Cause and Prevention of Pinhole Leaks in Gas Poly Pipe Production and Gathering Operations

Dirk Smith, President
Ionix Gas Technologies

Purpose

- Understand you won't know if you have pinhole leaks unless you leak survey.
- You WILL eventually be leak surveying all gathering lines. (Erin Murphy, Lead Methane Emissions Attorney at EDF is on public record stating that is EDF's goal).
- To understand how pinhole leaks in poly pipe occur.
- To understand the risks they create
  - Methane emissions
  - Fire risk

Agenda

- Review physics of pinhole creation in PE pipe done by Gas Research Institute (GRI) in the 90's.
- Review failure analysis of previously investigated incidents of pinhole leaks in PE fuel gas pipe confirming GRI research.
- Explain PHMSA's 2015 No-Regrind rule enacted for the purpose of preventing pinhole leaks (and PHMSA's tacit acknowledgement of the problem of pinhole leaks).
- Review field test results validating the research of the cause of pinhole leaks in PE fuel gas pipe.

Pinholes create 2 risks for upstream gas

1. **Underground pinhole leaks that will be mandated to be repaired due to methane emission standards.**
2. **Above ground pinhole leaks that ignite burning away poly pipe leading to serious fire.**

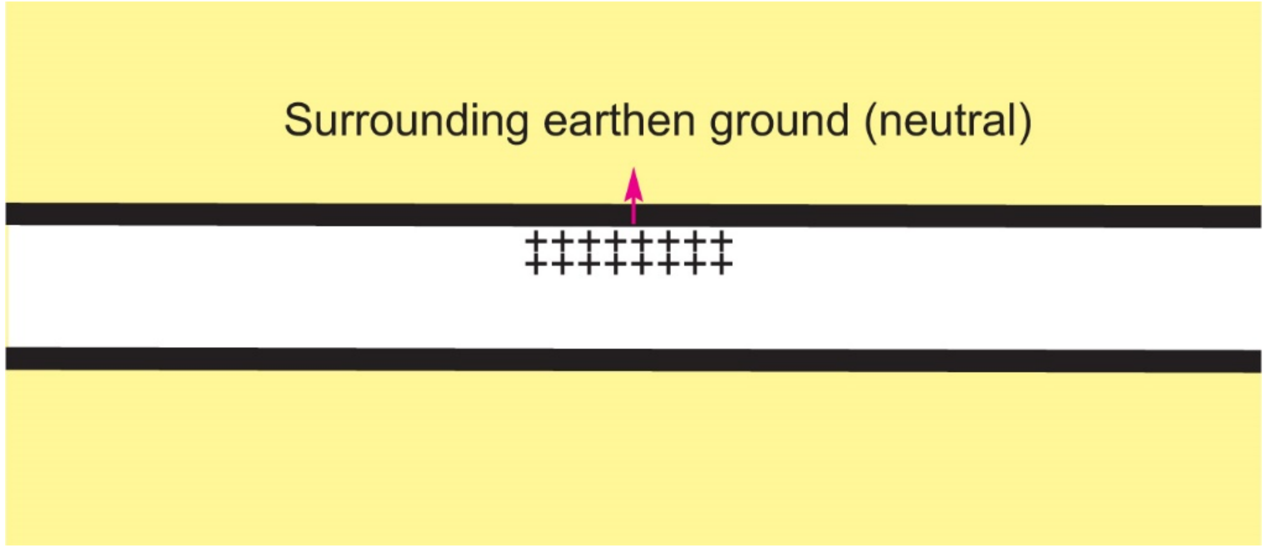
Cause of electrostatic pinholes

”The charge conditions across the pipe wall can increase high enough to exceed material breakdown. This breakdown phenomenon produces a small burned hole (about the size of a pinhole) through the pipe wall that can leak minute quantities of gas."

Gas Research Institute report 92-0460

Introduction page 1, 2nd paragraph.

