Pipeline Damage and Soil Gas Migration

Underground Construction Technology Conference

Nashville, TN

July 13, 2021

David Heldenbrand, PE CFI

Daniel Saavedra, MSCE

Bison Engineering, Inc.

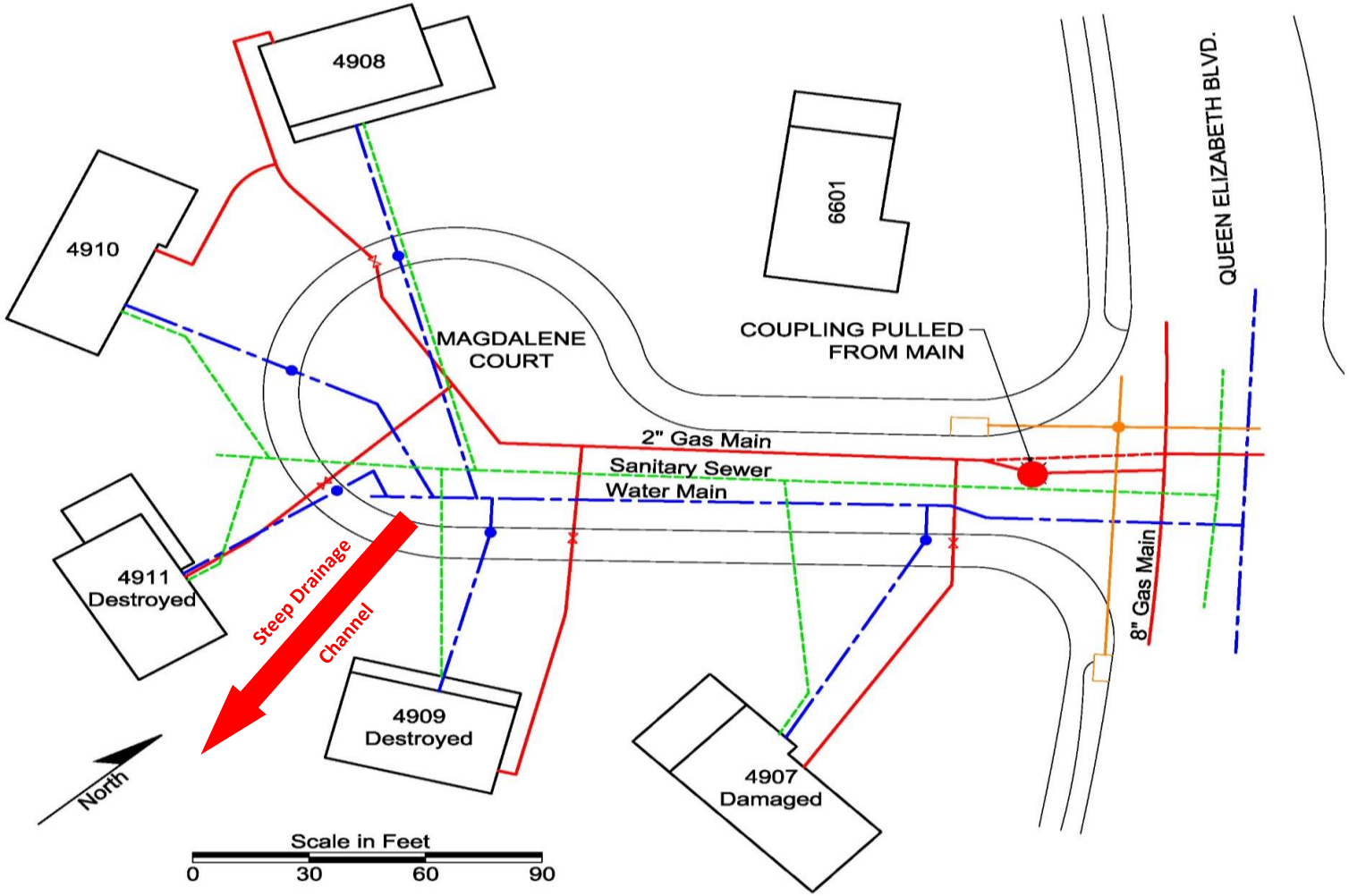
Pipeline Damage and Soil Gas Migration

- This presentation will review gas pipeline incidents which lead to a fire or explosion.
- We will compare similarities and differences.
- We will test theories of soil gas migration.
- We will review Emergency Response Procedures.

