court, looking east towards #5 Hagers Mill Court.

Photograph 6 Backyard of #6 Hagers Mill Court, looking north-northwest into backyard of residence on Hobbs Mill Drive.

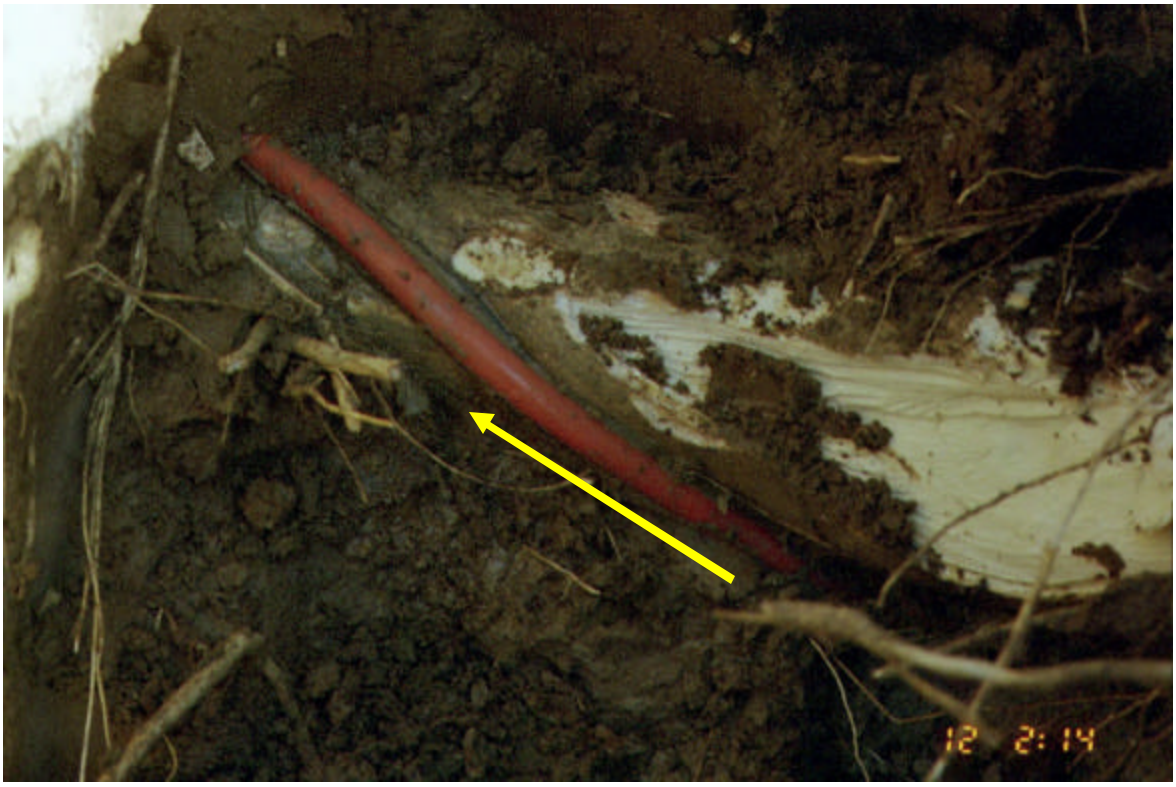
Photograph 7 Location of the natural gas meter and service entrance on the west side of foundation. Steel service line riser, manifold and fuel piping remain intact, while meter and service regulator have melted.

Photograph 8 Initial excavation on east side of tree, excavation work in progress on west side of tree.

Photograph 9 Tree growing over service tee for #6 Hagers Mill Court. View from cul-de-sac looking northwest.



Photograph 10 Dry soil located under the tree root ball. The natural gas service line and protective sleeve can be seen in the soil.

