# Journal of the National Academy of Forensic Engineers®

http://www.nafe.org
ISSN: 2379-3252

Vol. 33 No. 1 June 2016

# Forensic Engineering Analysis of a Shopping Mall Explosion

*By Jerry R. Tindal, PE (NAFE 642M)*

**Abstract**

*On May 7, 2009 a catastrophic explosion occurred at a shopping mall located just outside of Washington, D.C. As a result of the explosion, several persons, including multiple firefighters, were injured, and a large portion of the mall was destroyed. This paper examines the cause of the explosion.*

**Keywords**

Explosion, natural gas, underground pipe, distribution piping, gas main, utility clearances, underground electrical cables, gas leaks, NFPA 921, explosion investigation

## Introduction

The section of the mall that sustained the primary explosion damage was located on the southern-most end of the mall and contained several tenants, including (moving from north to south) a sandwich shop, pregnancy center, two vacant spaces under renovation, pizza shop, and two specialty shops. **Figures 1, 2** and **3** depict the shopping mall and the referenced tenant spaces.

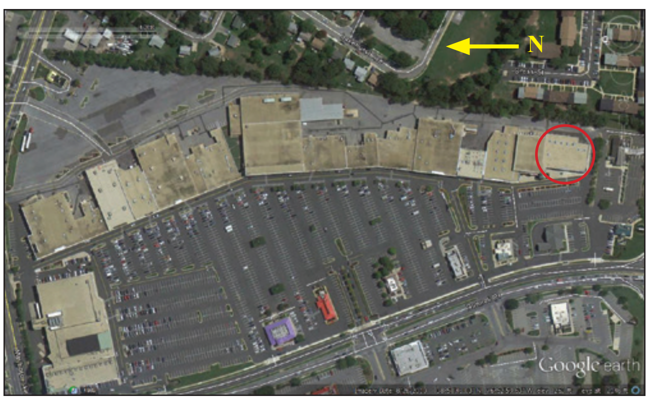


**Figure 1**
A Google earth image of the shopping mall. The section of the mall that sustained the most extensive explosion damage is circled.

**Figure 2**
A view from the front of the shopping mall of the tenant spaces that sustained the most extensive explosion damage.

**Figure 3**
A view from the rear of the shopping mall of the tenant spaces that sustained the most extensive explosion damage.

At approximately 10 a.m. on the date of the explosion, the owner of the pizza shop arrived and began preparing for the business day. The owner testified that at the time of his arrival there was no smell of gas in the restaurant, the oven and grill were operating normally, and there were no problems with the electrical power. Furthermore, there had been no gas or electrical problems with the tenant space since his original occupancy in January of 2005.

At approximately 11 a.m., the owner of the pizza shop opened to patrons for business as usual. Around 12 p.m., there was a sudden and complete loss of electrical power to the pizza shop, and the owner called and notified the electric utility of the outage. Utility company records indicated a power outage call was received at 12:08 p.m. Although no one in the pizza shop smelled gas at the time, the restaurant was evacuated due to the lights being out.

Jerry R. Tindal, PE, 922 Jeff Sharpe Road, Pelion, SC 29123; (803) 394-5671; jtindal@safe-labs.com

A short time after evacuating the restaurant, the owner re-entered to check on the conditions. The owner testified that he detected an odor of gas in the kitchen, though it was not strong initially. He verified that the kitchen equipment was off and called the gas company to report the odor of gas. Gas company records indicate a call reporting the gas odor around 12:27 p.m. A few minutes after calling in the report of a gas odor, the owner went to the back door of the restaurant and opened it. Outside he detected a strong smell of gas (stronger than inside), and observed an "eruption going on underground" as well as bubbling in a puddle of water collected on the asphalt surface.