Annandale, VA
March 19, 1972

- A backhoe fractured a gas line.
- One hour after the fracture, two houses exploded 240 feet away.
- Gas was smelled inside a home after 30 minutes.
- The theoretical path of least resistance from a backhoe strike is into the open air at the gas line. **How can it cause an explosion 240 feet away?**

Annandale, VA



Annandale, VA
March 19, 1972

Annandale, VA
1972

- I saw a **distinct drainage pattern between the two houses**.
- The cul-de-sac is the lowest point of the surrounding area and **natural drainage is between the two houses**.
- The **Path of Least Resistance** was directly to the surface but the explosions were 240 feet away.

Annandale, VA
1972

- The terrain was all a rocky material including the trenches.
- **The explosion occurred within 60 minutes** of the fracture.
- Gas did not get into the sanitary sewer line.
- Gas did not follow the surface of the gas line.
- The NTSB tested both possibilities.
- The NTSB concluded that followed the rocky backfill in ditch lines. But, all the ground was rocky.

Annandale, VA
1972

- All of the gas did not go “Up and Out”.
- Gas did not “Follow the Pipeline”
- Gas did not “Get into the sewer line”.
- New ideas are necessary to explain how gas leaks cause explosions.

Saratoga Springs, Utah
2007

- An HDD crew damaged a gas line 40 feet from the home causing a noticeable gas leak.
- A first responder arrived an hour later.
- The gas company first responder and homeowner were checking for gas in the basement with CGI when home exploded.
- Two fatalities resulted.

Saratoga Springs, Utah
2007

- Gas was not shut off prior to entering building.
- After the incident, an air compressor was used to simulate a gas leak.
- Immediately upon the startup of the compressor, dust blew out from the expansion joint all along the bottom of the basement wall

Saratoga Springs, Utah
2007

- Gas entered the structure **instantly** upon initiation of gas pressure.
- Gas was forced 7 feet below ground while the pipeline was only 3 feet deep.
- Gas did not go “up and out”.
- Gas did not “follow the pipeline” or the HDD bore.
- Under these conditions… (1) damage was less than 50 feet from structure and (2) significant leak…