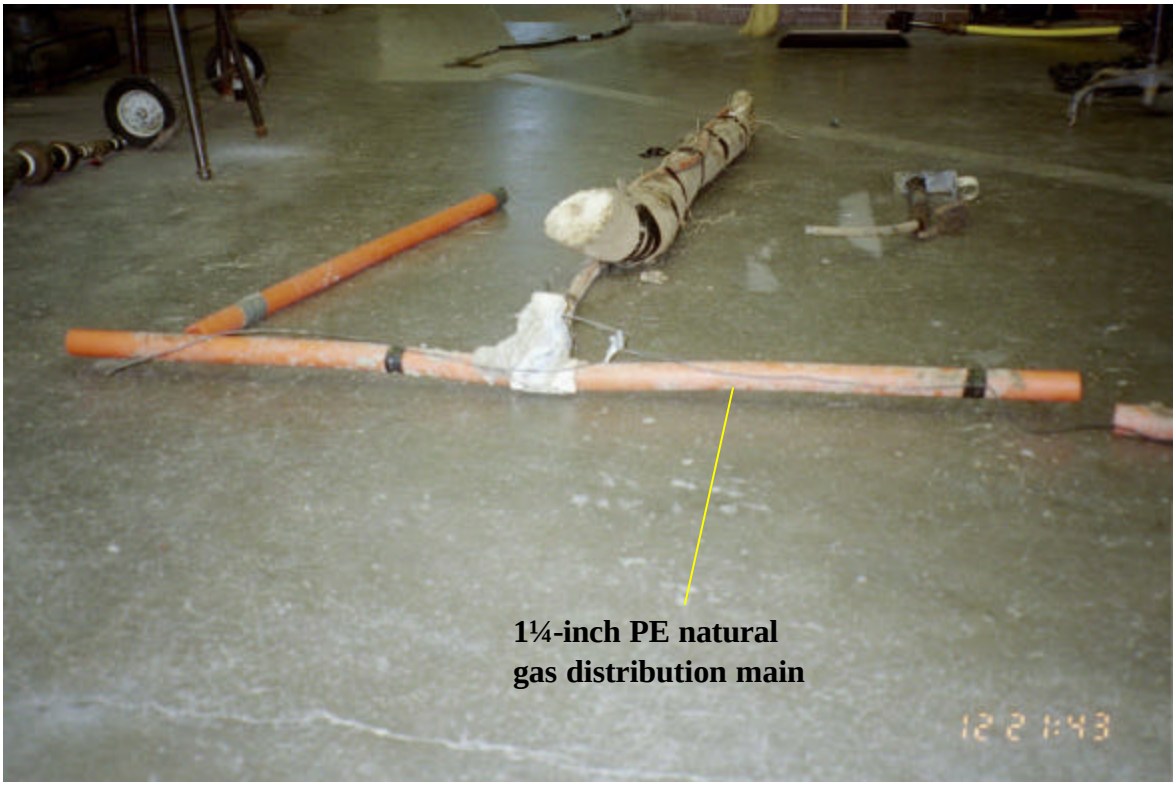


Photograph 11 Service line to #6 Hagers Mill Court--originating under tree root ball and tree root, proceeding along west side of tree root, and then along the top of the tree root. Normal flow of natural gas indicated by arrow.

Photograph 12 Tree root ball being lifted from ground. Section of distribution main, service tee and service line are suspended by the tracer wire. Dry soil can be seen beneath the service tee.

Photograph 13 Distribution main, service tee, service line and tracer wire serving #6 Hagers Mill Court.

Photograph 14 Distribution main/service line assembly in laboratory--portions of the distribution main were cut off to enable transport to laboratory. Tree root/service line configuration was maintained by taping them together. Service line riser from the incident site is also visible in the photograph.