Illustration of electrostatic pinhole



Electron microscope sectional view of electrostatic pinhole

Pinholes can be created during the normal operation of gas transport

”Even under apparently normal operations when the pipe is not being squeezed, pin holing is observable because of high-turbulent flow conditions occurring near tees, elbows, etc."

Gas Research Institute report 92-0460

Introduction page 1, 2nd paragraph.

PS – If your system has experienced pinholes, that demonstrates you have static in your system

The basics of static electricity

What is static electricity?

Static electricity is so called because it is an electrical charge at rest because it resides on an electrical insulator.

KEY CONCEPT TO UNDERSTAND!

How static electricity is created inside pipe?

Friction of one electrical insulator rubbing against another displaces electrons which accumulate on one of the surfaces.


ACL Staticide

Static starts INSIDE pipe

The movement of gas inside pipe creates static on the inside walls of the pipe.

Why? That's where the friction is!

Basics of static in PE pipe

1. Static originates inside the pipe.
2. Static charges will not “go away.” They are residing on a material which RESISTS the movement of electrons.
3. Mother Nature will seek electrical neutrality.

So what happens when static builds up inside a BURIED PE pipe?

Mother nature doesn't like electrical imbalances

The physical world is intended to be at electrical neutrality. Mother Nature will remedy the problem if you do not.

1989 Mountain Fuel Gas

Location: Utah

1 ¼" ALDYL MDPE Pipe

DuPont Lab

Static Electric Pinholing Through Polyethylene Pipe

MARK STAKER, Training Coordinator
Mountain Fuel Supply Company

INTRODUCTION

Static electricity pinholing occurs when dust or dirt particles are present in the gas stream and a high volume of flow exists through a restriction.

Prime examples are: broken lines, flow control through a squeeze off zone, close proximity of tube turns, saddle fittings near a break, etc. These circumstances create a sufficient static charge to build on the inside of the pipe, which can exceed the dielectric strength of the plastic pipe. When this occurs, the discharge can cause a pinhole through the pipe wall.

Thus far, our investigation indicates that prevention is the best solution in preventing electrostatic pinhole damage:

- Keep pipe end caps in place at all times before fusion takes place.
- Pig pipe sections, as needed.
- Purge new piping systems with a reusable steel purging fitting.
- Purge existing dead ends before tying on a new piping system.
- Vacuum new piping systems to eliminate the need to purge.

In August of 1984, our first field failure by a static electric discharge was brought to our attention. A contractor crew installing a 1¼ inch medium-density polyethylene line was in the process of filling and purging a new piping system. Controlling the flow of natural gas was done through a squeeze-off unit. It was during this process that a cracking or popping sound was heard in the vicinity of the squeeze-off or flow-control area. Inspection of the section of pipe revealed a small leak on the edge of the squeeze cheek area. A brittle squeeze failure was first diagnosed, which was later dismissed.

Closer examination of the failure revealed some small black dots (pinholes) that were leaking. Not fully understanding what had happened, our soaping of squeeze-off areas was emphasized. Field personnel were asked to look consciously for this pinholing leak. These efforts resulted in six pinholing squeeze-off failures reported in a two-week period, all of which were determined to be caused by static pinhole discharge. See Figures 1, 2, 3, and 4.

Only three known static pinholing discharges had been reported throughout the gas industry at this time. Evidence again had shown that a static charge had developed on the inside wall of the plastic pipe in sufficient voltage to cause a pinhole discharge. During this time frame, samples of pinhole discharge were sent to our pipe manufacturers for evaluation and verification. The results and information received are