Between 12:54 p.m. and 1 p.m., the fire department and the gas company arrived at the scene and began building evacuations and an investigation into the leaking gas. Around 1:02 p.m., the electric utility company arrived at the scene. At approximately 1:26 p.m., the building exploded. At the time of the explosion, several firefighters were near the front entrance of several of the tenant spaces in the building, and a gas utility worker was near the rear exit of the tenant spaces in the building. The explosion was captured by the dash camera of a fire truck parked in front of the building at the time. **Figures 4** through **9** depict captured images of the explosion from the dash cam video. The video was released and shown on multiple news outlets and can be easily located on Youtube.

## Shopping Mall Construction and Utility Configuration

The shopping mall, which faced west, was constructed sometime in 1977 and incorporated both one- and two-story sections. The structure was built on slab with primarily hollow core concrete masonry unit (CMU) exterior walls and mixed wood-framed and steel-framed drywall sheathed interior walls. The roof assembly consisted of open-web steel bar joists supported on steel beams and columns. The roof was covered with board-insulated corrugated steel sheeting and a built-up roof system. The underside of the steel sheeting was insulated with fiberglass batt insulation. Drop ceilings were utilized in the finished tenant spaces.

**Figure 4**
Firefighters making entry seconds before the explosion.

**Figure 5**
Additional firefighters approaching the front entry just as the explosion occurs. Note the expanding fireball through the glass window panes.

**Figure 6**
Explosion as viewed from the front of the building. Fireball venting through the front windows. Two of the firefighters are circled.

**Figure 7**
Explosion as viewed from the front of the building. Note displacement of the roof and subsequent venting of the fireball.

**Figure 8**
Fireball continuing to vent through the displaced roof.

**Figure 9**
Fireball continuing to vent.

The underground electrical service lines to the identified tenant spaces of the mall were installed as part of the original construction of the building. A pad-mounted transformer was located approximately 52 feet east of the rear wall of the sandwich shop tenant space. Direct-buried service cables routed from the transformer provided power to the meter bases located on the rear walls of the tenant spaces. In July of 1980, the utility company had severed service at the ground level to the two most southern-involved tenant spaces and provided service routed from a separate transformer.

The pizza shop was the only tenant space involved in the explosion that utilized natural gas. A 2-inch polyethylene (plastic) underground pipe distribution main was located approximately 9 feet from (and parallel to) the rear wall of the mall area near the restaurant. A ¾-inch plastic service line was connected to the 2-inch plastic main and routed to the gas meter installed on the south exterior wall, near the southeast corner of the restaurant. Asphalt covered the entire exterior rear area of the building, including up to the rear wall of the building. The distribution and service gas lines were installed in October of 1989 and were operating at a pressure of approximately 50 psig at the time of the explosion.

**Fuel Source**

The fuel source for the explosion was determined to be natural gas originating from multiple failures in the 2-inch plastic underground gas distribution main. Gas utility company personnel, utilizing combustible gas indicators, entered the front of the pizza shop and conducted measurements from the front of the restaurant to the rear. At the rear of the restaurant, they detected natural gas migrating into the structure along the rear CMU wall and through the electrical and plumbing penetrations. Evidence of natural gas was also directly observed by the owner of the pizza shop, fire department personnel, and gas utility employees; it was observed bubbling up through a puddle of water accumulated in a cracked area of the asphalt surface behind the restaurant prior to the occurrence of the explosion. The puddle was located directly above the gas distribution main.

The natural gas flowed from leaks in the main, through the ground, and beneath the asphalt into the building via the electrical and plumbing conduits as well as through the hollow core CMU walls and openings/penetrations in the walls. The gas accumulated in the building until it was ignited, at which point the explosion occurred. **Figures 10** through **13** depict some of the construction features of the building, which facilitated gas migration into the structure.

**Figure 10**
The asphalt surface behind the mall extends all the way to the exterior CMU wall of the structure.

**Figure 11**
The hollow core CMU exterior walls extend into the ground well below the asphalt surface.

**Figure 12**
Penetrations through the CMU walls and the concrete slab in the rear of the building included electrical and plumbing.

