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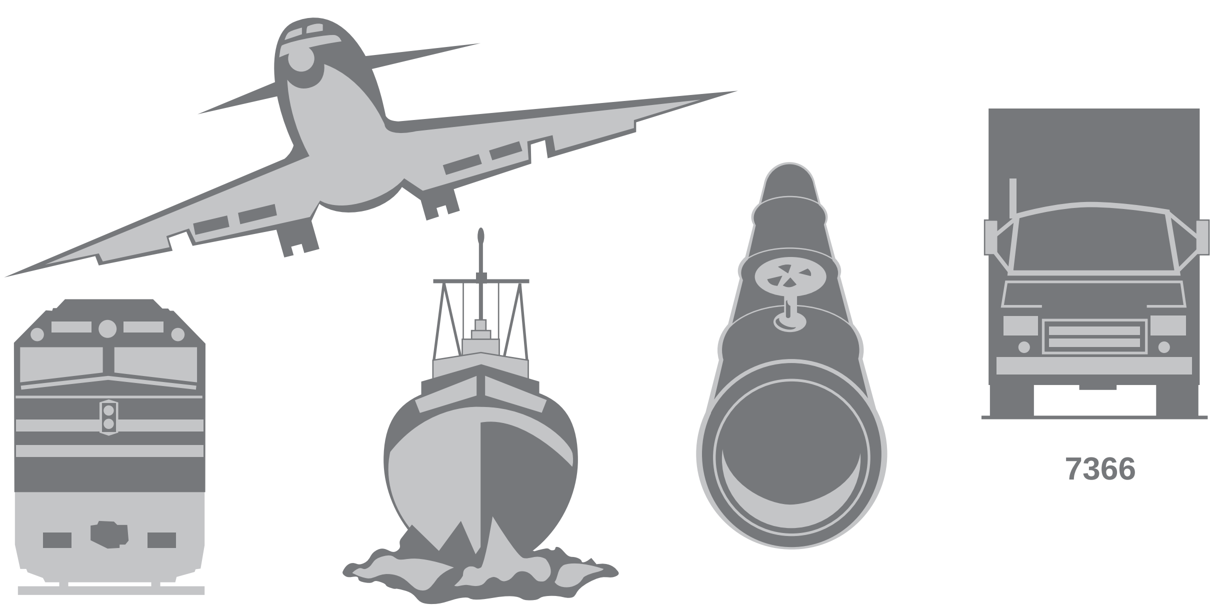
NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

PIPELINE ACCIDENT REPORT

NATURAL GAS EXPLOSION AND FIRE IN SOUTH RIDING, VIRGINIA JULY 7, 1998



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Adopted June 12, 2001

National Transportation Safety Board
490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

National Transportation Safety Board. 2001. ***Natural Gas Explosion and Fire in South Riding, Virginia, July 7, 1998.*** **Pipeline Accident Report NTSB/PAR-01/01. Washington, DC.**

Abstract: About 12:25 a.m. on July 7, 1998, a natural gas explosion and fire destroyed a newly constructed residence in the South Riding community in Loudoun County, Virginia. A family consisting of a husband and wife and their two children were spending their first night in their new home at the time of the explosion. As a result of the accident, the wife was killed, the husband was seriously injured, and the two children received minor injuries. Five other homes and two vehicles were damaged.

The safety issues identified during this investigation were (1) the adequacy of standards for minimum separation distances between gas service lines and electrical service lines and (2) the lack of a requirement for the installation of excess flow valves.

As a result of this investigation, the Safety Board made two recommendations to the Research and Special Programs Administration (RSPA) and one recommendation each to the Edison Electric Institute, the National Rural Electric Cooperative Association, the American Power Association, and the U.S. Department of Agriculture's Rural Utilities Service.

Contents

Executive Summary

About 12:25 a.m. on July 7, 1998, a natural gas explosion and fire destroyed a newly constructed residence in the South Riding community in Loudoun County, Virginia. A family consisting of a husband and wife and their two children were spending their first night in their new home at the time of the explosion. As a result of the accident, the wife was killed, the husband was seriously injured, and the two children received minor injuries. Five other homes and two vehicles were damaged.

The National Transportation Safety Board determines that the probable cause of the accident in South Riding, Virginia, was the corrosion and subsequent overheating and arcing at a splice in one of the conductors of the triplex electrical service line, which, because of inadequate separation between the electrical conductors and the gas service line, led to the failure of the gas service line and the subsequent uncontrolled release of natural gas that accumulated in the basement and was subsequently ignited. Precipitating the electrical service line failure was damage done to the electrical service line during installation of the gas service line and/or during subsequent excavation of the electrical line.

The safety issues identified during this investigation were (1) the adequacy of standards for minimum separation distances between gas service lines and electrical service lines and (2) the lack of a requirement for the installation of excess flow valves. As a result of this investigation, the Safety Board issues two recommendations to the Research and Special Programs Administration (RSPA) and one recommendation each to the Edison Electric Institute, the National Rural Electric Cooperative Association, the American Power Association, and the U.S. Department of Agriculture's Rural Utilities Service.

Factual Information

Accident Synopsis

About 12:25 a.m. on July 7, 1998, a natural gas explosion and fire destroyed a newly constructed residence in the South Riding community in Loudoun County, Virginia. A family consisting of a husband and wife and their two children were spending their first night in their new home at the time of the explosion. As a result of the accident, the wife was killed, the husband was seriously injured, and the two children received minor injuries. Five other homes and two vehicles were damaged.

The Accident

At the time of the accident, South Riding, Virginia, was a growing planned community in Loudoun County, Virginia, near Washington, D.C., and new homes were in various stages of construction. On April 22, 1998, a Northern Virginia Electric Cooperative (NOVEC) crew dug a trench and installed electrical service to a new home on Rickmansworth Lane, the home that would later be involved in the accident. Underground three-wire electrical service triplex[1] had previously been "stubbed in," that is, installed (buried in a trench) to within a short distance of the home site so that the service line to the house could be spliced onto it when the structure was ready for electrical service. The NOVEC crew spliced onto this stubbed-in triplex an additional 23-foot section of triplex that they then attached to the house's electric meter. (See figure 1.)

During the first week in May, a Washington Gas Light Company contractor, Northern Pipeline Company, installed a 3/4-inch-diameter polyethylene gas service line in a trench to the house. The one-call system was used before the excavation, and the location of the electrical lines had been marked. The contractor foreman said that during excavation for the gas service line, a portion of the electric service line to the house was exposed. He stated that he understood that gas pipelines needed to be separated at least 12 inches from electrical service lines, so at the point where the electrical line had been exposed, he moved the gas service line to maintain 12 inches of horizontal separation.

Bluestone rock dust was used as a backfill material around the gas pipelines and electric service installed in trenches and buried within the South Riding neighborhood to protect the utilities from damage from rocks and other materials in the local soil. Native soil was then placed atop the imported backfill to bring the surface back to its original grade.

[1] The electrical service triplex consisted of three twined cables: two 4/0 American Wire Gauge (AWG) current-carrying *conductors* (each approximately 5/8 inch in diameter) and one 2/0 AWG *neutral*. All three cables were constructed of compressed, 19-strand aluminum wire covered with high-density polyethylene insulation.