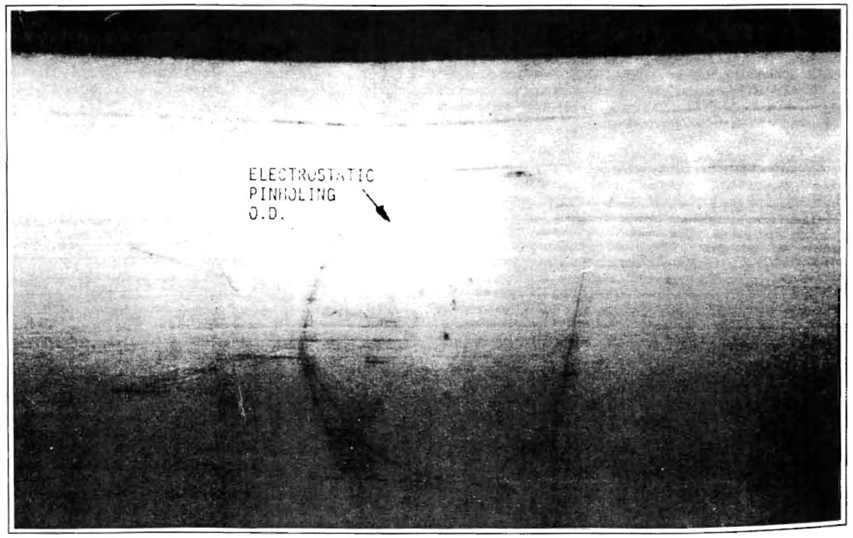


Figure 1. This 2" I.P.S. electrostatic pinhole occurred when purging a new piping system.

DuPont Lab conclusion

Pipe was manufactured within spec

Cause was internal static arcing through pipe wall.

FAILURE ANALYSIS FOR MOUNTAIN FUEL SUPPLY COMPANY
PINHOLE LEAKS IN 1 1/4" SDR 10 ALDYL PIPE

BACKGROUND

Mountain Fuel Supply submitted to DuPont an 8" long sample of 1 1/4" SDR 10 ALDYL "A" pipe, lot number T0308U24, for failure analysis. The pipe was installed in 1984 and operated at a pressure of 45 psig. After being squeezed-off, the pipe leaked through serveral pinholes (black spots) on the O.D. of the pipe.

ANALYSIS

The first step in determining the cause of this failure was to analyze physical properties of the pipe. Normally, melt index and density checks are performed to assure that the pipe is within specification. In this case, the melt index was 1.12 g/10 min. and the density was 0.942 g/cc. The specifications for ALDYL "A" polyethylene pipe are melt index .9 - 1.5 g/10 min. and density 0.940 - 0.948 g/cc. From these tests we can conclude that the pipe was in specification.

There have been three failures reported to DuPont that have been classified as electrostatic discharge pinholing failures. These failures have been photographed and studied very thoroughly. The physical characteristics of this failure were compared to past electrostatic discharge pinholing failures and serveral similarities were found. For example, two occurred during the squeeze-off O.D. and I.D. of the pipe. Since this failure has all the characteristics of past electrostatic discharge pinholing failures, it is believed that is is also an electrostatic discharge failure.

DISCUSSION

Normally there are no problems with electrostatic discharge when squeezing-off ALDYL pipe. There have only been three cases reported in the 20 years we have been manufacturing ALDYL pipe.

The pinhole leaks occur when an electrostatic voltage develops inside the pipe which exceeds the dielectric strength of the pipe. Polyethylene pipe has a dielectric strength of 4.06 x 10 V/in. Since 1 1/4" SDR 10 ALDYL "A" pipe has a wall thickness of .166 inches, it would take 67,400 volts before discharging would occur. In Medium Density Polyethylene Gas Piping Systems electrostatic voltages, under unusual circumstances, have been measured as high as 70,000 volts. Therefore, under certain conditions, electrostatic discharge can occur in polyethylene pipe which create pinhole leaks.

It is important to recognize that electrostatic discharging will only occur under certain conditions. During squeeze-off, the flow restriction drastically coupled with particles in the gas stream are what generate the excessive electrostatic voltage on the bore of the pipe. Only under these conditions will the electrostatic voltage exceed the dielectric strength of the pipe and result in a discharge through the pipe wall to the grounded squeeze-off tool.

CONCLUSIONS

Based on our analysis we can conclude that:

1 1/4" SDR 10 ALDYL "A" pipe (lot #T0308U24) was within specification.