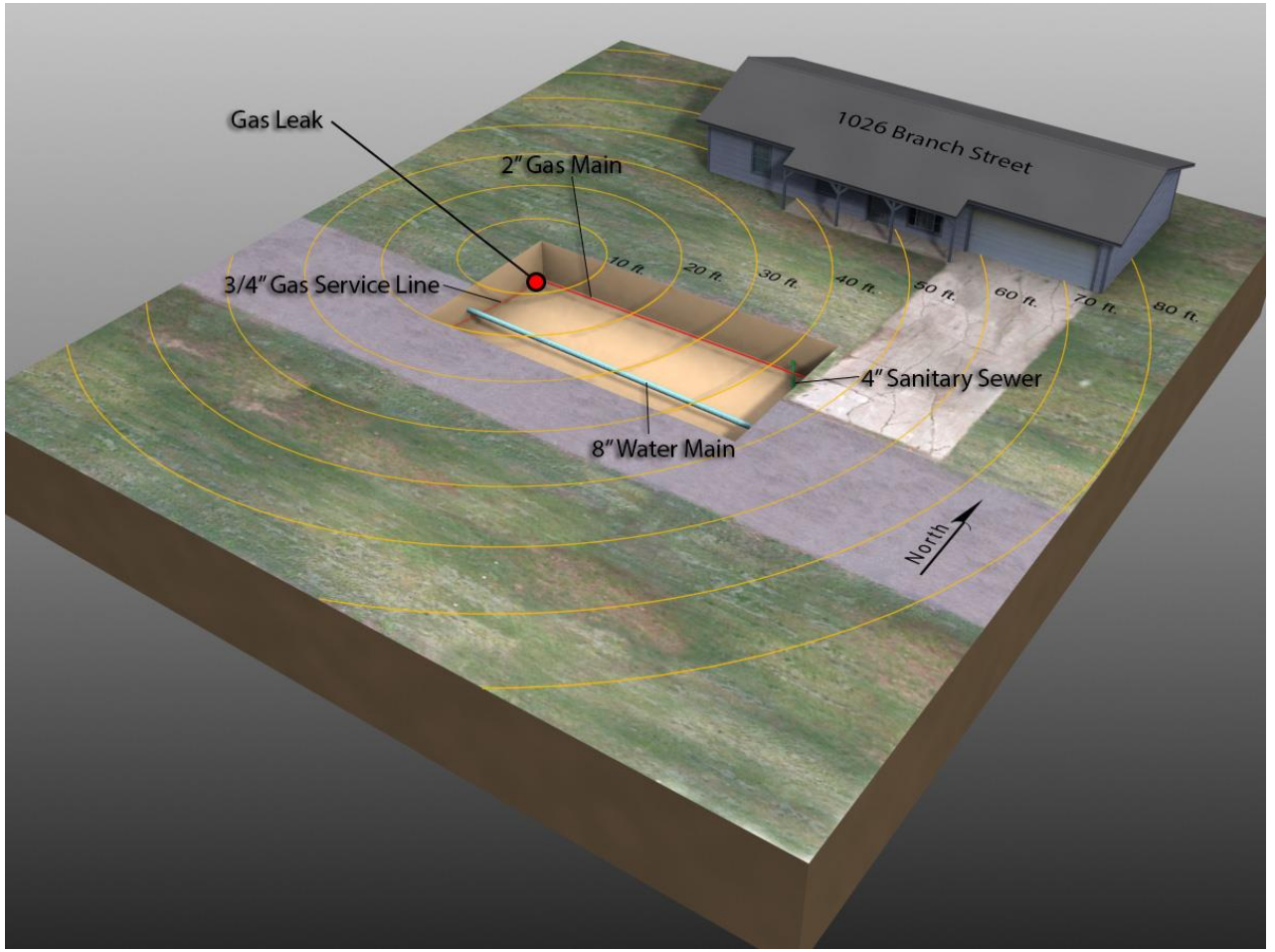
Saratoga Springs, Utah
2007

- In my opinion, the first responder should not have entered structure under these conditions.
- The gas should have been turned off and home should have been evacuated prior to entering the structure.
- Gas pressure forced enough gas 40 feet through the ground to cause the explosion.

Jackson, MS
December 24, 2008

- A water line contractor laid a water line crossing on top of a gas line.
- This may have caused the gas line to pull out of a coupling.
- There was a creek behind the house where the fire occurred.

Jackson, MS
December 24, 2008



Jackson, MS
December 24, 2008

- By traditional theories, gas should have followed the pipeline where the coupling pulled out.
- Home was downhill from the coupling, so gas did not go “up and out”
- All of this in heavy wet clay.
- Traditional gas migration theories need to be re-evaluted.

Jackson, MS
December 24, 2008

- The alleged "path of least resistance" was:
  1. Gas flowed along the service line to the main line,
  2. Followed the 2 inch main line for 30 feet,
  3. Jumped off of the gas line went down 2 feet for no reason **into** a sanitary sewer line at the location where they crossed,
  4. Floated up the sanitary sewer line to enter the house, but then, exited, the vented sewer line at another hole in the sewer vent inside the home where it was ignited and burned an individual.