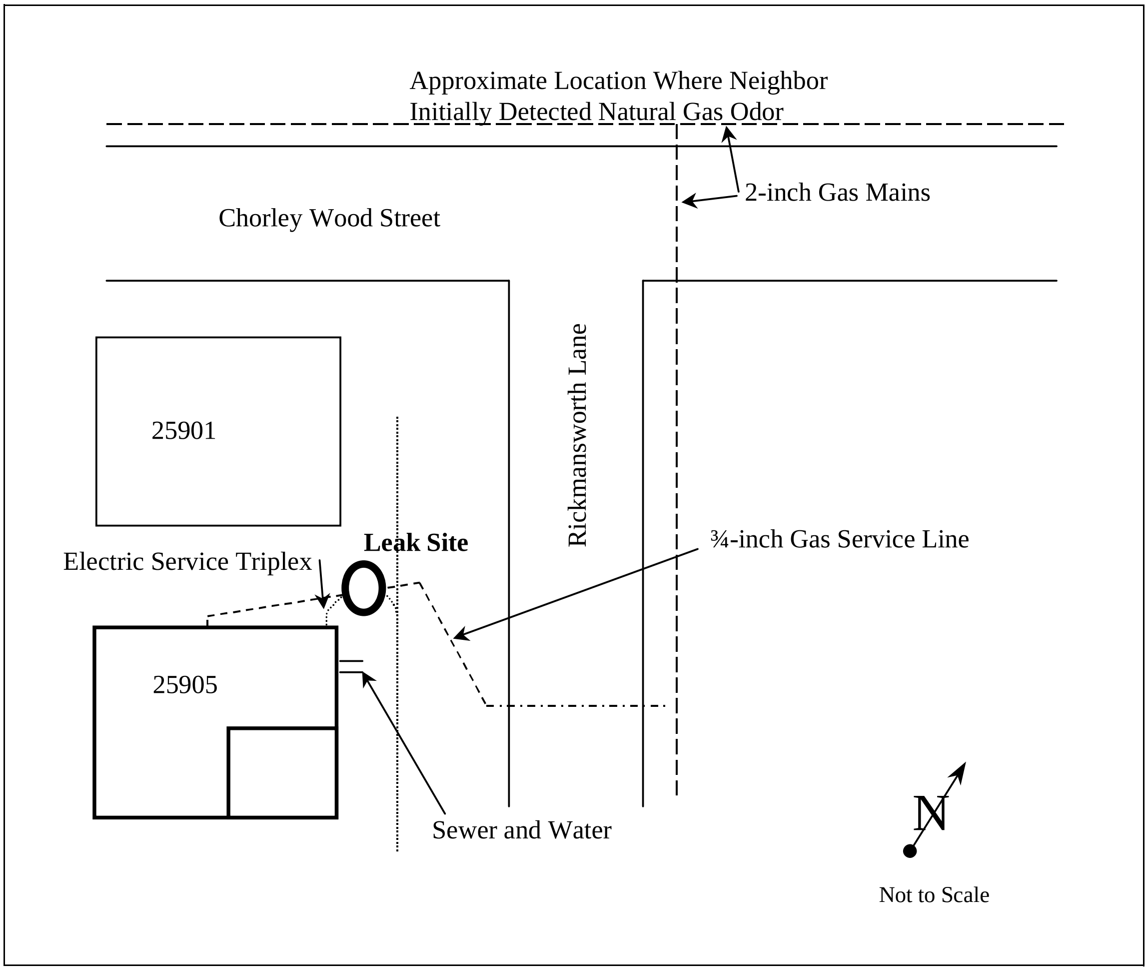

Figure 1. Accident area.

The gas meter was installed on June 9, 1998, and the gas piping was inspected, pressure-tested, and approved by the Loudoun County Department of Building and Development by June 11. The gas meter reading at the time of installation was 1645.[2] Washington Gas Light Company had verified the accuracy of the gas meter on January 14, 1997.[3] An excess flow valve (EFV)[4] was not installed in the gas service line supplying the residence.

On June 15, about 6 weeks after the gas service line was installed, a contractor working inside the house found that the house was not receiving full electrical service. He

[2] Gas meter readings are in hundreds of cubic feet. Meters are not reset when installed; the initial reading is used as a baseline for the subsequent monitoring of gas usage.

[3] On August 12, 1998, Safety Board investigators witnessed Washington Gas Light Company representatives verifying the accuracy of the meter that had been removed from the residence after the explosion.

[4] EFVs are designed to automatically close and stop the flow of natural gas through a service line if the flow exceeds a specified rate.

found a NOVEC supervisor working nearby and told him of the problem. The supervisor arranged for a NOVEC crew to go to the site when their current job was completed. Near the end of the day, according to the foreman of the NOVEC crew, the crew came to the site and exposed the electrical service line by hand-digging. He said they were unable to locate the fault before the end of their shift and, because the house was unoccupied, they left the repairs for the next day.

The next morning, June 16, another NOVEC crew was sent to make the permanent repairs. The one-call system was not used, but the crew said they recalled seeing utility markings on the ground near the site of the excavation. After excavating the site with mechanized equipment, the crew located a fault near a point at which the electrical service triplex crossed underneath the gas service line. This was also the area along the triplex where, before the gas pipeline was installed, the electrical service to the residence had been spliced to the preexisting triplex stub. The crew said they observed that the gas service line crossed about 6 inches above the electrical service line. They stated that they found that one conductor of the triplex had been damaged. They said they repaired the fault by cutting out the damaged section, which included the original splice connection, and splicing in a short section of new cable. They said they also examined the gas service line to ensure that their repairs had not damaged it. After their repair, the crew stated, they maintained or increased the 6-inch separation between the electric line and the gas service line while they backfilled the area.

The house was purchased on June 23, 1998. Construction of the house had just been completed, and a walk-through inspection was conducted a few days before settlement. The inspection noted no problems with any of the appliances. Shortly after settlement, the gas meter for the property was read so that the service could be transferred to the new owners. At the time of the transfer, on June 24, 1998, the gas meter reading was 1,654.

After purchase, the family began moving furniture into the residence. The husband stated that they experienced no problems with any of the appliances after they took possession and that they did not move or modify the gas appliances, nor had they installed new ones. The night of July 6, 1998, was to be the first night the family was to spend together in their new home. The husband said that on the evening of July 6, the air conditioner was working and the house was cool. He also stated that he had not smelled gas. He said the family retired between 10:00 and 10:30 p.m. Because not all the furniture had arrived, the parents were sleeping in the study on the main level of the three-level house; the children were sleeping on the upper level.

Shortly before the accident on July 7, a South Riding resident standing near his home at the corner of Chorley Wood Street and Rickmansworth Lane, about 150 feet from the accident house, noticed what he described as a “strong” odor of natural gas. He said that after attempting unsuccessfully to identify the source of the odor, he called Washington Gas Light Company at about 12:19 a.m. to report it. A few minutes later, the house at Rickmansworth Lane exploded and was engulfed in flames. (See figure 2.)

Figure 2. Postaccident debris.

The children were thrown out of the house and onto the lawn, suffering minor injuries. The husband and wife fell into the basement as the first floor collapsed. The husband was able to crawl to safety, but the wife did not escape. The husband was burned severely; the wife died as a result of her injuries. The adjacent, unoccupied house was damaged by the accident and had to be demolished. Four other houses and two vehicles were also damaged.

As a result of the explosion, the piping inside the house broke, and natural gas that was being metered escaped through the broken piping. Firefighters partially shut the valve to the meter upon their arrival. Natural gas continued to escape until shortly after the first Washington Gas Light Company personnel arrived at the scene shortly after 1:00 a.m. and closed the valve that stopped the flow of natural gas through the meter. At that time, the gas meter reading was 1,665. About 1:20 a.m., the fire was extinguished.

The Loudoun County Fire Marshal’s Office inspected the destroyed house and concluded that the explosion resulted when natural gas from a hole in the gas service pipeline to the house entered and accumulated in the basement of the residence, where it was ignited by the pilot light on the water heater.

The Residence

The house was a three-level detached home consisting of an unfinished walk-out concrete basement with wood frame construction above. The basement was "L" shaped: the back portion of the basement, or bottom of the "L," was 41.7 feet long by 13.8 feet wide, and the front portion, or top of the "L," was 22.2 by 22.3 feet. The height of the basement was 8.75 feet from the concrete slab floor to the subfloor of the main level. The calculated volume of the basement was about 9,370 cubic feet.

Three gas appliances were located in the residence: a water heater, a furnace, and a gas-burning fireplace. The water heater and furnace were installed in the basement. The water heater was rated for a maximum gas load of 40,000 Btu per hour (about 39 cubic feet per hour of gas).[5] A technical representative of the water heater manufacturer stated that, provided no hot water was used and assuming a basement temperature of 80° F, the water heater would operate about four times per day for a 15- to 25-minute heating cycle to maintain the preset water temperature of 120° F. Hot water use or a cool basement would increase the frequency of operation. The representative also stated that the water heater would use between 10,000 and 20,000 Btu (10 to 19 cubic feet of gas) in each heating cycle. In addition, the pilot light at the base of the water heater consumes 400 Btu (0.4 cubic feet of gas) per hour. The furnace and the fireplace may have been run occasionally during the approximate 12 1/2 days of occupancy. All other appliances in the house were electric.