**Figure 13**
Electrical conduit penetrations through the asphalt and into electrical panels that were located inside the building.

It is well known that gas leaking from an underground pipe failure, such as in this case, will migrate through the soil and into buildings, creating an explosion hazard[1,2]. The National Fire Protection Association (NFPA) 921 *Guide for Fire and Explosion Investigations* states[1]:

> ***10.9.9.1.1*** *It is common for fuel gases that have leaked from underground piping systems to migrate underground (sometimes for great distances), enter structures, and create flammable atmospheres. Both lighter-than-air and heavier-than-air fuel gases can migrate through soil; follow the exterior of underground lines; and seep into sewer lines, underground electrical or telephone conduits, drain tiles, or even directly through basement and foundation walls, none of which are as gastight as water or gas lines.*

> ***10.9.9.1.2*** *Such gases also tend to migrate upward, permeating the soil and dissipating harmlessly into the atmosphere. Whether the path of migration is lateral or upward is largely a matter of which path provides the least resistance to the travel of the fugitive gas, the depth at which the leak exists, the depth of any lateral buried lines that the gas might follow, and the nature of the surface of the ground. If the surface of the ground is obstructed by rain, snow, frozen earth, or paving, the gases may be forced to travel laterally. It is not uncommon for a long-existing leak to have been dissipating harmlessly into the air until the surface of the ground changes, such as by the installation of new paving or by heavy rains or freezing, and then be forced to migrate laterally and enter a structure, fueling a fire or explosion.*

The asphalt ground covering inhibited vertical dissipation of the gas and facilitated lateral travel of the gas toward and into the building.

## Source of Ignition

The source of ignition of the fugitive gas that accumulated in the building was not conclusively determined. However, immediately prior to the explosion, flames were first observed originating near an electrical meter base on the rear of the building, which then rapidly propagated upward toward the soffit/eaves of the building.

## Gas Main Failure

The underground distribution gas main leak point was excavated by natural gas utility company employees and their forensic engineering expert during the nighttime hours on the date of the explosion. The excavation work was not layered and was very poorly documented. The excavation pit was subsequently covered with plate steel, and the scene was secured.

A joint inspection of the scene and the excavated pit area was performed at a later date with all parties of interest. Examination of the excavated area indicated that the 2-inch plastic gas main converged on and crossed in between multiple direct buried electrical power cables in the area behind the pizza shop. Measured clearances between the plastic gas main and the remains of the electrical power cables within the excavated pit in the general area of the crossover were as little as 3 inches. Several feet of the electrical cables in the area of the crossover had been destroyed by an electrical arcing event that preceded the explosion. The faulted power cables with subsequent gas line damage were consistent with the loss of electrical power followed by a gas smell shortly before the explosion. The power cables were installed in 1977, and the extensive heat produced from the catastrophic electrical faulting of several feet of the cables resulted in multiple burned, charred, and melted holes in the plastic gas main. Although the cause of the power cable failure was undetermined due to the extent of damage, such cable failures (as will be discussed later) are engineering-foreseeable events. **Figures 14** through **19** indicate the excavated area of where the gas pipe main leaked.


**Figure 14**
A view of the excavated area immediately behind the pizza shop.

**Figure 15**
A close-up view of the excavated area. The 2-inch plastic gas main is approximately 9 feet from the rear exterior wall of the building.

**Figure 16**
The gas line converged on and crossed in between a nest of multiple electrical power cables. The power cable remains were located on both sides of the gas main.
The cable remains are circled.