Failure of this pipe specimen during squeeze-off was due to electrostatic discharge through the pipe wall as evidenced by the black spots on the I.D. and O.D. of the pipe and by the abraded inside surface.

Electrostatic voltage greater than 67,400 volts must have been generated inside the pipe due to very high gas velocity (flow restriction during squeeze-off) and a high level of particles.

Installation guidelines for Mountain Fuel Supply to consider for prevention of future electrostatic discharge failures during squeeze-off are:

Eliminate/reduce particles in the gas stream.

Isolate (do not ground) the squeeze-off tool.

United Cities Gas

Nashville TN area

½" Plexco PE pipe

Battelle Labs determined material breakdown due to a static electric field

RESEARCH SUMMARY

Title Analysis of Microscopic Leaks in Polyethylene Gas Distribution Piping

Contractors Battelle
Contract 5091-271-2351

Principal Investigator S. M. Pimputkar

Report Period January 1993 to September 1996
Topical Report GRI-96/0014

Objective To determine the cause of tiny holes (typically 5 μm to 50 μm) found in polyethylene (PE) gas distribution piping in service, with the intent of reducing the number of leaks and thereby the operational costs.

Technical Perspective Since 1993, United Cities Gas Co. (UCG) in Tennessee has discovered gas leaks that were traced to small holes (about 5 to 50 μm) that traversed the pipe wall approximately radially. These holes are smaller by an order of magnitude than other small holes known to occur in PE tubing because of electrostatic discharge. Although the length of pipe with pinholes is a tiny fraction of the length of installed pipe, the proliferating number of holes and the absence of a known cause concerned UCG, which contacted Gas Research Institute (GRI) for assistance. The study that resulted was funded by GRI, and Plexco provided some cofunding. In 1996, two such pinholes were found in tubing in Virginia.

Approach Battelle and its subcontractors used two approaches to identify the origin of the small leaks, termed "pinholes": (1) the pinholes were examined and characterized both physically and chemically, followed by tests to determine their likely origin, and (2) experiments were conducted, based on a knowledge of manufacturing and service procedures, in an attempt to reproduce the pinholes. Research was aimed at determining whether the holes occurred instantaneously or through a growth phenomenon, and whether the holes occurred during manufacture or in service.

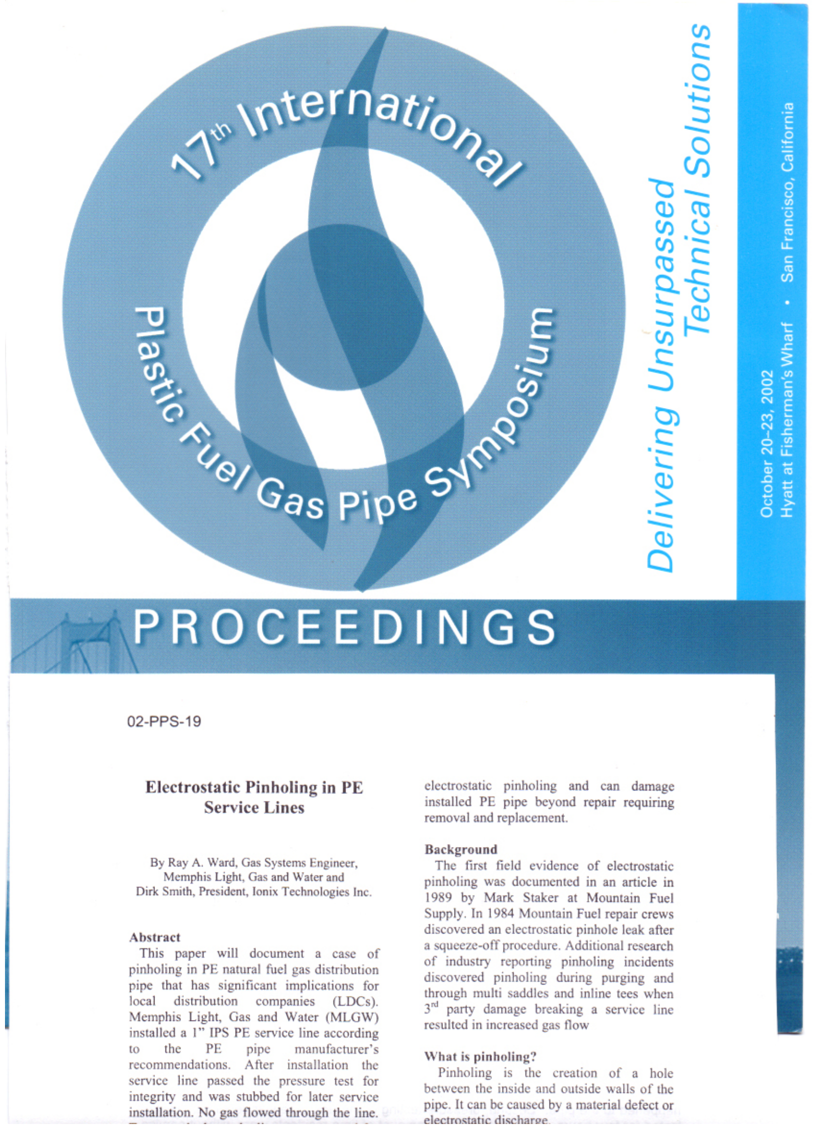
Results The reason for the existence of the pinholes could not be proven statistically. However, an evaluation of the accumulated information suggests that the pinholes occur because of a progressive breakdown in the electric resistance of the PE under a static electric field which is smaller than the electric field that would cause an instantaneous discharge. It is not clear whether this occurs prior to the pipe being put in service or while the pipe is in service.