Around the foundation of the house was an underground external drainage system. This system, consisting of a 4-inch-diameter perforated plastic pipe surrounded by gravel, was designed to collect water and direct it away from the foundation and out to the rear of the house. Another drainage system was located under the concrete basement floor. This system, also consisting of perforated pipe surrounded by gravel, was designed to direct any water accumulating under the foundation into the sump pit[6] in the floor of the basement. An automatic sump pump in the sump pit discharged the water toward the exterior of the house. "Weep holes" approximately 1 1/2 to 2 inches in diameter had been placed at intervals in the concrete footer around the perimeter of the foundation to allow water to flow between the drainage systems.

Water and sewer lines passed under the foundation of the house from a point just outside the northeast wall, near the north corner of the house. Both lines entered the basement through the concrete floor.

[5] *British thermal unit (Btu)*– The quantity of thermal energy required to raise the temperature of 1 pound of water 1 degree Fahrenheit at or near 39.2° F. One cubic foot of the natural gas supplied by Washington Gas at the time of the accident would generate approximately 1,033 Btu of heat.

[6] A *sump pit* is an opening in the floor that is designed to accumulate water for the sump pump. The sump pit for this residence was in the east corner of the back portion of the basement.

Postaccident Inspection and Testing

Testing and Examination

As part of postaccident testing to locate the source of the accumulated natural gas, the gas pipelines were pressure-tested to 31 pounds per square inch, gauge (psig).[7] The test revealed a leak in the 3/4-inch-diameter polyethylene gas service line leading to the house. The leakage flow rate was measured and calculated to be about 6,500 cubic feet per hour.

Excavation of the pipeline revealed a TV cable that had been installed at a depth of about 13 inches from the surface sometime after the electrical service line and gas pipeline had been installed. The pipeline was found at a depth of about 45 inches, and just underneath the pipeline was a portion of the electrical service to the house.

Examination of the gas service line revealed a roughly circular 0.38- to 0.44-inch-diameter hole in the pipeline about 7 feet from the north corner of the house. An insulated copper tracer wire ran alongside the gas service line,[8] and the electrical triplex crossed beneath it. One of the three cables of the triplex was found to be in contact with the gas service line. Because the electrical line was disturbed during the postaccident excavation, the exact preaccident location of the cables in relation to the gas service line and to the hole in the gas service line could not be determined. When excavated, one of the two conductors (current-carrying cables) (designated “cable A” for identification) was found touching the gas service line about 3.75 inches away from the hole along the horizontal axis of the pipe. At this location, the other conductor (designated “cable B”)[9] was underneath and touching cable A. The neutral cable was several inches away from the other two. (See figure 3.)

Examination at the Safety Board laboratory revealed that the polyethylene pipe material surrounding the hole in the gas service line was blackened and appeared thinner and cratered, consistent with heat damage.[10] Also, the thinned material formed a conical peak around the hole, consistent with the effect of pressure on a heated and softened pipeline wall. (See figure 4.)

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[7] A gas pressure of 31.5 psig for the leaking pipeline was recorded at 2:55 a.m. at the Washington Gas Chantilly Gate Station that supplied natural gas into the distribution system serving South Riding.

[8] The *tracer wire* is designed to carry an electrical signal that can be read by above-ground equipment and is used to locate the polyethylene pipeline. The signal is only applied to the wire when the pipeline location is being determined.

[9] Note for reference purposes: In the Safety Board Metallurgical Laboratory factual report that is part of the public docket for this accident (Docket DCA-98-MP-003), the conductors designated “cable A” and “cable B” in this report are referred to as “Hot Lead 1” and “Hot Lead 2,” respectively.

[10] The Vicat softening temperature for the material used in gas pipelines is 247° F (119° C). (The *Vicat softening temperature* is intended to provide a standard for comparing the softening effects of temperature on various thermoplastic resins. It is defined in American Society for Testing Materials standard D1525 as the temperature at which a flat-ended needle of 1-mm^2 circular cross section will penetrate a thermoplastic specimen to a depth of 1 mm under a specified load using a selected rate of temperature rise.) According to the manufacturer of the material used to construct the gas pipeline in this accident, the material becomes sufficiently molten to fuse with itself at 375 to 400° F (190 to 204° C).

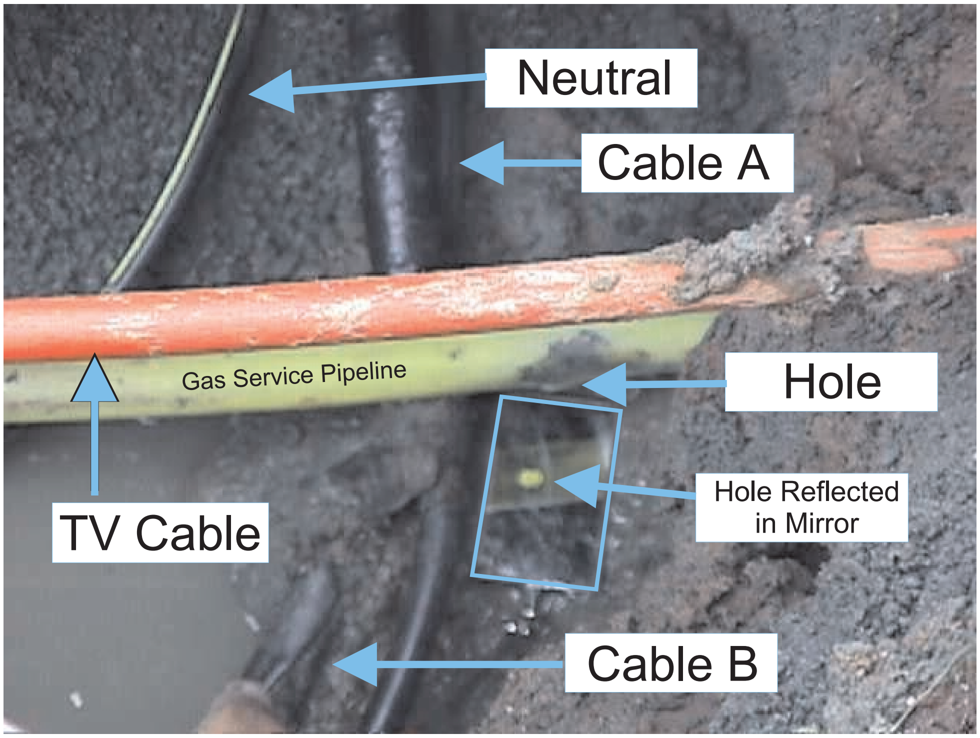

Figure 3. Cables and pipeline before removal. Although the TV cable appears to lie near the pipeline in this view, it was found at a depth of about 13 inches and was thus about 32 inches above the pipeline.

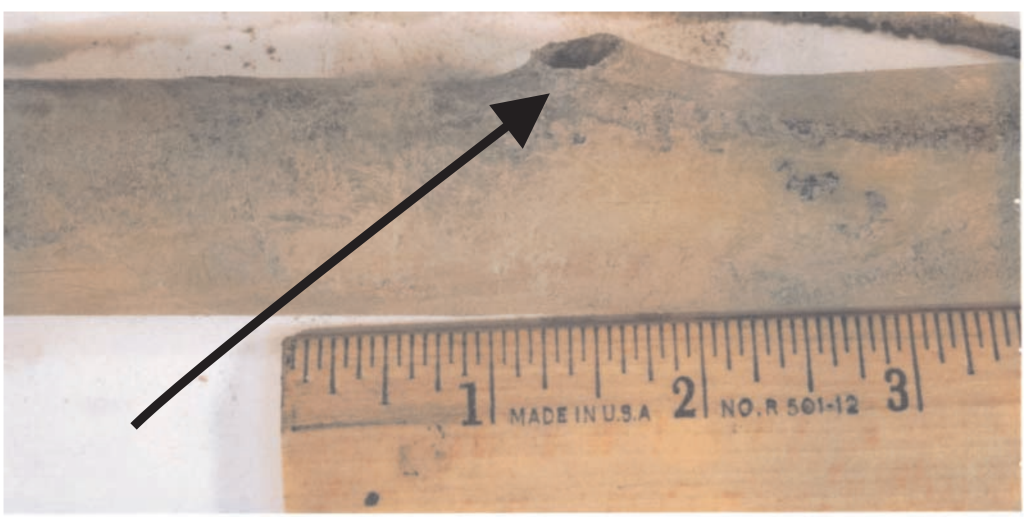

Figure 4. Hole discovered after accident in the 3/4-inch polyethylene natural gas pipeline leading to the residence.