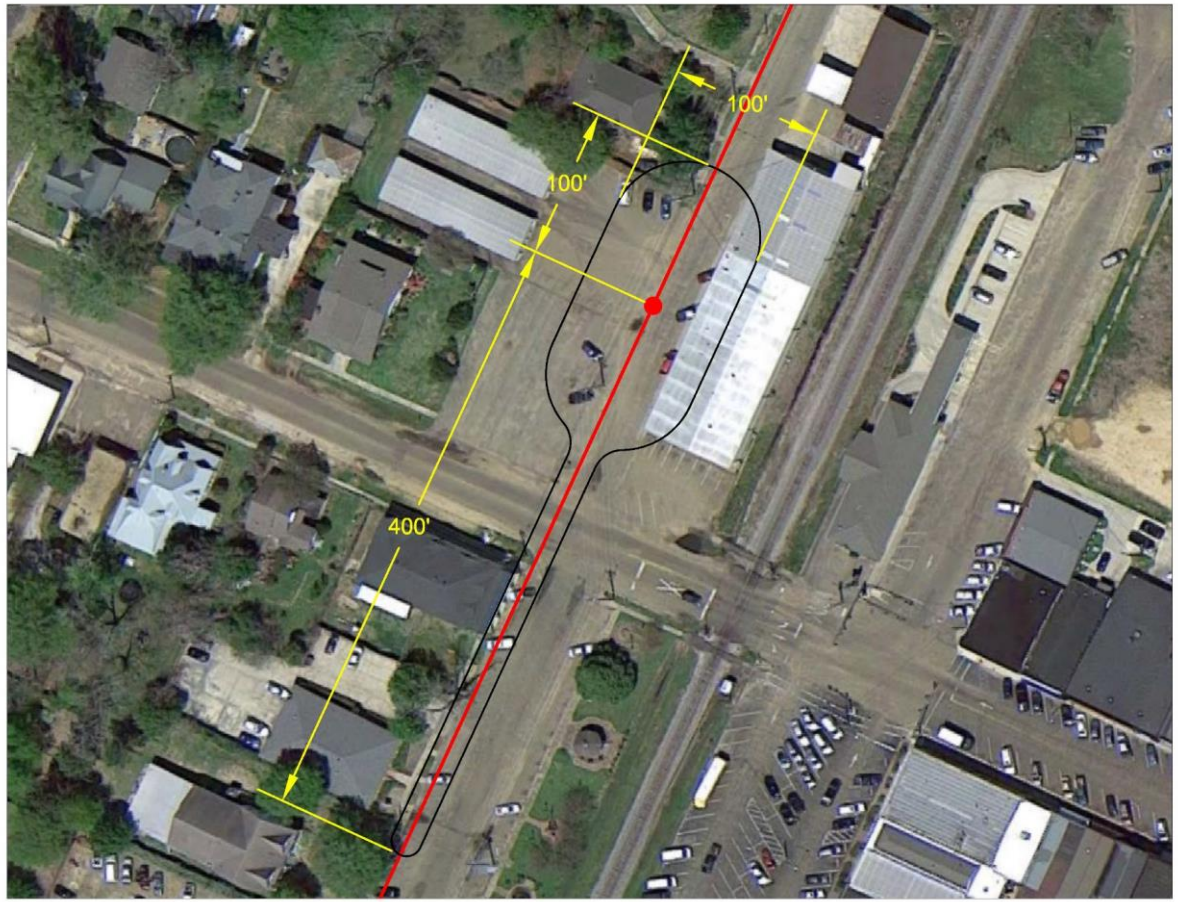
Crystal Springs, MS
February 1986

- A PE gas line was severed with a backhoe and repaired it with a PVC coupling.
- The gas line pulled out of the coupling and caused an explosion with 8 fatalities.
- The water line was installed in select sandy fill around the water line. The surrounding soil was clay.

Crystal Springs, MS
February 1986

- I found elevated gas concentrations from bar hole readings along the waterline for a distance of 400 feet **downhill** from the leak and 100 feet **uphill** from the leak, **but the explosion occurred in the building 50 feet <u>perpendicular</u> to the water line trench.**