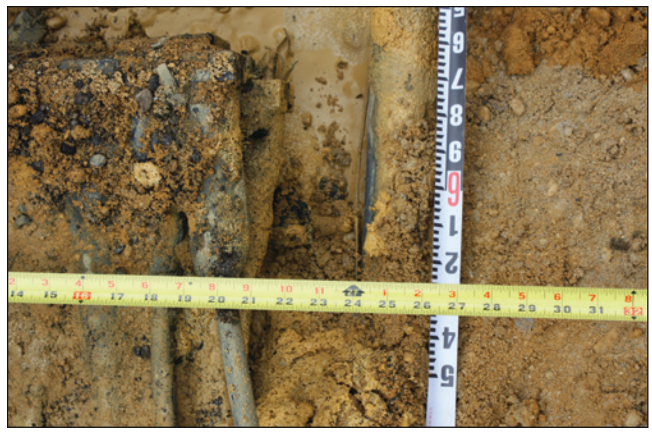

**Figure 17**
Most of the remains of the destroyed electrical cables were removed before the joint exam by employees of the gas company. Clearances to the remaining cable sections were approximately 3 inches.

**Figure 18**
The faulting cables had charred and burned holes through the plastic gas main, allowing gas to escape.
Note the stub of a destroyed section of power cable (circled) adjacent to the burned section of gas line.

**Figure 19**
A close-up view of some of the holes charred, melted, and burned in the plastic gas main. The pipe was heavily charred, melted, and burned around the circumference with multiple holes.

**Underground Power Cable Failure and Clearance Requirements**

The failure of an underground electrical power cable is an engineering-foreseeable event. The power cables at the time of the failure were more than 30 years old, and the electrical forensic engineer investigating on behalf of the plaintiff testified that the cables were subject to failure at that point in time. In addition, during discovery, the electrical power utility company stated:

> *It is well known in the industry that such cables fail, despite reasonable care in their manufacture, installation and use, and that with appropriate distance between underground facilities such failures will ordinarily not damage other utilities or cause customer damage.*

The National Electric Safety Code (NESC)[3] establishes minimum clearance requirements between direct buried cables and other underground structures (including fuel lines) for the purpose of protecting each system from the effects of the other. Such clearance requirements are established because of the foreseeable failure of electrical cables with subsequent arcing and production of heat.

The National Fire Protection Association (NFPA) *Fire Protection Handbook, 16th Edition*[4] provides some insight into the purposes of the NESC, stating the following [underlined emphasis added]:

> *Introduction*
> *Since its first edition exactly 90 years ago, the Fire Protection Handbook has endeavored to fulfill the needs of the fire protection community for a single-source handbook on the state of the art in fire protection and fire prevention practices.*
>
> *Electrical Systems and Appliances, Section 8 Chapter 2*:
>
> *….<u>All standards governing electric equipment include requirements to prevent fires caused by arcing</u> and overheating, and to prevent accidental contact, which may cause an electric shock…. [page 8-7]*
>
> *…National Electric Safety Code (ANSI Standard C2)*
>
> *As interest increased in electrical safety in the U.S., a need arose for a code to cover the practices of public utilities and others when installing and maintaining overhead and underground electric supply and communication lines. Accordingly, a National Electric Safety Code was completed in 1916. Currently this code is published by the Institute of Electrical and Electronic Engineers (IEEE). [Page 8-13]*

Over 10 years before the shopping mall explosion incident happened, a similar natural gas explosion event occurred in South Riding, Va. A plastic underground gas line was damaged by heat produced from electrical arcing from a faulting underground electrical line. Gas leaked from the damaged gas line and into a newly constructed home. Tragically, however, this explosion incident resulted in the fatality of a young mother, serious injuries to the father, and minor injuries to two children. The Natural Transportation Safety Board (NTSB) *Pipeline Accident Report: Natural Gas Explosion and Fire at South Riding Virginia,* July 7, 1998[5] states [underlined emphasis added]:

> *…The <u>Safety Board</u> therefore <u>concludes</u> that <u>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…</u>*
>
> *<u>…Since the National Electric Safety Code</u> <u>already addresses</u> <u>the separation issue for electrical facilities</u>, 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 <u>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.</u>*