The insulation on the section of tracer wire adjacent to the hole was completely missing, and the insulation on nearby portions of the tracer wire was blackened or otherwise discolored and showed evidence of melting. About 7 inches from the area of missing insulation, a 2.5-inch section of tracer wire was missing insulation along one side. The copper tracer wire in this area had separated and showed evidence of localized damage and thinning consistent with some type of electrochemical erosion or metal loss. Nicks and cuts typical of mechanical damage were also observed in the area of the damaged insulation.

Laboratory examination of the triplex's three electrical cables revealed evidence of prior repairs, corrosion, and heat and mechanical damage. As noted previously, the service triplex to the house had been spliced to the triplex stub at this location. Two of the three cables still had the original in-line aluminum compression crimp connectors installed near the damaged gas pipe. The original crimp connector in the third cable, one of the conductors (cable A), had been removed when the conductor was repaired by installing a short piece of new cable with two in-line crimp connectors. Both conductor cables were damaged and parted at or near one of the crimp connectors.

Cable B was completely separated. Between the two separated ends of the cable lay a clod of dirt. Portions of the interior of the clod showed a glassy appearance consistent with exposure to high heat. One end of the parted cable was attached to what remained of a crimp connector. Almost a third of the 4-inch-long crimp connector was missing. (See figure 5.)

Figure 5. Top: An aluminum crimp connector that was attached to one of the burned electrical cables found in proximity to the damaged natural gas pipeline. Bottom: An exemplar crimp connector (without its cold-shrink insulation).

Examination of the separated end of the connector revealed that approximately 60 percent of the surface was melted and had a glassy appearance, consistent with exposure of the connector to high temperature.[11] Removal of a small area of the melted and glassy material revealed white aluminum hydroxide deposits underneath. The aluminum hydroxide deposits were also observed on the remaining 40 percent of the damaged surface and on portions of the exterior surface of the connector. Aluminum hydroxide is a corrosion product that forms on aluminum that is exposed to moisture in a low-oxygen environment. Cuts and tears of various sizes were found in the cold-shrink insulation installed over the crimp connector immediately adjacent to the separation.

Examination of cable A revealed that a 1.3-inch section of the spliced-in repair cable was missing near one crimp connector. The connector still held almost 2 inches of the repair cable's end. The damaged ends of the repair cable near the missing section appeared to be undefined masses of solidified aluminum and debris, indicating that the cable had melted and resolidified. A small portion of cable A's insulation remained in place between the two melted ends of the aluminum cable. The interior surface of this section of insulation bore the imprint of the missing section of cable.

The neutral cable was intact. The insulation that had been placed over the crimp connector after a splice showed cuts and holes. Aside from the damaged electrical conductors, no potential sources of heat were discovered in the area around the pipeline failure.

Soil Sampling

On the day of the accident, soil samples were collected at four locations near the destroyed residence, including one sample from beneath the concrete basement slab near the sump pit. Testing revealed methane and a smaller concentration of ethane in each of the soil samples.

NOVEC Accident Report

NOVEC provided the Safety Board with its own accident report, which concluded that the hole in the gas pipeline occurred after and as an indirect result of the explosion. The report concluded that the gas that had accumulated in the residence and exploded came from some unknown source inside the house, possibly "through a defect or damage to the internal gas piping system, connection fittings, or the natural gas appliances."

NOVEC also examined the meter base and the associated service cables from the destroyed residence. The company reported evidence of pitting on the cables that company representatives said they believe indicates that arcing or shorting occurred between the cables within the meter base after the explosion.

[11] The melting range is 646 to 657° C (1195 to 1215° F) for the 1350 aluminum alloy used in the cable.

Pipeline and Electric Company Utility Separation Policies

Washington Gas Light Company internal procedures required that steel transmission[12] pipelines be installed at least 12 inches from other underground metallic objects. This procedure required all other steel pipelines (those not considered transmission pipelines) to be installed at least 6 inches away from other metallic objects. The company had no separation requirements for polyethylene pipelines; however, company officials stated that the company's routine practice was to apply the requirements for steel pipelines to polyethylene pipelines.

NOVEC trench specifications required various separation distances between the company's own cables and conduits. The company did not have a written procedure requiring a specific separation between NOVEC's buried secondary electric lines (those serving a single residence) and other underground facilities, such as gas pipelines. NOVEC's procedures did require that the National Electrical Safety Code be followed.[13] Several NOVEC personnel stated that, as a general practice, they maintained at least 6 inches of clearance between electrical lines and all other underground facilities.

Regulatory Standards and Guidance Regarding Facility Separation

Gas Pipeline Separation Requirements

The U.S. Department of Transportation's Research and Special Programs Administration (RSPA), through the Office of Pipeline Safety (OPS), promulgates regulations that establish minimum safety standards for the transportation of natural gas by pipeline. The regulations concerning underground clearance requirements for gas transmission lines and mains are in 49 *Code of Federal Regulations* (CFR) Section 192.325 and can be summarized as follows:

- Each transmission line must be installed with at least 12 inches of clearance from other underground structures. If this clearance cannot be attained, then the transmission line must be further protected from damage.
- Each main must be installed with sufficient clearance from other underground structures to allow for proper maintenance and to protect it from damage.

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[12] In simplified terms, *transmission* pipelines provide large volumes of product to utility companies or other distributors; smaller *main* lines then carry the product from the utility company or distributor to different locations within the service areas where *service* pipelines (such as the one involved in this accident) branch off to serve individual customers.

[13] See "Electrical Facility Installation Standards" section below for more information on National Electrical Safety Code requirements. The National Electrical Safety Code is an American National Standards Institute code that was developed by the Institute of Electrical and Electronics Engineers.

- Each plastic transmission line or main must be installed with sufficient clearance, or must be insulated, from any source of heat so as to prevent heat damage to the pipe.

These regulations are only applicable to gas transmission lines and mains. The separation requirements in 49 CFR Part 192 do not apply to residential gas service lines.

For intrastate pipeline facilities within Virginia, the Virginia State Corporation Commission has adopted and enforces the OPS Federal regulations as its minimum pipeline safety standards. The commission also has the authority to adopt more stringent regulations. Section 56-257 of the Code of Virginia was amended in 1996 to specifically authorize the commission to establish minimum separation requirements, not to exceed 12 inches, between crossings of underground pipes or conduits; however, the commission had not established any such minimum. The 1996 amendment also required that utility pipes and conduits be installed "with sufficient clearance, or shall be insulated from any source of heat, so as to prevent the heat from impairing the serviceability of the pipe or conduit." This provision applies to facilities laid in public streets and right-of-ways, not to those located on private property.

The Gas Piping Technology Committee publishes the *GPTC Guide for Gas Transmission and Distribution Piping Systems* to provide guidance for natural gas operators to ensure regulatory compliance.[14] The guide does not specifically address gas service lines but does suggest that:

> sufficient clearance should be maintained between mains and other underground structures to provide heat damage protection from other underground facilities such as steam or electric power lines, particularly where plastic piping is installed in common trenches with sources of heat.

Electrical Facility Installation Standards

No Federal agency analogous to the OPS is tasked specifically with ensuring the safety of electrical distribution systems. NOVEC, as a rural electric cooperative, falls under the purview of the U.S. Department of Agriculture's Rural Utilities Service. The Rural Utilities Service does not conduct routine safety inspections of the facilities of participating utilities. The Rural Utilities Service does require rural cooperatives that participate in the agency's loan program to certify that their facilities are installed in accordance with the provisions of the National Electrical Safety Code.

Section 1, Paragraph 010, of the National Electrical Safety Code states that its purpose is the "practical safeguarding of persons during the installation, operation, or maintenance of electric supply and communication lines and associated equipment." It further states in Paragraph 012.A. that "all electric supply and communication lines and equipment shall be designed, constructed, operated, and maintained to meet the requirements of these rules."