Memphis Light Gas and Water

Memphis TN

1” Performance MDPE

Performance Pipe Lab conclusion – Static electricity inside pipe causes pinhole



02-PPS-19

Electrostatic Pinholing in PE Service Lines

By Ray A. Ward, Gas Systems Engineer, Memphis Light, Gas and Water and Dirk Smith, President, Ionix Technologies Inc.

Abstract

This paper will document a case of pinholing in PE natural fuel gas distribution pipe that has significant implications for local distribution companies (LDCs). Memphis Light, Gas and Water (MLGW) installed a 1" IPS PE service line according to the PE pipe manufacturer's recommendations. After installation the service line passed the pressure test for integrity and was stubbed for later service installation. No gas flowed through the line.

electrostatic pinholing and can damage installed PE pipe beyond repair requiring removal and replacement.

Background

The first field evidence of electrostatic pinholing was documented in an article in 1989 by Mark Staker at Mountain Fuel Supply. In 1984 Mountain Fuel repair crews discovered an electrostatic pinhole leak after a squeeze-off procedure. Additional research of industry reporting pinholing incidents discovered pinholing during purging and through multi saddles and inline tees when 3rd party damage breaking a service line resulted in increased gas flow

What is pinholing?

Pinholing is the creation of a hole between the inside and outside walls of the pipe. It can be caused by a material defect or electrostatic discharge.

Connecticut Natural Gas

4” Plexco IPS PE 3408

Static electricity in pipe caused leaks

GTI Labs

gti

GTI Laboratories
1700 S. Mt. Prospect Road
Des Plaines, Illinois 60018

Static Discharge Failure of PE Pipe
for
Connecticut Natural Gas Corp.

May 5, 2003

Submitted to:

Mr. Ron Klezos
Connecticut Natural Gas Corporation
P.O. Box 1500
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Summary of failure analysis of pinholes

Mountain – Aldyl – Internal Static – DuPont Lab

United Cities - Plexco – Breakdown of PE from electromagnetic fields – Battelle Labs

Memphis LGW – Performance MDPE pipe – internal static - Performance Pipe lab

Connecticut Natural Gas – Plexco - internal static – Gas Research Institute

4 different labs – different materials – different US locations
SAME conclusion – static inside the pipe
no manufacturing defects (no holes at time of manufacture, no out of spec dimensions)

January 5, 2015

PHMSA issued final ruling prohibiting rework/regrind in PE fuel gas pipe.