The 1984 Edition of the NESC was the current edition of that standard published at the time the natural gas lines were installed in proximity to the electrical power cables behind the pizza shop at the shopping mall. The NESC Handbook, 1984 Edition, *Development and Application of the American National Standard National Electrical Safety Code Grounding Rules, General Rules, and Parts 1, 2, and 3,*[6] states the following [underlined emphasis added]:

*Section 35. Direct Buried Cable (This section was developed in the 1973 Edition…)*

> *350. General*
> *(This rule was added in the 1973 Edition)*
> *…The rules of this section detail the arrangement and installation conditions required for safe installations. These rules are essentially an expanded version of those included in Section 32.*
>
> *351. Location and Routing*
> *…The discussions of the rules in Section 32 apply to the similar or identical requirements in Rule 351. Because direct buried cables lack the protection of a conduit, they need additional care in installation in order to provide the same level of safety and reliability at an economical cost…*
>
> *352. Clearances From Other Underground Structures (sewers, water lines, fuel lines, building foundations, steam lines, other supply or communication conductors not in random separation, etc.)*
> *(This rule was developed in the 1973 Edition…)*
>
> *Special care is required in locating direct buried cables near other facilities. These rules are intended to provide (1) adequate room for maintenance of all facilities and (2) appropriate protection for each system from the effects of the other.*

The discussions in Section 32 of the NESC Handbook (referenced in Section 351 above) provide additional insight into reasons for clearance and protection measures. The clearance and protection requirements include foreseeable electrical cable failures and the impact on adjacent underground systems. Section 32 of the NESC Handbook states in part [underlined emphasis added]:

> *320B. Clearances From Other Underground Installations (This rule was developed in the 1973 Edition…)*
>
> *…Conduits should be located as far as practical from other underground structures, especially from water mains and gas mains….the greater the distance between such systems, the less the chances of damage….*
>
> *To arrest the action of an electric-power arc, and to prevent it from affecting communication cables, a barrier wall of concrete not less than three inches thick, or equivalent protection, should be placed between ducts carrying supply conductors and adjacent ducts carrying communication conductors…*
>
> *…When a supply cable fails, the arc may communicate the trouble to other cables…*

The clearance requirement stipulated in the NESC between underground gas lines and underground electrical cables is a minimum of 12 inches. Had the gas utility company contacted the electric utility at the time they were installing the gas line, the electric utility would likely have stipulated a 12-inch clearance be maintained between the two utilities.

**Underground Plastic Gas Line Protection**

The 12-inch clearance requirement was not limited to electrical industry standards and practices. It is also well known and established in gas industry standards and practices for the purposes of protecting the piping from damage, including damage resulting from heat sources.

The potential for damage to underground plastic gas piping due to heat exposure is well recognized in the gas industry. Natural gas distribution main systems are commonly engineered to incorporate polyethylene plastic pipe (an appropriate material) to transport natural gas. Polyethylene pipe has a relatively low melting temperature and is therefore highly susceptible to damage from potential heat sources. The pipe installed was identified as Polyethylene (PE) 2406, Dupont Aldyl A and was marked as compliant with ASTM D2513, which is entitled *Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing and Fittings.* NFPA 921 Table 6.2.8.2 "Approximate Melting Temperatures of Common Materials" indicates a melting temperature of 251°F to 275°F for polyethylene. NFPA 921 section 6.2.8.4 states that *"Thermoplastics soften and melt over a range of relatively low temperatures, from around 75°C (167°F) to near 400°C (750°F)."*

ASTM D2513 [7] references ASTM D2774 *Standard Recommended Practice for Underground Installation of Thermoplastic Pressure Piping.* As far back as the 1973 Edition of ASTM D2774 [8] (and subsequent editions), the standard cautions installers with the following [underlined emphasis added]:

*6. Installation Precautions*

*6.2 Care should be taken to protect the pipe from excessive heat or harmful chemicals…*