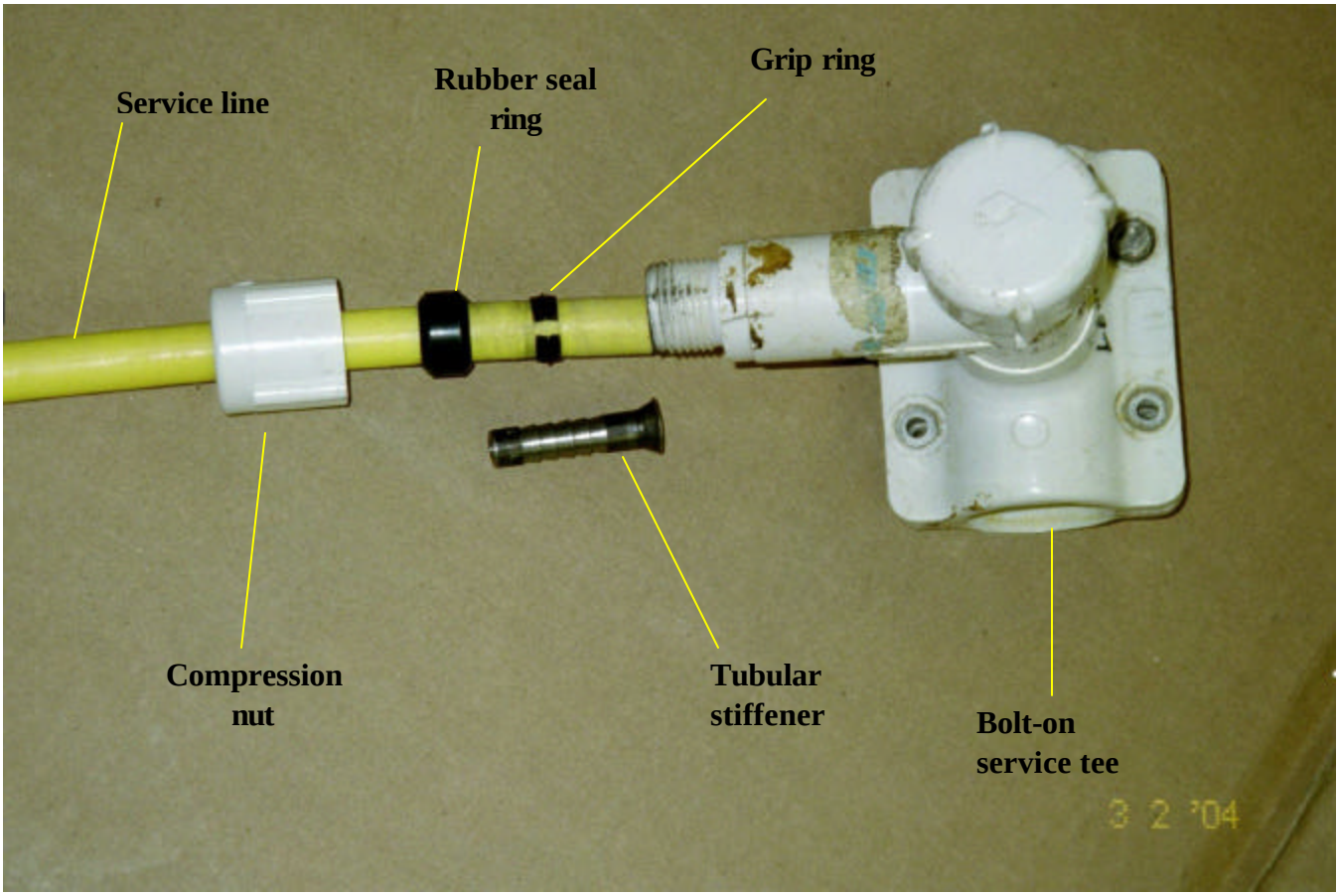


Photograph 15 Downward bow in the center of the distribution main can be seen by noting the elevated ends, relative to the center resting on the floor.

Photograph 16 Distribution main and service tee assembly--the service line is no longer attached, however the protective sleeve is still in place.

Photograph 17 Bottom of tree root ball with carpenter's folding ruler for size determination.

Photograph 18 Bottom of tree root ball showing imprint of distribution main, service tee and dried soil.



Photograph 19 Service tee similar to tee utilized at incident site. Tee is shown in disassembled configuration to illustrate component parts. Normally, the installation crew inserts the tubular stiffener into the end of service line (prior to service line insertion into the compression nut/service tee assembly). The compression nut is received from the manufacturer with the grip ring/rubber seal ring assembly installed in the compression nut. The as-received location of the grip ring is inside the rubber seal ring.