What is regrind?

Why did they come to this conclusion?

DEPARTMENT OF TRANSPORTATION

Pipeline and Hazardous Materials Safety Administration

49 CFR Parts 192, 193, 195, 198, and 199

[Docket No. PHMSA–2011–0337; Amdt. Nos. 192–119; 193–25; 195–99; 198–6; 199–26]

RIN 2137–AE85

Pipeline Safety: Periodic Updates of Regulatory References to Technical Standards and Miscellaneous Amendments

AGENCY: Pipeline and Hazardous Materials Safety Administration (PHMSA), Department of Transportation (DOT).

ACTION: Final rule.

SUMMARY: PHMSA is amending the Federal pipeline safety regulations to incorporate by reference new, updated or reaffirmed editions of the voluntary consensus standards that are applicable to pipelines subject to the requirements of the Federal pipeline safety regulations. This final rule also makes non-substantive editorial corrections clarifying regulatory language in certain provisions. These changes are minor and do not require pipeline operators to undertake any significant new pipeline safety initiatives.

DATES: This final rule is effective March 6, 2015. The incorporation by reference of certain publications listed in this final rule is approved by the Director of the Federal Register as of March 6, 2015.

FOR FURTHER INFORMATION CONTACT:

Technical Information: Mike Israni by phone at 202–366–4571 or by email at mike.israni@dot.gov.

Regulatory Information: Cheryl Whetsel by phone at 202–366–4431 or by email at *Cheryl.whetsel@dot.gov.*

SUPPLEMENTARY INFORMATION:

I. Background

The National Technology Transfer and Advancement Act of 1995 (NTTAA) (Pub. L. 104–113; March 7, 1996) directs Federal agencies to use voluntary consensus standards and design specifications developed by voluntary consensus standard bodies instead of government-developed voluntary technical standards when appropriate. The Office of Management and Budget (OMB) Circular A–119, "Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities," sets the policy for Federal use and development of voluntary consensus standards. As defined in OMB Circular A–119, voluntary consensus standards are technical standards developed or adopted by domestic and international organizations. These organizations use agreed-upon procedures to update and revise their published standards every three to five years to reflect modern technology and best technical practices.

The legal effect of incorporation by reference (IBR) is that the incorporated material is treated as if it were published in full in the **Federal Register** and the Code of Federal Regulations (CFR). This material, like any other properly issued rule, has the force and effect of law. Congress authorized incorporation by reference to reduce the volume of material published in the **Federal Register** and the CFR (see 5 U.S.C. 552(a) and 1 CFR part 51). Congress granted authority to the Director of the Federal Register to determine whether a proposed IBR serves the public interest. Unless expressly provided otherwise in a regulation, if a provision of a standard incorporated by reference conflicts with a regulation, the regulation takes precedence.

New or updated standards often further innovation and increase the use of new technologies, materials and management practices that improve the safety and operations of pipelines and pipeline facilities. Because pipeline safety regulation involves a great deal of technical subject matter, there are 64 standards and specifications that have long been incorporated by reference in 49 CFR part 192, Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards; 49 CFR part 193, Liquefied Natural Gas Facilities: Federal Safety Standards; and 49 CFR part 195, Transportation of Hazardous Liquids by Pipeline. PHMSA regularly reviews updates to currently referenced consensus standards as well as new editions of standards to ensure that their content remains consistent with the intent of the pipeline safety regulations. Previous updates to incorporate industry standards by reference were published on August 11, 2010 (75 FR 48593), February 1, 2007 (72 FR 4657), June 9, 2006 (71 FR 33402), June 14, 2004 (69 FR 32886), February 17, 1998 (63 FR 7721), June 6, 1996 (61 FR 2877), and May 24, 1996 (61 FR 26121). The list of publications that PHMSA has incorporated by reference is found in 49 CFR 192.7, 193.2013, and 195.3.