The Code of Federal Regulations (CFR) that provides the minimum installation requirements for gas distribution mains recognizes the need to provide proper clearances to protect plastic gas mains from damage and particularly plastic lines from any heat source. 49 CFR 192.325 (c)[9] states [underlined emphasis added]:

*192.325 Underground clearance*

*(b) Each main must be installed with enough clearance from any other underground structure to allow proper maintenance and to protect against damage that might result from proximity to other structures.*

*(c) In addition to meeting the requirements of paragraph (a) or (b) of this section, 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 the heat from impairing the serviceability of the pipe.*

The Federal Register[10] provides insight into the intent of the provisions of 49 CFR 192.325 cited above [underlined emphasis added]:

*In response to a great many comments pointing out the difficulties that distribution companies would have attaining the proposed 12 inches of clearance, the clearance requirements for mains are now couched in performance type language. This will allow these operators flexibility to attain the desired objectives of proper maintenance and protection from external damage…*

The proposed prescriptive clearance requirement in 49 CFR 192.325 for gas mains was 12 inches; however, it was reworded into performance-type language to allow operator flexibility (different means and methods) for achieving the same equivalent desired objectives of the provision. The objective provisions include not only achieving maintenance of the piping but also clearly and distinctly achieving the proper protection of the piping from external damage.

The American Society of Mechanical Engineers (ASME) developed the *ASME Guide for Gas Transmission and Distribution Piping Systems,*[11] which provides clarity and direction in the application of 49 CFR 192. The intent of the ASME guide document as it relates to Section 192.325 provides the following [underlined emphasis added]:

Page viii
*The basic objective of the Guide is to provide assistance to the operator in complying with the Minimum Federal Safety Standards by providing "how to" information related to the Standards.*

Page viii
*The guide material present in this Guide includes information and some of the acceptable methods to assist the operator in complying with the Minimum Federal Safety Standards. The recommendations contained in the Guide are based on sound engineering principles, developed by a committee balanced in accordance with accepted committee procedures, and must be applied by the use of sound and competent engineering judgment…*

Page 107:
1. *Clearance*
*Sufficient clearance should be maintained between mains and other underground structures to:*

*(a) Permit installation and operation of maintenance and emergency control devices (such as leak clamps, pressure control fittings and pinching equipment).*

*(b) Permit installation of service laterals to both mains and to other underground structures that might be required.*

*(c) 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 such sources of heat.*

Guide Material Appendix G-13, pages 299 and 300

*Considerations to Minimize Damage By Outside Forces*

*1 Introduction*

*This Guide Material Appendix is intended as an aid in minimizing the possibility of damage to underground gas piping facilities by outside forces.*

*5 Other*

*Consideration should be given to the following:*

*(d) Where a plastic pipeline is installed in a common trench with electric underground lines, the need for additional clearance to prevent damage to the gas line from heating or a fault in the power line.*

A primary objective of 49 CFR 192.325 is to provide protection of gas lines (particularly highlighting plastic gas lines) from heat damage from heat sources, including faulting electric power lines. Faulting electrical power lines are a known foreseeable source of heat, as indicated in the ASME guide document. As previously stated, the proposed prescriptive means of accomplishing this goal for the protection of mains was to provide a clearance of 12 inches between the main and the other underground structures, which is consistent with the 1973 National Electric Safety Code and subsequent editions of that standard.

The ANSI/ASME B31.8-1986 code *Gas Transmission and Distribution Piping Systems*[12] also highlights a design intent to protect plastic gas lines from sources of heat including power lines. The referenced code provides the following [underlined emphasis added]:

Page xiii

*…The Code sets forth engineering requirements deemed necessary for safe design and construction of pressure piping….*

Page 1

*802 Scope and Intent*

*802.11 This Code covers the design, fabrication, installation, inspection, testing and safety aspects of operation and maintenance of gas transmission and distribution systems, including gas pipelines….gas mains, and service lines up to the outlet of the customer's meter set assembly…*