[14] The Gas Piping Technology Committee is an American National Standards Institute technical committee made up of technical specialists from both industry and government.

Section 35, Paragraph 352.B.4. of the National Electrical Safety Code calls for direct-buried electrical cables to be installed and maintained with adequate vertical separation when crossing other underground structures "to permit access to and maintenance of either facility without damage to the other." This paragraph further states that "a vertical separation of 12 inches is, in general, considered adequate, but the parties involved may agree to a lesser separation." The Safety Board was not able to identify any written or oral agreement between Washington Gas Light Company and NOVEC that governed the separation of the two companies' lines.

Electrical distribution facilities are also subject to the Virginia State Corporation Commission's regulatory oversight. The commission had not adopted the National Electrical Safety Code or developed a comprehensive set of minimum safety standards applicable to electrical facilities.

Postaccident Actions

Washington Gas Light Company has revised its *Operating Instructions Manual* to include requirements for maintaining at least 12 inches of clearance between new polyethylene gas pipelines and existing electrical facilities. Allowances are made for lesser separation, given specific protections. The revision also requires that existing polyethylene gas pipelines be separated from electrical facilities as necessary whenever those pipelines are excavated for maintenance or other reasons. Since the accident, Washington Gas Light Company has also established a policy to voluntarily install EFVs in all new or renewed residential service lines.

OPS representatives have met with various industry and governmental organizations to discuss the issue of separation between underground gas pipelines and electrical lines. These OPS representatives also notified the Safety Board staff that the OPS plans to include the issue in the "Best Practices" initiative focusing on excavation damage prevention.

After the accident, several utility operators, including NOVEC and Washington Gas Light Company, formed the Utility Industry Coalition of Virginia. The coalition has developed preliminary voluntary standards that call for 12 inches of separation between utilities, unless an acceptable barrier is provided. NOVEC revised its policy to follow these voluntary standards.

The Virginia General Assembly has modified Virginia law to require every utility operator in the State that is not subject to U.S. Department of Transportation oversight to install its utility lines "in accordance with accepted industry standards." The new statute also requires that the State Corporation Commission "promulgate any rules or regulations necessary to enforce the provisions of this section as to those operators that do not comply with such accepted industry standards." The new laws become effective July 1, 2001.

Pipeline Accidents Involving Electric Line Failures

The Safety Board is aware of two accidents in which electric line failures reportedly generated heat that damaged polyethylene natural gas pipelines. The Georgia Public Service Commission investigated an April 9, 1998, natural gas leak and fire at the Oaks Shopping Center in Dublin, Georgia.[15] Just before the accident, the gas department was excavating a leaking pipeline. During the excavation, the gas ignited and a gas department employee received first- and second-degree burns to his hands and face. The Public Service Commission found that an electric cable serving a nearby house crossed underneath the gas pipeline. The electric cable had a splice connector "which appeared to have failed and melted the 2-inch PE [polyethylene] gas main that caused the leak."

The second accident was investigated by the Illinois Commerce Commission.[16] On February 3, 1999, flames coming from the ground near two gas meters spread to a multifamily residential building in Hanover Park, Illinois. The fire caused in excess of $250,000 damage to the house and its contents. There were no injuries. The Illinois Commerce Commission found that the day before the accident, a fault had been detected in one of the electric cables that ran near the pipeline. The electric cable was marked but not repaired that day; instead, electric service was restored to the affected house using "jumpers" that bypassed the fault and allowed the customer to have 120-volt electric service until the faulted cable could be repaired. Postaccident excavation of the pipeline revealed that a section of electrical cable had melted near the hole in the polyethylene gas pipeline. The Illinois Commerce Commission concluded that the electric cable was buried very close to the pipeline, and it appeared "that the heat generated by the fault in the cable melted the PE [polyethylene] service piping."

[15] Georgia Public Service Commission, *Report of Natural Gas Safety Inspection No. BM98-023*, City of Dublin, Georgia, April 9, 1998.

[16] Illinois Commerce Commission, *Incident Report*, Nicor Gas Company, Elgin, Illinois, February 3, 1999.

Analysis

The Accident

The Loudoun County Fire Marshal's Office inspected the destroyed house and concluded that the explosion occurred when gas leaking from the gas service line accumulated in the basement and was ignited by the pilot light on the water heater. Given the extent and physical nature of the destruction, the Safety Board agrees that the explosion occurred in the house basement and that the pilot light for the water heater, an open flame, was a likely ignition source.

All parties to the investigation agreed that gas from some source had accumulated inside the house. A question remained, however, about the source of the gas, with NOVEC contending in its own report that the explosive gas accumulation resulted from a leak or defect in the gas piping inside the house. Safety Board investigators assessed the possibility that the accumulated gas that ignited resulted from a gas leak inside the house rather than from the leak in the gas service pipeline that was found after the accident.

All physical evidence suggests that the gas that exploded accumulated in the basement rather than in some other part of the house. And the only known, constantly present ignition source was the water heater pilot light. Thus, for the explosion to have occurred as the evidence suggests that it did, enough natural gas would have had to accumulate inside the basement to bring the gas concentration there to at least 4.5 percent, because the flammability limits of natural gas in air are approximately 4.5 to 14.5 percent.[17] Because natural gas is lighter than air, the gas entering the basement may have initially tended to accumulate near the ceiling before beginning to mix throughout the basement. The pilot light for the water heater was near the floor. The volume of the basement was calculated to be about 9,370 cubic feet.[18] About 422 cubic feet of natural gas would therefore have been needed to fill the basement from the ceiling down to the level of the pilot light with a uniform concentration sufficient for ignition. According to the surviving homeowner, the air conditioner was on during the evening of the explosion and was circulating air throughout the house. This may have increased the air exchanges within the basement and thus the volume of gas needed to fill the basement to explosive levels.

[17] The flammability limits refer to the range of concentrations of natural gas in air that can be ignited. The limits of this range are referred to as the lower and upper explosive limits.

[18] Although investigators did not attempt to determine what furniture or other household items may have been in the basement at the time, such items would not, in the Safety Board's view, have significantly reduced the overall volume of the basement susceptible to gas permeation.

But 422 cubic feet of natural gas would have only brought the gas concentration to the lowest explosive limit—4.5 percent. According to the National Fire Protection Association,[19] "mixtures at or near the lower explosive limit (LEL) or upper explosive limit (UEL) of a gas or vapor produce less violent explosions than those near the optimum concentration."[20] The amount of damage inflicted on the residence suggests that the concentration was probably higher than the lower limit. While it is impossible to determine the exact gas concentration at the time of this accident, the violence of the explosion indicates that the accumulation of gas in the basement of the structure was likely greater than the 422 cubic feet that would have been required to produce the lowest explosive level.

Gas meter readings before and after the explosion indicated that a total of 1,100 cubic feet of gas had been supplied to the house during the 12 1/2 days leading up to the explosion. During that period, the water heater was the only continuously operating gas appliance in the house. Information provided by the water heater manufacturer indicated that, with no hot water usage, the water heater would have consumed about 700 cubic feet of gas in the 12 1/2 days before the explosion.[21] Because the house was occupied intermittently during this time and some hot water was used, the amount of gas consumed by the water heater was probably greater than 700 cubic feet.

Subtracting the gas used by the water heater from the total 1,100 cubic feet of gas supplied to the house leaves less than 400 cubic feet of metered gas not attributable to the water heater. An unknown amount of gas escaped through the meter during the 40 minutes or more that elapsed between the time of the explosion and the time the valve to the meter was completely shut off. Also, some gas could have been used to heat water during the family's periods of temporary occupancy in the 12 1/2 days before the accident or in testing the other gas-burning appliances as the family was taking residence. Even if the entire 400 cubic feet of gas had leaked inside the house, this would have been less than that necessary to reach even the lower explosive limit in the basement at the level of the water heater's pilot light. And as noted above, the explosive mixture was likely greater than the lower limit. The measured gas usage thus suggests that the source of the accumulated gas lay outside the house.