PHMSA employees participate in more than 25 national voluntary consensus standards-setting organizations that address pipeline design, construction, maintenance,

PHMSA's reasoning for including this research in their decision:

"These reports indicated that rework could potentially be an issue of concern, particularly through breakdown of dielectric properties, the development of pinhole leaks and static discharge"

5 January 2015 Federal Register

Restating PHMSA's conclusion:

There is an ongoing problem of pinholes leaks in PE pipe which we want to prevent and regrind/rework could be contributing to this problem and that's the reason from this rule.

Implied that contaminants in regrind the cause

(Differentiate between contaminants and regrind)

OSHA Hazard Information Bulletins
Static Electricity Buildup in Plastic Pipe

September 30, 1988

MEMORANDUM FOR: REGIONAL ADMINISTRATORS

THROUGH: LEO CAREY
Director
Office of Field Programs

FROM: EDWARD J. BAIER
Director
Directorate of Technical Support

SUBJECT: Safety **Hazard Information Bulletin** on Static Electricity Buildup in Plastic Pipe

The Dallas Regional Office has brought to our attention a potential hazard associated with the buildup of static electricity in plastic pipe used in the conveyance of flammable gas. Accidents including a fatality have been noted in investigations conducted by the Lubbock, Texas and Columbus, Ohio Area Offices. Explosions occurred due to the combination of a flammable gas-air mixture and the discharge of static electricity by arcing. These occurrences should not be confused with fires caused by heat generated by high pressure flammable gas discharges caused by small leaks.

Static charge on a plastic pipe can be generated by friction during the physical handling of the pipe in storage, shipping, installation, and repairing operations. Also, flowing gas in an operational plastic pipe containing particulate matter in the form of scale, rust, or dirt can generate static electricity. Other causes of static charge include gas flow disrupters such as pipe elbows, valves, neckdowns, and leaks.

The American Gas Association (AGA) in its February, 1985 Plastic Pipe Manual for Gas Service (Catalog No. XR0185, American Gas Association, 1515 Wilson Blvd., Arlington, VA 22209) states: "When conditions exist that a flammable gas-air mixture may be encountered and static charges may be present, such as when repairing a leak, squeezing off an open pipe, purging, making a connection, etc., arc preventing safety precautions are necessary." (Squeezing off involves clamping down a plastic pipe to stop flow upstream of a leak or rupture. This can be done with smaller-diameter pipe, typically two inches or less.)

The AGA Plastic Pipe Manual in Chapter VI, p. 57, "Maintenance, Operation, and Emergency Control", also urges the following recommended additional precautions:

Other similar techniques such as dissipating the static charge buildup with wet rags or a bare copper wire are used but may not be as effective.

1. The use of a grounded wet tape conductor wound around or laid in contact with the entire section of the exposed piping.
2. If gas is already present, the pipe should be wet with a very dilute water solution of dishwasher-type detergent starting from the ground end. The tape should then be applied immediately and left in place.
3. The tape should be kept wet by occasional applications of water. Where ambient temperatures below 0 degrees C. (32 degrees F.) are encountered, glycol may be added to the water to maintain tape flexibility. The tape should be grounded with a metal pin driven into the ground.
4. Do not vent gas using an ungrounded plastic pipe or tubing. Even with grounded metal piping, venting gas with high scale or dust content could generate a charge in the gas itself and could result in an arc from the dusty gas cloud back to the pipe and ignition. When venting, it should be done at a down-wind location remote from personnel or flammable material.
5. Ground the tools, such as saws, etc., that come in direct contact with the pipe.
6. In all cases, appropriate safety equipment such as flame-resistant clothing appropriately treated to avoid static buildup and respiratory protection equipment should be used.

Please note that requirements for operation and maintenance of pipelines, including plastic pipelines, are specified in 49 CFR 192. These requirements are enforced by the Department of Transportation, Office of Pipeline Safety, for those operations under its regulatory authority. Operations not so covered would normally fall under OSHA jurisdiction.

Please distribute this bulletin to Area Offices, State Plan States and Consultation Projects.