Page 45

*842.38 Clearance Between Mains and Other Underground Structures. Plastic piping shall conform to the applicable provisions of 841.142. Sufficient clearance shall be maintained between the plastic piping and steam, hot water, or power lines and other sources of heat to prevent operating temperatures in excess of the limitations of 842.32 (b) or 842.33(b).*

Finally, the American Gas Association (AGA), which is made up of the gas utility industry as a whole, published *GEOP: Gas engineering and operating practices, Vol. III, Distribution book D-2, Mains and services – Operating considerations*[13], which provides [underlined emphasis added]:

Page xiii

*Preface*

*Mains and Services – Operating Considerations is one of 12 books that will constitute the six-volume A.G.A. Gas Engineering and Operating Practices series addressing various technical aspects of gas supply, transmission, distribution, measurement, utilization, and related technical services. Series contributors were selected for their subject knowledge from 22 A.G.A. Operating Section committees, as well as from industry consultants, suppliers, and other specialist. Authors for Mains and Services – Operating Considerations came from the Distribution Construction and Maintenance, Distribution Design and Development, Laboratory and Chemical Services, and Plastic Materials Committees…*

Page 1

Scope

*The intent of this book is to provide engineers, technicians, managers, accountants, and other gas industry personnel – particularly those newly introduced from other operating areas to construction, operation, and maintenance of gas mains and services. The areas addressed provide fundamental knowledge, from construction planning through the various phases of maintenance and operations…*

Pages 77 to 79

*Installation of Plastic Pipe*

*The following is a listing of service pipe installation practices as set forth in the various plastic pipe codes. A summary of Minimum Federal Safety Standards from Part 192, which deal with*

> *or influence plastic piping, is found in the A.G.A. Plastic Pipe Manual for Gas Services…*
>
> *Maintain when possible 12 inches (0.3 metre) of clearance from other underground facilities, such as telephone cables, foreign pipelines, manholes and utility poles…when 12-inch clearance cannot be attained, the service should be cased or shielded with rock shield, plastic pipe of larger diameter, or sewer tile. Some companies use a heat shield (rock shield, ceramic pipe, etc.) if proper spacing cannot be attained around electric cables.*

The gas utility industry literature clearly recognizes that 12 inches clearance provides appropriate thermal protection of plastic gas piping relative to other underground structures, including electric cables, and when such clearance cannot be obtained proper shielding should be provided. As previously noted, this is consistent with the design goal intent of 49 CFR 192.325 for gas mains.

**Engineering Hazard Analysis**

Sound engineering design and construction practices follow available authoritative engineering guides, standards, and literature to appropriately address hazards related to a particular design issue.

A hazard is a condition in which harm or damage could occur. The hazard in this case was locating a plastic gas main in close proximity to an underground electrical power cable that could foreseeably fail, generate substantial heat, and compromise the plastic gas main.

Risk is typically defined in terms of the severity of an event combined with the probability of an occurrence. Should the plastic main become compromised by the heat generated during an electrical cable failure, natural gas would be released beneath the asphalt and likely migrate into the building creating conditions favorable for a catastrophic explosion. Such an explosion could destroy the building and cause severe injuries or death. The risk of not providing proper clearances between plastic gas mains and electrical cables is therefore unacceptable.

**Cause of the Explosion**

NFPA 921 defines the cause of a fire or an explosion as "*the circumstances, conditions, or agencies that brought about or resulted in the fire or explosion incident, damage to property resulting from the fire or explosion incident, or bodily injury or loss of life resulting from the fire or explosion incident*."

Natural gas has a very low ignition energy requirement and subsequently can be ignited from most *normally* present ignition sources located within buildings. If there is an explosive concentration of fugitive natural gas in a building, it is very difficult to avoid contact with *normally* present ignition sources. Subsequently, the potential for a catastrophic explosion is substantial. Therefore, the prevention of natural gas leaks (*fugitive* gases) into structures is more feasible than the elimination of normally present potential sources of ignition. The fugitive natural gas is what is *out of place*, generally not the ignition source; and, as a result, it is the presence of accumulated fugitive natural gas that leads to the explosion. The cause of the explosion in this case is therefore the circumstance that resulted in leakage from the plastic gas main.