Furthermore, a resident more than 150 feet away from the accident residence reported smelling a "strong" odor of natural gas in the 1/2 hour before the explosion. An outdoor pipeline leak would be the most likely source of a gas odor that could be detected at that distance. Moreover, the metered amount of gas into the house would fall even

[19] National Fire Protection Association. 2001. NFPA 921, *Guide for Fire and Explosion Investigations, 2001 Edition*, Quincy, Massachusetts, p. 133.

[20] For natural gas, the optimum concentration occurs near the middle portion of the range between LEL and UEL.

[21] Calculations use an average heating cycle consuming 12,000 Btu operating 4 times a day and the gas usage of the pilot light at 400 Btu per hour. This is approximately comparable to the average gas usage measured while the home was unoccupied between when the gas meter was originally installed and the gas service transferred to the new homeowners.

further short of the amount required to create an explosive mixture in the basement if enough of it had leaked out of the house to cause an odor of gas 150 feet away.

Finally, an outside source for the gas was found in the leaking gas service pipeline. Pressure testing of this line revealed a natural gas leak of about 6,500 cubic feet per hour. This leak rate was sufficient to have supplied the quantity of gas that would have been required to bring the gas concentration in the basement of the house to an explosive level. The location of the hole in the gas service line—about 7 feet from the house foundation—would account for the reported strong smell of gas some distance away and at the same time facilitate the underground migration of gas into the house. The trench in which the gas service line was installed, which was backfilled with relatively porous material, would have provided a path to the foundation of the house along which the gas could migrate. Tests of four soil samples collected at different sites near the accident residence showed the presence of methane and a smaller concentration of ethane, indicating that natural gas had migrated and permeated the soil around and underneath the house. (See “Soil Permeation With Gas” section below for more information.)

The Safety Board therefore concludes that, based on the size and location of the hole in the gas service line, the amount of gas that would have been needed to cause the accident, the presence of a strong smell of gas outside the house before the explosion, and the presence of natural gas in the soil underneath the residence, the most likely source of the natural gas that filled the residence basement and fueled the explosion was the damaged gas service line leading to the house.

Electrical Service Line Damage

The two damaged electrical conductors that were found crossing under the gas service line were melted and partially consumed. The damage was consistent with exposure to temperatures in excess of the melting point of aluminum, or 1,195 to 1,215° F. Because clay and rock are poor conductors of heat, the temperature in the earth environment surrounding an arcing cable will drop significantly as the distance from the arc increases. Thus, while the nearest conductor was found 3.75 inches from the hole along the horizontal axis of the gas service line, the conductors were disturbed during the excavation of the gas service line and were likely closer to the hole when they failed.

The insulation on the tracer wire and the cold-shrink insulation covering the crimp connectors on both cable B and the neutral cable contained nicks, cuts, and tears. Since NOVEC installers and service technicians are not likely to have initially installed torn or defective cables or insulation, the nicks, cuts, and tears found in the cables and insulation most likely resulted from post-installation mechanical damage that occurred during excavation or backfilling. Although a television cable was installed above the electrical cables and gas pipeline, this cable was buried only to a depth of about 13 inches. Furthermore, the equipment used to install such cable is incapable of reaching a depth of 45 or more inches, which was the depth at which the pipeline and electrical cables were found at the damage location. The Safety Board therefore concludes that work performed either during installation of the gas service line or during subsequent excavation of the electrical line, or both, damaged the protective insulation for the triplex electrical conductors and splices in the area of the hole in the gas service line.

Removal of a small area of the melted and resolidified material from the heat-damaged section of cable B revealed aluminum hydroxide deposits indicative of corrosion. The corrosion deposits were also observed on the unmelted 40 percent of the damaged surface of cable B, as well as on portions of the exterior surface of the connector. This corrosion likely resulted from moisture that reached the crimp connector of cable B through the cuts and tears in the crimp connector insulation.

Because the cable ends inside the crimp connector do not meet, the full current load of the conductor must be transferred through the crimp connector. Unimpeded current flow thus depends on there being firm contact between the crimp connector and the cable ends. Evidence indicates that in this accident, the corrosion that occurred on and/or within one side of the splice connection reduced the contact resistance between the cable end and the crimp connector. Because the rate of corrosion of aluminum can be significantly accelerated when the material is energized,[22] the amount of corrosion likely increased fairly rapidly, reducing the metal-to-metal contact. When the contact resistance increased sufficiently, the connector was no longer capable of supporting the required current flow without overheating and arcing. This arcing generated heat sufficient to destroy a portion of the conductor and the connector and to soften and weaken the nearby gas pipeline. Therefore, given the evidence of prior excavation damage to the insulation on cable B and the evidence of corrosion on the sides of the crimp connector near the damage, the Safety Board concludes that the damage to the protective insulation covering the splice in the electrical conductor identified as cable B allowed moisture to reach the crimp connector, causing corrosion that increased electrical resistance between the crimp connector and the cable sufficient to cause the splice to overheat and fail.

As the conductor failed under an inductive load, the additional mass of aluminum in the connector and the cable melted, vaporized, and burned. Given that no other heat source was present near the hole in the gas service line and that the temperature necessary to melt, vaporize, and burn the aluminum missing from the splice connection was far in excess of the approximately 250° F that would soften and weaken the polyethylene pipeline, the Safety Board concludes that heat generated from the arcing resulting from cable B's failure under load caused the gas service line wall to soften and weaken until the internal pressure breached the pipeline and it began to leak.

Cable A showed evidence of melting and resolidification, but unlike cable B, cable A did not show evidence of corrosion. Also unlike cable B, a small portion of cable A's insulation remained intact between the two melted ends of the cable, indicating that cable A was probably not at elevated temperatures for as long as cable B. Finally, the

[22] William H. French, "Alternating Current Corrosion of Aluminum," Paper T 73 120-3, recommended and approved by the Insulated Conductors Committee of the Institute of Electrical and Electronics Engineers (IEEE) Power Engineering Society (PES) for presentation at the IEEE PES Winter Meeting, New York, N.Y., January 28 through February 2, 1973.

evidence of potential electrical shorting within the meter base that was reported by NOVEC suggests that at least one conductor into the house may have been energized at the time of the explosion. Based on this evidence, the Safety Board concludes that the failure of the conductor identified as cable A was a secondary event that may have occurred after the explosion as a result of short circuiting within the damaged residence's electrical system.

Soil Permeation With Gas

Tests of four soil samples collected at different sites near the accident residence showed the presence of methane and a smaller concentration of ethane. The presence of ethane in the samples confirms that the combustible gas was natural gas, not another naturally occurring source of methane, such as sewer or landfill gas. The presence of natural gas in these samples also verifies that the natural gas had permeated the soil around and underneath the house.

Bluestone rock dust was used as a backfill material around the gas pipelines and electric cables installed in trenches and buried within the South Riding neighborhood. Because this material is more porous than the surrounding soil that was placed back on top of the imported backfill, it likely provided a path the escaped gas could follow from the buried utilities to the foundation of the house.

Underground drainage systems had been installed to collect water and route it away from the foundation of the house. Both drainage systems consisted of perforated plastic pipe surrounded by gravel. Both the perforated drain pipe and the gravel are readily permeated by gas. Weep holes had been installed in the concrete footer around the perimeter of the foundation to allow water to flow between the two systems. Gas could easily pass through these weep holes from the external drainage system to the internal system under the concrete slab.

The basement of the house offered several avenues by which gas could have entered and accumulated. (See figure 6.) For example, the sump pit penetrated the concrete floor and provided a possible path. Additionally, the water service line passed under the foundation of the house from a point just outside the northeast wall, near the north corner of the house in proximity to the hole in the gas service line. This line entered the basement through a sleeve penetrating the concrete floor. Also, since the concrete for new foundations is poured during discrete construction steps, cracks may have been present in the foundation where different pours adjoined. The Safety Board concludes that the gas present in the soil around and under the house entered the basement of the residence either through penetrations in the concrete slab or cracks in the foundation, or both.

