National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: June 22, 2001

In reply refer to: P-01-4

Mr. Blaine D. Stockton
Acting Administrator
Rural Utilities Service
U.S. Department of Agriculture
1400 Independence Avenue, S.W.
Washington, D.C. 20250-1510

The National Transportation Safety Board is an independent Federal agency charged by Congress with investigating transportation accidents, determining their probable cause, and making recommendations to prevent similar accidents from occurring. We are providing the following information to urge your organization to take action on the safety recommendation in this letter. The Safety Board is vitally interested in this recommendation because it is designed to prevent accidents and save lives.

This recommendation addresses the adequacy of standards for minimum separation distances between gas service lines and electrical service lines. The recommendation is derived from the Safety Board's investigation of the July 7, 1998, pipeline accident in South Riding, Virginia, and is consistent with the evidence we found and the analysis we performed. As a result of this investigation, the Safety Board has issued four safety recommendations, one of which is addressed to the Rural Utilities Service. Information supporting this recommendation is discussed below. The Safety Board would appreciate a response from you within 90 days addressing the actions you have taken or intend to take to implement our recommendation.

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.[1]

The National Transportation Safety Board determined that the probable cause of this accident 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

[1] For more information, see National Transportation Safety Board, *Natural Gas Explosion and Fire in South Riding, Virginia, July 7, 1998*, Pipeline Accident Report NTSB/PAR-01/01 (Washington, D.C.: NTSB, 2001).

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.

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[2] had previously been "stubbed in," and 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.

During the first week in May 1998, a Washington Gas Light Company contractor 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, so at the point where the electrical line had been exposed, he moved the gas service line to maintain 12 inches of horizontal separation.

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. The next morning, June 16, a NOVEC crew was sent to make 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.

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.

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[2] 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.

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 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).[3] 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.

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,[4] 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 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 was underneath and touching the other conductor. The neutral cable was several inches away from the two conductors.

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.[5] Also, the thinned material formed a conical peak around the hole, consistent with the effect of pressure on a heated and softened pipeline wall.

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.

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[3] 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.

[4] 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.

[5] 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).

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, had been removed when the conductor was repaired by installing a short piece of new cable with two in-line crimp connectors. Both conductors were damaged and parted at or near one of the crimp connectors.

One conductor 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. 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.[6] 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 the other conductor (the one that had been repaired after the initial installation) 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 the conductor'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.

As noted above, the insulation on the tracer wire and the cold-shrink insulation covering the crimp connectors on one of the conductors and on 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.

Removal of a small area of the melted and resolidified material from the heat-damaged section of the separated conductor revealed aluminum hydroxide deposits indicative of corrosion. The corrosion deposits were also observed on the unmelted 40 percent of the damaged surface of the conductor, as well as on portions of the exterior surface of the connector. This corrosion

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

likely resulted from moisture that reached the crimp connector of the conductor 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,[7] 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 one of the conductors and the evidence of corrosion on the sides of the crimp connector near the damage, the Safety Board concluded that the damage to the protective insulation covering the splice in that electrical conductor 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 concluded 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.

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 concluded 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.

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

[7] 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.

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.

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.

Based on its investigation of this accident, the National Transportation Safety Board makes the following safety recommendation to the 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 those facilities and plastic gas pipelines in accordance with the National Electrical Safety Code. (P-01-4)

The Safety Board also issued safety recommendations to the Research and Special Programs Administration, the Edison Electric Institute, the National Rural Electric Cooperative Association, and the American Public Power Association. In your response to the recommendation in this letter, please refer to P-01-4. If you need additional information, you may call (202) 314-6607.

Acting Chairman CARMODY and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in this recommendation.

Original Signed

By: Carol J. Carmody
Acting Chairman