There were in existence at the time the gas utility company installed the gas main, authoritative engineering guides, standards, and other industry literature that addressed the hazards associated with locating plastic gas piping in proximity to electrical power cables and the proper means of protecting the pipe in such circumstances. Based on a review of the referenced engineering guides, standards, and other industry literature, it is most probable that 12 inches of clearance would have prevented the damage to the plastic gas line during the arcing event of the failed electrical cable. Therefore, the gas leak — and subsequently the explosion — would have been prevented.

The gas utility company knew — or should have known — of the hazard associated with installing the underground plastic pipe main in close proximity to direct buried electrical power cables. The gas utility company was in the business of engineering, installing, operating, and maintaining gas distribution systems. Specifically, the gas utility company took on the task of installing a plastic gas main in close proximity to an existing direct-buried electrical power line, and subsequently knew (or should have known) the associated hazards and proper means of protecting the gas line in such an installation.

An understanding of the hazards represented by other underground structures (e.g., electrical cables) that the gas utility company was installing its gas mains in close proximity to would be necessary on the part of the gas utility company in order to know how to properly address and protect against such hazards and to comply with 49 CFR 192.325.

Sound engineering practices involve researching and evaluating the appropriate authoritative standards and industry literature provisions related to locating underground plastic gas piping in proximity to other underground structures, including direct-buried electrical power cables. Furthermore, sound engineering practices would involve contacting the owner/installer of adjacent utilities to determine what safe clearances were required from their structures. According to the electric utility company, that clearance would have been a minimum of 12 inches at the time the gas utility performed its installation.

The gas utility company's failure to comply with the provisions of 49 CRF 192.325 and follow sound engineering practices and industry standards caused the explosion.

**References**

1. NFPA 921-2014. Guide for fire and explosion investigations. Quincy, MA; National Fire Protection Association.

2. Kennedy P, Kennedy J. Explosion investigation and analysis: Kennedy on explosions. Chicago, IL: Investigations Institute; 1990.

3. ANSI/IEEE C2-1984. National Electric Safety Code. Piscataway, NJ: Institute of Electrical and Electronics Engineers, Inc.

4. National Fire Protection Association. Fire protection handbook, 16th edition. Quincy, MA: The National Fire Protection Association; 1986.

5. Pipeline accident report: natural gas explosion and fire at South Riding, Virginia. Washington, DC: National Transportation Safety Board; July 7, 1998 (adopted 2001).

6. Clapp A (ed). NESC Handbook: Development and application of the American National Standard National Electrical Safety Code grounding rules, general rules, and parts 1, 2, and 3. Piscataway, NJ: The Institute of Electrical and Electronics Engineers; 1984.

7. ASTM D 2513-87. Standard Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings. West Conshohocken, PA: ASTM International.

8. ASTM D2774-1973. Standard practice for underground installation of thermoplastic pressure piping. West Conshohocken, PA: ASTM International.

9. United States Department of Transportation. Code of Federal Regulations (CFR) Title 49 Transportation Part 192 Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards. Washington DC: United States Government Printing Office; October 1, 1988.

10. Federal Register, Volume 35, No. 161, Page 13254. Washington DC: United States Department of Transportation; August 19, 1970.

11. American Society of Mechanical Engineers. ASME Guide for gas transmission and distribution piping systems. New York, NY: American Society of Mechanical Engineers; 1986.

12. ANSI/ASME B31.8-1986. Gas transmission and distribution piping systems. New York, NY: American Society of Mechanical Engineers.

13. American Gas Association. GEOP: Gas engineering and operating practices, Vol. III, Distribution book D-2, Mains and services – Operating considerations. Arlington, VA: American Gas Association; 1986.