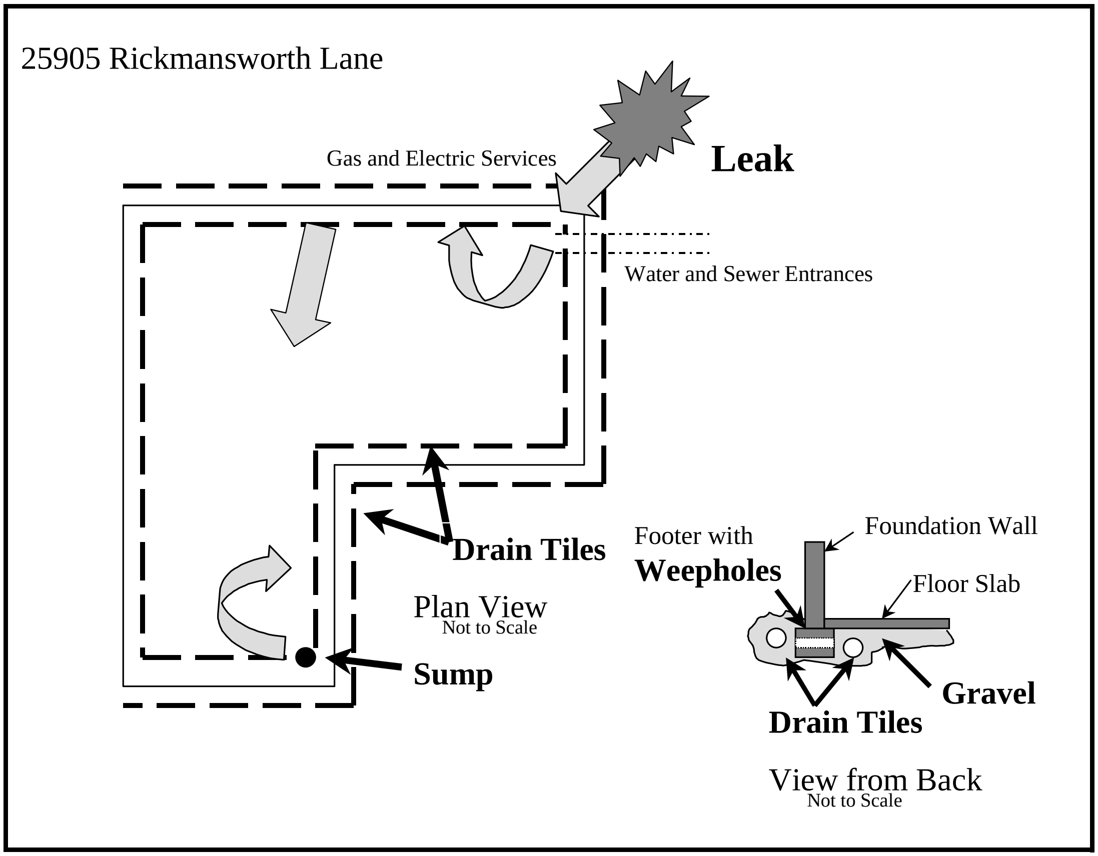

Figure 6. Paths of possible migration of gas into the basement of the residence.

Adequacy of Standards for Minimum Utility Separation Distances

Before the accident, Washington Gas Light Company specified separation distances for steel pipelines but not for polyethylene pipelines. Company management indicated that the company routinely applied the requirements for steel pipelines to polyethylene pipelines, and the installation contractor's foreman stated that he placed the gas service line in a trench with 12 inches of horizontal separation from the electrical line. Nonetheless, the NOVEC crew reported that they found the gas service line only 6 inches above the electrical cables when they excavated to repair an electrical line fault after the gas service line was installed and before the accident.

Since the accident, Washington Gas Light Company has revised its *Operating Instructions Manual* to require at least 12 inches of clearance between new polyethylene gas pipelines and existing electrical facilities. Allowances are made for lesser separation if specific protections are implemented. The revision also requires that existing polyethylene gas pipelines be separated from electrical facilities as necessary if a lack of separation is discovered during maintenance activities.

Before the accident, NOVEC trench specifications required various separation patterns between their own electrical facilities; however, the company did not have a written procedure requiring a minimum separation between its buried secondary electric lines and other underground facilities, such as gas pipelines. NOVEC's procedures did require NOVEC personnel to follow the National Electrical Safety Code, which called for electrical cables to be installed and maintained with a vertical separation of 12 inches when crossing other underground structures. But several NOVEC personnel stated that, as a general practice, they maintained at least 6 inches of clearance between electrical cables and all other underground facilities, which was not consistent with the code's separation requirements.

Postaccident excavation revealed that one of the failed electrical conductors may have been touching the gas service line; in any case, the conductors were close enough to the gas service line to damage it when a splice connection in one of the conductors faulted under load and generated an arc. The Safety Board therefore concludes that had the gas and electrical service lines involved in this accident been adequately separated, the heat from the arcing electrical conductor failure would probably not have damaged the gas service line, and the accident would not have occurred. Since the accident, NOVEC has adopted voluntary standards through its participation in the Utility Industry Coalition of Virginia that require a minimum separation distance of 12 inches from other underground facilities unless an acceptable barrier is provided.

While the OPS has promulgated regulations that establish minimum underground clearance requirements for gas transmission lines and mains, no similar regulation applies to a residential gas service line such as the one involved in this accident. Since the accident, OPS representatives have met with various industry and governmental organizations to discuss the issue of separation between underground gas pipelines and electrical lines. These representatives also reported to the Safety Board staff that the OPS plans to include the issue in the OPS "Best Practices" initiative focusing on damage prevention. RSPA has not, however, initiated any regulatory action to ensure that residential gas service pipelines are separated from other underground structures. Therefore, the Safety Board believes that RSPA should require gas utility operators to maintain a specified minimum separation distance, sufficient to protect against both thermal and mechanical damage, between plastic gas service lines and underground electrical facilities whenever they install a new gas service line or perform maintenance on existing lines.

Since the National Electrical Safety Code already addresses the separation issue for electrical facilities, the Safety Board believes that electrical industry associations and the U.S. Department of Agriculture's Rural Utilities Service should inform their member utilities of the circumstances of this accident and of the need to ensure that underground electrical facilities are installed and maintained with separation between plastic gas pipelines in accordance with the National Electrical Safety Code.

Excess Flow Valves

Excess flow valves (EFVs) are available that respond to an excessive flow of gas—such as may occur as a result of a leak— by automatically closing and restricting the gas flow. EFVs can greatly reduce the consequences of service line ruptures. They are typically installed at the connection of the service line to the main pipeline. Depending on the manufacturer, EFVs compatible with the operating conditions in this accident are available that are designed to close when the flow rate exceeds about 550 to 850 cubic feet per hour—about 1/10 of the flow rate measured in the service pipeline after the South Riding accident. Based upon the leakage flow rate measured after the explosion and before the pipeline was excavated, the Safety Board concludes that, had an EFV been installed in the gas line to the residence, the EFV would have closed after the hole in the pipeline developed, and the explosion likely would not have occurred.

In the early 1980s, the Safety Board advocated using EFVs on service lines to schools and other buildings in which large numbers of people gather. As EFVs became cheaper and more widely available, the Safety Board began advocating the installation of EFVs on new or renewed residential service lines. During the 1980s, RSPA, which has oversight responsibilities for the pipeline industry, did not require EFVs. Consequently, the Safety Board included the use of EFVs on its 1990 list of Most Wanted safety improvements.[23]

On September 26, 1990, as a result of its investigation of five natural gas accidents in the Kansas City-Topeka area, the Safety Board recommended that RSPA:

P-90-12

> Require the installation of excess flow valves on new and renewed single-family, residential high pressure service lines which have operating conditions compatible with the rated performance parameters of at least one model of commercially available excess flow valve.

On April 4, 1995, RSPA notified Congress by letter that it had decided not to require universal installation of EFVs and instead would issue performance standards and customer-notification requirements for EFVs. In a September 28, 1995, letter to RSPA, the Safety Board expressed its disappointment with this decision. The Board noted the continued strong evidence that a way was needed to quickly restrict the flow of gas to a failed pipe segment. On September 28, 1995, as a result of RSPA's failure to issue EFV requirements, the Safety Board classified Safety Recommendation P-90-12 "Closed—Unacceptable Action."