The common denominator in pinhole leaks:

Static Electricity

This is the ROOT CAUSE

At what voltage will a pipe pinhole?

It depends on the pipe wall thickness

MDPE dielectric - 510 Volts per mil thickness

MDPE 6” pipe with nominal wall thickness of .64

Threshold breakdown voltage:

640 mils x 510 per mil = 326,000 volts

(It takes a spark of 3000 volts minimum to a create 1100F in heat necessary to ignite a combustible gas mixture)

If internal static electricity in poly pipe is the cause of the pinhole, it follows:

Suppressing internal pipe static should stop pinhole creation.

City of Benton Kentucky Gas System – LDC test

317 miles of main - 7,033 services

Experienced the following pinhole leaks during surveys:

2007 – 1/3 survey	*8 total leaks*	*1 – 1”*	*2 – ¾”*	*5 – ½”*
2008 – 1/3 survey	*18 total leaks*	*1 – 1”*	*5 – ¾”*	*12 – 1/2”*
2009 – 1/3 survey	*6 total leaks*	*0 – 1”*	*5 – ¾”*	*1 – ½”*
2010 – 1/3 survey	*14 total leaks*	*0 – 1”*	*7 – ¾”*	*7 – ½”*
2011 – 1/3 survey	*13 total leaks*	*0 – 1”*	*1 – ¾”*	*12 – ½”*
2012 – 1/3 survey	*9 total leaks*	*0 – 1”*	*2 – ¾”*	*7 – ½*
2013 – 1/3 survey	*9 total leaks*	*0 – 1”*	*9 – ¾”*	*0 – ½”*

Average 11 leaks per year – found in orange, Aldyl, yellow pipe

2013/2014 installed Ionix Internal Static Suppression Cartridges at 3” and 4” gate stations (delivery point)

City of Benton Kentucky field test

After 2013/2014 Ionix Static Suppression Cartridges installed at 4” and 3” city gates

2014 – 1/3 survey	*2 total leaks*	*0 – 1”*	*1 – ¾”*	*1 – ½”*
2015 – 1/3 survey	*2 total leaks*	*0 – 1”*	*1 – ¾”*	*1 – ½”*
2016 – 1/3 survey	*0 total leaks*	*0 – 1”*	*0 – ¾”*	*0 – ½”*
2017 – 1/3 survey	*3 total leaks*	*0 - 1”*	*1 – ¾*	*2 – ½”*
2018 – 1/3 survey	*0 total leaks*	*0 - 1”*	*0 - ¾”*	*2 – ½”*
2019 – 1/3 survey	*1 total leaks*	*1 - 1”*	*0 – ¾”*	*0 – ½”*
2020 – 1/3 survey	*0 total leaks*	*0 – 1”*	*0 - ¾”*	*0 – ½”*
2021 – 1/3 survey	*1 total leaks*	*0 – 1”*	*0 - ¾”*	*1 – ½”*
Total leaks	*11 total leaks*	*0 – 1”*	*3 – ¾”*	*7 – ½”*

Internal static suppression installed (only change in system)

Average leaks per year – 1.375 - a 88% reduction in pinhole leaks after introduction of internal static suppression

All the research is right:
Internal static causes pinhole leaks

Therefore suppressing interior static prevents pinhole creation

Pin holes can only be prevented by INTERIOR static suppression installed upstream of the pin hole leaks.

There is NO one factor that causes interior static

First – it’s basic physics
Second – environmental factors

Above ground fire risk from pinhole leaks

Repeated pinholes in same area will ignite leaking gas from prior pinholes burning away the pipe.

If you suppress static electricity in your system, in addition to reducing leaks, you also

- Reduce the risk of ignitions
- Reduce the risk of shock to workers
- Reduce the risk of electronics burnout

Internal static suppression

is to poly pipe

as

Cathodic protection

is to metal pipe

Questions?

Dirk Smith

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Contact me about presenting this seminar to your industry meeting or to an inhouse company meeting.