Crystal Springs, MS
February 1986

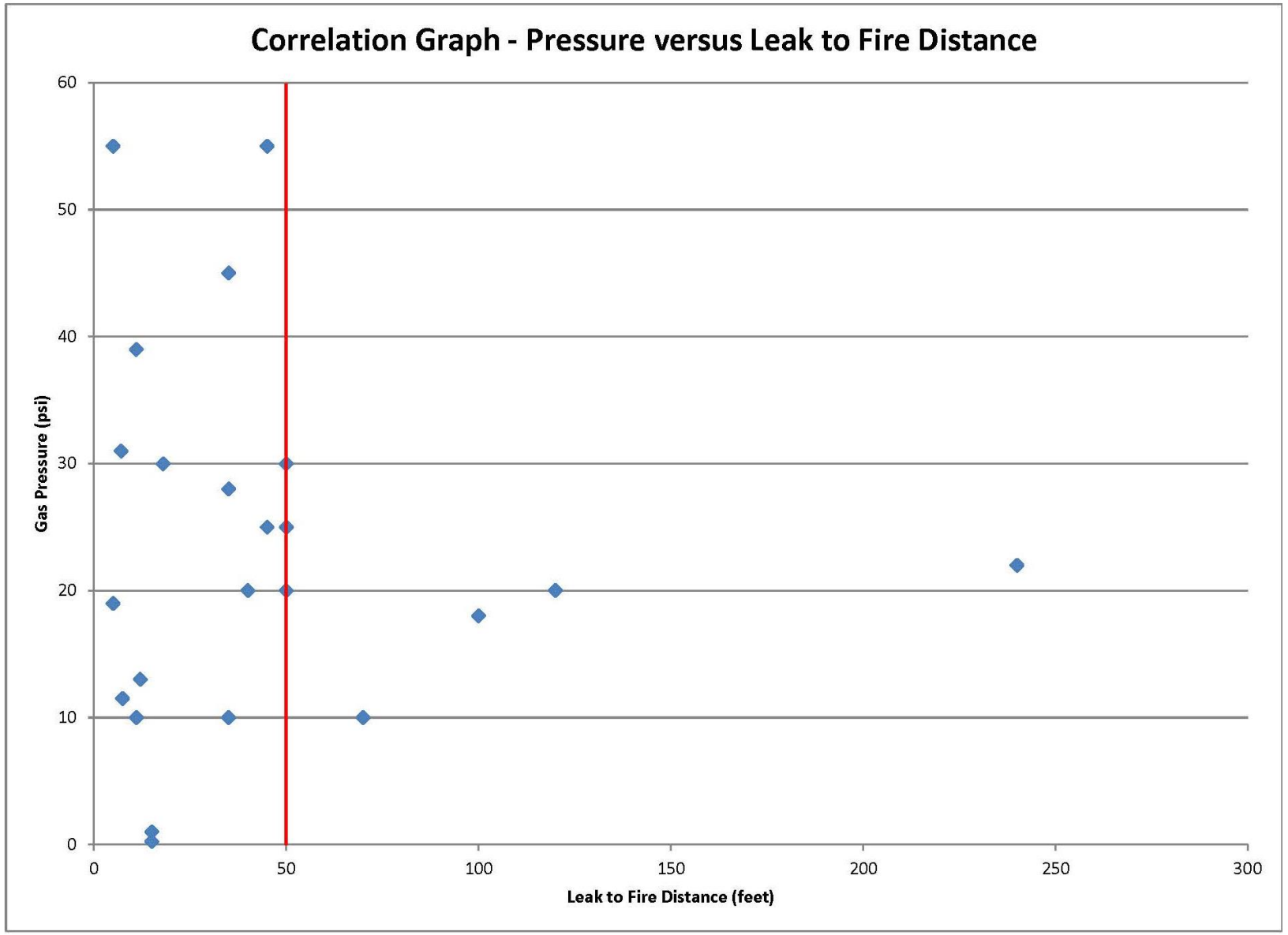


Crystal Springs, MS
February, 1986

- The “Path of least resistance” was along the sandy backfill of the water line, but the explosion was 50 feet perpendicular to the pipeline.
- Gas went uphill, downhill and laterally through clay.
- The theory of “the path of least resistance” implies a singular path.

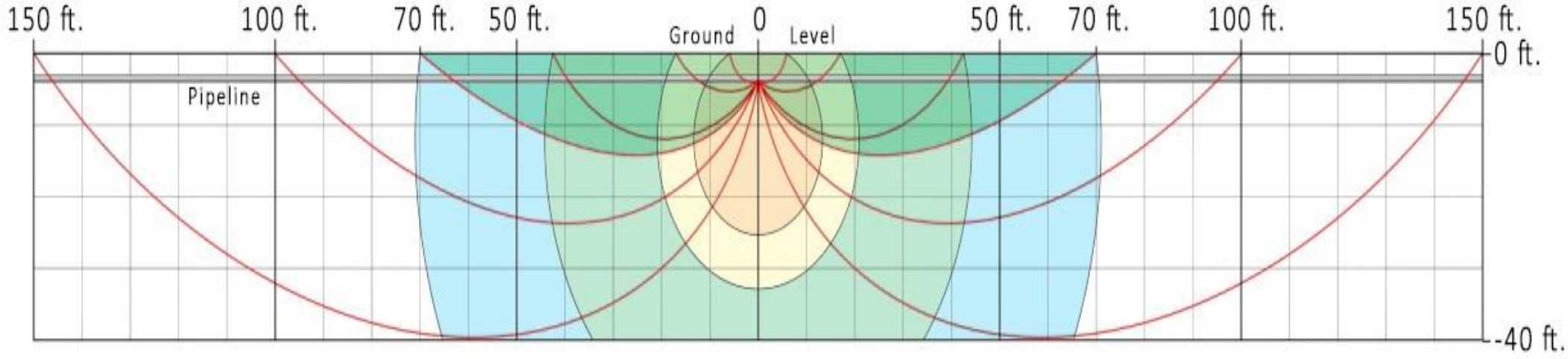
Crystal Springs, MS
February, 1986

- But, gas radiates in all directions from the source.
- A large flow rate is necessary to cause a fire.
- **A small residual pressure over a broad area forces gas into structures to cause an explosion.**