On March 6, 1996, as a result of its investigation of a June 9, 1994, natural gas explosion in Allentown, Pennsylvania, the Safety Board wrote to the governors of all

[23] In October 1990, the Safety Board developed the "Most Wanted" list, drawn up from previously issued safety recommendations, to bring special emphasis to the safety issues the Board deems most critical. The Most Wanted list is reviewed, revised, and reissued annually. The Most Wanted list is available on the Web at <http://www.ntsb.gov/Recs/MostWant.htm>.

50 states and the District of Columbia asking that they require gas distribution operators to install EFVs in all new or replaced gas service lines when operating conditions are compatible with commercially available valves (Safety Recommendation P-96-3). Of the States that replied, most advised that they intended to follow the lead of RSPA and had no plans to require the installation of EFVs. The State of Virginia did not initially respond to Safety Recommendation P-96-3.

Also on March 6, 1996, the Safety Board recommended that RSPA:

P-96-2

> Require gas distribution operators to notify all customers of the availability of excess flow valves; any customer to be served by a new or renewed service line with operating parameters that are compatible with any commercially available excess flow valve should be notified; an operator should not refuse to notify a customer because of the customer's classification or the diameter or operating pressure of the service line.

On February 3, 1998, RSPA issued its final rule regarding EFVs. The rule requires gas distribution operators either to install EFVs on new or replaced single-residence service lines expected to operate continuously at not less than 10 psig or to inform customers of the availability and benefits of EFVs and install them if the customer agrees to pay for their installation and maintenance.

On October 6, 1998, the Safety Board classified Safety Recommendation P-96-2 "Closed—Unacceptable Action," in part because RSPA's final rule limits required notifications by gas operators to residential customers even though many commercial service lines have operating characteristics compatible with the same EFVs used for residential service lines.

Because the Safety Board had no reasonable expectation that further action on EFVs was likely by either RSPA or the States, the Safety Board, on May 3, 2000, removed the recommendations regarding EFVs from its Most Wanted list. After the South Riding accident, on August 3, 2000, the Safety Board wrote the Governor of Virginia asking for information about Virginia's intentions with respect to Safety Recommendation P-96-3. In an August 16, 2000, response, the Virginia Corporation Commission noted that the State had adopted and will enforce RSPA's final rule. The commission further noted that it had not identified any noncompliance relative to the EFV provisions. It also noted that many Virginia gas operators install EFVs for existing customers upon request, provided the customer pays for the installation, and that all Virginia operators were now installing EFVs on all new and replaced service lines when operating conditions are compatible with commercially available EFVs. As a result, on October 3, 2000, the Safety Board classified Safety Recommendation P-96-3 to the State of Virginia "Closed—Acceptable Alternate Action."[24]

[24] Safety Recommendation P-96-3 was classified "Closed" to 30 States. In a July 5, 2000, letter, the Safety Board asked for updates from the States for whom the recommendation remained in an "Open" status.

According to an American Gas Association survey provided to the Safety Board in the spring of 2000, since the issuance of the RSPA final rule on EFVs, approximately one-half of the operators of gas distribution systems have elected to install EFVs, and one-half have developed procedures to inform customers of their availability. In the latter case, the RSPA rule permits operators to pass along the cost of EFV installation and maintenance to those customers who choose to have the valve installed. While the Safety Board is encouraged that utility companies that do not provide the valves are at least making them available to their customers, the Safety Board is concerned that customers may not fully understand the safety benefits that EFVs can provide when they are faced with a decision that may require that they pay for the installation and maintenance of the device.

Furthermore, Safety Board investigation of a fatal gas pipeline accident in St. Cloud, Minnesota, (four fatalities)[25] indicates that commercial establishments can also benefit from the protection offered by EFVs. Likewise, an accident in Bridgeport, Alabama, (three fatalities)[26] may have been prevented if the gas service line had been equipped with an EFV. Both accidents involved excavation damage to underground natural gas service lines, and both involved gas that migrated underground to nearby buildings, where it subsequently exploded. Although both the St. Cloud and Bridgeport accidents involved older gas lines that would not have been subject to a RSPA requirement unless they had required maintenance, an EFV may have prevented both accidents. Without a requirement that, where appropriate for operating conditions, commercial gas service lines be equipped with EFVs, further accidents involving pipeline failures leading to fires and explosions can be expected. As noted earlier, current RSPA rules do not require that new commercial customers be informed about the availability of EFVs, even though their operating environments may be compatible with commercially available and relatively inexpensive EFVs.

In light of the fact that accidents continue to occur that could have been prevented by the use of EFVs, the Safety Board believes that RSPA should require that EFVs be installed in all new and renewed gas service lines, regardless of a customer's classification, when the operating conditions are compatible with readily available valves.

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[25] National Transportation Safety Board, *Natural Gas Pipeline Rupture and Subsequent Explosion, St. Cloud, Minnesota, December 11, 1998,* Pipeline Accident Report NTSB/PAR-00/01 (Washington, D.C.: NTSB, 2000).

[26] National Transportation Safety Board, *Natural Gas Service Line Rupture and Subsequent Explosion and Fire, Bridgeport, Alabama, January 22, 1999,* Pipeline Accident Brief PAB-00-01 (Washington, D.C.: NTSB, 2000).

Conclusions

Findings

1. Based on the size and location of the hole in the gas service line, the amount of gas that would have been needed to cause the accident, the presence of a strong smell of gas outside the house before the explosion, and the presence of natural gas in the soil underneath the residence, the most likely source of the natural gas that filled the residence basement and fueled the explosion was the damaged gas service line leading to the house.

2. Work performed either during installation of the gas service line or during subsequent excavation of the electrical line, or both, damaged the protective insulation for the triplex electrical conductors and splices in the area of the hole in the gas service line.

3. The damage to the protective insulation covering the splice in the electrical conductor identified as cable B allowed moisture to reach the crimp connector, causing corrosion that increased electrical resistance between the crimp connector and the cable sufficient to cause the splice to overheat and fail.

4. Heat generated from the arcing resulting from cable B's failure under load caused the gas service line wall to soften and weaken until the internal pressure breached the pipeline and it began to leak.

5. The failure of the conductor identified as cable A was a secondary event that may have occurred after the explosion as a result of short circuiting within the damaged residence's electrical system.

6. The gas present in the soil around and under the house entered the basement of the residence either through penetrations in the concrete slab or cracks in the foundation, or both.

7. Had the gas and electrical service lines involved in this accident been adequately separated, the heat from the arcing electrical conductor failure would probably not have damaged the gas service line, and the accident would not have occurred.

8. Had an excess flow valve been installed in the gas line to the residence, the valve would have closed after the hole in the pipeline developed, and the explosion likely would not have occurred.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident in South Riding, Virginia, was the corrosion and subsequent overheating and arcing at a splice in one of the conductors of the triplex electrical service line, which, because of inadequate separation between the electrical conductors and the gas service line, led to the failure of the gas service line and the subsequent uncontrolled release of natural gas that accumulated in the basement and was subsequently ignited. Precipitating the electrical service line failure was damage done to the electrical service line during installation of the gas service line and/or during subsequent excavation of the electrical line.

Recommendations

As a result of its investigation of the South Riding, Virginia, accident, the National Transportation Safety Board makes the following safety recommendations:

To the Research and Special Programs Administration:

> Require gas utility operators to maintain a specified minimum separation distance, sufficient to protect against both thermal and mechanical damage, between plastic gas service lines and underground electrical facilities whenever they install a new gas service line or perform maintenance on existing lines. (P-01-1)
>
> Require that excess flow valves be installed in all new and renewed gas service lines, regardless of a customer's classification, when the operating conditions are compatible with readily available valves. (P-01-2)

To the Edison Electric Institute:

To the National Rural Electric Cooperative Association:

To the American Public Power Association:

> Inform your member utilities of the circumstances surrounding the July 7, 1998, explosion and fire in South Riding, Virginia, and of the need to ensure that underground electrical facilities are installed and maintained with separation between those facilities and plastic gas pipelines in accordance with the National Electrical Safety Code. (P-01-3)

To the U.S. Rural Utilities Service:

> Inform your participating rural utilities of the circumstances surrounding the July 7, 1998, explosion and fire in South Riding, Virginia, and of the need to ensure that underground electrical facilities are installed and maintained with separation between plastic gas pipelines in accordance with the National Electrical Safety Code. (P-01-4)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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