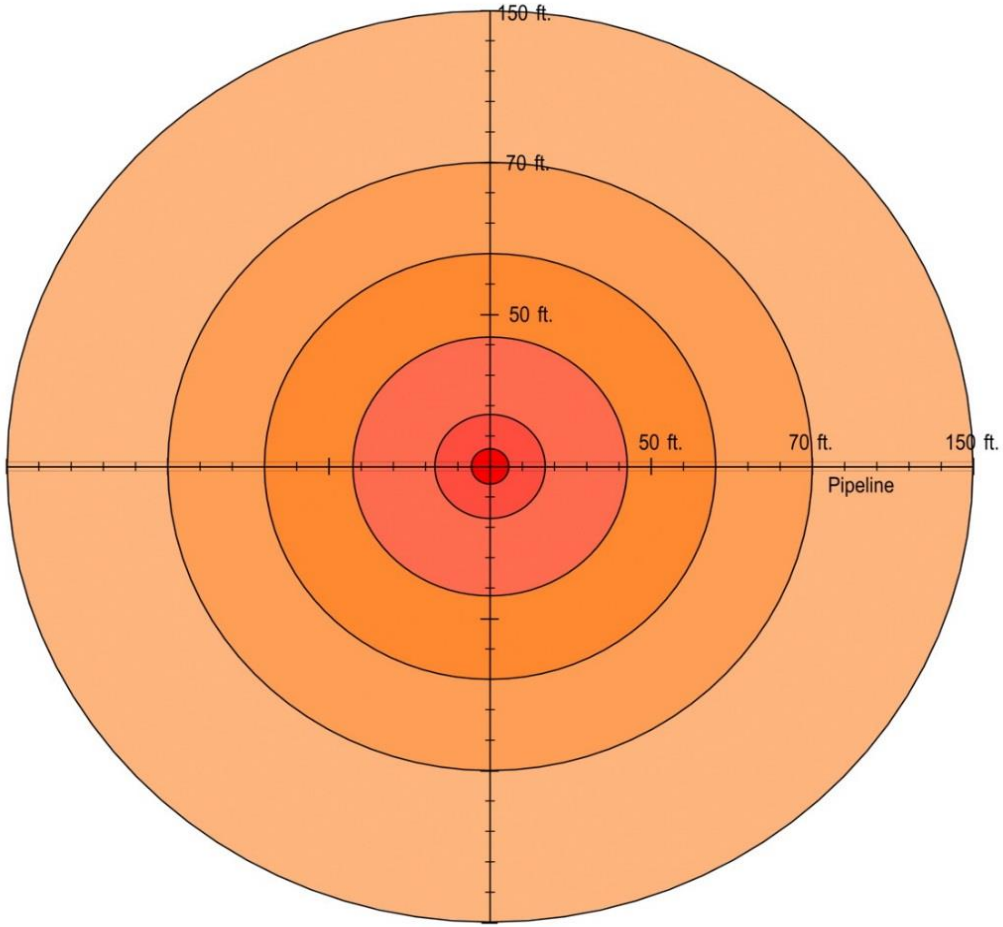

Correlation Graph - Pressure versus Leak to Fire Distance
Gas Pressure (psi)
60
50
40
30
20
10
0
0
50
100
150
200
250
300
Leak to Fire Distance (feet)

An Approximate Flow Net Diagram of the Radial Flow Pattern from a High Flow Rate Gas Leak

Stream lines : Red
Isobars perpendicular to stream lines



Top View of Flow Net Diagram



Ratio of Lateral Distance From the Leak to the Structure Compared to the Depth of Gas Line

• Sarasota Springs, UT	13
• Holly Springs, MS	17
• Jackson, MS	23
• Queen Creek, AZ	17
• Bowie, MD	40
• Annandale, VA	80

- So, concluding that gas from an underground gas leak goes “up and out” is simply not accurate.

How Much **Time** Does it Take for a Gas Leak to Cause an Explosion?

Let's look at some cases where we know the time factor.

- Annandale, VA - **240** feet in **60** minutes at **22 psi**
- Philadelphia, PA - **30 feet** in **15 minutes** at **0.25 psi**
- Chicago Heights, IL - **40** feet in **30** minutes at **28 psi**

How Does Soil Type Affect Soil Gas Migration?

• Queen Creek, AZ	Clayey sand, sandy silt	50	feet
• Jackson, MS	Dense wet clay	70	feet
• Odessa, WA	Rock and volcanic ash	60	feet
• Saratoga S, UT	Frozen silty clay	40	feet
• Ft. Worth, TX	Dense clay	40	feet
• Rancho C., CA	Silty clay loam	50	feet

How Does Pipeline Pressure Effect Natural Gas Migration Explosions?

• Philadelphia, PA	5/11/1979	0.25 psi, 30 ft.
• Williamsport, PA	1/25/1977	10 psi, 70 ft.
• Bowie, MD	6/23/1973	20 psi, 120 ft.
• Annandale, VA	3/24/1972	22 psi, 240 ft.
• Jackson, MS	12/24/2008	45 psi, 70 ft.
• Rancho C., CA	12/24/2008	55 psi, 45 ft.

Kansas City, KS
February 19, 2013

- HDD crew hit a gas line within a few feet of a restaurant wall.
- Gas company was on site for two hours prior to explosion.
- Customers were evacuated only minutes before the explosion.

Kansas City, KS
February 19, 2013

- One restaurant employee died and others injured.
- The large leak was in **close proximity** to a building.
- **There was time to evacuate, but the danger was not recognized.**

Canton, Illinois
November 16, 2016

- Explosion caused 1 fatality and 11 injuries outside of the structure.
- **The large leak was in close proximity to a building**.
- **The danger was not recognized prior to the incident**.

Canton, Illinois
November 16, 2016

- Explosion caused 1 fatality and 11 injuries outside of the structure.
- **The large leak was in close proximity to a building**.
- **The danger was not recognized prior to the incident**.

Durham, NC
April 10, 2019

- HDD crew hit a gas line 5 feet from the structure.
- Gas flowed for 1 hour prior to explosion.
- 100% LEL in the structure almost immediately.

Durham, NC
April 10, 2019

- A **large leak** in **close proximity** to the building.
- 2 Fatalities and 25 injuries resulted.
- **The danger was not recognized prior to the incident**.

Murrieta, CA
July 16, 2019

- Gas line struck outside of a residence.
- First Responders arrived 50 minutes prior to explosion.
- 1 Fatality and 15 injuries including 3 firefighters from flying debris outside of the structure.
- **The danger was not recognized prior to the incident**.

Summarizing Parameters

- Only one of these incidents is more than 50 feet from the damaged gas line.
- Pipeline damage from a backhoe caused an explosion 240 feet away in 60 minutes. This shows that the theory that all the gas takes the path of least resistance needs re-evaluation.

Summarizing Parameters

- Regarding pipeline damage caused by directional drilling, the gas theoretically follows the annular space caused by the drilling itself, but the incidents show that it is an incorrect assumption.
- Large gas leaks from pipeline damage create gas flow through the soil spherically as far as 50-150 feet in all directions.
- **Most gas fires occur within a 50 foot radius from the source**.

Summarizing Parameters

- Soil type, other pipelines, and buoyancy of the natural gas have little affect on the flow path of the gas from a leak.
- “The path of least resistance” is not a valid, practical concept when pipeline damage occurs.
- The **primary variable** in a gas explosion is the **ignition source** not the time for a gas enter the structure.

Summarizing Parameters

- The gas infiltrates structures by differential pressure on large surface areas.
- The gas is forced as far as 50 feet through voids such as wall penetrations, expansion joints, cracks, etc. to cause incidents.
- Many times the large leaks that cause explosions have readily visible and/or audible indications.

Pipeline Damage and Soil Gas Migration

If a gas line is damaged and a leak is created, a few instantaneous risk assessments can be made:

1. Is it a visible or audible leak?
2. Is the **distance** to occupied structures within **50 feet**? Risks increase the closer the leak is from a 50 foot radius but decrease at distances farther than 50 feet.
3. With these conditions, explosions can occur a short time after a gas pipeline is fractured.

Pipeline Damage and Soil Gas Migration

Questions? Comments?

Thank you for your interest in this subject.

David Heldenbrand, PE CFI – dave@bisonengineering.com

Daniel Saavedra, MSCE – daniel@bisonengineering.com

Bison Engineering, Inc.

281-359-2476